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Colombian ancillary services and international connections: Current weaknesses and policy challenges

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HIGHLIGHTS

- ▶ Blackout of 2007 forces Colombian regulator to improve security of power system.
- ▶ Four ancillary services are currently used for secure operation of Colombian system.
- ▶ Special Protection Systems service added in 2010.
- ▶ Frequency control is the only remunerated service in Colombia.
- ▶ Legislation should exist for remuneration of voltage control and black start services.

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ABSTRACT

Ancillary services are required to maintain the unity, stability, and quality of power systems. In Colombia these services are required to operate the national power system and the international connections with the neighboring countries. The system is influenced by factors ranging from system's topology to social and political aspects, such as the large number of terrorist attacks. In light of these particularities, we consider Colombia as a learning lab for ancillary services in the region. Colombia's power system relies on three ancillary services for its operation, namely frequency regulation, voltage control, and blackstart service. From 2010 Special Protection Systems were also added. In this paper we first analyze the technical aspects, operational restrictions, financial management, and the most relevant regulatory conditions of these ancillary services of the SIN. We also take into consideration the main regulatory characteristics and statistical data related to energy exchanges that have taken place between Colombia and Venezuela and Ecuador. Thereafter, we depict the main weaknesses and policy challenges that Colombia must address in order to increase the effectiveness and coverage of ancillary services in both the SIN and in the international interconnections. Finally, we propose new market oriented regulations to encourage investments and new tools for international connections.

1. Introduction

On April 26, 2007, a total disconnection in Colombia's National Interconnected System (SIN) occurred that was rated the worst of the last decade in Colombia owing to the extent of the blackout. The total disconnection time, from the time taken for the interconnected system to cease functioning to the restoration process to be completed, was four and a half hours (Ruiz et al., 2008). Following this blackout, concerns were raised by the Colombian regulator and operator relating to the need to improve the security and reliability of the interconnected system (XM, 2011).

Maintaining a secure and stable transmission system is a challenging balancing act in all modern economies (International Energy Agency, 2002). The key to success is the simultaneous balancing of electricity flows to maintain frequency and voltage subject to system stability limits (Stoft, 2002). In the case of the transmission system in Colombia the situation is more complex because in addition to the technical restrictions listed above, the system operator should be prepared for unexpected terrorist attacks, of which there were approximately 200 per year between 1999 and 2007 (Zuluaga et al., 2009).

The installed generation capacity in Colombia is 63% hydro, 32% thermal, and 5% alternative sources (XM, 2011), which increases the complexity for the system operator. The dependence on hydropower

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increases the challenge of ensuring reliability because the American equatorial zone presents the possibility of weather phenomena such as El Niño and its opposite, La Niña (Villareal and Córdoba, 2008), which are characterized by multiyear drought periods for El Niño and intense rains for La Niña. Moreover, a major cause of disturbance in bulk power systems in the world is lightning (Adibi, 2000), and Colombia is among the ten countries of the world with the greatest activity of atmospheric lightning (Gallego et al., 2004).

Despite these external conditions, the SIN maintains a generally stable operation, as the power system receives technical support services to avoid recurrent partial or total disconnections that could cause economic and technical losses affecting their customers (Adibi, 2000). These support services are globally known as ancillary services and are defined as those services required by the transmission or distribution system to maintain the unity and stability of the SIN (Bolton et al., 2000) and the quality of electrical power (Parida et al., 2009). In Colombia, the most used ancillary services in the operation of the SIN are frequency regulation, voltage control, and blackstart service.

Frequency regulation can be divided into three different services that differ in the way in which they operate and their respective response times. It is mandatory for all generators to provide the Primary Frequency Regulation service, which is evaluated qualitatively by comparing how generators respond in terms of power when faced with the changes in frequency. Secondary Frequency Regulation is the only recognized ancillary service in Colombia and is remunerated using the exchange price. This means that it does not have a differentiated price and, as such, high remunerative costs are incurred.

The Voltage Control and blackstart services have no specific regulation. Existing regulations mention these services only in a general operational code dating from 1995 and which does not take into account new technological advances such as microgrids and active distribution networks. Special Protection Services (SPS) are similarly not currently recognized as ancillary services since they are local protective devices only and are not implemented in the whole of electric power system (Adamiak et al., 2006). There is no regulation which specifies the minimum level of reliability required, nor the way in which agents are remunerated for these services.

This paper analyses the technical, economic, and regulatory conditions of the ancillary services of the SIN. These services require special attention in Colombia because of the conditions such as atmospheric lightning, terrorist attacks, and a complex hydro-thermal operation; furthermore, the system is experiencing a growing international electricity exchange with the neighboring countries. Thus, we argue that the system requires a revision and it can also be used as a learning laboratory. This paper aims to identify problems and propose changes that will improve the security of the Colombian interconnected system in the future.

The rest of the paper is organized as follows. Sections 2–5 review the relevant regulatory and technical aspects of frequency regulation, voltage control, blackstart and SPS. In Section 6 the use of ancillary services in Colombia's international connections with neighboring countries is examined, with an emphasis on the key achievements made to date in terms of improving the security of the interconnected power systems. Section 7 describes the challenges and proposals for the future that will help to improve the provision of ancillary services in the Colombian SIN. Section 8 concludes the paper and suggests policy recommendations.

2. Frequency control

Frequency control of the power system maintains a balance between generation and the load in real time within a control area (Raineri et al., 2006). This task is difficult as demand varies by the hour, week, and month and is even more difficult when considering that the typical demand-forecast error ranges between 3% and 5% (Grainger and Stevenson, 1994). Three services related to frequency control are used in Colombia. Fig. 1 shows the time ranges for each frequency regulation.

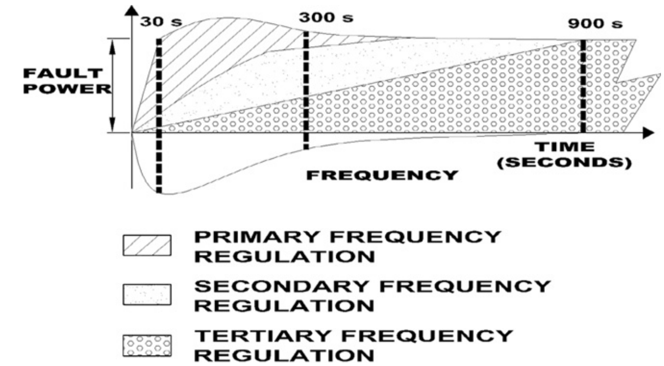

Fig. 1. Action sequence of reserve generation in the frequency test ().
Source: XM, 2011.

Primary Frequency Regulation acts at a local level. The controls of the generators connected to, and synchronized with, the SIN are activated immediately after detecting a disturbance, wherever the event may have occurred. Secondary and Tertiary Frequency Regulations are activated centrally and independently from the zone in which the disturbance takes place, and only those plants which provide this service in a way that is coordinated and supervised by the system operator will respond to the event. The next section explains the three frequency controls that allow the stable operation of the electrical power system.

2.1. Primary frequency regulation

In Colombia, primary frequency regulation is compulsory for centrally dispatched generators. All generating units must be able to increase or decrease their own generation, even if they are dispatched with the declared maximum availability (CREG, 2001b). Generating units must be capable of modifying 3% of scheduled generation in less than 10 s. A deadband is allowed but it must not exceed 30 mHz.

To determine whether the generator agent provides the primary frequency regulation service efficiently, the system operator continuously monitors each centrally dispatched unit. The system operator is authorized to keep records when frequency variations occur outside the normal operating ranges established in current regulations, in order to analyze and detect possible non-compliance (ISA, 2001). In the event of service default, the generator agents are penalized, based on Eq. (1) presented below, which presents a formula representing the calculation of compensation for each day of default (CREG, 2001a).

$$REC = \sum_{i=1}^{24} G_{ri} 2 R_{RP} PR \tag{1}$$

where REC is the compensation for failure in providing primary frequency regulation service (PFR). PR is the price agreed by all agents and established by current regulations. G_{ri} is the real generation at hour i. R_{RP} is the reserve percentage for PFR with regard to its programmed hourly generation.

2.2. Secondary frequency regulation

Secondary frequency regulation is a control service that is automatically centralized, coordinated, and supervised by the