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Active Power Sharing and Self Frequency Recovery in an Islanded Microgrid in DG System

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ABSTRACT: This paper mainly presented to implement active power sharing and self frequency recovery in Distribution Generation (DG) an islanded microgrid using PI controller for Distribution Generation system.The active power and frequency of Droop Control is used to implement the active power sharing and the frequency deviation is recovered by the DG itself via self frequency recovery control without requiring secondary frequency control.Because, the electrical distance between an each microgrid and a point where the load demand changes differs among DG units, the frequency deviations may differ between DG units. These differences are fed into the integrators and may result in errors in active power sharing. To overcome this problem and share active power more accurately, a proper control method is developed for active power sharing, which considers the droop coefficients of each of the DG units. Simulation results show that the proposed control method is effective.

KEYWORDS: Active power sharing, distributed generation , islanded microgrid, self-frequency recovery control, droop coefficients.

I. INTRODUCTION

Due to exceed the rated value of supply has been gradually saturated to the limits on account of environmental, social and geographical problems, the electrical energy demand has been continuously grown recently .To overcome the electrical energy demand locally using microgrids and distributed generation (DG) units[1].

The microgrid concept was first introduced in [2].The microgrid is used as the solution for power demand and supply balancing problems[3].Normally microgrid contains low or medium voltage distribution network containing loads and distributed resources. Microgrids contain a central controller, local controllers (LCs) [4], a static switch, loads, and various types of energy sources. Micro-grids can operate in two different modes: grid-connected mode and islanded mode. In grid-connected mode, a microgrid is directly connected to the main grid, which usually has large system inertia; hence, the microgrid frequency is almost same to the nominal value [5]. Thus, DG units in a microgrid typically inject the accurate output power, and the electrical power mismatch between supply and demand is balanced by the main grid. However, in an islanded mode, the microgrid must supply its own demand and maintain its frequency using DG units.

In [6], active power–frequency (P–f) droop control was developed for active power sharing by emulating conventional power systems composed of synchronous generators. In [7], in contrast to conventional droop control, a tunable droop controller with two degrees of freedom was proposed, considering an adaptive transient droop function.

A method for determining the droop coefficient based on the generation cost of each DG unit was proposed in [8]. In [9], a constant frequency control method was used rather than frequency droop, and the state of charge of a battery storage system was used to monitor changes in the system load.

The propose system using a control and implements accurate active power sharing and self- frequency recovery. In this method, DG units share the changes in load with a predetermined ratio and are able tore-store their output frequency to the nominal value. However, the self-frequency recovery action may arise to errors in power sharing due to variations in the impedance among DG units. Therefore, following frequency recovery, the active power sharing among DG units is readjusted to the predetermined ratio using a compensation control scheme. The control

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method was modeled and tested using MATLAB/Simulink, and the simulation results demonstrate the effectiveness of the approach.

II.MICROGRID CONFIGURATION

The microgrid configuration shown in the fig 1 and investigated here, which is based on that described in [5],with some slight modifications. Here, the microgrid consists of a static switch, a central controller, LCs, loads, and DGs. The static switch is located at the point of common coupling. By opening the static switch, the microgrid becomes isolated from the main grid. The central controller executes overall control of the microgrid, including protection via a communications system. The main objectives of the central controller is to maintain the system frequency and voltage at the specified level, as well as to operate the microgrid economically; however, the central controller was used only for compensation control , assuming that the dispatched output power for each DG unit has already been determined by the central controller. The proposed compensation control method is used for a short duration to reduce the dependence of the DG control system on the communications infrastructure; this is important due to the potential for failure of the communications network, which decreases system reliability. The main function of the LC is to control the power and frequency, as well as the voltage of DGs in response to a disturbance or change in load.

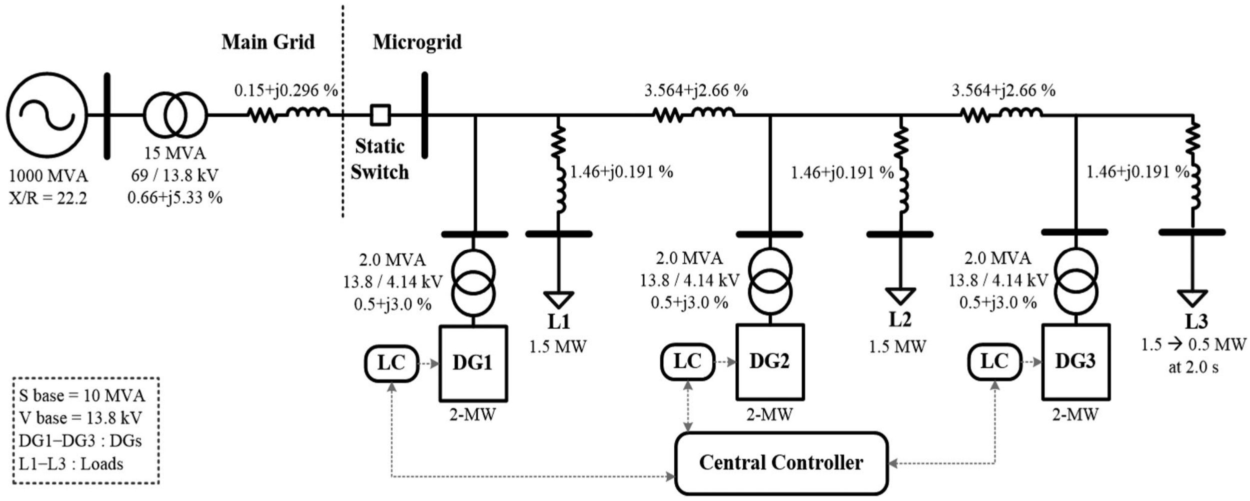

Fig 1:Microgrid configuration

In terms of active power control, DGs can be categorized as either dispatchable or non-dispatchable . Dispatchable DGs, such as micro turbines and fuel cells, are capable of producing controlled active power on demand, and are assigned the task of regulating the voltage and frequency during islanded operation. In contrast, non-dispatchable DGs, such as photovoltaic cells and wind turbines, normally cannot be dispatched, because their output power depends mainly on the weather, rather than the load. Here, three 2-MW DG units with voltage ratings of 4.14 kV were included in the micro grid, all are dispatchable. All the inverters included in the simulation were modeled as IGBT switches. The model to reflect dynamic characteristics of switching operation. *LC* filters were also included at the terminal of each inverter to filter harmonics out. The inductance and the capacitance of each *LC* filter are 5mH and 50 μF, respectively. The nominal voltage of the microgrid was 13.8 kV, and the frequency was 60 Hz.

III. PROPOSED DG CONTROL METHOD

The proposed control scheme is shown in Fig. 2, where the subscript i refers to the index of the DG; $P_{i,dis}$ and $Q_{i,dis}$ are the dispatched values of the active and there active power, respectively, from the CC; Pi and Qi are the active and the reactive output powers of the DG; fnom and Vnom are the nominal frequency and the voltage, respectively; $f_{i,ref}$ and $V_{i,ref}$ are the reference frequency and the voltage, respectively.f_i is the output frequency of the DG; $V_{abc,ref}$ is the

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three-phase voltage reference input to the voltage source a and b are the nodes of the switch; m_i and n_i are the droop coefficients of frequency droop and voltage droop, respectively; and k_f and k_c are the integral gains for the self-frequency recovery control and the compensation control, respectively. The coefficient c_i and the terms $\Delta P_{dis,tot}$ and $\Delta P_{i,dis}$ are described as compensation control.

Note that the proposed control scheme shown in Fig.2 controls the active power by adjusting the output frequency. This means that the proposed method cannot be applied to low voltage networks, because with low voltage networks the resistance is much higher than the reactance, and hence the voltage angle is more strongly related to the reactive power than the active power. For this reason, the proposed control method is mainly intended for medium-voltage microgrids rather than low voltage microgrids.

This paper focuses on active power sharing and frequency control. The control method for the reactive power sharing uses conventional reactive power–voltage magnitude (Q–V) droop control. For this reason, the reference of the voltage magnitude Vi,ref is expressed as follows:

$$V_{i,ref} = V_{nom} + n_i(Q_{i,dis} - Q_i) \qquad (1)$$

The reference voltage magnitude is determined from the deviation of the output reactive power from its dispatched value (which is usually zero with a unity power factor); therefore, the reference voltage magnitude is proportional to the Q–V droop coefficient n_i. The details of the reactive power-sharing scheme are not discussed here.

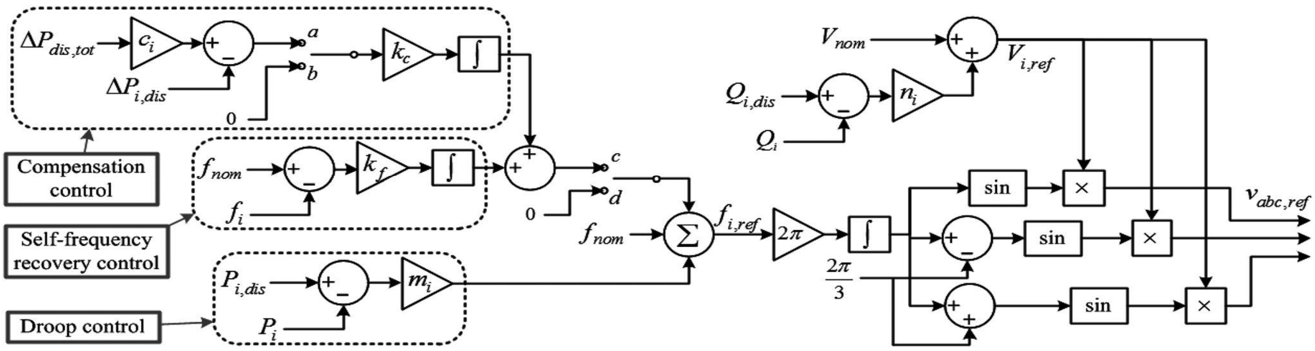

Fig 2:Proposed control scheme for DG

A.Droop Control

For active power sharing, the conventional P–f droop control was applied. The output frequency f_i can be expressed as

$$f_i = f_{nom} + m_i\,(P_{i,dis} - P_i) \qquad (2)$$

The reference output frequency was determined from the deviation of the active power from the dispatched value (determined by the CC), which is proportional to the P–f droop coefficient mi. As shown in Fig. 2, without self-frequency recovery control or compensation control, the frequency deviation from the nominal value can be determined using droop control only. With droop control, the exact load sharing among DG units is proportional to the droop coefficients. This process can be implemented by exchanging the same output frequency of each DG unit in the steady state however, because the frequency will inevitably deviate from the nominal value and must be restored according to the grid code requirements, an additional control scheme for the frequency restoration is required.

B. Self-Frequency Recovery Control

The principal objective of self-frequency recovery control is to distribute the measures required to achieve frequency recovery among the DG units that participate in active power sharing using P–f droop control according to a predetermined ratio. The frequency restoration of the ith DG unit due to self-frequency recovery control can be expressed as

$$\Delta f_{i,res} = k_f \int (f_{nom} - f_i)dt \qquad (3)$$

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where k_f is all the same value for every DG unit, which means that the burden of frequency restoration is shared equally among the DGs.

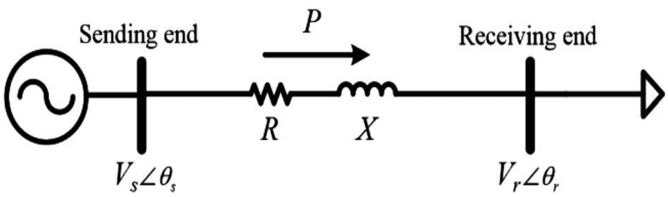

Fig 3: Single-line diagram of a simplified islanded microgrid.

In fig 3, P is the active power from the sending end to the receiving end; R and X are the resistance and reactance of the network impedance respectively; Vs and Vr are the voltage magnitudes of the sending end and the receiving end, respectively; and θs and θr are the voltage angle of the sending end and the receiving end, respectively. The active power can be expressed as follows

$$P = \frac{RV_rV_s\cos(\theta_s - \theta_r) + V_rV_s\sin(\theta_s - \theta_r) - RV_r^2}{R^2 + X^2} \quad (4)$$

In medium or high voltage networks, the resistance is assumed to be much smaller than the reactance ($R \leq X$), and the voltage angle difference is assumed to be small θs−θr = δ ≈0, such that sinδ ≈ δ and cosδ ≈ 1. The active power flow across the impedance can therefore be simplified to

$$P \approx \frac{V_rV_s(\theta_s - \theta_r)}{X} \quad (5)$$

The output frequency of the ith DG unit can be expressed as a function of the output voltage angle θ_i as follows:

$$\int 2\pi f_i dt = \theta_i \quad (6)$$

Consequently, from (3) and (6), the difference in voltage angle deviations among DG units leads to different frequency restorations Δf_{res}. These differences lead to unequal sharing of the output active power among the DG units, and as a result, the ratio of active power sharing among DG units no longer varies in proportion to the P–f droop coefficients of the DG units.

Note that the influence of voltage magnitude on the active power is not considered since medium-voltage network is studied in this paper. The influence of voltage magnitude on the active power is significant at low-voltage networks

C. Compensation Control

To offset the errors in active power sharing caused by self- frequency recovery control, a compensation control scheme was developed, as shown in Fig. 2. The main purpose of the compensation control is not to reduce transient frequency difference but to reduce the active power sharing error. The output active power deviation of the ith DG is given by

$$\Delta P_{i,dis} = P_i - P_{i,dis.} \quad (7)$$

The aggregate of all DG units can be found by summing the contributions from each unit;

$$\Delta P_{dis,\,tot} = \sum_{i=1}^{N} \Delta P_{i,\,dis.} \quad (8)$$

where N is the number of DG units participating in active power sharing. Because the objective of compensation control is to share the active power according to the ratio of the droop co- efficients (i.e., m1,...,mN), $\Delta P_{dis,tot}$ should be distributed among the DG units considering the droop coefficients. Hence, the parameter c_i was determined as follows:

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$$c_i = \frac{\frac{1}{m_i}}{\sum_{j=1}^{N} (\frac{1}{m_j})} \quad (9)$$

By multiplying ci by $\Delta P_{dis,tot,}$ we obtain the contribution of the ith DG unit to frequency recovery. Consequently, the compensation recovery control can be expressed as

$$\Delta f_{i,com} = k_c \int \left(c_i \Delta P_{dis,tot} - \Delta P_{i,dis_i} \right) dt \quad (10)$$

In the normal operation, the switch is connected to node c. If the communication failure happens, the switch is connected to node d and the controller operates as P–f droop controller. By combining these three control schemes, the reference out- put frequency of the ith DG unit can be expressed as

$$f_{i,ref} = f_{nom} + m_i (P_{i,dis} - P_i) + k_f \int (f_{nom} - f_i) dt + k_c \int (c_i \Delta P_{dis,tot} - \Delta P_{i,dis}) dt \quad (11)$$

IV. SIMULATION RESULTS AND DISCUSSION

The simulation of the proposed model was carried out in Power Simulator (PSIM). The conventional load–frequency control method is applied to the DG units to compare the load–frequency control method to the proposed control method. Fig. 4 shows the simulation results for grid voltage and current.Fig 4(a),4(b),4(c),4(d) shows the simulation results for islanded micro grid.

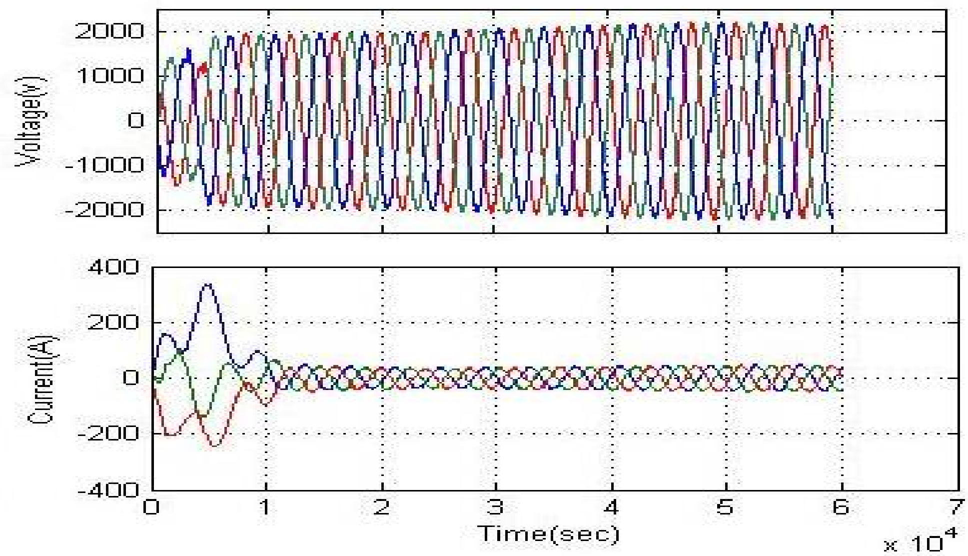

Fig 4.Grid voltage and current

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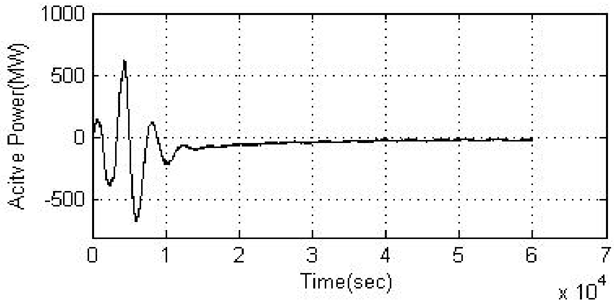

Fig 4(a) Microgrid Active power

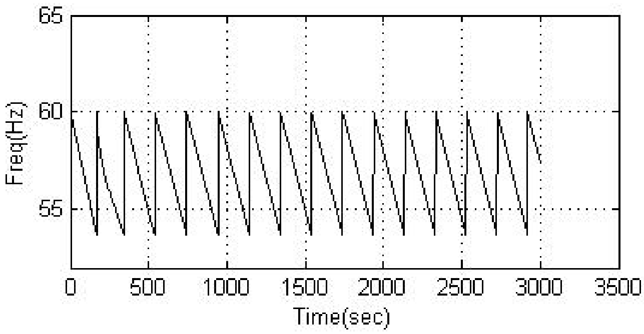

Fig 4(b) Microgrid Frequency

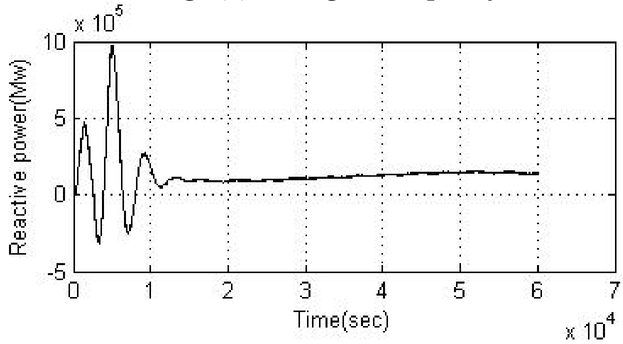

Fig 4(c) Microgrid Reactive Power

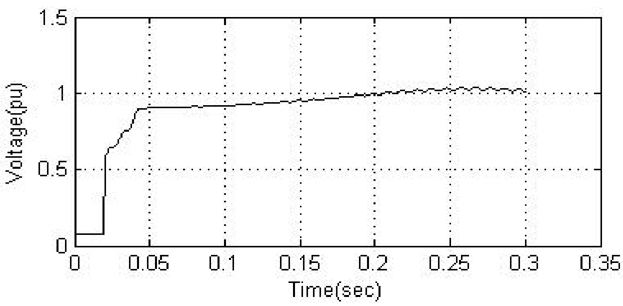

Fig 4(d)Microgrid Voltage

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V. CONCLUSION AND FUTURE WORK

In this paper has implemented accurate active power sharing and self-frequency recovery in an islanded microgrid. Islanded microgrids have low inertia, and so they are vulnerable to the frequency disturbances, and frequency recovery is important. Conventionally, frequency restoration is implemented via secondary frequency control units, where the active power sharing units and the frequency control units are controlled separately. Specific unit frequency are required to account for changes in load, which may cause them to reach their output limit more quickly and hence to increase generation cost exponentially. Moreover, if the frequency deviation is too great, this may lead to a loss of capability of the frequency control units. Hence, it is desirable to share the frequency deviation among all DG units according to a predetermined ratio.

The results shows the effectiveness of controller to control the frequency restored almost immediately to the frequency deviation using self-frequency control, and the active power has shared according to droop control and compensation control. The effectiveness of the proposed method was verified. However, further work is required, particularly in how to determine the ratio of the active power sharing. Although sharing the frequency restoration among all DG units may be preferable to using only some specific DG units for this from the perspective of generation cost and the remaining power of frequency control units, the optimal ratio of the active power sharing among DG units should be determined based on a specific. Another area for the future work is the communications delay. Although a communications system is required only for a short duration , the communications delay may affect the control stability.

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