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**CONTROL AND MANAGEMENT OF SOLAR
CHARGER USING MICROGRIDS AND
PHOTOVOLTAIC CELLS**

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Master's Thesis

Supervisor
Prof. Dr. Kevork MARDİKYAN

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DEDICATION

I would like to thank Prof. Dr. Kevork MARDIKYAN for agreeing to supervise my research and for the helpful suggestions and insightful criticism he offered as I was getting my study ready. Everyone who contributed to this study's publication in its current version has my sincere gratitude. Lastly, I'd want to express my gratitude to the professors who served on my defense committee for taking the time to review my work and contributing their extensive expertise to my study. integrity of their thinking and give me helpful views that, with any luck, may aid in directing our research in a positive direction.

ABSTRACT

CONTROL AND MANAGEMENT OF SOLAR CHARGER USING MICROGRIDS AND PHOTOVOLTAIC CELLS

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In a global scenario, there is an increase in demand in distribution networks, a decline in the use of fossil fuels motivated both by their scarcity and by the appeal to preserve the environment, especially through the mitigation of the emission of greenhouse gases (GHG). This paper is thus positioned with a view to using one or more storage means(s) within a solar charger comprising intermittent production and consumption sources, all of which are connected to the main grid. After having located the class of problem targeted and the particular project that constitutes our case study, the study aims to be more methodological by dealing with our main line of research in solar chargers. It concerns the optimization of the system design process integrating management and sizing issues for the solar charger elements. The solutions chosen in this thesis are presented in relation to the methods encountered in the literature. As in many studies, the operation of the solar charger is envisaged by optimizing energy flows so as to minimize the financial cost based on environmental and tariff data.

For an optimal design of the system, an approach that interweaves the management loop and the dimensioning loop is envisaged but requires an intelligent reduction in the complexity of the problem.

Keywords: ML, DL, MG, SG, Energy Optimization.



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ABBREVIATIONS

ML	:	Machine Learning
DL	:	Deep Learning
SHP	:	Small Hydroelectric Plants
EO	:	Energy Optimization
MG	:	Microgrid
CSC	:	Current Source Converters
DNN	:	Deep Neural Network
ANN	:	Artificial Neural Network
DQN	:	Deep Queue Neural Network
DPG	:	Deep Policy Gradient
DRL	:	Deep Reinforcement Learning
PV	:	Photo Volic
PSO	:	Partical Swarm Optimization
AMI	:	Advanced Metering Infrastructure
ReLU	:	Rectified Linear Units
MPPT	:	Maximum Power Point Traking
MDP	:	Markove Decision Process
GHG	:	Green House Gases
CC	:	Central Control

CB	: Circuit Breaker
LC	: Load Controller
DMS	: Distribution Management System
SoDGS	: Sources of Distributed Generation System
CHP	: Combined Head and Power
CVT	: Constant Voltage Tracking
N-CA	: Nickel-Cobalt Aluminum
HVAC	: High Voltage Alternating Current
HVDC	: High Voltage Direct Current
RL	: Reinforcement Learning
Q-L	: Queue-Learning
DW	: Dish Washer
EV	: Electric Vehicle
ACL	: Air Conditioning Load
VSC	: Voltage Source Converters
PMSG	: Permanent Magnet System Generators
LCC	: Losses Compared Converter
PWM	: Pulse Width Modulation
ANFIS	: Adaptive Neuro-Fuzzy Inference System
CCP	: Commone Coupling Point

MC : Microsource Controls

DoE : Department of Energy

DMS : Distribution Management System



1. INTRODUCTION

1.1 BACKGROUND

Concerns about the depletion of natural resources and the allure of preventing climate change by reducing carbon dioxide emissions are contributing reasons to the general trend away from utilizing fossil fuels, which coincides with the increasing need for distribution systems worldwide (GHG). Presently, conventional electrical systems are through a phase in which crucial modifications are being implemented. Considering the effects of climate change and pollution on the environment, it is plainly clear that we must seek other sources of power [1].

It makes sense that more study is being conducted on the most effective methods to convert and use energy, particularly energy obtained from basic sources that do not contribute to environmental deterioration. Even without including reserves that have not been identified, explored, or are unrecoverable, the quantity of solar energy received by Earth each year is at least 10 times more than the entire amount of known fossil fuel reserves. Because the availability of the solar resource may fluctuate over time, it makes sense for the first generating units to be mobile and situated near to the loads (due to climatic and geographical reasons).

As a result, a number of international agencies responsible for regulating the electric energy market are enabling users to create their own electricity via the use of renewable sources or cogeneration, and even permitting them to sell any extra power back into the local grid. The words "microgeneration" and "minigeneration" of electricity refer to developments that have the potential to combine cost reductions, heightened social and environmental consciousness, and greater independence. A schematic representation of a cogeneration system is shown in figure 1.1. Utilizing heat to satisfy local needs adds to an increase in the overall system efficiency.

Previously static distribution networks now actively participate in the flow of electricity in both directions. There are numerous advantages of systems with their own generation, among which we can mention:

- i. Reduction in GHG emissions in plants with renewable fuel.
- ii. Increased efficiency in cogeneration plants.
- iii. Diversification of the energy matrix.
- iv. Postponement of investments in expansion in energy transmission and distribution systems.

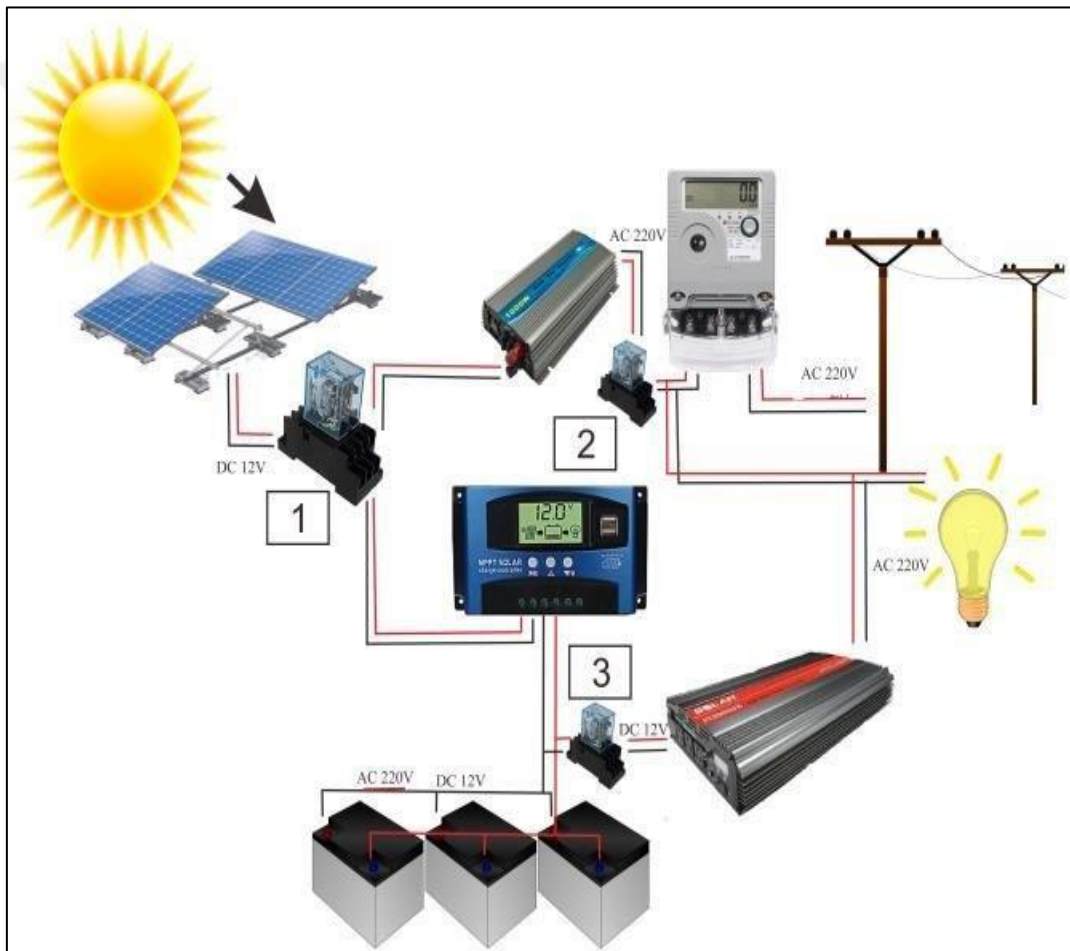


Figure 1.1: Distributed solar based cogeneration system.

In general, the Interconnected System relies almost exclusively on large generating units, being dimensioned to allow transfers of large blocks of energy between regions. Environmental restrictions make the construction of large hydroelectric plants unfeasible, underusing the national potential. Thermal plants, in turn, have a high operating cost (fuels) and are polluting. In recent years, increasing investments have been observed in projects for the generation of alternative energies to those mentioned, such as photovoltaic wind farms, small hydroelectric plants (SHP), the use of biodigesters among others. This context, when carried out close to consumption centers, is known as distributed generation, which consists of using smaller energy sources, close to final consumers, to supply a small number of installations locally. In the composition of distributed generation environments, several elements can be highlighted: photovoltaic panels, wind generators, diesel generators or microturbines (as alternatives when the electrical network fails).

or need for disconnection) and even battery banks or other energy storage technologies that can optimize the use of intermittent generation from panels and wind generators and improve power quality levels in the electrical networks to which they are connected. In this paradigm, the following can be pointed out as positive points:

- i. Lower cost of the initial investment compared to large-scale plants;
- ii. Greater reliability, as outages in large generating units of the interconnected system can leave thousands of consumers without energy;
- iii. Better energy profile for the final consumer;
- iv. Lower distribution and transmission losses, as the generation and the consumer are close.

However, the costs of some technologies involved are still high (but they are falling progressively) and the intermittence of some generation sources introduces an additional difficulty in the operation of the system as a whole.

1.2 PROBLEM STATEMENT

1.2.1 Environmental Problems

Electric energy is, among the secondary forms, the one that most permeates our lives, being present in almost all energy uses of final consumers, being certainly a decisive factor in the development and well-being of our society. This is remarkable when taking the period 1973-2010, when it was observed that, for an average increase of 3.2% in world GDP, the consumption of electric energy rose by 3.5%, while total energy consumption increased by only 2% [1]. In 2011, the total world energy consumption was around 13 billion toes (tons of oil equivalent), with around 81% coming from fossil fuels, totaling approximately 31 billion tons of CO₂ emissions [2]. It is also not new that society is increasingly concerned with a better use of natural resources, with the reduction of environmental damage - often resulting from obtaining electric energy, such as the construction of new plants that generate great impact - and certainly with the greenhouse effect, driven on a large scale by the burning of fossil fuels. Therefore, alternatives to conventional means of energy generation are being studied since now and are taking shape, aiming to avoid an electric energy deficit in the world and guarantee the development.

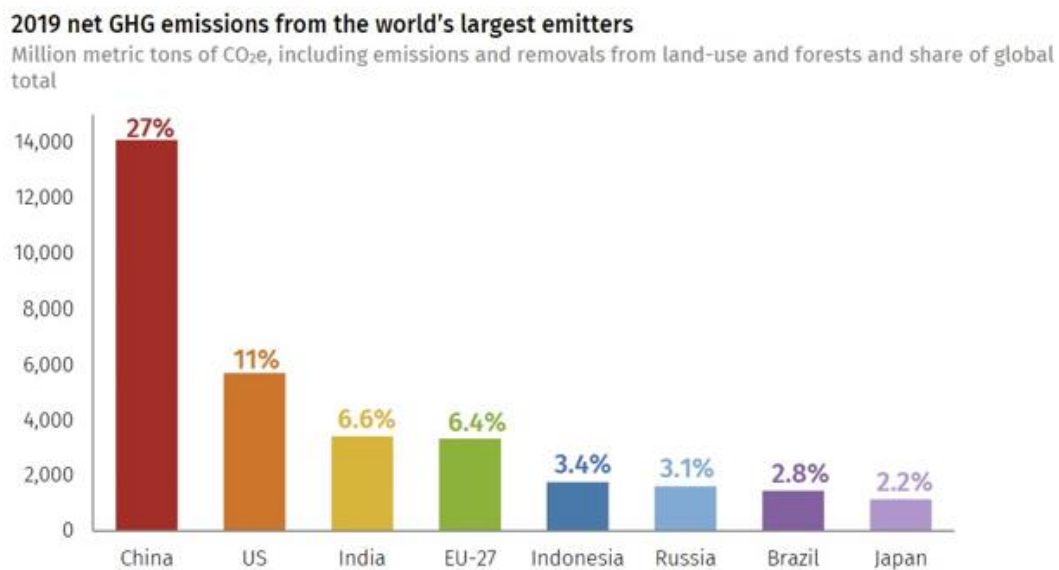


Figure 1.2: World GHG emissions measured in metric tons.

1.2.2 Humanitarian Problems

The increase in population, the race for growth and the development of the globalized economy have been accompanied by an explosion in energy consumption since the 1960s, and more particularly in electrical energy. Highlighted with the oil shocks of 1973 and 1980, energy issues took on a new form with the first two Earth Summits in Rio (1992) and Kyoto (1997) which highlighted the scarcity of terrestrial resources and the need to reduce greenhouse gas (GHG) emissions [7].

Thus, for the past fifteen years, the production of electrical energy from renewable sources has progressed with the installation of wind and solar farms, in addition to the hydraulic groups already present. An energy transition now appears inevitable in the organization of the production and marketing of electricity due to the profound changes of a physical nature (intermittent nature of renewable electricity sources), as well as of an economic nature (electricity also becoming a market product). From this energy context, this chapter presents the developments encountered in recent years in the electrical network and its management through the emergence of the concept of “Smart Grid”.

This designation covers a large number of areas, in particular the use of storage means to cope with the intermittency of renewable sources, but these technologies still come up against economic and regulatory obstacles.

1.2.3 Technical Problems

- i. Aging network infrastructure due to budget constraints that have prevented its renewal and accompanying security issues.
- ii. The limitation and inadequacy of existing production plants which are totally dependent on large capacity fossil fuel generators.
- iii. The electrical system with the current concept does not accept the integration of renewable resources and large-scale decentralized production, moreover it is incapable of managing the situation during the occurrence of climatic events.

- iv. The concentration of a large amount of power produced in one place.
- v. The increase in losses in the networks accompanied by a low efficiency of the production plants.
- vi. Increase in energy demand and reduction in global competitiveness.
- vii. Non-technical losses such as fraud and the lack of a control strategy. It is these major changes, both behavioral and structural, that have led to the development of a new type of network [3].

1.3 THESIS OBJECTIVES

1.3.1 Main Objective

The primary purpose of this project is to establish a system for precisely anticipating the production of renewable energy sources and implementing that plan to ease the administration of an intelligent electrical microgrid. To effectively administer this system, we will need to establish a plan for predicting the quantity of renewable energy the network will provide.

1.3.2 Specific Objectives

- i. Conduct a predictability study of solar energy data in order to define prediction expectations in the solar charger.
- ii. Develop a method for predicting renewable energy sources. This step is the essential part of the job. It consists in carrying out a method for predicting renewable energy sources, meeting the needs of the management of the intelligent electrical micro-grid.
- iii. Collecting and storing information on the wind speeds passing through the laboratory's wind tunnel so that the model may be evaluated using real-world conditions. Examine the findings of the chosen strategy for generating predictions in contrast to those of other, more traditional ways, and if necessary, validate the model by reproducing the data.

1.4 CONTRIBUTION

The contribution of this thesis is thus positioned with a view to using one or more storage means(s) within a solar charger comprising intermittent production and consumption sources, all of which are connected to the main grid. After having located the class of problem targeted and the particular project that constitutes our case study, the study aims to be more methodological by dealing with our main line of research in solar chargers.

It concerns the optimization of the system design process integrating management and sizing issues for the solar charger elements. The solutions chosen in this thesis are presented in relation to the methods encountered in the literature. As in many studies, the operation of the solar charger is envisaged by optimizing energy flows so as to minimize the financial cost based on environmental and tariff data. For an optimal design of the system, an approach that interweaves the management loop and the dimensioning loop is envisaged but requires an intelligent reduction in the complexity of the problem.

1.5 THESIS ORGANIZATION

This dissertation is organized in six chapters including the introduction and the general conclusion.

- i- The second chapter is based on bibliographic research, which allows us to have a good readability of existing prediction methods and see their advantages and disadvantages. This chapter also discusses prediction horizons and the contexts in which they are used.
- ii- In the third chapter, the theory related to the proposed prediction system will be discussed in order to highlight the advantages over the different prediction methods.
- iii- In the fourth chapter, the theory of multi-resolution analysis is studied in order to show the decomposition and reconstruction algorithms using wavelets. The basic aspects of wavelet network theory will also be analysed.

- iv- The fifth chapter is devoted to the description of the proposed system and the analysis of the prediction results.
- v- Finally, this last chapter will allow us to make a general conclusion, make a synthesis of the results and present the perspectives.



2. LITERATURE REVIEW

2.1 CHAPTER OVERVIEW

Despite being a relatively recent phenomena, the development of smart grids has attracted the attention of social science scholars who are interested in the socio-political issues associated with the deployment of smart grids from three main angles. Researchers have had a number of queries about the function of the actions engaged (1) in the development of smart grids up to this point. Some of these scholars have centered their attention on the national setting, others on the social acceptability of these innovations (2), and yet others on the role of the actions involved (3). In this essay, each of these views is addressed independently.

2.2 SMART MICRO-GRIDS

Author [9] defines A micro-grid as generally made up of one or more generators (electricity production facilities from variable or conventional renewable sources), energy storage facilities, loads, adjustment means, clearing system and information systems. All of these technologies must also allow the microgrid to disconnect from the main network to be islanded.

2.2.1 Concept of Micro-Grids

That solar chargers are effective is proved in [10], which was written by its author. Microgrids, also called mini-Smart grids or intelligent micro-grids, are decentralized power systems that serve a relatively small population. Other names for microgrids are smart microgrids and intelligent microgrids. They combine a wide variety of distributed and decentralized resources into a single manageable system, including generation, consumption, storage, monitoring, and control mechanisms. This allows the system to operate more efficiently and effectively. management of demand Either they can be physically connected to the system, or they can be used separately [10]. The application of micro networks to heat and gas networks enables multi-fluid thinking at a variety of geographical scales (building, district, industrial or artisanal zone, village, etc).

2.2.2 Classification of Smart Micro-Grids

There are five main types of businesses and industries that can benefit from electric micro-grid projects, each with its own unique set of needs (reliable, resilient, and efficient networks; difficulty in accessing energy; degraded weather; the emergence of eco-districts; multi-energy reflection; energy savings, etc.).

To achieve this goal, energy management must be streamlined to become less dependent on the distribution network.

- i. Solated areas that are either poorly connected to the electricity grids or not connected to the grids at all, or that are temporarily cut off from the network due to inclement weather, can be supplied by microgrids;
- ii. Micro-grids on university campuses: the issue is to improve the energy management of campuses in a scenario where universities must reduce the amount of energy they consume;
- iv. Eco-districts: they operate similarly to microgrids in commercial or industrial zones; "Base base" micro-grids (military camp or hospital): equipped with its own means of production and storage as well as its own distribution infrastructures, the microgrid guarantees energy autonomy by supplying electricity during periods of power cuts on the distribution network.
- v. Extreme weather can cause widespread power outages, but microgrids help communities recover more quickly and with less disruption.

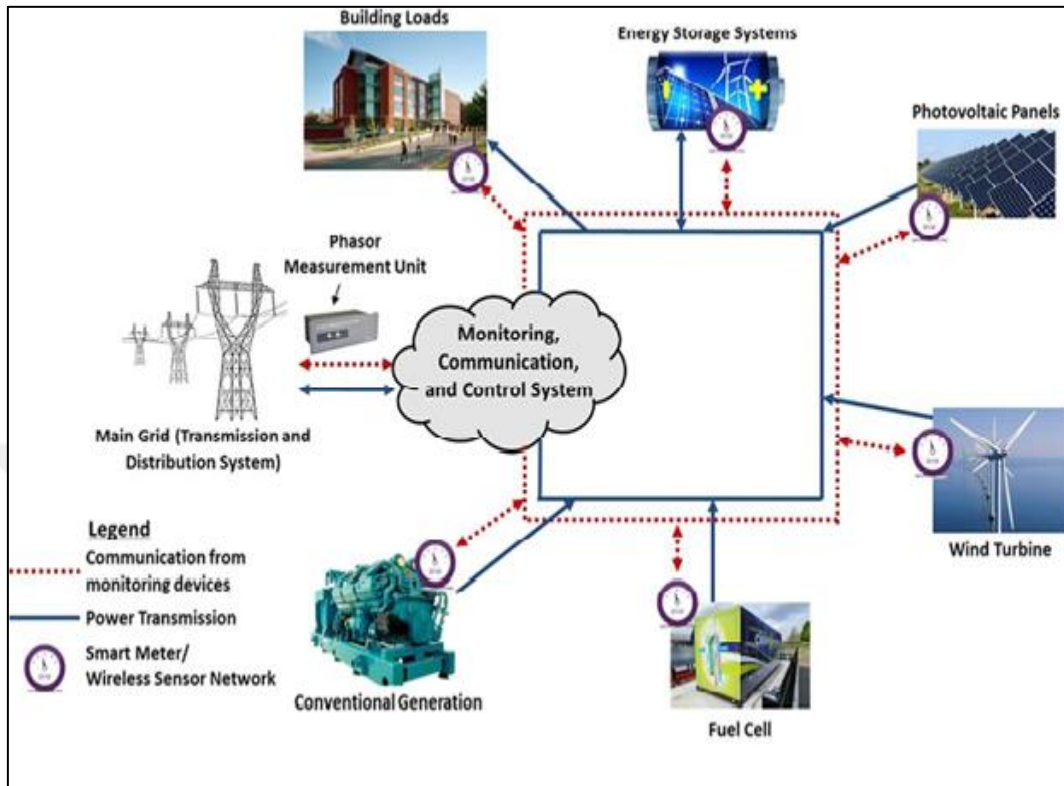


Figure 2.1: Smart micro-grid energy generation and distribution infrastructure.

2.2.3 Advantages of Deploying Smart Micro-Grids

The following is a list of the advantages that the author [12] enumerates as being derived by the utilization of microgrids:

- i. Microgrids, from a strictly technological point of view, make it feasible to undertake locally-focused optimization of the management of the generation of electricity from renewable sources. This is possible because microgrids allow for decentralized management of power distribution. They are able to provide the public distribution network with an auxiliary service, which not only helps the network maintain its voltage stability but also gives relief to the network when it is detached from the distribution network.
- ii. From a societal perspective, a micro-grid is able to answer questions regarding the development of the essential energy requirements of a region. This is something that

can be accomplished with the help of a micro-grid. In particular, it makes available a network that is both less risky and more reliable in the event of a mishap (assurance of energy supply even during peak consumption or blackouts). It is also easy for local players to develop new projects and ties with one another as a result of the fact that it is a local project:

On the economic front, depending on the size of the microgrid, it may be possible to use it as an aggregator, which would allow it to better adapt to market conditions. This would be possible because of the microgrid's ability to collect energy from multiple sources (spot market, adjustment market and capacity market). Microgrids also make it possible to reduce transits on the networks, which results in cost savings for the networks both in the short term (in terms of electrical losses from the network) and in the longer term. This generates savings in network costs both in the short term (in terms of electrical losses from the network) and in the longer term (in terms of investments in the networks). In addition, the use of microgrids results in cost reductions for the provision of electrical power, which contributes to a general cost reduction (shifting of loads when electricity is cheaper to produce, optimization of electricity supply according to energy prices on the markets and in the microgrids).

iii. In terms of the environment, they enable the integration of a bigger quantity of renewable energy into networks. This, in turn, helps to avoid the building of thermal power plants in environmentally sensitive locations, minimizes the consumption of fossil fuels, decreases thermal losses, etc. Microgrids are becoming an increasingly viable option, and as a consequence, they may play a pivotal part in the evolution of smart grids. This is due to the complexity of the needed infrastructure for smart grids, whose installation might take many years. Microgrids are being considered by an increasing number of persons due to the possible function they may play. Due to their decreasing complexity, it is conceivable that microgrids may play a key role in the energy market in the near future.

2.2.4 Technical and Economic Challenges of Microgrids

According to [13] The development and operation of microgrids induce technical and technological challenges of several kinds: - Ensure the stability of the microgrid in all circumstances, when the microgrid is connected to the main grid or when disconnected from it, when connecting and disconnecting: A micro-grid controller enables connection to the smart grid and provides control of voltage, energy flow, sharing or load shedding, and takes into account the constraints of the public network transmitted by a communication bus - Also ensure the protection of the micro-grid in the event of failures or disturbances of various origins on the main network: in the event of Otherwise, the microgrid must be decoupled quickly from the main grid to protect its own loads.

If the failure is attributable to the microgrid, protection functions must be able to detect short-circuit currents, in order to isolate the critical part of the microgrid. - If the electricity produced locally is not consumed locally, it is injected into the upstream network which becomes a collection network, which may require the reinforcement of the upstream networks.

2.3 INTEGRATION OF RENEWABLE ENERGIES

According to [14] The current model of the electricity system is at the dawn of a profound questioning. The economic model, organized around centralized electricity production, only makes sense if the electricity can be transported from the power stations to the consumer through the electricity networks. However, the public transport network will no longer be able to develop as before.

Local opposition to new public electricity transmission network structures, such as rows of pylons considered unsightly, is increasingly strong, which increases the cost of building structures or delays their commissioning. The electricity system of tomorrow could be above all a local model organized around multiple micro-grids, producing locally to consume locally, based essentially on decentralized production based on renewable energy sources.

2.3.1 Distributed Generation

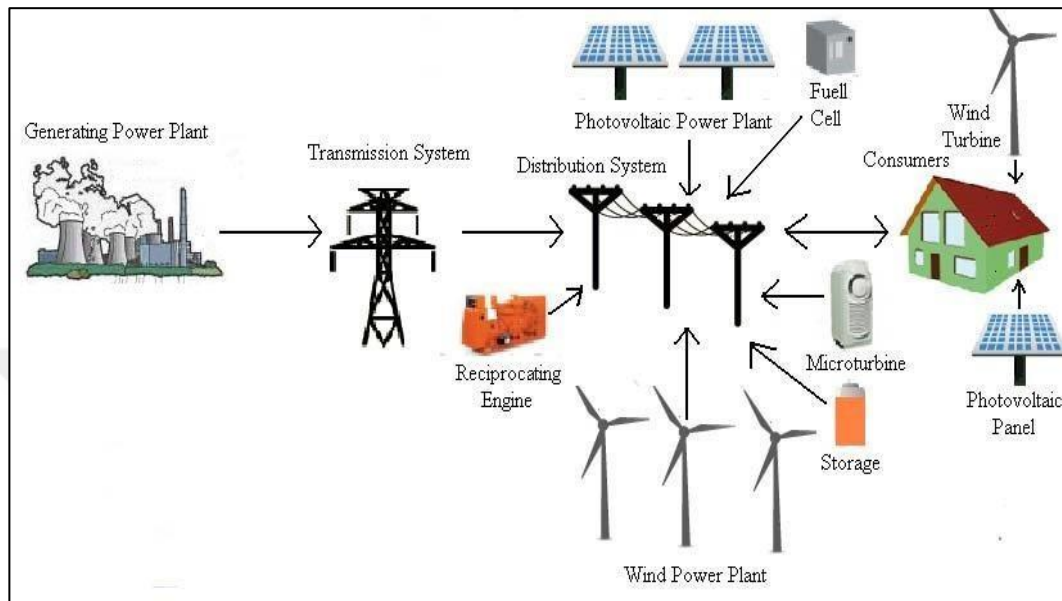


Figure 2.2: Microgrid and PV arrays.

DG is defined by the author [15] as "a set of small-scale power production technologies positioned near the serving load, capable of cutting prices, enhancing dependability, reducing emissions, and expanding options in the energy sector.

2.3.2 Causes of The Integration of Renewable Energies

According to [16] the reasons for integrating RE with DG are:

- i. Decrease in fossil energy resources and the sustainable rise in their price, Considerable increase in energy needs, - Difficulties in supply (supply),
- ii. Weight of the energy sector in emissions of CO₂ and the fight against climate change make it necessary to adapt energy production and consumption methods.
- iii. Among the main characteristics of the smart grid which has been defined by AIE is that it is able to accommodate any type of production technology, in particular the new dispersed generators which make it possible to supply electricity to isolated sites and to avoid the creation of new lines.

2.3.3 Different Types of Renewable Energies

The author [17] provides a definition of renewable energy, which states that the term refers to sources of power that are, at least on a human scale, endless in supply and easily accessible. Therefore, the sun, the wind, the water, the wood, and the rock heat are the five basic kinds of renewable energy. They have in common that during their operational phase they release low amounts of pollution, which helps in the fight against the greenhouse effect and global warming.



3. MATERIALS AND METHODS

3.1 INTRODUCTION

The generation of energy demands a substantial quantity of fossil fuel, putting both the availability of these resources and the state of the atmosphere on our planet at risk. If we are to be able to stay up with the global economy and preserve the environment for future generations, we must develop alternative energy sources that are clean, sustainable, and sustainable. Therefore, a coordinated global reaction is essential.

In recent years, the fraction of the nation's overall electrical production that comes from renewable sources has increased significantly. Quite perhaps, this increase is linked to the regulations put in place to combat the effects of climate change and ensure a sustainable energy supply.

It is probable that the efficacy of these efforts is directly responsible for this expansion (world energy outlook). The development of greenhouse gases such as nitrous oxide (N₂O), carbon dioxide (CO₂), and methane (CH₄) is responsible for global warming, according to the Intergovernmental Panel on Climate Change assessment (IPCC). Numerous nations, including the United States, Germany, and China, are doing research on the viability of converting to renewable energy sources (such as wind, solar, biomass, and hydroelectricity) and integrating these technologies into low voltage and high voltage electrical networks.

This research investigates the feasibility of transitioning to renewable energy sources. Alternative energy sources such as wind, solar, biomass, and hydroelectricity are being studied to discover whether or not fossil fuels can be effectively substituted with them. Photovoltaic cells turn sunlight directly into electricity, making them one of the most quickly developing renewable energy applications. This article's accompanying map, Figure 0.1, demonstrates how the potential for creating this kind of energy varies greatly by region.

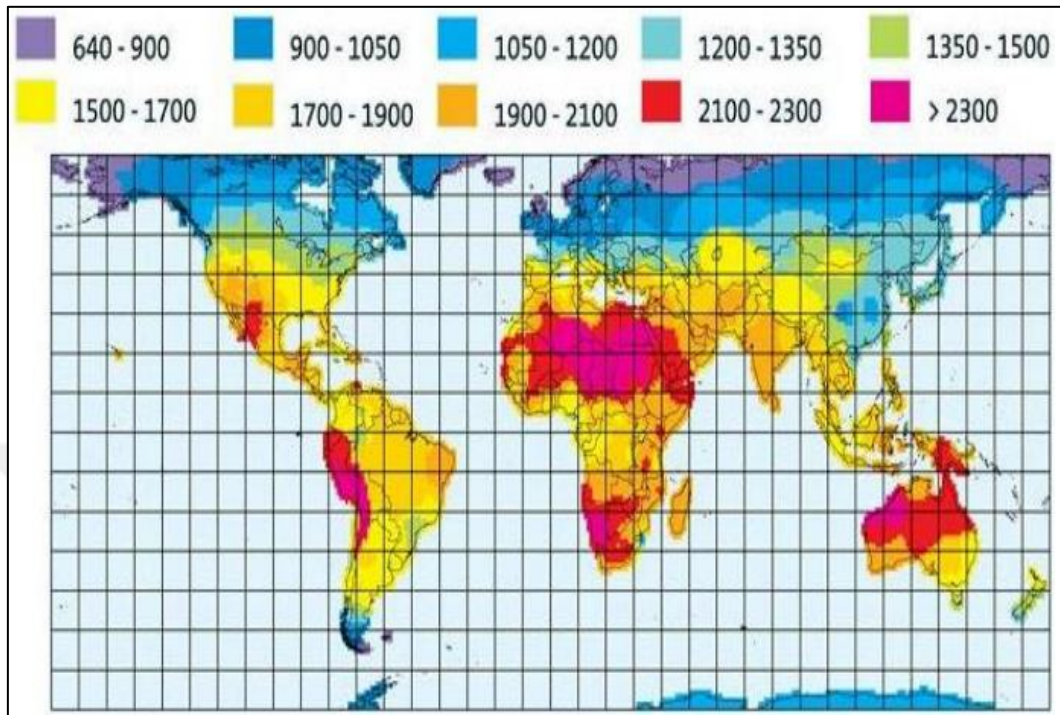


Figure 3.1: Distribution of solar energy around the world [12].

Renewable energy sources, such as wind and solar, may be challenging to incorporate into the electrical grid due to their unpredictability. This is particularly true for large-scale MICROGRID electrical network integration. Maintaining perfect synchronization and the requirement to increase energy quality are examples of variables that make it simpler to maintain the stability and dependability of a system. As part of this doctoral research, an optimal design of the global system based on multi-level converters and advanced control algorithms is being implemented to reduce energy losses during transport, ensure service continuity in the event of faults, and improve energy quality for greater exploitation of these energy sources and safe integration into electrical networks.

These objectives may be achieved by lowering energy losses during transit, assuring service continuity in the case of problems, and enhancing energy quality. Due to this, the effectiveness of an electrical system comprised of a wind-PV hybrid power plant, transmission lines, and HVDC stations can be evaluated based on its ability to continue providing service even as the surrounding environment undergoes a variety of changes, as well as its ability to withstand a

variety of faults and restore power to the grid while maintaining the highest quality possible. This project aims to maximize energy output from the micro-grid, a hybrid power plant comprised of wind and PV, while simultaneously lowering transmission losses and ensuring perfect synchronization with the electrical grid. [13] This research is motivated by the need to create greater synchronization between the system's three distinct paths (Production, Transport, and Network). Because renewable energy sources such as wind turbines and photovoltaics can be improved and used to a larger extent with the help of power electronics, this kind of energy will continue to be a better answer for the energy industry's future.

In reality, the increasing production of electricity via the use of fossil fuels such as oil and coal has had a direct impact not only on the reserves of fossil fuels but also on the global environment, causing concerns about pollution and warming. Wind turbines utilize the wind's energy to create power by transforming the air's velocity into rotating motion. The wind turbine is capable of producing megawatts of power. This is particularly true for offshore wind generators, which have access to a greater territory and more powerful winds. The production of photovoltaic, onshore and offshore wind power has experienced a rapid evolution in the last decade [15].

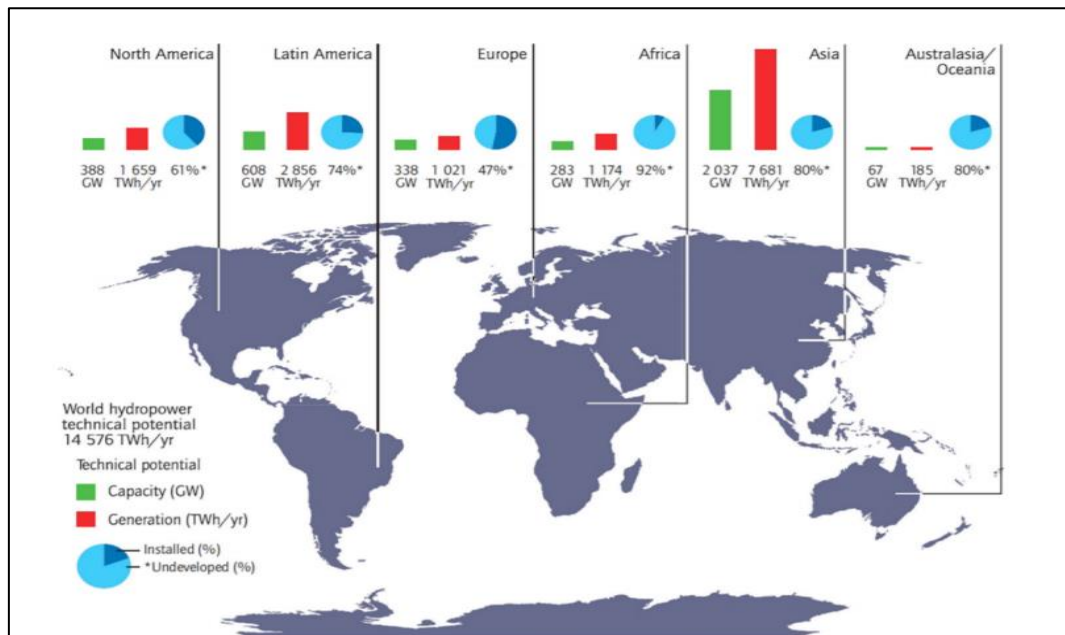


Figure 3.2: Wind PV energy integration around the world [16].

3.2 PROBLEMS OF HVAC AND HVD

Long-distance energy transmission often employs transfer systems using either high voltage alternating current (HVAC) or high voltage direct current (HVDC). When deciding between HVDC transmission and HVAC transmission, distance, equipment cost, installation, and maintenance, as well as energy losses, are factors to consider. In addition, when the transmission distance exceeds 50 kilometers, offshore farms use the HVDC system the most often.

This system's basis may consist of current source converters (CSC) based on thyristors and voltage source converters (VSC) based on field-effect bipolar transistors. One of the several advantages of VSC technology [16] is that the active and reactive power flows may be independently integrated at both ends of the network. In contrast, compared to VSC technology, the LCC system has a greater loss rate.

Connecting offshore wind farms using double-fed induction generators (MADA), squirrel-cage induction generators, or permanent magnet generators to the high-voltage direct current (HVDC) grid is conceivable (PMSG). The second alternative is the most popular since it is more lucrative, efficient, and requires less ongoing maintenance. The photovoltaic system is reliable, efficient, and cost-effective because it is basic, symmetrical, and needs fundamental control as well as an algorithm to extract maximum power (MPPT) with the ideal power.

High-voltage direct current (HVDC) transmission systems and cables are necessary to convey the energy produced by solar power plants across substantial distances. Technical challenges, particularly the existence of faults that might have a detrimental impact on the amount of energy generated and its route towards the network, are significant obstacles. This is in addition to the system size, prices, climatic conditions, modelling, control, and energy management of the associated HVDC transmission system.

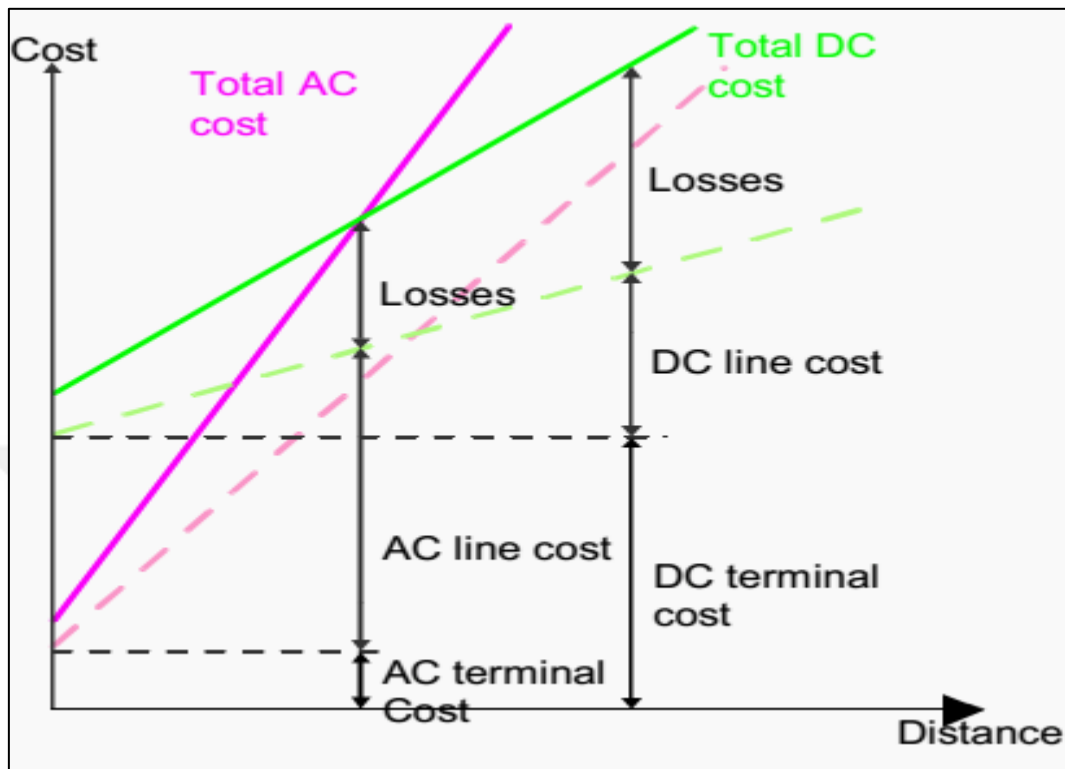


Figure 3.3: Cost analysis of HVAC and HVDC.

In this thesis, hybrid energy (offshore wind / onshore wind and photovoltaic) connected to the MICROGRID network is used to present a very detailed study on the power flow and the contribution to the maximization of this energy, the minimization of sensors, the reduction of the cost of installation and maintenance as well as the minimization of losses and the improvement of the quality of electrical energy.

In order to achieve these research objectives, a selected five-step methodology was made. each system is modeled independently, different control algorithms are offered for small and large systems, tests of different possible cases are performed using MATLAB/Simulink.

3.3 PROPOSED MICROGRID SOLUTION

This research also aims to present a study on the intelligent hybrid system (microgrid) and to analyze the interconnections of the different renewable energy sources. on electrical networks. Since there are standards that facilitate the interconnection of different energy sources, these

will be presented first. The problems that networks face with the addition of renewables are highlighted below. The proposed contributions to address these issues are presented under different categories such as sensor elimination, size reduction, cost reduction, maintenance reduction and downtime reduction. In addition, the contributions on maximizing the power of wind and solar turbines aim to reduce energy losses by using new control algorithms, which increases production and makes it possible to obtain more economic income.

The last contribution concerns the reduction of the impact of the various faults on the electrical networks (HVDC/HVAC). By taking the case of some renewable energy sources such as wind and photovoltaic, their operation as well as the interconnection diagrams and the means of mitigation are presented. This thesis deals with these main topics with the contributions presented previously.

The system is structured as follows

- i. We conducted research on the state of the art of hybrid energy (PV-wind turbines) on a small scale and on a large scale (high power), the different elements thus constituting them their choice is presented. The different topologies and configurations of the hybrid system connected to the MICROGRID network, the commands used, the faults and anomalies appearing on the system are also proposed. At the end of the chapter, an overview of the issues, objectives, methodology used and contributions are listed.
- ii. The modeling of a complete conversion chain of solar and wind energy is detailed. with main characteristics and constraints of PV generators and wind turbines. These constraints make it possible to define the functionalities required for these applications and the constraints on the dimensioning. The state of the art of the different photovoltaic (PV) system topologies and power electronics structures dedicated to these applications is presented. The results of the photovoltaic and wind model simulations obtained are presented.

- iii. A new control strategy is presented to improve the power quality of grid-connected renewable energy sources with maximum energy extraction from wind and photovoltaic (PV) hybrid systems. This system consists of wind turbine based on PMSG and a photovoltaic which are connected to the loads and to the electrical network. DC-DC (boost), AC-DC converters and a new approach for extracting MPPT from PV and PMSG side has been developed. Another command has been integrated to estimate the position and speed of the turbine rotor.
- iv. To increase the efficiency and speed of the system as well as reducing the cost and minimizing the size, the anti-windup PI-based SRF control is used to control the flow of the power generated by the wind and photovoltaic turbine. for the purpose of estimating DC bus DC voltage and reducing harmonics. The efficiency and robustness of the proposed system are demonstrated by the performance of the simulation results and the experiments
- v. The smart micro-grid (Smart Micro-Grid) is proposed and will be experienced using the case study. New algorithms are applied to achieve load forecast accuracy and grid power availability. In addition, the arc fault problem can be effectively solved for the different cases studied.

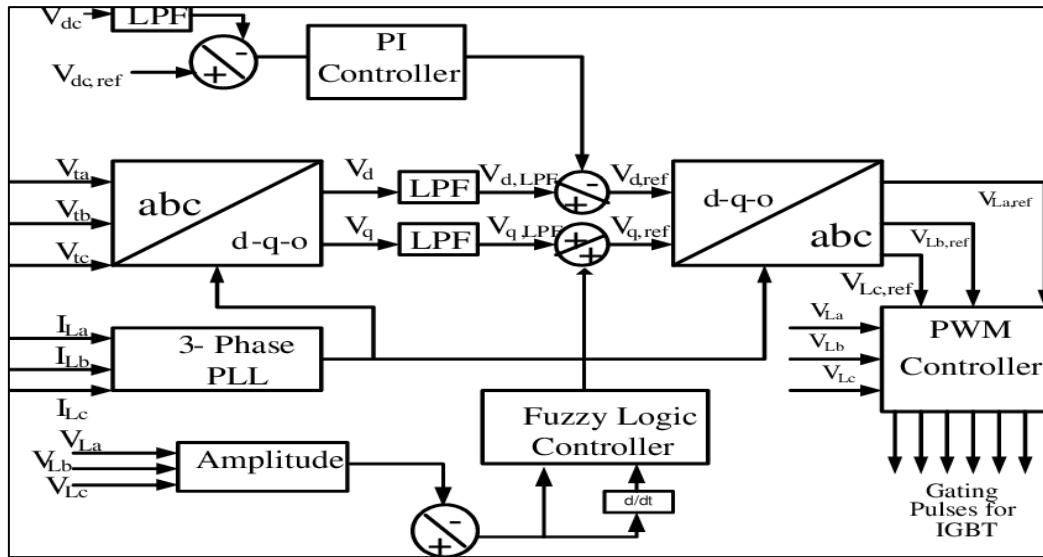


Figure 3.4: Proportional integrator PI controller with fuzzy logic [18].

- vi. First of all the different topologies of the converters and by modeling the VSC converter at two and three levels, the different faults applied on the MICROGRID systems and on the wind turbines, are then presented a connected wind farm to the grid via submarine cable and MICROGRID converter stations with different fault application scenarios by simulating them in MATLAB/Simulink is proposed. The research work in this part is based on new control approaches to improve the fault capacity.
- vii. We introduce a new algorithm based on Sliding Mode by comparing it with PI controller, the two methods are applied to a two-level station and correct the DC bus fault. Simulations and experimental results under the effect of DC faults, which has validated the usefulness and performance of SM.
- viii. A new control approach is proposed. It is based on the fault detection of the positive cable which is short-circuited to ground by measuring the voltage level of the cable and the variations of the DC voltage and the current. The control strategy developed at the MICROGRID offshore station based on three-level voltage converters (NPC), is based on the theory of instantaneous three-phase power. In addition, the anti-windup PI-based DC boost protection control action achieves the fault current to restore power transmission after the fault is cleared, thereby improving grid reliability and power quality. Simulations and experimental tests are carried out by validating the robustness of the proposed design, as well as the control approaches developed
- ix. An application of artificial intelligence on small and large systems (on BT and HT) is presented. A first study is based on the improvement of the power quality of a photovoltaic (PV) system connected to the grid.
- x. The proposed system employs a DC-DC chopper to obtain the maximum power (MPPT) using the ANFIS (Adaptive Neuro-Fuzzy Inference System). The Adaline control algorithm (adaptive element) is used to estimate the grid reference currents as well as DC voltage estimation using an ANFIS-PI. A simulation using MATLAB/Simulink software of the photovoltaic system using these commands was

introduced, subsequently it was experimentally tested under different scenarios with improved power quality.

- xi. The proposed control approach produces a clean and distortion-free model with improved power quality at the PCC. Also in this chapter, Adaline control and instantaneous power control are applied on MICROGRID transmission stations connected to an offshore oil and gas station. A fault on the offshore is applied with a correction by a protection system by protecting the park and ensuring its continuity of energy production and also protecting the oil station. Subsequently, the modified linear adaptive neural algorithm based on the Unified algorithm is applied to the MICROGRID system connected to the offshore farm and a photovoltaic power plant. A fault on MICROGRID was applied and tested with MATLAB, ensuring the continuity of electrical energy production.

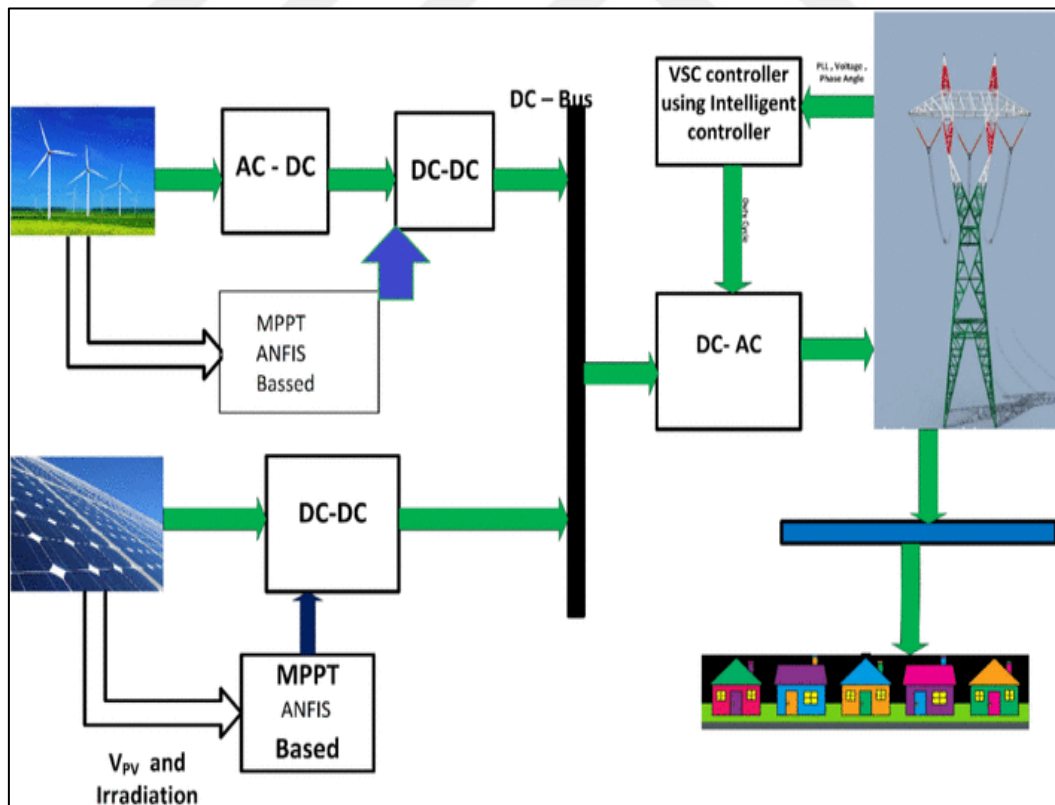


Figure 3.5: General view of the system [19].

3.4 MICROGRIDS

Microgrids are a type of distributed generating system that function on a scale that is far smaller than that of its larger analogues. One way to think of microgrids is as smaller versions of traditional power grids. Microgrids are small, decentralized power and heat networks that are made up of a collection of loads and small generation sources that work together as a single, controllable system. Microgrids are comprised of a collection of loads and small generation sources that work together as a single, controllable system. Microgrids are formed of a collection of loads and small generation sources that work together as a single, controllable system. Microgrids are also known as distributed energy resources (DERs).

Microgrids have the ability to provide their users with both electricity and heat, allowing them to satisfy all of their energy requirements. This concept presents a new paradigm that may be put into action in order to define the role of distributed generation in a manner that is more precise. It is possible that the user will draw the link that the microgrid functions in a manner that is analogous to that of a regulated subsystem of the larger power grid. This is an analogy that has the potential to be helpful.

Microgrids have the ability to be modified to address specific issues, such as ensuring constant power, minimizing losses, adapting to different voltages, making better use of waste heat, addressing voltage drops, and delivering uninterrupted electricity [20]. Microgrids also have the ability to make better use of waste heat. It is also possible to employ microgrids to make more efficient use of waste heat. In addition, there are a number of various methods in which microgrids can be adapted to maximize the effectiveness of the utilization of waste heat. When a microgrid is connected to a larger grid, it should be able to function as a single, controllable entity in order to satisfy the requirements that have been established by the DOE [27].

This is necessary in order for the microgrid to achieve the standards that have been established. In order to accomplish this, the electrical boundary of the microgrid needs to be delineated with extreme accuracy. Figure 3.3, which was taken from a reference, is an illustration that shows the general layout of a microgrid in its different forms (16).

The electrical and thermal loads are connected to the microgenerators through the utilization of low voltage distribution lines. Loads, the most majority of which consist of heat, are positioned in close proximity to the generators in order to cut down on the losses that occur as a result of the transit of heat and electricity.

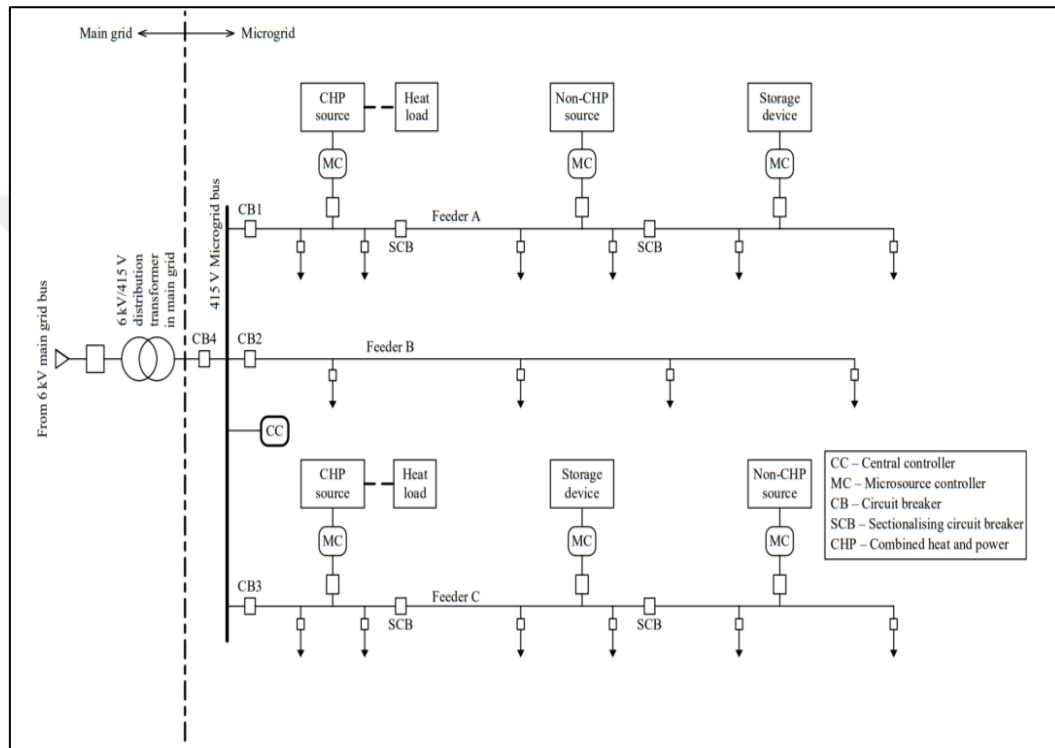


Figure 3.6: Typical configuration of a microgrid.

A microgrid may (or may not) have sources that combine the transmission of electrical power to heat with local loads. In this example, there are two sources that reuse temperature differences (CHP sources) and two that do not (non-CHP sources). In this example, one can also observe 3 circuits internal to the microgrid called Feeders.

They are distributed throughout the system by subdividing the loads and sources of the microgrid. These circuits can be differentiated in voltage level or even in frequency through internal microgrid transformers or converters. A common bus to the circuits connects them to the central control (CC) and to a circuit breaker (CB4) of the common coupling point (PCC), responsible for disconnecting and reconnecting the microgrid to the main grid. The

microsource controls (MC) are intermediate between the operation commands of the central controller and the microsource associated with this MC.

3.5 MODES OF OPERATION

Some of the major differences between microgrids and the direct use of renewable sources directly in the grid are in the possibilities of operations provided by microgrid control strategies [22].

What defines the mode of operation of a microgrid is its connection to the main grid, being able to operate in interconnected, isolated modes:

3.5.1 Interconnected Mode

When the microgrid is operating in the mode known as interconnected mode, it is able to either import or export power from the larger power grid. This mode is also known as grid-connected mode. Depending on the level of connectivity they have with the main grid, microgrids either have the ability to import or export electrical energy to the main grid [24].

In order to achieve maximum efficiency in the operation, control signals are transmitted from the central controller to the micro source controls as well as the load controls. In most circumstances, micro sources are controlled to inject active and reactive power at levels that have been previously defined [22].

3.5.2 Isolated Mode

Isolated mode (or islanding mode) can occur for several reasons. In isolated mode, the microgrid undertakes to supply its internal loads and there is no power flow between the microgrid and the main grid. Microgrids can switch between modes of operation depending on the physical, environmental, political or economic conditions to which they are subjected. The transition process between operating modes can be automatic or manual.

An islanding can occur for several reasons, from isolation between the microgrid and a short circuit in a transmission line of the main grid, to a simple incentive to energy quality when

supplying loads and possible storage systems with renewable energy resources, present in the own microgrid. In case of unplanned islanding, the microgrid may or may not have the ability to continue operating even after separation from the main grid, depending on the characteristics of faults in the main grid, the local controllers and the central controller, as well as the operating conditions of the grid. in the pre-failure scenario [24].

In this case, the rapid action of the source and load controllers must guarantee the stability of the transition. These will be responsible for distributing all the demand (including losses in the network) among the microsources that make up the microgrid [22].

3.6 MICROGRID CONTROL STRATEGIES

Both the design and operation of the central controller need a control strategy to meet the microgrid management needs. The choice of this strategy depends on the efficiency of its performance and the cost of its implementation [24]. Some suitable control strategies are presented below:

3.6.1 Decentralized Control

In this strategy, each microsource can belong to a different owner. Thus, each microsource controller must have a degree of intelligence to make local decisions. The objective is to generate competition between generators in order to maximize generation, meet demand and, in some cases, export as much energy as possible to the main grid according to instantaneous energy prices [22].

Some of the problems involving this strategy are linked to the complexity of the microgrid, since each microsource has a control and a microgrid with many microsources would have an equally large number of controls. In addition, each controlled unit receives only local information and is not aware of other system variables.

3.6.2 Centralized Control

In this strategy, the control of the entire network is centralized in a single system that processes the parameters for the entire microgrid. The centralized controller is responsible for

sharing power between the microsources, which may include external information as required by the utility. Some of the problems involving this strategy are linked to the dependence on the communication infrastructure and require complex control algorithms. However,

3.6.3 Hierarchical Control

The hierarchical structure is divided into three levels: local control; microgrid central control; management and control of the distribution system.

- i. Level 1: local control There are two types of control at this level: individual microsource controller (MC) and individual load controller (LC). The MC is responsible for controlling each microsource and provides great flexibility for the operation of the microgrid since it is linked, in most cases, to devices based on power electronics. In interconnected mode, it is responsible for controlling the levels of active and reactive power injection as established by the central control. In isolated mode, it has autonomy to promote the local optimization of the microsource's active and reactive power injections [22]. The LC is installed next to the controllable loads, in order to provide load control according to commands sent by the central controller [22].
- ii. Level 2: central control the central control (CC) is responsible for optimizing the microgrid operation. This controller requests the Distribution Management System (DMS) to determine the power flow from microsources and loads internal to the microgrid, optimizing internal generation and avoiding operations in unsafe regions [22].
- iii. Level 3: Distribution Management System the DMS is the highest level of the control hierarchy and can be interconnected with several CCs. For proper operation in the presence of microgrids, some new functions must be added to the traditional DMS, used in distribution system operations centers. Thus, adequate communication is established with the CCs, in addition to allowing the autonomous operation of each microgrid [22].

3.7 SOURCES OF DISTRIBUTED GENERATION

The power generators that are either renewable or non-conventional that are utilized in distributed generation (DG) systems are referred to as "Sources of Distributed Generation" (or simply "DG Sources") in the industry (SGDs). The primary objective of microgrids is to integrate low-carbon, unconventional, and renewable technologies with combined heat and power systems that operate at a high level of efficiency. This is one of their most important objectives (CHPs). CHP-based FGDs, by virtue of their capability to collect waste heat, enable energy-efficient power generation, which, in turn, contributes to the decrease of pollution levels and the production of "clean energy" [24].

The following list provides examples of some of the SGDs that have garnered the greatest attention in more recent times:

3.7.1 Photovoltaic Solar Energy

This generation source involves the free and inexhaustible energy present in our solar system, coming from the sun's own rays. It is deployed all over the world as FGDs for increasing local generation at the distribution voltage level [24]. The advantages of this technology involve:

- i. The sustainable nature of solar energy as a fuel.
- ii. More than 30 years functional life with minimal maintenance.
- iii. Silent generation. Some of the disadvantages include.
- iv. The variation of converted energy in relation to climatic situations.
- v. Low performance in relation to other energy sources, 25%.

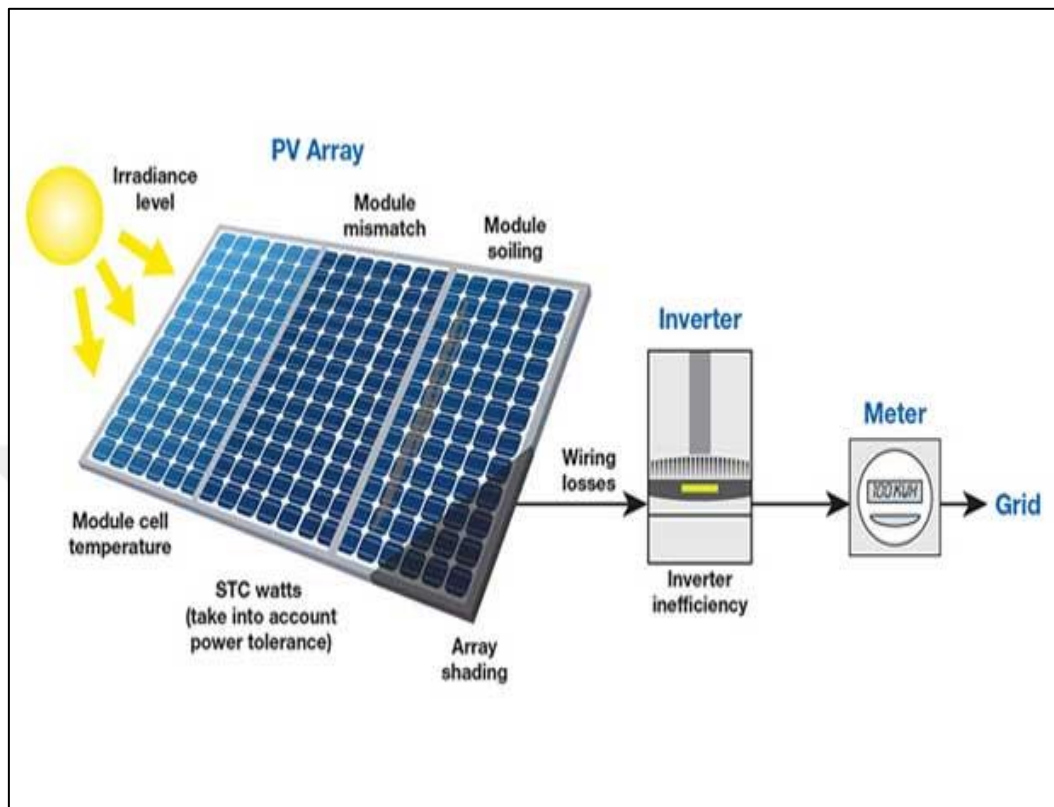


Figure 3.7: PV array workflow.

There are different methods of extracting the maximum power from the photovoltaic system:

Photovoltaic systems require control algorithms to extract the maximum MPPT (Maximum Power Point Tracking) power available. This power varies with the irradiation rate and the temperature).

The purpose of the MPPT is to constantly maintain the operation of the PV system around the maximum point of instantaneous power even under changing atmospheric conditions. Different studies aim to evaluate the different MPPT techniques and classify them to optimize the production of solar energy. Conventional methods are easy to implement, but they have shortcomings of imprecision and oscillation around the MPP. This is why new MPPT methods have appeared, such as CTV (Constant Voltage Tracking) Perturbation and Observation (P&O) algorithms, incremental conductance, Hill-climbing method, the Open circuit Voltage (OCV) method, and the Variable Section Stepped Climbing (SVSC) algorithm. These smart

methods are efficient and the oscillations are lower at the steady-state MPP level compared to conventional methods. The power provided by a solar panel is about 50W/m² which is relatively low compared to its surface. Optimization is therefore imperative to extract the maximum power. The following paragraphs explain the different MPPT techniques.

Disturbance and observation This method is very often used and cited by many authors (It uses an iterative method, the purpose of the algorithm is to seek the maximum power by calculating the current value of the power and the previous value, and to compare the two powers at the different successive points located on the curve of the Figure 3.8 The relationship between the power generated by a photovoltaic system and the output voltage is shown in the following figure:

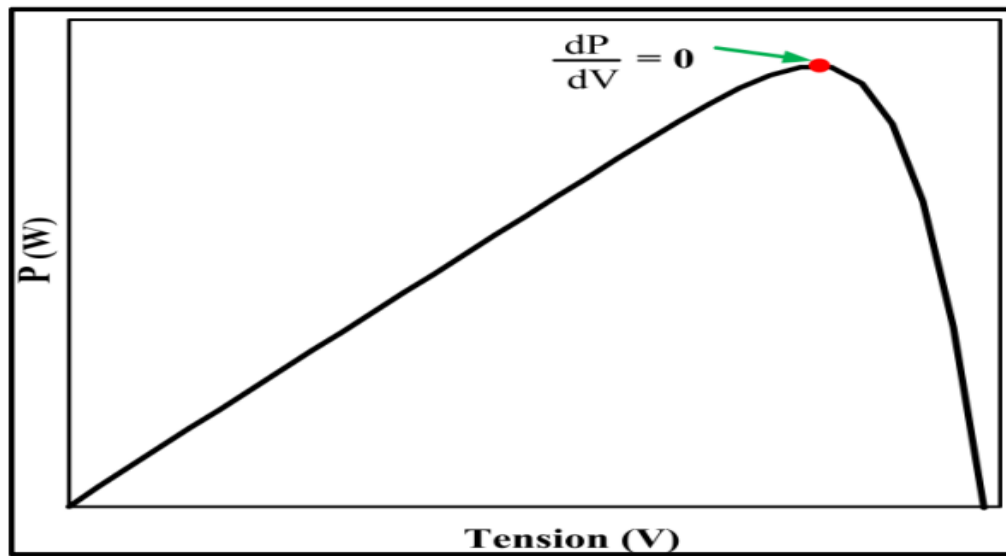


Figure 3.8: P&O tension in PV.

The algorithm indicates that, whatever the temperature and the insolation, the maximum power point is obtained by fulfilling the following condition:

$$\frac{dP}{dV} = 0 \quad (3.1)$$

i. Incremental conductance

This algorithm uses current values as well as previous values of voltage and power to calculate conductance. Depending on the result obtained, the algorithm could increase or decrease the duty cycle to thus make a movement in the direction allowing to reach the maximum point of the power. Figure 3.9 shows the power characteristic of a solar panel. This curve represents the maximum power point (MPP). The role of the incremental conductance algorithm (Cond & inc.) is to force the optimal operating point to move towards the maximum point independently of the insolation and the characteristics of the photovoltaic panels.

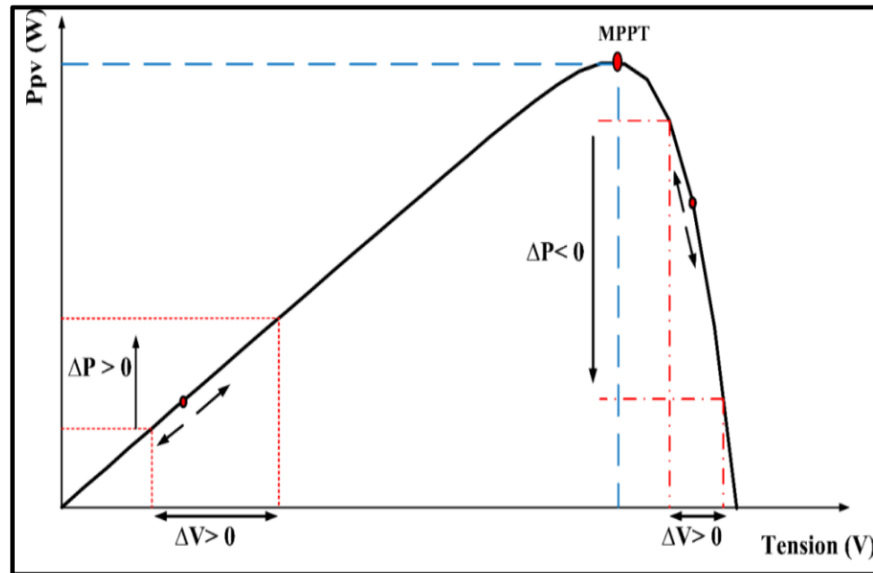


Figure 3.9: MPPT tension calculations in a PV.

$$\frac{dP}{dV} = \frac{V}{dV} \frac{dI}{dV} + I \quad (3.2)$$

This algorithm is widely used and based on the derivative of power with respect to voltage, it uses incremental conductance. The following equation shows the point of maximum power when the power derivative is zero.

$$\frac{dP}{dV} = 0 \leftrightarrow \frac{dVI}{dV} = 0 \leftrightarrow \frac{dV}{dV}I + \frac{dI}{dV}V = 0 \quad (3.3)$$

3.7.2 Wind Energy

This generation source comes from the flow of atmospheric gases, the wind, and its main component is the wind turbine.

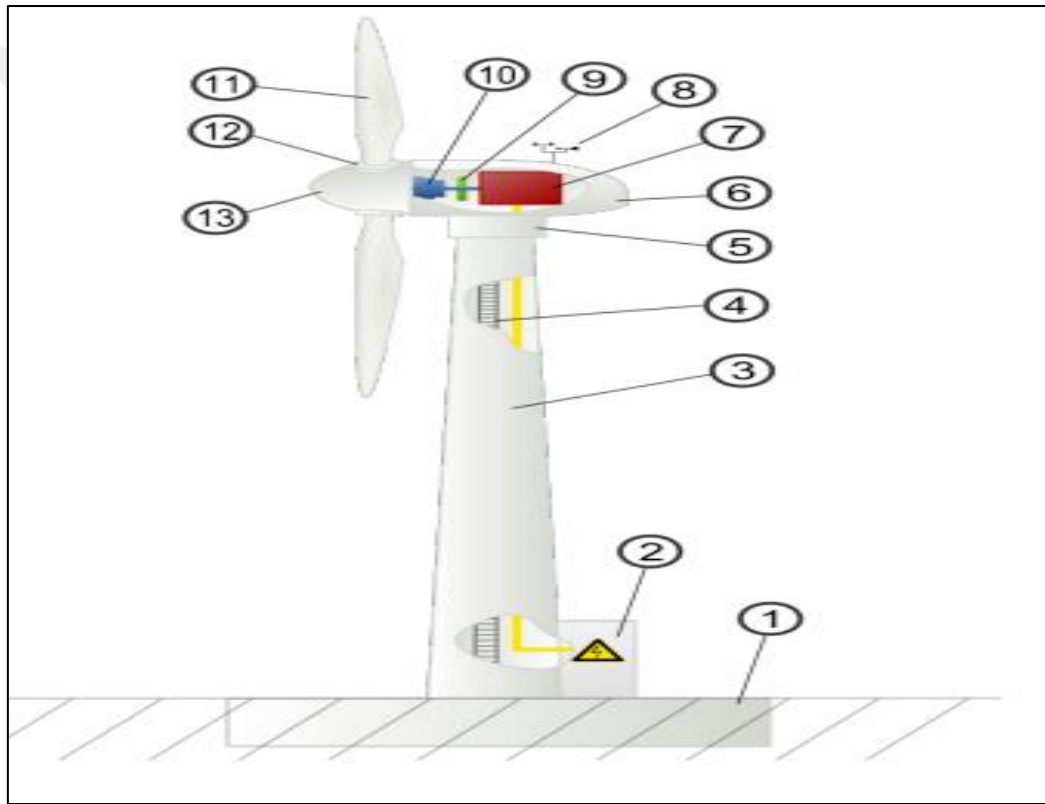


Figure 3.10: Wind turbine components [27].

The following image was taken from [25] and presents the basic composition of a wind turbine:

- i. Foundation
- ii. Connection to the electrical grid

- iii. Tower
- iv. Access Staircase
- v. Wind orientation control
- vi. Nacelle
- vii. Generator
- viii. Anemometer
- ix. Brake
- x. Gearbox
- xi. Rotating blade
- xii. Blade pitch control
- xiii. Rotor hub

The advantages of this technology involve:

- i. The sustainable nature of wind energy as a fuel.
- ii. Minimal environmental impact.
- iii. Generating investment in disadvantaged areas.
- iv. Low maintenance, semi-annual reviews. Some of the disadvantages include:
- v. Intermittent winds.
- vi. Visual impact.
- vii. Sound impact.
- viii. Avian impact

3.7.3 Storage Systems

Storage systems play a very important role in the operation of microgrids by ensuring uninterrupted power supply. Among the storage systems, the following stand out:

- i. Storage batteries

The storage battery technology is constantly evolving, thus creating different models of batteries that vary from their chemical compositions to their discharge capacities, voltage, size, weight and, mainly price. Currently, lithium batteries (specifically nickel-cobalt-aluminum-oxide cells, NCA, iron-phosphate cells, LiFePO_4 , and nickel-magnesium-cobalt-oxide cells, NMC) are expanding with the growing market for embedded systems. .

However, despite having a high energy density, that is, storing more energy in a smaller physical volume, the implementation costs of this type of cells are still very high. Another widely used type of battery is lead-acid cells. Despite having a much lower energy density than lithium cells, this type of battery is much cheaper and much more widespread on the market.

In this sense, lead-acid cells have a great advantage over lithium cells in microgrid designs: As long as there is space for the storage system in the microgrid, the energy density and weight of the system are irrelevant. In addition to these, there are several other possible battery technologies that can be used as a microgrid storage system. Among these, the molten salt battery, Na-Ni-Cl (more specifically the sodium-nickel chloride type, Na-NiCl_2) stands out, whose research at the Itaipu technology park stands out nationally as solutions in several areas (among them, the distributed generation) [18].

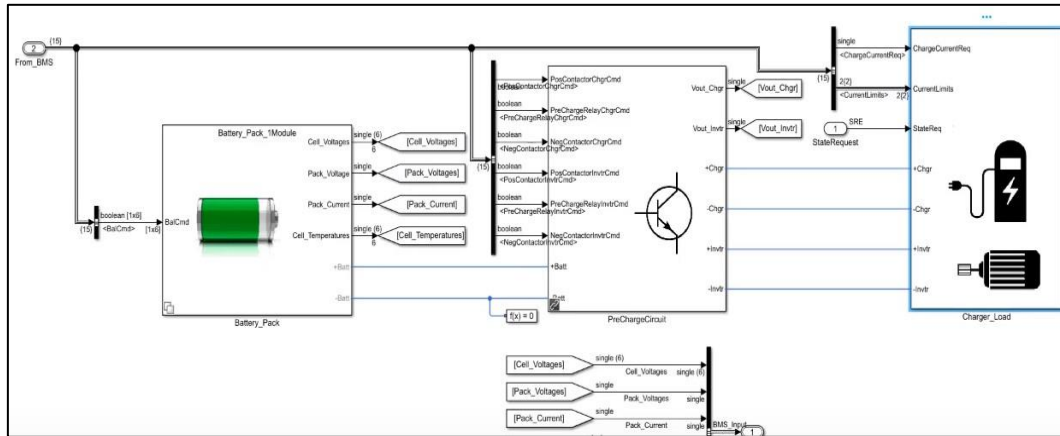


Figure 3.11: Simulation of Li-Ni-Cl battery system in MATLAB.

i. Inertial Battery

Inertial batteries (also called flywheels) are electrical machines capable of storing kinetic energy. An inertial battery works by accelerating a rotor (flywheel) at a speed of 20,000 to 50,000 rpm (the high speed is due to the fact that these machines are designed to work under vacuum, only for storage) inside a storage chamber. vacuum, thus reducing frictional losses with the environment [14].

This technology still has some unresolved burdens, including the gyroscopic effect produced by a disk at high rotations [14].

3.8 CONVERTERS AND INVERTERS

High voltage DC transmission directly linked to the PV panel has become a cost-effective option for modern photovoltaic power plant especially when the distance exceeds 50 km. The DC-DC converter model is adopted according to the use to generate the DC high voltage in the photovoltaic power station, they can be in parallel and in series.

They serve to increase the voltage and at the same time maximize the output power. The parallel module is a chopper connected directly to the PV to extract the MPPT, however the serial module extracts the MPPT and increases the voltage and efficiency. Both modules are shown in Figure 3.12.

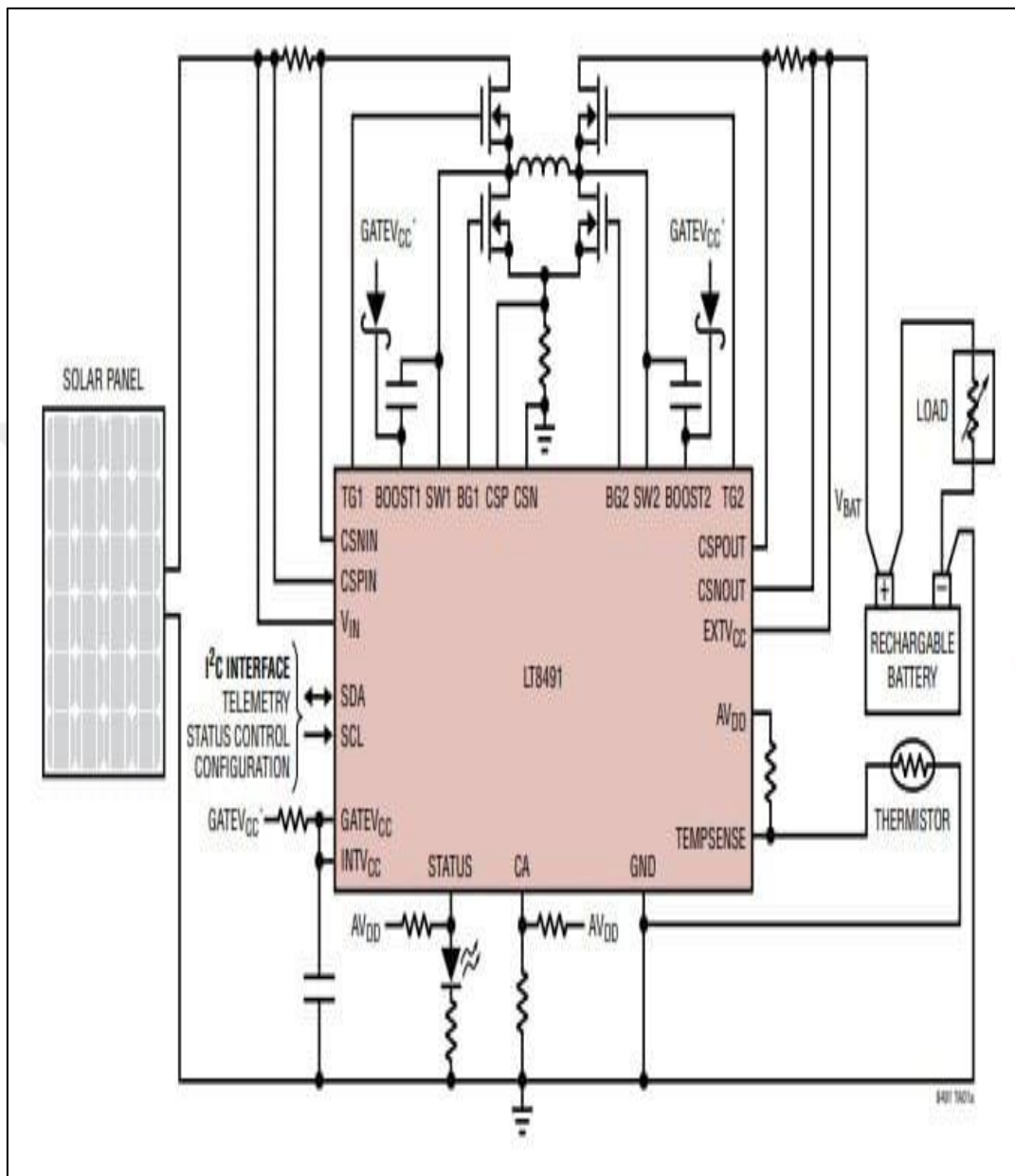


Figure 3.12: MPPT based buck boost converter.

4. PROPOSED METHOD

4.1 INTRODUCTION

Since the turn of the century, attempts have been undertaken to replace large, centralized power plants that use fossil fuels with smaller, more dispersed power plants that utilize renewable energy sources. These facilities are referred to as "micropower plants." As a consequence, both the unpredictability and complexity of power flow in a smart grid as well as economic transactions are made more challenging. It is vital, in order to improve energy efficiency and sustainability, to perform in-depth study on how buildings use energy, since they are the single largest consumer of electricity.

Advanced Metering Infrastructure collects voluminous amounts of data that may be used to infer individual consumption patterns, which is essential for boosting the energy efficiency of buildings. These designs may be used to save energy expenses. If this criterion is met, then we may analyze the remaining alternatives (AMI). The research was conducted under the assumption that the predicted gap between predicted energy consumption patterns and the supply of energy from variable sources such as wind and solar could be closed by efficiently allocating resources based on end-user patterns derived from daily profiles of intelligent electrical devices.

This would enable energy to be generated from wind and sun sources. This assumption served as the cornerstone for the intended investigation. The researchers anticipated that end-user behaviors, which might be gleaned from daily profiles of intelligent electrical devices, may mitigate tensions between the two sides. The objective of this study was to evaluate whether or not this assumption is correct. [10].

Prior to implementing real-time price-responsive behavior, cost reduction must be achieved. [11]. There are several ways to address the problem of reducing costs and increasing the energy efficiency of a building. On the lengthy list of 65 techniques are game theory, fuzzy methods, and Particle Swarm Optimization (PSO), among many more. [12] Large databases may be administered using either a centralized or decentralized technique; however, none of

these systems accounts for the possibility of individuals interacting with the database through the internet.

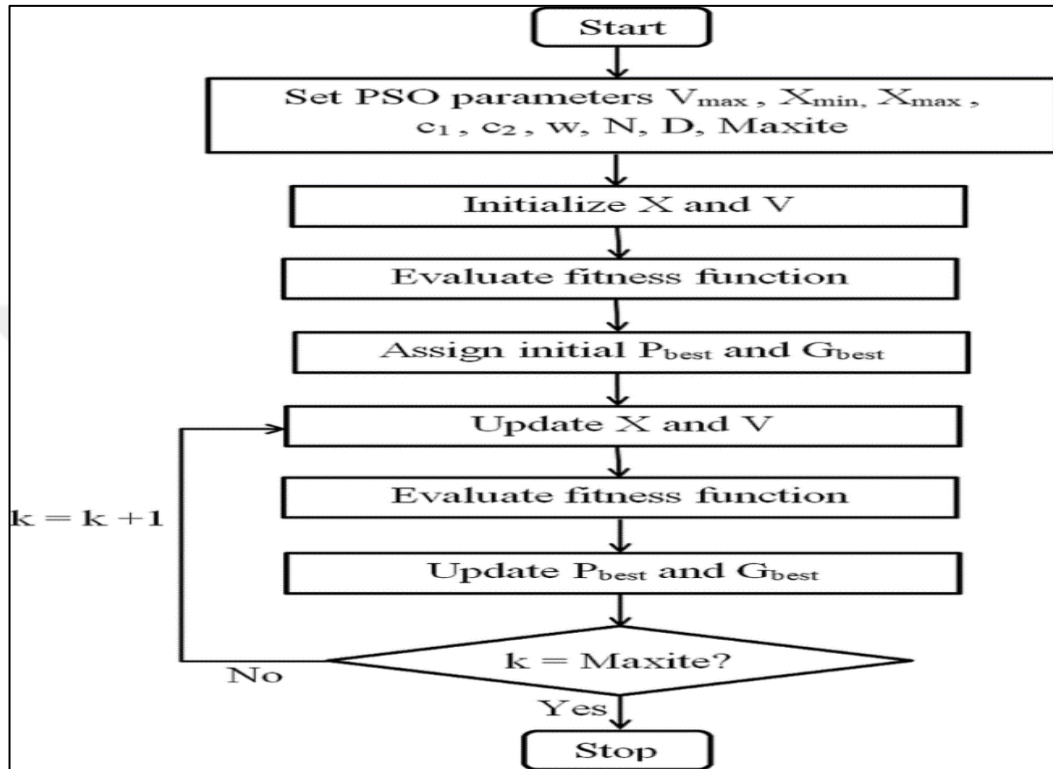


Figure 4.1: PSO optimization diagram.

If optimization is to be performed, then these approaches must compute all possible solutions, or at least a subset of them, before selecting the most effective one. This method requires a large amount of time to complete. Utilizing machine learning technology, which can automatically identify and manage demand patterns, is a straightforward method to circumvent this restriction and bypass its constraints.

Using continuously updated data, it is feasible to develop machine learning models that can adapt to shifting conditions. If models of this kind were ever created, they would be capable of accommodating the inevitable variations in demand patterns. In the building of these types of models, techniques from the field of machine learning may be used. Once these models are broadly applicable, they will be applied in real time (in milliseconds), resulting in a decrease in the amount of money or energy needed in new situations. Because they can learn optimum

behavior even when the global ideal is unknown, RL machine learning models are the most applicable for cost reduction. Therefore, they are the most suitable alternative. This is due to their ability to learn industry standards via a variety of training methods. In this section, we will study the most recent developments in RL approaches, with a special focus on Q-learning [43] and related techniques.

In addition to simulating the building environment, the Markov Decision Approach may be used to determine which design choices will be the most practically helpful over time. RL algorithms have previously been used to the stochastic optimal management of the power system and a scheduling problem for energy consumption under dynamic pricing. There were two obstacles, and both were related to the time of energy use. In the process of organizing a collection of electric water heaters for the household, the batch reinforcement learning approach might be used. This is the most effective course of action.

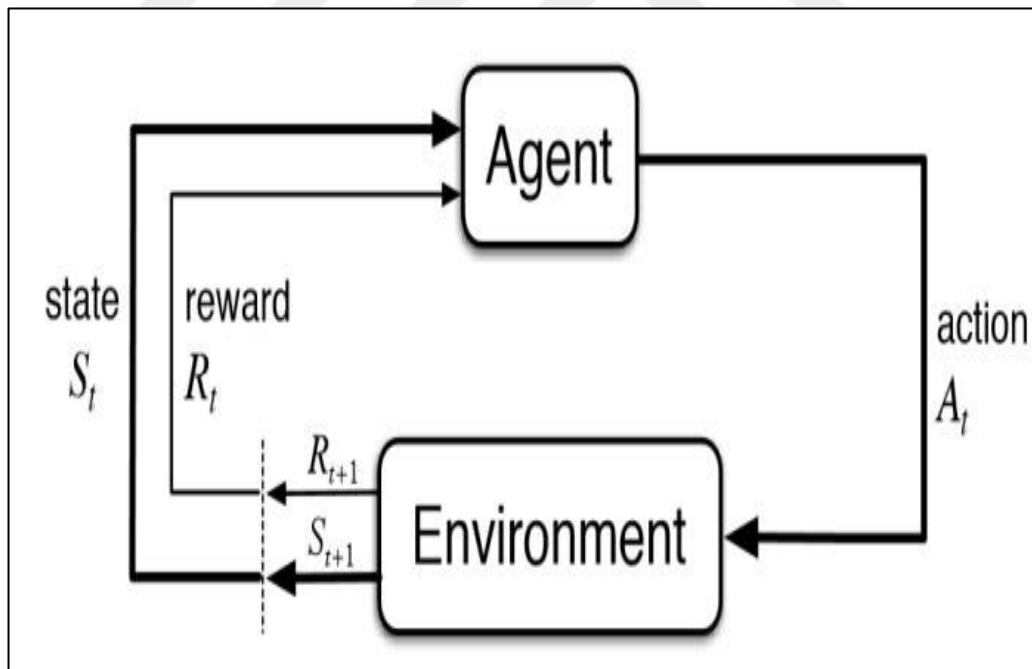


Figure 4.2: General diagram of reinforced learning.

These solutions are bound to failure when deployed to truly huge issues because of the curse of dimensionlessness. In recent years, there has been increased interest in merging deep learning with reinforcement learning. This interest has been mostly fueled by technical

progress. This is now conceivable as a result of the advancements made in these several specialized fields. Q-learning is a relatively recent addition to deep learning that has already shown astonishing capabilities, such as the capacity to play Atari 2600 games with human-like skill. If you want further information, please consult the source.

A challenger in the game of Go was successful in unseating the reigning world champion in 2016. Nobody has ever tried something like this before. Deep Q-learning might be a viable way for improving the scheduling of energy storage in microgrids, according to the results of our research. A completely new area of study known as ANN research came into existence as a consequence of the union of RL and NN (ANN) (ANN).

We showed that Reinforcement Learning, which leverages Deep Belief Networks to predict continuous states, can be utilized to offer unsupervised forecasts of energy levels. This learning approach may be found in the area of artificial intelligence. This collection of predictions is customizable and may be utilized in a variety of scenarios. In this work, the Deep Policy Gradient algorithm is used on a scale never previously seen in a true smart grid and smart building environment. The subsequent section will go even further into the implementation's particulars.

Motivated by the requirement for a rapid algorithm to learn electrical patterns and optimize the energy consumption or cost of a building in real time, we have devised a unique application for ANN algorithms. This application is now accessible to consumers. Due to the significance of this topic, a considerable amount of our research and development efforts have been focused on this area. This was the driving force behind our relentless attempts to make progress, and it was a significant one.

4.2 RESOURCE ALLOCATION

During this discussion, we will seek to reduce both peak demand and the overall expenditures connected with energy use. Assume that the in question structure has an index of B_i , $i \in N$. The total amount of energy a building uses during a given time period is equal to the sum of the energy it creates and the amount of electricity it consumes during that time period (and P).

In this part, we differentiate between flexible power, which includes things such as electric devices $d = 1, \dots, m_i$, and fixed consumption P , which accounts for the varying capacity of a building's numerous appliances. a) Difficulties in decreasing costs — For the purposes of this chapter, a utility-set price (λ_t) and a utility-purchased price (λ_t^+) in a certain time-slot are assumed to exist in the B-spatial domain since this is the easiest approach to describe the pricing structure of the B-spatial domain (λ_t).

In official papers, these two prices will be referred to as the utility fixed price and the utility acquired price, respectively. If we are optimizing for customer i at time t , the associated fee is determined as follows: if we are optimizing for customer i at time t , then. Use the following equation to determine a temporal horizon designated by the letter T :

$$\begin{aligned}
& \sum_{t=1}^T \left(\lambda_t^+ \sum_{i=1}^n P_{i,t}^+ - \lambda_t^- \sum_{i=1}^n (P_{i,t}^- + \sum_{d=1}^{m_i} a_{i,d,t} P_{i,d,t}^-) \right) \\
& \sum_{t=1}^T P_i^- \Delta t = E_i, \forall i \in \mathbb{N}, \forall t \in \mathbb{N}, \\
& \sum_{t=1}^T P_d^- \Delta t = E_d, \forall d \in \mathbb{N}, \forall t \in \mathbb{N}, \\
& a_{i,d,t} = \{1, 0\}, \forall a \in \mathcal{A}, \forall i \in \mathbb{N}, \forall d \in \mathbb{N}, \forall t \in \mathbb{N}, \\
& P_{i,t}^+, P_{i,t}^-, P_{i,d,t}^- \geq 0, \forall t = [1 : T] \in \mathbb{N},
\end{aligned} \tag{4.1}$$

- i. The values for $a_{i,d,t}$ are set to 1 if the electrical device is switched on, and to 0 if it is turned off. Be aware that in the proposed technique, calculating $a_{i,d,t}$ is comparable to making an educated guess of what will occur in the upcoming phases (see Fig.4.1).
- ii. When both production and consumption of energy are at the same price ($\lambda_t^+ = \lambda_t^-$), reducing costs becomes a matter of limiting peak demand, defined as

$$\sum_{t=1}^T \left(\sum_{i=1}^n P_{i,t}^+ - \sum_{i=1}^n (P_{i,t}^- + \sum_{d=1}^{m_i} a_{i,d,t} P_{i,d,t}^-) \right) \tag{4.2}$$

Consequently, the limits imposed by Equation 4.1 apply equally to both sets of conditions. As will be seen in the sections that follow, the general scope of the constraints has increased as a consequence of developments in the types of electrical devices accessible.

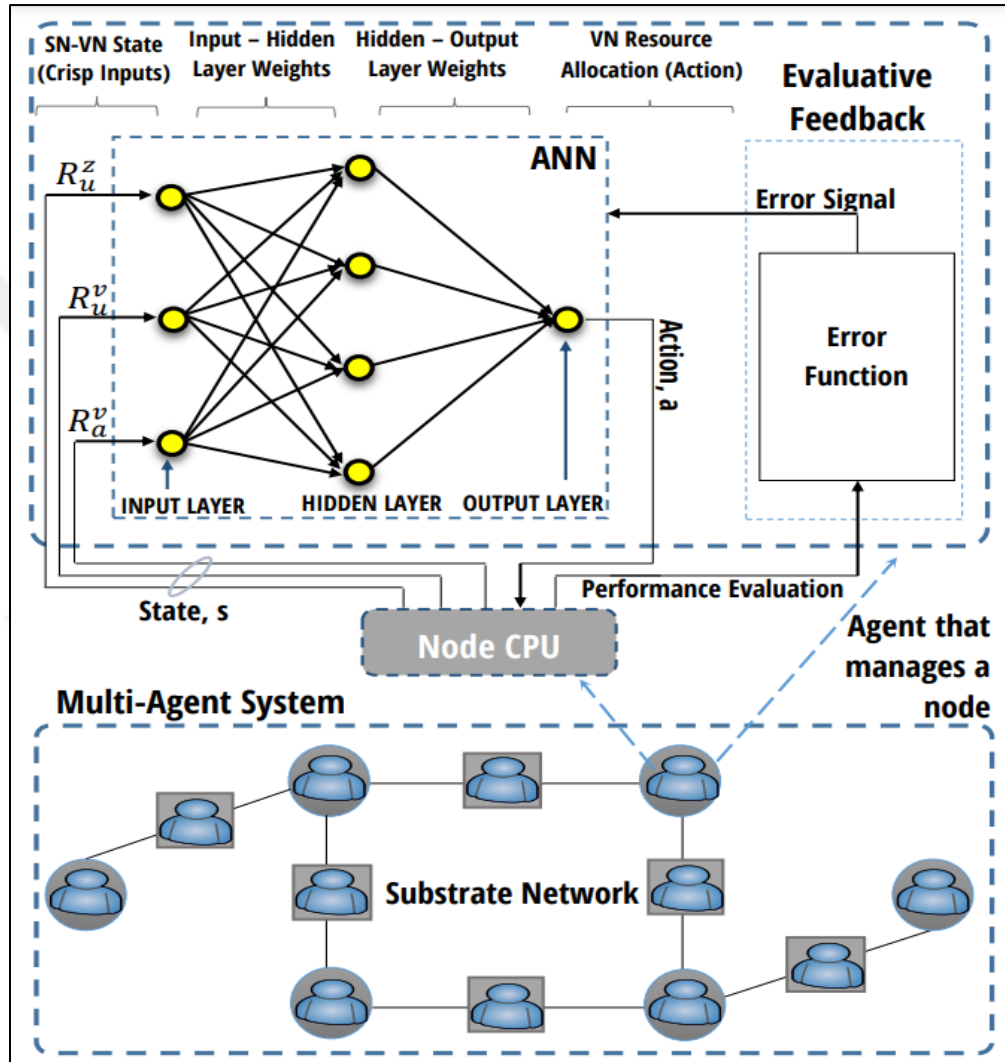


Figure 4.3: ANN-RL resource allocation workflow.

Electronic device-imposed restrictions on a person or object Our model's underlying assumptions include three unique consumption patterns. Let's study the shifting load across time as a starting point. Regarding this, we place significant focus on the air conditioning load, also known as dAC. This is simply one example of the vast array of electrical equipment

present in every structure, and it is the only one that can be switched on and off for a short time during an optimization phase.

Previous research has shown that transient decreases in air conditioning output have a negligible effect on overall comfort. user's The deferrable load is a time-shifting load that requires a low amount of energy over a specified time period. This is the second consideration that we make.

A particular number of continuous time steps are necessary to appropriately represent the dishwasher (dDW) as a non-interruptible load. In conclusion, the electric vehicle (dEV) is a kind of load that fluctuates over time and varies in magnitude. Please refer to [19] for a more comprehensive explanation of constructing electrical components and their accompanying restrictions. These assumptions are based on a probabilistic approach that complements the time-dependent aspects of our case.

Assumption 4.2 asserts that none of the optimization horizons for any of the time-scaling loads include R^+ constants. This is true regardless of the optimization horizon under consideration such that:

$$\begin{aligned} (P_t P_d^- \leq \delta d \quad \text{if } p(P_d^- = 0|t) \in (0, 1] \text{ iff } p(P_d^- = 0|t) = 0 \\ P_t P_d^- = \delta d \end{aligned} \quad (4.3)$$

It is possible to calculate, at any given moment in time t , the probability that the electrical device d will be operational using the following formula: $t = [1: T] \cap N(t)$. There exist d constants that, when applied to P_d time-shifting loads, cause P_t and P_d to be equal at all times for t values that occur within the range $[-1, T]$.

There are also P_d time-shifting loads that, when applied to P_d time-shifting loads, cause P_t and P_d to equal d . This gets us to the 4.2nd working hypothesis that we had previously discussed. This is what I saw when at 4.3. Photovoltaic (PV) production, for example, is seen as an irreducible resource in this study. Observation: In accordance with Assumptions 4.1 and 4.2, all dEVs and their associated consumption were treated as time-varying and varying loads.

This was done to allow for the possibility that the consumption of dEVs may fluctuate over time.

4.3 BACKGROUND AND PRELIMINARIES

We introduce reinforcement learning via the use of a Markov decision framework and deep neural networks.

Learning via Repetition — An agent will use the (Partial Observable) Markov Decision Process (MDP) formalism in a Reinforcement Learning (RL) [53] environment. It is well known that MDPs contain the 4-tuple $\mathcal{H}$, which is defined as follows:

- i. $\mathcal{S}$ denotes the state space,
- ii. $\mathcal{A}$ denotes the action space,
- iii. T denotes the time,

In order for the system to reach the following state, s_0 , at the next time, the chance that a will be chosen at time t must equal the likelihood that the system will be in the next state at time $t+1$. This is necessary for the system to proceed to the next time. R_a refers to the instant reward that an agent receives while moving from s to s_0 . This incentive is included into the R reward function (s, s_0) .

When the environment's structure (i.e., finite states and actions) is assumed, dynamic programming is often utilized to solve the Markov decision problem. In contrast, the model has a considerable (continuous) states space in the world that we have created. In the status space, both the quantity of energy required by structures and the cost of that energy are fixed, but the action space is severely constrained by the restrictions of electric equipment. All actions, represented by the letter a , are assessed based on the rewards, represented by the letter r . The agent will gain the information required to operate in the unique environment in order to enhance its future potential reward. Using the value function Q , one may calculate the total amount of the reward that the state is committed to offer under the policy (s, a) Q-learning [56] is one of the most common reinforcement learning algorithms now in use.

The construction of a Deep Neural Network, also known as a DNN, consists of several layers of neural connections. Neurons may be seen as nonlinear alterations of the linear sums they receive as input. The most basic representation of the data is included inside the first layer. During the design phase, the hidden layers of a neural network are constructed using an array of neurons that receive inputs from the layer below. In the design, the activation function of a neuron on the top k stacking levels is based on composite functions, such as $x_{1h2} h_{2hk}$.

Using Rectified Linear Units (ReLU) in the hidden layers of a deep neural network with severe non-linearities reduces the amount of time required for supervised training, according to research published in 2011 [20]. The ReLU activation has been more effective than both the logistic sigmoid and hyperbolic tangent activations, according to recent findings. Formal version of the ReLU function, which is stated as $f(x_i) = \max(0, x_i)$, uses the input variable x_i .

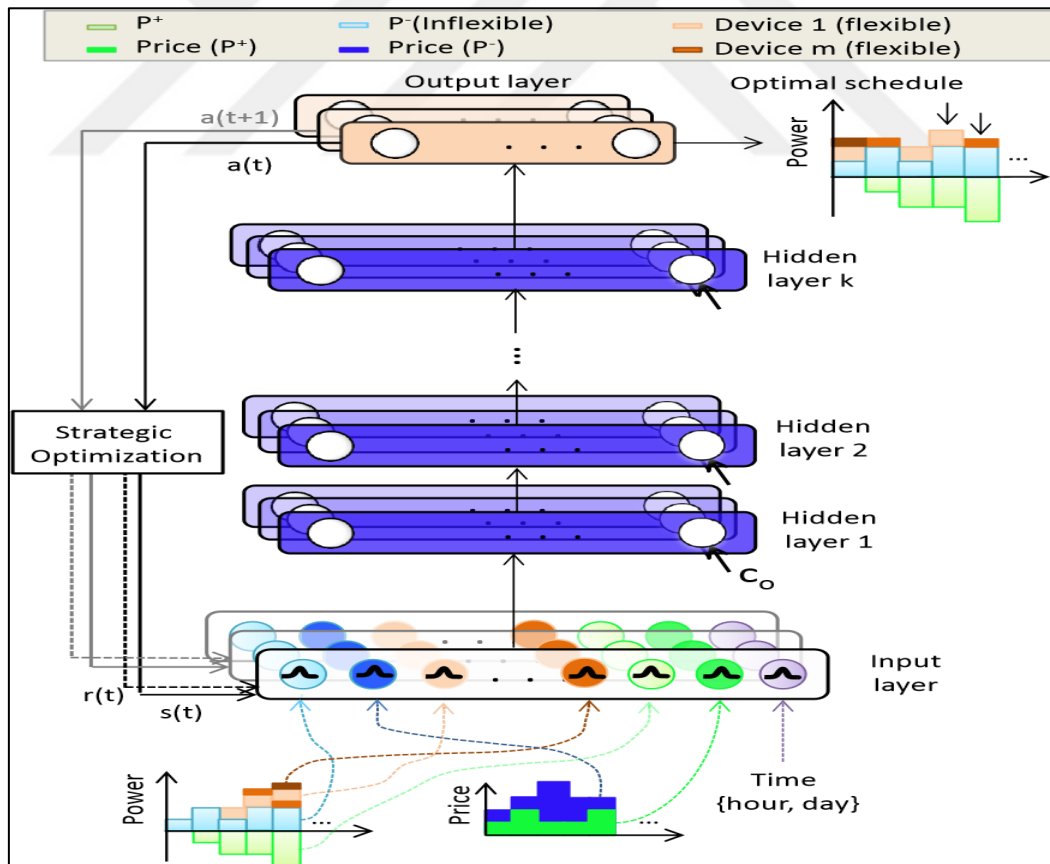


Figure 4.4: Construction of DNN from ANN and DRL.

We used a more adaptable version of the generic closed loop architecture for Artificial Neural Network described in [13]. Reinforcement Learning is combined with Deep Neural Network hidden units in this design given by

$$f(x_i) = \begin{cases} x_i & \text{if } x_i > 0, \forall i \in \mathbb{N} \\ \eta x_i & \text{if } x_i \leq 0, \forall i \in \mathbb{N} \end{cases} \quad (4.4)$$

This factor is responsible for the severe decreasing trend. In the event when the variable equals zero, the equation becomes ReLU.

The fact that the states of an MDP are used as input and the actions of the MDP are used as output makes a DNN a suitable tool for artificial neural networks (ANNs). A DNN is hence particularly effective for Artificial Neural Network.

4.4 ARTIFICIAL NEURAL NETWORK

In this part, a web-based variant of Artificial Neural Network (ANN) is provided for assigning the most efficient building resources over a spectrum of aggregation levels. Figure 4.1 depicts the schematic depiction of the technique that we have proposed. ANN, which is RL paired with DNNs of k hidden layers, may beat normal RL due to the automated extraction of patterns like power use trends. This is because RL mixed with DNNs of k hidden layers is more accurate. It is feasible to extend the DNN model to any input distribution, since it is a black box model with excellent generalization capabilities:

$$\xrightarrow[\text{data}]{\text{Input}} DNN_{(k)} \xrightarrow[\text{Data estimation}]{\text{Output}} \quad (4.5)$$

In the paragraphs that follow, we will go even further into the research and examination of deep q-learning (DQN) and deep policy gradient (DPG). These are two different classifications of machine learning. While value-based techniques concentrate their efforts on, DPG explicitly parameterizes policies and updates the parameters depending on the anticipated long-term reward. These methods do not need the usage of a model (e.g. DQN) [14].

4.4.1 Deep Q-Learning (DQN)

The following are the steps involved in learning using ANN. The stochastic gradient descent procedure is utilized to update the DNN's parameters using a variation of the Q-learning methodology [40]. First, a deep Q-network is substituted for the typical RL algorithm's value function. Each and every one of these configurations is decided by the weights and biases of the DNN, both of which are, in turn, changed by the user. This process is repeated for each and every one of these configurations. The method that is outlined in this article makes it feasible to calculate the mean squared error in Q-values of the function that is being sought for.

$$\mathcal{L}(\theta) = \mathbb{E}[(r + \gamma \max_{a_{t+1}} Q(s_{t+1}, a_{t+1}, \theta) - Q(s_t, a_t, \theta))^2] \quad (4.6)$$

Leading to the following Q-learning gradient

$$\frac{\partial \mathcal{L}(\theta)}{\partial \theta} = \mathbb{E}[(r + \gamma \max_{a_{t+1}} Q(s_{t+1}, a_{t+1}, \theta) - Q(s_t, a_t, \theta)) \frac{\partial Q(s_t, a_t, \theta)}{\partial \theta}] \quad (4.7)$$

As a consequence of the sequential nature of the input, the conventional Q-learning technique often oscillates or diverges when combined with neural networks [15].

In order to address the issue of non-stationary and correlated data, we make use of a method that is often referred to as "experience replay". This technique applies a sample from a previous mini-batch of the dataset D (s_{t+1}) to a new set of data. The recently proposed Deep RL strategy may be easily included into Eq (4.1). As a consequence of the addition of $Q(s_{t+1}, a_{t+1})$, the binary action vector at A has attained the maximum degree of control feasible.

Instead of subjecting the needs of end-users to the temporal constraints imposed by a single device d , as shown in A1, Eq, we want to include these requirements into the reward function. This will help us to serve end-users more effectively (4.8). In the next section (4.5), this method is discussed in further detail. Recent research has shown that policy gradient approaches may reduce the time required to achieve convergence in continuous games [17].

Instead of calculating $Q(st,a)$ as in DQN, neurons from the output layer (with parameters) corresponding to the DPG assess the probability of executing an action in any state st (e.g., $p(a|st,))$. DPG offers a considerable advantage over DQN in situations when many actions must be performed simultaneously. This is because the probabilities associated with each action may be sampled and included into the game simultaneously. The method of maximizing the total anticipated reward of a parameterized model while adhering to a policy is similar to the process of solving the approximation optimization issue outlined in Eq. (4.1) or Eq (4.7) as follows:

$$\text{maximize } \mathbb{E}_{x \sim p(x|\theta)} [R|\pi] \quad (4.8)$$

Within the context of the DPG, the DNN is the parameterized model. As seen in Equation 1, the Directed Neural Network (DNN) then becomes a probability density function ($f(x)$) over its inputs (the game states), leading to the following optimization challenge (4.5). As shown in [18], the unbiased gradient may be estimated using a scoring function based on the function $f(x)$.

$$\begin{aligned} \nabla_{\theta} \mathbb{E}_x [f(x)] &= \nabla_{\theta} \int dx \, p(x|\theta) f(x) = \int dx \, \nabla_{\theta} p(x|\theta) f(x) \\ &= \int dx \, p(x|\theta) \frac{\nabla_{\theta} p(x|\theta)}{p(x|\theta)} f(x) \\ &= \int dx \, p(x|\theta) \nabla_{\theta} \log p(x|\theta) f(x) \\ &= \mathbb{E}_x [f(x) \nabla_{\theta} \log p(x|\theta)] \end{aligned} \quad (4.9)$$

A depiction of the first-order partial derivative utilizing five distinct values depending on the collected data. The calculated gradient, as shown by $f(x)$, increases the log-probability of a specific sample x_i proportionally to the reward associated with that sample.

It is feasible to calculate this after taking a sample of x_i from $p(x)$ and solving Eq. The computed gradient increases the log-probability in proportion to the reward (4.6). (xi). This shows that the genuine quality of the sample is excellent, which is the implication of the statement. The fact that these samples were gathered along a path indicates that $\pi = (s_0, a_0, r_0, \dots, s_{T-1}, a_{T-1}, r_{T-1})$.

At the conclusion of the game, policy gradient-based prizes are distributed in a way substantially distinct to this. In order to calculate the gradient of a trajectory, several steps must be done. Begin by calculating and differentiating the density $p()$ in relation to the value of:

$$\hat{g}_\tau^\theta \propto \mathcal{R}_\tau \frac{\partial}{\partial \theta} \sum_{t=0}^{T-1} \log \pi(a_t | s_t, \theta) \quad (4.10)$$

4.5 IMPLEMENTATION

As a starting point for training the DQN and DPG models, an offline database was employed. Playing the developed environment game was the first step of the method. Although we did not alter the basic load in this game, we investigated a vast array of additional implementation choices for changeable loads (even if they not happened in reality). We explored every imaginable possibility that was open to us. Positive reinforcement was offered if it was near enough to our optimization objective to deserve it. In the case that it did not occur, we subtracted a reward from the corresponding probability. A model that employs reinforcement learning will ultimately converge and learn to choose only options that are near enough to the objective after a few iterations.

Even though we did not update the offline database that was "already accessible," we were provided with a more recent and improved version of the database. This is because if we had implemented our technique, the database would have been updated in this way. In conclusion, it is essential to note that the offline database was not optimized during the duration of this project.

After a model has been properly trained using an offline database, it is feasible to use artificial neural networks in applications that take place in the real world. Here, "deep learning" refers to the kind of analysis being undertaken (to assure a very excellent beginning model). When the "training" environment is compared to the actual online environment, reinforcement learning has the potential to rapidly modify its behavior in order to get the best possible outcomes.

Because of this, RL may be employed in many various scenarios, which is a direct effect of this reality. an internal study of the structural nature of the network's organizational composition.

When it comes to the architectures of their deep neural networks, DQN and DPG use similar designs and share several components, including the following: In the input layer of reinforcement learning, each state is encoded with the assistance of two-time steps that are done in succession, one after the other. Each neuron in the input layer of the peak reduction issue represents a single time step in the entire process. Due to the use of time steps to portray the base load, the production of photovoltaics (PV), the condition of an air conditioning unit (AC), the condition of an electric vehicle (EV), and the state of a dishwasher (D), this is the case. Due to the usage of many time steps to represent each of these unique components, this is the case. Each of the state components, with the exception of base load and generation, is governed by values that are dynamically adjusted to meet the environment.

In contrast to the initial values that were supplied by the smart meter, "dynamically changed values" refers to values that have been obtained during the process of learning. Due to the addition of one neuron to the input layer in order to encode the TOU tariff, the expenditures incurred as a direct consequence of this modification decreased. Rectifier Linear Units are used in the networks to allow the activation of three hidden layers, each consisting of one hundred neural connections, for a total of three hundred neuronal connections (ReLU). This edge contributes significantly to our successes. In order to distinguish themselves from one another, DQN and DPG each have their own set of layers that they employ to create their final products. Each neuron that makes up the output layer of the DQN is responsible for appropriately reflecting the Q value associated with a given action. The electric vehicle (a2), the air conditioner (a1), and the dishwasher (a3) are all examples of versatile devices that may be employed to carry out a variety of diverse functions. (Illustration:) (Illustration:) (Illustration:) [Example in (a3)] As a consequence of the fact that the DPG output layer only includes three neurons, which are in charge of processing each device action, it is a great deal less difficult to wrap one's mind around.

In response to each distinct input situation, it is possible to execute a related action associated with a flexible device. Since the growth of DPG is related to the number of flexible devices, it is evident that DPG is outpacing DQN in this regard. This is because the rise of DPG is proportional to the number of flexible devices. Here is a list of the many hyper-parameter values that may be used: The learning rate, which is represented by the equal sign = 102, the discount factor, which is represented by the equal sign = 0.99, and the skewed standard deviation, which is represented by the equal sign = 0.01, are all represented by the same equal sign. For the purpose of training the models, we use 5,000 unique episodes, each of which has 20 randomly selected days. The weights will be recalculated every hour on the hour and after every other episode to reflect the new values. After the end of the learning process, the final policy is closely adhered to.

There are a variety of ways to incentivize artificial neural networks (ANN), some of which are described below: The reward function for the multi-objective optimization problems addressed in this part is computed once per day, at the conclusion of each working day, as opposed to at each time step throughout the working day. This is because doing so is more efficient.

5. RESULTS

5.1 LOSS REDUCTION PROBLEM

Figure 5.1 show the peak reductions of the three separate buildings that were evaluated over the course of one year. The relevant buildings are BI, BII, and BIII.

The goal of Table 5.1 is to make it easier to compare the ideal peak value found by the DQN and DPG methods with the average daily peak value seen at the building level (B) over the course of a year..

DQN algorithm implemented inside the MPPT card. The MPPTcard deal with input values from sensors and output signal to drivers. DPG algorithm decided the output states of controller, which it connected directly to motor1 driver and motor2 driver that used to rotate the panel in X-axis and Y-axis. The input and output states of controller are:

- i. Right Sensor readings value larger than left value. At this values, the output of controller will be three signals (0 0 1) send to motor1 driver to move it in clockwise direction in x-axes in order to facing the sun.
- ii. Right Sensor readings value less than left value. At these values, the output of controller will be three signals (1 0 0) send to motor1 driver to move it in counter-clockwise direction in x axes in order to facing the sun.
- iii. Up Sensor readings value larger than down value. At these values, the output of controller will be three signals (1 0 0) send to motor2 driver to move it in clockwise direction in y-axes in order to facing the sun.
- iv. Up Sensor readings value less than down value. At these values, the output of controller will be three signals (0 0 1) send to motor2 driver to move it in counter-clockwise direction in y-axes in order to facing the sun.
- v. Equal reading values of sensor right and sensor left, Equal reading values of sensor up and sensor down at these two states the output of controller will be three signals

(0 1 0) to motor1 driver in order to stop rotation of motor1 and three signals (0 1 0) to motor2 driver in order to stop movement of motor2.

Then the algorithm runs an update order, which re-reads the sensor data and writes it over the old sensor data and run the algorithm again. This constant update operation helps update the direction of the motor to accommodate the ever-changing motion of the sun.

Table 5.1: Examples of input values (LDRs reading of the PV) and output values (directions of stepper motors) of the sun tracking system.

LEFT SENSOR READING	RIGHT SENSOR READING	UP SENSOR READING	DOWN SENSOR READING	BII			BIII		
				LEFT	STOP	RIGHR	UP	STOP	DOWN
2.3	2.3	2.3	2.3	0	1	0	0	1	0
2.5	3.7	4	4.6	0	0	1	0	0	1
3.1	2.5	3.1	2.5	1	0	0	1	0	0
4	4	3.4	2	0	1	0	1	0	0
4.2	4.8	3.5	3.5	0	0	1	0	1	0
2.7	2.7	1.6	1.8	0	1	0	0	0	1
1.1	1.3	2	2	0	0	1	0	1	0

5.2 COST MINIMIZATION PROBLEM

The results for the cost minimization problem are summarized. The difference between the cost minimization solutions obtained for every building correlated with their average electrical patterns (see Figure 5.2) give as a first.

5.3 LEARNING CAPABILITIES OF ANN

Using the Pecan Street smart grid testbed, we evaluate the applicability of our proposed methodologies in three situations. The purpose of these scenarios with varying user counts is to assess whether or not accurate forecasts can be made in practice and at scale. The purpose of these fictitious situations is to assess whether or not the model can generate accurate predictions.

Using two unique deep learning approaches, namely deep Q-learning and deep policy gradient, we are analyzing and evaluating the results for a total of 10, 20, and 48 structures. The data shown in Tables 4.3 and 4.4 indicate the scalability of our strategy. These data also illustrate that it reduces the system's peak demand and maintains a reasonable price. Even more remarkable is that they have shown an implied answer to the problem of peak reduction. This method becomes beneficial when an increasing number of customers examine the prospect of reducing their expenditures. During training, DPG is much more consistent than DQN. This is comparable to the scenario during the construction phase. As a direct result of this, the overall quality of the job has increased. DPG decreases the peak by 26.3% and expenditures by 27.4% in a sample of 48 structures, whereas DQN reduces the peak by 9.6% and expenses by 14.4%..

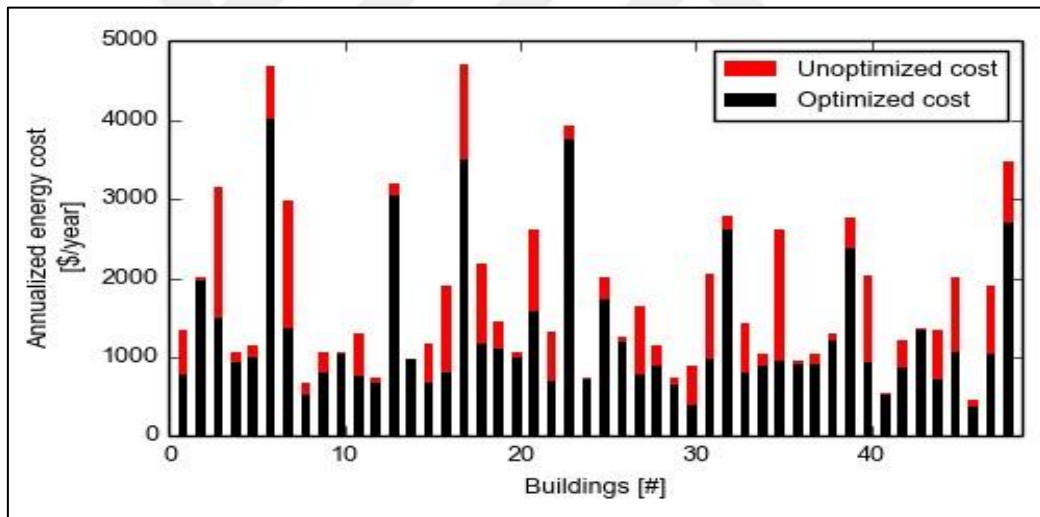


Figure 5.1: Shows the annual energy expenses of each of the 48 buildings.

While some of the structures have been optimized, others have not. For instance, In some cases, using DPG can reduce yearly expenses by up to 50%, while in others, it can only reduce them marginally. This is due to the fact that DPG may utilize economies of scale.

5.4 COMPUTATIONAL TIME

Both types of ANN are capable of achieving great performance due to their abilities to handle naturally vast, continuous state regions.

In contrast to heuristic optimization systems (such as PSO) that must repeat the expensive optimization process for each option, ANN reaches a result in a matter of milliseconds (such as picking the optimum control action).

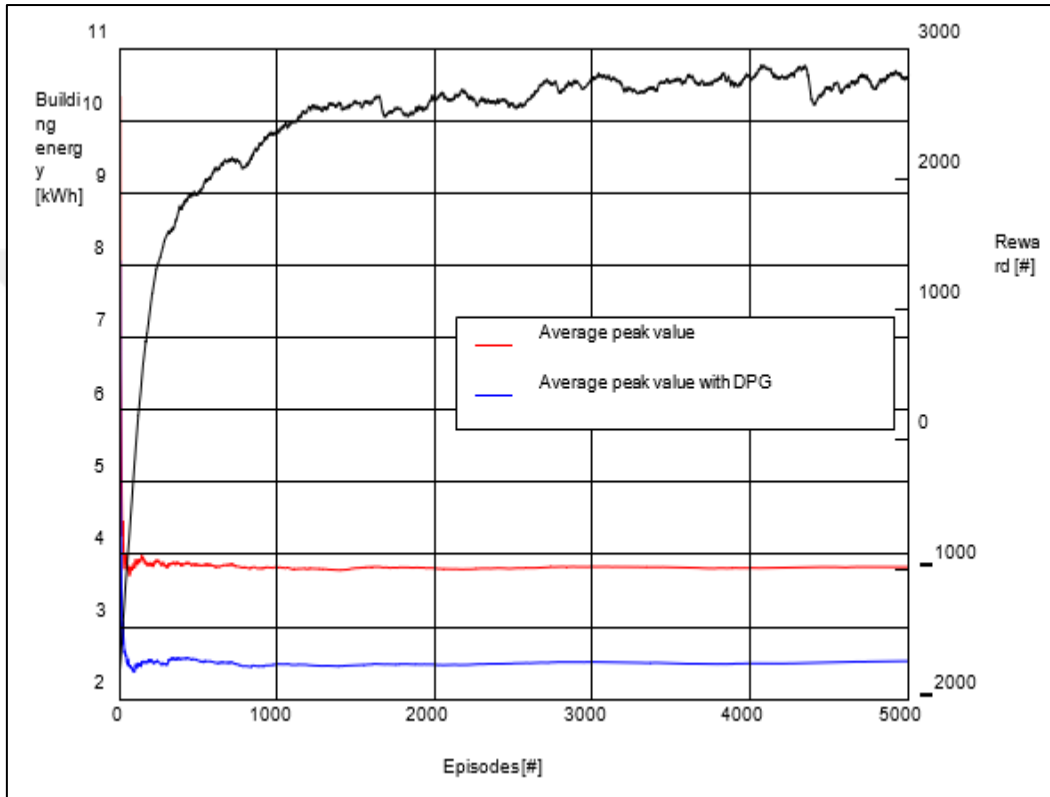


Figure 5.2: Average peak value of the DPG method compared to ANN.

6. CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

This study's primary purpose is to create and implement a system for anticipating the arrival of renewable energy sources in order to simplify the management of an intelligent electrical microgrid. This investigation was conducted with the aforementioned person or item in mind. The amount of predictability of the data collected from the solar charger might be evaluated to aid in the process of creating prediction expectations.

If we wish to run the network effectively, we must construct a time horizon for projecting the quantity of renewable energy sources it will utilize in the future. Create a strategy to compute the amount of energy that can be produced from renewable sources, and then implement that plan. It is hard to overstate the significance of completing this level. In order to fulfill the criteria of the administration of an intelligent electrical micro-grid, it is necessary to implement a strategy for forecasting the availability of renewable energy sources. This is how we behave ourselves in order to meet what is required of us.

On the test bench, wind speed measurements are collected and put into a database. This enables an evaluation of the accuracy of the prediction in reference to the actual system measurements. A preliminary test of the prediction approach must be conducted in a simulated environment. Next, it is necessary to compare the predicted efficiency of this methodology to that of more traditional approaches. Consequently, the contribution of this thesis is structured around the idea of combining one or more storage mechanisms into a solar charger that is connected to the main grid, incorporates intermittent sources of production and consumption, etc. The objective of this contribution is thus to incorporate a solar charger with an internal storage system of some kind.

This study is intended to help us become more systematic in our research on solar chargers, which is our core field of study. After defining the category of topics to be researched and the particular project to serve as our case study, the goal of this investigation is to adopt a more systematic strategy.

This will be achieved by using a more methodical approach. The technique for developing the system will be expedited, with one of the aims being to consider the management and size of the solar charger's components. In this thesis, the methods used to overcome the aforementioned hurdles are compared and contrasted with those revealed in previous research.

We anticipate that the solar charger's operation, similar to that of several other research projects, will entail optimizing the flow of energy to lower financial expenses based on environmental and tariff data. This is because it is expected that solar chargers would be used by electric cars. The optimal system design is projected to need the execution of a method that combines the management loop with the dimensioning loop. However, in order for this strategy to be effective, the underlying issue must first be skilfully simplified.

6.2 FUTURE WORK

Our long-term aim is to determine whether OEP may be used as an MPPT technique for PCM. The results of this study, like the results of any other study, have the potential to serve as the foundation for more research. Experiments to verify the OEPPC and OEPPCD when applied to PCMs would be extremely interesting.

Although it is true that the OEPPC is an effective method for optimizing PV cells, simulations have shown that the OEPPCD is more capable at enhancing PCM. Despite the fact that the OEPPC is an excellent approach for improving PV cells, this is the case. Only when PCM internal dynamics are somewhat steady will the OEPPC have a performance advantage over the OEPPCD. Therefore, doing research on the OEPPC and the OEPPCD on an operational system would be a crucial step toward real-time optimization of the PCM's output power. Additionally, the current potentiometers utilized in this memory should be replaced with legitimate DC/DC converters.

Certainly, in a real-world situation, the power generated by PCMs would be gathered in a load via a DC/DC converter, which may result in energy conversion losses. As a result, the development of a converter would represent another step toward the general use of PCMs in industry.

It has been observed that the time necessary for the PCM to converge varies according on the mode in which it is running. Because of this, it is possible to check the PCM's stability prior to modifying its operating point in order to increase the convergence rate of an algorithm. This method would not only ensure that the optimized PCM makes use of the right static power curve, but it would also save a significant amount of time. This approach would guarantee that the improved PCM use the right static power curve. Although the OEPPC is mentioned in this article, alternative real-time optimization techniques are available. These algorithms are often used as MPPT approaches, however they have not yet been implemented on PCMs.

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