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IoT-Enabled Smart Grid using PV panel

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Abstract

This project brings together a smart grid implementation that uses a Wi-Fi (IEEE 802.11) network to communicate with sensors (IEEE 802.15.4) and actuators from multiple nodes. Addresses normal energy consumption issues that consume a lot of power. The system can be easily configured via a mobile application-friendly interface (IEEE 802.15.2) to automatically control the power supply and light demand of various types of electrical installations. Mobile application dashboards (IEEE P 2301) can also provide complex system-wide analysis by collecting values from various sensors. The maximum consumption of electricity generated is 32 GW, with the waste of electricity that must be stored and used, the unknown cause of outages, and the high maintenance costs of relying on old electricity. There is a problem. You should rely on the smart grid for the following reasons. Therefore, we use IoT solutions to improve energy consumption and production, proposing an innovative smart energy grid to meet the growing population and electricity consumption. The proposed smart grid system is energy efficient, self-contained and user is easy to set up. Due to its modularity, the system is scalable and does not require more complicated materials or wiring. The proposed system improves energy consumption and production.The system is power efficient, self-sustained, set up easily and scalable without the requirement of more complicated materials. Also, it enables suppliers and consumers with unprecedented control and management capabilities.

Keywords: *Wi-Fi, IoT, Sustainable, Energy, Smart Grid.*

1. Introduction

Smart grid systems integrate renewable energy sources such as wind, solar, and storage into the grid system. These new power generation technologies are smaller, more widespread, greener, and able to maintain grid resilience and spread congestion points [1-2]. A smart grid uses an extensive sensor network supported by a two-way communication system to constantly monitor grid conditions. A bi-directional communication network enables the exchange of measurement data and control signals between network units, improving monitoring and management of network and user assets [3]. Additionally, the smart grid must be supported by sufficient computing resources to ensure that the collected data can be processed within the required timeframe. Control and monitoring are more distributed because the amount of data collected is enormous and sensors are distributed throughout the network [4]. Egypt has 58 GW of generating capacity, but summer peak consumption ranges from 30 to 32 GW [5]. The problem turns out to be that the investment in generating capacity far exceeds the rate of adding (and enhancing) grid capacity that makes up the national grid. Figure 1 shows how the smart grid works.

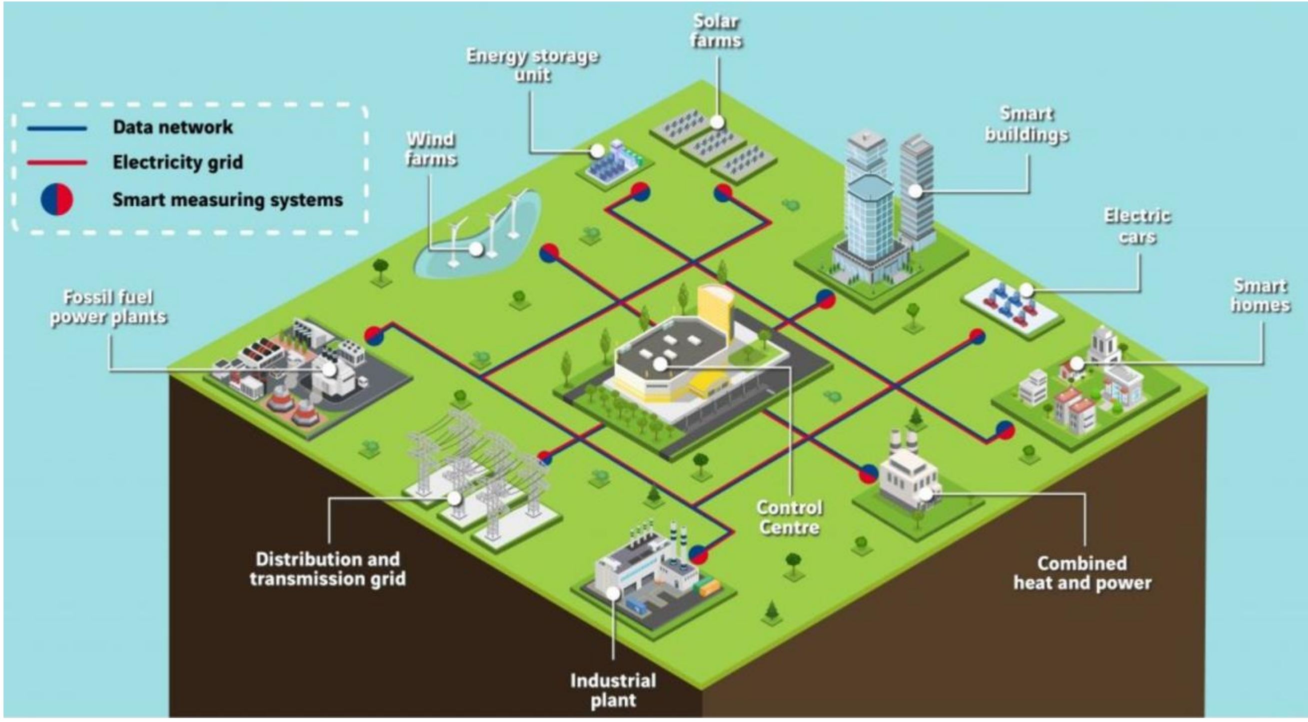


Fig.1. How Smart Grid Works, [Source: vinci.com].

A smart grid allows electricity distribution companies to analyze big data on the consumption of electricity using sophisticated servers and IT infrastructure embedded into control centers, former head of the New and Renewable Energy Authority (NREA) [6-7]. This also allows companies to anticipate problems with the grid or malfunctions in different parts, making the electrical system more reliable and efficient. The grid also helps to cut back on lost electricity, as engineers are able to keep a close eye on the performance, anticipate problems before they occur, and quickly maneuver to avoid interruptions. The new grid would also come with smart control units for street lights, which the ministry is piloting in Port Said before rolling them out to the rest of the country. Control centers are the main ingredient in a smart grid as the plan includes the establishment of 47 smart control centers nationwide, some of which are already under construction [8]. These centers will replace Egypt's current six control centers and more will be built to better manage and monitor Egypt's energy use [9].

One of the future-oriented solutions in the telecommunications sector is IoT. It is generally viewed as a network of embedded devices. Electronics, software, sensors and actuators that can exchange information Communication networks such as the Internet. Because IoT supports two-way communication and distributed computing capabilities, it can be seen as a potential solution to address the inevitable problems of transitioning traditional energy grids to upgraded smart grid systems [10-11]. Additionally, IoT-enabled smart grids can improve grid operations and management. It is efficient because it seamlessly integrates with other smart entities such as smart appliances, smart homes, smart buildings and smart cities to access and control more devices over the internet. However, this requires the use of more sophisticated computational capabilities and resource allocation mechanisms. Although energy systems are becoming more efficient to monitor and operate, there are many obstacles to IoT-enabled smart grid implementation.

Furthermore, IoT-Enabled Smart grid designs consider energy storage to maximize efficiency and make better use of renewable energy. The electricity produced is not always consumed due to varying and often unpredictable consumer behavior. In a conventional grid, that energy is simply wasted. One reason for this is that traditional grids were not designed to store electricity that will not be used immediately [12]. On the other hand, renewable energy sources such as solar and wind are not always reliable. Clouds can block the sun for days, and wind farms can stop spinning without strong winds. As Egypt seeks to increase its reliance on renewable energy, storage has become a priority to meet the days when the weather is not on our side, but the investment required to store just 1kWh of power in a battery is "massive" and simply not viable, so you can forget to go the battery route. Storing power in lithium-ion batteries costs about $1,000 per kWh, according to Vox [13]. Figure 2 shows the complete system of Smart-His grid using PV.

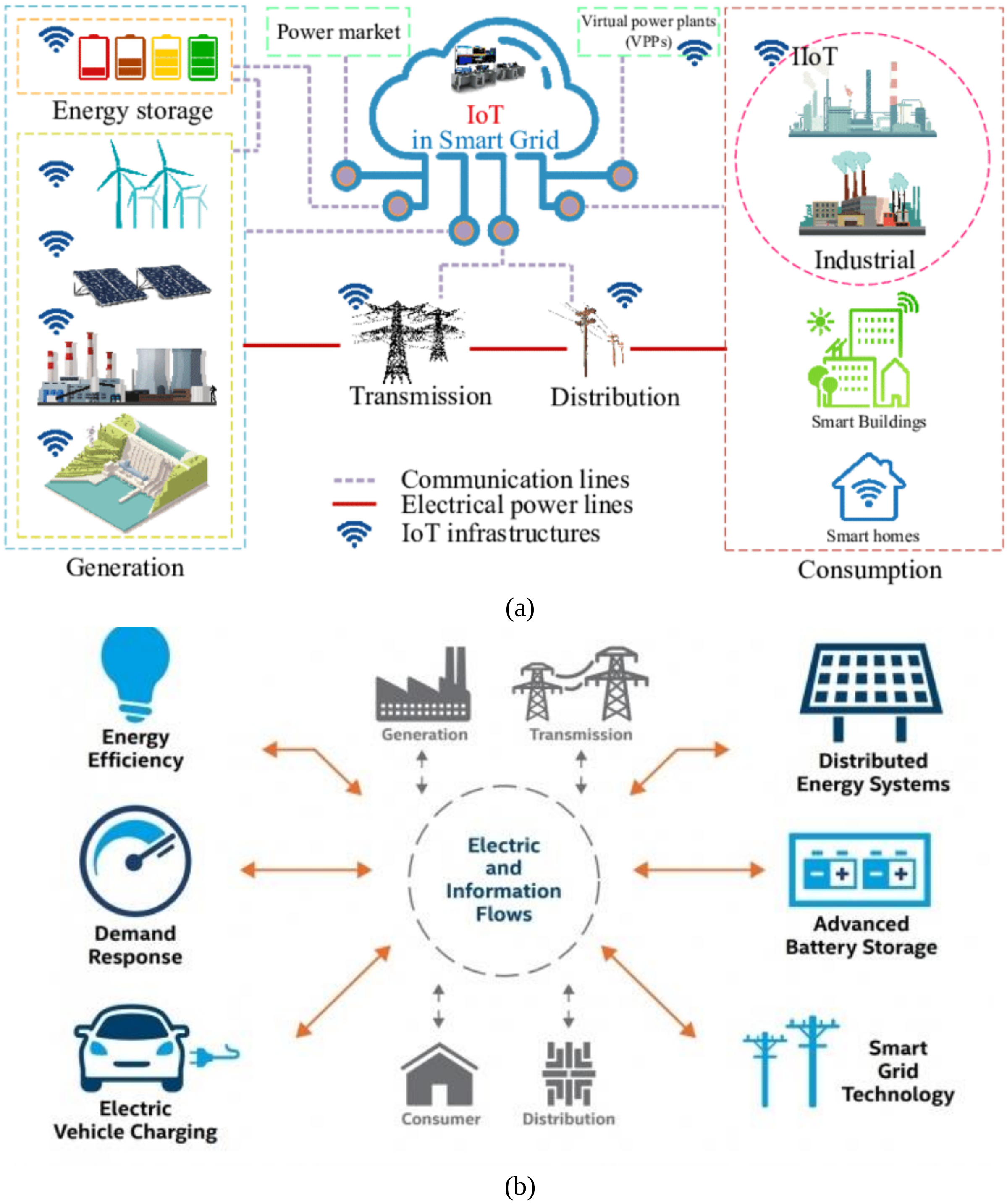


Fig.2. Smart Grid using PV System [14-15].

Finally, this study proposes a solution in the form of an IoT-enabled smart grid using PV to address these issues (IEEE P2301). The study offers a unique, fully self-contained and energy efficient smart grid that can be deployed anywhere. Solar power is the direct conversion of solar radiation into direct current. Solar radiation is captured by semiconductor devices called solar cells that can absorb photons of light and release electrons. If their free electrons are lead, an electric current, also called electricity, is produced. Therefore, photovoltaic power is a renewable energy source as it is derived from an inexhaustible source of energy, the sun. The sun is also a clean, sustainable and free resource. Our solar power system is directly connected to the main power grid and is also isolated from the power grid. The term isolation is used because these isolated power generation systems do not need to be connected to the mains power grid to generate energy from the sun. They are usually located in areas with limited access to electricity. Figure 3 shows a complete photovoltaic system.

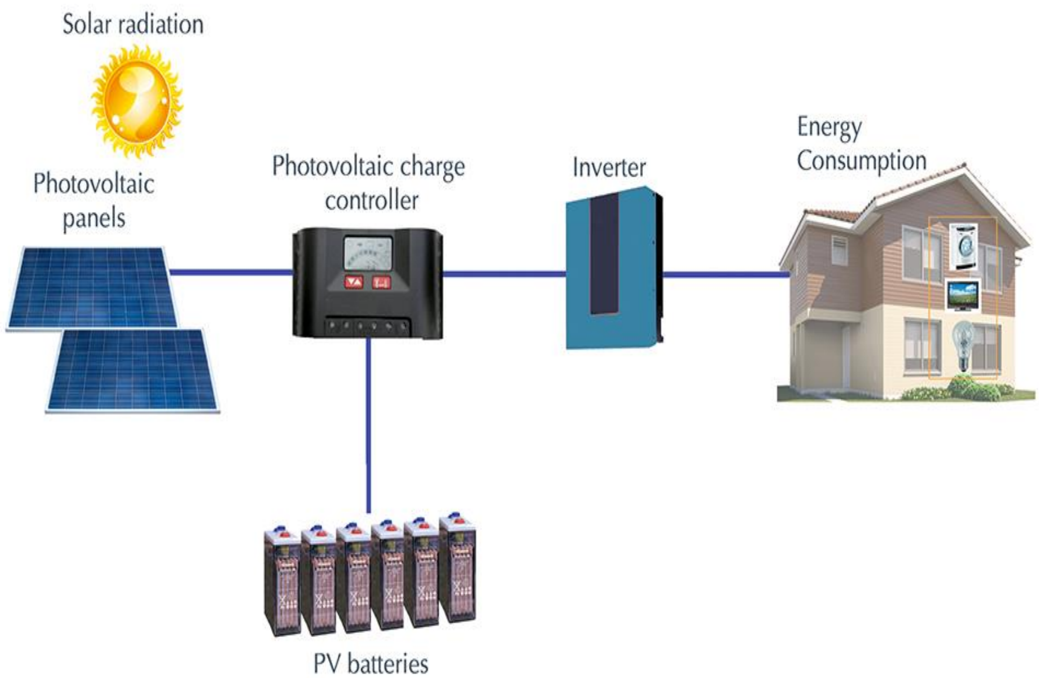


Fig.3. Photovoltaic System, [Source: Bester Energy].

1.1. Work Motivations

The motivation for this project in the smart grid area is Due to resource limitations in such as (i) Energy; (ii) Power; (iii) Wires; so it is essential to implement and develop smart grid system over IoT. Egypt currently produces 58 GW of power per year, and the maximum consumption that occurs will be 32 GW of power, and therefore I have a surplus of wasted electricity that we need to store and benefit from, and problems such as not knowing the cause of power outages and maintenance costs that take time and effort due to reliance on old technologies, so we You need to (i) resort to smart grids, because they provide the ability to store electricity, (ii) monitor consumption, (iii) reduce losses.

1.2. Work Aims

This project aims to achieve the following (i) Provide a renewable energy source. (ii) Storage of surplus electricity. (iii) Eliminate the problem of power outages. (iv) Reduce pollution from the use of non-renewable energy in electricity generation.

1.3. Work Contributions

This Project is a smart solution over IoT using PV Smart Grid. The project performs the following enhancements: (i) increase Power Savings: This project will contribute to the storage of existing surplus electricity, the treatment of power outage problems, and the provision of a reliable renewable power source. (ii) Achieving Sustainability: Using primarily renewable energy sources smart grid support grid independence and help to reduce carbon emissions. (iii) Resiliency: Smart grid provides uninterrupted 24/7 power and balance load demand for your changing power needs. (iv) Increase Power Systems Efficiency: With sophisticated control, user can optimize power usage based on demand, energy prices, and other factors.

1.4. Relation with Environment and Economic Benefits

Overcoming financial obstacles to a greener future of Energy. All these factors will save millions on the country as well as provide excellent service to the consumer. These Factors are presented in Fig. 4.

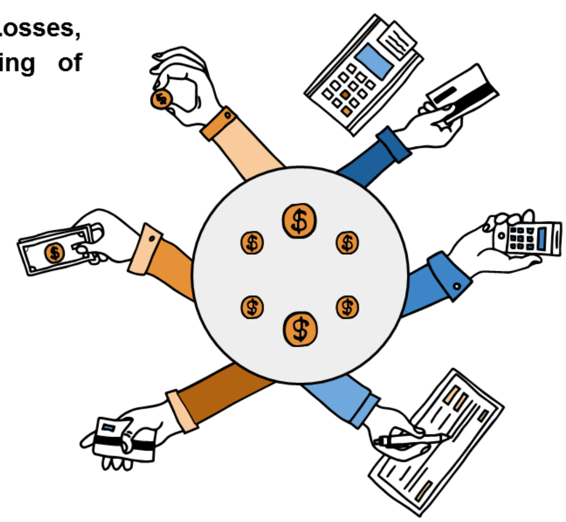


Fig.4. Economic and Environmental Benefits.

1.5. Paper Organization

The rest of this work is organized as follows: the second is a work background including a discussion about smart energy grids and integrated technologies in it. Section three present a literature review followed by the proposed system in section four. Section five discusses the results followed by the challenges and future research direction in section six. Finally, the paper is concluded.

2. Work Background

Smart Energy Grid is an electricity network that consists of a system of infrastructural, hardware and software solutions that enable two-way communication between all system parts and participants and provide efficient power generation and distribution in the supply chain [16-17].

It allows electricity distribution companies to analyze the consumption of electricity using IT infrastructure embedded into control centers, former head of the New and Renewable Energy Authority [18]. By 2025, it is expected that there will be 30.9 billion IoT devices installed worldwide, of which 19% will be used in the energy industry, increasing the emphasis of cyberattacks on this industry by 54% [19-20]. Figure 5 presents the used technologies in smart energy grids. It is often characterized as a self-sufficient distributed system. It can provide energy from different power sources, including renewables and storage [21]. Table 2 classifies and compares the widely used communication network technology in smart grid systems [22-25].

Fig.5. Technologies in Smart Energy Grids.

Table 1. Traditional Grid vs. Smart Grid.

Index	Metric	Traditional Grid	Smart Grid
1	Topology	Radial	Network
2	Generation	Centralized	Centralized and Distributed Generation
3	Operation and Maintenance	Manually Check Equipment	Remote Monitoring
4	Restoration	Manual	Self-Healing
5	Power Flow Control	Limited Protection	Adaptive Protection
6	Monitoring	Blind	Self-Monitoring
7	Reliability	Estimated based on Failures and Cascading Outages	Predictive with Real Time Protection and Islanding
8	Customer Interaction	Limited	Extensive

Table 2. Communication Network Technology in Smart Grids.

Index	Metric	ZigBee	Wi-Fi	WiMax	Satellite	4G/LTE	5G
1	Coverage	Up to 100 m	Up to 100 m	Up to 50 km	-	Up to 16 km	Up to 500 m
2	Data Rate	20-250 Kbps	2Mpbs-1.7 Gbps	75 Mbps	50 Mbps	979 Mbps	20Gbps
3	Network Type	NAN, FAN and Premise Network	NAN, FAN and Premise Network	WAN, NAN, and FAN	WAN	WAN, NAN, and FAN	WAN, NAN, and FAN
4	Pros	Mesh Capabilities, Ease of Use, Portability, Affordability, and Low Energy	Excellent For Short Distances	Low Cost and Energy	Good When There Are No Other Choices	Existing Network, Affordable Cost, Strong Security, and Extensive Coverage	Low Energy, Fast Response Times, Fast Data Rates, And Scalability
5	Cons	Limited Range, Low Interference, and Low Data Rate	Low Security	Not widespread, coverage drastically decreased if line of sight is lost	High Cost	Congestion may occur if consumers share the network.	-

3. Related Work

Many researchers and developers have worked on many systems that aim to develop smart solutions for optimal energy utilization. The following are the most prominent posts in this field. Germany has integrated IoT infrastructure and technology solutions to implement a smart grid project in Mannheim [26]. The project has enabled the widespread adoption of renewable energy and the coordination of energy consumption and production in the city.

The Lumin Energy Management Platform is a prime example of IoT applications in smart grids, reducing costs, reducing emissions, and facilitating the adoption of green energy. The company provides intelligent panels and data analysis tools to optimize storage, manage power consumption, and facilitate PV system integration at home [27].

Schneider Electric offers a range of connected solutions for bringing solar energy into your home. The company can equip homes with photovoltaic systems, monitoring and management tools to go completely off-grid, or generate and convert solar energy to partially meet home needs [28].

Cisco [29] is one of the leading providers of smart grids for the Internet of Things. The company, along with several partners, helps a variety of upstream and downstream players adopt connected technology and improve network operations. Their success story includes modernizing BC Hydro. Cisco uses smart metering and advanced analytics technology to improve utility efficiency and reliability.

Siemens has a large share of smart grid solutions in its IoT portfolio. The company offers a variety of software and infrastructure solutions for energy intelligence [30]. One of his customers, German electrical wholesaler Rexel, undertook a major retrofit project and for energy measurement and analysis he integrated a Siemens energy monitoring system. Finally, all previous systems lack a user-friendly application that facilitates waste collection and recycling while having a small, easy-to-use home device for the general public.

4. Proposed Model

We've been working to build a Smart Grid Energy System using IoT and PV panel. The basic operation of the system is similar to that of the conventional system only that the source of energy in the PV system is solar radiation. Other important elements of the system are used in synchronization for the appropriate power distribution, storage etc.

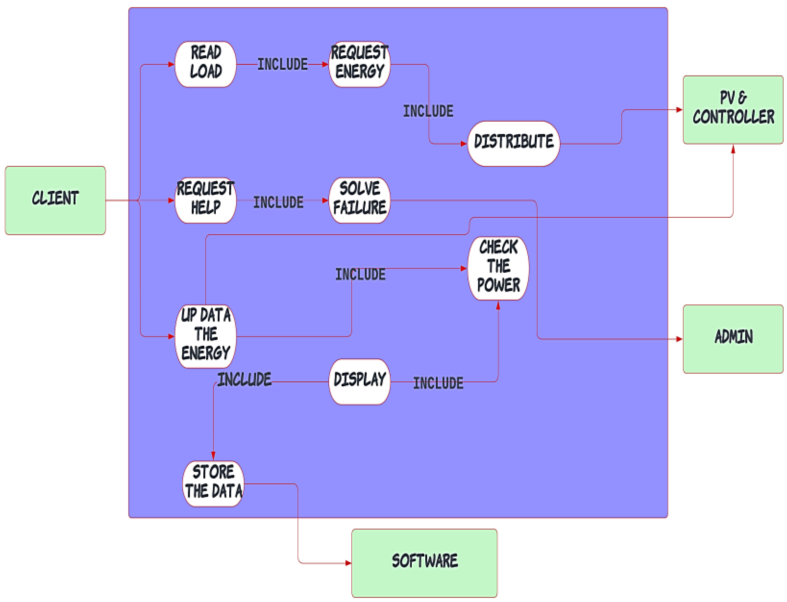


Fig.6. Proposed System Use Case Diagram.

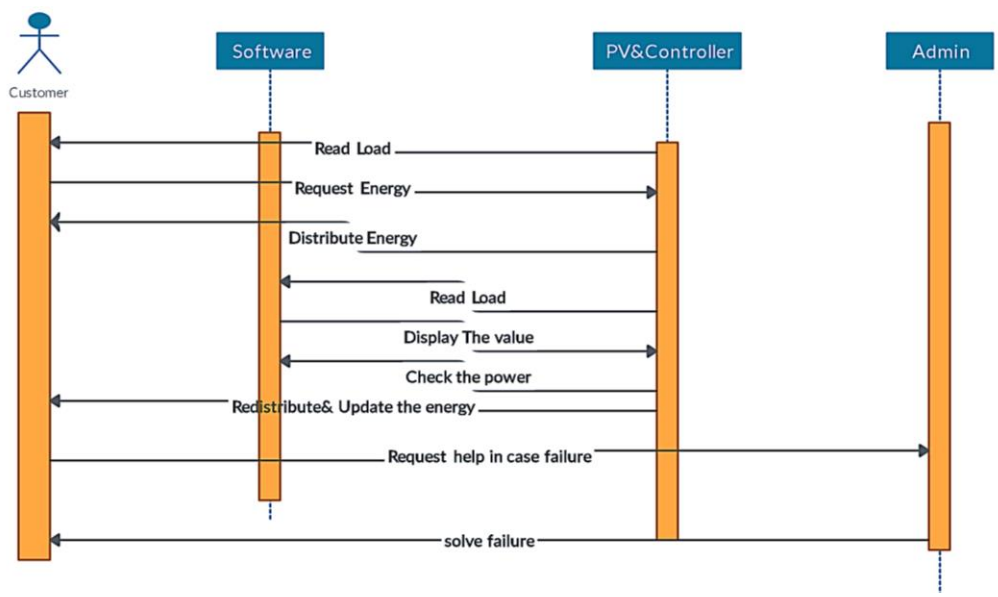


Fig.7. Proposed System Sequence Diagram.

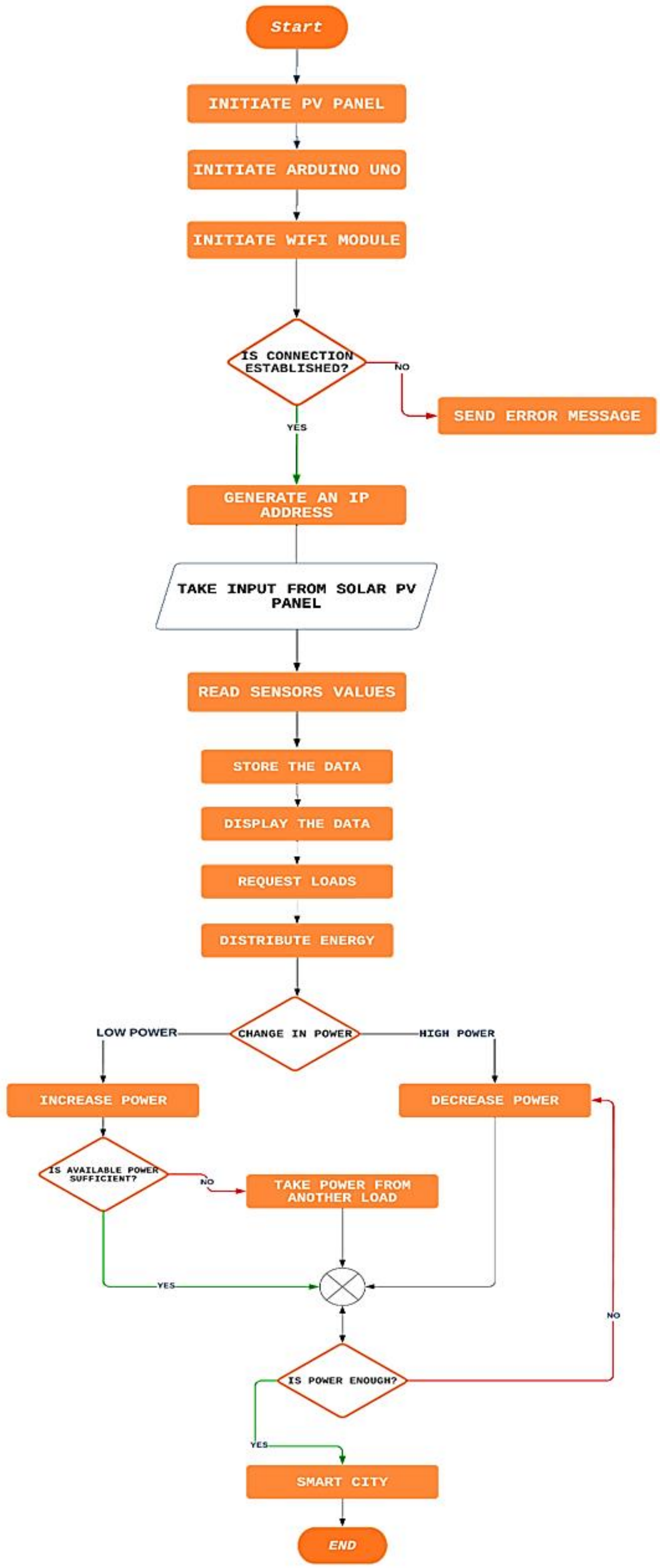


Fig.8. Proposed System Flowchart.

4.1. System Analysis and Design

In this simulation, PV solar panel model using solar cell model available in Simscape library in MATLAB. 36 solar cell are connected in series. Each solar cell having short circuit current of 8.9A and open circuit voltage of 0.632V.

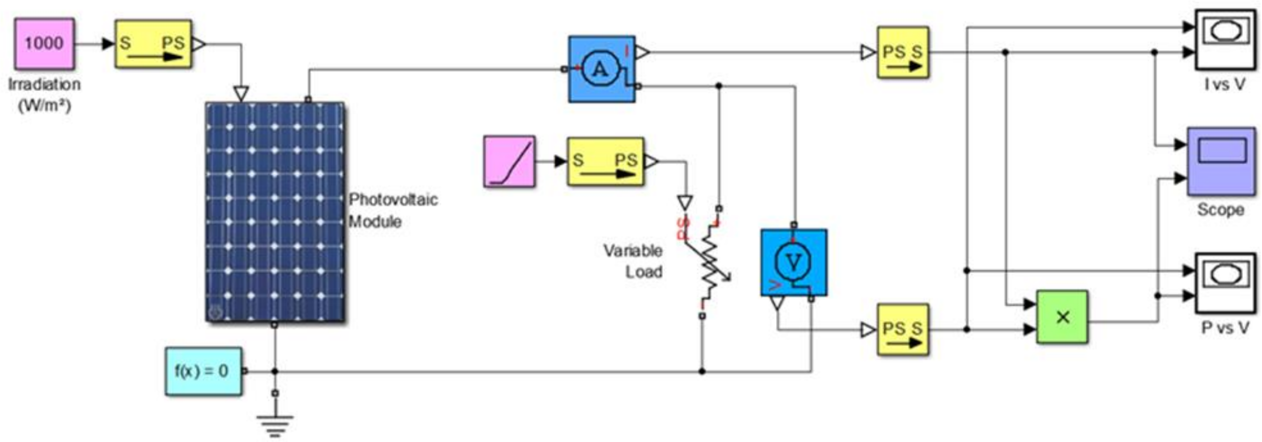


Fig.8. System Workflow.

Table 3. Standard test condition

Parameter	Symbol	Value	Unit
Irradiance at normal incidence	G	1000	Wm2
Cell temperature	T	25	0C
Solar spectrum	AM	1.5	-

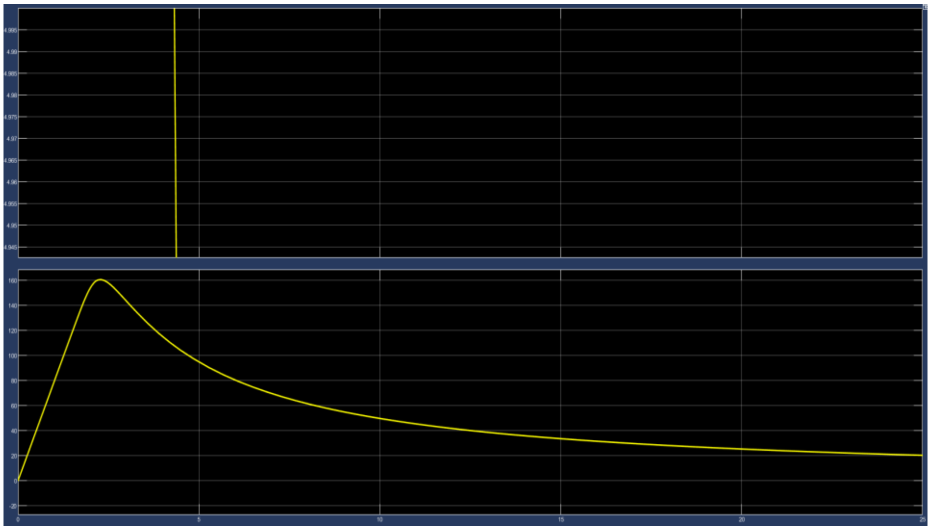


Fig.9. Scope Result.

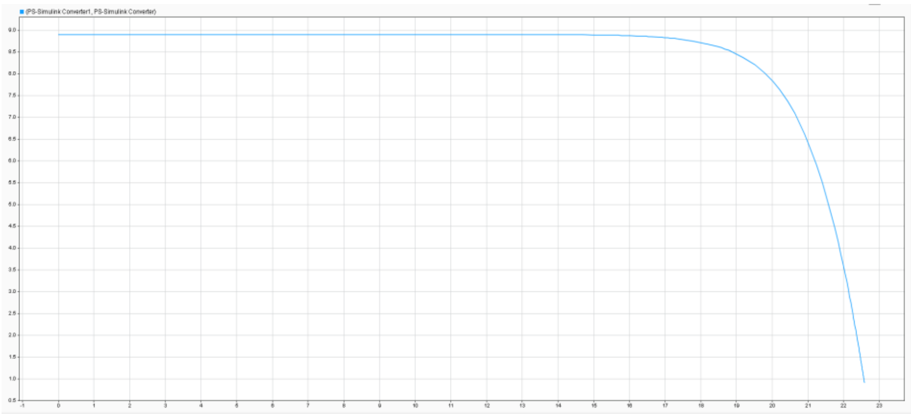


Fig.10. I (current) vs V (voltage) Result.

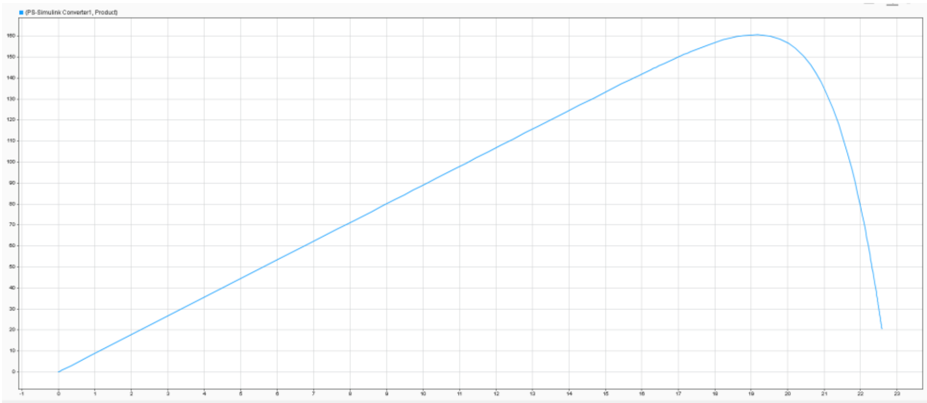


Fig.11. P (power) vs V (voltage) Result.

4.2. Methodology and Hardware Requirements

Table 3 discusses the required hardware for the proposed system.

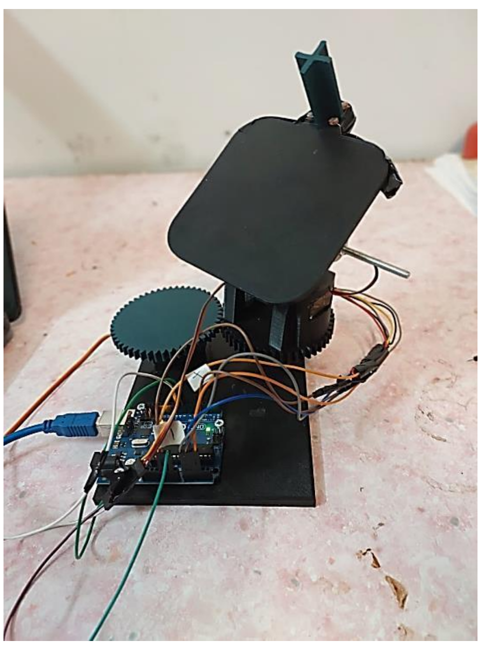
Table 3. Hardware Requirements and Corresponding Cost in L.E.

Index	Component	Price in L.E.
1	Atmega 32 microcontroller	290
2	Current sensor module (ACS712)	84
3	Energy meter	358
4	Wi-FI Module	100-125
5	LCD display	200
6	Crystal oscillator	2
7	Led	32
8	Capacitors	1-5
9	Transistors	1
10	Cables and connectors	92
11	Diodes	0.5-20
12	PCB and breadboards	32
13	PCB and breadboards	50
14	Adapter	35
15	Transformer	65
16	Push buttons	25
17	IC	18
18	IC sockets	30
19	Arduino UNO	353
20	Rain sensor module	100
21	Servo motor	78
22	DC motor	208
23	L293D motor driver	52
24	DHT11	94
25	Solar panel	500
26	LDR sensor X2	36
27	Rotary potentiometer	3.50

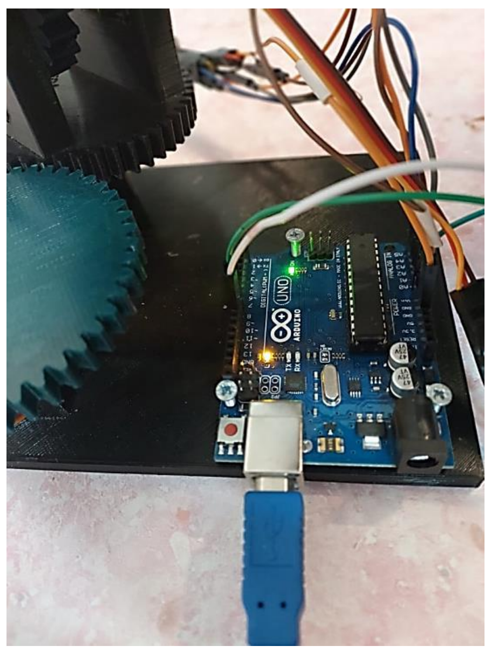
5. Results

Figure 12 (a, b, and c) presents the implemented PV controller circuit of the proposed system.

(a)



(b)



(c)

Fig.12. PV Panel Controller.

6. Challenges and Future Research Directions

To cope with the abovementioned issues and challenges, the subsequent guidelines for the development of IoT-primarily based totally clever strength structures are made [31-35]: (i) The framework and modeling of clever strength grids must be improved, and appropriate reconfiguration technology need to be advanced for the healing issue of energy grids. (ii) Secure AMI technology need to be broadly deployed in mixture with superior cloud and edge-computing centers and 5G telecommunication technology to beautify the capability and safety of the clever grids. (iii) Smart grids need to be geared up with extra stable conversation protocols that bear in mind the heterogeneity of IoT gadgets even as permitting the deployment of AI algorithms. (iv) onto the tool itself in place of being managed from afar to lessen the probability of conversation breaches. Advanced stable and records conversation structures primarily based totally on blockchain strategies need to be appreciably applied in IoT-primarily based totally clever strength structures.Figure 13 summarizes these and future research directions.

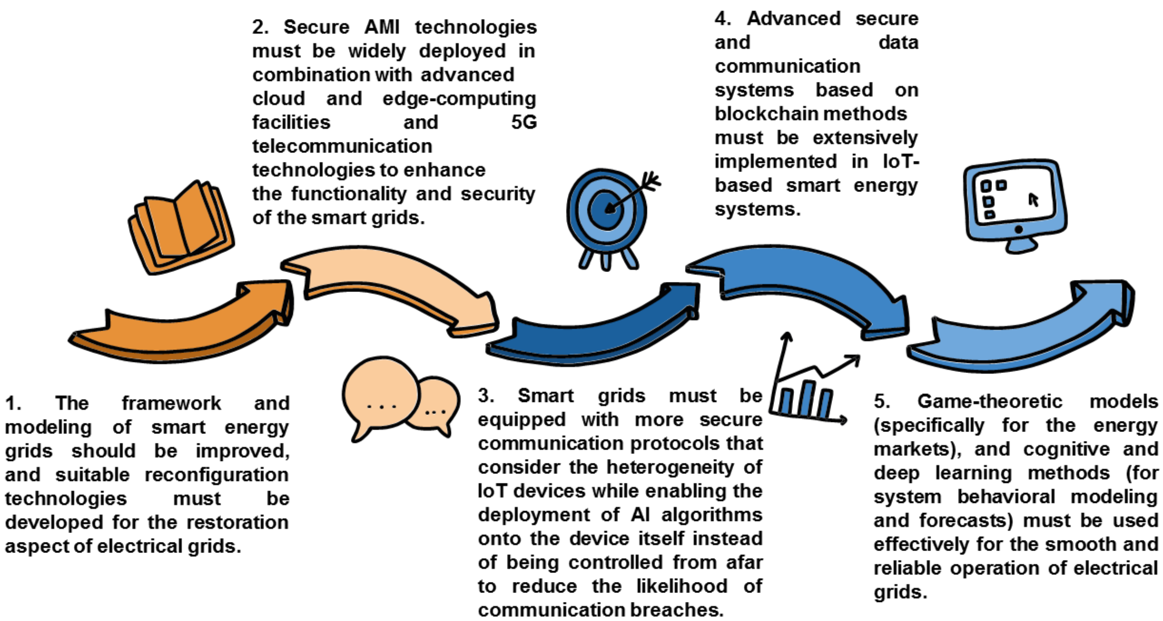


Fig.13. Challenges and Future Research Directions.

7. Conclusions

The Internet of Things (IoT) is the next step towards global pervasive connectivity to any device capable of communication and computing, regardless of access technology, available resources, or geographic location. The smart grid is the largest he IoT implementation using smart devices distributed throughout the energy chain from power plants to final consumers. IoT will enhance the existing smart energy grid by enabling real-time control and monitoring of grid components. However, over the past decade, as described in the literature, cybersecurity has been viewed as one of the major barriers to his IoT adoption and further deployment in smart energy grid systems worldwide. Due to the enormous number of devices connected to communication networks, which raises the possibility of a cyberattack and the danger of serious consequences, it is difficult to assure the safety of grid-connected devices. With the continued integration of IoT-enabled devices in smart grids, the size of the attack surface will become significantly larger in this regard.

8. Acknowledgement

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