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Hardware Implementation of Inverter-Interfaced Distributed Generation Units for Harmonic Current Filtering in Micro Grid

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Abstract

Harmonic current filtering and resonance damping have become important concerns in the operation and control of the islanded microgrids. To address these challenges, this paper proposes a control method for the inverter-interfaced distributed generation (DG) units to autonomously share the harmonic currents and resonance damping burdens. The approach employs a load compensator based on the decomposition of output current, inaddition to the outer droop-based power controller and the inner voltage and current controllers. The load compensator consists of a virtual-fundamental-impedance loop for the enhanced reactive power sharing and a variable-harmonic-impedance loop which al-lows to counteract the harmonic voltage drops across the grid-side inductance of the DG inverter and also to dampen out harmonic resonance propagation in the microgrid. Finally, the hardware implementation tests on a three-phase islanded microgrid setup are carried out to validate the performance of the proposed control scheme.

INTRODUCTION

THE MICROGRID paradigm is emerging as an attractive way to the future smart distribution grids, owing to its capability to operate in both grid-connected and islanded modes [1]. The dynamic islanding operations bring more flexibility to the integration of distributed generation (DG) units and provide a more reliable electricity service [2]. On the other hand, in islanded operations, the microgrids usually become much weaker than the traditional distribution grids, owing to the limited capacities of DG sources [3]. Consequently, the harmonic distortion tends to be more apparent in the islandedmicrogrids [4]. The presence of capacitive household loads, passive harmonic filters, and power factor correction (PFC) capacitors, as well as the parasitic capacitors in distribution feeders, can cause the low-order harmonic resonance with the line inductances [5]. Furthermore, a widespread use of inverters for interfacing DG units also bring harmonic interaction with other devices and even trigger resonances in the microgrid. The resonant frequencies may vary in a wide range depending on the number of the paralleled DG inverters. Therefore, the stringent requirements are being imposed on the ancillary services of DG inverters, such as the mitigation of circulating harmonic current, harmonic voltage reduction, and harmonic resonance damping [9], [10]. A number of research efforts have been made to address the aforementioned challenges [11]–[20]. In [11], the idea of a resistive– active power filter (R-APF) is implemented based on a high-bandwidth current controller, where DG inverters are controlled to behave as resistors at harmonic frequencies such that harmonic resonances and voltage distortions can be damped. To further autonomously share harmonic currents, a droop relationship between the output harmonic power of the DG inverter and the controlled harmonic resistance is built in [12]. However, it has been found that only the output voltage of the DG inverter can be regulated in this way, whereas the voltage at the point of connection (PoC) may be undamped when using the LCL filters [13]. The grid-side inductance in the LCL filters can lead to a mismatch between the emulated harmonic resistance and the characteristic impedance of the distribution line [14]. Another popular approach is the virtual output impedance concept, where a load current feed forward loop is introduced together with the output harmonic voltage controller [15]–[18]. This method is essentially a frequency-dependent voltage droop with the load current [18]. Either the virtual inductance or virtual resistance can be synthesized at the harmonic frequencies. As a consequence, the additional harmonic voltage distortion is inevitable and can become severe when a large virtual inductance is needed to attenuate the differences among the grid-side inductances in the LCL filters of DG inverters. To alleviate the adverse effect of the grid-side inductance, a PoC voltage feed forward control scheme is reported in [19]. With a positive gain Gin the PoC volt-age feed forward loop, the harmonic impedance seen from the PoC of the DG unit is scaled down by1/(1 +G). However, the performance of this scheme is limited to the damping of harmonic resonance due to the absence of the additional harmonic resistance. Considering the impact of the grid-side inductance in the LCL filter and the demand of harmonic resonance damping, a variable harmonic impedance (VHI) concept is developed for a single grid-interactive DG inverter [20], which comprises positive resistance and negative inductance at the dominant harmonic frequencies. In this paper, this concept is extended for an islanded microgrid with multiple DG inverters, and an autonomous control method of the DG inverters is proposed for the sharing of harmonic currents and harmonic resonance damping. The approach employs a frequency- and sequence-dependent load compensator that is composed of the virtual fundamental impedance (VFI) and VHI loops. The VFI loop improves the performance of the active power–frequency (P−ω) and reactive power–voltage (Q−V) droop controllers and mitigates the negative-sequence circulating current [21]. The VHI loop compensates for a portion of the grid-side inductance at the dominant harmonic frequencies and achieves a proper sharing of harmonic currents among all the DG inverters. Furthermore, in the presence of harmonic resonance, the VHI loop can shift the resonant points toward a higher frequency range where the harmonic resonance can be more easily damped. Laboratory test results are shown to validate the performance of the proposed control scheme.

EXISTING SYSTEM:

LCLfilter and the demand of harmonic resonance damping, a variable harmonic impedance (VHI) concept is developed for a single grid-interactive DG inverter [20], which comprises positive resistance and negative inductance at the dominant harmonic frequencies. In this paper, this concept is extendedfor an islanded microgrid with multiple DG inverters, and an autonomous control method of the DG inverters is proposed for the sharing of harmonic currents and harmonic resonance damping.

Proposed system:

The VFI loop improves the performance of the active power–frequency (P−ω) and reactive power–voltage (Q−V) droop controllers and mitigates the negative-sequence circulating current [21]. The VHI loop compensates for a portion of the grid-side inductance at the dominant harmonic frequencies and achieves a proper sharing of harmonic currents among all the DG in-verters. Furthermore, in the presence of harmonic resonance, the VHI loop can shift the resonant points toward a higher frequency range where the harmonic resonance can be more easily damped. Laboratory test results are shown to validate the performance of the proposed control scheme.

HARMONIC CURRENT FILTERING AND RESONANCE DAMPING APPROACHES

This section reviews two autonomous control approaches for harmonic current filtering and resonance damping in an islanded microgrid. The effect of grid-side inductance in the LCLfilter of the DG inverter is discussed. A. System Configuration illustrates an example of a low-voltage microgrid dominated by multiple inverter-interfaced DG units. A static switch is used to dynamically disconnect the microgrid from the upstream distribution system during abnormal conditions. For the local and common loads, the diode rectifiers denote the nonlinear loads, while the shunt capacitors represent the capacitive household loads and the parasitic capacitors in the distribution feeders. During islanded operations, the microgrid voltage usually becomes more distorted due to the limited capacities of DG sources..

Circuit diagram:

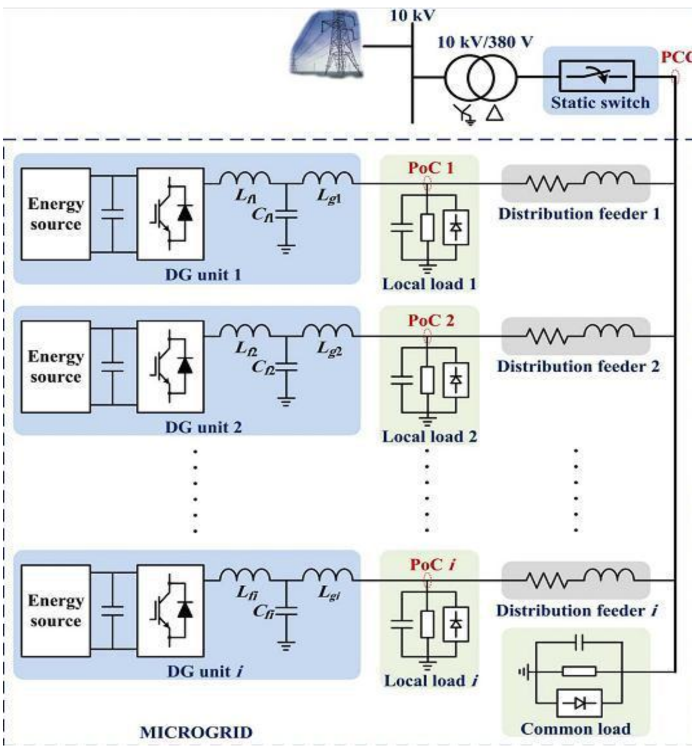

Figure 1. A low-voltage microgrid dominated with multiple inverter-interfaced DG units.

Also, the presence of shunt capacitors can result in harmonic resonance and propagation in the microgrid. As a consequence, the mitigation of circulating harmonic current among all the DG units is needed to prevent the overloading of some DG inverters, and meanwhile, the effective resonance damping measures are also important to suppress harmonic voltage amplifications. B. R-APF-Based Approach illustrates the block diagram of the R-APF-based control approach for the DG unit. The dc-link voltage of the DG inverter is regulated on the energy source side and is assumed to be constant. The basic idea behind this method is to make the DG inverter operate as a resistor at the harmonic frequencies. It is realized by multiplying the output harmonic voltages of a DG inverter with a conductance, which is then passed through a high-bandwidth current controller [11].

The sharing of harmonic currents in the paralleled DG inverters is achieved by a harmonic var–conductance (Hi−Gi) droop [12]. Under this control scheme, Depicts the equivalent circuit of the islanded microgrid at the harmonic frequencies, where nonlinear loads are equivalent to the harmonic current sources for the sake of simplicity. It is worthy to note that the sharing of harmonic current among the DG inverters not only depends on the emulated conductance Gi but also is subject to the grid-side inductance of the LCL filter, which differs from the islanded network considered in [12]. On the other hand, the grid-side inductance affects the characteristic impedance

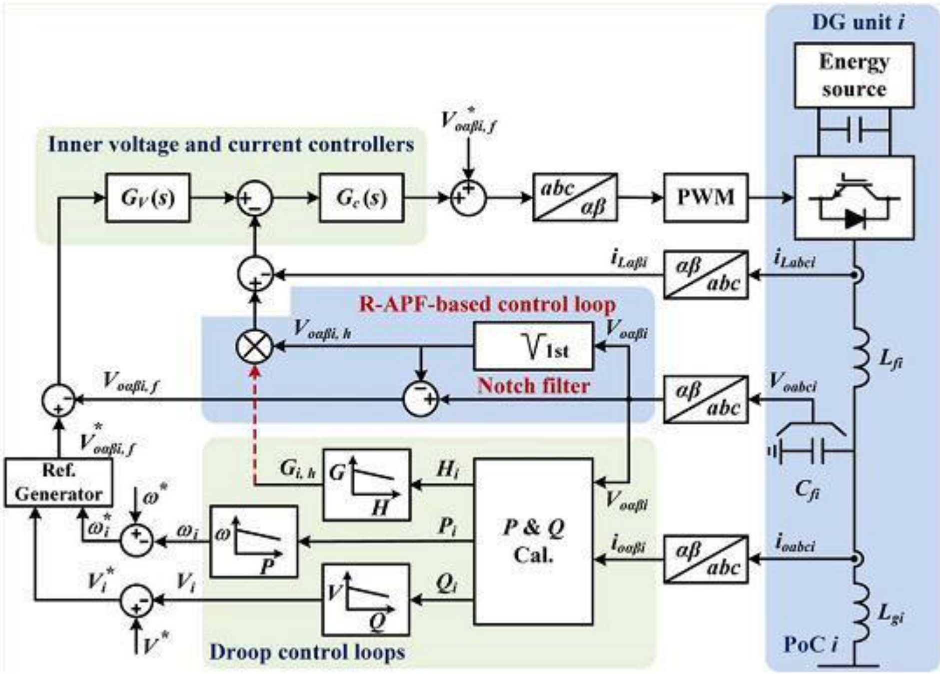

Figure 2. Control block diagram of the R-APF-based approach.

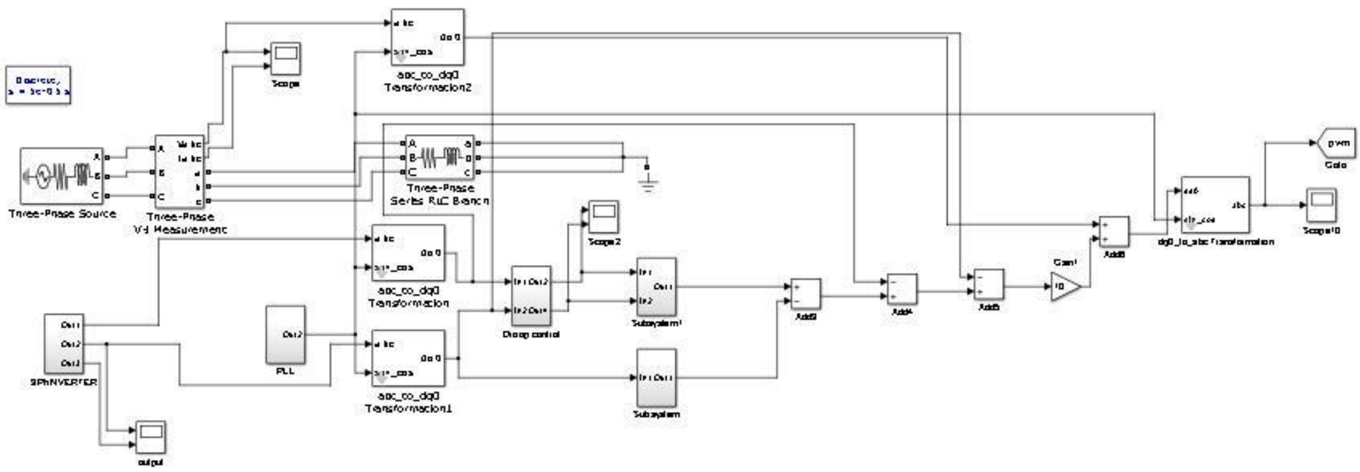

Figure 3. Simulation

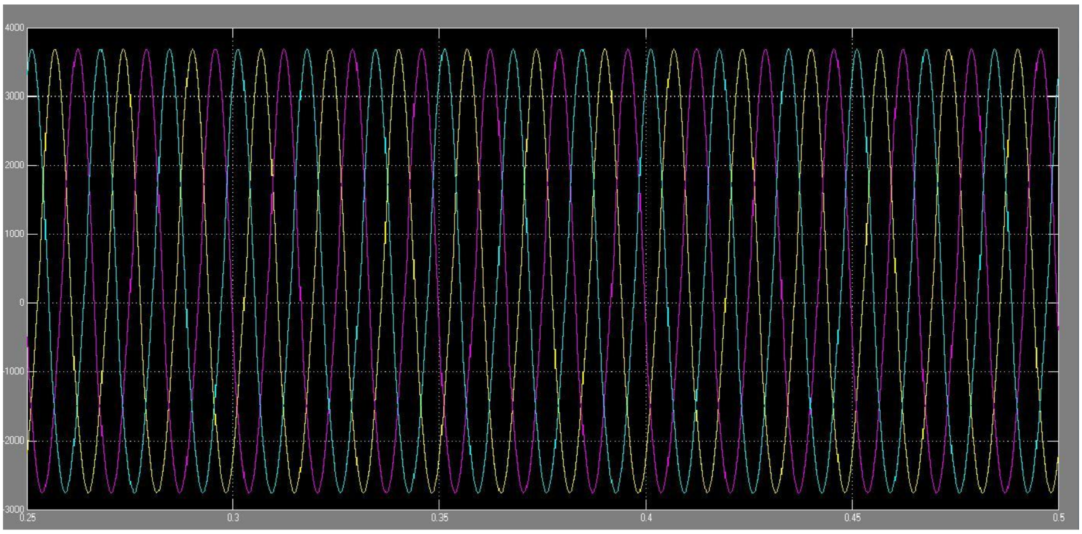

Figure 3.1. Source scope

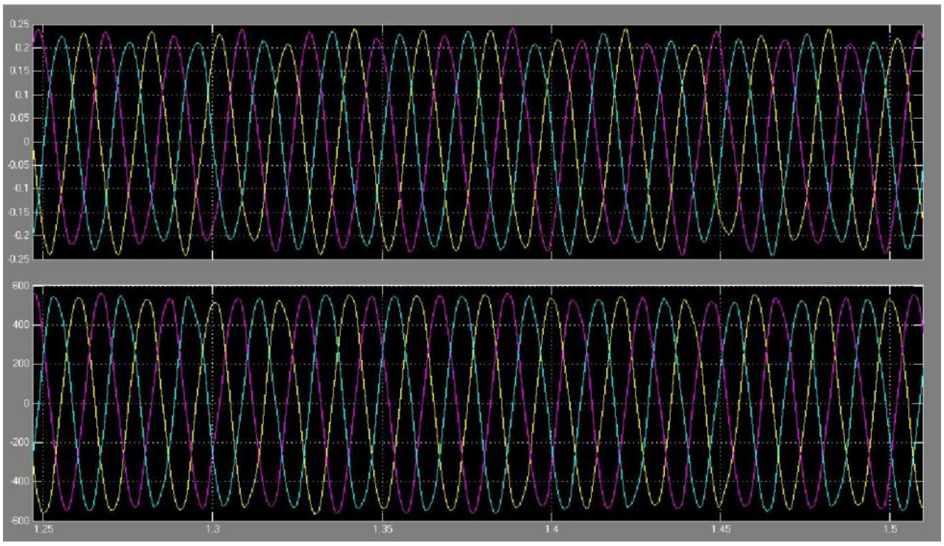

Figure 3.2. Output scope

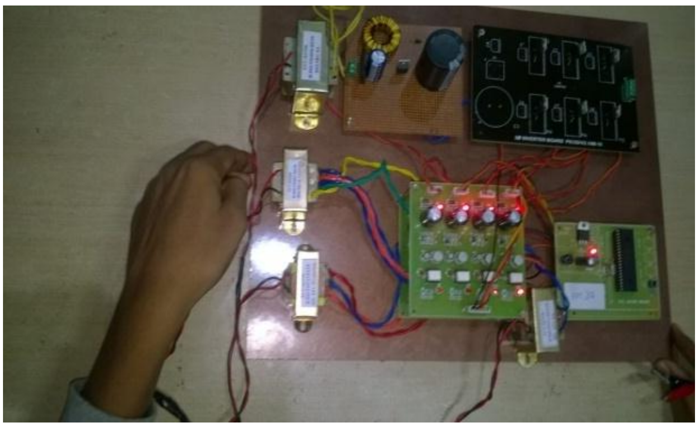

Figure 3.3. Hardware Module

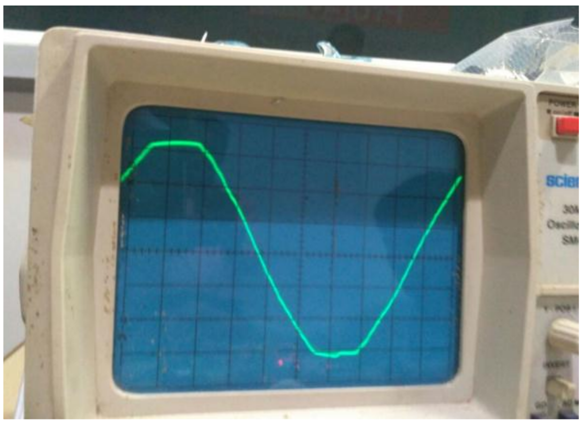

Figure 3.4. Hardware Output

Output of the Hard ware implementation without harmonics – Harmonics in the Micro grid system was eliminated and the graph shows the Harmonics reduced output

CONCLUSION

This paper has discussed harmonic current filtering and resonance damping methods of inverter-interfaced DG units in an islanded microgrid. First, the block diagrams of the R-APF-based approach and the conventional virtual output impedance schemes were presented. The adverse effects of a large grid-side inductance on these two methods have been pointed out. Then, to overcome the problems in the presence of large grid-side inductances, a load compensator including a VFI loop and a VHI loop was proposed. It has been shown that the negative inductances in the VHI loop can effectively counteract the harmonic voltage drops across the grid-side inductance, while the positive harmonic resistances achieve harmonic current filtering and resonance damping. Finally, the hardware implementation was done and test the islanded three-phase microgrid are performed to validate the theoretical analysis and harmonics in the Micro grid system was eliminated and the graph shows the harmonics reduced output this is the expected performance of the proposed control method.

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