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An overview of microgrid protection methods and the factors involved

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ABSTRACT

Microgrid is a distribution system composed of a set of micro-generators which are added to a network. One serious challenge facing a microgrid network is designing a proper protection scheme. This is because the fault current in a microgrid is constantly changing due to the presence of distributed generation (DG) resources at all levels of the distribution network and to the fact that they can operate in two islanding and normal modes. This makes the conventional methods inappropriate for microgrid protection. That is, new schemes should be developed for this purpose. This paper is a summary of studies recently carried out in the field of microgrid protection. Along this line, the structure and topology of microgrids are reviewed first. Afterwards, the protective challenges facing DG-equipped distribution networks are discussed. Then, the innovative methods proposed to solve these problems are analyzed. These methods can be divided up into six main categories: changing settings of protective devices at presence of DG units, disconnecting pertinent DG units when faults occur, creating a balance among different DG technologies, using fault current limiter, using smart transformers, and adaptive protection. In so doing, we consider the factors involved in selecting each method. The factors identified are microgrid type and topology, DG type, communication type and delay time, method of fault detection and analysis, relay type, fault type, method of grounding, and use of smart transformers in microgrid. It is hoped that this work will be useful to the researchers in the field of microgrid protection in finding relevant references and designing appropriate methods.

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1. Introduction

Over the past few decades, application of renewable or non-renewable resources has increased as a result of advances in exploiting renewable resources, aggravation of problems in transmission lines, a growing tendency to generate power at distribution level, reduction in fossil fuels, and the need for high power quality and reliability [1,2]. These types of power generation are called Distributed Generation (DG). Installing DG resources in an electric power network changes its behavior while enabling utilities to take advantages of smaller and more flexible resources. This new technology has transformed power systems into smaller networks called microgrids [3].

Microgrid is an active distribution network which consists of DG resources, different loads at the voltage level of distribution, and energy storage elements. From a network perspective, a microgrid is advantageous because it is a controlled unit and can be exploited as a concentrated load. From the point of view of customers, a microgrid can be designed to meet their special needs such as higher local reliability, fewer feeder losses, better local voltages, increased efficiency, voltage sag correction, and uninterruptible power supply. From an environmental standpoint, a microgrid reduces environmental pollution and global warming because it produces less carbon monoxide [4,5].

Despite the fact that microgrid is an appropriate replacement for limited fossil fuels and can efficiently solve power generation problems, it is still mostly restricted to a laboratory scale due to a number of technical challenges [6]. Some of the most important of these challenges are protection, security, power quality, operation in normal and islanded modes, voltage and frequency control, plug-and-play operation, energy management, and system stability [3,7,8].

Designing an appropriate method for microgrid protection is problematic in two important ways. One is that microgrids are particularly dynamic networks. In fact, a load or a DG unit can be connected to or disconnected from a microgrid at any given time. Another problem is that microgrids can operate in both parallel and islanded modes with different short-circuit currents [9]. Therefore, a comprehensive design scheme should be capable of protecting the network in both modes [10].

Much research has been performed to solve protection problems and pave the way for the implementation of microgrids in the near future. To this end, new devices, analytical methods, and implementation technologies have been proposed.

The presented paper aims to review and analyze all methods proposed for microgrid protection. After reviewing the topology of a microgrid, followed by an outline of the challenges facing the protection of traditional networks at the presence of DG resources, key factors in designing a comprehensive protection method will be discussed. Finally, innovative methods of solving protection challenges in the presence of DGs will be described. The methods include changing the settings of protective devices, disconnecting DG units when a fault occurs, creating a balance among different DG technologies, using Fault Current Limiter (FCL), using smart transformers, and adaptive protection.

It is worth noting at this point that the authors of [10–14] have also reviewed the studies into protection, control, and stability of microgrids. These studies do not thoroughly discuss the factors involved in microgrid protection. The works presented in [10,12–14] categorize protective plans as either normal or islanded mode depending on the mode of operation, although some of them can operate in both modes. Another shortcoming with the preceding review in [10–13] is that part of what they discuss as separate methods are indeed simply techniques for the fault detection.

2. Microgrid structure

A microgrid consists of three main components: micro-generators (such as wind turbine, photovoltaic array, diesel