A Reconfigurable Auto-Loop Microgrid

Tianqi Hong, *Student Member, IEEE*, and Francisco de León, *Fellow, IEEE*

***Abstract*—This letter proposes a novel reconfigurable auto-loop microgrid (ALMG). The new configuration combines the advantages of auto-loops and microgrids. In addition, the ALMG offers the possibility of balancing loads for economic operation.**

***Index Terms*—Auto-loop, distribution systems, microgrid, reliability.**

I. Introduction

Modern distribution systems can be extremely large and complex. The primary goals of distribution systems include the improvement of reliability, cost reduction, and better utilization of the installed equipment. Because of the large economic losses caused by natural disasters or other emergency situations, utilities now require a resilient power system that is able to reconfigure and recover.

During hurricane Sandy, power blackouts occurred in large sectors of New York City and it took up 18 days for the power to be fully restored [1]. Based on the data from Consolidated Edison, nearly 1.4 million customers lost electrical power and up to $U.S.600 million were spent in the restoration from severe storms in the past five years [2]. Hence, advanced concepts may be applied into distribution systems to improve their reliability and save time and money during restoration.

To reduce the impact of a disaster in a power grid and enhance the robustness of the system, smart-grid technologies offer promising solutions. Several possibilities exist to increase the resiliency of the system, for example: installing distributed generation or sectionalizing network areas by smart switches [2]–[4].

This paper puts forward a novel microgrid topology relying on dc links to simultaneously integrate (distributed) generation to supply critical loads and reconfigure to serve as an auto-loop, allowing the utility to supply external loads. The new topology even permits forming (nonsynchronous) loops between feeders from different substations. In addition, load balancing by power transfer for economic operation is possible.

According to previous studies, microgrids can improve the reliability and power quality (PQ) of distribution systems [5]. The proposed auto-loop structure can improve system reliability through the interconnection of different medium-voltage (primary) feeders. Hence, the new reconfiguration unit can improve reliability, PQ, and robustness, and can reduce losses of a distribution system.

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The authors are with the Department of Electrical and Computer Engineering of NYU Polytechnic School of Engineering, Brooklyn, NY, 11201 USA (e-mail: th1275@nyu.edu; fdeleon@nyu.edu).

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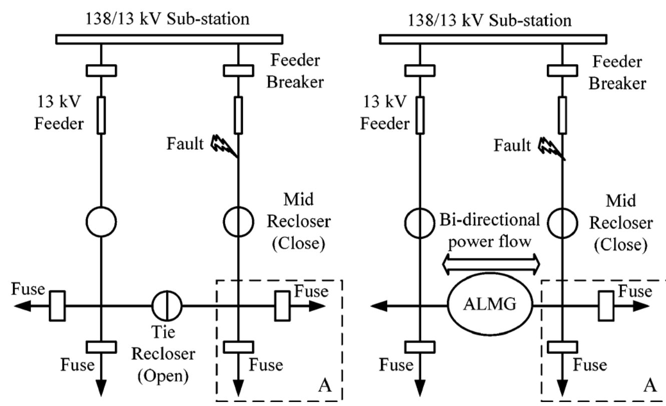

Fig. 1. Operation of auto-loops. (a) Configuration of a typical auto-loop distribution system. (b) Configuration of an auto-loop microgrid.

II. Auto-Loops in Distribution Systems

The highest levels of reliability in modern urban electric power systems are given by a meshed structure (secondary grid network) [6]. However, radial systems are the most common distribution system structures. To improve the reliability of radial systems, the auto-loop configuration is widely used; see Fig. 1(a).

When a fault occurs, the auto-loop configuration allows for some loads to still be supplied. For example, if a fault occurs between the feeder breaker and the mid recloser in Fig. 1(a), the feeder breaker will trip and the mid recloser will open to isolate the fault. The tie recloser will close to supply power to the customers in sector A. This typical auto-loop configuration improves the reliability of radial distribution systems; see [8].

III. Configuration of an Auto-Loop Microgrid in Distribution Systems

The underlying idea of this letter is to configure a dc-bus microgrid to perform the functions of the tie recloser when needed; see Fig. 1(b). The auto-loop microgrid (ALMG) can operate to import/export power from/to one or both of feeders or perform the functions of an auto-loop when called upon. Moreover, the ALMG offers greater flexibility than traditional auto-loops by allowing the *looping* of feeders from different substations.

The configuration of a general auto-loop microgrid is shown in Fig. 2. The ALMG can connect two or more feeders through a dc bus. The dc bus is isolated from the primary feeders through directional ac/dc converters (see Fig. 3). The system is designed for multi-input multi-output (MIMO) operation. Any primary feeder or distributed generator can be an input to the dc bus. The dc bus needs to be designed in a way that the reliability of the system is kept. A multibus sectionalized architecture is a possible approach.

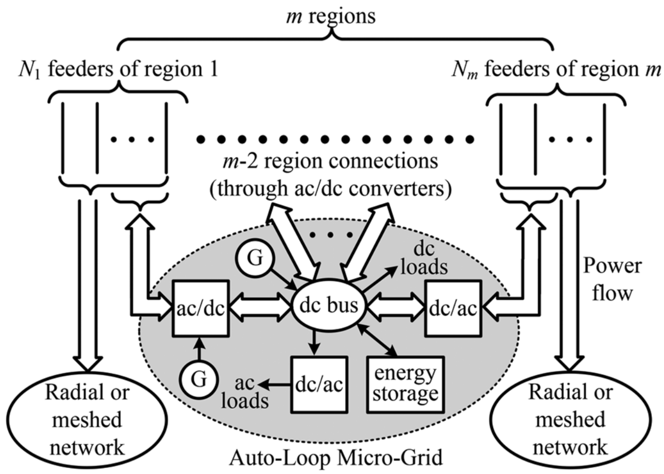

Fig. 2. Configuration of the auto-loop microgrid.

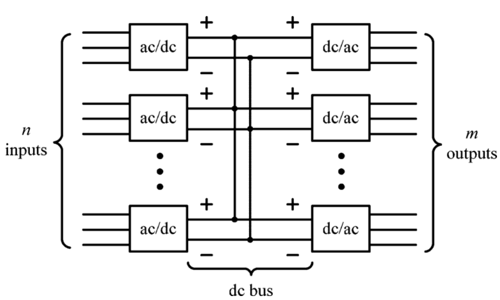

Fig. 3. Systematic structure of the dc link.

Multiple primary feeders from an area substation can connect to an ALMG and one substation can connect to several ALMGs. Similarly, one ALMG can connect to different area substations. The generation sources necessary for islanding operation can be ac or dc. Storage can also be integrated. AC distributed generation can be seen as another input through ac/dc converters. Any dc sources and loads (for example, electric vehicles) can potentially be connected directly to the dc bus. This controllable and flexible connection provides numerous choices to achieve a variety of objectives (see the next section). With modern power-electronics technologies, the load connected to the dc bus can be seen as a pure resistive load, which is isolated from upstream faults. Due to well-established technologies for ac/dc conversion, it is easy to meet the IEEE standard of network interconnection [7] and the requirements of local utilities.

IV. Operation Modes of the ALMG in the Distribution System

A. Normal Operation Mode

The normal operation mode is defined by the utility. The ALMG can be supplied from only one feeder or any number of feeders under usual operation. If the ALMGs are supplied from several feeders from different substations, the power distribution of each area network can be controlled based on the loading situation of each substation. The control strategies can be designed based on the daily load forecast. More advanced strategies can be applied by remote control of each auto-loop microgrid according to a particular situation.

B. Special Operation Mode

Special situations can be defined as upstream fault, recovery from disasters, or load balancing.

Upstream faults: if faults occur on one or several feeders, the sensor of the dc link can detect the undervoltage or overcurrent and open the connection to those faulted feeders. The ALMG can still be supplied by the remaining feeders. Its behavior is similar to the auto-loop.

Recovery from disasters: if during a blackout one or more areas substations are de-energized, the ALMG can be supplied by a substation that has not been affected. In the extreme circumstance, the ALMG may even operate as an island.

Load balancing: since the ALMG is an MIMO system, load can be transferred from heavily loaded feeders to lightly loaded ones.

V. Discussion

This letter has presented an innovative configuration of the microgrid, called auto-loop microgrid. By combining the advantages of auto-loops and dc microgrids, the ALMG has the potential ability to improve the distribution system reliability and enhance system resilience. The multioperation modes allow the utility to supply more customers and reduce the economic losses during blackouts. When comparing the ALMG with auxiliary backup power supplies, the ALMG can do much more, for example: power transfer and frequency control (inside the microgrid). However, by introducing dc links, the efficiency of distribution systems may be reduced since power circulates through several power-electronics stages.

System protection elements (recloser, fuses, etc.) need to be properly coordinated. Steady-state and transient studies are needed before an ALMG can be installed into an actual distribution system, but the potential gains are significant.

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