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Review

Grid functional blocks methodology to dynamic operation and decision making in Smart Grids

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ABSTRACT

Distribution systems are undergoing structural and topological changes, mainly due to the influence of the new distributed energy resources inserted along the feeders. In this context, the growth of the Smart Grids requires the evolution of the control and operation tools, since the decision-making should promote proactive actions. In this sense, the present paper proposes a method for subdividing the distribution system into grid functional blocks, associated to a method of forecasting of distributed electric quantities. The functional blocks allow the assets to be organized in a way to provide sufficient information to perform advanced analyzes of a geoelectric region. The proactive decisions, in the grid functional blocks, are taken from the very short term forecast of variables (voltage, current, active power and reactive power). These forecasts are based on an innovative method of selection of forecasting techniques, which takes into account the online and historical information for the performance ranking of forecasting techniques. The developed methodologies by authors provide greater flexibility for the Smart Grids regarding to the dynamic changes that occur in the distribution grids in the presence of distributed flexible resources, demand management, Volt-VAR Optimization, Conservation Voltage Reduction, protection, automatic reconfiguration, self-healing, storage and electric vehicles.

1. Introduction

The Electrical Sector has experienced a strong evolution in the recent years due to the advancement in the areas of Information Technology of Communication, Internet of Things (IoT), automation, real-time supervision, and mainly of the electronics applied to the Electric Power Systems. In the traditional electrical system, the following aspects are verified: centralized and controllable production, passive components, unidirectional energy flow, little interaction with the users, lack of state monitoring of the operational equipment, inefficient forecast and low availability of information. In contrast, at the end of the last century, some concepts were developed about Smart Grids, which points out some changes in distribution systems from Distributed Energy Resources (DER) [1] and Distributed Flexible Resources (DFR) [2], such as Distributed Generation (DG) [1], Net Metering [3], Energy Storage [3], Virtual Power Plant [4], Electric Springs [5], Demand Management [6], Electric Vehicles [7] and Microgrids [2].

Among the great challenges of the Smart Grids, there is the operation complexity of the distribution systems with DG connection based on intermittent sources, bidirectional power flow, significant user interaction, device interoperability, high degree of network element monitoring, high volume information and cybersecurity [8–11]. Other factors such as asset aging, security requirements, changes in the energy market, and the availability of new technologies also justify the need to develop new methods for distribution system operation, by considering Smart Grids.

In the Smart Grids, the load and generation can be managed according to price signals, providing changes that require the adaptation of the traditional model focused on the centralized energy supply to a dynamic model with the involved DERs, DFRs and demand management actions to the electrical system [1,2].

Knowing the effects of these changes, it motivates the research in how to monitor, supervise, control, and operate these elements in a more dynamic scenario. In this sense, it is fundamental the previous knowledge about the behavior of the electrical quantities in different horizons of time. The assets allocated along the feeders and the smart

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meters installed in the consumer units, make it possible to expand the information of the distribution systems [8,10], including some evidences of local problems, which until then, were not properly recognized and treated. The trouble lies in discovering which information is better to promote proactive actions in dynamic environment.

To get proactive answers for the Demand Side Management (DSM), Volt-VAR Optimization (VVO), Conservation Voltage Reduction (CVR), protection, automatic reconfiguration, self-healing and storage, this paper proposes to divide the feeder in Grid Functional Block (GFB). The constitution of GFB is associated with the type of control action required. The GFB configuration parameters may be amended in accordance with the purpose of the Distribution System Operator (DSO).

Given the need to consider the local conditions in the proactive actions, the solutions developed are based on innovative alternatives from the GFB system subdivision, considering the geoelectric conditions in the differential method for forecasting electric variables [12]. The forecast values are available for the autonomous controls of the equipment, supervisory systems and for the central controls.

2. Fundamentals of the subdivision in GFB

Actually, in the conventional system, subdivisions are used, usually related to the configuration of the system, for specific application, such as the “load block” in order to check the reliability analysis and “regulation area” for studies related to voltage drops. In the scenario of the Smart Grids are possible new alternatives of subdivision of the distribution systems, automatically configurable by computational tools.

2.1. Common divisions in distribution systems

The concept of “load block” is adopted for the analysis of the continuity indicators, limiting the block to the operation area of the equipment of protection and maneuvering. The delimitation of the scope about protection devices is sometimes referred to as “area of coverage, performance or scope” [11]. Fig. 1 illustrates the subdivision into load blocks delimited by protective and maneuvering equipment.

The Microgrids also is a subdivision that integrates elements of a geoelectric region [2]. A differentiated approach for subdivision is used in some simulation platforms, which uses the concept of “monitors” to perform the analysis of quantities in each network segments [17].

The authors discuss the “Area of Voltage Regulation” to delimit the scope of voltage control equipment, mainly in the analysis of the influence of one device on the operation of another [18,19]. Fig. 2 shows the subdivision into blocks related to voltage regulators V1, V2, V3 and V4. The main equipment is inserted in the zones of voltage regulation: recloser (R), reactive control (C), energy storage (S), distributed generation (G) and others.

An example of application is the voltage forecast, which is used as a reference parameter for the operation of the voltage control equipment. Thus, the planned quantities can be used to perform innovative actions by GFB, complementary to VVO and CVR [18]. New functionalities can be available in the control of these equipments, in order to allow the optimization of the actuations, in addition to the traditional parameters: reference voltage, timing, insensitivity and compensation of the line voltage drop [19,20].

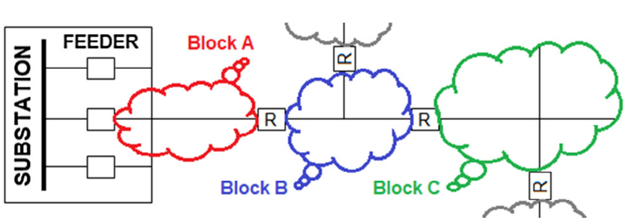

Fig. 1. Typical subdivision related to the load.

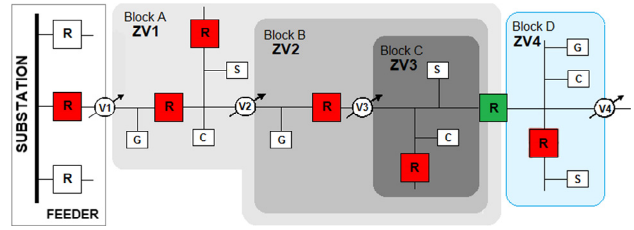

Fig. 2. Typical subdivision related to the voltage regulation zone.

2.2. Division into intelligent distribution systems

The traditional power flow calculations need to evolve, since DER and DFR have difficulty in modeling behavior. The functional blocks combined with forecasted quantities offer innovative alternatives for distribution systems, with advanced computing resources and significant presence of DERs and DFRs.

The Ref. [16] presents the concepts of a differentiated network architecture, the Dynamic Distribution System (DDS), which is aimed to facilitate the transition from the traditional grid to a system with more distributed functions, that consider the relevance of the DER. The GFB presented in this paper is distinguished of this reference by the versatility of the block configuration criteria, the innovative alternatives adopted for forecasting variables and the incentive on decision-making based on proactive actions.

The Ref. [15] highlights the importance of monitoring and controlling the distribution systems for the operations actions. The results of the research are important to substantiate the possibility of forecast electric quantities in addition to the load. The main phenomena related to electricity allow to be related to the time.

In addition to the traditional load forecast, the technical literature identifies alternatives for the estimation of other magnitude, such as frequency [20], phasorial [21], voltage [22], wind [23], solar radiation [24], temperature [24], price [25] and demand [13]. The management of the elements is also addressed in [8]. The challenge of extracting knowledge from this large volume of information – the “Big Data” – must be to overcome the alternative forms of subdivision of distribution systems [9].

The literature does not present a suitable approach for applicable subdivisions in distribution systems with a high degree of automation and significant presence of DER and DFR. This paper brings the process of the Grid Functional Blocks automatic configuration, which is presented next.

The remainder of this paper is organized as follows. Section 2 illustrates how to apply the concept of subdivision in block. Section 3 describes the methodology for block configuration. Section 4 details the forecast electrical quantities and Section 5 summarizes the resources developed in the form of technical analysis. Finally, Section 6 provides conclusions from this work.

3. Methodology for GFB configuration

The block GFB is a cluster composed by assets of distribution system, which are referenced as monitoring points and represent spatial allocation of electric quantities.

The methodology presented in this paper is more dynamic than the conventional subdivisions. This different form of subdivision of the distribution system is represented in Fig. 3, in which the GFBs represented are composed by voltage control (V), recloser (R), reactive control (C), energy storage (S), distributed generation (G) and others. The overlap block illustrated through block A, B, C and D evidences the diversity of configurations that can be adopted.

The nomenclature of the Grid Functional Blocks is related to subdivision, a part of the whole, the functional partitioning, which supports the dynamic changes to which the components of the distribution