# A Review On Development Of Microgrid With Renewable Energy Sources

[1]Yogita Pradhan, [2] Shweta Mishra
[1]M.Tech Student, ,[2] Assistant Professor
[1]Electrical Engineering,
[1]ITM UNIVERSITY, Raipur (Chhattisgarh), India

**Abstract - A small scale system and located near the consumer is called the Micro-Grid (MG) system. The interconnection of small generation to low voltage distribution systems can be termed as the Micro Grid. Micro Grids can be operated with and without a connection to the main power network. Micro-Grid(MG) is basically a low voltage (LV) or medium voltage (MV) distribution network which consists of a cluster of micro-sources such as photo-voltaic array, fuel cell, wind turbine etc. called distributed generators (DG's); energy storage systems and loads; operating as a single controllable system, able to operate in both grid-connected and islanded mode. In a micro-grid the DG's has sufficient capacity to carry all, or most of the load connected to the micro-grid. This paper presents the development of these micro-sources i.e photo voltaic array, fuel cell stack along with their power electronic interfacing circuits viz. boost converter, PWM inverter in Matlab/Simulink and finally combining these models to form a Micro-Grid. This paper aims at explaining a generalized Energy Management System involving the concept of a micro grid.**

**IndexTerms - Micro-grid, islanded mode, grid-connected mode, PWM inverter, distributed generators.**

## I. INTRODUCTION

The microgrid concept has been researched and implemented intensively by many experts worldwide with significant research conducted in U.S., E.U., Japan, and Canada. The interest on microgrid increases due to its potential benefits to provide reliable, secure, efficient, environmentally friendly, and sustainable electricity from renewable energy sources (RES). Before the microgrid concept was introduced, many researches had been conducted on distributed generation (DG). Researchers soon realized that installing individual DG in power systems may create problems as many as it solves. Hence, microgrid concept was proposed to overcome those problems [3]. MG provide higher flexibility and reliability as it is able to run in both grid connected and islanded mode of operation and its components may be physically close to each other or distributed geographically. To meet the increasingly growing demand of electricity, and to improve energy utilization efficiency and reliability , new power generation technologies, including renewable energy , clean and efficient fossil fuels, distributed generations have been developed. The micro grid concept is based on the assumption that large numbers of micro generators are connected to network to lower the need of transmission and high voltage distribution system. However the micro grid can be integrated with the distribution system but it can also produce a threat to the safe and reliable operation of the grid due to the net loss in line flow, voltage and power quality [1]. Micro-grids may play a useful role in the future evolution of energy sector but the modes may be at variance with those of developed economies [4].

As energy generation and distribution companies compete in the market place, we have seen an increasing interest in renewable and alternative energy sources. In addition to this competition, companies are seeking demands from customers for higher quality and cleaner electricity. Also, considering the worlds coal stocks are reducing and the creation of legislation which is pushing for greener energy solutions, we are led to seek new energy generation methods. One solution which is currently attracting attention is Micro-Grid systems [5]-[6].

A Micro-Grid is a low voltage or medium voltage distribution network which consists of a cluster of micro sources/distributed generators, energy storage systems and loads, operating as a single controllable system. In a MG, the distributed generators should have sufficient capacity to carry all, or most, of the load connected to the MG. Distributed generators are located at strategic points, normally at the distribution level, near load centres, and used for capacity support, voltage support and regulation, and line loss reduction [6].

The micro-sources or distributed generators are usually made of many new technologies, e.g. fuel cell, photo-voltaic system and several kinds of wind turbines. These units having small capacities are interfaced with power electronics and are placed at the consumer sites. Power electronics provides the control and flexibility required by the micro grid system. The inclusion of energy storage systems (batteries/flywheels/super capacitors) in a Micro grid system allows the excess power produced, to be stored or alternatively the excess power could be put into the main grid [7]-[8].

Micro-grid is inevitable in future due to its obvious advantages in reduced central generation capacity , increased utilization of transmission & distribution capacity ,enhanced system security and reduced CO2 emission. However, micro-grid adds a number of complexities in control and protection aspects in a traditional distribution system [2].

Research and implementation of microgrid have increased in last few years in several ways. Many aspects of microgrid ranging from architecture to controls have been researched and implemented in laboratory test-beds and field models. Indeed, this condition leads to more advanced development of microgrid. In accordance with the environmental awareness, technologies that support increasing renewable energy penetration in microgrids have become popular and important research topics. Microgrid

research fits very well within smartgrid activities with specific emphasis on demand side management and there is need to outline ongoing research in microgrid to benefit the researchers and policy makers. Two topics closely related to these technologies are microgrid controls and energy storage applications in microgrid [3].
A microgrids is an interconnection of distributed energy sources, such as microturbines, wind turbines, fuel cells and PVs integrated with storage devices, such as batteries, flywheels and power capacitors on low voltage distribution systems [3].

Microgrid controllers have responsibilities to ensure that [9]:

1. Microsources work properly at predefined operating point or slightly different from the predefined operating point but still satisfy the operating limits;
2. Active and reactive powers are transferred according to necessity of the microgrids and/or the distribution system;
3. Disconnection and reconnection processes are conducted seamlessly;
4. Market participation is optimized by optimizing production of local microsources and power exchanges with the utility;
5. Heat utilization for local installation is optimized;
6. Sensitive loads, such as medical equipment and computer servers are supplied uninterruptedly;
7. In case of general failure, the microgrid is able to operate through black-start; and
8. Energy storage systems can support the microgrid and increase the system reliability and efficiency.

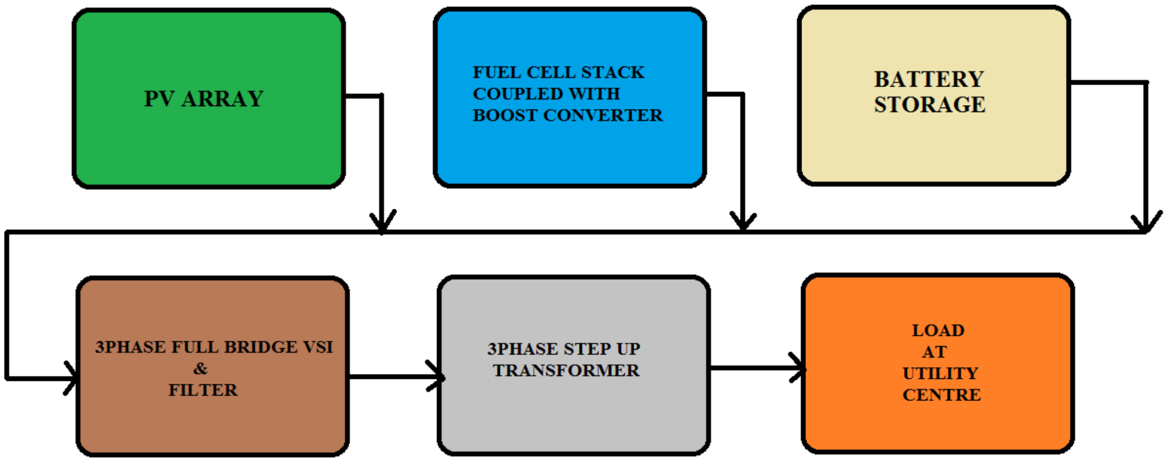


**Fig .Microgrid Model**

## II. MODES OF OPERATION

Power electronic devices acts as interfaces between DG and utility grid. MGCC (Microgrid Central controller) is the main controller which controls MC (Micro-source Controller) and LC (Load Controller). Inverter is the heart of entire microgrid. Energy from the DG is to be controlled as per load requirement and hence there should be a control scheme to regulate the power flow from the DG and maintain quality and reliability of supply. Motive behind any control scheme is accurate power sharing and required voltage and frequency regulation.Various modes of operation and controlling of inverters are explained in further sections. Depending upon the mode under which a microgrid operates, control strategies are designed [10].

A Microgrid can operate in two modes.

1) Grid connected mode
In grid connected mode/on-grid, DG is connected to the utility grid at the PCC (Point of Common Coupling) through STS (Static Transfer Switch). The amount of active and reactive power to be injected by a DG is decided by the MGCC. MGCC issues commands to the MCs and LCs and these devices in turn control the local devices. Communication between MGCC, MCs and LCs is to transfer the small information related to set points of active and reactive power, reference voltage and frequency etc., PQ control is employed in this mode to regulate active and reactive power from inverter [11]–[13].

2) Islanded mode
When the microgrid is working autonomously, it is said to be in islanded/stand-alone/off-grid mode. Microgrids enter into this mode due to maintenance, outage or economic reasons [14]. Inverters acting as Voltage Source Inverters in this mode requires voltage and frequency set points which can be obtained by centralized or decentralized control. In centralized control, all the loads and sources are controlled by a hierarchical management system which issues the set-points to inverters through a communication link. This control is possible for low distance distribution networks only since it involves high capital cost and also unreliable. In [15], control strategy involving communication between MGCC, LC, and MC are discussed. For

decentralised control, energy available in DG should be greater than the demand in the system. Inverters control the voltage and frequency of the grid in accordance to the load power requirement and share the demand. In this mode, LC's and MC's make their own control decisions [15], [16]. Droop control or master-slave control can be employed in this mode of operation [17]. But master-slave control is not preferred because of its low reliability [11], [13], [18]. In [19], both droop control and master-slave control schemes were implemented simultaneously in a system where, some inverters operating under PQ control while others as per droop control.

## III. CONTROL STRATEGIES

Based on the above responsibilities and the controller coordination, the microgrid controls can be classified as local controls, centralized controls, and decentralized controls.

1) Local Control

Local controls are the basic category of microgrid controls. The main usage of local controllers is to control microsources. This type of controllers is aimed to control operating points of the microsources and their power-electronic interfaces without communication systems. No communication systems result in simple circuitry and low cost. The measured data for local controllers are local voltages and currents. In most microgrid applications, local controllers will coexist with other type of controllers, while in fully islanded microgrids, the local controllers are the only required controllers. The local controllers must also ensure the ''plug-and-play'' function of microsources; a or several microsources must be able to seamlessly connect to or disconnect from the distribution network when and where they are needed.

Most microsources require power-electronic interfaces to convert their output to suit power system specifications. The general model for a microsource contains three basic elements: prime mover, DC interface, and voltage source inverter (VSI). The microsource couples to the microgrid using an inductor. The VSI controls both the magnitude and phase of its output voltage, $\bar{V}$, in order to control real and reactive powers. The voltage regulation is crucial for a microgrid with integration of large number of microsources in order to overcome oscillation caused by high penetration of microsources. The voltage regulation is also used to insure that there are no large circulating reactive current between sources. Besides the voltage regulation, microsources must also regulate active and reactive powers. The most common methods to regulate these powers are droop-based active and reactive power controls. These droop controls are scale-down versions of droop-basedcontrols in utility. The droop-based controls consist of voltage reactive power and frequency-active power droop controls. In voltage-reactive power droop control as the reactive current generated by the microsource becomes more capacitive, the operating voltage will increase. Therefore the local voltage set-point is reduced to keep the voltage at or near its initial set-point. On the other hand, the local voltage set-point is increased if the reactive current becomes more capacitive. The limit of reactive current increase and decrease is defined by Qmax, which is a function of volt-ampere (VA) rating of the inverter and the power generated by the prime mover. In a grid-connected operation, microgrid loads receive power both from the grid and from local microsources, depending on the customer's situation. If the grid power is lost because of voltage drops, faults, blackouts, etc., the microgrid can transfer smoothly to island operation. In addition, the microgrid is usually equipped with a capability to intentionally operate in islanded mode of operation. With this capability, the microgrid can be islanded intentionally for specific reasons even though there is no disturbance or power quality problem in the utility side. After the separation of the microgrid from the main grid, the voltage phase angles at each microsource in the microgrid change, resulting in an apparent reduction or increase in local frequency depending upon the power mismatches. The local frequency will decrease if the microgrid receives power from the utility in gridconnected operation but will increase if the microgrid sends power to the utility in grid-connected operation. The dependency of frequency on power allows each microsource to provide its proportional share of load without immediate new power dispatch from the Energy Manager [3].

2) Centralized Control

Centralized controls of microgrids can be explained based on hierarchical controls. In fact, hierarchical systems may have centralized or decentralized controllers. The control level of hierarchical systems can be classified as follows [3]:

- local controllers consisting of Microsource Controllers (MCs) and Load Controllers (LCs);
- Microgrid Cental Controllers (MGCCs); and
- Distribution Management System (DMS).

The MCs in centralized controls have similar principle as the local controllers discussed in previous section. In centralized controls, The MCs may also be enhanced with various degrees of intelligence. In addition, LCs are installed at the controllable loads to provide load control capabilities. LCs are commonly used for demand side management. For each microgrid, there is an MGCC that interfaces between the DMS and the microgrid. The MGCC may have different roles ranging from simple coordination of the local controllers to the main responsibility of optimizing the microgrid operation. The difference between centralized and decentralized controls is defined by the centralization roles assumed by the MGCC; the level of decentralization can vary depending on the share of responsibilities assumed by the MGCC and the MCs and LCs. In a centralized control, MCs and LCs follow the orders of MGCC during grid-connected mode and have autonomy to perform their own controls during islanded mode. DMS or Distribution Network Operator (DNO), to which several MGCCs are interfaced, has responsibility to manage the operation of medium and low voltage areas in which more than one microgrid may exist. In addition, one or more Market Operators (MO) will exist in the system if the microgrids participate in market operation. DNO and MO are not parts of microgrids but representatives of the utility [3].

Centralized control is best used for microgrids with the following characteristic [3]:

- The owners of microsources and loads have common goals and seek cooperation in order to meet their goals.
- Small-scale micogrids may be feasible to control with the presence of an operator.

3) Decentralized Control

Decentralized controls have similar description to the centralized controls. In decentralized controls, the main responsibility is given to MCs that compete to maximize their production in order to satisfy the demand and probably provide the maximum possible export to the grid taking into account current market prices. The decentralized control is aimed to maximize autonomy of the microsources and loads. Several intelligent methods based on peer-to-peer algorithm, such as multi-agent-based and gossip-based algorithms, may be used for decentralized controls [3].

Decentralized control is best used for microgrids with the following characteristics [3]:

- microsources can have different owners in which case several decisions should be taken locally,
- microgrids operating in a market environment require that the action of the controllers of each unit participating in the market should have a certain degree of intelligence,
- local microsources may have other tasks besides supplying power to the local distribution networks, like producing heat for local installations, keeping the voltage locally at a certain level or providing a backup system for local critical loads in case of main system failure.

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