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Deploying an IoT-Enabled Smart Grid Automation System for Continuous Optimization and Fault Identification

Kusum Tilkar[1], Jitendra Managre[2], Alka Karketta[3], Deepak Rathod[4], Gaurav Makwana[5]

Abstract

The proposed paper discusses the "integration of IoT in smart grid" which has been elevated facilitating new ideas to facilitate developments of infrastructure for electric power. IoT has been a very important tool for power grids which makes them smarter and more advanced as compared to traditional power grids. This paper focuses on to the prototype designing which will help in finding and monitoring the power, current, voltage, energy consumption, power theft, faulty grid, sensors/ equipment's status and to display the data on webpage for virtual online monitoring. The Internet of Things uses a variety of sensors to carry out its functions and maintenance. The primary purposes of the sensors are maintenance and anti-theft measures. The model presented in this study addresses several additional problems that a smart system may handle to prevent needless losses for the energy producers in addition to solving this one by employing IOT as a communication tool. Thethe formposed work is thus resolving in MATLAB with Simulink model of single phase and three phase fault detection in form of sudden change in voltage and current. After the detection of change in voltage and current, the data is transferred to data acquisition devices and then displayed on the webpage like things peak for monitoring.

Keywords: Smart grid, IOT, MATLAB, Power load, Producer side, Demand side, Fault detection etc.

INTRODUCTION

The development of smart grids is an improvement over traditional electricity grid. Energy is produced at centralised power plants in the conventional electrical system [1][2]. Although it is a communication that only goes in one direction, smart grids are becoming increasingly important to attain high reliability in power systems. This system has long-lasting models for making and distributing energy [3][4]. Implementing technology to increase the system's dynamic nature is key to the smart concept. Regarding the analysis by providing new ways, often known as "smart grids," for the distribution of electricity, the IoT has the potential to totally revolutionise power grids [5]. It is not a simple or straightforward task to implement Internet of Things technologies in electrical networks that are currently facing an issue. An IOT network is a flexible, compact grid that may be effectively operated using low-power devices with limited processing capacity [6][7]. We propose this network to stimulate the organisation of IOT-based frameworks in local scenarios [8]. This strategy has the potential to drastically cut down on the overall response time, as demonstrated by the results of our experiments, even when processing delays are present. It is critical to implement the smart concept

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in Grid Stations to improve the effectiveness of power systems and to facilitate their use of information technology [9][10]. To put it simply, a smart grid integrates electrical and infrastructure components that makes use of information technology services within an existing electrical network [11].

An emerging paradigm in the field of communications technology is the Internet of Things (IoT). In terms of communication technology, the Internet of Things notion that is "anywhere, anytime, any media" stimulates its development [12]. Some concerns and fresh requirements for improving the system's operation are raised because of the proliferation of communication technology between devices. The Internet of Things system is highly likely to be employed as a system that can perform the optimisation on its own [13][14] [15]. The Internet of Things (IoT) has been increasingly attractive in recent times because it allows for millions of devices to be readily connected to one another through a network [16][17][18]. The fundamental idea of the Internet of Things (IoT) is around the interconnectedness of various devices and services through the internet, which is demonstrated in figure 1.

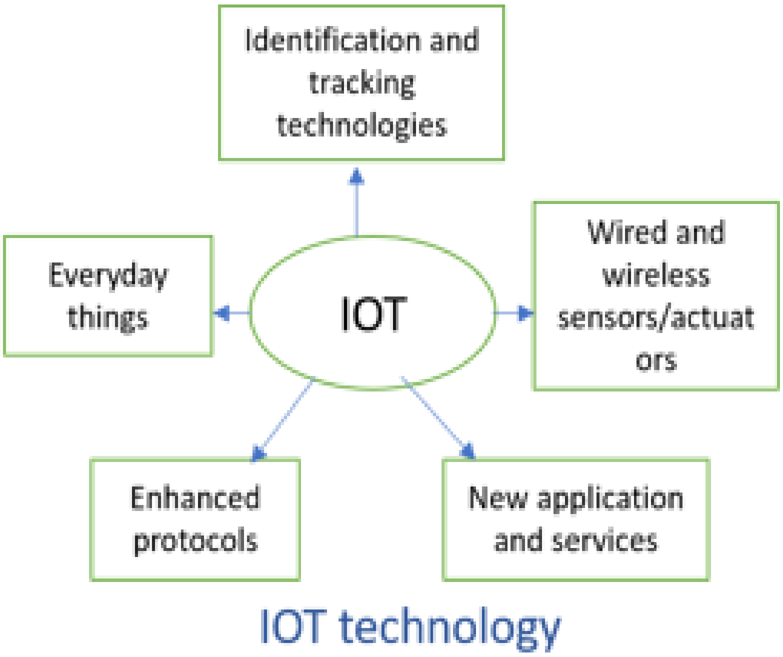

Figure 1. IOT Technology diagram

It is generally accepted that a smart grid is an advanced intelligence technology that incorporates technologies of improved sensing, control techniques, and communication capabilities into the existing energy system at both the transmission levels and the distribution levels [18][19] [20] [21]. The term "smart grid" refers to a powerful grid that serves as an Integration point connecting consumer appliances with the resources of conventional power systems at the levels of generation, transmission, and distribution [22][23][24][25]. The following figure 2 illustrates the structure of smart grid systems. This facilitates the optimisation of the traditional central power system by allowing for the incorporation of distributed generation.

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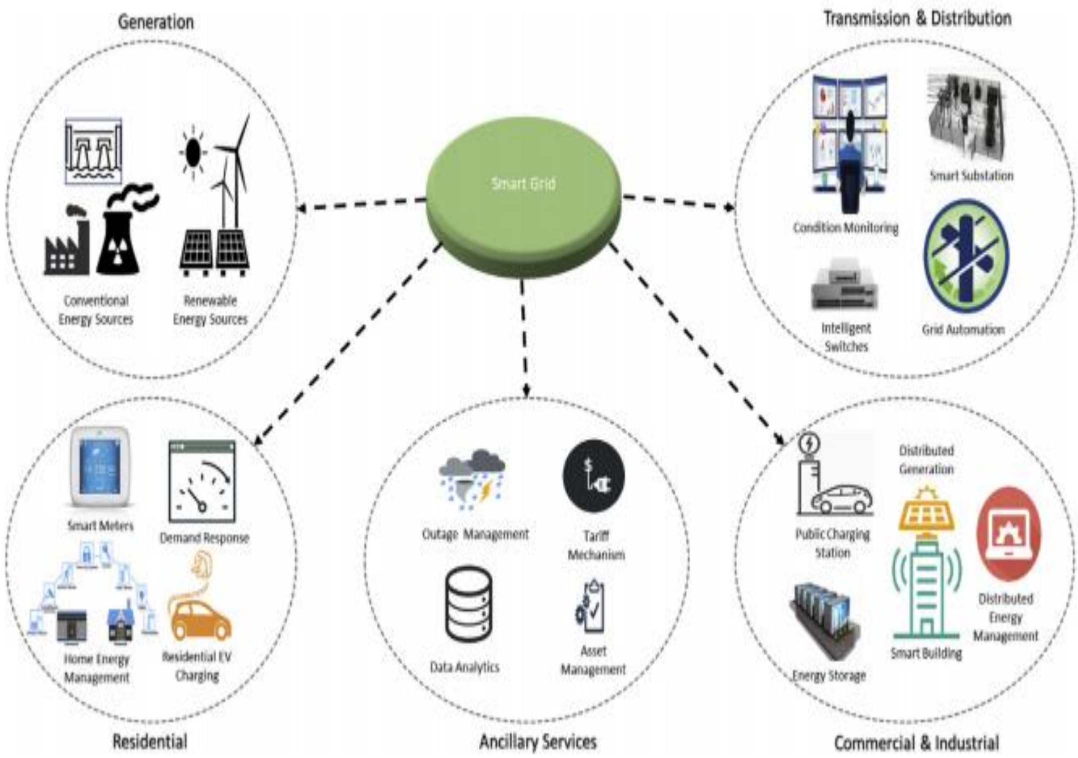

Figure 2. Structure of smart grid

In the event that a single grid station responsible for transferring power to homes experiences an outage, the smart grid model proposes using Internet of Things (IoT) based technologies to link all loads associated with that station to an alternative station, ensuring that power supply remains uninterrupted [25]-[35]. This model of smart grid automation technology has been demonstrated in figure 3.

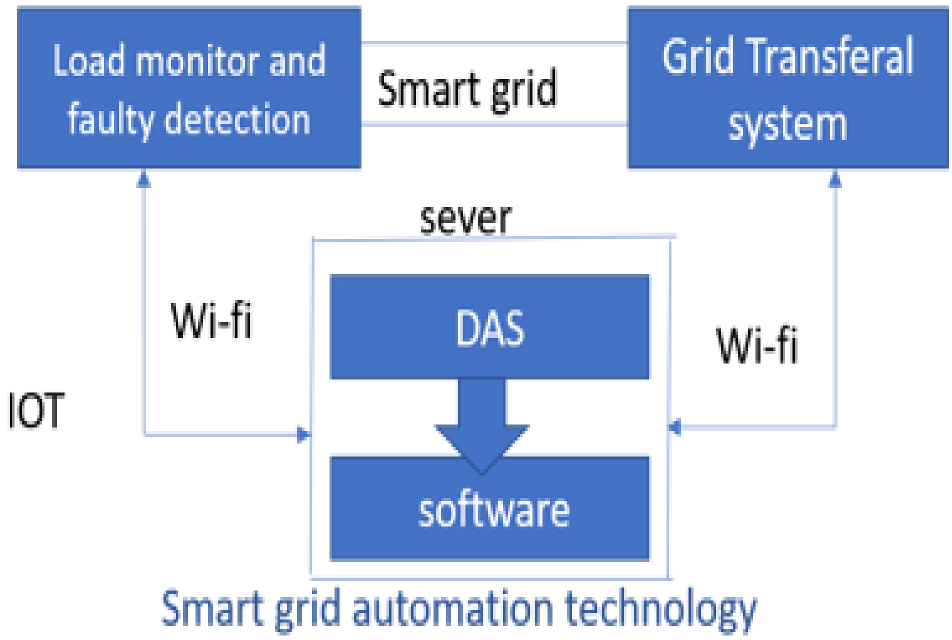

Figure 3. Smart grid automation technology [29]

Rationale

Smart grid technology, its purpose, its uses, and its potential for future advancements in conventional power networks have all been covered in the introductory section. The IoT is a tool which is integrated with smart grid to facilitate automation, intelligence, and smart labour. It explains the inner workings of an IoT-based smart grid, the notions of smart grids and IoT technology, how loads are transferred between grids, how loads are calculated, how energy is distributed, how atomization works, how faults are detected, and online monitoring concepts, among other things. The modelling and development of research technique, on the other hand, have not been pursued in any way. As a result, it is necessary to establish and build a research technique for the automation of smart grids based on the Internet of Things. In addition, its design and software simulation were necessary for future study, which was covered in the previous section.

Related work

V.C. Gungor et al.,[2] emphasised on information and communication technology (ICT) opportunities and challenges pertaining to smart grid technologies. The principal idea of this work is to present a current analysis in smart grid communications and to address unresolved research concerns in this domain.

R. Amin et al.,[3] In this article, we offer a solution for the communication architecture of Smart Grid Home Area Networks that relies on Hybrid wireless systems of the next generation. The heterogeneous wireless system consists of several Radio Access Technologies (RATs) that the customer can access on their property.

A. C. swastika et al.,[9] The design of a smart grid system that is based on the Internet of Things was proposed for smart homes In order to improve the optimisation of the Smart grid system itself, the proposed design is analysed in order to determine the architecture of the suggested protocols that are going to be utilised, the functioning of the system, and the challenges that are involved in the design of the system.

L. Zhao et al., [11] To demonstrate a real-world power substation application. While utilising an individual time source with a high resolution that serves as the reference for both steady-state and transient variables. The system integrates the attributes of an Internet of Things platform with the demand of fast response run time problems or applications.

Archana et al. [12], discussed about the development of the smart grid and creating the infrastructure for the customers' acceptance in India.

S. Muralidhara et al., [17], In the paper, it is said that when it comes to power usage at the device level, standard energy monitors do not provide any information. As a result, users are unable to monitor or log the amount of electricity that is spent by each item.

Manisha et al., [22] presented a suggested method that prioritises domestic power loads and ensures power consumption stays below preset values. To illustrate the value of the recommended approach in executing DR at the devices stage and to measure DR potentials for domestic consumers, he developed a technology that simulates the situation.

W. Shu-wen et al., [23] proposed that internet of Things is being utilised for a variety of purposes, including the monitoring and regulating of transmission lines, the management of equipment, the protection of towers, distribution automation, and intelligent substations.

X. Chen et al.,[26] As it is presented, the smart grid is significantly impacted by the auto metre reading system. This system bears the responsibility for collecting, analysing, and monitoring the power usage in real time in an intelligent manner.

D. Despa et al. [28] discussed an online monitoring system for the power distribution system that was finally deployed and put into operation. The measuring system is comprised of a number of sensors, including current sensors and voltage sensors, and Arduino is responsible for the processing of data. The data collected from the measurements is then saved on a database system.

Taha Shlebik et al., [29] the paper discussed the design of a smart grid management system through the use of the MATLAB programming language. This system displays the movement of smart metering

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data from households to the utility and demonstrates the utility's control over the user's consumption. Therefore, the system acts as a preparatory instrument for the development and testing of a more intelligent grid.

Problem domain and Proposed Methodology

Problem domain

A large portion of human existence depends on the reliable supply of electricity, which is provided by power grids or power hubs. Many issues, such as weather, can disrupt power systems, leading to total blackouts in the areas that rely on them. The focus of this study is on power grids and other electrical infrastructures that might benefit from the use of information technology. This project will implement new trends in electricity grids and the Internet of Things to make them smarter. To make good use of electricity, it is crucial to monitor not only the Grid but also energy usage and even theft. It is necessary to update the webpage with the most recent data on electricity consumption in addition to the Energy Grid details.

Research objectives

Based on the research gap and limitations found in the literature review, the design goals for the suggested model are as follows:

1. To design and develop a Simulink model for proposed work using simulation software.
2. To design and implement a software simulation for VI measurement and three phase fault detection using simulation.

Proposed Methodology and Tool Used

To implement the model, MATLAB was utilised. MATLAB Solutions illustrate the utilisation of the MATLAB software to conduct a smart grid simulation. Specifically, we used the MATLAB/Simulink platform to build a generic smart grid simulation model that incorporates control capabilities, load monitoring, and energy storage technology. Using a real-world data set and our own simulated scenarios, we validated the usefulness of our approach.

The MATLAB programme Designed specifically for the purpose of simulating dynamic systems, Simulink offers a graphical user interface. If you're familiar with the MATLAB environment, you may have come across Simulink, a MATLAB toolbox that stands out from the crowd because to its unique interface and distinctive "programming technique.". Although this research was conducted in an ideal setting using MATLAB, it will be difficult to apply this in real-life situations. The proposed methodology shown in figure 4, in which the simulation has been done for the VI measurements and three phase fault detection.

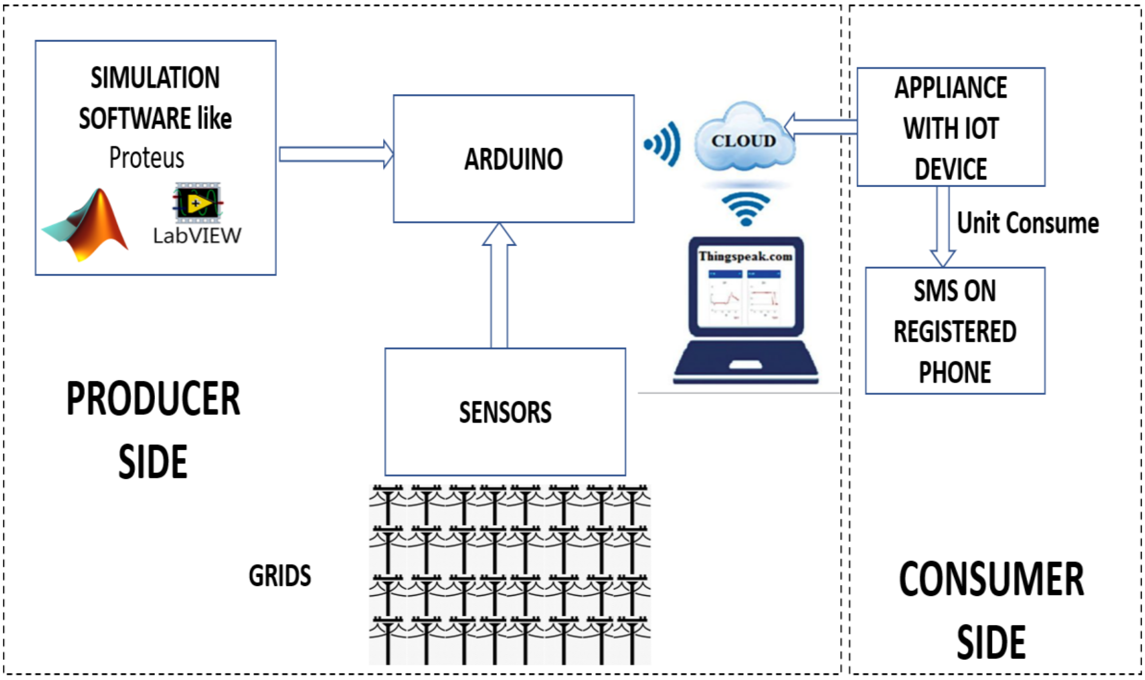


Figure 4. General Block diagram of Proposed work

To handle and control the system's many events, the Internet of Things (IoT) smart energy grid relies on microcontrollers. Using Wi-Fi technology, this system can communicate over the internet. To show what power is valid and what is not, consumer light bulbs will be utilised. The model streamlines the process of re-connecting transmission lines to active grids the most. Because the system will automatically transfer the Transmission Lines towards the active or alternative grid if there is any defect or technical difficulty present in the power grid, it is very important because it enables uninterrupted energy supply to be provided to the region whose power grid is faulty. In addition, it is essential to note that the information of the active grid is updated through a graphical user interface (GUI) webpage that is based on the Internet of Things (IoT). An expert can log in and check the updates. Not only does this model have the capability to monitor power networks, but it also has additional advanced capabilities, such as monitoring energy use and offering the option to detect electricity theft. The IoT webpage is constantly updated with the most up-to-date information on the energy grid, including consumption of electricity and the expected price of usage. It is planned to deploy two switches to imitate the conditions that exist within the system. When switch is on respectively for switches at each time, the theft indication will be alarmed, which will inform the experts through the graphical user interface of the Internet of Things. For this reason, the Smart Energy Grid project makes sure that there is always power and helps keep up-to-date records of usage and theft, which is very useful information for companies that serve energy.

To achieve the mentioned goal, the sequential block diagram and flow design chart of the proposed model has been demonstrated in figure 5 and figure 6 respectively. The technology is user-friendly and comes with a full set of instructions for using the devices. The scope of this varies considerably across sectors such as healthcare, industry, education, and more. The primary objective of this initiative is to monitor energy consumption and control devices via IoT. This paper can be implemented for both industrial and domestic purposes. To illustrate its methodology, the inputs are linked to a relay, which is subsequently connected to a microcontroller. The signal conditioning board is where the current and power transformers are hooked up. The signal conditioning board changes the AC to DC. Voltage and current consumption are used to calculate the energy, which is then uploaded to a website. Monitoring the devices from any location globally enables users to conveniently track the energy consumption.

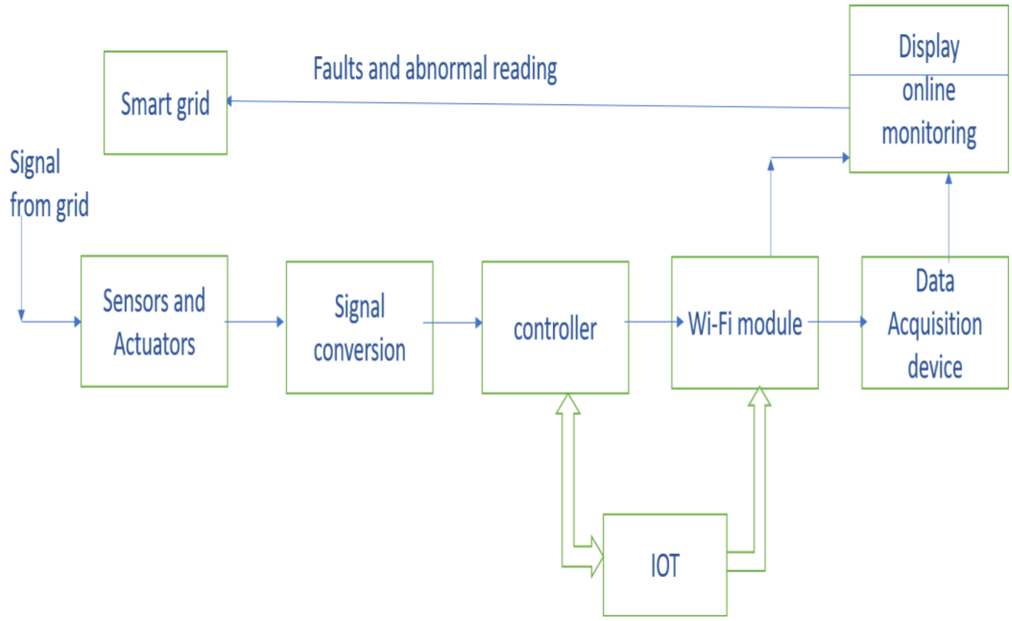


Figure 5. Functional and sequential block diagram of proposed work

The flow design chart shown in figure 6, the system initially, read values from each sensor and from IOT devices connected to each appliance. Then the result will display on things peak webpage and send SMS on smart phone for unit consumed by each appliance, if grid is not showing any value on webpage, overload, power theft are occurring then a consumer will send message to grid operator or smart grid will send SMS on mobile phone or on webpage for alert and intimation for further repairment. Person also can enquire about the issue from smart grid.

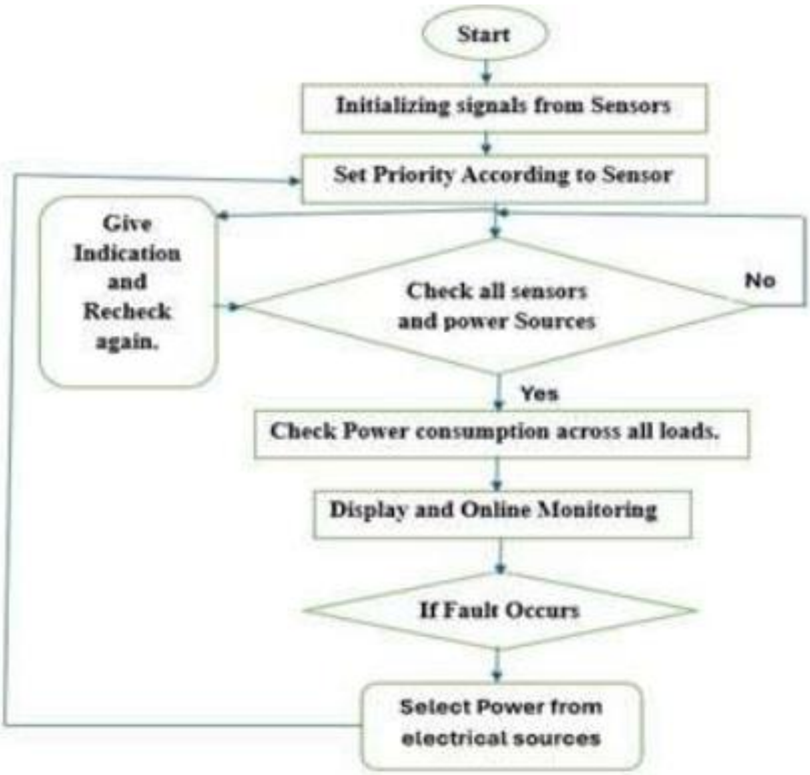


Figure 6. Flow design chart.

Results and Discussion

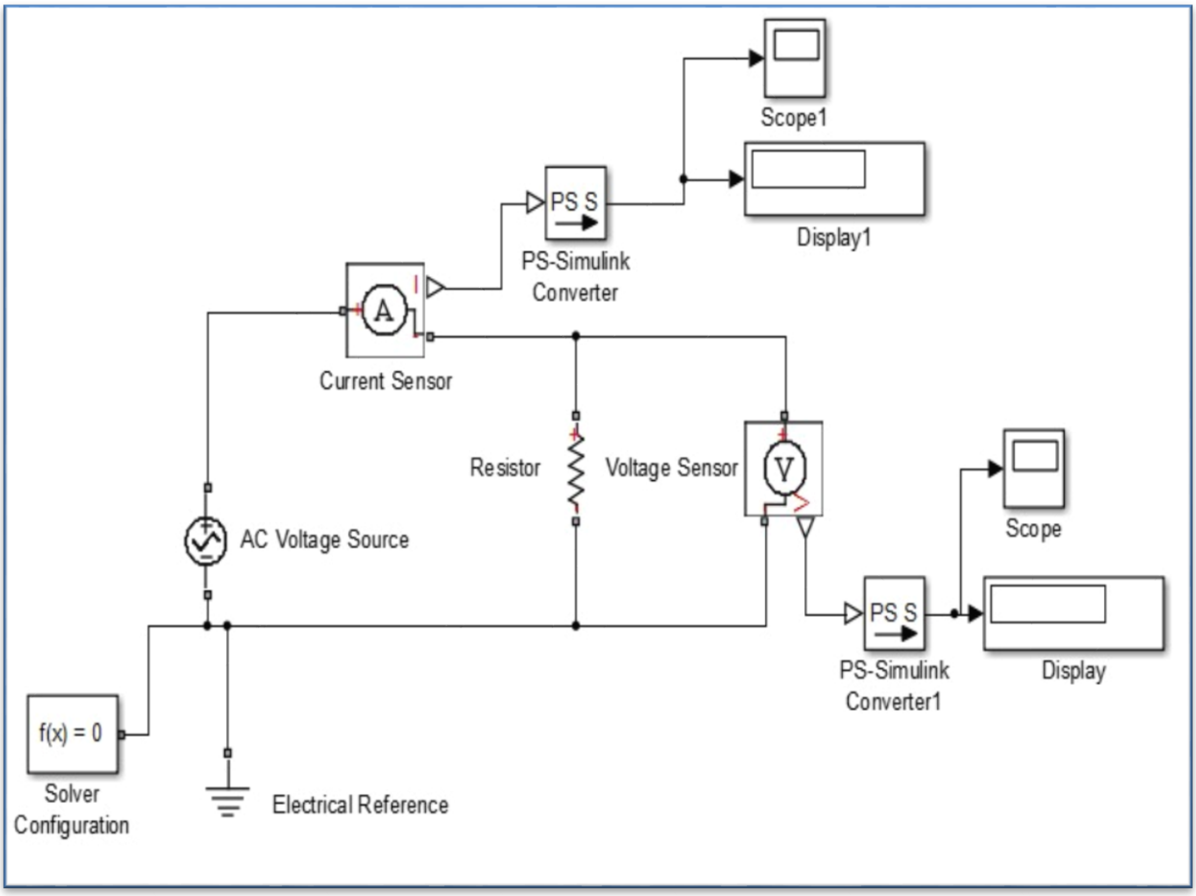
The figures below illustrate the simulation of an IoT-based smart grid, specifically focusing on three phase fault detection and voltage current measurement. The main aim of simulation is to calculate current (I) & voltage(V), based on the results, identify transmission line faults using MATLAB to implement the IoT in Smart Grid. The software provides coverage of both schematics for the fundamental layout and general circuit administration. Laboratory MATLAB With a graphical user interface designed specifically for this purpose, Simulink is a tool for simulating dynamic systems A MATLAB programme Among the many types of toolboxes available in Simulink, this paper employs sim power systems for straightforward manipulation and analysis. A virtual terminal is utilised to exhibit the outcomes. One of the MATLAB programmes This study makes use of Simulink's Power Systems Toolbox, which is one of the numerous types of toolboxes that are accessible in Simulink. It allows for basic manipulation and analysis. The outcomes are displayed using a virtual terminal.

As a means of conducting analysis, a three-phase measuring block has been connected. After this, an electrical source power is attached with three phase breakers. You may create several kinds of faults with fault-block. Depending on the nature of the fault, it may be turned on or off by an external control or by internal timing. To set the trigger's duration in seconds, use the step function. A Three Phase Breaker is a device that is utilised to establish or break connections between all three phases. This block, like the fault block, can be controlled by either an external trigger or the internal timing control. Through a three-phase breaker, an external controller, and a three-phase measuring block, the electrical energy supply is linked to the three-phase load. On the side of the electrical sources, the three-phase breaker is often open, and on the side of the three-phase VI measurement sources, it is typically closed. The entire process is carried out by the clever intelligent switch, also known as the relay, block It is made up of comparator circuitry that uses math or digital operations to compare all three voltages with fixed values. It then gives an output that controls whether the electrical power source is "ON" or "OFF". The results are visible on the screen and automatic control and monitor by the centralized IoT based system which is incorporated in smart grid. The following section is showing the design of Simulink model and its results window for current and voltage visualization and three phase fault detection model with captured window in terms of voltage and current.

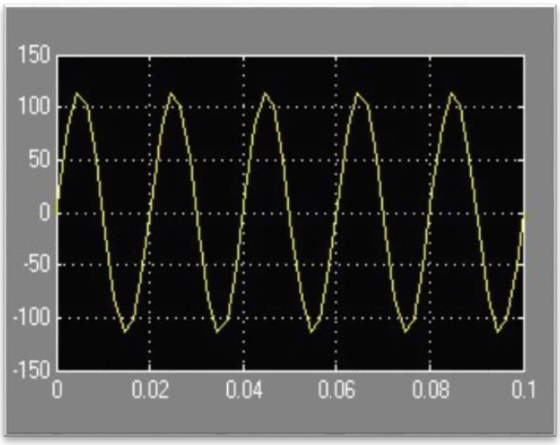
Simulink model and Results

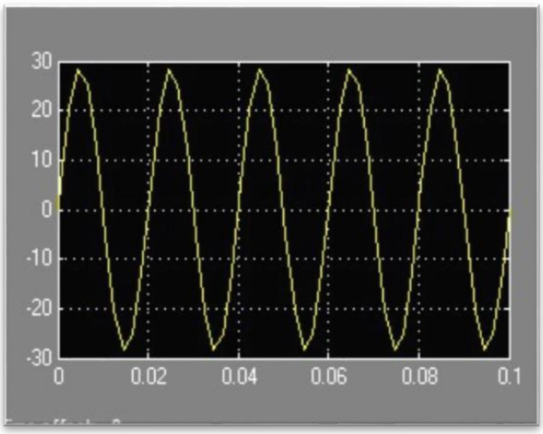
Simulation of Voltage and Current measurement

Figure 7(a) shows the Simulink model of the VI measurement. In this the function F(x) solver configuration has been taken and configured. After that Current sensor and voltage sensor have been selected and configured with the PS- Simulink converter. This simulation will generate the waveform of current and voltage at the display end. This will be monitored on scope-1 and scope-2 for visualization and analysis. Figure 7(b) and figure 7(c) show the current and voltage waveforms respectively as on the screen.as result. As it has been observed that current and voltage waveforms are showing stationary and constant throughout the monitoring and no-fault detection has been seen. It shows the system is working properly and can be used for further development or testing.



(a)





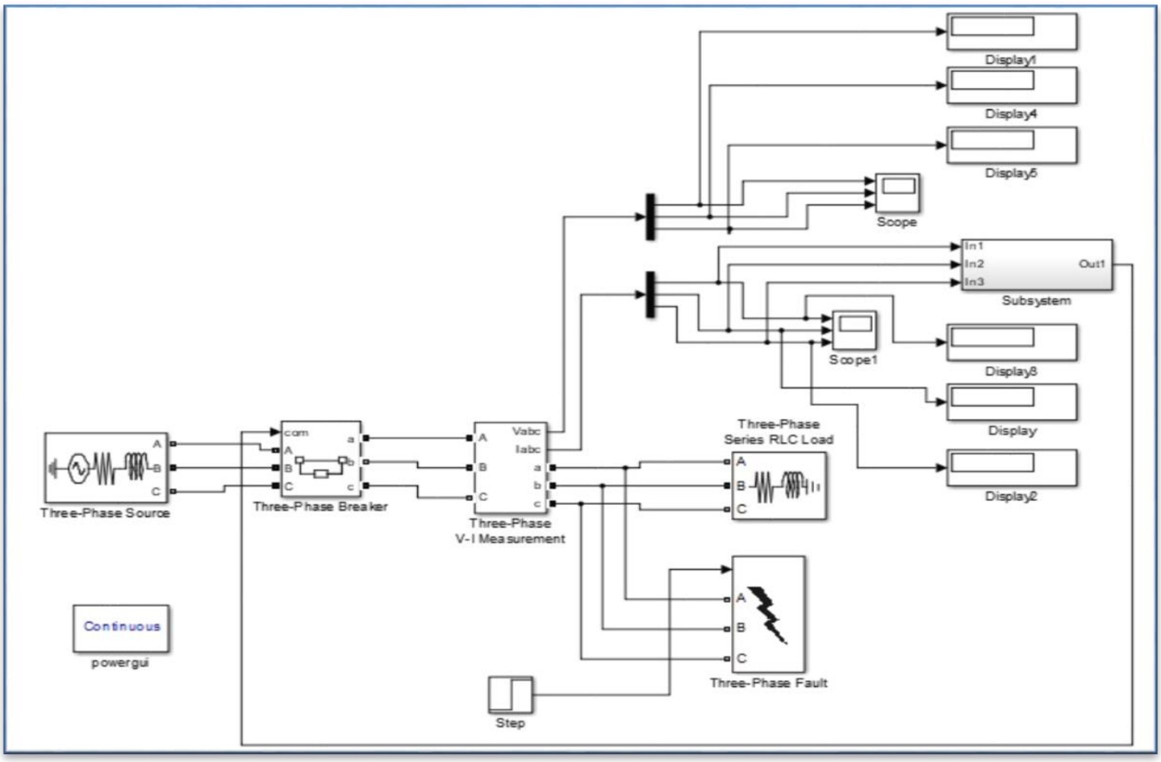
(b) (c)

Figure 7. (a) Simulink Model of VI (b) current measurement (c) Voltage measurement

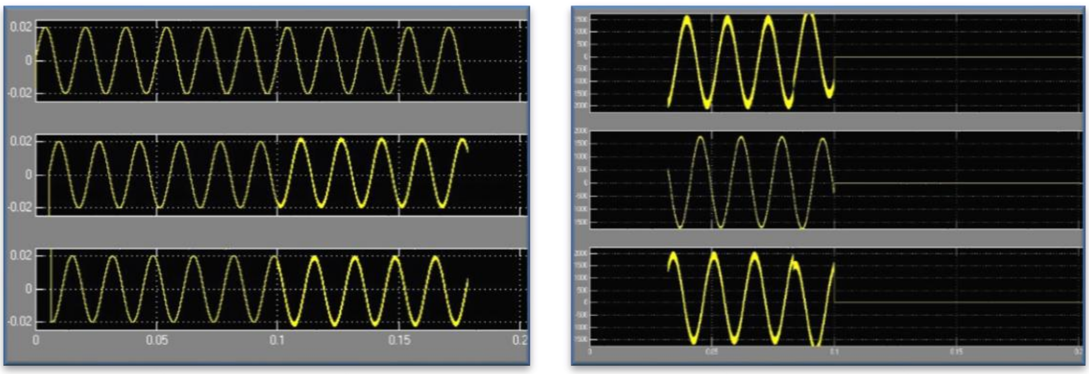
Simulink Model of three phase fault detection

In the following figure 8(a) demonstrates the Simulink model of three phase VI fault analysis. In this with the continuous power guide one three phase source has been taken which is connected to three phase breaker and after that three phase VI measurement block is connected to this. This block is connected to three phase series RLC load and then a step signal is given to the three-phase fault block for further analysis. Fault detection will be observed on the scope for the visualization and monitoring.

The results will be in the form of waveforms which are shown on the screen or display. As we can see that when the step signal is given to three phase fault blocks, fault detection has been observed in current and voltage waveforms. Figure 8(b) and figure 8(c)shows that When fault occurs, the signal is suddenly changed and shows the high intensity in the waveform of current and voltage. Increased intensity of waveforms shows that sudden change in load is occurred, and regarding this load change an indication will be generated for the alarm condition. With the help of this, theft detection of power load can be done. Also, by using this system we can minimize the load consumption and save the electricity.



(a)



(b) (c)

Figure 8. (a) Simulink model of three phase VI fault analysis (b) current fault detect (c) voltage faults detect

CONCLUSION

According to the preceding discussion on the primary concerns and obstacles for the Smart Grid, users can conveniently monitor their daily energy usage from any location via the internet. The smart grid is one of the most promising and popular applications that can be found on the internet of things.

As a result of the findings presented above, we were able to determine the power, current, and voltage theft, as well as the inefficiency of the grid in terms of the transmission of electricity. Additionally, all the results are included in the webpage to ensure that the end-user can efficiently and securely show some concern for the balance between energy consumption and production. The Internet of Things is the next step towards a comprehensive and unavoidable connection with items and devices that are capable of communication and computation, regardless of their access technology, available resources, and geographical location.

The Internet of Things (IoT) presents a tremendous opportunity for the smart grid. The Internet of Things (IoT) allows for the remote sensing and control of various things. This opens new possibilities for integration between physical and computer-based systems, which in turn improves efficiency. Aside from this, the use of IOT can facilitate the growth of the nation's economy. Theft of electricity is a huge problem in today's world, and it is getting worse every day. Its primary impact is on the national economy.

Conflicts of Interest: The Authors declare that they have no conflicts of interest in this work.

Data Availability: No data have been used.

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