An Islanding Microgrid Power Sharing Approach Using Adaptive Virtual Impedance control scheme

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Abstract **–This paper proposes an enhanced distributed generation (DG) unit with an adaptive virtual impedance control approachin order to address the inaccurate reactive power sharing problems. The proposed method can adaptively regulate the DG unit thanks to the equivalent impedance, andthe effect of the mismatch in feeder impedance is compensatedto share the reactive power accurately.The proposed control strategy can be implemented directly without any requirement of pre-knowledge of the feeder impedances. Simulations are performed to validate the effectiveness of the proposed control approach.**

Index Terms **–Distributed generation (DG), droop control, microgrid, and virtual impedance.**

I. INTRODUCTION

For the operation of autonomous microgrids, it is very important to share the load demand in proportion to DG rated power. In order to realize the power sharing successfully without the communication between DG units, the frequency and voltage droop controllers have been reported in [1]. Due to the mismatched feeder impedance, the voltage droop control commonly results in poor reactive power sharing [2], [3].In [2], the accurate power sharing is realized by incorporating the line voltage drop into the power control scheme. In [3], by introducing the proper virtual impedances, the equivalent DG unit impedance are designed to be inversely proportion to the DG rating, and the reactive power sharing errorsare eliminated. However, all of these methods require the impedance information, which is noteasily available; the impedance estimation algorithm will make the control system more complex.

In this paper, an adaptive virtual impedance controlmethod is applied to DG units in islandedmicrogrids, and the communication is utilized to tune the virtual impedancesadaptively in order to compensate the mismatch in feeder's impedance. Once the virtual impedance is tuned for a given load operating point, the accurate reactive power sharing is achieved. The proposed control strategy is verified by the digital simulation.

II. PROPOSED CONTROL APPROACH

A. Principle of DroopControl

The conventional frequency and voltage magnitude droop controls in a DG unit are given in (1) and (2):

$$f_{DG} = f^* - D_P \cdot P_{Ave} \tag{1}$$

$$E_{DG} = E^* - D_Q \cdot Q_{Ave} \tag{2}$$

where ω^* and ω_{DG} are the nominal and reference angular frequencies of the DG unit,respectively; E^* and E_{DG} are the nominal and reference DG voltage magnitudes, respectively; P_{Ave} and Q_{Ave} are the calculated powerafter low-pass filter withthe time constant τ as shown in (3), (4), respectively; D_P and D_Q are the real and reactive power droop slopes, respectively. Fromthe reference voltage magnitude and angular frequency, the reference voltage $V_{dr_\alpha}$of DG unit can be obtained accordingly:

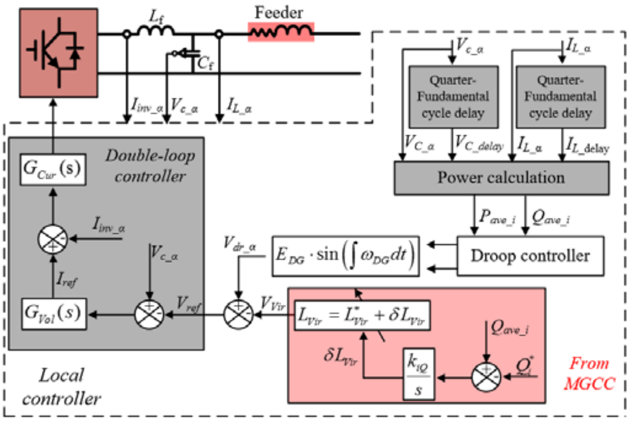

Fig. 1. Proposed control scheme

$$P_{Ave} = \frac{1}{2(\tau s+1)} \cdot \left(V_{C\_\alpha} \cdot I_{L\_\alpha} - V_{C\_delay} \cdot I_{L\_delay}\right) \tag{3}$$

$$Q_{Ave} = \frac{1}{2(\tau s+1)} \cdot \left(V_{C\_delay} \cdot I_{L\_\alpha} - V_{C\_\alpha} \cdot I_{2\_delay}\right) \tag{4}$$

B. Adaptive Virtual Impedance

The block diagram of the adaptive virtual impedance control is illustrated in Fig. 1. The inverters transmit the information of the respective reactive power outputs (Q_1 and Q_2) to the microgrid central control (MGCC). The MGCC determines the total reactive power supplied by the inverters in the microgridby considering the total rated reactive powers of the inverters. Thecalculated value is broadcast to all inverters in the microgrid and each inverter determines the respective reactive power demand (Q_1^* and Q_2^*) by multiplying the received value with its rated power as shown in (5), so that eachreactive power can be shared proportionally.

$$Q_i^* = \frac{Q_{total}}{\sum_{j=1}^{n} Q_{rated,j}} \cdot Q_{rated,i} \tag{5}$$

As shown in Fig. 1, the difference between the measured reactive power Q_{ave_i} and the reactive power demand Q_i^* is obtained to adjust the DG virtual impedancethrough the integral controller:

$$L_{vir} = L^*_{vir} + \frac{k_{iQ}}{s} \cdot \left(Q_{ave\_i} - Q_i^*\right), \tag{6}$$

where L^*_{vir} is the static virtual inductance which is used to ensure the equivalent inductive DG impedance; L_{vir} is the adaptive equivalent virtual inductance; k_{iQ} is the integral gain to adjust the virtual inductance. To emulate the behavior of virtual impedance, its associated voltage drop V_{Vir} iscalculated as (7):

$$V_{Vir} = -\omega_{DG} \cdot L_{Vir} \cdot I_{L\_delay} \tag{7}$$

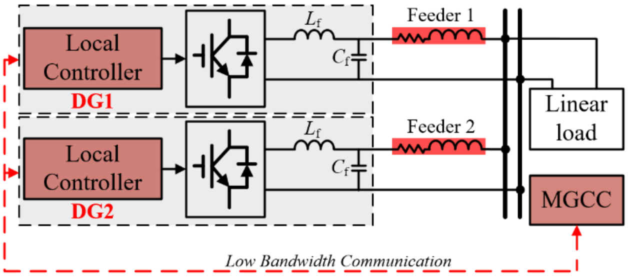

Fig. 2. Simulated microgrid configuration

TABLE I
DG SYSTEM PARAMETERS

Parameter	Values
Nominal operating voltage *(rms)*	60*V (60Hz)*
Sampling-switching frequency	10*kHz*
DC link voltage *(V_{dc})*	150*V*
LC Filter *(L_f/C_f/R_d)*	1.203*mH* /20*uF*/1*Ω*
Frequency droop coefficient D_P	0.00143 *Rad/(Sec·W)*
Voltage droop coefficient D_Q	0.00167 *V/Var*
Feeder 1/ Feeder 2	5.8*mH*, 0.33 *Ω*/2.9*mH*,0 1*Ω*
Loads (R_{load}/L_{load})	10*Ω*/ 30*mH*

C. Double-Loop Voltage Tracking Scheme

The modified voltage reference V_{ref} is obtained by combining the voltage reference from droop control andthe voltage drop due to the virtual impedance as shown in Fig. 1. Afterward, the double-loop voltage controller is appliedto track the modified voltage reference. In double-loop voltage controller, the outer loop uses a proportional controller tuned at the fundamental frequencyin (8):

$$G_{Vol}(s) = k_{pv} + \frac{2k_{iv}\omega_c s}{s^2 + 2\omega_c s + (2\pi f_{DG})^2}, \qquad (8)$$

where k_{PV} is the outer loop proportional gain, k_{iV} is the gain of resonant controller at fundamental frequency, and ω_c is the cutoff bandwidth of the resonant controller.

The inner loop is a simple proportional control K_{inner} with the filter inductor current feedback:

$$G_{Cur}(s) = K_{inner} \qquad (9)$$

III. SIMULATION RESULTS

The proposed power control strategy has been verified withPSIM simulations. As shown in Fig. 2, the simulated microgrid is composed of two identical DG units and several linear loads.The system parameters used in the simulation are listed in Table I.The MGCC exchanges the required information with DG local controller through low bandwidth communication links.Underthe same power rating, the two DG units shall share the load demand equally.

Fig. 3(b)shows the reactive powers of the DG units. Due to the mismatched feeder impedances, thereis significant reactive power sharing error with the conventional droop control method. On the other hand, the proposed compensation method can effectively adjust the reactive power sharing error to be almost zero.

Fig. 3(a) shows the real power of the DG units. Before the compensation, the real power is accurately shared with the conventional droop method. When the compensation is activated at 1 s, the output real powersare recovered their initial values at around 3 s after a short transient time.

Fig. 4 and Fig. 5 show the associated DG line currents. With the conventional droop control method, the magnitude and phase of DG currents are not the same as illustrated in Fig. 4. However, Fig. 5 shows that both of the DG line currents with the proposed control scheme are almost identical.

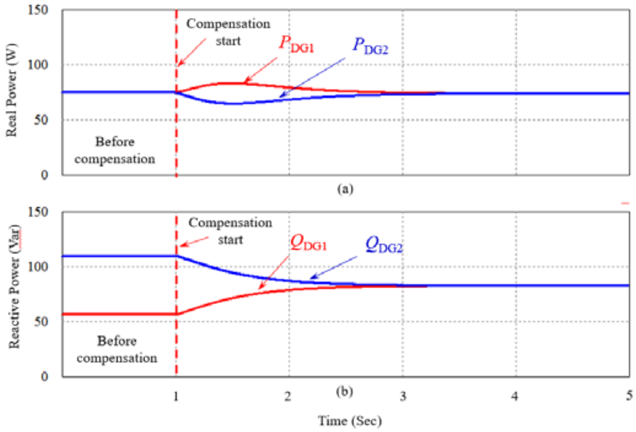

Fig. 3.Power sharing performance.(a) Real power. (b) Reactive power

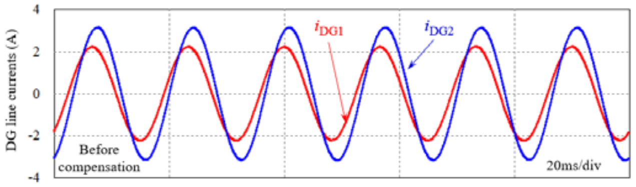

Fig. 4.DG output currents before compensation

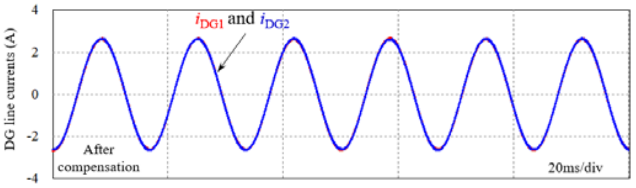

Fig. 5.DG output currents after compensation

IV. CONCLUSION

A control strategy to improve reactive power sharing in an islanded microgrid has been proposed and validated. A low bandwidth communication is employedto exchange all information to tune adaptive virtual impedances. The control strategy does not require any pre-knowledge of the feeder impedances, and is straightforward to implement in practice.

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