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A review of optimal power flow studies applied to smart grids and microgrids

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ABSTRACT

The term smart grid refers to a modernization of the electrical network consisting in the integration of various technologies such as dispersed generation, dispatchable loads, communication systems and storage devices which operates in grid-connected and islanded modes. As a result, traditional optimization techniques in new power systems have been seriously influenced during the last decade. One of the most important technical and economical tools in this regard is the Optimal Power Flow (OPF). As a fundamental optimization tool in the operation and planning fields, OPF has an undeniable role in the power system. This paper reviews and compares the OPF approaches mainly related to smart distribution grids. In this work, the main OPF approaches are compared in terms of their objective functions, constraints, and methodologies. Furthermore, computational performances, case study networks and the publication date of these methods are reported. Finally, some basic challenges arising from the new OPF methodologies in smart grids are addressed.

1. Introduction

Bulk power generators are directly connected to the transmission system in a complicated manner, while distribution networks with their simple topology have enabled many consumers to easily connect to them. Generation Companies (GenCos) search for optimum utilization of the available generation utilities using proper load distribution. Moreover, distribution companies and consumers look for lower prices with higher supply reliability. The Transmission Companies (TransCos), however, tend to maintain standard operating conditions in terms of low transmission line congestion, high value of minimum bus voltage and low level of transmission loss, which are considered in Optimal Power Flow (OPF) problems of transmission systems [1] .

In the current distribution systems, an operator has no real-time monitoring capability related to the network and consumers. In other words, the operator contains no feedback in this case. However, the purpose of a power system is to deliver the power to consumers based on their momentous and changing demands. Fig. 1 shows the evolution of power systems.

In current power systems, electrical losses are significant in the distribution of electrical energy, especially at lower voltage levels. Loss reduction can be achieved through the appropriate control of Distributed Generation (DG) resources in the distribution systems [2], or more generally, through the control of dispatchable resources (DG, load, storage), which can be effectively assessed by using tools such as OPF-like software. Connecting the new power sources to the current distribution systems leads to some technical and economic challenges [3]. A possible vision for the solution of modern distribution systems consists in the creation of more or less independent cells which can interact in an internet-like structure. Microgrids can constitute the single element of this cellular structure in a large interconnected power system or be the natural answer to power supply in remote areas. In this regard, considering multi-microgrids as a system of microgrids would lead to different economic effects on the future smart grids [4]. Also, preserving privacy of OPF models in this system is an important aspect which is discussed in [5].

The term microgrid refers to a set of loads, power resources, and energy storage devices [6] in the lower voltage levels which can be operated as a single controllable load or a generator unit and provides heat and power for a designated area. This concept introduces a new paradigm in order to exploit DGs in the distribution level. Thus, a microgrid has high control capability and flexibility in terms of system reliability and power quality [7,8].

Generally, the operational modes of microgrids can be classified as islanded mode or grid-connected. In the islanded mode, a microgrid must be stable while it is disconnected from the main grid. Furthermore, the role of DERs is critical [9]. In other words, in the grid-connected mode, the public grid operates as a supporter which

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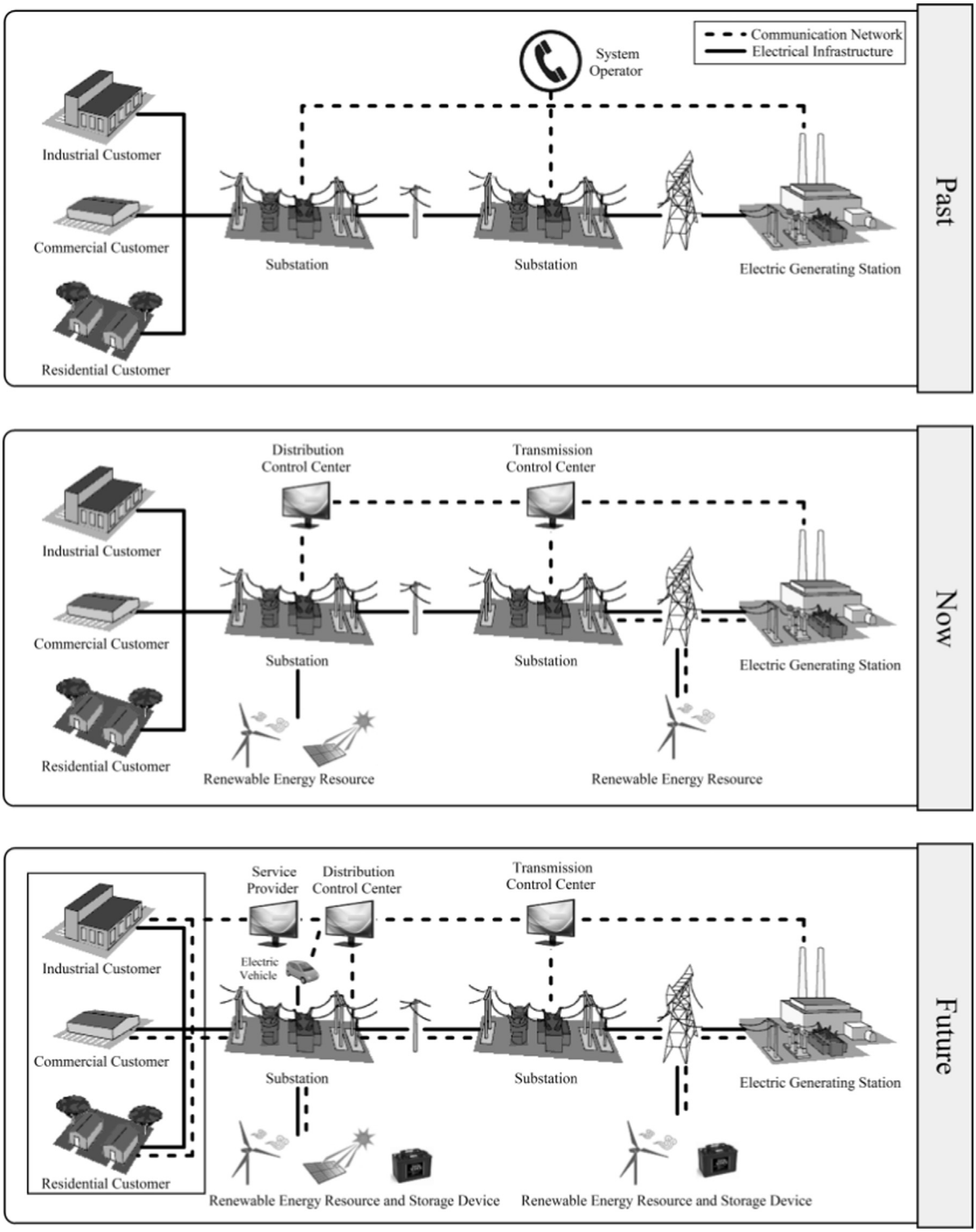

Fig. 1. The evolution of power systems.

microgrid can receive/send electrical power from/to it. Microsource Controller (MC) and Central Controller (CC) [10] manage and control the grids at different modes. Accordingly, changing from the grid-connected mode to islanded mode can be performed in two ways: full isolation of the national grid and isolation of each individual feeder. A typical configuration of a microgrid is shown in Fig. 2. In this system, the main purpose of MC is direct control of power flow and voltage level of connected loads to the grid at any conditions. Direct action indicates that MC can be operated separately from CC if required. Further, MC can participate in Economic Dispatch (ED), load management, and Demand-Side Management (DSM) through controlling the energy storage sources. In this context, CC applies control commands through MC [11]. In this regards, one of the most important commands is the optimal operation of microgrid. Since, one of the main objectives among the system operators is to minimize the microgrid cost, so, they should be able to consider and compare the energy cost of the main utility and the generation cost of the microgrid units while satisfying all constraints in the grid-connected mode.

The implementation of Advanced Metering Infrastructure (AMI) [12], real-time information systems, improved communication capabilities [13], greater number of sensors, and improved infrastructure for control systems transform the conventional distribution system into