UNIT-II
Analysis of Microgrids

Classification Based on Power Supply

According to the power supply available for the loads within the microgrid, it can be classified as either an AC microgrid, DC microgrid or hybrid microgrid.

AC Microgrids

AC microgrids are very *similar to* the legacy grid except that these will be powered by local generation, controlled through local controllers and cater to local loads. Almost all the power sources are connected to the AC network through power electronic converters.

The voltage and frequency regulation will be entrusted to one of the converters in the local network. A typical AC microgrid is shown in Figure 2.3. One of the major limitations of this type of microgrid is the additional conversion required for DC power. The outputs of major micro sources being DC, these need multistage converters with synchronization capability for sustained operation on AC network. The fastemerging DC loads like LED lights, infotainment systems and battery chargers of electronic gadgets obtain power through multiple AC-DC conversions, thus reducing the efficiency of the system. However, it is possible to directly integrate all the micro sources with minimum network modifications and using conventional grid following inverters. Transformers can be used to achieve different voltage levels required for the loads. The AC microgrids when operated in islanded condition need reactive power support, making it necessary to have reactive power sources within the local network.

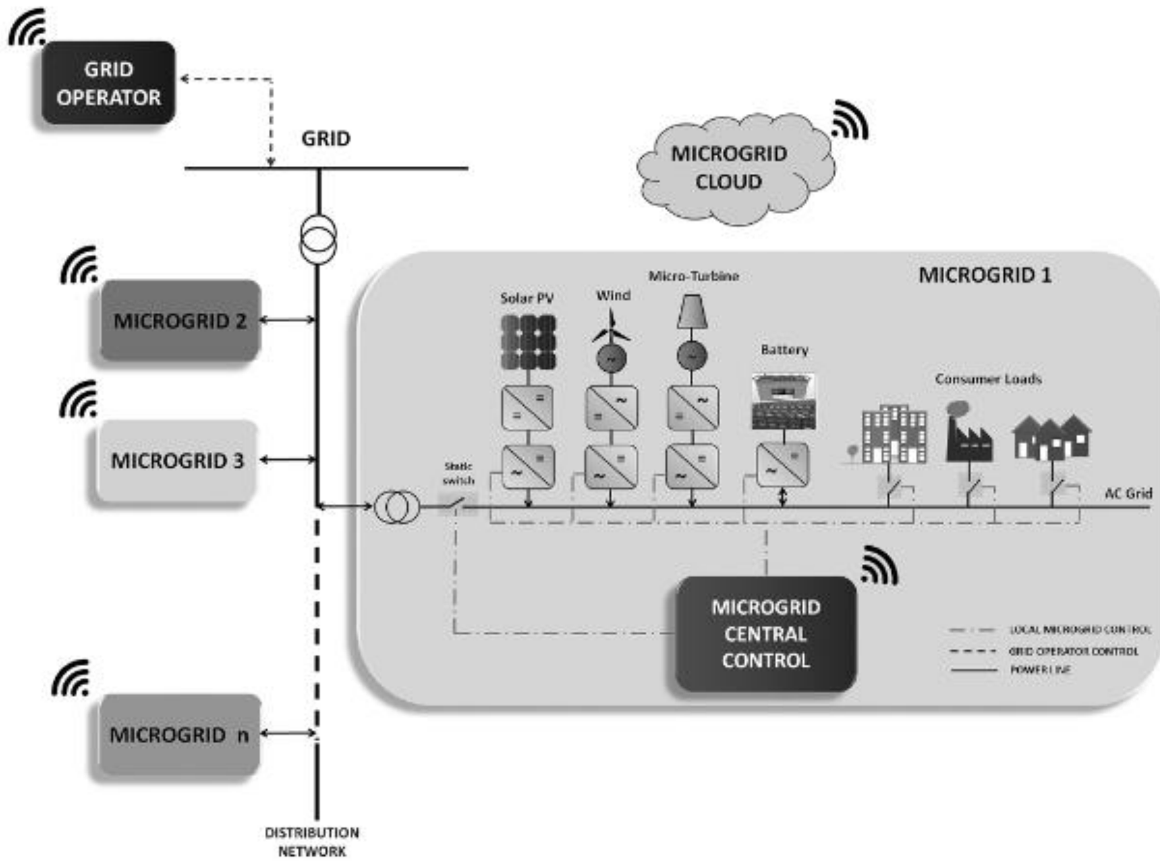

FIGURE 2.3 A typical microgrid-connected to legacy grid.

DC Microgrids

Solar PV generators integrated with BES offer a great opportunity for DC grids of any scale. DC microgrids can potentially be deployed anywhere, as solar radiation is omnipresent on the globe. Educational institutions, industrial facilities and residential apartments can have their lights (LED) and fans (Brushless DC Motor) as DC loads, besides mobile phone charger interfaces. DC loads along with Solar PV and BES are likely to be accommodated together to form dedicated DC grids. Unlike in AC grids, no reactive power support is required in DC network. The traditional AC loads need to be operated through inverters. However, this arrangement will be economically prohibitive with high power AC loads. A total grid restructuring would be required on the existing distribution network to accommodate such modification in power supply. A typical DC microgrid in depicted in Figure 2.5.

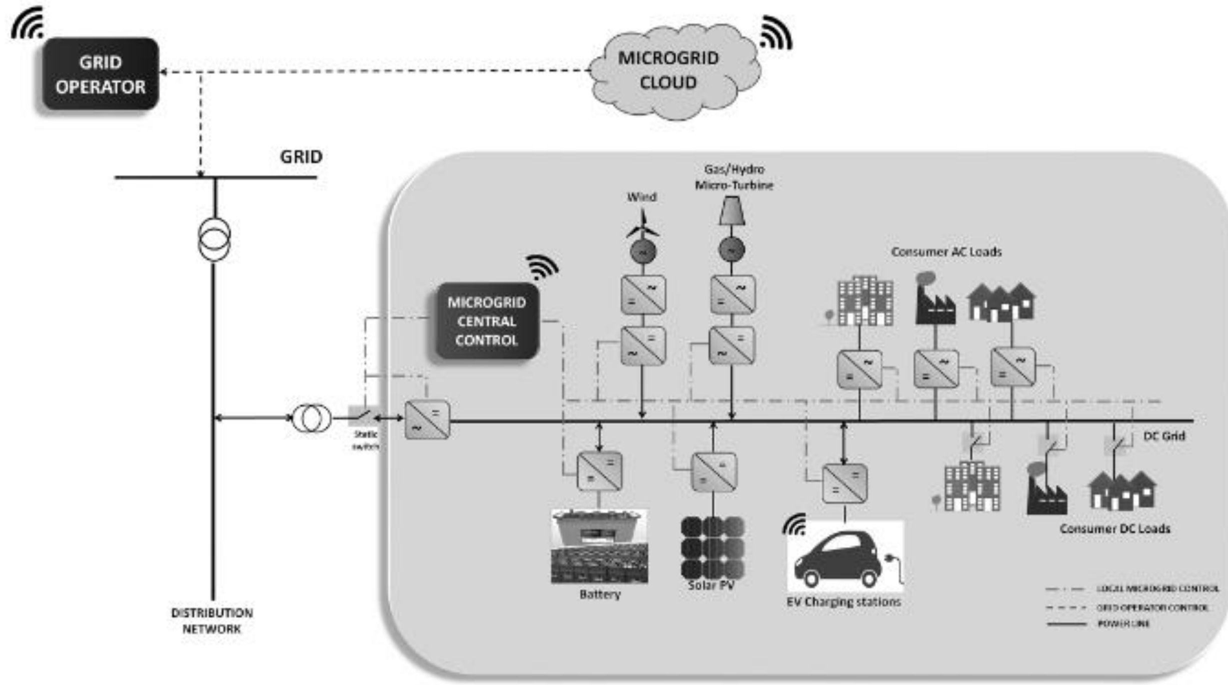

FIGURE 2.5 Structure of a typical DC microgrid.

Hybrid AC-DC Microgrids:

This configuration combines the advantages of both AC and DC network architectures. It has AC and DC sub-grids with generators and loads on either side.

Direct integration of both AC and DC based micro sources, BES and heterogeneous loads is thus made possible.

A typical hybrid AC-DC microgrid is depicted in Figure 2.6. Minimized conversion loss between AC and DC networks with reduced interfacing components also ensures increased reliability, improved system efficiency and reduced costs. Power exchange between the AC and DC networks will be facilitated as needed through bidirectional AC-DC converters.

Such exchanges ensure continuity of supply on both networks by sharing the excess generation on either side. It also helps to store excess AC generation in BES connected on the DC network as well as to extract BES stored energy to meet any deficit on the AC network. Further, the power exchange can ensure maximum utilization of RE sources by diverting the available generation to the needy locations or to the storage. On the consumer end, hybrid microgrids offer the flexibility to choose between AC and DC as required by their equipment. Minimum modification on the present AC distribution network will be sufficient to establish such hybrid systems.

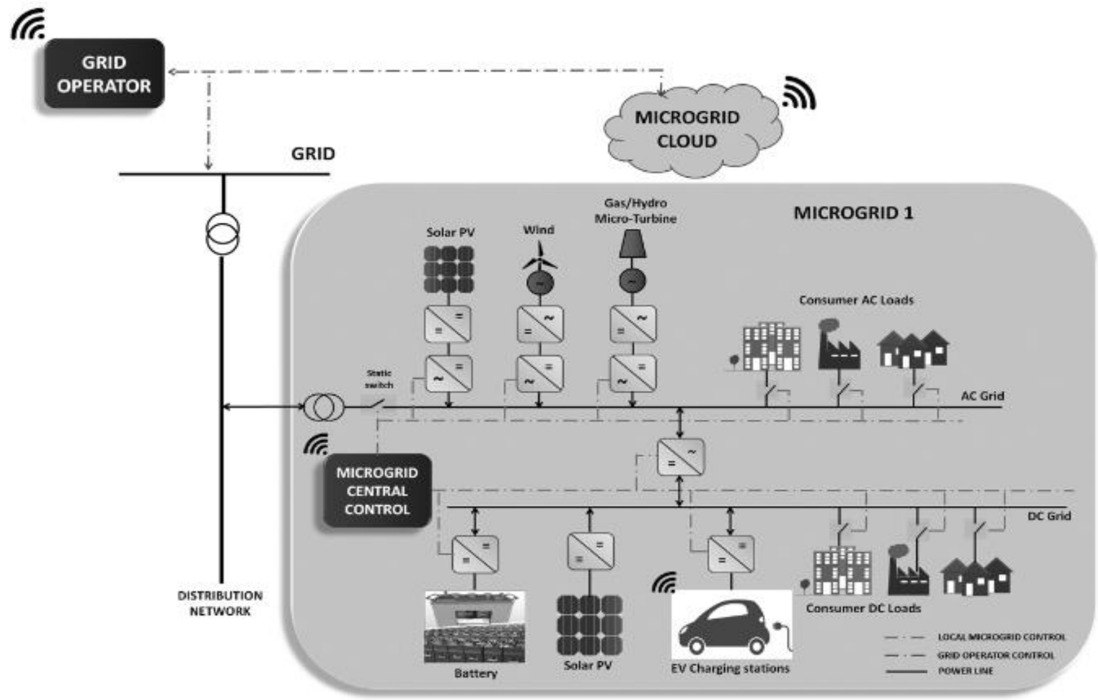

FIGURE 2.6 Structure of a typical AC-DC hybrid microgrid.

Classification Based on Location

Community or Campus Microgrid

Universities, schools, commercial complexes, military camps, corporate offices, etc., are well suited to be served by community microgrids. This type of microgrid can have a grid connection which serves as a backup power option. Beyond which fossil fuel–based generation can be kept as an emergency backup. The local community can take care of the maintenance of the microgrid assets and smart communication features can be utilized for its monitoring and control.

Industrial Microgrid

An industrial microgrid offers power supply security and reliability to industrial consumers like automated manufacturing and processing plants. In such premises, loss of power supply may result in severe revenue loss and further require long resumption time of the processes when power is restored. An appropriate generation mix including fossil fuel with adequate storage and fast acting controllers can bring additional advantages like secure power supply, reduced running cost, obligatory RE utilization and energy efficiency benchmark attainment. These microgrids are mainly intended as captive generation systems.

Stand-Alone or Off-Grid Microgrid

Sites such as islands, grid-deprived remote locations like tribal hamlets and isolated colonies can opt for stand-alone microgrids which are not connected to any local electric utility. Such microgrids are to be provided with black start capabilities to allow them to start generation at any required point.

Utility Microgrid

Utility microgrids are connected to the main grid and can exchange energy with the main grid at the point of common coupling. Such microgrids include a distribution feeder and one or more distribution substations within its spread. They may have several generators of different types and connected loads of various capacities. A distributed grid management system has to be in place to monitor and control the energy exchange within the grid at various segments. An islanding detection unit is mandatory as this can work both in the autonomous mode as well as in the grid-connected mode. Seamless mode change is targeted upon an outage. Additional operational features such as grid-forming operation, distribution state estimation and load flow calculation are often required for these microgrids.

Classification Based on Geographical Spread and Capacity

Based on their geographical spread and capacity, microgrids are classified as mini-grid, microgrid and nanogrid. World Bank defines minigrid as an "Isolated, small scale distribution network typically operating below 11 Kv that provides power to a localized group of customers and produce electricity from small generators, potentially coupled with energy storage," while Lawrence Berkeley National Laboratory defines nanogrid as, "A small electrical domain connected to the grid of no greater than 100 kW and limited to a single building structure or primary load or a network of off-grid loads not exceeding 5 kW, both categories representing devices capable of islanding and/or energy self-sufficiency through some level of intelligent distributed energy resources management or controls."

The terms mini-, micro- and nanogrids represent the size, capacity and configuration of both the off-grid or grid-connected systems.

Nanogrid is the smallest discrete network unit with the capability to operate independently like a building-level circuit with building-integrated power generation source(s).

micro grids with power electronic interfacing units:

The microsources are quite capable of contributing significantly to the generation augmentation. Power electronic interfaces are used for preferred microsources, viz. micro-CHPs, wind turbines, PV-arrays and fuel cells. It not only generates utility grade AC power, but also facilitates their overall integration in Microgrids. However, these interfaces are quite costly for their complicated technology and system packaging.

Power converter designs are normally customised for achieving economic performance. The applicability of electric power converters can greatly be enhanced by proper design to make them rugged, cheap, reliable and interchangeable. Recent trends in the design of power electronic converters include the integration of several components similar to computer architectures and digital electronics. In order to increase the applicability of power electronic converters in distributed power generation and Microgrids with economic viability, research is being focused on the development of modular architecture. It leads to systematic power electronic solutions by the use of pre-engineered components through mass production.

The microgrid concept has been discussed as a potential means to combat problems caused by the unconventional behaviour of DG, increasing DG penetration (Lasseter et al. 2002 a). In essence a microgrid (figure 1) consists of a combination of generation sources, loads and energy storage, interfaced through fast acting power electronics. This combination of units is connected to the distribution network through a single point of common coupling (PCC) and appears to the power network as a single unit. The aim of operating Microgrid sub-systems is to move away from considering DG as badly behaved system components, of which a limited amount can be tolerated in an area, to 'good citizens' (Lasseter 2001), i.e. an aggregate of generation and load which behave as nearly ideal conventional loads. Although the concept of using Microgrids to provide ancillary services to the local network has also been discussed, present commercial incentives are probably insufficient to encourage this. A critical feature of the Microgrid is the power electronics.

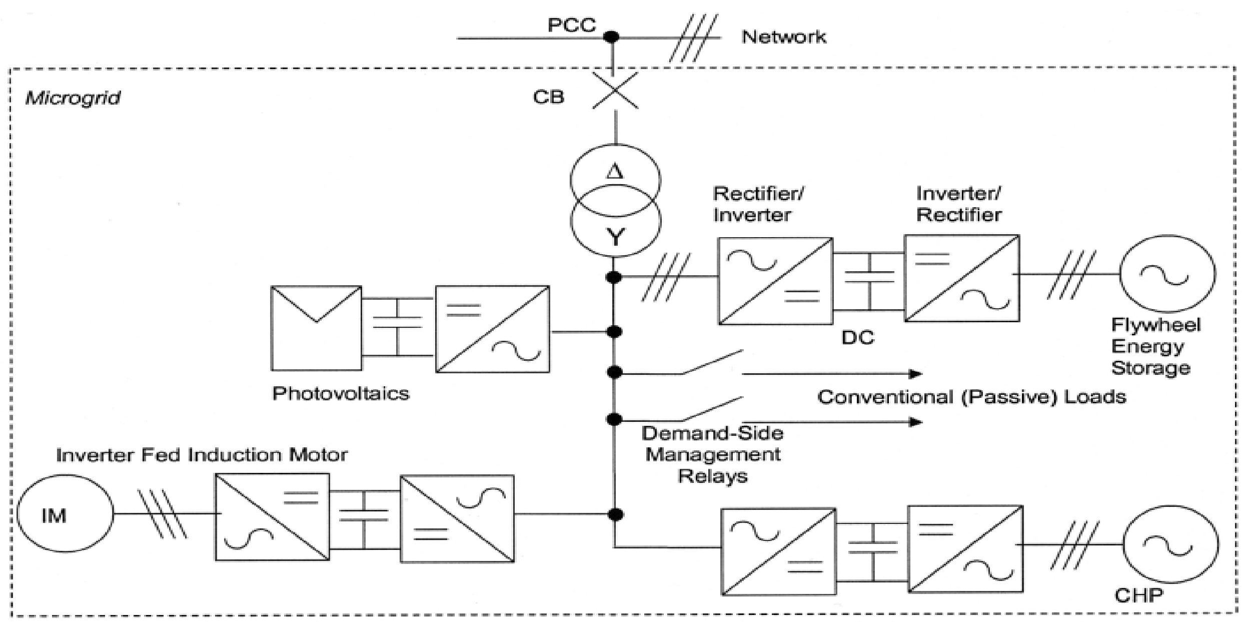

Figure 1. Simple example Microgrid.

‘The majority of the microsources must be power electronic based to provide the required flexibility to ensure controlled operation as a single aggregated system’ (Lasseter et al. 2002 a). Such as system must be capable of operating despite changes in the output of individual generators and loads. It should have ‘plug-and-play’ functionality: it should be possible to connect extra loads without reprogramming a central controller (up to a predefined limit). It should be possible that some of these are loads conventional. Likewise it must be possible to add generation capacity with minimal additional complexity. Key, immediate issues for the microgrid are power flow balancing, voltage control and behaviour during disconnection from the point of common coupling (islanding). Protection and stability also need to be considered, but are outside the scope of this article.

Protection issues for Microgrids:

A Microgrid is an aggregation of electrical/heat loads and small capacity on-site microsources operating as a single-controllable unit at the distribution voltage level. Conceptually, Microgrids should not be thought of as conventional distribution networks with additional local generation. In a Microgrid the microsources have sufficient capacity to supply all the local loads. Microgrids can operate both in synchronism with the utility (grid-connected mode) and in autonomous power islands (stand-alone mode). The operating philosophy is that under normal condition the Microgrid would operate in the grid-connected mode but in case of any disturbance in the utility, it would seamlessly disconnect from the utility at the point of common coupling (PCC) and continue to operate as an island. Figure 5.1 shows the protection system for a typical Microgrid network. This chapter reviews two major protection issues that must be dealt with to ensure stable operation of a Microgrid during any contingency. These are as follows:

(1) To determine at what instant the Microgrid should be islanded under a specific contingency.

(2) To sectionalise the stand-alone Microgrid and provide the sections with sufficiently co-ordinated fault protection.

Although the characteristics and performance of most protection elements of a Microgrid are consistent with those present in the utility distribution systems, it is not the same for the microsource power electronic inverter systems because of the following reasons:

(1) Characteristics of inverters may not be consistent with the existing conventional protection equipment.

(2) Different inverter designs have different constants and therefore, do not have any uniform characteristic that would represent inverters as a class of equipment.

(3) Basic characteristics of the inverter unit as seen by the system can change markedly depending on design and application.

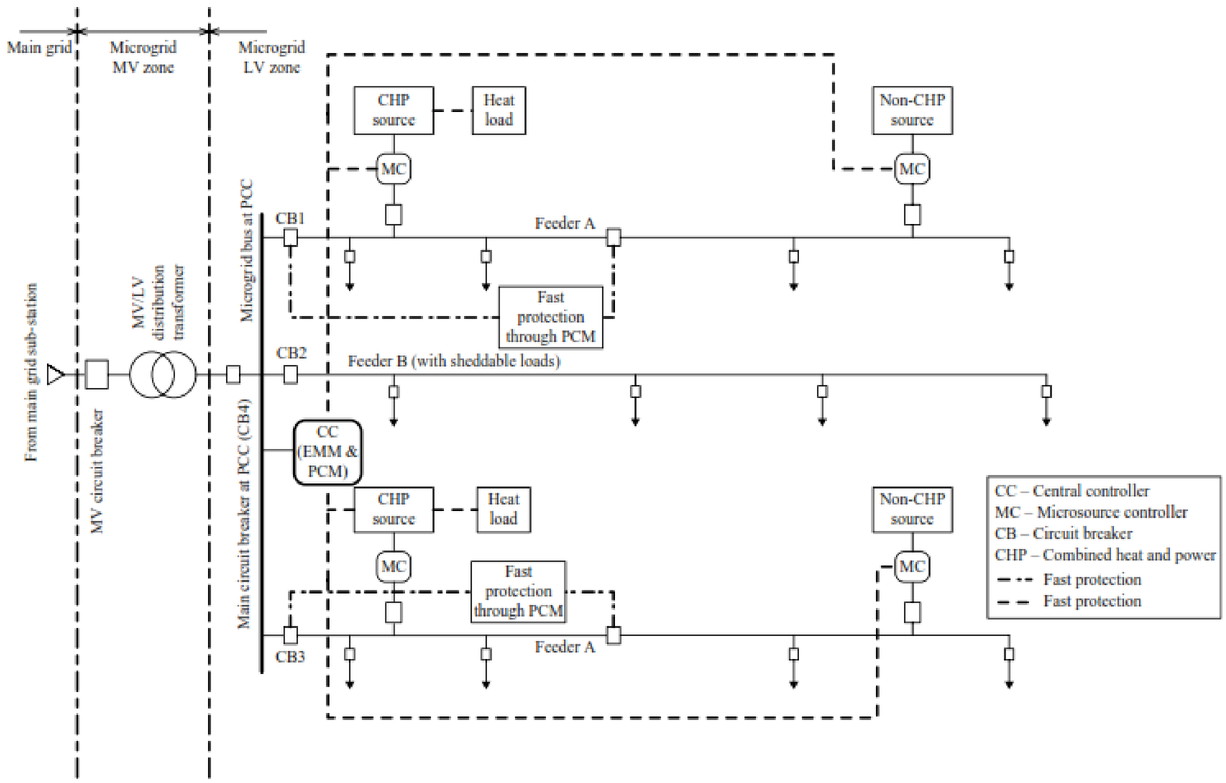

Figure 5.1 Protection of a typical Microgrid

Another problem posed by the inverter units is their extremely low-fault current capacity. It is usually less than 50% of the rated current unless they are specifically designed to provide a high fault current. This drastically reduces the fault current available from the microsources in comparison to utility generators. If a significant number of microsources have power electronic inverter interfaces, then the transition from grid-connected to stand-alone operation results in a marked reduction in Microgrid fault level. This affects the sensitivity and operation of the overcurrent relays in the system. If the relays are set for higher fault currents in case of grid-connected operation, then the same relays would operate very slowly or may not operate at all for the stand-alone operation due to lower fault currents. Protection issues for Microgrids cannot be properly resolved without a thorough understanding of Microgrid dynamics before, during and after islanding. Also, time of islanding the Microgrid should be preceded by a realistic assessment of what benefits the Microgrid will gain from rapid separation. Although the equipment standard SEMI F47 suggests that manufacturers would benefit from shorter separation times of less than 50 ms after the occurrence of any contingency in the utility, such times cannot be realised with currently available protective devices. If very high speed of separation is required and spurious trips are to be avoided at the same time, then transfer trip mechanisms should be installed between the utility grid sub-station and the PCC circuit breaker. Installation of high-speed communication channels between utility and Microgrid would also help in rapid islanding during non-fault conditions.

For secure and reliable operation of the stand-alone Microgrid, the protection system should ensure the following:

(1) Appropriate grounding must be provided for stand-alone Microgrid.

(2) Fault detection devices in Microgrid must work in compliance with the fault detection system in the grid-connected mode.

(3) A means of fault detection, not dependent on a large ratio between fault current and maximum load current, must be provided to take care of the reduced fault level after islanding.

(4) Any existing anti-islanding schemes should be examined and modified if necessary, to prevent instability or undesirable loss of microsources with sensitive settings.

(5) Any load shedding scheme set up by the utility in the Microgrid area must be closely co-ordinated.