Investigation of Operational Control Strategy for Three-Phase Inverter in Distributed Generation

K. Shanthi
M.Tech, Electrical Power Systems
Talla Padmavathi College Of Engineering, Kizipet, Warangal

Mr. D. Bheemaiah
Associate Professor, EEE
Talla Padmavathi College Of Engineering, Kizipet, Warangal

ABSTRACT: The proposed control strategy contains an inner inductor current loop, and a novel voltage loop in the synchronous reference frame. The inverter is regulated as a current source just by the inner inductor current loop in grid-tied operation, and the voltage controller is unavoidably activated to regulate the load voltage upon the occurrence of islanding. Additionally, the waveforms of the grid current in the grid-tied mode and the load voltage in the islanding mode are distorted under nonlinear local load with the conventional strategy. And this issue is addressed by proposing a unified load current feed-forward in this paper. Lastly, the effectiveness of the proposed control strategy is validated by the simulation results.

KEYWORDS: Distributed generation (DG), islanding, load current, seamless transfer, three-phase inverter.

I. INTRODUCTION

The integration of Distributed Generation systems into the main electricity network is currently changing the paradigm we used to live with, where the electric power was generated in large power plants, sent to the consumption areas through transmission plants, sent to the consumption areas through transmission lines and delivered to the consumers through a passive distribution infrastructure. The integration of DG into distribution networks in recent years has transformed them from being passive to active networks. The progress of Distributed Generation as an important energy option in the present scenario is the result of combination of utility restructuring, technology evolutions and recent environmental policies. Distributed or embedded generator is generally defined/accepted as a plant which is connected directly to utilities of distribution network or can operate independently. They are generally considered to be less than 100MW in capacity and are not centrally planned or dispatched. Distributed generation can be based on renewable technologies such as wind turbine, photovoltaic or recent promising nonrenewable technologies such as micro turbine and fuel cell.

Most of these resources are connected to the utility through power electronic interfacing converters, i.e., three-phase inverter. Moreover, DG is a suitable form to offer high reliable electrical power supply, as it is able to operate either in the grid-tied mode or in the islanded mode. Distributed generation using micro turbine is a typical and practical solution because of its environment-friendliness and high energy efficiency. Various applications such as peak saving, co-generation, remote power and premium power makes its penetration widespread. In the grid-tied operation, DG delivers power to the utility and the local critical load. Upon the occurrence of utility outage, the islanding is formed. Under this circumstance, the DG must be tripped and cease to energize the portion of utility as soon as possible. In order to improve the power reliability of some local critical load, the DG should disconnect to the utility and continue to feed the local critical load. The load voltage is key issue of these two operation modes, because it is fixed by the utility in the grid-tied mode, and formed by the DG in the islanded mode, respectively. In the hybrid voltage and current mode control, there is a need to switch the controller when the operation mode of DG is changed. During the interval from the occurrence of utility outage and switching the controller to voltage mode, the load voltage is neither fixed by the utility, nor regulated by the DG, and the length of the time intervalis...
determined by the islanding detection process. Therefore, the main issue in this approach is that it makes the quality of the load voltage heavily reliant on the speed and accuracy of the islanding detection method. In order to improve the power reliability of some local critical load, the DG should disconnect to the utility and continue to feed the local critical load. The load voltage is key issue of these two operation modes, because it is fixed by the utility in the grid-tied operation, and formed by the DG in the islanded mode, respectively. Therefore, upon the happening of islanding, DG must take over the load voltage as soon as possible, in order to reduce the transient in the load voltage. And this issue brings a challenge for the operation of DG.

A fuel cell converts chemical energy of a fuel directly into electrical energy. It consists of two electrodes and an electrolyte, retained in a matrix. The operation is similar to that of a storage battery except that the reactant and products are not stored, but are continuously fed to the cell. During operation, the hydrogen rich fuel and oxidant are separately supplied to the electrodes.

Fig 1: Basic Construction of a Fuel Cell

Fuel is fed to the anode and oxidant to the cathode, and the two streams are separated by an electrode-electrolyte system. Electrochemical oxidation and reduction takes place at the electrodes to produce electricity. Heat and water are produced as by-products. Fig 1 shows the basic construction of a fuel cell. The Flows and reactions in a Fuel Cell are shown in Fig 2.

This paper proposes a unified control strategy that avoids the aforementioned shortcomings. First, the traditional inductor current loop is employed to control the three-phase inverter in DG to act as a current source with a given reference in the synchronous reference frame (SRF). Second, a novel voltage controller is presented to supply reference for the inner inductor current loop, where a proportional-plus-integral (PI) compensator and a proportional (P) compensator are employed in D-axis and Q-axis, respectively.

II. PROPOSED CONTROL STRATEGY

This paper presents a unified control strategy for a three-phase inverter in DG to operate in both islanded and grid-tied modes. The schematic diagram of the DG based on the proposed control strategy is shown by Fig. 3. The DG is equipped with a three-phase interface inverter terminated with a LC filter. The primary energy is converted to the electrical energy, which is then converted to dc by the front-end power converter, and the output dc voltage is regulated by it. Therefore, they can be represented by the dc voltage source \( V_{dc} \) in Fig. 3. In the ac side of inverter, the local critical load is connected directly.

Fig 2: Flows and reactions in a fuel cell

Basic idea

With hybrid voltage and current mode control, the inverter is controlled as a current source to generate...
the reference power PDG+jQDG in the grid-tied mode. And its output power PDG+jQDG should be sum of the power injected to the grid Pg+jQg and the load demand Pload+jQload, which can be expressed followed by as assuming that the load is represented as a parallel RL circuit.

\[ P_{\text{load}} = \frac{3}{2} \frac{V_m^2}{R} \] ..........................(1)

\[ Q_{\text{load}} = \frac{3}{2} V_m \cdot \left( \frac{1}{\omega L} - \omega C \right) \] ..........................(2).

In (1) and (2), Vm and \( \omega \) represent the amplitude and frequency of the load voltage, respectively. When the nonlinear local load is fed, it can still be equivalent to the parallel RLC circuit by just taking account of the fundamental component.

Fig. 4 describes the overall block diagram for the proposed unified control strategy, where the inductor current \( i_{Labc} \), the utility voltage \( v_{g abc} \), the load voltage \( v_{Cabc} \), and the load current are sensed. And the three-phase inverter is controlled in the SRF, in which, the phase variable will be represented by dc quantity. The control diagram is mainly composed by the inductor current loop, the PLL, and the current reference generation module. In the inductor current loop, the PI compensator is employed in both D- and Q-axes, and a decoupling of the cross coupling denoted by \( \omega_0 L_f / k_{PWM} \) is implemented in order to mitigate the couplings due to the inductor.

Fig. 4. Overall block diagram of the proposed unified control strategy.

The output of the inner current loop \( \text{ddq} \) together with the decoupling of the capacitor voltage denoted by \( 1/k_{PWM} \), sets the current reference \( I_{grefdq} \) and the load current \( i_{LLdq} \). In other words, the inductor current tracks the current reference and the load current. If the steady state error is zero, \( I_{grefdq} \) represents the grid current.

The operation principle of DG with the proposed control strategy will be illustrated in detail in this section, and there are in total two states for the DG, including the grid-tied mode, the islanded mode.

A. Grid-Tied Mode

When the utility is normal, the DG is controlled as a current source to supply given active and reactive power by the inductor current loop, and the active and reactive power can be given by the current reference of D- and Q-axis independently.

Second, the filter inductor current, which has been transformed into SRF by the Park transformation, is fed back and compared with the inductor current reference \( i_{Lrefdq} \), and the inductor current is regulated to track the reference \( i_{Lrefdq} \) by the PI compensator \( G_1 \). The reference of the inductor current loop \( i_{Lrefdq} \) seems complex and it is explained as below.

The control diagram of the inverter can be simplified as Fig. 5 in the grid-tied mode, and the inverter is controlled as a current source by the inductor current loop with the inductor current reference being determined by the current reference \( I_{grefdq} \) and the load current \( i_{LLdq} \). In other words, the inductor current tracks the current reference and the load current. If the steady state error is zero, \( I_{grefdq} \) represents the grid current.

The reference of the inverter power \( PDG+jQDG \) in the grid-tied mode. And its output power \( PDG+jQDG \) should be sum of the power injected to the grid \( Pg+jQg \) and the load demand \( Pload+jQload \), which can be expressed followed by as assuming that the load is represented as a parallel RL circuit.
B. Transition From the Grid-Tied Mode to the Islanded Mode

When the utility switch Su opens, the islanding happens, and the amplitude and frequency of the load voltage will drift due to the active and reactive power mismatch between the DG and the load demand. The transition, shown in Fig. 6, can be divided into two time intervals. The first time interval is from the instant of turning off Su to the instant of turning off Si when islanding is confirmed. The second time interval begins from the instant of turning off inverterswitch Si.

C. Islanded Mode

In the islanded mode, switching Si and Su are both in OFF state. The PLL cannot track the utility voltagenormally, and the angle frequency is fixed. In this situation, the DG is controlled as a voltage source, because voltage compensator GV D and GV Q can regulate the load voltage $V_{d}$ and $V_{q}$ respectively. The voltage references in D and Q-axis are $V_{max}$ and zero, respectively.

D. Transition From the Islanded Mode to the Grid-Tied Mode

If the utility is restored and the utility switch Su is ON, the DG should be connected with utility by turning on switch Si. However, several preparation steps should be performed before turning on switch Si. First, as soon as a utility voltage is restored, the PLL will track the phase of the utility voltage. As a result, the phase angle of the load voltage $v_{Cabc}$ will follow the grid voltage $v_{abc}$. If the load voltage $v_{Cabc}$ is in phase with the utility voltage, $v_{gd}$ will equal the magnitude of the utility voltage according to (5). Second, as the magnitude of the load voltage $V_{max}$ is larger than the utility voltage magnitude $V_{g}$, the voltage reference $V_{ref}$ will be changed to $V_{g}$ by toggling the selector S from terminals 1 to 2. As a result, the load voltage will equal to the utility voltage in both phase and magnitude. Third, the switch $S_i$ is turned on, and the selector S is reset to terminal 1.

IV. SIMULATION AND EXPERIMENTAL RESULTS

To investigate the feasibility of the proposed efficient control strategy, the simulation has been done in SIMULINK. The power rating of a three-phase inverter is 3kW in the simulation. In the grid-tied mode, the dynamic performance of the conventional voltage mode control and the proposed control strategy is compared by stepping down the grid current reference. The simulation results can be seen that the dynamic performance of the proposed control strategy is better than the conventional voltage mode control. During the transition from the grid-tied mode to the islanded mode, the proposed control strategy is compared with the hybrid voltage and current mode control. The SIMULINK model for the proposed control strategy is shown in the below Fig. 6.
V. CONCLUSION

An efficient control strategy was proposed for threephase inverter in DG using Artificial neural networks to operate in both islanded and grid-tied modes, with no need for switching between two different control architectures or critical islanding detection. The voltage controller is inactivated in the grid-tied mode, and the DG operates as a current source with fast dynamic performance. Upon the utility outage, the voltage controller can automatically be activated to regulate the load voltage. Moreover, the load current feedforward can improve the waveform quality of both the grid current in the grid-tied mode and the load voltage in the islanded mode.

REFERENCES


Authors:


D. Bheemaiah working as Associate Professor, Department of EEE in Talla Padmavathi College Of Engineering, Kazipet, Warangal.