Is electricity regulation in Colombia prepared for to incentive modernization of distribution networks? : Challenges and proposal

¿Está la regulación eléctrica colombiana preparada para incentivar la modernización de las redes de distribución?: desafíos y propuestas

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ABSTRACT

The evolution towards active distribution networks implies new challenges in the operation of electric power system, specially related to minigrids operation. Integration of distributed generation, modernization of distribution network and demand response programs require energy policies that impulse the operators investment in new technologies. This paper present review of aspects associate to an evolution towards active distribution network considers technical, economic and regulatory issues, presents the actual Colombian regulatory framework related to modernization of distribution networks (devices and programs) and show the main challenges in the operation of minigrids in Colombia.

Keywords: Active distribution systems, energy policy, minigrids, islanding operation.

RESUMEN

La evolución hacia las redes activas de distribución implica nuevos desafíos en la operación del sistema de potencia especialmente relacionados con la operación por minirredes. La integración de generación distribuida, la modernización de la red de distribución y los programas de gestión de demanda requieren políticas energéticas que impulsen la inversión de los operadores en las nuevas tecnologías. Este paper presenta un análisis los aspectos considerados en la evolución hacia las redes activas de distribución considerando temas técnicos y regulatorios, presenta el marco regulatorio colombiano relacionado con la modernización de las redes de distribución (dispositivos y programas) y muestra los principales retos en la operación de las minirredes.

Palabras clave: Minirredes, Sistemas de distribución activos, Operación por isla, políticas regulatorias.

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Introduction

The evolution towards active distribution networks with distributed generation (DG), users respond to market signals, new communication devices, an integrated control system and the islanding capability when a failure occur in the Electric Power System (EPS), is a challenge in the operation of minigrids (Berry, Platt and Cornforth, 2010).

The operation of a minigrid with the islanding capability have a similar operation to a traditional EPS (Sioshansi, 2011), it implies that most operational problems encountered in the EPS appear in minigrids (Barnes, 2007). Therefore, the operation of a minigrid requires planning to a successful operation (IEEE, 2011), and to have ancillary services that allows a reliable and secure of supply (Dobakhshari, Azizi and Ranjbar, 2011).

It is necessary to define a smart planning of distribution system in order to make it and active and flexible system, taking into account new technical constraints, uncertainties associated with energy demand, the behavior of primary resources and geographic location of the minigrid (Borges and Martins, 2011).

Regulatory policies are fundamental pillar that ensure the development of minigrids. In Colombia, the future is conditioned to modify regulatory policies that allow investments in the modernization of distribution networks, in order to encourage network operators and demand to integrate to the operation of minigrid (Sioshansi, 2011).

With the publication of Law 1715 of 2014 (Gobierno de Colombia, 2014), Colombia opens up the possibility of integrate renewable resources with storage systems to the distribution network, which together with traditional DG by Small Hydro Power (SHP) or

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diesel plants diversifying the energy matrix and allows to give a dynamic to distribution networks.

In this paper we analyze the features involved in the evolution towards active distribution networks and minigrid operation. Finally we analyze the current regulation in Colombia facing to operate with active distribution system, including the possible connection of new generation sources, the automation and the participation in the energy market.

Evolution towards active distribution networks.

Nowadays, the integration of new resources and technologies to the distribution networks is transforming the operation of the current electrical power system. This leads to a modernization of the passive networks with unidirectional flow and centralized generation, to active distribution networks in which distributed generation, bidirectional communication and automated distribution networks are incorporated (Chowdhury and Crossley, 2009, Hatziargyriou, 2014). To accomplish this transition, it is necessary to develop a sustainable electric infrastructure with flexible and intelligent measure and control, in addition to the integration of new technologies, leading to the operation of smart grids and minigrids (Sioshansi, 2011; Chowdhury and Crossley, 2009).The main changes that must be performed in the distribution system are shown in Figure 1. Currently, a control center coordinates the operation of the entire EPS in order to maintain a balance between generation and demand, ordering maneuvers to the operator of the local control center which supervises and controls the operation of the distribution system. However, the evolution towards active distribution networks requires automated substations and the possibility of independence of the local control center to maintain a continuous communication with distributed generation, demand and the main network in order to ensure a reliable and security of supply.

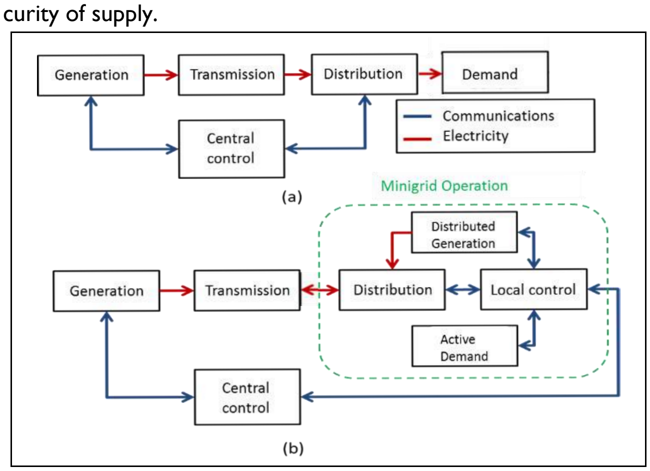

Figure 1. Operation structure (a) Current network (b) Active network. Source: Own

Minigrids operation

Minigrids operation allows to maximize small-scale integration of generation assets, automated distribution networks and demand response in order to create electrical power subsystems, which would be independent of the central interconnected system. Islanded operation of minigrid maintain the electricity supply to the connected users when a failure in the main grid causes partial or complete disconnections, therefore increasing the reliability and efficiency of the distribution network (Costa and Matos, 2005; Gharavi and Ghafurian, 2011). This disconnections would avoid expensive sanctions to transmission companies, respect of demands and penalties brought by users due to unexpected blackouts which generate economic losses (Aghamohammadi and Shahmohammadi, 2012; Carvajal and Arango, 2013). Develop islanded minigrids in order to provide reliable and security of supply, unlike the conventional operation of distribution networks, involves challenges (IEEE, 2011). Mainly, variations in generation may cause drastic changes in frequency or voltage, triggering problems in power quality, voltage collapses and abrupt changes in frequency, leading to a complete disconnection of the minigrid users (Iravani and Mehrizi-Sani, 2010).

To prevent any kind of failure in the operation by minigrids it is necessary to invest in frequency and voltage control systems in distributed plants when a failure occurs in generation (Arango-Manrique, Carvajal-Quintero and Arango-Aramburo, 2011).

As well, installing measuring and control devices across the demand to avoid disconnections when occurs power outages and in order to have an active demand response in the operation of islanded minigrids, which constitutes an additional ancillary service such as voluntary disconnection in event of faults (Vandoom, Zwaenepoel, Kooning, Meersman and Vandevelde, 2011).

Integration of new resources to the distribution system

In this section we analyze the features involved in the integration of distributed resources in the minigrid, the benefits of DG connected near to the consumption centers, and the operation of minigrids in an active distribution system.

The features required for distribution networks to operate as islanded minigrids when events occur in the EPS are defined in figure 2. The main support of minigrid operation is the regulatory policies that encourage investments of different actors in the elements required for this purpose (Ruester, Schwenen, Batlle and Pérez-Arriaga, 2014). This elements include, among others, a communication and control system that allows interoperability among the operator, minigrid sources and the users. Besides including new technologies in terms of generation, especially renewable, and meters that enable the demand to know market dynamic in order to actively participate in it. The benefits and contributions are the foundation for the efficient management of energy resources that support the EPS operation and allow the operation by islanded minigrids.

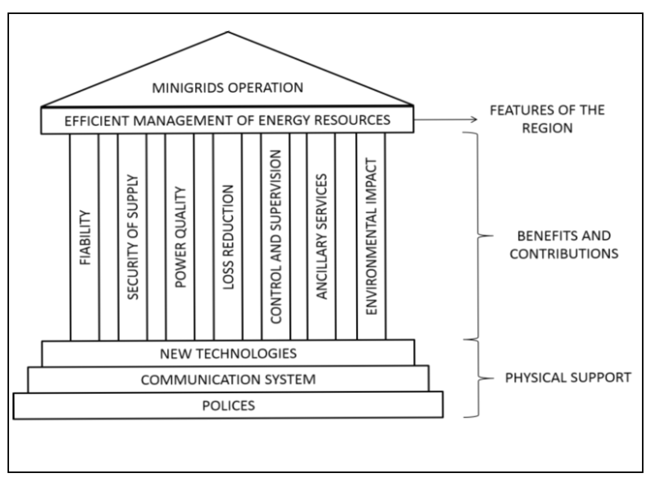

Figure 2. Synthesis of minigrids operation. Source: own

Distributed generation resources

Generation used in minigrids is small-scale generation commonly known as DG because it is connected to voltage levels of distribution networks (Belmans, Pepermans, D'haeseleer, Driesen and Haeseldonckx, 2005).

For the islanded minigrid operation, the frequency and voltage control is fundamental in order to maintain stability, because it no longer has the high inertia that is formed by interconnected generators. The converters guarantee the controllability of DER that are immersed in the minigrid (Mohamad, Mokhlis, Halim, Bakar and Wooi, 2011; Vásquez, Guerrero, Miret, Castilla and Garcia, 2010).

It is necessary to automate electrical substations in terms of communication and control according to the international standard IEC 61850 (IEC 61850, 2011) with the intention of ensure that the minigrid operate under different scenarios such as islanding detection, operation connected to the network, operation in island mode and reconnection to the network (IEEE, 2004).

The advantages of integrating DER in the distributed system are, among others, reduction of losses in distribution system, improvements in voltage profiles and power quality (Arango-Manrique, 2011). In economic terms changes are also presented when there are DER in distribution system because investments are delayed and losses costs are reduced (Matos et al, 2009).

When DER are integrated into the electricity market, the traditional operation changes and presents benefits in economic terms. In addition, it is easier for a distribution network have minigrids as local production units. It is possible to exploit the entire potential that minigrids offers to the distribution network (Barbosa Almada, 2010).

Colombia has a potential laboratory in terms of minigrids. Current distribution networks in Non Interconnected Area (ZNI by its Spanish initials) because it have advanced in issues associated with connecting generation near to consumption centers, centralized and controlled measure (smart metering) and minigrid remote control (IPSE, 2014), which would reduce the implementation cost and would allow the assessment of technical and economic impact of developing minigrids.

Relevant Laws to generation activity in Colombia are the laws 142 and 143 of 1994 which regulate public services and electricity service respectively, as well as Law 689 of 2001that refers to rational and efficient use of energy, and the law 1215 of 2008 corresponding to the cogeneration activity (Gobierno de Colombia, 1994; Gobierno de Colombia, 2001; Gobierno de Colombia 2008). To perform the generation process under clear rules in the market, CREG defines some resolutions that determine the operational and market process to each of them. With the Law 1715 of 2014 there is a possibility of deliver the surplus from self-generators to the network, their participation in the market would be regulated under the premise that they will be equal to the traditional generators. This means they must pay guarantees of the connection point, they need to be or have a generating agent who represent them in the market and have different boundaries to generation and consumption (Minminas, 2014).

Technically only large generators can provide ancillary services (CREG, 2008) and there is no regulation that requires or allows smaller plants provide ancillary services to the network or participate in secondary markets. This would provide adequate infrastructure for the islanding operation of the minigrids, keeping the variables within allowed ranges by the regulation when events are presented in the EPS (Lopes, Moreira and Madureira, 2006). However, in Colombia small-scale generation do not have frequency and voltage control devices, therefore it is unlikely minigrids operation at the present time.

There are gaps in Colombian regulation in terms of marginal or independent producer, in addition to the lack of regulation in DG issues and the consideration of the advantages for the distribution and transmission system in order to reduce costs and solve network congestions, increase reliability and reduce losses (Rodriguez Hernandez, 2009). For that reason, it is necessary to have resolutions that allow smaller plants provide ancillary services in emergencies or events that occur in the EPS.

Active distribution grid

Infrastructure of the current distribution system was mostly built several decades ago, this is why it need to be reconfigured and upgraded to connect new technologies, especially control and telecommunications to make it possible for minigrids to operate in island mode (Sioshansi, 2011).

Non-technical energy losses affect the EPS and users. Colombia registered 20% of losses in transmission and distribution systems compared to average losses of 17% in Latin America countries (World Bank, 2012).

In Colombia the technical regulated conditions in distribution systems are, in terms of regulation, associated with power quality, reliability and security of supply defined by CREG in resolution 070 of 1998 (CREG 070, 1998).

Nevertheless, based on modifications to the power quality regulation (CREG, 2005), the installation of power quality measurement devices and the report of registered information is required (IEEE, 2011) as the first step for registering information and with the aim of ensure the interoperability of the EPS, i.e. the installation of power quality measurement devices in the EPS with remote control and remote management.

Telecommunications are considered as one of the principal elements in minigrids operation and a new element that must be included in electrical infrastructure (IEEE, 2011), that is, Advance Metering Infrastructure (AMI) and Automatic Meter Reading (AMR) systems are required to ensure the participation of agents, and for an efficient management and control (Iravani et al, 2010).

Demand response

Advance metering initiatives in Colombia as still being developed. AMR systems in distribution companies are used for special clients (unregulated users) because of the market structure and according to CREG in resolutions 199 of 1997 and 131 of 1998 (CREG,1997; CREG, 1998) . Operators and electricity traders in Colombia use the measurements to perform the billing process and as a focus for the control of energy losses.

The number of meters installed in Colombia as a result of mandatory regulation and initiatives such as the Electricity Network Standardization Program (PRONE by its Spanish initials) is shown in Figure 3.

Developments related to the concentration of measurement are developed with the support of the national government, such as PRONE that is promoted by Article 63 of Law 812 of 2003 (Gobierno de Colombia, 2003) which was regulated by Decree No. 3735 of December 19 of 2003. With the aim of standardizing the electricity networks in subnormal neighborhoods associated with centralized measurement and with the purpose of reduce technical and non-technical losses in the system, this implies the installation or adjustment of the distribution networks, the connection to customers' homes and the energy meters in order to legalize users, optimize service and reduce non-technical losses (Minminas, 2003).

The Electricity Network Standardization Program will be financed even with the 20% of the collection of the Financial Support Fund for the Electrification of Interconnected Rural Areas – FAER, according to Law 1117 of 2006 and with the resources provided under the Article 68 of Law 1151 of 2007 (Gobierno de Colombia, 2006; Gobierno de Colombia, 2007).

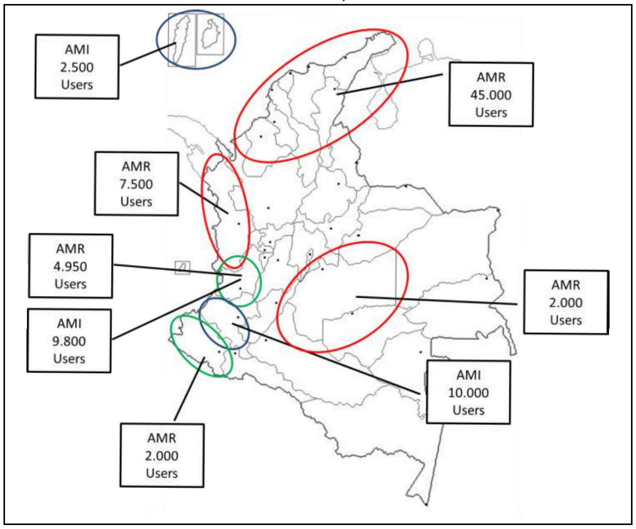

Figure 3. AMI and AMR meters installed in Colombia. Source: Own

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The demand response program in Colombia only appears in the reliability charge. This charge remunerates the maximum power that is able to deliver a generation plant for one year continuously in extreme drought conditions called Firm Energy Obligations (OEF by its Spanish initials)(CREG, 2006), and being a tool for generators that facilitates the compliance with the OEF. This mechanism allows generators which anticipate that their Firm Energy is not enough to meet the OEF to negotiate with users, through energy traders, voluntary reduction of energy demand (CREG, 2010). In Law 1715 of 2014 the demand participation activity is regulated, however, its implementation and its active participation in the market is unclear.

By the other side, a resolution Project define the mechanism to disconnect users when the EPS have critical conditions (CREG, 2015). However there are gaps according to the remuneration and the roll of the operators in front of the new technical conditions.

Demand is an active agent in the electricity market when a minigrid that participates in the market through disconnection schemes of non-critical users, stocks and voltage and reactive power control is implemented (NERC, 2007; Khamphanchai, Pipattanasomporn and Rahman, 2012; Torriti, Hassan and Leach, 2010); this participation promotes the reduction and the shift in demand curve, improving efficiency without interfering the quality of life of users (Ramírez Escobar, 2008).

Toward a Minigrids operation in Colombia, based in active distribution system: challenges and proposal

Although currently the development of minigrids in Colombia is just beginning, efforts must be made in order to have a regulatory scheme that enables to integrate new technologies to the distribution network. This will lead to new operational guidelines which generates additional costs to network operators, therefore it is proposed to analyze and implement regulatory policies that allow articulate ancillary services when events in the EPS or critical operating situations occur.

The resolution project CREG 179 of 2014 define the mechanism for the remuneration of the distribution networks, which gives light on automation, modernization and remuneration for increasing quality service, and for provide additional services to users (CREG, 2014).

With the implementation of a new remuneration scheme of distribution assets, the regulator expects advance toward active distribution networks. However, in the resolution project, the inclusion of DG within the operation dynamic is unclear. The benefits of connected generation near to consumption centers are neglected and only consider the surplus of the self-generators to contribute to the management of energy losses. Furthermore, benefits provided by demand to the losses management should be considered when financial compensation or payments for maintain system variables within the ranges are included.

Support capacity from the distribution system, which can be hired by users, according to the resolution project, has gaps because this could be considered as a complementary service and would increase the economic benefits for network operator.

The ideal scenario to define pilot projects that allow analyze the impacts on distribution networks without increasing risks to the interconnected power system are the ZNI. These areas operate in isolation of the main grid and as a result of PRONE, many of these areas already have centralized metering technologies that constantly monitors demand, which constitutes an important tool in minigrid operation. Nevertheless, many of the energy problems in the ZNI lies in the lack of technical information of the distribution networks conditions, the absence of studies and measurements of the energy potential of the area, and the deficient demand estimation (Pantoja, Guerrero and Fajardo, 2015). In light of the above, it is a priority obtain accurate information of the current network and of the energy potential of those areas in which the implementation is planned. Additionally, the regulation must be clear with respect to the role and the remuneration of the network operator in these new schemes of supply and respect to demand participation in the market. However, exploiting the entire potential of the ZNI as a natural laboratory for the penetration of minigrids in Colombia also depend on national efforts at research topics of energy management with the aim of articulate academic and government efforts to propose projects in active distribution networks.

Table 1 summarizes the challenges that must be faced in order to create scenarios to modernize the distribution system in Colombia, with respective proposal for how to improve interoperability, reliability, security and the use of ancillary services in distribution network.

Conclusions

Change the operation to an active distribution system involves an adjusting of existing electrical infrastructure (feeder reconfiguration and the inclusion of new measurement, control and protection devices) and include a local control to manage the resources of the minigrid.

With the perspective shown with respect to Colombian regulation, it is observed that it still requires a further development in resolutions and decrees related to the implementation of Law 1715 of 2014 in order to integrate and deploy minigrids to prevent that a monopolistic model governing the minigrids and to enable the active participation of the demand and the inclusion of independent producers.

Resolution project CREG 179 of 2014 allow progress towards the development of active distribution system, leading to modernization, automation and provision of ancillary services from medium voltage distribution networks.
In order to perform tests and analyze the behavior of minigrids, it is proposed implement pilot projects in the ZNI, because these areas have metering infrastructure and generation near to consumption centers that would allow the assessment of parameters and propose the operation of the distribution system as an isolated minigrid.
The possibility that the minigrid operation in island mode allowed to provide ancillary services when an event occur in the EPS or to postpone expansions in the distribution network is proposed. The combination of technical, regulatory and economic studies based on extensive research will guarantee a coordinate operation between the minigrid and the network operator of the distribution system to ensure an optimal operation of the minigrid and to define responsibilities among participant agents.
The offer of distributed resources, the automation and the control of the distribution system allows an efficient energy management that results in an optimization of resources and cost incurred in minigrids. Minigrids operation within a flexible distribution system changes the traditional pattern of operation giving emphasis on the DG sources installed close to centers of consumption and to the demand that actively participates in the market, turning the distribution system on an active system.
The offer of distributed resources, the automation and the control of the distribution system allows an efficient energy management that results in an optimization of resources and costs incurred in minigrids. Minigrids operation within a flexible distribution system changes the traditional pattern of operation giving emphasis on the sources of DG installed close to centers of consumption and to the demand that actively participates in the market, turning the distribution system on an active system.

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Table 1. Main regulatory challenges and proposal regarding minigrids operation in Colombia.

Item	Challenge	Proposal
Distributed Generation	To implement and enforce the proposed provisions of Law 1715 of 2014 with which renewable energies with storage systems can be integrated into the distribution network, it is necessary that CREG, XM and UPME stablish the guidelines that will allow its application.	Create a framework that integrates the proposal defined by self-generators with the network operators considering the communication between the control center of the network operator and the automation of the DG.
	In order to maintain stability and improve the reliability and security of the distribution network with the addition of DG, it is essential to conduct a thorough planning that allows analyse the benefits of each connection according to the characteristics of the connection point and the geographic location (Arango-Manrique et al, 2011).	Include the DG (less than 20 MW) connected to the local distribution system in the proposals for the management of energy losses because of the benefits it has in terms of maintaining the stability and security of the electricity supply.
	The resolution project CREG 179 of 2014 stipulate that self-generators may carry out studies in order to demonstrate the benefits in reducing energy losses and can would share this benefits with the network operator (mutual agreement).	
Distribution Network	To have an evolution towards active distribution networks, in the resolution project CREG 179 of 2014, remuneration is focused on the execution of investment plans, replacement of existing assets, losses management, and improvement of service quality and introduction of new technologies. Network operators must acquire new skills related to smart grids, interoperability and automated substations with the purpose of allow turning traditional distribution system on an active distribution system. Take advantage of the subsidies defined by the resolution project CREG 179 of 2014 with the aim of increase the remuneration of network operators associated with maintain indexes related to service quality, expansion plans with the inclusion of new technologies to reduce energy losses and for losses management.	Include in the expansion plan, programs of losses management with the implementation of new technologies associated with measurement, communication and network automation. A higher remuneration is obtained by including DG in the operation of the distribution system, because it is possible to have a support system to connected users, in addition to reduce the outages number which means economic benefits to network operators. Propose a market of support capacity, in order to increase the investments in the distribution system. Implement the proposed changes to the resolution project, in order to have a distribution system with islanded capability ensuring interoperability between all assets connected to the grid (DG and demand).
Demand	To develop minigrid operation in Colombia properly, it is necessary to have an active participation of the demand focused on energy efficiency, for which it is necessary to use controllability and bidirectional measurement devices to become an active agent that may constitute an ancillary service when events occur in the EPS. Articulate through the energy market agents the Document No. 087 of 2008 which establish the conditions for participation in the mechanism of voluntary disconnection of demand which allows a generator to negotiate with electrical consumers, through energy traders, a voluntary reduction or changes in electricity consumption, when it anticipates that its energy is not sufficient to meet the Firm Energy Obligations	Articulate laws and resolutions to create a robust regulatory scheme that allows interoperability, the inclusion of DER to the distribution system and an active demand in order to create a scenario where it is possible to have minigrids operation in Colombia. Implement demand management programs which enables grid operators meet with the obligations of Firm Energy framed in resolution 071 of 2006 issued by CREG, by introducing to all market agents the responsibilities and benefits of an active demand participation, stipulated by CREG in the document No. 087 which establish the conditions for participation in the mechanism of voluntary disconnection of demand. Take advantage of the benefits of implement smart meters in demand.

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