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Accurate Load Demand Sharing Strategy in a Grid Connected Network

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Abstract – **For the operation of autonomous microgrids, an important task is to share the load demand using multiple distributed generation (DG) units. In order to realize satisfied power sharing without the communication between DG units, the voltage droop control and its different variations have been reported in the literature. However, in a low-voltage microgrid, due to the effects of non- trivial feeder impedance, the conventional droop control is subject to the real and reactive power coupling and steady-state reactive power sharing errors. Furthermore, complex microgrid configurations (looped or mesh networks) often make the reactive power sharing more challenging. To improve the reactive power sharing accuracy, this paper proposes an enhanced control strategy that estimates the reactive power control error through injecting small real power disturbances, which is activated by the low-bandwidth synchronization signals from the central controller. At the same time, a slow integration term for reactive power sharing error elimination is added to the conventional reactive power droop control. The proposed compensation method achieves accurate reactive power sharing at the steady state, just like the performance of real power sharing through frequency droop control. Simulation and experimental results validate the feasibility of the proposed method.**

Keywords: **Distributed generation (DG), droop control, low-bandwidth communication, microgrid, reactive power compensation, real and reactive power sharing.at location in the distribution system**

I. INTRODUCTION

The application of distributed power generation has been increasing rapidly in the past decades. Compared to the conventional centralized power generation, distributed genera- tion (DG) units deliver clean and renewable power close to the customer's end [1]. Therefore, it can alleviate the stress of many conventional transmission and distribution infrastructures. As most of the DG units are interfaced to the grid using power electronic converters, they have the opportunity to realize enhanced power generation through a flexible digital control of the power converters. On the other hand, high penetration of power electronics- based DG units also introduces a few issues, such as system resonance, protection interference, etc. In order to overcome these problems the microgrid concept has been proposed, which is realized through the control of multiple DG units. Compared to a single DG unit, the microgrid can achieve superior power management within its distribution networks. In addition, the islanding operation of microgrid offers high reliability power supply to the critical loads. Therefore, microgrid is considered to pave the way to the future smart grid [1]. In an islanded microgrid, the loads must be properly shared by multiple DG units. Conventionally, the frequency and volt- age magnitude droop control is adopted, which aims to achieve microgrid power sharing in a decentralized manner [6], [11], [15]–[18], [20], [21]. However, the droop control governed mi- crogrid is prone to have some power control stability problems when the DG feeders are mainly resistive [2]. It can also be seen that the real power sharing at the steady state is always accurate while the reactive power sharing is sensitive to the impacts of mismatched feeder impedance [3]–[5], [7]. More- over, the existence of local loads and the networked microgrid configurations often further aggravate reactive power sharing problems [7], [18]. To solve the power control issues,a few improved methods have been proposed.In[1]and[2],the virtual frequency-voltage frame and virtual real and reactive power concept were developed,which improve the stability of the microgrid system. How- ever, these methods cannot suppress the reactive power sharing errors at the same time. Additionally, when small synchronous generators are incorporated into the microgrid, proper power sharing between inverter-based DG units and electric machine- based DG units will be more challenging in these methods. In [3], both the reactive power and the harmonic power sharing errors were reduced with the noncharacteristic harmonic current injection. Although the power sharing problem was addressed, the corresponding steady-state voltage distortions degrade the microgrid power quality. In [4], a "Q–V dot droop" method was presented. It can be observed from [4] that the reactive power sharing improvement is not obvious when local loads are included. In [18], the reactive power sharing error reduction is realized using additional PCC voltage measurement. In [5]–[8], the predominant virtual output inductor is placed at the DG out- put terminal, which is mainly focused on preventing the power control instability. In addition, within the virtual impedance control frame, the reactive power sharing errors can be further reduced through an interesting model-based droop slope modification scheme.

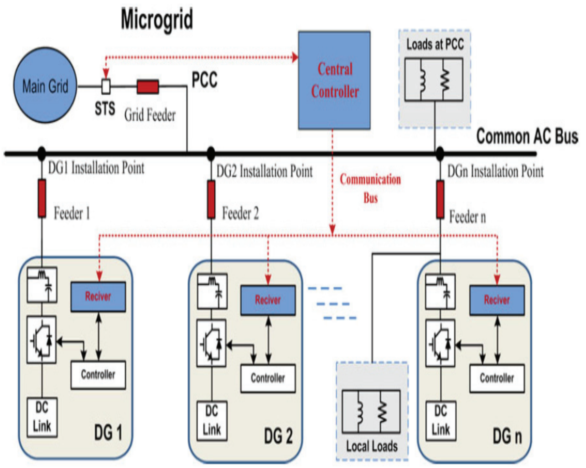


Fig.1 Illustration of microgrid configuration

II. ANALYSIS OF THE CONVENTIONAL DROOP CONTROL METHOD

A. Operation of Microgrid

Fig. 1 illustrates the configuration of a microgrid. As shown, the microgrid is composed of a number of DG units and loads. Each DG unit is interfaced to the microgrid with an inverter, and the inverters are connected to the common ac bus through their respective feeders. Considering that the focus of this paper is the fundamental real and reactive power control, nonlinear loads are not considered in the microgrid. The microgrid and main grid status are monitored by the secondary central con- troller [14]. According to the operation requirements, the micro- grid can be connected (grid-connected mode) or disconnected(islanding mode) from the main grid by controlling the static transfer switch (STS) at the point of common coupling (PCC). During the grid-connected operation, real and reactive power references are normally assigned by the central controller and the conventional droop control method can be used for power tracking. However, to eliminate the steady-state reactive power tracking errors, the PI regulation for the voltage magnitude con- trol was developed in [7] and [11]. Therefore, power sharing is not a real concern during the grid-connected operation. When the microgrid is switched to islanding operation, the total load demand of the microgrid must be properly shared by these DG units. During the islanding operation, DG units as illustrated in Fig. 1 can operate using the conventional real power–frequency droop control and reactive power–voltage magnitude droop control as

$$\omega = \omega 0 - DP \cdot P (1)$$

$$E = E0 - DQ \cdot Q \ (2)$$

where ω0 and E0 are the nominal values of DG angular fre- quency and DG voltage magnitude, P and Q are the measured real and reactive powers after the first-order low-pass filtering (LPF), DP and DQ are the real and reactive power droop slopes. With the derived angular frequency and voltage magnitude in (1) and (2), the instantaneous voltage reference can be obtained accordingly.

B. Reactive Power Sharing Analysis

It is not straightforward to evaluate the reactive power sharing accuracy in a complex networked microgrid. For the sake of simplicity, this section first considers a simplified microgrid with two DG units at the same power rating. The configuration is shown in Fig. 2(a), where each DG unit has a local load. R1 and X1, and R2 and X2 are the feeder impedances of DG1 and DG2, respectively. Further considering that DG units are often equipped with series virtual inductors to ensure the stability of the system, the corresponding equivalent circuit is sketched in Fig. 2(b). As shown, the virtual reactances XV 1 and XV 2 are placed at the outputs of voltage sources. The magnitudes of the voltage sources are obtained in (3) and (4) as

$$E1 = E0 - DQ \cdot Q1 \ (3)$$

$E2 = E0 - DQ \cdot Q2$ (4)where E1 and E2 are the DG volt

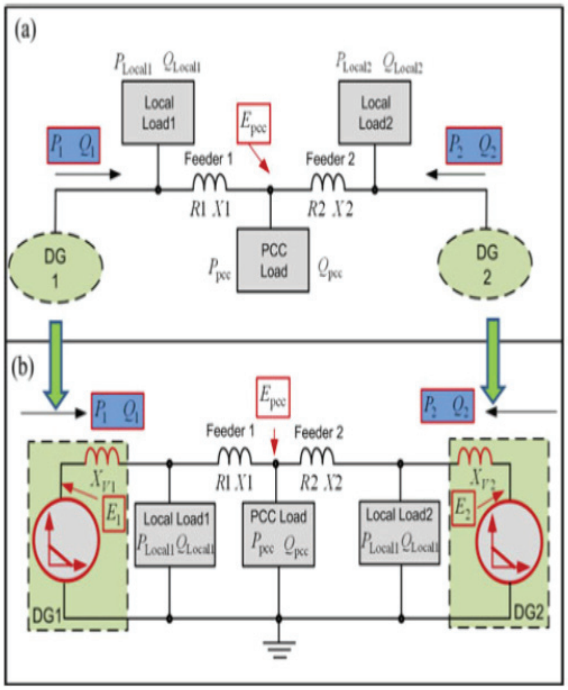


Fig. 2. Power flow in a simple microgrid: (a) configuration of the microgrid; (b) equivalent circuit model considering a virtual impedance control.

age magnitudes regulated by the droop control, and Q1 and Q2 are the output reactive powers of DG1 and DG2, respectively.

III. Proposed Reactive Power Sharing Error Compensation Method

Since the reactive power sharing errors are caused by a number of factors and microgrid often have complex configurations,developing the circuit model-based reactive power sharing error compensation strategy is difficult. Therefore, the objective of this section is to develop an enhanced compensation method that can eliminate the reactive power sharing errors without knowing the detailed microgrid configuration. This feature is very important to achieve the “plug-and-play” operation of DG units and loads in the microgrid.

A. Proposed Compensation Control

To initialize the compensation, the proposed method adopts a low-bandwidth communication link to connect the secondary central controller with DG local controllers [14]. The commuta- tion link sends out the synchronized compensation flag signals from the central controller to each DG unit, so that all the DG units can start the compensation at the same time. This commu- nication link is also responsible for sending the power reference for dispatchable DG units during the microgrid grid-tied oper- ation. Therefore, the proposed compensation scheme does not need any additional hardware cost. The communication mech- anism can be realized using power line signaling or smart me- tering technologies, or other commercial infrastructures, such as digital subscriber lines, or wireless communications. These techniques have already been suggested to construct the future smart grid systems in [20]. As the focus of this paper is the enhanced power sharing scheme realized at the DG unit lo- cal controller, further discussion on the communication system is out of the scope of this paper. Note that in the proposed compensation method, only one-way communication from thecentral controller to DG local controllers is needed for starting the DG compensation with a synchronized manner. The inter- communication among DG units is not necessary, so that the plug-and-play feature of a DG unit will not be affected. The enhanced power control strategy is realized through the following two stages.

1) Stage 1: Initial Power Sharing Using Conventional Droop Method: Before receiving the compensation flag signal, the conventional droop controllers (1) and (2) are adopted for initial load power sharing. Meanwhile, the DG local controller mon- itors the status of the compensation flag dispatched from the microgrid central controller. During this stage, the steady-state averaged real power (PAVE) shall also be measured for use in Stage 2. Note that although the first-order LPFs have already been used in measuring the real and reactive powers (P and Q) for the conventional droop controller in (1) and (2), the cutoff frequency of LPFs cannot be made very low to get the ripple- free averaged real power (PAVE) due to the consideration of system stability [9], [21]. Therefore, a moving average filter is used here to further filter out the power ripples (see Fig. 4). The measured average real power (PAVE) is also saved in this stage, so that when the synchronization signal flag changes, the last saved value can be used for a reactive power sharing accuracy improvement control in Stage 2.

2) Stage 2: Power Sharing Improvement ThroughSynchro- nized Compensation: In Stage 2, the reactive power sharing error is compensated by introducing a real-reactive power cou- pling transient and using an integral voltage magnitude control term. As this compensation is based on the transient coupling power control, it shall be carried out in all DG units in a syn- chronized manner. Once a compensation starting signal (sent from the central controller) is received by the DG unit local controller, the averaged real power calculation stops updating, and the last calculated PAVE is saved and used as an input of the compensation scheme.

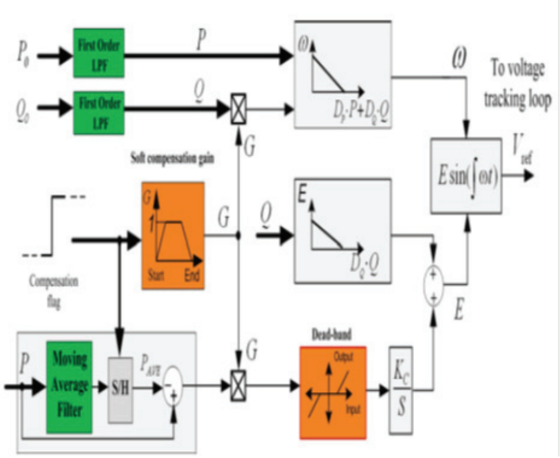


Fig.3 Synchronised reactive power compensation scheme

B. Small-Signal Modeling and Analysis

Compared to the conventional droop control, it can be seen that the renovated droop control method involves additional power couplings. In order to investigate the stability

DG Configuration

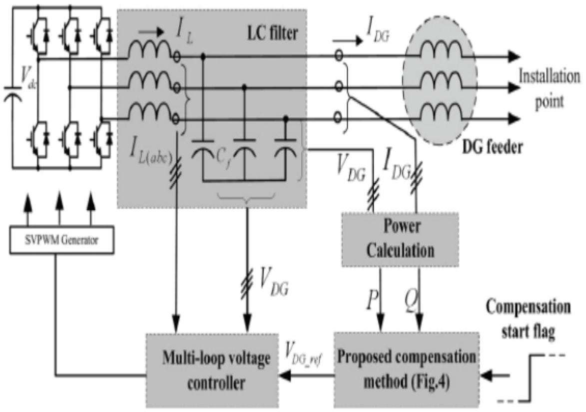


Fig.4 Configuration of DG unit

The output real power goes back to the original value at around 2.3 s. The associated DG line currents. With the conventional droop control method, the magnitude and phase of DG currents are Consistent with the power sharing analysis, the DG line currents. They are almost identical after the compensation. The voltage magnitudes at different locations of the micro grid are also obtained. The changes of DG unit voltage magnitudes during this process. In order to realize equal reactive power sharing, these voltages have small deviations during the compensation. This is because the unequal voltage drops on the feeders are compensated by the DG units.

IV. Simulation and Experimental Results

The implementation stage involves careful planning, investigation of the existing system and it's constraints on implementation, designing of methods to achieve changeover and evaluation of changeover methods.

Major Findings

1. Plot of DG1,DG2 voltages.
2. Plot of DG1,DG2current.
3. Plot of DG1,DG2 phase currents.

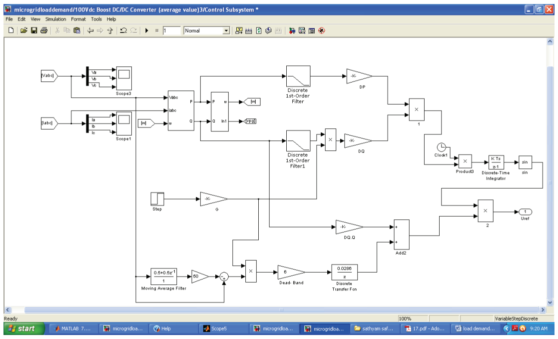
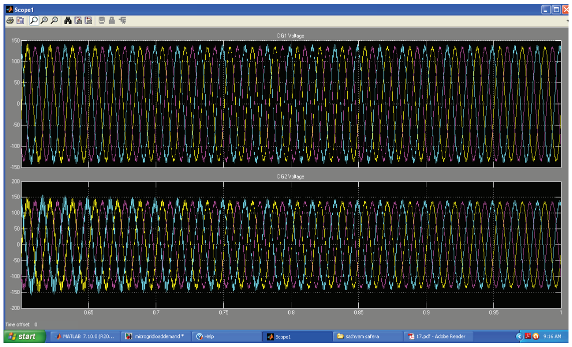
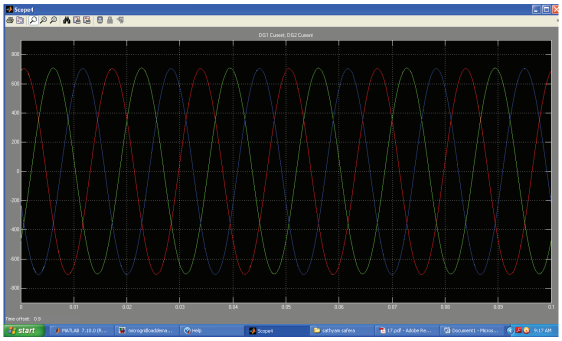


Fig:a Complete model in matlab

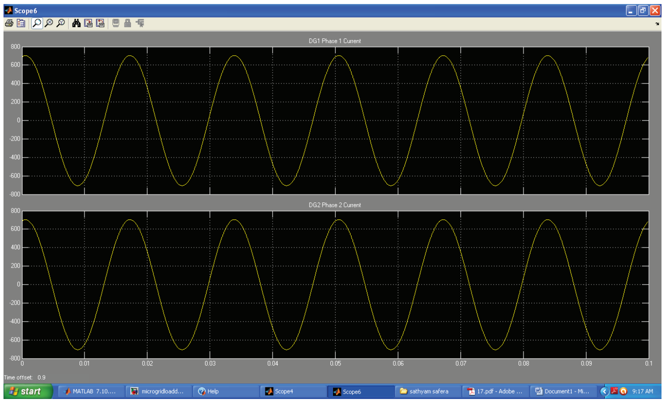
DG1,DG2 VOLTAGE WAVEFORM



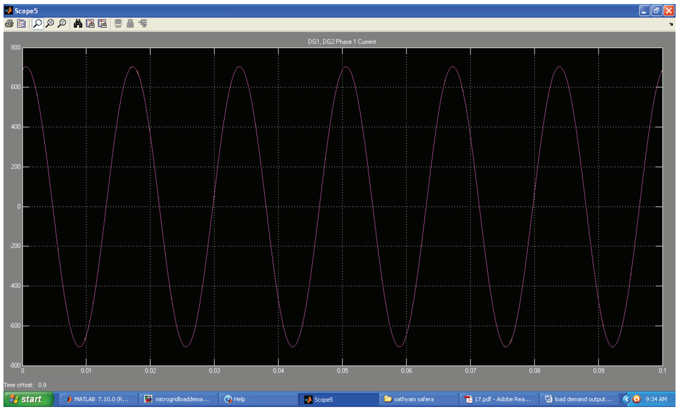
DG1.DG2 CURRENT WAVEFORM



DG1 PHASE1 CURRENT



DG2 PHASE2 CURRENT



V. CONCLUSION

In this project, an improved micro grid reactive power sharing strategy was proposed. The method injects a real-reactive power transient coupling term to identify the errors of reactive power sharing and then compensates the errors using a slow integral term for the DG voltage magnitude control. The compensation strategy also uses a low-bandwidth flag signal from the micro grid central controller to activate the compensation of all DG units in a synchronized manner. Therefore, accurate power sharing can be achieved while without any physical communications among DG units. In addition, the proposed method is not sensitive to micro grid configurations, which is especially suitable for a complex mesh or networked micro grid.

References

[1] A. Mehrizi-Sani and R. Iravani, “Potential-function based control of a microgrid in islanded and grid-connected modes,” *IEEE Trans. Power Syst.,* vol. 25, no. 4, pp. 1883–1891, Nov. 2010.

[2] K. D. Brabandere, B. Bolsens, J. V. D. Keybus, A. Woyte, J. Drisen, and R. Belmans, “A voltage and frequency droop control method for parallel inverters,” *IEEE Trans. Power Electron.,* vol. 22, no. 4, pp. 1107–1115, Jul. 2007.

[3] Y. Li and Y. W. Li, “Power management of inverter interfaced autonomous microgrid based on virtual frequency-voltage frame,” *IEEE Trans. Smart Grid.,* vol. 2, no. 1, pp. 30–40, Mar. 2011.

[4] A. Tuladhar, H. Jin, T. Unger, and K. Mauch, “Control of parallel inverters in distributed AC power system with consideration of line impedance effect,” *IEEE Trans. Ind. Appl.,* vol. 36, no. 1, pp. 131–138, Jan./Feb. 2000.

[5] C.-T. Lee, C.-C.Chu, and P.-T.Cheng, “A new droop control method for the autonomous operation of distributed energy resource interface converters,” in Proc. Conf. Rec. IEEE Energy Convers.Congr.Expo., Atlanta, GA, 2010, pp. 702–709.

[6] J. M. Guerrero, L. G. Vicuna, J. Matas, M. Castilla, and J. Miret, “Output impedance design of parallel-connected UPS inverters with wireless load sharing control,” *IEEE Trans. Ind. Electron.,* vol. 52, no. 4, pp. 1126– 1135, Aug. 2005.

[7] J. M. Guerrero, L. G. Vicuna, J. Matas, M. Castilla, and J. Miret, “A wireless controller to enhance dynamic performance of parallel inverters in distributed generation systems,” *IEEE Trans. Power Electron.,* vol. 19, no. 4, pp. 1205–1213, Sep. 2004.

[8] Y. W. Li and C.-N. Kao, “An accurate power control strategy for power- electronics-interfaced distributed generation units operation in a low volt- age multibusmicrogrid,” *IEEE Trans. Power Electron.,* vol. 24, no. 12, pp. 2977–2988, Dec. 2009.

[9] J. He and Y. W. Li, “Analysis, design and implementation of virtual impedance for power electronics interfaced distributed generation,” *IEEE Trans. Ind. Appl.,* vol. 47, no. 6, pp. 2525–2538, Nov./Dec. 2011.

[10] E. A. A. Coelho, P. C. Cortizo, and P. F. D. Garcia, “Small-signal stability for parallel-connected inverters in stand-alone AC supply systems,” *IEEE Trans. Ind. Appl.,* vol. 38, no. 2, pp. 533–542, Mar./ Apr. 2002.

[11] N. Pogaku, M. Prodanovic, and T. C. Green, “Modeling, analysis and testing of autonomous operation of an inverter-based microgrid,” *IEEE Trans. Power Electron.,* vol. 22, no. 2, pp. 613–625, Mar. 2007.

[12] Y. W. Li, D. M. Vilathgamuwa, and P. C. Loh, “Design, analysis and real- time testing of a controller for multibusmicrogrid system,” *IEEE Trans. Power Electron,* vol. 19, no. 5, pp. 1195–1204, Sep. 2004.