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Research on the Control Strategy of Parallel Converters for Distributed System

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Abstract

This paper introduces a parallel converter control technology that considers inertia and transient reaction speed to improve classical droop control. The suggested controller provides flexible and stable operation for both inductive and resistive lines, as well as a reduction in network line losses. The proposed controller achieves an automatic and accurate power sharing performance by combining the Q-f modification relationship with inertia considerations, which can reduce line losses in MG systems and boost the system's ability to operate in a variety of situations. The simulation verifed the effectiveness of the proposed controller, which demostrates the better performance regarding transient response and flexibility of line impedence.

Keywords

Parallel converters, Power sharing, Distributed system, droop.

1. Introduction

In the last 10 years, an expanded concept has been to unite a few of these converter-interfaced distributed generation (DG) units, as well as the different kinds of loads, to form a small local power system, known as a microgrid [1]-[5], that can operate in grid-connected or island mode. As the capacity of the distributed system grows, the impact on the main grid becomes more pronounced. Because DG always incorporate various renewable energy sources (for example, solar and wind power), which have characteristics such as intermittent, unpredictability, and volatility, the following issues arise. Without good real-/reactive-power adjustment capabilities, a DG system cannot support the safety and stable functioning of a power system [6].

The control performance of the interfaced inverters, the control interconnection required among the inverters to achieve proper load sharing, and the optimal sizing method for hybrid power systems that include photovoltaic, wind, storage, and any other distributed generators are all important factors in microgrid. The droop control method has dominated the autonomous regulation of parallel inverters in microgrids [7]. Despite the fact that this technique simply requires local information to function, it raised a number of issues that were addressed in the literature [8]-[10].

Power electronic converters functioning as voltage sources: voltage-source inverters (VSI) in the case of ac microgrids (MG) are frequently used as interfaces between prime movers and microgrids. Through the MG, these power-electronic converters are connected in parallel. For MGs, a general hierarchical multilevel control system with primary, secondary, and tertiary control levels is presented. The primary control level develops a power sharing algorithm [11]-[13]. At the fundamental control level of inverter-based microgrids, the droop control mechanism is well-known. In this famous

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control method, the droop coefficients that regulate frequency and amplitudes are essentially proportional terms, thus derivative terms were added to expand their range of values [14]. The second is that when the generator's output impedance is primarily inductive, frequency and voltage are connected to active and reactive power, respectively. However, power droop management has the problem of requiring instantaneous active and reactive powers to be calculated and then averaged via low pass filters, whose bandwidth may affect the system's transient speed [15]. As a result, a new, simpler, and quicker controller is required to address these issues.

The new controller should provide faster active and reactive power sharing among parallel connected inverters, faster active/reactive power rating adjustment, robust and high stability performance even with different line impedance [16].

The droop control combined with ineria has lately received a lot of interest as an advanced control approach that may provide extra inertia and damping characteristics to converter-based distributed generator. The virtual sychrous generator can simulate the behavior of a genuine synchronous generator, providing inertia support to the entire system during the transient phase [17]. A novel control technique based on droop is presented in AC distributed system to increase the flexibility and stability of parallel converters operation, and simulation comparisons are carried out to confirm its performance.

2. Proposed Controller

2.1 Standard droop control

Droop controller can be described as the P-f Q-V forms in the paralleling converters. Each inverter operates as a voltage source. Therefore, the power injected to the ac bus from the VSI is given by [7]:

$$P = \frac{EV_{pcc}}{Z}\cos(\theta - \varphi) - \frac{V_{pcc}{}^{2}}{Z}\cos\theta \tag{1}$$

$$Q = \frac{EV_{pcc}}{Z}\sin(\theta - \varphi) - \frac{V_{pcc}{}^{2}}{Z}\sin\theta \tag{2}$$

where E and V_{pcc} are the amplitude of the inverter output voltage and the ac bus voltage, φ is the power angle of the inverter, Z and θ represent the amplitude and the phase of the inverter output impedance.

When the output impedence is resistive, normally, the power angle φ is very small, then the active power P is mainly related with φ, and the reactive power Q is mainly influenced by the voltage error. Therefore, the voltage and frequency droop functions are given as [5], [7]:

$$E = E^{*} - m_q Q \tag{3}$$

$$\omega = \omega^{*} - m_p P \tag{4}$$

in which $\omega^{*}$and E^{*}indicate the frequency and voltage amplitude references, mp and mq are the droop coefficients.

2.2 The Proposed Controller

Because of the low inertia and damping, the rising penetration of renewable energy sources and dispersed generators is generating stability concerns in the power system [10]. Synchrous generator has lately received a lot of interest as an advanced control approach that may provide extra inertia and damping characteristics to inverter-based distributed generators.

In order to introduce the ineria, the new control function can be designed as:

$$E = E^{*} - m_p P \tag{5}$$

$$\omega = \omega^{*} + m_p Q + k_i \dot{\omega} \tag{6}$$

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Where mp is the droop coefficient of active power and mq is the droop coefficient of reactive power, ω is the virtual rotor angular frequency, ω* is the angular frequency of the point where the voltage sensor is installed.

For the inertia part, the coefficient ki is the proportional to the controlled inertia, which is defined as:

$$k_d = 2H\omega^* m_p \tag{7}$$

Where H is the virtual inertia constant. From (5) and (6), the droop characteristics are designed as active power-voltage and reacive power-frequency forms as seen in the resistive line. The Q-f droop control coefficient is denoted by mq. The innovation control system of the proposed control for parallel converters is shown in Figure 1. The innovation technique may be used in two modes: grid-connected and islanded. The output voltage and frequency in grid-connected mode are determined by the grid value. In islanded mode, difficulties with system stability and optimal load sharing occurred, which may be resolved by changing controller parameters [15].

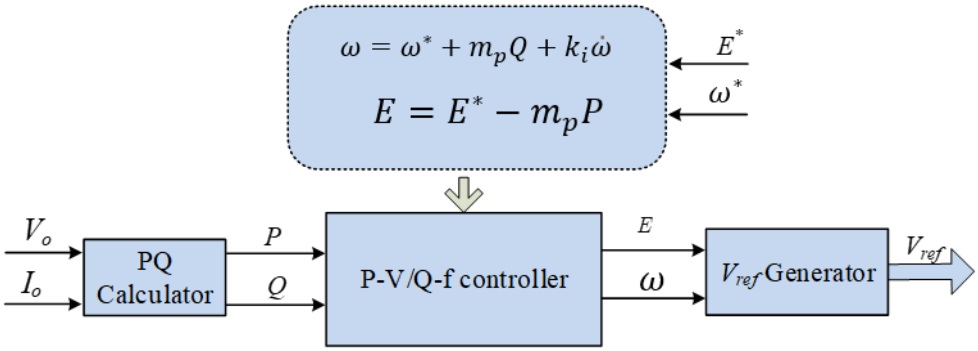

Figure 1. The control block of proposed method

Regarding the droop laws of the proposed controller, the active power is inversely proportional to voltage in operation rage. Meanwhile, the reactive power is in nonlinear directly proportional to frequency, which is major difference with the standard droop control[18]. The frequency and voltage can be changed to meet the demands of power for different load curve as shown in Figure 2.

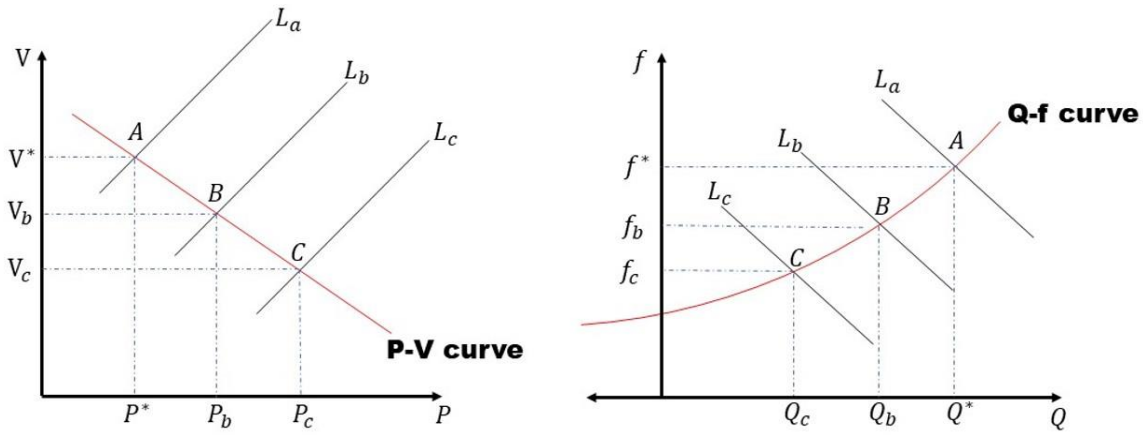

Figure 2. The droop characteristics of the proposed controller

According to (2), the reactive power and frequency relationship with different control parameters are shown in Figure 3.

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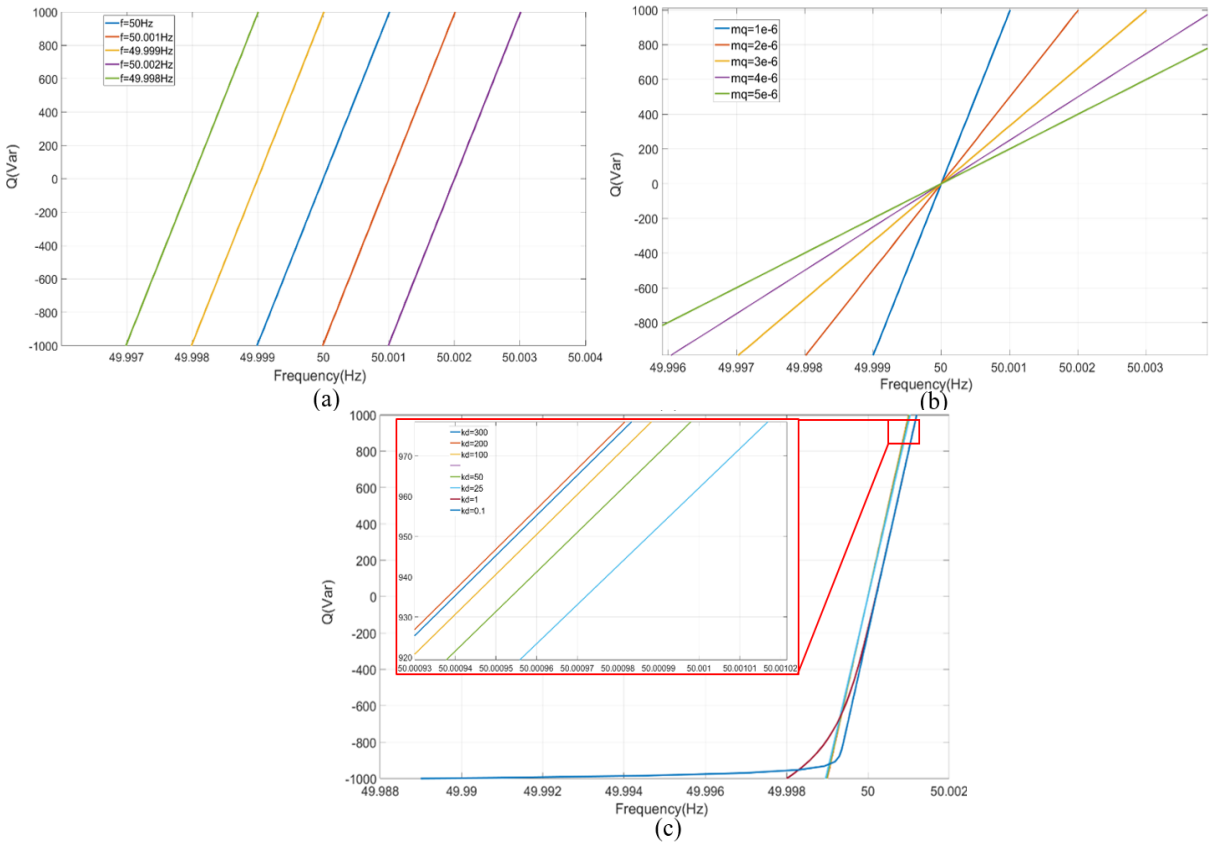

Figure 3. The droop characteristics under the parameters variation

It can be seen from Figure 3, the reactive power will be larger when the frequency increase, and the ki will influence the system setting point if the rated power changes in the converter operation.

3. Control Strategy Validation

The proof-of-concept has previously been demonstrated in a Matlab/Simulink simulation and compared to standard droop control. Between the power stations and the combiner point, there are 400V/400VAC transformers with local loads for each power station. The simulation key parametters are listed in Table 1.

Table 1. The system and control parameters

Parameters	Value
Nominal output voltage	400V
Fundamental frequency	50Hz
Rated power	33kVA
Virtual inertia	0.3s
Droop coefficient of voltage	0.0001V/Var
Droop coefficient of voltage	0.00003Hz/W

3.1 Case 1: Resistive Line Impedence

The trainset response performance under resistive line of two methods are shown in Figure 4. and Figure 4. In. Figure 5. the converter #2 connect to system at 0.05s and a large load removed at 0.4s. Due to inertia item, the proposed controller has a faster power sharing performance and the active power is more stable with lower harmonics ripples when a large load removed. From Figure 5. Under the large load removal action, the proposed controller has better frequency recovery performance compared with conventional droop.

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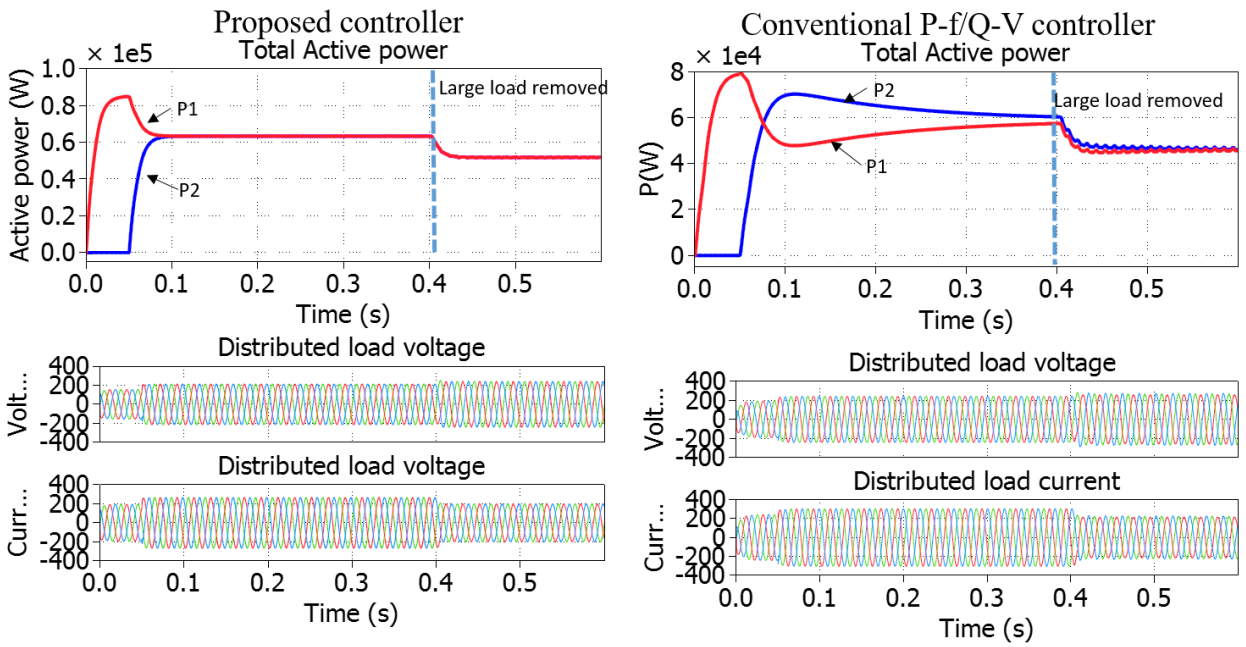

Figure 4. The active power and load voltage waveforms of two controller under resistive line

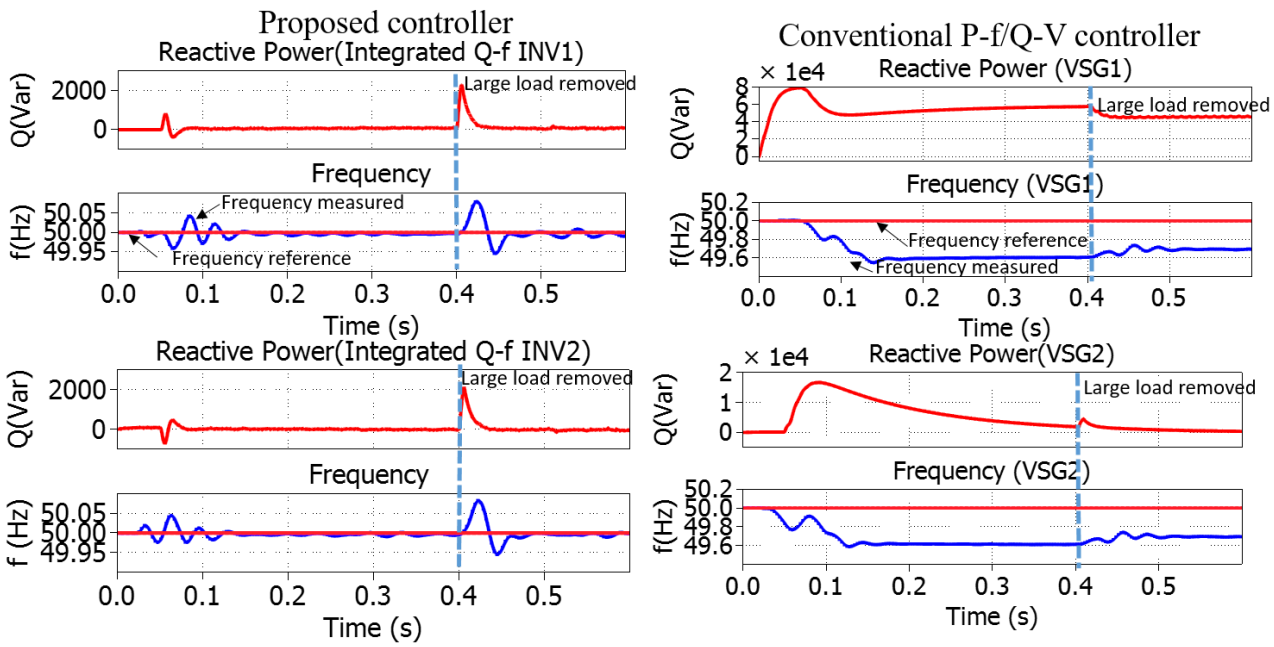

Figure 5. The reactive power and frequency waveforms of two controller under resistive line

3.2 Case 2: Inductive Line Impedence

The reactive power and frequency trainset response under inductive line of two methods are shown in Figure 6. It can be seen that the proposed controller has faster power tracking ability and the its frequency is stable around nominal frequency under the large load removal. By contrast, frequency of the conventional droop controller has big offset at the same case.

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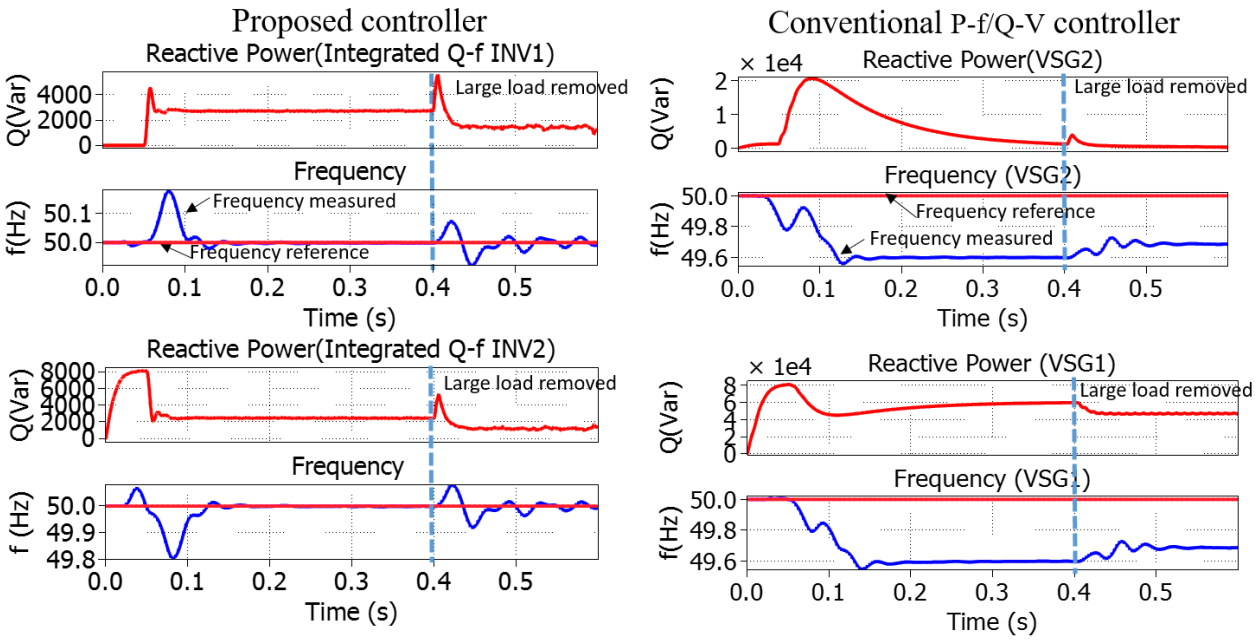

Figure 6. The reactive power waveforms of two controller under inductive line

In a nutshell, simulation results confirmed the invention technique's qualities, particularly its stability under both inductive and resistive lines, as well as its strong performance when the huge load was removed.

4. Conclusion

A novel control technique for parallel converters was developed in this paper. The new droop controller, unlike standard P-f Q-V droop control with limit application under diverse line impedance, can be constructed flexibly to adapt to different line impedance and also offer inertia. In compared to conventional droop, the suggested technique suppresses power oscillations and achieves faster frequency recovery, as well as providing optimal inertia and damping properties, especially under high load variations. The research method can be applied into distributed system operation, which is able to improve the system reliability and stability.

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