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Controlling Voltage and Frequency of a Power Network with Microgrid Using Droop Method

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Abstract - Microgrids (MG) are new concept of electric power networks consisting of distributed generation (DG), renewable energy resources and sensitive loads. The goal of microgrid operation is to provide reliable and high-quality electric power regardless of faults or abnormal operating conditions. Many control methods have been employed to regulate the output power of DGs used in MGs. This paper presents a control scheme for DGs of a power system, especially with voltage source inverter (VSI) interface, for both grid connected and islanded modes. A comprehensive study has been performed through PSCAD simulations of the inverter-fed MG behavior under both islanding and connected operation for different load conditions. The simulation results prove the droop method efficiency in controlling the voltage and frequency of the inverter output which is connected to the loads.

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1. INTRODUCTION

Renewable energy emerges as an alternative way of generating clean energy. As a result, increasing the use of green energy benefits the global environment. This topic relies on a variety of manufacturing and installation industries for its development. As a solution, continuously small and smart grid energy systems appeared, including renewable energy resources, micro-generators, small energy storage systems and critical and non-critical loads have formed among them a special type of distributed generation system called the Microgrid (MG) [1, 5].

Advantages of MGs can be cited as: i) MG can operate independently without any support from the upper stream of the network. It is one of the advantageous as the MG would not be affected, but rather separated from the upper stream where the fault occurs, and thus in islanding mode [1]. ii) MG has "plug-and-play" feature. This means that it can always be connected or disconnected to the medium-voltage network [3]. iii) They are clean sources of energy that have very little environmental impact on the community compared to those conventional energy technologies [5].

The high penetration of DGs like fuel cell, photovoltaic, wind turbine, micro turbine and etc, along with different types of loads, always raises concern about coordinated control and power quality issues.

In microgrid, DGs are connected through VSIs as an interface to deliver the sinusoidal voltage to the network and loads. parallel DGs are controlled to deliver the desired active and reactive power to the system while local signals are used as feedback to control the inverters. The power sharing among the DGs can be achieved by controlling two independent quantities of frequency and fundamental voltage magnitude [9, 10].

A MG can operate in grid-connected mode or islanding mode, hence increases the reliability of energy supplies by disconnecting from the grid in the case of network faults. When the MG is connected to the main grid, if the produced power of the MG is lower than the power demand level, main grid provides this difference in power. On the other hand, MG can send the excessive generated power to the main grid [6].

If the grid has to go in islanding mode due to fault or low-voltage, the network controllers must keep the system frequency and voltage in a desirable area leads to sending the qualified power to consumers. The MG should also recover the frequency and voltage in islanding mode rapidly. When MG goes to islanding mode, its last situation should be considered: if it was importing energy then after entering to the islanding mode, it has to increase the generation level to compensate the lost power; therefore in this mode the MG frequency will be decreased. On the other hand, if MG was exporting energy and afterwards it has gone to islanding mode, it should decrease the generation level so the grid frequency will rise [2, 4].

Now a considerable research has been undertaken on the control strategy of the MG. Flexible and fast controls of active and reactive power are important requirements during transient and steady-state operation of a MG system in both grid-connected and islanding modes.

A MG when subjected to disturbances can experience angle instability and poor voltage quality due to the presence of DGs with slow response rotating machines and DGs with power electronic converters as the interface to the utility system. To ensure stable operation during network disturbances while maintaining power quality in the islanded mode of operation, a more sophisticated control strategy for MG needs to be developed, in order to warranty both quality of supply and ensuring power management supervising critical and non-critical loads [8]. Also, the basic issue on small grids is the control of the number of micro-sources. MG concept allows larger distribution generation by placing

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many micro-sources behind singles interfaces to the utility grid. Some key power system concepts based on power against. Frequency droop methodology, voltage control and can be applied to improve system stability, enhance active and reactive support. Flexible and fast controls of active and reactive power are important requirements during transient and steady-state operation of a MG system in both grid-connected and islanding modes [11, 13].

This paper is organized as follows. In Section II, the structure of the MG has been described. Section III explains the droop method to control the DGs in a power network with MG. To prove the efficiency of droop method some simulations have been done in different situations with connected and islanding modes and the results are discussed in section IV. The simulation results show that droop method can regulate the voltage and frequency of the PCC (point of common coupling) where inverter has been attached to the load or network both in connected and islanding modes.

II. STUDY SYSTEM

Figure 1 shows a single-line diagram of the system used to investigate typical MG operational scenarios. The basic system's configuration and parameters were extracted from the benchmark system of the IEEE Standard 399-1997, with some modifications to allow for autonomous MG operation. The system is composed of a 13.8 KV, three-feeder distribution

subsystem which is connected to a large network through a 69 KV radial line. The 13.8 KV distribution substation is equipped with a three-phase 1.5 MVar, fixed shunt capacitor bank. The 13.8 KV substation busbar is radially connected to the main grid through the substation transformer and a 69 KV line. The network at the end of the 69 KV line is represented by a 69 KV, 1000 MVA short-circuit capacity bus. Combinations of linear and nonlinear loads (L_1 to L_5) are supplied through three radial feeders of the subsystem. Loads L_2 to L_5 are composed of linear RL branches. Load L_1 is a three-phase diode rectifier load. The aggregate of L_1 and L_2 constitutes a sensitive load within the distribution subsystem.

The system also includes two DG units, i.e., DG_1 (2.5 MVA) and DG_2 (5 MVA) on feeders F_1 and F_3 respectively. DG_1 utilizes a voltage-sourced converter (VSC) as the interface medium between its source and the power system. DG_1 Represents a dispatchable source with adequate capacity to meet the active/reactive power commands, within pre-specified limits, subsequent to disturbances. Such a dispatchable source may also include energy storage interfaced at the converter dc bus. DG_1 provides control on its output active and reactive power components independently. DG_2 is a synchronous rotating machine equipped with excitation and governor control systems. It may represent either a diesel-generator or a gas-turbine-generator unit [7].

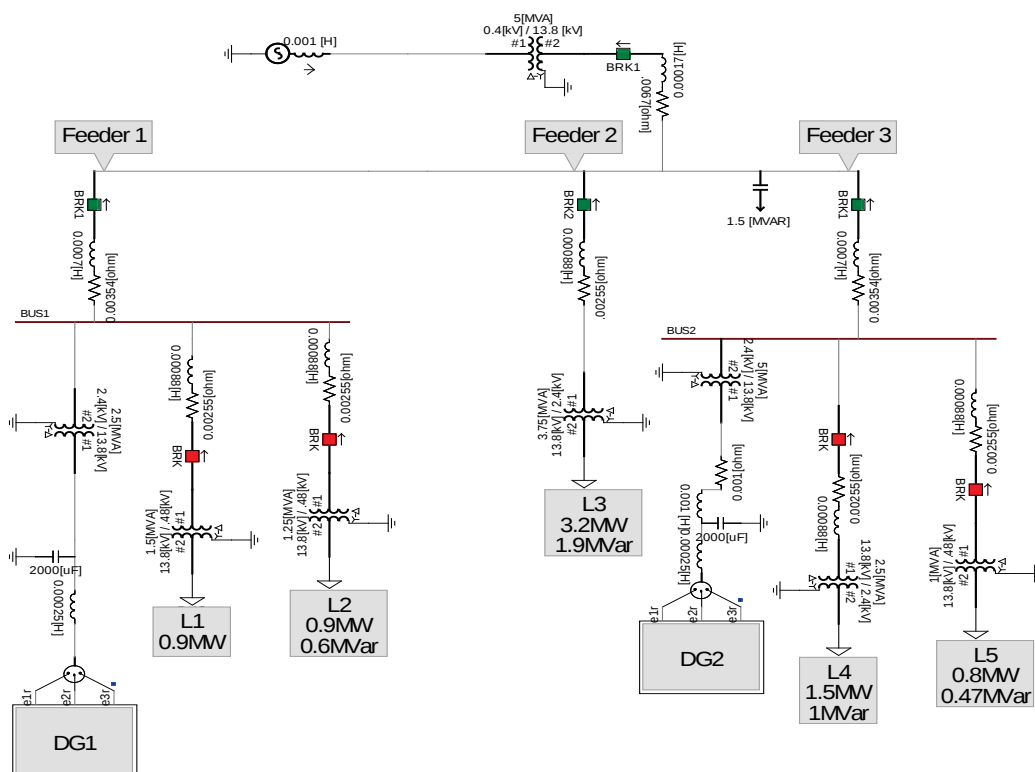


Figure 1 : Studied System

III. MICROGRID CONTROL

In a MG, the DG supply can be connected to a network using an inverter. An inverter can be tuned by frequency and voltage control.

For controlling the inverters usually the drop method is used. The active and reactive power of inverter can be controlled by means of this method in order to control the frequency and to produce voltage in a specific level. Active and reactive power has influence on voltage frequency and amplitude, so the control method can be described as follows:

a) Active power control versus frequency

In this mode, a frequency change is affected by changing in active power. Figure 2 shows the droop of power versus frequency changes.

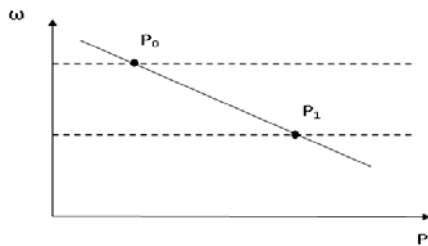


Figure 2 : Droop active power versus frequency

According to figure 2 it can be deduced that whenever frequency decreases in a network, controllers make the supplies to increase their production and it means the production level changes from P_0 to P_1 .

This state will happen to a MG when a fault occurs and it changes the status into islanding mode. The MG reconnects to main grid meanwhile the frequency increases then controllers make the DG to decrease the production level.

Equation 1 represents this controlling structure"

$$\omega = \omega^* - m.(P - P^*) \quad (1)$$

b) Reactive power control versus voltage

In this mode, changes in voltage have an interaction with changes in reactive power. According to figure 3, this controlling mode is represented by Eq. 2:

$$E = E^* - n.(Q - Q^*) \quad (2)$$

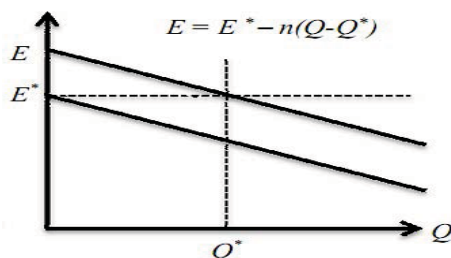


Figure 3 : Droop reactive power versus voltage

Where E is the amplitude of the inverter output voltage; Q is the reactive power of the inverter output, Q^* and E^* are the reactive power and voltage amplitude at no-load, respectively; and n is the proportional droop coefficient.

IV. SIMULATION AND RESULTS

To verify the proposed method some simulations have been done in PSCAD. To cases have been considered and explained as follows:

Case study1 : In this state the load of L3 in 0.5 seconds is disconnected. Then Micro Grid in the second 1 turns into the island state and the system acts as two separate Micro Grids. As in Figure 4 is observed, in the 0.5 seconds, DG1, in addition to producing the amount of MG1, exports the excess energy to L3, while MG2 only produces the which meets its own need. After the segregation of load L3 at 0.5 seconds due to the reduction in the amount of demand, the rate of the production of the units is decreased. In a run-time between 0.5 and 1 second DG1 supplies some portions of. MG1's energy need, but since the production in MG1 occurs in the first 0.5 second, its frequency is decreased. It is worth noting that since MG1 is importing, its frequency remains more than nominal amount. On the other hand, since the MG2 is importing energy, the frequency of it drops below the nominal value. In second 1, both Micro Grids are in an island state. According to the state before going into an island state, in which MG1 was importing and MG2 was exporting energy,, after going to a new state, (islanded mode), MG1 production levels set frequency to provide for themselves and 1.8 MW to reduce their production levels and MG2 increases to 2.3 MW.

As in the Figure 5 is shown, when the Micro Grids at second 1 go to an island state, due to the reduction in the amount of required reactive capacity in the network, the voltage is increased. Therefore, the unit which controls voltage for increasing the capacity of the reactive, issues an order for the reduction of voltage. After adjusting for this transient condition, the voltage returns to its stable value and is set.

Case study 2 : in this case the Microgrid issues energy to the main grid until 0.5th second and afterwards, the loads L3 and L5 are disconnected simultaneously. MG1 is also in this island state. As it is shown in figure 6, Since the power required in MG1 is 1.8 MW, DG1 reduces its production level to this amount. In other part of system, DG2 and L4 are responsible for the 0.8 MW by DG2 and 0.7 MW by the main supply network. At second 1, L3 and L5 are also disconnected mode. DG1 and DG2 at this time to meet the demands, they change their production levels. Production levels for DG1 and DG2 reach to 1.7 MW and 1.6 MW respectively.

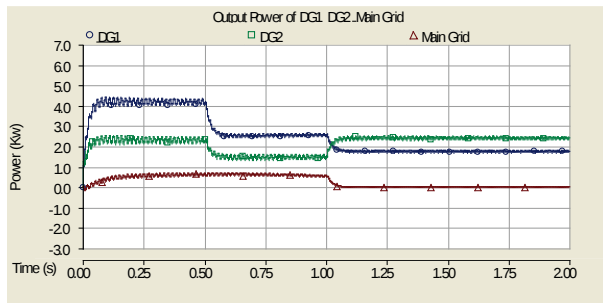


Figure 4 : power generation in case study 1

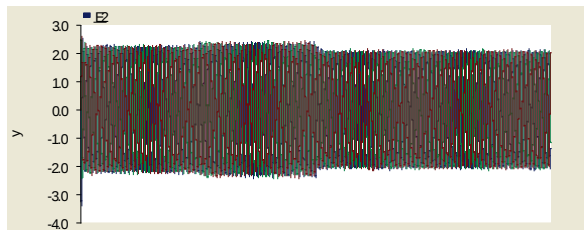


Figure 5 : voltage variation in case study 1

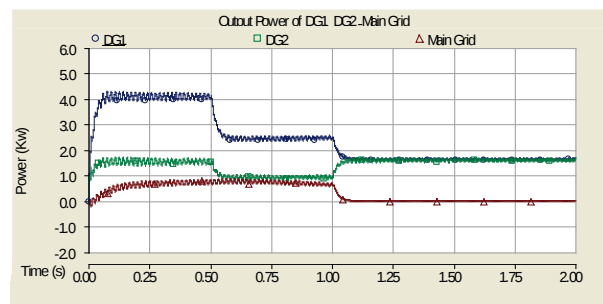


Figure 6 : power generation in case study 2

These results show that the droop method could fix the main grid generation, thus to supply the load changes, it orders the Microgrid to produce the amount of power that is required due to islanding mode and load variations.

V. CONCLUSION

In this paper the effect of drop method in voltage and frequency control has been discussed. As shown in Section III .in result of disconnection between network and microgrid, the active power generation level increases, if microgrid received energy before disconnection. If microgrid sends power to the network then active power generation level will reduce.

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