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Control issues of distribution system automation in smart grids

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ABSTRACT

In recent years, the world has been exposed to many developments in different areas esp. computer technology, resulting in computers with high power of processing to be built. Among these devices, intelligent electronic devices (IEDs) have the capability to process considerable volume of data at high speed. Since, real-time data processing is vital in distribution networks as the largest users during their operation, IEDs would be applicable in such systems. In addition to IEDS, communication systems have improved during recent decades, providing the desired conditions for a concept known as distribution system automation (DSA) which has been discussed in this paper. Furthermore, the application of distributed generation (DG) in the context of DSA is addressed. Then, different control schemes have been investigated for DG sources while power quality (PQ) issues with DSA in microgrids are proposed in this paper. Moreover, the global automation standard has been presented and a combined strategy is suggested for demand-side management (DSM).

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1. Introduction

IEDs have been developed drastically these years, mainly because of enhancement in processing power of computers. It is worth-mentioning that IEDS are digital relays having the ability to monitor the real-time system values on the local part of the electric network while such devices can provide the electrical distribution system with extra functionality. Besides monitoring the standard values, such as volts, amps, MW and MVAr, these devices are able to get the data on fault event logs, metering values and oscillography (voltage, current, power waveforms and harmonics). Thus, it would be useful to replace any faulty protection or monitoring relay with IEDs to move towards DSA. The development of IEDs has led to processing a remarkable data quantity at high speed. One of the industries involving real-time data processing is electric distribution network during its operation. Consequently, a new concept has been introduced to the power industry as DSA which is highly based on recent improvements in intelligent devices and communication protocols. DSA has been defined by IEEE as online remotely monitoring, coordinating and operating distribution network by an electric utility [1]. The need for true automation of distribution network was first realised due to conventional control methods that are all out-of-date [2]. The main factors beyond DSA development would lie in deficits of the conventional system, new competitive market [2] and legislation [3]. In recent years, Australian distribution companies and specifically, New South Wales (NSW) distribution system companies have invested a remarkable cost to enhance the reliability and also to care for extra load growth occurring near the main load centres. Besides the investment programs, the electric distribution industry is moving towards automation of the system as well as ways of implementing DSA.

Many new devices and systems must be installed in the distribution network to thoroughly implement DSA that cause severe challenges for electric utilities in the case of moving from the old system towards the new automated one. In order to maximise the benefit, utilities have already started installing new equipment, e.g. new devices, communication system as well as modern softwares, and hardwares [4]. The system used to control distribution networks all across the world is known as Supervisory Control And Data Acquisition (SCADA). This controlling structure involves a system operator to employ the available data in decisions of distribution network control [4].

An important item that has been recently added to distribution networks is DG. The concept of DG has been involved with local generation, i.e. energy conversion units that are located near the consumers [5]. DG esp. from renewable technologies can play a significant role to meet future energy demand while it has potential to decrease Greenhouse Gas (GHG) emission and enhance energy security and adding supply to meet rising energy demand, as well [6–9]. In general, a system consisting of DG to a large extent can be taken into consideration as an environmentally friendly alternative to conventional power supply systems [10]. However, installing DG has its own challenges and merits.

Generally, DG is defined as generation connected to the distribution system at lower voltage levels, i.e. 400 V to 11 kV levels. DG is normally has low capacity but it is able to relieve the distribution system during peak-load periods [11]. Typical distributed energy sources are solar, wind, wave and geothermal generation, etc. Ref. [12] provides a complete review on distributed multi-generation like Combined Heat and power [CHP] systems. Advantages of DG would be in reducing emission as the main merit as well as reducing power loss and increased reliability in power system [13,14], while comprehensive review on reliability models used to estimate Renewable Energy Sources (RESs) can be found in Ref. [15]. Many benefits may be obtained from using DG in distribution networks, such as supplying peak load which is taken into account as a severe challenge in conventional base load generation. The shortfall with conventional base load generation is in the case of providing additional capacity during peak-demand periods, although they usually provide large centralised generation capacity. DG technologies would be appropriate alternatives to serve the peak load on extreme weather like extremely hot or cold weather while providing the distribution system with RESs [11].

When DG is employed to smooth the peak load, it forms part of a concept known as DSM. It is worth-mentioning that, DSM refers to technologies, actions and programs on the demand-side of energy metres intending to manage or alleviate energy consumption in order to decrease total system cost or even for other purposes, such as reducing emissions [16], as well as balancing supply and demand [17]. In other words, DSM has been proposed as an effective program to achieve sustainable development [18,19]. On the other hand, in spite of all good features of DG, it may bring severe challenges into distribution networks due to the connection of additional generation to the electric grid. Among problems caused by connecting DG to the electric networks, frequency of DG source, synchronizing DG waveform with the grid and also the voltage profile of DG sources with the electric grid are the most important ones [20]. Moreover, the power electronic equipment needed to facilitate this connection would be another concern. The power produced by many types of DG has DC form while power electronic equipment transforms this waveform, so that it can be connected to the distribution network. It is worth-mentioning that these equipments themselves cause unwanted disturbances in distribution networks during their operation [11]. However, it is important to control these negative outcomes of DG with its integration into DSA.

2. DSA control of DG

The implementation of DSM is mainly based on real-time data as well as the possibility to fast enable DSM procedures, once it is appropriate to achieve the highest benefit of the distribution network. IEDs are responsible to deliver real-time data while this data is transmitted through the installed communication systems. When employing IEDs in electric distribution systems, the inputs obtained from such devices are the monitoring, protection and control links. It is worth to mention that IEDs are synchronised via satellite connection to have real-time analysis. All the data obtained from IEDS are stored by the substation server while the modem is used to concurrently send the data to other IEDs or centralised command for analysis.

Note that, the automated system decides on switching in or out of service to employ DSM. Ripple control methods and broadcasting would be two alternatives to do such actions [21].

2.1. Control issues in distribution networks

The concept of ripple control and its technology is well-known to distribution networks. In this regard, off-peak hot water system is considered as a ripple control system used by utilities to control electrical hot water systems for residential applications. This action is performed using a high frequency signal, usually injected at the zone substation level into the voltage waveform that is detected by a relay having the responsibility to switch the hot water system on or off which efficiently manages the heating load during maximum demand periods [22]. The aforementioned system is instigated on the time basis when power demand is at minimum. Hence, switching extra loads would cause a little stress on distribution network. On the contrary, ripple control system is

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