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RESEARCH ARTICLE

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ELECTRIC VEHICLE CHARGING STATION LOAD ON DISTRIBUTION NETWORK

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ABSTRACT

Recent concerns about environmental pollution and escalating energy consumption accompanied by the advancements in battery technology have initiated the electrification of the transportation sector and the exponential growth of electrical vehicles in the near future, utilities need to be prepared to maintain reliability of the grid. The primary impacts on electrical systems are generation adequacy, generation flexibility, transmission grid capacity, and distribution grid capacity. With the universal resurgence of Electric Vehicles (EVs) the adverse impact of the EV charging loads on the operating parameters of the power system has been noticed..Further, the penalty paid by the utility for the degrading performance of the power system cannot be neglected. The high charging loads of the fast charging stations results in increased peak load demand, reduced reserve margins, voltage instability, and reliability problems. This work aims to investigate the impact of the EV charging station loads on the voltage stability, power losses, reliability indices, as well as economic losses of the distribution network. The main challenge of electrification of transportation expansion lies in the distribution networks and the overloading of network assets: 1. Medium voltage substations may be needed 2. Replacement of the head feeders and the distribution transformers, optimal allocation of charging infrastructure and lack of regulation. Electrification of transportation provides utilities a way to solve the challenges of flat electricity demand, optimize decentralized systems, and improve customer engagement. Planning for E-Mobility can help mitigate utility pain points and provide new means of opportunity. Utilities are a critical partner for connecting vehicle charging stations to the grid and have the capabilities to own, operate, and support the charging infrastructure. In this project proposed approach for a real and reactive power analysis and harmonics in a charging current at the grid side and based on a novel Voltage stability, Reliability, and Power loss (VRP) index. The entire analysis is performed on the IEEE 14 bus test system representing a standard radial distribution network. The simulation model developed in a MATLAB Simulink tools and verified with corresponding factors.

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INTRODUCTION

In recent years, the use of electric vehicles (EV) is increasing as a solution for reduction of air pollution and global warming. EVs have the ability to increase energy efficiency and decrease fossil fuel dependency in road transportation, a review of infrastructure; highway and vehicle safety standards are included in the paper.

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The report also evaluates the barriers and challenges of deploying an expanded network of EV charging stations and makes recommendations to help standardize and expedite EVSE infrastructure deployment to support the accelerating growth of EVs. The infrastructure element that provides the crucial link between an Electric Vehicle (EV) with a depleted battery and the electrical source that will recharge those batteries is the Electric Vehicle Supply Equipment or EVSE. This report provides a review of the current and emerging EVSE technologies. The report also evaluates the barriers and challenges of deploying an expanded network of EV charging stations in the U.S. and makes recommendations to mitigate the challenges of deploying the infrastructure required to support the accelerating deployment of EVs.

Although there are many significant barriers to the expansion of the EVSE infrastructure, one of the primary barriers is inadequate communication of the needs and requirements of establishing an easily accessible PEV recharging network. Public officials and private enterprise want to better understand the PEV and infrastructure environment, focused and consistent public awareness campaigns supporting the continued adoption of PEVs and an expanded EVSE infrastructure are needed. Significant advancements are being made in PEV technologies, and many PEV manufactures have near-term expectations for advanced battery technology that will provide a travel range equal to that of conventionally fueled vehicles. The available model selection of PEVs has expanded quickly and the commitment of major car manufactures continues to intensify.

The continued growth and acceptance of PEVs cannot be sustained without an adequate recharging infrastructure; the lack of one may prove to be an extremely difficult negative perception to overcome. Promising research in wirelessly charging is underway, but more attention is needed to help realize the promise of untethered recharging of EVs. The successful development and deployment of this technology will provide the convenience of pulling into a garage or a parking spot and having the EV recharged without the need to connect and disconnect a cable. There is also the possibility of embedding wireless charging in the roadway as a method of continuously recharging the vehicle while in transit; a system that would allow a dramatic reduction in battery size and extend the travel range of EVs. Wireless Power Transfer (WPT) is a proven technology that also offers the potential of simpler, less expensive infrastructure elements.

Requirement of Charging Station Infrastructure: Charging infrastructure can play a polar role on eV preparation, and, within the absence of a proactive arrange and schedule, could be a major impediment to mass market adoption. Infrastructure limitations are significantly pertinent to BEVs because of their sole dependency on electricity. The charging infrastructure includes all of the hardware and software package that ensures energy is transferred from the electrical grid to the vehicle. It may be classified by location, power level and charging time strategy. Charging locations combined with a suitable charging time strategy will increase BEV practicality and reduces public charging needs. The approximation of the electrical vehicle offer instrumentality (EVSE) required at differing types of locations is projected supported an optimum charging strategy.

Algorithm for Charging Station Selection: Charging Station choice server (CSS) traces the instant location of a vehicle and taps they vary available with it. It proposes all the charging stations covering the limit.CSS communicates with different vehicles to work out the road traffic and offers an approximate time and charge remaining, till a selected charging station is reached. It also suggests an alternate route to the nearest charging station just in case of heavy traffic. The driving force chooses the charging sort and blocks a slot considering least waiting time. The CSS uses mobile network to speak with the vehicle. It additionally proposes the present metering theme at particular cs and compares with different metallic element value. It can also be done through a demand based mostly metering system wherever EVs are going to be charged according to peak time and peak load.

METHODOLOGY

The impact of EV charging on daily load demand in the parking lots and devised an optimal strategy for controlling the charging activities in the parking lots. In the authors analyzed the impact of fast EV chargers on a retail building's load demand and concluded that 38% of the PHEV load demand could be absorbed by demand management and photovoltaic's. In a two stage demand response model to control the increase in peak load due to the charging of EVs. The different detrimental impacts of EV charging station loads like voltage instability, harmonic distortion, and power losses on distribution network are analyzed. However, there is earth of literature focusing on the impact of the EV charging station load on the entire ad for mentioned parameters considered together. The analysis is usually performed for one or two parameters separately. All the fore mentioned limitations of the existing literature are addressed in this work and the major contributions of the work are summarized as follows:

- Profound analysis of the impact of the EV charging station loads on the voltage stability of the distribution network.
- Detailed analysis of the impact of the EV charging station loads on the customer and energy oriented reliability indices.
- Comprehensive analysis of the economic losses incurred in terms of the penalty paid by the utility due to introduction of the EV charging station loads.
- Comparative analysis of the EV charging load on different parameters of the distribution network such as the voltage stability, reliability and power losses.

DESCRIPTIVE OF IEEE BUS: The entire analysis was performed on IEEE 14 bus test system. This network is a radial network. The IEEE 14-bus test case represents a simple approximation of the American Electric Power system. It has 14 buses, 5 generators, and 11 loads. It is a distribution network with 14 bus and 20 branches. The line data, branch data, as well reliability data of this test network were taken from references. The PV curve of the IEEE 14 bus system for different loading factors. From the figure, it is clear that as the loading of the system increases the deviation of the bus voltage from base values becomes more and more prominent. Reports the VSF of all the buses for different loading factor. The VSF of bus 14 for loading factor 2, 3, and 4 were 0.1163, 0.2707, and 0.5533, respectively.

The values of VSF of bus 14 were highest in comparison to the other buses. Thus, bus 14 was regarded as the weakest bus of the system. Similarly, the VSF of bus 2 was least for all the loading factors making it the strongest bus of the system. The VSF values also signify that bus 9 and bus 12 were the second strongest and second weakest bus respectively. The IEEE 14 bus Test Network is shown in the Figure 3.6. EVs reduce the local emissions and have a positive impact on the environment. However, the detrimental impact of the EV charging station loads on the electricity distribution network cannot be neglected. The focus of this work was to present a detailed analysis of the impact of the EV charging station load on the different technical as well as economic parameters of the IEEE 14 bus system.

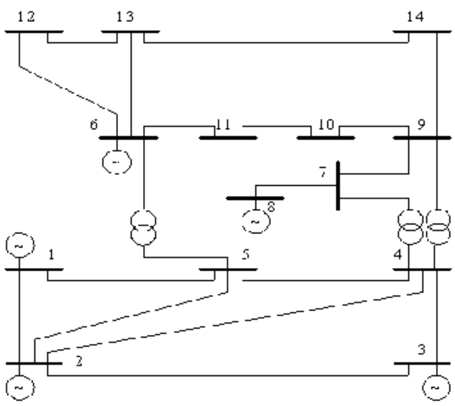


Fig. 1. IEEE 14 bus Test Network

The impact of the EV charging stations on the voltage stability, reliability, power loss, and economic loss were analyzed profoundly in this work and the key findings of the work are summarized as follows:

- The IEEE 14 bus test system was robust enough to withstand the placement of four charging stations at bus 2 representing the strongest bus of the system. It is observed that when five charging stations were placed at bus 2 the SAIDI increased by 44%. Thus, for increasing the number of charging stations beyond four up gradation of the network was required.
- The placement of the fast charging station at the weak bus of the network was detrimental to the security of the system. On placement of even a single charging station at the weakest bus the voltage of the weakest bus dropped to 0.7351 per unit. The reliability indices also deteriorated significantly on placement of fast charging stations at the weak buses. Moreover, it is observed that on placement of a single charging station at bus 12 and 9 representing the weak buses of the network the power losses increased by 85%. However, slow charging stations of 19.2 kW could be placed even at the weak buses.
- Distributing the charging stations between a numbers of buses was advantageous than concentrating the charging stations at a single bus in terms of voltage deviation, reliability as well as power loss. Also, in some cases, if the strong nodes of the distribution network and nodes of the road network with high traffic concentration merge then the routes leading to that node will be too congested. Therefore, another advantage of distributing the charging station is making the charging facility accessible to a larger number of EVs plying in different routes. This in turn will reduce the traffic congestion of the specific routes leading to the bus in which charging stations are concentrated.
- A considerable economic loss was incurred by the utility for placement of charging stations at the weak buses. It is observed that on placement of even a single fast charging station at the weakest bus 1,397,700.5 $ of economic loss is incurred. However, despite the fact that improper placement of charging station results in economic losses the EVs must be welcomed as the net benefit earned by implementing V2G scheme cannot be neglected. In V2G scheme the charging stations can earn revenue by selling the electricity back to the grid when the charging demand is low.
- The reliability indices were more affected than power loss and voltage stability for case 2, case 3and case 4 where the charging station was placed at strong buses. However, for case 7 where charging stations are placed at bus 14 and 12 power loss was most severely affected. All the aforementioned findings must be taken into account while dealing with the problem of optimal placement of charging stations. From the results obtained it is obvious that voltage stability, power loss as well as reliability indices degraded with the addition of EV charging station loads. Thus, for optimal placement of charging stations in the distribution network all the three parameters must be considered. A novel index named VRP index taking into account the voltage stability, reliability and power loss was also formulated. The novelty of VRP index lies in the fact that has the capability of considering voltage stability, power loss, and reliability together under a common frame. Further, a strategy for the placement of the charging stations in the distribution network based on VRP index was presented in this work. The results of the optimal placement of the charging stations based on VRP index established the efficacy of the index.

Future possible research directions in this area are

- Mitigation of the negative impacts of EV charging station placement by reconfiguration of the network.
- Analysis of the positive impact of the Vehicle to Grid scheme.
- Real time planning of EV charging stations based on VRP index.

EXPERIMENTAL SETUP AND PROCEDURE: This simulation block diagram represents the procedure of the real and reactive power calculation the modeling of the load with the algorithm in the 14 bus test system by measuring the 3 phase voltage and current value for the measurement of the waveform produced while varying the load in the bus system.

Simulation block diagram

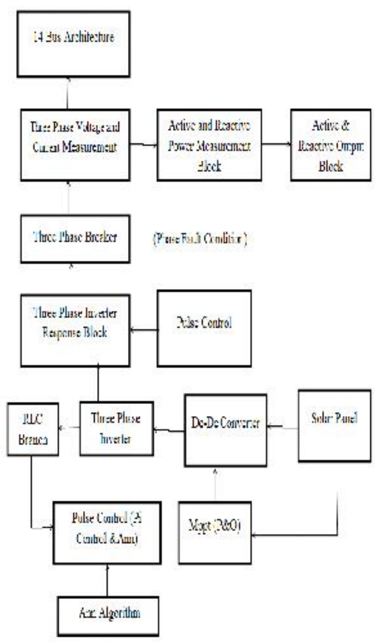


Fig. 2. Proposed System Block Diagram

TYPICAL POWER NETWORK: An understanding of basic design principles is essential in the operation of electric power systems. This chapter briefly describes and defines electric power generation, transmission, and distribution systems (primary and secondary). A discussion of emergency and standby power systems is also presented.

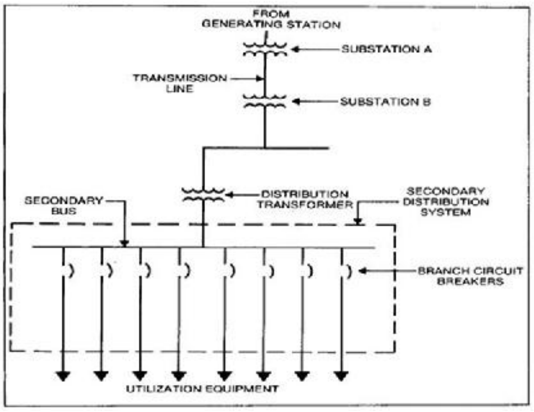


Figure 3. Typical Electric Power Generations, Transmission and Distribution System

The transmission systems are basically a bulk power transfer links between the power generating stations and the distribution sub-stations from which the power is carried to customer delivery points. The transmission system includes step-up and step-down transformers at the generating and distribution stations, respectively. The transmission system is usually part of the electric utility's network. Power transmission systems may include sub transmission stages to supply intermediate voltage levels. Sub-transmission stages are used to enable a more practical or economic transition between transmission and distribution systems. It operates at the highest voltage levels (typically, 230 kV and above).

The generator voltages are usually in the range of 11 kV to 35 kV. There are also a few transmission networks operating in the extremely high voltage class (345 kV to 765 kV). As compared to transmission system sub-transmission system transmits energy at a lower voltage level to the distribution substations. Generally, sub-transmission systems supply power directly to the industrial customers. The distribution system is the final link in the transfer of electrical energy to the individual customers.

Between 30 to 40% of total investment in the electrical sector goes to distribution systems, but nevertheless, they haven’t received the technological improvement in the same manner as the generation and transmission systems. The distribution network differs from its two of siblings in topological structure as well as associated voltage levels. The distribution networks are generally of radial or tree structure and hence referred as Radial Distribution Networks (RDNs). Its primary voltage level is typically between 4.0 to 35 kV, while the secondary distribution feeders supply residential and commercial customers at 120/240/440 volts. In general, the distribution system is the electrical system between the substation fed by the transmission system and the consumers’ premises. It generally consists of feeders, laterals (circuit-breakers) and the service mains.

ELEMENTS OF THE DISTRIBUTION SYSTEM: In general, the distribution system is derived from electrical system which is Substation ally fed by the consumers’ premises and the transmission system. It generally consists of feeders, laterals (circuit-breakers) and the service mains.

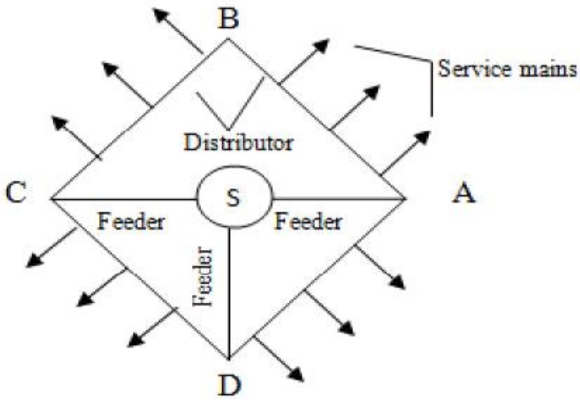


Fig 4. Elements of Distribution System

Distributed Feeders: A feeder is a conductor, which connects
Distributed Feeders: A feeder is a conductor, which connects
the sub-station (or localized generating station) to the area where power is to be distributed. Generally, no tapping are taken from the feeder so that the current in it remains the same throughout. The main consideration in the design of a feeder is the current carrying capacity. The elements of distribution system are shown in the Figure 4.3.

Distributor: A distributor is a conductor from which tapping are taken for supply to the consumers. In Figure4.2, AB, BC, CD, and DA are the distributors. The current through a distributor is not constant because tapping are taken at various places along its length. While designing a distributor, voltage drop along its length is the main consideration since the statutory limit of voltage variations is 10% of rated value at the consumer’s terminals.

Service mains: A service main is generally a small cable which connects the distributor to the consumer’s terminals.

REQUIREMENTS OF A DISTRIBUTION SYSTEM

It is mandatory to maintain the supply of electrical power within the requirements of many types of consumers. Following are the necessary requirements of a good distribution system:

Availability of power demand: Power should be made available to the consumers in large amount as per their requirement. This is very important requirement of a distribution system.

Reliability: As we can see that present day industry is now totally dependent on electrical power for its operation. So, there is an urgent need of a reliable service. If by chance, there is a power failure, it should be for the minimum possible time at every cost. Improvement in reliability can be made up to a considerable extent by

- Reliable automatic control system.
- Providing additional reserve facilities.

Proper voltage: Furthermost requirement of a distribution system is that the voltage variations at the consumer terminals should be as low as possible. The main cause of changes in voltage variation is variation of load on distribution side which has to be reduced. Thus, a distribution system is said to be only good, if it ensures that the voltage variations are within permissible limits at consumer terminals.

Loading: The transmission line should never be over loaded and under loaded.

Efficiency: The efficiency of transmission lines should be maximum say about 90%.

ARTIFICIAL NEURAL NETWORK: An artificial neural network (ANN) is the piece of a computing system designed to simulate the way the human brain analyzes and processes information. It is the foundation of artificial intelligence (AI) and solves problems that would prove impossible or difficult by human or statistical standards. ANNs have self-learning capabilities that enable them to produce better results as more data becomes available.

Understanding an Artificial Neural Network: An artificial neural network (ANN) is the component of artificial intelligence that is meant to simulate the functioning of a human brain.

- Processing units make up ANNs, which in turn consist of inputs and outputs. The inputs are what the ANN learns from to produce the desired output.
- Back propagation is the set of learning rules used to guide artificial neural networks.
- The practical applications for ANNs are far and wide, encompassing finance, personal communication, industry, education, and so on.

Artificial neural networks are built like the human brain, with neuron nodes interconnected like a web. The human brain has hundreds of billions of cells called neurons. Each neuron is made up of a cell body that is responsible for processing information by carrying information towards (inputs) and away (outputs) from the brain. An ANN has hundreds or thousands of artificial neurons called processing units, which are interconnected by nodes. These processing units are made up of input and output units. The input units receive various forms and structures of information based on an internal weighting system and the neural network attempts to learn about the information presented to produce one output report. Just like humans need rules and guidelines to come up with a result or output, ANNs also use a set of learning rules called back propagation, an abbreviation for backward propagation of error, to perfect their output results.

An ANN initially goes through a training phase where it learns to recognize patterns in data, whether visually, aurally, or textually. During this supervised phase, the network compares its actual output produced with what it was meant to produce—the desired output. The difference between both outcomes is adjusted using back propagation. This means that the network works backward, going from the output unit to the input units to adjust the weight of its connections between the units until the difference between the actual and desired outcome produces the lowest possible error.

Artificial Neural Network (Ann) Algorithm Work

- It helps us understand the impact of increasing / decreasing the dataset vertically or horizontally on computational time.
- It helps us understand the situations or cases where the model fits best.
- It also helps us explain why certain model works better in certain environment or situations.

Neural Network Algorithms works on three main layers of its architecture i.e input layer, hidden layer (though there can be many hidden layers) and output layer. The architecture of artificial neural network is shown in the Figure 4.4.

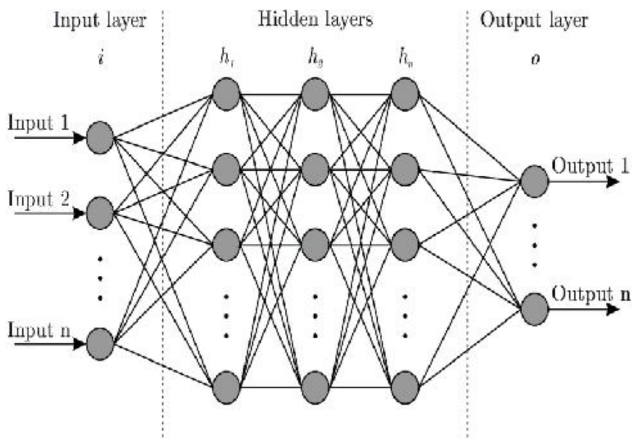


Fig 5. Architecture of artificial neural network

- Input layer – It contains those units (Artificial Neurons) which receive input from the outside world on which the network will learn recognize about or otherwise process.
- Output layer – It contains units that respond to the information about how it's learned any task
- Hidden layer – These units are in between input and output layers. The job of the hidden layer is to transform the input into something that the output unit can use in some way.

Most Neural Networks are fully connected which means to say each hidden neuron is fully linked to every neuron in its previous layer(input) and to the next layer (output) layer.

CLASSIFICATION OF BUSES

The buses in the power systems are mainly classified into the following categories:

- **Load Bus:** At this bus the active and reactive power are specified. It is desired to find out the magnitude of voltage and phase angle. It is not required to specify the voltage at a load bus as the voltage can vary within a permissible limit.
- **Generator Bus:** This is also known as voltage controlled bus. Here the net active power and the voltage magnitude are known.
- **Slack Bus:** Here the specified quantities are voltage magnitude and phase angle. Slack bus is generally a generator bus which is made to take additional active and reactive power to supply the losses caused in the network. There is one and only one bus of this kind in a given power system. This bus is also known as Swing bus or reference bus.

The purpose of Load analysis is as follows

- To determine the magnitude of voltage and phase angles at all nodes of the feeder.
- To determine the line flow in each line section specified in Kilo Watt (KW) and KVA, amperes and degrees or amperes and power factor.
- To determine the power loss.
- To determine the total input to the feeder Kilo Watt (KW) and KVAr.
- To determine the active and reactive power of load based on the defined model for the load.

IMPORTANCE OF LOAD MODELLING: The choices regarding system reinforcements and system performance is mostly based on the results of power flow and stability simulation studies. For performing analysis of power system, models must be integrated to include all relevant system components, such as generating stations, sub stations, transmission and distribution peripherals and load devices. Much attention has been given to modeling of generation and transmission or distribution devices. But the modeling of loads has received much less attention and remains to be an unexplored frontier and carries much scope for future development. Recent studies have revealed that representation and modeling of load can have a great impact on analysis results. Efforts in the directions of improving load-models have been given prime importance.

MATLAB SOFTWARE

MATLAB may be a superior language for technical computing. It integrates computation, image, associated programming in an easy to use setting wherever issues and solutions are expressed in acquainted notational system.

Typical uses include

- Scientific discipline and computation Algorithmic program development.
- Modelling, simulation, and prototyping knowledge analysis, exploration, and image,
- Scientific and engineering graphics.
- Application development, together with Graphical program building.

MATLAB is associate interactive system whose basic knowledge part is an array that doesn't need orienting. this permits you to resolve several technical computing issues, particularly those with matrix and vector formulations, in an exceedingly fraction of the time it'd go for write a program in a scalar non-interactive language like C or algebraic language.

Modeling and Simulation

MATLAB has several auxiliary Toolboxes distributed by Math works, Inc., which are useful in constructing models and simulating dynamical systems. These include the System Identification Toolbox, the Optimization Toolbox, and the Control System Toolbox. These toolboxes are collections of m-files that have been developed for specialized applications. There is also a specialized application, Simulink, which is useful in modular construction and real time simulation of dynamical systems.

Reactive Power Calculation

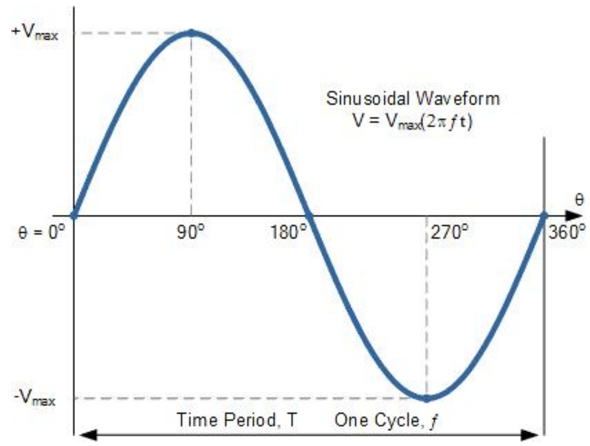


Fig 6. Active and Reactive power calculation sinusoidal waveform

$$\text{Active Power},(P) = \text{Apparant Power},(S) \times \text{Power Factor},(pf)$$

$$\text{Power Factor},(pf) = \frac{\text{Active Power},(P)\text{ in Watts}}{\text{Apparant Power},(S)\text{ in volt}-\text{amps}}$$

The fundamental frequency is given as; E = Vmax ($2\pi f$t), the values of the harmonics will be given as:

For a second harmonic:

$E_2 = V_{2max}(2*2\pi f t) = V_{2max}(4\pi f t), = V_{2max}(2\pi t)$
For a third harmonic:
$E_3 = V_{3max}(3*2\pi f t) = V_{3max}(6\pi f t), = V_{3max}(3\omega\pi t)$
For a fourth harmonic:
$E_4 = V_{4max}(4*2\pi f t) = V_{4max}(8\pi f t), = V_{4max}(4\pi t)$
and so on.

Then the equation given for the value of a complex waveform will be:

$$E_T - E_1 + E_2 + E_3 + \ldots\ldots E_{(r)} \text{ etc.}$$

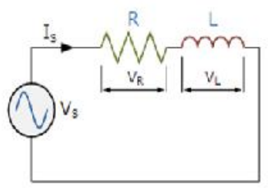
$$E_T = V_{1max}\sin(2\pi f\tau) + V_{2max}\sin(4\pi f\tau) + V_{3max}\sin(6\pi f\tau)\ldots\text{etc.}$$

Harmonics are generally classified by their name and frequency, for example, a 2nd harmonic of the fundamental frequency at 100 Hz, and also by their sequence. Harmonic sequence refers to the phase rotation of the harmonic voltages and currents with respect to the fundamental waveform in a balanced, 3-phase 4-wire system. A positive sequence harmonic (4th, 7th, 10th …) would rotate in the same direction (forward) as the fundamental frequency. Where as a negative sequence harmonic (2nd, 5th, 8th,) rotates in the opposite direction (reverse) of the fundamental frequency. Generally, positive sequence harmonics are undesirable because they are responsible for overheating of conductors, power lines and transformers due to the addition of the waveforms. Negative sequence harmonics on the other hand circulate between the phases creating additional problems with motors as the opposite phase rotation weakens the rotating magnetic field require by motors, and especially induction motors, causing them to produce less mechanical torque. Another set of special harmonics called “triplens” (multiple of three) have a zero rotational sequence. Triplens are multiples of the third harmonic (3rd, 6th, 9th …), etc, hence their name, and are therefore displaced by zero degrees. Zero sequence harmonics circulate between the phase and neutral or ground.

Unlike the positive and negative sequence harmonic currents that cancel each other out, third order or triple harmonics do not cancel out. Instead add up arithmetically in the common neutral wire which is subjected to currents from all three phases. The result is that current amplitude in the neutral wire due to these triple harmonics could be up to 3 times the amplitude of the phase current at the fundamental frequency causing it to become less efficient and overheat.

Series AC Circuits: Passive components in AC circuits can be connected together in series combinations to form RC, RL and LC circuits as shown.

Series RC Circuit: A circuit that contains pure resistance R ohms connected in series with a pure capacitor of capacitance C farads is known **as** RC Series Circuit. A sinusoidal voltage is applied and current I flows through the resistance (R) and the capacitance (C) of the circuit.

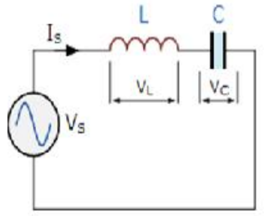


$$Z = \sqrt{R^2 + X_L^2}$$
$$Z = \angle + \phi = R + jX_L$$
$$\phi_{(0 \to 90)} = \tan^{-1}\left(\frac{X_L}{R}\right)$$
$$I_s = \frac{V_s}{Z} = \frac{V_s}{\sqrt{R^2 + X_L^2}}$$
$$V_s = \sqrt{V_R^2 + V_L^2}$$

Fig 4.7. RL Series circuit

Series RL Circuit: A circuit that contains pure resistance R ohms connected in series with a coil having a pure inductance of L (Henry) is known as **RL Series Circuit**. When an AC supply voltage V is applied, the current, I flow in the circuit. So, I_R and I_L will be the current flowing in the resistor and inductor respectively, but the amount of current flowing through both the elements will be same as they are connected in series with each other.

Series LC Circuit: A circuit that contains pure inductance of L connected in series with a coil having a pure capacitance of C (farad) is known as LC Series Circuit. When an AC supply voltage V is applied, the current, I flow in the circuit.



$$Z = \sqrt{X_L^2 - X_C^2}$$
$$\therefore Z = X_L - X_C \text{ or } X_C - X_L$$
$$Z = \angle\phi + j = 0 + (jX_L - jX_C)$$
$$f_R = \frac{1}{2\pi\sqrt{LC}}$$
$$\text{at } f_R \; X_L = X_C \text{ and } V_L = V_C$$
$$I_s = I_L = I_C$$

Fig 4.8. **LC Series circuit**

So, I_L and I_C will be the current flowing in the inductor and capacitor respectively, but the amount of current flowing through both the elements will be same as they are connected in series with each other.

ANALYSES OF RESULTS

Voltage Magnitude: It can be observed that, in case of loads that are voltage independent, the magnitude of voltages are less in value in comparison to that of voltage dependent loads. In the former case, the generation of active power is more pronounced when magnitude of voltages are greater than1 p.u. Incorporation of voltage dependent loads confirms a flat voltage profile, i.e. the load flow increases magnitudes of voltages below 1 p.u and decreases those above 1 p.u.

Swing bus Active Power: In both the type of loads the swing bus active power difference is 2.5 %. This is a quite high value and accounts for net decrease in power generation and hence the reduced cost of operation. The active power difference of swing bus is dependent both on voltage and phase angle difference and practically is very tough to predict from conventional load flow analysis without the incorporation of voltage dependent loads.

Generator Reactive Power: The difference in reactive power lies in the range of 4 % to 16 %. This range is even greater the swing bus active power difference. A generator bus which had reached the reactive-power limits in conventional load-flow analysis was well within the limits when the load was modeled to vary with voltage. The generator reactive power difference is also dependent on phase angle differences and voltage magnitudes.

Load Active Power: The Load active powers at different buses. The active power consumption at different buses in case of voltage dependent and independent loads is not equal. In case of the voltage dependent loads, the real power consumption is less as compared to the voltage independent loads. Decrease in active power consumption ensures less loss and better stability and security of the system.

Load Reactive Power: The reactive power at different buses doesn't follow any particular pattern, i.e. at some buses they have higher values for voltage dependent loads and at some, they have lower values. But basically the difference ranges from 0.6 % to 4.2 %.

IMPLEMENTATION OF ALGORITHM UNDER DAILY LOAD PATTERN

The total power loss before and after reconfiguration under daily load pattern has been revealed. It shows that with the successful implementation of the proposed algorithm total power loss of the system is reduced significantly. Also under different load conditions the bus voltages and the branch currents are maintained within the limit.

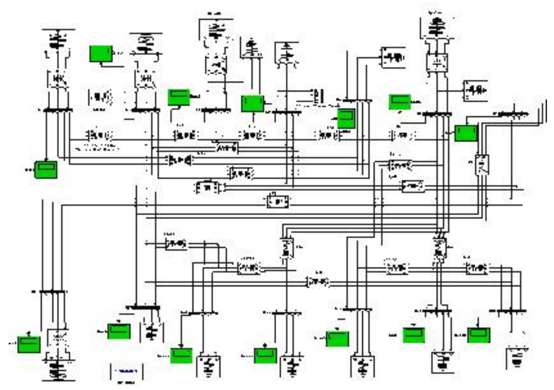


Fig 9. 14 Bus System Simulink Model

The 14 bus system simulink model is shown in the figure 9. The IEEE 14-bus test case represents a simple approximation of the American Electric Power system. It has 14 buses, 5 generators, and 11 loads. It is a distribution network with 14 bus and 20 branches.

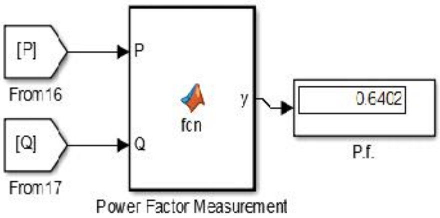


Fig 10 Power Factor Measurements

The Power Factor Measurement of the system by applying load resistance is shown in the figure10. When Load is varied in the bus, the power factor value is functioned and calculated.

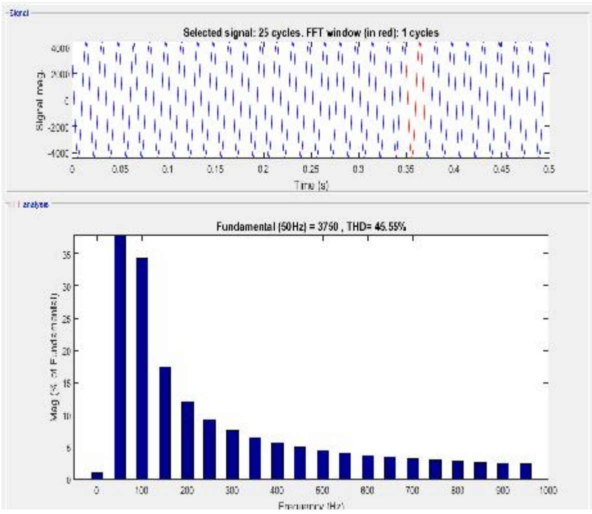


Fig 11 FFT Analysis for 1cycles

The FFT analysis is shown in the Figure 11. Here we are selecting signals at the range of 25 cycles. By considering the single cycle which is shown in the red color window and the magnitude is measured in the fundamentals of 50 Hz frequency.

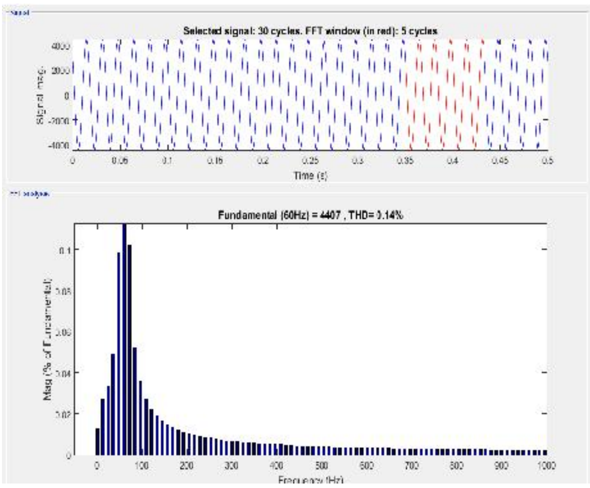


Fig 12 FFT Analysis for 5 cycles

The FFT analysis is shown in the Figure 12. Here we are selecting signals at the range of 30 cycles. By considering the single cycle which is shown in the red color FFT window and the magnitude is measured in the fundamentals of 60 Hz frequency.

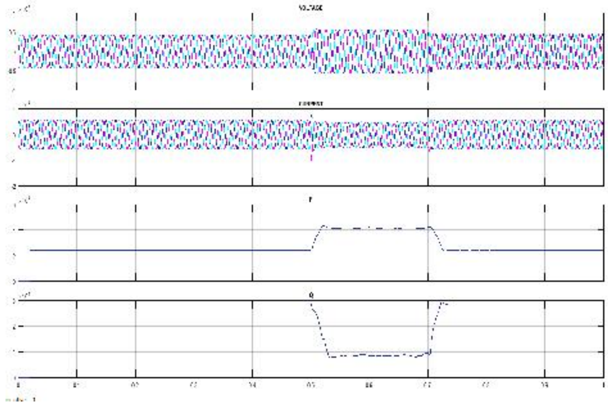


Fig 13 Voltage and Current Waveform

The output waveform is shown by giving current and voltage input in the Figure 13.when giving voltage and current input in the system the degree of magnitude in the system has been measured in the system.

When Load resistance is low:

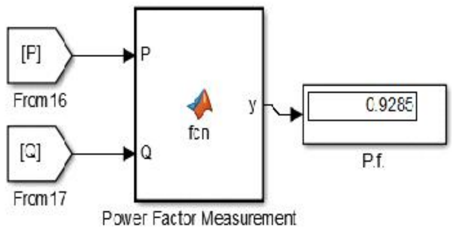


Fig 14 Power Factor Measurement When Load Resistance Is Low

The Power Factor Measurement of the system by applying load resistance is shown in the figure 14. When Load Resistance is Low in the bus, the power factor value is functioned and calculated in the range of 0.9.

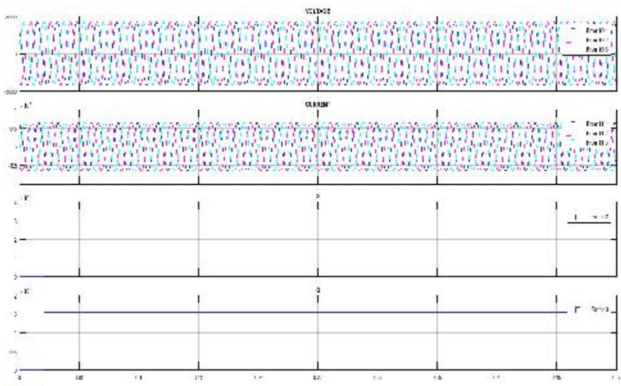


Fig 15 Bus Output Waveform from 12 And 13

The bus output waveform from 12 and 13 is shown by giving current input in bus 1, 2 and 3 and voltage input in bus 11, 12 and 13 the Figure 15.when giving voltage and current input in the system the degree of magnitude in the system has been measured in the system when Load resistance is low.

When load has more reactive power:

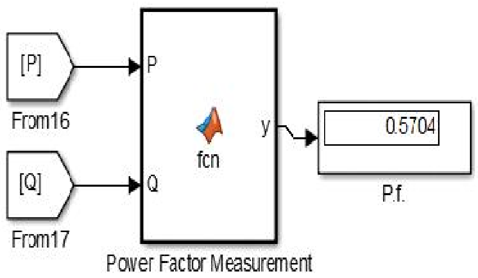


Fig 16. Power Factor Measurement When Load Reactive Power is high

The Power Factor Measurement of the system by applying load reactive power is shown in the figure 16. When Load reactive power is high in the bus, the power factor value is functioned and calculated in the range of 0.5.

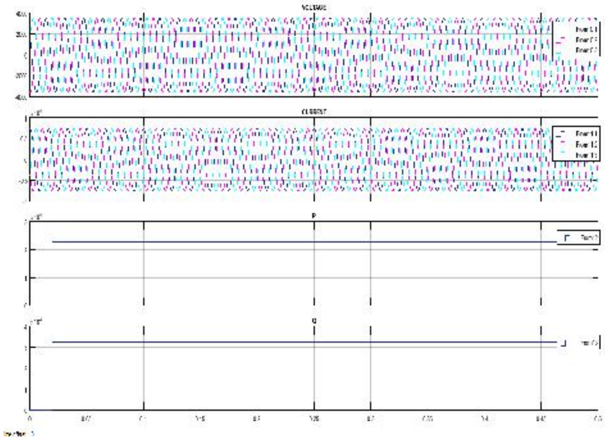


Fig 17. Bus Output Waveform from 12 And 13

The bus output waveform from 12 and 13 is shown by giving current input in bus 1, 2 and 3 and voltage input in bus 11, 12 and 13 the Figure 17.when giving voltage and current input in the system the degree of magnitude in the system has been measured in the system when load has more reactive power.

PV Input:

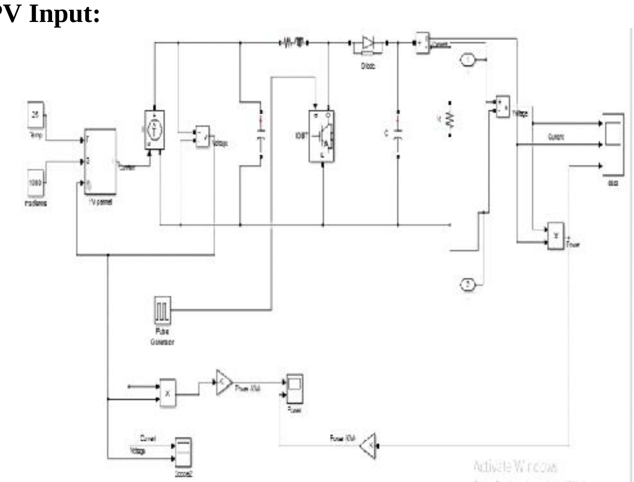


Fig 18. Photovoltaic Input for PV Panel

The photovoltaic input for pv panel is shown in the figure 18. Here the input with pulse is given in the system to caluculate the current an voltage variation of the system.

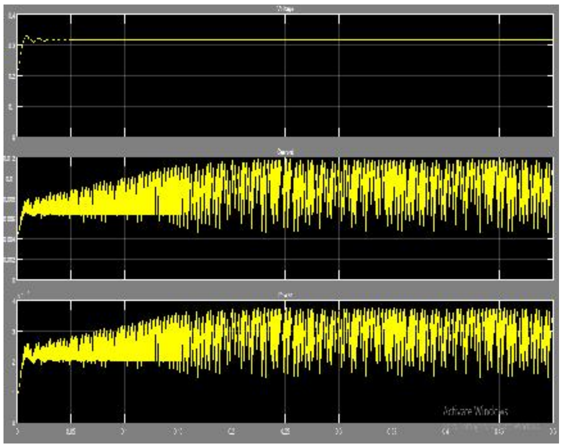


Fig 19 Voltage, Current and Power Output Waveform

The output waveform of voltage, current and power is shown in the Figure 19.here the system output is measured by giving the photovoltaic input in PV panel in the system.

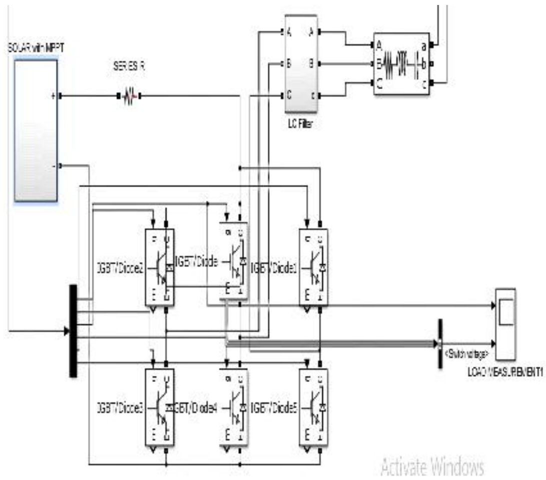


Fig 20. Load Measurement of Solar with MPPT

The load measurement for solar with MPPT is shown in the Figure 20.The input given as load measurement in solar with MPPT, series resistance, LC filter, RLC circuit in series and IGBT to get the load measurement in voltage switching.

Load Measurement 1 Output:

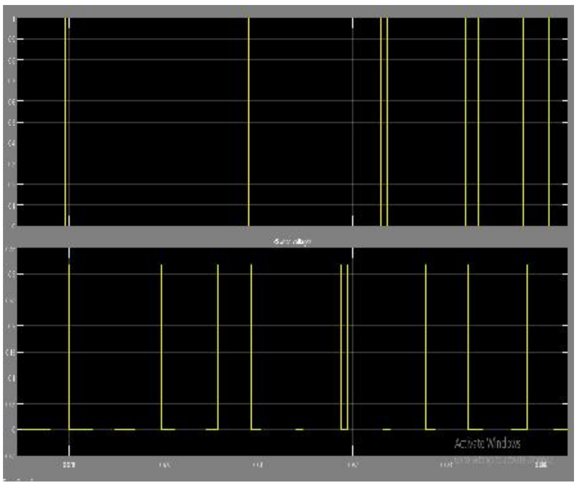


Fig 21. Output Waveform 1 for Load Measurement

The Output Waveform 1 for Load Measurement is shown in the Figure 21. In this voltage switching output is taken from the input load variation. When Load is varied in the bus, the power factor value is functioned and voltage is calculated.

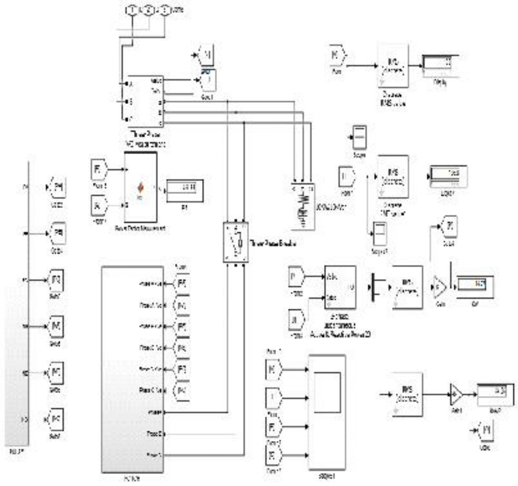


Fig 22. pulse for PC TCR

The pulse for PC TCR is shown in the Figure 22. Here the voltage is calculated in the form of 3 phase instantaneous active power KVA and reactive power KVAr.

Voltage, Current, P(Active Power), Q (Reactive Power)

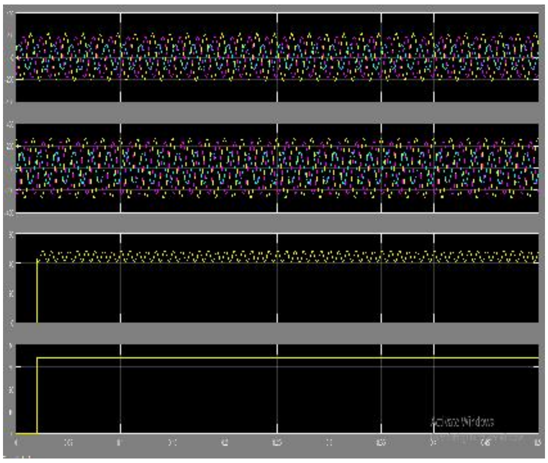


Fig 23 Voltage, Current and Power (Active, Reactive) Output Waveform

The Voltage, Current and Power (Active, Reactive) Output Waveform is shown in the Figure 23. The 3phase VI measurement is and 3phase instantaneous active and reactive power is given as an input is getting the obtained data.

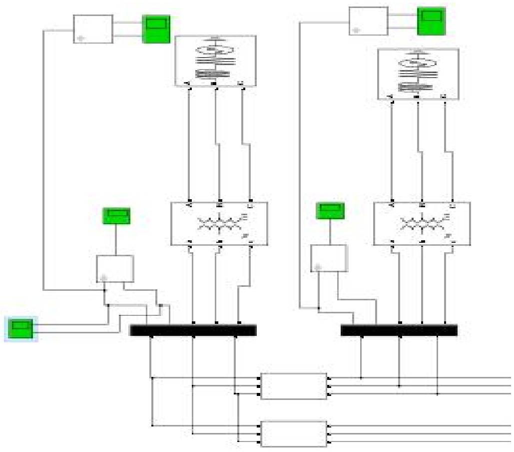


Fig 24. Bus Input Loading in 3 phase Transformer

The Bus Input Loading in 3 phases Transformer is shown in the Figure 24. By giving this variation in load the output waveform for magnitude, phase, voltage and current, active and reactive power is taken.

Magnitute and Phase:

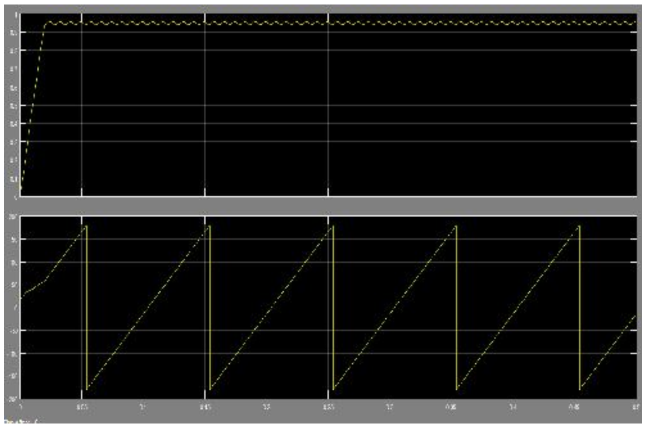


Fig 25 Magnitude and Phase Output Waveform

The magnitude and phase Output Waveform is shown in the Figure 25. The 3phase input is given this variation in load, the output waveform for magnitude and phase is taken.

P and Q:

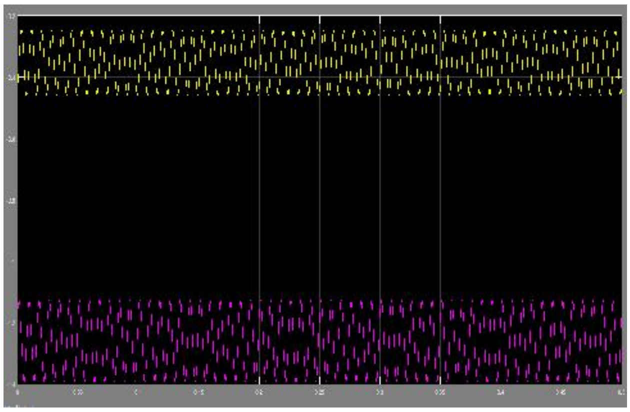


Fig 26 Active and Reactive Power Output Waveform

The active and reactive power output waveform is shown in the Figure 26. The 3phase input is given this variation in load; the output waveform for active and reactive power is taken.

Current and Voltage:

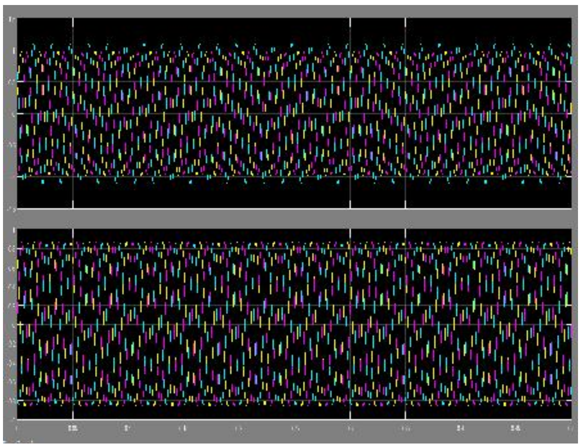


Fig 27 Output Waveform for current and voltage

The Voltage and Current Output Waveform is shown in the Figure 5.19. The 3phase input is given this variation in load; the output waveform for current and voltage is taken.

DISCUSSION

This Project analysis the effects of incorporation of load models i.e. the variation of active and reactive power demands with magnitude of voltage at different buses in load flow analysis. The simulation of a standard IEEE 14 bus bar system was conducted and the effects of load modeling were also incorporated in the experiment. The calculations become more accurate and system security and stability increase by incorporating the voltage dependent load models. The reactive power modeling greatly affects the voltage difference, whereas the active power modeling has a greater effect on phase angle differences. The total power generation is not much affected by the incorporation of load models but this small difference in generation power affects the generation cost difference and total losses because the generation cost function depends on square of generating power. The voltage profile remains flat which adds to the advantages of incorporation of load models. Thus it is deduced that incorporation of load models in load flow analysis is advantageous than conventional load flow analysis as generation costs and losses are reduced and security and stability of the system increases.

CONCLUSION

This project proposes a novel EV fast charging system structure with lower cost and higher efficiency. Proposed architecture of 14 bus system and EV Charging compared under fair efficiency analysis and evaluation including the power loss comparison of the transformers and converters. The whole system efficiency calculation results are also validated by the MATLAB Simulink simulation. This work meticulously analyzed the impact of EV charging station loads on the voltage stability, reliability indices, power losses, and economic loss of the IEEE 14 bus test system. The results obtained showed that the impact of placing fast charging stations at the weak buses affected the smooth operation of the power distribution network. A considerable amount of economic loss was also incurred if fast charging stations were placed at the weak buses of the network. However, the system was strong enough to withstand the placement of charging stations at the strong buses.

Further, the placement of the charging stations in the distribution network based on a new VRP index was proposed in this work. GA was used to solve the charger location problem with VRP 1index as the objective function. The results obtained indicate the efficacy of the VRP index in finding the most suitable locations for charging stations in the IEEE 14 bus test network. Thus, this work will serve as a guide to the power system engineers and help in planning of distribution networks in presence of EV charging loads. The compensation effect is validated by the simulation results. The proposed structure and lower order harmonic current compensation method could be simply used for improving the EV's fast charging system performance. This project essentially models variation of active and reactive power with voltage and neglects the effect of power on them. Basically for easier computation static load models are considered here. Load modeling taking into account the effect of frequency on active and reactive power demand and dynamics of load can bring more accuracy to the results obtained.

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