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ABSTRACT These The countries are in a process of energy transition, where the use of renewable energies is intensifying, in a centralized as well as distributed manner, since as much as large companies, small consumers seek to be prosumers[1].

The countries seek to contribute to the reduction of CO2 emissions, making a change from non-renewable energies[2], to clean energies such as solar energy, which has suffered considerable price reductions in recent years, thus stimulating the adoption of this type of energy in a much broader market, which ranges from large companies to independent households, where the now new prosumers are increasingly seeking to reduce the consumption of the traditional network; Additionally, energy markets require an estimate of energy demand by consumers, since short and long-term prices need to be determined[3]; To achieve an adequate estimate, it is also necessary to know the generation of energy that will be available at a given moment, an issue that is crucial for photovoltaic energy, given its variable nature[4].

These energy estimates also provide the necessary tools for the management and management planning of an electrical network, such as a microgrid, which has nodes that consume and/or generate energy; Microgrids are small systems that share energy with each other, but for which they need a management system that allows them to distribute energy more efficiently and precisely, prioritizing the consumption of energy generated by the microgrid itself. For these reasons, in this research, a methodology based on artificial intelligence tools, simulation systems, and user interfaces is carried out, in order to provide a system that allows contributing to the planning of energy management within a microgrid, where the results obtained with it were satisfactory, since the data provided by the system allows planning of energy distribution much more efficiently than traditional methods and contributes to the calculation of economic and environmental benefits.

INDEX TERMS microgrid-energy management-neural network-artificial intelligence-user interface-simulation.

1. INTRODUCTION

The rapid adoption of decentralized generation systems in transmission[1] and distribution system coupled with recent developments in storage technologies, microgrids have become one of the key domains in smart grid when we talk about resiliency and system reliability. With increased participation from various market players, the concept of microgrids has become an opportunity, but also a challenge for some traditional and regulated utilities. It all depends on the business strategy and future sustainability of any utility as to how they take it.

The energy sector is in a process of change, where adaptation has been progressive and increasing on the part of both generators and consumers, since trends change, consumption patterns adapt to the increase in technology and increasingly seeks efficiency in new ways, such as solar energy, so the planning problem is visible, since the inclusion of microgrids and distributed generation systems changes the dynamics of the traditional network, the tools used until now to planning, lower their performance, thus providing a space for other new technologies to fill that place and allow the identification of new trends with sufficient precision to be implemented in current systems.

With the advancement of computer systems and programming, a great deal of knowledge has been generated in terms of prediction and forecasting systems, through mathematical tools and artificial intelligence, where they are being used in all areas of the industry. measure that is being adopted massively.

The current whitepaper addresses many of these aspects of microgrids, components and characteristics, their operation, control and management, and pays special attention to the opportunities of microgrids for utilities and isolated microgrids as such through Management models and prediction of energy consumption and generation, thus seeking a more efficient management of energy, thus presenting a tool that allows simulating energy microgrids, analyzing their results and developing management strategies based on these data.

1. PROBLEM DESCRIPTION

With the arrival of the 4th industrial revolution, technological and regulatory changes, new business models emerge to transform the way in which companies and people carry out their productive activity. The electricity sector is proof of this, with the adoption of non-conventional sources of renewable energy to ensure reliable supply in an environmentally friendly manner[5].

In this sense, for the incorporation of renewable energy into the electricity sector, some technical, economic and regulatory mechanisms have been developed derived from Law 1715 of 2014 and today more recently, Law 2099 of 2021 on Energy Transition, refer to a concept key for this research, such as the microgrid.

A microgrid can be understood as “The Micro-Grid is an interconnection system with the capacity to be self-sufficient and operate in isolation if necessary. It includes both generation, storage and electricity transport, as well as equipment to optimize intelligent energy management by the end user"[6] A clear example of a microgrid is a group of houses, where each one has its own solar system installed to supply their consumption and they all connect to share their surplus energy.

With the rapid development of the Internet of Things (IOT) for energy networks and the implementation of Smart-Grids, the challenge of maintaining proper control and balance between supply and demand has grown significantly.

The inclusion in microgrids of more complex systems, such as monitoring stations, storage systems, self-generation systems and demand response capacity integrated into the electrical system, present new challenges when it comes to guaranteeing supply efficiently. technically and economically.

A clear example of this is the pilot projects that are being carried out in Colombia in the city of Medellín, where models of certain segments of the city are being generated and applied to microgrid simulation to understand how the passage of a standard energy structure affects to a microgrid structure[7].

The object of this research is the development of a support system for energy management in microgrids through a simulation of a microgrid and its behavior, as well as the prediction of generation and consumption patterns, for efficient energy management. in a microgrid, which requires adequate calculation and estimation of supply and demand, to reach a balance and obtain economic and environmental benefits.

This balance between supply and demand seeks to minimize energy losses, such as excess supply, where the additional energy generated cannot be used, causing additional costs due to oversizing and opportunity costs if said excess energy is not sold. On the other hand, problems such as blackouts and deficiencies in the energy supply service can arise when there is excess demand, since the supply is not capable of fully supplying the demand at any instant of time. This problem of imbalance between supply and demand usually also appears in microgrids as a result of an intermittent supply of energy from solar and wind systems, since there is no sun and wind all day, nor is it of the same intensity at the hours of their presence. .

The growth of the economy is associated with a growth in the demand for energy, due to the fact that the different economic activities require energy consumption for their development, in this sense, the impacts of health events such as COVID-19 and climate events such as El Niño and la Niña, generate changes in the load profiles of consumers[8], as well as in the availability and price of the energy supply, which puts at risk the supply of energy to end users at reasonable prices.

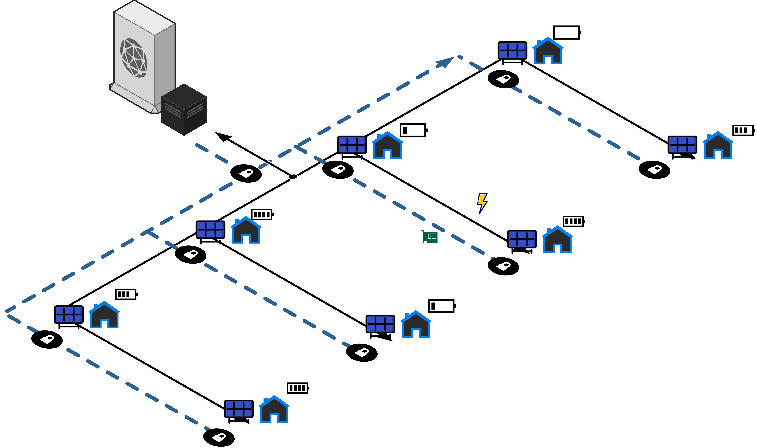
Self-generation plants are normally based on renewable energies based on non-conventional sources (FNCER) such as photovoltaic solar energy, wind power and small hydroelectric plants. The availability of energy that these generation plants can deliver depends on various climatic factors, such as such as cloudiness, precipitation, temperature, wind speed, hours of sunshine during the day and its intensity per unit area, among other factors, which determine a variable and intermittent generation, thus causing uncertainty in the amount of energy available to meet demand in the short, medium and long term[9].

Similarly, the energy demand of households and companies is variable [10], either due to the incorporation of new efficient technologies that reduce consumption, due to the entry of new equipment and machinery to support growth, due to reduction or increase in industrial and commercial production as a result of economic and commercial changes, due to restrictions on mobility due to the effect of a pandemic, among many other factors that explain why the energy demanded by a home or by a company varies over time.

PRELIMINARIES

The necessary backgrounds, including the entry dynamic equations, multiple trajectory constraints, and threats detected during the entry process, for HGVs are described in this section

1. MICROGRID



1. Microgrid illustration.

Microgrids are small systems or networks capable of generating energy and that, in addition, also have the ability to function autonomously[6].

The traditional electrical network connects homes, companies, among other infrastructures, to the central network, which is supplied with energy by large power plants, whether they are coal-fired, hydroelectric, or fuel plants, among others. Thanks to this network, electricity travels from where it is produced to where it is consumed.

On many occasions, microgrids are also connected to the traditional electricity grid, but this does not mean that they cannot function on their own.

Microgrids are generally made up of self-generating systems, which means that they can become self-sufficient and can operate in isolation from the electrical grid.

Mainly this means that when the electrical network fails, these microgrids can continue to function and generate electricity autonomously.

Microgrids are generally connected to the traditional electrical network, through a point that maintains the voltage at the same level. But if problems are detected, it goes offline and can continue to function normally[7].

The operation of a microgrid depends on how it is powered, since they can receive energy from solar panels, batteries, wind generators, distributed generators, small hydroelectric plants, among other energy sources. Depending on how it is managed, a microgrid can run indefinitely and cleanly, for example if it is powered by renewable energy.

Microgrids can be defined in the following categories:

• Commercial and industrial microgrids are installed with the objective of reducing demand and costs, during normal operation of construction operations, or other activities, such as data centers, supply of RGD operations, among others.

• Business and service microgrids are generally designed to improve reliability and also promote community participation.

• In the field of campus and institutional microgrids, it is understood that today, most institutions and campuses already have distributed generation systems installed due to its boom and the trend towards green energy.

• In military networks, they focus on physical security and cybersecurity, both for fixed bases and forward operating bases.

It is also worth clarifying the modes of operation of microgrids, which are systems connected to the traditional network and the island mode.

Remote microgrids are permanently disconnected from other power grids and operate in island mode.

In the figure above you can see an example of a microgrid connected to the traditional network.

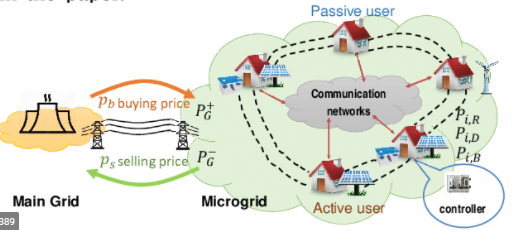
As defined in [8], for a microgrid disconnected from the network, the example is the same, only that the part of the main network is not included in the connection scheme, since it works completely isolated in island mode.

The traditional grid connection mode is the normal operating mode of a microgrid, without disturbing the energy quality of the traditional grid. In this mode, the microgrid can take over its entire supply, or, depending on the total generation of energy from the local distribution network, in the traditional network environment, it can export or import energy.

In island mode, the microgrid operates isolated from the traditional grid, producing and consuming its own energy. In this mode of operation, the continuity of the service to the connected loads is guaranteed in case of failures in the traditional network. Its autonomy will depend on the generation capacity vs. KWh consumption of the connected loads.

In addition to the modes of operation, the types of microgrids must be taken into account, which are alternating current, direct current and hybrid microgrids.

AC microgrids have a common AC bus to which loads running on AC/DC, renewable energy sources, and energy storage systems are connected. They are easily integrated into the conventional electrical network, but they present a decrease in their energy efficiency, due to the direct/alternating current conversion of their resources, synchronization problems of distributed generators and three-phase imbalance.



1. Illustration of a microgrid connected to the traditional network[9].

As can be seen in Fig. 2, direct current microgrids use a DC bus to connect to their local network with an AC/DC converter. Compared to the AC microgrid, the DC microgrid is more efficient by reducing power conversion losses. In this type of microgrids, household appliances, lighting, computers, electric vehicles, photovoltaic panels, batteries, flywheels, etc., work with high-efficiency DC/DC converters [10].

Hybrid microgrids are a combination of AC and DC microgrids in the same network segment, facilitating the integration of AC and DC distributed generation resources, energy storage systems and loads. With the advantages of both types of microgrids, RGD integration is facilitated, and energy conversion stages and energy losses are reduced.

1. MANAGEMENT SYSTEMS

A management system is the way an organization manages and manages all the interrelated parts of its business in order to achieve its objectives.

The objectives can be related to many different topics, such as service quality, operational efficiency, health, performance, among others.

The level of complexity of a system depends entirely on the organization of the company.

There are different types of management systems, such as process control, inventory control, sales and marketing, human resources, accounts and finance, decision support systems, expert systems, transaction processing and database[11].

In the field of management support software, there are three types of management support systems: executive information systems, expert systems and DSS decision support systems.

Then there are the executive information systems, which focus more on the management of packages and deliveries, since this level is different from the administrative level, it needs its own approach, since the need for fast and updated information on packages, status of warehouses, deliveries and other logistics issues is something required in the management of a company or projects if efficiency and improvement are sought in them.

The information systems developed for the management of Logistics and status reports, whether of materials or personnel, are the executive information systems or EIS for its acronym in English; The EIS act as an electronic instruction system, offering great flexibility in its use, using internal and external information on the status of the company's logistics processes.

In addition to the EIS, there are also expert systems, which were created to meet the exponential increase in complexity of the processes of some companies, since a greater flow of information and faster decision-making are required, which can become a problem if you only work with the human factor, which is why expert systems were implemented, since they can interact with several variables at the same time in a faster and more effective way than a human.

The EIS work, simulating human activity taken from human experts in a certain specific subject, recreating the inputs of information, whether qualitative or quantitative, identification of requirements and analysis of information regarding decision-making rules; Delivering a solution to the problem in a way that explains to the user the reasoning used to arrive at that solution and how to execute it.

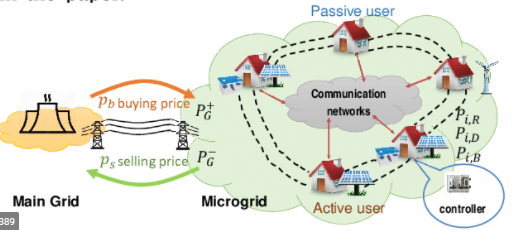
On the other hand, there are decision support systems, they are designed to support decision making in a company or project, making the process of administrators improve in effectiveness and efficiency, since they are based on the premise that the judgment of the administrator cannot be replaced by a computer-based solution. However, by offering the support of models and data, it is possible to improve the decision-making process.

The basic purpose of decision support systems or DSS for its acronym in English, is to extend the decision capacity of the manager by supporting him with tools and data available under his control. The DSS do not presuppose specific information requirements or predefined analysis tools for different types of information, nor do they impose solutions on the administrator.

The flexibility mentioned in the previous paragraph, then, implies that these DSS systems are flexible and allow plasticity to the administrator when entering data, depth of analysis and dependence on the result of an analysis for making a specific decision. DSSs offer an interactive environment for the user, thus allowing the administrator to experiment with the data and models to develop an optimal decision-making strategy for a specific situation.

DSS systems can be used in operations management and other planning departments within an organization to synthesize executable solutions from information and data from the same operations[11].

For example, a DSS system can be used to project a company's profit into a future time interval, based on assumptions about the sales of a specific product. Given the large number of factors that surround a profit projection figure, these calculations are not easy to perform manually, therefore, this task is offloaded in a system of this class.



1. Illustration of a microgrid connected to the traditional network[9].

The operation of a microgrid depends on how it is powered, since they can receive energy from solar panels, batteries, wind generators, distributed generators, small hydroelectric plants, among other energy sources. Depending on how it is managed, a microgrid can run indefinitely and cleanly, for example if it is powered by renewable energy.

1. NEURAL NETWORKS

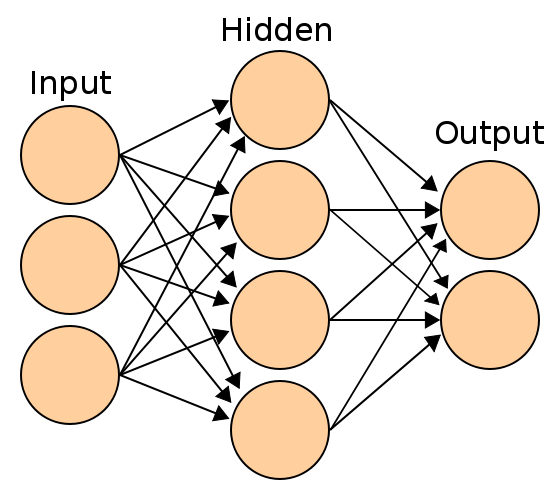
Artificial intelligence copies nature's behavior of learning and adapting to an environment[12].

AI makes it possible for machines or programs to learn from experience, adjust to new ideas or problems, and perform increasingly efficient tasks[13].

Artificial intelligence is based on the behavior of neurons, which adapt as needed for a specific task, where each neuron has defined values ​​for each connection and these values ​​change as it adapts, thus reinforcing the connections that are needed and discard those that are not needed.

Artificial intelligence presents different ways of performing learning, where among the best known are deep learning, machine learning and natural language processing[14].

Artificial neural networks were the first way to approach the idea of ​​thinking machines, where they seek to imitate the behavior of neurons in the brain, strengthening and weakening connections as needed.



1. Illustration of a neural network internal connection diagram[15].

In the figure 4 you can see a scheme of a simple neural network, where there are 3 layers, one input, where the information is fed to the network, the hidden layer, where the information is processed and the output where it is delivered. an answer.

Automatic or machine learning is an implementation of these neural networks on a large scale[14], since large collections of these are implemented to learn about a specific task automatically and without human intervention, where the system is left to find answers on its own as it progresses in “understanding” a specific problem.

To complement, a formal definition of machine learning is a discipline in the field of artificial intelligence that, through algorithms, gives computers the ability to identify patterns in massive data and make predictions. This learning allows computers to perform specific tasks autonomously, that is, without the need to be programmed.

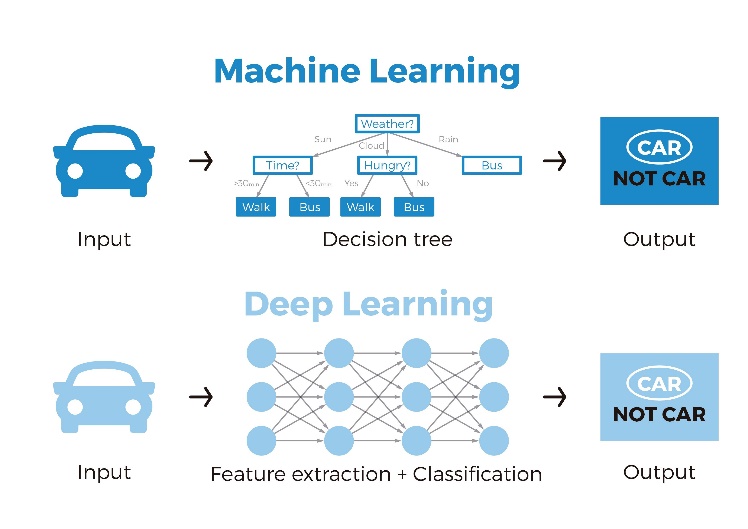
In addition to the definition of machine learning, there are definitions of the different types of machine learning, such as supervised, unsupervised, semi-supervised and reinforcement learning[16].

Supervised learning needs labeled data sets. That is, you tell the model what you want it to learn.

On the other hand, unsupervised learning is the opposite, since it works with data that has not been labeled. You don't have a label to predict. These algorithms are mainly used in tasks where it is necessary to analyze the data to extract new knowledge or group entities by affinity.

Semi-supervised learning is used on occasions where it is difficult to obtain a completely labeled data set, this means that only a portion of the data is marked, which is solved with this type of learning, since it is delivered to the model a sample of the data to be learned and another part of the data, which the system must analyze according to what was learned in the initial labeled sample[14].

Deep learning or Deep learning (DL) is an additional layer that is added to the collections of neurons implemented in machine learning (ML), with multiple layers connected to each other, where each layer is assigned a specific function in a problem[17]; It should be clarified that functions or tasks are not always assigned to a specific layer, but it is also possible to let the same program find and divide the problem into simpler subproblems, thus achieving a greater abstraction of the problem and possibly a better solution to the same problem.



1. Illustration of a neural network in ML and DL[18].

Figure 5 shows the difference between machine learning and deep learning, where deep learning finds different parameters such as characteristics of a particular object as it is trained, using filters applied to each of the layers, where each of them will be adjusted to a specific feature of the information being analyzed, among others. While machine learning does not select characteristics of the object, but the information is passed through the layers of the network, which are adjusted until they deliver the desired output.

Neural networks as an emerging and widely accepted tool worldwide, have been implemented in more and more areas with the emergence of new needs in the world in constant growth, globalization and search for more efficient solutions; As is the case of the inherent need to forecast data in the future, since the search for greater efficiency, both in energy and in the very processes that are carried out in the industry, has triggered a search to predict data, either for system control , economy, stock market, weather forecast, among others[16].

Neural networks with their ability to adapt and infer the behavior of all kinds of dynamic systems, are presented as a useful tool for this purpose, since by inferring the behavior of a system at a given instant of time, they can be used to determine the response of a system in the future, since its behavior has already been determined by a neural network, can be used to deliver an approximate future response to what the real system would deliver in a future horizon[19].

These applications of prediction and forecasting of the response of any measurable system with respect to a time axis, have gained greater strength since they allow actions to be taken prior to the event and to anticipate with an adequate response to it, resulting in resource savings, either of personnel, energetic and economic, as for example in control systems, where a respective response can result in energy savings and avoid excessive wear and tear on the system, since the behavior can be given more smoothly if it is known with certainty. anticipate the action to be taken.

On the other hand, in energy distribution systems, the energy demand can be known in advance, thus achieving the respective preventive actions that allow a response to the adequate demand to result; These preventive actions can trigger a more efficient distribution system.

Taking into consideration the scope of decision making mentioned above, neural networks are of great help to meet this objective, since the ability to estimate the behavior of a system or situation in the future allows decisions to be made that result in better management. power of a microgrid. With neural networks, an identification of the behavior of the entities that make up the micronetwork can then be achieved, in order to make a forecast of generation and consumption, where this information is used to distribute the energy in the most appropriate way possible, achieving efficient management. as balanced as possible and thus provide a balanced response to the demand of the microgrid itself, since the predictions of patterns allow anticipating the facts and taking the necessary actions before the events occur; In this case, energy generation and consumption events.

1. METHODOLOGY

The methodology for this project will be made up of 4 stages, starting with previous theoretical research that allows supporting the entire development, and then going through a breakdown and definition of components where a synthesis of all the necessary elements will be made.

The following stages are composed of the implementation of the synthesized components in an algorithmic way, since it was sought to carry out a simulation assembly where various tests and tests of different microgrid topologies can be carried out, in order to carry out a parameter adjustment and analyze results.

1. METHODOLOGY STAGES

* STAGE 1: Characterization of Micro-Grid systems.
* STAGE 2: System design and model development.
* STAGE 3: Model implementation and simulation.
* STAGE 4: Implementation, testing and validation.

1. STAGE 1:

It was then sought to characterize a microgrid under study according to the first specific objective.

* The different types of existing microgrids were analyzed and the type of microgrid to be used in this application case will be defined.
* The node was defined as a representative element of a consumer or prosumer or distributed generator component of the microgrid.
* A set of relationships between the nodes of the microgrid was defined and specified.
* The form of relationship of the microgrid with the external network or distribution system was defined.
* The behavior of the determining components or variables of the node, consumption and generation curves were identified and specified.

A model was developed, which allowed characterizing a microgrid object of the study, its components and representative variables. Thus, for example, it was possible to define consumer-type nodes with their type of load curve or prosumer-type nodes, which have energy consumption and production. The consumption of energy from different types of loads or consumption in the unit of time and generation from different sources of energy such as solar photovoltaic, wind, etc.

As a result of this stage, we obtain a complete microgrid model.

1. STAGE 2:

In this stage, the support system for energy management in the microgrid was designed considering the microgrid model defined in the previous stage. For this, models of the components of the microgrid must be developed, including the following:

* A model that allows defining the load curve or energy demand of the node
* A model that allows defining the node generation curve
* A model that allows forecasting the energy demand for the next day
* A model that allows forecasting the generation of the node for the following day.
* An energy management model for the microgrid.

After the models per node, it is necessary to define the aggregator models for the microgrid.

* A network model of the microgrid that allows interaction with the traditional distribution network.
* A model for estimating the energy benefits of the microgrid
* A model for estimating the economic benefits of the microgrid
* A model for estimating the environmental benefits of the microgrid

For the development of the forecast models, several machine learning algorithms were tested that were adjusted to the specified case study, using the node variables defined in the previous step, that is, to the micronetwork under study. Then the set of algorithms that best represent the expected future behavior was selected.

Finally, the needs that the final interface must meet were defined, what it must have, such as the interaction with the user, what platform to use to implement the interface, how the variables should be configured, the implementation mode of all the components and communication between them.

1. STAGE 3:

With the components, models defined and algorithms established, it was implemented in a software that allows the simulation of the interaction of the components of the microgrid and of this as a whole with the distribution network.

For the simulation, the literature was analyzed and the appropriate tools were defined for this case that allowed the fulfillment of the objectives.

In the simulation platform, a graphical interface was developed, where the user can parameterize the microgrid, such as the behavior of each node in terms of generation and consumption, as well as the capacities of the energy networks that connect the nodes of the microgrid and It is with the distribution network.

1. STAGE 4:

Functional and operational tests were carried out on the support system developed with its integrated models in such a way that it was possible to identify errors and other aspects of improvement.

With results obtained from multiple successful tests in different operating situations, the management system was tested with different models of microgrids.

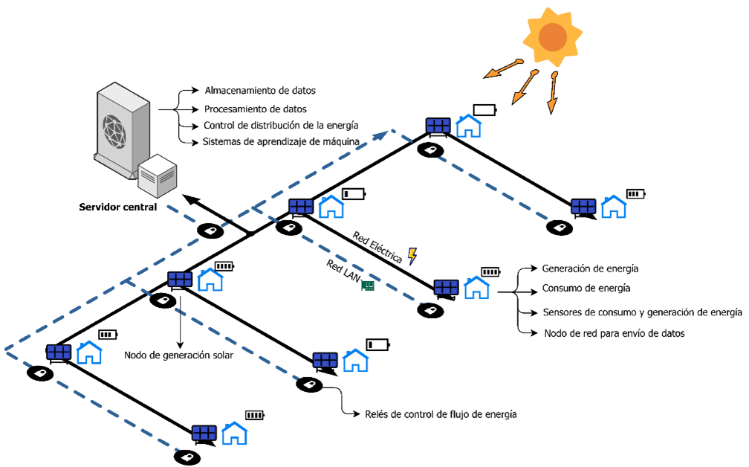
1. METHODOLOGY PROCESS
2. STAGE 1:

EXISTING MICROGRID ANALYSIS

For the analysis of the existing microgrids, a previous investigation was carried out in the background section where the types of existing microgrids were identified, which are found in the theoretical framework. Solar energy was determined as a non-conventional source of renewable energy in this case due to its technical and economic benefits, that is, widely used commercial technology of low cost and easy appropriation by users.

With the types of existing microgrids, we proceed to define the topology to be used for this project, which is a microgrid, connected in alternating current to the national interconnected system with the possibility of selling surpluses.

The diagram of the type of microgrid to be used is illustrated in figure 6 below.



1. Illustration of the microgrid topology to use.

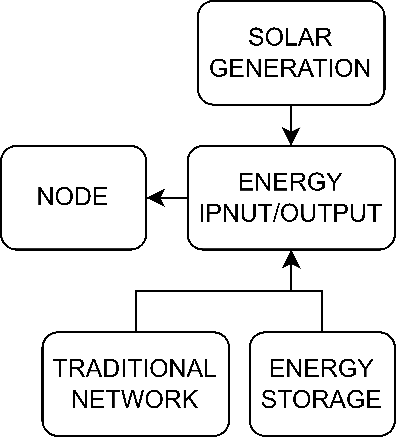
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MICROGRID NODE DEFINITION

With the topology defined and the energy source defined, we proceed to develop a definition of the components of a node that make up the microgrid.

The synthesis performed for the components of each node and its operation is described in figure 7.



1. Illustration of microgrid node components.

Figure 7 shows the 4 general components that define the node, which can be described as follows:

* SOLAR GENERATION: The node has the option of having a solar generation point (photovoltaic system), where you can configure the hours of the day that the system receives depending on the area where it is installed, as well as the installed power, in order to be able to calculate the energy self-generation curve of the node.
* TRADITIONAL NETWORK: The node has the option of connecting to the traditional network to be able to supply its own energy consumption when the micro-network cannot supply it. This with the purpose of modeling the real situation. At present and in general terms, consumers receive their energy supply from a distribution network, so the development of microgrids for the most part would be carried out with this type of existing topology, users connected to the distribution network that make up a microgrid connected to the grid.
* ENERGY INPUT/OUTPUT: The node is managed by this element, which will receive orders from the central management system, to enter or remove energy from the node at a given time. Said input/output system is defined by a bidirectional meter that allows accounting for energy consumption or the delivery of surpluses to the internal network and an intelligent control system that, working as a "slave", implements the orders of the centralized master management system of the microgrid. In some cases, such as in those nodes where there is storage, the storage management system would be used, in other cases where there is only self-generation in the node without storage, inverter control is used, in other cases, a intelligent control system. For this work it is assumed that the node has said intelligent control system.
* ENERGY STORAGE: The node can be configured with a storage system with a certain capacity.

NODE INTERACTION DEFINITION

Once the node is defined, we proceed to make a scheme and interactions between the nodes as shown in figure 27.

Imagen que contiene interior, tabla, luz, colgando

Descripción generada automáticamente

1. Illustration of node interactions.

Figure 8 illustrates the interaction between nodes, which has been taken up to now, without a management system, since it is necessary to define the basic structure of the microgrid first, in order to then implement a management layer to the system.

The nodes are connected to a connection system that is general for the entire microgrid, through which energy can flow in all directions to any node at a given time. This system corresponds to an internal electrical network that physically connects the nodes, similar to the internal distribution network of a subdivision, building or free zone.

The component of each node that connects to the connection system would be the ENERGY INPUT/OUTPUT component, mentioned above in figure 7, which will function as a kind of gate to enter or extract energy from the node as needed.

For the connection of the microgrid with the external energy network, it is carried out via the connection of the internal electrical system with the local distribution system, that is, it would have the equipment of a self-generation commercial frontier such as the advanced measurement system bidirectional, and intelligent energy management system. To cite an example, in a subdivision or in a building or in a free zone there is an electrical substation that supplies energy to users, the connection of this substation with the external electrical network of the local distributor would be modified so that under compliance of current regulations can consume and deliver surpluses to the network operator's distribution network.

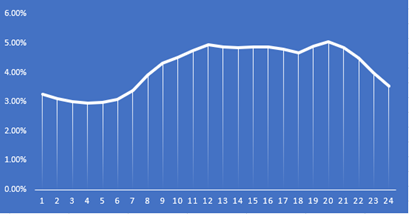
ENERGY DEMAND CURVE DEFINITION

For the consumption curves, an extensive investigation of load profiles was carried out for different types of users, which are:

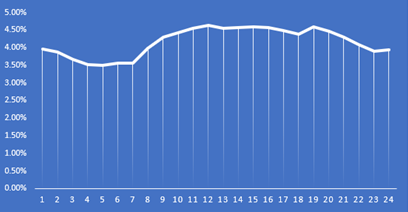
* Residential
* Commercial
* Industry

information taken directly from the public information system of the operator of the national interconnected system (XM), for a minimum analysis horizon of one year, in hourly resolution. On the other hand, the technical information provided by the Energy Mining Planning Unit (UPME) corresponding to the xxx study was used, where load curves were determined by users, this being the validation mechanism of the load profile obtained for the type of user used. in this case study.

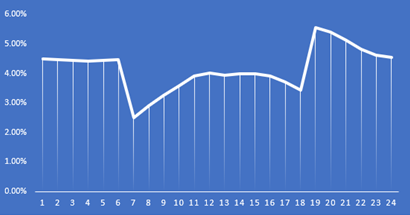
The curves were made for an interval of 24 hours divided by hour, where there are 24 data per node, whether in a residential, commercial or industrial curve.



1. Residential curve.



1. Industrial curve.



1. Commercial curve.

Figures 9, 10 and 11 show the synthesized percentile graphs of the residential, commercial and industrial sectors, respectively. These curves allow defining the load profile of each node and distributing the specified average consumption for each user at each hour of the day.

OPERATING VARIABLE DEFINITION

With the consumption data defined, we proceed to define the variables that will be taken into account for the operation of the microgrid:

* Node consumption.
* Node generation or node self-generation.
* Node storage.
* Prediction of node consumption.
* Prediction of node generation or node self-generation.

MICROGRID DIAGRAM AND DECISION SUPPORT SYSTEM DEFINITION

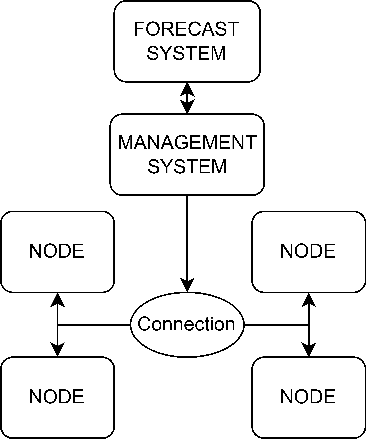
With the components of the microgrid and the variables defined, we proceed to define the missing components necessary for the management of the microgrid, which are:

* Microgrid energy management system.
* Consumption and generation prediction system.

The management system is the one that will make decisions about who and when energy will be delivered, based on the information that the prediction system will deliver.

The prediction system will be constantly training itself with the consumption and generation information of each node in order to deliver a response to the management system.

The diagram of the complete microgrid can be seen in figure 12 and an example of the functional design of the microgrid in figure 6.



1. Complete microgrid diagram.

Figure 12 shows how the microgrid is arranged, where the management system is directly connected to each node through the connection system to the ENERGY INPUT/OUTPUT components of each node, where this component will fulfill certain functions described below:

* Energy “gate” operation to enter and extract energy from the node.
* Collection of generation and consumption data of each node.
* Delivery of information from each node to the management system.

The management system receives the information from each node and delivers it to the prediction system, which will perform the necessary calculations and return the results, where it will already make the decisions for energy distribution applied through the INPUT/OUTPUT component of each node.

For the storage issue, the system takes into account the total installed power in the microgrid and uses the batteries that each node has installed as global for the entire microgrid and thus distributes as needed.

1. STAGE 2:

NODE MODEO DESIGN

With all the components and interactions defined, we proceed to develop the models of the components of the node.

DEMAND COMPONENT DESIGN

For the design of the demand component of a node, the curves found for the residential, commercial and industrial sectors were taken as a reference, where an average daily energy consumption is taken and multiplied by the percentile values ​​contained in the curve, in order to generate an hourly power consumed by that node at a given time.

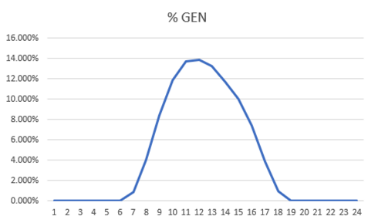
The curves are defined using the data shown in figures 9, 10 and 11, where there are 24 data points for every hour in a day.

GENERATION COMPONENT DESIGN

For the design of the generation component, values ​​were taken from curves already established for the solar energy sector by the industry and companies in the energy sector.

This generation curve was taken in percentage values ​​of a total of 100% daily, for each instant of time.

The data used is shown on figure 13.



1. Solar generation curve.

As can be seen, the percentage of generation is distributed in the mid-day hours, as expected due to the nature of the solar resource.

With these data, we proceed to implement the curve in the next stage.

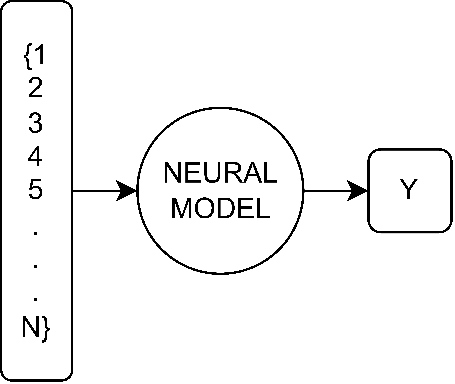
FORECAST MODEL DESIGN

For the forecast model, the AI ​​route was chosen, using artificial intelligence tools for time series forecasting, to determine the consumption or generation of a node at a given future instant and thus achieve more efficient energy management.

For this model, something light and fast was sought, but at the same time robust and efficient, so a previous investigation of neural models applied to this type of problem was carried out and it was concluded that the most suitable model for this type of systems is a regression system, since it manages to successfully determine any type of time series in an approximate way.

For the portability and weight section of the algorithm, it was determined that a gradient tree is the best network structure to use because it is lightweight and robust, so for the final model, it was determined to use a regressor from the XGBoost library in Python.

Once the model is defined, we proceed to determine the structure of the data that will be entered into the system, opting for the time series model for their partitioning.



1. Data format for neural model.

For the neural model, a data vector is entered, with an adjustable window size, to process a future value, either generation or consumption.

FORECAST ALGORITHM SELECTION

For the neural model, a data vector is entered, with an adjustable window size, to process a future value, either generation or consumption.

TABLE I

Units for Magnetic Properties

|  |  |  |
| --- | --- | --- |
| Symbol | Quantity | Conversion from Gaussian and  CGS EMU to SI a |
| Φ | magnetic flux | 1 Mx → 10−8 Wb = 10−8 V·s |
| *B* | magnetic flux density,  magnetic induction | 1 G → 10−4 T = 10−4 Wb/m2 |
| *H* | magnetic field strength | 1 Oe → 103/(4π) A/m |
| *m* | magnetic moment | 1 erg/G = 1 emu  → 10−3 A·m2 = 10−3 J/T |
| *M* | magnetization | 1 erg/(G·cm3) = 1 emu/cm3  → 103 A/m |
| 4π*M* | magnetization | 1 G → 103/(4π) A/m |
| σ | specific magnetization | 1 erg/(G·g) = 1 emu/g → 1 A·m2/kg |
| *j* | magnetic dipole  moment | 1 erg/G = 1 emu  → 4π × 10−10 Wb·m |
| *J* | magnetic polarization | 1 erg/(G·cm3) = 1 emu/cm3  → 4π × 10−4 T |
| χ*,* κ | susceptibility | 1 → 4π |
| χρ | mass susceptibility | 1 cm3/g → 4π × 10−3 m3/kg |
| μ | permeability | 1 → 4π × 10−7 H/m  = 4π × 10−7 Wb/(A·m) |
| μr | relative permeability | μ → μr |
| *w, W* | energy density | 1 erg/cm3 → 10−1 J/m3 |
| *N, D* | demagnetizing factor | 1 → 1/(4π) |

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.

aGaussian units are the same as cg emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

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There is currently one publication with column measurements that do not coincide with those listed above. Proceedings of the IEEE has a column measurement of 3.25 inches (82.5 millimeters / 19.5 picas).

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APPENDIX

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REFERENCES

[1] C. R. Binder, C. Knoeri, and M. Hecher, “Modeling transition paths towards decentralized regional energy autonomy: the role of legislation, technology adoption, and resource availability,” *Raumforsch. und Raumordnung | Spat. Res. Plan.*, vol. 74, no. 3, 2016, doi: 10.1007/s13147-016-0396-5.

[2] I. Iskin, R. A. Taha, and T. U. Daim, “Exploring the adoption of alternative energy technologies: A literature review,” *Int. J. Sustain. Soc.*, vol. 5, no. 1, pp. 43–61, 2013, doi: 10.1504/IJSSOC.2013.050534.

[3] T. Hong, P. Pinson, Y. Wang, R. Weron, D. Yang, and H. Zareipour, “Energy Forecasting: A Review and Outlook,” *IEEE Open Access J. Power Energy*, vol. 7, no. October, pp. 376–388, 2020, doi: 10.1109/OAJPE.2020.3029979.

[4] Vikas Pratap Singh, Vivek Vijay, Gaurishankar S. H., D. K. Chaturvedi, and N. Rajkumar, “Analysis of solar power variability due to seasonal variation and its forecasting for Jodhpur region using Artificial Neural Network,” *J. CPRI*, vol. 09, no. 03, pp. 110–118, 2013.

[5] L. Dogaru, “The main goals of the fourth industrial revolution. Renewable energy perspectives,” *Procedia Manuf.*, vol. 46, pp. 397–401, 2020, doi: 10.1016/j.promfg.2020.03.058.

[6] Villar Mir, “Qué son las micro redes,” *Enérgya VM*, 2021. https://www.energyavm.es/que-son-las-micro-redes-y-por-que-seran-importantes/.

[7] Q. Tang, N. Liu, and J. Zhang, “Optimal operation method for microgrid with wind/PV/diesel generator/battery and desalination,” *J. Appl. Math.*, vol. 2014, 2014, doi: 10.1155/2014/857541.

[8] E. Hossain, E. Kabalci, R. Bayindir, and R. Perez, “A comprehensive study on microgrid technology,” *Int. J. Renew. Energy Res.*, vol. 4, no. 4, pp. 1094–1104, 2014.

[9] “Connected Microgrid,” *Research Gate*, 2020. https://www.researchgate.net/figure/Grid-connected-microgrid-system\_fig1\_332082946.

[10] S. Saponara, R. Saletti, and L. Mihet-Popa, “Hybrid micro-grids exploiting renewables sources, battery energy storages, and bi-directional converters,” *Appl. Sci.*, vol. 9, no. 22, 2019, doi: 10.3390/APP9224973.

[11] S. French and M. Turoff, “Decision support systems,” *Commun. ACM*, vol. 50, no. 3, pp. 39–40, 2007, doi: 10.1145/1226736.1226762.

[12] E. S. Brunette, R. C. Flemmer, and C. L. Flemmer, “A review of artificial intelligence,” *ICARA 2009 - Proc. 4th Int. Conf. Auton. Robot. Agents*, no. March, pp. 385–392, 2009, doi: 10.1109/ICARA.2000.4804025.

[13] W. is artificial Inteligence, “https://www.sas.com/es\_co/insights/analytics/what-is-artificial-intelligence.html,” 2020. .

[14] S. Sah, “Machine Learning: A Review of Learning Types,” *ResearchGate*, no. July, 2020, doi: 10.20944/preprints202007.0230.v1.

[15] “Que son las redes neuronales,” *ATRIA Innovation*, 2020. https://www.atriainnovation.com/que-son-las-redes-neuronales-y-sus-funciones/.

[16] T. Oladipupo, “Machine Learning Overview,” *New Adv. Mach. Learn.*, no. February 2010, pp. 8–18, 2010, doi: 10.5772/9374.

[17] N. F. Hordri, S. S. Yuhaniz, and S. M. Shamsuddin, “Deep Learning and Its Applications: A Review,” *Conf. Postgrad. Annu. Res. Informatics*, no. October, pp. 1–5, 2016.

[18] “Deep Learning,” *Cyberclick*, 2020. https://www.cyberclick.es/numerical-blog/como-puede-el-deep-learning-mejorar-tu-estrategia-de-marketing.

[19] N. Adams, “How Artificial Intelligence Works How Artificial Intelligence < Currently > Works [ Working Paper ] For this paper , a basic introduction to how AI works is most apt . The writer follows tradition by introducing AI by comparing it to a human . In particul,” no. October, 2019.

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*Examples:*

1. E. E. Reber, R. L. Michell, and C. J. Carter, “Oxygen absorption in the earth’s atmosphere,” Aerospace Corp., Los Angeles, CA, USA, Tech. Rep. TR-0200 (4230-46)-3, Nov. 1988.
2. J. H. Davis and J. R. Cogdell, “Calibration program for the 16-foot antenna,” Elect. Eng. Res. Lab., Univ. Texas, Austin, TX, USA, Tech. Memo. NGL-006-69-3, Nov. 15, 1987.

*Basic format for handbooks:*

*Name of Manual/Handbook, x* ed., Abbrev. Name of Co., City of Co., Abbrev. State, Country, year, pp. *xxx-xxx.*

*Examples:*

1. *Transmission Systems for Communications*, 3rd ed., Western Electric Co., Winston-Salem, NC, USA, 1985, pp. 44–60.
2. *Motorola Semiconductor Data Manual*, Motorola Semiconductor Products Inc., Phoenix, AZ, USA, 1989.

*Basic format for books (when available online):*

J. K. Author, “Title of chapter in the book,” in *Title of Published Book*, *x*th ed. City of Publisher, State, Country: Abbrev. of Publisher, year, ch.*x*, sec. *x*, pp. *xxx–xxx*. [Online]. Available: http://www.web.com

*Examples:*

1. G. O. Young, “Synthetic structure of industrial plastics,” in Plastics, vol. 3, Polymers of Hexadromicon, J. Peters, Ed., 2nd ed. New York, NY, USA: McGraw-Hill, 1964, pp. 15-64. [Online]. Available: http://www.bookref.com.
2. *The Founders’ Constitution*, Philip B. Kurland and Ralph Lerner, eds., Chicago, IL, USA: Univ. Chicago Press, 1987. [Online]. Available: http://press-pubs.uchicago.edu/founders/
3. The Terahertz Wave eBook. ZOmega Terahertz Corp., 2014. [Online]. Available: http://dl.z-thz.com/eBook/zomega\_ebook\_pdf\_1206\_sr.pdf. Accessed on: May 19, 2014.
4. Philip B. Kurland and Ralph Lerner, eds., *The Founders’ Constitution.* Chicago, IL, USA: Univ. of Chicago Press, 1987, Accessed on: Feb. 28, 2010, [Online] Available: http://press-pubs.uchicago.edu/founders/

*Basic format for journals (when available online):*

J. K. Author, “Name of paper,” *Abbrev. Title of Periodical*, vol. *x*, no. *x*, pp. *xxx-xxx*, Abbrev. Month, year. Accessed on: Month, Day, year, DOI: 10.1109.*XXX*.123456, [Online].

*Examples:*

1. J. S. Turner, “New directions in communications,” *IEEE J. Sel. Areas Commun*., vol. 13, no. 1, pp. 11-23, Jan. 1995.
2. W. P. Risk, G. S. Kino, and H. J. Shaw, “Fiber-optic frequency shifter using a surface acoustic wave incident at an oblique angle,” *Opt. Lett.*, vol. 11, no. 2, pp. 115–117, Feb. 1986.
3. P. Kopyt *et al., “*Electric properties of graphene-based conductive layers from DC up to terahertz range,” *IEEE THz Sci. Technol.,* to be published. DOI: 10.1109/TTHZ.2016.2544142.

*Basic format for papers presented at conferences (when available online):*

J.K. Author. (year, month). Title. presented at abbrev. conference title. [Type of Medium]. Available: site/path/file

*Example:*

1. PROCESS Corporation, Boston, MA, USA. Intranets: Internet technologies deployed behind the firewall for corporate productivity. Presented at INET96 Annual Meeting. [Online]. Available: http://home.process.com/Intranets/wp2.htp

*Basic format for reports and handbooks (when available online):*

J. K. Author. “Title of report,” Company. City, State, Country. Rep. no., (optional: vol./issue), Date. [Online] Available: site/path/file

*Examples:*

1. R. J. Hijmans and J. van Etten, “Raster: Geographic analysis and modeling with raster data,” R Package Version 2.0-12, Jan. 12, 2012. [Online]. Available: http://CRAN.R-project.org/package=raster
2. Teralyzer. Lytera UG, Kirchhain, Germany [Online]. Available: http://www.lytera.de/Terahertz\_THz\_Spectroscopy.php?id=home, Accessed on: Jun. 5, 2014

*Basic format for computer programs and electronic documents (when available online):*

Legislative body. Number of Congress, Session. (year, month day). *Number of bill or resolution*, *Title*. [Type of medium]. Available: site/path/file

***NOTE:*** ISO recommends that capitalization follow the accepted practice for the language or script in which the information is given.

*Example:*

1. U.S. House. 102nd Congress, 1st Session. (1991, Jan. 11). *H. Con. Res. 1, Sense of the Congress on Approval of Military Action*. [Online]. Available: LEXIS Library: GENFED File: BILLS

*Basic format for patents (when available online):*

Name of the invention, by inventor’s name. (year, month day). Patent Number[Type of medium]. Available: site/path/file

*Example:*

1. Musical toothbrush with mirror, by L.M.R. Brooks. (1992, May 19). Patent D 326 189

[Online]. Available: NEXIS Library: LEXPAT File: DES

*Basic format for conference proceedings (published):*

J. K. Author, “Title of paper,” in *Abbreviated Name of Conf.*, City of Conf., Abbrev. State (if given), Country, year, pp. *xxxxxx.*

*Example:*

1. D. B. Payne and J. R. Stern, “Wavelength-switched pas- sively coupled single-mode optical network,” in *Proc. IOOC-ECOC,* Boston, MA, USA,1985,   
   pp. 585–590.

*Example for papers presented at conferences (unpublished):*

1. D. Ebehard and E. Voges, “Digital single sideband detection for interferometric sensors,” presented at the *2nd Int. Conf. Optical Fiber Sensors,* Stuttgart, Germany, Jan. 2-5, 1984.

*Basic format for patents:*

J. K. Author, “Title of patent,” U.S. Patent *x xxx xxx*, Abbrev. Month, day, year.

*Example:*

1. G. Brandli and M. Dick, “Alternating current fed power supply,” U.S. Patent 4 084 217, Nov. 4, 1978.

*Basic format**for theses (M.S.) and dissertations (Ph.D.):*

a) J. K. Author, “Title of thesis,” M.S. thesis, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

b) J. K. Author, “Title of dissertation,” Ph.D. dissertation, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

*Examples:*

1. J. O. Williams, “Narrow-band analyzer,” Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, USA, 1993.
2. N. Kawasaki, “Parametric study of thermal and chemical nonequilibrium nozzle flow,” M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.

*Basic format for the most common types of unpublished references:*

a) J. K. Author, private communication, Abbrev. Month, year.

b) J. K. Author, “Title of paper,” unpublished.

c) J. K. Author, “Title of paper,” to be published.

*Examples:*

1. A. Harrison, private communication, May 1995.
2. B. Smith, “An approach to graphs of linear forms,” unpublished.
3. A. Brahms, “Representation error for real numbers in binary computer arithmetic,” IEEE Computer Group Repository, Paper R-67-85.

*Basic formats for standards:*

a) *Title of Standard*, Standard number, date.

b) *Title of Standard*, Standard number, Corporate author, location, date.

*Examples:*

1. IEEE Criteria for Class IE Electric Systems, IEEE Standard 308, 1969.
2. Letter Symbols for Quantities, ANSI Standard Y10.5-1968.

*Article number in reference examples:*

1. R. Fardel, M. Nagel, F. Nuesch, T. Lippert, and A. Wokaun, “Fabrication of organic light emitting diode pixels by laser-assisted forward transfer,” *Appl. Phys. Lett.*, vol. 91, no. 6, Aug. 2007, Art. no. 061103.
2. J. Zhang and N. Tansu, “Optical gain and laser characteristics of InGaN quantum wells on ternary InGaN substrates,” *IEEE Photon. J.*, vol. 5, no. 2, Apr. 2013, Art. no. 2600111.

*Example when using et al.:*

1. S. Azodolmolky *et al.*, Experimental demonstration of an impairment aware network planning and operation tool for transparent/translucent optical networks,” *J. Lightw. Technol.*, vol. 29, no. 4, pp. 439–448, Sep. 2011.

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