Voltage and Frequency Droop Control for Accurate Power Sharing of Parallel DG Inverters in Low Voltage Microgrid

Tien Hai Nguyen, Kyeong−Hwa Kim†
Seoul National University of Science and Technology

ABSTRACT

This paper presents a voltage and frequency droop control for accurate power sharing of parallel distributed generation (DG) inverters in low voltage microgrid. In practice, line impedances between inverters and the point of common coupling of a microgrid are not always equal. This inequality in line impedances often results in reactive power sharing mismatch among inverters. To address this problem, intensive researches have been conducting. Although these methods can solve the unbalanced reactive power sharing, there are still problems remain unresolved, such as complicated structure or circulating current. To overcome such problems, a new droop control scheme is proposed, which not only guarantees accurate reactive power sharing but also has simple structure so that it can be easily implemented in existing systems without any hardware modification. The simulation is performed using Matlab/Simulinks to validate the proposed scheme.

1. Introduction

Microgrid has drawn a lot of attention from academia recently due to the growth of DG systems using renewable energy sources. One of the most fundamental issues of microgrid is to operate parallel inverters cooperatively so that every inverter in the system shares active and reactive power properly. Droop control has been proven to be the most suitable control scheme to ensure good power sharing between DG systems [1].

In a standard droop control based microgrid as illustrated in Fig. 1, it is essential for every inverter in the system to share the active and reactive power equally. Even though the active power is properly shared for most scenarios, the reactive power is extremely sensitive to line impedance. To overcome such a problem, the virtual impedance has been introduced to compensate the difference of output impedance in each inverter, resulting in improvement of reactive power sharing performance [2][3].

Although the virtual impedance method has been proved to perform well under unbalanced line impedance, its performance deteriorates when the line impedance changes during operation. To solve such a problem in the virtual impedance method, an adaptive virtual impedance scheme is introduced in this paper. The effectiveness of the proposed scheme is confirmed through simulation results.

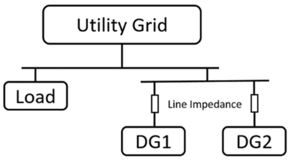

Fig. 1 Schematic diagram of a microgrid.

2. Virtual Impedance Method

The virtual impedance method has been presented to compensate the line impedance mismatch between inverters. In this method, the voltage reference was adjusted by considering the effect of virtual impedance as follows:

$$v_{ref} = v^*_{ref} - Z_v . i_o \tag{1}$$

where v^*_{ref} is the reference voltage from the droop control, Z_v is the virtual impedance, and v_{ref} is the final reference voltage, respectively. Fig. 2 illustrates the virtual impedance method.

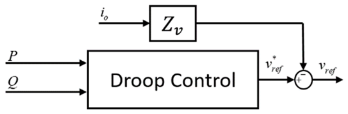

Fig. 2 Block diagram of virtual impedance scheme.

3. Adaptive Virtual Impedance Using Impedance Calculation

To improve the robustness of the virtual impedance method with regard to the change in line impedance during operation, an adaptive virtual impedance method is proposed:

$$Z_{vi} = Z_{eq} - Z_i \tag{2}$$

where Z_{vi} is the virtual impedance of inverter, Z_i is the physical impedance between inverter and the point of common coupling (PCC), and Z_{eq} is a constant parameter, respectively. From (2), it is easy to notice that the virtual impedance parameter is adjusted to compensate the impedance change when the physical impedance of an inverter is changed during operation. The proposed adaptive virtual impedance scheme is

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† Corresponding author

demonstrated in Fig. 3.

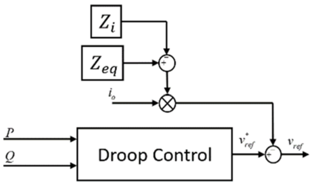

Fig. 3 Adaptive virtual impedance scheme.

In order to apply the proposed adaptive virtual impedance scheme, it is necessary to estimate the real line impedance between inverter and the PCC.

This real line impedance can be easily estimated by the simplified equivalent circuit representing the grid connected inverter in Fig. 4.

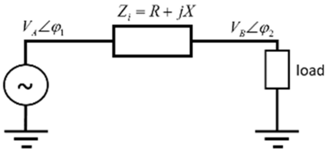

Fig. 4 Simplified circuit of grid connected inverter.

Using Fig. 4, the line impedance can be estimated by using the following phasor equation:

$$Z\angle\theta = \frac{V_A\angle\varphi_1 - V_B\angle\varphi_2}{I\angle\varphi_2} \tag{3}$$

where $V_A\angle\varphi_1$, $V_B\angle\varphi_2$, $I\angle\varphi_2$, and $Z\angle\theta$ are the inverter output voltage, the voltage at PCC, the current in transmission line, and the line impedance, respectively.

4. Simulation Results

To prove the performance of the proposed scheme, the comparative simulation is carried out. The overall system consists of two DG inverter systems as in Fig. 1 and the line impedance is doubled from its nominal values at 0.4s. Fig. 5 shows the reactive power sharing performance with the conventional virtual impedance method. Fig. 6 and Fig. 7 show the reactive power sharing performance under line impedance change at 0.4s for the the conventional method and the proposed method, respectively. Whereas the reactive power is not shared properly in the case of using the conventional method as shown in the Fig. 6, the proposed method exhibits a good balance in reactive power sharing as is Fig. 7.

5. Conclusion

This paper has presented an adaptive virtual impedance method to enhance the power sharing performance of a microgrid in case that the line impedance is changed during operation. The simulation has confirmed that the proposed method can guarantee the proper reactive power sharing even when the line impedance is changed during operation.

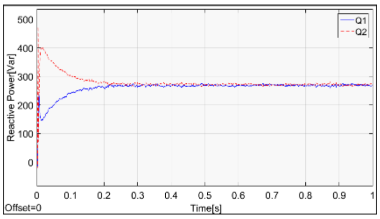

Fig. 5 Reactive power sharing with the conventional virtual impedance method.

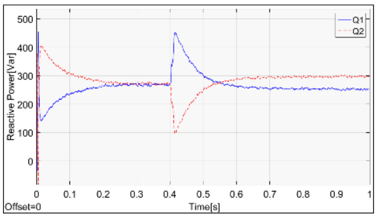

Fig. 6 Reactive power sharing with the conventional method under line impedance change at 0.4s.

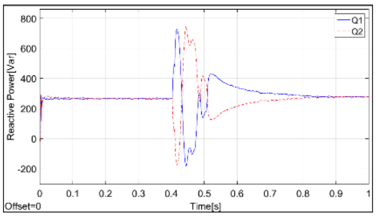

Fig. 7 Reactive power sharing with the proposed method under line impedance change at 0.4s.

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6. References

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