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ALTINBAŞ UNIVERSITY

Graduate School of Science and Engineering

Electrical and Computer Engineering

ENERGY MANAGEMENT IN MICRO GRID BASED HYBRID SYSTEM USING MACHINE LEARNING

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Istanbul, 2021

Energy Management in Micro Grid Based Hybrid System Using Machine Learning

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Electrical and Computer Engineering

Submitted to the graduate school of science and engineering

In partial fulfillment of the requirements for the degree of

Master of Science

ALTINBAŞ UNIVERSIT

2021

The thesis titled “ENERGY MANAGEMENT IN MICRO GRID BASED HYBRID SYSTEM USING MACHINE LEARNING” prepared and presented by Ammar ALATTABI was accepted as a Master of Science Thesis in Electrical and computer engineering.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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Ammar Mohsin ALATTABI

Signature

DEDICATION

To my family

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my supervisor, Prof. Dr. Abdullahi Ibrahim for his wonderful guidance throughout the course of my research work. I am indebted to him for his continual encouragement and support to carry out the current study. On the other hand.

ABSTRACT

ENERGY MANAGEMENT IN MICRO GRID BASED HYBRID SYSTEM USING MACHINE LEARNING

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Data : September /2021

Pages: (58)

Smart grids are electric grids that are composed of multiple power sources and devices connected to each other to provide better reliability in power generation and power management, modern developments of the smart grid aim at either improving the control of power sources and loads connected to the smart grid by developing a specialized software/hardware, or by improving the communication within the parts of the smart grid and the central control. In this paper we aim at improving both sides of the smart grid system (communication and control), we propose a fuzzy logic-based controller for renewable energy and fossil fuel sources in a grid and an internet of things-based monitoring system which oversees the state of the smart grid, faults that occur in the grid, and how the fuzzy controller overcomes those faults, all in which provide an extra layer of support to the smart grid.

Keywords: Fuzzy logic, EMS, EDS, IDS, ANN, Smart Grid.

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LIST OF ABBREVIATIONS

IDS	:	Intrusion Detection System
PSO	:	particle swarm optimization
OSI	:	Open Systems Interconnection Model
CAN	:	Controller Area Network
ROC	:	Receiver operating characteristic
AI	:	Artificial Intelligence
AUC	:	Area under the ROC Curve
ACC	:	Accuracy
LS-svm	:	Least square Support Vector Machine
	:	Support Vector Machine

1. INTRODUCTION

1.1 BACKGROUND

Electric energy is important to maintain and boost the economy by improving the standard of living of its population. The foregoing imposes the need for a supply of electrical fluid with a very high level of security and its delivery with quality at reasonable prices. On the other hand, the electricity sector has responsibilities, with society and with the environment, to contribute to the construction of a sustainable environment, which implies that energy resources can be used today, but guaranteeing the same right to future generations. In the current situation, the electricity sector in several countries faces important challenges that include:

a. Maintenance of an infrastructure that is approaching the end of its useful life for several of its assets,

b. Integration of new technologies in the field of:

- generation with renewable sources (mainly wind and solar),

- transportation, for example, flexible transportation systems, (FACTs),

- the distribution where it is already common practice to install systems for the automatic management of certain processes,

- the final consumer, where there is already a high degree of implementation of infrastructure for basic measurement and control.

c. Greater attention and participation of electricity consumers. [2]:

1.2 MOTIVATION

The above challenges also correspond to opportunities for progress in the sector to modernize the system and improve the performance characteristics of the electricity networks, in terms of flexibility to better cope with climate changes and consider the changing aspects both on the generation side and on the demand side. These challenges have a particularly strong impact on electrical energy distribution systems the adoption of renewable energy, especially in the long term, is inevitable, efficiency in the end use and throughout the supply chain will be an imperative, the impact of uses non-conventional such as electric vehicles will be substantial, efficient appliances will be integrated into smart home grids, etc. All these aspects are occurring, some of them very recently, but in great numbers and simultaneously, which makes a new conception of the electrical system necessary.

1.3 PROBLEM STATEMENT

In this transformation of the electricity sector, the common denominator of the solutions that are being conceived and developed today is the massive use of communications and information technologies to monitor and control the networks under the concept of “Smart Grids ”Or Smart Networks. Consequently, the convergence between the electricity and communications sector in an “electric internet” is one of the pillars of smart grids. Figure 1.1 graphically presents the convergence of these two platforms [12]:

Figure 1.1: Basic smart grid system[1]

1.4 CONTRIBUTION

The main study of this project focuses on the planning methodology for the expansion of the primary and secondary electrical distribution networks for the short, medium and long term, in accordance with the objectives and goals of smart grids. For this, it is necessary to consider the incorporation of distributed generation, response to demand, electric vehicles, induction cookers and the influence of the communications network. In short, it will take into account, apart from the system itself for the distribution of electricity to all consumers, the distribution automation system and information technologies in order to improve reliability, quality of service , operational efficiency, have a lower environmental impact and an active participation of the clients. The specific objectives that are proposed are the following: • Develop a model of agents and interactions for the implementation of smart grids, in such a way that the communication and information needs of the different agents involved are collected based on a conceptual design, in such a way that it allows us to propose a communications architecture based fundamentally on Distribution Automation (DA), Advanced Metering Infrastructure (AMI, for its acronym in English) and Resource management Distributed Energy (DER). This model will make it possible to propose a proposal for the systems necessary to implement demand management, electric vehicle management, among others, and finally describe the technical design of the architecture.

1.5 THESIS ORGANIZATION

The thesis is structured as follows: Section 2 is where we review some of the previous work and implementation on smart grids. Section 3 is where we give a background about all the components. Section 4 is where we explain our model in details and implementation of that model in details, Section 5 is where we simulate our model and record the results obtained. Section 6 is where we conclude our work and put a future scope into perspective.

2. LITERATURE REVIEW

According to the analysis, planning will be used to satisfy customer demand. The prediction of demand is critical since it is essential to the whole process and will influence the conclusions of sufficient outcomes. To better plan, a sufficient demand prediction for the research region is required. Whether one wants to admit it or not, planning and predicting supply are always connected with uncertainty. Demand forecasting is hindered by data volume, complexity, fluctuating generating variables, and a lack of previous information. A hierarchical demand forecasting framework is flexible enough to accommodate new technology, consumer behaviors, and environmental concerns. The distribution network's planners will consider a variety of distribution network configurations to meet the supply of spatial electrical needs scattered throughout a geographic region. Companies nowadays need improved distribution grid planning to allow them to reactively upgrade their networks in response to the growing number of distributed generating and smart grid products. Existing distribution systems. One of the biggest technical challenges is to transform the present electrical system into a smart grid. Electrical power distribution systems have become more and more fundamental to information technology because of these systems' vital role in supporting the smart grid. Distribution network design, which is often blind to the intimate relationship between distribution and the smart grid, is unable to satisfy smart grid development demands. This thesis introduces a new collaborative planning paradigm for electric power distribution networks. To explore how well the electrical distribution network, communication system, and automation of the distribution system function together is a worthwhile project. This chapter looks at present practices and ways that they are likely to develop in the future. There are problems to be found while dealing with wise planning, and they are mentioned and quickly explained.

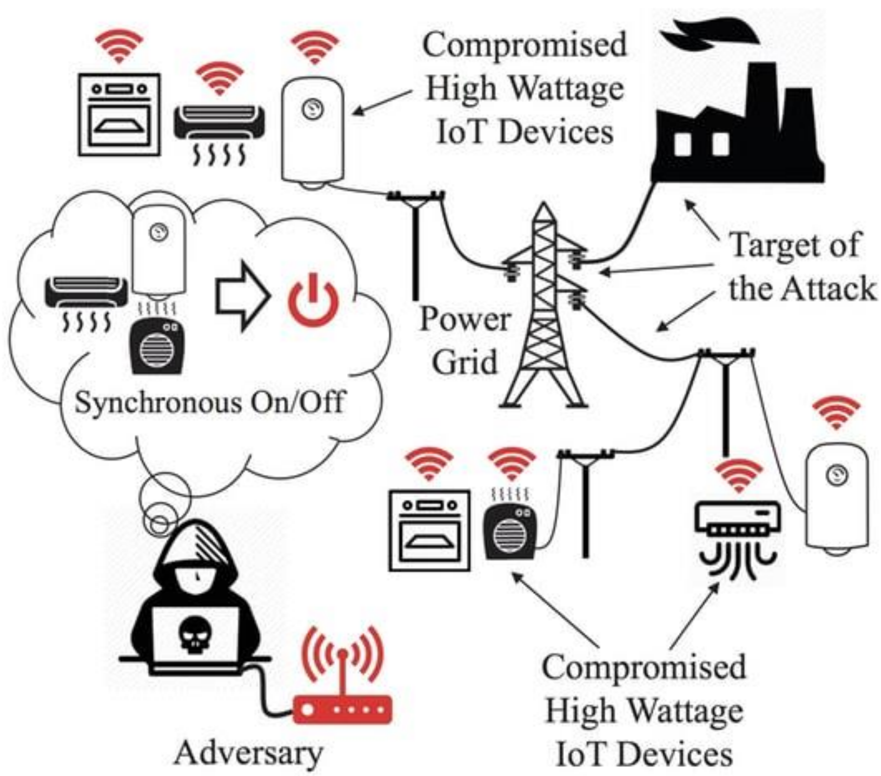

Figure 2.1: Wireless communication based smart grid [2]

Predict and supply processes formerly used in the distribution network planning process are known as "predict and supply." Planning processes are followed, and network planners search for an acceptable solution set given the increases in expected electrical load, as well as other limitations, geographic information, and performance objectives (such as voltage, reliability, and protection). Capacity sizing, topology design, substation location, component selection, and other engineering-related activities may be engaged in regular engineering assignments. In the past, network designers have been compelled to respond quickly to the deployment of distributed energy resources (DER) and must now contend with the competing interests of grid security, while the security of the grid connection must still be a priority. With this "respond and deliver" strategy, planners do not change network planning approaches to adapt to new conditions. Increasing numbers of distributed energy resources (DER) as well as a greater focus on developing new smart grid technologies, especially around the operation of the distribution network, demand management (DSM) and information and communication technologies (ICT) are among several converging factors that will revolutionize the electric power distribution

(DPDS) industry in the future. A series of publications - [15] to [16] in the Smart Grid series show how a completely non-fossil fuel future would be made possible utilizing large quantities of wind energy for transportation and heating, as well as suggest that the smart grid is the most effective way to make this future a reality. To have a better handle on new technologies, distribution organizations should also work to improve their existing conventional planning techniques. Distribution network planning prioritizes physical network construction and transformer size. Distribution automation, communication, and management are seldom acknowledged when looking at the overall performance of the physical system operation and the system's dependability. Distribution planning, distribution automation, and distribution communication planning are undertaken individually, and few appropriate theoretical approaches are available for the coordination of these projects. SGCC has created ways in the last several years for designing the automation distribution and communication network distribution. In parallel, while the scholarly study of this issue discloses coupling patterns [19] between the electrical power system and the corresponding communication system, advancement on this issue also shows how the two systems are interrelated. All of these projects are essential in laying the groundwork for future studies on collaborative planning of the physical aspect of the electrical power distribution system, as well as the informational side. This statement is an indication that the published book "Analysis for the implementation of the smart grids program Conceptual design and application to a pilot plan" describes part of the given work.

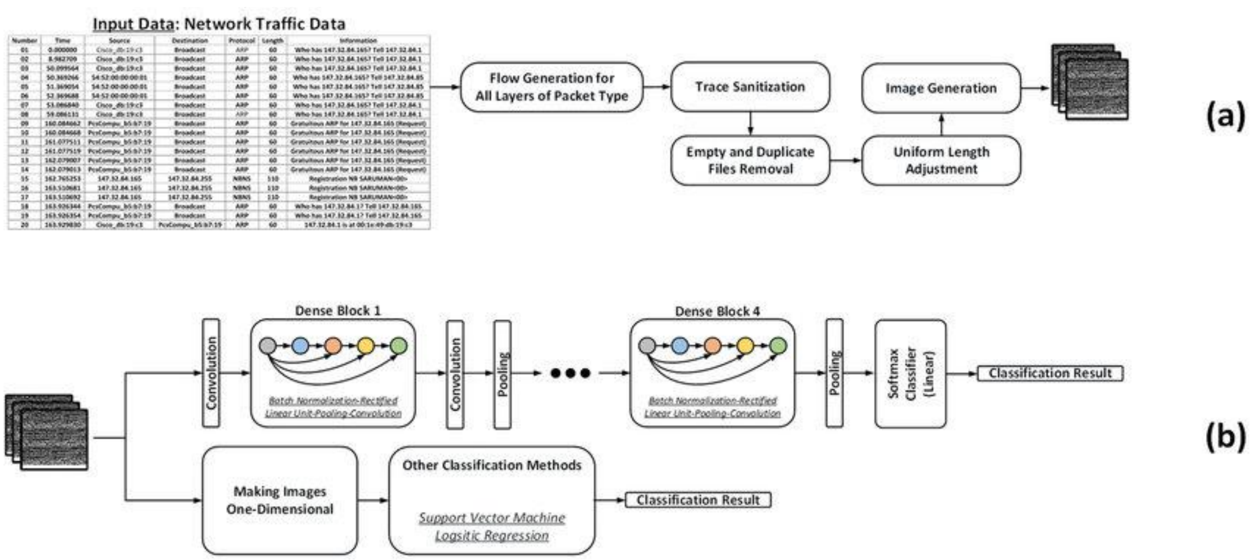

Figure 2.2: Conceptual design and application to a pilot plan [3]

3.MATERIALS AND METHODS

In this chapter we review some of the essential components that we used to implement our model; we give a brief introduction to the component.

3.1 DEMAND FORECAST

Predicting future energy usage (LP) using prior data, meteorological conditions, and renewable energy sources (RES) is known as load prediction (LP). It provides a measure of balance between the supply and demand of energy. A logistic function is most often used to anticipate future load on a particular system for a specified time period. Predictions may be in reference to the operating process for a fraction of an hour to 20-50 years, and they may be for long-term planning. There are three major categories in which LF may be placed:

A short-term LF is used to estimate how much electricity is required during a seven-day period, up to the first week of operation. This is done to save expenses and maintain minimum levels of service.

Medium-term load forecasting often offers accurate guidance for organizational operational planning on a weekly, monthly, and annual basis.

LF is used to forecast up to 50 years in advance to help with long-term planning.

The ability to anticipate future energy demand is vital to the operation and planning of an energy system, and these predictions have considerable potential for reducing the energy service provider's costs [as found in the study 'Potential Savings and Market Demand Forecasting of an Energy System']. An rise in operating costs due to an inaccuracy in the forecasting model was why a mathematical model that takes into account several influencing factors, such as weather, climate, and the economy, was necessary. The model parameters must be estimated if prediction models are to be created. Multiple linear regressions I stochastic time series (ii), generic exponential smoothing (iii), state space and Kalman filter (iv), and knowledge-based approach (v) are used in the literature.

The models in this class may be broken down into two types: ones that are based on mathematical models and ones that are based on artificial intelligence (AI).

3.1.1 a statistical model

The models are represented by the mathematical equation in statistical modeling. A number of autoregressive (AR), moving average (MA), and autoregressive moving average (ARMA) models exist, and their mathematics is described in [23]. Other types of linear fit analysis approaches that are often used for long-term forecasting include multiple regressions, exponential smoothing, iterative reweighted least squares, and adaptive linear fit analysis.

3.1.2 Regression with many predictors

This model is used to build a link between several factors, including weight, weather, kind of day, and consumption class. This model has been used by El-Hawary and Mbamalu in their research on load measurement. Load-climate model to estimate load demand was created by Hyde and Hodnett based on a regression analysis. A modeling methodology developed by Al-Garni utilizes historical meteorological data, solar radiation, region population, and consumption class information to estimate energy consumption. [26]

3.1.3 ExpoSmoothing

A well-known forecasting methodology is exponential smoothing, which incorporates the loading of the previous day to anticipate the loading of the next day. Fit was modeled as a function of load for Moghran and Rahman. An exponentially smoothing model in which power spectrum exponent and adaptive autoregressive modeling rise with the spectrum has been described by El-Keib [27]. Infield and Hills investigated short-term trend removal methods for LF, with their study focusing on optimum smoothing. Using this approach, the demand error is reduced by 12% [28].

3.1.4 The reweighted least-squares iterative algorithm

To determine the order and parameters of the model, iterative reweighted least squares are utilized. In the model, each variable is controlled separately and has its best beginning point defined. The study's auto correlation and partial auto correlation research used machine learning and diversified historical load data to find the suboptimal model for load dynamics [25]

3.1.5 Estimation via Auto-Regression

A stochastic time series model is called auto regression. The linear combination of historical load data is used to simulate the current load. For accurate forecasts, the algorithm needs at least a minimum amount of parameters. Zhao [30] proposed the PAR for the hour-based LF.

3.1.6 Simple moving average

At the present time series value, the white noise series has a weight of one.

A moving average that compensates for auto-correlation.

a novel temperature and time-based prediction model is provided in [31] The random walk and deterministic components of the maximum monthly load are divided into an ARMA model, which calculates the deterministic and stochastic components. [32] uses the "Weighted Regressive Least-Square" (WRLS) technique to update the parameters of the ARMA adaptive model. A special ARMA (Autoregressive Moving Average) model is used to anticipate LF error, which is then used to re-adjust model parameters.

3.1.7 AR, MA

ARMA are stationary time series. If the time series is not stationary, it must turn into a stationary time series. To attain this goal, the ARIMA model is applied. This model incorporates trend and meteorological factors to estimate the system load, which is then fed into an ARIMA model to provide a cyclical component that does not depend on the weather. ARIMA is an example of a seasonal model, which incorporates past data to predict the seasonal fluctuations of cargo.

3.1.8 Using artificial intelligence to create a model

Some artificial intelligence-based prediction models include the Expert System, the Gray System, the Artificial Neural Network (ANN, for its short form "Difus Logic") and the Artificial Evolutionary System (AES).

3.1.9 artificial neural network

A computer model inspired by the human or animal central nervous system is called an artificial neural network (ANN). This system is made up of "neurons" that link information from different inputs to provide it to other cells in the network. This article focuses on an in-depth examination of neural networks, which is summarized in [35,36]. In the majority of the review, ANNs are categorized into two groups: The first group consists of just one exit node, whereas the second comprises multiple. Thirty US utilities employed a software-based neural network technique in 1998. LF utilizes radial function base network [39], self-organizing maps [40], clustering and recurrent neural network [41] as some of its neural prediction models. A hybrid neural-fuzzy system that attempts to forecast future load is proposed by Srinivasan and Lee [42]. Unsupervised learning (Unsupervised learning) and supervised learning (Supervised learning) are used in tandem to develop a link between load and temperature. [24] proposes an LF model that incorporates neural networks with error correction. The findings reveal that the system's mean absolute percentage error (MAPE) of 0.72% is better than older methods.

3.1.10 Specialist system

In an export operation, they're removing knowledge-based (LF) facts from the environment and it's termed a knowledge-based export system. A combination of knowledge-based knowledge and statistical methodology is used in [44] to create an expert system. Brown [45] has suggested a predictive model based on both current system information and system expansion in terms of load. There are various hybrid approaches, which integrate expert systems with other load forecasting models, that may provide accurate predictions of load. Expert systems and fuzzy logic are both a blend of concepts such as these, as mentioned in [46]. Artificial neural network and fuzzy export system are utilized by the Korean electricity utility to forecast the anticipated load for the country [47]. A neural network and an export system are used to make an hourly projection of the demand of the Egyptian power company. [48]

3.1.11 "Fuzzy Logic"

Fuzzy logic is a method of approximate, probabilistic determination that can accurately identify and measure any unknown system. He focused on the fact that fuzzy logic is able to extract a lot of correlations from a wide range of data. Fuzzy logic has two phases for work, the first of which is known as "training" and the second is "online prediction." To train two meters of entrance, the training stages employ the past data from the meters. Generating a fuzzy rule utilizing first and second difference of provided data is equivalent to employing two-times the outputs of pattern-based fuzzy logic. After the training phase, it connects to the controller, and uses that information to estimate the load. Once the most likely function has been found, the output pattern is created. Load prediction is accomplished using a number of different fuzzy models. Using fuzzy logic, the load prediction for Taiwan's electrical system is determined. Fuzzy linear programming (FLP) models a linear programming problem, taking into consideration the data uncertainty and the forecast. Non-linear optimization models are used to reduce model error in the short term by using a fuzzy inference approach to create the LF model. The non-linear optimization model is introduced in [42]. Combining three methodologies such as fuzzy logic, neural networks, and export systems, together with unsupervised learning that is researched by Srinivasan [51], produces a hybrid model for short-term load forecasting (STLF).

3.2 OPTIMIZATION ALGORITHMS

To find the optimal solution to a problem there are numerous algorithms and techniques with which to achieve it, but due to the diversity of models that exist and their differences in specifications, there are algorithms indicated for one type and not so useful for others. Here we present a classification according to types of models and briefly describe some algorithms that can be used and have been used as seen in the previous section.

According to the nature of the variables for models of continuous variables: composed of variables that can assume real variables in continuous steps.

a. Simplex: it is an iterative method for solving linear problems that repeats simple operations until the solution is found. It looks for the solution by moving from one vertex to another of the polyhedron formed by the restrictions, therefore, it always finds a solution. It is limited when solving problems with a single objective function and where all variables are continuous. Interior point algorithms: they do not look for the solution only at the ends of the feasible area, they look for it from the inside of it.

b. Ellipsoidal method: starts from an interior point and an ellipsoid is defined with a center in it and strictly included in the admissible region, optimization on the ellipsoid of the objective function provides a new interior point closer to the optimal solution, and thus is generates a succession of interior points that converges to the optimal solution. Limited in its inefficiency due to slowness. • Primal-Dual Method: each linear programming problem has a second problem associated with it so that the optimal solution of one provides complete information on the optimal solution of the other. The solution of both is calculated for each feasible point and the distance between both solutions is calculated, and in each stage an attempt is made to minimize that distance until it converges to the optimum. It requires fewer iterations than Simplex. External approximation algorithms: also known as relaxation methods, they are based on removing some restrictions from the set of feasible solutions, which are added little by little as the algorithm and the solutions obtained so far require it, with this it is possible to have easier problems to solve. For models of integer or mixed variables.

c. Total Enumeration Method: lists all possible solutions, evaluates them and selects the best one. It contemplates all possible solutions so it limits its application to small problems.

d. • Branch and Bound (branching and bounding or pruning): establishes the search for the solution through a partial enumeration. It consists of a partition of the continuous space of solutions into a subset, the idea is to eliminate parts of the continuous space that are not feasible for the entire problem, the best solution of the subset is bounded and subsets are discarded that the bound indicates that it is not possible that contains the optimal solution. In this way, the problem state tree is traversed along the most advantageous paths. It is based on the “divide and conquer” technique (decompose the problem into k different problems of the same type as the main one, but smaller).

e. • Branch and Cut: it is a meta-heuristic algorithm for solving difficult integer linear problems, which combines Simplex, Branch and Bound strategies, Cut Plane algorithms and Prime heuristics. Use the "divide and rule" technique. Nonlinear programming algorithms: in these, convergence to local maximums or minimums must be avoided. • Classic algorithms: Least Squares method, Taylor series based methods, Newton's method, but none ensures global convergence. Those based on heuristic rules are oriented to the search for the global optimum. Algorithms based on meta-heuristic and heuristic rules: aimed at reducing computation times and which are applicable to non-linear models. They establish various rules that allow obtaining approximate but satisfactory solutions to problems that are difficult to solve exactly. They do not guarantee convergence to global. In order to avoid convergence to local solutions, the linearization of the mathematical formulation can be chosen, thus allowing the use of linear algorithms. • Greedy algorithm: it is a sweep heuristic algorithm, based on a single evaluation of the available variables, it selects in each stage the variable that best adapts to the objective, but does not guarantee optimal exchange solutions: Exchange heuristics: starts at starting from a complete solution, and the algorithm makes variations of it in an environment close to the initial approach, trying to reach solutions that offer improvements in the objective function, to avoid convergence to local solutions, the algorithm can be developed from a certain number of different initial solutions and compare results using each of them at algorithm initiation. • Branch Exchange: classic meta-heuristic algorithm, of simple application whose idea of branch exchange is to calculate the change involved in operating a pair of switches, with the goal of reducing losses. He starts from a radial feasible solution, and modifies it. Certain solutions that worsen the objective function can be allowed to be analyzed and varied, looking for a better solution in other surroundings close to the function, reducing the probability of finding local optimum. It can be directly adapted to multi-stage problems. Widely used in network expansion. • Genetic or Evolutionary Algorithms: it is an algorithm based on the observation of the natural evolution of the species. It is a probabilistic algorithm, that is, its behavior is not deterministic and therefore it does not have to find the same solution in two different executions. Due to its search it is compatible for non-linear models. They are search and optimization algorithms, which consist of a population of bit strings transformed by three genetic operators: selection, crossing and mutation. Each string (chromosome) represents a possible solution for the problem to be optimized and each bit (or group of bits) represents a value of some variable of the problem (gene). They basically encode a solution in a chromosome, as a data structure, and apply operators (crossing and mutation) to obtain new structures looking for the solution. Crossing is dividing two chromosomes and mixing the proportions, mutation is randomly changing one or more elements of the chromosome. Starting from a set of probable solutions, it evolves towards better solution versions, which are generated by incorporating genetic operators, it is necessary to establish adequate criteria that allow efficient maintenance and reproduction of solutions with a better acceptance measure. The size of the population, which is the number of chromosomes, is a fundamental element to find a solution close to the optimal one and for the speed of execution. • Simulated Annealing: heuristic local search algorithm based on calculating the states of least energy requirement of solid-state materials. By reducing the temperature to the materials in a controlled way, they stabilize in solid configurations whose energy generation depends on the cooling rate. The method after reaching a local solution allows to obtain new states, the process is restarted with a new random value and the resulting solutions are evaluated and compared with the previous ones, taking the best one. The temperature of the process is dropping which means that finally the algorithm only accepts solutions that improve the objective function. Probabilities close to 1 of finding the global solution can be obtained if the cooling process is slow enough. Mainly used in problems like reconfiguration and network expansion.

f. • Tabu Search: it is an adaptive memory heuristic method, it follows a simple iterative process that explores the solution space starting from an initial solution and making movements from a solution to the best of its neighbors, therefore, it solves problems relatively easily and quickly. of high complexity. Assign penalties to movements that worsen the solution by guiding the search to more promising areas, only use these to avoid following an already evaluated direction. A Tabu list is created that stores solutions that have already been reached and that cannot be used during several iterations, this list is updated as new iterations are solved, it ends when a specified maximum number of iterations is reached or when the function target does not improve. It is efficient for dealing with large and complex problems.

g. • Colony of ants: came up with the idea of finding the optimal path in a graph based on the behavior of ants when exploiting food resources. An ant wanders until it finds food, then it returns to the colony more or less by a short path, the other ants will be attracted by the pheromone that it gives off and they will travel the roads leaving their trail as well and thus the most direct paths will increase their amount of pheromones and will be more attractive to the next ants. When a solution is found, it is evaluated and the value of the components of the route used is modified, this information will direct the search for the next iteration. For this problem, a number of colonies or iterations is set and has the limitation that each colony performs the complete network construction process, so it is only used in small problems.

3.3 ELECTRICAL GRID SYSTEM

The operation of the electrical system is developed by the System Operator (SO) [36] and its main objective is the maintenance in real time of the security of the system and, to the extent that it is not threatened , do it in the most economical way possible. Safety refers to the ability of the system to maintain itself in an acceptable state (with variables within its operating regions) and to cope with changes in demand and other unforeseeable events. Those in charge of the operation must decide the use they give to the available resources of the system based on the needs that exist at all times. It should be borne in mind that the operation, although it is related to real time, is part of a much broader time process, where planning and system programming fit. During planning, consider the needs of the system to meet your operational requirements. This is a process that has a long-term time horizon, since it contemplates the construction of expensive facilities that require a relatively long time to start operating. It is during system programming that the generation units that will be in operation in the short / medium term are established, as well as the lines, generators or other devices that will not be in operation. operating due to being under maintenance. All these aspects condition the decision-making process in which the operation consists. Among the activities that the OS should carry out, the following deserve to be highlighted: Make an estimate of the demand that will support the system in a short / medium term horizon and guarantee the maintenance in real time of the necessary balance between consumption and generation. on. Maintain power flows through lines and transformers within the proper operating ranges. Maintain the fundamental electrical magnitudes, voltage and frequency, within the preset operating values. Ensure adequate control of the contracted energy exchanges both within the system itself and with others outside its control area. Establish the necessary measures to deal with possible contingencies that may occur in the system, in such a way that the probability of supply shortages is minimized.

Evaluate the way the system operates and look for more efficient methods of action that lead to an improvement in both the security and the economy of the system. One of the characteristics to be highlighted of the electrical system is the possibility of separately controlling the frequency (f) of the system, acting on the active power, and the voltage on the busbars (V), the use of reactive resources present in the system being useful for this [71]. There is another feature, related to the previous one, that should also be mentioned. While the frequency of the system has a global character, that is, it is practically the same at all points in the system, the voltage of a specific bus depends a lot on the local support of reactive power, losing this relationship as we move away from the bar under study. Therefore, voltage control has a marked local character, a particularity that must be taken into account in the structure of the corresponding control. An important difference that must also be considered is the different time scale in which the actions carried out on the voltage and frequency controls are noted. While in the first case, the actuation time is usually a few seconds or less, in the case of frequency, being related to the mechanical inertia of the system, these controls take from a few seconds to minutes. to get noticed in the system.

3.3.1 Energy management system

The typical functions of EMS [89] can be grouped into data acquisition, generation control, and network control and analysis. Data acquisition typically collects real-time measurements of voltages, currents, active power, reactive power, breaker status, transformer TAP positions, and so on. from the RTUs (remote transmission units, for its acronym in English) from the SCADAs (supervision, control and data acquisition systems, for its acronym in English). The data is stored in a real-time operation database, to be used by the different applications, where the sampling period is usually two seconds. RTUs also have the capacity to store event sequences with sufficient granularity to perform post-contingency analysis. Generation control essentially manages the balance between generation, demand and losses. To do this, short-term demand predictions (in 15-minute intervals) are used and the optimal way in which generation can contribute to the system is calculated. By means of the automatic generation controls (AGC, for its acronym in English), the instantaneous balance of the system is achieved by monitoring and acting on the basis of frequency changes, normally associated with changes in the distributions of power injections in the network (eg connection of a new load, exit from service of a generator, etc.). Network control and security analysis are functions that have to do with the reliability of the network. From the state estimator, the control center can transform the data sent by the SCADA into an accurate view of the current operating state of the system. To evaluate the security of the network, the behavior of the network is analyzed through power flows for a list of contingencies, built on the basis of the previously defined security policy (for example N-1), where they go out of operation. on generators, lines, etc. This is called a contingency analysis or security analysis. Likewise, it is necessary to consider their characteristics when conducting frequent studies and analyzes [35] in S.E.E. such as those related to: Short-circuit Power flow Stability Contingency analysis The rest of the network control functions are related to the analysis and actions once a contingency or violation occurs and with the restoration On the SSEE.

3.3.2 The control center environment

The restructuring of the electricity industry has caused, and will continue to cause, changes in the composition of SSEE participants. These changes cause the control centers to require reordering of their geographic coverage and the functions they must perform. For example, the not infrequent modifications to regulatory schemes imply changes in the functions required of the control centers. Also, both the entry of new market participants and the exit of others, modifies the environment in which the control center operates. A change in functionalities and responsibilities may be caused by the outsourcing of some of the services assigned to traditional control centers or by a technological and / or innovation change:

Figure 3.1: Smart grid control centers [4]

Control centers must be able not only to deal with other control centers but also with a growing number of players in the market: regulatory agencies, independent energy producers, large energy producers and consumers, service providers for control centers, etc. Additionally, as markets expand and the network becomes more congested, reliable operation becomes a critical task. Keeping the system running reliably requires more data acquisition, better analysis, and quick, coordinated controls. Achieving these objectives of reliability and speed requires the evolution towards distributed systems.

3.4 SMART GRIDS

Although there is no consensual definition, the Smart Grid concept can, in principle, be associated with the improvement of current electric power systems, which generally works by distributing it from some power plants to millions of users. Smart Grid performs a more optimized distribution of this energy, allowing a better response to situations in which the distribution centers are stressed by high consumption. According to the SDD, Strategic Deployment Document [109], an official document of the Smart Grid project in the European Union, the Smart Grid is an electrical network that can intelligently integrate the actions of all connected users. generators, consumers and those who act both in order to produce a secure supply of electrical energy. This network uses new technologies and offers new services such as intelligent monitoring, control and communication to: Facilitate the connection and operation of generators of any size and technology. Allow users to be an active part of the system. Provide consumers with more information and sourcing options. Reduce the environmental impact of electrical supply systems. Offer a safer and more reliable energy supply. Smart Grid is a union of technology, environmental impact, a set of regularization laws, ICT (Information and Communication Technology) and migration strategies, as well as the control by governments for their correct application and use. This system tries to change the current centralized distribution system, even allowing each one of the households to have their own resources that allow them not to depend exclusively on the power plants, thereby achieving less overload of the systems current. This would be achieved using technologies that allow regulating energy consumption and the storage of natural energy (such as solar or wind) that could be used by households or even commercialized by the same, thus generating a new market aimed at improving the living conditions of society through an essential resource these days.

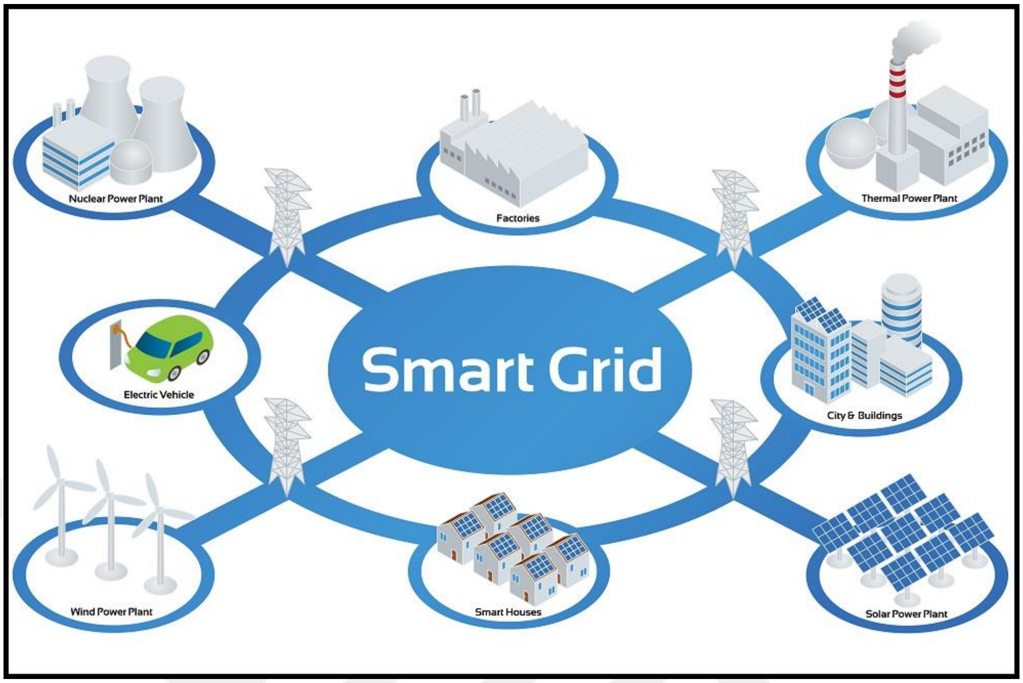

Figure 3.2: Smart grid scheme [5]

According to the SDD, the main challenges that will improve the efficiency of energy use and the reduction of carbon consumption between 2020 and 2050, as well as the reduction of the Dependence on energy distribution systems and line safety are: Ensuring that there is sufficient transmission capacity to interconnect energy sources, especially renewables throughout Europe. Develop efficient connections for the maximum use of offshore wind energy. Develop decentralized architectures, enabling smaller power supply systems to operate harmoniously with the complete system Create the communication infrastructure necessary to achieve the operation of the different parts and their management in a single market. Allow consumers, with or without their own generators, to be able to play an active role in the operation of the system, even participating in the management of demand. Allow the generation, demand and use of intelligent energy. Utilize the benefits of energy storage. Prepare the way for the use of electric vehicles, accommodating all the needs of consumers. The proposed work aims to be part of this challenge by providing an operation methodology that facilitates obtaining the challenges posed based on the technologies of intelligent agents.

4.PROPOSED METHOD

4.1 MICROGRID ENERGY DEMAND

The increase in energy demand foreseen for our country, according to the electricity and energy prospects for the coming years, as well as the dependence on energy sources that use oil as the main energy source, requires a panorama in which a increase in the cost of energy mainly for the industrial sector. To cite an example, companies with demand characteristics are so high that they must request a service at sub-transmission levels, the Federal Electricity Commission (CFE) charges them charges for both billable demand and net energy consumption, in addition that these types of rates (HS H-SL HT H-TL) are adjusted monthly according to considerations that include the variations in fuel prices, as well as the variation of a producer price index of seven economic divisions [one]. For these cases in particular, the own generation systems based on renewable energies are a very good option to reduce the costs of energy consumption, since in addition to being self-sustaining systems from the economic point of view, they can take advantage of the support government such as that established in article 34, section XIII, of the Income Tax Law, which establishes that up to 100% of fixed assets for machinery and equipment can be deducted for the generation of energy from renewable sources or from systems of efficient electricity cogeneration [2]. In addition to the above, another aspect of great importance associated with this type of systems based on renewable energies is the beneficial environmental impact.On the other hand, a large number of works have been reported on this subject, in which the feasibility is analyzed. of micro-grids based on renewable energies, but generally these are low power industrial installations [3], or residential applications [4]. In general, in this type of analysis, proposed micro-grids are presented based on average generation values, assuming constant all the conditions that affect the operation of the system during the entire useful life period. Likewise, a control strategy is not considered to make the most of the energy generated by the micro-grid. This work shows the operation of a micro-network made up of renewable energy sources, trying to accurately recreate its operation through the use of detailed models of the elements that make it up. In the same way, real measurements are used to estimate the environmental conditions for each day in a twenty-year time horizon. As a case study, the energy consumption of a company located in the city of Salamanca, Gto., Which operates at the H-SL electricity tariff [5], is analyzed. The electrical micro-grid used to reduce electricity consumption is dimensioned to cover the daily energy consumption of the company at peak hours, and the objective of the micro-grid's operational control is focused on determining the optimal operation that allows obtaining the best economic benefit at the end of the useful life of the microgrid.

4.2 MICROGRID OPERATION

Initially, the microgrid proposed for this study had two sources of power generation, photovoltaic panels and wind turbines. The configuration of the system for the initial simulations is illustrated in a general way in Figure below In this figure, the models implemented in Simulink for the main elements are also displayed, noting that in the case of the battery the software model itself was used The operation of the system shown in Figure below can be summarized as follows: - The energy sources of the micro-grid will generate according to the curves of both solar radiation and wind speed, therefore their generation level it won't be constant

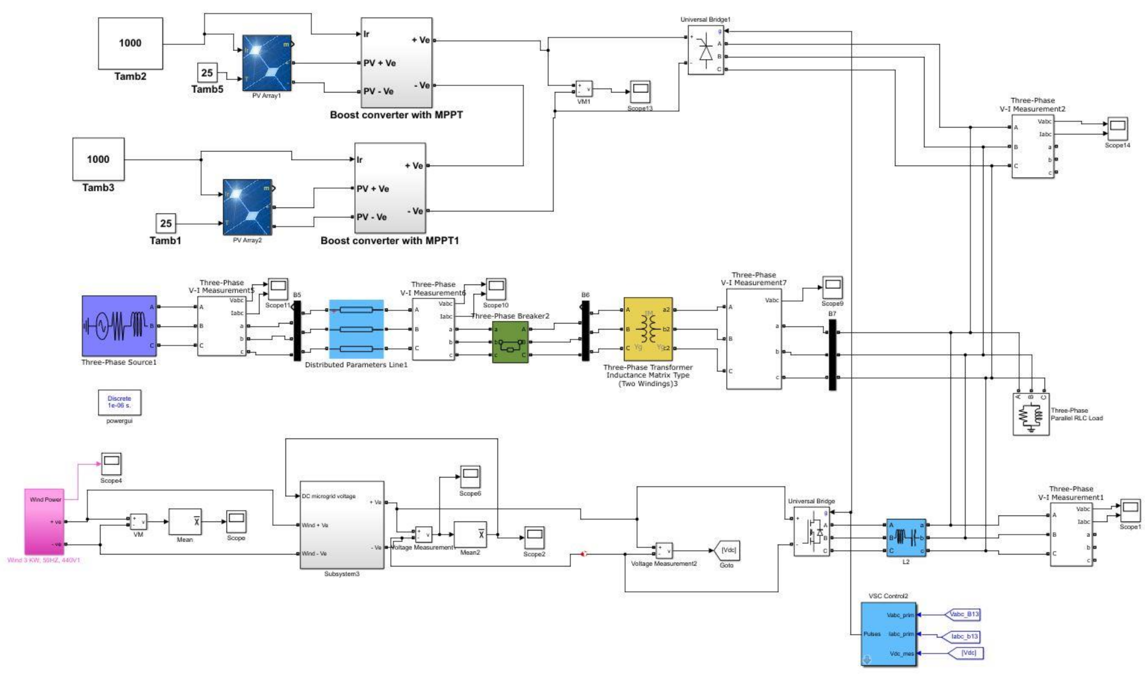

Figure 4.1: Proposed system design [6]

The energy generated may be stored in a storage system based on batteries, whose charge level will be controlled by a regulator. The energy stored during the first hours of generation will be used to feed part of the load at times considered for peak energy according to the corresponding tariff. Similarly, when the batteries are fully charged, the excess energy produced will be injected directly into the load in real time. The control of the micro-grid is very simple and its main function is to control the flow of energy between each of the elements (photovoltaic panels, wind turbine, battery and load) throughout the day, in order to obtain the most economic benefit.

4.3 MICROGID COMPONENTS

4.3.1 Microgrids in direct current

Direct current (DC) systems have been widely used, first converting high levels of transmission voltage to low levels of distribution voltage, which are used to operate different loads in both the residential and industrial sectors [5] On the other hand, direct current (DC) is used in industrial distribution systems to feed highly sensitive electronic loads, in telecommunications infrastructures and point-to-point transmissions for long distances, a scheme is presented in the following figure:

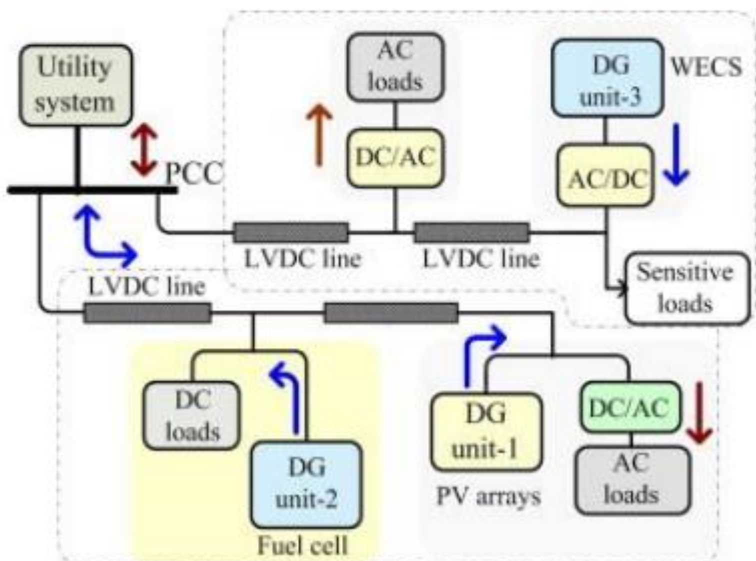

Figure 4.2: Utility system in the smart grid [7]

At present, a large part of electrical loads are controlled or act with power electronics, which require direct current for their operation; that necessarily requires a conversion from AC to DC, which in most cases uses rectifiers that do not have high efficiency In most cases the energy produced by direct current generators must be converted into alternating current to synchronize with the conventional electrical network and this one again in CC for some applications; these conversions involve energy losses [6]. The direct current distribution network increases efficiency in terms of delivering energy to the distribution network and improves energy quality. Although DC networks also present problems such as the synchronization of generators, there are similarly problems in the high starting currents of transformers, motors and generators. Some advantages of the use of DC microgrids are determined such as low losses, the absence of reactive power or power factor correction, the lack of harmonics and it is not necessary to change the conductors in some cases. On the other hand, there are also disadvantages such as the use of more complex protection systems, there are no zero crossing points and higher voltage levels are needed.

4.3.2 Microgrids in alternative current

One of the main characteristics of Alternating Current (AC) microgrids is the direct connection to the conventional electrical network [7]. The main advantage is the direct power supply to the loads, also considering that the coupling of an AC microgrid is less expensive in economic terms since a smaller size of AC-DC converter is required to handle the energy flows between the power supply network and the direct current network, this can be seen in the following figure:

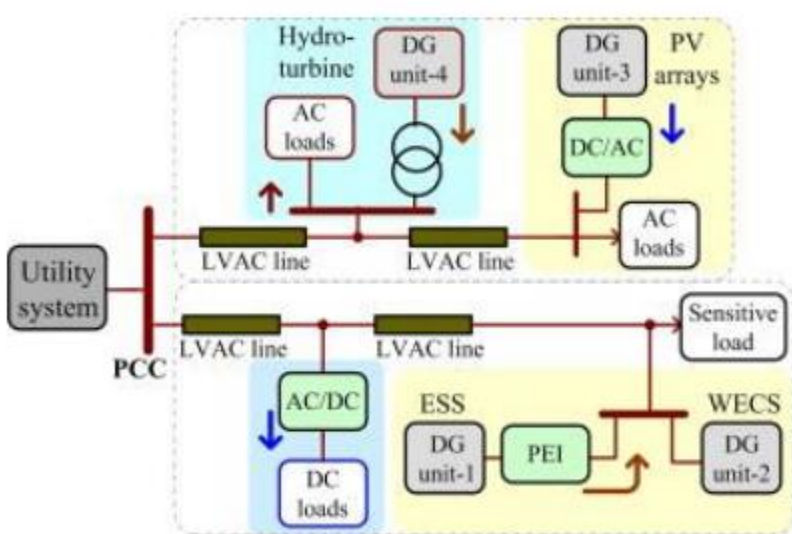

Figure 4.3: AC/DC converters in the system [8]

In general, under normal conditions, the operation of an AC microgrid consists of feeding from local sources if the load power demand is less than the power produced by the microgrid generation units, also considering that excess energy can be exported to the main system.

4.3.3 Integration of Energy Sources in A Microgrid

The different sources that make up a microgrid depend on the necessary power requested by the load, the technology used, environmental impact, and mode of use; In addition, they are not exactly defined since they depend on the location. What is defined is that the generation sources must be as close as possible to the consumer or consumers as the case may be. In these processes, the consumer becomes an energy self-generator, and may or may not be connected to the conventional medium voltage or low voltage electrical network, which in many cases, depending on the regulation of each country, can be poured into the network of distribution the surplus energy generated by these sources. Regarding voltage levels, it is advisable to make low voltage connections in such a way that a greater number of consumers are covered. All the technologies of renewable generation sources can be implemented in the microgrids, always taking into account that the energy supply is safe both in quality and reliability and that the prices are competitive compared to conventional technologies. In the same way, non-renewable energy sources can be implemented that are based on the use of fossil fuels and conventional energy. Among the technologies most used in microgrids are biomass, photovoltaic and wind [1]; highlighting that photovoltaic energy can cover the largest amount of power demanded. Performing a review, it is determined that within the conventional energy sources are cogeneration, gas turbines, internal combustion engines, microturbines. And within renewable energies, mini-hydraulic, photovoltaic, wind, biomass, geothermal and marine technologies are emphasized. [1]

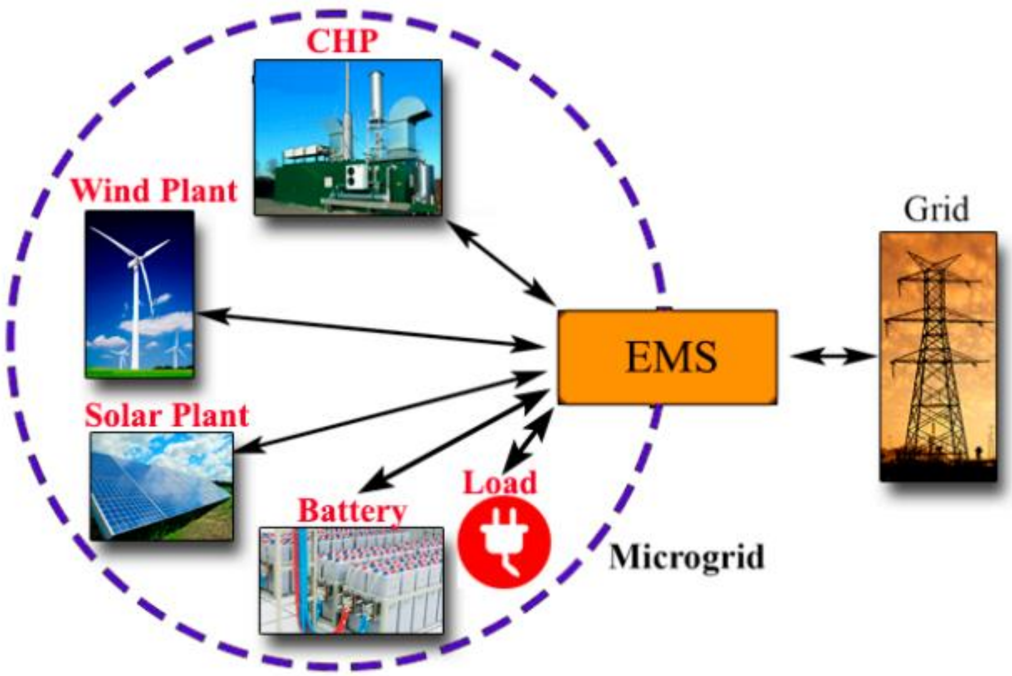

Figure 4.4: Microgrid type smart grid [9]

4.3.4 PV Arrays

Photovoltaic solar energy is the direct conversion of the energy contained in solar radiation into electrical energy, without the production of smoke or noise [1]. Solar radiation hits the earth in the form of photons, which are particles in the form of energy. The conversion is carried out by exposing crystalline semiconductor materials to the sun in which the action of photons produces a difference in electric potential, this is visualized in the following figure:

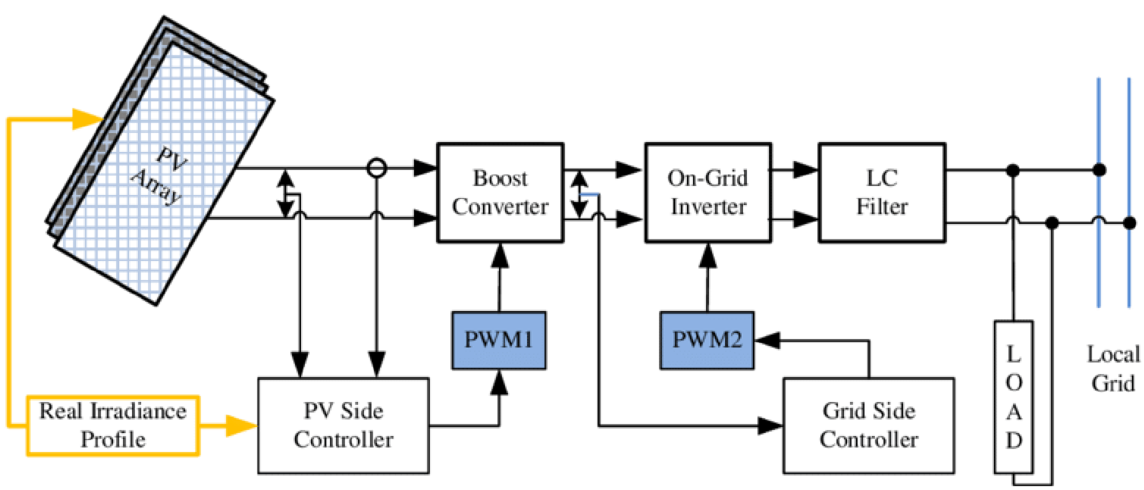

Figure 4.4: PV arrays in microgrid [10]

If a conductor is then connected between the faces of the semiconductor material, the set of electrons will circulate through the conductive wire establishing an electric current which is called photovoltaic solar energy.One of the most conventional applications of photovoltaic solar energy is to provide electrical energy to isolated areas specifically for electrification of homes, pumping systems, road signaling systems, communication systems, etc. As a second option, photovoltaic energy is used for direct injection to the conventional electrical grid, in this case it is large installed power capacities.

In accordance with [9] solar energy has a large number of advantages over other technologies, among the main ones are the following:

a. "The sun's energy is free, indigenous, has no limit and is friendly to the environment, which favors energy self-sufficiency and less dependence on the outside.
b. - It is a technology of modular design, which produces energy at any scale while the cost of the energy generated remains constant, and is flexible or easily extended. - Its handling is simple, and basic maintenance can be carried out locally.
c. - Motivates the development of various sectors.
d. - It presents profitability in rural electrification applications, this compared to conventional generation systems
e. - Maintenance is simple and inexpensive.
f. - Modules of all sizes can be made.

Despite having a large number of advantages, photovoltaic energy also has limitations and disadvantages that are described below:

g. - The energy produced depends on the availability of sunlight.
h. - It requires a storage or back-up system consisting of batteries or the distribution network. - It requires a lot of physical space and produces visual impact.
i. - The amortization period of the investment is long.
j. - Performance is low

The sun is a high-temperature gaseous spherical star of the spectral type G2 that is located in the center of the Solar System and constitutes the largest source of electromagnetic radiation in this planetary system. The sun is made up mainly of helium, carbon, and hydrogen; and solar radiation is not distributed uniformly on the earth since it depends on the distance from the sun to the earth, the time of day, the tilt of the globe and the area of the earth's surface. The earth is characterized by moving around the sun with two types of movements; the rotational movement that occurs around the polar axis which is an imaginary axis that is not perpendicular to the plane of the orbit but is inclined 23 ° 27 'with respect to it. The second movement is that of translation, which consists of the rotation of the earth around the sun and whose period is 365.25 days; what is described is displayed in the following figure:

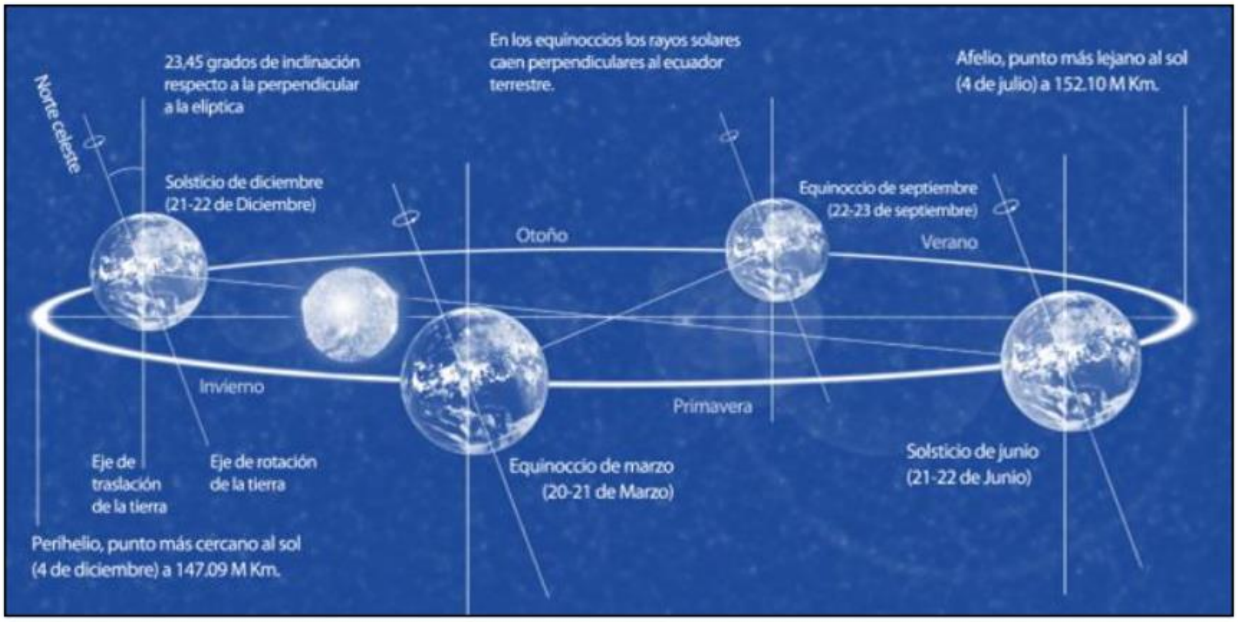

Figure 4.5: Solar cycle [11]

In addition to the movements of the earth, concepts that are important for this work are defined, such as: The line of the apses, which is the axis that joins the aphelion (point furthest from the sun) with the perihelion (point closest to the sun). The solstices, which are the times of the year when the sun reaches its highest or lowest apparent height in the sky, and the duration of the day or night are the maximum of the year. Latitude and longitude are geographic coordinates that are used as a reference system to position any point on the surface of the earth, as shown in figure 6. Latitude expresses the north-south distance from the Equator; it takes absolute values of 0 ° in Ecuador and up to 90 ° at the poles. Longitude expresses the east-west distance from the Greenwich meridian; takes absolute values from 0 ° in Greenwich to 180 °:

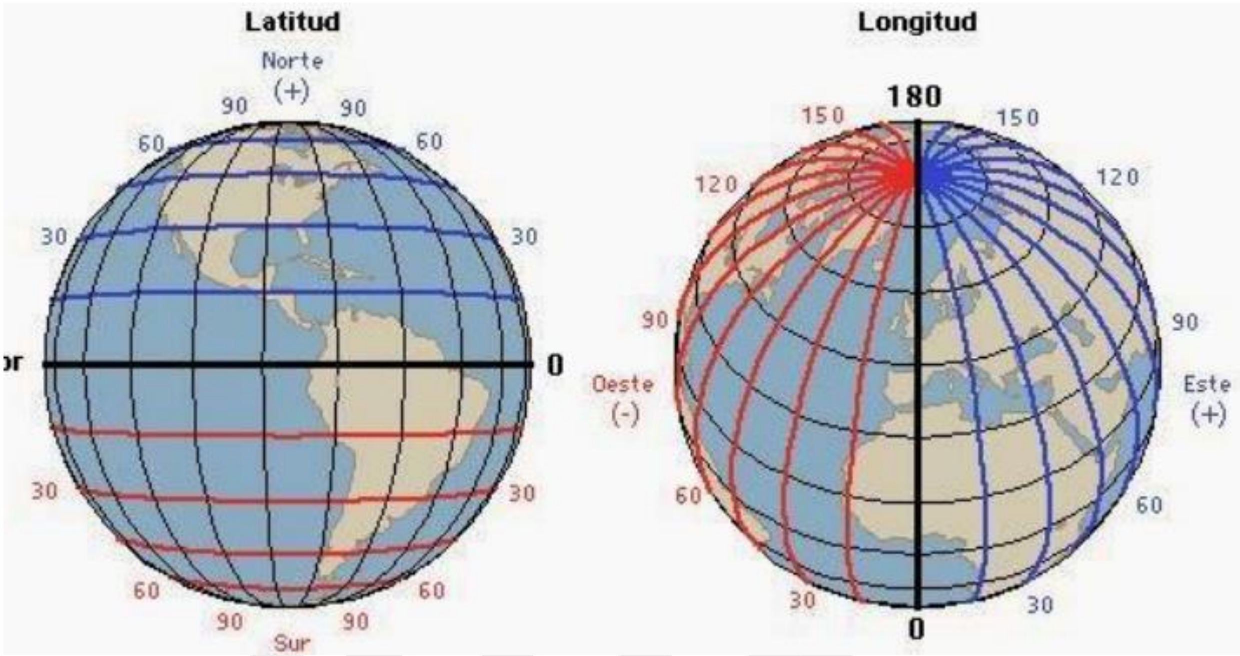

Figure 4.6: Equators in solar cycle [12]

The optimal inclination of the solar panels depends mainly on the latitude where the installation is located. This inclination varies daily throughout the year. In small installations the angle of inclination is fixed or it is changed manually two or four times a year. If the installation of photovoltaic panels is located in the northern hemisphere, then they must be oriented to the southern hemisphere and vice versa. Caution must be exercised with the generation of possible shadows as they can affect the operation of the panels and cause losses; this can be determined by knowing the solar height and azimuth throughout the year. To calculate the minimum distance between the photovoltaic modules, the following expressions are presented, given the following figure:

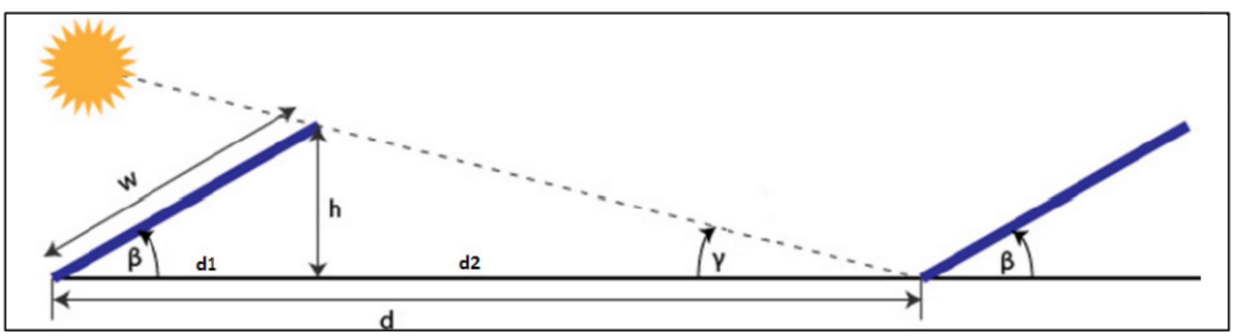

Figure 4.7: Solar irradiance on PV [13]

The calculation of $d1$, $h\ y\ d2$ are given by the following expressions:

$$\gamma = 90 - \delta - L$$

$$d_1 = w * \cos(\beta)$$

$$h = d_1 * \tan(\beta)$$

$$d_2 = \frac{h}{\tan(\gamma)}$$

To take advantage of the radiant energy of the sun, photovoltaic solar panels are used, which are built with semiconductor materials that have certain characteristics, and can be electrically connected in such a way that they produce voltages and currents that can be used in everyday applications. The main component of photovoltaic cells is silicon, which according to the amount used for construction can be divided into three classes. The monocrystalline panel is made of a high purity silicon whose cell has a single crystal; These are easy to recognize due to their uniform color and appearance, and their efficiency ranges between 11% and 16%. The polycrystalline panel is formed by a silicon that is melted raw and placed in square molds causing each crystal to form different crystal lattices; its efficiency is lower than monocrystalline panels since it ranges between 8% and 14%. Another type of photovoltaic panel is the amorphous one in which there is no crystalline lattice but the material is deposited on thin layers that are joined together, as shown in figure the efficiency of this type of panel is between 6% and 8%

Figure 4.8: solar panel in PV [14]

In accordance with [1], when purchasing photovoltaic panels, the following operating parameters must be taken into account: The maximum or peak power, in the voltage-intensity curve (IV), the panel has a maximum power that depends on the peak current Ip and peak voltage Vp. The short-circuit current is the maximum current of the panel and is obtained when the cell contacts its terminals. The open circuit voltage is the maximum voltage that can be obtained in the photovoltaic panel when it has no load connected. Based on the connection or configuration of the photovoltaic modules, it is necessary to bear in mind the following electrical parameters. The short-circuit current Isc, is equal to the product of the short-circuit current of a module and the number of rows connected in parallel. The open circuit voltage Voc is equal to the product of the open circuit voltage of a module and the number of modules connected in series. The maximum power or peak $PMPP$ is the maximum power that the photovoltaic panel can deliver. The voltage at the point of maximum power $VMPP$ is the output voltage of the photovoltaic module at maximum power. The intensity at the point of maximum power $IMPP$ is the current delivered by the photovoltaic module at maximum power.

4.3.5 Grid Inverter

The inverter is one of the most important components and used in electrical microgrids; is responsible for transforming the direct current from the photovoltaic generator into alternating current. The investor's return ranges from 85% to 95%; And they can be of different classes such as isolated, network connection and hybrids; this is visualized in the following figure

When working with inverters it is necessary to bear in mind the following concepts [1]: Nominal voltage is the voltage at which the inverter is electrically powered. The nominal power is the power that the inverter can deliver continuously. The overload capacity is the time that the inverter can deliver more than the nominal power. The performance is the quotient between the output power and the input power of the inverter. The waveform is characterized by being a sinusoidal signal with an effective voltage value and its respective frequency, which depend on the region where the inverter is installed. The inverters connected to the grid can be single-phase or three-phase, in this equipment synchronization plays an important role in the operation of a microgrid. To get the maximum power from the solar panels; An inverter should obtain the maximum possible power from an array, always trying to work in the so-called knee of the IV curve, in addition to having low consumption and responding quickly and accurately to changes in environmental conditions

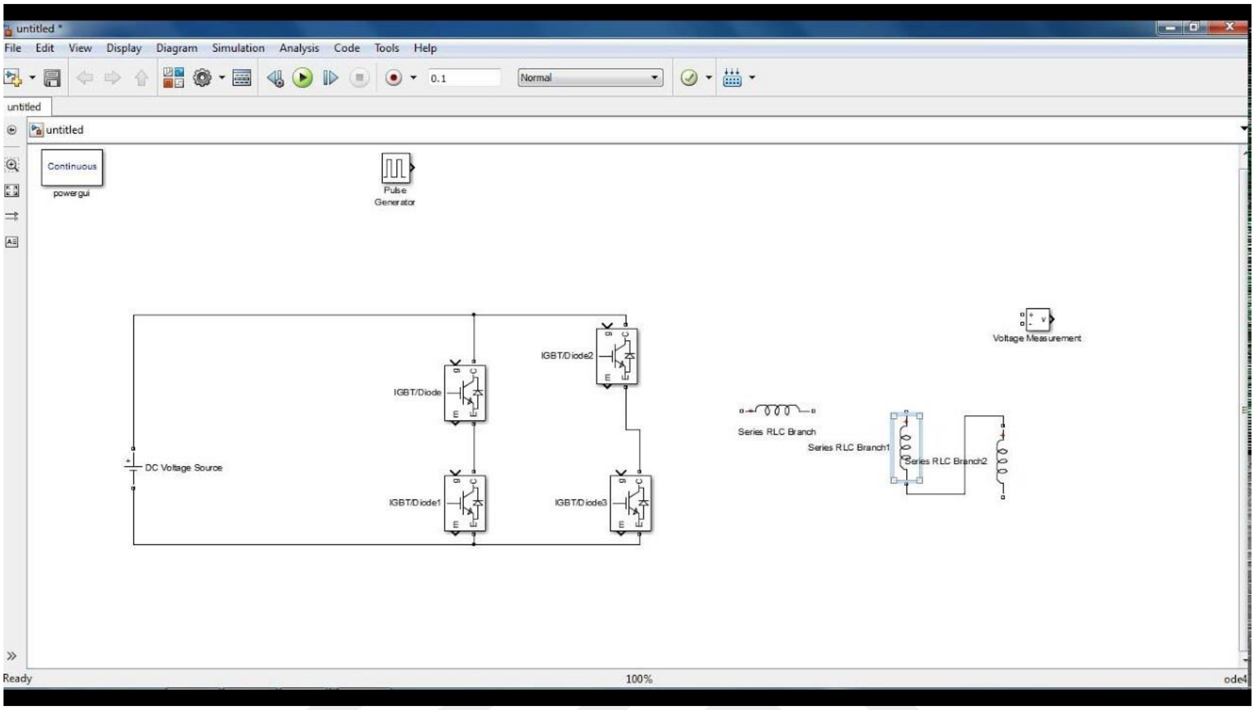

Figure 4.9: Implementation of converters in MATLAB [15]

4.3.6 Batteries

According to [15], "the electric battery is a device that consists of one or more electrochemical cells that have the ability to convert stored chemical energy into electricity. In turn, each cell has a cathode or positive electrode and an anode or negative electrode, it also has electrolytes that facilitate the movement of ions between the electrodes, facilitating the flow of electric current ". In a microgrid, the main function of batteries is to store energy when there is surplus at zero cost and use it when renewable sources whose primary fuel has no cost do not generate enough to cover demand. Differences in battery manufacturing technologies define cost, charge storage capacity, useful life, and size. There are basically two types of batteries; primary batteries have the energy stored in chemical reagents and is released when connected to a load in a single cycle; Secondary batteries are those where the chemical reactions that participate in the conversion of energy are reversible allowing the accumulation and discharge of electricity. The batteries used in microgrids are called secondary as they allow recharging from electrical energy reversing the electrochemical process. Lead acid technology is the most mature, its disadvantages are the limitation in the number of charge and discharge cycles, contamination due to the electrolyte and the low energy density that translates into weight and size so they are not recommended for systems that require mobility or portability. The cost of this technology is low and its efficiency is close to 75%; It is important to take into account the following technical specifications when handling and operating the batteries [13]: The nominal voltage is the voltage per battery element, in the case of lead acid batteries they have 2 V / cup. The discharge capacity is the total amount of charge in ampere hours (Ah) that the battery can supply during a time tN from full charge until reaching the cut-off voltage Vd (1.8 V / glass for lead-acid). This capacity depends on the discharge current and temperature. The nominal capacity is the amount of charge that can be extracted in 20 hours, at a temperature of 20 ° C, until the voltage between terminals reaches 1.8 V / vessel. The discharge or charge regime is the relationship between the nominal capacity of the battery and the value of the current at which the discharge or charge is carried out. With high discharge currents the battery capacity is lower since the internal transformations are more superficial. The life of the battery is defined as the number of cycles that the battery withstands maintaining a residual capacity above 80% of the nominal capacity. The life time decreases when the depth of discharge (DOD) increases and when the working temperature increases. The discharge level (DOD) is defined by the percentage of battery discharge

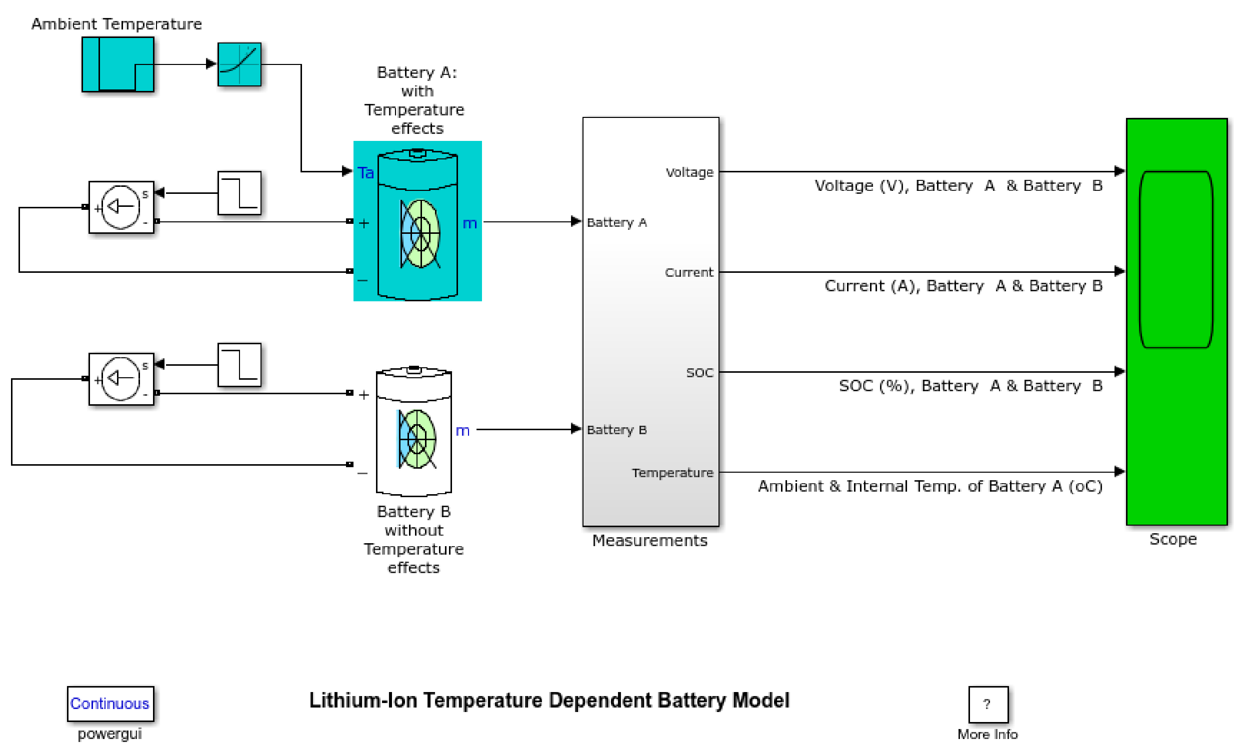

Figure 4.10: Battery system implementation [16]

4.3.7 Wind power

In accordance with [16] "Wind energy is the energy obtained from the wind, that is, the kinetic energy generated by the effect of air currents, and which is transformed into other forms useful for human activities." Since ancient times, wind energy has been used for activities such as moving the sails of ships and moving the blades of mills. “The origin of the wind is in the solar radiation, since the axis of the earth is tilted, the solar radiation is not the same throughout the earth; This produces different temperatures in each area of the planet and therefore, a different density, causing a pressure gradient that produces the movement of air. On a planetary scale, the wind is produced by the difference in temperature between the poles and the Equator; the warmer air rises to the atmosphere and the cold goes down. The rotation of the earth causes that in the northern and southern hemispheres the wind blows to the east above approximately 30 ° latitude and to the west below ”[13]. On a local scale, the wind is influenced by winds or sea breezes that are produced by the temperature difference between the water and the land surface; Mountain winds also intervene due to the difference in temperature between day and night. Currently, wind energy is used to produce electrical energy through wind turbines, in many cases this energy source is cheaper and competitive with conventional energy sources Wind energy is of renewable origin and could be integrated as a source more in a microgrid; In addition, it has more potential in urban areas where the wind speed measurements are higher and there are no obstacles. For wind power generation to be profitable, the wind speed must be capable of generating at least 25-30% of the maximum capacity of an efficient wind turbine in one year. To be able to use the energy of the wind, it is necessary to obtain minimum speeds of 3 m / s (cut in speed) and that do not exceed 25 m / s (cut out speed). Wind power has an advantage over photovoltaic power as it requires less space and can be generated at night, and can be a complement for small consumers

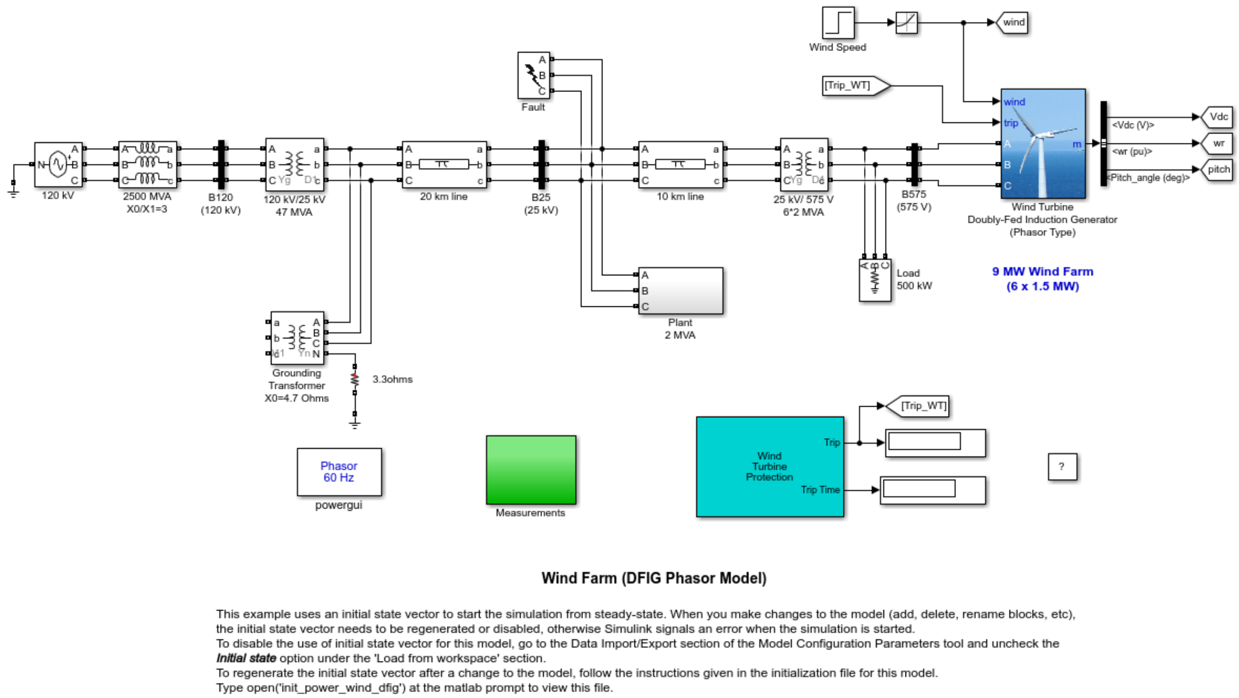

Figure 4.11: Wind turbine implementation [17]

The variation of the wind in a typical location is described using the so-called Weibull distribution. By knowing the distribution of wind speed, it is possible to analytically determine the energy potential and the annual energy that the wind turbine can produce. With this law for a certain location and height, the behavior of the speeds is expressed for an average year or type [19]. The Weibull distribution is found in function of two parameters; the scale factor c and the shape factor k; as shown in the following equation:

$$f(v) = \frac{k}{c} * \left(\frac{v}{c}\right)^{k-1} * e^{-\left(\frac{v}{c}\right)^{k}}$$

k: factor form

c: scale factor $(m\ s)$

v: air velocity $(m\ s)$

4.4 GENETIC ALGORITHM

4.4.1 Definition

It is a mathematical model with origin in biology, which takes a population of solutions and applies an aptitude test on it that judges its performance and is disturbed by means of genetic operators, it is an evolutionary process, to generate a new population, a process that is repeated until a generation is very close to the optimum

4.4.2 Applications

One of the areas in which genetic algorithms perform quite well is in optimization. A Genetic Algorithm (GA.) is very robust, this means that it works with a wide range of problems. When comparing the more traditional optimization algorithms, the biggest differences are:

a. Genetic algorithms work with a coded version of the parameters;
b. They do not search from a single point, but from a population of points;
c. They use results information instead of derivatives or other ancillary knowledge;
d. They use stochastic reproduction instead of deterministic rules. Many problems can be seen as optimization problems. computer aided Design (CAD), financial forecasting, production schedules, oil exploration, robot control, in combination with neural networks and of course in the field of logistics

4.4.3 Problem

Optimization problems are mathematically formulated models with many independent parameters that result in a function called fitness. This fitness function describes the quality of the model (or individual) for the set of parameters. All kinds of conflicting demands can be modeled in the fitness function [11]. In general, a function is defined as: f (x 1, x2, x3, ..., xn) Where x I, x2, x3, ..., xn are the independent parameters that need to be determined. If you want to use a genetic algorithm you need to make sure that this function is always greater than zero.

4.4.4 Elements

Based on natural selection, the following are considered: • The algorithm operates on a population of individuals.

a. Each individual is a potential solution to the given problem.
b. After an initial randomly generated population, the algorithm evolves using three operators:
   a) The selection that is equal to the survival of the elite strategy. The key is the preference of the best individuals (elite strategy), allowing their genes to be passed on to the next generation. The performance of each individual depends on her aptitude that can be determined by an objective function or by a subjective judgment.

b) The crossover that represents the mix between individuals. Of two individuals chosen from the elite population, in a randomly chosen link within their bit strings a cut is made, the values of the two strings are exchanged up to this point, for example: S 1 = 000000 and S2 = 111111 and the crossover point is 2, so: S1 '= 110000 yS2'. 001111

c) The mutation that introduces random modifications. With a low probability, a group of the new individuals will have some of their bits altered, their purpose is to maintain diversity within the population and inhibit premature convergence

d) Species or Individual: The solution to the problem of sequences is given by a vector composed of parameters or segments, in this case the species will not be of a binary nature but of a floating type and the segments to work are 2:

The first one that represents the types of vehicles to be used, the second, which shows the order of visit to the different depots or destinations.

c. Population: In keeping with the aforementioned theorists, on the convenience of relatively large populations [12], we work with a population of 100 individuals.

d. The fitness function: It is a transportation cost function that involves components given by the cost of activating the vehicles, the cost from the load to be transported per distance traveled and a penalty cost when restrictions are violated.

e. Restrictions: Each vehicle has a capacity in volume and weight, which cannot be exceeded, additionally, each tank must reach the exact amount of its demands or requirements;

Penalty Function: Every time one or more of the restrictions is violated by the species, the value of the fitness function takes a value corresponding to K * 10 d. Where K is the value of the sum of activating all the vehicles, plus the value of traveling all the distances multiplied by the sum of the loads to be transported, d is an expansion constant and it is recommended that it be the value of the number of digits of the largest amount. The Selection or Survival of the Elite is guaranteed through the generation of a cost function, which is ordered in ascending order. This species is made up of two floating point vectors, the first determines the visited node and the second the means of transport used. If it is not a feasible species, it is penalized with a value such as that already described. To select the species to be crossed, we work with the elite, that is, the 30 best solutions that are crossed in the next phase to generate another 60 solutions.

The crossover that represents the mixture between individuals is carried out by linking the two constitutive segments of the species, that is, the types of vehicles to be used in their order and the depots to visit in a specific order. Then, a segment of deposits to visit of the first species is combined with a segment of vehicles to be used of the second species; its cost is generated as in the previous point. The two new children created from this mix are placed in the next generation of the population. - The random mutation or modification is generated as in the first solution, that is, through the generation of random variables and which is explained later. - The stopping criterion allows determining the convergence of the solution, but it must take care that this solution (local optimum) is not at a value far from the global optimum, for this the system must be disturbed in such a way that the above is fulfilled This can be done by changing the structure of the elite and the crossover.

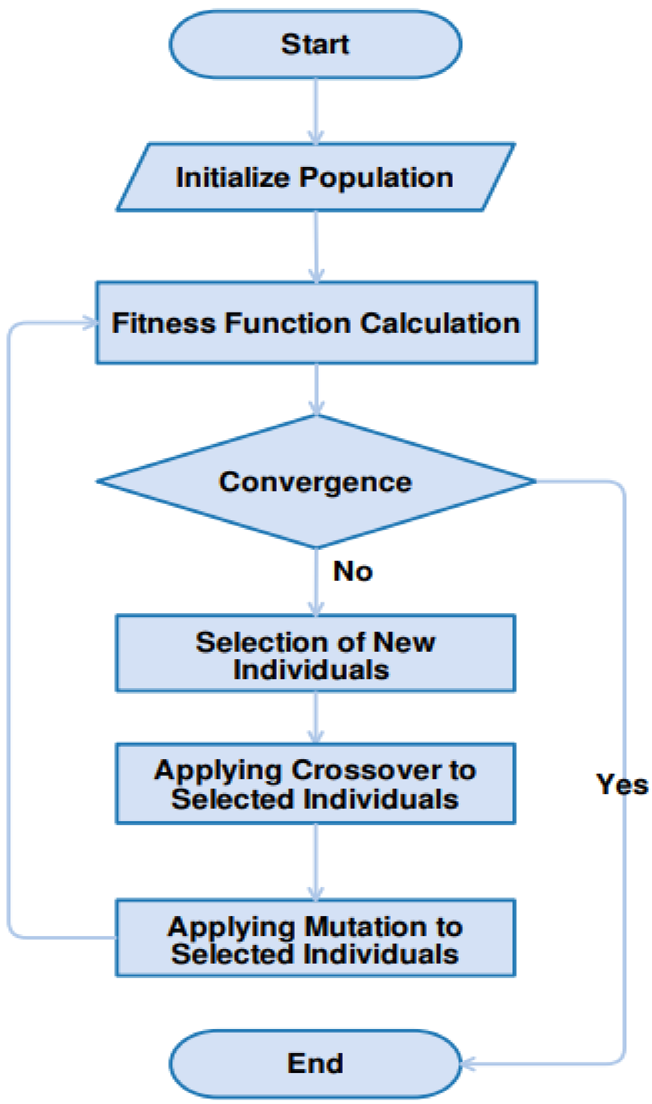

Figure 4.12: Proposed system [18]

5. SIMULATION AND RESULTS

The image of the final population through the vector of objective functions $F\ (\vec{P})$ is called the Pareto frontier. An example of a Pareto frontier can be seen in figure 8; the abscissa axis corresponds to economic costs and the ordinate axis corresponds to the amount of emissions. All points on the boundary represent non-dominated solutions, so it is not trivial to distinguish which solution is better than another. Therefore, higher-level considerations are required, through the decision maker DM, to choose a solution. For each of the 24:

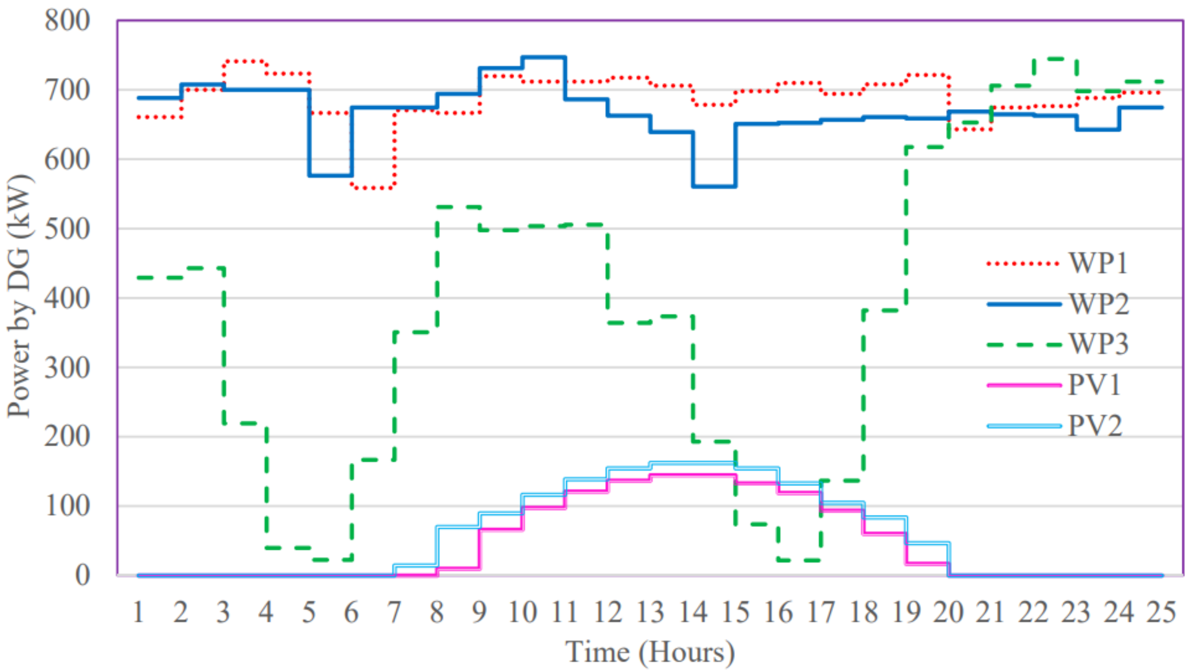

Figure 5.1: Electrical load profile PL and power in AEDG technologies evaluated over 24 hours[19]

hours of operation of the microgrid, a set of solutions was generated like the one in the figure Pareto frontier example of the GA optimization algorithm obtained in a microgrid, operating with connection to the main network Population = 100, Iterations = 400

Given that the microgrid can interact with the main electrical network, making exchanges of the electrical resource, this section makes a comparison of economic costs and environmental emissions between the management strategy carried out by GA and a strategy for the total importation of energy, where there is no contribution from DER generators. The results of economic costs obtained under the MOGA strategy, including the DM, are compared with the costs generated by the total import strategy; This comparison is observed

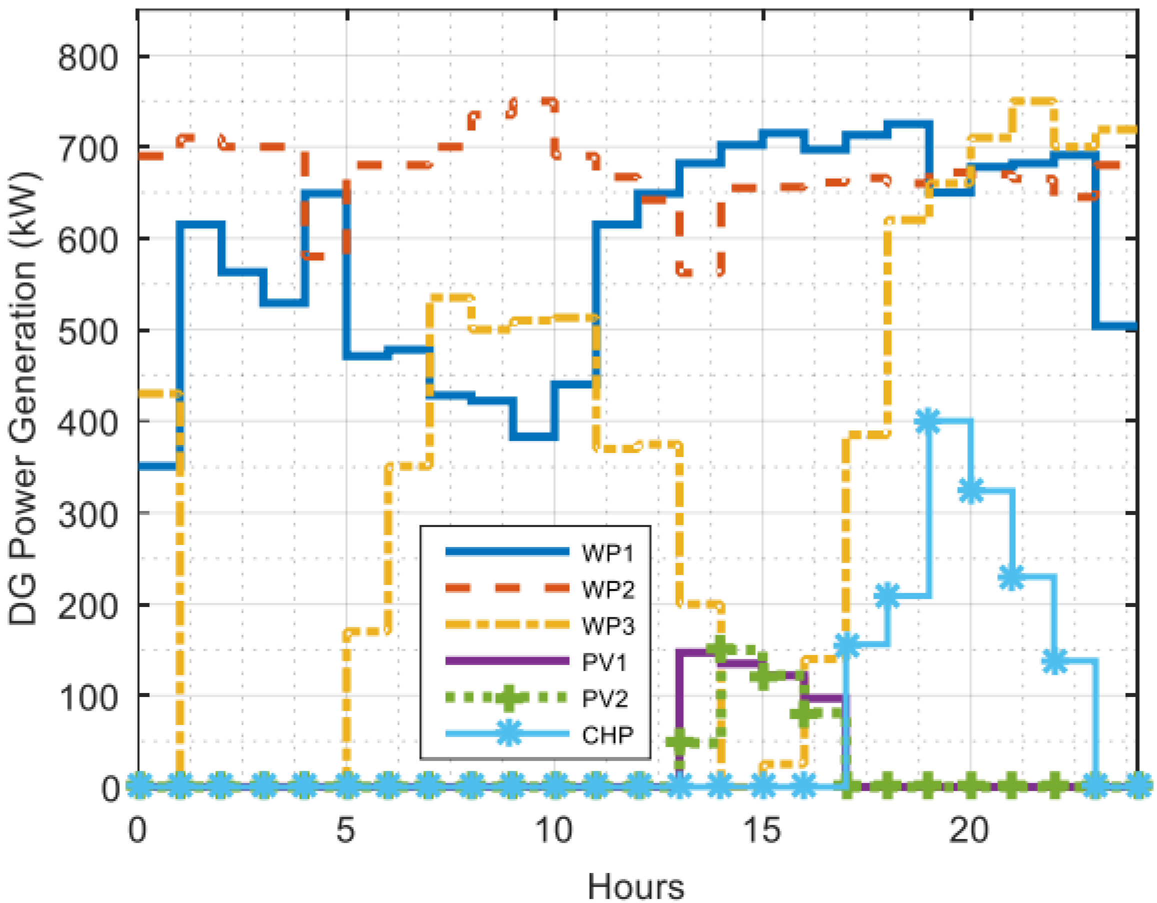

Figure 5.2: Optimized electricity consumption in 20 hrs. [20]

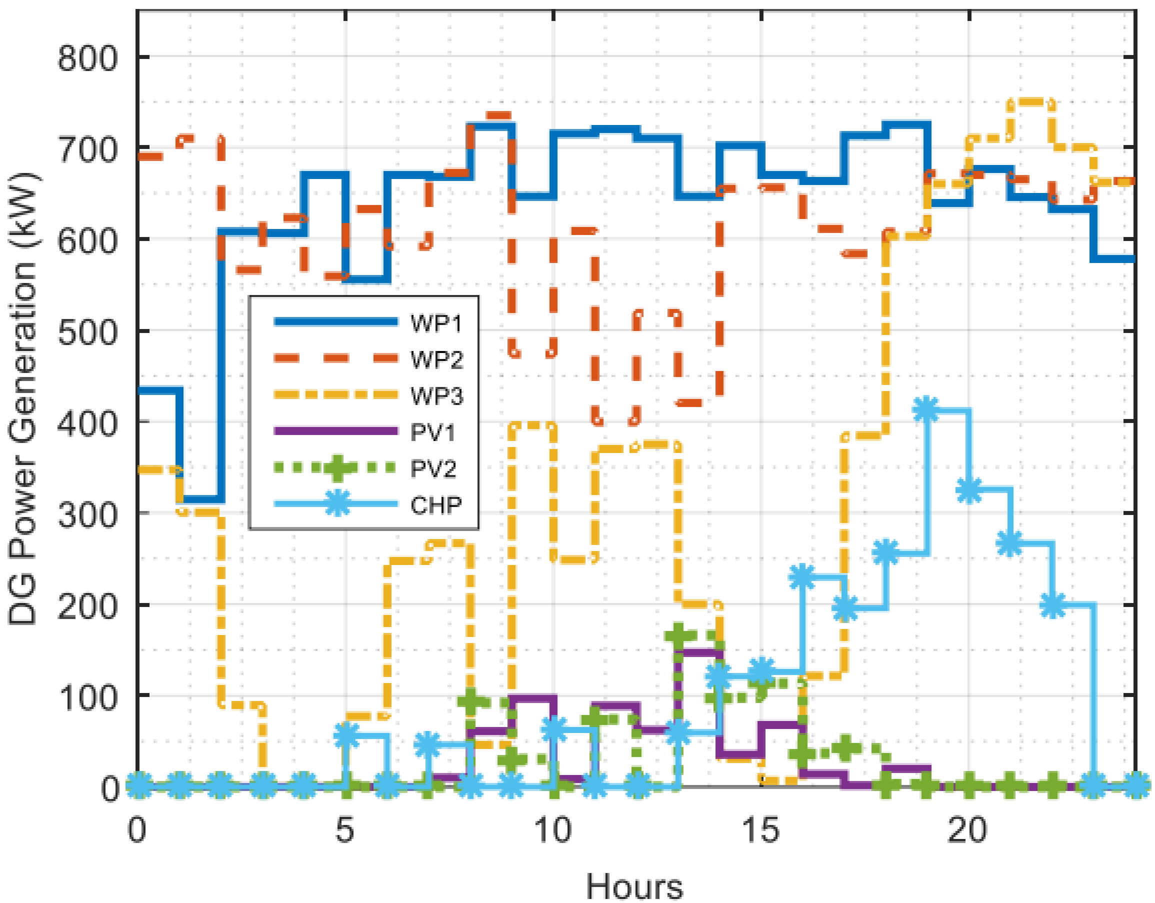

Figure 5.3: Optimized electricity consumption in another 20 hrs. [21]

Note how there is a significant cost reduction when implementing the GA strategy. Compared to the total import strategy, this reduction in percentage terms is 51.7%, for the 24 hours of operation The reduction in the amount of polluting gas emissions between the total import strategy and the GA strategy is quite noticeable, as can be seen in figure Here, the emission curve of the import strategy shows a fairly high trend in the peak hours, where the relationship between demand and emissions exhibits exponential behavior.

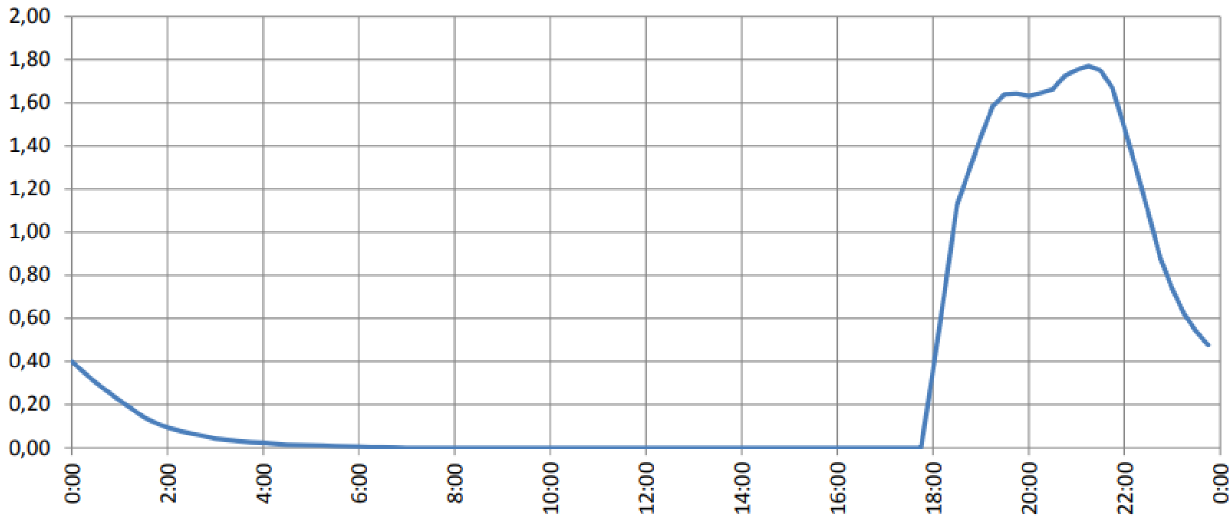

Figure 5.4: Energy optimization using GA [22]

The energy participation graph shown in the bar diagram of figure above shows how the GA optimization strategy offers a trend towards the use of the least polluting and cheaper DER technologies - this is the case of the microturbines (MT01 and MT02) and fuel cells (FC01, FC02 and FC03) -, while reducing the participation of the most polluting technologies such as diesel (DG01 and DG02) and biodiesel (BG01, BG02 and BG03). In addition, the DS system has been charged almost four times to its maximum capacity (as indicated by the negative sign) during the 24 hours of operation.

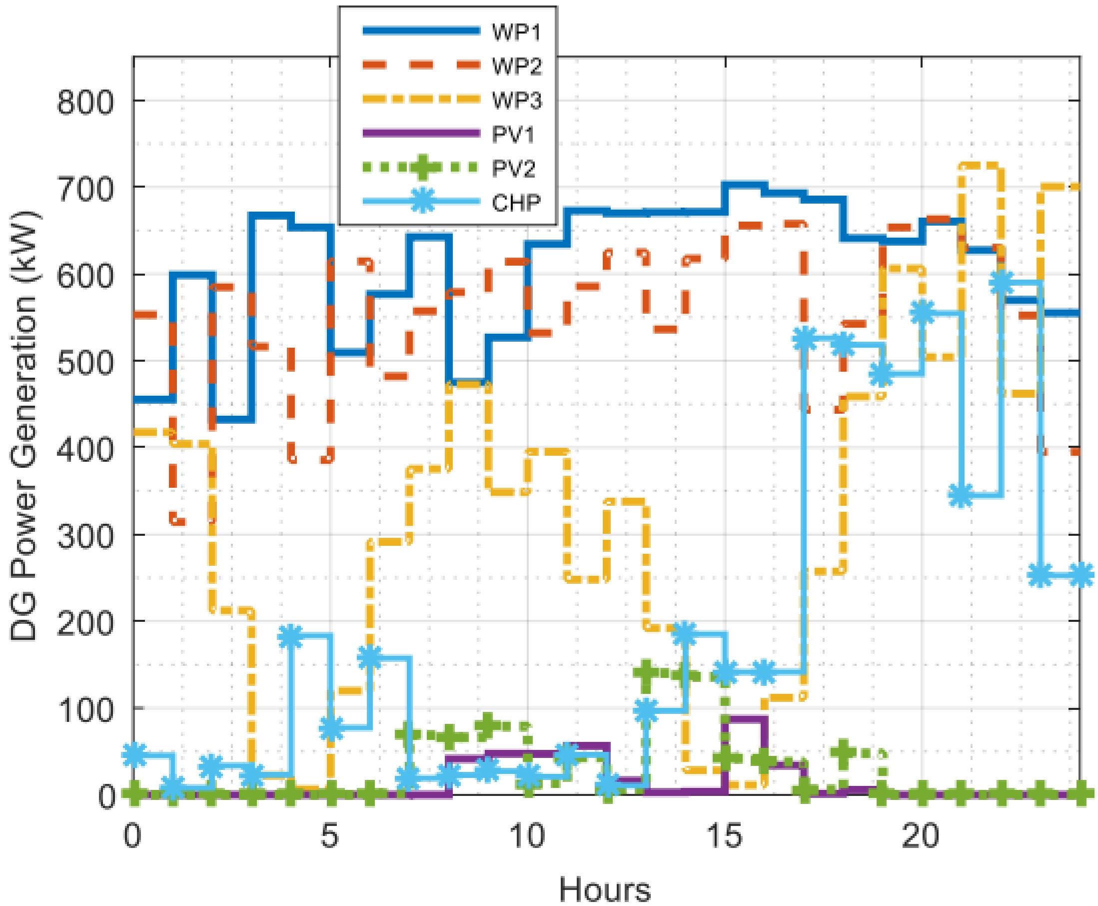

Figure 5.5: Optimized electricity consumption in 20 hrs. using GA [23]

To forecast future demand, a growth projection of the base scenario has been made with the growth data of the CNEL Guayaquil concession area. This approach has been taken due to the lack of higher quality information on the specific growth of the area. The specific growth of the area by types of consumers has been calculated, obtaining 0.19% for residential consumers and 0.93% for commercial consumers. On the other hand, an expansive growth of 9.77% was obtained derived from the value obtained for the concession area, and considering that the growth of the pilot area will decrease over time due to the saturation of the buildable space:

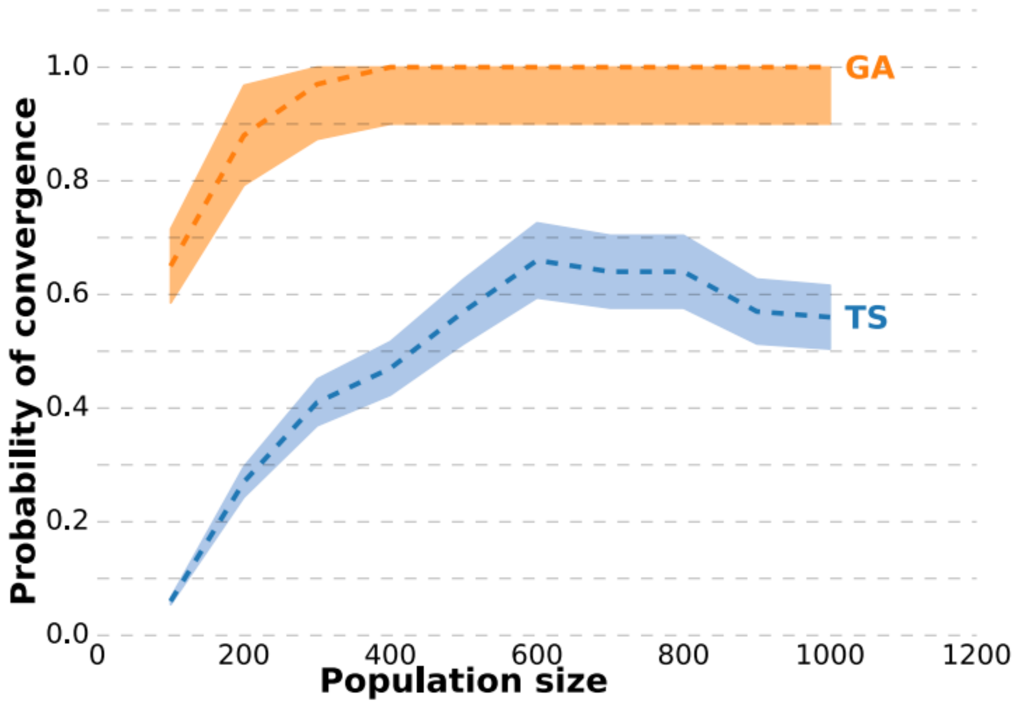

Figure 5.6: GA accuracy [24]

In order to evaluate the efficiency of our model we must monitor the performance of the grid in multiple cases, one case being the performance in normal conditions where all the loads receive power and all the source work normally, and another case where there are faults and errors in a source or a load demand or both, the figure below figure 9 shows the stability of the voltage flow in the busses

As seen in the figure 9 above, the stability is volatile in the first stage of the power generation, because all the sources generate power at once and all the loads demand power, but when the fuzzy logic respond to that generation/demand, the controller achieved voltage stability, the figure 10 below further shows the stability of the voltage in a bus:

Lets take the other case where one power source fails to generate power yielding a gap in the power generation and the voltage stability, lets take for example a fail in the fuel generator, the fuzzy logic control acts fast and increase the power acquired from the solar PV array battery to compensate for the gap, the figure below figure 11 shows the voltage flow as it drops in the fossil fuel generator bus in the first yellow line , and increase in the battery bus in the middle yellow line, while the last yellow line shows the stability in the load demand bus, we can see that it was not effected by power fluctuation thus proving the effectiveness of our model.

6.CONCLUSION

A contextualized strategy was presented for the optimal management of electrical power in a microgrid, seeking the best economic and ecological solution available, while meeting the energy demand requirements. The experience emphasizes the use of innovative techniques to solve the problem of power management in microgrids. In this case, GA was presented as a possible candidate to support the solution. Likewise, a microgrid model is presented with all its characterization parameters, in order to facilitate the comparison of the performance of similar techniques. The GA strategy produced a significant reduction in costs and emissions, compared to a strategy of total import of energy from the main grid. This cost reduction in percentage terms was approximately 51% for the 24 hours of operation. As for the reduction in emissions, it was quite noticeable, approximately 96%. This highlights that the strategy favors the use of less polluting and costly DER technologies, within the available mix of GD. The simulations carried out are a first approximation to the operation of a microgrid energy management system that contains DER, AEDG and electrical energy storage sources, as well as a complementary supply from the main electrical network. From the above, it can be concluded that it is possible to have an energy manager based on IC techniques, which determines an optimal functioning of a microgrid. This methodology could be applied in the same way in other types of systems

7.REFERENCES

[1] D. Layden and B. Jeyasurya. Integrating security constraints in optimal power flow studies. In Power Engineering Society General Meeting, 2004. IEEE, pages 125–129, June 2004.

[2] F. Lee. Short-term unit commitment - a new method. Power Systems, IEEE Transactions on, 3:421–428, 1988.

[3] F. Lee. The application of commitment utilization factor (CUF) to thermal unit commitment. Power Systems, IEEE Transactions on, 6:691–698, 1991.

[4] F. Lee and Q. Feng. Multi-area unit commitment. Power Systems, IEEE Transactions on, 7:591–599, 1992.

[5] Hyung Do Lee, Sung Soo Moon, Suk Jung Yong, and Hee Yong Youn. Reducing response time with dynamic load balancing and agent pool in multiagent system. In Computational Science and Engineering (CSE), 2011 IEEE 14th International Conference on, pages 503–510, Aug 2011.

[6] H. Li, G.W. Rosenwald, J. Jung, and Chen-Ching Liu. Strategic power infrastructure defense. Proceedings of the IEEE, 93(5):918–933, May 2005.

[7] Yuan Li and J.D. McCalley. A general benders decomposition structure for power system decision problems. In Electro/Information Technology, 2008. EIT 2008. IEEE International Conference on, pages 72–77, May 2008.

[8] J. Licheng, R. Kumar, and N. Elia. Model predictive control-based real-time power system protection schemes. Power Systems, IEEE Transactions on, 25:988–998, 2010.

[9] Jiaomin Liu, Yi Sun, and Haibo Li. The research of real-time database technique used in power system dispatcher training simulator. In Innovative Computing Information and Control, 2008. ICICIC ’08. 3rd International Conference on, pages 9–9, June 2008.

[10] K. Liu, S. Subbarayan, R. Shoults, M. Manry, C. Kwan, L. lewis, and J.Nac- ˜ carino. Comparison of very short term load forecasting techniques. power systems, IEEE Transactions on, 11(2):877–882, 1996. 302 Bibliograf´ıa

[11] P. Lowery. Generating unit commitment by dynamic programming. Power Apparatus and Systems, IEEE Transactions on, 5:422–426, 1996.

[12] Khosrow M. and Ranjit K. Una visi´on de red el´ectrica autocorrectora. Revista ABB, 4:21–25, 2006. [88] C. Macal and M.North. Tutorial on agent-based modelling and simulation. ˜ Journal of Simulation, 4:151–162, 2010.

[13] F. Maghsoodlou, R. Masiello, and T. Ray. Energy management systems. IEEE Power and Energy Magazine, 2:49–57, 2004.

[14] D. Marihart. Communications technology guidelines for EMS SCADA systems. Power Delivery, IEEE Transactions on, 16:181–188, 2001.Marija and W. Felix. Research and applications on real-time control of power grids: Past successes and future opportunities. In Bulk Power System Dynamics and Control, Cortina d'Ampezzo, Italy, 2004.

[15] C. Mart´ınez, H. Huang, and R. Guttromson. Archiving and management of power systems data for real-time performance monitoring platform. Technical Report PNNL-15036, Consortium of Electric Reliability Technology Solutions, 2005.

[16] S. McArthur, E. Davidson, V. Catterson, A. Dimeas, N. Hatziargyriou, and T. Sarosh. Multi-agent organizations for real-time operations. Proceedings of the IEEE, 80:765 – 778, 1992.

[17] S.D.J. McArthur, E.M. Davidson, V.M. Catterson, A.L. Dimeas, N.D. Hatziargyriou, F. Ponci, and T. Funabashi. Multi agent systems for power engineering applications - part I: Concepts, approaches, and technical challenges. Power Systems, IEEE Transactions on, 22:1743–1752, 2007.

[18] S.D.J. McArthur, E.M. Davidson, V.M. Catterson, A.L. Dimeas, N.D. Hatziargyriou, F. Ponci, and T. Funabashi. Multi-agent systems for power engineering applications - part II: Technologies, standards, and tools for building multi-agent systems. Power Systems, IEEE Transactions on, 22:1753–1759, 2007. Bibliograf´ıa 303

[19] S.D.J McArthur, E.M Davidson, J.A Hossack, and J.R McDonald. Automating power system fault diagnosis through multi-agent system technology. In Proceedings of the 37th Annual Hawaii International Conference on System Sciences, 2004, Jan 2004.

[20] B. Meliopoulos and S. Fardanesh. Power system state estimation: Modeling error effects and impact on system operation. EEE Transactions Power App. Syst, 11:939–946, 1996.

[21] Merlin and P. Sandrin. A new method for unit commitment at electricit´e de france. Power Apparatus and Systems, IEEE Transactions on, 5:1218–1225, 1993.

[22] Ding Ming, Xie Tian, and Wang Lei. Research of real-time database system for microgrid. In Power Electronics for Distributed Generation Systems (PEDG), 2010 2nd IEEE International Symposium on, pages 708–712, June 2010.

[23] M. Moghavvemi and M. Faruque. Power system security and voltage collapse: a line outage based indicator for prediction. International Journal of Electrical Power & Energy Systems, 21:455–461, 1999.

[24] I.S. Moghram and S. Rahman. Analysis and evaluation of five shortterm load forecasting techniques. Power Systems, IEEE Transactions on, 4(4):1484–1491, Nov 1989.

[25] S. Mokhtari, J. Singh, and B. Wollenberg. A unit commitment expert system. Power Systems, IEEE Transactions on, 3:272–277, 1988.

[26] K. Moslehi, A.B.R. Kumar, D. Shurtleff, M. Laufenberg, A. Bose, and P. Hirsch. Framework for a self-healing power grid. In Power Engineering Society General Meeting, 2005. IEEE, June 2005.

[27] T.Nagata and H. Sasaki. A multi-agent approach to power system restora- ˜ tion. Power Systems, IEEE Transactions on, 17(2):457–462, May 2002.

[28] J.Nasser, S. Louis, D. Ewart, and L. Fink. Understanding automatic gener- ˜ ation control. Power Systems, IEEE Transactions on, 7:1106 –1122, 1992. 304 Bibliograf´ıa

[29] M.North, V. Conzelmann, C. Koritarov, and P. Macal. E-laboratories: agent ˜ based modelling of electricity markets. In American Power Conference, Chigaco, 2002.

[30] N.Noy and D. McGuinness. Ontology development 101: A guide to creating ˜ your first ontology. Technical Report KSL-01-05 / SMI-2001-0880, Stanford Knowledge Systems Laboratory and Stanford Medical Informatics, 2001.

[31] D. Obioma and A. Izuchukwu. Comparative analysis of techniques for economic dispatch of generated power with modified lambda-iteration method. In IEEE International Conference on Emerging & Sustainable Technologies for Power & ICT in a Developing Society, 2013.

[32] Advisory Council of the European Technology Platform (ETP) for Europe's Electricity Networks of the Future. Strategic deployment document for europe electricity networks of the future. http://www.smartgrids.eu/documents/SmartGrids SDD FINAL APRIL2010.pdf.

[33] Oracle. Mysql 5.0 reference manual. http://dev.mysql.com/doc/refman/5.0/en/. [111] Z. Ouyang and S. Shahidehpour. A hybrid artificial neural-dynamic programming approach to unit commitment. Power Systems, IEEE Transactions, 7:236–242, 1992.

[34] S. Padr´on. Estudio del impacto en el sistema el´ectrico de la implantaci´on de una central hidroel´ectrica de bombeo en la isla de gran canaria. Master's thesis, Escuela T´ecnica Superior de Ingenieros Industriales, University of Las Palmas de Gran Canaria, 2010.

[35] S. Padr´on. Estudio sobre la gesti´on inteligente de la generaci´on en sistemas electricos de potencia aislados para minimizar los deslastres por subfrecuencia. Master's thesis, University Institute SIANI, Universidad de Las Palmas de Gran Canaria, 2011. Bibliograf´ıa 305

[36] P. Pai and W. Hong. Forecasting regional electricity load based on recurrent support vector machines with genetic algorithms. Electric Power Systems Research, 74:417–425, 2005.

[37] R. Palma Behnke. Los Sistemas El´ectricos De Potencia. Pearson, Prentice Hall, 2008. [116] S. Panta and S. Premrudeepreechacharn. Economic dispatch for power generation using artificial neural network icpe-07 conference in daegu, korea. In Power Electronics, 2007. ICPE '07. 7th Internatonal Conference on, pages 558–562, Oct 2007.

[38] H. Pinto, F. Magnago, S. Brignone, O. Alsac, and B. Stott. Security constrained unit commitment: Network modeling and solution issues. In Power Systems Conference and Exposition, 2006. PSCE '06. 2006 IEEE PES, pages 1759–1766, Oct 2006.

[39] M. Pipattanasomporn, H. Feroze, and S. Rahman. Multi-agent systems in a distributed smart grid: Design and implementation. In Power Systems Conference and Exposition, 2009. PSCE '09. IEEE/PES, pages 1–8, March 2009.

[40] R. Podmore and M. Robinson. The role of simulators for smart grid development. Smart grid, IEEE transactions on, 1:150–158, 2010

[41] Y. Pradeep, K. Shrikrishna, and R. Joshi. High level event ontology for multiarea power system. Smart grid, IEEE transactions on, 3:193–202, 2012.

[42] Ma Qian, Guo Jinzhi, and Yang Yihan. An ontology for power system operation analysis. In Electric Utility Deregulation, Restructuring and Power Technologies, 2004. (DRPT 2004). Proceedings of the 2004 IEEE International Conference on, volume 2, pages 597–601 Vol.2, April 2004.

[43] S. Rahimi, T.Niknam, and F. Fallahi. A new approach based on benders de- ˜ composition for unit commitment. World Applied Science Journal, 6:1665– 1672, 2009. 306 Bibliograf´ıa

[44] S.J. Ranade, M. Uraguchi, and P. Tan. An expert system prototype for secure operation guidelines for electric power system line-overloads. In Proceedings of the 5th IEEE International Symposium on Intelligent Control, pages 1127–1132 vol.2, Sep 1990.

[45] Rao and M. Georgeff. BDI agents: From theory to practice. In Proceedings of the First International Conference on Multiagent Systems (ICMAS-95), 1995.

[46] Rehtanz. Autonomous Systems and Intelligent Agents in Power System Control and Operation. Springer, 2003

[47] J. Rong-Mow and C.Nanming. Application of the fast newton-raphson eco- ˜ nomic dispatch and reactive power/voltage dispatch by sensitivity factors to optimal power flow. Energy Conversion, IEEE Transactions on, 10:293–301, 1995.

[48] D. Ruiz-Vega, M. Glavic, and D. Ernst. Transient stability emergency control combining open-loop closed-loop techniques. In Proceedings of IEEE PES 2003 Summer Meeting, Toronto, Canada, 2002.

[49] S. Russell and P.Norvig. ˜ Inteligencia Artificial. Un enfoque moderno. Prentice-Hall, 1996.

[50] Saboya. An´alisis de planes de deslastre de cargas en sistemas el´ectricos aislados. Master’s thesis, ICAI - Universidad Pontificia Comillas, 2010.

[51] T. Sakaguchi and K. Matsumoto. Development of a knowledge based system for power system restoration. Power Apparatus and Systems, IEEE Transactions on, 102:320–329, 1983.

[52] Saleem and M. Lind. Requirement analysis for autonomous systems and intelligent agents in future danish electric power systems. International Journal of Engineering, Science and Technology, 2:60–68, 2010.

[53] Saleem, M. Lind, and S. Singh. Modeling control situations in power system operations. In International Conference on Autonomous and Intelligent Systems, AIS, Povoa de Varzim, Portugal, 2010. Bibliograf´ıa 307

[54] P. Samadi, H. Mohsenian-Rad, R. Schober, and V.W.S. Wong. Advanced demand side management for the future smart grid using mechanism design. Smart Grid, IEEE Transactions on, 3:1170–1189, 2012.

[55] H. Sasaki, N. Yorino, and R. Yokoyama. An expert system for power system security control. In IEEE Power Industry Computer Application Conference, 1989.

[56] T. Senjyu, H. Takara, K. Uezato, and T. Funabashi. One-hour-ahead load forecasting using neural network. Power Systems, IEEE Transactions on, 17:113 – 118, 2002.

[57] S. Sivasubramani and Swarup K. Multiagent based particle swarm optimization approach to economic dispatch with security constraints. In Third International Conference on Power Systems, Kharagpur, INDIA, 2009.

[58] H. Steinherz, C. Pedreira, and R. Souza. Neural networks for short-term load forecasting: A review and evaluation. Power Systems, IEEE Transactions on, 16:44–55, 2001.

[59] K.K. Swarnkar, S. Wadhwani, and A.K. Wadhwani. Optimal power flow of large distribution system solution for combined economic emission dispatch problem using partical swarm optimization. In Power Systems, 2009. ICPS ’09. International Conference on, pages 1–5, Dec 2009.

[60] S. Tam. Real-time security-constrained economic dispatch and commitment in the pjm : Experiences and challenges. In PJM Interconnection, 2011.

[61] L. Tan and M.Negnevitsky. Expert system application for voltage and var ˜ control in power transmission and distribution systems. In IEEE Transmission and Distribution Conference, 1996.

[62] Taylor. Response-based, feedforward wide-area control. In Elect. Power Res. Inst. Sponsored Workshop on Future Research Directions for Complex Interactive Networks, Washington DC, USA, 2002

[63] J. Taylor, L. de Menezes, and P. McSharry. A comparison of univariate methods for forecasting electricity demand up to a day ahead. International Journal of Forecasting, 22:1–16, 2006.

[64] V. Terzija, G. Valverde, C. Deyu, and P. Regulski. Wide-area monitoring, protection, and control of future electric power networks. Proceedings of the IEEE, 99:80–93, 2010.

[65] R. Wang and R. Lasseter. Re-dispatching generation to increase power system security margin and support low voltage bus. Power Systems, IEEE Transactions on, 15:496–501, 2000.

[66] Watanabe, K. Okada, K. Tokoro, and S. Matsui. Adaptive multiagent model of electric power market with congestion management. In Proceedings of the 2002 Congress on Evolutionary Computation, 2002. CEC ’02, pages 523–528, May 2002.

[67] H. Wedde, S. Lehnhoff, and K. Moritz. Distributed learning strategies for collaborative agents in adaptive decentralized power systems. In 15th Annual IEEE International Conference and Workshop on Engineering of Computer Based Systems, 2008.

[68] L. Wehenkel. Emergency control and its strategies. In 13th Power Syst. Comput. Conf., Trondheim, Norway, 1999.

[69] G. Weiss, editor. Multi-agent Systems. MIT Press, Cambridge, MA, USA, 2013.

[70] F. Wollenberg and T. Sakaguchi. Artificial intelligence in power system operation. Proceedings of the IEEE, 75:1678–1685, 1987.

[71] M. Wooldridge. The computational complexity of agent design problems. In Proceedings. Fourth International Conference on MultiAgent Systems, pages 341–348, 2000. Bibliograf´ıa 309

[72] F.F. Wu, K. Moslehi, and A. Bose. Power system control centers: Past, present, and future. Proceedings of the IEEE, 93(11):1890–1908, Nov 2005.

[73] Jian Wu, Yong Cheng, and N.N. Schulz. Overview of real-time database management system design for power system scada system. In SoutheastCon, 2006. Proceedings of the IEEE, pages 62–66, March 2006.

[74] T. Yalcinoz and U. Eminoglu. Short term and medium term power distribution load forecasting by neural networks. Energy Conversion and Management, 46:1393–1405, 2005.

[75] Z. Yongli, Y. Yang, B. Hogg, W. Zhang, and S. Gao. An expert system for power systems fault analysis. Power Systems, IEEE Transactions on, 9:503–509, 1994.

[76] M. Yoshimi, K. Swarup, and Y. Izui. Optimal economic power dispatch using genetic algorithms. In Proceedings of the Second International Forum on Applications of Neural Networks to Power Systems, 1993.

[77] Xue Y.S. Defense schemes against power system blackouts in china with load growth. In Proceedings of the 15th power system computation conference, Liege, 2005.

[78] N. Yu and C.C. Liu. Multi-agent systems and electricity markets: Stateof-the-art and the future. In Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, 2008.

[79] G. Zhabelova and V. Vyatkin. Multiagent smart grid automation architecture based on iec 61850/61499 intelligent logical nodes. Industrial Electronics, IEEE Transactions on, 59(5):2351–2362, May 2012.

[80] Pei Zhang, Fangxing Li, and N. Bhatt. Next-generation monitoring, analysis, and control for the future smart control center. Smart Grid, IEEE Transactions on, 1(2):186–192, Sept 2010.

[81] Y. Zhang, H. Wang, Z. Zhang, and R. Zhang. A practical method for solving economic dispatch problem. In IEEE International Conference on Power System Technology, 2002.