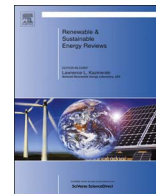




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## Renewable and Sustainable Energy Reviews

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## A review on control of ac microgrid

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## ABSTRACT

The demand and acceptance of the renewable energy power plants are steadily increasing because of its positive environmental impacts and free availability of fuels such as wind and solar. Because of the intermittent and volatile nature of the output of these plants, neighboring plants are interconnected and controlled simultaneously using intelligent controllers. Loads and other conventional generators like diesel generators are also connected to this network and forms a microgrid which may or may not be connected to the main utility grid. For effectively controlling the resources and the loads connected to a microgrids, many control strategies are developed and successfully implemented nowadays. This paper looks at the possible control schemes used in an AC microgrid.

## 1. Introduction

Microgrid is introduced by USA's CERTS (Consortium for Electric Reliability Technology Solutions) to improve consumer confidence and power quality. Microgrids, defined as power systems which include loads, distributed generation, energy storage and are managed as a single unit in order to exchange power with the grid through a single coupling point, are becoming a way of integrating renewable energies, lowering costs and providing better grid quality all around the world. The microgrid configuration can be dc, ac, or hybrid. The ac microgrid is more focused nowadays due to its ability to operate in conjunction with main grid, simple structure and cost effectiveness.

The typical structure of a microgrid is shown in Fig. 1. The inverter act as an interface between distributed energy resources and utility grid. 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. Power generated by the DGs are controlled according to the load demand and thus reliability and quality of supply is maintained. Using different control scheme, the voltage and frequency of the microgrid kept constant which is the main aim of any control technique used in microgrid [1]. The control techniques and strategies employed in a microgrid depends on the operating mode of the microgrid [2].

Many reviews are available in the area of microgrid regarding its control strategies, optimization techniques, applications, operating algorithms, protection devices, software tools etc. Even though differ-

ent configurations are available, ac microgrid become increasingly popular nowadays because of its easiness to work in conjunction with main grid, cost effectiveness and less complicated structure.

Lots of researches are being carried out in the area of ac microgrid and not many reviews are available in this specific area detailing different aspects of control strategies. So a review on control of ac microgrid will be much awaiting.

The paper organized as follows: operating modes of microgrid and its literature review is presented in this section II. Section III gives a detailed literature review on different control techniques in ac microgrid. Section IV is dedicated to the detailed review on the different control aspects of ac microgrid. Section V and section VI includes future trends in control of ac microgrid and conclusions respectively.

## 2. The operating modes of microgrid

The possible modes of operation of a microgrid are islanded mode and grid connected mode [3–5].

## 2.1. Islanded mode of operation

In islanded mode there is no support from grid and the control of microgrid become much more complex. In this stage the microgrid become very sensitive to fluctuation in generation and load variation because of low inertia of the system [5]. A reliable power source is necessary to support the microgrid in islanded condition. Normally

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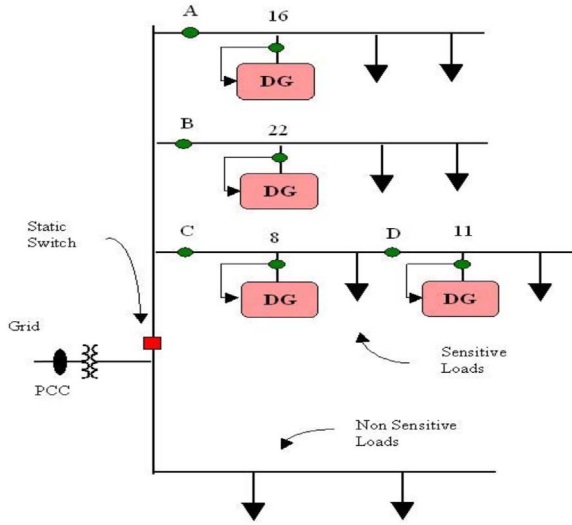


Fig. 1. Structure of a Microgrid [3].

electrostatic or electrochemical energy storage devices are used for this purpose [4]. The voltage and frequency can be kept constant in islanded condition by efficiently controlling the storage devices like batteries, super capacitors etc. [6,7]. Since the power distribution between inverters of different generators are an important issue for autonomous operation, different control strategies have been investigated in islanded MGs until now such as master-slave control method [8–11], control area network communication [12], voltage and frequency droop strategy based on local measurements [13,14].

Microgrids operate in this mode due to fault or maintenance in grid side or by considering economic aspects [15]. Centralized or decentralized control can be used in autonomous mode which gives voltage and frequency set points. Centralized control is used for short distance distribution networks by a hierarchical management of sources and loads [16]. When energy demand is less than generation, decentralized control is used. Droop control or master slave or combination of both control methods can be implemented in decentralized mode [17–21].

## 2.2. Grid connected mode of operation

In this mode of operation, microgrid is coupled to the utility grid through a static transfer switch. The connection point is called point of common coupling (PCC). The microgrid controller continuously monitor the generation and demand in the microgrid and the excess power is exported or deficient power is imported through the inverter according to the load and source conditions. Once connected to grid, the microgrid loose its control over frequency and voltage in the system and shifts to P-Q control to regulate active and reactive power [22].

## 3. Different control techniques in microgrid

### 3.1. V-f control

This control strategy is mainly employed to support the autonomous operation of microgrid. In islanded mode of operation, the microgrid itself has to meet all the load requirements connected to it while keeping voltage and frequency at rated values. But a pure V-f control can not respond with the load changes effectively. So a master-slave control configuration of a microgrid is proposed [23]. It is obtained by a loop which shifts the characteristics up or down with the change in load (Fig. 2).

In [60] V-f control of low voltage network in the events of switching has been studied.

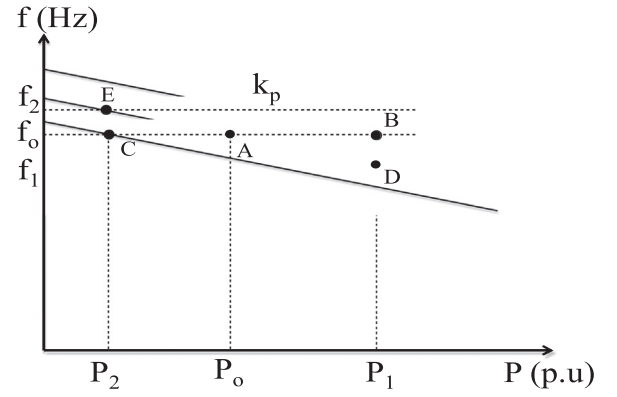


Fig. 2. V/f control [23].

### 3.2. P-Q control

The P-Q control is employed when microgrid is connected to the grid. At grid connected mode the frequency and voltage of the microgrid become equal to that of grid so that the microgrid controller no longer need to follow the V-f control strategy. Now the inverter injects maximum active power and reactive power in to the grid in order to achieve economic operation of microgrid [24,25]. To control the output voltage of the inverter, two methods are proposed [26]. In current control of inverter, the renewable energy source generators are at maximum power generation mode (with help of MPPT). This time the reactive power generation would be minimum.

In voltage regulation control, the amplitude and phase of generator output voltage is controlled to regulate the power flow. The real and reactive power controllers are generating reference phase angle and reference voltage respectively. The P-Q control technique is shown in Fig. 3.

### 3.3. Droop control

The voltage and frequency droop characteristics, i.e., when active power output increases, the load angle decreases there by decreasing frequency and when reactive power drawn increases, the terminal voltage drops are used in the inverters of the microgrid. More power can be drawn from the inverter by slightly reducing the frequency and by reducing terminal voltage, the more reactive power can be drawn. In a microgrid each inverter is assigned with its own droop characteristics based on their generation capabilities [27]. The droop control method can be defined as [28],

$$\begin{aligned} \omega &= \omega^* - m(P - P^*) \\ V &= V^* - n(Q - Q^*) \end{aligned} \quad (1)$$

where  $P^*$  and  $Q^*$  are the reference real and reactive power,  $\omega^*$  and  $V^*$

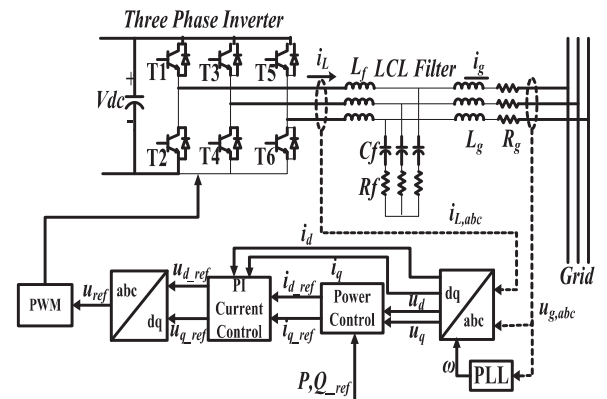


Fig. 3. Schematic of P-Q control [24].

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