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# Issues, Control and Protection of Microgrid

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***Abstract:*** *A microgrid is defined as a type of the grid consisting of prime energy movers, power electronics converters, distributed energy storage systems and local loads. Microgrid network enables an improved management of energy. The main goal of power management is to stabilize the system, in terms of frequency and voltage. This paper includes issues such as faults during grid connected mode and faults during islanded mode, voltage control, load sharing through P-f control and various types of protection schemes are discussed. Overall stability and reliability of microgrid depends on these factors.*

***Keywords:*** *Microgrid, power, voltage control, protection.*

## I. Introduction

Conventional power system is facing the problems of depletion of fossil fuel resources, poor energy efficiency and environmental pollution. These problems have led to a new trend of generating power locally at distribution voltage level by using renewable energy sources such as natural gas, biogas, windpower,solarphoto-voltaiccells,fuelcells,combinedheat and power (CHP) systems, microturbines and their integration into the utility distribution network. This type of power generation is termed as distributed generation (DG) and the energy sources are termed as distributed energy resources (DERs). Microgrid is essentially an active distribution network because it is the combination of DG systems and different types of loads at distribution voltage level. The generators or micro sources employed in a Microgrid are usually renewable DERs integrated together for generating power at distribution voltage [1]. Microgrids have increasing the attention as a means of integrating distributed generation into the electricity grid. Usually it is described as confined clusters of loads, storage devices and small generators, these autonomous networks connected as a single entity to the public distribution grid, means through a point of common coupling (PCC). Microgrids comprise a variety of technologies: renewable sources, such as solar photovoltaic and wind generators are operated also with the traditional high inertia synchronous generators, batteries and fuel cells. Thus, the energy is generated near the loads, enabling the utilization of small scale generators that for increase the reliability and reduces the power line losses.

Microgrid network that enables for an improved management of energy. Generators (and possibly loads) can be controlled by an energy management system (EMS) to optimize power flow within the network. The objectives of energy management system depends on the mode of operation such as Islanded or grid connected. A microgrid is defined as a type of the grid consisting of prime energy movers, power electronics converters, distributed energy storage systems and local loads [2]. In islanded mode, the main goal of power management is to stabilize the system, by stabilizing the frequency and voltage. In grid connected mode, typical objectives are to minimize the price of energy import at the point of common coupling, to improve power factor at the point of common coupling and also to optimize the voltage profile within the microgrid. Energy management in microgrids is usually a three-level hierarchical control system. The first level of control often called as a primary or autonomous control, consists of a number of local, autonomous controllers. Each controller is governed by a power electronics converter and it is responsible to interface generators, storage devices and loads with the microgrid. A secondary level of control employs a lowbandwidth communication to fix the frequency and amplitude of the microgrids units, restoring their nominal values. Finally, the tertiary level of control is related to the control of active power flow and reactive power flow. This level of control is related to energy management system and also for the optimization of the microgrid resources [14].

Intelligent microgrids are required to integrate the distributed generation (DG), the distributed storage (DS) and the loads into the future smart grid. This will be a key point to integrate with new functionalities and also with the renewable energy resources into the grid. Those small grids should be able to generate and the store energy near to the consumption points. This can avoids large distribution lines coming from big power plants located far away from the consumption areas. The impact of these distribution lines could result in low efficiency due to the high conduction losses, voltage collapse which is caused by reactive power instabilities, low reliability due to single point failures and contingencies, among other problems. The main idea of this, is to connect these microgrids to the main grid or interconnect them through tie lines forming microgrid clusters [2]. Microgrids can be able to operate autonomously but also interact with the main grid. The transfer from grid-connected mode to islanded mode, it is also a desirable feature. These tie lines will act as interchange the energy channels to balance the energy required by each microgrid, thus it reduces the power flow of the lines. Moreover, microgrids can be represented by a low voltage distribution systems, since the generation is based on small generation machines, on small prime movers, such as photovoltaic (PV) arrays, small wind turbines (WTs) or fuel cells, which requires for power electronics interfacessuch as ac-ac or dc-ac inverters. Those the power electronics equipments act very fast, which has the full control of the transient response. However, in contrast with generation machines, the power electronics do not have inherent inertia that ensures the stability of the system and the steady-state synchronization of each unit. With the objective to achieve this performance, virtual inertias are mostly implemented through control loops known as the droop method. This method consists on reducing the frequency and the amplitude of the inverter output voltage which are proportional to the active and reactive powers. Thus, microgrids can be able to keep active and reactive power balance, as well as to avoid voltage collapses. Further, microgrids have additional performances such as fully and independent active and reactive power flow control and energy management, slow-voltage ride-through, active power filtering and uninterruptible power supply (UPS) capabilities, black start and islanding operation, synchronization with the main grid [3]. In Figure 1 shows a microgrid based on small wind generators, photo-voltaic sources, energy storage systems and distributed loads. The microgrid can be connected to the point of common coupling of the main grid through the intelligent bypass switch. The overall microgrid system consists of a number of Distributed Generation and Distributed Storage systems that requires for power electronics inverters[2].

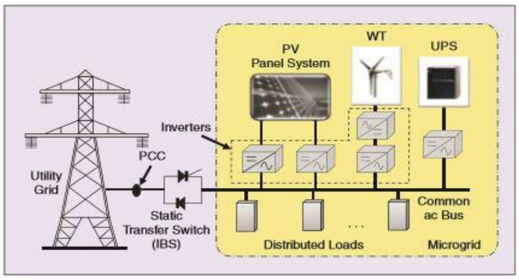

**Fig. 1.** Typical structure of a flexible microgrid based on renewable energy resources.[2]

The point of electrical connection of the microgrid to the utility system, at the low voltage bus of the substation transformer, which constitutes the microgrid point of common coupling (PCC). The microgrid serves a variety of customers such as, residential buildings, commercial entities and industrial parks. At the point of common coupling, it is expected to provide a sufficient generation capacity, operational strategies and controls to supply at least a portion of the load after being disconnected from the distribution system and remain operational as an autonomous (islanded) entity. Primarily due to the human and equipment safety concerns, the existing power utility practice often does not permit accidental islanding and automatic resynchronization of a microgrid. However, the high amount of penetration of DER units potentially necessitates provisions for both islanded and grid-connected modesof operations and smooth transition between the two (i.e.,islanding and synchronization transients) which enables the best utilization of the microgrid resources [5].

## II. IIssues

Protection issues of microgrid, when it is grid connected mode and islanded mode of opearation are as follws:

A. Events or Faults During Grid Connected Mode : For a fault within microgrid, the response of line or feeder protection must be to disconnect the faulty portion from the rest of the system as quick as possible and how it is done depends on the features and complexity of microgrid and protection strategy is used. There may be some non fault cases which are resulting in low voltages at PCC like voltage unbalance and non fault open phases which are difficult to be detected and it may create hazards for sensitive loads, microsources etc. Therefore, some protection mechanisms must be developed to avoid such situations [8].

B. Events or Faults During Islanded Mode : The nature of problems are different in islanded mode than grid connected mode. In grid connected mode, the fault currents of higher magnitude (10-50 times the full load current) which are available from the utility grid for activate conventional OC protection devices. For islanded mode of microgrid, fault current is five times the full load current. When a large number of converter based DERs are connected in microgrid, the fault currents are 2-3 times the full load current or even less depending on the control method of converter. The conventional OC protection devices are usually setat2-10timesthefullloadcurrent.Hence,duetothisdrastic reduction in fault level, the time current coordination of OC protective devices is disturbed, the high set instantaneous OC devices and extremely inverse characteristics OC devices like fuses are most likely to be affected [8].

The other major issues in microgrid protection and control include :
- Bidirectional power flows: The power flow in a conventional distribution system is unidirectional, i.e. from the substation to the loads. Reverse power flows when integration of DGs on the distribution side of the grid . As a result, the conventional protection coordination schemes are no longer valid;
- Stability issues: As a result of the interaction of the control system of microgenerators local oscillations may arise. Hence, small signal stability analysis and transientstability analysis are required to ensure proper operation in a microgrid;
- For maintaining power quality, active and reactive power balance must be maintained within the Microgrid on a short-term basis ;
- Intermittent Output: Renewable energy resources (photovoltaic, or wind) in microgrid as distributed generation are intermittent in their power output because of the availability of sources. Hence, coordination between DGs and storage devices is essential [7].

## III. Control

The microgrid control center (MGCC) is the core of the microgrid control system. It centrally manages DGs, ESs and loads and monitors and controls the entire microgrid. It has the control strategy based on the operating conditions to ensure smooth transfer between grid connection, islanding and shutdown. In grid connected operation, the layer regulates the microgrid for best operational performance; in islanded operation, the layer adjusts the DG output and load consumption to ensure stable and safe operation of the microgrid. In grid-connected operation, the central control layer dispatches the microgrid for best economic performance and coordinates various DGs and ESs for load shifting to smooth the load curve, During transfer between grid-connected mode and islanded mode, the local controller to realize quick transfer, In islanded operation, the layer coordinates various DGs, ESs and loads to maintain supply to important loads and also it coordinates for safe operation of the microgrid, When the microgrid stops operation, the layer initiates black-start to rapidly resume operation. The CC performs the overall control, operation, protection of Microgrid. Also it maintains the specified voltage and frequency at the load end through power−frequency (P−f) and voltagecontrol.TheCCalsoperformsprotectionco-ordination and provides the power dispatch and voltage set points. When necessary the CC is designed to operate in automatic mode with provision for manual intervention. In centralized monitoring system, the central monitoring unitcommunicateswithvariousswitches,givesordersandalso sets the switch action range. The monitoring mode is easy and cheap, but it has the disadvantage that operation of all switches relies on the central monitoring unit, the failure of which will cause collapse of the entire protection system. A decentralized monitoring system is composed of multiple central monitoring units which are fulfilling the different functions. When one unit fails, the others will automatically take over, thus avoiding system collapse. This mode offers high reliability but calls for more investment [10]. An interesting approach to designing and developing decentralized systems is based on multi-agent system (MAS) theory[6]. The core idea is that an autonomous control process is assumed by each controllable element, namely inverters, DGs or loads. The MAS theory describes the coordination algorithms, the communication between the agents and the organization of the whole system.There is no formal definition ofan agent, but the following basic characteristics are provided: An agent can be a physical entity that acts in the environment or a virtual one, that is, with no physical existence. Agents have a certain level of autonomy, which means that they can take decisions without a central controller or commander. For a battery system, a tendency could be: charge the batteries when the price for the kWh is low and the state of charge is low, too. Thus, the MAS decides when to start charging, based on its own rules, not by an external command.

### 3.1 Voltage control

Active and reactive power control, voltage control at the Microgrid bus are needed for overall stability and reliability of Microgrids. Microgrids may suffer from reactive power oscillations without proper voltage control with a large number of microsource. Similar to that for large synchronous generators, voltage control function of MC addresses the issue of all eviating large circulating reactive currents amongst microsources. For utility, this circulating current is normally restricted by the large impedance between generators, whereas in case of Microgrids, the problem getting more attention as the feeders are mostly radial with small impedance between the sources. Sometimes, these circulating currents get exceed the rated currents of the microsources even with small differences in their voltage set points. The circulating currents can be controlled by using voltage reactive power (V-Q) droop controllers with droop characteristics as shown in Figure 3. The controller function is to increase the local voltage set point when the microsource reactive currents become predominantly inductive and when the current becomes capacitive it has to decrease the set point [1]. The reactive power limits is set by VA rating (VAR; S) of the inverter and active power (P) output of the microsource as per the following relation:

$Qmax=\sqrt{(s^2-p^2)}$

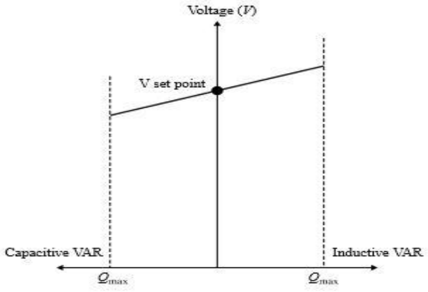

**Fig. 2.** Droop characteristics for V-Q droop controllers [1]

### 3. 2 Load sharing through P-f control

Microgrid controllers have smooth and automatic change over from grid-connected mode to stand-alone mode and viceversa. This is similar to the operation of uninterrupted power supply (UPS) systems. During transition to standalone mode, the MC of each microsource exerts local P-f control to change the operating point so as to achieve local power balance at the new loading. The controller does this autonomously after proper load tracking without waiting for any command from the CC or neighbouring MCs. Figure 4 shows the drooping P-f characteristic used by the MCs for P-f control [9],[1].

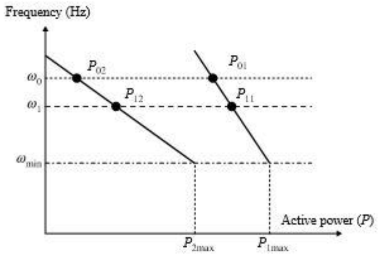

**Fig. 3.** Active power versus frequency droop characteristics.

In grid-connected mode, Microgrid loads are supplied both from the main utility grid and the microsources, depending on customer needs. When utility supply is interrupted due to any contingency, the Microgrid switch over to the standalone mode. During change over, the voltage phase angles of the microsources also change, leading to obvious drop in their power output. Hence, local frequency also changes, then each microsource quickly picks up its share of load without any new power dispatch schedule from the CC. For example, it is assumed that two microsources operate at a common minimum frequency with their maximum capacities P1max and P2max. In grid-connected mode they operate at a base frequency delivering powers P01 and P02 respectively. With the change in load demand, the microsources operate at different frequencies which causes a change in relative power angles and the frequency of operation shift to a lower common value with different proportions of load sharing. This occurs as per the droops of the P-f characteristics as shown in Figure 4. Since droop regulation decreases the Microgrid frequency, the MC needs a control function to restore the operation to the rated frequency with proper load sharing. The devices, processes and the time span that must be taken into consideration in order to assess stability [9],[1].

## IV. The Protection Schemes Formicrogrid

Thereare three main catagories in protection schemes which are as follws: the schemes for only grid connected mode, the schemes for islanded mode and the schemes for both grid connected and islanded mode.

### 4.1 The Protection Schemes For Only Grid Connected Mode:

Protection scheme based on over current principle and time depdendent characteristics of current to prevent highfault clearing time and maximizing the DG connection to the distribution network strategy provides extra benifit of running extensive radial networks with directly coupled DGs (D-DGs) or closed loop networks with converter based DGs (C-DGs). However, this scheme is more effective when number of relays are increased. Overcurrent pickup strategy for MV feeder with CDGs updates the OC relay minimum pickup current on the basis of the fault analysis of the system. However, when some of DGs are disconnected, then this scheme is more effective. A protection strategy using conventional OC relays with definite time grading for LV microgrid with both C-DGs and D-DGs scheme is economical because, this scheme does not use any communication link and can be applied without any modification of existing protection scheme. Based on intelligent protection scheme for radial OHL distribution system without DG and for closed loop system with DG scheme, as compared to conventional protection provides higher speed of back up protection, autonomous system monitoring and adjustment of parameters, but needs a high speed communication. It has been used to fault current limier(FCL) in series with DG unit to limit the fault current duringfaultandthusreturnthesystemtoit'soriginalstateasif no DG was connected. In this way, without disconnection of DG, the original directional OC relay settings can be used. The use of TCSC (thyristor controlled series capacitor) as an FCL offers many advantages like no DG disconnection, use of original relay settings, for handling large currents avoids upgrading of equipment. But, its cost increases due to impedance of FCL increases with increase in individual DG capacity [13],[8].

### 4.2 The Protection Schemes For Only Islanded Mode:

A protection scheme based on monitoring harmonic content of C-DGs in an islanded mode, which includes the total harmonic distortion (THD) of the voltage at the converter terminal. The protection relay monitores DG continuously and when THD exceeds a threshold value during a fault, the converter gets shut down by relay. For detecting the fault type, the variation of the amplitude of fundamental frequency of faulted the phase is used, it means that the frequency of faulted phase is dropped as compared to sound phase and also comparision of THD of voltage between sound and faulted phase is used for fault location i.e., faulted phase has greater THD than sound phase. The relay with more THD is considered to be in fault zone and it has to be trip for clear the fault. However, for correct relay to trip, communication links are provided for synchronisation of relays. A protection scheme based on the principle of symmetrical components and residual current measurement also used. The differential current measurement is also applied. The scheme uses residual current devices as primary protection of LG faults for the zones of upstream faults and the zero sequence currents for primary protection of LG faults for the zones of downstream the faults. The negative sequence current is used for primary protection of LL faults. $I^2t$protection is used for primary backup protection for both LG and LL events.Protection scheme based on telecommunication and modern protection relays or IEDs for microgrid with C-DGs has been applied to MV feeder divided into four protection zones and between each zone a cicuit breaker is installed which is controlled by IED [13],[8]. The IEDs are provided with voltage and current measurement, directional OC protection and these are connected with each other through high speed communication links. This method uses the voltage measurement for fault detection and current direction for fault location. The complete system selectivity and speed is obtained through transfer of fault direction and interlocking information between IEDs.

### 4.3 The Protection Schemes For Both Grid Connected and Islanded Mode:

1) Differential Protection Scheme: Differential protection scheme using digital relays working on the principle of synchronized phasormeasurementforMVmicrogridincluding C-DGs and D-DGs. Instaneous differential protection is used for primary protection and for backup protection adjecentrelays are used in case of breaker failure. In case of relay failure, voltage protection is used as a tertiary protection. However, the proposed scheme is un economical to implement and assumes advanced technical features such as high performance relays and breakers, high sensitive current transformers, which are still not present. A protection scheme based on the principle of differential current and utilizing the traditional OC relay and communication link for microgrid including C-DGs and D-DGs. This protection offers economical implementation, but not effective during unbalanced load.A differential protection scheme used for primary protection for MV microgrid with C-DGs for grid connected and islanded mode of operation uses OC and under voltage based protection for backup protection in case of breaker failure. Current differential relays used for feeder and bus protection, while DGs are protected using under voltage, reverse power flow, over voltage. This scheme may suffer due to switching transients and unbalanced loads [11].

2) Adaptive Protection Schemes : Adaptive protection scheme is based on the principle of network zoning which includes zoning of the feeders in such a way that each zone has appropriate balance of DG and load with DG capacity slightly larger than load. Each zone, at least largest DG is equipped with load frequency control capability. After zoning, fast operating switches are equipped with synchronisation check relays and having capability to receive remote signals from substation breaker which are placed between each of two zones. A computer based relays are used, which having high processing power, large storage capacity, capability to communicate with zone breakers and DG relays which are installed at sub transmission sub station. A computer based relays performs the online fault detection and isolate the faulty zone by tripping of appropriate zone breaker and DG connected to that zone [12].

## V. Conclusion

In microgrid, if fault occurs or any other contingency happens, then the problems would be created which are relatedto power flow, also there are various protection schemes are used for minimize or eliminate these problems. Voltage control is used for reactive power balance and P-f control is used for active power control. Various protection schemes such as, over current protection, differential protection scheme, zoning of network in adaptive protection scheme are used in microgrid system

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