A Review on Schemes for Interconnecting Microgrids of Urban Buildings

S. N. V. Bramareswara Rao and Kottala Padma

Abstract Interconnected operation of microgrids is one of the prominent solutions to meet the increased demand of electricity by large consumer such as urban buildings. Besides, the present-day urbanization motivations further enhance the power crisis problem. So, this creates major burden on the utility grid and consequently leading to grid failures. So, these buildings can be integrated to share their generation and load appropriately. However, the microgrids deployed for all the individual buildings maybe equipped with heterogeneous energy sources and type of power generation with different capacities. So, clear understanding about the integration possibility has to be known to create above-mentioned integrating environment. Hence, this paper gives an overview of all the possible schemes for integrating microgrids of various urban community buildings.

Keywords Urban Community · Renewable energy sources (RES) · Microgrid

1 Introduction

In the present scenario, the demand for electricity is growing rapidly due to industrialization around the world. On the other hand, conventional grid is overloaded and faces lot of problems like global pollution by CO_2 emissions, investment costs, operating costs, etc. As the conventional fossil fuels are deploying, focus of research is moving toward searching of other alternative energy sources. So, microgrids are increasingly attractive to the customers, and also in the future, greater numbers of the microgrids are installed at consumer's premises [1–4]. This increases a burden to the operation and control of conventional grid, and also, some technical limitations will appear

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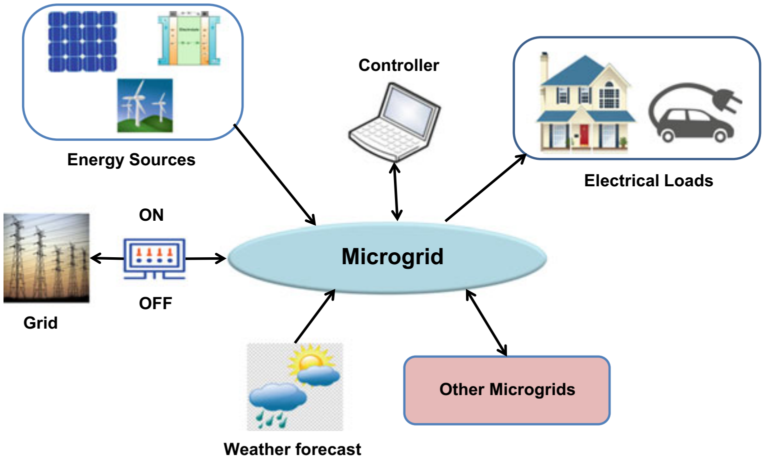

Fig. 1 Schematic view of microgrid architecture

when huge amount of distributed generations are installed. Microgrids interconnection is the unique opportunity in Indian power scenario due to key issues in rural electrification, power demands, peak loads, reliability and quality of power. Microgrid is either alternative current (AC), direct current (DC) or AC and DC (hybrid) facilitates the connection of any architecture and is operated in (1) standalone/off-grid/islanding mode (2) grid-connected mode. Interconnection of microgrids with utility at the level of distribution will enhance reliability of electrical power with some benefits to private electricity generators. The microgrid system thus designed feeds the power independently to remote/rural areas where the access of power is limited. Figure 1 shows a general microgrid architecture, which consists of several distributed energy sources such as wind, solar photovoltaic, fuel cell, diesel generator, controller unit, storage devices and AC and DC loads. Also, there is a possibility of interconnecting other microgrids to the existing microgrid/utility grid. Some control strategies are implemented for the interconnection of different microgrids.

This paper organized as follows: The literature details of interconnection of microgrids are presented in Sect. 2. The possible methods and techniques for interconnection of microgrids and their integral operation were discussed in Sect. 3. In Sect. 4, summary describes the importance of interconnection and integration of microgrids for urban community buildings.

2 Literature Review

Interconnection and integration of neighboring microgrids are the prominent solution for reducing burden on utility grid. So many research works were carried out on microgrids, but only limited researches have been focused on interconnection possibilities of microgrids. Various microgrid architectures were surveyed, and system configurations, energy management, control, generator unit sizing were discussed [5]. Two neighboring DC microgrids were connected by using DC cable and bidirectional converter. Robustness of the proposed system is also verified by transferring power from both sides [6]. Issues involved in the implementation and development, such as protections, power converters, economic analysis and availability, are discussed in [7]. Technical, environmental, economic benefits of integration of renewable sources were briefly discussed in [8]. Multimicrogrid architectures to form a grid were surveyed; thereafter, architectures were defined and compared in terms of layout, line technologies and interface technologies [9]. A brief survey on intelligent methods which are applied to microgrids to study stability aspects, uncertainty in parameters, tracking error has been illustrated in [10].

A multiobjective particle swarm optimization was introduced to minimize the operating cost and also to find the best configuration of system [11]. A parametric mixed-integer linear programming technique was introduced to reduce the burden, and uncertainty in parameters when the microgrids are interconnected was discussed in [12]. Operation cost, pollution rate are the two important factors to be discussed in the design of energy management of microgrid interconnections was described in [13]. Cost plays an important role in the formation of interconnecting microgrids, and different optimization techniques were used to solve economic dispatch problem [14]. A model predictive control coupled with mixed-integer linear programming technique used for load side of the microgrid [15]. A hybrid Nelder-Mead Cuckoo search algorithm was presented in [16] to minimize the power loss in hybrid AC/DC microgrid systems by optimizing the output power of renewable energy distributed generators. Microgrids are intertied together with the use of some droop control techniques and interlinking power converters [17]. An innovative load management tool was proposed for effective load management in intertied microgrids through artificial neural networks [18]. This paper mainly describes and discussed about various microgrid architectures available for interconnection. Figure 2a–c shows standard microgrid architectures [19].

3 Methods of Interconnection

The interconnected system may be operated in standalone/grid-connected mode, which will provide the reliable power to the rural areas where the people are perusing higher quality of life. The interconnected microgrid system developed will reduce the burden on utility grid and also providing stable and reliable power. This section summarizes possible methods and technologies such as switch gear mechanism, power electronic interface and static switches for interconnection of microgrids. There are so many standards which enumerate different aspects for interconnection of grid networks, out of which IEEE 1547 is most important. In this standard, main provision is of having network protections on the grid side.

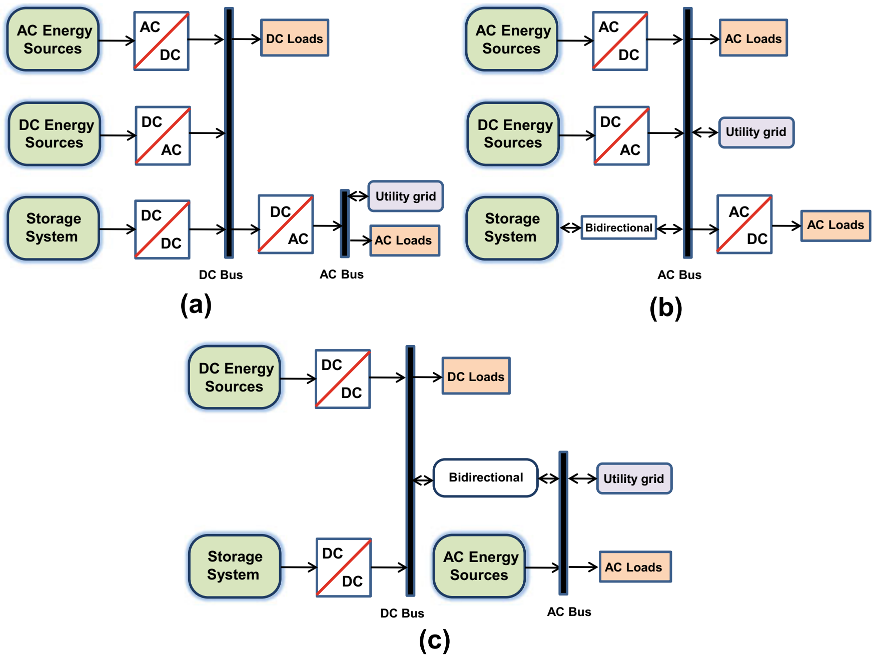

Fig. 2 Architectures of microgrid

3.1 Interconnection of Two DC Microgrids

Microgrid-1, Microgrid-2 are two neighboring dc microgrids (DCMGs), with different voltages and are tied together through a bidirectional DC/DC (BDC) converter and a DC cable shown in Fig. 3. Each microgrid consists of energy sources such as diesel, wind, photovoltaic, fuel cells and storage systems. The two microgrids are operating in islanded mode, which creates an opportunity to supply the power to rural areas.

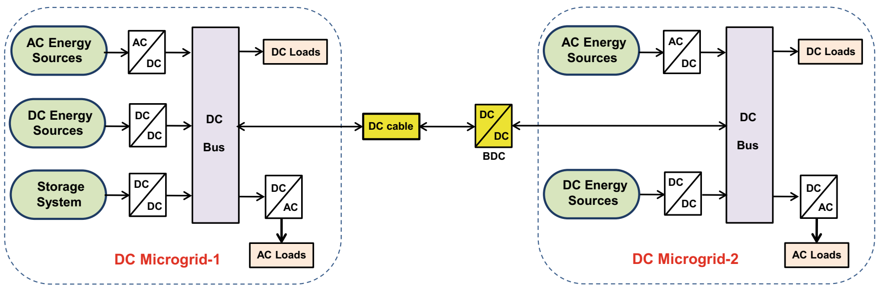

Fig. 3 Architecture of interconnecting DC microgrids

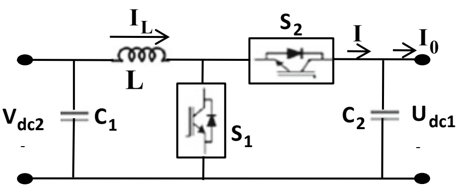

Fig. 4 Equivalent circuit of bidirectional DC/DC converter (BDC)

The distance between two DC microgrids is of any value. The DGs which are connected to each microgrid operate independently without any communication between microgrid-1 and microgrid-2. In the system shown in Fig. 4, a bidirectional DC/DC converter is modeled and functions as a boost converter when power flowing from low voltage microgrid to high voltage microgrid, and it works as buck converter when power flowing from high voltage microgrid to low voltage microgrid. The average value of voltage across an inductor and current in capacitor in boost converter mode of operation are given in Eqs. (1) and (2).

$$\frac{\mathrm{d}I_L}{\mathrm{d}t} = -\frac{rI_L}{L} - \frac{(1-D)U_{\mathrm{dc1}}}{L} + \frac{V_{\mathrm{dc2}}}{L} \tag{1}$$

$$\frac{\mathrm{d}U_{\mathrm{dc1}}}{\mathrm{d}t} = \frac{(1-D)I_L}{C_2} - \frac{I_0}{C_2} \tag{2}$$

where V_{dc2} is the average voltage across C_1, U_{dc1} is the average value of voltage across $C_{2,}$ and D is the duty cycle. Similarly, during the operation of buck converter, the average values of voltage across inductor and current through the capacitor are given by Eqs. (3) and (4).

$$\frac{\mathrm{d}I_L}{\mathrm{d}t} = -\frac{rI_L}{L} + \frac{DU_{\mathrm{dc1}}}{L} - \frac{V_{\mathrm{dc2}}}{L} \tag{3}$$

$$\frac{dV_{dc2}}{dt} = \frac{I_L}{C_1} - \frac{I_0}{C_1} \tag{4}$$

where 'I' is the average value of the current through C_2 and 'I_L' is the average value of current flowing through L.

3.2 *Interconnection of Two AC Microgrids*

Two AC microgrids are interconnected through the switchgear mechanism shown in Fig. 5. Each microgrid consists of AC and DC energy sources such as wind, solar, fuel cell and AC load. Each microgrid is designed to operate in standalone/grid-connected mode. The switchgear mechanism consists of circuit breaker, relay unit, communication system and monitoring system, all together acts as a digital signal

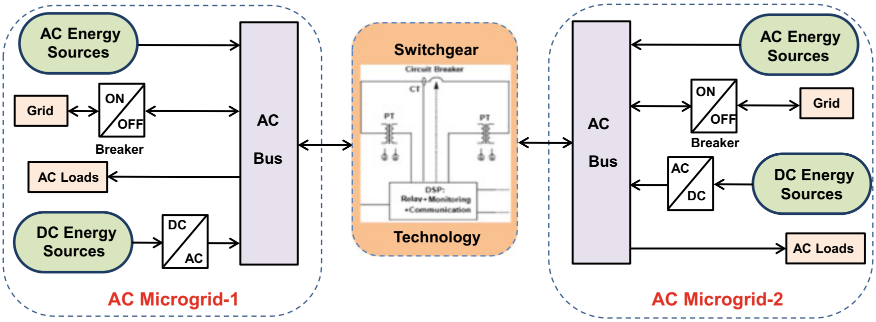

Fig. 5 Architecture of interconnecting AC microgrids

processing (DSP) unit. This unit will monitor the information transferring between the two AC microgrids. The total system is capable of supplying electricity to rural areas independently. This mechanism is relatively simple and inexpensive. Since the electrical characteristics on both the sides (microgrid side and utility grid side) of circuit breaker must be same, the microgrid characteristics are dependent on the utility grid characteristics.

3.3 Interconnection of AC and DC (Hybrid) Microgrids

AC microgrid and DC microgrid connected together to form a hybrid microgrid shown in Fig. 6. Both AC and DC microgrids were connected with the power electronic interface technology. This technology reduces multiple reverse connections in an individual grid has been reduced and is more flexible. To maintain the stability of the microgrid under variable supply and load conditions, advanced control strategies of power electronics are used to control the microgrid operation either in island mode or grid-connected mode. It is easy to control active, reactive powers with

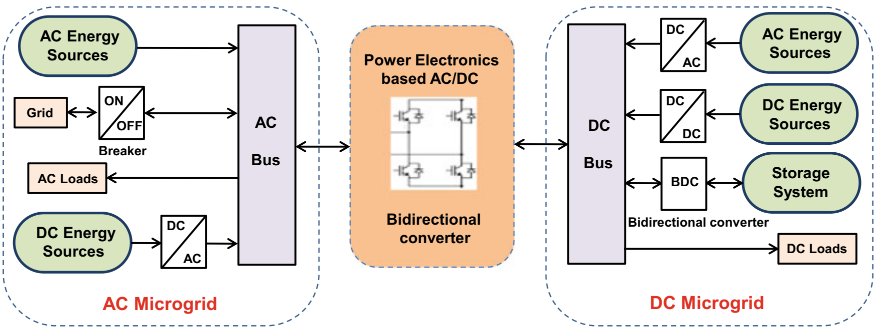

Fig. 6 Architecture of interconnecting AC and DC (hybrid) microgrids

this technology. The power transfers between AC microgrid and DC microgrid were continuously monitored and controlled by the switches in bidirectional converters.

4 Summary

Thus, in view of present-day energy requirements and types of energy resources and consumer loads, this paper summarizes the possibilities of interconnecting different microgrids located in an urban community. These presented architectures improve the reliability of the electrical power by facilitating power exchange among the interconnected microgrids. This further leads to overcome frequent utility grid outages. Besides, the effectiveness of this integrated operation can be further improved with the design of proper control mechanisms. So, the details in this paper will also be useful for the control engineers to develop the required control strategies for the building microgrids.

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