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Power Quality Enhancement of a Grid-Following Inverter under Grid Voltage Unbalance and Impedance Uncertainty in Modern Energy Systems

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INTRODUCTION & AIM

Grid-connected inverters (GCIs) are very important components for the implementation of the integration of distributed generation systems with utility power grids. Unfortunately, three-phase grid voltages might be unbalanced as a result of possible faults, disturbances, or loading imbalance. Voltage unbalance leads to the appearance of power oscillations and causes performance deterioration of the inverter. Thus, high-performance GCIs should have the capability of working in a steady state in both balanced and unbalanced grids. The solution to this problem is provided by some different approaches that were studied in the literature. Direct Power Control (DPC) is extensively used for GCIs that work under unbalanced grid voltages. In [1], a DPC based on hysteresis comparators and a switching table was designed in the synchronous dq frame for the control of active and reactive power. This approach was modified in [2] using the sliding mode control in the stationary frame. Even though the approaches provide appropriate control of the currents and power, there is still the possibility of improvement for reducing power oscillations.

The research on the suppression of power oscillations in a three-phase grid-connected inverter using robust control has been carried out for the following purposes: to control the active power (P) in a constant value. An All-Pass Filter (APF) is utilized to separate the positive and negative sequence components of the grid voltage and current. On the other hand, the Phase Locked Loop (PLL) is used to follow the grid voltage angle.

METHOD

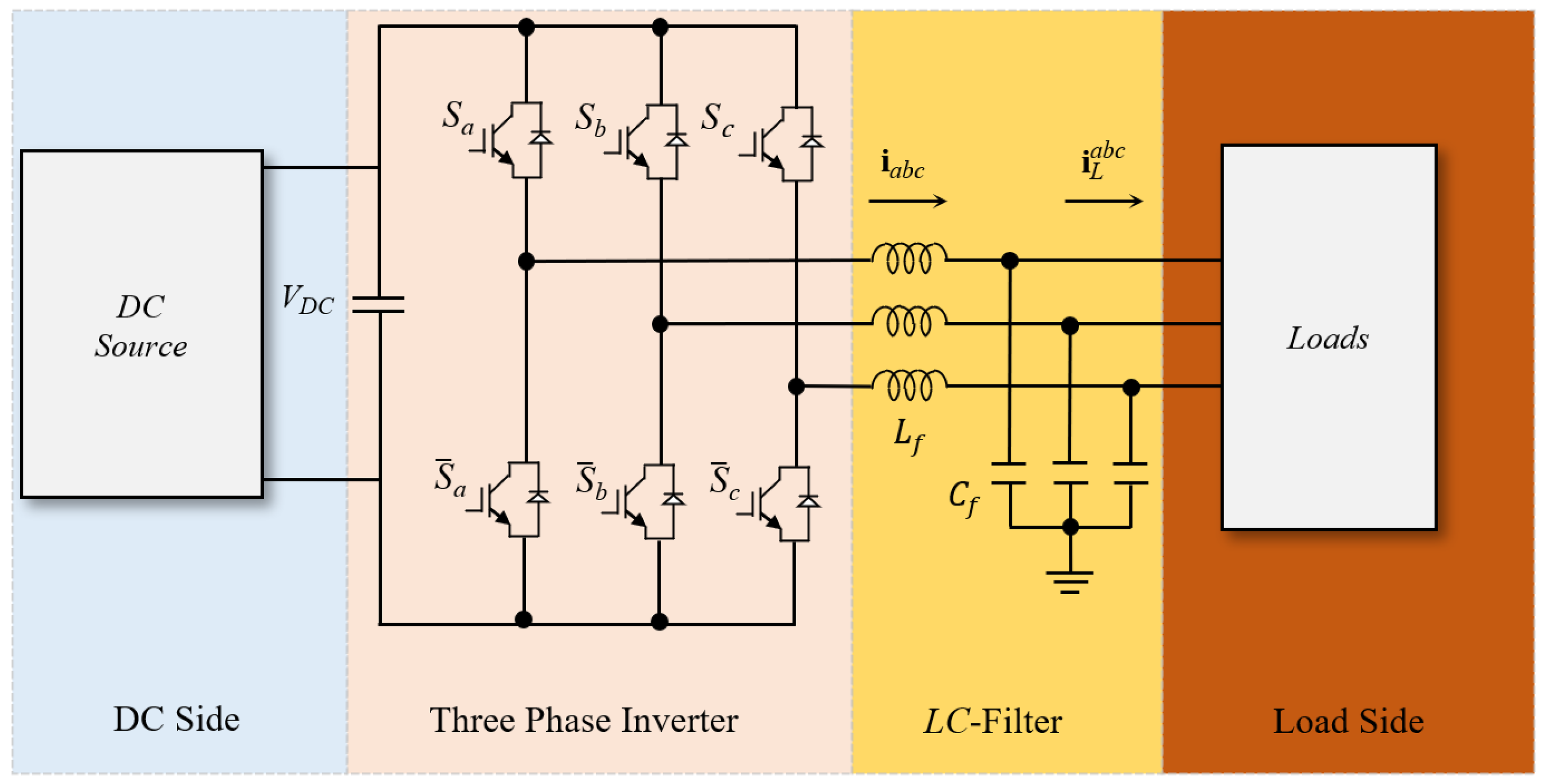

Figure 1. Topology of the three-phase Inverter with filter components and grid voltage unbalance.

RESULTS & DISCUSSION

In this section, the simulation results are presented and compared with the theoretical analysis to validate the proposed control strategy. The simulations were carried out using the PSIM simulation platform, while the MATLAB LMI Toolbox was employed to calculate the robust controller gains for each sequence component. The system parameters used in the study are listed in Table I. The control algorithm was implemented using a Dynamic Link Library (DLL) block developed in Microsoft Visual Studio, enabling efficient integration with the simulation environment. Furthermore, the sampling frequency was set to 10 kHz to ensure accurate digital control implementation and satisfactory dynamic performance.

Table 1. Simulation parameter of three-phase inverter with grid voltage unbalance system

Parameter	Value
DC link voltage Vdc	650V
DC link Capacitance	2200µF
Power Reference	1kW
Output frequency ω	100 πrad/s
Inductance L0	5mH
Resistance R	0.1Ω
ea	220V
eb	20V
ec	220V

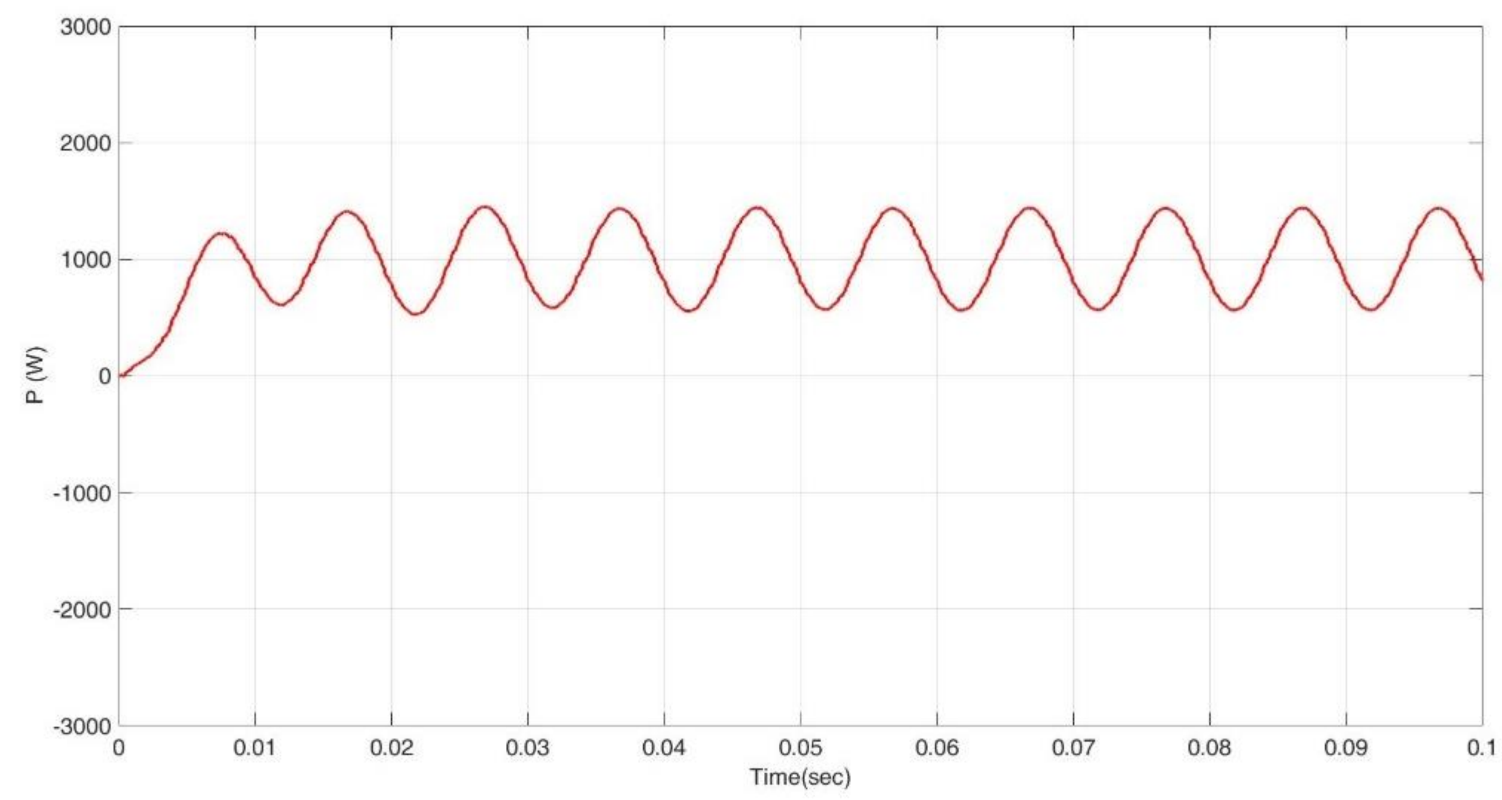

Figure 3. The Simulation for the three-phase Inverter grid power oscillation.

Case 1. The simulation for a three-phase inverter with a grid voltage unbalance system and power oscillation.

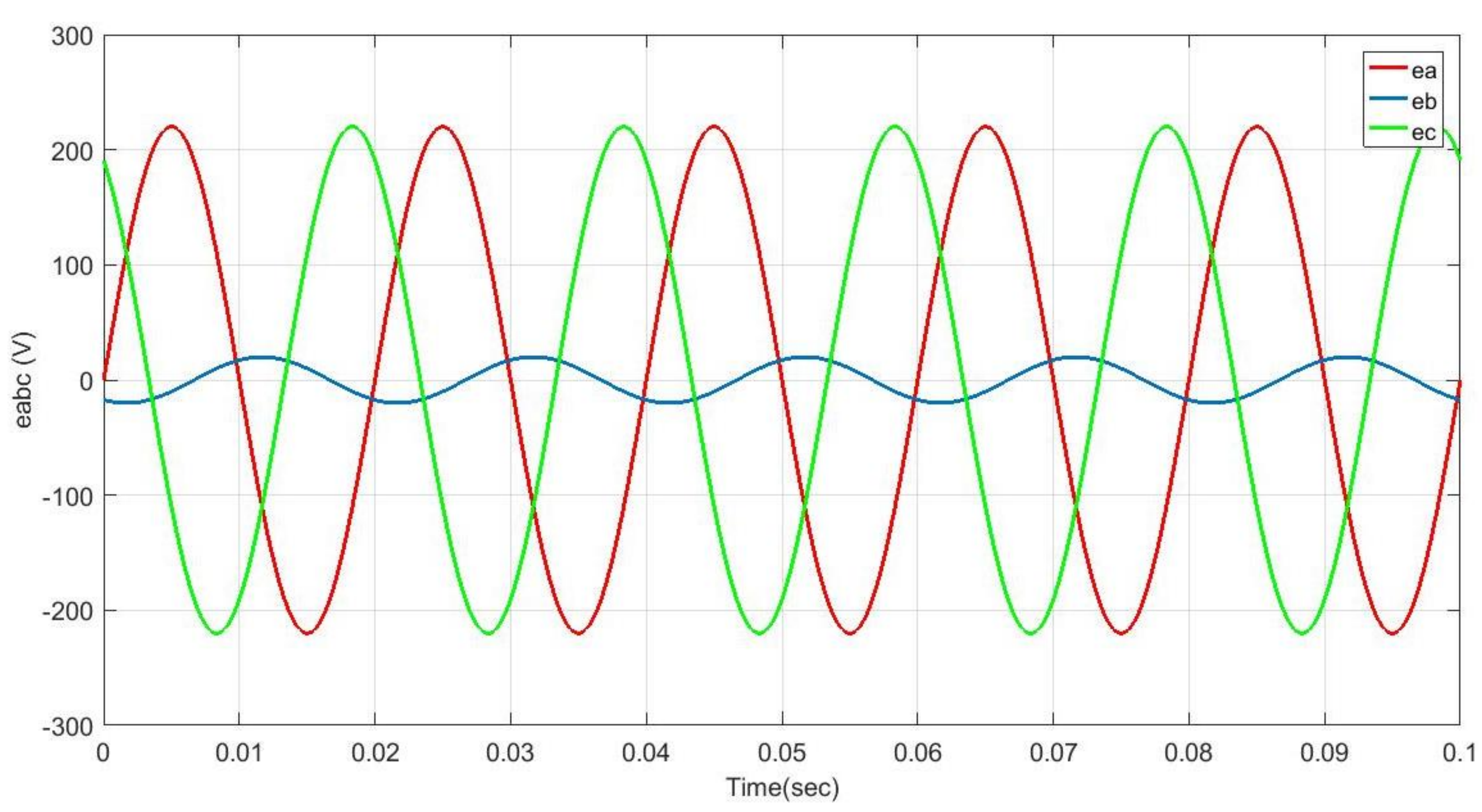

Figure 2. The Simulation for the three-phase Inverter grid voltage unbalance.

Case 2. The simulation for a three-phase inverter with a grid voltage unbalance and Control power to constant.

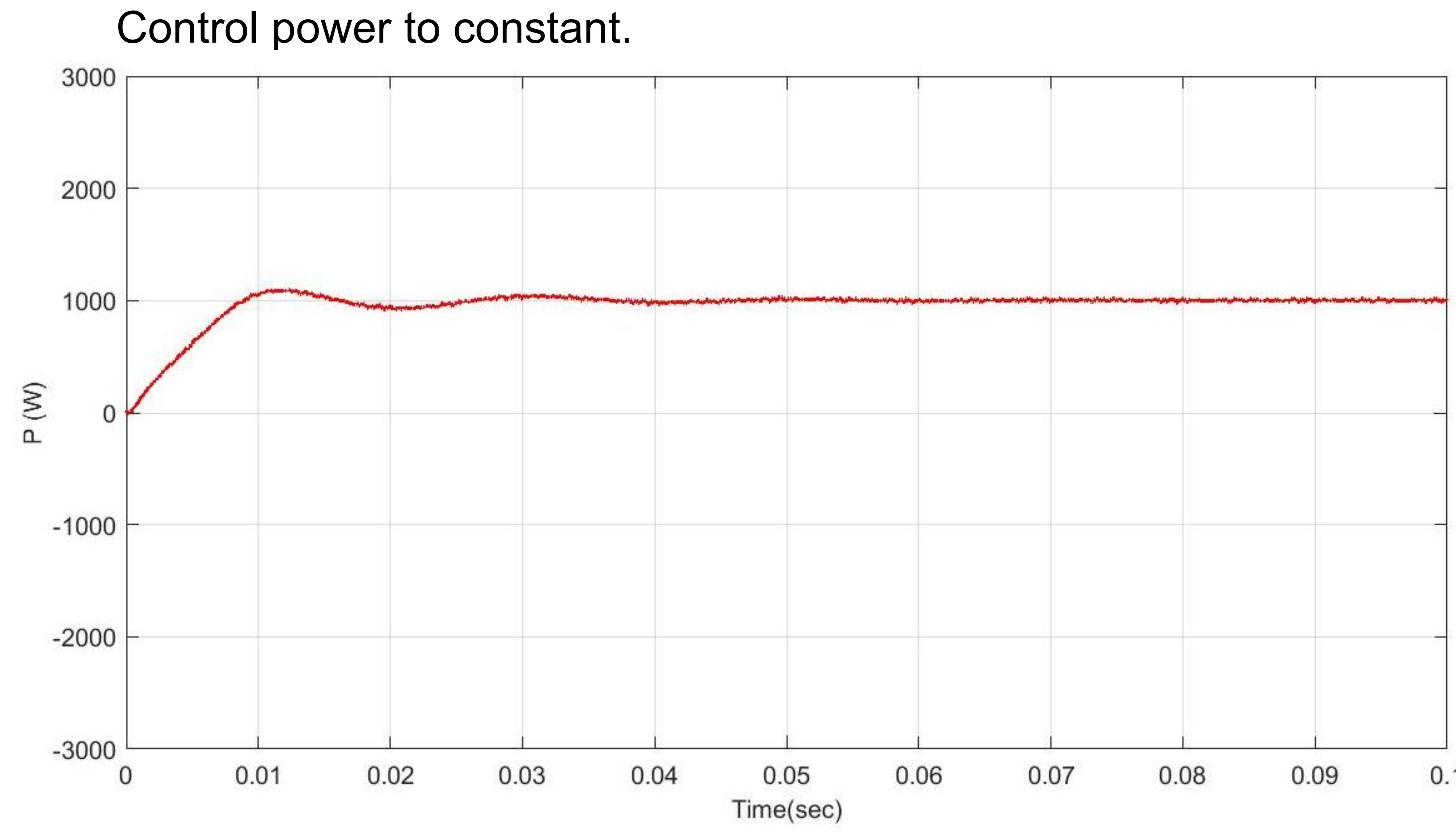

Figure 4. The Simulation for the three-phase Inverter grid for control power to constant.

CONCLUSIONS

This study has revealed the viability of using a robust control technique to mitigate the problem of power oscillation in a grid-connected three-phase inverter system under conditions of unbalanced voltage supply from the electricity grid. This method has been found to effectively control the active power (P), thus ensuring that there is very little power fluctuation even when the electrical network is experiencing voltage unbalance. The simulation findings have proved the analytical work done and show that robust control has reduced the active power fluctuations considerably.

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[2] Shang, L., Sun, D., Hu, J.: 'Sliding-mode-based direct power control of grid-connected voltage-sourced inverters under unbalanced network conditions', IET Power Electronics, 2011, 4, (5), pp. 570-579