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Microgrid Control In Islanding And Connected Mode

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Abstract—**In common practice a Microgrid can operate while connected to a MV network. When a preplanned or unplanned event like holding or occurring fault occurs in the MV network it is possible to cause the islanding state in the Microgrid. In this Paper the operation of the MV network in the islanding mode and how to control the Microgrid by using the controlling structure are investigated. In this paper the conventional droop method has been described and a new controlling methods for controlling the Microgrid are also proposed which in the first method the AC power theory for the controlling of the Microgrid. For comparing these two methods with the controlling method which is proposed in reference [14], these three methods have been simulated with PSCAD/EMTDC software.**

Keywords-Connected mode, DG, Droop method, Islanding mode, Microgrid, SPWM, Hysteresis Switching,Fuell Cell, Micro turbin.

I. INTRODUCTION

Micro-scale distributed generators (DGs), or micro sources, are being considered increasingly to provide electricity for the expanding energy demands in the network. In the last decades, the interest on distributed generation has been increasing, essentially due to technical developments on generation systems that meet environmental and energy policy concerns. The interconnection of distributed generation has been predominately confined to MV and HV levels, but the development of micro generation technology, the decline of its costs and the public incentives to distributed generation lead to an increased installation of micro generation in LV networks. [1] This legislation is intended to encourage the investment on micro generation, namely by subsidizing the remuneration of the electricity produced by these generators and partially funding the investment. The simple integration of micro generation in LV networks, similar to the one that is being used to integrate distributed generation on MV networks [1], may result in technical problems on LV and MV networks (excessive voltages, increase in fault levels, voltage unbalance, overloading, etc.), namely when the penetration of micro generation becomes high [2][3]. The new concept of Microgrid emerged as a way to ease this integration, but in fact corresponds to an entirely new way of understanding LV networks, with potential benefits far beyond the easy integration of micro generation [5]- [8].

A Microgrid can operate in grid-connected mode or islanded mode and hence increase the reliability of energy supplies by disconnecting from the grid in the case of network faults.

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 Microgrid should also recover the frequency and voltage in islanding mode rapidly. When Microgrid 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 Microgrid frequency will be decreased. On the other hand, if Microgrid was exporting energy and afterwards it has gone to islanding mode, it should decrease the generation level so the grid frequency will rise.

Now a considerable research has been undertaken on the control strategy of the Microgrid. Flexible and fast controls of real and reactive power are important requirements during transient and steady-state operation of a Microgrid system in both grid-connected and islanded modes [4].

Operation during network disturbances while maintaining power quality in the islanded mode of operation, a more sophisticated control strategy for Microgrid needs to be developed. In order to warranty both quality of supply and ensuring power management supervising critical and non-critical loads. A Microgrid when subjected to disturbances can experience angle instability and poor voltage quality due to the presence of DG units with slow response rotating machines and DG units 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 Microgrid needs to be developed.

The work described in this paper regards the evaluation, through numerical simulation, of the inverter-fed MG behavior under islanded operation and connected operation for different load conditions and using different control strategies with limiter for power. This paper is organized as follows, in section II shows droop controlling method, In Section III, was described proposing the suggested controlling methods. Section IV shows case study system. In Section V the Microgrid simulation and results was shown. In Section VI, the conclusions of this paper are given.

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II. Droop Controlling Method

In the Microgrid, the DG supply can be connected to a network by 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.

The fundamental frequency selective filter is a first tool to handle some of the higher harmonics of the noise, but the calculated values of active and reactive power, as well as the voltage magnitude still suffered from oscillations determined by random spikes in the measured quantities.

The complete control of the micro source is shown in Fig. 1.

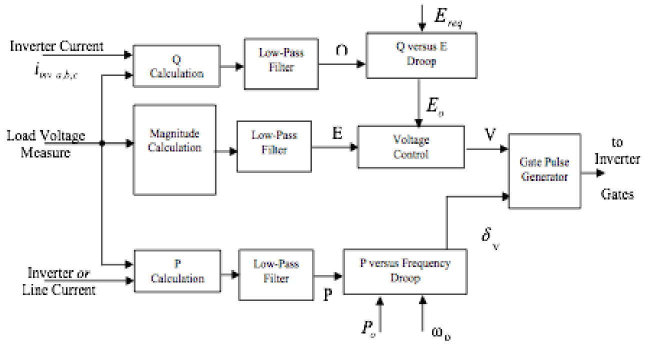


Figure 1. Micro source Control

In this method frequency changes are affected by changing in active power. Fig. 2 shows the Droop of power versus frequency changes.

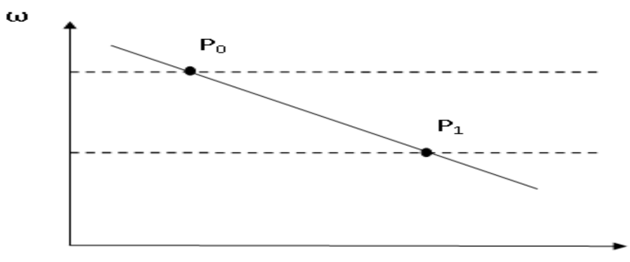


Figure 2. Power versus Frequency

According to Fig. 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 p0 to p1.

This state will happen to a Microgrid whenever a fault occurs and it changes a Microgrid status into islanding state. The Microgrid reconnects to principle network meanwhile the frequency increases then controllers make the DG to decrease the production level. Equation 1 represents this controlling structure:

$$\omega = \omega^{*} - m.(P - P^{*}) \tag{1}$$

Reactive power control versus voltage

This control mode, changes in voltage have an interaction with changes in reactive power. According to Fig. 3, this controlling mode is representing by Equation 2:

$$E = E^{*} - n.(Q - Q^{*}) \tag{2}$$

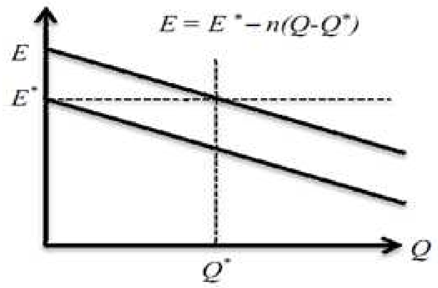


Figure 3. Voltage versus Reactive Power

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

III. Proposing the Suggested Controlling Methods

In this chapter first of all the proposed controlling method for controlling the Microgrid will be introduced. Then by implementing these methods on a Microgrid by using the PSCAD/EMTDC software, the results obtained by using the proposed method will be compared with the SOFT controlling method.

Applying the instantaneous active power theory for controlling the Microgrid:

In this method AC powers are used for supplying the essential amount of power of load. According to this theory AC powers can be calculated by using the voltage and current amount. In equation 3 the voltage and current are in α and β coordinate which result in the amounts of p and q.

$$\begin{bmatrix} p(t) \\ q(t) \end{bmatrix} = \begin{bmatrix} v_{\alpha}(t) & v_{\beta}(t) \\ -v_{\beta}(t) & v_{\alpha}(t) \end{bmatrix} \begin{bmatrix} i_{\alpha}(t) \\ i_{\beta}(t) \end{bmatrix} \tag{3}$$

This method compensates the reactive power by active filter. So that if by using equation 4 the current harmonic values which are effective in generating the reactive power could be obtained, it would be well possible to compensate the reactive power and to eliminate harmonically current by inserting the aforementioned obtained current to system by an inverter.

$$\begin{bmatrix} i_{\alpha}(t) \\ i_{\beta}(t) \end{bmatrix} = \begin{bmatrix} v_{\alpha}(t) & v_{\beta}(t) \\ -v_{\beta}(t) & v_{\alpha}(t) \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ q(t) \end{bmatrix} \tag{4}$$

This theory can also be used for controlling the level of generating in the Microgrid. If the values of active and reactive power which should be generated by DG are set in the Equation 5, the DC source of the inverter is compelled to supply these values of p and q through inverter.

$$\begin{bmatrix} i_\alpha(t) \\ i_\beta(t) \end{bmatrix} = \begin{bmatrix} v_\alpha(t) & v_\beta(t) \\ -v_\beta(t) & v_\alpha(t) \end{bmatrix}^{-1} \begin{bmatrix} p(t) \\ q(t) \end{bmatrix} \quad (5)$$

Now we consider the two situation of islanding state and connected in the DG. In each situation if the source power values of for generating and distributing to the network are put in Equation 5, the inverter output could be changed according to system demand. In this situation with the change of the demand of the load (change of state from connected to islanding state or vice versa), the power value and consequently the source current value in Equation 5 will change and thus for doing this change in the inverter output, the level of DG generating connected to it under the appropriate controlling method, would be changed.

After that for switching the inverter the hysteresis controlling method could be used which has advantages like good stability, simple and economically designing and implementing and quick dynamical response.

IV. CASE STUDY

A. *The structure of the Microgrid*

In the Fig. 5 the single line diagram of the tested Microgrid is shown. The Microgrid is consisted of radial distribution system which is connected to a 1/1 KV system. The distribution system is consisted of feeder 5, 2 DG unit and 3 load of 100 KVA which are modeled as RLC. The DG units are consisted of one Fuel cell unit and one micro turbine unit which are connected to the system through a DC-DC converter and an inverter.

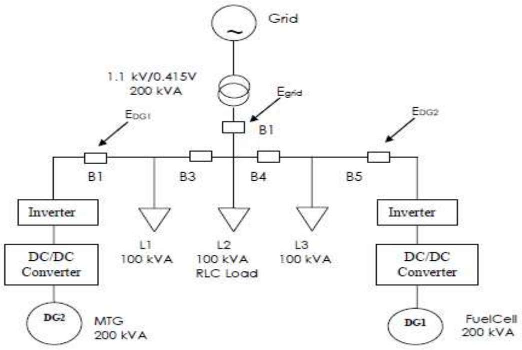


Figure 5. Case Stusy

B. *The controlling method used in reference [14]*

In this method SPWM is used for inverter's switching. The switching signals are obtained by using two control PI loops which are used for controlling the voltage and frequency values. The phase voltages and currents are moved to d-q space. Id-ref is the reference current value of the d axis and

Iq-ref is the reference current value of the q axis.

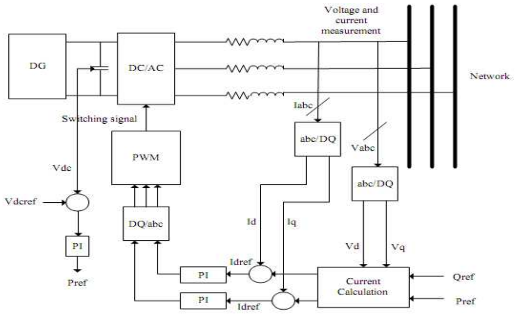


Figure 6. Reference Method

V. SIMULATION AND ANALYSIS

In this section the operation of DG sources in Microgrid by using proposed controlling methods in this Paper will be investigated and the obtained results are compared to obtained results in reference [14]. Here three tests have been carried out on the Microgrid which is respectively as follows:

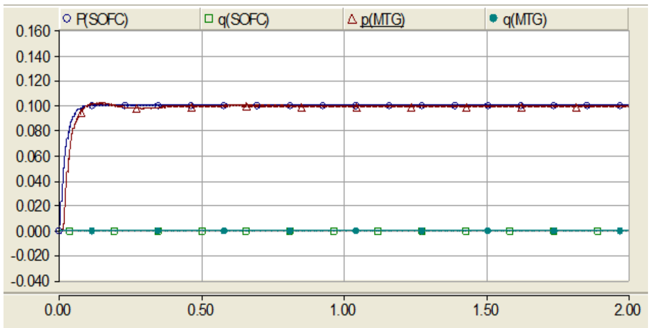
1) The distinct operation of each DG unit : in which the DG1 and DG2 are alone responsible for supplying the load of L1 and L3 in the steady state.

2) The connected state : in this situation some of the required power in Microgridis supplied by the major network.

3) Islanding Mode: In this situation the Microgridis separated from major network and goes to islanding mode.

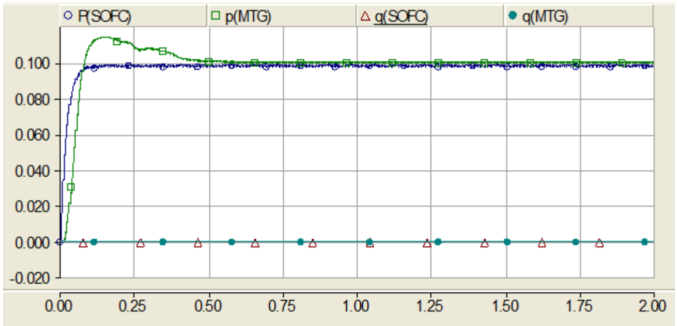
A. *The results from the distinct operation of each DG unit*

In this situation each DG unit is responsible for supplying a defined load of 100 KVA. The results of this simulation are shown in Figs 7-9. As it could be seen in each of these figures, the micro turbine has a transient state in the first moment which is because of absorbing the reactive power. The voltage profile of each unit is shown in the B part of each figure which is showing the similar response of both units for approaching the desired voltage level. As it could be seen applying the AC power theory for controlling the Microgrid have the best response and had the ability to stabilize the transient state of the micro turbine quickly. Also it can be deduced from the diagrams that using the PID controller and the AC power theory control method has the better voltage profile compared to droop method.



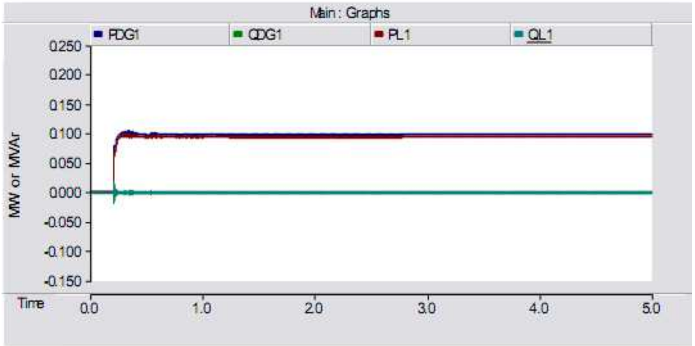
a) Active & Reactive power for DG1 & DG2

Figure 7. distinct operation of each DG unit with instantaneous active power theory Controlling Method



a) Active & Reactive power for DG1 & DG2

Figure 8. distinct operation of each DG unit with Droop Controlling Method



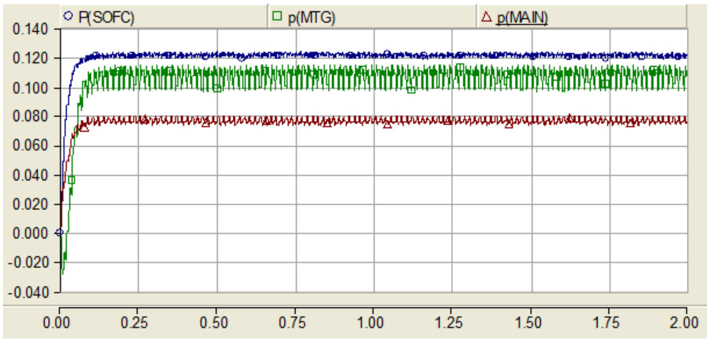
a) Active & Reactive power for SOFC

b) Active & Reactive power for Micro turbine

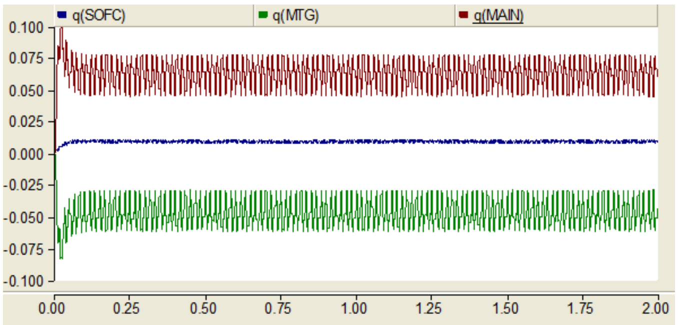
Figure 9. distinct operation of each DG unit with Controlling Method used in reference [13]

B. *The results from the operation of each DG unit while connecting to the major network*

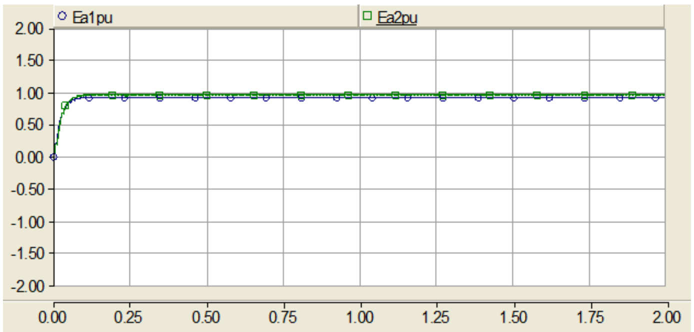
In this situation Microgridis connected to the major network and is exchanging energy with it. In this situation DG1 and DG2 are responsible for supplying the required power for L1, L2 and L3 loads which 73% of the required power in the connected situation is supplied by the generating units of the Microgridand 23% of it is supplied by the major network. And the controller could keep stabling the voltage within 98% of the nominal voltage.



a) Active power for DG1 & DG2

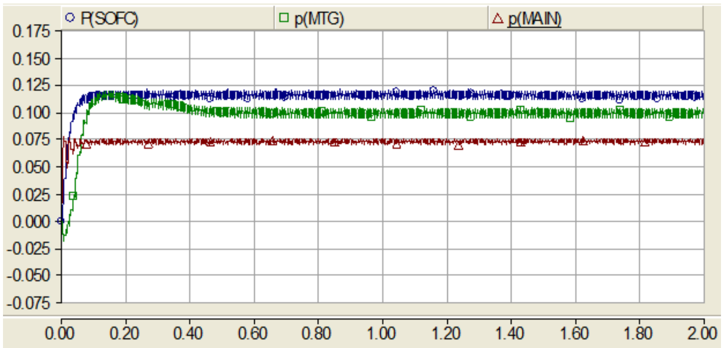


b) Reactive power for DG1 & DG2

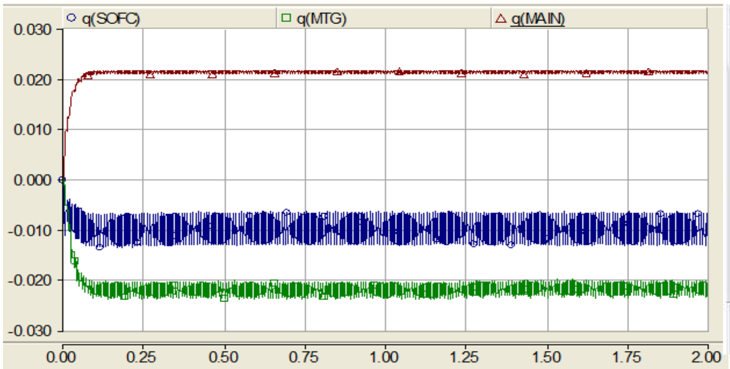


c) Voltage Profile of Unit 1 & 2

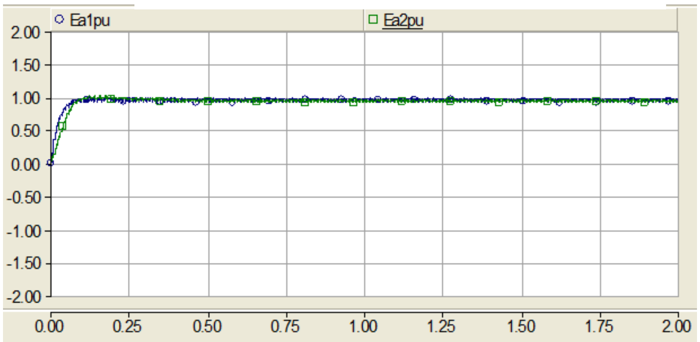
Figure 10. Performance of DG units in connected mode with instantaneous active power theory Controlling Method



a) Active power for DG1 & DG2

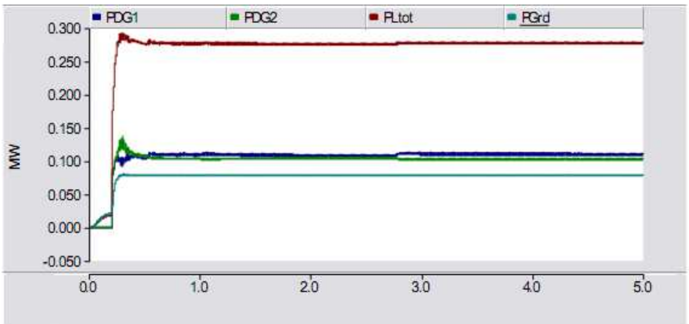


b) Reactive power for DG1 & DG2

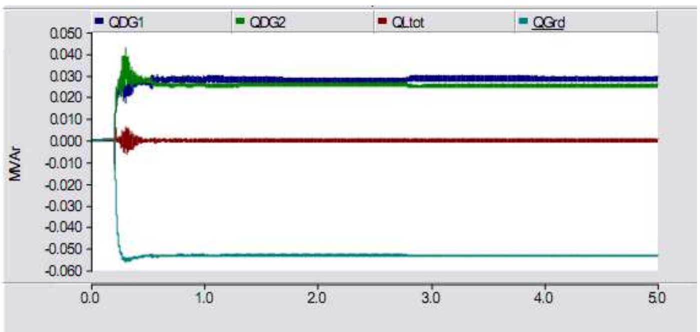


c) Voltage Profile of Unit 1 & 2

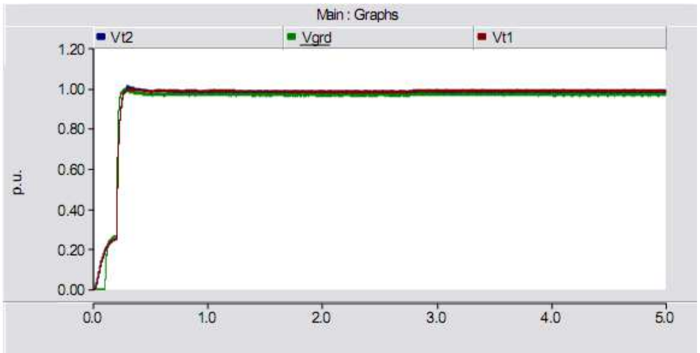
Figure 11. Performance of DG units in connected mode with Droop Controlling Method



a) Active power for DG1 & DG2



b) Reactive power for DG1 & DG2

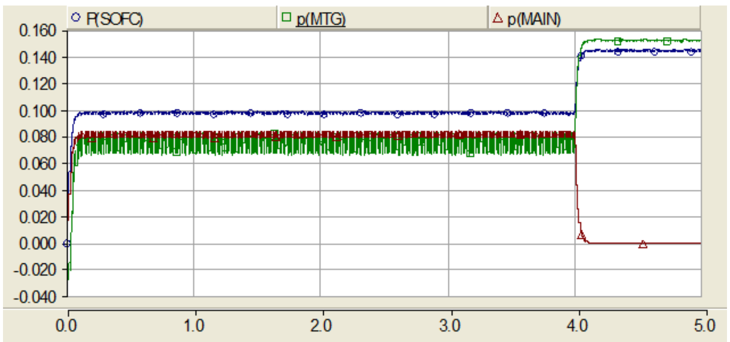


c) Voltage Profile Of Unit 1 & 2

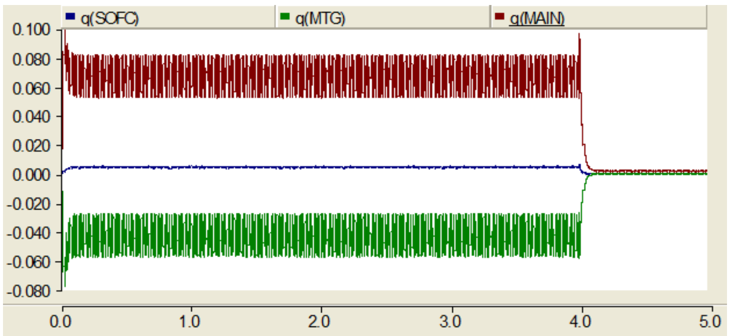
Figure 12. Performance of DG units in connected mode with Controlling Method used in reference [14]

D. *Investigating the operation of Microgrid in the islanding mode*

In the fourth second the Microgrid in the state of B2 will cut and the Microgrid goes to islanding mode. In this situation the controllers command increase generation to the generating units in Microgrid to supply the demand. The diagram of generated power changes are shown in Figs. 13-15. In the islanding mode, the reactive power of DG units diminishes because the reactive power produced by the network is cut.

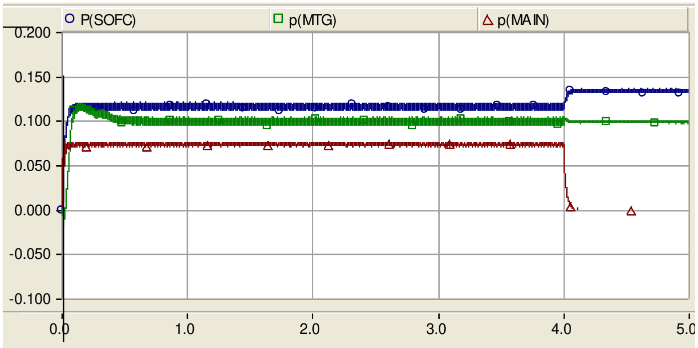


a) Active power for DG1 & DG2

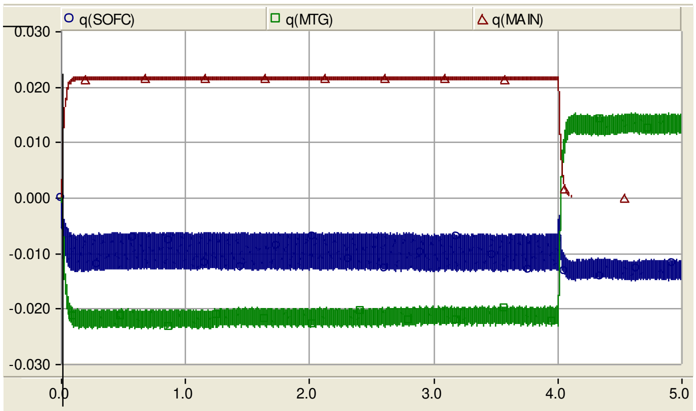


b) Reactive power for DG1 & DG2

Figure 13. Performance of DG units in islanding mode with instantaneous active power theory Controlling Method

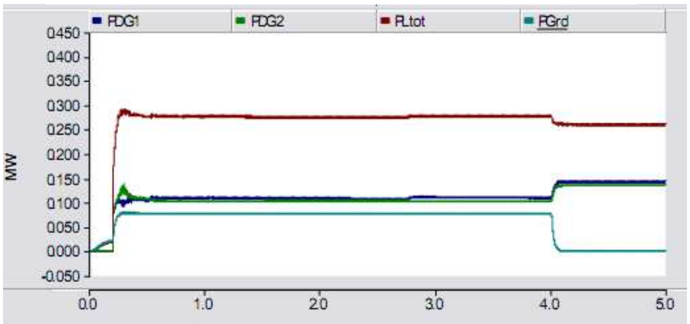


a) Active power for DG1 & DG2

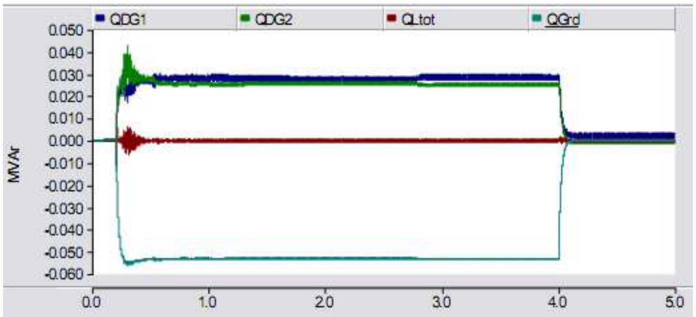


b) Reactive power for DG1 & DG2

Figure 14. Performance of DG units in islanding mode with Droop Controlling Method



a) Active power for DG1 & DG2



b) Reactive power for DG1 & DG2

Figure 15. Performance of DG units in islanding mode with Controlling Method used in reference [14]

VI. CONCLUSIONS

In this paper we have investigate and simulated some approaches for controlling Microgrid as follows:

1) A full description of the Droop controlling method and using it for controlling the voltage and frequency of the inverter as a bridge between DG and Microgrid.
2) Applying the AC power theory as a new approach to control the active and reactive power of Microgrid.
3) Simulating the Droop controlling method and two new controlling methods and comparing them with each other and observing the superiority of these two controlling methods in their speed to responding to the changes in the load and reducing the time constant of the system and improving the dynamical operation of the system compared to Droop controlling method.

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