Planning, Operation, and Protection of Microgrids: An Overview

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Abstract

The significance of microgrids is growing rapidly. Microgrids have a huge potential in boosting the sustainable growth. A microgrid can operate in grid-connected or islanded mode. In islanded mode, microgrids can provide electricity to the rural areas with lower cost and minimum power losses. In grid-connected mode, microgrids can help in supporting the main grid in many ways with voltage control, frequency control, and can provide more flexibility, control, and reliability. However, successful operation of a microgrid requires proper planning and there are major challenges regarding the operation, control, and protection of microgrids that need to be tackled for successful deployment of microgrids. Depending on the mode of operation (grid connected mode or islanded mode), necessary control strategies and protection schemes are required. Several methods have been proposed in the literature for the successful operation of a microgrid. This paper presents an overview of the major challenges and their possible solutions for planning, operation, and control of islanded operation of a microgrid.

Keywords: Islanded microgrids; microgrids protection; planning and operation.

1. Introduction

Power generation from fossil fuels is associated with several environmental concerns and poor energy efficiency. Use of renewable energy resources as distributed generation (DG) can be a potential solution to these problems. As the penetration of these DGs in the distribution network increases, they create a microgrid. A microgrid is a low voltage, the small-scale power grid (on distribution side) with DG, storage devices and controllable loads [1].
Microgrids can operate independently called the islanded (autonomous) mode of operation or in conjunction with the main grid called the grid connected mode of operation [2]. Fig. 1 shows the typical structure of a microgrid in which there is distributed energy resources (DERs), distribution network and loads. A microgrid can be connected or disconnected from the main grid at the point of common coupling (PCC). The limited capacity of microgrids has resulted in the evolution of multi-microgrids. Multi-microgrids are an interconnection of several microgrids which can operate with or without the main grid support.

Microgrids offer several advantages and benefits including increased reliability, improved energy efficiency and resiliency, cost reduction, reduction in transmission losses, CO$_2$ emission reduction, and other environmental benefits. However, they also introduce several major challenges regarding the operation, control, and protection of microgrid. Furthermore, each mode of operation (grid connected or islanded) requires unique control and protection schemes. In literature, several methods have been proposed for the successful operation of microgrids. According to the IEEE standard 1547, DGs are allowed to be connected to a distribution network but are required to be disconnected in case of a fault. This approach can be applied to very small grid-connected microgrids. However, if the DG penetration is very high, disconnection of all DGs can have adverse effects on the main grid. The major issues and potential solutions in microgrid protection and control include:

- **Bidirectional power flows:** The power flow in a conventional distribution system is unidirectional, i.e. from the substation to the loads. Integration of DGs on the distribution side of the grid can cause reverse power flows. As a result, the conventional protection coordination schemes are no longer valid [3];
- **Short circuit capacity:** In the case of inverter based DGs, the fault current is limited (maximum 2 p.u.). Hence, the conventional overcurrent relay cannot sense the fault [3];
- **Stability issues:** Local oscillations may arise as a result of the interaction of the control system of micro-generators. Hence, small signal stability analysis and transient stability analysis are required to ensure proper operation in a microgrid [4];
- **Low inertia:** In a conventional power system, the bulk power is generated at power plants and hence they have high inertia. Microgrids, on the other hand, have dispersed generation and sizes of the DGs are very small. Consequently, they have a low inertia characteristic, especially for inverter based DGs. Low inertia can result in severe frequency deviations in islanded mode operation. Hence, special control mechanism is required [4];

![Microgrid schematic](image-url)
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