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ENERGY OPTIMIZATION AND LOAD BALANCING USING HYBRID SMART GRID AND LIFE TECHNOLOGY

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Master's Thesis

Supervisor

Asst. Prof. Dr. Abdullahi Abdu IBRAHIM

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The thesis titled ENERGY OPTIMIZATION AND LOAD BALANCING USING HYBRID SMART GRID AND LIFE TECHNOLOGY prepared by ROUWAIDA ABBAS JAWAD ALHETHANI and submitted on 28/04/2023 has been **accepted unanimously** for the degree of Master of Science in Electrical and Computer Engineering.

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Rouwaida Abbas Jawad ALHETHANI

Signature

DEDICATION

Before I continue, I want to praise and thank Allah, the Almighty, for giving me the knowledge, abilities, and opportunity to carry out and successfully complete my research. My parents have my sincere thanks. Everything wonderful that has happened to me has been motivated by them, and their love is the energy that enables this to be the case. I'd like to end by thanking my sister and brother for their support and affection during this process.

PREFACE

My advisor, Asst. Prof. Dr. Abdullahi Abdu IBRAHIM, deserves a lot of credit for giving me the guidance, supervision, encouragement, and help I needed to finish my study. His willingness to collaborate with me, persistence, constructive criticism, and useful suggestions have greatly boosted my understanding and confidence. I value the time he spent reviewing my work and pointing out my mistakes. Last but not least, I would like to express my gratitude to everyone who helped in any way, whether it was by offering support, prayers, or useful advice.

ABSTRACT

ENERGY OPTIMIZATION AND LOAD BALANCING USING HYBRID SMART GRID AND LIFE TECHNOLOGY

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In this thesis we will explore lifi based smart grid special load frequency control in the next part. lifi based smart grid created this approach. This method was inspired by the active parallel filter (apf), which produces a disturbed current to superimpose the polluted load current to maintain the source current harmonically low. The active parallel filter (apf) superimposes load polluted current with a disturbed current. This method superimposes a distorted current on the load's polluted current. The controller's disturbed frequency is superimposed on the load's average frequency in lifi based smart grid. This maintains grid frequency.in order to limit frequency variation in the busbar, the lifi based smart grid approach installs a particular load at the level of the busbar and nozzle and connects it to the busbar with a controlled switch.

KEYWORDS: Lifi, Smart Grid, APF, LED, ML, AI.

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ABBREVIATIONS

LIFI	:	Light Fidelity
SG	:	Smart Grid
APF	:	Active Parallel Filter
CO2	:	Carbon Dioxide
GW	:	Giga Watts
PV	:	Photo Voltaic
PSO	:	Particle Swarm Optimization
GA	:	Genetic Algorithms
BP	:	Back Propagation
ANN	:	Artificial Neural Networks
RBF	:	Radial Basis Functions
EP	:	Evolutionary programming
IFEP	:	Improved Fast Evolutionary Program
DSM	:	Demand-Side Management
DSP	:	Digital Signal Processor
CFES	:	Compressed Form Energy Storage
CAES	:	Compressed Air Energy Storage
AMR	:	Automated Meter Reading
AMM	:	Automated Meter Management
AMI	:	Advanced Metering Infrastructure

PLC : Power Line Carrier

MW : Megawatts

IM : Intensity Modulation

DD : Direct Detection

MMSE : Minimum Mean Squared Error

ISI : Intermember Interference

OFDM : Orthogonal Frequency-Division Multiplexing

IBI : Inter-block interference

BPSK : Binary Phase Shift Keying

QAM : Quadrature Amplitude Modulation

PWM : Pulse Width modulation

ADC : Analog-Digital Converter

SNR : Signal-To-Noise Ratio

GW : Gigawatts

1. INTRODUCTION

3.2 INTRODUCTION

The 1973 and 1979 oil shocks demonstrated the significance of energy data in sustaining growth and satisfying consumption demands driven by population and lifestyle growth. These requirements are a direct result of societal shifts and population growth. Although we now know how much oil, gas, and coal are in the ground, we still have a way to go before we can say with any certainty how much of each resource can be extracted at peak efficiency. Meeting the world's rising energy demand has become more difficult as a result of environmental issues discussed at the Earth Summits in Rio (1992) and Kyoto (1995). (1997). Global warming is exacerbated by human activity. Several proposals to reduce carbon dioxide (CO2) emissions from burning fossil fuels (IAE 13) are consequently put forth. The debate over how quickly we should transition to a new energy source centers on this question. Utilization of vector power is the basis for many transition hypotheses, but consumption models are rarely questioned (Gov 13). The concept vehicle for transportation is the electric car for the private consumer. Coal generates 40% of the world's electricity, therefore the problem is more likely to be shifted than solved. Thus, increasing renewable energy generation is a crucial energy (or power) transition lever. The fact that it is so significant makes it a primary control. Example: Power plants have been using renewable sources like hydroelectricity and biogas for decades. However, in the last two decades, this method of production has expanded in the wind and photovoltaic industries (PV). Depending on the location, many generators have hooked up to the grid to begin selling power generated by wind farms and PV arrays. Increasing numbers of grid-connected producers are a result of technological advancements as well as regulation and subsidy initiatives. High-capacity power plants, ranging in size from 100 MW for gas-fired power plants to gigawatts (GW) for nuclear units, form the backbone of the electrical grid. This design was motivated by the decades-old "production-transmission-distribution" triptych. The backbone of any reliable electricity grid is the power plants that generate the most power. This centralized production is regularly adjusted to meet demand in order to prevent energy network imbalance. This ensures that electricity can flow freely. The electricity grid is being revolutionized by the use of intermittent sources by decentralized, uncontrollable generators. There is now a horizontal layout instead of the former vertical one. Intermittent sources are utilized by

decentralized, uncontrollable generators. The reason for this is that the structure of generators is dependent on unreliable sources. There is a new term for these people now; consumer-players. What we now call new actors who play both a consumer and producer role. With so many moving parts, management becomes less clear. The unpredictability of renewable energy sources makes installation of new renewable energy parks more time-consuming. Installation of new renewable energy parks is slowed as a result of this, and line capacity constraints in some locations further reduce energy production. If all of the islands' power grids are to remain operational, the production cap must include renewable energy sources at a rate of at least 30%.

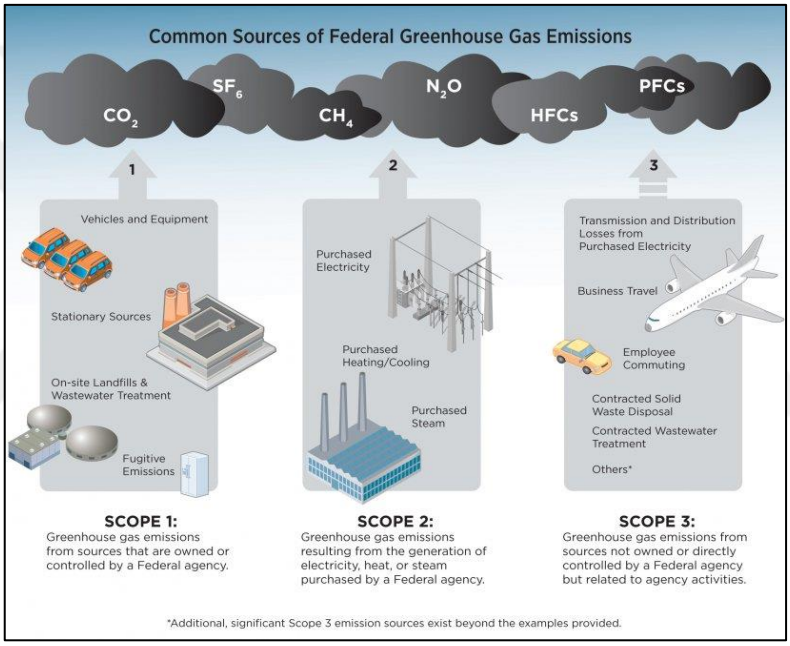

Figure 1.1: Sources of GHG Emissions.

Promoting the construction of renewable energy generators and kickstarting the energy transition requires "intelligent" management of production and consumption. This is a standard part of the Smart Grid. The long-term objective is to consider the electrical grid as a collection of numerous microgrids, each of which is autonomously controlled but must achieve and maintain supply-and-demand parity. Controlling energy flows in a microgrid is made easier with the help of storage. Regulatory shifts, including tariffs, may make decentralized storage feasible if large-scale centralized storage is not technically and economically viable. Multiple technologies make distributed storage a viable option. In reality, the possibility of connecting storage mechanisms is being examined to define use

and remuneration restrictions for the services provided, just like solar or wind power was fifteen years ago. Reduced consumption, reduced output, buffering the intermittent nature of renewable energy sources, etc. A solar-powered microgrid serving a tertiary consumer and equipped with energy storage is the focus of this thesis. Power sources including flywheels and chemical batteries are being examined (Li-ion). Management must take into account the cost of buying and selling parts in the market, as the system is linked to the main network. Therefore, increasing the predictability of power withdrawal and injection is essential for the development of microgrids. Since the energy provider can anticipate his clients' requirements better in advance, he can reduce the amount of energy he purchases in real time from the wholesale market at higher prices. This thesis involves developing an optimal design technique for the systems under study, in addition to management approaches. The objective is to establish a technically and economically viable solution by combining the installation costs of individual components, taking into account consumption, production, and tariff statistics. This overall cost is affected by the energy bill and the advantages of smart microgrid management. The management loop will thus be built into the design process from the beginning. For the microgrid's environment to be understood, months or even years of simulation are required (production deposit and consumption missions). Depending on the models and management strategies used, the processing time involved may make them unworkable. In order to scale the system and investigate the impacts of different input elements, the authors of this thesis identified a suitable resolution method and model granularity. This adjustment was made to accommodate the price context necessities of this thesis.

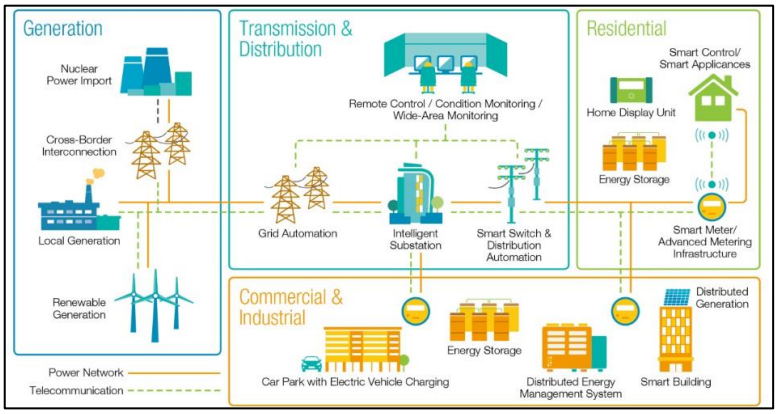

Figure 1.2: General Layout of Smart Grid Systems.

3.2 MOTIVATION

The significance of the nodal injection problem increased with the paradigm shift in electric power generation and distribution. Large-scale electricity generation, transmission, and distribution systems have been shut down. Eliminated. Instead, energy is injected by smaller power plants at nodes in the distribution network, where their techniques of generating are most suited. The use of renewable resources has contributed significantly. Considering their specific characteristics, renewable energy plants with a lower installed power are typically constructed in areas where the wind blows. Maximum yield is achieved in the plant. This lowers the cost of producing renewable energy (wind turbines are installed where there is wind and this is favorable to the generation of wind energy). This shift in thinking is not just attributable the development of renewable energy sources. When production happens closer to where it will ultimately be used, less energy is wasted in transit from there to the consumer. To reduce the amount of infrastructure upgrades required to accommodate the new energy generation, it is important to determine which network nodes are most amenable to the introduction of the new technology. There will be a greater requirement for reinforcements to handle the energy increase if the network nodes that support the next generation are unknown. If you know which nodes in your network have the highest power consumption, you can place your new generation there.

3.2 GENERAL OBJECTIVES

PROJ Dispatching should aim to generate and use electricity at the lowest cost possible. By meeting all demand within system restrictions, this aim is achievable. Traditional and creative ways have been used to solve the dispatching of electrical energy efficiently and cost-effectively. Genetic algorithms (GA) and particle swarm optimization methods have become popular recently. Both are AI-based. This strategy developed recently (PSO). Thus, this work uses these two methods to solve the problem of cheap electrical energy dispatch in a groundbreaking expedited smart grid design. This work has distinct goals: This study will examine maximum nodal injection of active power in an electrical energy network to provide a solution. To clarify, the goal is to find the nodes that can maximize this power's worth and inject it. It was intended to alter the Particle Swarm Optimization (PSO) algorithm to apply it to nodal injection, whether simultaneous or non-simultaneous, and encode it such

that it may be utilized on most networks. These steps were needed to apply the algorithm on the most networks. We also planned to suggest ways to advance this effort.

3.2 CONTRIBUTIONS

This thesis creates algorithms (agents) that can independently learn multitasks. We want to move from offline optimization to smart grid, real-time responses. Smart grid users can improve their consumption patterns by using real-time applications built on massive data sets [28]. One must understand energy consumption trends and strategies to maximize a building's energy consumption and grid impact. We will explore LIFI BASED SMART GRID Special Load Frequency Control in the next part. LIFI BASED SMART GRID created this approach. This method was inspired by the active parallel filter (APF), which produces a disturbed current to superimpose the polluted load current to maintain the source current harmonically low. The active parallel filter (APF) superimposes load polluted current with a disturbed current. This method superimposes a distorted current on the load's polluted current. The controller's disturbed frequency is superimposed on the load's average frequency in LIFI BASED SMART GRID. This maintains grid frequency. In order to limit frequency variation in the busbar, the LIFI BASED SMART GRID approach installs a particular load at the level of the busbar and nozzle and connects it to the busbar with a controlled switch (see figure 1.3).

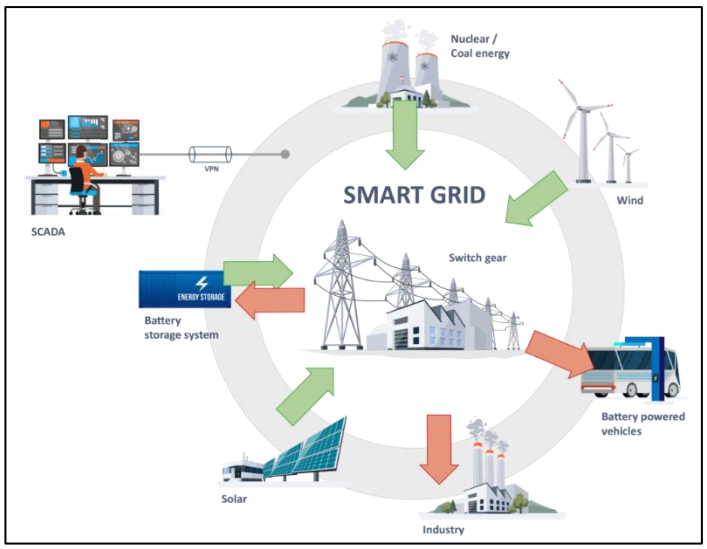

Figure 1.3: Proposed Accelerated Smart Grid Architecture.

Loads P is an informal term that can refer to a number of different types of facilities, like as substations, industries, and others. As can be seen in the image above, the instruction to monitor and manage network or inverter frequency distinguishes the main loads from the special load CS. This command sets the parameters under which the latter operates (1.3). Customers in SH and LA, on the other hand, are responsible for regulating the large loads either manually or automatically. We are unable to identify the overall number of loads connected to the network or the types of loads that are there since thousands of loads are joining or departing the network at any one moment, making it impossible for us to ascertain either value. For HV customers, the network dispatcher can provide a rough estimate of the time needed for start-up and shut-down. In the business world, for instance, the normal workday begins at 8:00 a.m. and concludes at 4:00 p.m. The system administrator also considered the nonstop production facilities that operate until there is an unexpected problem or an update to the program. Like any well-oiled machine, these plants have a set routine they always follow.

1.5 PROBLEM STATEMENT

This study sought to provide a solution that could optimize electricity absorption in most networks. The first half of this challenge involves injecting power into each network node individually to compute the maximum amount of power that can be injected into each node; the second portion involves injecting power into all network nodes simultaneously. Network simultaneously, all nodes must be injected to determine the maximum power that can be injected into each. After that, we will formulate these two instances separately. Combinatorial problems have many, combinable solutions. One of these options will solve the problem. Harrison and Wallace's inverse load approach [3], Joo Nunes' genetic algorithms [4], Jorge de Almeida's probabilistic methods [6], and other methods can yield plausible answers. The PSO method was chosen to find all feasible challenge responses. This algorithm was chosen because it is one of the possible algorithms to solve the problem, because it is part of the group of artificial intelligence algorithms that derive from collective intelligence, and because only one study was found that applies this algorithm to this problem with the restriction that the new losses cannot be greater than those that existed in the case that t The problem can be solved with this algorithm. This investigation's purpose

is to determine the network's maximum energy absorption, regardless of losses, hence this limitation will not be imposed.

This thesis is organized into four chapters as follows:

Chapter 1: this first chapter gives the state of the art of the classic and modern methods used to solve the problem of economic dispatching and the problems encountered by each method.

Chapter2: in this chapter, and after having defined what economic dispatching is, we have mathematically formulated the problem of economic dispatching in order to be able to solve it in the last chapter.

Chapter 3: this chapter is devoted to the two optimization methods that we used in this work and which are the genetic algorithms (GA) and the optimization algorithm by particle swarms (PSO).

Chapter 4: In this chapter we applied PSO and GA to the proposed accelerated smart grid. We took the IEEE 30-bus system as a test.

Finally, we close this thesis with a general conclusion concerning the general contribution of our work. We will also present the perspectives that may follow from this work.

2. LITERATURE REVIEW

2.1 CHAPTER INTRODUCTION

In a highly competitive market, optimizing production costs typically necessitates the use of a precise mathematical model. As a result, he learned of a number of methods, both ancient and cutting-edge, that have been applied to this optimization issue. According to [1], these methods have already been put into practice. The classical methods include the Newton-Raphson, iterative lambda, basis point, and participation factor approaches; however, they become confused when the cost function is non-linear with multiple minima, making it difficult for these algorithms to determine the global minimum, leading to sub-optimal solutions. [2].

3.2 RELATED WORKS

Inference engines and databases comprise expert systems. Both components make the whole. The inference engine controls the user interface, external files, programs, and scheduling. We save problem-specific data in the database. With this database, a process expert may explain its principles. SE models are used to reduce solution time because they do not involve complex mathematical calculations. Lowering process work does this. However, if the new load model cannot be compared to the dynamic database model, it will not work. Despite this, the SE proved successful in several applications, including defect discovery [1].

Lotfi A. Zadeh introduced fuzzy set theory in 1965. In 1973, he introduced his revised notions of a linguistic variable and fuzzy if then rules. Both ideas were his. This study lay the framework for fuzzy logic control, which is mostly used in sectors that can only represent imprecise or uncertain input. Fuzzy systems use approximation reasoning. This lets these algorithms draw conclusions from confusing and insufficient data like people do. Expert systems use binary logic to define and manipulate accurate concepts, while scrambled systems allow issue formulation with uncertainty. Expert systems describe and manipulate concepts.

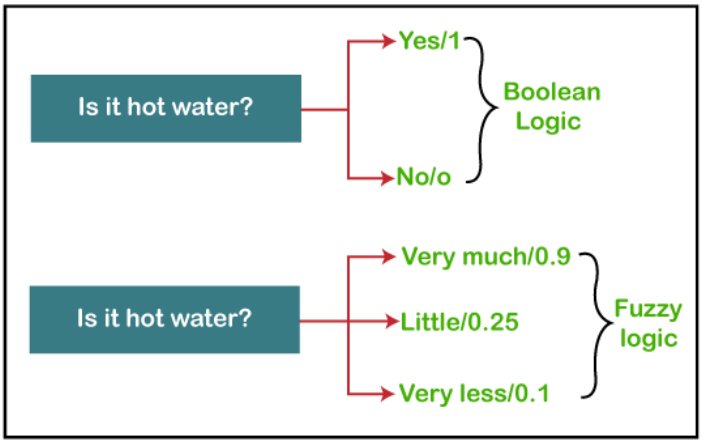

Figure 2.1: Basic Concept of Fuzzy Logic.

The scrambled expert system has gained popularity in recent years, and much work has been done to meet situations with several competing objectives. Due to their fast processing, adaptive scrambling algorithms are better for real-time applications. However, if work increases unexpectedly, these approaches may backfire. [2] Also notes that the techniques do not totally remove mathematical complexity. Procedures have this downside. Due to their fast processing, adaptive scrambling algorithms are better for real-time applications. These tactics can backfire if load capacity demand is unexpectedly high. [3] Further notes that the techniques do not totally remove mathematical complexity. Procedures have this downside. Due to their fast processing, adaptive scrambling algorithms are better for real-time applications. These tactics can backfire if load capacity demand is unexpectedly high. These methods' mathematics remains difficult [4]. Another drawback. Artificial neural networks can solve many "real-world" problems. Learning from past experiences helps them adapt faster to changing circumstances. They also understand noisy or incomplete data. They can also be effective, especially when it is difficult to articulate the guidelines or procedures needed to solve a problem. They may work well in this situation. ANNs are data processing systems that can predict output patterns based on input patterns. This lets ANNs be compared to black boxes. After training, the neural network can discover patterns of similarity in new input patterns and construct a model for the expected yield. ANN-based interpolations can produce accurate results even with noisy and unshaped inputs, a major gain. It's advantageous. Learning is the neural network's most critical task. Instructor-led or self-directed learning is possible. Directed training includes inputs and outputs. Then, the network processes the inputs and compares its outputs to the desired results [5]. After then,

the mistakes are computed and used to change the weights to manage the network. Twisting the weights in the other direction repeats this procedure. Unsupervised training produces inputs but no desired results. After that, the system will arrange incoming data depending on its own discretion. According to [6], this phenomenon, also known as self-organization or adoption, most electrical power system ANN implementations use the back propagation (BP)-based multilayer perceptron model for training. Their simplicity and hardware accessibility explain this propensity. Boiling point techniques are frequently employed, although local minima make convergence challenging. Due to several local minima. Standard ANN uses nonlinear parameters, and the study relies on nonlinear optimization methods like steepest descent. Particularly, sharpest descent. The other main downside of ANN is that there are no clear rules to determine the number of hidden layers, the number of neurons in each layer, or the type of activation employed in each layer, making it difficult to identify an appropriate configuration.

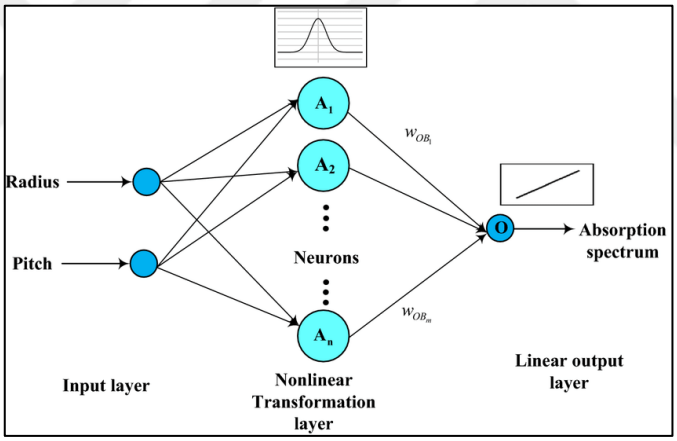

Figure 2.2: ANN and RBF Networks.

ANN configuration is one of the hardest parts. ANN's worst weakness. A new generation of artificial neural networks (ANN) uses radial basis functions to approximate (RBF). Radial Basic ANNs (RBF networks) are self-configuring, quicker, and more reliable than BP networks. This avoids boiling point-based neural network problems. Artificial neural networks (ANNs) have been popular for two decades, and many studies have been published on their use to solve the power system problem [7]. A new generation of artificial neural networks (ANN) uses radial basis functions to approximate (RBF). This step avoided boiling point-based neural network difficulties. Radial Basic ANNs (RBF networks) self-configure

and are faster and more reliable than BP networks. They are RBANNs. Artificial neural networks (ANNs) have been popular for two decades, and many studies on their use to solve the power system problem have been published [8]. [8] Adds details. A new generation of artificial neural networks (ANN) uses radial basis functions to approximate (RBF). This step avoided boiling point-based neural network difficulties. Radial Basic ANNs (RBF networks) are self-configuring, quicker, and more reliable than BP networks. These are Radial Basic ANNs. Artificial neural networks (ANNs) have been popular for two decades, and many studies have been published on their use to solve power system problems [9]. Radial basis functions (RBF) are used for approximations and artificial neural networks (ANNs). Radial Basic ANNs (RBF networks) self-configure and are faster and more reliable than BP networks. They are RBANNs. Over the past two decades, artificial neural networks (ANNs) have garnered substantial interest, resulting in a large number of research publications on their use to improve power systems [10]. Another approximation theory, radial basis functions (RBF), has been used to build ANNs. ANNs also solve complex power system challenges. Radial Basic ANNs (RBF networks) self-configure and are faster and more reliable than BP networks. They are RBANNs. Artificial neural networks (ANNs) have garnered attention for 20 years. According to [11], many publications on using ANNs to solve power system problems have been published during this time.

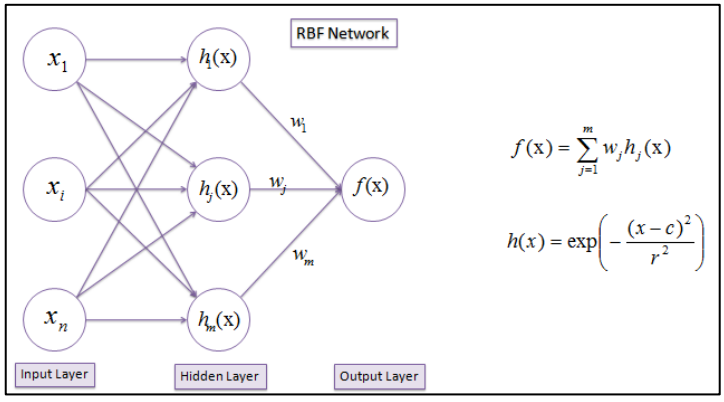

Figure 2.3: RBANN According to [11].

Until it solidifies, molten metal is gradually cooled. Temperature can be compared to SA algorithm iterations. Each cycle generates a possible solution. If the new solution is better, the procedure will be repeated to create another candidate solution. If its likelihood of approval exceeds a randomly generated value between 0 and 1, it will be accepted. Finding

a solution can continue indefinitely until either the maximum number of iterations is achieved or the best solution is found. If the SA annealing schedule is not carefully controlled, the solution will always be locally optimal. SA was initially used since it can be done easily. Annealing is slow in a practical big-scale other feed system, but a good annealing program takes a lot of computational time [12]. Fred Glover introduced forbidden search in 1986. Gradient-driven research moves from one area to the next in the direction with the steepest or most decent ascent. Gradient-driven research. Because it uses short-term and long-term memory, the TS technique can break out from a local optimal solution while keeping search space variety. Short-term and long-term memory achieve this. Because research changes taboos, maintaining a short-term list requires constant maintenance relocation. Remember this. The dimensions and features of the latest prohibited list are the most crucial search parameters. However, the situation will strongly influence how to alter such elements. This heuristic strategy involves many search rounds. However, WM Lin, et al. recently proposed an upgraded TS method for inexpensive shipping with non-smooth cost functions [13]. TS algorithm improvements enabled this. Delivery was cheap. Evolutionary programming (EP), invented by Fogel in 1960, begins with a population of possible replies. Unlike crossover, phenotypic evolution relies on a variety of mutagenic mechanisms. The PE is also unconstrained by GA binary genome representations. The binary genome does not limit the PE.

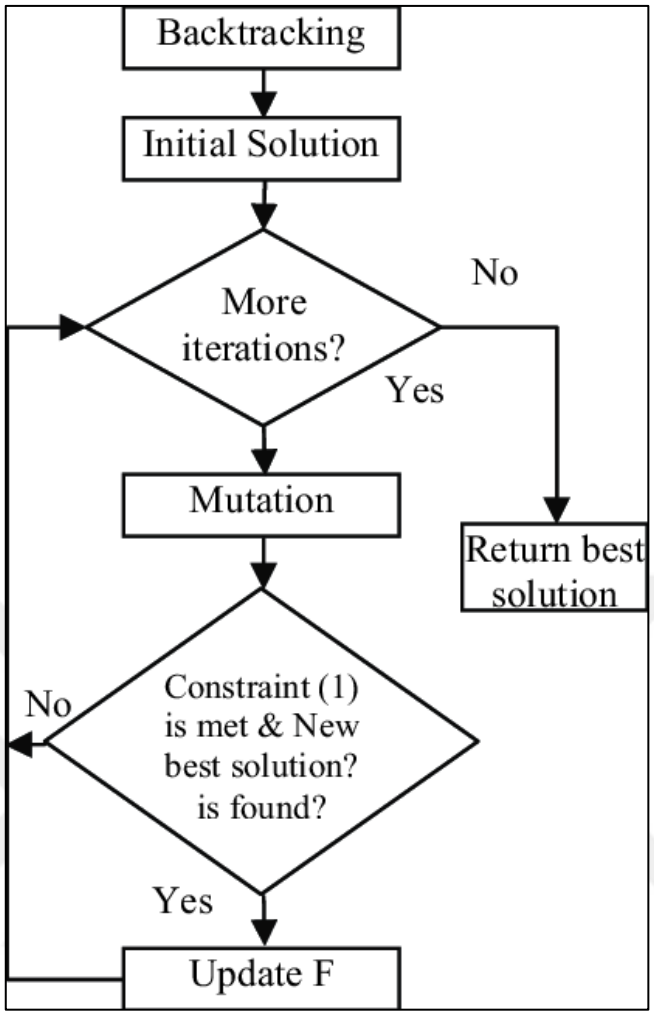

Figure 2.4: Diagram of Evolutionary Programming EP.

Because of this, PE processing saves time. HT Yang et al. found that the PE algorithm can handle the ELD problem with non-smooth fuel cost curves. After some time, several investigations showed that evolutionary programming outperformed genetic algorithms. However, many more modifications to PE approaches have been studied to solve stochastically variable and very complex optimization problems. Evolutionary programming algorithms are now much faster. The improvement makers have been lauded. Nidul Sinha and colleagues explored several mutation strategies to apply evolutionary algorithms to ELD challenges (EP). Recently published study results. The research created an Improved Fast Evolutionary Program (IFEP). This program outperforms all other EP procedures in convergence rate, solution time, cost, and success rate. Customers care about two things about the infrastructure that generates and delivers electricity. These are infrastructure

reliability and supply cost. This study examines how strategic and operational planning lowers electric power production costs under certain limits. Due to recent electricity industry deregulation, this task must be done in real time with great reliability and a time constraint. The evolutionary-based algorithms SA, TS, GA, PE, and PSO can identify the global or near-optimal value for extremely non-convex ELD problems, but they take too long to run in real time. SA, TS, GA, PE, and PSO are evolutionary approaches. In an evolutionary process, the quality of the solution depends on the number of iterations, hence increasing the number of iterations will take longer to find a solution with the same quality. These issues prevent PE-based algorithms from being used in real-time economic load speed, although their outputs can be used for efficient operation. If the artificial neural network is properly trained using exact training data, it can be a reliable and cost-effective real-time delivery solution [14]. This technology works well and reliably. Newer artificial neural network categories are becoming more popular because of this. Iterations should grow with time spent on the topic. PE-based algorithms cannot be developed at a fraction of the real-time economic load speed, but their outputs can be used for optimal operation. If the neural network is trained properly utilizing exact training modems, it can be a very efficient and reliable approach for real-time economical shipping operation [15]. This approach is also effective. Recent classifications of artificial neural networks have proven their efficacy. Iterations should grow with time spent on the topic. PE-based algorithms cannot be developed at a fraction of the real-time economic load speed, but their outputs can be used for optimal operation. When correctly taught with accurate training modems, it can be used for real-time, economical shipping [16]. This has contributed to its recent popularity. Recent artificial neural networks have shown potential in this area. PE-based algorithms can advocate optimal operation even though they cannot be included in a real-time economically viable load speed. If the neural network is properly trained utilizing exact training data, it can be a very efficient and reliable approach for real-time, economical delivery [17]. This approach is also effective. Recent classifications of artificial neural networks have proven their efficacy. PE-based algorithms can advocate optimal operation even though they cannot be included in a real-time economically viable load speed. If the neural network is properly trained using exact training data, it can be a very efficient and reliable solution for real-time economical shipping operation [18]. This approach is also effective. Recent classifications

of artificial neural networks have proven their efficacy. Recently, hybrid systems that combine artificial neural networks with global search methods have garnered attention. Those systems have received special attention. Global search approaches can train neural networks in this case. Real-time calculations value dependability over precision. Real-time applications require high availability. An integrated system using PE and ANN approaches may meet the real-time performance criteria of economically efficient load dispatch. In the hybrid approach, ANN training models are built offline using EP-based methods. This ensures the hybrid technique finds the optimal answer for the whole. The ANN learns about the input and output data sets while being built off-line. Online mining will include simple arithmetic calculations that can be done quickly once the network is established. It will improve efficiency. This will happen when the network is complete. This makes globally qualified ANN an analytical option to PE-based approaches. As indicated in [19], the aforementioned collection of scholarly literature also describes fascinating hybrid approach uses in power system research. Online cryptocurrency mining involves simple mathematical processes that can be accomplished quickly. Globally qualified ANN is an analytical alternative to PE-based techniques. The aforementioned work also describes many unique power system applications of the hybrid technique [20]. [20] [20] provides examples. Online cryptocurrency mining involves simple mathematical processes that can be accomplished quickly. Thus, PE-based approaches compete with globally qualified ANN as an analytical option. As indicated in [21], the aforementioned collection of scholarly work also describes many fascinating power system applications of the hybrid approach. Online mining involves simple mathematical calculations that can be done quickly. Thus, globally qualified ANN is an analytical alternative to PE-based approaches, and several intriguing power system applications of the hybrid technique have been reported in the literature [21].

3. MATERIALS AND METHODS

3.2 DISTRIBUTED ELECTRICAL SYSTEMS

The primary responsibility of electric power generation and distribution networks is to supply consumers with energy that meets their needs in terms of quantity, quality, and timing. Generally speaking, electrical power systems can be broken down into the three primary areas of generation, transmission, and distribution. There are three main parts to the power grid: transmission, which moves energy from generators to load centers; distribution, which delivers power to residential, commercial, and industrial customers; and generation, which converts a different kind of energy into electricity. Actual voltages at 60 Hz are used nationwide. In any one of the 50 states, you can find voltages like this. It is safe to say that 220 and 127 V are the most prevalent voltages for Secondary Distribution, as they are the lowest voltages typically seen. The goals of this undertaking necessitate a restructuring of the Electric Energy System to concentrate greater weight on Distribution, and more especially on the load and demand resulting from the proliferation of electrical appliances in residential households.

Lines, feeders, service branches, and step-down stations are only few of the many parts that make up the distribution system. All of these parts function on service voltages ranging from 110 V to 35 kV, with the goal of providing some sort of benefit to the end user. We settled on that price range to ensure compatibility between the various parts. Engineers have considerable leeway in selecting distribution system elements due to the extensive research and planning that goes into their design. This is due to the extensive planning that goes into constructing a distribution network. The variety of loads that will be supplied by the system is, without a question, the most relevant facet of this study and will have the most impact. The "load" is the quantity of electrical power drawn from a given supply source, and it is measured in watts. As a result, in a Distribution System, many various kinds of loads can be distinguished from one another, depending on the type of source being evaluated. Consumer loads, transformer loads, main network or distribution line loads, and system loads are all examples. Load is the sum of the electricity required to run all of a consumer's motors, appliances, lights, and other electrical equipment. When all of the appliances and devices that are wired into a transformer are powered on, this is known as the load. When talking

about the electrical energy consumed by all of the transformers that are supplied by a sizable network, we talk about the "load." All the energy consumed by the feeders from the distribution buses will be factored into the total load of the electrical system. This is done so that an exact calculation of the load may be made. Remember that the pattern of these loads is not constant, but rather has a minimum and a maximum intensity. Remembering this will be very helpful. Because this maximum value rarely appears all at once, the distribution network must be prepared for it. The two values are not coexistent. It is important to consider a wide range of consumption patterns for each of the previously mentioned load levels to ensure that the system is not excessive. This will guarantee that the system is sized properly. As a result, the installed load is factored into the demand calculation. Installation demand, as defined by Bovolato (2010), is the average load exerted on the receiving terminals over a given time period. The amount of electricity needed to run the setup is calculated based on this number. The term "load" is used to describe a device or system whose power (active, reactive, or apparent) is quantified or whose current intensity is evaluated in terms of its effective value. The phrase "load" may refer to active power, reactive power, or perceived power, depending on the context. The time period over which the mean is calculated is known as the "demand interval." The average length of this break is 15 minutes. In addition, there is the peak demand for that facility, which is the highest level of demand for that time period and is expressed in demand hours. That request is by far the biggest of its kind within that time frame. This interval can be chosen on a daily, weekly, monthly, or annual basis.

3.1.1 Load Demand Management

Load shifting, the third and final typical method for load control, is redistributing power consumption away from peak times and towards off-peak times. Because it can be helpful, and because there are financial incentives to restrict consumption at certain periods, this strategy can be appealing when considered. One method of resource conservation is to switch up how things are hauled about. Usually the outcome of switching to energy-efficient appliances rather than those with a larger negative impact on the environment. Strategic load expansion, or the gradual increase in demand over time, is the concessionaire's responsibility. Just past the valley filling we discussed earlier, you'll find it. The term "flexible load shape" describes a concept related to deliberate restraint. The payload format

can be changed in exchange for various client incentives, but only if the customers agree to the change.

3.1.2 Smart Meters

An electrical load creates an energy demand that may be measured with the help of electric power meters. The purpose of this test is to establish the maximum amount of energy that can be delivered by the electrical load. To ensure that the corporation providing the service is appropriately billing clients for the quantity of electricity utilized by each customer, concessionaires are tasked with doing these measurements. This is done to guarantee a profit for the concessionaires. Because of its reliability, accuracy, and longevity, induction meters are now in use. Power is measured in the here-and-now, but energy considers how long the gadget was on; to rephrase, energy accounts for how long the power was actually being used. There is a direct numerical measurement of the power. Multiplying the average power by the complete time period yields the energy output. Therefore, a meter that measures cumulative power over the whole measurement period is required for accurate energy measurement. This is the only way to get a true picture of energy consumption. The watt-hour is the most basic unit of measurement that can be used to determine the total amount of electrical energy present. Traditional electrical energy consumption is measured in kilowatt-hours (kWh), with the abbreviation indicating that active energy output is being measured. Energy that can be measured in terms of how much work it can do is called "active energy." The meters mentioned here are the most common ones used for measuring energy. Two broad categories exist for measuring devices: induction meters and electronic meters. Meters are used to take readings in both single-phase and three-phase ac systems. These meters function in a way that is analogous to electric induction motors in that they are governed by the principle of electromagnetic induction. Induction meters are by far the most common type of meter when it comes to measuring energy in alternating current circuits. Induction meters are the standard since they are the only kind that can be used in ac circuits. For this reason, only induction meters can be utilized. Since the fundamental goal of this effort is to ascertain the energy spent by electronic components, meters based on this application method will be more accurate. Since calculating the total energy used by electronic parts is a complex task. The transduction foundation of digital electricity meters consists of voltage

and current sensors. These sensors generate low-amplitude signals that, when compared to the originals, are used as a standard for the aforementioned quantities throughout the subsequent digitization process. This then can be used as a baseline against which energy consumption can be measured and analyzed. Resistive dividers, the building blocks of voltage transducers, are commonly put together using precision resistors. Many current transducers use shunt resistors, transformers, or Hall Effect sensors in their circuits. The calculation and administration solution for electronic meters can be constructed in a number of different ways. Most meter activities are processed by a single CPU in the most affordable variants. Depending on the model, this CPU could be a microcontroller or a Digital Signal Processor (DSP). There is a dedicated chip used in the construction of more complex models (such as electronic meters with advanced functions and meters for large consumers) that calculates metrological functions, while a microcontroller handles communication management, memories, anti-fraud functions, and man-machine interface. Among their many other uses, electronic meters with sophisticated features are one of the most useful inventions of the modern era. This is why the more involved models can yield more reliable findings. Moreover, the most up-to-date versions already feature a serial connection port. This connector is standard on modern models and is used by a regional communication standard. Through this port, not only can the meter's settings be setup and saved, but the data it generates can also be readily inspected by the user. Costing more to manufacture, this communication link is typically only used on more sophisticated electronic meters. Due to the port's increased complexity and cost, this is inevitable. In Figure 3.1, we see a schematic of the basic layout of an electronic meter's inner workings.

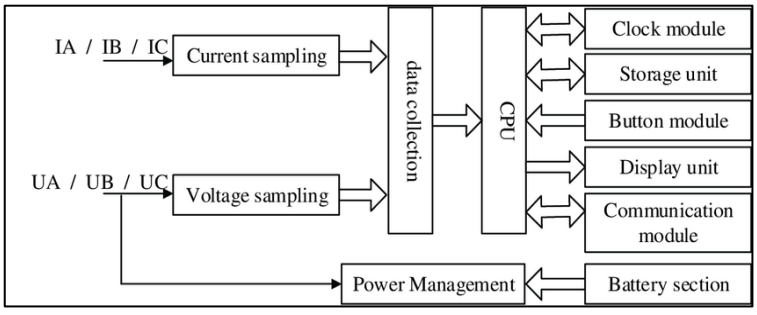

Figure 3.1: Block Diagram of an Electronic Meter.

3.1.3 Microcontrollers

One of the main reasons for the development of the microcontroller is the ability to do computational activities; nevertheless, these jobs do not necessarily involve big numbers. It must have superior input and output processing capability to begin with. For instance, it must be able to process and respond to input and output signals from devices such as refrigerators and automobiles. It also needs to be able to talk to other gadgets like a computer. Microcontrollers need to be compact, self-sufficient, and reasonably priced because of the prevalence of small, low-cost embedded devices.

Microcontrollers include all the basic features of computers into a single device, including a central processing unit, data and program memory, and input and output interfaces. These add-ons give the microcontroller the power to function as a minicomputer. Because of this, we may talk about it as if it were a computer built into a single chip. Considering its name, one may assume that the microcontroller was designed to manage both the physical components and the corresponding operations. Therefore, the microcontroller chip incorporates a wide range of ancillary components such timers, A/D converters, voltage references, PWM generators, UART serial interfaces, and USB. Different sorts of microcontrollers include the Harvard design and the Von Neumann architecture. The microcontroller, which was based on the Von Neumann architecture, was designed with shared memory. Data and code can both be stored in this RAM. Because of this, the microcontroller has a shared bus for sending both data and addresses in the form of instructions. The Harvard architecture features dedicated program and data memory modules, as well as instruction address and data bus separation. Thanks to these enhancements, the Harvard design is more effective. The Harvard design allows for dramatically increased throughput of sent data. According to the Harvard design, a microcontroller can carry out a single operation in the time span of a single machine cycle. This architecture was crucial in the development of the vast majority of microcontroller families. The fundamental distinction between the two types of microcontrollers is their instruction sets. Microcontrollers come in a wide variety of forms, some of which are RISC and others which are CISC (CISC). As the name implies, a RISC processor is distinguished by its simple, modular instruction complement. In contrast to other types of processors, RISC

computers can generate more complicated instructions by building on top of the fundamental instructions. RISC-based systems are more amenable to having straightforward central processing unit architectures. When comparing the CISC architecture to the RISC architecture, it is clear that the CISC design has more complex features and instructions. It is not always obvious in advance whether a RISC-based instruction set or a CISC-based instruction set will provide more efficient code for a given application. It is crucial to think about how well an algorithm fits with the capabilities of a certain CPU. To design the vast majority of modern microcontrollers, the RISC principle is used. Currently, microprocessors are the most common hardware component in computers that use the CISC architecture. As can be seen in FIGURE 3.2, a microcontroller consists of a microprocessor's CPU, together with associated data and software stored in the device's memory. Also, make sure to include any and all extras that are necessary for a certain device to connect to another. Microcontrollers require a time signal, often generated on the chip itself, in order to manage the logic of the circuits, much as any other electronic circuit requires electricity.

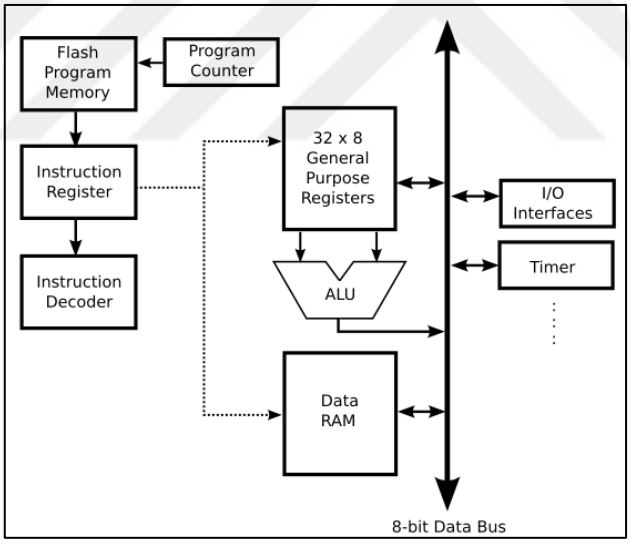

Figure 3.2: Architecture of a Microcontroller.

3.2 MACHINE LEARNING

The fundamental focus of machine learning, the field that attempts to develop such systems, is on making computers capable of autonomously learning from the data they are given. One definition of learning is the formation of new understanding through reflection on one's past experiences. [Footnote required] To cite an example: [Citation needed] the learner's actual

experiences are substituted with training data provided to the learning algorithm. The newly acquired knowledge is what the learning algorithm outputs, and it can be used by another program to accomplish a task. An algorithm that can recognize spam in email can be built using this idea as a foundation. The program will store all incoming emails and create a database of potential spam messages. In this case, the user will see this list. The machine will determine whether or not a newly received email is spam based on what it has learnt in the past, and then deliver the email to its intended recipient. This choice is made just before the email is sent. Such a form of deductive thinking is known as inductive reasoning. The issue with this method of studying is that it does not actually lead to the acquisition of new knowledge; all it does is compare and contrast new and old data, but it does not actually learn anything new as a result. This means there is no progress made through this kind of instruction, which could lead to erroneous inferences. Machine learning is a technique whereby rules for doing a task are discovered through the analysis of data and the presentation of examples of what needs to be predicted. This means the following three things are required for carrying out machine learning: Factors Considered as an Input If voice recognition is the goal, for instance, these audio files of people talking could serve as an example of a data point. Examples of future production that are being planned include the following: These files are almost certainly transcriptions of audio files that people have created for the purpose of entering a speech recognition competition. Algorithm performance may be measured in a variety of ways, and one of them is by contrasting the actual result with the expected one. One of many options here. To do so, it is important to measure the discrepancy between the algorithm's actual output and its expected result. One approach to get there is to figure out how far apart they are. Using the result of the measurement as a feedback signal, the algorithm can be fine-tuned to provide the desired results. Learning refers to the process by which an individual modifies their actions to fit their new environment.

3.3 SMART GRID ELEMENTS

Materials for the development of the proposed project were selected after careful evaluation of how the components perform and how much they cost. This selection was based on the research presented in earlier chapters. In order to measure and manage the power

consumption of an electrical equipment, it was determined that a microcontroller, a current sensor, a voltage sensor, and a relay would all be required components. You can't possibly fulfill the prerequisites without doing all of these things. The microprocessor and components will run on direct current; thus a voltage converter is needed to turn 127V into alternating current for use as a power source. Before the parts may be powered, this transformation must occur. After the components were characterized, they were used to inform the circuit's layout. There are no longer any issues due to the limitations of the microcontroller hardware, which previously caused them. All of the NodeMCU module's inputs and outputs operate at 3.3V. The sensor's output signal can swing up to 5V, thus a voltage divider has been integrated to smooth out the voltage swings. This was done to ensure that the signal's fluctuations stay within the module's usable parameters. It's also worth noting that the ESP8266's single port for reading analog data can be a hindrance. The current and voltage sensors don't have separate ports for each measurement type to avoid any potential misinterpretation. To solve this problem, a 5V relay was installed; however, since the NodeMCU module's output voltage is 3.3V, it is not essential to activate the 5V relay for the module to function properly. An NPN transistor was activated as a solution to the problem. One of the coil ports was coupled to the collector, and the ground terminal was connected to both the collector and the emitter. Finally, a wire was run from the base to the microcontroller's port D1 to enable on/off switching of the relay via the base. The schematic depiction of the circuit block shown in FIGURE 3.3 allows one to view both the solutions and the electrical connections.

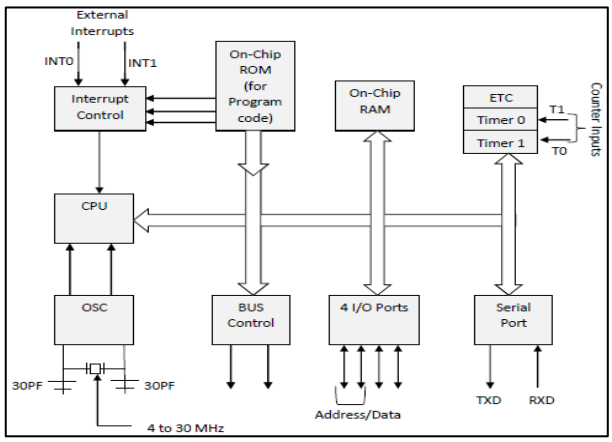

Figure 3.3: Block Diagram of the Smart Outlet.

Energy storage is a technological solution to a problem, as well as a long-term asset necessary for the decarbonization of the power mix mandated by public legislation, notably in Europe.

Energy storage is an economic lever since it may be used to profit from price fluctuations in the power market or to reduce energy costs. These two advantages may be accomplished by storing energy. This is a win-win scenario for everyone (individuals, communities, and businesses) with the potential to store energy. The current environment is ideal for the introduction of energy storage devices, as it meets both the technological requirements and the suggested economic incentives.

3.3.1 Pumped Energy Transfer Stations PETS

A Step (transfer station energy by pumping) is a means of store electricity qui exploits the difference of potential between two basins. It consists of two water tanks separated by a drop. When there is a surplus of energy, a pump draws water from the lower basin to convey it to the upper basin. During consumption peaks, water from the upper basin is released to the lower basin and powers a turbine that produces electricity, as show
n in Figure 3.25.

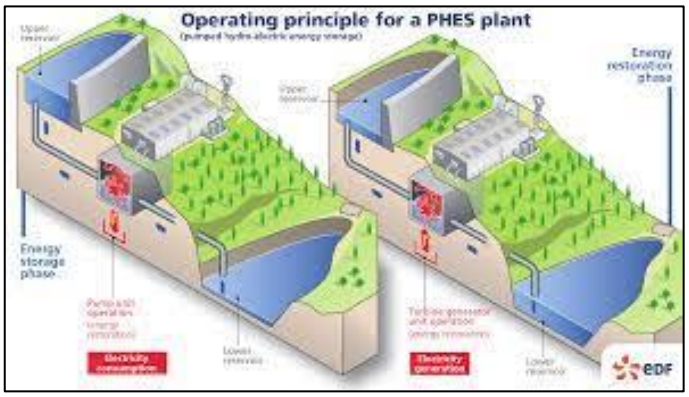

Figure 3.4: Principle of Operation of PETS.

3.3.2 Compressed Form Energy Storage (CFES)

“CAES” (Compressed Air Energy Storage) is a mode of storage energy par compressed air that is to say of potential mechanical energy, which is grafted onto gas turbines. In a conventional gas turbine, ambient air is captured and compressed in a compressor at very

high pressure (100 to 300 bar). This compression of the air is accompanied by a heating that can go up to a few hundred degrees. Hot compressed air is injected with gas into a combustion chamber. The output mixture drives a turbine and generator to generate electricity, as shown in Figure 3.26. The principle of CAES consists of storing the compressed air and thus decorrelated the air compression phase from the rest of the process. To do this, a storage system of this type is inserted between the compressor and the combustion chamber. In the storage phase, the compressor uses the energy available on the electrical grid to compress air. This compressed air is then routed and stored in a suitable tank. In the destocking phase, the compressed air is extracted from its tank and sent to the combustion chamber which precedes the turbine. The energy produced is finally returned or sold to the grid.

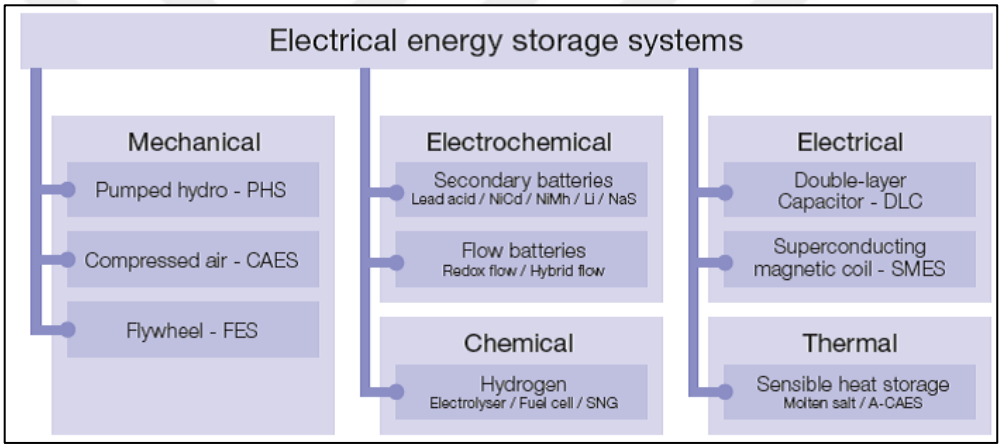

Figure 3.5: Storage in Compressed Form.

3.3.3 Energy Storage Using Hydrogen

Hydrogen energy storage systems use an intermittent electrolyser. During periods of low electricity consumption, the electrolyser uses electricity to decompose water into oxygen and hydrogen, according to the equation 2 H2O= 2H2 + O2. This hydrogen is then compressed, liquefied or stored in the form of metal hydride.

Then there are three different ways to feed electricity back to the grid from the stored hydrogen:

a. The first consists of powering a fuel cell

b. The second consists of synthesizing natural gas using the methanation process. This gas can of course be injected directly into the existing gas grid, but above all be used to supply a “conventional” gas-fired power station, producing electricity.

c. The third consists of using the hydrogen directly in a gas-powered plant specially designed for this purpose, in order to produce electricity.

3.3.4 Electrochemical Batteries

Electrochemical batteries are designed by stacking discs composed of different types of chemical elements. There are thus lead-acid, nickel-cadmium, nickel-metal hydride, lithium-ion, lithium-polymer, lithium-air, sodium-sulfur, sodium chloride (zebra) batteries, their efficiency varies between (60 -90%)

3.4 THE SMART METERING SYSTEM

One of the conditions for developing an advanced (intelligent) metering system is the installation of communicating meters. This is required so that the data collected from energy measurements may be kept (with bidirectional communication capabilities).

In order to guarantee the accurate and effective distribution of meter data to end users, grid administrators, and suppliers, it is essential to implement data transmission systems, which are systems responsible for the transmission and reception of information.

3.4.1 Characteristic of Smart Metering

Two levels of smart metering devices can be distinguished:

a. Automated Meter Reading (AMR): Consists of an automated remote reading. It is a device that allows information to be fed back from the meter to the counting operator.
b. Automated Meter Management (AMM): Corresponds to an AMR supplemented with additional services.

This pertains to the computerization of formerly manual technical services in the metering industry (commissioning, power change, etc.). This piece of hardware enables bidirectional communication between the meter and the metering system administrator.

Advanced Metering Infrastructure (AMI) should not be confused with Advanced Metering Reporting (AMR) or Advanced Metering Management (AMM) (AMM). It describes the components of intelligent metering and the technological underpinning necessary for AMM to function successfully.

3.4.2 Presentation of the Smart Metering System

The meter's two-way communication capabilities (information transmission and reception) enable remote meter reading and energy regulation.

a. Power Line Carrier (PLC) technology permits connection between a collection of meters placed at customers' residences and a concentrator situated nearby in the public distribution substation, which subsequently collects and sends this data to grid management. This technique is shown in Figure 3.29 below. Each meter and concentrator is outfitted with a PLC modem that converts acquired data into an electrical signal that is then overlaid on the existing 50 Hz power line.
b. The information is then converted to a digital code at the concentrator level and transferred to the grid administrator's computer over the GPRS or GSM telephone grid.

3.4.3 PLC Operating Principle

Power line carrier enables the transmission of digital data over an electrical grid. Its structure resembles that of a wired ethernet (rj45) or wi-fi grid. In the case of plc, the electrical grid is used as the communications medium.

The current passing through the electrical cables has a frequency of 50hz. Plc technology superimposes on this signal another signals whose frequency is higher (between 1.6 and 30 mhz). This signal therefore travels on the electrical grid and can be seen by any receiver on the same electrical grid.

3.4.4 Main Functionalities of Smart Metering Systems

Smart meters must be able to provide:

a. Reading meter data at regular intervals.

b. The TV takes meter data from a remote information system.

c. Remote meter management (power reduction, cut-off, demand management) by the distribution grid manager.

d. The measurement of consumption and, where applicable, of decentralized production.

e. Remote management of meter parameters such as tariff structures, contract power, meter reading intervals by suppliers.

f. The remote transfer of messages from market players for the customer (consumer/producer) such as, for example, tariff signals.

g. The display of information on the meter and/or a remote report from the customer remote information (TIC) installed.

h. a main communication port allowing the transfer of information via GPRS, GSM or PLC;

i. Quality measurement (including continuity of supply and voltage quality).

3.5 APPLICATIONS OF SMART MICROGRIDS

3.5.1 Communicating House and Smart Building

The term smart building covers both the notion of individual communicating house (Smart home) and positive energy building (Smart building).

The automatic character is, in fact, the cornerstone of the intelligent building concept. Thus the word home automation is formed from the Latin word "domus", the house, the building and the suffix "- tick" for automatic. A concept born in the 1980s, home automation consists of griding, coordinating and automating the operation of electrical equipment in a house or building, in order to save energy, improve comfort and safety in the building, see Figure 3.30.

The first visible signs of this evolution towards an intelligent building appear thirty years later, due to the development of new information and communication technologies (NTIC), the regulatory context, environmental objectives and the appearance of the meter

communicating, interface between the public electricity grids and the building's private grid, which opens up prospects for major innovations downstream of the meter.

Figure 3.6: Advanced Electricity Metering System.

Energy efficiency depends on building construction techniques, such as insulation. The smart building concept corresponds to the integration of energy management solutions in housing and business buildings, in particular to achieve positive energy buildings, see Figure 3.3 Many solutions exist and are complementary:

a. Better building insulation: it is the most effective method for avoiding heat waste and makes it possible to dispense with heating outside periods of extreme cold (many materials: glass wool, hemp or straw).

b. New energy generation techniques: the building makes it possible to easily integrate energies from renewable sources. The roof can accommodate photovoltaic panels which compensate or even exceed the energy expenditure of the inhabitants or solar thermal collectors which heat water for heating or sanitary facilities.

c. The development and strengthening of ventilation systemsin order to avoid losing the benefit of insulation by opening a window whether in very cold or very hot weather (double flow ventilation or Canadian well).

d. More virtuous heating and air conditioning systems (wood stove, heat pump, geothermal) and other systems to better regulate the temperature (thermostat, efficient boilers, etc).

e. A more thoughtful choice on the location of the buildingin terms of location and orientation in order to make the most of insulation, openings and photovoltaic panels.

The intelligent building is therefore defined as a building with high energy efficiency, integrating in the intelligent management of the building the consumer equipment, the production equipment and the electricity storage equipment, such as electric vehicles.

Energy efficiency also depends on building construction techniques, such as insulation. The smart building concept corresponds to the integration of energy management solutions in housing and business buildings, in particular to achieve positive energy buildings.

3.5.2 Smart City

People may be familiar with the term "smart city," which refers to a municipality that optimizes the use of its resources by collecting and analyzing data meticulously. Utilizing sensors, the city is able to monitor the actions of its residents and give them with information and services that are especially customized to their requirements in real time. This helps the city to optimize its energy and other resource consumption. This "intelligence" affects many areas such as transport (traffic, parking, etc.), electricity and water supply, garbage collection, etc. For waste, for example, connected bins measure filling levels and trigger the collection signal when they are full. This makes it possible to optimize the traffic of garbage trucks (noise, pollution, traffic jams), to avoid deposits at the foot of full bins but also to better plan the location of bins according to needs.

a. Context of the smart city.

The high concentration of population: today, more than half of the population lives in cities, by 2050 this proportion should rise to two thirds.

Then cities are energy-intensive, although they represent only 2% of the planetary surface, they consume 75% of the energy produced and are responsible for 80% of CO2 emissions.

The transition and the fight against global warming will therefore inevitably involve a transformation of cities. The principle of smart city work in this direction.

b. Characteristics of the smart city

The European Union is inspired by the vision of Rudolf Giff Inger, expert in analytical

research on urban and regional development at the Vienna University of Technology, and reference in the field, whose work indicates that the smart city must perform well in six domains A smart economy: It is the economic competitiveness of the city. It is measured through factors such as innovation, entrepreneurship, productivity, flexibility of the labor market or integration into the national and international market. Smart Citizens: In other words, the human and social capital of the city. It is a question of the level of qualification of the population but also of its plurality, its open-mindedness, its creativity, the quality of social interactions or participation in public life. Smart governance: That is to say a mode of administration of the city transparent, transverse and shared, integrating the participation of the citizen. Smart mobility: Giff Inger emphasizes local and international access to the city, the existence of connected infrastructures using ICTs and innovative, sustainable and safe transport systems. A smart environment: The smart city must promote a quality environment (green spaces, air quality), sustainably manage its resources and work to protect the environment. Eco-districts are localized examples of an intelligently managed environment. A smart lifestyle: It brings together factors related to the quality of life: culture, health, safety, habitat, education, tourism, social cohesion, etc.

c. Open Data at the service of smart cities

Collecting a lot of data all over the city and in all areas is good, being able to cross-reference them to create innovative services is even better. Open Data, by offering data that is accessible, shareable and usable by everyone, allows interoperability, ie the possibility for different systems or companies to work together by mixing their data.

It is therefore a principle, the opposite of operating in silos, essential to the development of the smart city, which benefits both public and private actors, see figure 3.33.

In the field of mobility, for example, the provision of certain data by mobility service operators helps to facilitate the organization of multimodal journeys. This collected data provides a clear view of the transport offer available at a given time, with the aim, for the operators concerned, of better meeting the needs of users.

4 PROPOSED METHO

4.1 DESIGN OF DISTRIBUTION NETWORK

The most secure method of power distribution is a network of substations and cables [43], but it is also the most expensive and complicated method. Distribution is broken up into its more common substation, primary distribution, and secondary distribution components at Oklahoma State University. At the on-campus substation, the voltage that is used by the many buildings on campus as well as other components of the electrical infrastructure of the campus is regulated. To put it another way, OG&E is the primary supplier of electrical power to the educational institution. In addition to this, there is a power plant right on campus that has the ability to generate 8 megawatts of electricity from natural gas. The plant is located right in the middle of the campus. Due to the generator's limited capacity, it is only able to supply power to 18 of the more than 80 buildings that are situated on the campus. It has been found that the total cost of producing and transporting electricity is higher than the price that one would pay to purchase the same amount of electricity from a utility company. This was a surprising finding because it was previously believed that producing and transporting electricity was less expensive. As a result of this financial constraint, the power plant on campus generates as little electricity as is physically possible, and in order to heat the entire campus, the chiller plants are used significantly more frequently than is typical. Despite this, the power plant that is located on the campus does help to meet peak demand during peak load conditions, particularly during the warmer months of the year when there is a greater demand for electricity. One of the six parts that comprise the current distribution system at the Stillwater campus of Oklahoma State University is depicted in Figure 4.1, which can be found further down on this page. Figure 4.1 can be found further down this page. It provides electricity to a total of 13 buildings, four of which are considered to have critical loads as a result of the high concentration of expensive machinery and the volume of research that is carried out within those buildings. These absolutely necessary loads are especially vulnerable to power outages and fluctuations in voltage because of their high consumption. S&C fuses are utilized in the various protection systems at the university in order to ensure the safety of the university's distribution grid. If the power plant that is situated on the campus is not connected to the grid that is depicted in Figure 4.1, then the overall redundancy

of the distribution system that is being considered will suffer as a result. The entire distribution on campus is carried out with the assistance of cables buried beneath the ground, and the number of distribution lines is exceptionally high. Nodes are how buses are represented in Figure 4.1, which can be found here. It is of critical importance to this research and would be of great benefit to it if it could gain a better understanding of the various types of buses that are already well-known to exist in the world. It is common practice to classify the various kinds of buses according to the operational parameters that they are constrained by on a functional level. The terms "load buses" and "generator buses" are used to refer to the two different kinds of buses that are most commonly found in distribution systems. Because it is generally accepted that the end user will be the one to supply the data regarding the power consumption at the load bus, these buses are frequently referred to as PQ buses. This is because it is generally accepted that the end user will be the one to supply the data. This suggests that the requirements for both real power and reactive power must be stated in an individual manner for each load bus. Figure 4.1 depicts a total of 13 load buses, some of which include the following names and locations: Bus 9, Bus 10, Bus 14, Bus 15, Bus 18, Bus 19, Bus 22, Bus 23, Bus 31, Bus 32, Bus 35, Bus 36, and Bus 37. P and Q are, in principle, able to be altered at the generator buses where they are located. Having said that, doing so would be fraught with difficulties. The first thing that needs to be done is to make sure that the system's power needs are met, and the second thing that needs to be done is to make sure that the generators that are currently being utilized are managed correctly. As a consequence of this, it is more prudent to specify P for all generators, with the exception of the generator that is connected to the slack bus, and to use the generator bus voltage, V, as the second variable rather than the reactive power, Q. This is because it is easier to measure the voltage of the generator bus than it is the power that the generator is actually producing. This is due to the fact that it is easier to accomplish this goal. Because of this, "power generation buses" can also be abbreviated as "PV buses," which stands for "photovoltaic buses." [44].

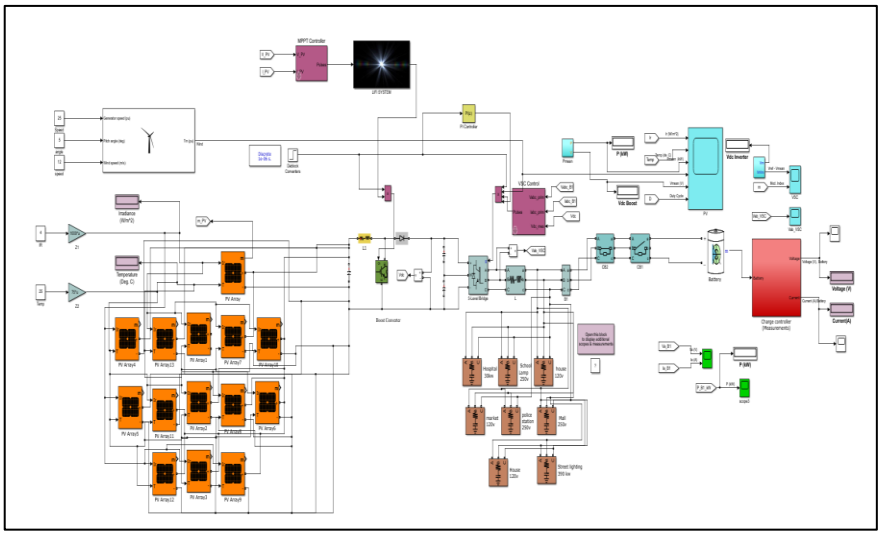

Figure 4.1: A Segment of the Current Distribution System Layout.

Table 4.1 summarizes the known and unknown variables for the various types of buses used in load flow studies.

Table 4.1: Types of Buses and Associated Variables in Load Flow Study.

LOAD BUS	Real Power (P) Reactive Power (Q)	Voltage Magnitude (V) Voltage Angle ( )
GENERATOR BUS	Real Power (P) Voltage Magnitude (V)	Reactive Power (Q) Voltage Angle ( )
SLACK BUS	Voltage Magnitude (V) Voltage Angle ( )	Real Power (P) Reactive Power (Q)

A load flow model for an existing portion of the distribution system was developed in MATLAB. This model considered the current configuration of the distribution system. The load data, bus voltages, and distribution line parameters are used as known values in the load flow analysis of the system that is being considered in order to determine the variation of bus voltages in response to changing load conditions or outages. This is done in order to determine whether or not the system can handle the load that will be placed on it in the

future. In addition, the currents in each of the various lines can be determined by applying Ohm's law to each individual connection in turn. This can be done in the order that the lines are connected. It is impossible to calculate the total line losses in the system without first determining all of the currents at a specific point in time. This is because the total line losses are proportional to the sum of the currents. The primary output variables of the software, such as line currents, can be expressed in amperes depending on the user's programming preferences; alternatively, the flow in each link can be expressed in terms of the real (Megawatts) and reactive (MVAr) power values, respectively. The user has the ability to select either of these two choices.

4.2 DISTRINUTIOM SUBSTATION

For the most part, the electric utility industry has standardized the design of distribution substations based on previous projects' successes and failures. The following pieces of machinery may be found in a typical substation:

a. Power transformers,

b. Circuit innovators,

c. Disconnecting switches,

d. Station buses and insulators,

e. Current limiting reactors,

f. Shunt power plants,

g. Current transformers,

h. Potential transformers,

i. Capacitor current transformers,

j. Coupling capacitors,

k. Series capacitors that are charged

l. Shunt capacitors that are charged

m. Grounding system,

n. Lightning arrestors/or gaps,

o. Line traps,

p. Protective relays,

q. Station batteries,

r. Another device [45].

4.3 DESTRIBUTION FEEDERS

Distribution feeders most frequently take the form of radial or loop structures. At distribution levels across the entirety of North America, radial feeder designs are the ones that are utilized the most frequently as opposed to any other type of design. This is as a result of the lower costs associated with them as well as the ease with which they can be planned, designed, put into operation, and analyzed. However, the most significant drawback of a radial system is that it only offers a single path for electrical current to travel from the substation to the consumer. This limits the amount of flexibility that the current has. On the other hand, a loop system, such as the one depicted in Figure 4.1, possesses dual pathways for delivering power to the loads. This is in contrast to a system that only has a single path. Network feeder systems are superior to loop feeder systems because they have multiple ways to supply power to the load. Loop feeder systems only have one way to supply power. This can only be accomplished in one way using a loop feeder system. The loop and network feeders' systems both make significant contributions to the increased redundancy of the entire network, which ultimately results in an exponential increase. Figure 4.2 illustrates a few of the many possible.

configurations that can be used for distribution systems. These configurations are available to purchase.

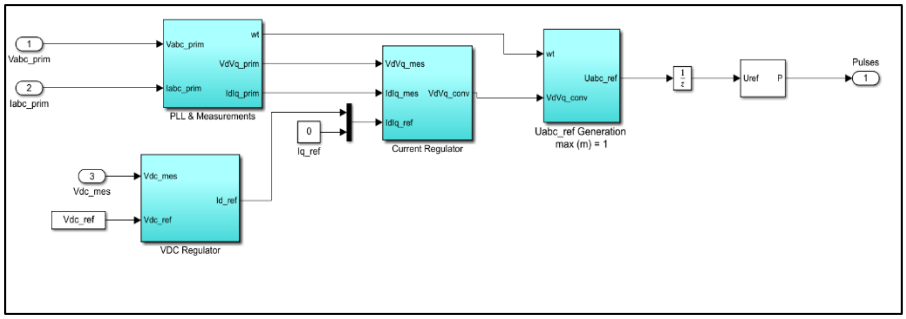

Figure 4.2: Simplified Illustration of the Concepts Behind Power Regulation and Distribution Configurations [5].

Figure 4.1 depicts the current OSU distribution system under consideration; Figure 4.2 shows how the loop system corresponds to this system. The current system's feedback loop is linked between Bus 28 and Bus 33. The complexity of a loop feeder system is only marginally higher than that of a radial system because power flows out from both sides and into the center, with only two possible paths. Slightly more engineering complexity is required for axial systems with regards to voltage drop, sizing, and protection. [43].

4.4 CHALLENGES OF BIG DATA IN SMART GRID

The utilities team faces a challenging obstacle on a daily basis, 24 hours a day, seven days a week, in the form of keeping the lights on throughout a main grid that consists of approximately 80 buildings. This challenge must be overcome. An electrical power plant that operates on natural gas and has the capability to generate 8 megawatts (MW) of electricity can be found on the grounds of the educational institution. Even though the majority of the electricity required comes from OG&E, the university still runs its own power plant, which serves both as a backup and as a buffer for the grid. Concerns about the visual impact of the cables prompted the decision to bury all of them; however, this has resulted in complications such as the cracking of underground banks as a result of movement in the ground, water seepage, and increased costs for installation and maintenance of the cables. Even though redundancy is provided by a feedback loop connected from Bus 28 to Bus 33, the S&C switches, and the protection devices being fuses, as shown in Figure 4.1, it still takes a significant amount of time to restore power after a power outage. This is the case despite the fact that the feedback loop is connected from Bus 28 to Bus 33. In the event that there was a problem with Bus 1, there would be a complete blackout, which would lead to

significant financial losses for the university. In addition to this, there would be a complete lack of power if there was a problem with Bus 2. Figure III.1 depicts the current distribution system, but it has a major flaw that needs to be addressed: the power plant that is located on campus is not connected to this loop. As a consequence of this, the system's very own feedback loop is required whenever there is a disruption in the power supply in order to reroute the power. As a direct result of taking this action, there will be fluctuations in the voltage that is present on each of the buses. Bus routes 10, 35, 31, and 32 are considered indispensable due to the volume of passengers that they transport. As a direct result of this fact, the buildings in question house an abundance of electronic components as well as machinery that has been finely tuned. As a direct result of this, it is of the utmost importance to ensure that there is adequate redundancy within the electric grid that services these loads in the event that there is an interruption in service. In addition, it is strongly suggested that the voltage be kept at or above 0.99 p.u. across all of the buses. This recommendation applies to the overall system.

4.4.1 Solving Big Data Issues with Lifi

Calculations play a significant role in the engineering of power systems. The load instruction flow or data flow study is considered to be the most important of these calculations. The purpose of this study is to determine how well the network functions under normal conditions as well as in situations where there are faults, disturbances, or outages. The designer can use load flow calculations to ensure that the current in the various nodes of the network does not exceed the safe working limits or reach a value that is unsuitable by ensuring that the current does not reach an unsuitable value [46]. Its primary application is in the process of expansion planning studies, where it is applied in conjunction with the optimal power flow technique to determine how the existing system can be operated in a manner that is both economically and productively feasible in the most optimal manner. This is its primary use. The activity of analyzing load flows and putting that knowledge to use in the process of forming protection plans is a situation in which everyone involved comes out ahead.

The prototype of the VLC system that was developed with the intention of developing a method for sending data through the air in a unidirectional manner in which the intensity of

the light that was being used was adjusted was developed with the intention of developing a method that was proposed. The streamlined architecture of the system is depicted in figure 4.3, which can be found below.

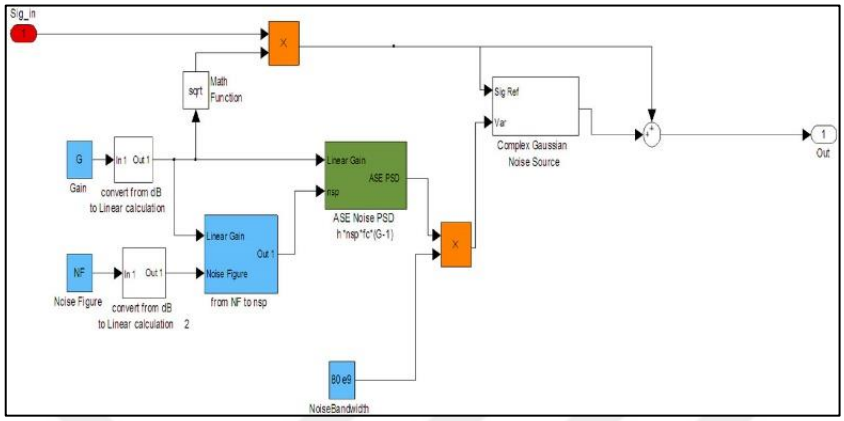

Figure 4.3: Simplified Assembly Diagram of the VLC System.

After that, the message is transferred from the computer to the microprocessor in order for it to be processed. This happens in order for the Arduino Uno to function properly. MATLAB is the tool that is utilized in order to carry out this process. Adjusting the level of brightness that LEDs emit is one of the ways in which a microprocessor responds to commands received from a computer. A confined space serves as the location for the radio transmitter, which is responsible for broadcasting signals into the air around it. At the receiving end, another ATmega328 microprocessor receives data in the form of an electrical signal from a sensor that detects the varying light intensity. This data is transmitted in the form of an electrical signal. Following this step, the values that were received are either sent back to the computer that had sent them in the first place or they are sent to a different computer that is operating the same system in order for them to be processed and displayed to the user.

A comparison system was constructed for the purposes of this project. (DCO-OFDM). (DC-Biased Optical OFDM). A more in-depth discussion on the communication strategies, circuits, and components that are all essential parts of the system will take place throughout the course of this chapter. Switching Between on and Off (OOK) Line Coding is a simple method that represents binary data by using either the presence or absence of the carrier wave. This wave can either be present or absent. This type of transmission is an example of

a single-carrier transmission because it only uses one carrier at a time. In optical communications, incoherent light sources are used, and a technique known as intensity modulation and direct detection (IM/DD) is used to transmit the data. Additionally, this kind of communication is one of the techniques that can be used for the technique. The modulated transmission in OOK is demonstrated in figure 10, which can be found here. In this specific illustration, the signal current is caused to oscillate between two different levels that are centered around a DC level. These levels are located around the DC level. The binary data that is being transmitted serves as the determining factor for these levels. Within the transmitter of the system that has been idealized for this project, the message that needs to be transmitted is given a binary representation. This allows it to be transmitted more efficiently. Based on the binary data that has been received, the D/A converter is the component that is responsible for adjusting the level of brightness emitted by the LEDs. The binary digit "0" is represented by the absence of light, which can be thought of as the voltage level at its absolute lowest point, and the binary digit "1" is represented by the presence of light. Both of these concepts can be thought of as the voltage level at its highest point. (Or highest voltage level). The receiver is able to pick up both the light signal and any background noise that may or may not be present in the optical channel. Both of these things can be present in the optical channel. In order to decode a message, it is necessary to first convert an analog representation of the message into its digital form as it was originally transmitted. To accomplish this, a digital representation of the signal is first converted back to its analog form, and then the process is repeated. Equalization strategies, such as Zero-Forcing and Minimum Mean Squared Error (MMSE), are typically utilized by OOK systems in order to mitigate the unfavorable effects that are brought on by the channel. On the other hand, it won't be implemented in the system that's being used for this project; on the other hand, it won't be implemented in the system that's being It is also important to note this fact, as it is important to note that the SNR of the OOK system is susceptible to degradation due to low-frequency distortion. Both of these aspects can make it more challenging to get back on track after making a mistake. Regarding the method of communicating, one's thoughts to another.

4.5 DCO-OFDM DC-BIASED OPTICAL OFDM

As the transmission speed increases in systems such as OOK, PAM, PPM or PWM, the intermember interference (ISI) caused by the frequency dispersion of the optical channel also increases. The effect of this interference degrades the signal and reduces the SNR, requiring modulation techniques that are more robust to interference, such as OFDM (Orthogonal Frequency-Division Multiplexing). The OFDM technique applied to SISO (Single-Input Single-Output) systems consists of dividing the message to be sent into data blocks, whose inputs (symbols) modulate a subcarrier, or tone. Unlike the OOK technique, therefore, OFDM is a form of multicarrier transmission. To facilitate the retrieval of symbols at the receiver, the subcarriers must be orthogonal to each other, so that at the central frequency of each subcarrier, all others have amplitude equal to zero in the frequency domain (Figure 4.4). Thus, OFDM transmissions occupy the frequency spectrum more efficiently than FDM transmissions, which need to keep the center frequencies of the subcarriers farther apart to avoid overlap.

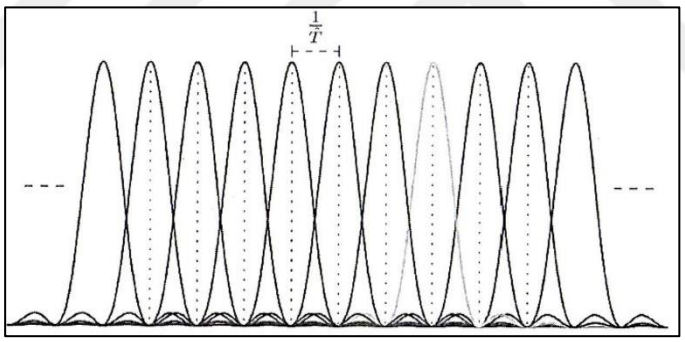

Figure 4.4: Representation of OFDM Subcarriers in the Frequency Domain.

Inter-block interference (IBI), or interference between OFDM symbols, caused by delayed and attenuated versions of the signal transmitted in a multipath channel, makes it difficult to maintain the orthogonality of the subcarriers when they arrive at the receiver. To avoid this type of interference, a guard period is used, which works as an extended OFDM symbol.

One of the techniques that make use of this type of extension, and which will be used in this project, is to insert a copy of an initial part of the OFDM symbol into the guard period (Figure 4.5). This extension is called a cyclic prefix. The introduction of this redundancy decreases the throughput of the system, but manages to maintain orthogonality, as long as

the cyclic prefix is discarded at the receiver, thus eliminating the IBI. Remaining interference (ISI) is eliminated at the receiver using a channel equalization technique known as Zero-Forcing.

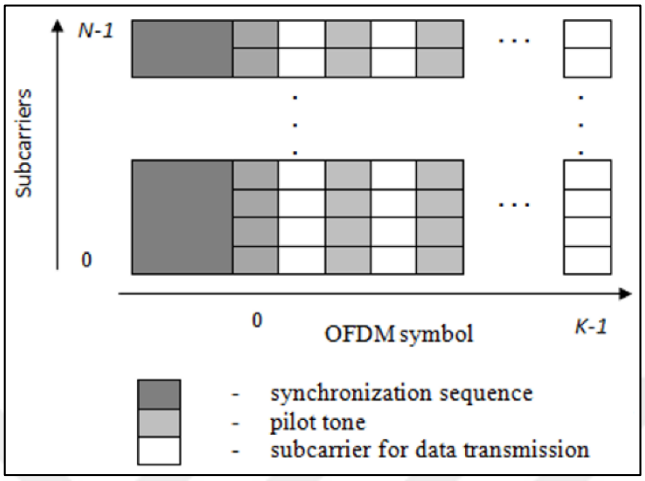

Figure 4.5: Insertion of the Cyclic Prefix in the Guard Period Between OFDM Symbols.

Finally, Figure 4.6 shows the complete diagram of the OFDM system that was developed in MATLAB As the data input is serial, the serial-parallel conversion is performed first, for the division of the message into blocks of size = 64, and before send to the transmitter module, parallel-to-serial conversion is performed. In the receiver, the procedure is reversed.

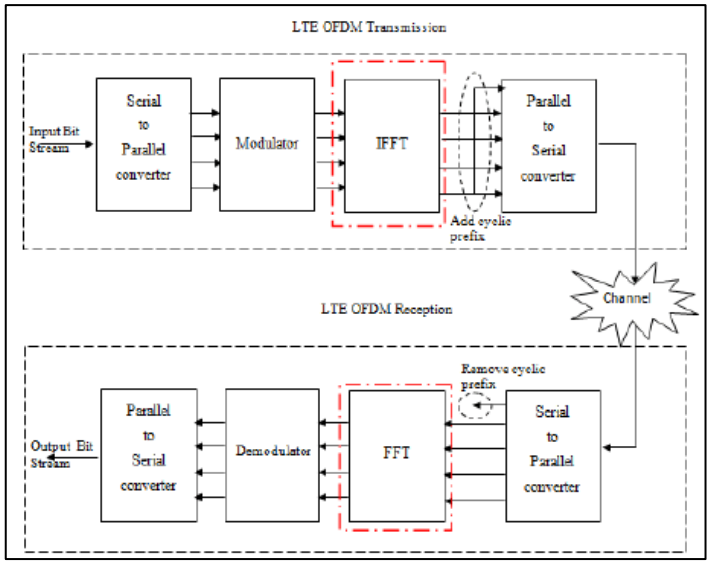

Figure 4.6: Complete Block Diagram of the OFDM System.

The internal modulation techniques used were BPSK (Binary Phase Shift Keying) and 4-QAM (Quadrature Amplitude Modulation). In the first, the binary data are modulated into two symbols (-1 and 1) shifted in the complex plane by 180°. In the second technique, the modulation occurs with a 90° lag between the four possible symbols ($\pm\frac{\sqrt{2}}{2}\pm\frac{\sqrt{2}}{2}i$). BPSK modulation is less susceptible to detection errors caused by noise due to the greater distance between symbols, but it transmits less information per symbol than quadrature modulation.

4.5.1 Optical Transmitter

For the optical transmission module, an ATmega328 microprocessor, present in the Arduino Uno prototyping platform, was used. The blocks processed by the computer in the MATLAB software are sent via serial interface to the Arduino, which uses one of its analog outputs to transmit the signal electrically to the LED. For the DCO-OFDM system, knowing that optical transmissions do not allow negative values, a DC-biasing is performed to shift the DC level of the signal and make negative values positive.

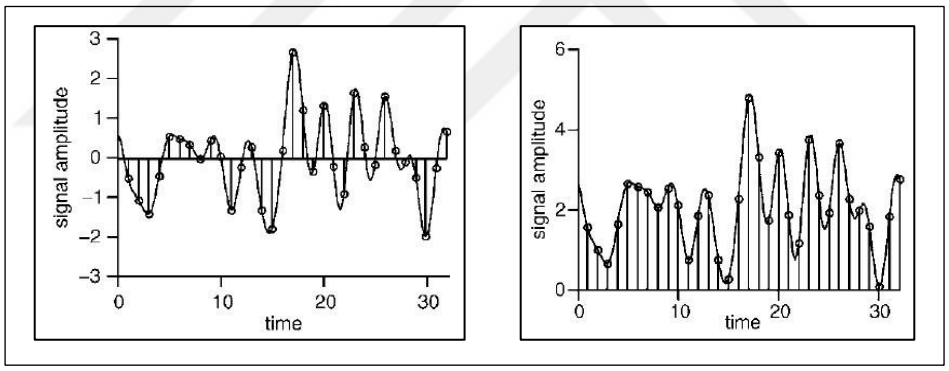

Figure 4.7: DCO-OFDM Transmission: (a) Without DC-Bias (b) With DC-Bias.

4.5.2 DAC Analog-to-Digital Converter

The analog outputs perform pulse width modulation (PWM – Pulse Width modulation) using the received values as a duty cycle percentage value, which determines the time the signal is kept at a high level (Figure 4.8). These should take levels from 0 to 255, as PWM precision is 8 bits. However, to obtain the expected waveform signal, performing the digital-to-analog conversion (DAC), it is necessary to filter the PWM frequency using a low-pass circuit, in order to obtain the average level of the signal. Thus, each duty cycle value will be associated with a voltage level at the output of the circuit. For this, a simple first-order low-pass RC

filter was used, as shown in Figure 4.9.

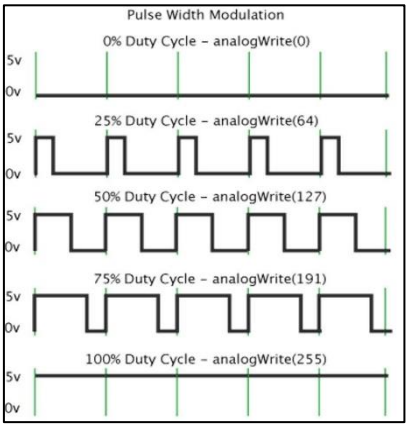

Figure 4.8: PWM Modulation on the Atmega328 with Duty Cycle Variation.

The cutoff frequency of the RC Low Pass Filter of the circuit can be calculated by the expression below:

$$= \frac{1}{2\pi RC} \quad (4.1)$$

Component values were scaled to R = 1 kΩ and C = 1 μF. Substituting them in (4.1), we have the value of the cutoff frequency = 159 Hz. The filter therefore begins to attenuate the amplitude of frequencies greater than, which includes the ATmega328 PWM frequency of 31,372 kHz. Despite the tests carried out using higher frequencies, these are not much higher than the cutoff frequency, being little attenuated. The main objective of using this cut-off frequency value is to eliminate as much as possible the variation caused by the PWM frequency, which impairs the quality of the signal.

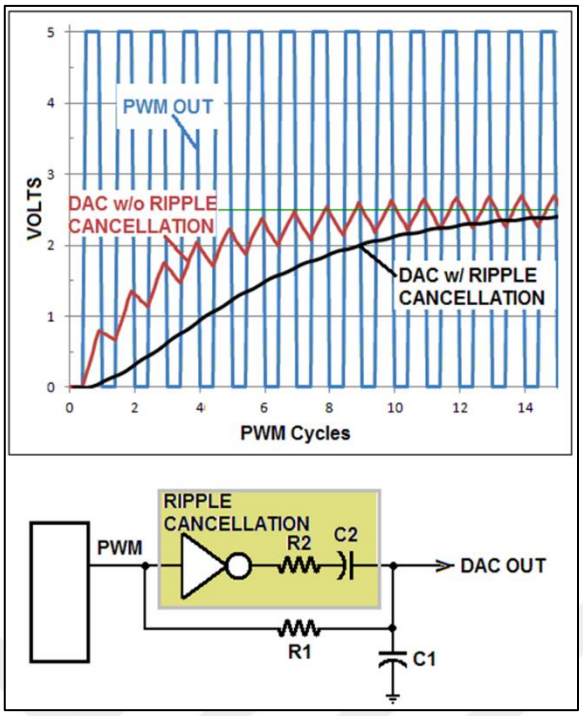

Figure 4.9: DAC Using PWM and RC Low-Pass.

4.5.3 Led Driver

For the project, only a 5mm high-brightness white LED with a maximum power of 100mW was used. Figure 4.10 (a) shows the spectral distribution of the LED, indicating a peak in the violet light region (~410nm), but also in the green light region (~500nm). Figure 4.10 (b) shows the LED radiation diagram, which is quite directive, which in an indoor application may not be ideal, since the more diffused the lighting, the better the capture around the environment.

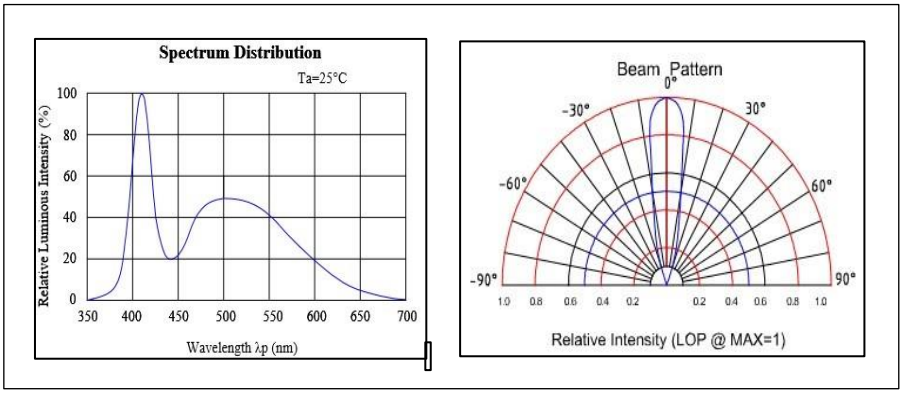

Figure 4.10: LED Characteristics: (A) Spectral Distribution (B) Radiation Diagram.

However, in the case of using several LEDs, such as an LED lamp, it is necessary to use a driver to support the current consumed by the set. Thus, the current is drawn directly from a source and the signal to be transmitted is controlled at the base of the transistor, whose collector current specification is in accordance with the current demanded. Therefore, the driver of Figure 4.11 was added to the transmitter circuit, using the following components:

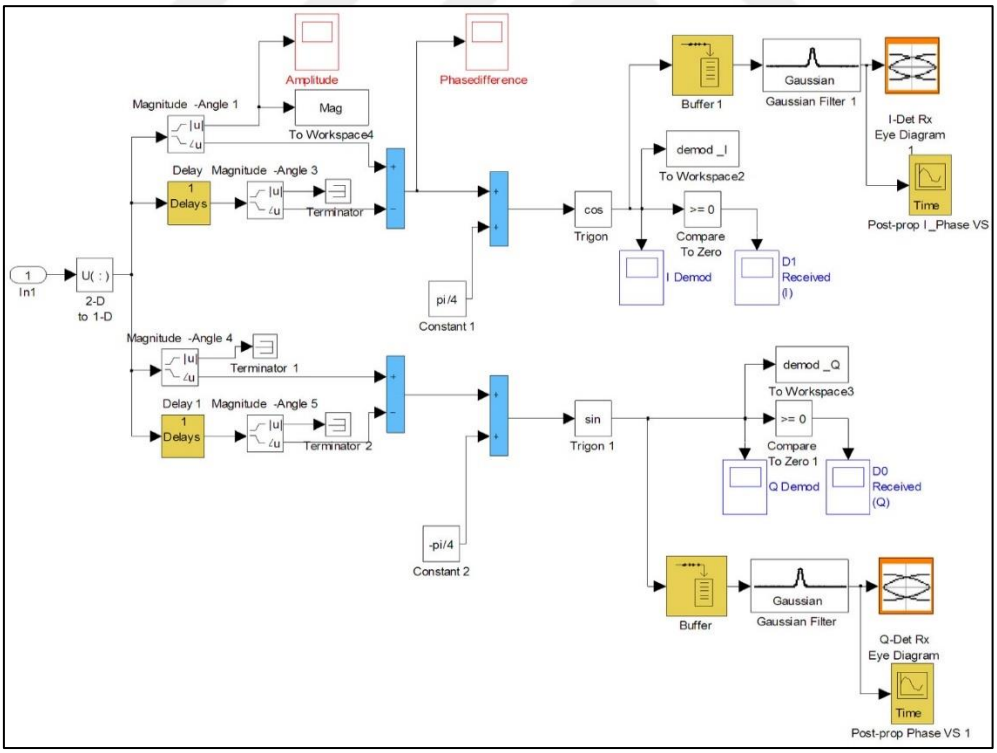

Figure 4.11: Complete Circuit of the Optical Transmitter with Driver.

The operational amplifier (U1) works as a buffer, isolating the RC Filter from the LED circuit. In its input pin, a resistive divider (R2 and R3) is used to make an analogue DC-biasing. This procedure is necessary because, due to the non-linearity of the LED and also of the transistor (Q1), it is necessary to limit the signal to be transmitted within the region with the most linear response of the component. Another way to avoid distortion caused by semiconductor non-linearity, but which is not included in this project, is to compensate for it by performing a pre-distortion before the digital-to-analog conversion. Thus, it is possible to use the maximum excursion of the signal to the component output with little or no distortion.

4.6 TRANSMISSION ALGORITHM

The microprocessor has limitations regarding the memory available for storing variables and also regarding the size of the serial interface buffer memory (64 bytes). Thus, it is not possible to send the entire message to the microprocessor at once – in the case of a large number of values, such as an image, Therefore, the message is sent in blocks (of size M+L-1, in the case of OFDM) and, at the end of sending a block, it is transmitted through the analog output, until it reaches the LED. In addition, transmission of a message start value corresponding to the lowest voltage level (0V) is used, so that the receiver knows when to start reading the message. This is transmitted at a predetermined rate, which varies according to the test being performed.

4.7 OPTICAL RECEIVER

As well as the transmission module, an ATmega328 microprocessor (Arduino Uno) was used for the receiver module. The signal sent by the LED is detected by a light sensor or photodiode, which transduces the optical signal into an electrical signal. After amplified and filtered, this electrical signal passes through an Analog-Digital Converter (ADC), present in the microprocessor. The precision of the ATmega328 converter is 10 bits, allowing the representation of 0 to 5 input volts in 1024 levels, with a sampling rate of 10 kHz. The values are sampled again according to the symbol sending rate of the transmitter and the received blocks are sent via serial interface to the computer, for processing in the MATLAB software.

4.8 LIGHT SENSOR

For the sensor, the OPT101 integrated circuit was chosen, which in addition to the photodiode to convert the light signal into an electrical signal, also has an integrated transimpedance amplifier, which avoids the effects of leakage currents and noise caused by parasitic capacitances, common in discrete amplification circuits In addition, it has a response with a bandwidth of 14 kHz, which is sufficient for the transmission rates used. In Figure 4.12, the internal circuit of the IC and its pinout is detailed.

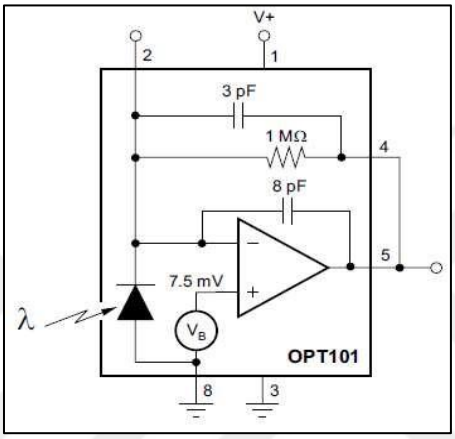

Figure 4.12: Internal Circuit Diagram of the OPT101 IC.

The sensor's spectral response, as seen in Figure 4.13 has its peak in the infrared region (~850 nm), which is common in most optical sensors. Even so, the sensor has a good response in the visible light range, which goes from 400 nm to 700 nm, approximately. In Figure 4.13 (b) the sensor response relative to the light incidence angle can be seen. The response to the angle of incidence θx, relative to the front view of the sensor, presents a better gain than the response to the angle θy, relative to the side view. Both, however, have equal and maximum gain when the light falls at an angle of 0° on the photodiode.

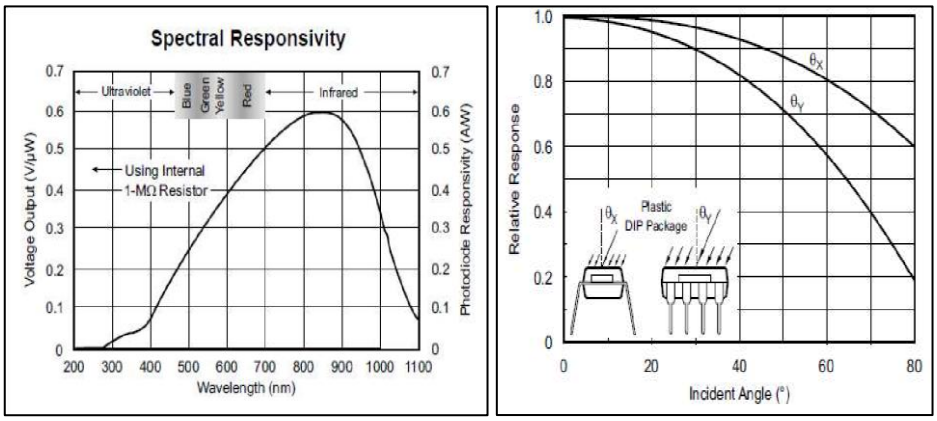

Figure 4.13: OPT101: (a) Spectral Response (b) Response to the Angle of Incidence.

5. RESULTS AND DISCISSION

In this chapter, the results obtained, both in the simulation of the OFDM optical system and in the smart grid set up will be discussed, with the objective of comparatively evaluating the performance of the systems and verifying the feasibility of implementing the developed techniques.

5.1 SIMULATION

For the simulation of the OFDM optical system, the code developed in the MATLAB software was used, which digitally implements the system.

Random data streams were transmitted using two different modulation techniques: BPSK and 4-QAM; with size of 2400 and 4800 bits, respectively. Figure 5.1 presents the results obtained for a transmission with an SNR level of 20 dB and channel length L=41. The size M used for the input blocks was 64, in order to have a length greater than the length of the chosen channel.

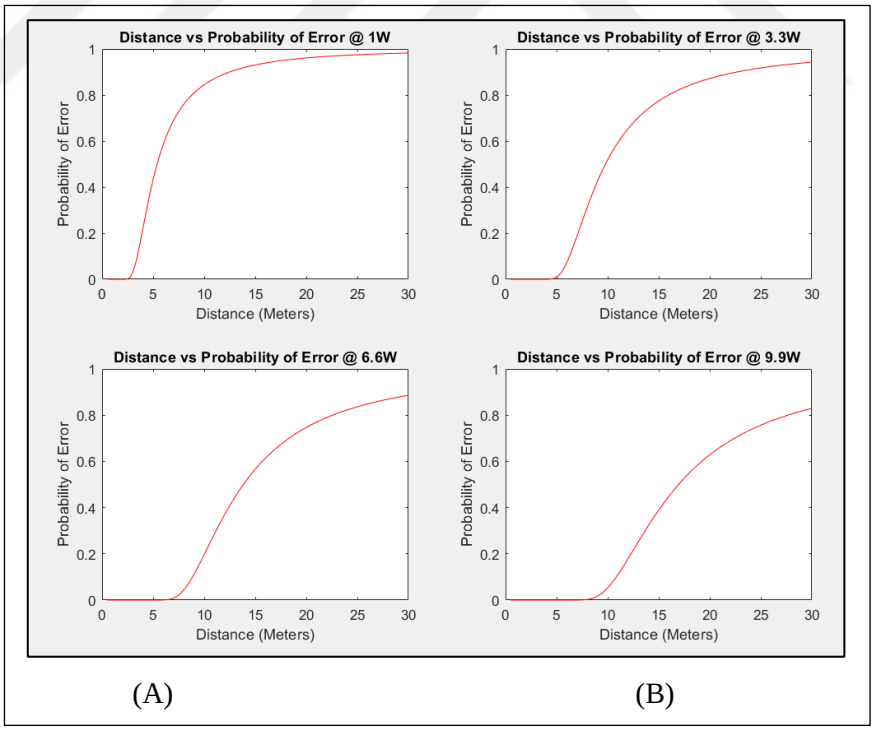

Figure 5.1: Constellation Diagrams of the Simulated OFDM System: (A) BPSK (B) 4-QAM.

It is possible to notice in Figure 5.1 that, when using the BPSK modulation technique, the decision-making process tends to commit fewer errors, since the symbols are farther apart. While with the 4-QAM technique, despite transmitting more bits per symbol – which increases the throughput of the system – it keeps the symbols closer to each other, increasing the chances of errors. For a more complete analysis of the system performance in relation to the noise level of the channel, a sweep of SNR values was carried out, varying them between levels from -20 dB to 20 dB with a step of 0.5 dB and creating a graph of BER (Bit Error Rate) x SNR. A set of 5000 random channels of length L=41 was generated to perform an average between the error probability results (BER) obtained for each SNR. Figure 5.2 shows the result of this simulation, showing the BER curve for the BPSK and 4-QAM techniques.

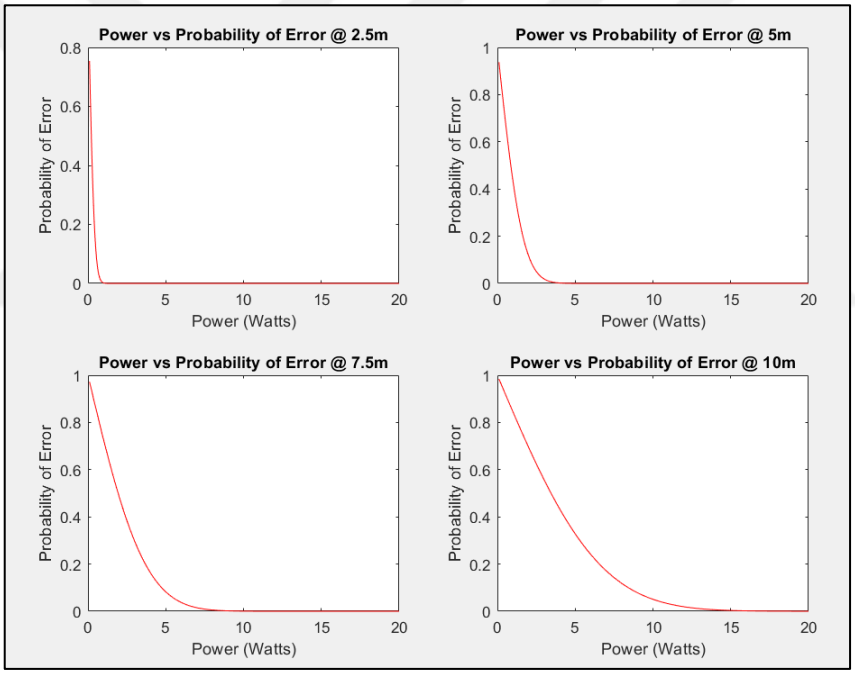

Figure 5.2: BER X SNR Graph for OFDM System.

It is noted that the performance of the BPSK modulation technique is, as expected, better than the 4-QAM modulation, having a steeper curve, which decreases more quickly as the signal-to-noise ratio of the channel (SNR) increases.

6. CONCLUSION AND FUTURE WORK

A significant number of generators are now able to begin selling the power that they produce because they are connected to the grid. Wind farms and photovoltaic arrays are the most common sources of this type of power generation. The number of producers who are wired into the grid is steadily climbing as a result of developments in both technology and policy, the latter of which includes both regulation and financial assistance. The high-capacity power plants that make up the backbone of the electrical grid can range in size anywhere from 100 megawatts (MW) for gas-fired power plants to gigawatts (GW) for nuclear units. These power plants provide the majority of the nation's electricity. This design was conceived with the "production-transmission-distribution" triptych, which has been in existence for many years, serving as a source of inspiration. The construction of any reliable electrical grid must begin with the establishment of power plants that are capable of producing the greatest amount of electricity. This centralized production is routinely adjusted to meet the requirements of the customers in order to prevent an imbalance in the energy network. This makes certain that there are no obstructions to the flow of electrical current. The use of intermittent sources by decentralized generators that cannot be controlled is currently undergoing a revolution that is transforming the electricity grid. This revolution is currently taking place. In its place, the vertical layout that was previously present has been replaced with a layout that is horizontal. Generators that are decentralized and cannot be controlled use sources that are intermittent in order to power themselves. This is due to the fact that the framework of generators is dependent on unreliable sources, which is the cause of this predicament. A brand-new term, "consumer-players," has recently been coined to describe these types of individuals. People who act in the capacity of both a consumer and a producer are examples of what are now being referred to as "new actors." The management of a situation is made more challenging when there are a lot of moving parts involved. The installation of new renewable energy parks typically takes significantly more time as a consequence of the unpredictability that is inherent to the use of renewable energy sources. The installation of new renewable energy parks is slowed down as a result of this, and line capacity constraints in certain locations further reduce the amount of energy that can be produced. There are a number of potential solutions, including lowering output and consumption, as well as providing a buffer for the intermittent nature of renewable

energy sources. The primary focus of this thesis is a solar-powered microgrid with integrated energy storage that is planned to supply power to tertiary consumers. Investigations are currently being carried out into numerous potential sources of power, including chemical batteries and flywheels. (Li-ion). As a result of the fact that the system is linked to the primary network, the management team is obligated to take into consideration the cost at which components can be acquired and resold on the open market. Because of this, it is necessary to improve the predictability of power withdrawal and injection in order to make the development of microgrids easier. Because the energy provider is better able to anticipate the requirements of his customers in advance, he is able to reduce the amount of energy that he purchases in real time from the wholesale market at prices that are higher. This allows the energy provider to save money. The development of an optimal design method for the systems that are the focus of this thesis is also included, in addition to the various management strategies that are included in this thesis' scope of investigation. Combining the costs of installing the various components while also taking into account consumption, production, and tariff statistics is necessary in order to arrive at a solution that is technically and economically viable. The goal is to find a solution that is technically and economically feasible. This overall cost is affected not only by the cost of energy on a monthly basis but also by the benefits gained from the effective management of smart microgrids. As a direct consequence of this, the management loop will be integrated into the process of design right from the start. Before one can have a complete understanding of the environment of the microgrid, it is necessary to perform simulations for a period of time that can range from months to even years. (Production deposit and consumption missions). Depending on the models and management strategies that are utilized, the amount of processing time involved might render them infeasible to use in their current form. The authors of this thesis came up with an appropriate resolution method and model granularity so that they could scale the system and investigate the effects of a variety of input elements. This modification was carried out in order to fulfill the prerequisites posed by the pricing context of this thesis, and it was successful in doing so.

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