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Management of Distributed Energetic Resources

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Abstract

The integration of distributed energy resources for the production of electricity is related to the evolution of future distribution and transmission networks. That is how, to achieve: flexibility, reliability, quality and economy are the most important pillars in the great impulse to transform the electric sector according to the increasing energy demand. In this framework, this paper presents some results of a joint research project between the Francisco José de Caldas District University and the Administrative Department of Science, Technology, and Innovation (Colciencias). The main research focuses on a proposal for the integration of the main functionalities of a centralized distribution management system (DMS) for the operation and control of energy resources. Establishing the evolutionary pillars of distribution networks along with the principles of operation, where generation, storage, automation, protection, and monitoring are part of the construction of modern systems for the administration of electric energy.

Keywords: renewable energy, distributed energy resources, distributed generation, distribution management system

INTRODUCTION

The integration of the Distributed Energetic Resources (DER) for the production of electrical energy is related to the evolution of the future distribution networks with the purpose of achieving [1]: (1) Flexibility: to satisfy the needs of the final users. (2) Accessibility: to allow the access to the local integration and particularly to the renewable energies. (3) Reliability: to ensure the best possible security and high-quality levels of energy. (4) Economy: to allow a proper management of the supply in an efficient and competitive way.

Thus the DER deployment has brought with it several benefits, but at the same time, there are many concerns regarding the successful management of the distributed and diverse, energetic combination.

That is why numerous researches have detailed that to satisfy the aforementioned presented objectives brings adopting alternatives that allow: Firstly, developing innovative methodologies and technologies for the operation and control of the energetic resources connected to the distribution networks. In the second place, the standard definition, protocols and proper structures of market regulation, that would make possible the evolution from the old to the new active of the electronic network.

Under the two aforementioned presented points, this paper describes how the DER will contribute to achieving a smart electronic network and how the planning, the supervision, the analysis and the control, will be under the DMS perimeter. Under the premise of a system that faces a decreasing margin between the system load and its capacity, which in turn it needs innovative solutions that help to disperse and storage energy effectively, and of course, managing the resources to satisfy the load.

Following this line of action, the present research proposes the implementation of the DMS between users and supply companies of the electric service, with the aim to help to fill the gap, between the emission reduction and the energetic independence. The implementation of this type of technologies will face the challenge of predicting and controlling with exactitude the DER contributions, to ensure safety and the reliability of the electronic network.

This article is structured as follows: in the section tow, the most relevant concepts for the proposed DMS are presented. In section three the most important aspects of SG are shown. In section four a proposal is submitted to implement the DMS from the user until the operator and/or administrator of the electronic network. Finally, in section five conclusions are drawn.

SUBSTANTIATION

Approximately the 81% of consumed energy worldwide comes from fossil fuels, while the 19% comes from renewable sources [2]. Currently, these alternatives are mainly related to the traditional use of the biomass in applications as the fuelwood use for cooking and warming spaces, and the hydropower for the electric generation.

The previous precedents have allowed that today the supply systems are reconsidered, defining new concepts and actors for the current models of generation and consumption. For this reason, the main interest concepts and their outstanding contributions to the electric sector are described as follows/

Distributed energetic resources

Several types of research have defined that the DER are resources of generation and storage of energy, whose installation is close to the consumption points. Such resources have the capacity of injecting energy into the distribution system through the supply sources, among which stand out: Photovoltaic solar energy, wind turbines, cogeneration, diesel engines, among others. Likewise, the DER promise to be solutions for the storage and promotion in order to ameliorate the energetic efficiency of system [3].

Distributed generation

Also known as a decentralized generation, where the supply points are very close to the consumption points. In other words, the Distributed Generation (DG) is characterized because the large part of the users has a system of self-supply with considerable advantages, such as the reduction of losses for transport, demand control, storage capacity and reliability of supply [4].

The term "Distributed" is used to describe a series of scenarios of generation. Firstly, there is the methodology set, system, and norms that have been boosting the nations, as a governmental compromise to decrease CO2 emissions. Nevertheless, the technological advances in the generation and storage of energy, as well as the information and communication technologies are promoting a new change in the conception of the energetic supply.

Energetic efficiency

This term refers to a set of practices whose aim is to reduce energy consumption as much as possible. This way, the energetic efficiency allows optimizing the productive processes with the greater use of the energetic sources [5]. In other words, the related practices with the efficient use of energy are the core of a low-carbon economy, which pretends to achieve an energetic balance between the supply and demand of the system, characterizing the set of activities from the manufacturer to the consumer, maintaining the quality and the access to goods and services that may be in the residential, commercial and industrial area.

Response to the demand

According to the Energy Department of the United States of America, the Demand Response (DR) indicates variations in the electricity consumption of the users in response to the changes in the energy prices in function of time [6]. Those as mentioned earlier, because the electric power cannot be stored easily, which has led to the companies of public services to change the models of supply and demand. Thus allowing the implementation of a structure of measurement with automated power consumption programming devices, which in turn have been recognized as tools to train clients in order to obtain cheaper energy and much more reliable systems.

Microgrid

A Microgrid (MG) is a small supply network with the autonomy of being present or not in the temporality of the load. In the same way, several researches have defined that the MG are groups of loads with a topology that underlies in the DER. On the other hand, in [7] is detailed how the MG are small distribution systems and storage with a specific role in the energy management between the supply and the demand.

A communal MG could also be very helpful for a small community of then homes, and it can work for a municipality of thousands of homes and commercial clients, covering a wide geographic are and a variety of types of load, including residential, commercial and other critics as a situated load in a remote city or part of a city.

Electric Vehicles

This type of avant-garde technology is taking place the new schemes of energetic distribution and storage, given its main contributions to the reduction of greenhouse gas emissions and mainly for being an option of sustainable mobility and friendly with the environment [8]. However, the increasing investments in renewable energy pose operational challenges due to the intermittency that the system can experiment. Nevertheless, the integration on a big scale of the electric vehicles (EV) also means contemplate the projection of the demand for new loads in the distribution network. By doing so, it is important to foresee congestions and undesirable fluctuations in the continuous operation of the system.

The EV will start to have an impact on the distribution system. It is not expected that their initial effects will be in the entire network. However, it is possible that the first implementations of this type of technologies are located within specific areas of urban area, impacting the network at the level of the distribution transformer or primary feeder

Thought leaders agree that the penetration of the EV will be focused initially in localized areas (neighborhoods of early adoption), impacting the secondary networks of the distribution system. However, the EV penetration will require the following planning points: (1) the battery loading scenarios vary: when higher is the loading level, higher the energy demand will be; (2) the tariff structures are necessary to help to control the balance between the supply and the demand in the system; (3) the real-time supervision can contribute to model the demand with precision; (4) the network planning can address in a preventive way the potential problems.

Having a clear vision of the planning scenarios, the public services companies can help to promote the desired loading habits. Where the network operator or the distributor will adopt mitigation strategies with the purpose of satisfying the challenges of the supply and the demand.

Energy policies

Energy policies are evolving around the world with different regulations in each country [9]. Furthermore, most of the policies are helping to promote the investment priorities of the SmartGrid (SG), where the use of renewable energy resources is becoming one of the most important pillars in the supply chain. Hence, while the impetus to embark on SG initiatives is advancing, nowadays there are not two same projects because the implementation of each solution is unique and depends on countless variables to control. However, all projects share the following topics described below:

- ✓ Regulation that promotes the reduction of carbon emissions
- ✓ Study of regulations, since there are regulatory frameworks more advanced in some countries than in others
- ✓ Study of potential exploration variables. Primarily, wind energy and solar energy have become viable energy sources
- ✓ Energy storage as an incident factor to ensure the service reliability in the face the increasing energy demand
- ✓ Search for help and/or stimuli for the advanced deployment of emerging technologies
- ✓ Convergence of traditional generation capacity and increased system load.

As the renewable resources as the solar energy and wind power have a positive deployment, the Information Technology (IT) solutions will be an integral part of their success. Likewise, storage technologies will have to move forward to leverage supply and avoid vulnerability in system reliability.

IMPORTANT ASPECTS OF THE SG IMPLEMENTATION

Load and system capacity

The electric sector is experimenting a common tendency: the margin between the load and the system capacity is decreasing, and it is expected to continue with a declining tendency in the backing capacity. Which it implies that the companies that provide the energy service must incorporate new “supply” sources to foresee the improvement in the demand management, and add the storage capacity for the purpose of maintaining a healthy margin between the energy consumption and the constant projection of the demand in the regulated and non-regulated users [10]. The demand management is the least used option, but it represents a significant potential due to the various innovative forms of implementation.

Energy Sources

The Ontario Power Authority in Canada recollected data to identify the existing energy sources, through a scavenging capacity installed in the system and determining the current energy demand of the population [11]. Likewise, the recollected data in the inform foresee the withdrawal of the majority of existing nuclear installations, due to the main policies of a decrease in the dependency of the conventional sources as oil, gas, and coal.

By the above, it is important to identify the change actors that will fulfill the void against the forecasts of the growth of the energy demand, since many companies will have to administrate the resources in order to satisfy the load requirements. Thus, it will be possible to free the electric service from the exponential dependence that today exists with the conventional sources of energy.

Energy consumption control

While some public service clients are installing renewable generation on their initiative, the decision comes mostly from the regulations that promote the emission reduction and energy independence. For instance, the Canadian providence Ontario has implemented a strategy to support the DER penetration [11].

The general strategy consists of reducing the emission and create green jobs, including the increasing of a 33% of the energy from renewable sources. Through the installation of one million solar roofs and the leverage for the automotive electric sector in the deployment of EV, whose energy storage structure will be the most important SG pillar.

Without a doubt, with this type of policies, the users could control and regulate the energy consumption. In other words, the users will have an active role since they can interact with energy market with the contribution of surplus energy and that it is outside of its consumption.

Business model of public services

The companies from the electric sector that incorporate DER will have to plan the new distribution connections. Likewise, they will have to adopt the mechanisms of renewable energy policies, including instruments based on the quantity as the renewable portfolio standards used widely in the United States, where the price structures are based on tariffs and auctions [12].

For marketers, distributors and network operators, the distributed energy resources will become a key factor in the new business model of public services (See Figure 1). At the heart of the new business system lies the centralized intelligence system which integrates and manage devices. Thus allowing the digital interconnection through a variety of protocols, domains, and applications.

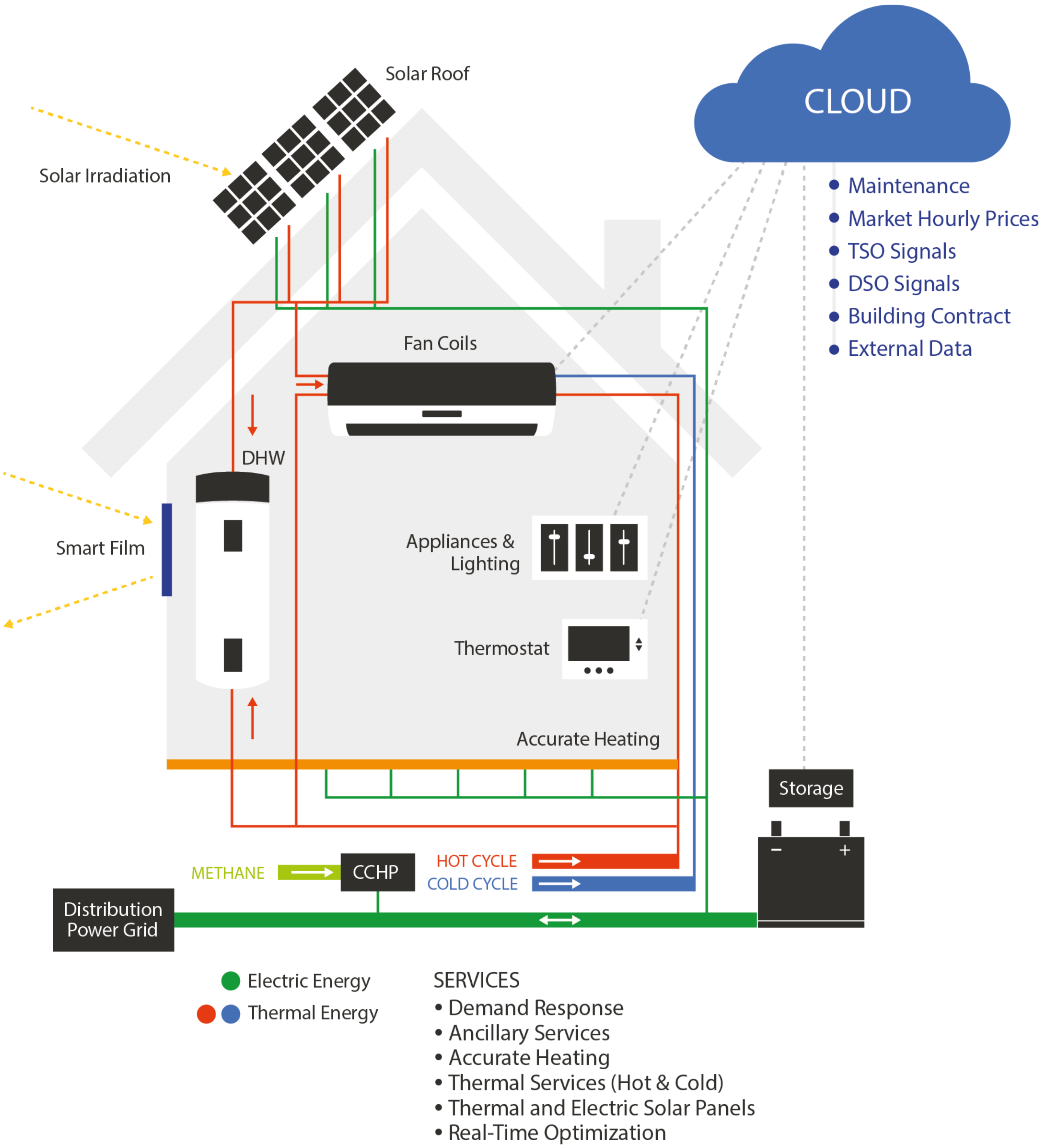

Figure 1: Smart Home with DERs [13]

Figure 1 shows the presence of DG for the energy supply of a single-family house. Where it is presented the continuous cycle of supply with key actors to control and supervise the value chain of the service. That is how the real-time data and accurate network representations, allow easing decisions to necessary response for a secure and reliable transference of the load.

Industry necessities

Nowadays and with technology's progress, the electric and electronic processes of domestic and industrial use are each time more rigorous. The loads have evolved to a constant human-machine interaction [14]. Thus, it is necessary an evolution in the supply concepts, efficiency, and continuity of supply. In accordance with the demand evolution, it is important to highlight what changes are making the agents of the electric sector in pursuit of going forward in the relationship between energy supply and demand. According to the aforementioned, the raised research question in this paper was: How does the network operator or distributor manage the power supply for loads of the system?

Undoubtedly, and visualizing the necessity of the electric sector, it is key that the public services companies integrate new supply models, computational tools with the capacity of monitoring the integration of the GD with the users. Where it can be detailed in real time the network optimization and thus having an integral planning of the consumption needs. Nevertheless, the primary focus of this type of tools would be in smart structure or SG. In Figure 2 is shown a block diagram of a computational tool or software that requires the control and monitoring of a distribution network.

DMS PROPOSAL

Taking into consideration the challenges of the new electric structure that the sector demands, the current research proposes an energy administration system for residential, industrial and commercial users that adjust to the necessities of incorporating change agents such as GD, DER, MG y SG. The advantages, technologic challenges, and implementation structure are described as follows.

Objectives that the DMS must have

A DMS solution can provide a series of analytic functions, that will optimize the network efficiency and will allow an effective and efficient integration of the system. Some of which are identified as follows:

Controlling network operation – Including fault localization, isolation and service restoration with optional closed loop (automated) control switching, as well as large surface restoration and load shedding to help maintain system stability during extreme peak periods.

Optimizing network operation – Including a Volt/ VAR control to administrate the switches and/or the load controllers, voltage capacitors and regulators with closed loop control, optional for an auto restoration operation [15]. A DMS also allows monitoring the renewable energies through detailed load profiles and with integrated meteorological data in real time, it supports better short and long term load forecasting. It is also compatible with thermal energy storage and evolution of battery technology.

Analyzing the network operation – Including energy losses, as technical as commercial, protection relays through device adjust and coordination, and harmonic distortion notification. Likewise, the contingency and security assessment with the purpose of identifying service reset options after a fault has occurred.

Planning the supply network – Including the simulation which supports the development, minimizing the losses and detecting overload to reinforce the network, taking into consideration the load forecast, in the medium and long term, and its increase in the electrical system

Network operation

The management systems of the energy administration are the brain of the distribution network. For its implementation, it is relevant to understand how the SG technologies can be integrated with the purpose of producing a useful system, as for public services suppliers as for Information and Communication Technologies operators (ICT). All this, despite the objective of carrying out the opening of new markets and producing new business models [16].

Due to the significant energy infrastructure challenges in the current business model, concepts as supervision, control and data acquisition (SCADA) [17], have been articulated with the centralized management system (DMS) to create a real-time network model, with the capacity of interacting with interruption management systems (OMS) thus having an optimum control of the distribution networks necessities.

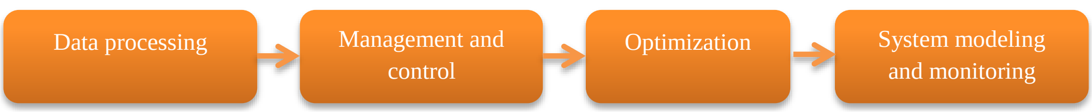

Figure 1: Focus of the energy management system

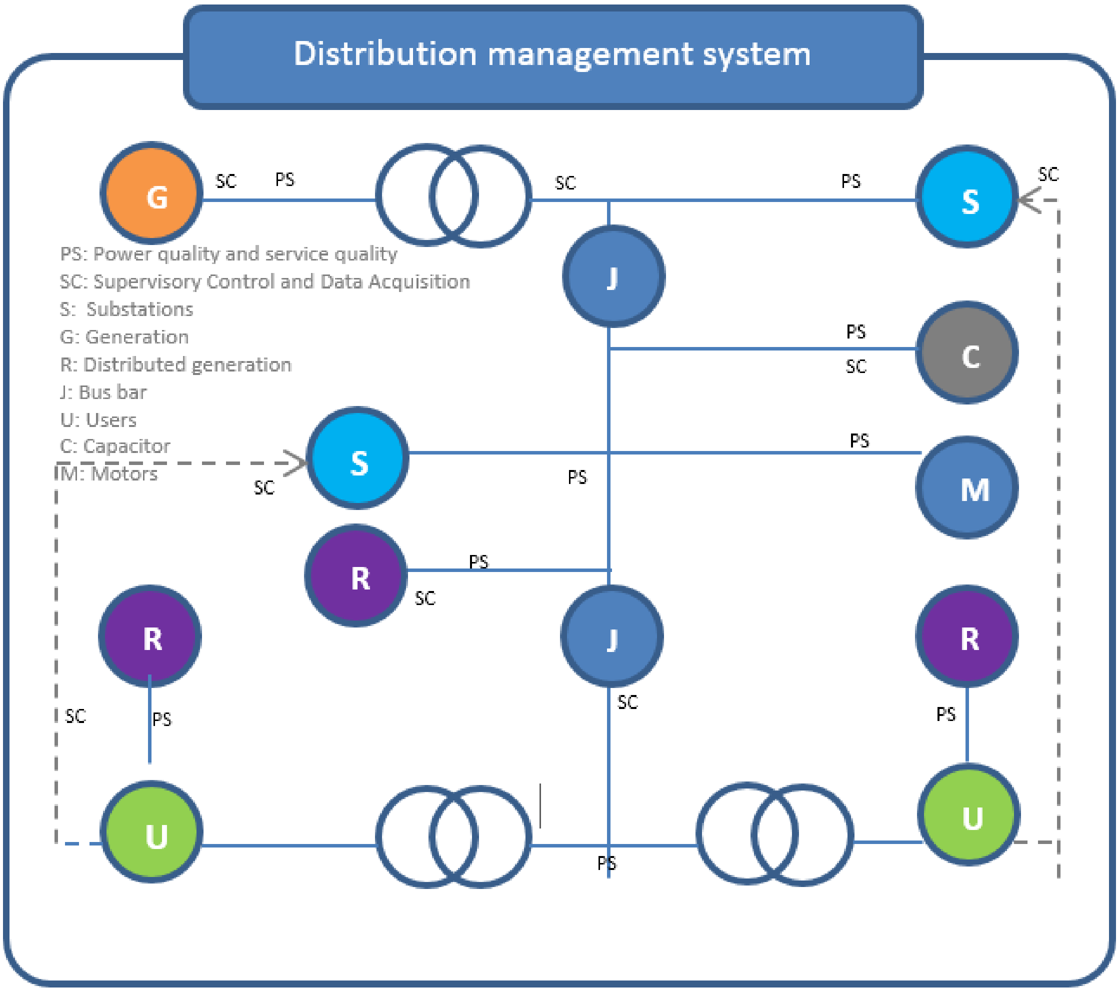

Figure 2: DMS Distribution Management System

For instance, figure 3 shows a distribution network with multiple conventional generation points (G) and no conventional (R), stressing the importance of interconnection (J) of the different load systems, such as motors (M), capacitor banks (C) and final users (U). Undoubtedly, it is easy to notice how the GD is very close to consumption places; thus increasing the reliability level and electrical supply quality, due to a constant monitoring through communication systems.

Likewise, it can be noticed in the picture how the control and operation points (S) develop a fundamental role since all the electrical power system is supervised with the objective of detecting all the generation and consumption variables strategically. Accordingly, the SG system allows integrating the behavior and the actions of every connected user efficiently, ensuring the network to be sustainable and efficient, with low losses and high-quality levels.

Based on the aforementioned, it would hope that the ideal DMS perspective offers three operative approaches to fulfill better the reliability and efficiency objectives: (1) to provide the users the ability to visualize the events that may affect the quality and/or the reliability of the energy supply. In general terms, the users can detect the discontinuity of the service in a specific point in the network. Consequently, proceeding with the network operator's notification in pursuit of the system restoration. (2) Automation in the consumption profiles, for instance, a residential user will have the capacity to operate some loads from their home when they consider that the energy price is not within the trend of peak values. (3) Monitoring the electrical consumption variables with the estimation of the price of the consumed and generated energy, if there is a user with a distributed generation system.

From a company providing the electric power service, the DMS must have the capacity to perform the following actions: (1) monitoring, analysis, and control of network operations; (2) load management and adjustment of the demand curve; (3) plan the integration of new resources incorporated in the network, under the precept of the load flow and demand capacity; (4) prepare an efficient and safe deployment of DER, including storage and MG.

DMS Architecture

It is well known that the local controls are no longer adequate to mitigate the voltage regulation problems caused by the bidirectional energy flows or to manage failures in the distribution systems with high DER levels. There is a consensus about the necessity of hierarchy control, but the technics for the optimization of the system go from the main control system until autonomous agents. The autonomous agents have a great benefit of decreasing the necessity of employing broadband communication systems, but in many cases, there is a need for central coordination that reduces the value of agents [18]. This is why the network operators often tend to look for hierarchical strategies for transparent market-based decision making. However, to achieve an improvement in the energy management, the network operators state that necessity was born, of implementing technologic resources intelligently and autonomously for decision making that may count with a centralized system with following characteristics.

- ✓ Installation of expert monitoring systems at each common coupling point (CCP) for the different actors that interact in generation, transmission, distribution and consumption
- ✓ The primary substation or feeder equipped by SG, it will act as a control center to take the control and operation actions with respect to DER
- ✓ Intelligent measurement will allow the MG or those small generation units to interact in the surplus energy supply for the system
- ✓ Satellite navigation systems (GPS) will allow the determination of the time reference and the exchange of measurement data, with the sending of control signals between the control center, generation sources and consumption points. The most typical functionalities will be oriented to the detection of failures and the restoration of the network.

In order to achieve the pillars mentioned above, the DMS algorithms must provide the real-time network status, through data collection of the measurement system and all the available information obtained with the historical system data. The DMS will supervise the functioning of the electrical distribution network, and if it is needed, it will modify the operation itself (for instance, in generators (GD) and storage devices) according to with the optimization result.

Now that it has been defined the field of action of the DMS, it is key to understand that DER must send day after day the offers to the control center for the generation of active power and reactive of the system. Offering changes in the energy production schedule and the demand projection. This is how the network operator could provide to the DER control actions for the network active management, based on the results of an intra-daily optimization. Finally, if the active management reaches an advanced level of implementation, the reconfiguration of the network can also be profitable.

All of the above would only be possible if the DMS implement expert real-time signal processing systems such as digital processors (DPS), with the dedication of continuously studying the state of the network, technical limitations as well as the market prices and information on energy trades. These devices must necessarily be equipped with actuators that allow to carry out the requests of operation from the control center. Communication between the control center and the actuators is possible through the use of secondary devices called intelligent electronic devices. For this reason, all the integration of the control, supervision and operation system would be integrated into the concept of "intelligent network."

Control Algorithms

The main challenge that must face the intelligent energy network is the way in which it is administrated the great quantity of associated information. Where the new regulation schemes address a vast number of interconnected nodes, where the information flows in real time about the different characteristics of the system, such as energy demand, price, power quality, the reliability of supply, load profiles, among others. In this sense, one of the main objectives of computational intelligence will be intelligent management, so that conclusions can be obtained that support decision-making [19]. This challenge fundamentally contemplates the complex processing techniques for the search of patterns. For example, Figure 4 illustrates artificial or computational intelligence models that must be incorporated into energy management systems. Thus, computational intelligence plays an imperative role in the analysis but more importantly in making intelligent decisions in conditions of uncertainty.

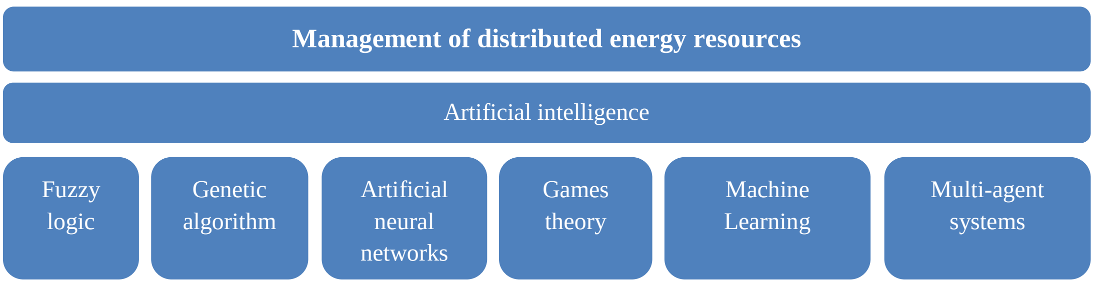

Figure 3. Artificial intelligence to DMS

Avant-garde DMS projects

As mentioned in [20] using DMS Volt / VAR functionality, companies that provide the electricity service are reducing the feeder voltage automatically, with no effect on the consumer, and delaying or eliminating the need to build a large-scale generation.

Another critical aspect in the DMS is the utility of maximizing distributed generation in a large mainly rural territory and seek support in tariff regulations regarding supply through distributed renewable energy. Those mentioned above, with the aim of leveraging energy coverage in areas not interconnected or difficult to access.

For example, in [21] the functionality of the DMS model is identified to monitor the high growth of the DG and to plan the clearance and efficient control of the same proactively. Energy service companies are doing this in a way that also provides economic benefits, taking advantage of the load forecast based on consumption profiles in the records made by energy meters as well as integrated meteorological data.

Likewise, to optimize the efficiency and reliability of the network, it is desirable that the deployment of the DMS allows optimum operation and control, ensuring reliability in the face of ever greater constraints on energy management challenges. Thus, the present research proposes that the DMS system should provide three operational approaches to success in its implementation, which are: (1) the availability of advanced tools whose leverage is supported by ICT; (2) the integration of users into an automated control and monitoring system; And (3) the planning of smart supply networks based on new energy policies.

CONCLUSIONS

The evolution of loads of domestic and industrial use and the exponential demand for the electric energy has brought with it the rethinking of the systems of energetic supply. Where distributed energy resources tend to the supply management paradigm, and whose primary objective is to ensure that expert systems have the possibility to study a large number of variables that interact to make decisions that help leverage the electricity industry.

This is how the DMS architecture has been recognized in the present study as the great tool for the operation, control, and planning of DERs. Therefore, this type of instruments demands a series of optimization techniques in which the needs of the sector are articulated together with the analysis tools such as computational intelligence or artificial intelligence.

Once the study models are identified, it is important that the DMS is alienated with the ability to respond to a system that demands capacity to support thousands of connected smart devices, data delivery in real time and last but not least perform The motorization of the electric network everywhere.

This type of research is crucial for the traditional Colombian electricity sector since at present a small part of the area is aligned with the global trends in energy supply (distributed generation, distributed energy resources, energy storage). The current research thus provides a brief overview of the crucial need to adopt new concepts for the planning and operation of future distribution networks.

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