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Original Article

A Model Design of Green Communication for Smart Grid Systems

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Abstract - *The electricity grid's upcoming update will be called Smart Grid. It covers all power production, management, transmission, distribution, and use aspects. It uses a variety of renewable resources to produce energy. The user and control unit can communicate in multiple directions. For smart grid applications, various wired and wireless technologies are available. We prefer wireless technology to wired technology because it has many advantages. Key wireless technology features are critical for rapid deployment, mobility, and inexpensive installation costs. This work uses solar cells, wind turbines, and water turbines to produce energy. Energy is produced by the generation unit and sent to the control unit. After that, the control unit gives to the user by their instructions. The critical attribute of the smart grid is that it improves the economy, agility, efficiency, reliability, and security.*

Keywords - *Prediction, Data mining, Decision tree, Random forest, Regression process.*

1. Introduction

A GRID network comprises various lines that cross one another to form a matrix. Electricity travels along the lines, which are electrical cables. These grids can be classified as old grids and smart grids. Power is distributed via cable lines in the old grid. There were a few significant lines through which the power was distributed. Feeders are the term for these lines. To deliver electricity to users, they had switches that had to be manually closed and opened. Every time a short circuit occurs, one must manually check everything, which is dangerous and would need much time to patch again. We discovered the POWER GRID or SMART GRID to solve this problem. The future of electricity and data transmission lies in the Smart grid [1]. An electrical system that uses various operational and energy-saving technologies, such as smart meters, smart appliances, and renewable energy sources, is known as a "smart grid." Essential components of the smart grid include electronic power conditioning [2], production unit control [3], and distribution of electricity [4, 5]. The applications where smart grid is used are shown in figure no. 1. It shows the diverse applications of the smart grid, highlighting its versatility and impact across different sectors and industries. The smart grid offers numerous benefits and possibilities, from enhanced energy management to improved reliability.

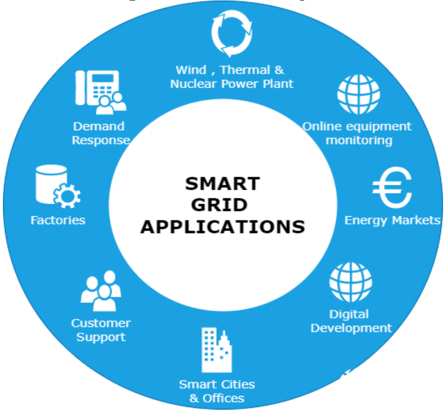

Fig. 1 Smart grid applications

Given the rising importance of environmental sustainability, green communication in smart grid systems has gained significant attention. The integration of renewable energy sources and the need to reduce greenhouse gas emissions have driven the exploration of eco-friendly communication models for the smart grid.

2. Literature Survey

Green communication for smart grid systems has become an increasingly important topic in recent years due to the rapid development of renewable energy and the need to reduce greenhouse gas emissions [6]. This literature review will examine various model designs for green communication in smart grid systems and their potential benefits. One proposed model design for green communication in smart grid systems uses energy-efficient routing algorithms. In a study by Zhang et al. (2018), a routing algorithm based on particle swarm optimization was proposed to minimize energy consumption in wireless sensor networks for smart grids [7, 8]. The results showed that the proposed algorithm outperformed other algorithms regarding energy efficiency.

Another proposed model design is the use of energy-efficient communication protocols. In a study by Nasrin et al. (2018), an energy-efficient communication protocol was proposed for smart grid systems using a hierarchical routing approach. The results showed that the proposed protocol reduced energy consumption and improved network lifetime [9].

Furthermore, using renewable energy sources to power smart grid systems has also been proposed as a model design for green communication. In a study by Han et al. (2018), a renewable energy-powered wireless sensor network was proposed for smart grid systems. The results showed that the proposed system could reduce greenhouse gas emissions and improve energy efficiency [10].

Moreover, machine learning algorithms have been proposed as a model design for green communication in smart grid systems. In a study by Singh et al. (2020), a machine learning-based energy-efficient routing algorithm was proposed for smart grid systems [11]. The results showed that the proposed algorithm improved energy efficiency and reduced energy consumption. In conclusion, the model designs discussed above promise to improve energy efficiency, reduce greenhouse gas emissions, and increase network lifetime in smart grid systems. However, more research is needed to determine their feasibility and scalability in real-world smart grid systems.

Based on the literature review, there are gaps in the current smart grid communication system. The traditional communication systems may not be able to handle the growing demand for renewable energy sources and the need to reduce greenhouse gas emissions. New communication systems are needed to integrate renewable energy sources and facilitate green communication in smart grid systems. The literature survey presented above highlights the importance of green communication in smart grid systems and provides insights into various model designs that can facilitate sustainable and efficient communication.

The increasing use of renewable energy sources and the need to reduce greenhouse gas emissions have made it necessary to develop new communication systems that can handle the complexity of smart grid networks. Therefore, the need for a new system of green communication for smart grid systems is essential to address the limitations of traditional communication systems and achieve sustainable and efficient smart grid networks. The proposed model designs provide a foundation for developing a comprehensive framework that integrates different aspects of smart grid communication, such as renewable energy sources, energy-efficient routing, and communication protocols, to achieve a sustainable and efficient smart grid communication system. Systems-of-systems make up smart cities, including energy, transportation, and others. Since the city is a complex entity [12, 13] and each of its systems is autonomous in its structure, operation, and behaviour while connected and cooperating to produce the emergent global features the city displays, one must speak of systems of systems [14].

We can analyze the intelligence of smart cities at least three different levels [15].

1) Technical intelligence at the component level:

All components can become "smarter" by a) extending access to input data, such as that from sensors, relevant for situational awareness regarding its operational conditions; b) processing the input data in a predictive or adaptive manner; and c) transmitting the output information to the pertinent command and control units, and the final actuators necessary for carrying out the needed actions.

2) System intelligence is a system's ability to perform tasks autonomously by coordinating and synchronizing the actions of its numerous components while communicating with other systems. The smart system satisfies various demands, including cost, energy, and environmental goals [16].
3) System-of-systems intelligence: Systems-of-systems comprise several independent, autonomous systems collaborating to achieve larger objectives. In this sense, a smart city is a system of systems that integrates energy, transportation, water, and building systems. Its smartness refers to its ability to manage, connect, and adapt its various resources and functionalities (including technical, economic, and social factors) to achieve those objectives [6]. A smart grid would employ a smart meter to detect consumer needs and send requests to the generation unit by those needs [17,18].

2.1. Collation of Communication Infrastructure Between the Legacy Grid and The Smart Grid

The current communication infrastructure, a legacy power grid, is used only in unidirectional power flow from central power plants toward consumers, with limited efficiency and information sharing. These systems are primarily used for data acquisition with restricted sensors in the main transmission and distribution points, faults detection and a limited number of control signals transmission. The data acquisition is performed by Supervisory Control and Data Acquisition Systems (SCADA) [19, 20]. The smart grid has a much greater number of sensors and actuators than the legacy grid. They are dep-loved at all levels of the grid components: Power plants and substation equipment, generators, transformers, and home users. The sensors are used for data acquisition and information exchange between equipment and data centers. The actuators are used for optimal control of all grid components. To handle such vast data flow, the smart grid must have upgraded, reliable and robust communication infrastructure to provide real-time secure communications. The communication infrastructure must have wide bandwidth to ensure a high rate of information flow. Furthermore, the communication infrastructure must be self-healing and automatically adaptive to changes [21].

There are certain benefits of the smart grid over an outdated system. Because we have used wireless technology, the smart grid is more dependable because it enhances mistake detection and enables the network to self-heal [22]. Network topology flexibility is vital since traditional grids were built for one-way communication while smart grids are built for two-way communication. Thus, it is more adaptable than a traditional grid. Load adjustment depends on the user's needs; the load may be raised or changed over time. To generate additional loads using various renewable resources, the smart grid will alert the user about the current load [23].

Wireless communication has created a path between the user and the distributor. Wireless communication sends data or power to numerous locations that are not wired together. Radio waves, for example, are frequently utilised in wireless technology [24]. These radio waves can cut distances by hundreds of meters for Bluetooth and millions of kilometres for deep-space communication. It includes several mobile and portable applications, including wireless networking, cell phones, and two-way radio. There are various ways to create wireless communication, including using sound, light, or other wireless technologies like a magnetic, electric, or electric field. Wireless technology transfers data without the usage of wires [25, 26]. Smart grid uses bi-directional information flow to modify smart applications on the customers' side to save energy intake and lose the subsequent outflow. Meanwhile, grows network stability and transparency [27]. Smart metering and tracking structures assist in establishing feedback to manipulate mechanisms for actual-time power intake and correspond with the call for to/from utilities [28]. A detailed description of ICT's role in enhancing grid automation in each power area is provided in the following sub-sections [29, 30]. The power flow and information flow are shown in figure no. 2.

3. Hardware

The generation unit, a crucial component of a smart grid, was created using three renewable resources. They are as mentioned below:

- Solar panels: Solar panels are a renewable energy source that has been incorporated into the generation unit of the smart grid. It will provide 6 volts of power. As it will only use sunshine to produce power, solar panel plays a crucial part in smart grids because of their poor expression capability.
- Windmills: As a renewable energy source that has been incorporated into the smart grid and as a readily available resource for power grid generation, windmills are also a highly significant and practical part of power generation for the smart grid. It will produce 3 volts of power.
- Hydraulic power plants: These plants use water to produce electricity. The pump will produce 12 volts of power as we increase the pressure inside of it using water (max). We can increase and reduce the hydraulic power plant's power based on the water pressure. It is utilized in the smart grid's generation unit.
- When all three are combined, power may be produced to charge two 18-volt batteries.
- Control unit: This unit would regulate the flow of energy and, if more were to be produced, would store it in the battery. The primary critical unit is this. A. The Arduino is a gadget that regulates the production and transfer of power.
- When we supplied 55 volts to Arduino, the output displayed 5 volts.
- Wireless communication has been done using the USRP (universal software radio peripheral). Software frequently uses it to define radio. There are two ports on it, one of which is a transmitter and the other a transceiver. Although a transceiver has been used to transmit and receive information, the transmitter can only send data. Through USRP, the antenna has been utilized to transmit and receive data. Depending on the length of the antenna, we can send and receive data. USRP can serve applications that operate between DC and 6 GHz.
- Relays function as switches because they open and close circuits as needed. Therefore, a relay controls an electrical circuit. When the batteries are insufficient to charge, smart grids function similarly to a controller and switch to charger mode to charge the batteries. However, after the battery is fully charged, the relay creates a circuit to allow a user to use the power efficiently.

Four users have been used in this unit. They are fans - as our first users, we used a fan. The fan's motor requires 5 volts to operate, which is why the fan is fixed.

We have a second user of led-led. It dissipates 0.05 watts of power and has a forward current of 20 Ma; 5 volts would make it.

4. Software

A tool called Laboratory Virtual Instrument Engineering Workbench (LabVIEW), created by the national instrument, is used to develop environments and design systems using graphical programming. It is crucial to distinguish G-code from the graphical language. The system design process uses this software. This is used on various operating systems, including Windows, Linux and UNIX versions, industrial automation, instrument control, and data collection. LabVIEW 2018 is the most recent version, made available in May 2018.

4.1. Data Flow Programming

The G programming language, a dataflow programming language, has been utilized. The program in this language takes the shape of a graphical block diagram, on which the programmer connects the various function nodes by drawing wires. These wires propagate variables, and once all the node's data is available, any node can be used to carry out the operation. Given that numerous nodes may experience this simultaneously, G can complete inherently in parallel. The built-in scheduler has automatically utilized a variety of multiprocessing and multithreading hardware to multiplex several OS threads among the nodes prepared for execution.

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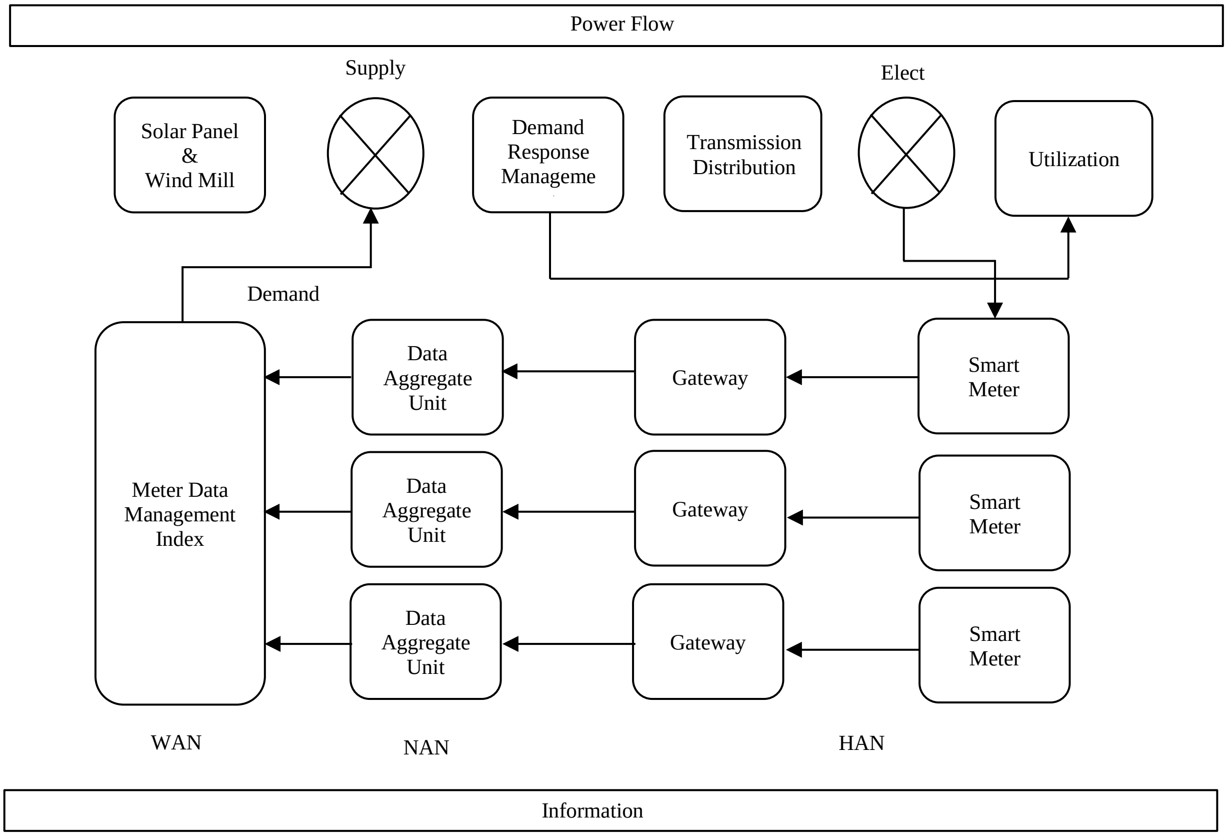


Fig. 2 Information and power flow in smart grid

The built-in scheduler has automatically utilized a variety of multiprocessing and multithreading hardware to multiplex several OS threads among the nodes prepared for execution.

4.2. Graphical Programming

Creating user interfaces, often known as front panels, is integrated into the development process by LabVIEW—the LabVIEW program subroutine for virtual instruments. Three parts comprise a virtual instrument: a block diagram, a front panel, and a connector panel. In the block diagram of others, they are referred to as VIS; the connector panel is utilized to depict the VI. Two items, such as controls and indicators, are on the front panel. The control section receives inputs, enabling the user to transmit data to the VI. Indicators provide output as they do or exhibit or display the outcomes depending on the input given to the VI. The entire graphical code is included in a panel known as the rear panel.

The block diagram will show terminals for items placed on the front panel. Additionally, several structures and functions in this back panel or block diagram area operate on controls and provide information to indicators. The top of the back panel can be used to position the function palette, which is a palette that contains all the structures and functions. Nodes are referred to as such because they contain all the indicators, structures, controls, and functions. Two indicators and four controls can be attached to the subtraction function for the indicator to display the output as the difference of four controls utilizing one indication at a time. The front panel of a virtual instrument may therefore be used to define the inputs and outputs for the node when it is dropped as a node into a block diagram or run as a program with the front panel acting as the user interface. This demonstrates the ability to test every VI before including it as a function in a more extensive program.

This method of creating programs graphically by dragging and dropping virtual representations, which they are highly familiar with from lab equipment, is for non-programmers. Because it has so many examples and documentation, is a little application and is extremely easy, anyone can understand this LabVIEW programming. This is one of the advantages, but one should not believe that understanding or learning it will be simple; high-quality G programming requires specialists.

Depending on the goal, algorithms can be either sophisticated or straightforward; thus, a programmer must be well-versed in the unique LabVIEW syntax and the memory management architecture. Large-scale coding for complex algorithms will be required, and it must be done carefully. This LabVIEW program can create an independent application. Additionally, this LabVIEW application software makes it simple to design a distributed application. Since the client-server architecture would be used to communicate with these distributed apps, it is simpler to construct due to G's inherent parallelism.

4.3. LabVIEW Communication Suite

When LabVIEW communication is used with LabVIEW NXG and its tools, one may quickly demonstrate wireless communication. NI real-time operating systems, FPGAs, and general-purpose processors are just a few examples of the hardware targets that LabVIEW makes it easy to design, build, and deploy wireless communication systems too. The most crucial aspect is that a graphical programming technique can shorten the time required to authorize an algorithm with signals over the air (OTA). We have saved time by utilizing graphical programming in a single environment for LabVIEW communication.

The best part is that all the necessary components are included so that we can create your design, implement it in software, and quickly implement it in hardware if the design is successful. It supports a variety of devices, including FGPA hardware. We have designed the transmitter and receiver, the two primary components of the LabVIEW communication suite, for our smart grid. Implement our design in software, and if the design is successful, quickly implement it in hardware. It supports a variety of devices, including FGPA hardware. We have designed the transmitter and receiver, the two primary components of the LabVIEW communication suite, for our smart grid.

5. Methodology

This flowchart in figure no. 3 outlines the capabilities of the smart grid concept that we developed.

5.1. Users Generating Requests

This block covers a variety of procedures that are essential to the user's request for efficient operation. It comprises several gadgets the user uses to request the necessary units. After processing, it is given to them in generation-by-generation units. Here, the many methods employed include Requesting something from the control unit and getting the control unit's generated power. First, the user will timely request the power consumption he needs, which can range from 0 to 600 units. The control unit will get the request to produce the required power.

Second, the control block will communicate the necessary amount of electricity to the user, which the generation unit produces. In an emergency, the remaining power can be routed from RPS, but only this quantity of power is what the user needs.

5.2. Control System

To make up the control unit, one can first obtain a request from the user and then send it to the generating block after obtaining the necessary power-generated acknowledgement from the generation block. In the digital realm of the smart grid, the control unit functions as a translator, converting the user's power requirements into a language that the generating block understands. It ensures clear communication and accurate power delivery, enabling a seamless user experience. The control unit conveys the user's power transmission needs with precision and clarity through its communication format. The address signifies the destination of the electricity, while the number of units reflects the specific power requirement, leaving no room for ambiguity. The control unit completes the feedback loop by delivering the requested power and providing an acknowledgement, reassuring users that their electricity needs have been met. It instils confidence in the smart grid system, fostering trust and reliability.

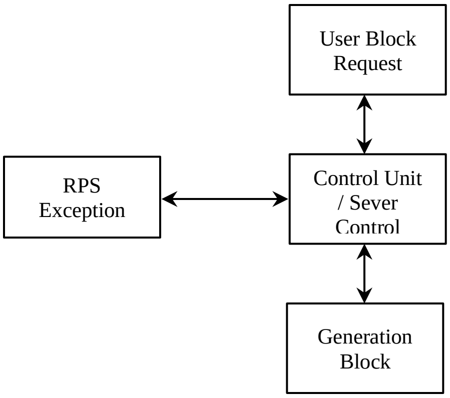


Fig. 3 Capabilities of smart grid

Giving us recognition for the power we have generated. First, the control block in this situation oversees receiving the user's request for generating electricity. The generating block receives the request from the control block and gives it to it. Second, as soon as the generation block receives the user request, it generates the closest high-order number and gives the user the necessary power, reserving the additional power produced in the RPS (Reserved Power System). The control unit subsequently distributes the generated power to the user so that true smart power transmission occurs. After the excess power is stored in the RPS, the generated power, as the user requested and acknowledged, is delivered to the control unit. The control unit then communicates data in the following format: First, the address where the power is to be transmitted, followed by a semicolon, the number of units needed, and again followed by a semicolon.

5.3. Unit of Generation

The generation block's primary purpose can be summed up as taking note of the control unit's request, producing the necessary number of units, or delivering the created unit along with an acknowledgement to the control unit. An essential component of the smart grid architecture is the generation unit. The energy-generating equipment uses water turbines, windmills, and solar panels to produce electricity without harming the environment. When the generation unit receives the information from the control unit, it immediately generates the required amount of electricity for the user. When the energy is produced, the control unit receives the energy requested by the user, while the excess energy is stored in the RPS (Reserved power system). The output voltage of a solar panel is directly proportional to light intensity (LUX).

5.4. Power Reserve System

The control unit then passes the units to the user when the generating unit generates the necessary number of units as requested. When the generation unit produces the necessary number of units, more may be produced than the user requested. Thus, those units are transferred to the system of reserved power. In an emergency, you can use this power that has been reserved. The RPS enters the picture if the user needs additional units, if demand unexpectedly rises, or possibly if there is a sudden demand for the units in terms of the unit. Additionally, it stores any power the user may produce for their usage. It serves as a reserve for all the units, preventing waste and enabling use in the event of an unexpected rise in demand. The above-defined blocks are the main parts of a smart grid model. The software also supports these blocks. These blocks and the programs designed in this software make the unit.

The LABVIEW Communication Suite 2.0 and LABVIEW software is the heart of this smart grid model. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a widely used system design and development platform. It provides a graphical programming environment where engineers and scientists can create applications by connecting functional nodes in a block diagram structure. LabVIEW includes strong data visualization, analysis, and presentation features. It has several built-in graphical user interface (GUI) components that allow users to design interfaces to display obtained data, analyse outcomes, and generate reports. There are several VI that together combined work as a single unit to run this model.

The programs written in LABVIEW OR LABVIEW Communication Suite 2.0 are known as VI. The software domain is subdivided into three main VI. Those VI are as follows:

- The VI for transmission of message (at user end)
- The VI for receiving a message (at the control unit)
- The VI is for controlling the hardware.
- The VI for transmission of the message (at the user end)

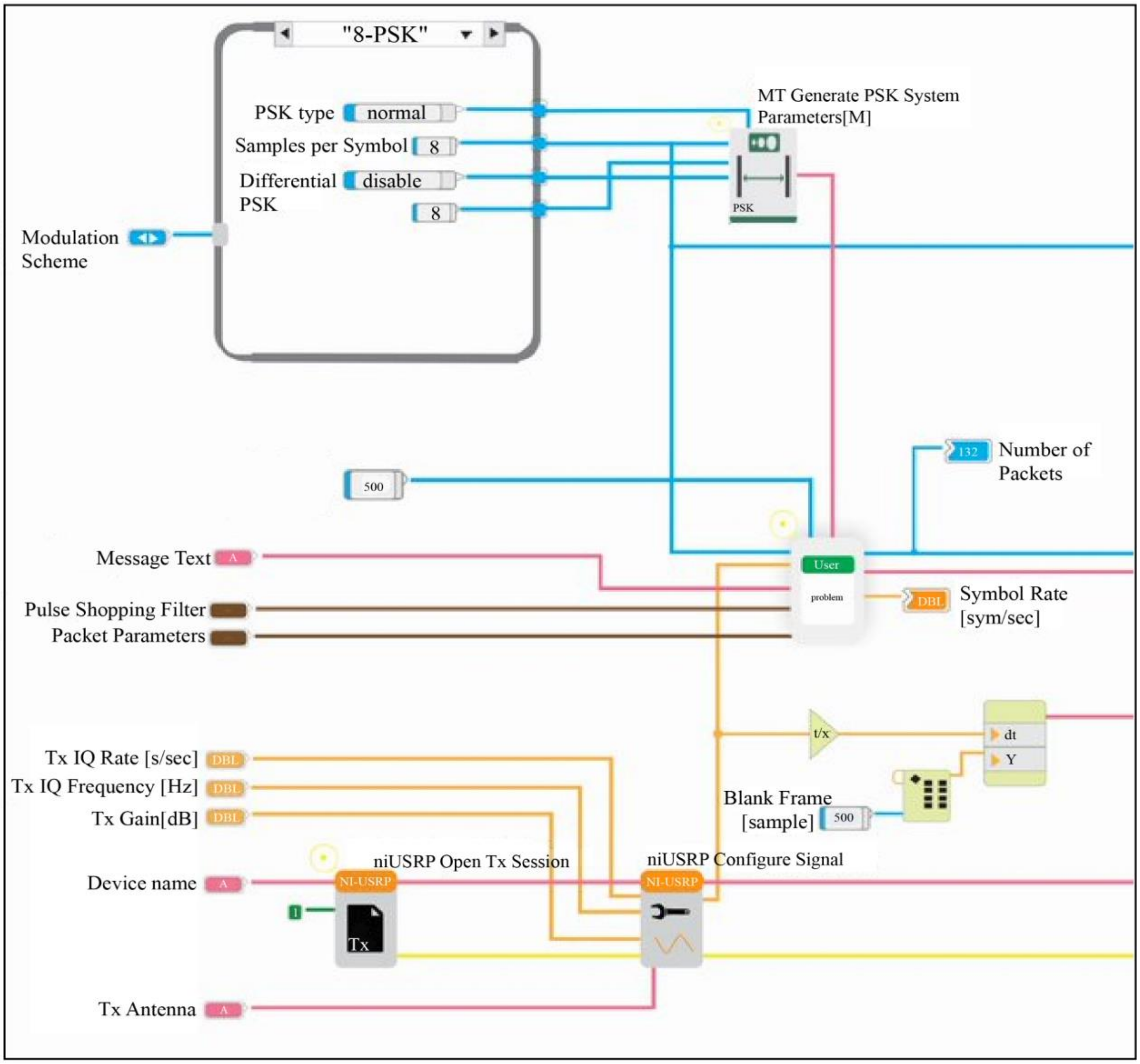


Fig. 4 VI LabVIEW communication suite 2.0

For designing this, VI LABVIEW Communication suite 2.0 software was used. The primary function of this transmission VI is to transmit user data or generate a user request.

The user data comprises the user address and the units required by the user for daily use. Initially, we used the block in our software to generate a format for the user request. This is done so that the transmission and the receiving of the data are not a problem, and the programming at the user end also depends on the same. After designing the format for the generation message, as shown in figure no. 4, we designed the modulation technique to convert the information from text to code that can be transmitted using the antennas. Further, we configured the USRP to transmit the code.

USRP is an essential hardware tool that is responsible for the transmission and reception of message signals. The modulated text is converted into a queue and transmitted bit by bit to prevent packet loss and maintain the code's positional composition.

Block Diagram Panel of current data that is being processed. The user can enter data here, convert it into packets and then send it to the VI at the control unit with the help of a tool known as USRP. For designing this VI, we, too, used the LABVIEW Communication suite 2.0 software. In layman's terms, the all-over working of this VI is the reception of the user request. So, to receive the user request, we first configured the USRP to receive the user request.

As shown in Figure 6, the message received is logged into a file for our VI controlling the hardware domain to work with after this process. As shown in figure no.7, this is the front end of the block diagram that controls and makes it easier for a user to control the entire block diagram. With an intuitive design and interactive features, users can effortlessly navigate and command the various components of the block diagram, empowering them with complete control and ease of operation. Figure 8 shows Power Generation Unit, Whereas figure 9 shows Control Unit shows User Request.

After the configuration, the next task is to sense the type of modulation used to send the signal by the transmitter. After confirming the modulation technique and automatically changing the settings, we defined a mechanism to receive the message packet by packet.

As shown in Figure 9, the message received is logged into a file for our VI controlling the hardware domain to work with after this process. Figure 4 is the front end of the block diagram that controls and makes it easier for a user to control the entire block diagram. Receiver. We can see user received power in figure no.8.

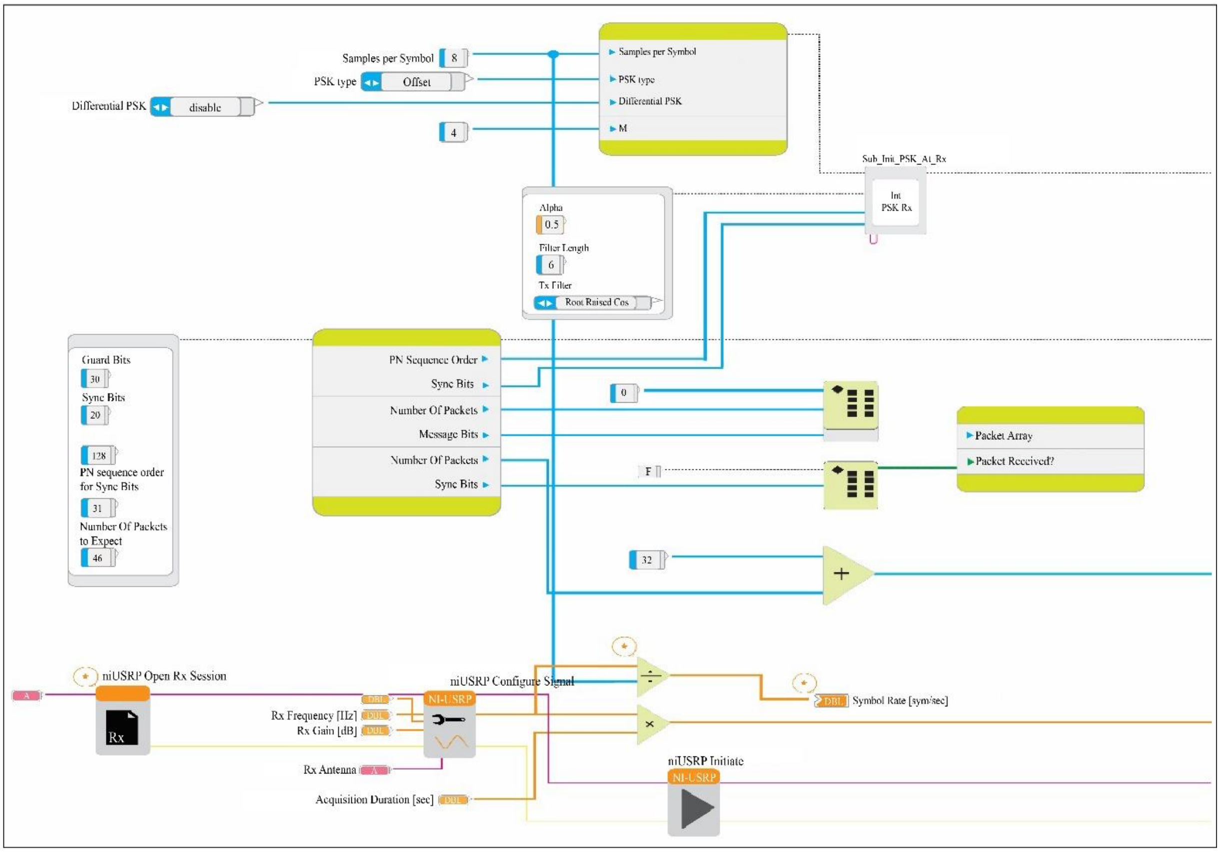


Fig. 5 The VI for the reception of the message (at the control unit)

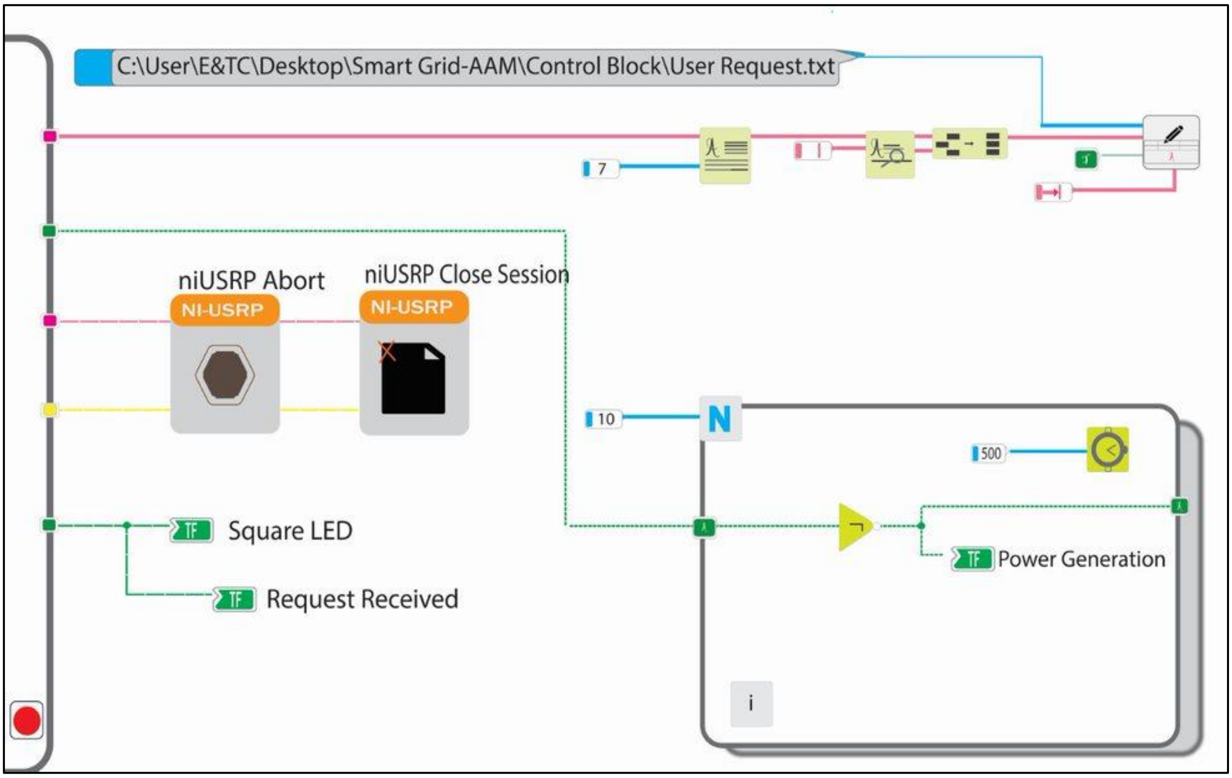
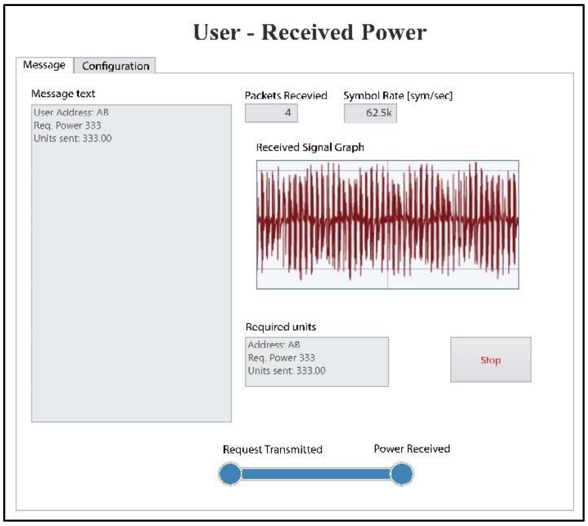


Fig. 6 The VI for the reception of the message (at the control unit)

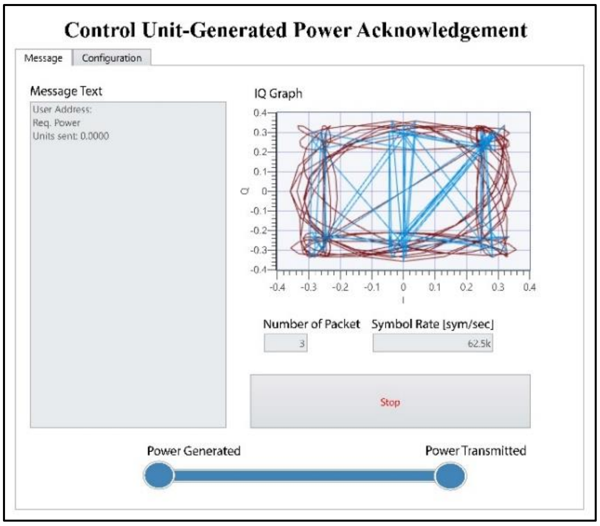


Message text
User Address: AB
Req. Power 333
Units sent: 333.00

Packets Recevied: 4
Symbol Rate [sym/sec]: 62.5k

Required units
Address: AB
Req. Power 333
Units sent: 333.00

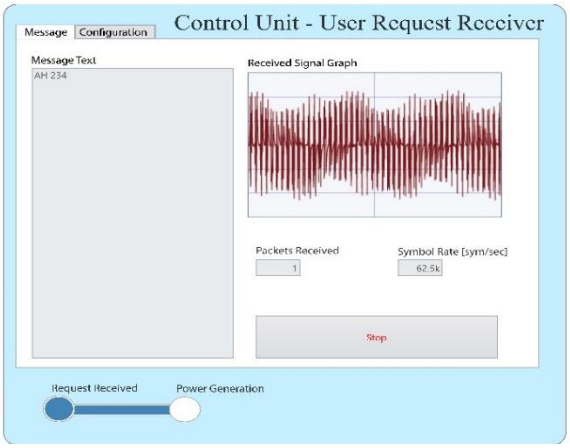
Fig. 7 User received power



Message Text
User Address:
Req. Power
Units sent: 0.0000

Number of Packet: 3
Symbol Rate [sym/sec]: 62.5k

Fig. 8 Power generation unit

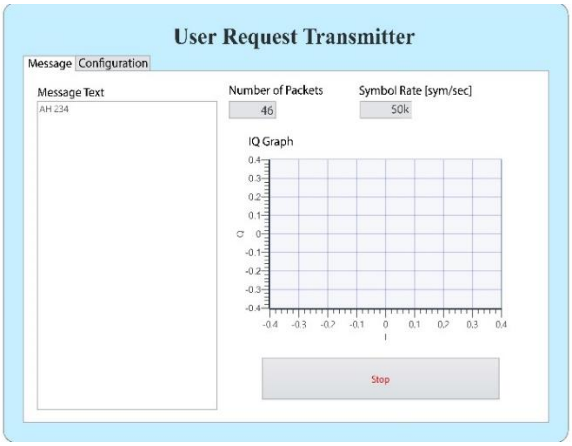


Message Text: AH 234

Packets Received: 1

Symbol Rate [sym/sec]: 62.5k

Fig. 9 Control unit shows user request receiver



Message Text: AH 234

Number of Packets: 46

Symbol Rate [sym/sec]: 50k

Fig. 10 User request transmitter

5.5. The VI to Control the Hardware

For this VI, we used the LABVIEW software and first configured the Arduino with the LABVIEW software. This is done to make the Arduino work as directed by the VI design. The data that this VI then accesses the VI logs in for reception for further processing. This is followed by a unit solely dedicated to data parsing, i.e., acquiring valuable data for further use. First, the address is abstracted from the message, and then the unit request is extracted from the message signal, as shown in Figure 7. After abstracting the data, the primary process starts. Where the unit by the users is compared, and then the main battery is supplied with specified power. Then this is forwarded to the battery at the relay side. This transfer of the units from the main battery to the battery at the user end is controlled via relays.

The relays are like a switch that completes the circuit if and only if supplied with a threshold voltage. This threshold voltage controls the flow in and out of the relay. If the voltage is supplied, the relay will complete the circuit, leaving the circuit completely broken. Figure no. 7 shows Control Unit shows User Request Receiver. This shows the current data being processed and the reserve battery voltage that RPS, the place where the data is logged and from where the VI can abstract data, the renewably generated voltage, and it gives the idea of the units required by the user.

6. Future Scope

India is the world's third-largest transmission and distribution network and still faces problems of inadequate electricity supply, poor quality, network losses and reliability. To overcome these problems, the smart grid is the best solution as it generates energy from various renewable resources such as wind, water, and solar. In the current generation, we are taking energy from the government according to the consumption we are paying them. However, for the future, we are proposing a smart grid system that will encourage an individual to generate energy. Due to the rules and regulations of India, we cannot directly use that energy. We will transmit that generated energy to the government grid. We must pay for the energy according to the total generation and consumption. Let us assume that if we are generating more energy than our consume, then the government will pay us for that extra energy that we are generating. If we are generating less energy than our consumption, then we must pay for that extra energy that we are consuming.

7. Conclusion

A smart grid is a next-generation power grid. It includes power generation, management, transmission, distribution, and utilization. The main features of a smart grid are that it is highly efficient, reliable, and secure. There are various wired and wireless technologies available for smart grid applications. In this project, we are using wireless technology-based Lab View software. Power distribution in the smart grid is simulated using Lab View. In this project, we generate energy through solar, wind and water turbine. The solar panel will generate 6V power; Windmill will generate 2V power, and the water turbine will generate 6V power. The control unit will distribute this generated energy to the users according to their request if generated energy is more significant than the consumed energy. The excess energy can be stored in energy storage systems such as batteries or fed back into the primary power grid. This allows for efficient utilization of renewable energy sources and reduces reliance on traditional fossil fuel-based power generation.

Furthermore, wireless technology-based Lab View software enables real-time monitoring and control of power distribution in the smart grid. This enhances the grid's efficiency by optimizing the allocation of energy resources and minimizing wastage. In conclusion, implementing a smart grid with wireless technology-based Lab View software and renewable energy sources offers numerous benefits. It promotes sustainable energy generation and improves grid efficiency, reliability, and security. By harnessing the power of advanced technologies, we can pave the way for a greener and more sustainable future.

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