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CONTROL AND MANAGEMENT OF SOLAR PV GRID USING SCADA SYSTEM

May ALSHIBIL

Master's Thesis

Supervisor

Asst. Prof. Dr. Sefer KURNAZ

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The thesis titled “CONTROL AND MANAGEMENT OF SOLAR PV GRİD USİNG SCADA SYSTEM” prepared by MAY ALSHIBIL and submitted on 18/05/2022 has been **accepted unanimously** for the degree of Master of Science in Electrical and Computer Engineering

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I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

May ALSHIBIL

DEDICATION

Firstly, I want to thank Asst. Prof. Dr Sefer KURNAZ because of his unique guidance and helps during the period of this thesis. I believe that without his guidance and comments, writing the idea was not have been possible. Secondly, I want to thank all jury members for their valuable comments and suggestions. Their words help to improve the quality of the current research. Lastly, I want to appreciate my family for their support and help throughout my master's education.

ABSTRACT

CONTROL AND MANAGEMENT OF SOLAR PV GRID USING SCADA SYSTEM

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Solar radiation is plentiful in the Middle East, and it is one of the most sustainable renewable energy sources. On the other hand, our countries have yet to make it one of the most essential energy sources.

We created a testing method based on SCADA simulation to achieve maximum voltage stability in the PV grid in this thesis.

Two key advantages are the ability to be flexible and the speed with which testing are completed.

Thanks to recent advancements in "smart sensors" based on smart grid technology, measurement instruments may now be changed to meet the size and kind of equipment being evaluated.

The results indicate that the built open-source SCADA system functions optimally and precisely, and that it might be used as a variable control and monitoring system for PV grids with little modifications.

Keywords: Smart Grid, PV, SCADA, Renewable Energy

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ABBREVIATIONS

IoT	:	Internet of Things
HMI	:	Human Machine Interface
PLC	:	Programmable Logic Controller
MTU	:	Master Terminal Unit
RTU	:	Remote Terminal Unit
PV	:	Photo Voltaic
MPPT	:	Maximum Power Point Tracking
RES	:	Renewable Energy System
AGC	:	Automatic Generation Control
EMS	:	Energy Management System
DMS	:	Distribution Management System
IED	:	Intelligent Electronic Device

1. INTRODUCTION

1.1 BACKGROUND

SCADA systems or supervision, control and data acquisition systems for its acronym in English, can be defined in simple terms as networks of controllers and computers that are created in order to remotely control and monitor all types of industrial processes [1]. Basically, they use a physical layer quite similar to traditional information systems, however, they differ from them in their priorities, with availability being the most important in control systems [2]. Due to the fact that in recent years these systems have been the target of various attacks, it is necessary to implement security systems that allow the detection of possible attacks in real time. It is intended that in this way an operator is alerted and consequently can act immediately in the event of an imminent case of improper manipulation of the plant.

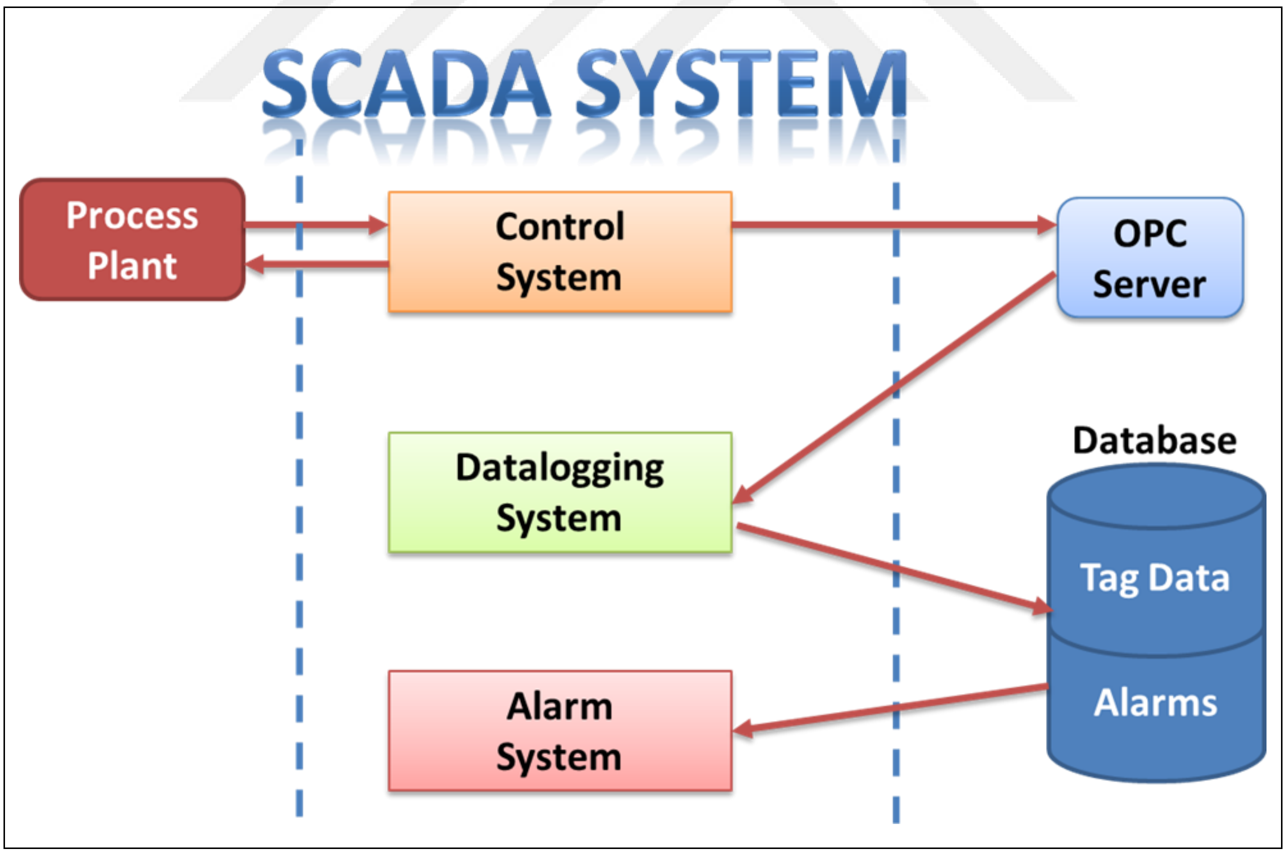

Figure 1.1: SCADA Architecture

1.2 CLASSES OF SCADA SYSTEMS

SCADA hardware and software are divided into two categories: proprietary and open source.

i. Commercial (Private) SCADA:

A proprietary system is one in which all main components are manufactured by a single firm, and the standards are developed particularly for that system by that business. Custom SCADA hardware and software are developed by businesses and sold as turnkey systems. With a proprietary SCADA system, the manufacturer is solely responsible for system stability and security, leaving the user vulnerable to a single manufacturer who may be sluggish to adapt to technical advancements in a SCADA subsystem. The client is also at risk if the provider fails. This option is somewhat pricey due to the manufacturer/location supplier's in the United States.

ii. There's also the issue of inflexible outdated devices and networks. In a major Electrical Utility system, for example, the SCADA system's devices must interact with all other network devices, and if those devices are from multiple vendors, the SCADA system must support each vendor's protocol, which raises costs and needs more engineering time to deploy. Siemens, Allen Bradley, General Electric, Emerson, Schneider Electric, Modicon, Mitsubishi, Omron, and other well-known proprietary SCAD vendors include.

iii. Open-Source SCADA :

In an Open-Source system, a user may mix components and then choose the best one from several vendors. Because the user is not limited to a single source, he or she has more options. This means that with an Open-Source system, no one vendor is accountable for overall performance. To be interchangeable with identical components created to the same standards by others, the key components of an Open-Source SCADA system must comply to particular standards. These standards govern the interfaces between important system components such as instruments and remote terminal units (RTU) (encompassing connection types)

RTU and communications carrier (impedance, communication protocols, signaling methods, and frequencies), as well as communications bearer to Master Station There are a few open-source SCADA systems available on the market today, each with their unique set of benefits. Alternatively, disadvantages.

1.3 PROBLEM STATEMENT

Costs, quality, flexibility, and reaction time are only a few examples of competitive differences in the sectors. These elements are strongly connected to the production system of the metal-mechanical sector, especially the shop floor and its administration. If production management isn't well-prepared with appropriate information, detailed and real-time information, these competitiveness factors can be negatively affected. Understanding the true capacity of the manufacturing system is essential to balance consumer demands in a short time, and meet batches of varying sizes and at low cost, says [1] The means to do this is the exchange of information between the shop floor and the other upper levels where managerial decisions are made. The manual collection of information is deficient in terms of reliability, update speed, detection of non-conformities and other factors that are detrimental to production, in addition to generating redundancy of work in collecting and feeding the database. Consequently, the information generated from these notes can create a different perception of reality, and with enough delay to make critical decisions from them impossible, concludes [2] Thus, the flow of information between Information Technology (IT) systems at high management levels and factory floor automation levels is highly desirable.

1.4 MOTIVATION

Due to the geographical conditions of most countries, there are still communities isolated from the four electrical systems that distribute energy within the country. Smart micro-grids based on renewable energies represent a solution to this problem, taking into account the abundance of resources that exist to generate non-conventional renewable energies. With this in mind, the Energy most countries installed a distributed generation micro-grid which incorporates renewable resources (solar and wind energy). Before the installation of the microgrid, these countries had only 10 hours of daily power, a situation that changed, currently having electricity 24 hours a day. The installed microgrid currently operates with an energy management system EMS which dispatches the units, minimizing generation costs. The EMS inputs are: consumption prediction, prediction of climatic variables and the state of charge of the batteries.

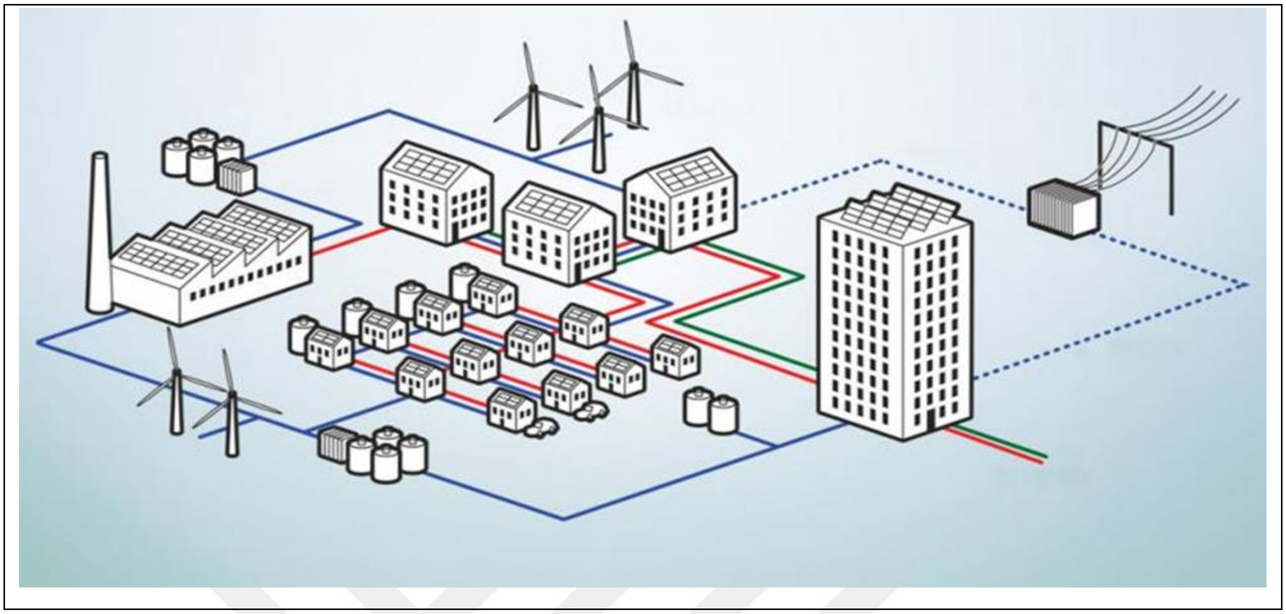

Figure 1.2: Distributed Energy Storage Systems

1.5 CONTRIBUTION

The PV installation's technical excellence is measured by the Performance Ratio (PR). To monitor and compare PV plants across multiple sites, it's best to use weekly or hourly performance indicators over a long period of time (like one year). Using modest SCADA simulations, our team created a method for checking the PV grid's voltage stability. Flexibility and speed of testing are the two biggest benefits of this method. Recently developed "smart" sensors on smart grid have made it possible to adapt and reconfigure the measurement instrument to the size and kind of equipment being tested. Site sensors gather and interpret data, and performance indicators are gleaned almost in real-time from that data. The technique and actual experience in two PV and SCADA application examples are described in this thesis.

1.6 THESIS ORGANIZATION

The thesis is organized as follows: Section 2 is where we review some of the previous work and implementation on smart grids. Section 3 is where we give a background about all the components. Section 4 has detailed explanations of our concept and its implementation, while Section 5 contains simulations and records of the outcomes gained. Section 6 is where we wrap up our work and look ahead to a future scope.

2. RELATED WORKS

The operational automation system is composed of the following general components: There is a Master Station and Remote Interface Devices (also known as Remote Terminal Units) at the central/host site (RTUs). Station Master: During the 1920s, some of the first SCADA (Supervisory Control and Data Acquisition) systems were put into place. Some high-voltage substations (also known as producing stations) near power plants may be monitored and operated from the control room of the power plant at the time. [The interconnection of electric utilities began in the 1930s as a means of reducing operational expenses for each utility. Analog computers were created to monitor and manage the output of generators, tie-line power flows and frequency as a result of this. As early as the 1950s, analog computers had been improved such that generation could be scheduled so that each generator had the lowest cost possible. Economic Dispatch (ED) and Automatic Generation Control (AGC) were the functions, while Energy Management Systems (EMS) were the systems (EMS). The analog EMS systems were phased out in favor of digital ones in the late 1960s. It was decided to create software programs that would include transmission system analysis models as well as off-lineanalysis features. Vendors adapted the computer supplier's operating system to their requirements, and each customer got a customized set of application software. As a result, upgrading the computers or adding new functionality necessitated replacing the complete Master System. As a result, until open-standard operating systems supporting real-time applications were established in the 1980s and 1990s, this pattern continued to be seen. Examples of current SCADA control systems are shown in Figure (1.2). The use of distributed control systems with local transmission and distribution control centres has increased in recent years as utilities look for cost savings. DMS (Distribution Management Systems) established by other utilities interface with distribution substations and feeder devices in their regional areas. The majority of the time, feeding devices communicate wirelessly. In order to enhance service restoration times, these systems provide better control over feeder voltage profiles and quicker identification of faulty feeder sections.

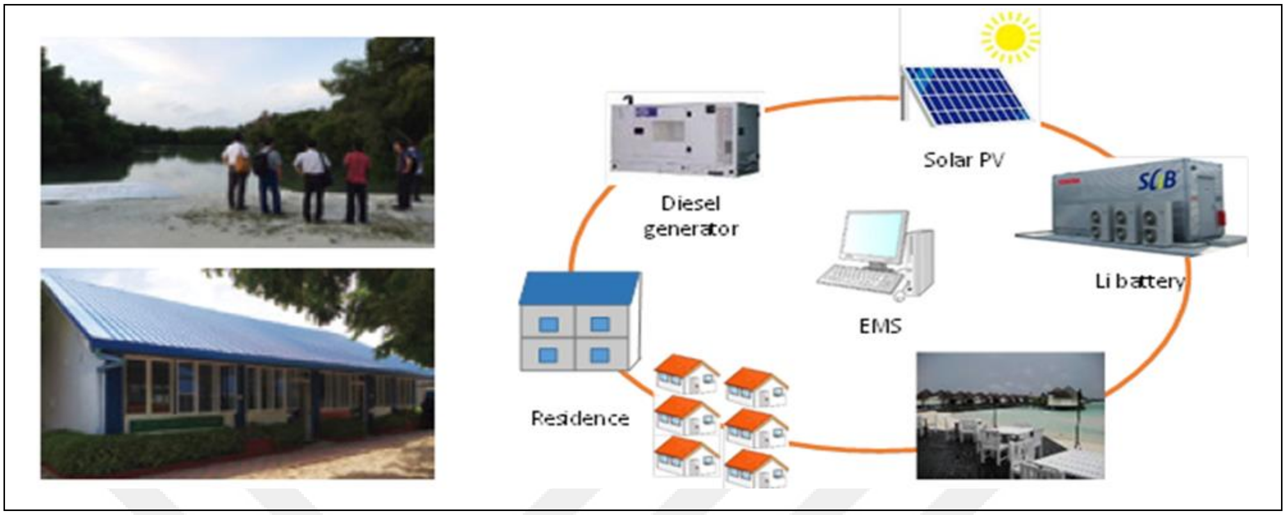

Figure 2.1: PV Energy Management System.

Terminal Units Operated from a Distance: Control systems used to communicate with power systems remotely when they were first being implemented, but this has changed in recent years. The Remote Terminal Unit, or RTU, was the name given to this interface. In order to connect to the power supply, an RTU included a cabinet or panel of terminals for the instruments and control cables. Auxiliary relays kept tabs on the location of the electrical system's switches and breakers. By closing the relay, a current flowed from the power switch to the circuit board, resulting in an unambiguous binary value of 1. There was a binary count of 0 when both the relay and the switch were open. Potential transformers and current transformers attached to the power system buses and circuits provided analog values for the analysis. The transformer produced 120 volts AC and a nominal 5 amps AC, which were then converted to +/-1 milliampere DC using transducers. For converting analog values into binary values, the RTU used analog devices [5]. This means that the power system's digital and analog input data might be converted to binary values and transferred to the master station for display and analysis. The RTU's power system auxiliary relays were addressable, allowing the operator to choose the address and function (open or shut) for a particular power system device before sending the instruction to the RTU [5]. It was not until the mid-1970s that robust microprocessors that could endure the harsh conditions of a power plant were made available that the RTU underwent any significant change. Even though microprocessors simplified the RTU's hardware, the interface wire stayed the same or even became worse when external milliamp transducers were replaced by internal analog to digital converters. Due to the need for AC secondary amperes and voltages, these analog-to-digital (A/D) converters had to be connected to the RTU. The introduction of microprocessors allowed the RTU's capabilities to soar. These additional capabilities included individual point numbering, local recording and time marking of events, quicker connections, more communication ports, and a variety of other features. The pricey and time-consuming interface cable, however, remained in place, keeping costs high. In the 1980s, microprocessors were first used in protective relays, meters, various controllers, and other devices having a communications interface.

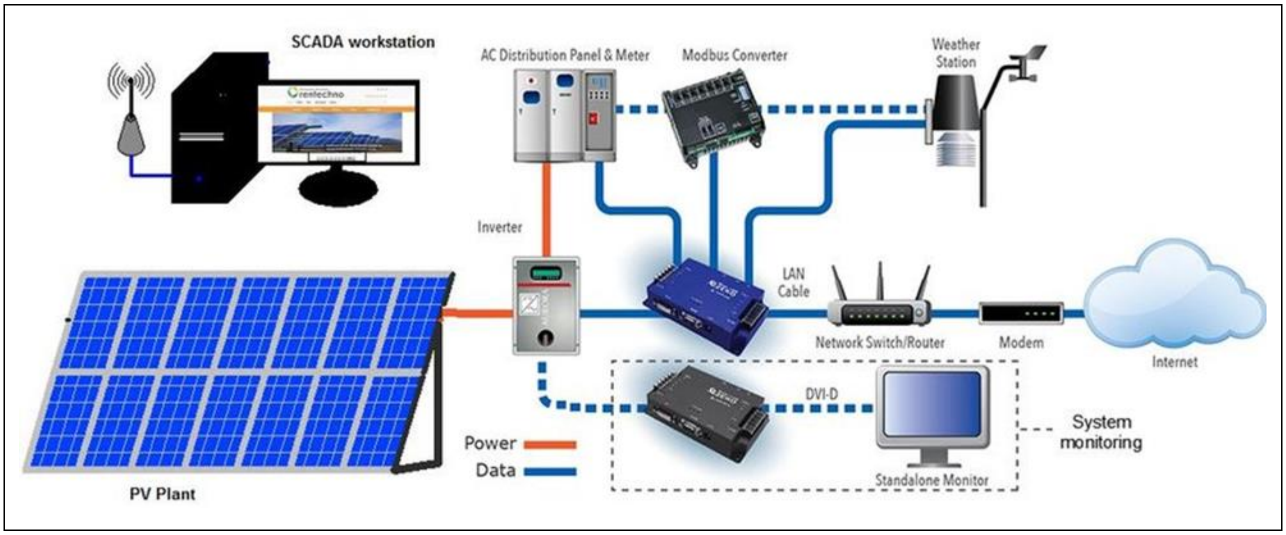

Figure 2.2: SCADA Control System of PV Panels

By connecting these newer, more powerful devices directly to the RTU, utilities and system manufacturers recognized that their substation designs and complexity could be considerably reduced. The IEEE Power and Energy Society (PES) Substations Committee recognized the necessity for a distinct term to differentiate these devices as their usage grew. The term "intelligent electronic device" (IED) was invented and defined around this time. Almost every gadget with a microprocessor and a communications connection was labeled as an IED within a few years [5]. Utilities started placing IEDs on their distribution feeders in the 1990s, some of which interacted with the substation RTU and others which spoke with the network operations centre directly. Both situations saw their control systems' reach extended to the distribution feeder stage as a result of this. Tens of thousands of these feeder IED devices are now in operation being queried by the SCADA master on a regular basis for new analog and status data. The system operator can monitor and operate these distant IEDs, but automation is non-existent. As a production system management tool, an automated distributed information acquisition system that shares information both locally and remotely across the company is very valuable. Using supervisory systems, companies may swiftly respond to market changes, enhance customer service, and save operational expenses. Continuous and batch operations both need supervision systems. They are common in both situations. The only problem is that they haven't been used for discrete procedures like machining yet. Machine tool monitoring in real time is becoming more important for manufacturing companies since their equipment must be connected with other IT systems (MINTCHELL, 2000 [11]; KRAR & GILL, 2002 [12]; WIENDAHL & LUTZ, 2002 [13]).

However, owing to proprietary restrictions that restrict access or the types of data that may be accessed, there have been few beneficial information flows thus far (ROCKWELL, 2004 [14]; KRAR & GILL, 2002 [15]).

Different sectors compete on the basis of a variety of differentiating qualities, such as price, quality, responsiveness, and flexibility. This is especially true in the metal-mechanical sector, where the shop floor and its administration are integral parts of the production system. These competitiveness characteristics may be harmed if production management isn't adequately equipped with precise, thorough, and up-to-date information. In order to satisfy customer expectations quickly and in a cost-effective manner, knowing the exact capacity of the production system is critical, according to ROCKWELL (2004 [14]).

For this, information must be shared between the shop floor and the various layers above it, where management decisions are made. Manual data collection lacks dependability, update speed, identification of non-conformities, and other production-damaging issues, as well as resulting in redundant effort in data gathering and database feeding. As a result, MINTCHELL [15] says, the knowledge derived from these notes might lead to a distorted view of reality, and could even cause important judgments to be impracticable (2001). ROCKWELL [14]: Managers are still making strategic choices based on data that is both incomplete and out-of-date (2004) [16].

According to the authors LANDERS & ULSOY (1998) [17], product quality monitoring systems are essential for reducing production times, improving product quality, and promptly adapting to production changes. Choosing the right sensors and signal conditioners / amplifiers, on the other hand, is a difficult process. Sensors are often expensive, bulky, and obtrusive, all of which may interfere with workflow and make them difficult to utilize. There is noise in the signals, and in order to get the desired information out of the noise, signal conditioners and amplifiers must be selected, along with their setup settings. For this reason, developing monitoring systems that are dirt, chip, electromagnetic, and mechanical influence resistant while not incurring additional costs or reducing the work area is extremely advantageous (using only the resources already available on machine tools such as sensors, a communication network, signal conditioners, and amplifiers). This is when open architecture CNC comes in handy. The so-called hybrid architecture, often known as open HMI, is one of the several open architecture CNC setups (Human Machine Interface). When using this design, just a small portion of the CNC remains locked off, but the CNC's Human Machine Interface (HMI) is built on a PC with open (non-proprietary) standards and resources for application integration. With the resources available, machine tools may provide managers with managerial and technical information, improving communication between the factory floor and other levels.

According to the authors Suriadi& Soib Taib, (2012) [45], The solar, wind, and generator systems are all included in the REHPGS model. SCADA is a real-time monitoring and control system for hybrid power systems (HPS). ViscontDua Remote Terminal Unit (RTU)-IO Module was used to plan a smart grid concept . The RTU is in charge of gathering data from the power HPS plant. The SCADA Expert controller is used to control renewable energy sources automatically. REHPGS' monitoring and control system operates in real time and under a variety of operational circumstances. The HPS plant will be fully automated, which means the power plant's whole operation will be controlled by the SCADA system. The proposed system can monitor and optimize the output power generation of REHPGS, according to the results.

The results of the experiments reveal that the web-Scada is capable of monitoring and controlling the hybrid power system. The developed sensor systems have a 2.87 percent average inaccuracy.

The RTUs that have been created can acquire sensor data and connect with the Scada server in real time (2014).ARYUANTO&NAKHODA [46]

The proposed SCADA system by LAWRENCE O. AGHENTA & M. TARIQ IQBAL includes current and voltage sensors for data collection, an ESP 32 Micro controller for receiving and processing sensor data, and a things board IOT server for historic data storage and human machine interactions.

On a Raspberry Pi single board computer, the things board IoT server is locally installed.

Queuing System Data is sent via a local WI-FI connection using the Telemetry transport protocol [47]

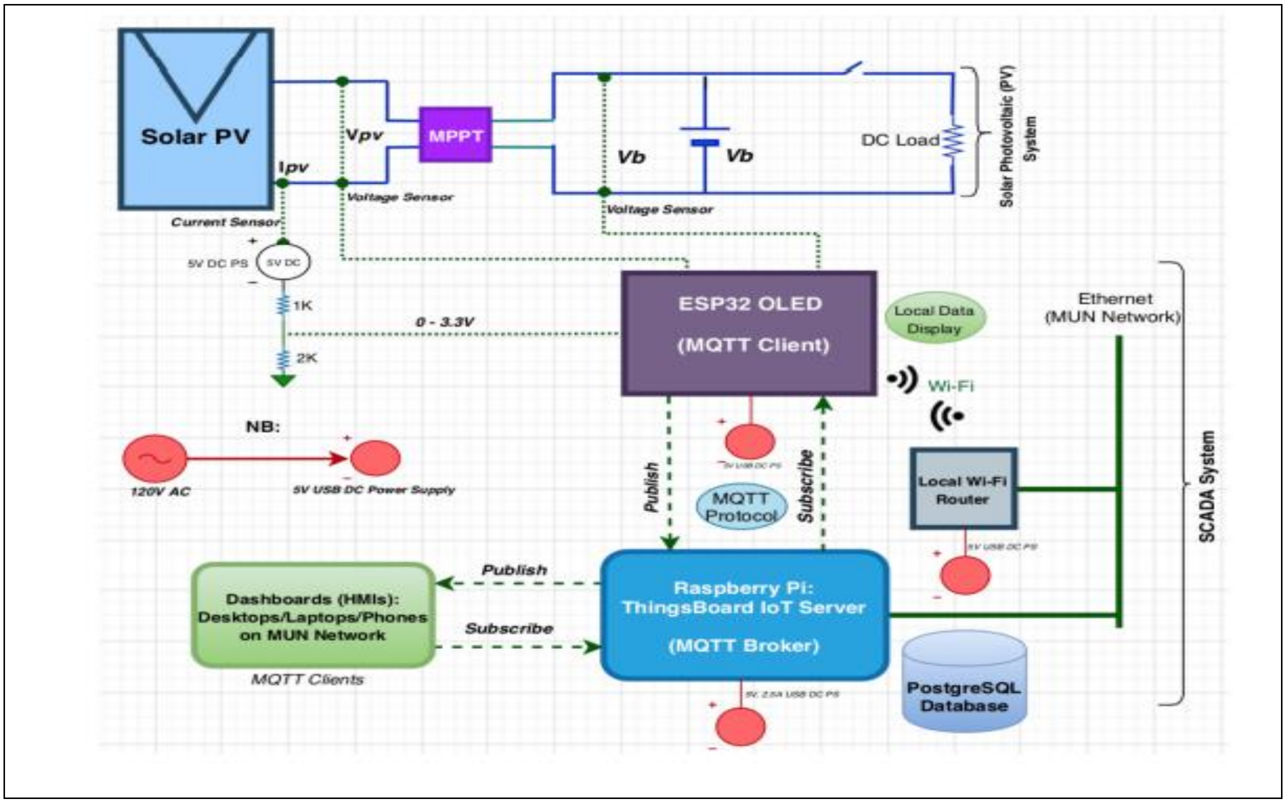

Figure 2.3: Telemetry Transport Protocol Via Local WI-FI Connection

3. MATERIALS AND METHODS

3.1 MONITORING AND CONTROL SYSTEMS

For a business to function properly, thousands of details have to be taken into account, but computer systems always represent a priority. They must be able to respond at any time and situation, avoiding later problems. The monitoring of systems every day is a more necessary job to manage the variables in such a way that a continuous and efficient production chain is obtained. The productive efficiency implies the constant levels of production of the installed machinery, the improvement of the quality of the final product, the reduction of production costs, and the safety for both the personnel and the equipment. If we want to obtain this, it is necessary that the production processes are carried out at a higher speed and the variables to be controlled are within constant values. That is why the industry has to develop the use of new and more complex processes, that many times an operator (human being) cannot control it to the complexity. It is there that we must understand how automation and control systems emerge as a solution that will allow production to meet modern quality standards. Correct information gathering is essential to have quality data for subsequent analysis. Normally, for the collection of this data, specific sensors are used, through hardware or software elements. One of the commonly used methods is the so-called mirror port.

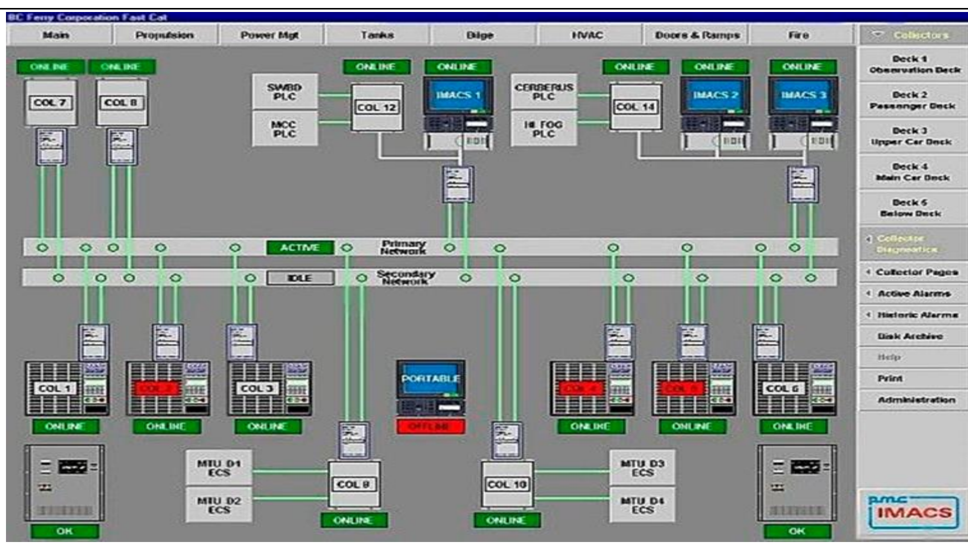

Figure 3.1: Example of Sensor Monitoring and Control System

3.1.1 Monitoring System

Through this mechanism, a copy of the network traffic that is transmitted through one or more ports of the switch is made and extracted through a dedicated port on which the inspection is applied. However, in order not to overload the network elements with the realization of the mirror port, which could incorporate delays in the transmission of the packets, in industrial networks it is advisable to use network listening devices such as TAPs, since they allow to examine the network traffic in a totally passive way, without overloading the network elements used for other tasks. To complement the information obtained from network traffic, it is necessary to collect all the data from the operating system and other events generated by the rest of the network security systems, such as intrusion detection systems, firewalls, etc. Although data gathering is critical, it must be remembered that for monitoring to be effective, the system must be able to handle all of the data collected. Packets or information might be lost if this is not done, indicating unusual or malicious activity. As a result, data gathering is critical in order to assess all of the acquired data and determine if the observed condition is normal or abnormal, and, if so, to activate an alarm mechanism. There are various methods of anomaly detection, but in essence they can be grouped into signature-based detection mechanisms and detection based on anomalous events. Industrial control systems continue to be increasingly integrated with other networks, enabling agile data exchange and improved remote operability. Remote locations can be connected to corporate facilities or offices, and these, in turn, be connected to the central control system. The different connections with other networks that industrial control systems have are helping to improve productivity, but on the other hand they have the potential to introduce a series of elements that are susceptible to vulnerabilities. Thus, for example, some vulnerabilities associated with network segmentation, such as configuration failures, could allow intrusions into the system or anomalies in the routing of traffic. These vulnerabilities can be exploited intentionally or unintentionally by individuals or groups inside and outside the organization and therefore pose a risk to it.

Industrial control systems processes can provide real-time notifications of potential and apparent problems; however, both reliance on existing commercial systems and orientation towards standardized connections (TCP / IP) can lead to malicious cyber intrusions. As in the IT sector, to achieve an acceptable level of security in industrial control environments, it is necessary to measure the state of cybersecurity and compare the current level of security with appropriate benchmarks Set of equipment and components, which will allow control operations to be carried out. Any controlled system can be controlled in two ways, if we stick to the information paths within it:

a) Absolutely trusting that the design parameters are correct and that the orders that we send to the system will be fulfilled.

b) Continuously monitoring that the orders sent are fulfilled and making the appropriate corrections whenever necessary. All the control systems that are included in the first model are called Open Loop Regulation Systems. They are based on the adequate design of the parameters and the working conditions of the control element so that it is able to maintain the controlled system within the desired limits. Those that fall within the second definition are called Closed Loop Regulation Systems, or Feedback, and they work continuously monitoring the reactions of the system to be controlled, taking the necessary corrective actions to maintain control within the desired limits. For example, in electrical axis positioning tasks, when using a stepper motor, we have an open loop system. There is no real information on where the actuator is, you start from a known point, called the reference point, and work from there, trusting that the motor will not lose steps and will be able to move the actuator reliably.

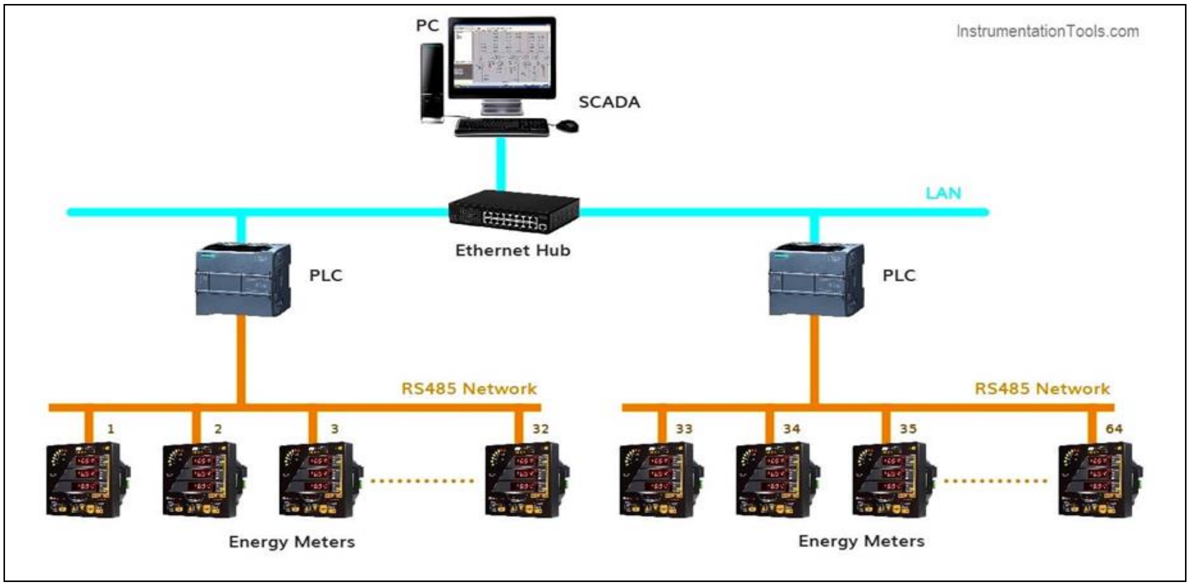

Figure 3.2: Electrical Monitoring and Control System

If what we use is a motor with a position sensor (encoder), then we will have real information on the state of the motor (is it moving?), Thus composing a closed control loop. The safest system is based on surveillance, therefore, control systems that require reliability (all, if possible), will use closed-loop regulation.

The basic closed-loop control system has always been represented by this man who has been holding a key that controls the passage of steam from a boiler for several decades, paying attention to the pressure gauge that indicates the pressure of the pipe. The basic idea is very simple, but putting it into practice may not be so simple:

a) There may be several stopcocks controlled by several people with different conditions (external and internal).

b) The cause-effect relationship may not be direct.

c) The sensors may not be the same.

d) The actuators, either.

3.1.2 Automatic Control System

Automatic process control is one of the disciplines that has developed at breakneck speed, laying the foundations for what today some authors call the second industrial revolution. The intensive use of automatic process control techniques has as its origin the evolution and modernization of measurement and control technologies applied to the industrial environment. Its study and application have contributed to the universal recognition of its advantages and benefits associated with the industrial field, which is where it has one of its greatest applications due to the need to control a large number of variables, added to the increasing complexity of the systems. Automatic process control is used primarily because it reduces the cost associated with the generation of goods and services, increases the quality and production volumes of an industrial plant, among other benefits associated with its application. The elimination of errors and an increase in the safety of the processes is another contribution of the use and application of this control technique. At this point it is important to note that prior to the massive application of automatic control techniques in industry, it was man who applied his calculation capabilities and even his physical strength to execute the control of a process or machine associated with the production. At present, thanks to the development and application of modern control techniques, a large number of tasks and calculations associated with the manipulation of variables have been delegated to specialized computers, controllers and drives to achieve the system requirements. The application of the notion of feedback is the foundation of every autonomous control system, and its unique feature is that it keeps the central controller informed of the state. when required, variables to produce corrective actions. This same principle is applied in fields as diverse as the control of chemical processes, control of furnaces in the manufacture of steel, control of machine tools, control of variables at a medical level and even in the control of the trajectory of a military projectile.

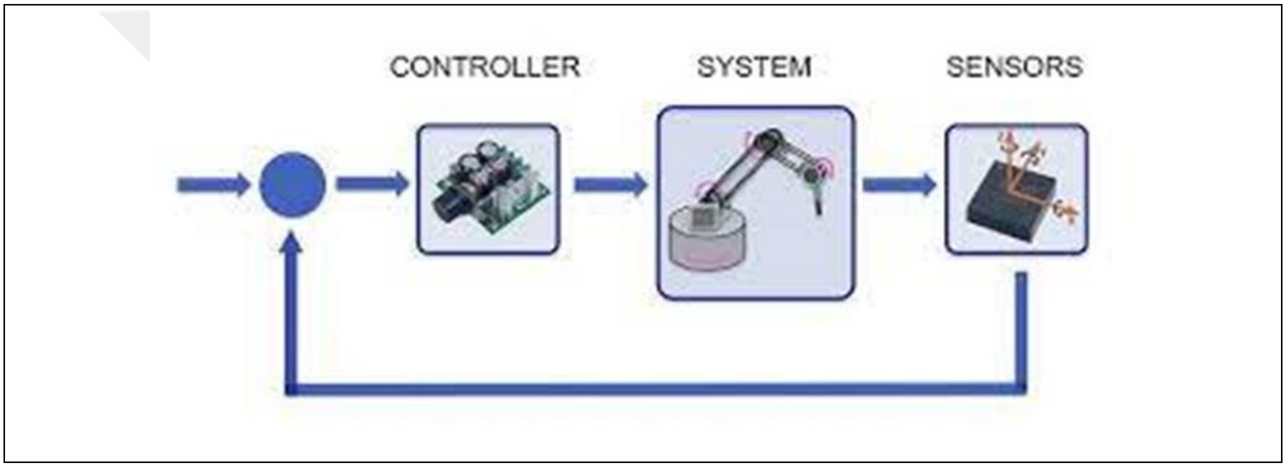

Figure 3.3: Automated Control System Elements

The use of digital computers has made it possible to optimally apply automatic control to physical systems that some years ago were impossible to analyse or control. One of these advances is given by the application of fuzzy control techniques, applications with neural networks, simulation of control systems and expert systems, among others. The application of the so-called adaptive control is of vital importance, the main characteristic of which is its ability to modify the parameters of the control system in response to changes in the dynamics and / or disturbances of the system. This was the main reason for introducing this type of regulator, that is, the internal changes that the dynamics of the plant may undergo to be controlled by environmental factors or other factors inherent to the systems such as aging, wear and changes in the environment of the assembly. regulator-plant, such as changes in pressure and temperature among others. One of the first fields where this control technique was introduced was in automatic flight pilots, where atmospheric conditions and those of the vehicle, such as weight and speed, can change radically.

At this point it is important to ask the question about what is automatic control, the answer to this question being the following: “Automatic control is the maintenance of a desired value for a quantity or physical condition, measuring its current value, comparing it with the reference value, and using the difference to proceed to reduce it through corrective action. Consequently, automatic control requires a closed loop of action and reaction that works without human intervention”

The feedback control loop is a closed pathway formed by a sensor, a controller, and a final control element, is the most critical component of any autonomous control system. The concept of feedback control is not new, the first feedback control loop was used in 1774 by James Watt to control the speed of a steam engine. Although the principles of operation of the control loop were already known, stability analysis and control techniques developed slowly until the first pneumatic transmission systems began to become common in the 1940s. From this date on they were used. marks a milestone due to the need for analysis tools and new technologies applied to control equipment, necessary for the implementation of more secure, robust and stable systems.

3.2 DISTRBUTED POWER GENERATION

Depending on the country, the terms integrated generation, dispersed generation or decentralized generation are used to refer to “Distributed Generation” (DG). Although there is consensus that DG corresponds to generation connected to distribution networks or consumer facilities, in the international literature the concept of DG does not find a precise definition, particularly when the objective is rather to establish what it is and what it is not GD [18]. Additionally, the definition of distributed generation may vary depending on the regulatory regulations of each country, which refer to different aspects and which can be summarized in the following factors [3]:

a) Purpose: to provide an active source of electrical power.

b) Location: generation units directly connected to the distribution networks in the vicinity of the consumptions.

c) Capacity: energy sources capable of generating powers, depending on their category, less than 300 MW.

d) Area of influence: provide energy to local consumption.

e) Technology: renewable energy, cogeneration, among others.

f) Environmental impact: they have a lower environmental impact because they are smaller-scale generation units.

g) Mode of operation: according to dispatch, pre-dispatch or price setting.

h) Ownership: depending on whether the generating unit belongs to independent energy producers, or directly to consumers.

i) Level of penetration: depending on the percentage of energy that is supplied to local demand

The term "distributed generation" should not be used to describe capacity, influence area, technology, environmental effect, method of operation, ownership, or penetration level. Because these depend on the particular case where the generation source is connected. In general, DG can be defined as a source of electrical energy directly connected to the distribution network or within a user's facilities [3]. However, it is possible to narrow down the previous definition taking into account the characteristics and restrictions imposed by distribution systems regarding the amount of power that the electrical energy source can inject into these systems, leaving the concept of size explicit in the definition.

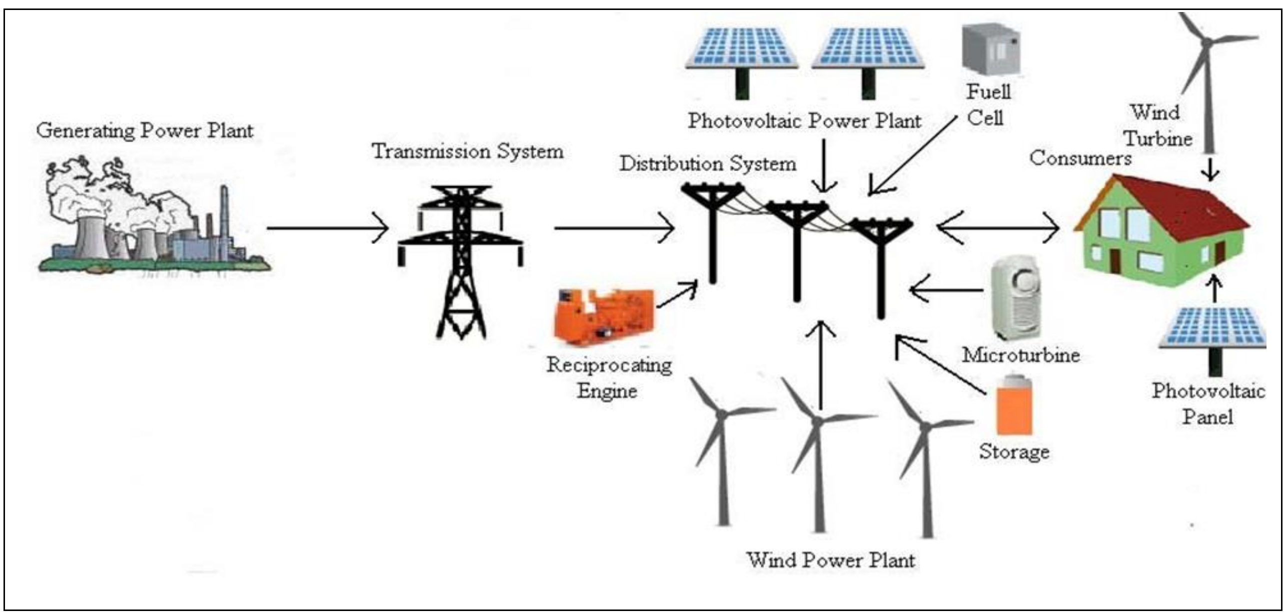

Figure 3.4: Elements of Distributed Generation System

Thus, DG can be defined as the integrated use of small generation units directly connected to a distribution system DG or within a user's facilities [18]. Although Chilean legislation1 does not explicitly define, it is established through legal amendment 19.940 of 2004 that establishes the right of all generation means, whose power injected into the system does not exceed 9 MW, to connect to the distribution networks. Additionally, in Supreme Decree 244 of 2006, the definition of DG in terms of injected power and location is implicit by distinguishing the difference between A small means of generation (PMG) and a small means of distributed generation (PMGD) are two types of small means of generation. PMG being understood as that means of generation whose surplus power available to the system is less than or equal to 9 MW connected to facilities belonging to a trunk, sub-transmission or additional system. And by PMGD that means of generation whose power surpluses are less than or equal to 9 MW, connected to facilities of a distribution concessionaire company, or to facilities of a company that has electricity distribution lines that use national goods for public use.

3.2.1 Micro Grid

A microgrid is an integrated energy system comprised of linked loads and distributed energy sources that may run in parallel with the network or independently [8]. The generators used in micro-grids usually use non-conventional renewable distributed resources, which in a coordinated way generate energy together. These generators must be supplied with power and control electronics interfaces to ensure that they operate as a single system and that the quality of the supply delivered is maintained. The microgrid may be presented as a single unit that fits local demands for dependability, security, and electricity because of its control flexibility. The following are the primary distinctions between a micro-grid and a traditional generating plant [6]:

a) The generators are of lower capacity compared to the large generators of conventional plants.

b) The energy generated at distribution voltage can be directly injected into the distribution networks.

c) The small generators are normally located close to the consumptions, allowing an efficient supply with low losses in the lines.

The primary benefit of micro-devices from a network perspective is that they are a manageable entity within a power system that can be operated as a single gross payload. Small grids are particularly useful to customers in meeting local energy needs because they can provide uninterrupted electricity, enhance reliability, reduce losses and manage the power voltage of the local grid. But to be everywhere, the technological, organizational and economic issues must be resolved. The unpredictable nature of generation and weather dependence based on dispersed resources is one of the problems that needs to be addressed, and the lack of regulations for the operation of the micro-grids in synchronism with the electricity companies.

The development of micro-grids is beneficial for the energy sector due to the following advantages:

Environmental: micro-grids have less environmental impact compared to large conventional power plants because they use small generators, an area in which they operate preferentially the SCADA.

Operational and investment: reducing the physical and electrical distance between generating sources and consumption contributes:

a) Improving the voltage profile.

b) The reduction of congestion and losses in the distribution networks.

c) The reduction and / or postponement of investments in distribution networks.

Energy quality: an improvement in the quality and reliability of the supply can be obtained thanks to:

a) The decentralization of the offers.

b) A balance between energy supply and energy demand in the network.

c) A better operation of the generating units in terms of black starting, which reduces cut-off and restoration times.

Cost savings: microgrids present the following savings:

a) By increasing the energy efficiency from the use of waste heat in SCADA units.

b) By integrating a large number of generating units it is possible to reduce the import of energy from the transmission grid.

Market: the following advantages are achieved in the event that the micro-grids participate in the market:

a) Greater competition due to the introduction of new energy suppliers.

b) They can be used to provide complementary services.

c) The application of small plug-and-play modular units contributes to the increase in the energy supply.

Despite the possible benefits, the development of micro-networks has the following drawbacks: Technical difficulties: it is related to the lack of technical experience in controlling a large number of small generating units, frequently of the plug-and-play type.

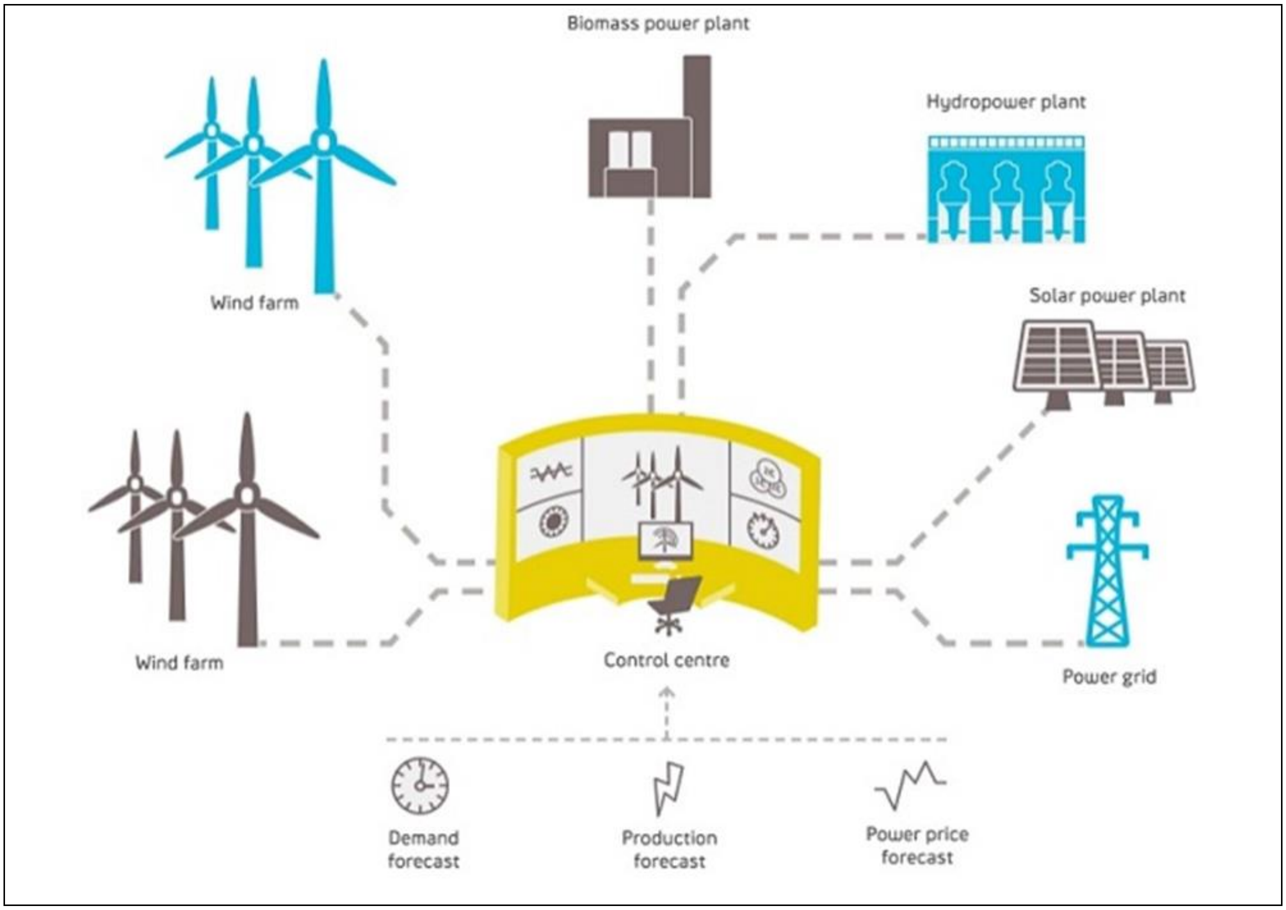

Figure 3.5: Microgrid Based DG System

This aspect requires expanding the line of research, on management, protection and control aspects, as well as the choice of the size and location of the generating units. Additionally, the necessary infrastructure and specific telecommunications protocols for unit coordination must be developed. In this area, a potential disadvantage is identified in the implementation of rural micro-networks, since they generally do not have telecommunications infrastructure. Lack of standards: there is still no specific standard for microgrids, however, published the first version of the structure and work plan of a standard for interoperability of smart grids [16]. Along the same lines, Legal and administrative barriers: despite the fact that many countries have incorporated distributed generation into their energy matrix, in most of them there is no legislation or technical standards to regulate the operation of micro-grids. Some governments are promoting the creation of microgrids using green energy, but the regulatory framework has not yet been developed for future application.

3.3 SCADA SYSTEM

SCADA stands for "Supervisory Control and Data Acquisition" and refers to the combination of telemetry and data acquisition. It encompasses the collection of information through remote terminal units transferring it to a central unit that processes and analyses it to be displayed on the screen to an operator and / or take required control actions [22]. SCADA systems can always be found where there is a control system. This is why they are widely used in the control of industrial processes such as; chemical plants, refineries, manufacturing, mining, power generation and transportation, among others [12]. By providing real-time management of data in a production process, SCADA systems make it possible to implement more efficient control paradigms, improve plant safety and reduce operating costs. In the old days, the first SCADAs displayed information on huge panels fitted with a series of clocks and lights. The data was stored on recording tapes and the operator exercised the supervisory control action through the manual action of buttons and knobs. Subsequently, the relay logic was used to implement the control systems. With the development of microprocessors, along with other electronic devices, digital electronics were incorporated into relays, thus creating "programmable logic controllers" These being one of the most used control devices in the industry. As the monitoring and control needs of various devices in the plant have increased, PLCs have diversified their use, decreased their size, and increased their capabilities. Today, SCADA systems use “smart electronic devices” (or IEDs). These equipment’s, in general, are sensors with capabilities similar to those of PLCs and can be connected directly to the SCADA central unit. They can acquire data, communicate with other devices, and run little programming routines. Typically, an IED has analog inputs and outputs, digital inputs and outputs, processing capacity and memory, communication system and PID control [4].

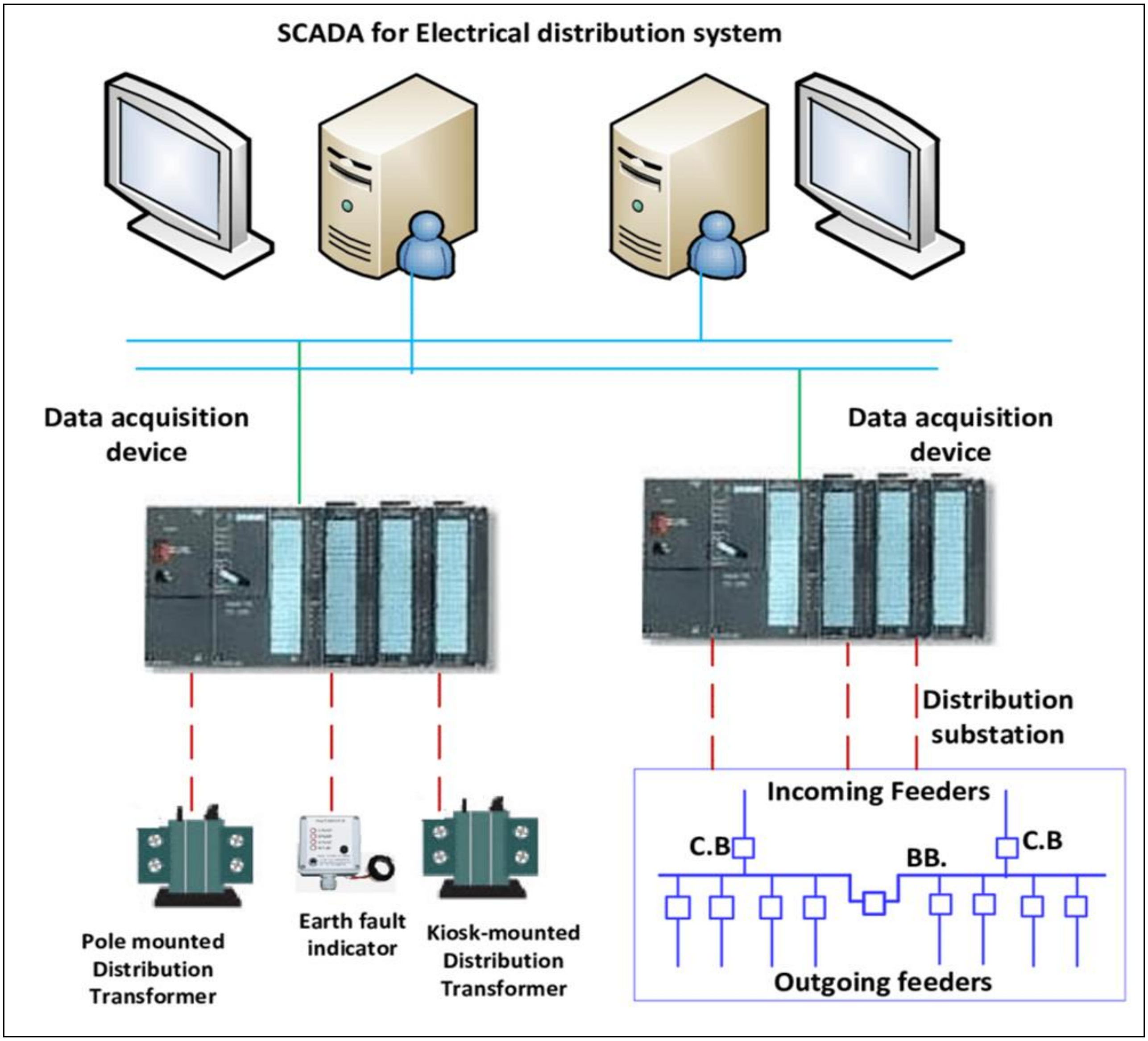

Figure 3.6 :SCADA For DG Systems

3.3.1 Scada Hardware

A SCADA system is composed of the following elements that are identified in figure below: Operator: Person who remotely monitors the operation of a plant and performs supervisory control functions. Human-machine interface (HMI): Software in charge of interacting with the System Operator. It provides information and control variables through graphics, diagrams, screens and menus. (MTU): In a master/slave architecture, this corresponds to the central unit. Through HMI software, the MTU shows data to the Operator, gathers data from distant units, and delivers control signals to remote locations. The data transmission between the MTU and the distant units is intermittent, slow, and has a long delay. This makes the control methods generally open-loop. Communication means: They serve as a conduit for communication between the MTU and the distant devices. Communication systems can be implemented over wired, fiber optic networks, wireless links, telephone lines, radio and microwave links, satellite links and the Internet. (RTU): Corresponds to the slave in a master / slave architecture. Sends control signals to actuators and receives signals from sensors. Additionally, it collects the information from these devices and transmits the data to the MTU. Good examples of RTU are IED and PLC equipment. The transmission speed between an RTU and sensor or actuator devices is high, making it possible to implement closed-loop control methods.

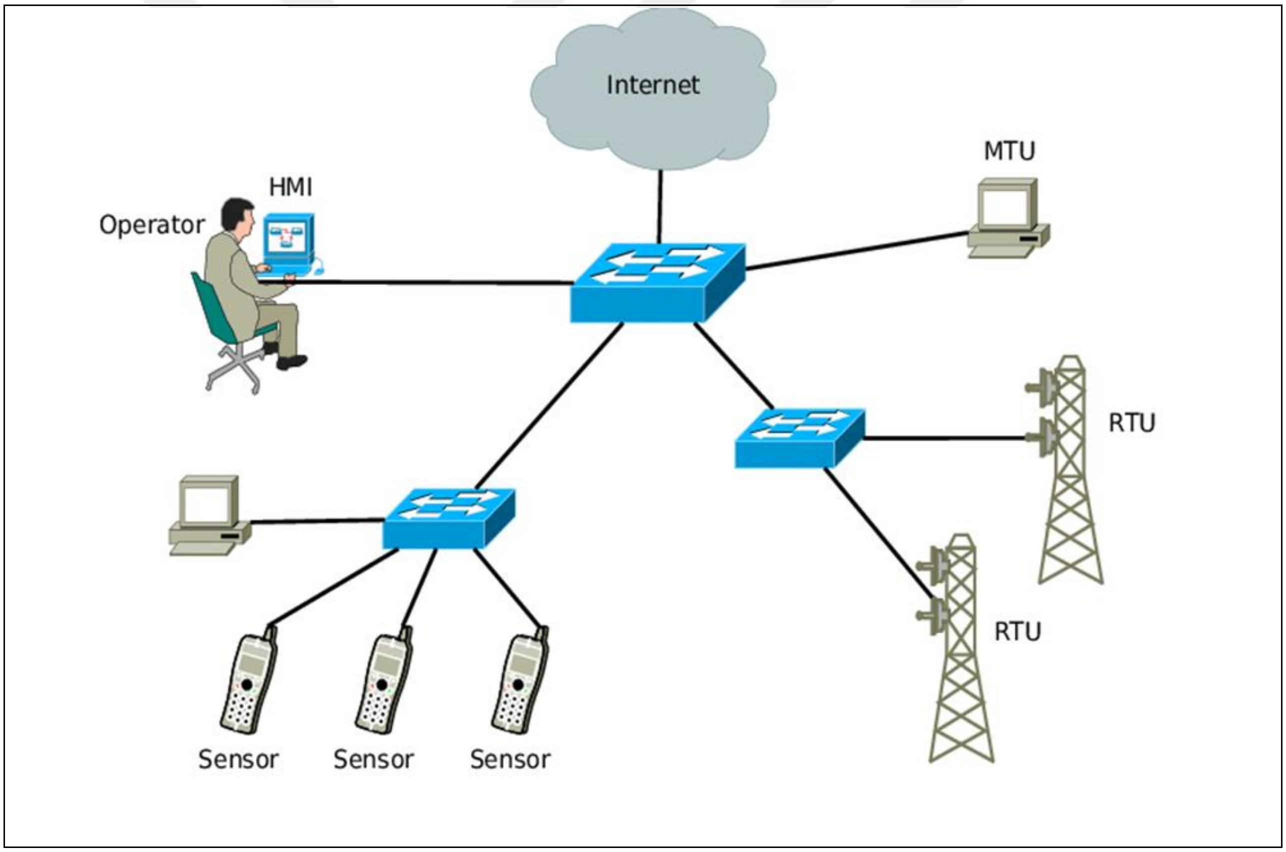

Figure 3.7: SCADA Architecture

3.3.2 Scada Software

Almost all of the software components present in a SCADA system are housed in the MTU. There are three software platforms that are described below: Operating system: It is the software that acts as an interface between the hardware and the other software of the MTU. He is responsible for managing and coordinating hardware resources for applications to run. The operating system must present stability and reliability characteristics that ensure the best performance and fulfillment of the functional requirements of the platform. Main software: Also called "SCADA Core", it corresponds to a standard software package that is configured for each particular system. In general, this software is developed by manufacturers to communicate with their own control devices, and they use proprietary communication protocols that are not compatible with the developments of other companies. This required the use of devices and software from a single manufacturer in the implementation of a platform.

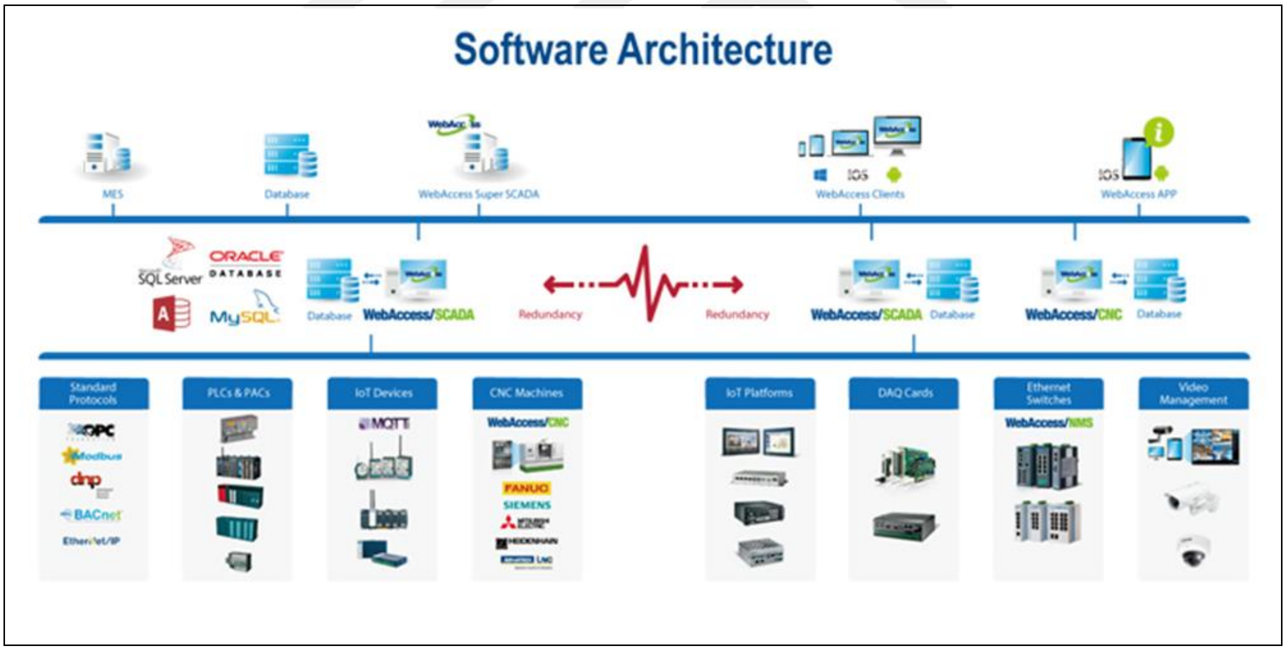

Figure 3.8: Scada Software Architecture

However, the development of open source "Core SCADA" systems capable of interoperating with devices from different manufacturers have gained popularity. The ability to implement standard and proprietary communication protocols allows equipment from different manufacturers to be used in the same implementation. The main software is characterized by implementing the following five tasks, whose functionality is detailed below: Input and output: it is the interface between the control and monitoring systems, and the plant. Alarms: manages alarms by monitoring values and thresholds.

Trends: acquire data for long-term monitoring Reports: create reports based on plant data. They can be scheduled, initiated by the Operator, or triggered by certain circumstances. Visualization is the duty that controls the data that the Operator monitors and the control actions that are requested. The core software is arranged into the following modules to fulfill the activities listed above: Data Acquisition, Control, Data Storage, and Human-Machine Interface or HMI:

a) Data Acquisition Module: Data acquisition refers to the reception, analysis and processing of all plant data sent by remote devices to the central unit. Normally, the data processed in real time is displayed graphically depending on the configuration. The information received is compared with predefined thresholds, automatically triggering the corresponding alarms when the configured limits are exceeded. The alarms can be identified by the RTUs or by the SCADA Core depending on the platform configuration. The way remote devices are accessed depends on the network topology and the communication protocol used. This determines whether the main system actively controls the communications network, or just acts as a remote control and information center.

b) Control module: Sends the control commands from the MTU to the remote devices. Sending can be automatically or triggered by the operator.

c) Data Storage Module: Data storage depends on the software, hardware and configuration used. Historical data must be able to be consulted to perform trend analysis, generate reports and search for faults. It is important to consider backup and storage policies for your historic data.

d) (HMI): The HMI interface is composed of input and output devices to interact between the Operator and the supervisory control system.

e) Normally a screen is used as the output device where the data is displayed in real time. Keyboard and mouse are used as input devices. A good design of the visualization interface must have different levels that show the operation of the plant in real time. The first level should show an overview of the plant to be controlled. The second level must show the detail of a sector or a sub-process of the plant and only the most important variables will be displayed. A third level must present all the details of each of the sub-process equipment, such as alarms, sensor information, variables and control commands. The visuals should be as clear as possible, displaying all of the necessary information while avoiding oversaturating the screen with data.

3.4 PHOTOVOLTAIC CELL

PV cells are devices that convert the thermodynamical energy of the sunrays into a constant DC electric energy which charges a battery that serves as a repository of energy, the goal of using the PV cell is to provide a source of continuous and sustainable energy source that helps heal the system when an error in one of the conventional power sources occur, the figure below shows the PV cell implementation in MATLAB and the two main elements that effect the power quality of the PV array.

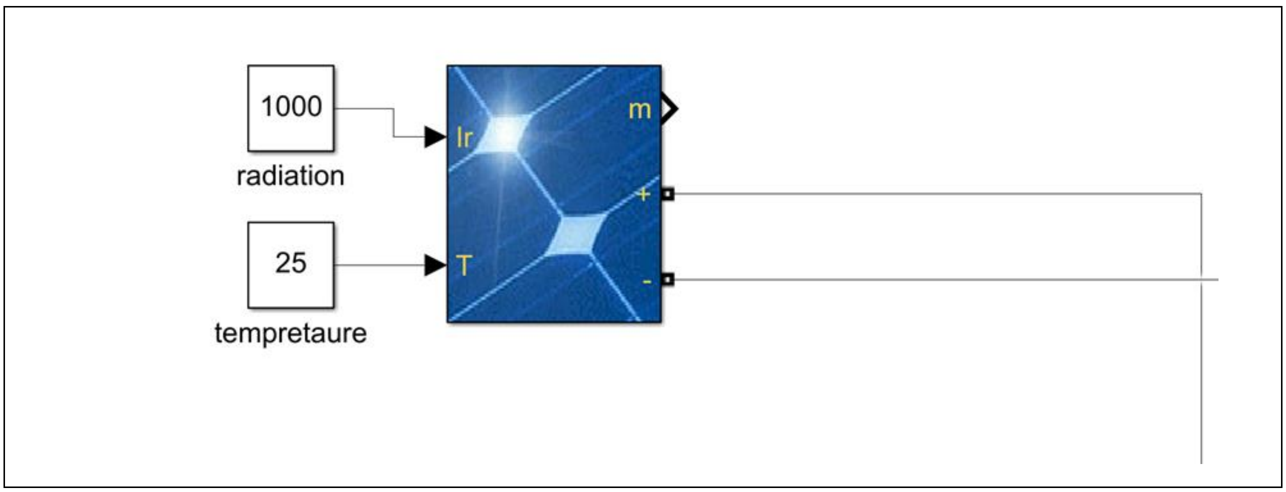

Figure 3.9: The Two Main Elements That Affect the PV Power Generation.

The yield intensity of a PV array relies on upon the accessible sun oriented radiation (G) and the surrounding temperature (T). yield the intensity of a PV cluster increments straightly as the sun-powered radiation increments, and diminishes as the surrounding temperature increments. Along these lines, the immediate yield intensity of a PV cluster [39]can be given by,

$$P_{PV}(t) = P_{Peak}\left(\frac{o(t)}{G_{\text{sramalara}}}\right) - \alpha_T[T_c(t) - T_{\text{standard}}] \qquad (3.1)$$

While the figure below shows the mathmatical model that calculates the temprature and the sunray radiation in order to simulate realistic values of energy generation.

Photovoltaic arrays are an assembly of linked modules that has the ability to harvest the power of the sun and convert it into useful energy that is used to charge a battery, The single-diode model, commonly known as the model with five parameters, is one of the most extensively used cell models. This model combines an IPH source-generated current picture, a diode specified by a single-exponential Shockley equation, and a transistor. The I–V characteristic of a solar cell is determined by the following implicit and nonlinear equation [30]:

$$I = i0[exp\frac{(qV-1)}{kT}] \text{----------------------------------}(3.2)$$

$$I = Il - i0\left[exp\frac{q(V+Rs.I)}{kT} - 1\right] - \frac{V+Rs.I}{Rsh} - \text{----------------------------------}(3.3)$$

While the table below table 3.1 shows the common variable parameters used in the solar PV simulation [42]:

Table 3.1: Variable Parameters Used In the Solar PV Simulation.

Rated Power	37.08 W
Voltage at Maximum power (V_{mp})	16.56 V
Current at Maximum power (I_{mp})	2.25 A
Open circuit voltage (V_{OC})	21.24 V
Short circuit current (I_{SCr})	2.55 A
Total number of cells in series (N_s)	36
Total number of cells in parallel (N_p)	1

Mathematically photovoltaic panel modeling equations:

I = [I + K (T - 298)]*λ /1000 ph SCr i ----------------------------------(3.4)

Module reverse saturation current - Irs:

I = I /[exp(qV / N k AT) -1] rs SCr OC S ----------------------------------(3.5)

Where $V_{pv} = V_{oc}$, $N_p = 1$ and $N_s = 36$----------------------------------(3.6)

The figure below shows the variation radiation and temperature in the simulated PV cell.

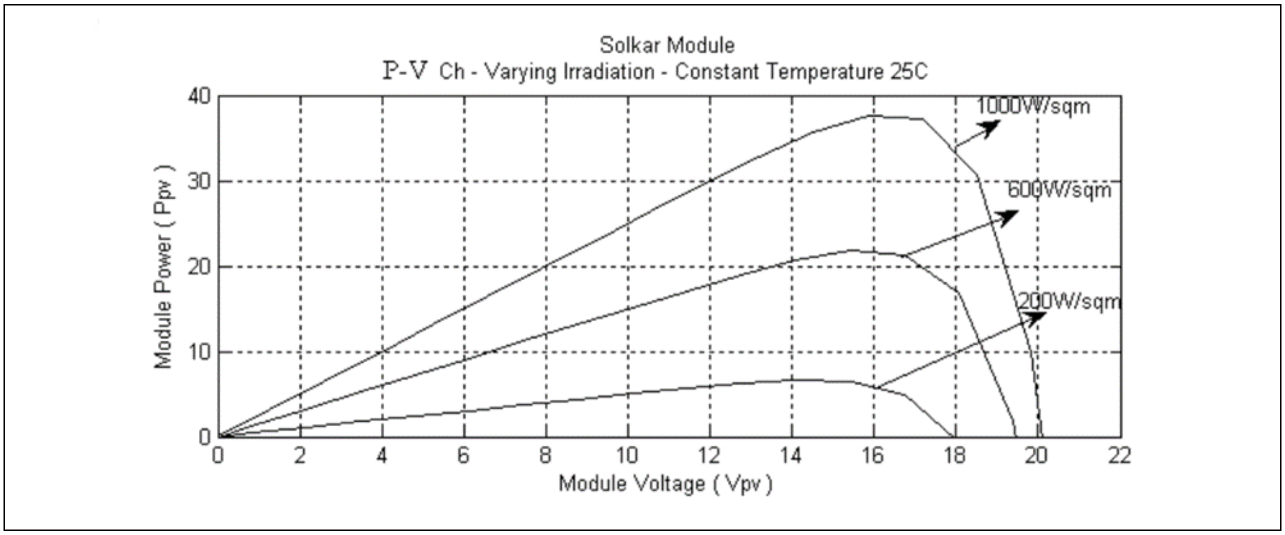

Figure 3.10: Simulated PV Radiation and Temperature.

While the figure below shows the power generation output effected by radiation and temperature

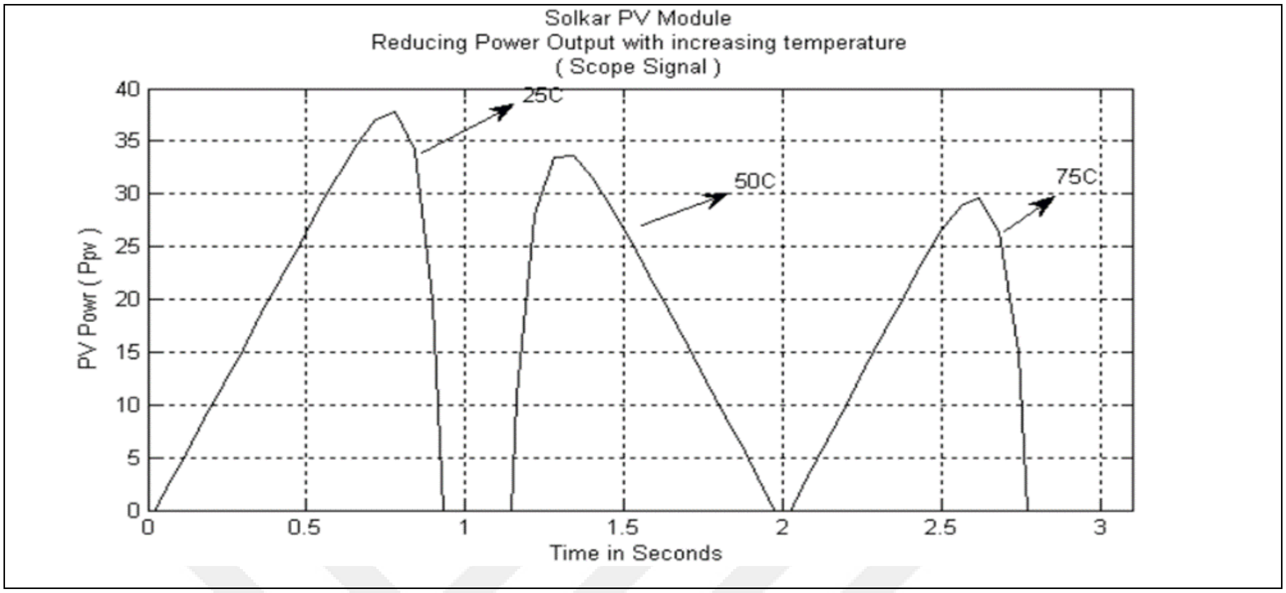

Figure 3.11: Simulated PV Power Output.

The PV normally is connected to a motor to direct the panel towards the sun, a voltage regulator such as space vector pulse width modulation SVPWM and a DC converter in order to convert the DC into AC voltage [18], the figure below shows the MATLAB implementation of our PV panel.

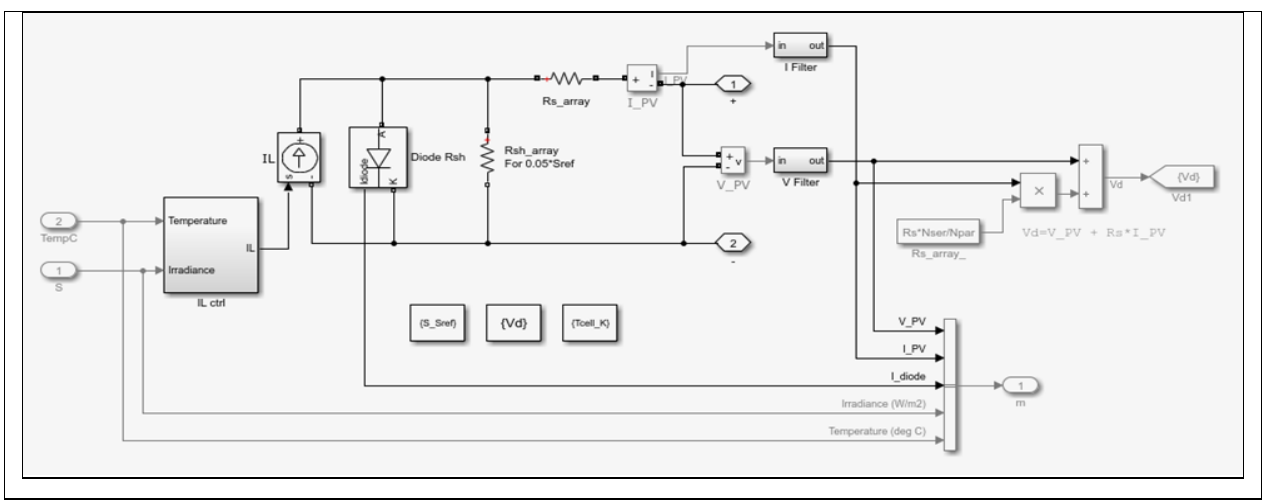

Figure 3.12: PV Panel MATLAB Implementation.

The figure below shows the math used to calculate the different elements that effect power generation in that PV panel and the blocks that simulate those factor

4. PROPOSED METHOD

4.1 SCADA DESIGN

The term "Supervisory Control and Data Acquisition" gave it its name (Control, supervision and data acquisition system). It's a computer-based software solution that allows you to regulate process and production factors while also communicating with field equipment. The SCADA system, which stands for "Supervisory Control and Data Acquisition," is an abbreviation for "Supervisory Control and Data Acquisition. It is a software application specially designed to work on computers in the control of process variables and production variables, providing communication with field devices. Which takes into account the SCADA system as a software that promotes the use of free software, respecting the complexity, compatibility, resources and operational and security requirements of SMEs. Currently, open-source software is in a phase of strong growth and is already competing at the same level as paid software, even the operating systems that companies use for their operation are open source because they offer greater security than commercial ones. Another characteristic of payment software is that it is designed to work on payment platforms, which require a lot of resources, have many implementation restrictions and are not fully integrable with the company, in addition to also having a high cost. According to the pyramid of automation or pyramid of manufacturing integrated by computer CIM (Computer Integrated Manufacturing). The supervision and data acquisition systems are located at level 2. This pyramid has four levels that define the hierarchical structure of the project. From the highest level, high-level business decisions are made, which go down until finally reaching the elements directly related to the process at the last level. In the same way, to verify the correct operation of these business policies, data is collected from the lower levels until it is translated into business results at the top of the pyramid.

Based on the background presented, the design of a SCADA platform is approached from the point of view of a local power electrical system. Subsequently, the design is extended to achieve control, monitoring and coordination of multiple control centers that can be connected to different areas. It is important to highlight that a coordination system can be developed both in a (managing the joint operation of several DG units), and in a group of them (managing the joint operation of several micro-networks). In a first approach, the architecture of the SCADA Platform is considered from the point of view of a local electrical system. The mechanism that allows communication with each distributed generation unit and the components that achieve the coordinated operation of the set are shown. Subsequently, the data flow between the different components of the system and the software required for it is explained. Finally, the proposed local coordination design is complemented to operate multiple microgrids. The above, through communication with a central coordinator.

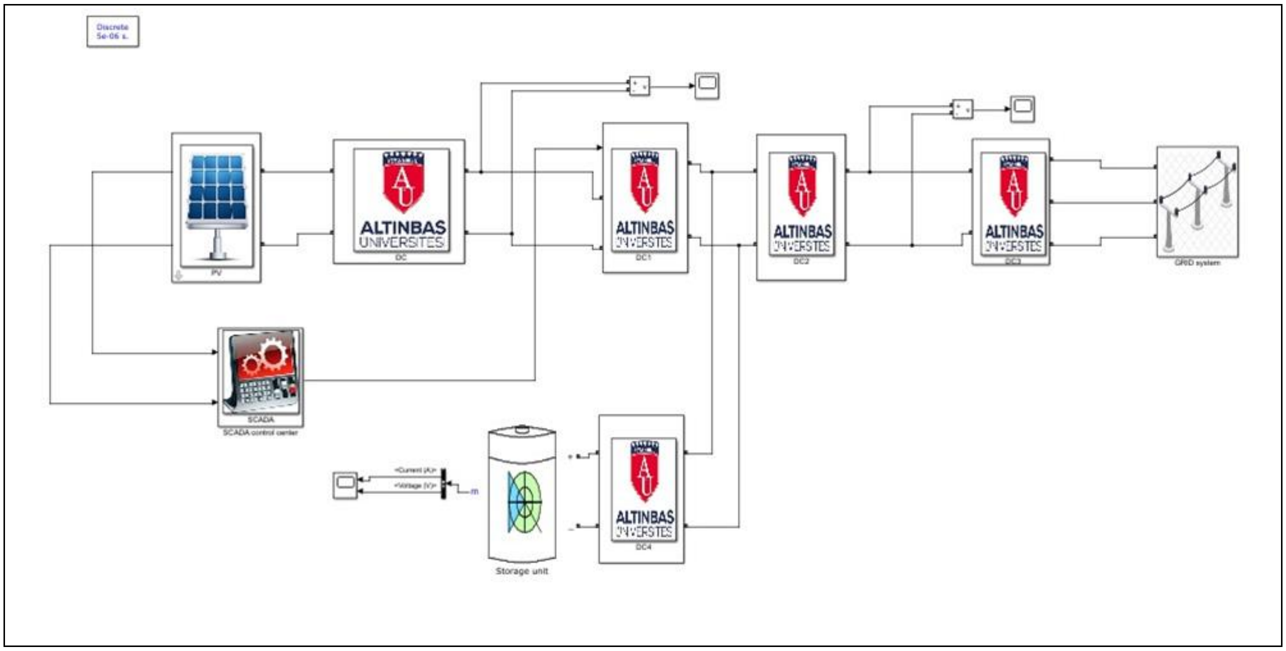

Figure 4.1: SCADA Based DG Management System

4.1.1 Controller Design

In the control centre all the parameters are monitored for the correct management of the photovoltaic plant. It is in this room where the server dedicated to the management of the local SCADA software and the router (manageable network electronics) is located, which serves as a link with all the equipment of the photovoltaic plant through the fiber optic ring. In addition, the VPN router outputs to a superior supervision system located outside the plant, for external supervision of the system for optimal management of a photovoltaic generation plant, it is essential to have a real-time monitoring tool, which facilitates its proper maintenance. With the SCADA solution, the manager of the photovoltaic plant will be able to have data from all the interconnected devices within the system in order to guarantee its correct operation. In addition to having productivity reports to ensure the highest possible performance.

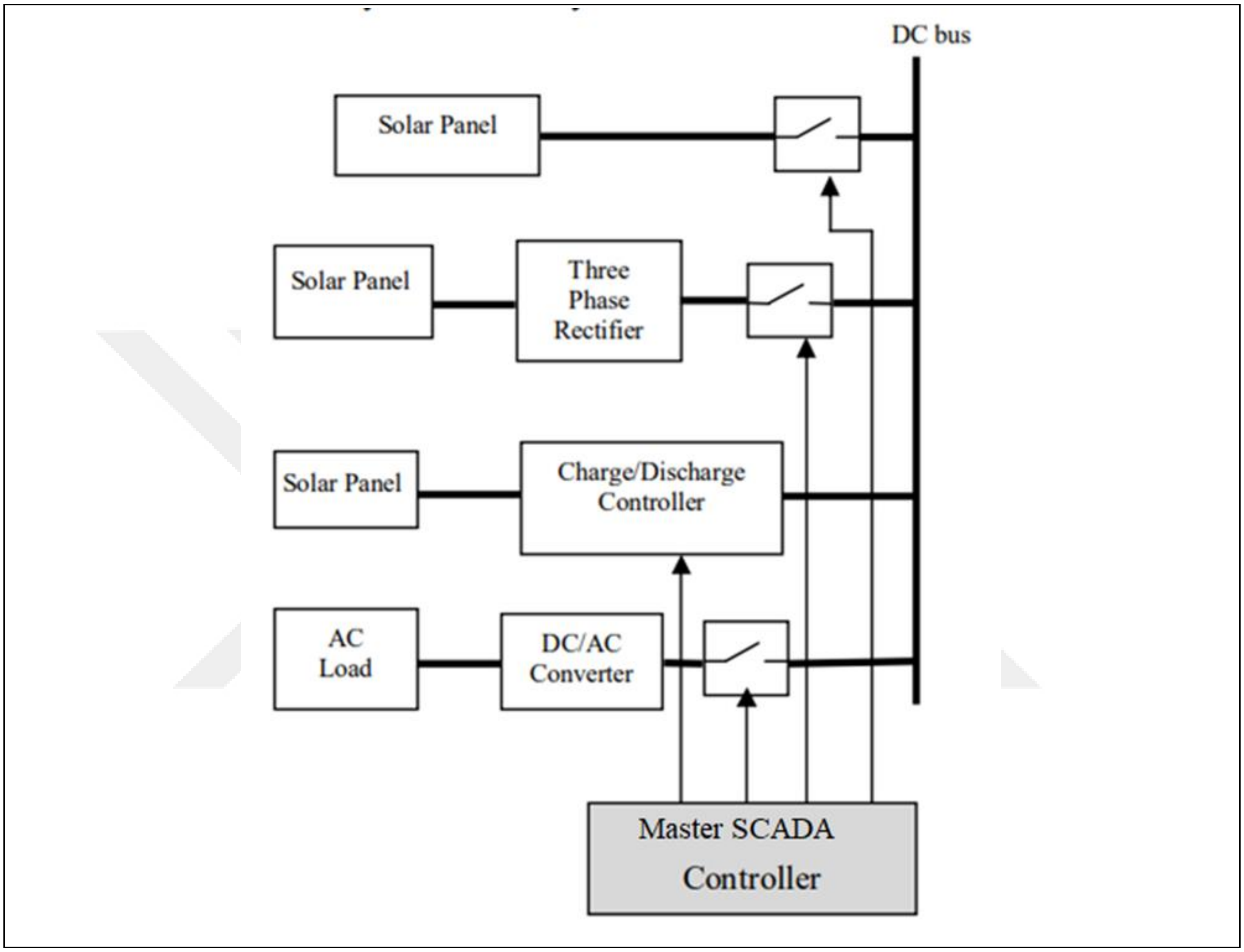

Figure 4.2: Controller Design of SCADA Based Controller

The Master SCADA controller (or main server) implements the software and protocols necessary to establish communication with the controllers of each of the components. It accesses the control, monitoring and steady-state operation variables through the communication interface of the local controller of each unit. In the context micro-networks, it is not within the main server's tasks to execute control actions on the electrical variables of each of the generating units. Therefore, it is not necessary to impose, on the communication system, and the rest of the system components, the transmission of information in real time. In the Master SCADA server each variable of a local controller is defined as a tag. These are organized in groups and can be accessed by other applications through protocols defined by SCADA systems for these purposes. The proposed architecture between the Master SCADA controller, communication system and the local controllers define a traditional SCADA system, identifying: the Master SCADA controller, as the MTU: to the communication system, such as the link layer with remote equipment or communication media; and to local controllers, such as Remote Terminal Units or RTUs. A database specially designed and pre-configured to operate in a SCADA system is what characterizes the Historization Controller and whose functionality corresponds to the Data Storage Module. In it, the operating variables of the generation units and the status of the micro-network are stored, as well as the alarms and system events.

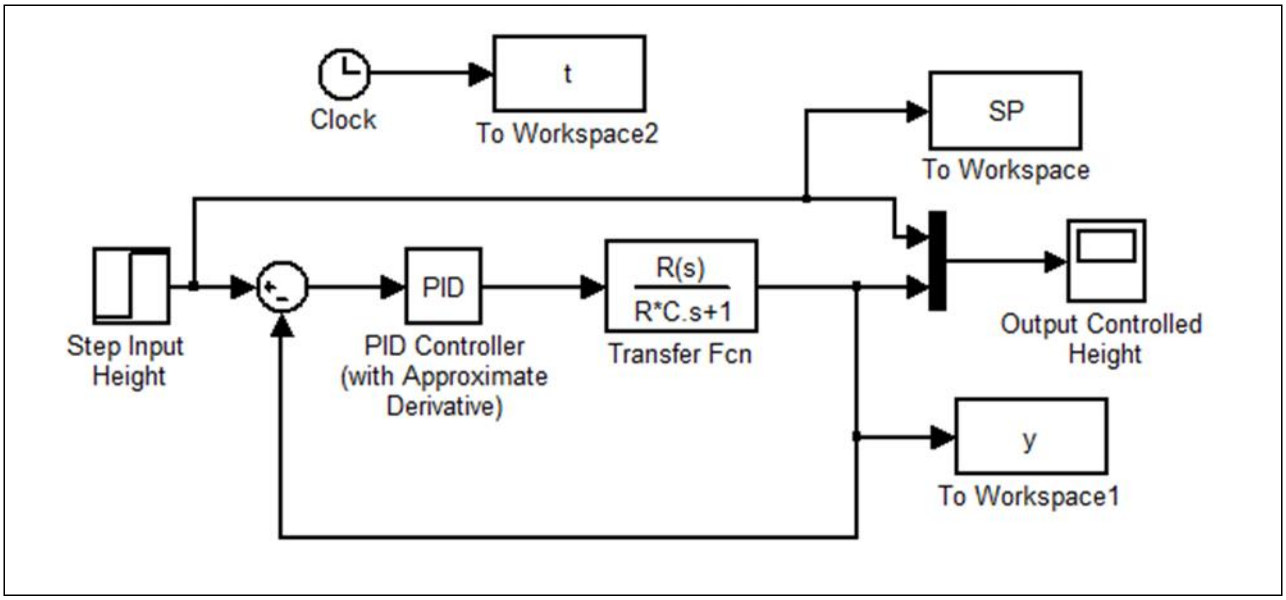

Figure 4.3: Master Controller Inputs in MATLAB

The database accesses the operating variables of the units through the main controller. The Application Controller hosts the programs corresponding to the Energy Management System, that is, all those applications that allow optimal operation of the micro-network. This ensures, for example, minimum cost operation, stability, quality of supply, load control and demand control. This equipment also implements the man / machine interface or HMI, which is responsible for showing the operator the status of the network and the generation units. The operator can take control actions on the units through this interface. The applications can access the current and historical operating variables of the micro-network components, through the SCADA Master and Historization Controller respectively. The components described above make up the Local

Coordinator, who is in charge of managing the distributed resources to operate the system ensuring stability, quality of supply and generation at minimum cost.

4.1.2 Generation System Design

The generation system is the source of energy supply for the community, it depends on its achieving sustainable development, and therefore it is important that people take a close look at how the generation units work to supply the demand. Therefore, the community must have the ability to monitor the system through the computational tool. People can interact with the interfaces without the fear that clicking on the icons will cause damage or a malfunction in the system, this is one of the general and important requirements of the computational tool. Community members receive signals from the system based on the availability of renewable resources and in order to minimize fuel consumption, this process is running in the Optimizer application. The demand control displays warnings in such a way that the population has the following consumption options: - Without restrictions, that is, they can freely connect loads to the network. - Consumption in a measured way - Consumption in a restricted way, that is, no type of load can be connected to the system. To comply with the global optimization of the system, what is intended is that the demand is adapted to the availability of generation. The figure below shows the PV grid as designed in MATLAB.

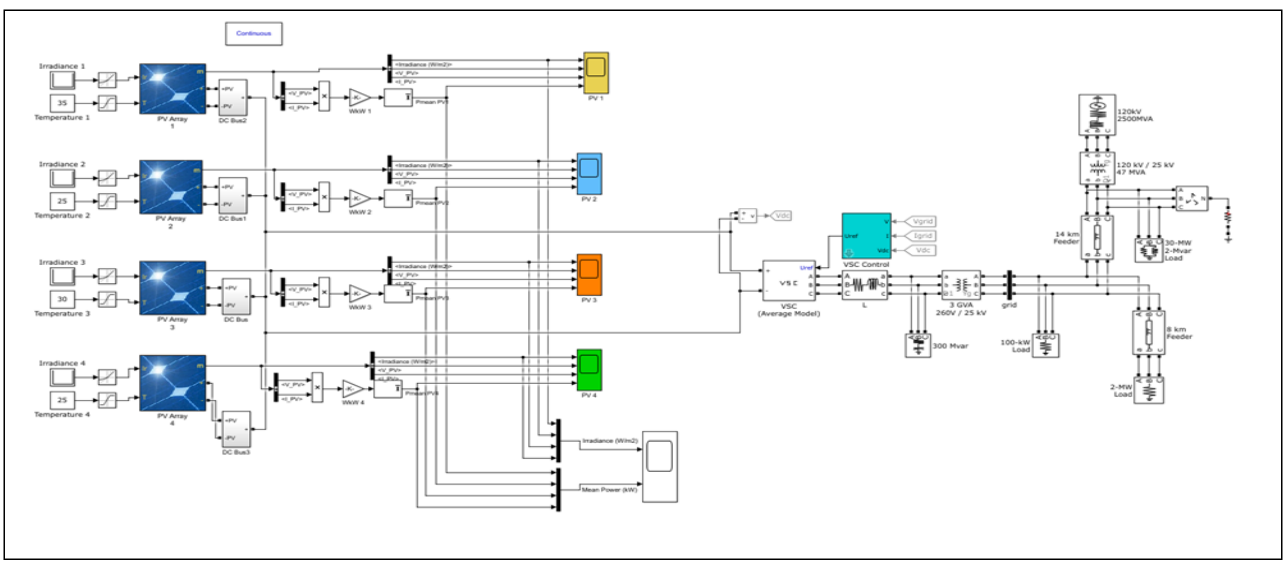

Figure 4.4: PV Grid as Design in MATLAB

The SVPWM technique is a frequently utilized to generate a sinusoidal output waveform with a lower total harmonic distort using more complex approaches. The basic principle of the SVPWM technique can be explained with the help of the inverter power stage schematic diagram.

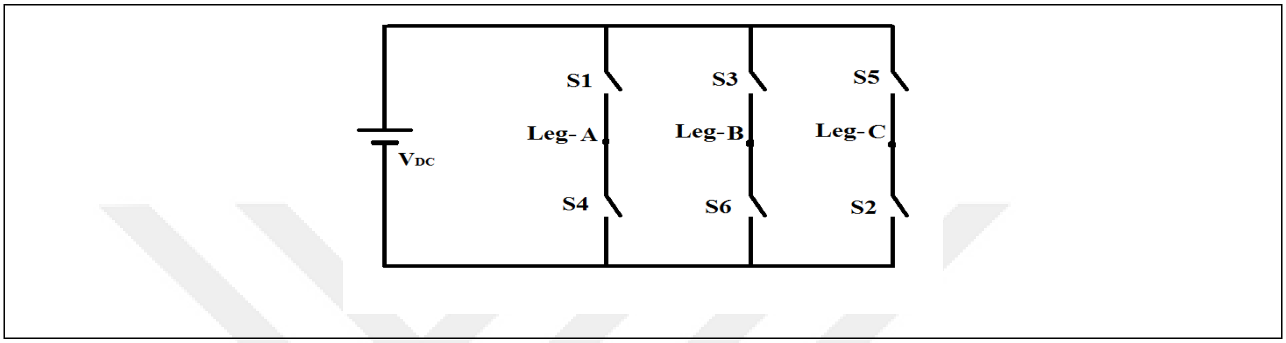

Figure 4.5: Schematic Diagram of the Inverter

While the figure below shows the SVPWM that is widely used to control the current, PWM spacer is an improved method that is preferred to maximize the inverter output power with more harmonic stability:

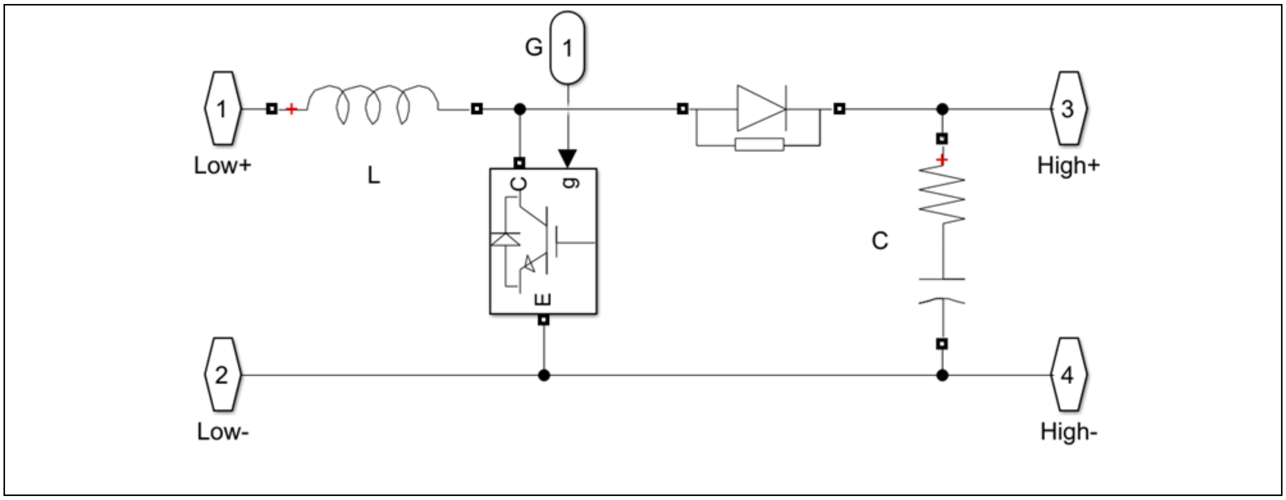

Figure 4.6: MATLAB Implementation of the SVPWM in the PV.

The vectors of the SVPWM topology representation is shown in the figure below [35]:

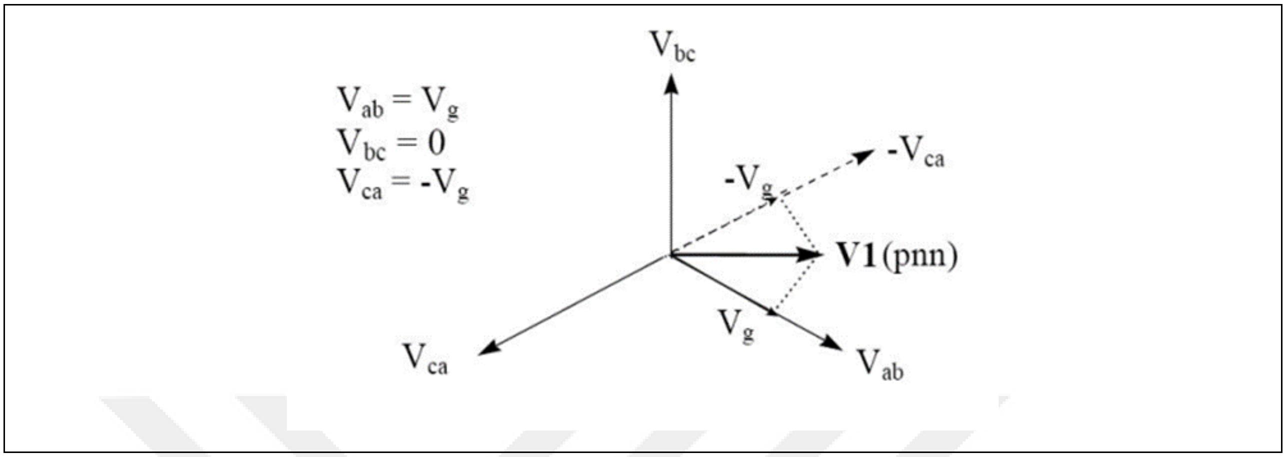

Figure 4.7: The angles of the SVPWM topology in the PV.

While the figure below shows the output voltage after it was stabilized by the SVPWM:

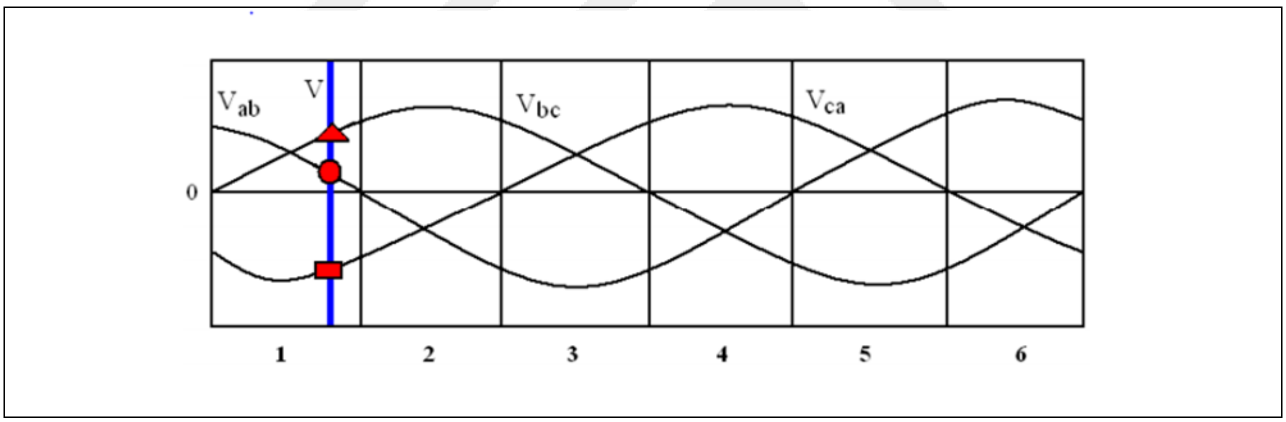

Figure 4.8: Output Voltage from the SVPWM in the PV.

The battery serves as repository for the excessive power generation, the role of the battery is to store over generated power to use it in later time as a power source, thus the battery is used to regulate and level of power presented to the load at the peak load demand or peak generation [36], the battery charge varies as it relies on the power generation of the solar PV as the figure below shows the visualization of the battery charge variance according to the PV power generation:

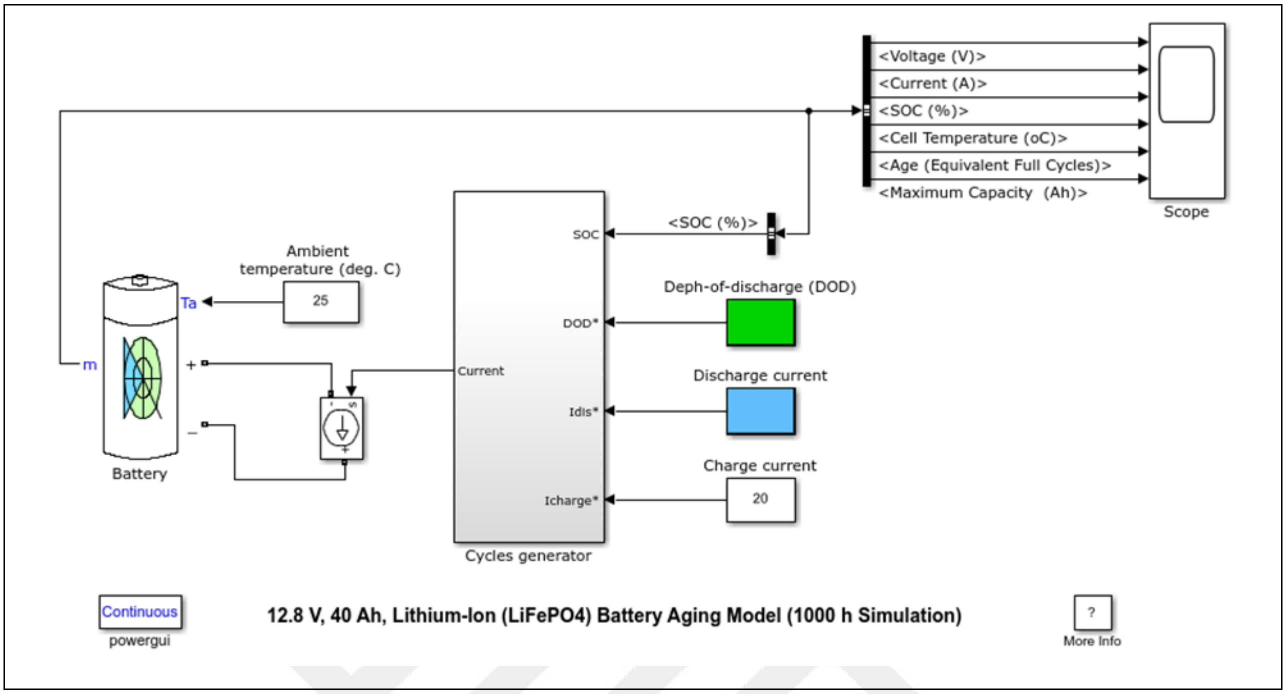

Figure 4.9: MATLAB implementation of the smart grid battery.

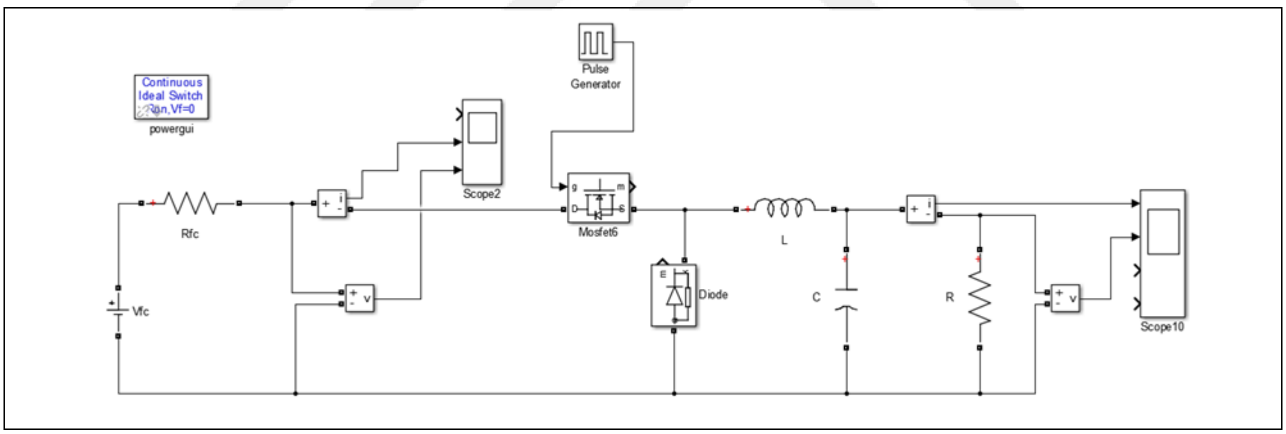

Figure 4.10: MATLAB Implementation of the Charge and Discharge Cycle in the Battery.

While the figure below shows the switch mode in the battery and the mathematical calculation of the remaining capacity and other parameters that effect the charge and discharge cycle:

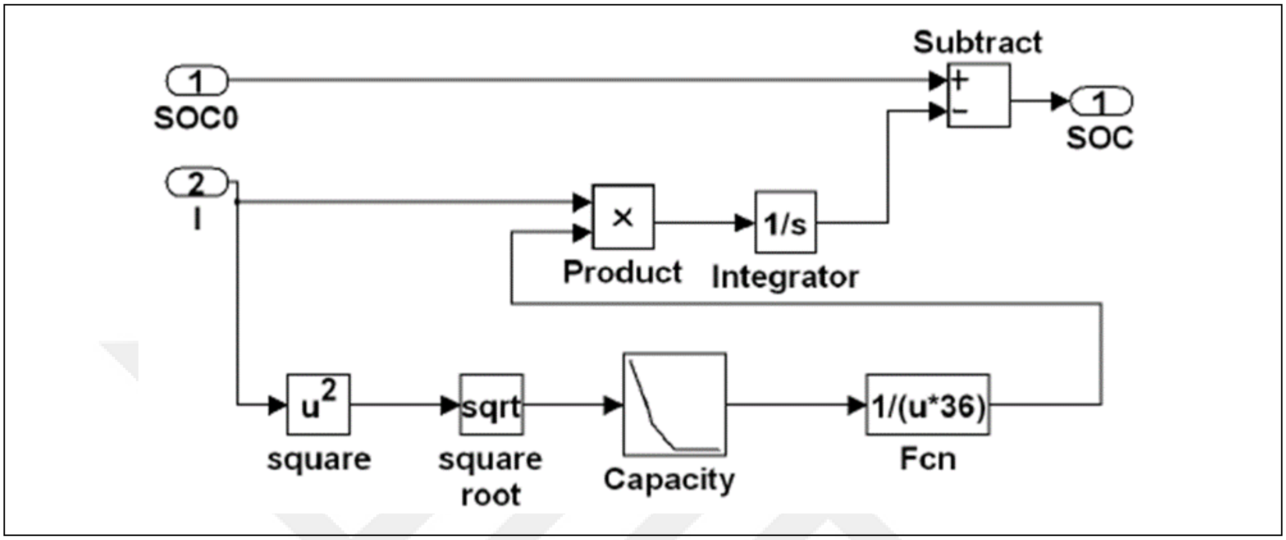

Figure 4.11: Switch Mode, Remaining Capacity, and other parameters of the battery simulated in MATLAB.

4.1.3 Design of Monitoring System

A network of distributed SCADAs operates a collection of distributed sensors and actuators at the developed operational level, and all of this distributed information is sent into the SCADA system. Because the dispersed sensors are individually recognized, various correction factors may be applied to the data given by these inputs, varied circumstances of temperature, luminosity, and other qualities in large area rooms can be readily included in the produced model. As an illustration of how this technique may handle complicated control structures, this study shows the possibilities of this control structure by creating a predictive controller at the interaction level, linked with SCADA supervisory control. This supervisory and control method originally arose in complicated MIMO industrial processes (multiple input/multiple output) with several operating points that needed to be finely monitored and managed. The figure below further illustrates the control and monitoring system in the proposed system design.

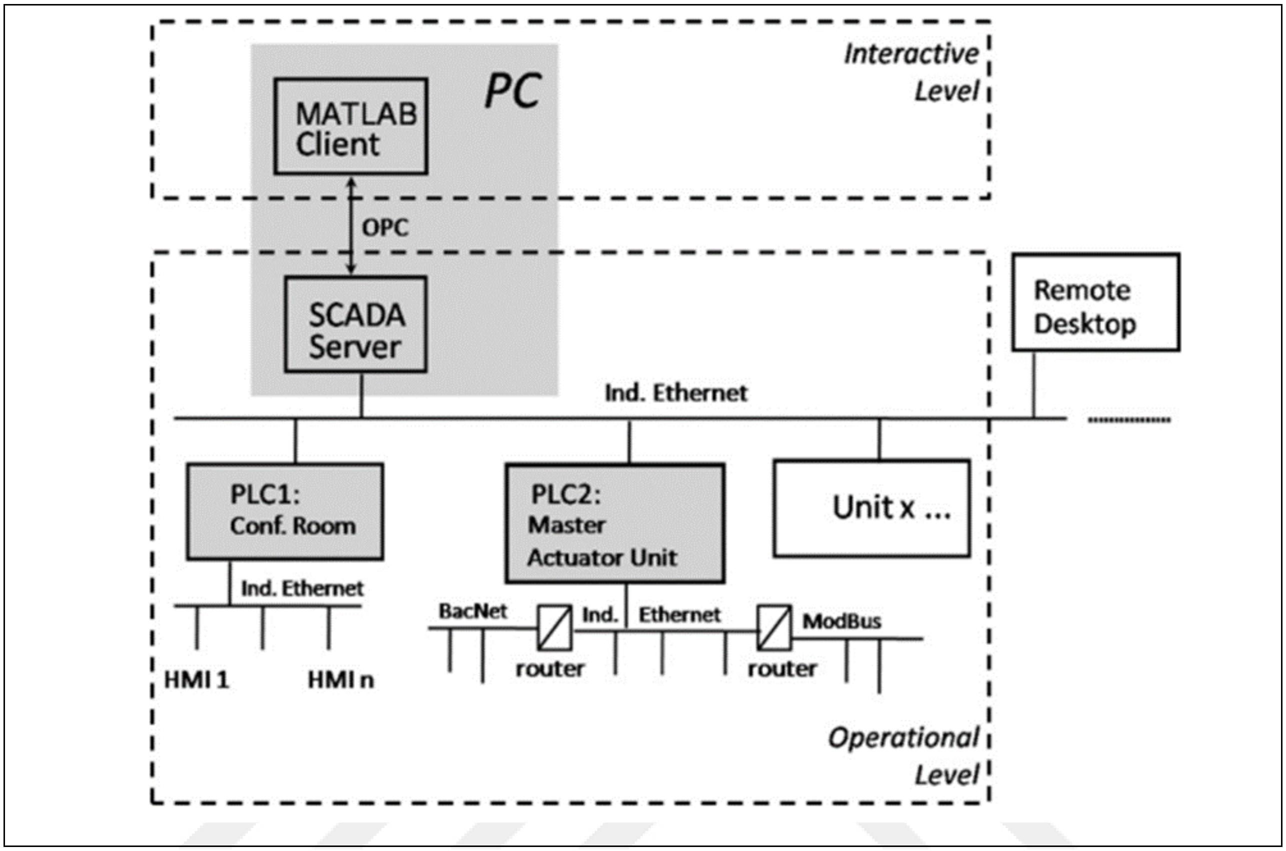

Figure 4.12: Mentoring Level of the Proposed System

To obtain greater control over smart networks, we need a dynamic view and monitoring of the general circumstances of all components of the smart network. We may get this using information and communication technology (ICT) systems, in which we deploy our most advanced system. We implement our IOT system by sending a visualization of the smart grid status to a receiver device that acts as a system monitor, which we accomplish by using the UDP/IP modules in MATLAB, where we set an IP for communication between devices and a timer for communication between devices. Figure 4.10 shows the UDP module in MATLAB, while Figure 4.11 shows a real application of the same module:

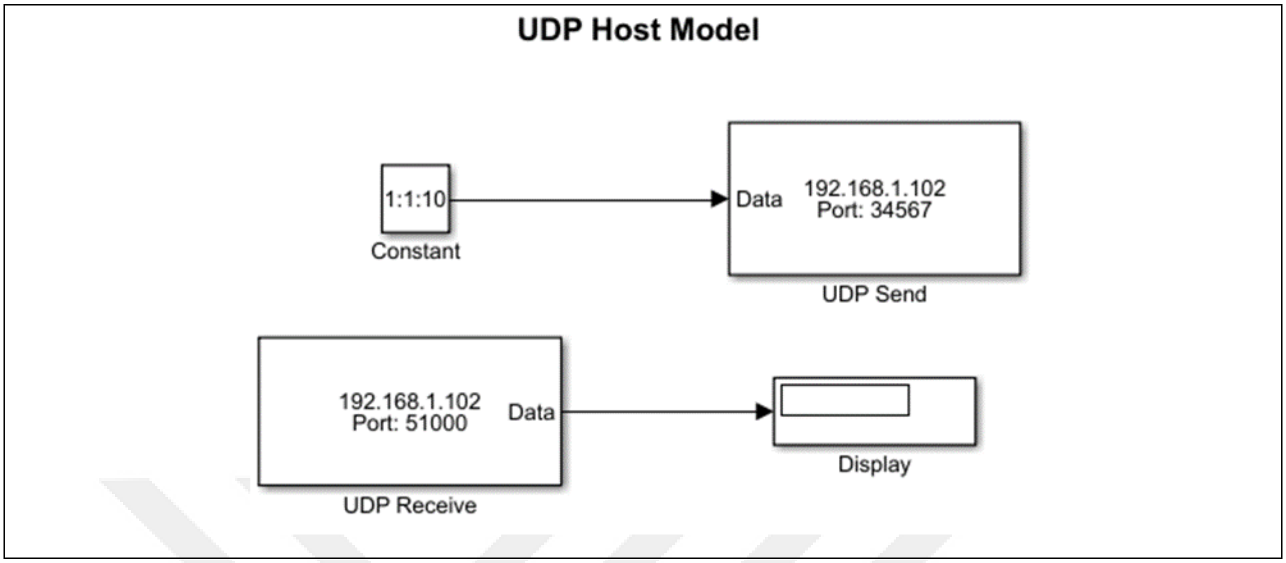

Figure 4.13: MATLAB UDP Send and Receive Module.

The figure below figure 4.12 shows the packet assembly and reconstruction in the receiver side of the smart grid monitoring system:

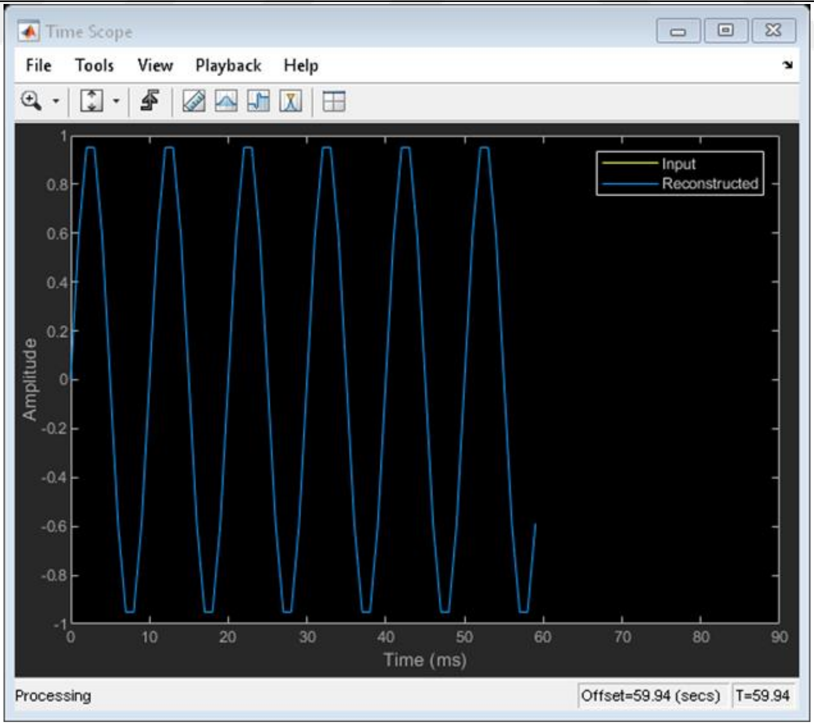

Figure 4.14: Packet Assembly in the Receiver Side of the Monitoring System.

While the figure 4.13 shows the assembled packets visualized in the receiver scope of the monitoring system:

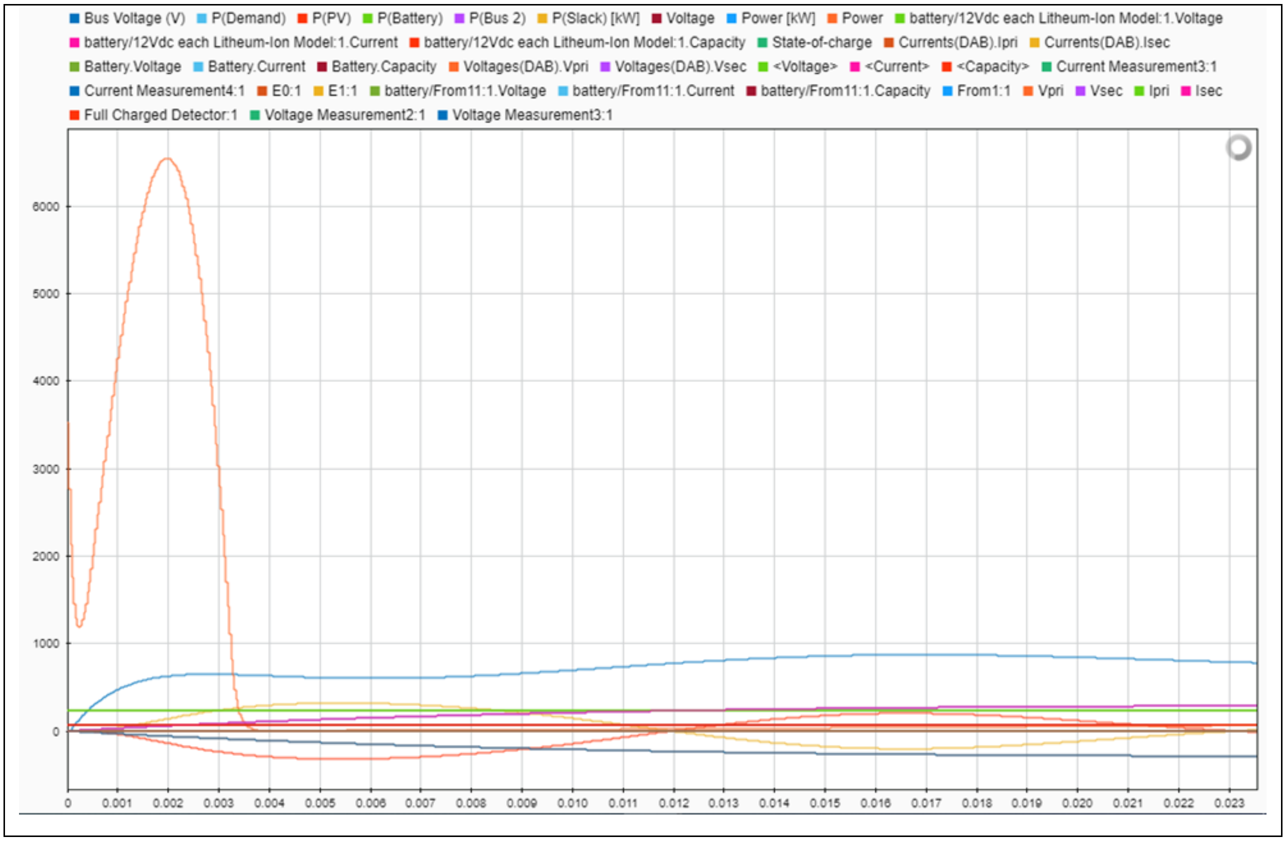

Figure 4.15: Reassembled Packets as a Grid Status Visualization.

4.2 SIMULATION RESULTS

The model's implemented blocks were separately validated for completeness and maximal generation at the time. After completing the construction of the solar system, which comprises of a control panel and equations blocks that depict the solar system, the data for the parameters to be compared must be added. When the simulation is executed, a predetermined code in the m-file is applied to display the characteristic curves on the same figure, as seen in figure 4.14 and 4.15 below:

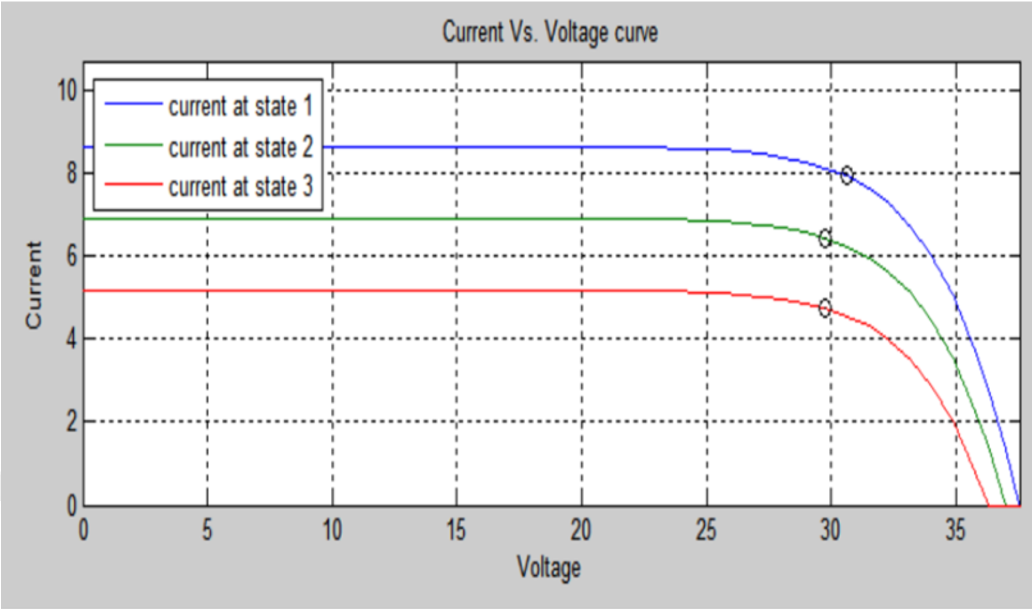

Figure 4.16: Current and Voltage Generation in PVs Before SCADA Management

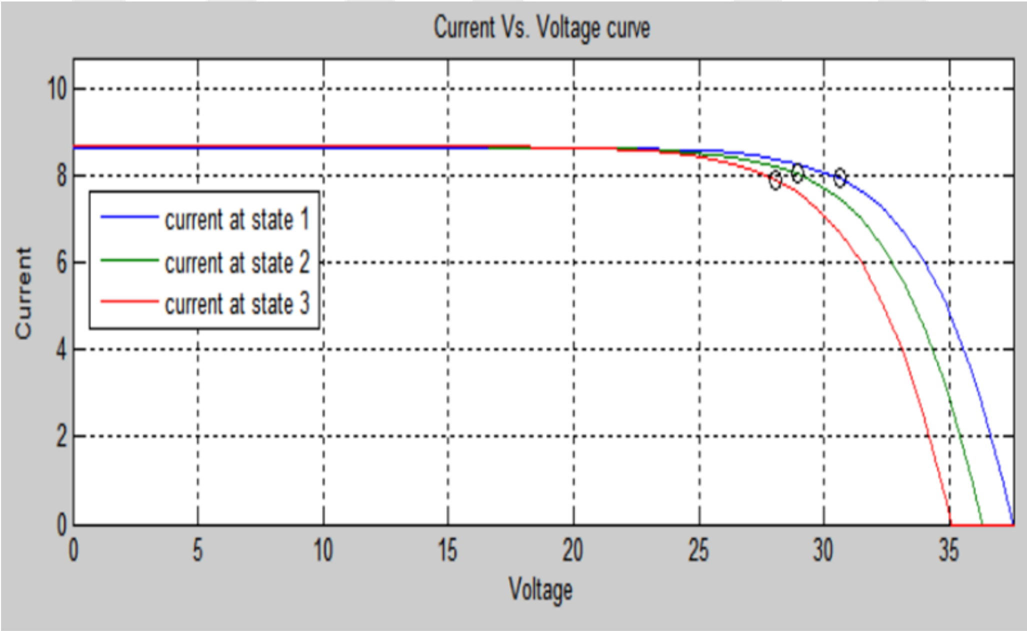

Figure 4.17: Current and Voltage Generation in PVs after SCADA Management.

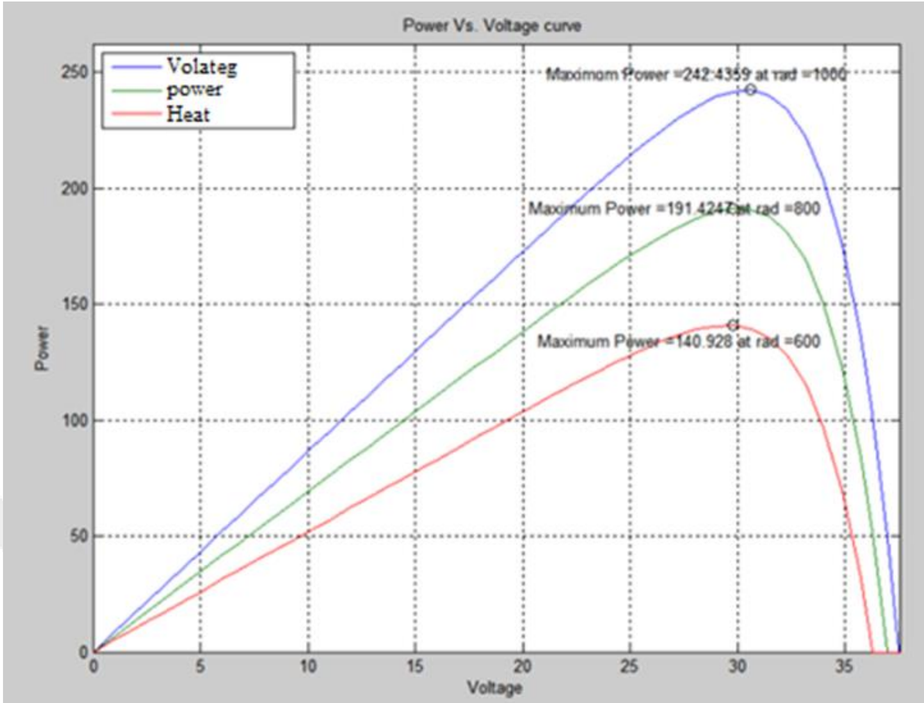

Figure 4.18: Voltage Output in Relation to the Irradiation in PVs before SCADA Management.

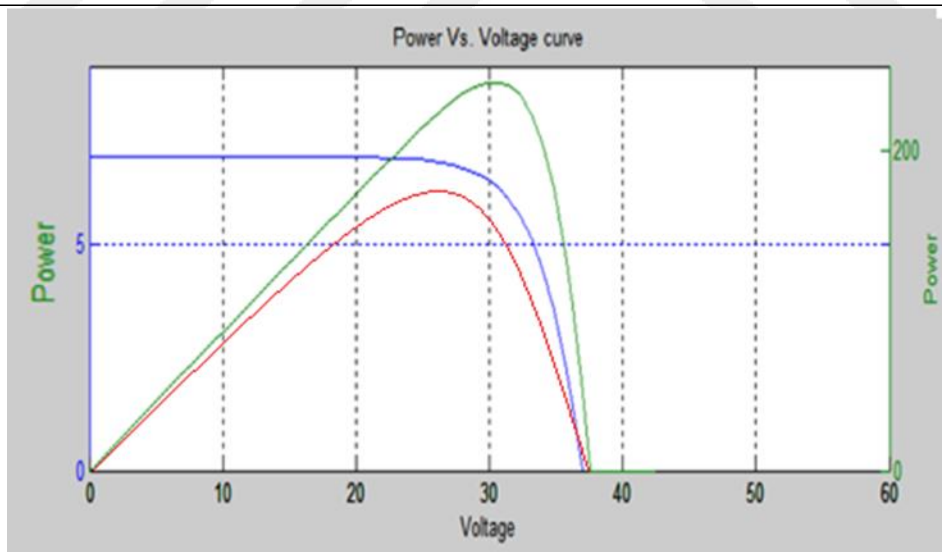

Figure 4.19: Voltage Output in Relation to the Irradiation in PVs after SCADA Management.

5. COCNLUSION

This thesis offers a conceptual approach for managing pedestrian normal and abnormal activity in the network using IoT technologies. All the work has been carried out in depth on the various techniques used to identify and classify normal and abnormal activity in the network and the appropriate framework to implement the method. The main goal was to assess the feasibility of the conceptual approach such that the individual integrated methods proposed provide the possibility of its practical implementation in future. The structure proposed consists of a data monitoring which captures sequences and acts as a network sensor and transmits these sequences to a central server responsible for analysis. The strategic approach is focused on deep learning using a previously trained CNN classification. It is now estimated that each day, the number of IoT devices that are linked globally increases by a large amount; and its applications include many different projects. Through this study, we have found more harmful assaults on Internet of Things (IoT) devices that show no signs of slowing down; security researchers and professionals constantly discover vulnerabilities utilized by cybercriminals that might endanger privacy, security, and the safety of the general public. Security threats to these systems have become more frequent and diverse, which demonstrates the need of a good intrusion detection system. Conversely, in order to wrap it up, we discussed a very thorough assessment of softwaredefined IDS solutions for IoT security, presenting a multi-layered approach in several chapters, and addressing IoT security risks and convergence. The results of the experimental assessment reveal that the suggested architecture is better at detecting and understanding things than standard techniques. We have big plans in the future that include implementing and improving a more stable and secure SD-IDS system for the IoT environment. The technical approach proposed centered on the accounting of pedestrian normal and abnormal activity in the network, although the same technique can also be considered in other fields, such as vehicle flow accounting, also within the smart cities framework of the future.

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