



Improved efficiency, enhanced reliability and reduced cost: The transition from static microgrids to reconfigurable microgrids



Abdollah Kavousi-Fard^a, Amin Khodaei^{*,b}, Shay Bahramirad^c

^a University of Michigan, Dearborn, United States

^b University of Denver, United States

^c Commonwealth Edison, United States

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ABSTRACT

Thanks to smart switches, the current generation of static microgrids is about to transition to a new generation of reconfigurable microgrids (RMG). RMGs use remotely controlled switches to control and change the microgrid topology to ensure that desired objectives can be achieved. RMGs can provide customers with a greater degree of cost-effectiveness, efficiency, reliability, and power quality, though challenges remain.

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1. Introduction

A microgrid is defined as a group of interconnected loads and distributed energy resources (DERs) within clearly defined electrical boundaries that can act as a single controllable entity with respect to the grid and can operate in grid-connected or islanded modes (Khodaei, 2014). Microgrids, which were primarily introduced to address the emergence of high-penetration DERs in distribution grids, can potentially provide significant benefits for local electricity customers and the system as a whole, such as reduced power losses, increased energy efficiency, improved power quality, enhanced reliability, and diversification of energy resources (Parhizi et al., 2015). In addition, fast commissioning and deployment, conceivably due to the small size of assets to be installed, is another significant factor that supports the idea of microgrids. The generation units in microgrids can range in form from dispatchable fossil-fuel-based units to nondispatchable photovoltaics, wind turbines, and mini-hydro units.

A wide range of studies can be found on microgrids, from the earliest works defining the microgrid concept (Meliopoulos, 2002; Jiayi et al., 2008) to the latest works on microgrid economics, operations, control, power electronics, protection, and communication (Elmitwally and Rashed, 2012; Abbasi et al., 2015). These studies, however, have mainly relied on static network models, i.e., a fixed and pre-determined topology, where the distribution network needed to be considered (Marnay et al., 2001). A viable

and untapped area of research and development, therefore, is to investigate how a flexible distribution network would support microgrid operations.

This article introduces the next generation of microgrids by transitioning from the static structure to the reconfigurable structure through smart switches. The main idea in reconfigurable microgrids (RMGs) is to use remotely controlled switches (RCSs) to control and change the microgrid topology to ensure that desired objectives can be achieved. The main benefits, challenges, and fundamental infrastructure requirements are discussed and assessed in this article. It is further discussed that the reconfigurable structure can go far in meeting the main operational objectives of microgrids for supplying the consumers with a higher level of cost-effectiveness, efficiency, reliability, and power quality.

2. Traditional microgrids

Increased penetration of DERs into distribution grids along with the maturing trend of new customer-focused technologies and increased expectations for high-reliability power support the widespread growth of microgrids. A microgrid with intermittent DERs and responsive loads can play a key role in helping electric utilities to stabilize long-term energy costs. In addition, it can be used to mitigate the amount of greenhouse gases produced through the burning of fossil fuels. Fig. 1 shows the schematic diagram of a grid-connected microgrid. The three main components of a microgrid from a technical perspective include distributed generators, energy storage, and loads. Both dispatchable and nondispatchable generation can be used, while energy storage can draw from a wide range of technologies such as

* Corresponding author.

E-mail address: amin.khodaei@du.edu (A. Khodaei).

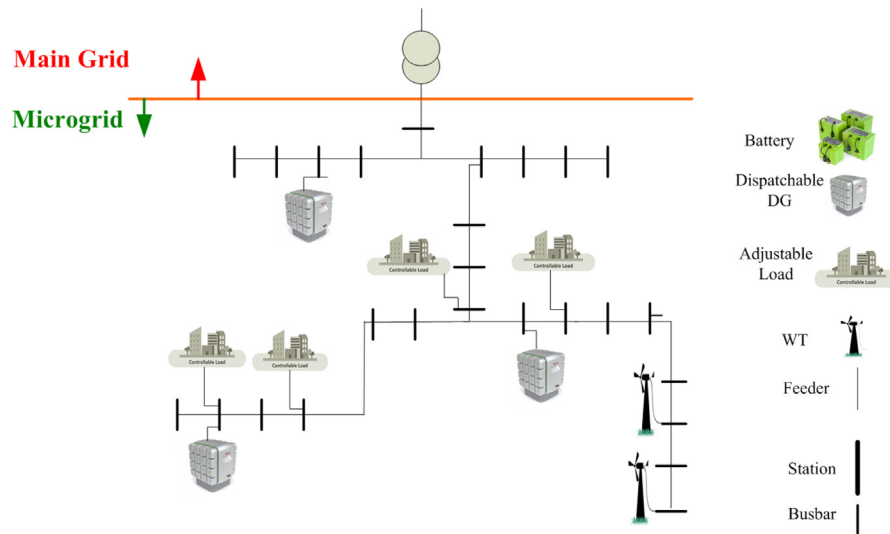


Fig. 1. Schematic diagram of a typical grid-connected microgrid.

electrical, pressure-based, gravitational, flywheel, and heat-based storage. Microgrid loads can be controllable (such as dimmable lighting or delayed pumping) or fixed. It is clear that power balance, both real and reactive, is the most critical concern within the microgrid. Otherwise, microgrid voltage and frequency will deviate from the rated values. According to the pre-determined objectives, microgrid can benefit the system in different ways. Fig. 2 shows some of the main advantages of the microgrid.

As it can be seen from Fig. 2, the traditional static microgrid offers significant benefits in both steady-state and dynamic analyses. Nevertheless, these benefits can be increased by providing a flexible network structure, which can be achieved through the reconfiguration process.

3. Reconfiguration strategy

Reconfiguration is defined as the process of changing the microgrid network topology through some RCSs, which are normally open (called tie switches) or normally closed (called sectionalizing switches) (Kavousi-Fard et al., 2014). Reconfiguration can benefit the electric utility by providing a fast method for improving the reliability, supporting load balance, reducing power losses, and decreasing congestion in transmission and distribution networks. At the distribution level, reconfiguration strategy can restore the faulty part of the network under emergency situations. This can mitigate the crew travel time by dispatching them to the

fault location directly. The recent researches show that reconfiguration can help reduce 20–30% in average outage duration in the overhead lines per year (Kavousi-Fard et al., 2015). The recent progress in data mining, communications, and signal processing has attracted the attention of most of distribution companies for automation of these networks, which is partly achieved through the reconfiguration. The important point is that since most of the distribution systems are constructed in a radial topology, the topology of the network should also be preserved radial after reconfiguration. In order to understand the idea of reconfiguration, Fig. 3 shows a sample distribution grid including three main feeders. The dotted lines show the location of tie switches that can help to reconfigure the network topology. Before the reconfiguration, all tie switches 1, 2 and 3 are open (*Tie 1*, *Tie 2* and *Tie 4*). Therefore, all loads are supplied and the system is operated as radial. By closing *Tie 1*, switch *S3* is opened to keep the radial structure of the network. Therefore, the network topology is changed such that *Tie 1* would supply part of the network load through feeder 2. The new topology may bring additional benefits which can be determined by power flow studies and other relevant analyses.

Other advantages of the reconfiguration under the normal operation can be listed as the potential to avoid the transformer overloading, feeder thermal overload, and abnormal voltages. During the emergency situation, one significant benefit of the reconfiguration is network restoration. Whenever a fault happens

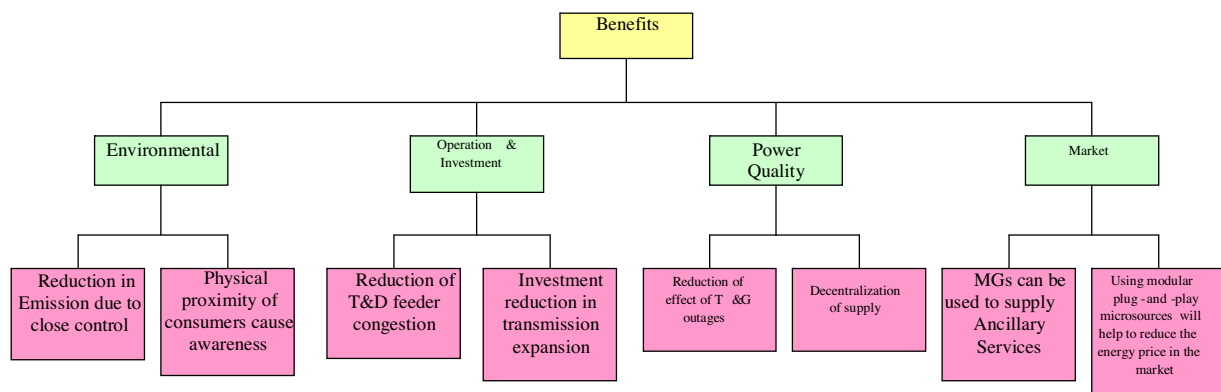


Fig. 2. Advantages of microgrids.

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