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Optimization Framework in Electrical & Electronics Engineering

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Mr. Manoj Chaudhary

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Flow Process Optimization in Electrical Safety Program

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ABSTRACT

The labour task is what matters most! Are they reactive or scheduled activity or job for electrical work? A work order has it been issued? Is the job energized or not, and what does the qualified electrical worker do if it is energised? QEW) must take to implement it in accordance with the guidelines in an employer's overall Occupational Health & Safety Management System (OHSMS) and related Electrical Safety Programme (ESP). In carrying out the work task, consideration must be given to the CSA Z462 and NFPA 70E Standards. Before, during, and after the work task has been completed, documentation must be employed. The "Work Package" for the given work job is this collection of documents. The method of carrying out the energized electrical work task follows a natural flow of necessary processes, and once all steps are finished, it provides the best level of due diligence for the employer and employee and guarantees that the requirements of the employer's Electrical Safety Programme are met. Is the focus of your company's electrical safety programme on the job activity and what needs to be done to carry it out?

Keywords- *Energized Electrical Job Risk Assessment (EEJRA), Electrical Safety Programme, Occupational Health & Safety Management System, Work Order, Electrical Hazard Identification, Field Level Hazard Assessment (FLHA), Safe Work Permit, Energized Electrical Work Permit, Field Level Risk Assessment (FLRA), Risk Assessment Procedure, Risk Level, Risk Class, Arc Flash Risk Assessment, Shock Risk Assessment, Job Safety Analysis, Job Hazard Analysis, Hazard Task Analysis.*

INTRODUCTION

Both the NFPA 70E Standard for Electrical Safety in the Workplace and the CSA Z462 Workplace Electrical Safety Standard are task-based standards. The updated Hazard/Risk Category Tables to the 2015 Arc Flash Hazard Identification for alternating current (AC) and direct current (DC) found in CSA Z462 Table 4A and NFPA 70E Table 130.7(C)(15(A)(a) added further emphasis to the fact that they have existed from the beginning.

The basis of the tables is first the identification of the task to be performed, in which a qualified electrician assesses the condition of the device as normal or abnormal, or the condition of the equipment second, and then the arc flash decides Personal protective equipment is required, yes or no.

Most importantly, the task must guide the analytical process exposure to arc flash and/or electric shock hazard. This paper further emphasizes that the electrical safety of the company Program the framework elements of the security management system focus on the task and the role of the employee performing it and that an electrical safety program could include workA flow process flowchart (see Figure 1) as a visual tool administrative processes required by an electrical safety programis documented and completed. The focus is ensure field documents are completed and signed qualified electrician before proceeding

STEP 1 - WORK ORDER

The work order or work request is delivered to a qualified electrician Employee in maintenance work. This work order can be manual, automated or verbal.

Depending on the company, computer maintenance Management system and#40;CMMSand#41; can be used with precise details intended for the necessary electrical equipment maintenance, prescribed maintenance requirement and frequency and relevant electrical information equipment (e.g. there may be arc flash energy data are added to the CMMS database and printed work order, one-line diagram or detailed electrical safe working conditions, necessary materials, etc.).The work order will note an electrical equipment issue, and if the issue is reactive (such as critical service, process dependability, etc.) or it can indicate the need for planned preventative maintenance. To solve the identified issue (e.g., diagnostics and troubleshooting) or complete the preventive maintenance (e.g., electrical equipment switching and isolation, infrared testing, ultrasonic testing, cleaning, testing of power circuit breakers, etc.), the qualified electrical worker should be required to define the discrete energized electrical work task(s) that may be needed. The possible perceived urgency of the work job(s) may have an effect on how the risk level associated with the work activity is assessed. When given a task, a qualified electrical worker must also be able to decide whether it must be carried out in an energised or de-energized state. To find out the rationale behind doing the work assignment in an energised state, the qualified electrical worker may additionally need to follow up with the task requestor.

STEP 2 & 3 - TEMPORARY POWER REQUIRED

The installation of temporary power related to construction or significant electrical equipment maintenance where normal utility power is not available or may need to be isolated for a long time poses a number of challenges and may be noted as needing special attention in the company's Electrical Safety Programme. Multiple temporary power generators, transformers, and power distribution equipment may be used to provide temporary power at major industrial construction sites, and their configurations will probably change frequently throughout the course of the project. According to the company's Electrical Safety Programme, a "Temporary Power Certificate" may be created to document initial Code (such as NEC or CEC) compliance and continuous confirmation that the integrity of the temporary power system is maintained in a "Normal Operating condition. The Temporary Power Certificate would impose specific inspection requirements and at a determined frequency to ensure a "Normal Operating" condition is in place at all times. Temporary power equipment can very quickly degrade in its condition and increase the potential risk of exposure to electrical shock for Non-Electrical Workers that utilize the system for portable electrical equipment necessary for completing the construction or maintenance activity.

Step 4 - Pre-Job Briefing & Planning

The company's overall OHSMS and ESP should mandate that the job be planned after the QEW receives a work task or **job assignment**, and that eventually at the work task location some sort of Pre-Job Briefing be done and documented. A specific ESP document from the Pre Job Briefing may be used, or it may be a step in the process of finishing a Field Level Hazard Assessment (FLHA) or Field Level Risk Assessment (FLRA). The HNFLRA will have many different company-specific designations and may contain a range of data that the company has identified as crucial for the particular jobsite (for example, manufacturing, mining, oil & gas, forestry, building, etc.).

1. **Overhead Power Line Encroachment**

The QEW may be directly exposed to operating near overhead power lines depending on the company and the work done (for example, electric utility or independent power producer). Specific Limits of Approach or Minimum Approach Distances are mandated by law, as stated in Canadian OH&S law or American OSHA regulation .Additionally, the QEW may have work projects finished that are unrelated to the Overhead Power Lines yet close by.

Other workers that are not QEWs may also have to complete work tasks in proximity of Overhead Power Lines (e.g. pipeline construction, drilling rig companies, general excavation, etc.). It is statistically known that electrical shock and electrocutions related to Overhead Power Line proximity or contact are the highest frequency of fatal electrical injuries.

It might not be necessary for all businesses to identify Power Line Encroachment in the "Work Flow Process" of their Electrical Safety Programme, but if they do, it is crucial that they place equal emphasis on proactive management of Overhead Power Line encroachment related to a given work task.
This part of the "Work Flow Process" stipulates that a "Power Line Encroachment Authorization Permit" must be finished and the necessary signature(s) obtained before the work job may be carried out. This administrative element is used to lower the Risk Level, which has a beneficial effect on the Likelihood of Occurrence by giving extra attention to a task that is assigned that is connected to or near overhead power lines.

2. Risk Assessment Procedure

The QEW must finish the CSA or NFPA Risk Assessment Procedure at this point in the "Work Flow Process". There are three distinct steps in this process: Identifying electrical risks to which the QEW may be exposed while doing the activity in an energised state, assessing the risk, and implementing risk controls in accordance with the hierarchy of approaches are the first three steps. Further information on how the QEW can determine the specific Risk Level of the specific work task(s) he or she has identified in order to carry out the given work order is provided in the company's electrical safety programme.

It is recommended that the Risk Level of typical energized electrical work tasks performed by a company's QEWs be proactively determined by the Electrical Safety Steering Committee (ESSC) following the process outlined in the Electrical Safety Program or in conjunction with the company's overall risk assessment process. The ESSC makes and documents assumptions to determine a work tasks Risk Level. The QEW must field verify the assumptions made (e.g. Qualified & Competent QEW, Human Performance Behavior validated as normal, condition of electrical equipment verified as normal and appropriate Electrical Specific PPE, Tools & Equipment identified, documented, pre-use inspected and applied). Field based validation of the application of the Hierarchy of Controls shall be documented as outlined in a company's Electrical Safety Program.
It should be noted that, in order to accomplish the task listed on the work order, a number of discrete energised electrical work activities may need to be finished, with varying risk levels for each task.

3. Shock Risk Assessment

The QEW will be expected to perform and document a Shock Risk Assessment if they have determined that one or more of their job duties could put them in danger of receiving an electric shock. The Shock Risk Assessment described in CSA Z462 or NFPA 70E is a particular risk assessment that will be used to identify: 1. The voltage to which personnel would be exposed; 2. Boundary requirements; and 3. The PPE required to reduce the danger of electric shock to persons.

It should be mentioned that the Shock Risk Assessment is used by the QEW to apply shock PPE, tools, and equipment prior to finishing the work activity and encroaching within the Restricted Approach Boundary in order to reduce the result or damage to health associated to the entire Risk Assessment Procedure.

4. Arc Flash Risk Assessment

They must complete and record an Arc Flash Risk Assessment if their work exposes them to an electric arcing fault and arc flash. The NFPA 70E or CSA Z462 Arc Flash Risk Assessment is a particular risk assessment that will be used to: 1. Ascertain whether there is an arc flash hazard associated with the particular discrete work task. This particular sort of risk assessment must establish the following if an arc flash hazard exists: suitable safety-related work practices, the arc flash boundary distance, and the arc-rated PPE that employees within the arc flash boundary shall use. 2When a major modification or renovation occurs, the information should be updated, and it must be reviewed periodically, at intervals not exceeding five years, to take into account changes in the electrical distribution system that could affect the results of the analysis. If a specific documented incident energy analysis report has been completed, or if the "Table Method" has been documented for the specific electrical equipment the work task will be performed on, then that information should be updated.

5. Energized Electrical Work Permit (EEWP)

A significant requirement of the CSA Z462 and NFPA 70E Standards is the execution of an Energised Electrical Work Permit (EEWP), and the QEW is responsible for determining whether the given work order and its associated discrete work assignment would need the execution of an EEWP. The requirements for the EEWP and certain exemptions must be adhered to and used by the QEW. The EEWP needs to be approved. Where the reason is implausible, the EEWP may be "Annualized" forcertain job duties and issued to a particular QEW.

6. Safe Work Permit (SWP)

Not every business will employ a safe work permit. The Work Flow Process flow chart would not include this as a required component. A safe work control "Safe Work Permit" system may be used at large industrial facilities with considerable operations, maintenance, and continuing building activities. Every employee who enters the company's facilities to complete any maintenance or construction work orders assigned to them is required to have a valid Safe Work Permit. This safe work permit normally has certain high-level standards for hazard identification and may focus especially on particular needs (such air testing and hazardous sites) and distinct risks.

7. **Field Level Hazard Assessment (FLHA) I Field Level Risk Assessment (FLRA)**

A field-based "all hazards" identification form that personnel undertaking construction or maintenance work activities must complete at the facility / field location where the actual work will be performed is an essential documentation component of an overall OHSMS. Both the arc flash and shock dangers must be mentioned as a part of the FLHAlFLRA so that affected personnel may identify them. Depending on the task(s) they are assigned, a QEW should be the one who can distinguish between an arc flash and a shock. All other non-electrical personnel (such as mechanics, welders, general laborer’s, etc.) should be aware that using portable plug-and-cord-connected electrical equipment puts them at risk for electric shock.

Arc flash and shock should be included in the list of potential hazards if a corporation employs a field-based document to identify hazards for workers.

8. **Energized Electrical Job Risk Assessment (EEJRA)**

A business may also have a special FLHA or FLRA document with an electrical focus that was tailored for use as a major field-based document of their recorded Electrical Safety Programme.

The company's Electrical Safety Programme mandates that the QEW record particular information connected to the assigned work order and specific discrete energised electrical work tasks that would expose them to arc flash and/or shock in order to utilise this document in the field.

The QEW would also use this EEJRA form or an equivalent to field-verify the presumptions made in completing the risk level (e.g., low, medium, or high) identified by the risk assessment procedure. If the Risk Level has not been established by the Electrical Safety Steering Committee (ESSC) and proactively communicated to the QEWs, this document could also be used to document the Risk Assessment Procedure at the workplace location in real time.

9. **Establish an Electrical Work Zone**

Despite not being specifically mentioned in CSA Z462 or NFPA 70E, a company's electrical safety programme may define the Electrical Work Zone (EWZ) as the area beyond the Limited Approach Boundary for shock or the Arc Flash Boundary in further detail.

The QEW shall put on electrical-specific PPE, enter the Electrical Work Zone, and use the designated tools and equipment to carry out the energised work with an acceptable Risk Level after the Electrical Work Zone has been formed with a sufficient barricade. Electrical-specific PPE, tools, and equipment are utilized to lower risk by preventing or lessening harm.

10. Post Job Analysis

A company's electrical safety programme would determine the need for a post review of the job once the task was completed.

11. Are there any changes?

Changes to single line diagrams, procedures, personal protective equipment, tools, or other components of the Electrical Safety Program's criteria may be required, as determined by the post job analysis.
Basically, it's possible that the Hierarchy of Preventive and Protective Control Measures needs to be revised. To have the change requested, justified, and authorized, a written Management of Change procedure may need to be followed.

12. Submit Work Package Documentation

The company will require the QEW to submit completed documentation for tracking billable hours, confirming materials used, and for record management purposes related to the overall OHSMS, depending on the requirements of the company and the work order management system used (e.g., manual work order issued or CMMS). Normally, any documentation used to identify hazards must be kept on file for 3, 5, or 7 years.

13. Conclusion

For electrical safety to perform in a sustainable and measurable way, the CSA Z462 and NFPA 70E Standards must be applied through the creation and implementation of an Electrical Safety Programme. The administration of the job assignment that would be given to a QEW should be a crucial part of the electrical safety programme. The "Work Flow Process" for an organization's Electrical Safety Programme is defined in this article and is shown in a flow chart as a visual representation of the administrative and documentation needs.

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Optimized Controller Design

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ABSTRACT

The present focus of internal combustion engine control system development is on performance, fuel efficiency, and exhaust emissions. This is brought on by growing fuel prices, which created a crisis in the transportation industry; as a result, it is critical to develop a technology for fuel-efficient automobiles. Controlling the air-to-fuel ratio (AFR) is one of various ways to increase the fuel economy of gasoline engines. Due to its challenging setting characteristic since AFR control is typically used as internal engine control, AFR technology still has a lot of issues. The external engine system's effect can increase fuel efficiency. An external engine system that was utilised in this study was the brake control system. To increase the fuel efficiency of gasoline engines during braking, the aim of this research is to build and implement an AFR and brake control system in a vehicle. The controller must, in general, limit fuel injection use during braking periods. A smart controller, such as a fuzzy logic controller (FLC), is used by the applied control system on the vehicle. The ECU brake control system regulates fuel injection when the vehicle brakes. The default vehicle control system and this control system operate simultaneously. The findings indicate that optimum efficiency is reached when the engine speed exceeds 2500 rpm and the AFR value increases indefinitely. Engine speed below 2500 rpm causes the AFR reading to reach a value of 22. The fuel measurement was able to demonstrate a reduction in gasoline usage over the course of the 50.7 km, from 6 to 4 litres. An improvement in fuel efficiency of about 33.3% is possible.

Key words- *AFR, brake control system, efficiency, fuel injection, gasoline engine.*

1. INTRODUCTION

Over the past 30 years, the development of control systems for internal combustion engines in the global automobile sector has focused on exhaust emissions, performance, and fuel efficiency [1]. The reason for this was the number of automobiles rapidly increasing each year, which raises fuel demand. According to information from the Indonesia Statistics Board, there were 104.118.969 automobiles on the road in 2013. On the other hand, there is still a limited quantity of fuel in the planet. Since 2005 [2], the world's crude supply has been stagnant, and it has even declined in more recent years. The effects of this circumstance led to an increase in fuel prices. The Organisation for Economic Co-operation and Development (OECD) data indicate that the price of crude oil climbed considerably between 2004 and 2014 [3]. The economic decline in several areas, particularly the transportation industry, has turned out to be mostly caused by this price hike. It is essential to create a transportation technology that is highly efficient to save fuel in order to deal with the rising cost of fuel. There are numerous ways to increase the fuel efficiency of cars with gasoline engines. The first is Spark Advance - SA's optimisation techniques [4]. According to the state of the engine, the SA optimisation method is a way of managing the ignition at the spark plug with high voltage at a few degrees before top dead point of the piston. The second is the setting for the air to fuel ratio (AFR), which is the proportion of fuel to air [5][6][7] mixing. According to their research, controlling AFR allows for the achievement of the ideal ratio and, consequently, an increase in fuel efficiency. All of the research is still focused on internal engine controls, though. The development of hybrid technology systems comes in third [8]. They make advantage of the hybrid system to increase fuel efficiency. This technique uses a gasoline engine and an electric motor in conjunction with a fuzzy logic controller to operate the vehicle. The generated performance of hybrid engines is lower than that of gasoline engines, and they still cost a lot of money.

The fourth option is to use alternate energy sources, such as by adding ethanol [9], methanol [10], or using other systems. To increase fuel efficiency and enhance engine performance, alternative energy sources are increasingly being researched for use in gasoline engines. The limitation of the available alternative fuel resources is a drawback of this approach. The AFR settings are the best way now available in our nation to increase fuel efficiency because they are less expensive and can be extensively used on a variety of vehicles.

The AFR setting is done using a variety of techniques. The first technique uses an AFR setting that is controlled by vacuum produced by the engine. This method's flaw is that it's challenging to get the perfect ratio, which results in a wasteful use of gasoline. This is brought on by an unpredictable process of combining gasoline and air using a vacuum system produced by the engine's piston.

The second technique involves either directly (direct injection) [11] or indirectly (indirect injection) injecting fuel into the engine. This approach has the benefit of making it simple to get the ideal air-to-fuel ratio, but it also necessitates specific handling and attention. The optimal ratio results in increased fuel efficiency, high torque, and minimal exhaust emissions.

The AFR could be impacted by the heat engine specs ratio [12]. AFR can lower exhaust emissions [13] under specific circumstances when combined with an additional component [14][15]. This study looked into how adding more material and increasing the water to fuel ratio affected the amount of exhaust emissions. Through the use of fuzzy logic controllers, AFR control has developed extremely quickly [16][17][18][19]. The benefits of fuzzy logic controllers include reasonably well managed system stability, the capacity to solve black box system issues, and the ability to use the multi input multi output (MIMO) approach. Neural network applications [20][21] are another technique. The drawback of this approach is that it necessitates extensive training to achieve optimal results.

Currently, AFR technology is having issues. One of the issues is that the technology that is currently in use is controlled by industrialised nations and is a "black box." The AFR setting procedure, which falls primarily under the purview of the internal engine, has not been connected with the engine of external systems. With this knowledge, research should be done to provide the science and technology necessary to integrate the AFR setting with external engine systems.

One component of the vehicle system that regulates movement, slows, accelerates, and stops a vehicle is the braking control system. In essence, while the braking system (brake control system) is in operation, the machine acts more like a standby than a driving force. The vehicle is slowed down in this situation by the engine. Based on this circumstance, one of the engine's AFR controls could be the brake control system. It functions when the braking system is engaged since stopping the vehicle instead of moving it requires more power from the engine. Fuel economy can be increased by using this circumstance.

To increase fuel efficiency, it is important to research the integration of the AFR control system and the brake control system.

AFR in a gasoline engine is used to control fuel efficiency, so since internal control still exists, the fuel efficiency is not at its highest. Research should be done to make fuel better. efficiency. AFR control could be included into the engine's external control system to increase fuel efficiency. A brake control system is one of the external systems.

The goal of this research is to better understand how a vehicle's AFR system and brake control system may work together to increase fuel efficiency in the gasoline engine.

2. METHODOLOGHY

The amount of fuel used by the engine each minute is known as fuel consumption. The goal of this study is to control fuel economy since braking causes the air-fuel mixture AFR to become less (lean). The amount of gasoline injected into the engine is decreased with a lean mixture. The engine must run on a mixture of more air and gasoline when the machine needs a very large force. The most important topic is AFR gasoline engine efficiency. One way to improve the fuel efficiency of gasoline engines is to use the AFR setting. One component of the car that is utilised to slow down and stop is the brake control system. In some circumstances, the engine is employed to slow the car down.

The air-to-fuel ratio, or AFR, measures how much gasoline is in relation to the air. 14:67:1 AFR concept ratio. This situation is characterised by the best internal combustion engine performance, minimal exhaust emissions, and good engine efficiency [22]. A 14.67:1 ratio means comparing 14.67 air units to one unit of gasoline. The automobile engine's AFR is represented by the lambda () symbol. The amount of ideal air needed is called lambda (). The amount of air that enters the engine cylinder at lambda () = 1 is equal to the amount of ideal air that is needed. In this case, the engine needs more air since the mixture is fat, which, within certain bounds, might improve engine power. Lambda () 1: the quantity of air that is less than the amount of ideal air necessary. When the amount of air entering the engine is greater than the appropriate amount, the engine runs leaner and with less power (lambda () > 1). A larger range of combustion may be achievable when lambda () > 1.2 since the air-fuel mixture is relatively low.

An ideal situation mixing system for fuel and air is called stoichiometry. The ratio of 14.7:1 between fuel and air could improve engine performance, low exhaust emissions, and fuel efficiency. Increased efficiency is possible.

According to the data, AFR Stoichiometry can be accomplished on a real vehicle once the engine has reached operating temperature and is moving at speeds of up to 50 km/h on average. Future automobiles, the state of the roads, and driving habits all affect it.

A braking system is a safety feature in a car that is intended to control movement, slow down, and halt the car. The braking force in a brake system is typically produced by the friction of brake shoes on a field of friction that rotates along with the wheel. The brake system converts motion energy into heat energy as its main mode of operation. In the hybrid technology system, the brake system is employed to enhance the battery's charging status. The battery will soon fill up because the generator charges it frequently while the car brakes. When the battery is fully charged, the electric motor may continue to move the car for longer. The brake system was employed in this study to increase fuel efficiency.

In this study, a gasoline engine with the specifications listed in Table 1 was used. We utilised the wiring layout design depicted in Figure 1 for a realisable design since the ECU Brake Control System was created utilising a microcontroller (with a fuzzy logic controller) and a programmable logic controller.

Table 1. Engine specification

Item	*Specification*
Vehicle	Toyota Soluna
Number of Cylinder	4
Type	4 tag, injection system
Volume	1500 cc

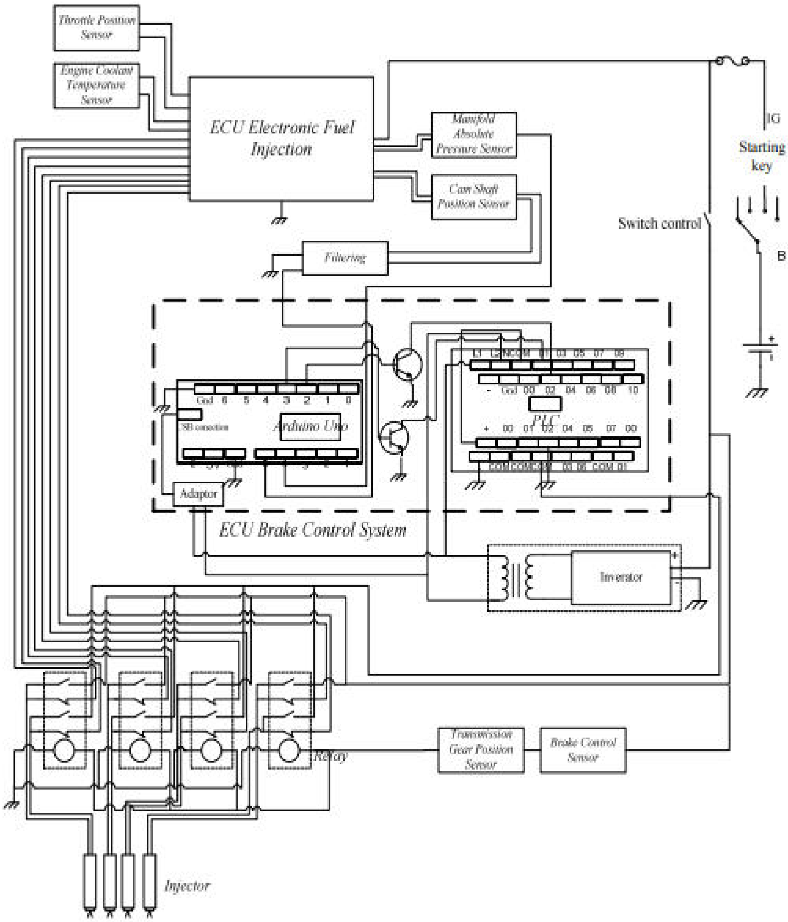


Fig.1: Coils architecture for wireless charging

Embedded fuzzy logic controller in an Arduino Based on the input from the camshaft position sensor and the manifold absolute pressure sensor, a microcontroller system) was created. the pressure sensor. The camshaft position sensor produces an Alternating Current (AC) voltage signal with a voltage range of 0 to 5 volts. These sensors' signals are noisy, making the results of the signals they produce irrelevant. By altering the AC voltage, converting it to voltage Direct Current (DC), and using a number of filters, these issues can be resolved. The PLC was created to produce a pulse signal that would trigger the fuel injector. The length of the pulse signal used by this PLC, which operates on fuzzy logic controller commands, indicates how much gasoline should be supplied into the engine. Controlling fuel injection (to be high AFR or low fuel concentration) during the braking period will result in significantly less fuel use than the default system.

The major goal of this system control design is to achieve fuel efficiency by replacing the ECU default with the ECU Brake Control System when the brake is applied by the driver. If not, the vehicle's ECU will run normally by default.

The architecture for the embedded system's fuzzy logic control input membership functions is shown in Figure 2. The Takagi-Sugeno system is used by the output membership functions, and the switching parameter is 5.

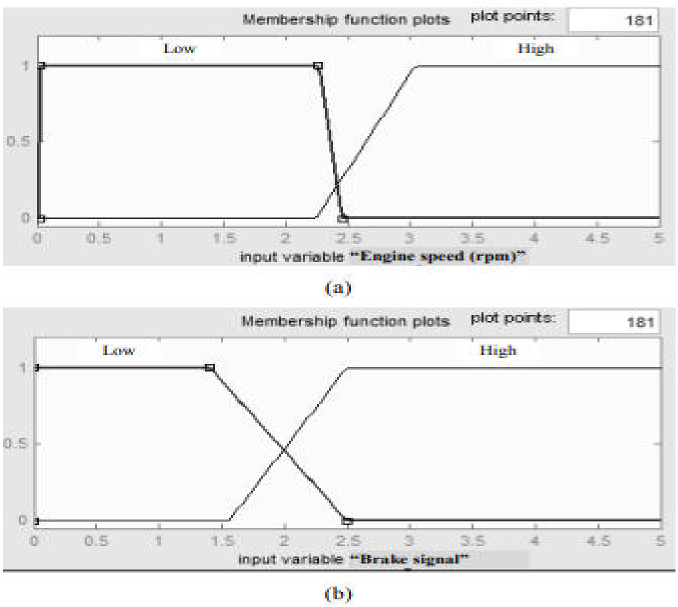


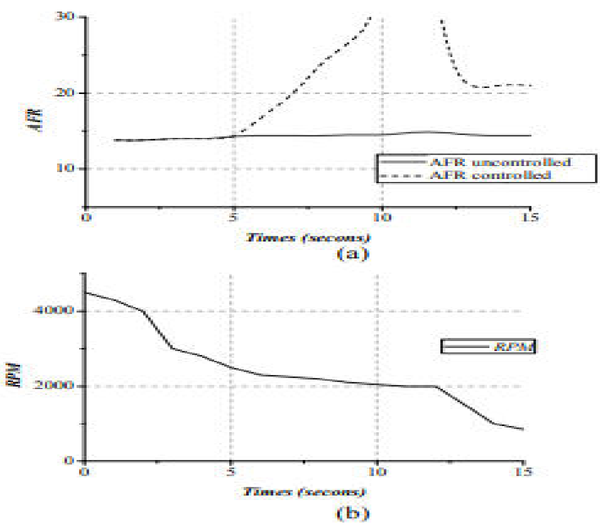
Fig. 2. Input membership functions,

(a) Engine speed input (from camshaft position sensor),
(b) Brake signal (from manifold absolute pressure sensor)

3. IMPLEMENTATION AND RESULT

Engine information gathering AFR was carried out with the help of an engine gas analyzer while the engine was running, the brakes were applied, and the vehicle was moving. The procedure for gathering engine data involved retrieving information based on a phenomenon that occurs in a gasoline engine and was detected by the measuring device.

The value of AFR was read at times of the fifth second while the car was on brakes and the speed transmission gear position 2 of these conditions provided some information, as shown in Figure 3. Between the exhaust from the engine and the car with the gas engine analyser is about 3 metres, so the instrument measures the distance. The steady state system is seen occasionally when it is almost close to 10th second, but when it is more than 10th second, the system functions normally. The car is shown to increase the value of AFR after braking five seconds later. In the graph, the effect of braking on the value of AFR is already apparent, or the fuel and air mixture is reduced.



(a) (b)

Fig. 3. Data AFR with 2 speed gear transmission position, (a) AFR output, (b) Engine speed output

Figure 4 shows the AFR data obtained when the transmission was in the fifth gear and the car was braking

The findings indicate that the trends between speed gears 4 and 3 were nearly identical. Brake When braking,

The control system displays an impact on the AFR value or a decrease in the fuel/air mixture. While

rotation of the AFR value between 3000 and 4500 RPM can reach an unlimited value or result in the complete

termination of fuel injection into the intake manifold, rotation of the AFR value between 2500 and 2500 RPM

achieves the maximum limit on lean mixture. The highest efficiency was produced by this circumstance. Engine

rotation at 2500 RPM without brakes almost reaches AFR stoichiometry Summary result of a running experiment on normal asphalt road about 50.7 km is shown in Table 2.

TABLE 2. RESULTS OF MEASUREMENT OF FUEL CONSUMPTION

No.	Distance	Fuel Consumption	Control
1.	50,7 km	6 liter	-
2.	50,7 km	4 liter	√
	Consumption differences	2 liter	
	Efficiency	33,3 %	

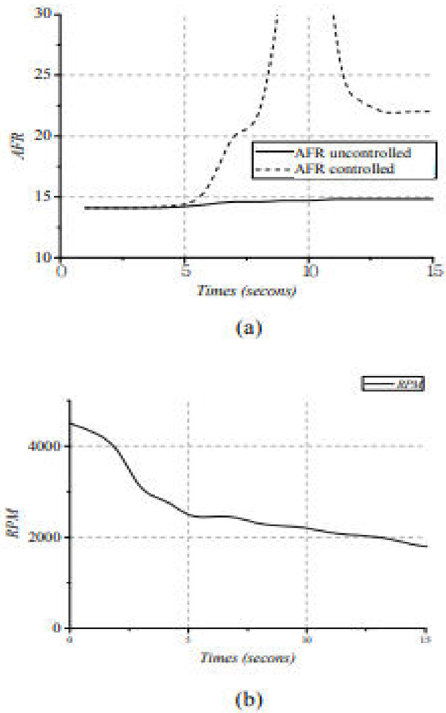


Fig. 4. AFR Data with speed transmission gear position 5, (a) AFR output, (b) Engine speed output.

CONCLUSIONS

Vehicle in a stop-and-go situation while operating in gear position 1 on a straight, a curved, or a descending road, either with or without the brake control system, and AFR levels are normal. This demonstrates that the economizer system in this location is broken. The value of AFR increases when the vehicle travels through horizontal, twisting, downhill, and uphill conditions at speeds greater than 1. At 2000 rpm, the AFR value of the economizer can reach 22, but when the rotation exceeds 2500 rpm, the AFR value increases infinitely or the fuel supply is completely cut off. The AFR system and brake control system developed have been able to cut the fuel consumption from 6 litres to 4 litres when the vehicle is driven over a distance of 50.7 km. Fuel efficiency has increased by about 33.3%. As a result, this study was successful in increasing vehicle efficiency. The vehicle operated on congested city streets or in rural areas where the drivers are preoccupied with braking operations can use this created control system. When the vehicle is operating at a speed above 2500 rpm, the highest efficiency is attained.

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Optimal Electrical Breaking Performamnce

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ABSTRACT

The use of electric braking in traction systems is a promising area of modern research and development. This is also necessary for substantial advancements in the operation of electric vehicles, including the development of performance efficiency, energy utilisation, and a decrease in polluting emissions. The induction machine (IM), with its durability and added benefits of dynamic modelling and identical torque-speed characteristics to those of the traction characteristics, is frequently chosen for electric drive in the traction industry. Regenerative braking is quite effective in the area of energy regeneration, but it has low braking time performance when taking into account the braking performance of the IM.

On the other side, plug braking is extremely effective in terms of how quickly it can stop, but it does so without wasting any kinetic energy in the process. In the current situation, a comparison of the effectiveness of plug braking and regenerative braking has been done in order to create an algorithm that can take use of both techniques' benefits at once.Key words- AFR, brake control system, efficiency, fuel injection, gasoline engine.

***Keywords** : Electric traction; induction machine; regenerative braking; plug braking; V/f control;*

INTRODUCTION

The need for automobiles has multiplied due to the increase in on-road traffic demand. Hybrid Electric Vehicles (HEVs) and Electric Vehicles (EVs) are essential as smart alternatives to conventional vehicles with an emphasis on energy conservation and pollution reduction. The HEVs combine an electrical propulsion system with a mechanical propulsion system. In terms of driving performance & efficiency as well as pollutant emission, this hybridization of HEVs demonstrates its advantages over conventional vehicles with internal combustion (ICs) engines.

However, as mentioned in [1], [2], [4], and [6], the use of two power sources leads to a complex design in terms of energy flow and braking process.To comprehend the complexity of HEVs, there are basically three configurations to consider: (i) series topology; (ii) parallel topology; and (iii) series-parallel topology.

A high starting torque, high instantaneous power, high power density, a wide speed range with constant power and torque region, a quick torque response with high torque at low speeds and high power at high speeds, an efficient operation over wide speed ranges, and a satisfactory operation with regenerative braking are all requirements for an effective traction system. Additionally, it need to be reliable and have operating costs that are acceptable.and durability [5]. The Induction Machine (IM) is chosen because its torque-speed profile is pretty similar to the traction characteristics as illustrated in Figures 1 and 2. EV/HEV applications due to its superior performance and robustness over alternative electrical traction drives [4][6]. The induction machine is chosen as the workhorse for industrial drive systems because to its inherent qualities of dependability, robustness, cheaper costs, low maintenance, and established speed control methods [5]. The IM was modeled using dynamic modeling/d-q modeling [3],[9]; as a result, it functions like a DC machine that is powered by a battery supply.

However, compared to EVs and HEVs, the braking abilities of conventional IC engine vehicles are fairly effective. In the area of electric traction, the braking phenomena are crucial [6]. In conventional cars, the efficiency of the brakes is debatable since a significant portion of mechanical energy is lost as heat during braking, even though the braking is fairly efficient in terms of braking time. The auto industry has responded to this in an overwhelmingly positive manner. A promising area for research and development is the need to enhance the braking capabilities of EVs and HEVs. Regenerative braking and plug braking are frequently utilized as alternatives to mechanical braking in electrical traction systems. This work proposes an algorithm to integrate the utilization of plug braking and regenerative braking while optimizing the drawbacks of each with respect to one another. The entire analysis is completed in MATLAB with the machine's fan load being kept constant.

1. MODELLING OF TRACTION DRIVE

2.

The Electric Vehicles use a suitable battery as their energy source and an acceptable electrical machine for traction. The Induction Machine, which is one of the best traction drive performers when all propulsion system requirements are taken into account, has the added benefit of dynamic modelling, which reduces the mathematical complexity of the 3 IM into its equivalent d-q model in synchronous frame, as shown in Fig. 3.

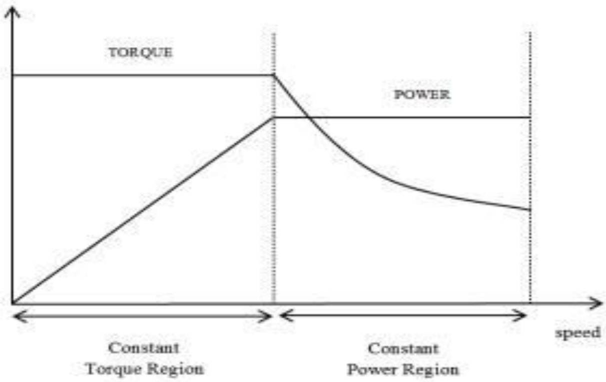

Figure 1. Traction Characteristics

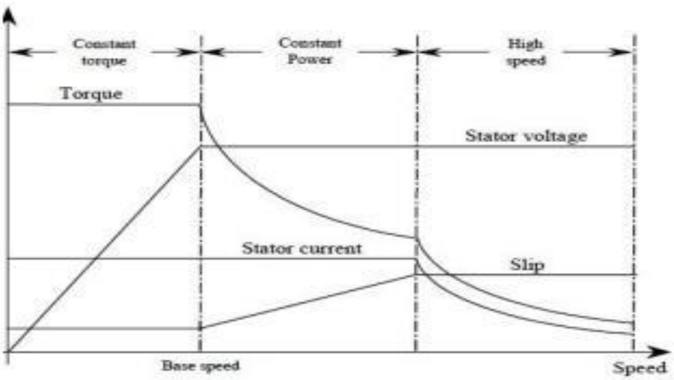

Figure 2. IM Characteristics Curves

A. Mathematical Modeling of IM

Three stationary reference frame variables (a-b-c) can be converted to lessen the mathematical complexity. variables in two stationary reference frames (--0). These are then changed into reference frame variables (d-q-0) that rotate synchronously. Inverse transformations [3], [8]-[11] can be used to extract the three phase variables from the synchronously rotating frame variables. The induction machine's state space model under dynamic settings is given by

TABLE I. DEFINITION OF SYMBOLS USED

d	: direct axis
q	: quadrature axis
s	: stator variables
r	: rotor variables
F_{ij}	: flux linkage variables ($i = q$ or d and $j = s$ or r)
F_{mq}, F_{md}	: q and d axis magnetizing flux linkage variables
v_{qs}, v_{ds}	: q and d axis stator voltages
v_{qr}, v_{dr}	: q and d axis rotor voltages
i_{qs}, i_{ds}	: q and d axis stator currents
i_{qr}, i_{dr}	: q and d axis rotor currents
R_r	: rotor resistance
R_s	: stator resistance
X_{lr}	: rotor leakage reactance
X_{ls}	: stator leakage reactance
L_s	: stator inductance
L_r	: rotor inductance
L_m	: mutual inductance
P	: number of poles
J	: moment of inertia
T_e	: electrical output torque
T_L	: load torque
ω_e	: stator angular electrical speed
ω_b	: motor angular base electrical speed
ω_m	: rotor angular electrical speed
V_{batt}	: Battery Voltage
E_0	: Battery Constant Voltage
K	: Polarization Constant or Polarization Resistance
Q	: Battery Capacity
it	: Actual Battery Charge
A	: Exponential Zone Amplitude
B	: Exponential Zone Time Constant Inverse
R	: Internal Resistance
i(t)	: Battery Current
i*	: Filtered Current

$$\frac{dx}{dt} = Ax + B \tag{1}$$

The state variables can be represented in the form of state vector given as

$$x = \left[F_{qs}\ F_{ds}\ F_{qr}\ F_{dr}\ \omega_r\right]^T \tag{2}$$

Hence the governing equations of a squirrel cage IM can be represented in the state space form

$$\frac{dF_{qs}}{dt} = \omega_b\left[v_{qs} - \frac{\omega_e}{\omega_b}F_{ds} - \frac{R_s}{X_{ls}}\left(F_{qs} - F_{qm}\right)\right] \tag{3}$$

$$\frac{dF_{ds}}{dt} = \omega_b\left[v_{ds} + \frac{\omega_e}{\omega_b}F_{qs} - \frac{R_s}{X_{ls}}\left(F_{ds} - F_{dm}\right)\right] \tag{4}$$

$$\frac{dF_{qr}}{dt} = -\omega_b\left[v_{qr} + \frac{(\omega_e - \omega_r)}{\omega_b}F_{dr} + \frac{R_r}{X_{lr}}\left(F_{qr} - F_{qm}\right)\right] \tag{5}$$

$$\frac{dF_{dr}}{dt} = -\omega_b\left[v_{dr} - \frac{(\omega_e - \omega_r)}{\omega_b}F_{qr} + \frac{R_r}{X_{lr}}\left(F_{dr} - F_{dm}\right)\right] \tag{6}$$

$$\frac{d\omega_r}{dt} = \left(\frac{P}{2J}\right)\left(T_e - T_L\right) \tag{7}$$

The definition of the various acronyms used are defined in Table 1

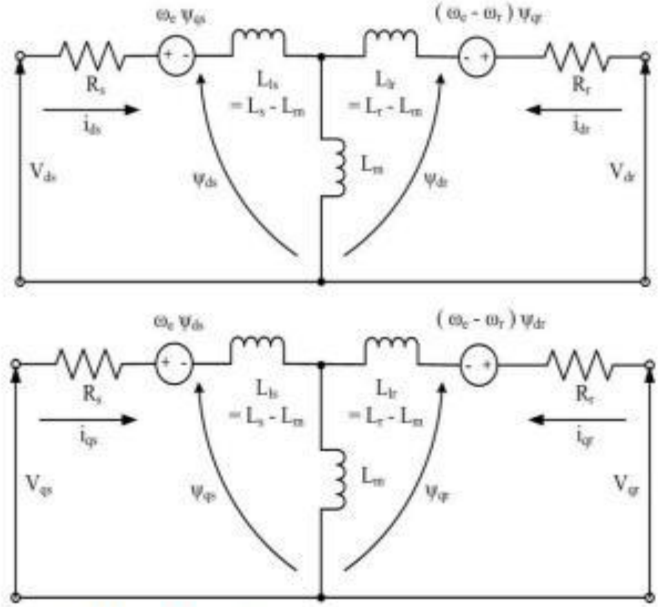

Figure 3. DQ Modelling of IM

B. Mathematical Modeling of Battery

The main source of power in EVs and HEVs is batteries. When applied to electric traction drives, rechargeable batteries are typically used for the purpose of supplying energy to the machine while cruising (discharging mode), receiving energy from the machine during regenerative braking (charging mode), and storing energy when not in use (storage). In terms of particular power, specific energy, efficiency, cost, and maintenance, the batteries should be effective.

The three fundamental characteristics of battery voltage, battery current, and state of charge can be used to mathematically characterise the battery's non-linear characteristic for examination. The Shepherd Model [12]–[16] differs from the Peukerts Model in a number of important ways. According to the internal resistance, discharge current, terminal voltage, open circuit voltage, and state of charge of the battery, the Shepherd model represents the electrochemical behavior of the battery. Here, a Shepherd Model-based mathematical model for

Li-Ion batteries that is available in MATLAB has been applied. Equations (8) and (9) provide the governing equations for battery voltage during charging and discharging. The state of charge (SOC) variation equation is denoted by the number 10.

$$V_{batt} = E_o - R \times i - K \times \left(\frac{Q}{it - 0.1 \times Q} \right) \times i^* - K \times \left(\frac{Q}{Q - it} \right) \times it + A \exp\left(-B \times it\right) \quad (8)$$

$$V_{batt} = E_o - R \times i - K \times \left(\frac{Q}{Q - it} \right) \times \left(it + i^* \right) + A \exp\left(-B \times it\right) \quad (9)$$

$$SOC = 1 - \frac{it}{Q} ; \quad (10)$$

3. BRAKING PERFORMANCE IN INDUCTION MACHINE

The most crucial component of all electrical drives is braking. Any vehicle dynamic system must have efficient braking performance for it to be designed perfectly. We restrict our discussion in this context to simply electrical braking as it relates to EVs and HEVs with electric traction drives [17]–[21]. Regenerative braking, plug braking, and dissipative braking are the three fundamental types of electrical braking. Dissipative braking is ineffective in comparison to regenerative braking, which is renowned for its braking energy efficiency, and to plug braking, which is renowned for its braking time efficiency. As a result, plug braking and regenerative braking are both frequently employed.

Any two of the three supply terminals on the IM can be reversed to reverse the phase sequence of the supply, which tends to move the machine in the opposite direction. In terms of how quickly it can stop, plug braking is highly effective, but there is no power regeneration; instead, more power is used. The machine functions as a generator when operated with a negative slip by moving the rotor in front of the spinning magnetic field, which causes the load to supply power to the supply. Regenerative braking is achieved as the current changes direction and the torque reverses, developing brakes in the drive. Regenerative braking efficiently recharges the battery, but it can't keep up with the fast demand of adequate.

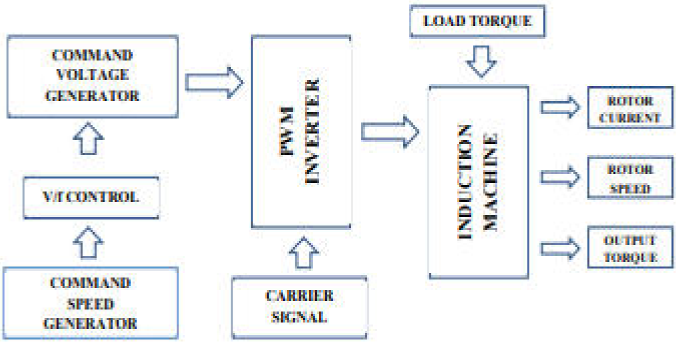

Figure 4. MATLAB/Simulink Model for the Proposed Algorithm

Any two of the three supply terminals on the IM can be reversed to reverse the phase sequence of the supply, which tends to move the machine in the opposite direction. In terms of how quickly it can stop, plug braking is highly effective, but there is no power regeneration; instead, more power is used. The machine functions as a generator when operated with a negative slip by moving the rotor in front of the spinning magnetic field, which causes the load to supply power to the supply. Regenerative braking is achieved as the current changes direction and the torque reverses, developing brakes in the drive. Regenerative braking efficiently recharges the battery, but it can't keep up with the fast demand of adequate of sufficient braking force.

4. CASE STUDY

One of the best techniques for variable Induction machine speed is controlled using the V/f Algorithm [22]-[26]. This approach varies the supplied voltage in proportional to the magnetic field's rotational frequency. The workhorse of commercial enterprises, induction machines find extensive use in electric cars as well as fans, pumps, and hoists. The general purpose inverters are used for operation since they enhance the drive's controlling capability. The V/f control algorithm is thought to be both straightforward and resistant to vector control techniques without speed sensors. In the current situation, the simultaneous variation of the IM's supply voltage and the synchronous rotational speed in the same proportion results in the implementation of the V/f algorithm with dynamic modeling.

An induction machine with the chosen characteristics as shown in Table II has been chosen to demonstrate the discussed algorithm. The IM is dynamically modelled in MATLAB, and the results have been examined to comprehend how braking performance develops while taking into account a typical rated continuous fan load. The block diagram in Fig. 4 illustrates the power and control flow algorithm for the same.

The supply is connected to the IM via an inverter. PWM switching is a technique used to regulate an inverter's operation where a PWM signal generator is regulated by the traditional V/f control technique using the IM speed. The harmonics in the load circuit have been eliminated using a filter circuit.

The input supply voltage to the DQ model of the Induction Machine is changed (as shown in Fig. 6) in proportion to the speed of the rotating magnetic field, and as a result, the voltage changes in relation to the supply frequency. This is done in order to implement V/f control of the IM. The torque fluctuation of an arbitrary load is taken into consideration and is depicted in Fig. 7. As depicted in Fig. 8, the machine's output torque follows the load torque.

Due to surge transients, the output torque initially has a pulsing quality. It calms down and stays steady. The torque fluctuates at t = 0.4 and t = 0.6 s as a result of changes in stator speed. The output torque eventually reaches steady state. According to Fig. 9, the rotor speed corresponds to the stator speed, which is the rate at which the rotating magnetic field rotates. When the load torque reaches 20 N/m at time t = 0.8 s, the rotor speed falls behind the stator speed, indicating that the machine is acting as a motor.

TABLE II. MACHINES PARAMETERS USED

SL.	PARAMETER	NOTATION	VALUE
1	Voltage	V_{RMS}	220 V(l-l rms)
2	Poles	P	4
3	Stator Resistance	Rs	0.435 Ω
4	Rotor Resistance	Rr	0.816 Ω
5	Stator Leakage Reactance	Xls	0.754 Ω
6	Rotor Leakage Reactance	Xlr	0.754 Ω
7	Magnetizing Reactance	Xm	26.13 Ω
8	Base Frequency	fb	60 Hz
9	Base Torque	Tb	11.9 N-m
10	Base Current	Ib (abc)	5.8 Amps

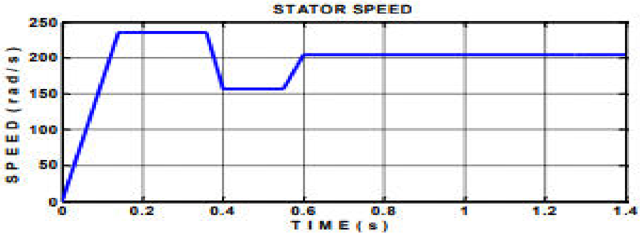

Figure 5. Variation of Stator Speed

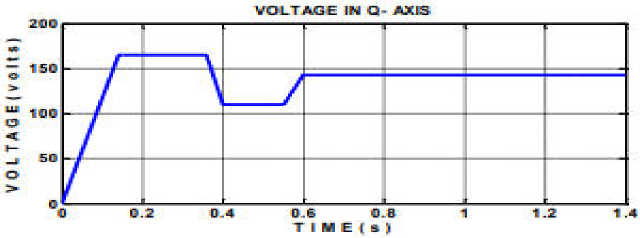

Figure 6. Variation of Q-Axis Voltage

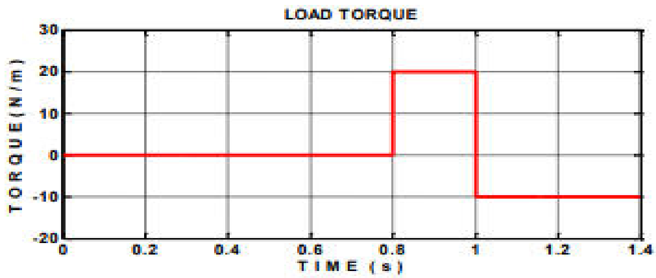

Figure 7. Variation of Load Torque

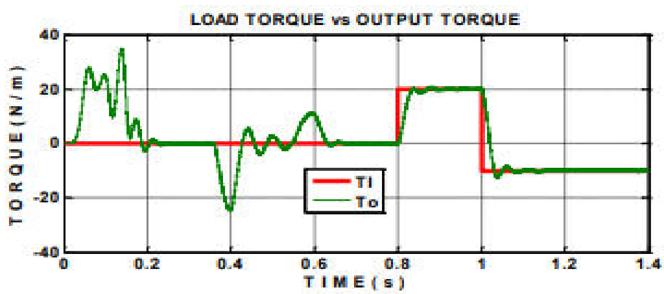

Figure 8. Comparision of Load Torque & Output Torque

When the load torque is decreased at time t = 1, the rotor speed increases and surpasses the synchronous speed, driving the IM like a generator. Figure 10 depicts the corresponding variation in rotor currents. The effectiveness of the induction machine's dynamic modelling has been carefully checked, with the induction machine electric drive being considered to be the best performer for traction systems. The dynamic modelling of the induction machine has simplified the complexity of modelling an induction motor. Through the use of the V/f Control Algorithm, the Induction Machine's operation is examined. The performance of the modelled induction machine is satisfactorily characterised by the variation of the output torque, driving speed, and motor currents with the variation in the defined stator speed and the load torque.

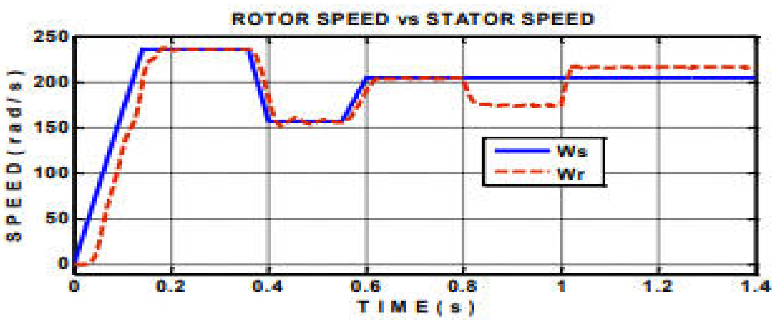

Figure 9. Comparision of Stator Speed with RMF Speed

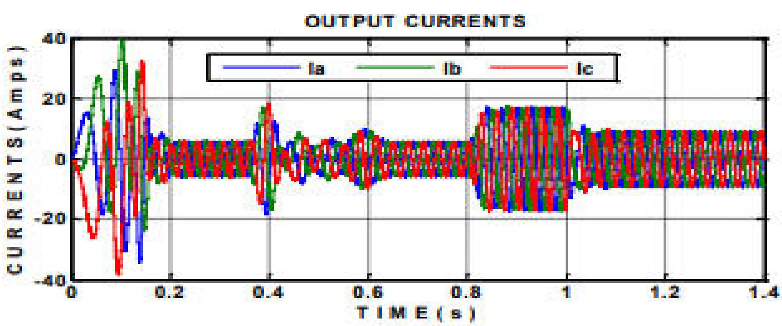

Figure 10. Variation of Output Currents

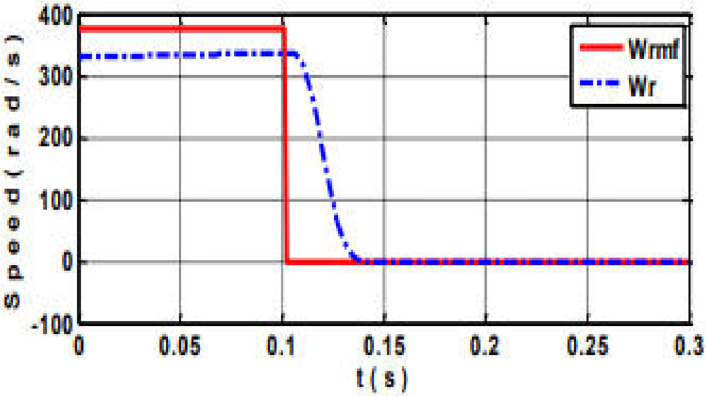

Figure 11. Machine Speed with Normal Load during Plug Braking

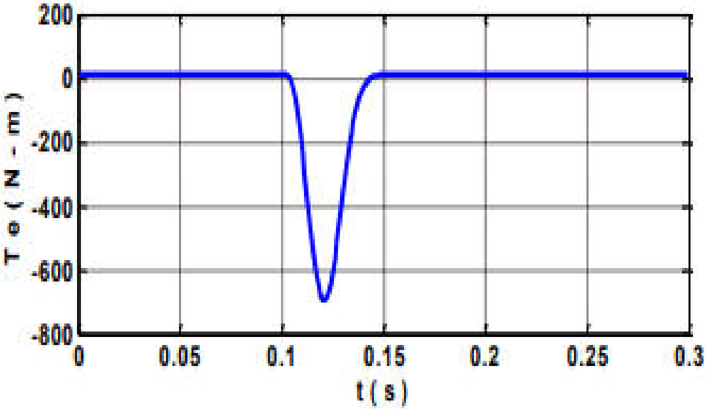

Figure 12. Machine Torque with Normal Load during Plug Braking

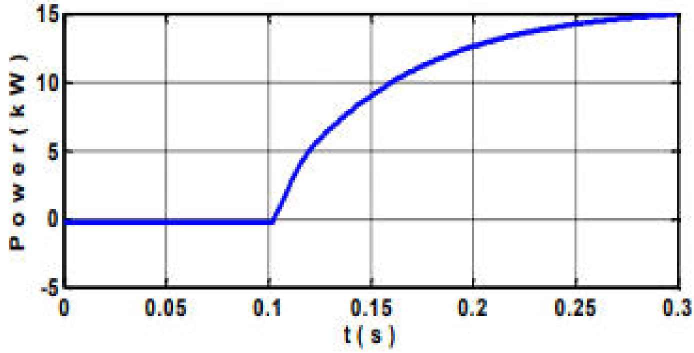

Figure 13. Battery Supply Power with Normal Load during Plug Braking

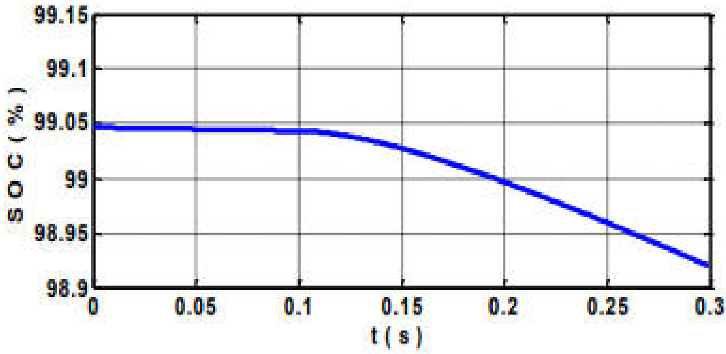

Figure 14. Battery SOC with Normal Load during Plug Braking

Up until it reaches the rated speed, the induction machine is operated at the rated parameters. At time t = 0.1s, the magnetic field's rotation is reversed to start the plug-braking process. However, caution must be exercised to prevent the machine from moving in the opposite way. The results of the analysis have been condensed to just the braking length in order to better understand the performance at the instant of braking. As illustrated in Fig. 11, the rotor speed rapidly decreases and finally retards at t = 0.14s, indicating a quick braking time.

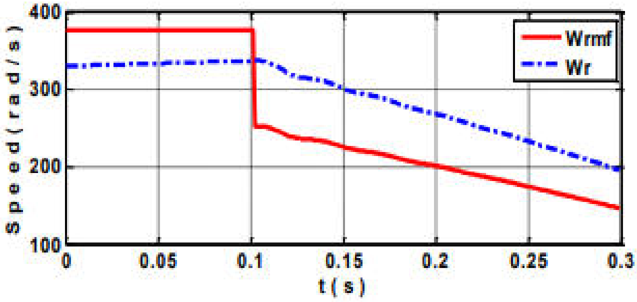

Figure 15. Machine Speed with Normal Load during Regenerative Braking

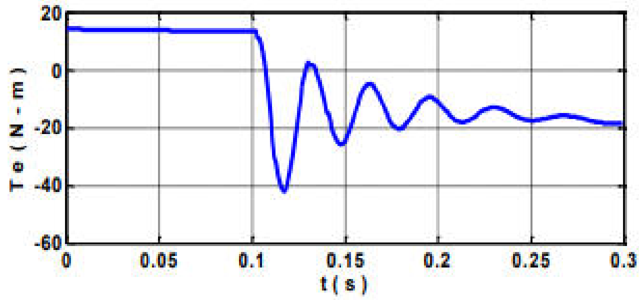

Figure 16. Machine Torque with Normal Load during Regenerative Braking

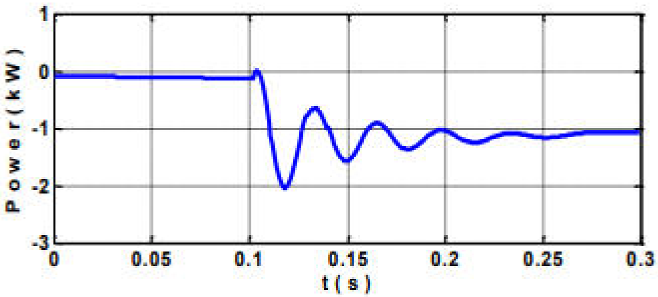

Figure 17. Battery Supply Power with during Regenerative Braking

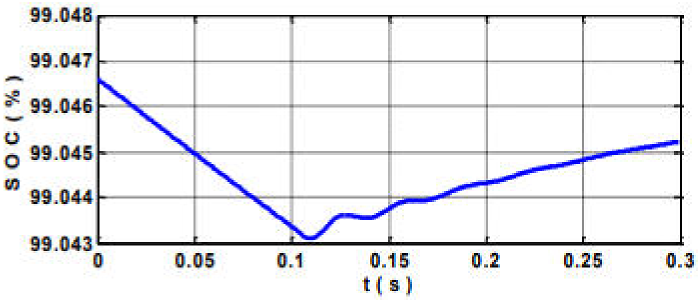

Figure 18. Battery SOC with Normal Load during Regenerative Braking

A peak retarding torque of 700 Nm is generated during the braking process, which is adequate to bring the machine to a complete stop in a brief period of time (Fig. 12). The battery powers the device, which is depicted in Fig. 13 as having positive power. The state of charge (SOC) of the battery decreases from 99.05% to 98.93% when power is dissipated to the associated load, confirming that plug braking uses energy. According to the examination of the results shown in Figs. 11 through 14, plug braking performs extremely well in terms of braking time but falls short when it comes to recovering energy lost during braking. Analysis of Induction Machine with Regenerative Braking Regenerative braking is accomplished by the machine. Driving must be done with a negative slip. This can be accomplished by adjusting the rotational magnetic field's speed so that it always keeps up with the rotor's speed. As can be seen in Fig. 15, the machine needs more time to come to a stop than with plug braking. According to Figure 16, the peak braking torque is just 40 Nm, which is significantly less than the peak plug braking torque. The fact that the machine takes longer to stop due to a lower retarding torque value shows that regenerative braking is less effective than plug braking in terms of braking speed. Although Fig. 17's negative battery supply power indicates that the load is sending power back into the battery, regenerative braking is still extremely favourable as it regenerates power during this braking phase. Fig. 18, which depicts an increase in battery SOC from 99.043% to 99.045%, confirms this.

CONCLUSION

It has been compared how well Plug Braking and Regenerative Braking perform on an Induction Machine Drive with a constant load. This explains both the benefits and drawbacks of plug braking and regenerative braking. When compared to regenerative braking, plug braking produces a quicker braking procedure, making it quite efficient in terms of braking time. However, when looking at how well batteries perform in terms of energy efficiency, regenerative braking feeds power back into the battery from the machine during the braking process, increasing the battery's capacity as opposed to plug braking, which draws power from the battery and subsequently reduces the battery's capacity.

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Optimal Smart Micro-grid integration in DC railway systems

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ABSTRACT

In order to recuperate the energy used in train brakes, this article suggests incorporating the Smart DC micro-grid idea into railway systems. It is founded on keeping extras of increasing the overall energy efficiency by storing braking energy in a hybrid storage system and reusing it for non-railway uses like auxiliary loads nearby or in a station.

Keywords: Railway, Smart Micro-Grid, Electrical braking energy, Hybrid storage system, Power management system.

1. INTRODUCTION

B. Concept of the Smart DC station

A critical load that consumes high power in a brief (several minutes) timeframe is a charging station for electric hybrid buses. It needs a specific subscription agreement in order to have a grid connection. Due to the proximity of some bus stops to metro stations in multimodal transportation systems, the braking energy lost in the metro's rheostat can be utilized to power these buses. However, the braking energy is a variable and intermittent source of power with large instantaneous peaks, making it challenging to use directly without local storage cells to overcome the braking energy's sporadic nature and the time mismatch between the sources and demand (electric buses, station auxiliary loads, etc.). An energy distribution system known as a Smart DC micro-Grid can be used to connect these various components. The fundamental goal of this DC-based idea is to improve power quality by aggregating sources and loads through a DC busbar. Through a shared AC/DC inverter, the DC micro-grid is connected to the AC distribution grid. Depending on the condition and capability of the energy, more energy may then be sent back to the grid storage unit.

Because a load can connect with both sources and loads a common DC bus bar with fewer redundant power conversion stages, which results in less heat being wasted and possibly lower cheaper than a built-in charging station. A "smart power management system" will also optimise power flow between various terminals and tolerate intermittent loads and generators. It will make it possible to reduce the lost energy on metro lines by 15% and make the energy recovered usable for charging the electric hybrid buses parked at metro stations.

No power quality issues exist due to the local management of the energy Even with transformer less**operation (as assumed here) and the utilization of 2-phase AC power, problems will still arise on the AC** grid side. Inverter for levels. This is true even though the energy used for metro braking and electric bus recharge is incredibly sporadic. Moreover, as the bus charging station uses a low power AC/DC inverter, no new contract with the electricity supplier is required. In actuality, the storage system is used to interchange electricity between the loads and the railway system. When there are excess or insufficient voltages, the AC/DC inverter solely controls the DC bus bar voltage. For instance, it might be directly connected to the metro station's current LV power supply. The diagram below depicts the Smart DC micro-grid's architecture:

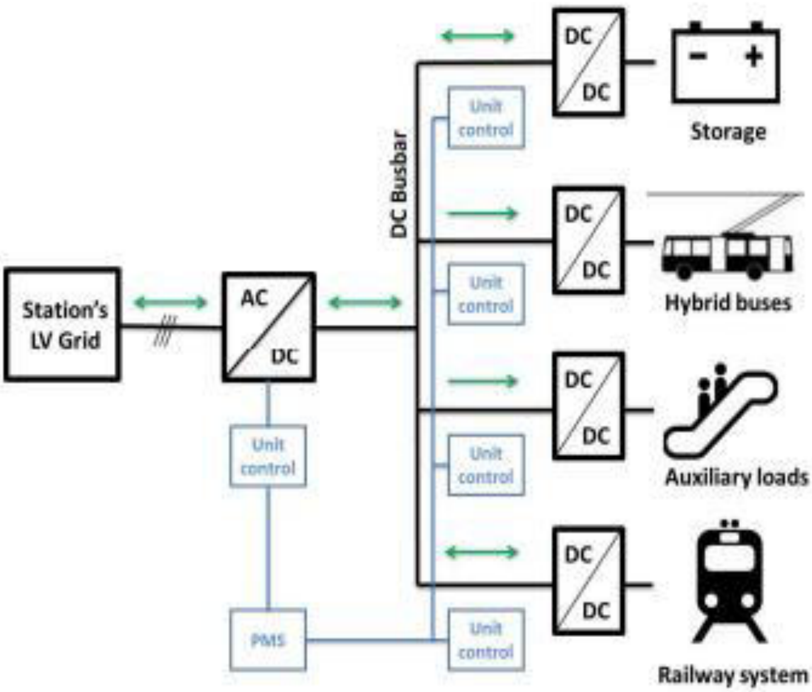

Figure 1. Smart DC micro-grid architecture. Black lines: Power transmission; Blue lines: communication signal transmission

C. Power electronics architecture

A first study will focus on the solution's electronic components. The figure below represents the global architecture of the system:

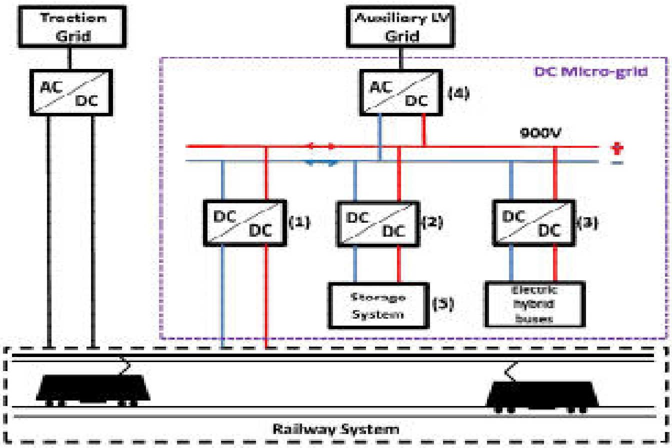

Figure 2. DC Micro-Grid concept

The DC micro-grid architecture consists of the following components:

• A 900V DC Busbar

• 2-level bidirectional inverter (4) connected to the LV power supply already available in the metro station

• DC/DC converters connecting the energy storage (2), railway system (1) and the hybrid buses (3) to the common DC Bus bar

• Hybrid energy storage (5) device containing super capacitors (SC) and batteries.

All these components are modelled and simulated using MATLAB-Simulink.

The DC micro-grid is connected to an auxiliary low voltage grid, as seen in Figure 2. As a result, the DC micro-grid makes it possible to connect the normally separate auxiliary and traction grids. The catenary (or third rail) voltage rises when a train brakes. The converter (1) will recover the braking energy and inject it into the DC bus once the voltage reaches a predetermined threshold. The regulation of this converter should prioritise energy transfer between trains. The converter is controlled at 820V at the railway side in this study. The second DC/DC converter (2) will help lower the DC bus voltage by storing energy. The DC bus voltage is controlled by the AC/DC bidirectional inverter to prevent voltage peaks or drops.

1) AC/DC bidirectional inverter

The DC busbar voltage is controlled by the inverter. It when the voltage is greater than 940V returns energy to the grid and uses energy from the grid when the voltage inferior to 860V. The storage system is given precedence because of this 80V dead zone(figure 3).

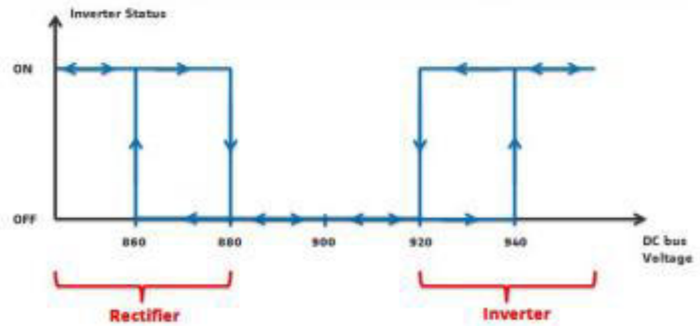

Figure 3. Bidirectional inverter ON/OFF command

Two cascaded control loops make up the inverter's regulating [5]. The DC Bus bar voltage is controlled by the outer loop. On the AC side, it produces the reference current. The AC current is adjusted by the inner loop to match the reference current. It produces the three phase control voltages for the inverter, which are then translated into six pulses using PWM and used to drive the IGBTs.The regulator reduces the DC Busbar voltage to 920V when the inverter recovers the energy. Contrarily, the DC Busbar voltage is raisedto 880V when it injects energy from the grid (the rectifier role).

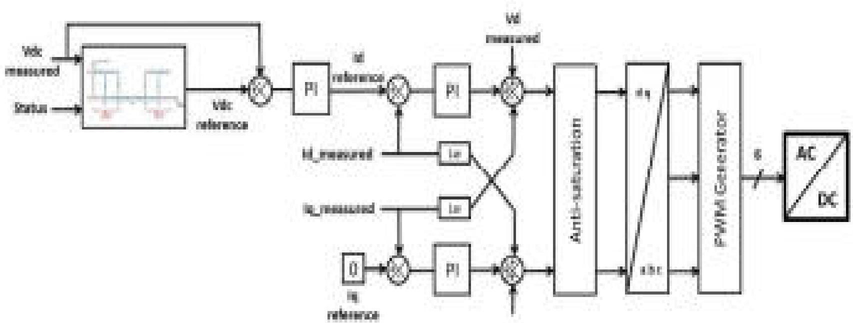

Figure 4. Inverter control loop

2) Hybrid energy storage system

Energy storage systems must be incorporated in order to convert an erratic supply of power to a short-term steady charge. Currently, lithium-ion batteries are the most widely utilized type of technology. However, despite having a high energy density, it has a low power density (figure 5). In addition, the battery has a limited number of charging and discharging cycles, and its properties will deteriorate quickly over time. Therefore, it is doubtful that braking energy will be stored solely in batteries. To match the instantaneous braking power peaks to the battery's finite power, an intermediary storage device is required. Figure 5 makes it abundantly evident that supercapacitors, often referred to as ultra capacitors, are the best option for this application.

In actuality, a super capacitor employs a different form of storage than batteries. The energy has a high power density since it is stored electro statically rather than electrochemically. Supercapacitors can also withstand millions of charge/discharge cycles without losing their ability to store energy.

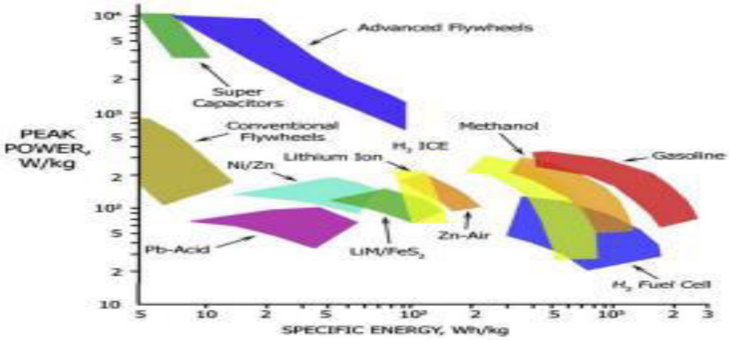

Figure 5. Energy Density & Power Density of Energy Storage Technologies [6]

Therefore, the braking energy is stored using a hybrid storage system. It is composed of two cascading stages, the first of which is a buck-boost converter that is programmed to charge the super capacitor with the recovered braking power and discharge it when a hybrid bus arrives at the station. A steady current is used to charge and discharge the battery in the second buck boost converter. The hybrid storage system modeled with Simulink is depicted in the following figure:

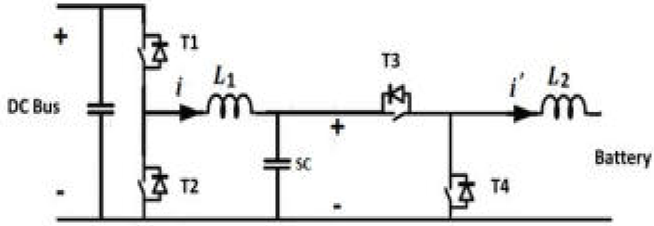

Figure 6. Hybrid storage system model

Two separate control loops, one for each converter, are used to manage this model. The control signals of the IGBTs T1 and T2 guarantee that the reference power Pref (table I) is equivalent to the power absorbed/delivered by the super capacitor. Pref is dependent on the computed super capacitor state of energy (SOE)

$$SOE(\%) = \frac{V_{SC}^2}{V_{SC\_max}^2} \times 100 \qquad (1)$$

The figure below shows the corresponding control loop:

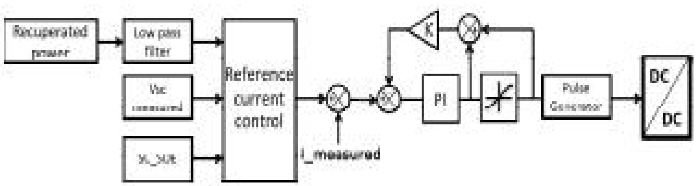

Figure 7. Supercapacitor control loop

The control loop below makes sure that the nominal current (Ibat) used to charge and discharge the battery is constant (In). Table II displays the charging and discharging modes. The super capacitor's SOE affects the reference current for the battery (I_bat_ref). The SOE of the super capacitor is restored to 50% in both modes. In fact, the best case scenario is to have 50% of the usable energy in the SC, which equates to an SOE of 62.5% (table I), if we assume that the charging and discharging modes are equiprobable. However, the SOE will be set to 50% to give precedence to the braking energy because it occurs more frequently. The system will still be capable of responding promptly to the operation mode chosen by the user.

The figure below shows the corresponding control loop:

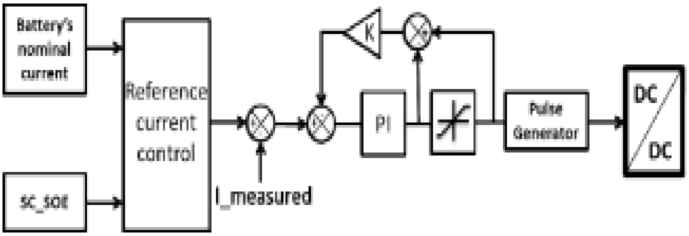

Figure 8 Battery's control loop

The table I represents how the PMS controls the hybrid storage system:

TABLE I. HYBRID STORAGE POWER MANAGEMENT

Charging mode		
Supercapacitor SOE	**Supercapacitor Pref**	**Battery current**
SOE < 50%	Pref=Prec*	Ibat** = 0
50% < SOE < 95%	Pref=Prec*	Ibat** = In
95% < SOE <100%	Pref = (-20*SOE+20).Prec*	Ibat** = In
Discharging mode		
Supercapacitor SOE	**Supercapacitor Pref**	**Battery current**
SOE < 25%	Pref = 0	Ibat = - In
25% < SOE < 30%	Pref = (20*SOE-5).P_discharge	Ibat = - In
30% < SOE < 50%	Pref=P_discharge	Ibat = - In
50% < SOE < 100%	Pref=P_discharge	Ibat = 0

*Recuperated braking power absorbed by the SC

** Battery's reference current

D. Power management system

The Power Management System (PMS) will optimize energy flow by selecting the proper operation mode (OM), controlling the converters and the storage system's SOE.

TABLE II. PMS OPERATION MODE SELECTION

OM	Railway	SC	Battery	Hybrid buses	Auxiliary Loads	Inverter
RM 1	Braking energy available	SOE < 1 (Charging) P1	SOE ≤ 1 (Charging) P2	Not connected	Connected (consuming) P3	Feeding power to the grid P4
RM 2	Braking energy available	SOE = 1 (fully charged)	SOE = 1 (fully charged)	Not connected	Connected (consuming) P1	Feeding power to the grid P2
RM 3	Braking energy available	SOE = 1 (fully charged)	SOE = 1 (fully charged)	Not connected	Not connected	Feeding power to the grid P1
RM 4	Braking energy available	SOE < 1 (charging) P2	SOE ≤ 1 (charging) P3	Connected (Charging) P1	Connected (consuming) P4	Feeding power to the grid P5
SM	No braking energy	Standby	Standby	Not connected	Not connected	Standby
FM	No braking energy	SOE>25% (discharging) P1	SOE>30% (discharging) P2	Connected (charging) P1	To be disconnected	Consuming power from the grid P3
EM	Fault case*	SOE>25% (discharging) P1	SOE>30% (discharging) P2	To be disconnected	To be disconnected	Consuming power from the grid P3

*a need to feed power into the catenary or 3rd rail after fault detection in railway system

The control loop below makes sure that the nominal current (Ibat) used to charge and discharge the battery is constant (In). Table II displays the charging and discharging modes. The super capacitor's SOE affects the reference current for the battery (I_bat_ref). The SOE of the super capacitor is restored to 50% in both modes. In fact, the best case scenario is to have 50% of the usable energy in the SC, which equates to an SOE of 62.5% (table I), if we assume that the charging and discharging modes are equiprobable. However, the SOE will be set to 50% to give precedence to the braking energy because it occurs more frequently. The system will still be capable of responding promptly to the operation mode chosen by the user.

2. SIMULATION

Since it is not possible to establish a direct link between ELBAS and Simulink that would permit a simultaneous simulation, separate simulations should be performed using MATLAB-Simulink and ELBAS [7], a multi-train simulator used by Alstom Transport, to show the effectiveness of the DC grid concept. As a result, ELBAS is first used to simulate the railway system. The recovered power as a function of time is the simulation's output. To be used in the Simulink model, it is provided in the form of an Excel file and then saved as MATLAB variables.

A. ELBAS simulation

The simulation used in this study's evaluation of the amount of braking energy that can be stored is based on RATP metro line 13 in Paris. One of the metro stations is anticipated to include a DC microgrid with a hybrid bus charging station.

Simulated scenarios for four different headways (the amount of time between two consecutive trains) have been created. The simulation timetable was developed in a way that accounts for many potential train crossings:

TABLE III. SIMULATION TIME CALCULATED FOR EACH HEADWAY

Headway (s)	Simulation time
95	2 h 23 min
100	2 h 38 min
175	5 h 08 min
290	5 h 50 min

The line voltage rises when the trains brake. The on-board rheostats are turned on when the voltage hits 900V to safeguard the line against over voltages. To prevent using electricity from the nearest substation, the input voltage of the converter should be lower than 900V and higher than the no load voltage. The closest substation in this situation has a no-load voltage of 750V. The input voltage of the converter was then set to 820V.

The simulations were run with a 10 m KP (Kilometric point) step and a 1 s time step. At each time step, ELBAS calculated the converter's recovered power. The profile of the power recovered by the DC/DC converter connected to the railway system is depicted in the image below. In order to use it as an input for a MATLAB Simulink model, it is extracted into an Excel file.

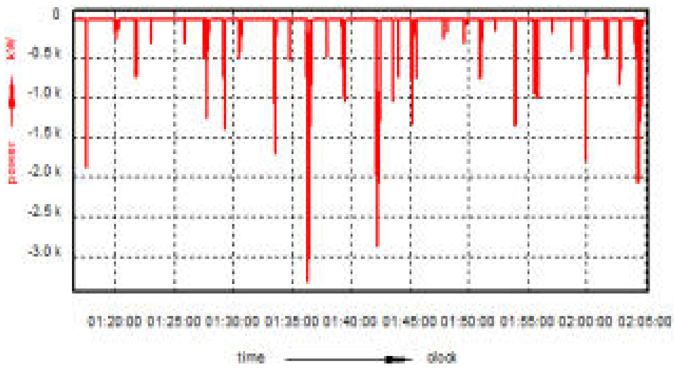

Figure 9. Converter's time function power curve extracted from ELBAS

The trains' speed profile and relative position affect the intermittent power pulses. When multiple trains are braking simultaneously and sufficiently close to the DC/DC converter, more power is recovered. The use of supercapacitors is justified by the fact that these power peaks typically last less than 10 seconds.

B.MATLAB-Simulink simulation

The system was modelled in MATLAB-Simulink to determine the quantity of energy that may be stored once the recovered power from ELBAS was extracted. The Maxwell 125V modules make up the used super capacitor model [8]. It has a continuous total power output of 735 kW, and its absolute maximum power is 9.5 MW. The battery is made up of Nano phosphate AMP20 Energy Modules from A123 [9]. These batteries are famous for their 2400 W/kg high power density.

When there are no connected hybrid buses, the figures 10 and 11 depict the temporal evolution of energy fed back to the LV grid from the battery. These energies are now lowest for the headways 95s and 290s, which correspond to peak and off-peak hours, respectively. In the first instance, trains are too near to one another and use up a lot of the braking power. In the second scenario, there are significantly fewer trains, which leads to poor station-level energy recovery from braking.

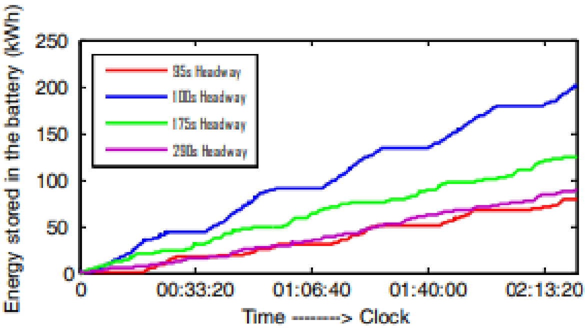

Figure 10. Energy stored in the battery for different headways

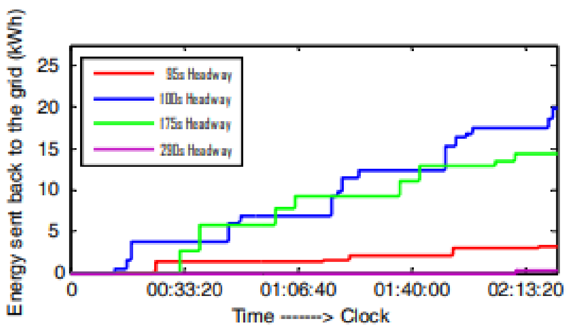

Figure 11. Energy sent back to the grid for different headways

The figure below represents the braking energy distribution per hour:

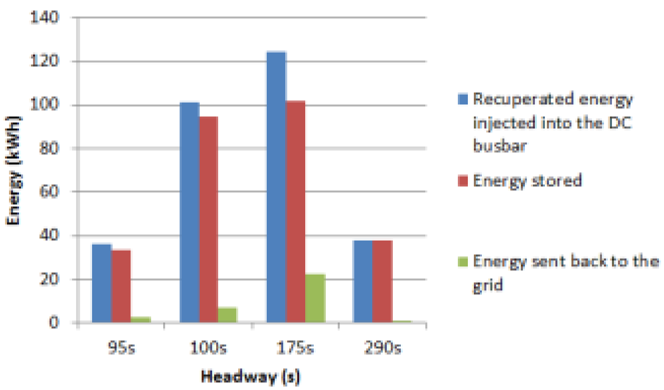

Figure 12. Braking energy distribution per hour

A significant portion of the recovered energy can be stored by the hybrid storage system. Even for the headways 95s and 290s, where the energy stored is comparatively smaller than the other two headways, this energy can fully charge a hybrid bus with a constant power of 200 kW per hour in under 4 minutes. The energy that is given back to the grid, on the other hand, will be consumed by the station's loads (lights, screens, escalators, etc.), lowering the overall energy bill.

CONCLUSION

In this study, awas g smart DC micro-grid solution for brake energy losses in railway systems iven. It investigated the viability of storing this energy and using it again in different contexts. It was made up of a DC busbar that connected several parts, including an inverter for controlling the voltage of the busbar, DC/DC converters for linking the railway system, static loads, hybrid buses, and lastly a hybrid storage system. In order to optimize power flow and energy usage in a plug-and-play fashion, a power management technique was devised. Simulations have demonstrated that it is feasible to recover enough energy to refuel hybrid buses. This approach has the benefit of being connected to the low voltage grid (230V/400V), which eliminates the need for a separate contract to charge the buses and instead allows the extra braking energy to be used internally by other loads in the station, lowering overall energy usage.

It is significant to note that these outcomes are dependent on the railroad system under simulation. They could significantly vary from one line to the next. Because of this, each line should be viewed as a distinct use case with its own study; however the process can be repeated.

ACKNOWLEDGMENT

Without the direction and assistance of numerous people who all participated in some manner, this project would not have been feasible. I want to start by thanking ALSTOM Transport for giving me the chance to work on the European project OSIRIS and for assisting me in growing as a professional. A special thanks to Supélec for providing me with the academic assistance I required. I also want to thank ALSTOM Grid Stafford and RATP for their assistance with this project. Finally, I want to express my gratitude to the ANRT (association national research et de la technologies) for funding my thesis and believing in this creative idea.

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Optimal Operation Control Strategy for Photovoltaic/Battery Micro-grid

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ABSTRACT

One of the important technologies for ensuring the security and stability of micro-grid operation is the control strategy. The micro-grid system with energy storage device's grid-connected/islanding operation control method is examined in this study. The outer voltage loop and inner current loop method is used for grid-connected inverters in this mode. The V/f control technique with the battery system is utilized in island mode to maintain steady PV system voltage and frequency. Improved V/f control strategy based on double closed-loop quasi-PR control technique is proposed to reduce the steady state error on tracking the AC voltage and to achieve zero steady-state error control across a larger frequency range. In the meantime, the power quality has improved and the PCC bus voltage fluctuation has been significantly reduced. The simulation results demonstrate that the suggested control method is effective.

Keywords:*photovoltaic/battery micro-grid system; battery system; PCC bus voltage; V/f control; PR control*

INTRODUCTION

Solar energy, which is green and clean energy in the face of an intensifying energy crisis and a deteriorating ecological environment, is becoming a worldwide hotspot and is enjoying strong government support.

A successful method to increase the effectiveness of dispersed generation is to use a micro-grid, a cutting-edge technology that is based on solar power generation. However, the micro-grid system includes flaws including randomness and volatility, which impairs the micro-grid's ability to operate safely and steadily [1-2].

There have been numerous studies conducted on solar micro-grids with energy storage technologies both domestically and overseas .Because the optical storage system is unstable when the micro-grid is operating, literature[3] suggests using PQ control and V/f control to assure the stability of the micro-grid voltage and frequency. And according to the literature[4], several micro-grid integrated control strategies may be created based on the various access methods for energy storage devices, realising steady functioning of the micro-grid in both grid-connected mode and island mode as well as seamless changeover between the two modes. A multi-main power control technique based on V/f regulated micro-power supply is proposed in the literature[5] as a master-slave control strategy for island operation. It is capable of good adaptation. A novel multi-master-slave control method was discovered in literature[6]. The control approach improves upon the weaknesses of both the conventional droop control and the V/f control by combining their strengths. Less study has been done on micro-grid systems that use energy storage, though, according to the literature [7]. Additionally, the Traditional V/f control has a steady-state inaccuracy and a poor response time when utilized to track the AC voltage.

This research investigates the grid-connected/island operation control approach of the micro-grid system with energy storage device in response to the aforementioned circumstance. The outer voltage loop and inner current loop strategies are used for grid-connected inverters in this mode. In island mode, the addition of the battery storage device and the adoption of better V/f management may offer a voltage source for the microgrid system that has a constant voltage amplitude and frequency and ensure the voltage and frequency of the PV system are stable. The double closed-loop quasi PR control technique serves as the foundation for the improved V/f control strategy. A broader frequency band can be used to produce trace load switching that responds more quickly and zero steady-state error control. In the meantime, the power quality has improved and the PCC bus voltage fluctuation has been significantly reduced. The V/f control model is designed for examination and comparison in the MATLAB/Simulink simulation environment. Control Mechanism analysis of photovoltaic/battery micro-grid the photovoltaic/battery micro-grid operating structure diagram is shown in Figure 1 of this research. The components of the solar inverter are the front stage boost circuit and the last stage inverter circuit are both separate components. The front stage circuit achieves boost and maximum power point tracking on the input side of the inverter to produce a steady DC voltage. The photovoltaic power supply's DC inverter and grid connection are implemented in the final stage circuit. Line impedance is line Z. s L and s R stand for filter inductance and parasitic resistance, respectively. Filter capacitor C is.

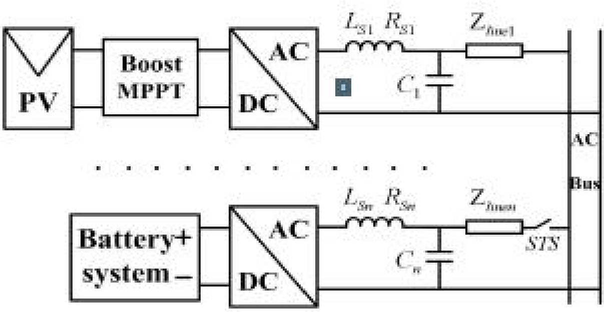

Fig1 The operational structure diagram of the photovoltaic/battery micro-grid

The connection between the energy storage system and the electricity grid is made by a static switch. When the micro grid is running normally, When the micro grid fails, the static switch is closed and the energy storage device is added to provide the constant voltage amplitude and frequency for the micro-grid system. This also provides phase-locked reference for photovoltaic grid-connected inverters. The static switch is disconnected and the inverter operates in the grid-connected mode .Control mechanism of photovoltaic grid-connected When the inverter is in the grid-connected mode, the outer voltage loop and inner current loop strategy is mainly adopted.

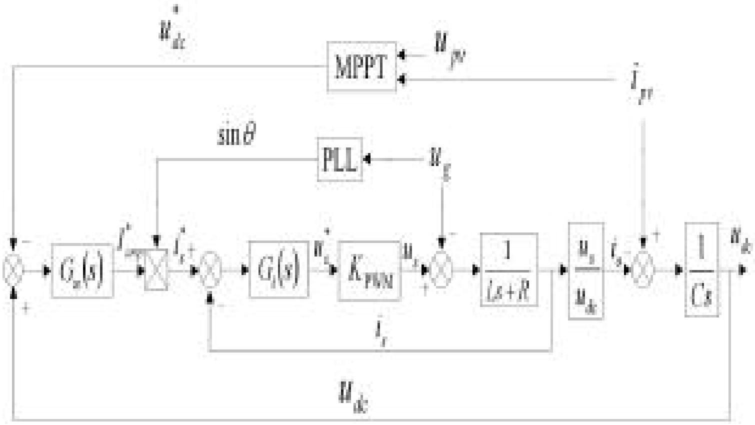

Fig 2 Control strategy block diagram of single-phase photovoltaic grid-connected inverter

A single-phase motor block schematic is shown in Figure 2. Regarding the grid-connected control scheme for the inverter. Commanding the DC bus voltage. The MPPT module determines dc u. The voltage loop controller Gu(s) receives the difference between the actually detected DC bus voltage and the reference value in order to determine the inverter current reference value To guarantee the voltage on the DC side of the inverter is steady, a PI controller is typically utilized. When the grid voltage is detected, the phase-locked loop (PLL) generates a sinusoidal signal sin with a frequency, phase, and amplitude of 1.The inverter current reference value is equal to the amplifier of sin and the inverter current reference amplitude .We can control the inverter output with a certain current to connect to the grid after the current loop controller receives the difference between the inverter current reference value and the actual value. Island control mechanism of battery system**.** When in island mode, the energy storage device controlled by V/f can supply the system's inverter with the voltage and frequency it needs .Currently, the energy storage device serves as the primary control power source, and the grid connection mode controls the other inverters. Figure 3 displays the V/f power supply's controller output properties. When the active power of the V/f power supply output is between Pmin and Pmax, it can keep its output frequency constant.

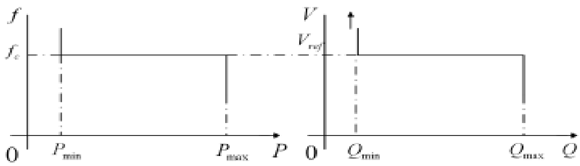

Fig 3 Output characteristics

Operation scheme of photovoltaic/battery micro-grid

When the photovoltaic/battery micro-grid is operating in the grid-connected mode, the battery system works in tandem with the photovoltaic system to provide high-quality power for the distribution network and the load; the grid connection switch is turned off when the frequency and voltage of the distribution network or the PCC point are detected to have been crossed.In this instance, the control mode is changed to the operating mode for the island.

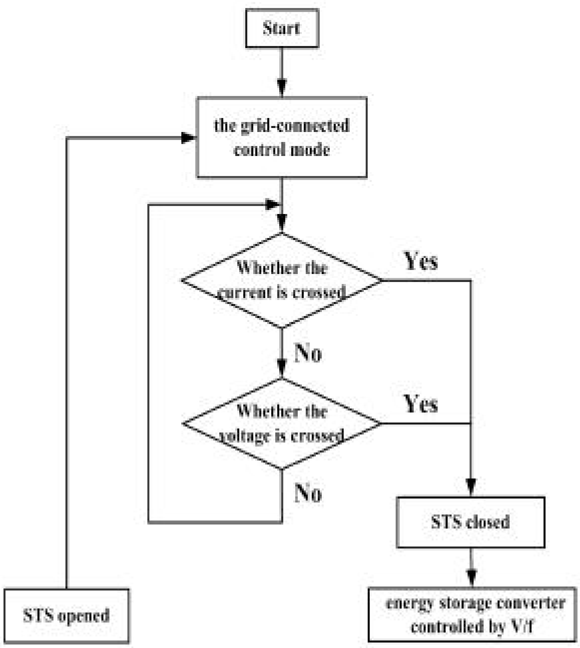

Fig 4 The operational flow chart of the Photovoltaic/Battery Micro-grid

Design of the improved V/f control

The PCC voltage is frequently impacted by load changes in the microgrid when in island mode. The V/f control mode needs to have a high dynamic response capability in order to react quickly to load changes and maintain steady inverter output voltage. Voltage and current double closed-loop quasi PR control is used in the V/f control scheme.It may ensure the output voltage's stability by adjusting the AC side voltage using the inverter feedback voltage. The inverter's dynamic reaction quickens, its bandwidth of the inverter control system expands, and its capacity to adapt to nonlinear load disturbances also improves. Figure 5 depicts the revised V/f control mode's organizational structure.

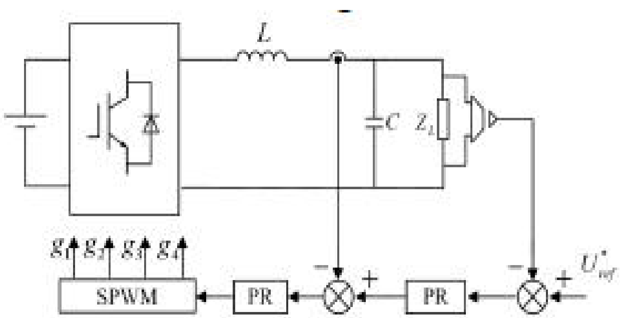

Fig 5 Operation control Strategy of battery system

It is challenging to implement the control without static because the conventional PI regulator lacks infinite gain at the base frequency. Difference. As a result, in this paper, the PR control approach is used. The output voltage can be controlled non-statically with the PR controller, which also enhances the parallel system's uniform flow effect. A PR controller is used in the current loop to reduce current fluctuation and strengthen the system's ability to block interference.

The transfer function expression of quasi- PR controller is:

$$G(s) = k_p + \frac{2k_r\omega_b s}{s^2 + 2\omega_b s + \omega_1^2} \qquad (1)$$

The proportional coefficient (kp), resonance coefficient (kr), bandwidth frequency (b), and fundamental angular frequency (b1) are all part of the formula. Maximum gain is attained using the quasi-PR control approach at the fundamental frequency:

$$G(s) = k_p + k_r \qquad (2)$$

Take, for example, the inner current loop,according to the current control loop of Figure 6:

$$i_L = \frac{G_i(s)K_{PWM}}{sL_S + R_S + G_i(s)K_{PWM}} i_{ref} - \frac{1}{sL_S + R_S + G_i(s)K_{PWM}} u_o \quad (3)$$

Bring formula (1) into formula (3), and if kp and kr are properly chosen, the output current of the inverter can be as consistent as possible with the reference value of the current, realising non-static control of the current and enhancing the system's response time.

5. Analysis of simulation result

Simulation software is used to set up the model in order to validate the timeliness of the V/f control model in Micro-grid operation. In the simulation, the output of the pre-stage circuit of the PV inverter is replaced by the 400V DC power source. Table 1 displays the parameters of the system.

The power grid is out of order during time t=0.2s, during which the system is converted to island mode. during time t=0, the master-slaver inverter is operating in the grid-connected mode. P = 3 kW at this time.

Table 1 Main parameters of single-phase micro-grid

Nomenclature	Symbol	Value
Storage device voltage	U_{dc}	400V
Bus voltage	u_g	220V
Filter inductance	L_S	5mH
Filter capacitor	C	10μF
Switching frequency	f	50Hz
Line impedance	L	0.01+j0.0314Ω

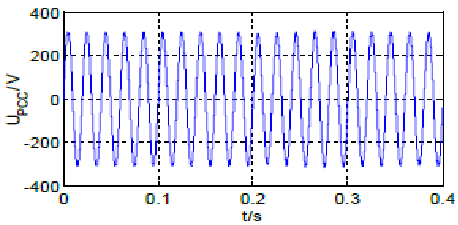

Fig 6 The voltage of PCC point

The PCC point's voltage is displayed in Figure 6. When using the improved V/f control, the system's frequency remains constant within the permitted range and the voltage fluctuation is less than 20V. The master-slave module monitors the power change caused by load switching; when a load is added, the master-slave module's output of active power and reactive power decreases; when a load is removed, the output of active power and reactive power increases. It is clear that the master-slave control model can properly track the load disturbance, ensuring the stability of the isolated island's operation and effectively realising the load average flow.

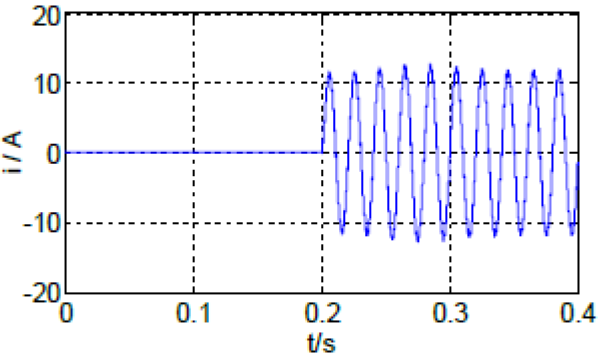

Fig7(a) The output current of energy Storage converter

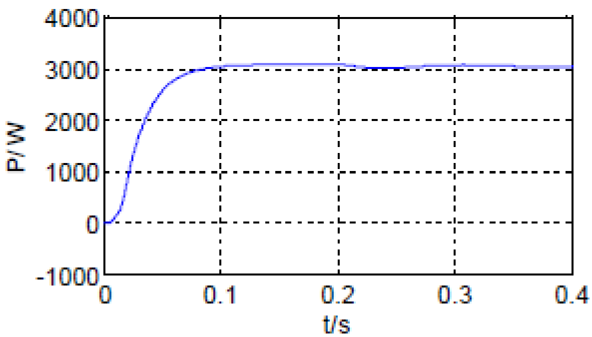

Fig7(b) The output active power of Inverter

The output of the energy storage system for better V/f management is shown in Figure 7. As demonstrated in figure 7(a), the system's dynamic response time is quicker, and after the initial period, the output current of the energy storage converter is stable. As a result, the output current can be achieved with static control using the PR controller that has been adopted. Figure 7(b) demonstrates that the photovoltaic inverter's output power fluctuation is minimal, allowing for greater V/f management to guarantee the stability of the photovoltaic/battery micro-grid.

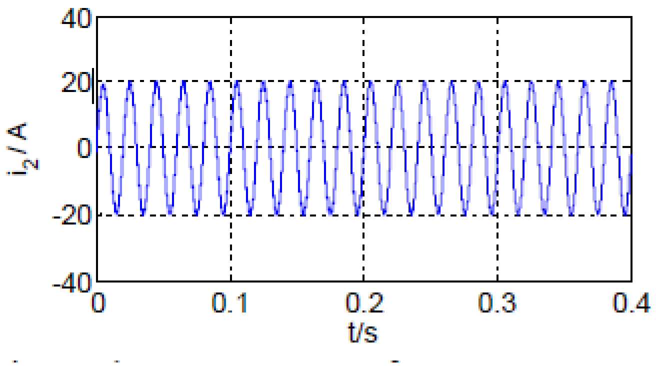

Fig8 The output current of energy storage device

The output current of the energy storage device is shown in Figure 8. The output current fluctuates very little when the load is reduced, as shown in the figure, and the enhanced V/f is implemented may offer steady voltage and frequency reference, giving the system a reasonable degree of robustness.

6. Conclusion

The control mechanism of the optical storage micro-grid system and island mode is first examined in the article. The grid-connected inverters use double closed loop control in grid-connected mode. In island mode, a battery storage device is introduced and an improved V/f control is used. This allows for the export of a voltage source that has a constant voltage amplitude and frequency and serves as a voltage reference for inverters that are linked to the grid. The V/f control model is created in the Matlab/Simulink simulation environment for study and comparison. The simulation findings demonstrate that the double closed-loop quasi PR and better V/f management can increase optical storage system stability by lowering PCC point voltage fluctuations.

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Optimized Monitoring of Electrical Bus

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ABSTRACT

The impact of smart grid technologies on national grids is highlighted in this article, which also makes some practical recommendations for policymakers looking to upgrade their traditional grid system to a smart grid system. This problem is especially vital for keeping an eye on the health of employees working in hazardous locations, like mines and construction sites. In this study, we offer a wireless charging system for a smart-wear health monitoring application for workers while taking into account the power consumption needs of communication technology, sensory hardware, and real-world charging circumstances. We also show a functioning prototype of the 5-watt wireless charger that our wearable health monitoring device uses. In this article, we present the design of a "wireless charging bin" that we are currently designing for our application environment, as well as an analysis of the needs and the important components.

Key words-*resonant wireless charging, smart wearable, health monitoring.*

1. INTRODUCTION

For customers to check their health and fitness, using smart wearable devices to monitor daily activities has become a key trend. Smart watches and fitness trackers like Fit bit, and Xiaomi have grown significantly in the last few years. For instance, the second quarter of 2018 saw a 5.5% increase in the global wearables market growth over the same period in 2017, with 27.9 million devices sold, according to the International Data Corporation [1]. Furthermore, 233 million smart wearable devices are anticipated to be sold globally by 2022, growing the market to $27 billion [2], according to Forbes.

The use of smart wearable devices to monitor the health and safety of workers, especially those who operate in hazardous environments, is a new trend that has been made possible by improvements in the creation of biometric sensors. Operate in challenging work conditions like those found in mining, construction, manufacturing, and agriculture. Wearable electroencephalogram (EEG) sensors, infrared temperature sensors, and wearable heart rate monitors, for instance, make up a unique method for real-time monitoring of fatigue in construction workers [3]. It has also been suggested to use a wearable system based on accelerometers to measure skeletal muscle vibrations in order to identify skeletal muscle fatigue [4]. Additionally, workers' spike movements can be monitored using wearable technology to avoid major injuries [5].

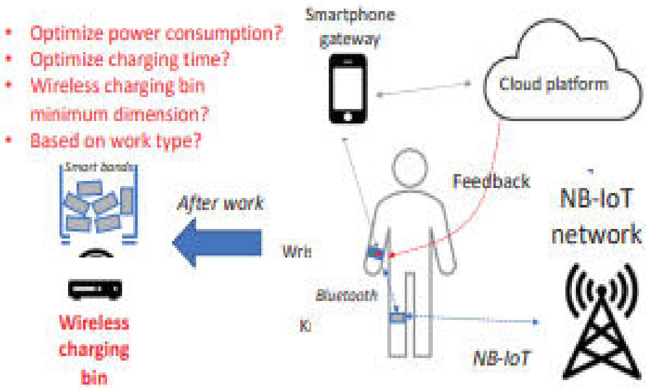


Fig.1.Wireless charging bin for smart wear of workers after use.

The system architecture of the smart wearable system we created for employees, as well as the "wireless charging bin" system for charging the batteries of smart bands, are shown in Fig. 1. The intelligent wearable system gathers biometric data and sends it to the cloud for analysis in order to keep track of the health and safety of employees. When workers are in danger, alert signals can be issued through a feedback system to let them know. Employees will place their smart bands in a "wireless charging bin" at the conclusion of their shift so that they are completely charged for their subsequent shift. In order to create a useful "wireless charging bin" for our scenarios, it is crucial to think about the following issues:

1) How should the smart bands' power usage and wireless charging time be optimised to maximise battery size?
2) What wireless charging efficiency should be used to determine the 'wireless charging bin's' design specifications?

We discovered that a device's acceptance by users and employers decreases with its level of intrusiveness [6].
As a result, there are a lot of limitations to designing an efficient smart wearable for work contexts.
(i) Small size
(ii) Many sensors for gathering various biometric measures,
(iii) Technology for communication. The aforesaid limitations have led to a significant issue with battery life per charge and overall battery lifetime.

It has been a long-standing scientific challenge to create a long battery life for smart wearable devices while keeping it small [7]. The obligation to continuously monitor employee health in order to maintain compliance with safety regulations exacerbates this problem [8]. In addition, wired plug-ins of cables are expensive and may limit the flexibility of such a system [9] when used to recharge the batteries of numerous devices after usage. As a result, wireless charging for wearable technology has gained popularity [10].

The analysis of power consumption of (ii) and (iii) and an understanding of the application context for monitoring the health and safety of workers need to be jointly considered when designing an efficient wireless charging system because the battery embedded in the smart wearable device faces significant size constraints. Following are our contributions to this paper:
• We demonstrate the creation of two wirelessly rechargeable wearable health monitoring modules (a knee and bracelet, respectively) for workers in challenging conditions.
• We examine the energy usage of the wearable health monitoring modules and the data transmission system that sends measurements to the cloud.
• Following that, we give the findings from our recently created resonant wireless charging system, which will enable us to gauge the 'wireless charging bin's' design specifications.
• As a last step, we demonstrate a functional prototype of a 5-Watt wireless charging system for our wearables.

2. Health monitoring wearables for worker

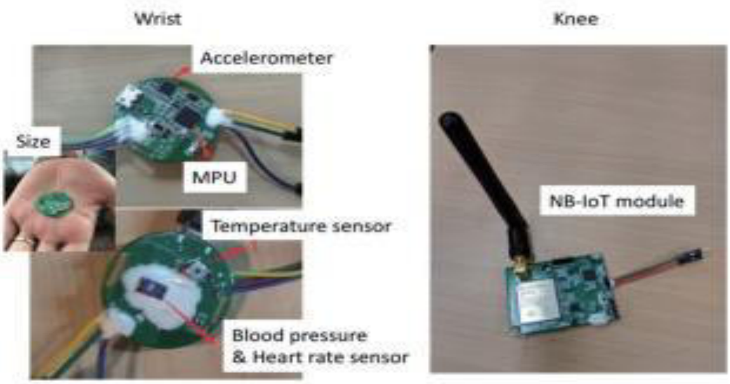
A. Multiple sensors to generate health metrics

The majority of the fitness wearables on the market now offer basic data on physiological parameters like heart rate, body temperature, and number of steps. Normal users might lack the information necessary to understand the significance of these measures' variances. Supervisors and employees need accurate health measurements, such as the degree of exhaustion, dehydration, and osteoarthritis, to show the workers' current health state in high-risk physical activity work situations.

Multiple sensors are needed to gather the biometric data needed to do that. As depicted in Fig. 1, a wristband with an accelerometer measures the worker's movement and posture; a temperature sensor measures the worker's body temperature; and a blood pressure and heart rate sensor measures the variability of the worker's heart rate and blood pressure while they are performing physical tasks. These unprocessed biometric measurements will then be used as inputs by the health metric algorithms to calculate worker risk for osteoarthritis, level of weariness, and dehydration.

B. Size of the wearable modules

As stated in the Introduction, the likelihood that a gadget will be accepted by users and employers decreases as it becomes more obtrusive.



As a result, the wearable gadget is severely limited in terms of size. The wrist wearable prototype module we created is smaller and less obtrusive than the knee module, as illustrated in Fig. 2. The physical dimensions of the former are 3 3 cm, whereas the latter are 3 5 cm. Both modules are prepared for commercial implementation as bracelets that users can wear. However, due to the small size of the modules, building a wireless charging system for the modules has proven to be extremely difficult.

C. Communication Technology

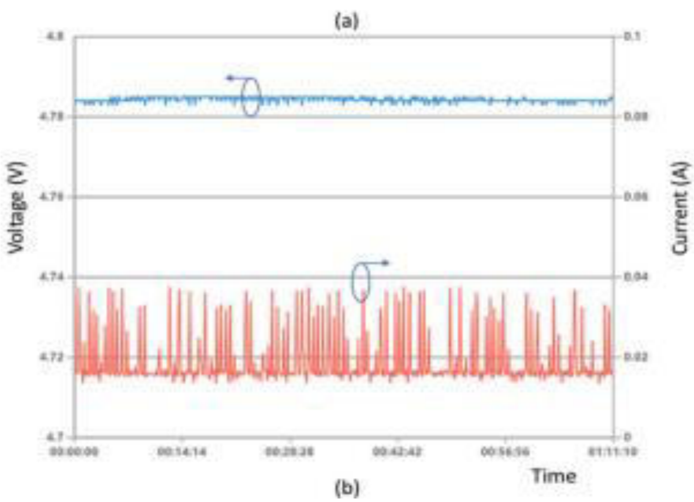
A communication module is necessary for wearable devices to communicate data to the cloud, where health analytics will be performed. WiFi and Bluetooth with a smartphone acting as a gateway appear to be the customers' preferred communication methods at home. Communication technology like Zigbee is crucial for Internet-of-Things (IoT) applications like smart agriculture, home automation, and smart grid.

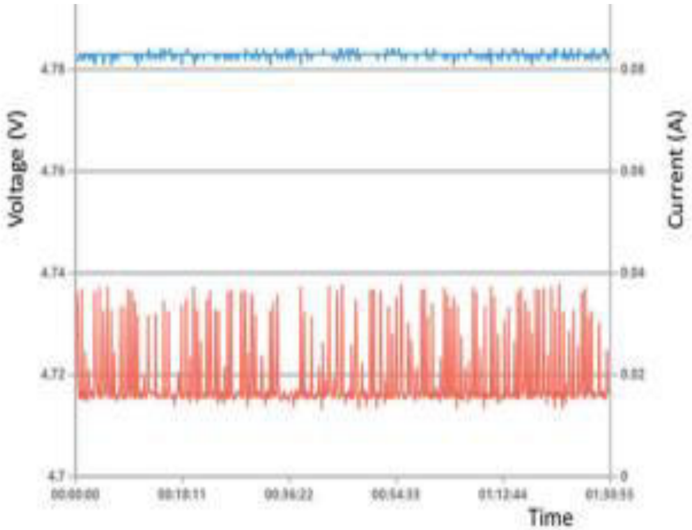
However, the workplace might not have an existing broadband communication system for an application environment like worker health and safety monitoring. As a result, it's possible that the aforementioned communication methods won't work given the need for a gateway to send data to the cloud.
We use Narrowband IoT (NB-IoT) as the communication technology for the wearable modules in our project as a result. The promising NB-IoT technology extends the battery life of wearable devices by enabling wide-area connectivity at a modest data rate with simplified device processing [11].

The knee module, as depicted in Fig. 2, is in charge of gathering the biometric measurement data from the wristband using Bluetooth connectivity, packaging the data, and transmitting it. employing an inbuilt NB-IoT module, to the cloud.

D. Wirelessly charged system

Because the created wearable gadget modules are small, the size of the battery is constrained. For instance, an Apple Watch requires daily recharging in accordance with usual usage. usage. Hundreds of wearable devices are required in the application of using smart wearables to monitor the health and safety of workers. to be recharged between shifts so that they are ready to be used for the next shift.





In our application setting, wireless charging is crucial to avoiding the inconveniences associated with wireline charging and the need for regular battery replacement for wearable sensor equipment. Magnetic induction technology is currently used in the majority of widely used wireless charging gadgets, including the Apple Watch. The wireless charging range is this technology's drawback. The charging distance of our suggested magnetic resonance-based wireless charging system can be increased from millimetres (mm) (magnetic induction) to centimetres (cm), which is crucial to improve the convenience of putting used-up wearable devices into small spaces like a basket (that serves as a charging platform) without having to carefully align each device to the charging platform.

We are developing a new wireless charging system to support our proposed charging application, which aims to simultaneously charge multiple wearable devices in a small space, such as a basket. Our new innovations include a new micro magnetic resonance coil for higher charging efficiency, a one-to-many wireless charging bowl disc for multi-charge applications, a priority-based wireless charging method, and a new frequency.

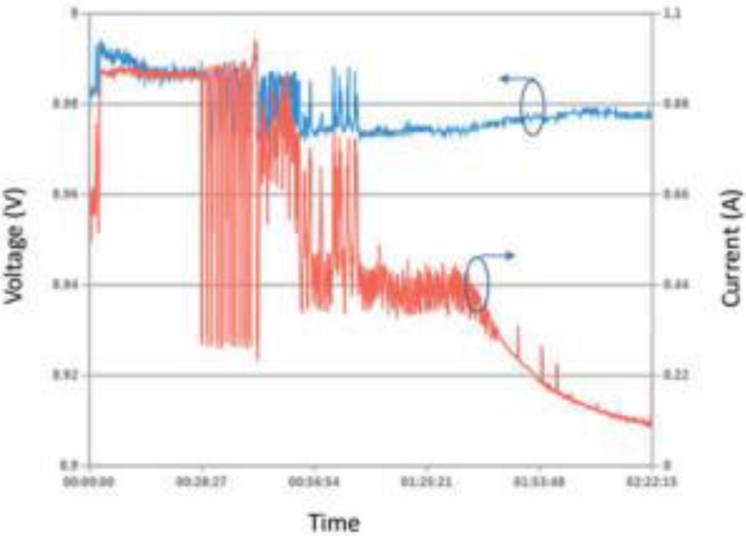


Figure 4 shows an 1821 mAh battery being wirelessly charged from 0% to 100% in accordance with the Qi wireless charging standard (the distance between the transmitter and receiver coils is between 5 mm and 8 mm).

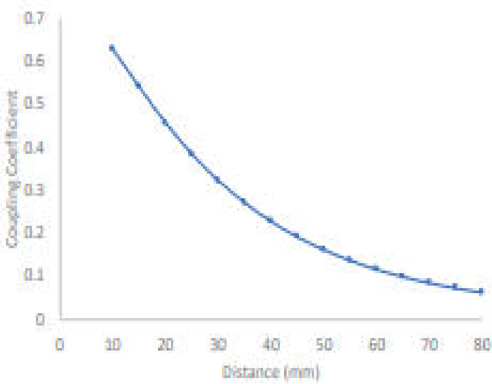


Figure 5 illustrates the effectiveness of a wireless charging system based on magnetic resonance in relation to various distances between the transmitter and receiver coils.

However, in order to design the battery capacity and wireless charging mechanism to their best advantage, a thorough examination of the wearable modules' power consumption is necessary.

3. POWER REQUIREMENTS OF WEARABLE MODULES FOR WORKPLACE

A. POWER CONSUMPTION MEASUREMENTS

The wristband's power consumption measurements and In Fig. 3, knee modules are displayed. The voltage values are represented by the blue lines in both subfigures, while the current values are represented by the red curves in both subplots. The current spikes in Fig. 3 (a) are the result of the sensor's transmission of measurement data.Through Bluetooth, connect the knee module to the wristband module. In contrast, the current spikes in Fig. 3 (b) are caused by data being sent to the cloud via the implanted NB-IoT module. Real-time and continuous monitoring is necessary to prevent workplace health and safety issues from occurring. As a result, our wearable modules broadcast data to the cloud every second, as seen in Figs. 3(a) and (b). This requirement's disadvantage is an increase in current and power consumption.

We discovered that the wristband module is anticipated to use 0.0222 Ah of battery capacity and 0.1064 Wh of power through power measurements of the wearable modules. The knee module uses somewhat more battery capacity (0.0287 Ah) and electricity (0.1374 Wh) because it must transmit data across a wide-area NB-IoT connection.

B. WIRELESS CHARGING CONSIDERATIONS

Battery capacity: A wireless charging system can be constructed for our application using the data from the power measurements in the previous section. Think about the scenario where employees hang the wearable modules when they first arrive at work. The battery should now have enough energy to power the modules for the duration of the workday. The wearable modules are disposed of at the end of the workday into a wireless charging platform resembling a basket so that each module's batteries can be recharged. The minimal battery needs for the wristband and knee modules, including safety margins, are approximately 300 mAh and 350 mAh for 10 hours of continuous monitoring (example: normal working hours for workers).

Charging time: Fig. 4 depicts the fluctuations in voltage and current for charging a 1,821 mAh battery using magnetic resonance from 0% battery capacity to 100% battery capacity. wireless charging system with a base. According to the Qi wireless charging standard, the separation between the transmission and receiver coils should be between 5 mm and 8 mm. The total time for charging was 2 hours and 22 minutes. The findings indicate that our

wearable modules ought to be fully charged over night and prepared for use the following day.
However, the battery utilized in Fig. 4 is almost the same size as an iPhone 8. The physical size of the battery that powers our wearable modules is anticipated to be substantially lower. However, the effectiveness of a magnetic resonance-based wireless charging system, as demonstrated in Fig. 4, offers a suitable starting point for the creation of a wireless charging system specifically tailored to our purpose.

REQUIREMENTS OF OUR PROPOSED 'WIRELESS CHARGING BIN':
After daily use, wearable modules are anticipated to be momentarily disposed of on a wireless charging platform resembling a basket so that many modules can be charged simultaneously. This charging situation makes simultaneous one-to-many charging possible. The wearable modules positioned in the basket in this instance won't have the same transmitter to receiver distance, though. As a result, it is important to analyse the charging effectiveness of various distances between the gearbox and receiver coils.
The coupling coefficient of a wireless charging system based on magnetic resonance is depicted in Fig. 5 versus various distances between the transmission and receiving coils. MAXWELL was used to run the simulation with secret configuration parameters. The findings, which are depicted in Fig. 5, indicate that the "wireless charging bin" might be 8 to 10 cm in size and yet be able to fully charge a number of smart bands during non-working hours (i.e., 12 hours) with a small battery capacity (i.e., 350 mAh).

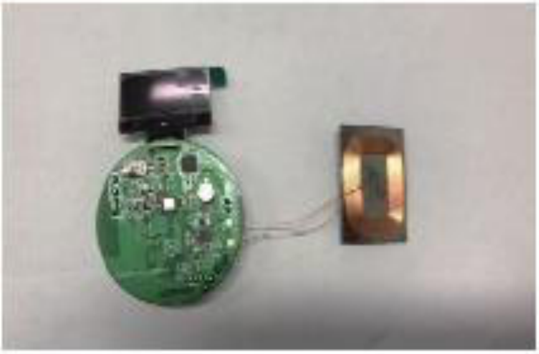


FIG. 6. 5-WATT WIRELESS CHARGING PROTOTYPE FOR OUR WEARABLE WRIST MODULE.

4. ON-GOING WIRELESS CHARGING PROTOTYPE

A 5- Watt wireless charging prototype, seen in Fig. 6, has recently been created by taking into account the factors in Section III. The wireless charging prototype is a receiver that complies with the Wireless Power Consortium (WPC)/Qi 5 Watts baseline power profile (BPP) and has dimensions of 1.5 cm by 2.5 cm. The transmitter to receiver (TX-RX) efficiency ranges from 60% to 75% at the shortest distance, which is in line with Fig. 5, when the output voltage is 5V. Technical specifications that are more in-depth are still being tested and validated and will be presented.

5. CONCLUSION

The trend towards using smart wearable devices to monitor the health and safety of workers operating in hazardous environments, such as emergency response, construction, mining, manufacturing, and farming, has been driven by recent advances and progress in the development of biometric sensors and smart wearable gadgets. Our goal in this paper is to provide a wireless charging mechanism for created smart wearable technology. The development of wearable modules, which include several important biometric sensors for the monitoring of workers' health and safety, was the first thing we discussed. In particular, we examined the design limitations imposed by the need for numerous sensors, system size, and communication technology. Then, in order to establish the necessary power, we measured the wearable modules' power consumption. Enlighten us on how to best design the battery capacity and magnetic resonance wireless charging technology for our application. As a result, we discussed the wireless charging issues for our application environment in terms of the battery needs for the wearable modules, charging duration, and distance between the transmission and receiver coils. We demonstrated that, despite being 8 to 10 cm away from the charging transmitters, a "wireless charging bin" design may offer flexibility, conveniences, and the capacity to fully recharge the smart wearable gadgets. Finally, we demonstrated the development of a wireless charging receiver for our wearable modules that is 5-Watt WPC/Qi compliant.

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Optimized Progression of Smart Metering Infrastructure for Electric Vehicle Charging Stations

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ABSTRACT

This article provides information on smart meter. Design and creation of infrastructure for public charging stations for electric automobiles. a requirement for charging. The need for electric car charging and increased use of electric vehicles is evident. Some security mechanisms are deployed in charging stations based on consumer needs. This study describes the creation of public charging stations with smart meters to direct users and accurately track the flow of electricity when an issue arises. When charging is complete, auto shutdowns stop the charging process to indicate the level, ensuring energy conservation that can be used later. In the charging station, a KWhmeter with an accuracy of up to 0.5 watts is utilized to measure the electrical energy used during the charging process. A microprocessor is used to process data. it will display the information for the user on the 15-inch screen. Smart Cards allow the charge cycle to be finished during the purchasing process.

Key words-*electric vehicle, charging point, KWh meter, HMI, vehicle to grid, EVSE.*

INTRODUCTION

Electric vehicles are becoming more and more popular today, which helps reduce the need for fossil fuels. Electric bikes, electric vehicles, and electric buses served as the foundation for the development of EVs. Electricity serves as the primary fuel for aircraft. In terms of economics and the environment, the electric car has a number of significant and positive benefits [1]. Additionally, the growth of renewable energy sources has somewhat reduced the need for fossil fuels. Additionally, it allows for increased energy supply flexibility and a decrease in greenhouse gas emissions, which manages both sound and air pollution. One of the most crucial elements in the advancement of electric vehicles is the availability of public charging stations. According to Chynoweth et al. in [2,] the necessity for charging stations is crucial for the lengthy trip back home. According to Chynoweth et al., the presence of a charging station allayed EV users' concerns about the bike's electric energy balance.

Research [3] over the past few decades demonstrates how universal charging hardware and software that is more user-friendly are used in public and private facilities. It is incredibly user-friendly and simple to use for the user in relation to grid smart charging work [3]. to employ smart meters to monitor electrical energy in the distribution network [5]. A problem with smart charging occurs during the charging process via information transfer and energy flow, claims research [6]. Figure 1 depicts how information and energy move through several components.

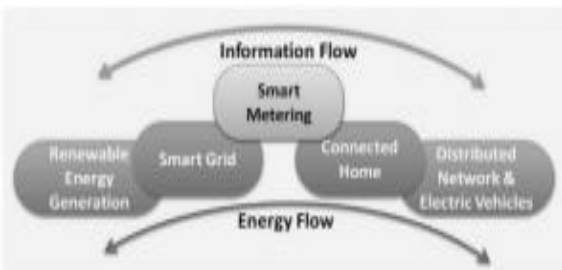

Fig. 1. Connectivity of energy and information flow [6].

Analyzing how EV charging affects carbon intensity and electricity use is the other part of smart charging [7]. According to Lam's research, advance metering charging stations with third-party engagement, website development, and EV charging schedules are crucial. The infrastructure of smart metering development for charging points to handle the process of charging for EVs is the topic of research of Aam Muharam [1]. When the following criteria are fulfilled during charging and the charging process is stopped, such as when the purchase limit is reached, a battery is being charged, a system charging point malfunctions, or a connection is lost, the smart metering design has the capability to shut off the main power supply. Either in KW or in rupees is the pricing method. Additionally, a process data log of the charging purchase is kept for future use, and using a smart card makes buying energy easier.

2. CHARGING INFRASTRUCTURE OF ELECTRICAL VEHICLE

A charging outlet, smart meter, and an electronic payment system, which is occasionally connected to the internet, make up the infrastructure of a charging station. Some of the more advanced charging stations have the ability to recognize when an electric vehicle is connected to a charging point. Infrastructure for charging has been given a higher level of security; without the user's consent, no data is communicated, and charge is halted.

Four pricing methods are available [7] [9] [12]-[17]: Mode 1 for modest charging (an AC attachment plug for a family unit); Mode 2 for slow charging (used an in-link security device in AC); Mode 3 for slow or speedy

TABLE 1: CHARACTERISTICS OF CHARGING INFRASTRUCTURE

Name of Manufactures	Battery Capacity	Electric Range	Connector Type	Charging Time
BMW-i4	80 Kwh	450 km	Mennekes	8H 45M
Tesla-Model 3	75 Kwh	460 km	Mennekes	7H 45M
Volkswagen-ID.3 Pure	48 Kwh	275 km	Mennekes	7H 30M
Skoda- Enyaq iV 50	55 Kwh	290 km	Mennekes	8H 30M
Porsche-Taycan Turbo S	93.4 Kwh	380 km	Mennekes	9H

Direct DC quick charging is available in Mode 4 (explicit EV attachment outlet control capacity and insurance work introduced in AC). Quick charging mode 4 in DC sub modes into DC level 1 (voltage inferior to 500 V, current inferior to 80 A, power inferior to 40 kW). DC level 2 (power at 100 kW; voltage inferior to 500 V; current inferior to 200 A). The charging infrastructure's characteristics are displayed in Table I. Each producer employs a type 2 slow charging Mennekes connector. The makers may also employ additional connector types including SAE J1772, Chademo, and SAE CCS, among others.

Table II

lists the parts of the infrastructure for charging. It includes power requirements [18–20], safety measures [10–21], and network requirements [4]. Display unit [8] [18] [20] [22] - [24] and [18] [22] [25].

TABLE 2: SMART CHARGING INFRASTRUCTURE COMPONENTS

Component of Charging	Features and Specifications
Power Specifications	240 Volt, 60 Hz,30 A,7.2 kW
Safety Specifications	Surge Protection 6kV@ 3,000A per UL 2231-2
Network Specifications	GPRS, 128-bit AES Encryption, Smart Card Reader ISO 15693 (iCLASS), ISO14443 (MIFARE, DESFIRE)
Display unit	LED Array 270° visibility, multi-color visual status indicator

3. EV CHARGING POINT WITH DEVELOPMENT IN SMART METERING INFRASTRUCTURE

Based on table II, improvements have been made to some components and their capabilities to provide a robust EV charging infrastructure.

A. Charging point configuration

To gain a sense of how an EV works at a petrol station and to remember this for a seamless transfer of ownership. The Bosch exposure of public charging point layout is depicted in Fig. 2 [16]. With connection SAE J1772 2012, flexible cable with a 220 volt AC, 60 ampere capacity is used in this setup. The vehicle connector's female connector is coupled with this cable's male connector.

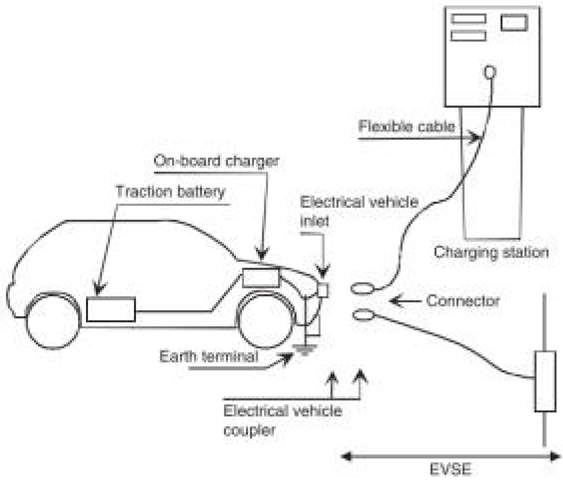

Fig. 2. Configuration of public charging point [15].

B. Control unit of charging point and user interface

The charging point's control panel is depicted in Fig. 3. It includes. Comprising an AC plug, a contactor switch, a KWhmeter, a communication module, a CPU unit, a keypad and a monitor (LCD). Display).

The KWhmeter's job is to measure frequency and power flow to an EV that is connected to the power line. In order to perform calculations, this meter generates a signal based on power transmission and delivers it to the processor unit. The cost of the energy that the user will be charged is calculated in the processing

The user can view all the data on the LCD screen, and it is also all kept in the computer's memory for data management purposes. No electricity is transferred if the EV plug is not fixed to the charging point plug.

The keypad is interfaced to enter data for security purposes; if the data matches, only charging will start.The system offers a number of features, including the ability to instantly stop charging if the cable is unplugged accidentally while it is charging. Even if the user balance is intact and the battery is completely charged, power transmission is restricted using an active contactor switch when the transfer power reaches the user-paid amount. A smart card is used to identify the user payment gateway.

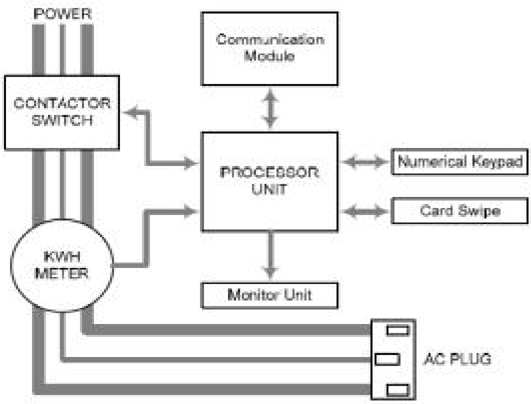

Fig. 3. Process of charging station [25].

FIG. 4 SHOWS CHARGING INFRASTRUCTURE. IT HAS THE FOLLOWING PARTS.

A. AC Charging
B. DC Charging
C. Electric Vehicle Supply Equipment (EVSE) Human Machine Interface (HMI) Module
D. EVSE communication Module
E. EVSE Control Module
F. Others

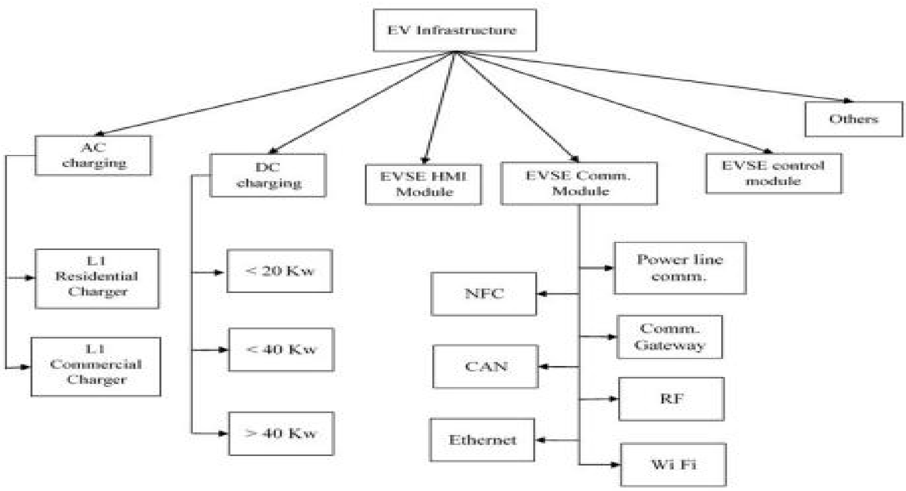

FIG. 4 CHARGING INFRASTRUCTURE PARAMETERS

4. FACTORS AFFECTING CHARGING INFRASTRUCTURE DESIGN

The infrastructure for charging should be built with user-accepted comfort, cost, and technology. Observing factors that cause a significant change in the evolution of the charging infrastructure.

1. Charge Power
2. Charge Energy
3. Charge time
4. Daily vehicle trips
5. Daily Kilometers travelled

According to research, if there is no domestic charging infrastructure, 65 km of charge will be needed to store; however, if there is residential charging infrastructure, 52 km of charge would be needed, reducing the size and cost of the battery. Therefore, there is a need to evolve both residential and commercial charging infrastructures. Level 1, 2 or 3 charge modalities are suitable for both infrastructures [25].

5. STUDY OF CHARGING & ITS FEEDBACK PROCESS

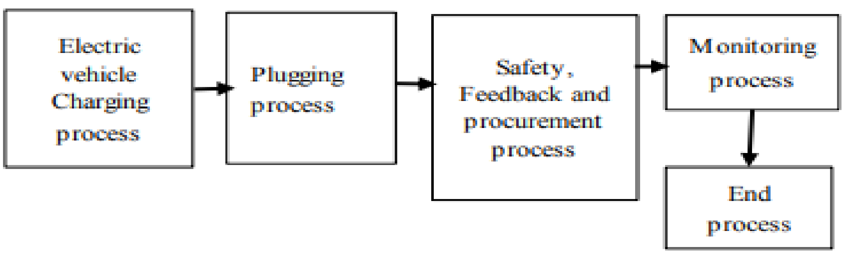

FIG.5 OVERALL CHARGING PROCEDURE

The whole process for charging an EV is depicted in Fig. 5. The electric car pulls up to the charging point to start the process, and then the charging point connector is plugged in. using a car plug. When the plugging combination is complete, the monitor will indicate if the device is connected or not. The procurement procedure then begins by questioning the user about inserting a smart card and checking to see if the smart card is inserted correctly or not. The monitor will also display this information. The user enters the required amount of energy to purchase either in the form of KWh or rupees once a smart card has been properly inserted. The charging station now has a specific feature that allows you to check things like battery charge level, whether the cable is plugged in, etc. The mechanism will automatically cut off the supply and stop the charging process if it detects any malfunction.

6. CONCLUSION

This essay focuses on the examination of the growth of infrastructures for charging. It also discusses the requirement for a charging infrastructure and the range of capabilities and features that can handle. Levels 1 to 3 are suitable for charging with variable charging times. Level 3 suggests quick charging. Level 1 is used for high-cost, always-present security requirements in both residential and business settings. While level 2 charging is an improvement over level 1 charging that takes greater safety precautions and reduces charging time. In the future, it should be possible to employ batteries that require less maintenance, have greater storage capacity, and only mild levels of safety during charging.

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Optimal Design of Smart Grid Monitoring System Based on Cloud Computing

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ABSTRACT

Real-time data of power system is an important data for power system equipment measurement and acquisition. These data are important basis for analyzing power system stability, predicting grid load and power equipment failure an daging, and are the data that must be monitored for grid operation. Aiming at the problem of massive monitoring data access and processing in smart grid monitoring system, this paper proposes a smart grid monitoring system based on cloud computing framework by comprehensively utilizing geographic information technology, network communication technology and distributed data base technology. The system's work flow is more efficient and reliable for information processing than traditional database models and existing methods.

INTRODUCTION

Numerous power equipment and monitoring instruments in the power grid form real-time status datathat requires the power information system to continuously receive and process. The amount of data in these status data is huge, and high reliability and real-time requirements are imposed on the monitoring system .However, in the face of massive state data, the traditional system shows that the storage capacity and processing capacity are seriously insufficient, which restricts the working efficiency of the power grid monitoring system to a large extent. Therefore, storing information data and processing these data has become the key to restricting smart grid monitoring. Hadoop is a decomposition/aggregation cloud computing framework for large dataset object analysis processing. Through the coordinated management of the distributed file system HDF Sand the parallel programming model Map/Reduce, the system can effectively segment and reasonably schedule massive data, thus achieving efficient parallel processing for big data.

At present, China is accelerating the construction of smart grids, and adopting cloud computing technology for reliable storage and parallel processing of state monitoring data will inevitably play a huge role in promoting the establishment of smart grids in the future. Based on this, based on the research of the combination of geographic information system and smart grid, this paper develops intelligent grid monitoring system based on cloud computing to realize efficient parallel storage and processing of large data set grid monitoring information, and it is difficult to solve real-time monitoring of grid operation. The problem of slowness and improvement of the monitoring of the operation of the power grid to improve the overall emergency support capability of the power grid.

GRID MONITORING TECHNOLOGY

Grid monitoring refers to the process of providing the basis for equipment fault diagnosis by detecting, transforming, analyzing, processing and displaying the characteristic signals under a certain operating state, and outputting the information collected by the diagnosis. Through the combination of advanced automatic control, communication technology, computer technology, information technology, etc., telemetry, remote signaling, remote control, remote adjustment operation, and secondary equipment and auxiliary equipment for power operation equipment facilities monitored in a physical area of the system Realize remote control, realize monitoring, measurement, control, recording and alarm of all primary equipment, realize optimal operation, optimization control and optimization management of power grid, thereby improving grid operation status, safety level and forecast level of accident disaster prediction.

The data to be faced and processed by the smart grid monitoring system mainly includes three types: basic geographic information data, grid equipment facility spatial data and other data with spatial attribute characteristics. The basic geographic information data includes national grid map data, provincial network map data, and key city grid map data of various scales. Grid equipment facility spatial data is grid data with spatial location information, including power plants, substations, overhead lines, towers, cable lines, and soon. Other data with spatial attribute characteristics are grid environment information, including meteorological information, disaster information, geological monitoring (earthquake), natural disasters (typhoons, ice disasters, etc.), and sources of danger. These will have an impact on the grid, which is the focus of the monitoring system. The smart grid monitoring system belongs to a complex adaptive system and requires comprehensive support of geographic information technology, network communication technology and database technology.

While the monitoring system displays and monitors the power parameters, in order to perform statistics, analysis and processing on the data in the future, and realize the dynamic display of the data curve, it is also required to provide a database storage function for the system. Since the power information has many kinds of data, large amount of data, inconsistent format, one-time writing, multiple readings, etc., the power monitoring equipment needs to continuously write real-time monitoring data into the database. In order to meet the requirements of reliability and real-time, the traditional relational database is not used, and the distributed data management mode based on column storage is adopted to support the efficient management of large data sets. Although the distributed data base spreads the data records on each physical node, it still logically belongs to the same system. This data is shared by the method of data distribution. A global database is responsible for the management of the entire system, and some data base share undertaken by the local data base of each node. In this way, the data is dispersed to maximize the local application, and the mutual interference between the computing nodes is also minimized. Tasks are shared among nodes, thus avoiding load bottlenecks and improving work efficiency.

SYSTEM DESIGN

The smart grid monitoring geographic information system designed in this paper is divided into three levels, namely the on-site monitoring layer, the network communication layer and the management application layer. The on-site monitoring layer is also called the sensing player. It consists of various sensors and sensor network tubes, including temperature sensors, humidity sensors, two-dimensional code labels, RFID tags, readers, cameras and other sensing terminals. It mainly monitors the operating parameters of all links in the power grid. Real-time monitoring including transmission line monitoring, substation station monitoring, substation monitoring, etc., including geographic attribute information with geographic coordinates, network communication network operation status and grid environment information.

The network communication layer mainly realizes the transmission and control of information. The various operating parameters of the power grid obtained from the on-site monitoring layer and the grid environment information are transmitted to the management application layer through the network communication layer. On the other hand, instructions issued from the management application layer need to be forwarded to the monitor of the power running device on the field monitoring layer through the network communication layer. The network communication layer undertakes a two-way, massive grid data transmission task. The system uses a variety of communication technologies such as power private network and public wireless network to complete the data transmission of the network communication layer.

According to the characteristics of smart grid equipment monitoring, this paper uses distributed redundant storage system and column storage-based data management mode to store and manage data to ensure the reliability and efficient management of smart grid massive state data. The operating condition data of the power equipment facility acquired by the sensor network, the power private network, and the like are generated and stored in the database through the Map Reduce-based grid monitoring data parallel processing platform. Other information databases with spatial attribute features include remote sensing information, road information, and weather information. For meteorological information, relevant meteorological geographic information data such as grid dispatching meteorological warning and forecasting service data are obtained from the meteorological department through a dedicated cable or the Internet. This article uses Hive and H Base database to store data. As a distributed database, H Base has high query efficiency. Install H Base on the already configured Hadoop smart grid monitoring platform, edit and modify the hive-site. Xmlin the conf directory. The modification is shown in Figure 1.

```
<property>
<name> hive.aux.jars.path</name>
<value> file:///home/hadoop/hive-0.10.0/lib/hive-hbase-0.10.0.jar , file:///home/hadoop/hive-0.
10.0/lib/hbase-0.94.4.jar , file:///home/hadoop/hive-0.10.0/zookeeper-3.4.5.jar </value>
</property >
```

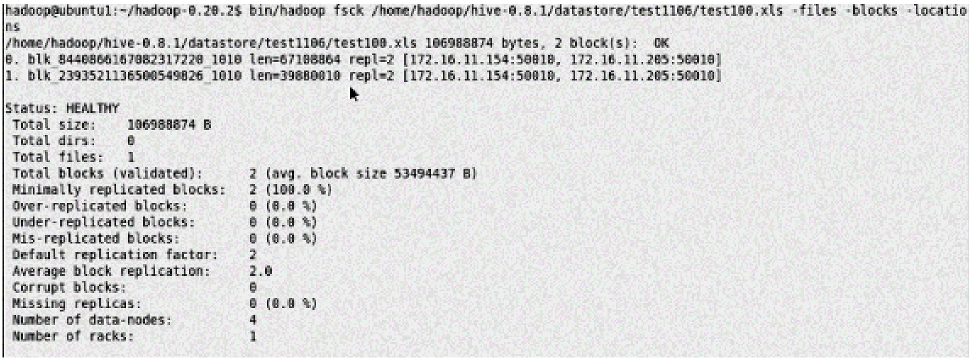
FIGURE1.EDITANDMODIFYTHEFILEINTHECONFDIRECTORY

Through the system read and write test, no matter which end of the data is written, the data can beread at the other end, indicating that the Hive data base can be used for large data storage and processing, and H Base can quickly display data, indicating that the two technologies are obtained. Effective integration.

PARALLEL PROCESSING BASED ON MAP REDUCE

When processing the monitoring dataset, Map Reduce first divides it into hundreds or thousands of small datasets, and then each node in the cluster processes one or several divided small data sets and

produces intermediate results, and finally passes merging a large number of nodes translates these intermediate results into final results. The whole work process is divided into two stages: Map and Reduce.



```
hadoop@ubuntu1:~/hadoop-0.20.2$ bin/hadoop fsck /home/hadoop/hive-0.8.1/datastore/test1106/test100.xls -files -blocks -locatio
ns
/home/hadoop/hive-0.8.1/datastore/test1106/test100.xls 106988874 bytes, 2 block(s):  OK
0. blk_8440866167082317220_1010 len=67108864 repl=2 [172.16.11.154:50010, 172.16.11.205:50010]
1. blk_2393521136500549826_1010 len=39880010 repl=2 [172.16.11.154:50010, 172.16.11.205:50010]

Status: HEALTHY
 Total size:    106988874 B
 Total dirs:    0
 Total files:   1
 Total blocks (validated):      2 (avg. block size 53494437 B)
 Minimally replicated blocks:   2 (100.0 %)
 Over-replicated blocks:        0 (0.0 %)
 Under-replicated blocks:       0 (0.0 %)
 Mis-replicated blocks:         0 (0.0 %)
 Default replication factor:    2
 Average block replication:     2.0
 Corrupt blocks:                0
 Missing replicas:              0 (0.0 %)
 Number of data-nodes:          4
 Number of racks:               1
```

FIGURE2.PARALLELPROCESSINGOPERATION

Usually, there are many duplicate keys in the intermediate results processed by the Map operation. In order to all eviate the burden f Reduce operation and network transmission, the system is optimized, that is, a custom Combiner method is used to locally integrate and stipulate the intermediate results. The Combiner operation runs on each node that performs the Map operation, usually using the same process as the Reduce operation. The only difference is that the result of the Reduce operation is written to the final output file, and the result of the Combiner operation is sent to the Reduce operation as an intermediate file. The specific steps of the improved Map Reduce execution process are as follows:

(1) First, the monitoring data set of the cloud computing platform that is imported into the running user program is preprocessed, and data noise reduction and the like are processed.

(2) The Map Reduce function library in the user program divides the imported monitoring data file into 16 to 64 megabytes of M blocks (which can be adjusted by parameters), and then executes a copy of the program on different machines in the cluster. It should be pointed out that the split does not need to understand the internal logical structure of the file. The specific split mode can be specified by itself or by several simple partitions that Hadoop has defined.

(3) In all running processes, the master program master is responsible for the allocation of the remaining execution tasks. The master program in the execution program assigns Map and Reduce tasks according to the idle status of the worker.

(4) The working node assigned the Map task reads and processes the input

data block, and the Map function finally out puts the intermediate result pair. In addition, in order to further shorten the processing time, when performing the Combine operation, the merged key pairs are first indexed, then merged into several large new data pairs, and after being transferred to the Reduce process, the decomposition is performed, and the index is utilized.

(5) The system packs the key/value pair data and sends the index information to the Master, and then transmits it to Reduce through the Master.

(6) The Reducer Worker calls the user-defined Reduce function to analyze and sort the set of intermediate results.

(7) After executing all the Map Reduce tasks, the Master is responsible for controlling the corresponding monitoring data to be stored in the library and generating a corresponding copy file for transmission.

CONCLUSION

Based on the research of the combination of geographic information system and smart grid, this paper designs a smart grid monitoring system based on cloud computing for the problem of large data set storage in the traditional mode of power grid monitoring system. The method stores and processes massive amounts of monitoring data. Through the development of cloud computing-based smart grid monitoring system, the efficient parallel storage and processing of large data set grid monitoring information is realized, the problem of difficult and slow real-time monitoring of power grid operation is solved, and the monitoring of grid operation is improved to the overall emergency of the grid.

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Design of Optimal Car Parking System with the assistance of Line Following Robot

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ABSTRACT

This essay suggests a clever indoor parking system that might be both time and money efficient. Help is referred described as "assistance" to denote that Robots that follow lines will park cars by bringing them in from the parking area entrance. We have covered a practical application of a traditional line-following robot in this research, enhancing an indoor parking system with some extra capabilities in addition to line-following. Due to the simplicity of obtaining the necessary technologies, our suggested solution will have extremely minimal implementation costs. The technologies that are currently on the market to assist with indoor parking typically call for certain additional structural designs that can only be added during the construction of new structures. However, traditional parking systems already in place are very numerous and cannot be renovated in a practical way to match those systems; in certain cases, even the reconstruction is not possible. As a result, the recently introduced queue following robot can be a suggested remedy for those ongoing issues in the accessible indoor parking systems, providing an effective alternative for the users.

Keywords:*PR control parking, car-parking robot, indoor car parking, smart parking system*

INTRODUCTION

Currently, we can observe a significant rise in the number of automobiles worldwide due to their high utility and affordable price. Having stated that, car administration in every city has become a significant obstacle for everyone. Numerous cutting-edge methods have been invented in recent years to address this issue by researchers and engineers. However, the majority of these technologies can only be used with freshly designed parking spaces and modernized management. Additionally, to park a car quickly and correctly, talented and experienced drivers are required.As a result, their implementation in current car parking systems that rely entirely on human parking is challenging. In Additionally, if the parking lot is large, the majority of the systems direct or help the driver to available parking spaces at the expense of the driver's time. This is a typical occurrence because many people around the world drive their own automobiles instead of hiring a chauffeur, which can lead to a monotonous and exhausting work [1]. Additionally, motorists squander billions by overpaying for parking spaces and seeking for spots [2].

Once more, in order to implement the majority of current car parking systems, the users need to have new constructions [3]. Additionally, a thorough evaluation of the required slots, space availability, and traffic flow will be necessary. This study makes a system suggestion to address these issues and make the best use of the currently available indoor parking spaces. A previously existing technology is introduced here with new functionality. These days, the Line Following Robot (LFR) and its mechanism are well known to most people. These robots are often inexpensive to create, basic, and have autonomous movements. Furthermore, they serve as automated equipment haulers for large distances in several sectors. Here, the LFR will transport the vehicle from the entry to the closest open parking space in that location. Additionally, it will employ a variety of sensors to find open parking spaces, enabling the LFR to park the car there and then drive away from it.And the planned system achieves its goal of being sustainable by cutting down on the amount of time needed for parking, doing away with the need to look for a spot, and making it simple to deploy in the current parking places. This subsequently reduces the wastage of additional fuel and associated money. As a result, the suggested system is progressing towards sustainability and user-friendliness.

1. Finding a solution for the current issue with indoor parking by implementing the widely utilized line-following robot.
2. This system can be made effective by adding a new feature called hooking.
3. Redesigning the parking system currently in place to eliminate the requirement for infrastructure improvements.
4. Putting into practice an algorithm that is simpler and more comprehensible.

The remainder of the essay is structured as follows. Section II compares our parking method to earlier research on the subject and explains how and why it differs from those earlier studies. part III presents a thorough discussion of the proposed system, and part IV presents the algorithm. The flowchart and block diagram of the entire system are shown in Section V. The exact hardware implementation in the bot itself is shown in Section VI. The performance evaluation of our suggested system is determined in Section VII through graphical comparisons with various systems that are currently in use. Section VIII, which also serves as our paper's conclusion, provides information about how we want to improve the suggested system in the future.

2. RELATED WORKS

The need for parking spots has increased as the number of city cars has increased. Automatic parking control, which serves as a parking assistance system for both conventional cars and autonomous vehicles, has thus become a hot research area in the automotive industry. The automatic parking system, which provides efficiency, convenience, safety, and dependability, is a perfect answer for the car parking issue of today. Various ways have been proposed in numerous recent studies to address this challenge. Many of these ideas are based on the principles in [4], where an ideal algorithm was proposed to determine the path for a car that goes both forward and backward in an area devoid of obstacles. However, it does not take into account the limitations of the parking lot and is simply intended to handle a car that moves from one location to another.

A skill-based technique that makes use of fuzzy logic [5] simulates the parking ability of an experienced motorist. The primary problem with this method is that there is no reference path that a robot may follow and that it depends on an accurate car position in relation to the parking slot.

Another technology uses ultrasonic sensors for parking and is known as a sensor-guided automated parallel parking approach [6]. But because of the angle of reflection, ultrasonic sensors frequently exhibit a distance inaccuracy. Furthermore, even in a parking lot with no impediments, it cannot get the distance.

Then, a smart parking system was created using the Zig Bee wireless communication standard [7]. In this case, GSM is used to receive notifications from SMS or other software programmes. Although this method is significantly more efficient than others, GSM technology is somewhat slower than this method in comparison. Additionally, it is more expensive than alternative solutions.

Another author suggested an electronic parking system in which the author utilizes a parking meter and ultrasonic sensors to determine whether a parking place is available [8]. This technique may work well for sharing parking spaces, as previous authors have noted, but it will not be effective for distributing parking places.

A reservation-based smart parking system has been proposed [9] to intelligently direct cars to their selected parking locations, where they can then park. without having to look around. The closest parking spot can be found with the aid of GPS technology. To assist the driver in choosing an appropriate place and reserving it for a predetermined amount of time, a graphical interface displays available and reserved spaces to the user. However, this is not the case with indoor parking because it is more difficult to find the slots than it would be if they were outside.

However, this system also has issues [3] [1] When a person parks longer than the allotted period, other people have parked in their reserved spot etc. Additionally, picture-taking tools are employed for continuously taking images of the parking lot to make sure there are no empty spaces, which uses a lot of electricity, High maintenance costs are also necessary [10].

Then there are other solutions available on the market, such as smart parking services that rely on wireless sensor networks and employ wireless sensors to efficiently locate open parking spaces. However, in order to use this system, additional hardware must be put in the vehicle, which is not practical for all cars [11].

On the other hand, in another system, a car carrier robot autonomously moves the vehicle from the parking place to the garage or back out [12]. However, the robot itself is not cost-effective because it is significantly more expensive than our LFR-based solution.

In order to use a number of contemporary automobile parking systems, multistory parking foundation must be completed [13]. However, our technology may be used effectively with both outdated and conventional parking systems. In order to discover a parking spot and reserve a space while parking, we can also find device-based programmes [17], available for iOS or Android. However, each of the systems requires a driver to park their vehicle, which is considered manual time wasted in the parking space.

Given that most individuals drive their own automobiles, an effective alternative would thus be this technology, which uses an automated robot to assist the car in parking without taking the driver's time. most places on earth [12]. The system itself is also less complicated because the human work is done by a straightforward line-following robot mechanism, which saves time, fuel, and additional parking fees.

3. PROPOSED SYSTEM

This system's major feature is a line-following robot that can automatically park a car after it is in the entrance position. Additionally, the system's architecture:

Line following algorithm was utilized in the design of our robot. If there is a black line at the parking place, each sensor reads one in the 8 array IR module. Additionally, the colour sensor reads numerical values. The step-by-step process is described below:

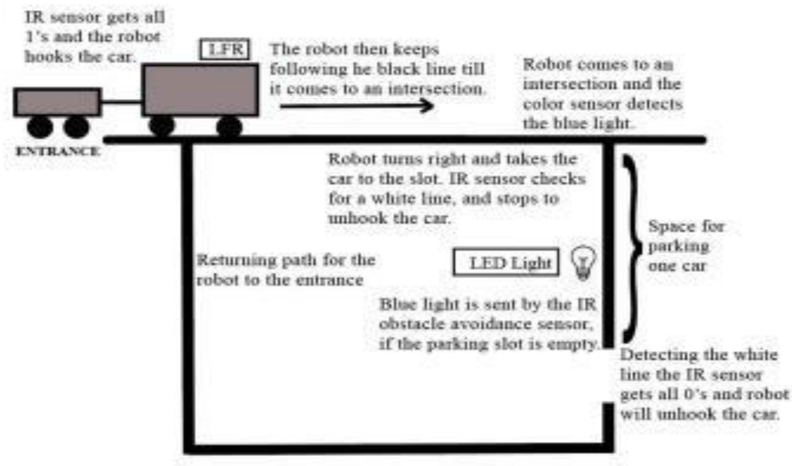


Fig 1. LFR carrying a car in the parking area using different sensors

• Car moves into driving position.

• The robot stops and connects the automobile using the servo motor after receiving the signal 11111111 from the IR sensor.

• Along a straight path, the robot and the car begin to move together. The LFR will only turn right in this system prototype in order to show how the car parking would function.

• The IR on the bot will read 00001111, and when the automobile reaches an intersection, the bot will turn right. The colour sensor on the bot checks to see if there is an open slot before turning right.

• The colour sensor on the bot receives a signal first from the IR obstacle avoidance sensor that is inserted into the slot via a blue LED. If the slot is already taken, the IR module won't send a signal, preventing the robot from turning right and causing it to continue moving forward.

• The module makes the LED become blue if the slot is vacant, and the robot's colour sensor can detect this blue light. then makes a right turn.

• If the robot makes a right turn, the IR sensor will search for a white line; if it finds one, it will return the value 00000000, indicating that the robot will immediately stop and unhook the car. Thus, it is parked in a vacant space.
Section IV contains the suggested system's algorithm.

4. Algorithm

In this part, we've presented the potential inputs that the sensor might receive as well as the ensuing navigation. These commands will control how the bot moves the automobile as it moves forward, to the left, or to the right.

```
Color Sensor = false
Sensor Pin [ ] = {S1, S2, S3, S4, S5, S6, S7, S8}
void loop ( ){
Sensor read ( ) updates the Sensor Pin [ ] with 1 or 0

if ( [S1....S8]==[1,1,1,1,1,1,1,1] )
            Servo motor picks up the car
if ( [S1....S8]==[0,0,0,1,1,0,0,0]
            The bot goes forward
if ( [S1....S8]==[0,0,0,0,1,1,0,0] )
            The bot goes little bit to the right
if ( [S1....S8]==[0,0,0,0,0,1,1,0] )
            The bot goes more to the right
if ( [S1....S8]==[0,0,0,0,0,0,1,1] )
            The bot goes mostly to the right
if ( [S1....S8]==[0,0,1,1,0,0,0,0] )
            The bot goes little bit to the left
if ( [S1....S8]==[0,1,1,0,0,0,0,0] )
            The bot goes but more to the left
if ( [S1....S8]==[1,1,0,0,0,0,0,0] )
            The bot goes but most to the left
if ( [S1....S8]==([0,0,0,0,0,1,1,1] or [0,0,0,0,1,1,1,1] ) )
            The bot stops
            if (Color Sensor detects blue light)
                        The bot turns right
            else    The bot goes forward
if([S1....S8]==[0,0,0,0,0,0,0,0])
            Puts down the car and then goes forward
Repeat until the bot is switched off.
```

5. FLOWCHART AND BLOCK DIAGRAM

Figure 2's block diagram shows the system we suggest. It is made up of motors, microcontrollers, and sensors. The overall flowchart for the LFR assisted smart parking system is shown in Figure 3.

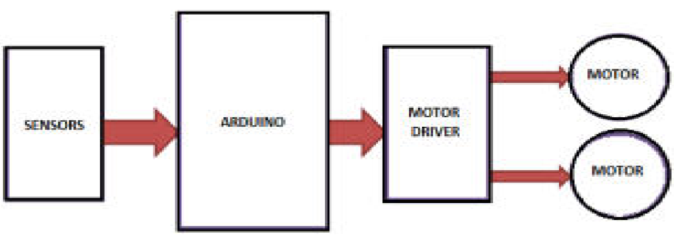
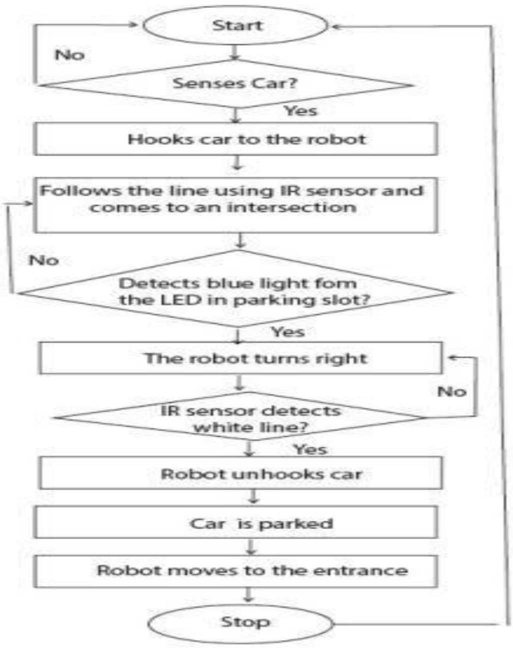


Fig 2. Simple Block Diagram

Fig 3. Flowchart for LFR assisted smart parking system



6. IMPLEMENTATION DETAILS

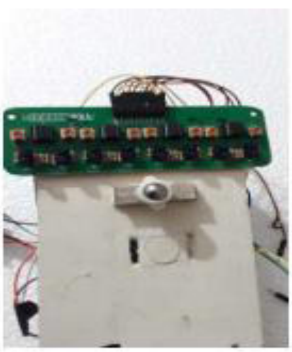


Fig 4. IR sensor (TCRT5000)

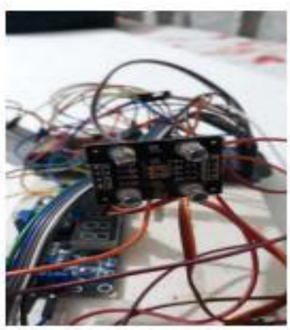


Fig 5. RGB color sensor (TCS3200)

IR sensor (TCRT5000):

A sensor module with eight IR LED colour phototransistor pairs is shown in Figure 4. All eight sensors can be read simultaneously for the best possible use of the LED power option. This sensor is used to determine whether the robot will halt, turn left or right when it comes to an intersection, and whether an automobile has been left in the entrance position.

RGB color sensor (TCS3200):

A colour sensor, shown in Fig. 5, works by shining a white light onto an item and then capturing the light that is reflected. The photodiode transforms the light into current by using red, green, and blue colour filters. The converter then changes the current to voltage so that the Arduino in the LFR can read it.

Fig 6. L298 Motor Driver

Fig 7. Servo Motor

L298 Motor Driver:
Figure 6 shows a dual H-bridge driver that can simultaneously regulate the speed and direction of two DC motors. The module has a peak current capacity of 2A and can operate DC motors with voltages ranging from 5 to 35V. It is employed in the LFR's movement.

Servo Motor:
A highly accurate electrical gadget, shown in Fig. 7, may push or spin an object. The automobile is attached to the LFR and pulled along the bot by the motor's rotating mechanism so that it may be parked in an open space.

Fig 8. Arduino mega 2560 *Fig 9. Arduino UNO*

Arduino mega 2560:
A microcontroller board based on the one in Figure 8 ATmega2560. The bot is being controlled by this microcontroller. It will facilitate the robot's path navigation. Utilizing digital IR to control the motor driver.

Arduino UNO:
A microcontroller is shown in Fig. 9 and is utilized for the parking space. The UNO is connected to an IR module that can detect whether a car is present in the slot or not.

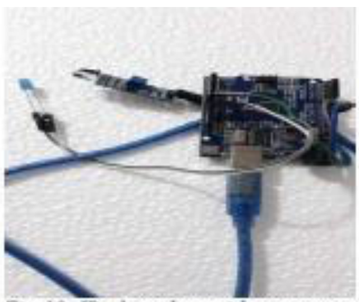


Fig 10. IR obstacle avoidance sensor

IR obstacle avoidance sensor:
Fig. 10 has a blue LED attached to it. The LED does not light up when the sensor detects an impediment, but the colour sensor underneath the robot can detect this when the LED becomes blue in the absence of an obstacle. There is an IR module in each parking space.

7. PERFORMANCE EVALUATION

The effectiveness of the aforementioned technique to resolve parking issues on a small scale was demonstrated by its implementation for lightweight cars in the lab. The following is a comparative table based on various factors:

Systems for comparison	*Cost Factors*
Mobile Robot Car Parking	(1) Cost to build a smart parking area (2) Cost to build a smart car compatible for the parking slot (3) Cost for wireless network system
GPS parking system	(1) Setting up the GPS system with the car (2) Storing information about the desired outdoor parking area on the system (3) Satellite imaging of the area. Information sent back and forth via the system to the car from the system
Online parking reservation	(1) Setting up the whole system with the wireless network (2) System setup that continuously sends images to the car (3) Getting the car connected to that network
Our Proposed system	(1) Line following robot assembling (2) IR obstacle avoidance sensors

Systems for comparison	*Time Factors*
Mobile Robot Car Parking	(1) Driver entering the parking area entering the car registration number and additional information. (2) Scanning the parking area, finding a parking position and maneuvering path for the smart car via a wireless network (3) Positioning the smart car, reversing to the edge of the parking space (4) Maneuvering the smart car to move to the parking position which may require backward and forward maneuvers
GPS parking system	(1) Finding the nearby parking slot via the GPS system (2) Following the produced route to the desired parking slot.
Online parking reservation	(1) Connecting the phone to the network of the parking slot (2) Finding the non-reserved slot. (3) Notifying the user with the image and location of the slot. (4) Finding the best route to the slot (5) The driver is navigated on each movement through the satellite imaging. (6) The driver has to wait to get each update to know where to go next (7) Guiding to the slot and let the car park.
Our Proposed system	(1)Sensing that the car has been positioned in the entry slot. (2)Hooking the car and guiding it towards an empty nearby slot. (3) Parking the car, unhooking, and returning to the entry position.

Systems for comparison	*Complexity Factors*
Mobile Robot Car Parking	(1) The wireless network system (2) System for scanning the parking area (3) System that tells the smart car how to exactly park in the empty slot
GPS parking system	(1) GPS setup (2) Network connection (3) Proper imaging
Online parking reservation	(1) Network that connects the car to the online reservation system (2) Continuous satellite imaging of the slot Transfer of images to the car (3) Transfer of images to the car
Our Proposed system	(1) Using Servo motor in the robot (2) Sensing the blue light from IR obstacle avoidance sensor.

The y-axis in the figures 11, 12, and 13 below has an arbitrary unit. Given that each component in the table represents one unit in the graph:

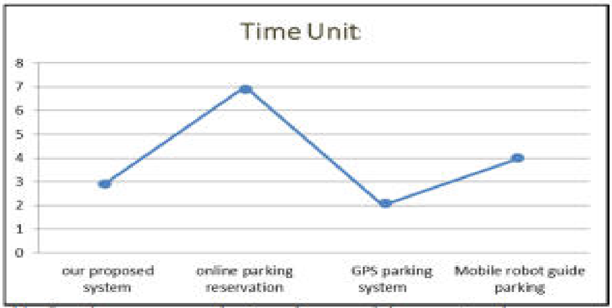


Fig 11. Graph to compare the time factors of the mentioned systems vs. the proposed system.

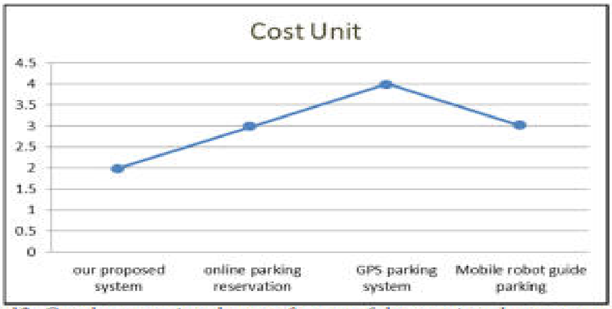


Fig 12. Graph comparing the cost factors of the mentioned systems vs. the proposed system

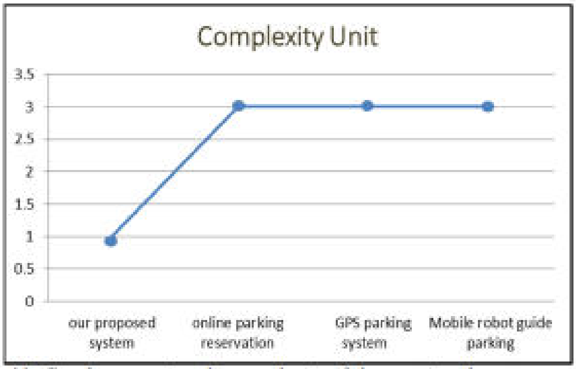


Fig 13. Graph comparing the complexity of the mentioned systems vs. the proposed system.

Comparisons of the graphs:

Our approach is more effective, as can be observed from the cost and complexity unit graphs [Fig 12] [Fig 13]. One exception, nevertheless, may be shown in the time graph [Fig 11], where it is clear that the GPS parking system requires fewer time units than our suggested approach does.

Let's examine some of these two systems' characteristics in to determine which of the two is more effective for indoor parking: Our technique is less time-efficient than the GPS auto parking system, but it has certain shortcomings as well. inside of our system. Our method is intended for indoor parking, whereas GPS parking is only available for outside parking. The requirement for an interior parking area has increased as multi-story shopping mall building has increased. Here, our technique beats the GPS parking system for cars. While the setup costs for GPS auto parking are relatively high, our solution uses a straightforward LFR and sensors, which are comparatively very affordable. However, a GPS auto parking system's network connection may occasionally not work or may take some time to establish, in which case the entire system fails. Our solution doesn't have this issue because it uses an offline technique and doesn't require a network connection. By comparing these properties to the features of the systems stated above, it can be said that our proposed system is superior.

8. FUTURE WORKS AND CONCLUSIONS

This study introduces a widely utilized and affordable LFR to haul a car utilizing a hooking mechanism. The paper suggests the inclusion of a robot using a straightforward LFR. an automobile to a vacant parking space using an algorithm and IR sensors. The goal is to use a simple, fully automated method to cut down on the time needed to park an automobile. In an additional effort to alleviate traffic issues, promoting simple and better-facilitated parking would decrease the number of cars parked on the streets.

Nevertheless, there are a few issues that arise with the suggested system. Despite the low cost of the LFR implementation, the power needed for the bot to lift the car Itself is much bigger, so it would need to be moved at a fair speed to avoid clogging the entrance and to take friction and air drag into account. It is necessary to conduct further research on a suction system to examine its effectiveness in dragging the car as opposed to hooking, which takes more time. It will also be necessary to investigate more sustainable, eco-friendly electricity sources. Only smaller parking spaces are being explored at this time, where the routes for the LFR to follow can be constructed to allow the bot to move through them as quickly as possible. The following stage would also involve reformulating our suggested approach to provide a method for collecting the car that is just as effective. In order to improve the implementation of the criterion overall, our future work will concentrate on strengthening these criteria.

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Optimized Control Subsystem in the Energy Management of Wind/Solar Hybrid Power System

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ABSTRACT

In this paper, the realization of the energy management and control subsystem of a grid-connected wind/solar hybrid power system has been introduced. The hybrid power system is based on multi-agents theory, so the control subsystem is regarded as an agent. It is composed of programmable logic controller (PLC), human-machine interface (HMI), grid-connected control module, AC multi-function electric power meters, DC electric power meters, RS485/TCP converter etc., to control and manage the operation of multi-source, such as power grid, wind turbine generation, solar photovoltaic, storage batteries and loads, also to acquire data and communicate with others. In this paper we put the emphases on its hardware, communication and how to meet its requests and functions. Experiments show that this system is competent for both grid-connected mode and stand-alone mode.

Keywords: *Wind/Solar Hybrid Power System, Energy Management, Modbus RTU.*

INTRODUCTION

Because of energy crisis and environment pollution, many attentions are put on alternative energy in recent years. Solar and wind energy sources are clean and renewable energy. Wind energy and solar radiation could complement each other during different months of the year, when the availability of wind energy is low (e.g. during summer months), solar energy availability may be high to complement it, or vice versa [1]. The complementarity is also existed in daytime and night. Wind/solar hybrid power generation system can maximize the use of the nature resource, plays high performance on reliability, efficiency and economy. As a result, more and more scholars are devoted to the research of wind/solar hybrid power generation.

Wind/solar hybrid power system usually contains several subsystems: wind turbine generation, solar photovoltaic (PV), storage batteries, grid-connected inverter and loads. The system generally runs in either stand-alone mode or grid-connection mode for providing reliable power to loads. Due to multi-source operation and decentralized distribution of subsystems, how to achieve better energy management and control is one of hot topics on hybrid power generation research.

M. Hashem Nehrir, Caisheng Wang and S.R. Guda [2] introduced wind, PV, micro turbines (MTs) and fuel cells (FCs) etc., multi-source alternative energy distributed generation system (AEDGs). The need for multi-source operation of AEDGs was explored, and four different on figurations of such hybrid DGs were presented. Then the need for their modeling and control was discussed, and simulation was given. Based on the characteristics of decentralized power generation and distributed power supply, Liu Dan, Wu Jie, Zeng Jun etc., [3] studied a hybrid power generation mode for various reproducible energy sources, and developed a mathematical model for it. By applying the principle of distributed multi-agent system, the hybrid power generation was planned in a macroscopic point of view. The agent is endowed with the independence in operation as well as the cooperation ability to cope with the random variations in natural resources.

The above mentioned techniques and most existing literature mainly centralize the modelling, control arithmetic and theory about hybrid power system energy management and control. They provide concerned requirements, methods and guides for energy management and control, could make hybrid power system more reliable and efficient.

In this paper, the hardware realization of the energy management and control subsystem of a grid-connected wind/solar hybrid power system has been introduced. The hybrid power system is based on multi-agent theory, so the control subsystem is regarded as an agent. It is composed of programmable logic controller (PLC), human-machine interface (HMI), grid-connected control module, ac multi-function electric power meters, dc electric power meters, RS485/TCP converter etc., to control and manage the operation of multi-source, such as power grid, wind turbine generation, PV, storage batteries and loads, also to acquire data and communicate with others. The communication protocol in the subsystem and between subsystems is Modbus RTU, while the communication with computer is implemented by RS485/TCP converters. So then we will discuss the work about its communication.

MULTI-AGENT SYSTEM AND ITS CHARACTERISTICS

The proposed wind/solar power system, shown in figure 1, containing several subsystems, is a decentralized, complex hybrid system. Further more, the nature of both wind and solar energy is unpredictable. Thus a distributed energy management should be applied to it. Multi-agent technology is a new technology of artificial intelligence farther development. In comparison with multi-agent system (MAS), there are many similarities between them.

MAS consists of many interactional agents that together realize a complicated task on the basis of communication and cooperation one another so as to optimize a system. It is a loose coupling agent network and these agents that have autonomous behaviour are dispersive in physical unit and in logistic unit. The agents which associate one anther by some protocol can solve a problem beyond single agent's solving ability [4]. Therefore, the wind/solar power system adopts multi-agent theory, and its subsystems are all taken as agents, which are not only independent with each other, but also work with tight cooperation.

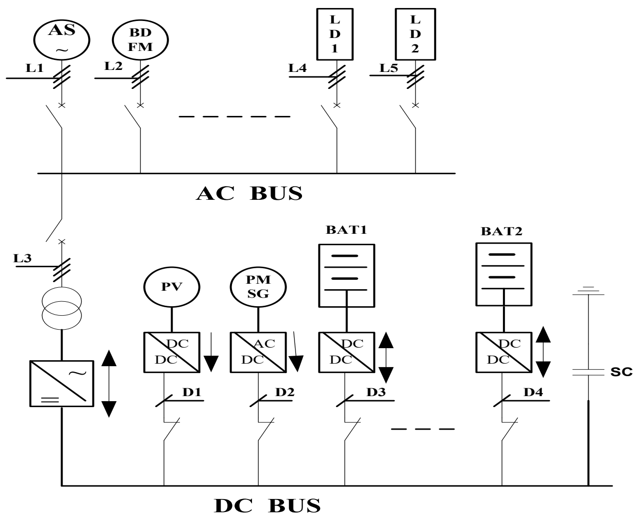

Fig. 1: Block diagram of the hybrid power system.

INTRODUCTION OF HARDWARE AND COMMUNICATION

The energy management and control system is designed to realize energy management and control with the cooperation of other subsystem. Thus it acquires the information about real time power of wind and solar energy, as well as residual capacity for batteries. In the light of loads, the system should realize the purpose of maximal use of nature resource.

A. Hardware introduction

The system is composed of several modules (shown in Fig. 2). Their function and materials are introduced below in detail. PLC, the controller of the sub system, is FBs-40MAT from FATEK. It is responsible for energy management and control of the whole system.

AC multi-function electric power meters detect and transmit the state parameter of the power sources, for example, the AC meter (1#) acquires the information including voltage, current, active and reactive power, power factor, frequency of the power grid. Then these data are displayed on the panel and transferred to PLC. DC electric power meters have the same work on DC side. All the meters are integrated communication module.

HMI in this subsystem is MT500 touch screen from WEINVIEW. It displays the information and operation status of each power source, also provides control command and instruction input.

Grid-connection control module mainly executes grid-connection command, connects AC sources together. As different AC power source will connect together, it should monitor the instantaneous voltage and find whether the voltage conditions are suitable for connection after the module receives the connection command. The controller is mainly composed of an AVR microcontroller, ATmega16, from ATMEL, and a high speed, 8-bit, 8-channel analog-to-digital converter with simultaneous track/holds, MAX155, from MAXIM. When the controller receives the grid-connection request of some channel, it will continuously sample the voltage of this channel and that of AC bus at high speed. The sample interval is about 312.5μs, namely it will sample the voltage 64 times in an AC cycle. And the sample will continue two cycles. Then calculate voltage virtual value, frequency and voltage phase difference of the two channels. If the results are in the range of allowable error, this channel is regarded in phase with the bus, and the controller sends real grid-connection command to the contactor and solid state relay (SSR), also the MCU will transfer the information to PLC. Once the grid-connection completes, the controller will maintain this status until the PLC sends a break request. Other apparatus, such as relays and contactors, compose the whole subsystem with above parts.

B. COMMUNICATION INTRODUCTION

Communication plays an important role in the system safe, reliable and precise operation. As shown in Fig. 3, it is the sketch map of communication in the system. According to different position of the communication objects, we classify two communication ways. Inner communication just refers to the devices of the control system, while extend communication is done between the subsystem of the wind/solar power system.

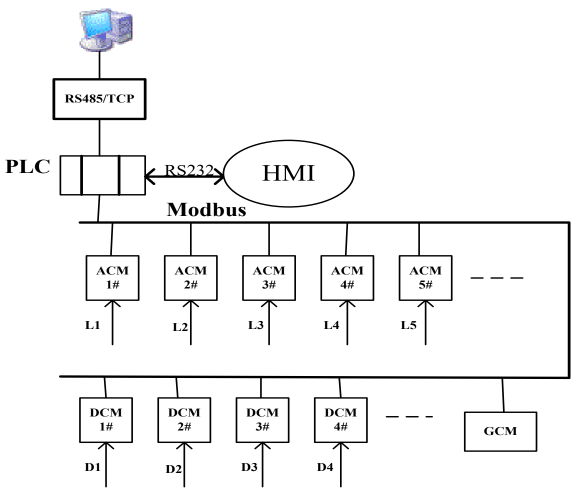

Fig. 3: Sketch map of communication in the control system

In the subsystem, there are two lines of communications: one is the line between PLC and HMI. As the protocol between them is fixed, sending/receiving data and commands must be in accord with FATEK communication protocol which the company has instituted. HMI is connected with the port0 of the PLC via RS232 interface. Because the HMI will display the information and operational status of each power source, when programming with HMI, PLC memory address of the parameters which will show on the HMI should be written to corresponding position. During running if the screen will show several data, touch screen immediately sends command to PLC according to FATEK communication protocol. Then PLC responds the command, transmits the right data to HMI.

The other line of communication is between PLC, multi-function electric power meters and grid-connection control module. It employs Modbus RTU. This protocol defines a message structure that controllers will recognize and use, regardless of the type of networks over which they communicate. It describes the process a controller uses to request access to another device, how it will respond to requests from the other devices, and how errors will be detected and reported. It establishes a common format for the layout and contents of message fields. During communications on a Modbus network, the protocol determines how each controller will know its device address, recognize a message addressed to it, determine the kind of action to be taken, and extract any data or other information contained in the message. If a reply is required, the controller will construct the reply message and send it using Modbus [6].

Each parts has integrated communication module, therefore it is necessary to set suited communication parameters. In PLC communication setting, WinPro ladder, the PLC programming software, provides Modbus Master table. In the table, PLC assigned device address number 1 is set as master node; electric power meters and grid-connection control module are set as slave node, respectively assigned device address number 2, 3, 4, etc. Usually, PLC reads data from other slave node. As each operation contains address field, function field, data field and contents of the error checking field, the later work in communication setting is setting initial store address of data in PLC, data length and function code. As for electric power meters, only the transfer rate and slave address need be set, transfer rate is 9600bps. The meters connect to port 1 of PLC by RS485 interface.

Grid-connected control module is based on MCU Atmega16. So it is necessary to think over communication process. As the message frame in Modbus RTU doesn’t include any code or character to show transfer end, parameters receiving time-out sets to 12ms. If a silent interval of more than 12ms occurs after the later character, it means this communication ending. Similarly, abnormity checking time-out sets to 0.5s. PLC uses time-out to find whether the inquired device runs in normal situation. When master node queries one slave node, if slave node has no response beyond the time, it means communication time-out abnormity.

Therefore even one slave device is off or runs abnormity during multi-devices running, it doesn't impact other device's running and communication. In order to respond in time, Modbus communication in grid-connected control module works on interrupt mode. So timer is to turn on, after the MCU receives a character. Until the timer counts 12ms, if MCU doesn't receive a new character, then the program turns to interrupt mode, and ends this communication, if does, MCU continues the communication. After communication end, MCU checks the received node address to find whether PLC query to it. If true, MCU continues error check, i.e. cyclical redundancy check (CRC). Till all is true, MCU executes the commands that PLC has queried, or gives up the operation.

The control system is taken as an agent in a multi-agent system. It has not only the characteristic of self-determination, but also has social ability, therefore it must associate with other agents. There are two ways to communicate with others. One is connecting to local Internet by RS485/TCP converter, the system transmits the data to computers. In that way, the system can work on remote control mode by computer, and we can do farther work about complex energy management and control. The other way adopts Modbus protocol. In the proposed wind/solar power system, other subsystems, for example, wind turbine generation system and storage batteries management system, should have good cooperation with the energy management and control system. All subsystems are considered as agents, and have their own controller. The communication between them also employs Modbus RTU. By communication with them, the control system gets information about real time power of wind and solar energy, as well as charge residual capacity for batteries. Meanwhile, the system can calculate the current loads by measuring the current and voltage of loads. Eventually, the system can realize energy management and control to better and maximally use nature resource.

The communication between the subsystems is more difficult then the one between PLCs. For example, how to tell storage batteries management system to charge or to discharge with character should be predefined. In Modbus, the code in the function field of the message frame has been defined (as listed in table 1), but these definitions mainly refer PLC. In storage batteries management system, the controller is MCU or DSP, so we need predefine the operation with each other. Now we take the communication between the control system and storage batteries management system as an example to introduce the process.

Table 1: The part function codes

Code	Name and mean
01	Read Coil Status
02	Read Input Status
03	Read Holding Registers
04	Read Input Registers
05	Force Single Coil
06	Preset Single Register

The control system needs to get the information about the charge residual capacity of batteries, and tells storage batteries management system to charge or to discharge. So the control system should have communication with the later system two times. First, the control system reads charge residual capacity of batteries, which is saved in the controller of storage batteries management system. According to the function codes listed in table 1, it can use code 03 to read concerned registers in Modbus communication. The second communication is to tell storage batteries management system to charge or to discharge. In the controller of this system, a variable is defined to indicate the status of batteries, for instance, binary number 00 means discharge, 01 charge, and other number means the batteries is off the DC bus. Actually, the PLC of the control system transfers different commands to the controller according to actual situation. Code 06 is used to write a binary number to the register. If the controller of storage batteries management system is assigned the device address 18, and the address of the register about charge residual capacity in controller is 00FA (in Hex format), Table 2 gives an example of a request the PLC in control system has queried to read current capacity about batteries:

Table 2: Query Example

Field Name	Hex
Slave Address	12
Function	03
Starting Address Hi	00
Starting Address Lo	FA
No. of Points Hi	00
No. of Points Lo	01
CRC	--

CONCLUSIONS

In this paper we have introduced the hardware and its functions of the control system in the energy management of a wind/solar hybrid power system. It is composed of PLC, HMI, grid-connected control module, ac multi-function electric power meters, dc electric power meters, RS485/TCP converter etc. Then we introduce the communication of the system. The control system is regarded as an agent, and under cooperation with other subsystem, it can be competent for medium-to-large-size of hybrid power systems or other similar applications. Experiments show that this system can run under both grid-connected mode and stand-alone mode. Further investigation and experiments will be done to optimize the operation of the system.

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An Effective Solution for Monitoring and Optimizing Energy Utilization for Smart Grid

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ABSTRACT

India's century-old electrical grids brought the nation inexpensive, abundant power and changed the way the country worked filling homes, streets, businesses, towns and cities with energy. What they also did was pay little regard to the environment. Unidirectional by nature, the grids were designed to distribute power, not to manage a dynamic global network of energy supply and demand. The result is, today India's grids account for some of the highest transmission and distribution losses in the world, at around 27%. This inadequacy could possibly become an obstacle to the country's progress in the years to come. Regardless, a report earlier this year on the top 10 smart grid countries by the research firm Innovation Observatory ranked India No.3 behind the U.S. and China. Smart grid refers to an improved electricity supply chain using digital technology. It enables monitoring, analysis, control and two-way communication between the electrical delivery system and the consumer end. Smart grids use sensors, digital meters and controls and analytical tools to automate, monitor and control flow of energy and hence provide detailed and timely information on energy consumption. In this paper the proposed system with effective solutions for multiple problems faced by India's electricity distribution system such as varying voltage levels experienced due to the varying electrical consumption, power theft, manual billing system, and transmission line fault for single phase electricity distribution system also various techniques used for the energy optimization along with the consumption scheduling algorithm using linear programming method are mentioned.

Keywords: *Smart grid, Optimization, Simplex algorithm.*

1. INTRODUCTION

A smart grid is a digitally enabled electrical grid that gathers, distributes, and acts on information about the behavior of all participants (suppliers and consumers) in order to improve the efficiency of electricity services or it is a technique used to increase the connectivity, automation and coordination between the suppliers, consumers and networks that perform either long distance transmission or distribution. The objectives of smart grid are: fully satisfy customer requirements for electrical power, optimize resources allocation, ensure the security, reliability and economic of power supply, satisfy environment protection constraints, guarantee power quality and adapt to power market development. Smart grid can provide customer with reliable, economical, clean and interactive power supply and value added services.

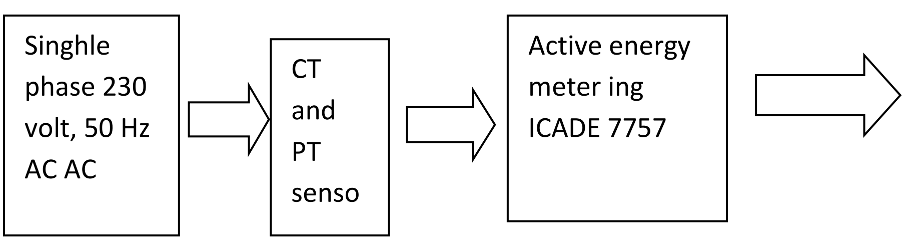
2. COMPARISON OF SMART GRID WITH EXISTING GRID

Smart grid has many advantages as compared with existing grid some of the advantages and the comparison with the existing grid is given in Table 1

Existing Grid	Smart Grid
Electromechanical	Digital
One-way communication	Two-way communication
Centralized generation	Distributed generation
Few sensors	Sensors throughout
Manual monitoring	Self-monitoring
Manual restoration	Self-healing
Limited control	Pervasive control
Few customer choices	Many customer choices

The proposed system with effective solutions for multiple problems faced by India's electricity distribution system such as varying voltage levels experienced due to the varying electrical consumption, power theft, manual billing system, and transmission line fault for single phase electricity distribution system also various techniques used for the energy optimization along with the detail mathematical model of consumption scheduling algorithm using linearprogramming method are mentioned.

3. BLOCK DIAGRAM AND DESCRIPTION



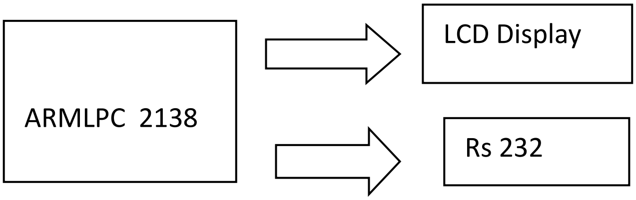


Fig 1. Block Diagram For monitoring of Energy Utilization

Initially the 230 V 50 Hz supply is given to the circuit CT & PT Sensors:Current Transformer sensor is step down transformer (5A :50mA) and Potential Transformer sensor is also a step down transformer(230V: 9V). Active Energy Metering IC ADE 7757: The ADE7757 is a high accuracy electrical energy measurement IC. It is a pin reduction version of the ADE7755 with an enhancement of a precise oscillator circuit that serves as a clock source to the chip. The ADE7757 supplies average real power information on the low frequency outputs F1 and F2. These outputs may be used to directly drive an electromechanical counter or interface with an MCU. The high frequency CF logic output, ideal for calibration purposes, provides instantaneous real power information.3.ARM 7(LPC 2138):The LPC2131/32/34/36/38 microcontrollers are based on a 16/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combine the microcontroller with 32 kB, 64 kB, 128 kB, 256 kB and 512 kB of embedded high-speed flash memory. A 128-bit wide memory interface and a unique accelerator architecture enable 32-bit code execution at maximum clock rate. Due to their tiny size and low power consumption, these microcontrollers are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. With a wide range of serial communications interfaces and on-chip SRAM options of 8 kB, 16 kB, and 32 kB, they are very well suited for communication gateways and protocol converters, soft modems, voice recognition and low-end imaging, providingboth large buffer size and high processing power.

LCD Display: Available Modules:-

Based on Alphanumeric Displays

- 16×2 ("16" Represents Columns & "2" RepresentsRows)
- 16×1
- 16×4
- 20×2

For system 16×1 is used.

RS 232:

DS232A Dual RS-232 Transmitter/Receiver is used with the following features:

a. High data rate - 250 kbits/sec under load
b. 16-pin DIP or SOIC package
c. 20-pin TSSOP package for height restrictedapplications
d. Operate from single +5V power
e. Meets all EIA-232E and V0.28 specifications
f. Uses small capacitors: 0.1 µF
g. Optional industrial temperature range

Implementation of simplex algorithm: Implementation is possible with the help of MATLAB which is a high- performance language used for technical computing. Typical uses include : Math and computation Algorithm development, data acquisition Modeling, simulation, and prototyping Data analysis, exploration, and visualization. Scientific and engineering graphics Application development, including graphical user interface building. Linear Programming Strategies Using the Simplex Method

- Identify the problem
- Formulate the problem using LP
- Solve the problem using LP
- Test the model (correlation and sensitivityanalysis)
- Establish controls over the model
- Implementation
- Model re-evaluation

4. OPTIMIZATION ALGORITHM

The focus of the work in this paper is on power consumption scheduling known as demand-side management. The optimization technique is proposed to schedule the power of individual appliances centralized optimization based on linear programming[1].The consumption scheduling optimization mainly carried out for the home appliances which does not have the fixed power consumption like washing machine or water boiler. Optimization mean is to optimize is to make as perfect effective and functional as possible. The technology optimization is a set of methods and techniques for the design and use of technical systems as fully as possible within the parameters. Engineers and scientists use mathematical modeling to describe the behavior of systems under study. This mathematical program, or optimization problem description, can then be solved using optimization techniques. Linear programming is one class of mathematical programs where the objective and constraints consist of linear relationships. Linear programming problems consist of a linear expression for the objective function and this technique is widely used. There are three types of optimization algorithms. The interior point algorithm used for solving linear programming problems. Interior point is especially useful for large-scale problems can be defined using complex matrices. The active-set algorithm minimizes the objective at each iteration over the active set until it reaches a solution and it is used for small scale problems. The simplex algorithm is a systematic procedure for generating and testing a linear program. The simplex algorithm is the most widely used algorithm for linear programming. The advantages of the simplex algorithm are Simple and easy to implement. It can be used to tackle problems in which there are more than two decision variables. It is a method that can be programmed on a computer fairly and easily.

Implementation of simplex algorithm: Implementation is possible with the help of MATLAB which is a high- performance language used for technical computing. Typical uses include : Math and computation Algorithm development, data acquisition Modeling, simulation, and prototyping Data analysis, exploration, and visualization. Scientific and engineering graphics Application development, including graphical user interface building. Linear Programming Strategies Using the Simplex Method

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- Implementation
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5. CONCLUSION AND FUTURE SCOPE

The proposed system will provide an effective solution for some of the main problems faced by Indian Electricity distribution system like line fault and power theft along with optimizing energy utilization by using an simplex optimization algorithm which is simple and easy to implement. It will reduce the energy wastage and save a lot of energy ,that can be returned back to the grid.The system may able to schedule optimal power and operation time according to user preference and the power consumption pattern. In future it is possible to implement the system for three phase electric distribution system and multiple users to achieve co-operative scheduling in India. Using this proposed system it is possible to save a lot of energy for future use.

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Design of Optimal Fault Analysis of Grid Connected MPPT Based Photovoltaic System

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ABSTRACT

This paper presents the simulation model of a 158kW PV array followed by a boost converter, which boost up the output voltage of the PV array. Maximum power point tracking (MPPT) can effectively improve the solar energy conversion efficiency of PV array, in this paper perturb- and – observe (P&O) algorithm has been used to achieve this function. Grid connected PV system needs a three phase inverter for synchronization. The inverter control system modeling has been carried out in Matlab/Simulink 2010 environment with the aids of the proportional-integral controllers, sinusoidal vectored pulse width modulation technique and park transformation. Phase locked loop (PLL) is used to lock the grid frequency and phase. Finally different types of AC faults are created on the grid side and total harmonic distortion (THD)is calculated in each of the case.

Keywords: *Photovoltaic (PV), Voltage source inverter (VSI), sinusoidal vectored pulse width modulation (SVPWM), Total harmonic distortion (THD), Maximum power point tracking (MPPT).*

INTRODUCTION

Renewable energy sources play an important role in electric power generation. Various renewable energy sources such as solar energy, wind energy, geothermal energy etc, are harness for electric power generation specifically solar energy has the advantages of no pollution, low maintenance cost, no installation area limitation and no noise due to the absence of moving parts. In recent years, photovoltaic (PV) systems have received unprecedented attention due to the concerns about adverse effects of extensive use of fossil fuels on the environment and energy security. Despite this high interest, grid connected PV systems are still outnumbered by the power generation schemes based on oil, natural gas, coal, nuclear, hydro, and wind [1]. So far, PV system of capacities on the order of tens of megawatts have been installed and interfaced to the grid mainly at the primary distribution level.

1. The main drawbacks are the initial installation cost is considerably high and

the energy conversion efficiency is relatively low, to overcome these problems the following two essential ways can be used (1) increase the efficiency of conversion of solar array (2) maximize the output power from the solar array. A grid-connected PV system includes a PV array, a voltage source inverter, an inverter control system, a load and a grid. The PV array consists of a number of individual photovoltaic cells that are connected in series and parallel array to convert sunlight to electricity by use of photovoltaic effect since the PV array produces DC power so the power electronics and control equipments are required to convert DC to AC power, this AC power is injected to utility grid.
Maximum power point tracking (MPPT)can effectively improve the solar energy conversion efficiency of PV system. In this paper*perturb- and – observe* (P&O)method is used to achieve this function. This paper establishes a dynamic model PV system by Matlab/simulink with d-axis and q-axis as coordinates which is synchronously rotating with the grid voltage to reflect the characteristics of system accurately. Reliability is an important issue in large-scale grid-connected photovoltaic (PV) systems as their operations rely on business plans developed over periods of time of at least twenty years, which often assume fault-free functioning. Not many papers discussing PV systems reliability are available in literature. For instance, [2] analyzes simple stand-alone PV systems using failure mode effect analysis (FMEA) and fault tree analysis (FTA). Failure rates estimates are also given assuming that time to failure is exponentially distributed. The failure rate for a PV array is hypothesized as being $33.3*10^{-6}$ failures/month, while inverter failure rate is assumed to be $342.5*10^{-6}$ failures/month[3].Since the inverter failure rate is more than the failure rate of PV array it is being necessary to analyze the fault in the inverter side i.e. L-G, L-L-G, L-L-L-G, L-L, L-L-L and the total harmonic distortion (THD) is calculated for without fault condition and with different types of fault condition.

MATHEMATICAL Modelling

The direct conversion of the solar energy into electrical power is obtained by solar cells. A PV is composed by many strings of solar cells connected in series and in parallel combination, in order to provide desired values of output voltage and current.

The mathematical model of the PV cell is implemented in the form of a current source controlled by voltage, sensible to two input parameters, i.e. temperature (°C) and solar irradiation power (W/m2). An equivalent simplified

electric circuit of a photovoltaic cell is presented in Fig.1.

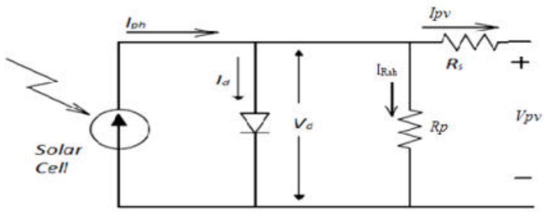

Fig.1. Equivalent circuit diagram of PV cell.

The net current of the PV cell is the difference between the photo generated current I_{SC} and diode current I_d.

$I_{PV} = I_{SC} - I_0*(e^{q*(V+I*R_S)/(n*K*T)}-1)$ (1)

Where

I_0 is the reverse saturation current of the diode.

q is the electron charge ($1.602*10^{-19}$ C).

V is the terminal voltage.

K is the Boltzmann constant ($1.381*10^{-23}$ J/K)

T is the junction temperature in Kelvin (K)

Now equation (1) can be solved using Newton's method [4]

$x_{n+1}= x_n - f(x_n) / f'(x_n)$

Where: $f'(x)$ is the derivative of the function, $f(x) = 0$, x_n is a present value, and x_{n+1} is the next value.

Now equation (1) can be written as

$f(I_{PV}) = I_{SC} - I - I_0*(e^{q*(V+I*R_S)/(n*K*T)}-1) = 0$

Then using Newton's equation

$$I_{PV\,n+1} = I_n - \frac{I_{SC} - I_n - I_0*(e^{q*(V+I_n*R_S)/(n*K*T)} - 1)}{-1-(I_0*q*R_S*e^{[q*\frac{V+I_n*R_S}{n*K*T}]})/(n*K*T)} \qquad (2)$$

The MATLAB function written to solve equation (2) performs the calculation five times iteratively.

The figure 2 and 3 represents the V-I and V-P characteristics of solar cell.

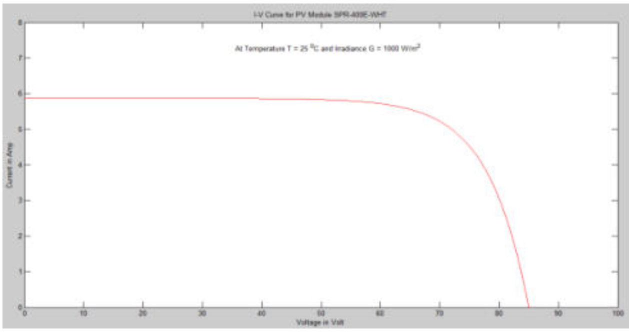

Fig.2. V-I characteristics of solar cell

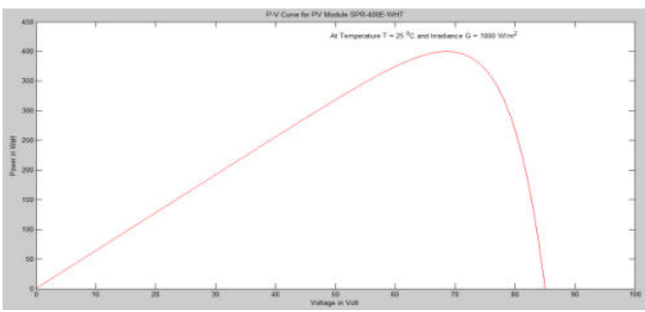

Fig.3. V-P characteristics of solar cell

The photon generated current at a given irradiance is given by

[5, 6, 7, 8]

$$I_{SC} = (I_{scn} + K_1 * \Delta T) * GG_n \qquad (3)$$

Where

I_{scn} = light-generated current at the nominal condition (Usually 25^oC and $1000W/m^2$)

$\Delta T = T - T_n$ (T and T_n are the actual and nominal temperature in Kelvin)

G = Actual irradiance available.

G_n = Irradiance available under nominal condition.

The diode saturation current at a given temperature is given by [7, 9, 10, 11]

$$I_0 = I_{0n} * \left(\frac{T}{T_n}\right)^3 * e^{\left[\left(\frac{T}{T_n} - 1\right) * \frac{E_g}{n*V_t}\right]} \qquad (4)$$

Where

E_g = Bandgap energy of the semiconductor.

I_{0n} = Nominal reverse saturation current.

V_t = Junction thermal voltage It is a characteristic voltage that relates current flow in the p-n junction to the electrostatic potential across it.

Fig-4, 5, 6 and 7 represents the characteristics of solar cell under different irradiance and temperature.

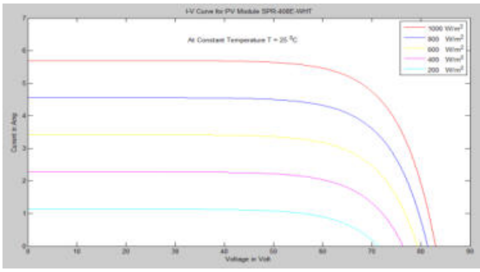

Fig.4. V-I characteristics of solar cell under constant temperature and different irradiance.

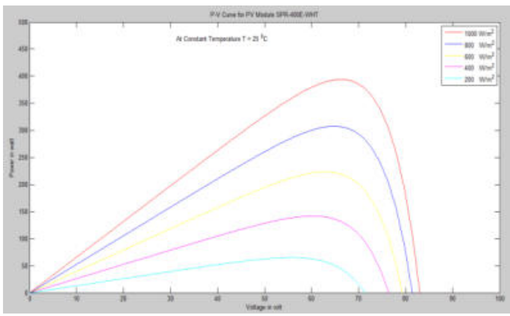

Fig.5. V-P characteristics of solar cell under constant temperature and different irradiance.

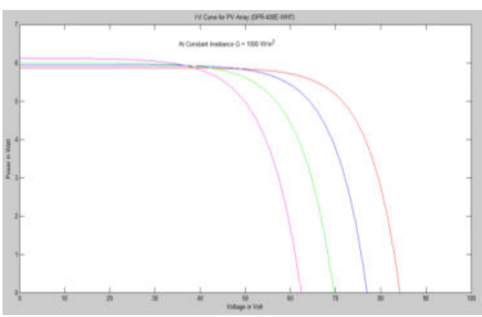

Fig.6. V-I characteristics of solar cell under constant irradiance and different temperature.

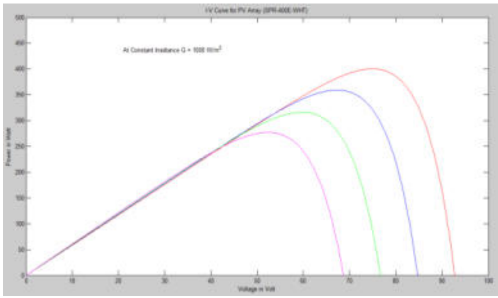

Fig.7. V-P characteristics of solar cell under constant irradiance and different temperature

4. PRINCIPLE OF MPPT ALGORITHM

Peak power is reached with the help of a dc/dc converter between the PV generator and the load by adjusting its duty cycle such that the resistance matching is obtained. Now the question arises how to vary the duty cycle. The automatic tracking can be performed by implementing various algorithms. These algorithms are the heart of MPPT controller. The algorithm changes the duty cycle of the dc/dc converter to maximize the power output of the module and make it operate at the peak power point of the module. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation or popularity, among others. From a state owned monopoly with administrated prices, the power sector is now moving towards private ownership and market controlled pricing. Many new players have entered the scene. Many international consultants, leading agencies and equipment manufacturers have come to India;

regulatory commissions have been set up and they have started having public hearing; consumer organizations and other civil society installations have increased their role in policy discussions.

Ministry of power and central electricity authority (CEA) are responsible for formulation of national power policy, overall panning and coordinating power development at the national level. central electricity authority (CEA) has been originally established under the section 3 of electricity supply act 1948 and continuous to exercise such function and perform duties are assigned to it under the electricity act 2003. CEA is responsible for overall planning and development of the power sector in the country. CEA is technical organization to advise and assist central government on matters of relating to generation, transmission, distribution, trading and utilization of electricity. Linkages with other ministries/departments in the central government, planning commission and the state governments are also essential for the overall development of the power sector. The erstwhile regional electricity boards (REBs), now regional power committees (RPCs) are non-stationary bodies under the government of india, which coordinate and formulate policies and guidelines for integrated operation of the regional power grids.

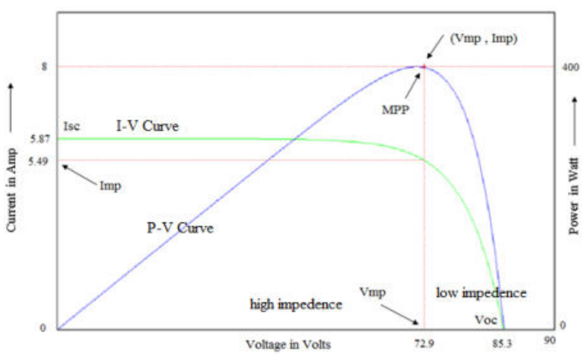

Fig.8. I-V & P-V curve & maximum power point

In this paper perturb and observe algorithm is implemented. In this algorithm a slight perturbation is introduced in to the system. Due to this perturbation the power of the module changes. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses. At MPP, Vref= VMPP. Once the MPP is reached, operation of PV array is maintained at the point unless change in power is noted, indicating change in atmospheric conditions and the MPP. The algorithm decrements or increments Vref back to new MPP. The flowchart is shown in Fig.9.

5. DESIGN DETAILS OF THE SYSTEM

A photovoltaic array of 3.5 kW is used to convert sunlight into DC current. The output of the array is connected to a boost DC converter that is used to perform MPPT functions and increase the array terminal voltage to a higher value so it can be interfaced to the distribution system grid of 25 kV. The DC converter controller is used to perform these two functions. A DC link capacitor is used after the DC converter and acts as a temporary power storage device to provide the voltage source inverter with a steady flow of power. The capacitor's voltage is regulated using a DC link controller that balances input and output powers of the capacitor. An LC low pass filter is connected at the output of the inverter to attenuate high frequency harmonics and prevent them from propagating into the power system grid. This provides a smooth output current which is low in harmonic content.

The voltage source inverter is controlled in the rotating dq frame to inject a controllable three phase AC current into the grid. To achieve unity power factor operation, current is injected in phase with the grid voltage. A phase locked loop (PLL) is used to lock on the grid frequency and provide a stable reference synchronization signal for the inverter control system, which works to minimize the error between the actual injected current and the reference current obtained from the DC link controller. The brief description of the controlling components of grid connected PV array system is discussed below.

LC Filter

Output voltage wave is synchronized with the grid voltage. So the PWM inverter will inject ripple current in to the grid. The output LC filter is connected to remove high switching frequency components from output current of inverter [12]. The value of L is design based on current ripple. Smaller ripple results in lower switching and conduction losses.Typically the ripple current can be chosen as 10% - 15% of rated current. Considering 10% ripple at the rated current the designed value of inductor (L) in the system [13, 14] is given by (5)

$$\Delta i_{Lmax} = 1/8 * V_{dc} / L * f_s \quad (5)$$

The capacitor C is designed based on reactive power supplied by the capacitor at fundamental frequency. In this design reactive power is chosen as 15% of the rated power [13] is given by (6)

$$C = 15\% * P_{rated} / 3 * 2\pi f * V_{rated}^2 \quad (6)$$

Phase Locked Loop

Grid synchronizations plays important role for grid connected systems. It synchronizes the output frequency and phase of grid voltage with grid current using different transformation. Different methods to extract phase angle have been developed and presented in many papers [15, 16]. PLL techniques causes one signal to track another one. Phase-locked loop (PLL) is a feedback loop which locks two waveforms with same frequency but shifted in phase. The fundamental use of this loop is in comparing frequencies of two waveforms and then adjusting the frequency of the waveform in the loop to equal the input waveform frequency.The role of the phase locked loop is to provide the rotation frequency, direct and quadrature voltage components at the point of common coupling (PCC) by resolving the grid voltage abc components. Multiple control blocks of the PV system rely on this information to regulate their output command signals. The PLL computes the rotation frequency of the grid voltage vector by first transforming it to the dq frame, and then force the quadrature component of the voltage to zero to eliminate cross coupling in the active and reactive power terms [17]. To simulate the system and the resulting output currents and voltages at various levels, the array was subjected to a 1000 W/m2 of solar irradiation and a temperature of 25° C. The DC output current, terminal voltage and power of PV array was monitored during simulation at the specified atmospheric conditions. The switching action of the DC converter caused some ripple in the output current with an average value of about 13.5 A, the ripple magnitude can be reduced by increasing the size of the inductor used in the boost converter. There are some initial transients in the current waveform at the beginning of simulation as the system started operation and the DC converter drove the array to the estimated maximum power point. All the simulations given below are for 0.5 seconds.Fig.24, 25shows the comparison of voltage, current and power of PV array without and with MPPT and boost converter power with MPPT respectively. It can be observed that PV array feeds 3.5 kW to the inverter using MPPT. Without MPPT the power reduces drastically from 3.5 kW to 2.9 kW.

CONCLUSIONS

A 158 kW PV array with MPPT has been modeled and simulated. The MPPT employed perturb and observe algorithm. The simulated results confirm the effectiveness of the MPPT. It is observed that with MPPT the power fed to the inverter from PV array has increased by 14%. A PLL has been designed for grid synchronization and it effectively synchronizes the inverter voltage and frequency with the grid voltage and frequency. In case of fault it is observed that it takes only 0.2 sec for the system to become stable at nominal frequency. Fault analysis on grid side have been performed for various fault conditions like; LG, LL, LLL, LLG faults. The variations of active and reactive power and variation of voltage and current THD without fault and with fault conditions are studied. The findings of the fault analysis are essential for designing the protection circuit.

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Optimized Speed Control of DC Motor Using adaptive Techniques (MRAC)

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ABSTRACT

Speed control is a common requirement in the industrial drives in the presence of varying operating conditions ie .load disturbance, parameter uncertainties and noise. Conventional controllers with fixed parameters are not successful in the real time applications because of the drift in the plants operating conditions. Adaptive control techniques are best suited for these situations. This paper presents a case study on speed control of dc drive using Model Reference Adaptive Control (MRAC). MRAC is one of the main adaptive control schemes. The fluctuation in load is assumed to be an input disturbance on the plant, which causes the deviation in the desired speed. In the literature various adaptive control algorithms have been developed. An adaptive algorithm by Ioannou [8, 9] is applied and simulations have been carried out for different values of load disturbances, parameter uncertainties and output measurement noise. The simulation results reported in this paper demonstrates the effectiveness of the proposed controller against varying operating conditions.

Keywords: *dc drives, MRAC, Adaptive control, Lyapunov approach, tracking control.*

INTRODUCTION

A common actuator in control systems is a dc motor and is obvious choice for implementation of advanced control algorithms in electric drives, due to the stable and linear characteristics associated with it. It is also ideally suited for tracking control applications as shown in references [1, 3, 4, 6,]. From a control system point of view, the dc motor can be considered as a SISO plant eliminating the complexity associated with multi-input drive systems. The speed of a driven load often needs to run at a speed that varies according to the operation it is required to perform. The speed in some cases (such as fluctuating loads like rolling mills) may need to change dynamically to suit the conditions, and in other cases may only change with a change in process. In real time control the parameters are always time variant and are subject to various drifts depending on the operating conditions. It is found that the controllers designed with fixed parameters are not effective in achieving the desired performance and therefore adaptive controllers are best suited. In adaptive control the controller parameters are updated at every instant of time to satisfy the design requirements, unlike the conventional controllers.

This paper describes the rejection of deviation in speed caused by load disturbance for a separately excited dc motor under various load-disturbing situations, parameter uncertainties and measurement noise with an adaptive control approach resulting in an improved performance.

Apart from various conventional control strategies, adaptive control has proved its potential application in tracking/trajectory control problem. Siri Weerasooriya [2] developed a modified adaptive controller based on minimum variance self tuning controller. This scheme is effective even in the presence of external disturbances; provided that the system exhibits minimum phase characteristics. El- Shar kawi (1989) [1 3] developed the variable structure tracking of dc motor for high performance applications. In his work variable structure system control is used for on-line tracking of dc motor. In 1990, Sharkawi [4] developed adaptive control strategy based on self tuning control. The purpose of the controller is to force the motor states such as speed, position or armature current to follow pre specified tracks without excessive overshoots and oscillations. Siri Weera sooriya (1991) [6, 7] used the ability of Artificial Intelligence to identify the system dynamics and for trajectory control, the indirect MRAC is used, which is specifically useful in tracking applications. An attempt has been made to merge the accuracy of MRAC system and calculation speed of ANNs to come up with a trajectory controller for dc motor applications .El Samahy (2000)[10] described the design of robust adaptive discrete variable structure control scheme for high performance dc drives. Jianguo Zhou (2001) [11] proposed a global speed controller for the separately excited dc motor. In this work the motor is modeled in two local areas, the first model is a linear one when speed is under the base speed and other is nonlinear when speed is to be obtained using field weakening method. For first part linear robust linear state feedback controller and for nonlinear part adaptive back stepping controller is used. Crnosiya P. (2002) [12] presented In [1 5] a fuzzy control has been developed with a fuzzy based MRAC for wide range of speed but the sensing of speed due to load change and corresponding determination of fuzzy control parameters in real time is not included. This may be cause of concern in real time applications. the application of MRAC with signal adaptation to permanent magnet brushless dc motor drives. MRAC with signal adaptation algorithm has been applied to compensate parameter sensitivity and influence of load disturbances In this paper MRAC has been tested for load disturbances as well as for parametric variations using adaptive gain control mechanism explained in sections 3, 4 to achieve zero steady state error. Results of simulation are presented along with comparisons to demonstrate the general applicability .The results are very encouraging compared to earlier studies.

MODELING OF DC MOTOR [10, 12]

Control of the motor is achieved by changing the armature voltage as shown in figure 1. The separately excited dc motor drive is characterized in continuous time domain by using following differential equations.

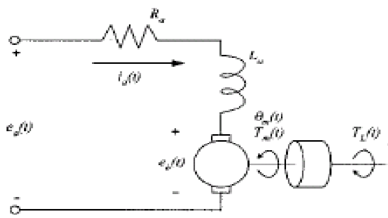

Fig. 1 Armature controlled dc motor

The main assumptions for describing the motor dynamics are:

1. The magnetic circuit is linear (because due to saturation of the magnetic core linear relationship does not hold for high values of field current)

2. The mechanical friction including viscous friction and Coulomb friction is linear in the rated speed region.

In the dc motor model the variables and parameters are as given below:

=Armature winding resistance [ohms];

=Armature winding inductance [Henry];

= Armature current [amps];

=Field current [amps]=a constant;

=Applied armature voltage [volts];

= Back emf [volts];

= Angular velocity of the motor [rad/sec];

=Torque developed by the motor [Newton-m];

=Moment of inertia of the motor rotor [kg-m2 or Newton-m/(rad/sec2];

=Viscous friction coefficient of the motor [Newton-m/(rad/sec)];

=Disturbance load torque [Newton-m];

The input voltage Va is applied to the armature which has a resistance of Ra and inductance of La. The field current supplied supplied to the field winding is kept constant and thus the armature voltage controls the motor shaft output. The moment of inertia and the coefficient of viscous friction at the motor shaft bein and respectively. The speed of the motor is being radian per second. The related dynamics equations.

STATE SPACE REPRESENTATION [5]

Let the armature current ($i_a = x_1$) and angular velocity ($\omega_m = x_2$) be the state variable and the angular velocity be the output variable. Therefore the following state space model can represent the dynamics of dc motor.

$$\frac{di_a}{dt} = -\frac{R_a}{L_a}.i_a - \frac{K_b}{L_a}.\omega_m + \frac{V_a}{L_a}$$

(3.1) $$\frac{d\omega_m}{dt} = \frac{K_T}{J_m}.i_a - \frac{B_m}{J_m}.\omega_m - \frac{T_w}{J_m}$$ (3.2)

$$\dot{X} = Ax + Bu + Fw \quad (3.3)$$

$$y = Cx$$

6.
7.

(3.4)

where $x = [x_1 \quad x_2]$; state vector u = Input to the motor (scalar) T_w = Load disturbance, Nm

Matrix A, B and F are given as:

8. $$A = \begin{bmatrix} -\frac{B_m}{J_m} & \frac{K_T}{J_m} \\ -\frac{K_b}{L_a} & -\frac{R_a}{L_a} \end{bmatrix}; B = \begin{bmatrix} 0 \\ \frac{1}{L_a} \end{bmatrix}; F = \begin{bmatrix} -\frac{1}{J_m} \\ 0 \end{bmatrix}$$

9. $$C = [1 \quad 0]$$

For the design of MRAC controller the triple (A, B, C) are assumed to be completely controllable and observable. The load changes are considered as changes in motor rotor inertia and viscous-friction coefficient as practically seen in most control applications. Hence plant parameter changes in the simulation studies reflect abrupt load changes of the system

MODEL REFERENCE ADAPTIVE CONTROL

The objective of model reference control is to ensure the output of a controlled system (plant) to track the output of a chosen reference model, in addition to closed-loop stability [1, 7, 8]. When the plant parameters are unknown, adaptive laws are designed to update the parameters of a controller to provide the desired output. In this scheme, the objectives of control are specified by the output of the reference model. The design problem involves the adaptation of controller parameters based on past values of controller parameters and the control inputs such that the error between the plant and model outputs approaches zero asymptotically. The tracking error represents the deviation of the plant output from the desired trajectory. The closed-loop plant consists of output feedback, controller (with adjustable parameters) and an adjustment mechanism that adapts the controller parameters online. The main issues are controller parameterization, error model derivation, minimum priori plant knowledge, adaptive law design, and stability analysis [15].The basic structure of this MRAC scheme is shown in figure 3.

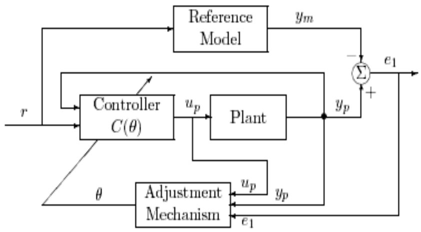

Fig. 2: Basic structure of MRAC scheme

- **DIRECT AND INDIRECT MRAC**

An adaptive controller is formed by combining a parameter estimator, which provides estimates of unknown parameters at each instant, with a control law that is motivated from the known parameter case. The way the parameter estimator (adaptive law) is combined with the control law give rise to two different approaches. In the first approach, referred to as indirect adaptive control, the plant parameters are estimated on-line and used to calculate the controller parameters. In the second approach, referred to as direct adaptive control, the plant model is parameterized in terms of the controller parameters that are estimated directly without intermediate calculations involving plant parameter estimates. [2, 9, 10, 11]

The main differences between indirect and direct adaptive control lies in the following two facts:

- A model of the desired behaviour is explicitly used in direct control whereas a model of the plant identified on-line is used in indirect control.
- Identification error in indirect control and the control error in direct

control are used to update the controller parameters.

- **DESIGN BASED ON LYAPUNOV APPROACH**

Stability is an extremely important factor, which must be taken into consideration in the design of MRAC systems because these systems behave like non-linear, time-varying systems. In earlier designs (MRAC)based on MIT rule) instability may arise because of faster adaptations and also for large inputs. Hence, to achieve acceptable design, stability aspect should be incorporated by using the Lyapunov approach. This method of developing adaptive laws is based on direct method of Lyapunov and its relationship with positive real functions. In this approach, the problem of designing adaptive law is formulated as a stability problem where the dynamical equation of the adaptive law is chosen such that certain stability conditions based on Lyapunov theory were satisfied. In this approach, first step is to obtain differential equation that describes the error between the output of the reference model and that of plant. The objective is parameter updation for controller equations, which also assures that the differential equation, which describes the error gradually leads to asymptotic stability. To achieve this, a positive-definite Lyapunov function is formulated for the error equation. The adaptation mechanism is then selected so as to insure the time derivative of the Lyapunov function to be negative definite and result in globally asymptotically stable closed-loop system. Next section describes the design method with above objective [9, 12].

DESIGN OF MRAC FOR LTI SISO SYSTEM

Consider an unknown, single input, single output, and linear time-invariant plant in the form of $G_p(s) = k_p \dfrac{Z_p(s)}{R_p(s)}$ (5.1) or in the equivalent state space form as

$$\dot{x}_p = A_p x_p + B_p u_p, x_p(0) = x_0$$
$$y_p = C_p^T x_p \qquad (5.2)$$

where

$x_p \in R^n; y_p, u_p \in R^1$ and A_p, B_p, C_p have the appropriate dimensions.

Z_p, R_p are the monic polynomials and k_p is a constant referred to as the High Frequency Gain (HFG). In order to meet the MRAC objective plant model satisfy the following assumptions.

P1. $Z_p(s)$ is a monic Hurwitz polynomial of degree m_p.

P2. An upper bound n of the degree n_p of $R_p(s)$.

P3. The relative degree $n^* = n_p - m_p$ of $G_p(s)$, and

P4. The sign of the high frequency gain k_p is known

REFERENCE MODEL

The objective of control system is to find a direct controller that is differentiator free and the output of the plant should follow the output of the pre-specified reference model. The model is chosen in the form of (5.3) where are monic polynomials and km is constant gain and is the reference input assumed to be a uniformly bounded and piecewise continuous function of time. The following assumptions regarding reference model are assumed to hold:

M1. Zm(s), Rm(s) are monic Hurwitz polynomials of degree qm, pm respectively, where pm<=n.

M2. The relative degree of Wm(s) is same as that of Gp(s), i.e.

- **STATEMENT OF THE PROBLEM**

The problem statement can be stated as follows:

Given input and output from dc motor as in (5.1) and a reference model described by (5.3), the control input u(t) to the plant is be determined such that In the plant considered the occurrence of load on the motor causes disturbance. Due to this load disturbance the speed of the motor fluctuates, so the designed scheme must be able to reject the variation in motor speed and reach the steady desired speed within time by reference model.

- **CONTROLLER STRUCTURE**

To meet the above specifications, the controller structure is organized as:

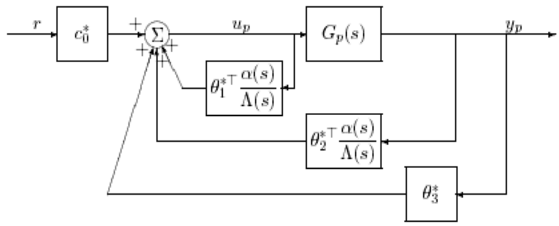

Fig. 4: Controller structure

$$u(t) = \theta_1^T(t)\frac{\alpha(s)}{\Lambda(s)}u + \theta_2^T(t)\frac{\alpha(s)}{\Lambda(s)}y_p + \theta_0(t)y_p + c_0 r \tag{5.5}$$

$$\theta^*(t) = [\theta^{*T}_1(t), \theta^{*T}_2(t), \theta^*_0(t), c_0^*]^T$$

where $\alpha(s) = [s^{n-2}, s^{n-3}, \ldots, s, 1]^T$; for n>=2

$\alpha(s) = 0$; for n=1

where $\Lambda(s)$ is an arbitrary monic Hurwitz polynomial of degree n-1 that contains $Z_m(s)$ as a factor, i.e.,

$$\Lambda(s) = \Lambda_0(s)Z_m(s) \tag{5.6}$$

which implies that $\Lambda_0(s)$ is monic, Hurwitz and of degree $n_0=n-1-q_m$.The controller parameter vector is chosen such that the transfer function from r to y_p equals to $W_m(s)$.The I/O properties of the closed loop plant are described by the transfer equation

$$y_p = G_c(s).r \tag{5.7}$$

we can now meet the control objective if we select the controller parameters ,so that the closed loop poles are stable and the closed loop transfer function $G_c(s) = W_m(s)$ is satisfied.

4. SELECTION OF REFERENCE MODEL

The first step in controller design is to select a suitable reference model for the motor to follow. Let us assume that the dc motor is to behave as a second order system whose input is $r(t)$ and the output is $\omega_m(t)$. For a continuous- time system, the reference model can be selected as the ideal second order system transfer function.

$$\frac{\omega_m(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

In this case, speed desired is 57.6 rad/s (550rpm). The damping coefficient (ξ) is taken as one in order to represent critical damping. The above design procedure ensures that the reference model is compatible with the actual motor dynamics. This is an important consideration since an arbitrarily selected reference model can degrade the tracking performance. In case of large and abrupt reference tracks, a bound on the control signal is needed or the control technique must be modified to include the control signal in the performance index. The desired trajectory is as given For the system considered under case study desired specification are given in the following table.

CONCLUSIONS

From the simulation results it is inferred that for the limiting value of the control input, the value of adaptation gain can be varied up to certain maximum value. If it is further increased controller parameter does not converge to some constant value. Although as the adaptation gain is increased (within that max value) the adaptation becomes faster on account of becoming control input violently high this may not be compatible to the system. It is also inferred that with the increase in adaptation gain the error becomes smaller .All the results are found for the adaptation gain of 0.0008. All the results show the values of control input (armature voltage), input current (armature current) and speed as per the motor ratings (plots are not shown due to space constraints).

To demonstrate the effectiveness of the MRAC, the system (dc motor) has been simulated under various operating conditions such as load disturbance, parameter uncertainties, and measurement noise and for different shapes of tracks selected. Robustness is of particular importance in most of the control applications. Controllers with the fixed parameters cannot be robust unless unrealistically high gains are used. Hence the fixed controller parameter controllers cannot be considered for high performance applications. Simulation result shows that the robustness is greatly enhanced by this adaptive scheme, by continually adjusting the controller parameters to counteract the change in system operating conditions

The adaptive scheme used for the dc motor also demonstrates the load disturbance rejection capability. So, this capability is important when motor is to be operated at constant speed under varying load perturbations. The oscillatory nature in the control input is due to external load disturbances. .

Simulation study shows some initial oscillations in the control signal are evident because the initial values of controller parameters are obtained by the off-line estimation, which may not be accurate enough. However, once on-line updation begins the controller parameters are more accurate and the control signal is much smoother. In order to get the more smooth control signal, controller parameter estimation can be started from some intermediate values by providing initial values of the controller parameters. The initial parameters can be chosen on the basis of simulations carried for particular operating conditions. It results to the faster adaptation of the reference trajectory.

A dc motor has been successfully controlled using MRAC.The unknown, time variant nonlinear load characteristics have been successfully captured by this adaptive scheme. Particularly the robustness of the controller is of importance because noisy operating conditions are very common in practical applications.

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Optimal Analysis for Short-Term Variable Hydropower Generation scheduling for Heuristic Method

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ABSTRACT

This paper based on Heuristic method to solve the short-term variable hydropower generation scheduling problem. It uses Heuristic search method to find the result of all thermal and hydro power plants optimization. Numerical experiment show, this method to solve the non-linear problem with its available of constraints in acceptable time.

Keywords: *Variable HeadHydro-power generation system, Heuristic method and maximum iterations.*

INTRODUCTION

The optimum hydro generation scheduling of an electric power system is the find of the generation for every generating station such that the total system optimum generation cost is minimum while satisfying the constrains. However due to insignificant operating cost of hydro plants the scheduling problem essentially reduces to minimizing the fuel cost of thermal plants constrained by the generation limits, available water, and the energy balance condition for the given period of time.

This paper is based on hybrid based on a Heuristic search method which finds the optimization schedules of all hydroelectric power plants optimization without decomposition.

HEURISTIC SEARCH METHOD

This method is not found the best solution but guaranteed the find good solution in reasonable time, and increases the efficiency, useful in solve the problems which, Could not be solved any other way, and Solutions take an infinite time or very long time to compute.

This problem formulates and solve in mathematically.

$F_i(P_{ik})$ The cost of a fuel function of thermal power generating in the Interval k.

S_j-Reservoir surface area of j^{th}reservoir.

t_k - Duration of the k^{th} sub –interval.

P_{Dk} -Load demand during the k^{th} sub-interval.

V_j- Available water for whole period for j^{th} hydro unit.

P_{ik}- Power plant of i^{th} thermal generation in k^{th}interval.

P_i^{max}- Maximum energy of i^{th}generatingthermal and hydro unit in MW.

P_i^{min}- Maximum energy of i^{th}generatingthermal and hydro unit in MW.

$a_{(i,)}$ $b_{(i,)}$ c-Coefficients of cost the i^{th} thermal units.

$x_{(j,)}$ $y_{(j,)}$ z_j- Coefficients of Discharge thej^{th} hydro plant.

$\alpha_{(j,)}$ $\beta_{(j,)}$ γ_j-Discharge coefficients of head of the j^{th} hydro plant.

F_i-Thermal cost of the i^{th}unit.

q_{jk}-the discharge rate from the j^{th} hydro in the k^{th}interval.

h_{jk}-Head of j^{th} hydro unit during k^{th}sub interval.

I_{jk} -Inflow in j^{th} hydro plant in k^{th} interval.

P_{Lk}-Transmission losses during the k^{th} interval.

r_k - Penalty parameter.

j-Index for hydro units.

i-Index for thermal units.

k-Index of time period.

B-Coefficients of transmission losses.

Y- Mutation factor.

M- Number of hydro plants.

T- All period for generation scheduling.

N- Number of thermal units

$$\text{Minimize} J=\sum_{k=1}^{T}\sum_{i=1}^{N} t_k F(P_{ik}) \quad (1)$$

Energy continuity equation

$$\sum_{i=1}^{N+M} P_{ik} = P_{Dk}+P_{Lk} \quad (2)$$

Water continuity equation

$$\sum_{k=1}^{T} \left[t_k q_{jk} \right] = V_j \quad (j = 1,2.....M) \quad (3)$$

Minimum and maximum limit on discharge

$$q_{min} \le q \le q_{max} \quad (4)$$

4. Maximum and minimum limit on hydrothermal generation

$$P_i^{max} \le P \le P_i^{min} \quad (5)$$

10. COMPUTER IMPLEMENTATION

The system test consists of hydro and thermal generation plant as

The operating cost is given by-

$$(P_{1k}) = aP_{1k}^2 + bP_{1k} + C1 \qquad Rs/h$$

$$F_2(P_{2k}) = aP_{2k}^2 + bP_{2k} + C_2 \qquad Rs/h$$

The variation rates of discharge of hydro generating station are given by quadratic function of effective head and active hydro power.

$$\phi(W_{3k}) = x_1W_{3k}^2 + y_1W + z_1Mft^3/h$$

$$\phi(W_{4k}) = x_2W_{4k}^2 + y_2W_{4k} + z_2Mft^3/h$$

$$\psi(h_{1k}) = \alpha_1h_{1k}^2 + \beta_1h_{1k} + \gamma_1 \quad ft$$

$$\psi(h_{2k}) = \alpha_2h_{2k}^2 + \beta_2h_{2k} + \gamma_2 \quad ft$$

The reservoirs have small capacity and vertical sides. The coefficients of fuel cost, discharge coefficients of hydro plants, constant of proportionality, water available, surface area, initial height of the head, maximum and minimum power limits, load demand and water inflow are given in respectively. The B coefficients of the power system network are given by

$$\begin{bmatrix} 0.000140 & 0.000010 & 0.000015 & 0.000015 \\ 0.000010 & 0.000060 & 0.000010 & 0.000013 \\ 0.000015 & 0.000010 & 0.000068 & 0.000065 \\ 0.000015 & 0.000013 & 0.000065 & 0.000070 \end{bmatrix}$$

Table 5.1 Thermal unit cost function coefficient

2. Unit	3. a_i 4. (Rs/ MW^2h)	5. b_i 6. (Rs/MWh)	7. c_i 8. (Rs/h)
9. 1	10. 0.0025	11. 3.20	12. 25.0
13. 2	14. 0.0008	15. 3.40	16. 30.0

Table 5.2Water discharge rate hydro generation function

17. Unit	18. x_i 19. (Mft^3/MW^2h)	20. y_i 21. (Mft^3/MWh)
22. 1	23. 0.000216	24. 0.306
25. 2	26. 0.000360	27. 0.612

Table 5.3 Water discharge rate head function

28. Unit	29. α_i 30. (ft/h^3)	31. β_i 32. (ft/h^2)
33. 1	34. 0.00001	35. -0.0030
36. 2	37. 0.00002	38. -0.0025

Table 5.4 Reservoir data

39. Unit	40. Constant of proportionality K_j	41. Volume of water V_j (Mft^3)	42. Surface area S_j (Mft^2)	43. Initial height 44. h_{j0} (ft)
45. 1	46. 1	47. 2850	48. 1000	49. 300
50. 2	51. 1	52. 2450	53. 400	54. 250

Table 5.5 Power generation limits

55. Unit	56. Minimum Limit 57. (MW)	58. Maximum Limit 59. (MW)
60. 1	61. 135	62. 281
63. 2	64. 316	65. 759
66. 3	67. 252	68. 439
69. 4	70. 11	71. 184

Table 5.6 Load demand and water inflows

72. Interval 73. (hrs)	74. Load demand W_D 75. (MW)	76. Water inflow I1 (Mft^3/h)	77. Water inflow I2 (Mft^3/h)
78. 1	79. 800	80. 1	81. 0.1
82. 2	83. 750	84. 2	85. 1.3
86. 3	87. 700	88. 2.75	89. 1.75
90. 4	91. 700	92. 2.9	93. 1.95
94. 5	95. 700	96. 3	97. 2
98. 6	99. 750	100. 3.25	101. 2.25
102. 7	103. 800	104. 3.4	105. 2.4
106. 8	107. 1000	108. 3.75	109. 3
110. 9	111. 1330	112. 2	113. 2.95
114. 10	115. 1350	116. 3.5	117. 3
118. 11	119. 1450	120. 4.2	121. 3.25
122. 12	123. 1500	124. 3	125. 3

11. OPTIMAL SOLUTION FOR TEST SYSTEM

The solution of hydrothermal generation scheduling of power systems presented here. The various parameters like population size is taken 20, variable-head hydro and thermal scheduling problem having two hydro unit and two thermal units has been solved using heuristic search method. Other different parameters maximum iterations are set to 200, the obtained value of objective function using heuristic search method algorithm is Rs 69588.9087

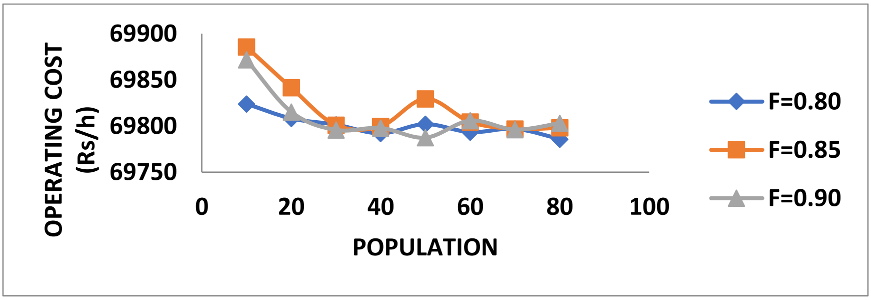

Fig. 6.1 Operating cost over the population at different mutation factors

Table 6.10 Total system operating cost w.r.t maximum iteration

POPULATION	TOTAL SYSTEM OPERATING COST (Rs)		
	Generation (Iterations) is 100	Generation (Iterations) is 150	Generation (Iterations) is 200
10	69824.04	69824.04	69824.04
20	69808.22	69808.22	69808.22
30	69801.53	69801.53	69801.53
40	69792.07	69792.07	69792.07
50	69802.09	69802.05	69802.04

XI=39 ZETA=0.26 F=0.8

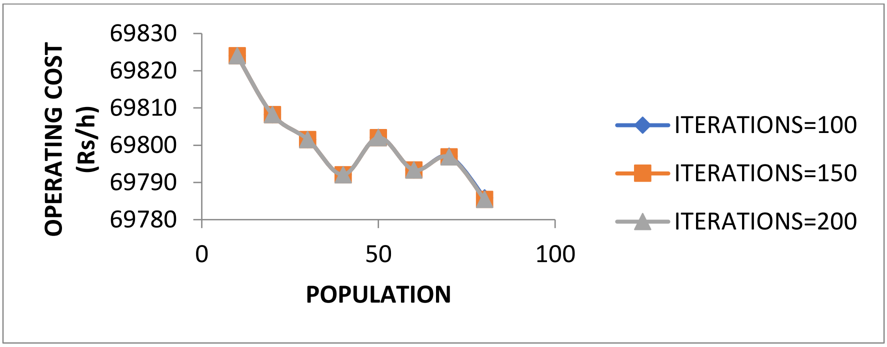

Fig. 6.2 Operating cost over the population at different maximum iterations

Table 6.11 Comparisons of results

Method	Operating cost (Rs)
Newton-Raphson	69801.08/-
Heuristic search method	69785.88/-

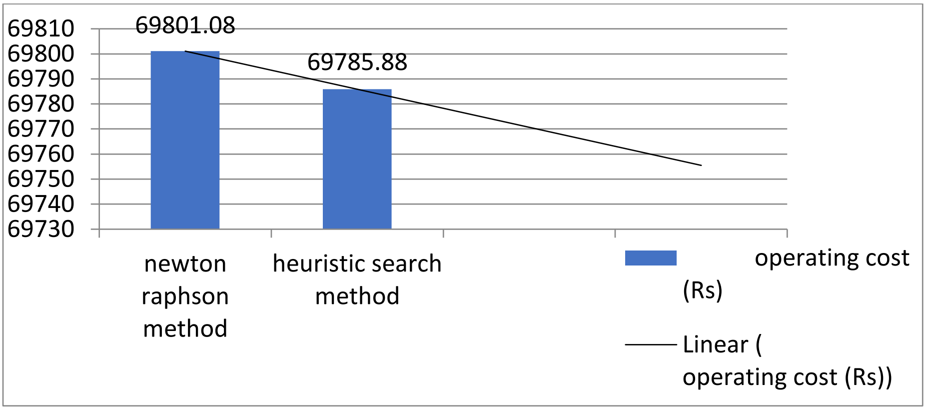

Fig 6.3 Comparison Chart

The total cost obtained from the heuristic search method is less as that of newton-rapson method [6].

Thus it can be concluded that heuristic search method technique provides optimum results the newton-rapson method. It is better to use heuristic search method because newton-rapson method cannot be applied to the hydrothermal scheduling problem having prohibited zone constraints.. While implementing heuristic search method there is no need of initial guess of power and water discharge. Hence it is better to use heuristic search method.

CONCLUSIONS

The heuristic method is based and used to solve the variable-head hydropower scheduling problem. A hydrothermal model has been implemented to find the optimum power generation schedule considering the transmission power losses. The heuristic search technique is having dynamic characteristics function utilized to update the solution vector and improves the convergence properties of the algorithm.

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Design of Optimal Power System Security Assessment ML Approaches

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ABSTRACT

This paper describes ongoing research and development of machine learning and other complemen- tary automatic learning techniques in a framework adapted to the specific needs of power system security assessment. In the proposed approach, random sampling techniques are considered to screen all relevant power system operating situations, while existing numerical simulation tools are exploited to derive detailed security information. The heart of the framework is provided by machine learning methods used to extract and synthesize security knowledge reformulated in a suitable way for decision making. This consists of transforming the data base of case by case numerical simulations into a power system security knowledge base. The main expected fallouts with respect to existing security assessment methods are computational efficiency, better physical insight into non-linear problems, and management of uncertainties. The paper discusses also the complementary roles of various automatic learning methods in this framework, such as decision tree induction, multilayer perceptrons and nearest neighbor classifiers. Illustrations are taken from two different real large scale power system security problems : transient stability assessment of the Hydro-Que´bec system and voltage security assessment of the system of Electricite´ de France.

Keywords: *Electric power systems; security assessment; decision tree induction; neural net- works; nearest neighbor.*

1.INTRODUCTION

Security assessment is a major topic in planning and operation of electric power systems. It consists of evaluating the ability of the power system to face various contingencies and of proposing appropriate remedial actions able to counter its main weaknesses, whenever deemed necessary. Contingencies may be external or internal events (e.g. faults subsequent to lightning vs operator initiated switching sequences) and may consist of small/slow or large/fast disturbances (e.g. random behavior of the demand pattern vs generator or line tripping).

The effect of a contingency on a power system in a given state is usually assessed by numerical (e.g. time-domain) simulation of the corresponding scenario. However, the nonlinear nature of the physical phenomena and the growing complexity of real-life power systems make security assessment a difficult task. For example, the everyday monitoring of a power system calls for fast analysis, sensitivity analysis (which are the salient parameters driving the phenomena, and to which extent?), suggestions to control. On the other hand, increasing economic and environmental pressure make the conflicting aspects of security and economy even more challenging. Overall, the need for methods different from the standard time domain simulation is increasingly felt.

This paper describes ongoing research and development of such methods, using machine learning (and other automatic learning) techniques in a framework adapted to the specific needs of power system security assessment. In the proposed approach, schematically sketched in Fig. 1, random sampling techniques are considered to screen all relevant situations in a given context, while existing numerical simulation tools are exploited - if necessary in parallel - to derive detailed security information. The heart of the framework is provided by machine learning methods used to extract and synthesize relevant information and to reformulate it in a suitable way for decision making. This consists of transforming the data base (DB) of case by case numerical simulations into a power system security knowledge base (KB). As illustrated in Fig. 1, a large variety of automatic learning methods may be used here in a toolbox fashion, according to the type of information they may exploit and/or produce. The final step consists of using the extracted synthetic information (decision trees, rules, statistical or neural network approximators) either in real-time, for fast and effective decision making, or in the off-line study environment, so as to gain new physical insight and to derive better system and/or operation planning strategies.

How will this automatic learning based framework complement classical system theory oriented methods (relying on analytical power system models, such as numerical simulation) for security assessment? In practice, there are three dimensions along which we expect important fallouts.

First of all computational efficiency. By using synthetic information extracted by automatic learn- ing, instead of analytical methods, much higher speed may be reached for real-time decision making. Further, in terms of data requirements, whereas analytical methods require a full description of the system model, the approximate models constructed via automatic learning may be tailored in order to exploit only the significant input parameters. Computational efficiency was actually the motivation of Dy Liacco, when he first envisioned in the late sixties the use of automatic learning (at that time, statistical pattern recognition) for real-time security assessment [1]. Even today, and in spite of the very significant increase in computing powers in the last twenty-five years, this remains a strong motivation.

But the synthetic information extracted by automatic learning methods, may itself be complementary to and generally more powerful than that provided in a case by case fashion by existing analytical methods. In particular, much more attention is paid nowadays to interpretability and management of uncertainties, the two other important fallouts expected from automatic learning methods.

As concerns interpretability, the use of automatic learning to provide physical insight into the nonlinear system behavior was first proposed by Pao et al in the mid-eighties [2]. In the meanwhile, it has been demonstrated that machine learning is indeed an efficient and effective way to generate reliable and interpretable security rules from very large bodies of simulated examples [3, 4], even for as complex systems as are real large-scale power systems. The extracted rules are found to express explicitly problem specific properties, similarly to human expertise, and hence may be easily appraised, criticized and eventually adopted by engineers in charge of security studies. This means that the above framework should also be viewed as an approach to the maintenance and enhancement of utility expertise. The flexibility of the machine learning framework allows one to tailor the resulting information to analysis, sensitivity analysis and control applications.

As concerns management of uncertainties, the need to devise a rational way to take decisions whenever there are major uncertainties about the power system state becomes more and more apparent. Today, for example, it is well known that operators are often sorely missing guidance in the context of unusual system states reached after major disturbances, where reliable real-time information is generally lacking. Tomorrow, technological and economic changes will probably lead to a higher and physically more irrational distribution of decision making and thus to more uncertainties in routine operation and planning activities. Indeed, on the one hand, new devices (e.g. flexible alternating current transmission systems (FACTS)) may cause stronger interactions among remote components of very large interconnections. On the other hand, increased competition among economic actors may further reduce their willingness to share information on their respective subsystems, in spite of the stronger physical interactions. Under such circumstances, approaches able to manage uncertainties, such as the above framework based on automatic learning, will be urgently needed.

Nonetheless and despite repetitive attempts, there are still no large-scale industrial applications of the machine learning framework to power system security assessment. This is mainly due to the fact that until recently, the existing automatic learning methods were not powerful enough while the amount of possible security studies was limited by available simulation hardware and software.

Today, however, all the required conditions are met. Present day computer networks together with fast simulation tools allow the generation of large amounts of detailed studies. At the same time much progress has recently been achieved in automatic learning methods and their application to large-scale power systems was shown to be feasible. Hence, automatic information synthesis tools to assist engineers to compare and interpret the numerous elementary results, and extract and appraise useful synthetic information are at the same time strongly needed and technically feasible.

Therefore, while we expect additional progress in learning methods and application methodologies, we foresee that some important electric power companies e.g. in North America or Europe will soon start using this approach more or less routinely for security studies.

1. Aspects of power system security problems

In this section we provide a guided tour of power system security for the unfamiliar reader. We will first analyze the different types of physical problems, then consider the practical application environments where security is treated, and finally mention briefly the main classes of existing analytical tools for security assessment. In our discussion, we will focus on security problems involving *large* disturbances corresponding to nonlinear system behaviour. Although such disturbances are generally very unlikely to happen, their potential consequences can be extremely important and may lead to complete system blackouts, freezing the economic activity of a whole country for many hours.

Classification of operating states

The different operating modes of a power system were defined by Dy Liacco [1]. Figure 2 shows a more detailed description of the "Dy Liacco state diagram".

Preventive security assessment is concerned with the question whether a system in its normal state is able to withstand every plausible disturbance, and if not, preventive control would consist of moving this system state into a secure operating region. Since predicting future disturbances is difficult, preventive security assessment will essentially aim at balancing the reduction of the probability of losing integrity with the economic cost of operation.
Emergency state detection aims at assessing whether the system is in the process of losing integrity, following an actual disturbance inception. This is a more deterministic evolution, where response time is critical while economic considerations become temporarily secondary. Emergency control aims at taking fast last resort actions, to avoid partial or complete service interruption.

When both preventive and emergency controls have failed to bring system parameters back within their inequality constraints, automatic local protective devices will act so as to preserve power system components operating under unacceptable conditions from undergoing irrevocable damages. This leads to further disturbances, which may result in system splitting and partial or complete blackouts.

Consequently, the system enters the restorative mode, where the task of the operator is to minimize the amount of un-delivered energy by resynchronizing lost generation as soon as possible and picking up the disconnected load, in order of priority. We will confine ourselves to preventive and emergency aspects.

Physical classification of security problems Various security problems are distinguished according to the time scales of the dynamics, the characteristic symptoms (low voltage, large angular deviations: : :), and the control means (reactive power, switching: : :) to alleviate problems.

Transient stability. Transient stability concerns the ability of the generators of a power system to recover synchronous operation following the electromechanical oscillations caused by a large disturbance. In this context, the dynamic performance is a matter of seconds and is mainly affected by switching operations and fast power controls (e.g. fast valving, high voltage direct current converters, FACTS) and voltage support by the automatic voltage regulators of synchronous generators and static var compensators (SVCs). To determine the degree of stability we may evaluate the critical clearing time of a fault, which is the maximum time duration it may take to clear the fault without the system losing its ability to maintain synchronism.

Voltage security. The fastest voltage instabilities are characterized by sudden voltage collapse phenomena which may develop at the same or even higher speeds than loss of synchronism. More classical is the mid-term voltage instability, which corresponds to a typical time frame of one to.

Table 1: Security assessment environments. Adapted from [6]

Environment	Time scales	Typical problems	Operator	Expert
System planning	1 - 10 years	Generation Transmission Protection	No	Yes
Operation planning	1 week - 1 year	Maintenance Unit commitment Protection settings	No	Yes
On-line operation	1 hour - 1 day	Preventive mode Security assessment	Yes	Partly
Real-time monitoring	sec. - min. - hour	Emergency control Protective actions	No	No
Training	months - days	Improve operator skill	Yes	No

Here we distinguish between *real-time*, which considers dynamic situations following a disturbance inception, from merely on-line which considers static pre-disturbance situations. except for static security corrective control five minutes. In this case voltage collapse is mainly driven by automatic transformer on-load tap changers trying to restore voltage nearby the loads. There is a third, even slower time frame, corresponding to the so-called long-term voltage instability, which involves the gradual build up in load demand. This interacts with classical static security and is well within the scope of operator intervention.

Although a voltage collapse may result in a wide spread degradation of the voltage profile and subsequent loss of synchronism, it is normally initiated by a local deficiency in reactive power reserves and/or a reduced reactive power transmission capability into a given load area. The distance to voltage insecurity may be evaluated by a load power margin which is the maximum additional amount of power which may be transferred safely from the generation to a given load area.

Static security. It concerns essentially thermal overload problems of generation transmission system components, where phenomena span over significantly longer periods of time. For example, line overloads may be tolerated during 30 to 60 minutes under favourable weather conditions.

- **Practical application domains**

Table 1 shows the practical study contexts or environments which may be distinguished in security assessment applications. The first column identifies the study context; the second specifies how long in advance (with respect to real-time) studies may be carried out; the third column indicates the type of subproblems that are generally considered in a given environment; the last two columns indicate respectively if an operator is involved in the decision making procedure and if an expert in the field of power system security is available.

In the first three contexts one currently relies mostly on the intervention of human experts exploiting the numerical simulation tools. In real-time monitoring and emergency control, the reduced time available calls for more automatic procedures.

System planning. Multitudinous system configurations must be screened for several load pat- terns, and for each one a large number of contingencies. An order of magnitude of 100,000 different scenarios per study would be realistic for a medium sized system. While enough time may be available to carry out so many security simulations, there is still room for improved data analysis methods to exploit their results more effectively for the identification of structural system weaknesses and to provide guidelines to improve reliability.

Operation planning. As suggested in Table 1, operation planning concerns a broad range of problems, including maintenance scheduling (one year to one month ahead), design of operating strategies for usual and abnormal situations, and setting of protection delays and thresholds. The number of combinations of situations which must be considered for maintenance scheduling is also generally very large, and automatic learning approaches would equally be useful to make better use of the available information and to exploit the system more economically.

Similarly, for the closer to real-time determination of operating security criteria, machine learning is particularly well adapted. It would allow engineers to screen more systematically representative samples of situations, in order to identify critical operating parameters and determine their security limit tables needed for on-line operation. This would actually consist of automating and enhancing such manual approaches presently in use at many utilities.

Online operation. In the context of this framework, it would consist of exploiting on-line the security knowledge bases set up off-line, e.g. in operation planning. Appropriate strategies are required in order to update this information when major changes happen in the system. For example, several weeks ahead routine security criteria could be designed for a forecast range of topologies, load levels and generation schedules, while, closer to real-time, maybe a day or some hours ahead, these criteria might then be refreshed to handle previously unexpected situations. In order to be compatible with the way operators usually appraise their system, it is particularly important for the synthetic information extracted by automatic learning to be as simple as possible to interpret.

Real-time monitoring. Here, the purpose is to design criteria to trigger more or less automatically emergency control actions, so as to prevent a disturbed system state to evolve towards blackout. An important aspect is the use of appropriate models1 to reflect the disturbed power system behaviour, when designing the security criteria. Furthermore, the use of readily available system measurements as inputs to the derived emergency control rules is often an operational constraint in addition to minimal data requirements and ultra-high speed.

Training. During operator training, the security criteria derived in either of the preceding contexts might be usefully exploited as guidelines, provided that they are presented in an intelligible way. In addition, these models might be used internally in training simulator software, in order to set up particular scenarios presenting particular insecurity modes.

- **Analytical tools**

A rather large set of numerical methods are available for security assessment in the different time frames mentioned. We call them analytical tools since they exploit analytical power system models in contrast to the synthetic ones extracted by automatic learning techniques. Some of them are based on general purpose power system dynamic simulation packages and have a very broad scope. Others are based on simplified models or approaches representing only those features which are relevant for the particular study. The latter methods may be significantly more efficient, although at the expense of being restricted to some particular physical phenomena and/or some particular

(types of) power systems. We briefly discuss them since they provide the raw input data exploited by the automatic learning methods in order to synthesize the high level security information.

- **Transient stability**

There are two main classes of analytical tools for transient stability assessment: time-domain (or step-by-step) simulation approach and direct methods, based on the second Lyapunov method.

Time-domain simulation. The general power system dynamic model is composed of mixed algebraic and differential equations strongly nonlinear, involving typically a few thousand discrete or continuous time state variables. To assess transient stability, the time-domain approach consists of simulating the during and post-fault behaviour of the system for a given disturbance, and observing its electromechanical angular and voltage swings during a few seconds. Practical criteria vary from one utility to another, but an unacceptable performance would generally imply too large or undamped angular deviations (e.g. pole slips) or excessively large variations of voltage or frequency. To obtain stability margins, repetitive simulations must be carried out for various pre- fault operating states or for various assumptions concerning the delays of protection devices. While this approach is still considered as very CPU intensive, we observe that within the last three years the time required for a typical power system simulation with high order models has shrunk from one hour to some minutes.

Direct Lyapunov type methods. They aim at identifying when the system leaves its stability domain without further integration of the system trajectory. By avoiding the simulation of the post-fault trajectory, they reduce the simulated time period to a fraction of a second instead of the several seconds of time-domain methods. Some of them are thus able to provide a rich stability assessment (margins, sensitivities, mode of instability) within a fraction of the time required for a single time-domain simulation. A major drawback is their difficulty to exploit accurately models of generators and control loops as well as nonlinear or dynamic loads. However, since the first multimachine direct methods developed in the late sixties much progress has been achieved in incorporating more realistic models.

- **Voltage stability and security**

Tools for voltage security assessment range from static load-flow calculations to full short- term / mid-term time domain simulations. It is worth mentioning that due to the rather recent emergence of voltage security problems, modelling practices have not yet reached maturity comparable to those used in transient stability studies. In particular, one intrinsic difficulty of analyzing voltage collapse phenomena is the very strong dependence on load behaviour, for which good models are generally missing.

Short-term / mid-term dynamic simulations. Since voltage collapse phenomena may involve time constants ranging from a fraction of a second to a few minutes, a variable step-size numerical integration method with stiff system simulation capability is preferable for the sake of efficiency and accuracy, in contrast to transient stability where fixed step-size methods have been widely used.

Simplified simulations. Since many voltage security problems are essentially driven by automatic on-load tap changer mechanisms, it is possible to neglect sometimes the faster interactions among load and generation dynamics. The differential equations corresponding to the faster phenomena are then replaced by equilibrium equations and only the slower dynamics are modelled. With the intrinsic limitation of neglecting problems caused by the fast dynamics, this kind of approach allows drastic reduction in computing times.

Post-contingency load-flow. A further simplification consists of neglecting totally the dynamics, and using only purely static post-contingency load-flow calculations. Typically, this allows one to compute maximal loading limits, based on successive computations or even on direct optimization.

2. Aspects of automatic learning

In this section we introduce classes of potentially useful automatic learning methods for the synthesis of security assessment information. We first give a definition of the generic supervised learning problem and introduce three important classes of algorithms for this problem, and finish with some comments on the use of unsupervised learning methods.

- **Supervised learning problem**

The generic problem of supervised learning from examples can be formulated as follows:

Given a learning set of examples of associated input/output pairs, derive a general model for the underlying input/output relationship, which may be used to explain the observed pairs and/or predict output values for any new unseen input.

In the context of security assessment, an example corresponds to a given operating situation. The input attributes would be (hopefully) relevant parameters describing its electrical state and topology and the output could be information concerning its security, in the form of either a discrete classification (e.g. secure / marginal / insecure) or a numerical value derived from security margins.

In general, the solution of this overall learning problem is decomposed into several subtasks.

Representation consists of (i) choosing appropriate input attributes to represent the power system state, (ii) defining the output security information, and (iii) choosing a class of models suitable to represent input/output relations.

The representation problem is left to the engineer. A compromise has to be found between the use of very elementary standard operating parameters and more or less sophisticated compound features. Below we discuss how unsupervised learning techniques may help to choose appropriate input attributes.

Feature selection aims at reducing the dimensionality of the input space by dismissing attributes which do not carry useful information to predict the considered security information. This allows one to exploit the more or less local nature of many security problems.

Model selection (or learning per se) will typically identify in the predefined class of models the one which best fits the learning states. This generally requires choice of model structure and parameters, using an appropriate search technique.

The distinction between feature selection and model selection is somewhat arbitrary, and some of the methods actually solve these two problems simultaneously rather than successively.

Interpretation and validation are very important in order to understand the physical meaning of the synthesized model and to determine its range of validity. It consists of testing the model on a set of unseen test examples and comparing its information with prior expertise about the security problem.

From the interpretation and validation point of view, some supervised learning methods provide rather black-box information, difficult to interpret, while some others provide explicit and very transparent models, easy to compare with prior knowledge.

Model use consists of applying the model to predict security of new situations on the basis of the values assumed by the input parameters, and if necessary to "invert" the model in order to provide information on how to modify input parameters so as to achieve a security enhancement goal.

As far as the use of the model for fast decision making is concerned, we notice that there are speed variations of several orders of magnitude between various techniques, but most of the methods are sufficiently fast in the context of control centre oriented power system security analysis.

- **Supervised learning methods [7]**

In what follows, we consider only non-parametric automatic learning methods. Parametric methods may be useful in some particular circumstances, but are not powerful enough to treat the wide variety of practical security problems. We will discuss three classes of methods providing three complementary types of information. Although we have selected them from three different paradigms (machine learning, neural nets, pattern recognition) we insist on the type of information provided rather than on the paradigm itself.

- **Symbolic knowledge via machine learning**

Machine learning is the subfield of artificial intelligence concerned with the design of automatic procedures able to learn from examples. Concept learning from examples denotes the process of deriving a logical description of the necessary and sufficient conditions corresponding to a class of objects, i.e. a rule in some given representation language. A major concern is to find out adequate compromises between rule complexity and data fit, so as to avoid over-fitting and to privilege interpretability.

Top down induction of decision trees (TDIDT) is one of the most successful classes of such methods which was popularized by Quinlan [8]. Figure 3 shows a hypothetical binary decision tree (DT) : to infer the output information corresponding to given input attribute values, one traverses the tree, starting at the top-node, and applying sequentially the dichotomous tests encountered to select the appropriate successor. When a terminal node is reached, the output information stored there is retrieved.

As suggested by the acronym, TDIDT approaches the decision tree learning in a divide and conquer fashion, whereby a decision tree is progressively built up, starting with the top-node and ending up with the terminal nodes. At each step, a tip-node of the growing tree is considered and the algorithm decides whether it will be a terminal node or should be further developed. To develop anode, an appropriate attribute is first identified, together with a dichotomy on its values. The subset of its learning examples corresponding to the node is then split according to this dichotomy into two subsets corresponding to the successors of the current node. The terminal nodes are "decorated" with appropriate information on the output values derived from their learning examples, e.g. the majority class label or probabilities, or expected value and standard deviation of numerical output information.

The right part of Fig. 3 shows how the decision tree in its left decomposes its input space into non-overlapping subregions. The number of such regions should ideally be as small as possible and at the same time the states contained by each region should belong to a same class. Thus, to build good decision trees, an algorithm must rely on appropriate optimal splitting and stop splitting rules. Optimal splitting has to do with selecting a dichotomy at a test node so as to provide a maximum amount of information on the output value (i.e. separate states of different classes) whereas stop splitting has to identify situations where further splitting would either be useless or lead to performance degradation, due to over-fitting.

Decision trees have been quite extensively studied in the context of various security assessment problems [6]. A main asset lies in the explicit and logical representation of the induced classification rules and the resulting unique explanatory capability. In particular, the method provides systematic correlation analyses among different attributes and identifies the most discriminating attributes at each tree node. From the computational viewpoint it is efficient at the learning stage as well as at the prediction stage.

There are two generalizations of decision trees of interest in the context of security assessment. First, regression trees which infer information about a numerical output variable; they are illustrated below. Second, fuzzy trees which use fuzzy logic instead of standard logic to represent output information in a smooth fashion. Both approaches allow us to infer information about security margins, similarly to the techniques discussed below. Fuzzy trees have not yet reached the maturity of crisp classification or regression trees, but they seem particularly well suited to our types of problems. Indeed, they appear to be more robust with respect to noise than classical machine learning methods and are able to combine smooth input/output approximation capabilities of neural networks with interpretability features of symbolic machine learning [9].

- Smooth nonlinear approximations via artificial neural networks

The field of artificial neural networks has grown since the early work on perceptrons to an important and productive research field. We restrict ourselves to multilayer perceptrons; for further information, a widely recommended theoretical introduction to neural networks is given in [10].

The single-layer perceptron, is basically a simple linear threshold unit together with an error correcting learning algorithm. It is able to represent a linear boundary in its input space. Its limited representation capabilities have motivated the consideration of more complex models composed of multiple interconnected layers of perceptrons, MLPs for short. Figure 4 illustrates the classical feed-forward MLP. The first or input layer corresponds to the attribute values, and the last or output layer to the desired security classification or margin information. Intermediate layers enable the network to approximate arbitrarily complex input/output mappings, provided that its topology and its weights are chosen appropriately.

The discovery of the back-propagation algorithm has been central to the success of MLPs. It allows one to compute efficiently and locally the gradient of the output error of the network with respect to its weights and thresholds. It may be exploited iteratively in order to adjust the weights so as to reduce the total mean square output error for learning examples. In recent years, much progress has been made in improving efficiency of optimization techniques for the learning procedures of MLPs, but the MLPs are still very slow at the learning stage, which may prevent extensive experimentations for data base sizes typical of security assessment of realistic power systems.

Similarly to decision trees, an interesting property of MLPs is their ability to achieve feature extraction and learning in a single step : the weights connecting the input layer with the first hidden layer may be interpreted as projecting the input vector in some particular directions, realizing a linear transformation of the input space, which is used in subsequent layers to approximate outputs. However, one of the difficulties with MLPs comes from the very high number of weights and thresholds related in a nonlinear fashion, which makes it almost impossible to give any insight into the relationship learned. All in all, one can say that MLPs offer a flexible, easy to apply, but essentially black-box type of approach to function approximation.

It should be observed that a bunch of similar methods exist nowadays, such as radial basis functions and projection pursuit regression techniques. They offer the possibility of translating the case by case information provided in the learning sets into an approximate but closed form numerical model. The latter one may be used for fast assessment of unseen situations and direct computation of sensitivities.

Memory based reasoning via statistical pattern recognition [11]

The previous two approaches essentially compress detailed information about individual simulation results into general, more or less global security characterizations.

Additional information may however be provided in a case by case fashion, by matching an unseen (e.g. real-time) situation with similar situations found in the data base. This may be achieved by defining generalized distances so as to evaluate similarities among power system situations, together with appropriate fast data base search algorithms.

A well known such technique is the "K nearest neighbours" (K N N) method able to complete decision trees and multilayer perceptrons. It consists of classifying a state into the majority class among its K nearest neighbours in the learning set. The main characteristics of this method are high simplicity but sensitivity to the type of distances used. In particular, to be practical, ad hoc algorithms must be developed to choose the distances on the basis of the learning set. While in the past this method was generally exploiting a small number of sophisticated ad hoc input features manually selected on the basis of engineering judgment, nowadays the emphasis is more on the research of automatic distance design methods exploiting the learning states.

Clustering and unsupervised learning

In contrast to supervised learning, where the objective is clearly defined in terms of modeling the underlying correlations between some input variables and some particular output variables, unsupervised learning methods are not oriented towards a particular prediction task. Rather, they try to identify existing underlying relationships among a set of objects characterized by a set of variables or among a set of variables used to characterize a set of objects.

Thus, one of the purposes of clustering is to identify homogeneous groups of similar objects, in order to represent a large set of objects by a small number of representative prototypes. Graphical, two-dimensional scatter plots may be used as a tool in order to analyze the data and identify clusters. Another application of the same techniques is to identify similarities (and redundancies) among the different attributes used to characterize objects. In the context of power system security both applications may be useful as complementary data analysis and preprocessing tools.

Unsupervised learning algorithms have been proposed under the three umbrellas given above to classify classification methods, termed cluster analysis in the statistics literature, conceptual clustering in the machine learning community, and self-organizing maps or vector quantization in the neural net community [12].

3. APPLICATION OF AUTOMATIC LEARNING TO POWER SYSTEM SECURITY

Below we will first describe a hypothetical application of the automatic learning based framework to a hypothetical security problem. Then we will provide a short overview of some real-life applications to large-scale security problems.

- A hypothetical illustration of the framework
- A security problem

Let us imagine that our hypothetical power system is voltage security limited in some reactive power weak area, and let us suppose this security problem was discovered in a preliminary screening security study, where also the possibly constraining disturbances were identified.

Then, a practical problem would be the characterization of security regions with respect to these disturbances, so as to provide operators with preventive security assessment criteria and effective preventive control means to alleviate potential insecurities, such as optimal rescheduling of available reactive power resources.

Another, different problem would be the design of emergency state indicators to be applied in case of a disturbance, ideally highly anticipative and reliable at the same time while providing information on appropriate emergency control means, such as on-load tap changer blocking and load shedding.

- **How could we generate a data base ?**

In order to provide a representative sample of voltage security scenarios for the above problems, we would first ask for the advice of planning and operation planning engineers and operators of that system, so as to gather information about known system weaknesses and operating practices.

From this information, data base building software would then be designed in order to generate randomized samples representative of normal operating conditions, including also a sufficient number of unusual situations, deemed relevant for security characterization. In particular, with respect to real-life operating statistics, this sample would typically be biased towards the insecure regions of the state space.

According to that sampling procedure, an initial data base would be generated, typically comprising several thousand states and the security of each state would be pre-analyzed with respect to the studied disturbances. For example, post-contingency load power margins could be computed for real large-scale power system models on existing computer networks within some hours of response time, by using an efficient simulation software and exploiting trivial parallelism. In addition to this information, appropriate preventive or emergency control information could be pre-determined for the insecure states and secure economic generation dispatch for the secure ones.

Further, a certain number of attributes would be computed, which would be proposed as input variables to formulate security criteria. In the preventive mode security assessment problem, these attributes would typically be contingency-independent pre-fault operating parameters, such as voltages, reactive power generation and compensation reserves, power flows, topology indicators. For the emergency state detection problem, we would rather use raw system measurements (e.g. voltage magnitudes, power flows, transformer ratios, breaker status) of the intermediate just after disturbance state. In contrast to the preventive mode attributes, the emergency state attributes would depend on the disturbance and on the short-term system modelling, in addition to the pre- fault operating state.

When designing the data base generation software, care must be taken so as to appropriately take into account various kind of uncertainties. For example, random noise terms should be added to the attribute values so as to model measurement or state estimation errors and delays. Further, static and dynamic power system model parameters are often uncertain (load distribution and sensitivity to voltage, external systems, parameter variations with temperature : : :) and should thus be accordingly randomized.

- **Unsupervised learning for data pre-processing**

In practical security problems, many different attributes often turn out to provide equivalent in- formation, due to the very strong physical correlations among geographically close components of a power system. Thus, clustering methods may be used to define a small set of representative attributes from a larger number of elementary variables.

To fix ideas, let us consider the case of voltage magnitudes. Correlation coefficients among any pair of bus voltages may be easily computed on the basis of the data base statistical sample. They may then be used as similarity measures by a clustering algorithm searching for a reduced number of voltage “coherent” regions. For each region an equivalent (e.g. mean) voltage would be used as an attribute instead of individual bus voltages, and the computational burden of the subsequent supervised learning of security criteria would be reduced, while robustness and interpretability would be improved. For example, two-dimensional Kohonen feature maps may be exploited in order to visualize the relationships among voltage regions and compare them easily with the geographic location of busbars in the power system.

In addition to the above “feature extraction” application, clustering techniques have also been proposed in a more conventional way, to identify groups of similar power system operating states. One possible purpose is to partition a very large data base into smaller subsets for which the security assessment problem could be easier to solve. Another interesting application would be to “condense” the full data base into a reduced number of representative prototypes, thereby decreasing the number of required security simulations and shortening the associated computation delays.

- **Supervised learning of security criteria**

Given a data base composed of examples, for which security margins have been determined for several contingencies and a number of candidate attributes have been computed, supervised learning would proceed so as to derive appropriate security criteria. First of all however, the data base would be partitioned into disjoint learning and test samples. The learning sample will be used to build the synthetic security criteria, whereas the test set will be used to assess their reliability by comparing the security information predicted by them and the "real" one determined by simulation. In addition to the unseen test states generated automatically together with the learning states, a test sample representative of actual operating statistics should be collected from historical on-line records.

What can decision trees do ? We need first to define security classes by appropriate thresholds on the security margin. Then, the decision tree building includes (i) the automatic identification of the subset of attributes among the candidate ones relevant for the prediction of the security class (say ten to twenty among one or two hundred), and (ii) the definition of appropriate threshold values for these attributes so as to provide an approximate model of the voltage security region of the studied area of the power system. In addition to a global DT covering all disturbances simultaneously, single- contingency DTs may also be constructed to provide more specific information and additional insight. Further, various DTs may be constructed for various security margin threshold values, so as to discriminate between marginally secure and very secure situations. Depending upon whether normal pre-disturbance or just after disturbance attribute values are used, the DTs can be used either in a preventive or in an emergency wise approach.

If there is too much non-detection of insecure states, the threshold value used to define the secure class in terms of the security margin may be increased before rebuilding a tree. If there are too many false alarms, additional candidate attributes or learning states should be used.What can neural networks add? In addition to the simplified view on security, provided by the DTs in terms of a discrete model relating a small number of security classes and thresholds on attribute values, one is generally interested in providing a continuous security margin, at least in the neighbourhood of the threshold values used to define security classes.

As we have mentioned, one of the strong points of the MLP is its nonlinear modelling capability. On the other hand, the decision tree identifies the attributes in strong correlation with the security class. Thus, in a hybrid approach we may use the latter attributes as input variables to a MLP model, while using a normalized security margin as output information.

In practice it may be necessary to proceed by trial and error to determine an appropriate number of hidden neurons and topology for the MLP structure. Once its structure and weights have been adapted on the basis of the learning states, the MLP provides a closed-form and differentiable security approximator, which may be used for fast margin prediction for any seen or unseen state and as well to compute margin sensitivities to attribute values.

Practical experiments reported below with various security problems have shown that this leads to richer and more reliable security assessment information.

What do distance based methods offer? With the previous two approaches, we have essentially compressed detailed information about individual simulation results into general, more or less global security characterizations. This allows us to provide the required physical understanding,

Thanks to the data analysis component of decision trees and attribute clustering techniques. In addition, the derived models may be used efficiently for on-line security analysis.In this latter context, further information may be obtained via memory based reasoning exploiting appropriate distances to find the most similar pre-analyzed situations to the real-time state. Once identified, these may be used in multitudinous ways. For example, their distance to the current state would provide a measure of confidence of the security information provided by any model derived from the data base (DT and/or MLP). If the latter were too large, it would then be concluded that for the current state no reliable security information may be derived from the data base. If the nearest neighbours were on the contrary sufficiently close to the current state, then various kinds of detailed and specific security information may be extrapolated from these states to the current situation and shown to the operator, including detailed contingency analysis and preventive and/or emergency controls.

Overview of some real-life applications Below we provide more specific information about feasibility studies of the automatic learning approach, made for some real practical power system security problems.

Transient stability

A first large-scale feasibility study was initiated in early 1990, for preventive transient stability assessment of an important generation plant within the large-scale EHV system of Electricite´ de France (EDF) [13].

A more recent study was carried out on the Hydro-Que´bec system which is illustrated in Fig. 5. Its normal operating condition is considered secure if it withstands any permanent single-phase to ground fault, followed by line tripping, fast re-closure and subsequent permanent tripping. It is notable that this system is mainly constrained by its transient stability limits, due to the very large power flows and long transmission distances.

More specifically, in our investigations we have considered only faults occurring within the James' Bay transmission corridor in the Western part of the system. With respect to such faults, the stability is mainly influenced by the power flows and topology within the same corridor. A set of transient stability limits have previously been developed, in a manual approach, where operation planning engineers have determined off-line, on the basis of carefully chosen simulation scenarios, a set of approximate limit tables relating the system topology and power flows to a Stable/Unstable classification. These limit tables have been implemented on the real-time computer of Hydro- Que´bec, via an ad hoc data base tool called LIMSEL, presently in use for operation. The purpose of our investigation was to evaluate the capability of the automatic learning approach to provide a more systematic and potentially more efficient methodology to derive these operating guidelines.

A data base, composed of 12,500 normal operating states was generated via random sampling and chained load flow computations; it comprises more than 300 different combinations of up to 6 line outages, and about 700 different combinations of reactive voltage support equipment in operation, and a wide variety of power flow distributions. The dashed lines in Fig. 5 show the variable topology part of the 735kV system. For each state, the corresponding classification Stable/Unstable was obtained from LIMSEL, running on the backup on-line computer, resulting in 3,939 stable states and 8,561 unstable ones, among which 393 are marginally and 8,168 fairly unstable.

CONCLUSIONS

In this paper we have attempted to survey state of the art and future potentials of machine learning approaches for power system security assessment.

We have described the high diversity of power system security problems so as to justify the combined use of machine learning and other statistical and neural network based automatic learning methods, in a tool box fashion. To provide insight into the possible complementary uses of these various methods, we have put the emphasis on illustrations and discussions, rather than on theoretical presentations. To render credible machine learning approaches to power system security, we have reported a small subset of results obtained with two different real-life problems.

One of the messages we would like to convey is that to make automatic learning methods really successful it is important to include the human expert in the process of deriving security information. For example, to guide the security studies it is necessary to exploit his prior expertise and then to allow him to criticize, assimilate and accept the new information. The results must therefore be provided in a form compatible with his own way of thinking. In the general class of automatic learning approaches, machine learning is presently the only one able to meet this requirement; it is therefore a key element of the tool box.

Clearly, machine learning as well as other learning methods can produce interesting security information only when they exploit representative data bases. To obtain them, the initial investment is quite important for each new security problem, but the subsequent data base generations take full advantage of the previous ones. To further enhance the approach, powerful parallel simulation environments could be developed to enable a transparent allocation of simulations on virtual machines composed of the large numbers of elementary workstations available through local or wide area networks, and not fully exploited today.

After eight years of research, we deem that automatic learning methods are indeed able to provide interesting security information for various physical problems and practical contexts. Actually, in their philosophy they are quite similar to existing practices in power system security studies, where limits are derived from simulations, though in a manual fashion. But automatic learning approaches are more systematic, easier to handle and master, in short more reliable and powerful.

These possibilities open up new perspectives to power system engineers to respond to the challenge of planning and operating future power systems with an acceptable level of security, in spite of growing complexity and level of uncertainties (e.g. due to the de-regulation of transmission systems and faster technological changes) and increasing economical and environmental pressures.

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Design of Optimal Grids: A Cyber–Physical Systems Perspective

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ABSTRACT

Smart grids are electric networks that employ advanced monitoring, control, and communication technolo- gies to deliver reliable and secure energy supply, enhance operation efficiency for generators and distributors, and pro- vide flexible choices for prosumers. Smart grids are a combi- nation of complex physical network systems and cyber systems that face many technological challenges. In this pa- per, we will first present an overview of these challenges in the context of cyber–physical systems. We will then outline potential contributions that cyber–physical systems can make to smart grids, as well as the challenges that smart grids present to cyber–physical systems. Finally, implications of current technological advances to smart grids are outlined.

Keywords:*computing; complex networks; control; cyber–physical systems; intelligent systems; modeling; multiagent systems; optimization; renewable energy; smart grids.*

INTRODUCTION

The greatest discovery of the 19th century was that of electricity which has led to revolutionary progression in our society and economy. Electricity became a funda-mental form of energy carrier easier to transmit over long distance than any other form, and it has become es- essential to our social and economic activities. The electric grids, which are essentially massive interconnected physical networks, are the infrastructure backbone for energy supply and use of today [1].In recent years, there have been increasing demands for cleaner energy generation and more efficient use of energy due to environmental concerns as well as limited availability of nonrenewable energy sources such as coal, gas, and oil. The 2014 World Energy Outlook Report [2] indicates that the global energy demand is set to grow by 37% by 2040, and energy efficiency is critical to relieve pressure on energy supply while accommodating increasing demands without severing the environments. While renewable energy (RE) sources such as hydro, biomass, solar, geothermal, and wind are in abundance, they are much harder to harvest. Advanced technologies are needed in order to make these energy supplies more reliable and secure. Internationally, governments of many countries have adopted/are adopting new energy policies and incentives, and larger scale deployments of smart technologies are now in place. In the United States, the all-of-the-above energy strategy has been launched by President Obama. RE generation from wind, solar, and geothermal sources has doubled since 2008, and a 20% RE target by 2020 has been set [3]. In Europe, a 20% RE target by 2020 has also been set by the European Com- mission [4]. In China, a 15% RE target was set to achieve by 2020 [5], and an even more ambitious target of 86% RE by 2050 has recently been set by the Chinese Government [6].

All the above require a revolutionary rethinking of how to supply and use electric energy in a more efficient, effective, economical, and environmentally sustainable way. Smart grids (SGs) are such a new paradigm for energy supply and use in response to the a forementioned challenges. They aim to intelligently integrate the behaviors and actions of all the stakeholders in the energy supply chain to efficiently deliver sustainable, eco- nomic, and secure electric energy, and ensure economical and environmentally sustainable use. Key to the success of SGs is the seamless integration and inter- action of the power network infrastructure as the physical systems, and information sensing, processing, intelligence, and control as the cyber systems. Further- more, the emerging new technology platform, called cyber–physical systems (CPSs), is exactly the answer to address the particular integration and interaction issues in SGs, focusing on effective and efficient interaction be- tween and integration of physical systems and cyber systems. Adopting CPS technologies in SGs will make them more efficient in operations, more responsive to prosumers, more economically viable, and environmentally sustainable. Furthermore, the peculiar characteristics of SGs will present new challenges to the development of CPSs.

In this paper, we will first give an overview of these challenges in the context of CPSs. We will then outline potential contributions that CPSs can make to SGs, as well as the challenges that SGs present to CPSs. Finally, implications of current technological advances to SGs will be outlined.

SMART GRIDS

The term smart grids (SGs) has been widely used with different definitions and meanings. Essential to the SG definitions is the integration of enabling ICT and other advanced technologies with the large-scale power net- works to enable electric energy generation, transmission, distribution, and usage to be more efficient, effective, economical, and environmentally sustainable. The U.S.

National Institute of Standards and Technology provides a conceptual model which defines seven important do- mains: bulk generation, transmission, distribution, customers, service provider, operations and markets. In the United States, the meaning of SGs is broad, referring to the transformation of the electric industry from a centralized, producer-controlled network to one that is more consumer interactive [7]. In Europe, SGs refer to broad society participation and integration of all Euro- pean countries [8]. In China, SGs refer to a more physical-network-based approach to ensure energy supply is secure, reliable, more responsive, and economic in an environmentally sustainable manner [9]. Recently, significant attention has been paid by the Chinese Government to leverage the infrastructure to bring more socioeconomic benefits, and furthermore, introduce a market-driven national demand-side management frame- work and system [10].

The structure of SGs is depicted in Fig. 1, where it can be seen that there are many stakeholders and players in the highly networked and large-scale system [1]. In IEEE Grid Vision 2050 [11], the broad expectation of SGs is to have operations and control spread to the entire power systems encompassing all the present and future power technologies to enable bidirectional power flows.

The future requirements of greater flexibility, portability, safety, and security of energy supply and usage

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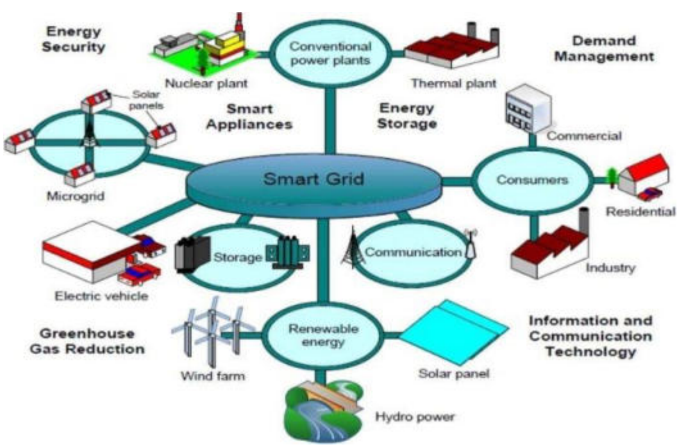


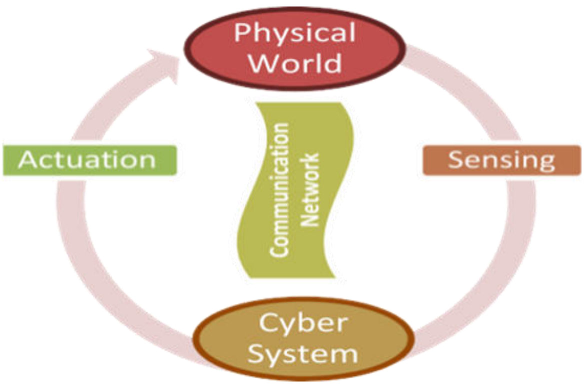
Fig. 1. Smart grid.

SGs require a rethinking of how to interact be- tween the power networks, the cyber systems, and users. Greater cooperation and interaction between physical systems (power network infrastructure) and cyber systems (ICT and advanced technologies) are a must. The technical challenges that must be addressed include intermittency of RE generation that affects electricity qual- ity, large-scale networks of small distributed generation mechanisms, such as photovoltaic (PV) panels, batteries, wind and solar, plug-in hybrid electric vehicles (PHEVs), and uncertainties incurred due to introduction of energy market mechanism.

One key characteristic of power usage is the significant difference between the peak and average demands of electricity. For example, the ratio of peak and average demands in Australia reached around just less than 50% between 2013 and 2014 [12]. Reducing peak usage would increase the capacity of the energy supply with more margins to accommodate higher energy needs without building new power generation plants. Another way is to reduce the unnecessary waste, for example, the long distance transmission of electricity, which accounts for a substantial portion of energy generated. This supports the argument of embedded generation and siting genera- tors close to the point of consumption (a concept usually called "distributed generation"). Another issue is how to use ICT and other advanced technologies to enhance efficiency of energy use, such as smart meters, telecommu- nication technologies for sensing, transmission, and processing information relating to grid conditions. To ad- dress the above issues, several key technological advances are required. 1) Control mechanisms need to be distrib- uted, enabling lower communication needs if grid com- ponents such as source, loads, and storage units can be controlled locally or can make some decisions themselves. 2) There should be a relatively accurate pre- diction of demand at the distribution level, estimating demand in any part of the grid a few hours or days in advance. 3) There should also be a relatively accurate estimation of energy generation from RE sources such as solar panels and wind turbines. This requires linkage with weather forecasting, so intermittent energy sources can be smoothly integrated with the grid. 4) Peak de- mand should be reduced to achieve a more efficient grid through methods such as load shedding, intelligent load management, and dynamic pricing. 5) Advanced energy storage technology is also needed that helps shave peaks in energy demands. All the above issues and challenges require a holistic systematic approach to deal with. CPSs provide such a par- adigm that can help resolve them in a systematic way. In the following, we will discuss their applications in SGs.

CYBER–PHYSICAL SYSTEMS

The term of cyber–physical systems (CPSs), coined in 2006 by the U.S. National Science Foundation, describes essentially a broad range of complex, multidisciplinary, physically aware next-generation engineered systems that integrate embedded computing technologies (cyber part) into the physical world (see Fig. 2). The U.S. vision of CPSs is more concentrated on connection between embedded systems and the physical world, while the European version highlights interaction with the cloud/cyberspace and human factors [13].



and synthesis such as sensing, modelling, and control, as well as computer science and engineering in programming, real-time computing, visualization, embedded de- sign, and modelling formalisms and verification tools [15]. Systems science and engineering methods and tools excel at dealing with temporal information while com- puter science and engineering are good at dealing with large-scale spatial information at ease. CPSs will bring these two fields together to deal with modern industrial problems which are high in dimension and complexity and require time-critical responses. Bridging the systems science and engineering and the computer science and engineering for CPS development faces significant technological challenges which are summarized in the following two key aspects

Architecture and design. To enable seamless integration of control, communication, and computation for rapid design and deployment of CPSs, architecture and design are essential for infra- structure. Examples include communication interfaces between power networks and cyber systems, allowing heterogeneous systems to be composed in a plug-and-play fashion, and massive proliferation of technology and development of the cyber systems. Standardized abstractions and architectures that permit modular design and development of CPSs are urgently needed. Further- more, design methodology and tools are needed to support system and network specifications, inter operability, hybrid and heterogeneous models, and modelling and analysis. Cybersecurity is an-other important issue for CPSs, given the inti- mate integration of cyber systems and physical systems where the processes and mechanisms for computing devices such as computers, smart- phones, computer networks, and smart meters are essential, hence requiring protection from un- authorized access and change. New architectures and techniques are needed to ensure confidential- ity, integrity, and availability of data, as well as protection of assets and humans.

Information science and engineering. Seamless integration and interaction between cyber and physical systems demand information sensing, processing, intelligence, and control to be delivered fast and in real time. The proliferation of cost-effective sensors such as smart meters results in very large volumes of data streams which must be processed fast and efficiently in order to be useful for decision making and control, especially for the transient processes in SGs. The traditional centralized paradigms for computation, information intelligence acquisition, and control are not suitable for delivering fast real-time actions. Distributed computation, information intelligence, and control mechanisms, subject to network-base

Uncertainties, must be adopted in order for distributed decision making, which is especially critical for the SGs. Information sensing, processing, intelligence, and control are at the heart of all the operations.

SGs involve many stakeholders, from generator to distributor and prosumer in an interconnected world of social, economic, and technological environments. The increasing complexity of and connectivity between com- ponents such as smart meters, solar panels, wind tur- bines, and their sheer numbers require rethinking of how to analyze and design the CPS aspects of the SG. The applications involve components that interact through complex, highly interconnected physical environments. In the following, we will discuss the SG developments from a CPS viewpoint.

SG: A CPS PERSPECTIVE

SGs integrate the physical systems (power network infra- structure) and cyber systems (sensors, ICT, and advanced technologies), and exhibit characteristics typical of CPSs, such as [17]:

- integration of real and virtual worlds in a dynamic environment where situations from the physical systems are fed to CPS control centers as input and help adjust the simulation models to influence how the physical systems perform in future times;

- dynamic connections and interactions between components in both physical and cyber systems through communication networks (e.g., AD hoc networks) where timely responses are essentially in their dynamic cooperation;

- real-time parallel computation and distributed in- formation processing of big data and data streams required in order to help deliver timely decisions for SG operations across transient, distribution, and scheduling layers through the CPS;

- self-adaption, self-organization, and self-learning by which the CPS can respond to faults, attacks, and emergencies, in order to enable SG resilience and secure and safe energy supply.

An open question is whether all the currently avail- able CPS technologies are readily applicable. The answer is not directly either “yes” or “no.” The core issue is how much integration between the cyber systems and the physical systems there should be. Often, cyber technologies such as communication networks and sensing de- vices are fixed on power systems without tailoring them to suit power system characteristics; a lot of calibration and patching fixtures are usually required to allow them to function together to meet the stringent SG safety and security requirements. For example, telecommunication protocols for wireless communication networks are used for retrieving measurements from smart meters installed

with SIM cards and operated through public communication networks. This makes the data sensing prone to con- gestion, hindering decision making based on smart metering data (e.g., energy consumption reading from millions of meters at the same time) when there are competing demands on communication times during peak hours. Another example is the distributed control over communication networks which falls victim to communication time delay, packet dropouts, and packet errors, severing the control performance, and in the worst scenarios, causing the power network to collapse.

A seamless integration between these two (cyber and physical) systems will bring enormous benefits to SGs, just like what mechatronics brought to the car manufacturing industry where a blend of mechanical, electrical, telecommunications, control, and computer engineering delivers much simplified mechanical design, rapid machine setup, rapid development trials, optimized performance, productivity, reliability, and affordability.

In order to improve cyber–physical relationship in SGs, six key functionalities are required [13], namely, 1) high dependability so that the system has to be repaired in a simple and timely manner when a fault occurs, maintaining accessibility even the fault occurs, while at the same time not causing any harm when some part is malfunctioning; 2) high reliability in open, evolving, and uncertain environments, so that the system can continue to operate even in the presence of failures without fundamental changes to its original configuration; 3) high predictability which guarantees the specified outcomes within the time span it is required to operate accurately;

4) high sustainability embedded with self-healing and adjusting mechanisms and adapting to changing environ- ments; 5) high security so that the system has

adequate means to protect itself from unauthorized access and attack; and 6) high interoperability which enables the system to provide or accept services conducive to effective communication and interoperation among system components.

There have already been some attempts to address the particular issues associated with the relationship be- tween SGs and CPSs. The name of cyber–physical energy systems (CPESs) was used in [18] where integration of SGs and CPSs was discussed from several angles. The co- simulation environment of CPESs was proposed in [19], the communication mechanism for CPESs was discussed in [20], and a modeling analysis and control framework was proposed in [21]. However, in this paper, we will treat SGs and CPSs as two separate entities and examine the interplay and interaction between them, posing emerging mutual challenges to both fields.

In the following, we will outline the progresses and challenges in the two key broad aspects, namely, architecture and design, and information science and engineering. Fig. 3 depicts the general.

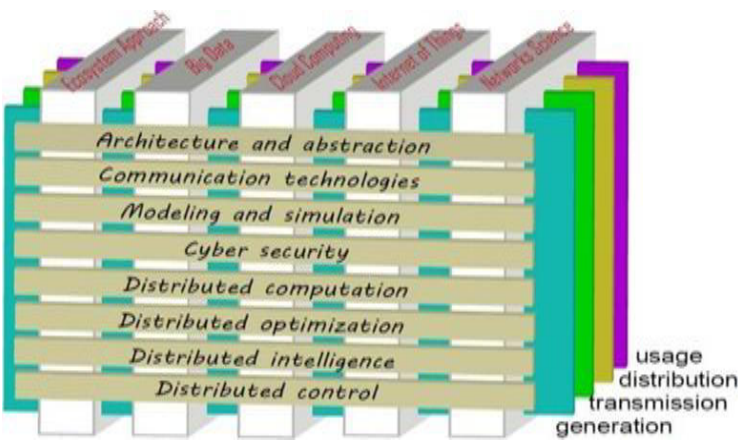
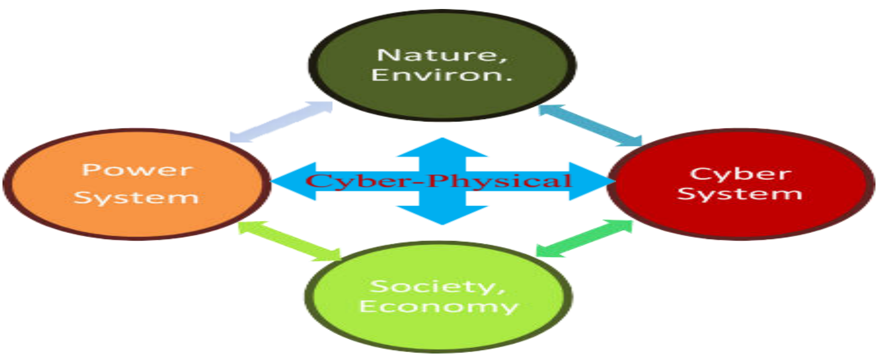


Fig. 2: Basic structure of MRAC scheme

FUTURE CHALLENGES AND OPPORTUNITIES

In this section, we will outline what we believe the key challenges and opportunities facing SGs from CPS perspective, in viewpoints of ecosystems, big data, cloud computing, Internet of Things, network science, and leg islation and regulation, respectively. While they are dis- cussed individually, they should not be considered in isolation. A system of system (or codesign) approach should be considered which will deliver optimal total system peAn Ecosystem View SG developments cannot be done in isolation with environmental, social, and economic environments. A supply chain management (cross-functional) approach needs to be taken. For example, for coal-fired power generation, the costs and impact from mining to transport- ing, burning, and usage should be considered holistically. For solar panels, the costs and impact for their manufacturing from raw materials mined should also be considered. All these can be considered in a framework of "ecosystem," which is commonly defined as an ecological community interacting with the environment as a function unit [46]. Its principles can equally apply to SGs, treating it within its environments as an ecosystem consisting of many networked and interconnected elements of different life cycles, from raw materials to end- user consumption, and from physical systems to cyber systems and social–economic systems. Designing such a large-scale system requires a holistic approach taking consideration of entire life cycles of individual elements. Key elements in ecosystems are self-regulation and control through an internal feedback mechanism and resilience after disturbance, which are also shared by SGs.

In the future, operations of SGs must also be integrated with environmental, social, and economic systems, as shown in Fig. 4, which can be called energy ecosystem. Here the power system refers to the physical behaviours to be monitored, controlled, or created. The cyber system refers to the advanced embedded software and hardware, equipment, and infrastructure for information processing and communication within their dis- tributed environments. The society and economy refer to the human dimensions of participation such as users, ser- vice providers, operators, the social dimension including community and society, and the economic dimension including energy markets, broader economic environments. The nature and environments refer to the environmental dimension including impact on flora and fauna, climate change, and natural environments. The interfaces refer to the communication networks and mediums that en- able information flows between these component systems. All the key elements need to work together concurrently with key functions, namely.



- **Big Data**

Big data is a term that is being widely used in the data gathering and analytics. While it may have many meanings and interpretations, there are five key features, namely, volume, velocity, veracity, variance, and value [47]. Data captured by smart metering devices such as smart meters exhibit these five typical features. For ex- ample, moving from 1-m reading per month to every 5 min would transform into 308 million readings for every million consumers, resulting in a massive volume of data streams to manage. Data analytics capable of near-real- time analysis across large-volume, time-series, heterogeneous, and autonomous sources would be advantageous for both utilities and users, and if integrated with other information such as consumption data, weather, and various grid behaviour-based readings, would help transform high-volume data into actionable insights that are critical for efficient operations of SGs.

- **Cloud Computing**

SG enables distributed and renewable energy generation though real-time management to meet demands in a timely manner. Cloud computing has been a very recent paradigm in which services such as computation, storage, and network are packaged as computing resources [50]. Cloud computing brings out benefits such as on-demand self-service, resource pooling, however elasticity through use of a cloud service raises security and privacy issues. This concept has already been adopted in dynamic pay-per-use pricing modelling for regulation [51], and the first cloud-based smart metering system was developed in Denmark for small utilities and communities. There are also initiatives worldwide, for example, U.K. Smart Energy Cloud, to support the United Kingdom's smart meter implementation program, which is expected to roll out more than 50 million meters throughout the country by 2016. The solution is expected to provide for more accurate billing, greater smart grid functionality, and other benefits. There have also been some cloud platforms developed for power systems, e.g., IBM Core metrics and Google Big Query. A cloud-based software platform for data-driven analytics [35] was developed as a part of the Los Angeles Smart Grid Project. The benefits of cloud computing include easy management, cost reduction, un- interrupted services, disaster management, and green computing [50]. The key challenge is the security and privacy issue where confidential data may be handed over to the third party service providers resulting in exposure of confidential information to outsiders. These complex issues will need to be addressed from a broad scope of perspectives, such as legislative, regulatory, and operational viewpoints [52], which will have impact on architecture and design, information science, and engineering aspects of SG.

- **Internet of Things**

Internet of Things (IoT) is considered the expansion of the Internet services due to the proliferation of RFID, sensors, smart devices, and “things” on the Internet [53]. IoT is expected to grow to 50 billion connected devices by 2020 [54].

SG has a communication network that connect all the energy-related equipment of the future, from the trans- mission and distribution power infrastructure, electrical, water, gas, and heat meters, to home and building auto mation. Effective functioning of the SG can be achieved by using the IoT computing paradigms as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols. Here physical and virtual “things” have identities, physical attributes, virtual personalities, and user intelligent interfaces, and are seamlessly integrated into the IoT network [1]. The connectivity and accessibility that the IoT brings in further enhances customer experience and efficiencies allowing greater interaction and control for consumers. Additionally, IoT delivers more data for manufacturers and utility providers to reduce costs through diagnostics and neighbourhood-wide meter reading capabilities. Ultimately, the IoT will be instrumental in building a more connected, cost-effective, and smarter SG.

There are three challenges in application of IoTs: the “things” need to be identified uniquely and tracked with their IDs through sensors and pervasive technologies. Sophisticated sensing and computing devices are required to enable various “things” to be connected globally and information/data collected be transmitted out; From the Internet viewpoint, the objects whether physical or cyber, need to work on an IP platform on which they can communicate and work together; the diverse data of homogeneous and heterogeneous types need to be interop erable under a unified semantic platform for effective data fusion [52]. Such an attempt has already been made, for example, in [56], an IoT architecture was pro- posed for SGs which consists of four components: intelligent electric transmission, substation, distribution, and usage, which are connected through an electric power central (wide area) network.

In SG environments, IoT represents a vast network of anything that is part of the power system. Such an environment was also named as the Internet of Energy [57]. However, due to the fact that physical laws governing electric flows are different from those for information flow, and electricity is indistinguishable between sources, and because of the physical and chemical transformation from primary sources to end use, it may be more appropriate to refer to such an environment as a cyber energy system in the context of the broader energy ecosystem to capture the landscape of the vast areas and aspects in in- formation and physical layers covered. The information security and stringent real-time responsiveness of SG may still require closed, specialized communication net- works separate from the public communication networks which are prone to cyber attacks and are poor in real- time responses. Greater integration of the Internet and specialized, closed, secure communication networks will accommodate the need for security and reliability of SG, as well as the need for effective architecture and design to enable interaction and communication between stake- holders across social, economic, and environmental do- mains to achieve collective goals in an optimal manner.

- **Network Science**

In recent years, network science, which is defined as the study of network representations of physical, biological, and social phenomena leading to predictive models of these phenomena by the U.S. National Research Council, has attracted increasing attention. It studies complex networks found in natural and man-made systems such as communication networks, biological systems, social networks, computer networks, and power networks. Complex networks research draws theories and methodologies from a wide range of areas such as graph theory, statistics, mechanics, data mining, and sociology [58]. The essence of this theory is to study the subject system from the aspects of structure, topology, and dynamical function of a collection of nodes and links without relying heavily on the dimensionality of the sys- tem which is usually focused on in existing theories such as control and optimization theories. Typical complex networks include regular networks, random networks, small-world networks, and scale-free networks. Such a theory has found its application in the vulnerability analysis of the power network [59], [60].

The new way of thinking embedded in the complex network theories is to consider the connectivity, topological structures, and strengths of connections as key factors to understand, model, and manage the networks without bogging down with the huge dimensionality and complex- ity, which are usually NP-hard problems [58]. This may result in achieving close-to-ideal modelling or control effects focusing only on few drive nodes [61] or few smaller

subnetworks so that modelling, optimization, and control tasks for complex networks can be performed much faster and simpler. Some exploitation of this idea has been implemented in pinning control of complex networks (taking advantage of the topological structure of the net- work to simplify the analysis and control design) [62]. However, the existing results suffer from several problems: 1) the node dynamics are homogeneously simplistic, usually linear systems of same dimensions which are far from reality; 2) the links are static where in SGs the links can be dynamic; 3) the complex networks them- selves are not heterogeneous where in SGs there are mixes of dynamic, static, nonlinear models interconnected; and 4) there is also an aspect of network of net- work where the power networks have different layers of functional networks acting upon the physical energy net- work system such as telecommunication, smart meter, and demand-side management networks, which have not been studied before. The aforementioned issues are frontiers in complex networks, SGs, and CPSs; solving them will have significant impact on these areas individually and as a whole. For example, SG architecture design can use network topological information for differential treatment of components upon their importance. Such information can also be used to discriminate less important components to deliver time-critical feasible solutions.

- **Legislation and Regulation**

As SG becomes an increasingly important development across the globe, legislators and regulators in various countries are considering possible implementation barriers based on numerous analyses done, which are different from country to country and have different focuses. For example, in the United States and Europe, the barriers are both legislative and regulative [63], [64], while in developing countries such as China, the focus is placed more on regulations and standards which aim to enable the SG to function seamlessly.

There are a broad range of issues concerning SG's up- take as a national infrastructure, most of which are closely related to cyber–physical aspects of SGs, for ex- ample, stakeholder participation and incentives for demand-side response, legal barriers to the SG development, regulatory instruments to facilitate it. In here, we mainly focus on legislative and regulatory issues closely related to the two key central aspects of this paper: architecture and design, and information science and engineering. For architecture and design, the challenges include legislative encouragement for SG development, regulatory requirements for standards, models, and architectures that enable interoperability and interconnectivity, data collection and handling, cyber and network security, and compliances of enabling ICT such software platforms, hardware infrastructure and devices, as well as legal responsibilities of various stakeholders such as vendors and prosumers. For information systems and engineering, there are outstanding legal and regulatory is- sues concerning data access, data provision, data privacy, software/hardware liabilities, and automated decision making. They are expected to be treated differently within the legislative and regulatory frameworks of individual countries.

CONCLUSIONS

In this paper, we have presented an overview of the chal- lenges in SGs from a CPS perspective. We have outlined potential contributions that CPSs can make to SGs, as well as the challenges that SGs present to CPSs. We have particularly discussed the impact of the latest frontier technologies on SGs, including big data, cloud comput- ing, the Internet of Things, and network science as well as challenges in legislation and regulation A number of open questions have also been posed which will be im- portant for future developments of SGs, CPSs, as well as the energy ecosystem as a whole.

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Optimal strategies to improve grid connected typical 10KW Photovoltaic system

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ABSTRACT

This paper presents a modelling method of photovoltaic systems (SPR305E-WHT) and an implementation and comparison of three MPPT techniques ,fuzzy logic control, incremental conductance ,perturb observe method for maximum power point tracking (MPPT) algorithm. The method is used to study the influence of rapidly changing irradiance level concerning performance of 10KW photovoltaic systems. A simple circuit model of the boost converter connected to the photovoltaic systems is used to easily simulate the incremental conductance MPPT method. The model has been implemented in MATLAB / Simulink 2013 . The simulation results are presented and analysed to validate that the proposed simulation model is effective for MPPT control of the photovoltaic systems at rapidly changing irradiation condition.

Keywords: *photovoltaic array(SPR305E-WHT), boost converter,Maximum Power Point Tracking techniques, R-L filter, multilevel inverter, RLC load.*

INTRODUCTION

Nowadays the fossil fuel has been consumed increasingly. Solar energy, as one kind of clean and renewable energy, because of its rich reserves of raw materials-silicon, a decline in the cost of production and improving of the conversion efficiency, has prompted the photovoltaic power generation to become an important role in the future development. Whether from the point of environmental protection or solving the energy problem, the development and utilization of solar energy is of great strategic significance [1].

As we know, the electric energy can't be stored on a large scale, and islanding phenomenon may occur whenever the power system breaks down, which requires that the photovoltaic power system store electrical energy in normal circumstances and release it in case of islanding status, thus maintaining the voltage and frequency stable. So it’s necessary to add storage device to the photovoltaic grid-connected system. Energy storage device introduced into the system can realize management of demand side, eliminate valley-to-peak difference between day and night and smooth load [1]

- **Basic photovoltaic cell**

The basic structure of solar cells is to use a p-type semiconductor with a small quantity of boron atoms as the substrate. Phosphorous atoms are then added to the substrate using high-temperature diffusion method in order to form the p-n junction. In the p-n junction, holes and electrons will be rearranged to form a potential barrier in order to prevent the motion of electrical charges. When the p-n structure is irradiated by sunlight, the energy supplied by photons will excite the electrons in the structure to produce hole-electron pairs. These electrical charges are separated by the potential barrier at the p-n junction[4].

The electrons will move towards the n-type semiconductor and the holes will move towards the p-type semiconductor at the same time. If the n-type and p-type semiconductors of a solar cell are connected with an external circuit at this moment, the electrons in the n-type semiconductor will move to the other side through the external circuit to combine with the holes in the p-type semiconductor.

The photovoltaic (PV) provide one of the most efficient ways of producing energy, with real perspectives in the future, considering the actual situation of the resources around the world. It becomes a real problem the fact that we have insufficient supplies of this kind of resources for insuring the world's needs. Usually, when a PV module is directly connected to a load, the operating point is rarely at the maximum power point or MPP[5].

The principle of maximum power point tracking(MPPT) is to place a convertor between the load and the PVarray.it regulates the array output voltage (or current) so that the maximum available power is extracted [5]. A power converter is necessary to adjust the energy flow from the PV array to the load.

- **Mathematical description of photovoltaic cell**

General mathematical description of I-V output characteristics for a PV cell has been studied for over the past four decades. Such an equivalent circuit-based model is mainly used for the MPPT technologies. The equivalent circuit of the general model which consists of a photo current, a diode, a parallel resistor expressing a leakage current, and a series resistor describing an internal resistance to the current flow, is shown in Fig.1 [6]. The voltage-current characteristic equation of a solar cell is given a

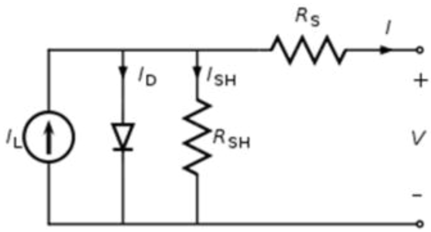


Figure:1 Photovoltaic equivalent cells

from the equivalent circuit it is evident that the current produced by the solar cell is equal to

that produced by the current source, minus that which flows through the diode,

minus that which flows through the shunt resistor:

$$I = I_L - I_D - I_{SH} \quad (1.1)$$

where

I = output current (ampere)

I_L = photogenerated current (ampere)

I_D = diode current (ampere)

I_{SH} = shunt current (ampere).

The current through these elements is governed by the voltage across them:

$$V_j = V + IR_S \quad (1.2)$$

where

V_j = voltage across both diode and resistor R_{SH} (volt)

V = voltage across the output terminals (volt)

I = output current (ampere)

R_S = series resistance (Ω).

By the Shockley diode equation, the current diverted through the diode is:

I_D = [exp $\frac{Vj}{Nkt}$ – 1] (1.3)

where

I_0 = reverse saturation current (ampere)

n = diode ideality factor (1 for an ideal diode)

q = elementary charge

k = Boltzmann's constant

T = absolute temperature

At 25°C, KT ≈ 0.0259 volt

By Ohm's law, the current diverted through the shunt resistor is:

$I_{SH} = \frac{Vj}{RSH}$ (1.4)

Where

R_{SH} = shunt resistance (Ω).

SIMULINK MODEL OF PV SYSTEM WITH MPPTPV

solarpanel connected to resistive load through a boost converter with MPPT controller.

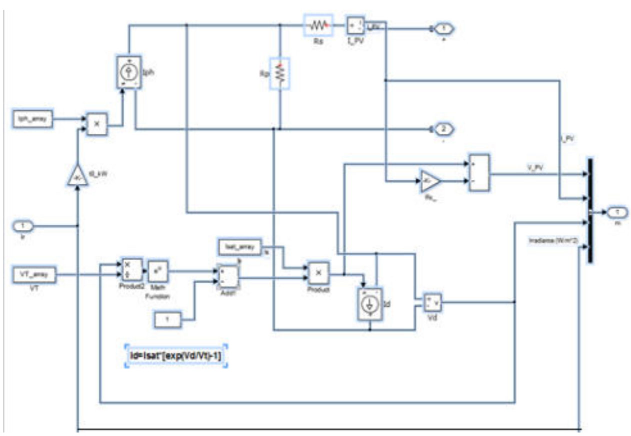
```
BlockName=gcb;
Type=1;
k= 1.3806e-23; % Boltzman constant (J.K^-1)
q=1.6022e-19;  % electron charge  (C)
T=273+25;
Pmp=305
nCells=96;
Voc=64.20;
Isc=5.96;
Vm=72.9;
Im=5.58;
```

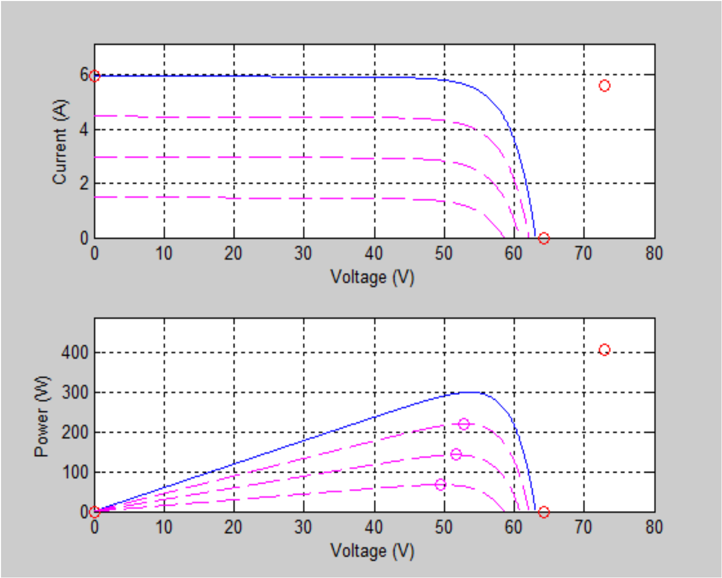
```
Rs=0.037998;
Rp=993.51;
Isat=1.6753e-08;
Iph=5.9602;
Qd=1.3;
Voc_TrK = 85.7 /nCells;
TrK=298
n = 1.3;
Isc1 = Isat * (1 + (Vm * (Iph - Im)));
%  G( G=1KW/m2)
Iph2 = Qd * Isc1;
Vt_TrK = nCells * k * T / q;
b = Rp * q /(nCells * k);
Ir_TrK = Isc / (exp(Voc_TrK / Vt_TrK) -1);
Ir = Ir_TrK * (T / TrK)^(3/n) * exp(-b * (1 / T -1 / TrK));
% Take dV/dI @ Voc from I-V curve of datasheet
dVdI_Voc = -1.0/nCells;
Xv = Ir_TrK / Vt_TrK * exp(Voc / Vt_TrK);
Rs = - dVdI_Voc - 1/Xv;
Vt_Ta = n * k * T / q;
% Ia = Iph - Ir * (exp((Vc + Ia * Rs) / Vt_Ta) -1)
% f(Ia) = Iph - Ia - Ir * ( exp((Vc + Ia * Rs) / Vt_Ta) -1) = 0
% Solve for Ia by Newton's method: Ia2 = Ia1 - f(Ia1)/f'(Ia1)


VT=k*T/q*nCells*Qd;

set_param(BlockName,'Ncell',num2str(nCells));
str=sprintf('[ %g  %g  %g  %g ]',Voc,Isc,Vm,Im);
set_param(BlockName,'ModuleParameter',str);
str=sprintf('[ %g  %g  %g  %g  %g ]',Rs,Rp,Isat,Iph, Qd);
set_param(BlockName,'ModelParameters',str)

Iph_array=Iph*Npar;
Isat_array=Isat*Npar;
VT_array=VT*Nser;
Rs_array=Rs*Nser/Npar;
Rp_array=Rp*Nser/Npar;
%
%% Plot I-V & P-V characteristics of one module
%
ifPlotVI_module | PlotVI_array
assignin('base','Voc',Voc);
```

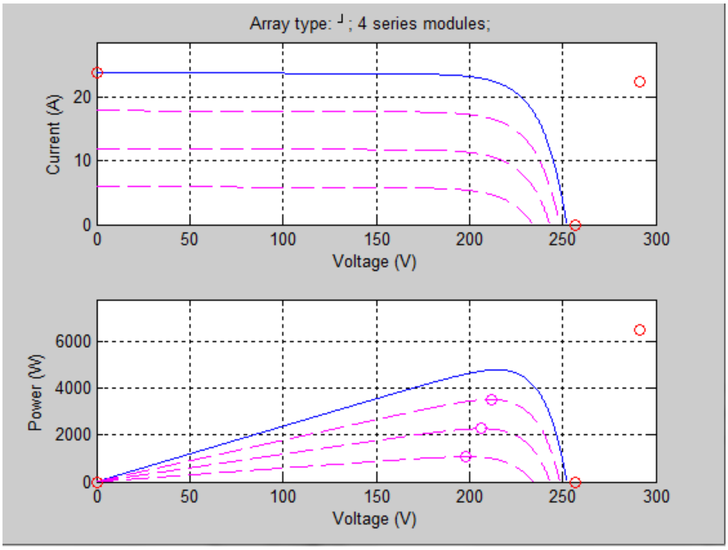
```
assignin('base','Isc',Isc);
assignin('base','Rs',Rs);
assignin('base','Rp',Rp);
assignin('base','Isat',Isat);
assignin('base','VT',VT);

ifPlotVI_module,
F1=figure('Name','I-V and P-V characteristics of one module at 25 deg.C');
end
ifPlotVI_array ,
F2=figure('Name','I-V and P-V characteristics of array at 25 deg.C');
end

load_system('PV_model_Param');

forksun=1:-0.25:0.25
assignin('base','Iph',Iph*ksun)
sim('PV_model_Param');
n=find(I_PV>=0);

I_PV=I_PV(n);
V_PV=V_PV(n);

P_PV=V_PV.*I_PV;

ifPlotVI_module
figure(F1);
subplot(211)
ifksun==1
plot(V_PV,I_PV,'b',[0  VmVoc], [IscIm 0],'ro')
% text(Voc/15,Isc*1.1,'')
holdon
grid
else
plot(V_PV,I_PV,'--m')
% text(Voc/15, Isc*(ksun+0.1) , sprintf('%g kW/m^2',ksun))
end

subplot(212)
ifksun==1
plot(V_PV,P_PV,'b',[0  VmVoc], [0 Im*Vm 0],'ro')
%  text(Vm*1.02,Vm*Im,'1 kW/m^2')
holdon
```

```
grid
else
n= find(P_PV==max(P_PV));
plot(V_PV,P_PV,'--m', V_PV(n) , P_PV(n),'mo')
%  text(Vm*1.02, Vm*Im*ksun, sprintf('%g kW/m^2',ksun))
end
subplot(211)
ylabel('Current (A)')
xlabel('Voltage (V)')
% title(sprintf('Module type: %s',SolarModuleSpec(Type).Desc))
axis_xy=axis;
axis_xy(4)=Isc*1.2;
axis(axis_xy);
subplot(212)
ylabel('Power (W)')
xlabel('Voltage (V)')
axis_xy=axis;
axis_xy(4)=Vm*Im*1.2;
axis(axis_xy);
set_param(BlockName,'PlotVI_module', 'off')
end

ifPlotVI_array
figure(F2);
subplot(211)
ifksun==1
plot(V_PV*Nser,I_PV*Npar,'b',[0  VmVoc]*Nser, [IscIm 0]*Npar,'ro')
% text(Voc/15*Nser,Isc*1.1*Npar,'')
holdon
grid
else
plot(V_PV*Nser,I_PV*Npar,'--m')
%text(Voc*Nser/15, Isc*Npar*(ksun+0.1) , sprintf('',ksun))
end


subplot(212)
ifksun==1
plot(V_PV*Nser,P_PV*Nser*Npar,'b',[0  VmVoc]*Nser, [0 Im*Vm
0]*Nser*Npar,'ro')
% text(Vm*Nser*1.02,Vm*Im*Nser*Npar,'')
holdon
grid
```

```
else
n= find(P_PV==max(P_PV));
plot(V_PV*Nser,P_PV*Nser*Npar,'--m', V_PV(n)*Nser ,
P_PV(n)*Nser*Npar,'mo')
% text(Vm*Nser*1.02, Vm*Im*Nser*Npar*ksun, sprintf('',ksun))
End


subplot(211)
ylabel('Current (A)')
xlabel('Voltage (V)')
title(sprintf('Array type: %s; %d series modules; %d parallel
strings',Nser,Npar));
axis_xy=axis;
axis_xy(4)=Isc*Npar*1.2;
axis(axis_xy);

subplot(212)
ylabel('Power (W)')
xlabel('Voltage (V)')
xis_xy=axis;
axis_xy(4)=Vm*Im*Nser*Npar*1.2;
axis(axis_xy);

set_param(BlockName,'PlotVI_array', 'off')
end
end
end
```







CHOICE OF MPPT TECHNIQUE

Photovoltaic array (SPR 305E-WHT) is an unregulated dc power source, which has to be properly conditioned in order to interface it to the grid. The dc/dc converter is present at the PV array output for MPPT purposes, i.e. for extracting the maximum available power for a given insolation level. The step-down dc/dc converter (boost converter) is used as a dc transformer which can match the Parry optimum load by changing its switching duty ratio.

1. Implementation complexity
2. Sensors required
3. Ability to detect multiple local maxima
4. Cost
5. Application
6. Response time
7.

MAXIMUM POWERPOINT TECHNIQUES

[1] Perturb & observe method
2] Incremental Conductance
[3] Fuzzy Logic Control

1.5.1 Perturb & observe method Hill climbing involves a perturbation in the duty ratio of the power converter; P&O involves a perturbation in the operating voltage of the PV array. In the case of a PV array connected to a power converter, perturbing the duty ratio of power converter perturbs the PV array current, and consequently perturbs the PV array voltage; hill climbing andP&O methods are two different ways to perform the same fundamental method.
(1)

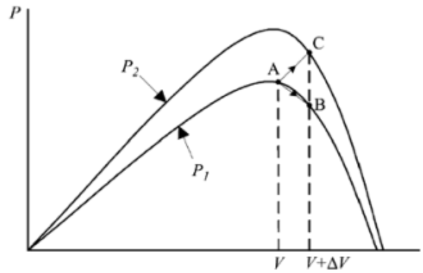


Figure-4. Divergence of hill climbing/P&O from MPP

Incremental Conductance The incremental conductance method is based on the fact that the slope of the PV array power curves at the MPP is zero, positive on the left, and negative on the right of the MPP.figure. the mathematical relations are shown below

(2) dP/dV = 0 (1.6)

(3) dP/dV>0 left of MPP (1.7)

(4) dP/dV<0 right of MPP (1.8)
(5) SINCE dP/dV = d(IV)/dV = 1+V(dI/dV) (1.9)
(6) = -I/V = (dI/dV**)**
(1.10**)**
(7) The MPP can thus be tracked by comparing the instantaneous conductance term (*I/V)* with the incremental conductance term (d*I/*d*V)*

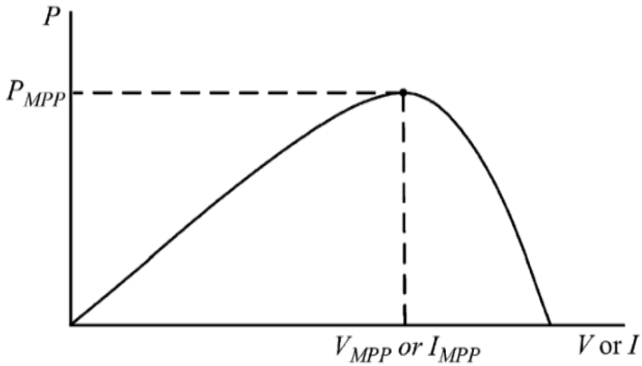
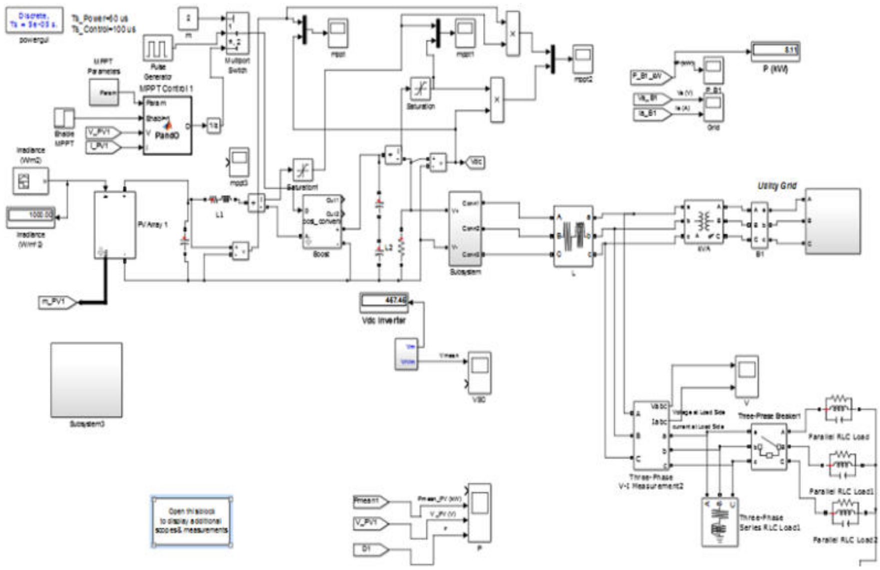


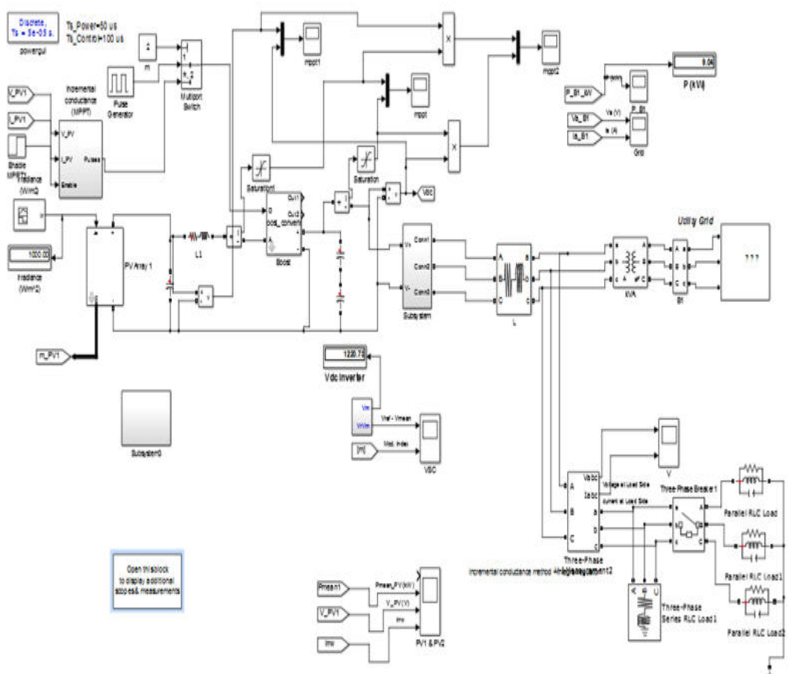
Figure-5 Characteristic photovoltaic Array power curve

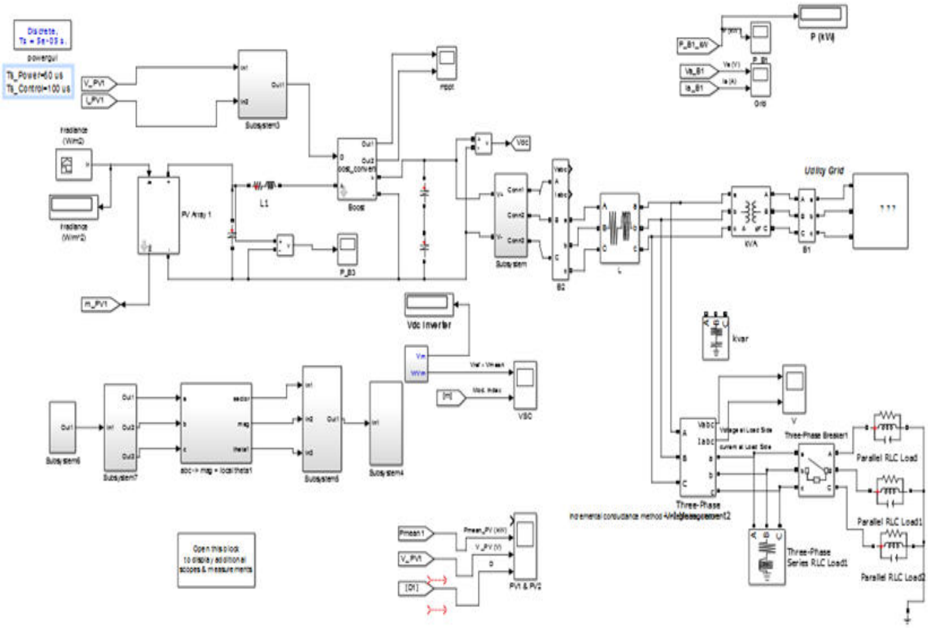
Fuzzy Logic Control : Fuzzy logic controllers have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity. Fuzzy logic control generally consists of three stages: fuzzification, rule base lookup table, and defuzzification.

During fuzzification, numerical input variables are converted into linguistic variables based on a membership function. In this case, five fuzzy levels are used: NB (negative big), NS (negative small), ZE (zero), PS (positive small), and PB (positive big) [3].The inputs to a MPPT fuzzy logic controller are usually an error E and a change in error ΔE. The user has the flexibility of choosing how to compute E and ΔE. Since *dP/dV*vanishes at the MPP [3]. By calculate the following
E(n) = [P(n) – p(n-1)]/[V(n) – V(n-1) (1.11)
ΔE(n) = E(n) – E(n-1)

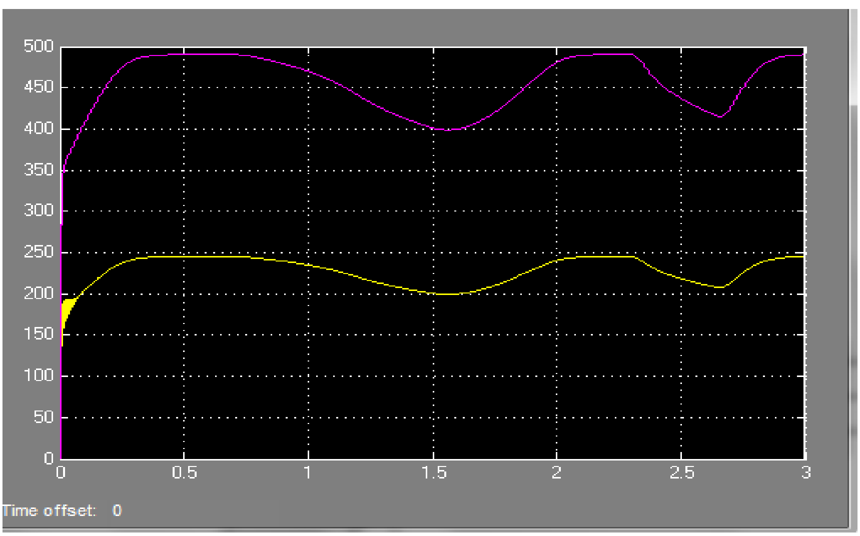
4. MATLAB SIMULINK MODEL OF 10KW PHOTOVOLTAIC (SPR305E-WHT)

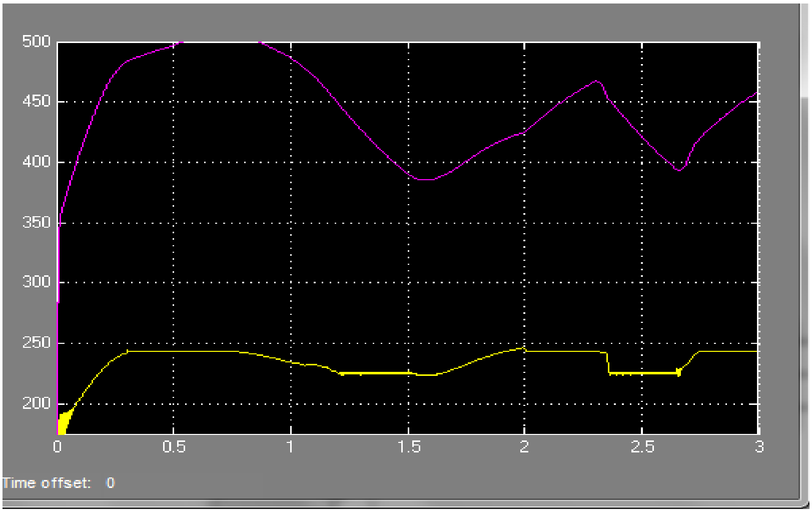






5. RESULT ANALYSIS OF 10 KW CRITICAL PV SYSTEM IN DIFFERENT MAXIMUM POWER POINT TRACKING





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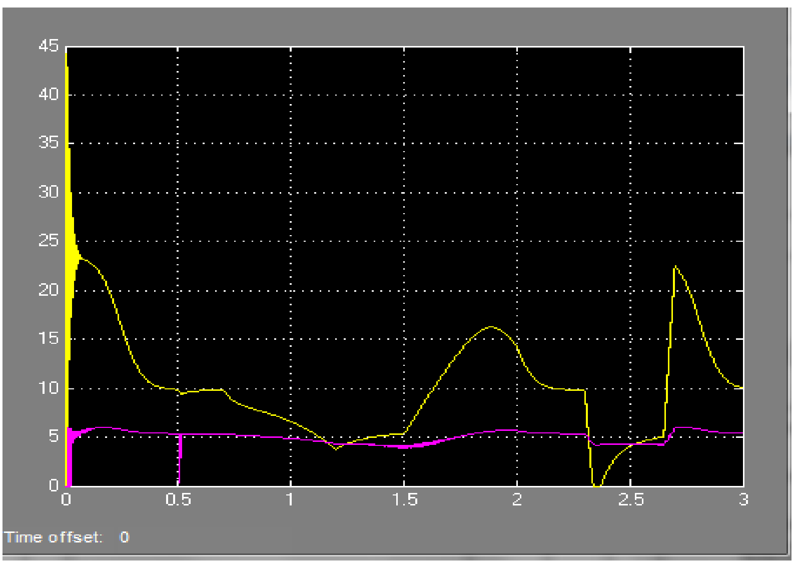

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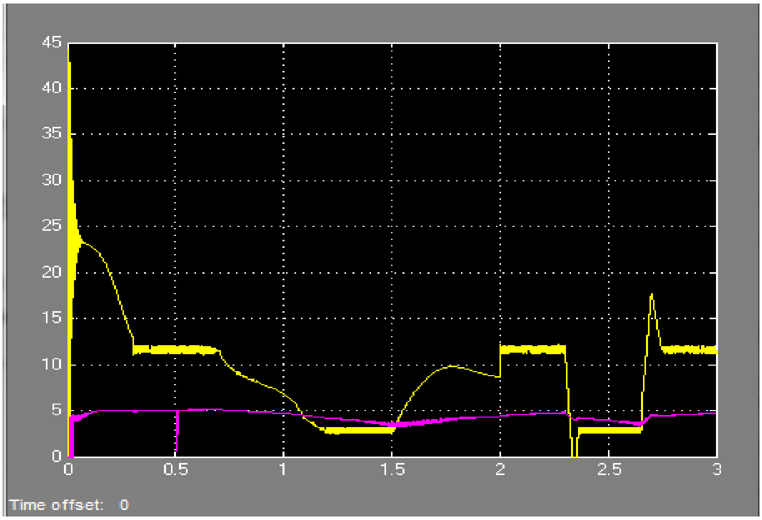
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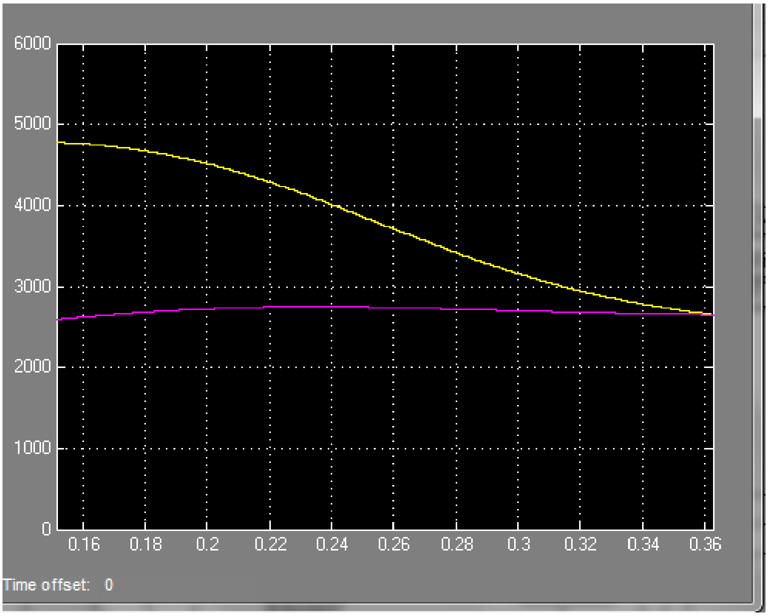
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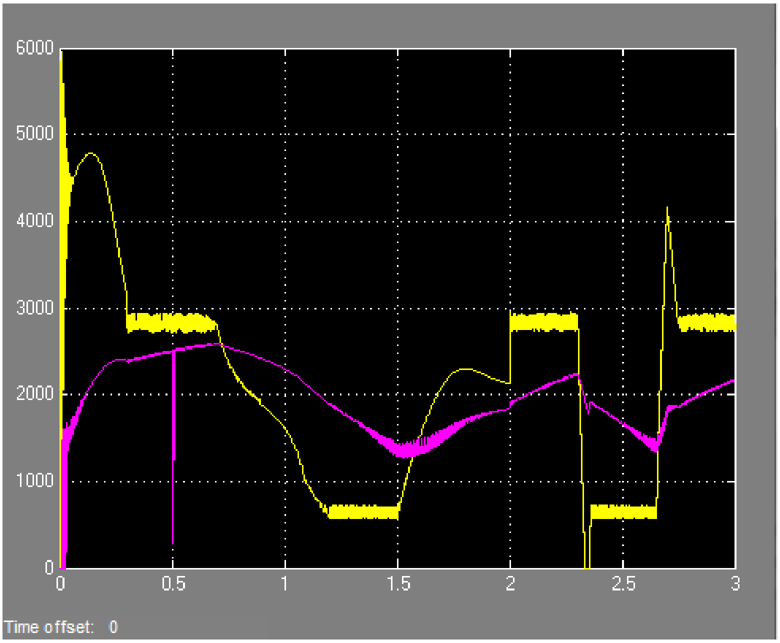

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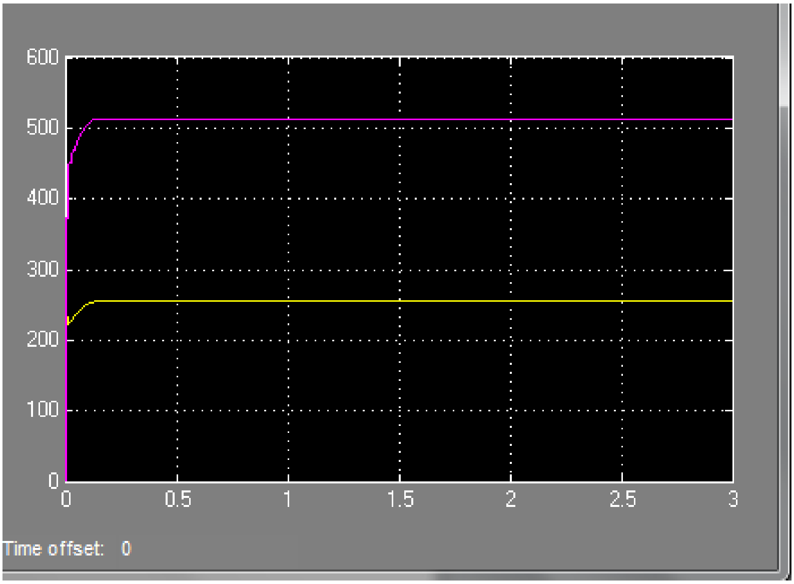

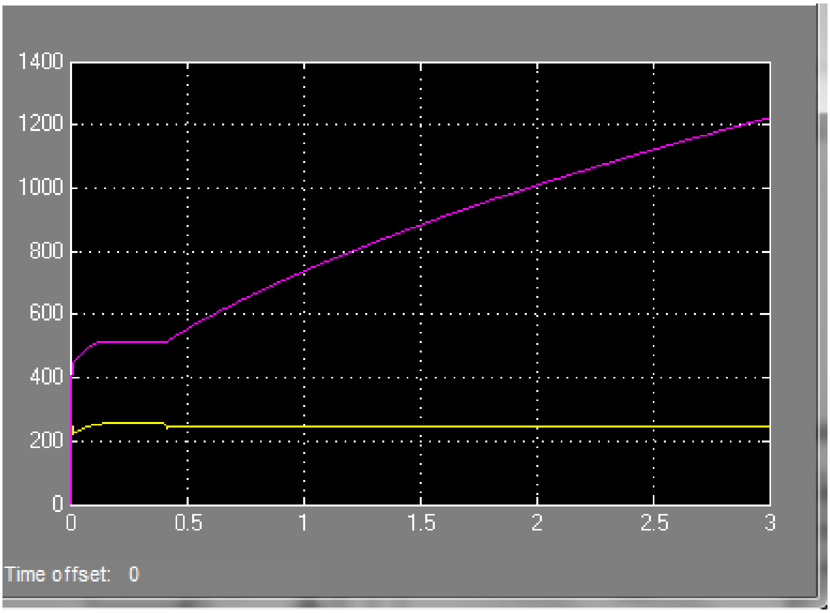
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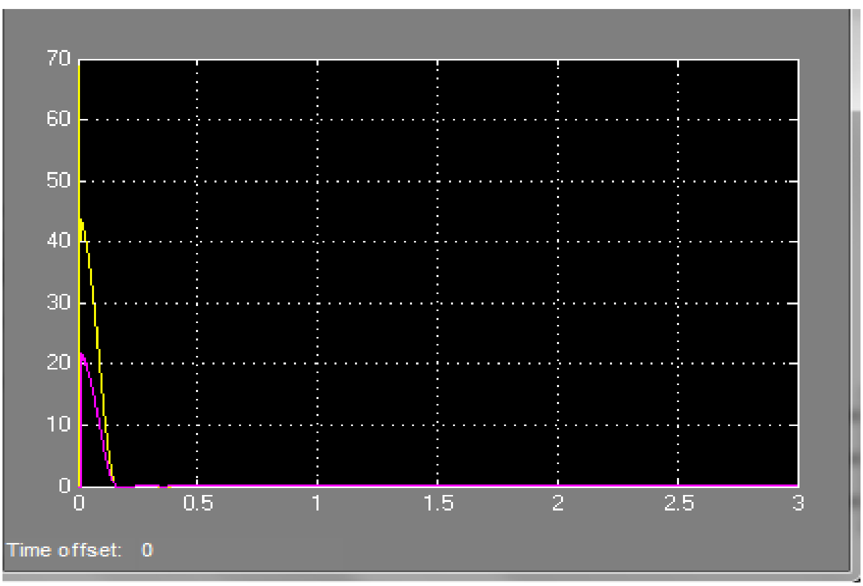
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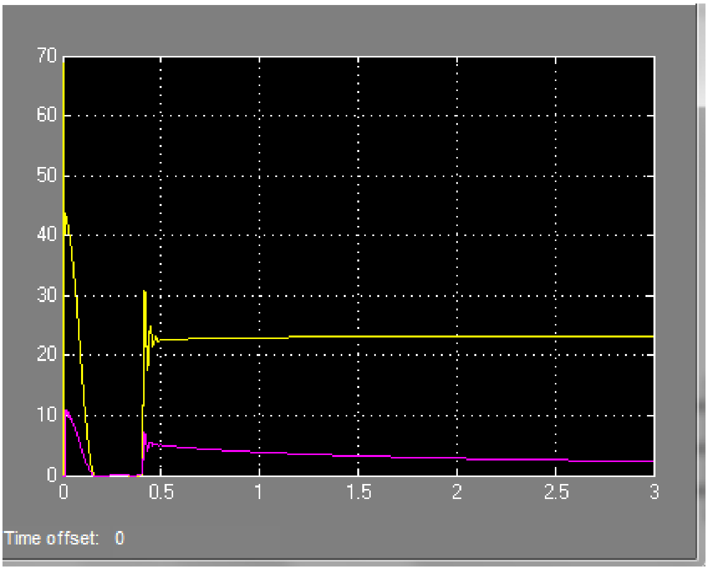
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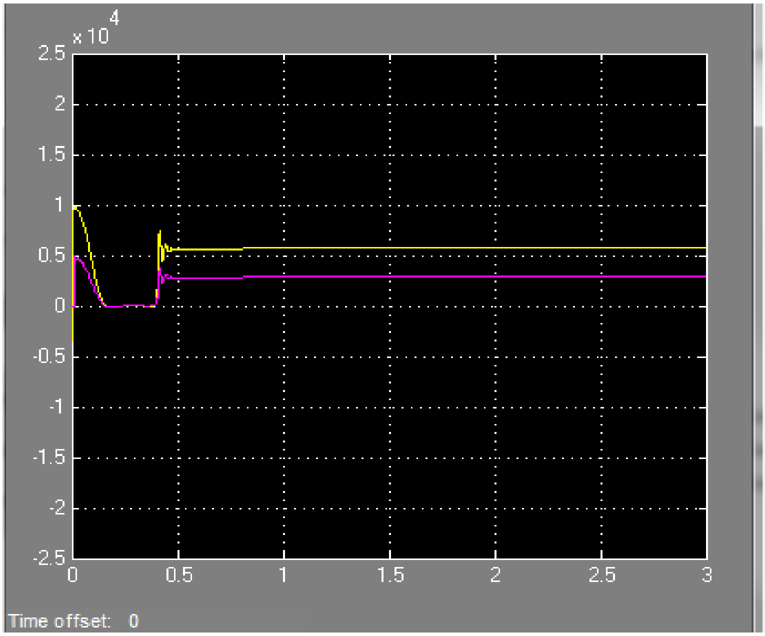
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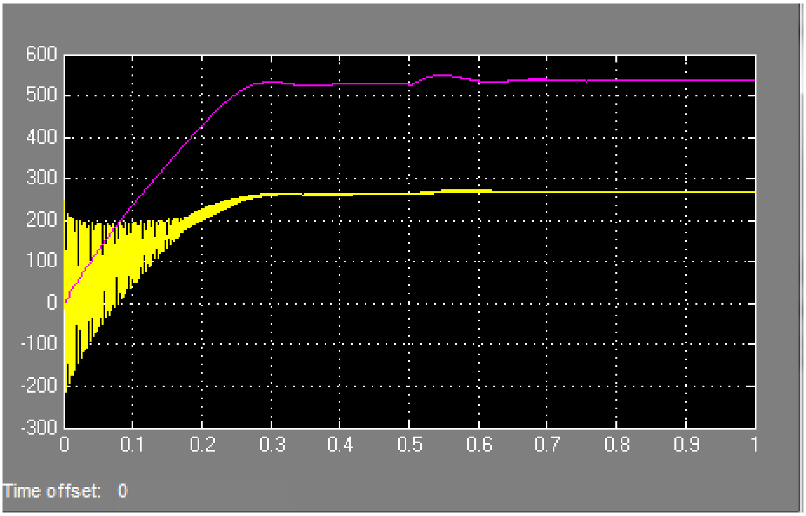
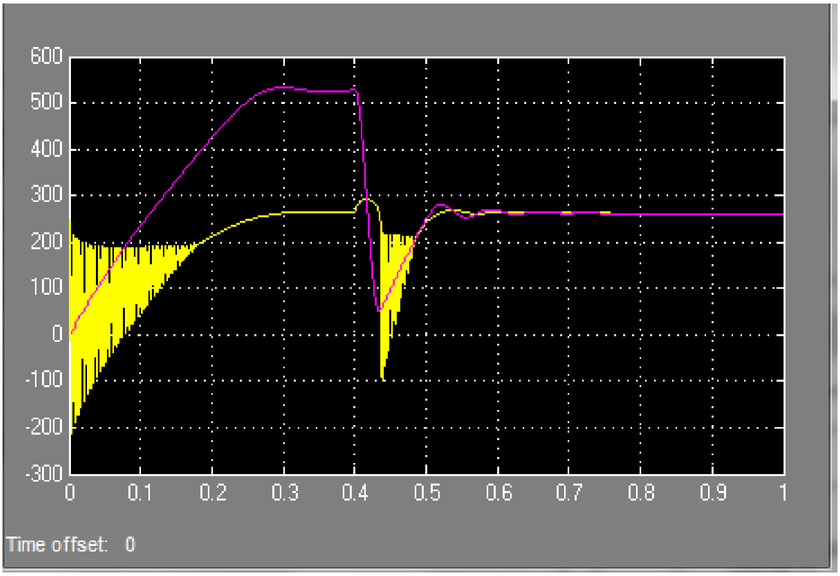
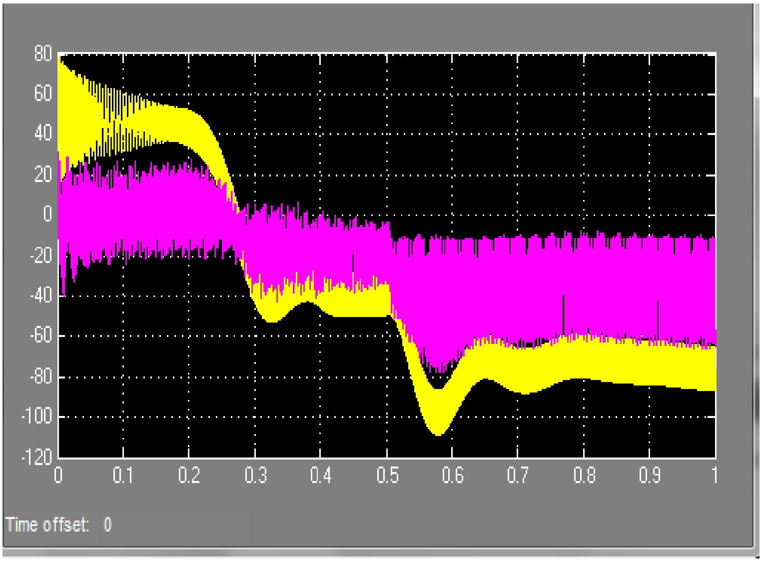
7. Fuzzy Logic Control







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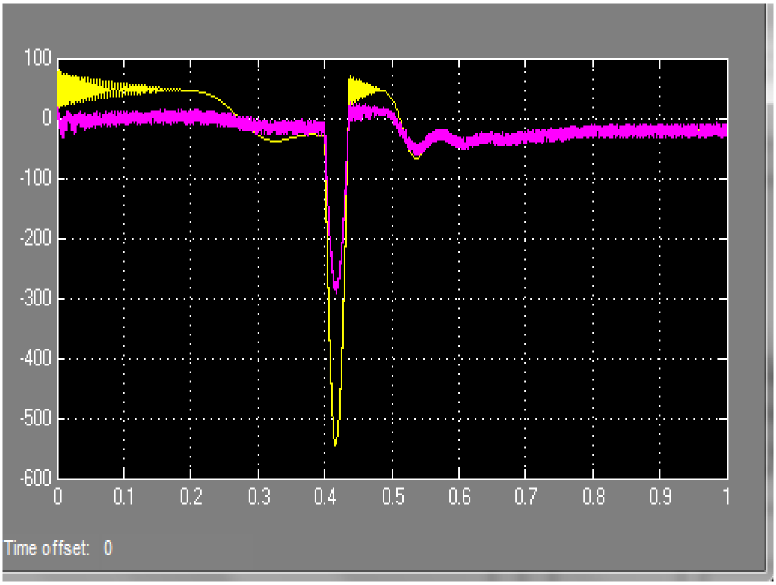

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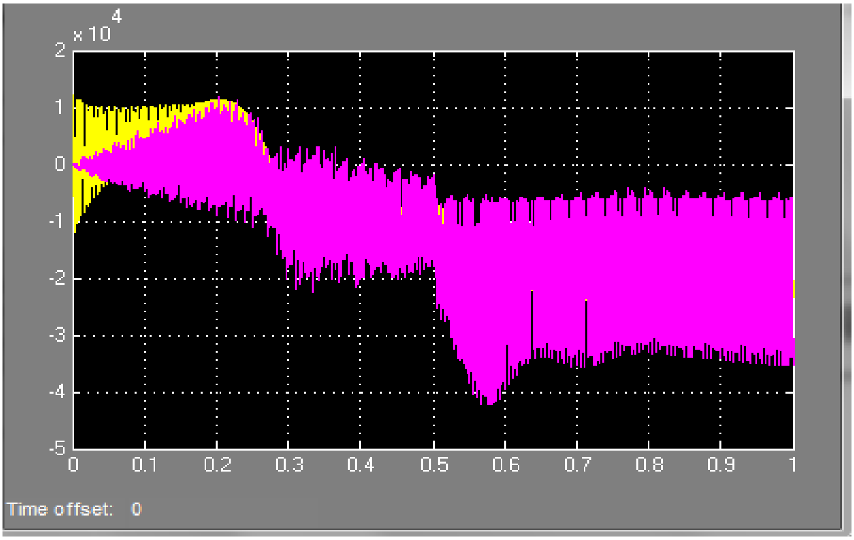
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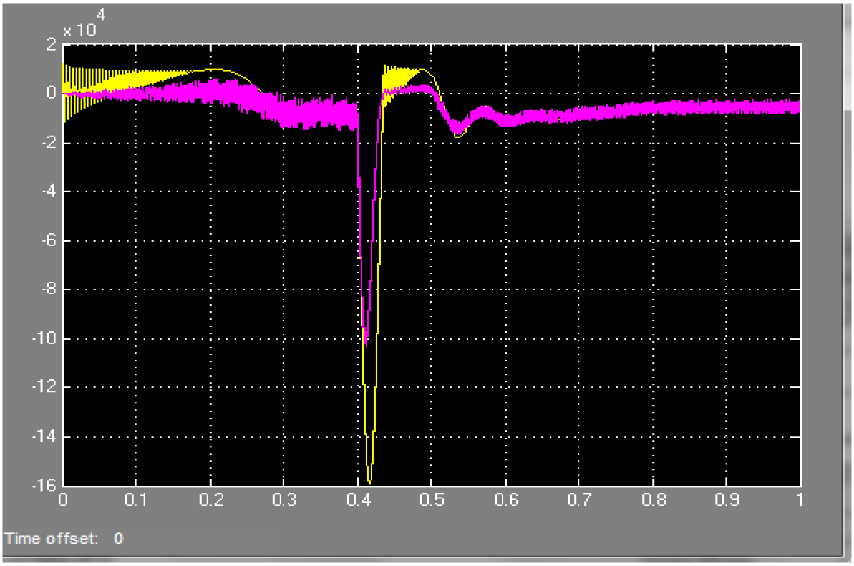
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Time offset: 0

CON CLUSION

The Model of a photovoltaic cell and photovoltaic array is built in the Matlab/Simulink software. Photovoltaic cell model is in single diode model and it is based by familiar Newton Raphson method. Voltage, Current and Power characteristics are simulated in Matlab/Simulink and it verified at different irradiance and temperature conditions. Maximum power point tracking is incorporated in the simulation of Photovoltaic array and the Maximum power point, voltage and current at this maximum power point were simulated at standard conditions and verified the result. The simulation system used for the analysis of solar photovoltaic array at different temperature value, solar irradiation value, series resistance $R_S$and shunt resistanceR_{sh}. Behavior of the photovoltaic array in different diode ideality factor also analysed. This model can be used for analysis of Photovoltaic array characteristics and for simulation with different Maximum Power Point Tracking Algorithm (MPPT) algorithms.
The grid connected 10kW Photovoltaic system simulated on Matlab/Simulink is shown in Fig.6.1. Fig.6.3. and Fig.6.5(without MPPT) and comprise three graph in Fig6.2,Fig 6.4 and Fig 6.6 of Voltage, Current and power with Maximum power point tracking (MPPT). The input to the simulation is given from the manufactures datasheets. The other simulation parameters are set as following values: Ta= 25 Degree Celsius, A=1.3(Polycrystalline solar cell),. The simulation is carried standard condition to verify the working of Matlab/Simulink Photovoltaic model. The unknown parameters are calculated and voltage, current and power characteristics are simulated. The simulating system draws the voltage, current and Power of Maximum power point tracking graph are drawn and shown in Fig.6.2 and Fig.6.4 and Fig.6.6.

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Self Regulating Solar Tracker System

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ABSTRACT

The paper deals with utilization possibilities of solar energy in hardware design and implementation of a system that ensures a perpendicular profile of the solar panel with the sun in order to extract maximum energy falling on it renewable energy is rapidly gaining importance as an energy resource as fossil fuel prices fluctuate. The unique feature of the proposed system is that instead of taking the earth as its reference, it takes the sun as a guiding source. Its active sensor constantly monitors the sunlight and rotates the panel towards the direction where the intensity of sunlight is maximum. The light dependent resistor's do the job of sensing the change in the position of the sun which is dealt by the respective change in the solar panel's position by switching on and off the geared motor the control circuit does the job of fetching the input from the sensor and gives command to the motor to run in order to tackle the change in the position of the sun. With the implementation the proposed system the additional energy generated is around 25% to 30% with very less consumption by the system itself. In this paper, an improvement in the hardware design of the existing solar energy collector system has been implemented in order to provide higher efficiency at lower cost.

Keywords: *Four quadrant sensor, Light Dependent Resistor (LDR), Self-regulating solar tracker system (SRSTS).*

INTRODUCTION

With the increasing demand of energy via greener methods and the gradual depletion of fossil fuels, solar energy conversion has regained the spotlight of the global energy activities. Our planet receives 160,000TW solar energy, while the present global energy demand is about 16TW. While the solar resource is virtually unlimited, conversion of solar energy to readily usable form is too expensive to be commercially successful at present. Furthermore, reliable solar technology has to be complemented by energy storage system to accommodate the daily and seasonal variations in the solar radiation. From this perspective, many countries have formulated their long term solar energy utilization roadmap. For instance, the Japanese roadmap includes development of solar photovoltaic at competitive price by 2030.

In remote areas the sun is a cheap source of electricity because instead of hydraulic generators it uses solar cells to produce electricity. While the output of solar cells depends on the intensity of sunlight and the angle of incidence. It means to get maximum efficiency; the solar panels1 must remain in front of sun during the whole day. But due to rotation of earth those panels can't maintain their position always in front of sun. This problem results in decrease of their efficiency. Thus to get a constant output, an automated system is required which should be capable to constantly rotate the solar panel..

The Self-regulating solar tracker system (SRSTS) was made as a prototype to solve the problem, mentioned above. It is completely automatic and keeps the panel in front of sun until that is visible. The unique feature of this system is that instead of take the earth as in its reference, it takes the sun as a guiding source. Its active sensors constantly monitor the sunlight and rotate the panel towards the direction where the intensity of sunlight is maximum. In case the sun gets invisible e.g. in cloudy weather, then without tracking the sun the SRSTS keeps rotating the solar panel in opposite direction to the rotation of earth. But its speed of rotation is same as that of earth's rotation2. Due to this property when after some time e.g. half an hour when the sun again gets visible, the solar panel is exactly in front of sun. Moreover the system can manage the errors and also provides the error messages on the LCD display. In manual mode, through the software (GUI) at computer, the solar panel can be rotated at any desired angle.

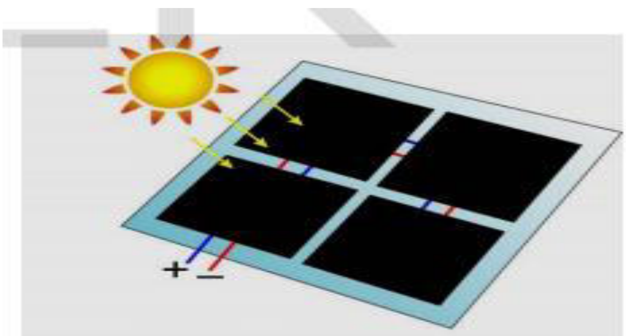

Fig1: Solar panel

Heliostat and Parabolic Trough. SRSTS can be used for Parabolic Trough tracker, Dishes tracker, PV (Photovoltaic generator) tracker, Heliostat, Solar Furnace and so on. Even though the theory of the controller system is similar to all the applications, there are some differences: the precision requirement for dishes tracker is stricter than PV tracker, while the Heliostat and solar furnace need the strictest precision requirement, and more difficult to apply solar sensor to make a closed-loop control system. So, when design these systems, selection of motor type, controller type and tracking mode should be different.

STRUCTURES OF SRSTS

SRSTS is a hybrid hardware/software project. Its general structural diagram is shown in figure-3.

The software includes:

• VB 6.0 based GUI.

• Microsoft Access Database.

• Embedded Software (written in C) for microcontroller AT89c52.

The hardware includes:

• Solar panel assembly structure containing six functional sensors, stepper motor and solar cells.

• System Control Unit containing LCD, Keypad, Error Indicators and Emergency Stop switch.

• Complete PCB containing two microcontrollers (89c52). First one is the "Master Microcontroller" which controls the automatic operation of SRSTS. While second one, the "Slave Microcontroller" serially communicates (RS232) with VB software in computer.

Fig.2: General Assembly of SRSTS

MOTOR SELECTIONS

There are many types of motor can be selected in SRSTS design. Currently, several types of motors being used in the area of SRSTS around the world are Step- motor, Servo-motor, AC asynchronous motor, permanent magnetic DC servo motor, permanent magnetic brushless synchronous motor, etc. Generally speaking, as the gear ratio is high for the transmission system, motor control precision has very small impact to the tracking precision. For example, for a system with the gear ratio of 20000:1, the tracker only covers an angle of 0.314mrad when a one complete circle is finished by the motor. Therefore, all kinds of the motor can satisfy the precision of the tracking system. However the feature of each type of motor is different. First of all, let's take a look at the AC asynchronous motor. To use this kind of motor, we need an encoder to locate the position of the tracker. In our project, we install an encoder at the end of AC motor. The PLC accepts the pulse to locate the tracker, while the transducer is used to adjust the tracker's speed. Certainly, we can install an encoder at the end of the transmission to ensure the position of the tracker. The obvious advantage to use AC asynchronous motor is its price. Even though it can achieve all the needed functions, AC asynchronous motor is too heavy, too large, and too low in efficiency to be installed. Also, for this type of motor, the torque at low speed is very small. In addition to these disadvantages, it needs the work frequency be above 5Hz to function properly. The lowest work frequency in our project is 10Hz. As such, the possibility for us to use AC asynchronous motor in the future is eliminated. Secondly, let's compare the features of DC Servo-Motor and AC servo-motor. There are two types of DC servo-motor: motor with brush and motor without brush. Motor with brush is low in cost, simple in structure, and high in start torque. Also it has wide range of speed adjustment, is easy to control. Though it needs maintenance from time to time, it is very convenient to repair (replace the brush). However it produces electro-magnetic interfere. Motor without brush is small in size, light in weight, high in output, fast in response, small in inertia, smooth in spinning, stable in output torque, low motor maintenance fee, high in efficiency, low in electro-magnetic radiation, long life, and can be applied in different working environments. However it has more complex control system. AC servo-motor is also type of motor without brush.

There are two types of AC servo-motor: synchronous AC motor and asynchronous AC motor. Currently, synchronous AC motor is generally used in movement control. It can cover a wide power range, which could be up to a very high power level. Nowadays, with the fast development of semiconductor technology, the shift frequency of power assembly, and the processing speed of microcomputer have been increased significantly. As such, it is possible to put the AC motor controller into a twoaxial coordinate system to control the directional current components, in order to achieve the performance similar to the DC motor.

Fourthly, the comparison between AC servomotor and step motor is done. AC servo-motor runs smoothly during low speed period; while step-motor is apt to have low-frequency vibration. In terms of the frequency-torque Characteristics, the output torque of step-motor decreases with the increasing of rotation speed. Furthermore the decrease is steep in high-speed range. AC servo-motor has a comparably stable output torque, when the rotation speed is within the rated rotation speed. It gives the constant output power when the rotation speed is beyond the rated value. Step-motor doesn’t have the overload capability; while AC servo-motor possess a satisfactory overload capability.

The Panasonic AC servo-system is an example: The maximum Output torque is three times big of the rated output torque, which can be used to overcome the inertia load during the start period. As the step-motor doesn’t have the overload capability, a much bigger size of step-motor is needed. Obviously the step-motor will be over-sized during normal operation. Controller’s type of Step-motor is open loop type. It is easy to have the error of “step loss” or blockage when the start frequency is high or the load is heavy. Also it is easy to have the error of overshoot when it is stopped. So, to make sure the precision of control be achieved, designer needs to pay more attention to the speed-increase or speed-decrease periods. AC servo-motor system is a closed-loop system. It is possible for the driver-component to sample the signal from the motor encoder to complete a “position cycle” and “speed cycle” internally. As such, AC servo-motor system generally will not have the errors of “step loss” or “overshooting”, and is more reliable in terms of controlling performance. Stepmotor needs 200 to 400 mil-seconds to accelerate from still to a typical working speed of several hundred rpm. AC servo-motor is better in terms of acceleration performance. For example, Panasonic MSMA 400W needs only a few mil-seconds to accelerate from still to its rated speed of 3000RPM. So it is clear that step motor’s performance is not so good. However it’s cheaper. Started from late 70s and early 80s, with the development of micro-process technology, high power, high-performance semiconductor technology, and manufacturing technology of permanent magnetic material, the performance price ratio of AC servo system has been improved significantly. Price of AC servo-system also is gradually deceasing in recent years. AC servo motor is becoming the dominant product. The conclusion is that all the motors, step motor, AC asynchronous motor, DC motor with/without brush, AC servo-motor, can be applied in SRSTS. Asynchronous AC motor is the cheapest. But it is big in size, and low in technical specification. The step-motor has a simple controlling mode and is also low in price. AC servo-motor has the best performance and wide power range. Its price is also the highest. As for the performance and price for permanent magnetic DC brushless motor, they are both rated between step motor and AC servo-motor. Its performance is close to servomotor. For the situations that the output torque is not very high (less than 2 NM), permanent magnetic DC brushless motor is a good option.

SOLAR SENSORS

Dish type tracking controller and PV tracking controller can be both applied as four quadrants solar sensor to correct tracking bias. It is known that solar sensor will lose its functionality temporally when it's cloudy. In the area of solar thermal generation, solar sensor system usually follows the equation based on the astronomic formula to locate the position of the sun. When a MPU (microprocessor unit) is applied to calculate the sun's position, because of its low process speed and low precision, it's necessary to include a solar sensor to make a closed loop system. If the tracking system uses a PC or a high-performance DSP as the controller, the bias for the calculated sun position will be within one percent of mrad (milliradian), when the system clock is precisely set (Direct time from GPS is an option). No solar sensor is needed to track the sun, especially when the slope error and the gear-diastema are all small. Exception happens when the motor is a step motor and the output torque is not enough. The situation can lead to a blockage of the motor (For example, a windy weather), which will fail the tracking system to track the sun precisely. As such, a closed loop solar sensor is recommended in such system. There are many kinds of solar sensor. The four- quadrants sensor was used in our project as shown in.

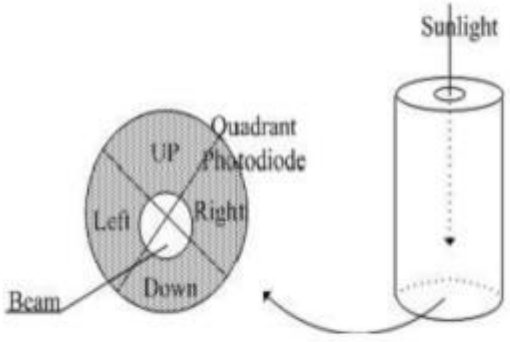

Fig 4: Four quadrants Sensor In four quadrant sensor system

In four quadrant sensor system, the Photovoltaic current will be bigger for the quadrant of bigger solar facular area, which will indicate whether the sun's incident ray is parallel with the axial direction of the sensor, then to adjust the angle by the motor. It should be stressed during the solar sensor design that the inside wall of the solar sensor needs to be blacken to avoid misjudgment by the reflection of sunray inside the solar sensor.

CONTROL STRATEGIES

For a successful operation, the SRSTS has two types of control approach.

• Automatic Control

• Manual Control

6.1. Automatic Control

With the help of an efficient algorithm (written in C) only one Master Microcontroller1 is being used to manage the automatic operation of SRSTS. This controller has following functions.

• Senses all of six sensors.

• Drives stepper motor.

• Drives LCD.

• Controls the warning indicators e.g. buzzer, LED's etc.

• Communicates (by parallel port) with the slave microcontroller. The central driving components of automatic control are only six sensors. Their operation has been explained on the previous page.

6.2. Manual Control

As no human made system is so perfect so an unpredictable fault may occur in the any system. That is why a manual control option was also kept in SRSTS. While designing this part of control two objectives were kept in mind:

• The manual control should work efficiently.

• It should be as user friendly as possible. Following two approaches have been used to accomplish the manual control.

• Stand Alone System Control Unit

• Computer based control unit

6.3. Stand Alone System Control Unit

It is a simple user interface, which includes onboard LCD, Keypad, Buzzer and a complete PCB of the system circuit. The LCD (Hitachi HD44780) displays different messages, which can help the user in manually operating the system. While the keypad includes keys of Numeric Digits, Emergency Stop, clock wise rotation and counter clockwise rotation. Using keypad a user can manually rotate the solar panel by entering angle from 0o to 180o. The angle value is limited to only 180 values because after sunrise, the earth almost rotates only 180 degrees and then the sun disappears. The advantage of this unit is that to run the system it does not need computer but its disadvantage is that at a time it controls only one solar panel. In figure-3 this unit shown in yellow color, in middle of solar panel and computer terminal.

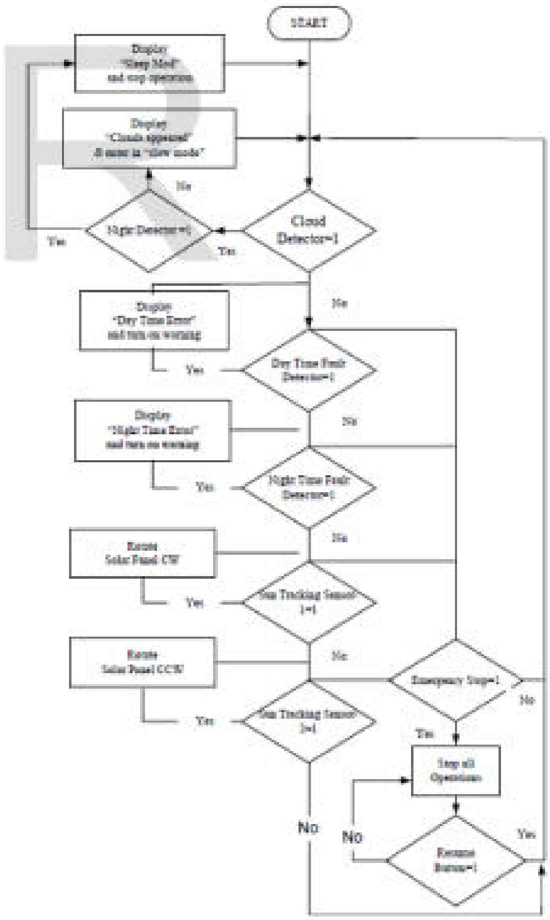

Fig. 5: Flow Chart showing automatic operation of SRSTS

This is completely software based control, written in VB 6.0. It incorporates a GUI (figure-10) and a Database, linked with Microsoft Access. Using this software the computer serially communicates (RS232) with the SRSTS. The Slave microcontroller (89c51) of the system makes this communication successful. Due to some fault if the solar panel stops rotating, then with the help of this software a user can:

• rotate the solar panel manually.

• stop all operations of SRSTS (in emergency case)

The database of this system can be used to keep records, which can be retrieved even after a long time. While saving the new data, the database automatically takes the date and time from the computer and keeps them saved along with the data, entered by the human being. The advantages of computer-based control include:

• Facility of Database.

• At a time this software can handle three SRSTS systems.

• It has an attracting GUI

CONCLUSIONS

The designed that system which ensures 25 to 30% of more energy conversion than the existing static solar module system. Although SRSTS is a prototype towards a real system, but still its software and hardware can be used to drive a real and very huge solar panel. A small portable battery can drive its control circuitry. Therefore by just replacing the sensing instrument, its algorithm and control system can be used in RADAR and moveable dish antennas.

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Optimal Design of Electrical Circuits Protection Devices: A Survey Study

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ABSTRACT

Electric circuit protection devices are known as the protection devices for different electrical circuits. These devices are used for reducing the overall ratio of hazardous occurrence in the electric circuit. The research of importance of electrical circuit protection devices in industries is undertaken through the primary quantitative method by taking the 70 respondents inthe survey analysis. Hazardous conditions occur due to lack of availability of electrical circuit protection devices. Therefore, the utilization of these devices is proved as beneficial for industries.

***Keywords**: Circuit Protection, Fuse, Breaker, Sampling, Hazardous Conditions.*

INTRODUCTION

Electrical circuit protection is referred as the protection of different electrical circuits with the help of intentional installation of the weak link. The protection of electrical circuits is done through different protection devices such as; fuse or circuit breakers. The complexity and importance ofelectrical equipment are continuously increasing within the commercial, residential and industrial installation. However, the protection equipment is also deemed critical for different system operations in industries. Electrical protection devices also have the large value in industries context as any fault or misleading of current can cause huge loss for industries in terms of safety and productivity. Additionally, these devices are proven as the essential hand in different industries as these devices provide safety and protection from facing any electrical hazard.

The importance and need of circuit protection are continuously increasing as there are various cases in which industries have faced the huge amount of loss due to the electrical fault. Every electrical circuit has the large value as it helps industries and individual with numerous electrical facilities. The word current has its value as various people get furious but this current provides people the required electricity through which numerous tasks can be performed. The protection circuits help current to follow the intended path and to overcome any electrical hazards. Moreover, the very small problems within electrical circuits can cause large problems for industries if these problems do not get corrected or detected on time. It is known to all that electrical circuits protection has the large value in different operations of industries. Therefore, the research will try to identify the impact of electrical circuit protection devices in the context of industries. This section of introduction will cover the detailed concepts of electrical circuit protection devices and the overall utilization of these devices within different industries. The section of introduction also covers the aim of undertaking the research and the objectives and questions of research that will help in fulfilling the aim of this research.

1. BACKGROUNDOF THESTUDY

Electricity provides people various benefits as it has become the most important asset for a human to survive in this world. However, electricity has also become the reason of death for many as the different fault of electricity or wrong connection cause death for people. Gan, (2014) mentioned in his study that there are various advantages of electricity, but it is necessary for people to take the proper protection of different electrical circuits [1]. Furthermore, the different cases of electrical death show that electrical current should be kept under high control regularly for the security of people and equipment. Dougherty (2015) stated that electrical devices have achieved the high value in people's lives as these devices are used for the safety of people in different electrical circuits that are used at residential, commercial or industrial areas [2].

Gan, (2014) also claimed that the devices of electric circuit protection are developed for protecting people and different electrical circuits from the high voltages and current outside their normal ranges [1]. It is necessary to have over current protection for preventing the small and controllable program from getting them such large issue. Electrical protection devices are used in various industries as these devices provide people the required protection while working with different and high voltage electrical circuits. There is other equipment that is also used by the electrical engineers while working with high voltage electrical circuits, but the devices like circuit breakers or fuse have high efficiency in restricting current and in saving people from any danger. Kage yama,Takeda, Murano, and Itagaki, (2015) also mentioned that the potential damage in govern current is also alarm geo-regular raised issue as this issue can arise from component failure ,accidental shorting or excessive voltage of circuits

[3].Expósito et al. (2016) identified that the failure of different electrical circuits is due to the increased rate of the heat of different components within circuits[4]. The excessive amount of heat level of components within electrical circuits may result in fire[3].Therefore, these electrical circuit protection devices also help industries and individuals in preventing the production of excessive current from damaging heat. However, it can be stated that both electrical and electronic devices do not have the capability of distinguishing the normal load and overloads as different circuits draw more current due to the increased of current which at last result in the burned equipment due to lack of circuit protection.

2. CIRCUIT CONDITIONS REQUIRINGPROTECTIONDEVICES

There are various conditions within industrial operations in which different electrical circuit protection devices are used. Franks, Williams, and Cole, (2014) claimed that various conditions can be occurred while using the electrical and electronic devices. However, it can be stated that changes in the working of the circuit can cause problems for the circuit and for the people who work near the circuits. Padilla et al. (2014) stated that it is necessary to have electrical circuit protection devices for securing and protecting the electrical circuits. However, the conditions in which these devices are use dare excessive current, excessive heat, and direct shorts.

Excessive Current

The excessive current is referred as the increase of current within electrical circuit due to any fault in the circuit. Circuit current can easily increase without the direct short within the circuit. It can be stated that the change in the value of any resistor, inductor, and capacitor cause the change in the value of circuit impedance. Mitolo and Montaz emi, (2014) stated that excessive current is the most identified situation in which electric circuit protection devices are required to be used as any resistor of the circuit decreased its ohmic value, the overall resistance of the circuit gets low [7]. Furthermore, the change in the capacitor or rise of dielectric leakage also causes the decrease in the resistance of the capacitor. However, Roscoe et al.(2015) identified in the study of Padilla et al. (2016) that any change within inductor, capacitor or resistor of the electric circuit results in the raise of the current of the circuit [6]. Furthermore, any short at the winding of the inductor can also decrease the inductive reactance of the circuit. The electrical circuits in which wiring and designing of components are made with normal circuit current can also cause over heating due to the increment of current. Therefore, these overall conditions can be the reason for excessive heat.

Direct Short

Direct Short is one of the most and serious troubles that are identified in the different electric circuit. Direct short is referred as contact between the full system voltage with ground or return side of the circuit. Neitzel, (2016)mentioned that direct short cause high effects on the circuit and it is also known as the Short Circuit [8]. However, the path on which high voltage and ground get into contact has the minimum resistance which helps current to flow through that path. Direct short cause large problems for industries as there are various cases of death due to direct short in the high electric circuit. It can be stated that maximum current will flow when there is low resistance in the circuit. For example, if the wires of battery came into contact with each other while running of the motor there will be high chances of producing direct shortin the circuit. Both wires are the symbol of the forward and backward path, and as the result of this contact the motor stop running and the motor get burned or can have the explosion [8]. Xin, Xiong, and Li, (2014) mentioned that the most of the wires that are used in the electrical circuits are smaller and have the very low current capacity [9]. Moreover, Neitzel,(2016) expressed that the size of wires in any given circuit is based on the different cost factors, space considerations and on the expected amount of current under the normal operating conditions [8]. The high flow of current in wires and the low resistance of the circuit leads to the excessive heat within the circuit. The excessive high heat within wires can also cause the short in between other wires and can result in the explosion [9].

Excessive Heat

The excessive of heat is also one of the conditions in which protection devices are required. Lud winek, Szczepanik and Sułowicz, (2017) mentioned that every issue or problem that is associated with the excessive current and direct short within electrical circuit directly concern the heat which is generated through higher current [10]. Excessive heat has different consequences such as; the possibility of hazardous fumes, damage to circuit components and the possibility of fire. Mitolo and Montazemi, (2014) claimed that excessive heat could occur without the excessive current or direct short. However, the practical example of excessive heat is the failure of the bearings on motor or generator which cause them to overheat [7]. Furthermore, Padilla et al.(2014) stated that excessive heat would be a problem if the overall temperature around any electrical or electronic circuit rise due to the failure of the cooling system [6]. Therefore, it can be stated that if excessive heat is present in any circuit, then there is the high possibility of damage, the existence of hazardous fumes and fire. The overall conditions that are mentioned in these sections have high potential danger. Therefore, different electrical or electronics engineers use different circuit protection devices to reduce the overall impact of all these conditions [10].

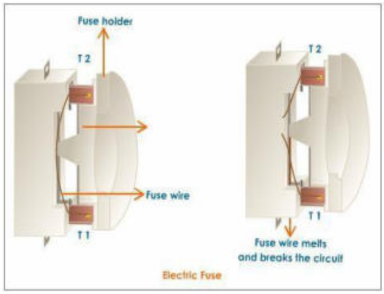
Circuit Protection Devices

Circuit protection devices have the large value in reducing the impact of hazardous conditions or in restricting the hazardous conditions from rising. These devices are also used for stopping the flow of current in the electric circuit therefore; these devices are called circuit protection devices. Expósito et al. (2016) mentioned that it is necessary to use these devices efficiently as these circuit protection devices are required to be connected in series with the specific protected circuit [4]. However, it is analyzed that the devices of circuit protection usually operates by opening or intruding the current within the circuit. The opening of protection devices is necessary for the electric circuit as it identifies the issues or problem within the circuit that are required to be resolved before the restoration of current. Franks, Williams, and Cole, (2014) stated that if any problem occurs within the electric circuit, engineers or circuit designers use the protection devices for the isolation of faulty circuit from the unaffected circuit [5]. These protection devices respond in time for protecting the different unaffected components in the faulty electric circuit. Gan, (2014) described that these devices should not be opened during the operation of the normal circuit [1]. As the technologies are getting improved, various devices are getting introduced, but the two major circuit protection devices; Fuses and Circuit breakers are analyzed in this section.

Fuses

In this study, the supplier performance is considered as the first Circuit protection devices are for the protection of electric circuit and fuse is referred as the simplest and efficient circuit protection devices. This protection device is usually used at the beginning of the circuit at which electricity isused. Zainal, (2017) stated that there is the large evolution of different electronic devices and components as old fuses are referred as a bare wire between two different connections [11]. However, the length of that wire within the fuse is smaller than the conductor that is placed inside the fuse. Ludwinek, Szczepanik, and Sułowicz, (2017) claimed that the wire of that old fuses usually melts before the conductor which was protected [10]. Moreover, it is observed that there center new fuses do not have the copper fuse link which was used as the fuse element inside the fuse. The copper fuse link is also known as the meeting part of the fuse. Therefore, other metals replaced it. Mitolo and Montazemi, (2014) stated that different tubes or enclosures were developed after the change of copper to other metals for holding the melting point [7]. Whereas, the arc that occurs after the melting of elements is also contained by the enclosed fuses which helped in the addition of different materials. However, these devices used by most of the circuit designers to protect the devices and to restrict the different hazardous conditions from occurrence [9]. Figure 1 shows the utilization of wires within fuse to get the clearer concept.

Fig1: Fuse Diagram Source: (www.tutorvista.com)



Circuit Breakers

Circuit breakers are also efficient circuit protection devices which have the more effective in protecting the electric circuit. Franks, Williams, and Cole, (2014) claimed that fuses are used for the protecting the electric circuits, but it can also be destroyed within the process of opening any circuit [5]. The problems of excessive heat or direct short of current within any electric circuit require the replacement of fuse in the circuit as these circuit protection devices can be used more than once only when it solves the problems of replacement fuses. These devices can be reused without replacement of parts as such devices are resettable, reliable and tamper-proof and are known as the circuit breakers. Circuit breakers are used for breaking (open) the circuit and help different circuit designers to manage the flow of current efficiently. Kageya maetal. (2015) identified that circuit breaker has the more preference than fuses as this circuit protection devices are used for the protection of electric circuits and can be used multiple times[3]. Figure2 shows the sample of circuit breakers that are used in daily routing electrical appliances and also in industries.

Fig2: Sample of Circuit Breaker Source

3. METHODOLOGY

Research studies cover different method for undertaking there search more appropriately and efficiently such as qualitative and quantitative research method. Both these methods have different approaches and methods for collecting the overall information regarding the efficiency of electric circuit protection devices. The qualitative research method is known for analyzing the data through the understanding and perspectives of different theories and studies. Whereas, the other method is quantitative research method which covers the data analysis through the information collected by specific and selected participants. There search of electric circuit protection devices is undertaken through using the quantitative research method. Quantitative Research Method. The research of electrical circuit protection devices is based on survey analysis for recognizing the impact of these devices on different industries and for finding the overall issues while designing the protection system. This research method covers a large number of participants as it has the large focus on identifying the proper and efficient values through the survey. It can be stated that there are various studies related to the electrical protection devices in which quantitative research method is used. Therefore, this research will try to identify the required information through quantitative research method [12]. Moreover, quantitative research method also helps the researcher in getting the more accurate and appropriate values of this research study.

Data Collection Method Collection of data is the necessary step in every research, but this step covers two different methods such as; secondary data or primary data. It can be stated that both these methods have the large value in the research context as it helps research in exploring the research phenomenon and in analyzing a large amount of data. Secondary data is known as the result or identified outcomes of different studies. Smith,(2015) stated that secondary data is known as the collection of data from various theories and studies [12]. Furthermore, the other data collection method is primary data which is referred as thecollection of data through analyzing the different concepts andperspectives of participants. This data collection tool has thelarge value as it provides the more effective and authentic data. Therefore, the research will use this method for collecting the data sampling.

Sampling is referred as the technique of selecting the appropriate population for the research study. Smith, (2015) mentioned that sampling is referred as the selection of participants for collecting the data through specific data collection method [12]. The selected sampling for this surveyis 70 different technicians and managers of different industries through which utilization of electrical circuit protection devices is analyzed. Furthermore, this research has the focus on identifying the appropriate and authentic facts and results, therefore, all these elected participants have the detailed knowledge about electrical circuit designing and troubleshooting.

4. RESULTS AND ANALYSIS

The table of statistics shows that all the questions are responded by the participants appropriately as the answer ratio of every question is 70 and there is no missing answer in the result. The survey covers the five different questions for identifying the importance of electrical circuit protection devices in the industries. The result of every individual question is described below.

Table1. How efficiently electrical circuit protection devices are used within industries?

	Frequency	Percent	Valid Percent	Cumulative Percent
Extremely efficient	18	25.7	25.7	25.7
Very efficient	32	45.7	45.7	71.4
Quite efficient	8	11.4	11.4	82.9
Valid Some what important	3	4.3	4.3	87.1
inefficient	9	12.9	12.9	100.0
Total	70	100.0	100.0	

The first question is about the efficient utilization of electrical circuit protection devices in the industries which shows the positive result of this question. It can be analyzed that maximum of the participants were in favor of high utilization of these devices whereas, some ratio of participants refused to use these devices. It can be stated by analyzing the result of the first question that industries have the large utilization of electric circuit protection devices. Furthermore, the result is also justified by the following graph.

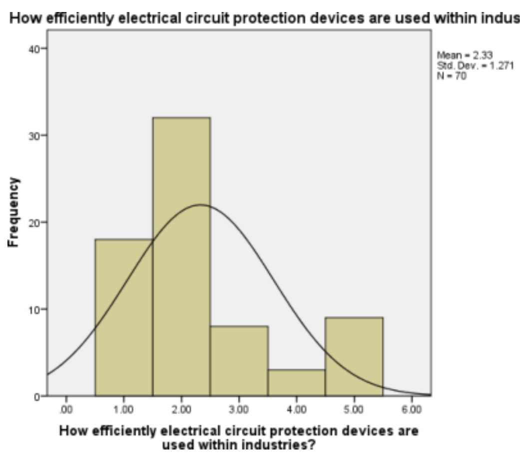


Fig3: Utilization of protection devices by Industry

Table2. Do all them a jorplants have Fuses and Circuit breakers for protecting the circuits?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	54	77.1	77.1	77.1
Valid No	16	22.9	22.9	100.0
Total	70	100.0	100.0	

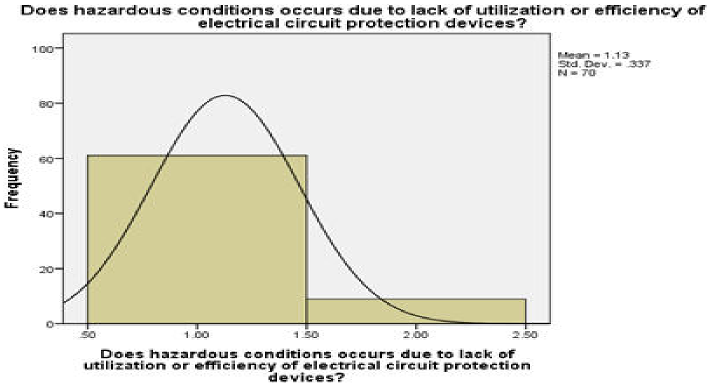
The other question is for identifying the usage of fused andcircuit breaker for the protection of electric circuit at major plants of industries. The result of this question is also positive as more than75% participants responded positively. Therefore, it is identified from this question that all major plants use the protection devices of Fuses and Circuit breaker for the protection of their circuit.

Table3. Do hazardous conditions occurs due to lack of utilization or efficiency of electrical circuit protection devices?

		Frequency	Percent	Vlid Percent	Cumulative Percent
	Yes	61	87.1	87.1	87.1
Valid	No	9	12.9	12.9	100.0
	Total	70	100.0	100.0	

Fig7:Effect of Hazardous Conditions

The last question is about the efficient use of electrical circuit protection devices against hazardous conditions. The table shows 87% respondent answered positively for this question. Therefore, it can be analyzed that hazardous conditions are due to the effectiveness of protection devices. Furthermore, it is identified that maximum of the respondent answered positively that increase in the hazardous conditions is due to lack of efficient utilization of electrical circuit protection devices.



CONCLUSION

Electric circuit protection devices are the most effective devices which are used for the protection of different circuits. The research identified that all these instruments have the large value for the protection of electrical circuits. Different industries use the devices for reducing the overall ratio of occurrence of hazardous conditions. It is also identified that most industries used circuit breakers and fuses as the electrical circuit protection devices for protecting their circuits from different hazardous conditions.

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Artificial Intelligence in Gaming

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ABSTRACT

Artificial intelligence (AI) is the intelligence exhibited by an artificial entity, generally assumed to be a computer. It has been involved with gaming since day one. It is progressively being widely used in the gaming industry. AI in games is commonly used for creating player's opponents. It is the foundation of all video games. Games like Num. checkers, or chess took advantage of smart algorithms to beat human players. AI-based games are based on a finite set of actions or reactions whose sequence can be easily predicted by expert players. This paper provides an introduction on the applications of AI in different games.

Keywords- *games, artificial intelligence, computer games, artificial intelligence in gaming, game AI, gamification of AI*

INTRODUCTION

Game developers have been programming software both to pretend like it is a human. The origin of the application of artificial intelligence in gaming can be found in the chess games between the computer IBM AI known as Deep Blue and the Russian master Gary Kasparov in 1996. In 2016, a Google AI system AlphaGo defeated top ranked player Lee Sedol in a game match of the Chinese board game Go. These examples suggest that AI systems can be dominant in just about any kind of game we humans can think of. Gaming and AI have been bedfellows for nearly 70 years. The games industry is one of the most lucrative industries due to the billion dollar sales of digital games. The motivations for playing digital games are varied and different for different age groups. People play digital games for several reasons, from entertainment to professional training [1]. Game developers have been employing AI in unique and interesting ways for decades. They become especially adept at using traditional techniques to achieve the illusion of intelligence. They have used AI to create art for games and push automated game design to new heights [2]. Their intent has not been to try and achieve some unprecedented level of human-like intelligence, but to create an experience that stimulates players in ways only the real world used to be capable of. The goal is to make the AI more human or at least appear to be.

OVERVIEW ON ARTIFICIAL INTELLIGENCE

The term "artificial intelligence" (AI) was first used at a Dartmouth College conference in 1956. AI is now one of the most important global issues of the 21st century. AI is the branch of computer science that deals with designing intelligent computer systems that mimic human intelligence, e.g. visual perception, speech recognition, decision-making, and language translation. The ability of machines to process natural language, to learn, to plan makes it possible for new tasks to be performed by intelligent systems. The main purpose of AI is to mimic the cognitive function of human beings and perform activities that would typically be performed by a human being. Without being taught by humans, machines use their own experience to solve a problem. AI is stand-alone independent electronic entity that functions much like human expert. Today, AI is integrated into our daily lives in several forms, such as personal assistants, automated mass transportation, aviation, computer gaming, facial recognition at passport control, voice recognition on virtual assistants, driverless cars, companion robots, etc. AI is not a single technology but a range of computational models and algorithms .Some forms of AI that are most commonly used in different applications include the following

Expert systems: They solve problems with an inference engine that draws from a knowledge base equipped with information about a specialized domain, mainly in the form of if-then rules. Expert systems are the earliest, most extensive, the most active, and most fruitful area.

Fuzzy logic: This makes it possible to create rules for how machines respond to inputs that account for a continuum of possible conditions, rather than straightforward binary**.**

Neural networks: These are specific types of machine learning systems that consist of artificial synapses designed to imitate the structure and function of brains. They are similar to the human brain. They are made up of artificial neurons, take in multiple inputs, and produce a single output. The network observes and learns as the synapses transmit data to one another, processing information as it passes through multiple layers.

Machine learning: This includes a broad range of algorithms and statistical models that make it possible for systems to find patterns, draw inferences, and learn to perform tasks without specific instructions. Machine learning is a process that involves the application of AI to automatically perform a specific task without explicitly programming it. ML techniques may result in data insights that increase production efficiency. Today, artificial intelligence is narrow and mainly based on machine learning.

Deep learning: This is a form of machine learning based on artificial neural networks. Deep learning architectures are able to process hierarchies of increasingly abstract features, making them especially useful for purposes like speech and image recognition and natural language processing. Deep learning networks can deal with complex non-linear problems.

Natural Language Processors: For AI to be useful to us humans, it needs to be able to communicate with us in our language. Human language is complex, but AI can be trained to slowly pick up the language. Computer programs can translate or interpret language as it is spoken by normal people.

Robots: These are computer-based programmable machines that have physical manipulators and sensors. Sensors can monitor temperature, humidity, pressure, time, record data, and make critical decisions in some cases. Robots have moved from science fiction to your local hospital. In jobs with repetitive and monotonous functions they might even completely replace humans. Robotics and autonomous systems are regarded as the fourth industrial revolution.

AI In Gaming

In a game can simply act as the player. The player learns to think either strategically, tactically, or reactively. The player can give his squad two kinds of orders: explicit and implicit. Most games support only explicit orders: move, attack, guard, build, etc. Unlike explicit orders, implicit orders transmit information from the player to the units and assists them in making better autonomous decisions. To influence the player to perceive the creatures as intelligent, he has to be provided more insight on their actions, intentions, thoughts, and emotions (such as joy, fear, are trust, surprise, fear, disgust, and anticipation), which are simple to model. Autonomous behavior is hard to program manually, but it can be taught by providing examples. Game playing has been an active research area in AI from the beginning. Artificial intelligence can be used in games in various ways. AI tools are used in a wide variety of fields inside a game. AI can mimic, imitate, learn, forget, teach, and collaborate. It could be a testing tool to make your code or design more robust. It may be the unseen hand directing the whole affair. AI creates entirely new elements for the game — new levels, new rules, new environments. AI techniques can help generate intelligent, responsive behavior that molds on your reactions as a player. AI makes the game more interactive by boosting player's experience. They can adjust parameters such as speed and time. While you are playing the game, the game is also playing you. AI is more geared towards automation. In order to give the player non-human opponents, AI is needed in almost all games. AI-based games make you feel like you are playing against another person. You will not need other human interactions when you play some of the multiplayer video games.

1. Applications Of AI In Gaming

Modern games have advanced in multiple ways over the past decades. AI technologies such as machine learning, deep learning, neural networks, and natural language processing can produce high-quality video game and make modern games look amazing.

Video Games: Artificial intelligence has been an integral part of video games since the 1950s. If you have played a video game, you have interacted with AI. Various video games, whether they are racing games, shooting games, or strategy games, have numerous features that are affected by AI. In video games, AI is used to generate responsive, behaviors in non-player characters similar to human-like intelligence. Video game AI has revolutionized the way humans interact with all forms of technology. As far as video games are concerned, AI may be regarded as the set of techniques used to design the behavior of the "Non-Playable Characters" (NPC). In most video games, NPCs' behavior patterns are programmed and cannot learn anything from players. The main component of AI techniques that is widely used in video games is machine learning or more specifically, reinforcement learning. Game inventors dream of building video games and provide machine learning with a flexible environment for quick changes and easy customization. The most widely used AI technique in games is cheating. In AI-based video games, cheating refers to the programmer giving agents actions and access to information that would be unavailable to the player in the same situation. Instead of learning how best to beat human players, AI in video games tends to enhance human players' gaming experience.

VR Games: Virtual reality (VR) is the simulation of a real environment using visual, auditory, and other stimuli. It involves using computer technology to create a simulated environment. The common method of participating in VR is through a headset. Virtual reality game is a niche category when compared to the rest of the gaming industry. Machine learning is used in the video game industry, especially in virtual reality. VR is the future of gaming. VR games (or even just regular console games) will become more immersive and dynamic. Figure 4 illustrates an example of virtual reality game that brings people together. Big tech companies like Facebook, Google, Microsoft, and Sony have greatly invested in developing VR hardware and games. These companies are busy making VR more consumer-friendly.

AR Games: AR is a variation of VR. It plays a supplemental role rather than a replacement of reality. Typical augmented reality (AR) devices include mobile phones and specially made glasses. The AR technology powered Pokémon Go. It took a well-established brand (Pokémon) to get consumers to give it a try. AR is taking off faster than VR because people have an appetite for games that interact with reality, not remove them from it.

Mobile Games: Companies are already rolling out 5G for mobile devices, which make data available quickly, enable you to pull up an

AR game, look through your screen, and get data on the world around you.

2. BENEFITS

Gaming is the future of entertainment. In essence, games are learning devices. Human enjoyment of games is derived from enjoying progress, mastery, proficiency, experimentation, and learning. AI is initiating a new era of smart video games. AI essentially consists of algorithms which you can tame whichever you want. AI has a rich history and has been the backbone for countless aspects of computing, gaming, and more. AI in games takes the role of a never-bored and never boring opponent. AI serves to improve the game-player experience. AI can also be used to enhance existing games. "Video games offer the best test of intelligence we have. Combining AI with virtual or augmented reality opens the gates to add reality factor to video games.

3. CHALLENGES

AI is not yet capable of creating entire high-quality games from scratch. Games can be addictive to the player. Elon Musk has recently warned the world that the fast development of AI with learning capability by Google and Facebook would put humanity in danger. The gaming industry are pretty conservative and publishers or game makers need to take risks. There is the temptation of preferring to keep doing that same thing. Perhaps the only barrier to fully utilizing AI technology in gaming is the eventual limit of money and time. A related challenge is the cost incurred in the maintenance and repair. The idea of machines replacing human beings sounds threating. If robots begin to replace humans in every field, it will eventually lead to unemployment. It is difficult to create thoroughly robust AI because its development is constrained to the scope of an individual game project.

4. The Future Of AI in Gaming

The future of the application of AI technology lies in the development of video games and the ability of the technology to increase the human connection, i.e. AI that is human-like, emotional, and responsive. AI is clearly the future of gaming and the future of AI in video games would naturally point to automation. In the future, AI becomes a kind of collaborator with humans, helping designers and developers create art assets, design levels, and even build entire games from the ground up. Big tech companies such as Sony, Nintendo, Microsoft, Apple, Google, and Amazon are seizing the moment and developing gaming products.

CONCLUSION

Games have been regarded as the perfect test-bed for artificial intelligence (AI) techniques. Modern computer games often feature realistic environments by employing 3D animated graphics to give the impression of reality. State-of the-art games can recreate real-life environments with a surprising level of detail. The demands of the gaming community and the games themselves keep evolving.

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