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Solar Grid Connected Harmonic Filtering Using Current-Controlled Closed System

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ABSTRACT:

The increasing application of nonlinear loads may cause distribution system power quality issues. In order to utilize distributed generation (DG) unit interfacing converters to actively compensate harmonics, this paper proposes an enhanced current control approach, which seamlessly integrates system harmonic mitigation capabilities with the primary DG power generation function. As the proposed current controller have two well decoupled control branches to independently control fundamental and harmonic DG currents, local nonlinear load harmonic current detection and distribution system harmonic voltage detection are not necessary for the proposed harmonic compensation method. Moreover, a closed-loop power control scheme is employed to directly derive the fundamental current reference without using any phase-locked loops (PLL). The proposed power control scheme effectively eliminates the impacts of steady-state fundamental current tracking errors in the DG units. Thus, an accurate power control is realized even when the harmonic compensation functions are activated. In addition, this paper also briefly discusses the performance of the proposed method when DG unit is connected to a grid with frequency deviation. Simulated and experimental results from a single-phase DG unit validate the correctness of the proposed methods.

Index Terms—*Active power filter, distributed generation, harmonic compensation, harmonic extraction, phase-locked loop (PLL), resonant controller, virtual impedance.*

INTRODUCTION:

Due to the growing importance of renewable-energy-based power generation, a large number of power electronics interfaced DG units have been installed in the low-voltage power distribution systems [1]. It has been reported that the control of interfacing converters can introduce system resonance issues [2]. Moreover, the increasing presence of nonlinear loads, such as variable-speed drives, light-emitting diode (LED) lamps, compact fluorescent lamps (CFLS), etc., will further degrade distribution system power quality.

To compensate distribution system harmonic distortions, a number of active and passive filtering methods have been developed [3]. However, installing additional filters is not very favorable due to cost concerns. Alternatively, distribution system power quality enhancement using flexible control of grid connected DG units is becoming an interesting topic [5]–[12], where the ancillary harmonic compensation capability is integrated with the DG primary power generation function through modifying control references. This idea is especially attractive considering that the available power from backstage renewable energy resources is often lower than the power rating of DG interfacing converters.

For the local load harmonic current compensation methods as discussed in [5]–[12], an accurate detection of local load harmonic current is important. Various types of harmonic detection methods [4] have been presented, such as the Fourier transformation based detection method in [13], the detection scheme using instantaneous real and reactive power theory in [14], second-order generalized integrator (SOGI) in [15],

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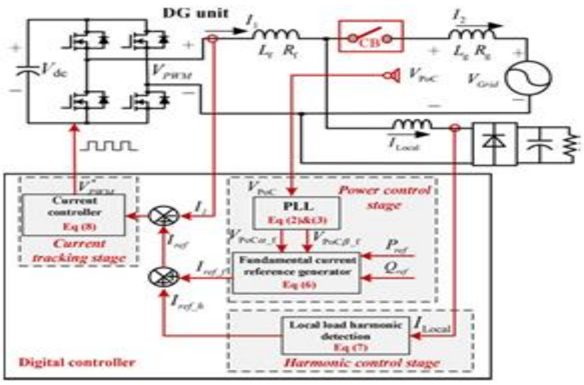
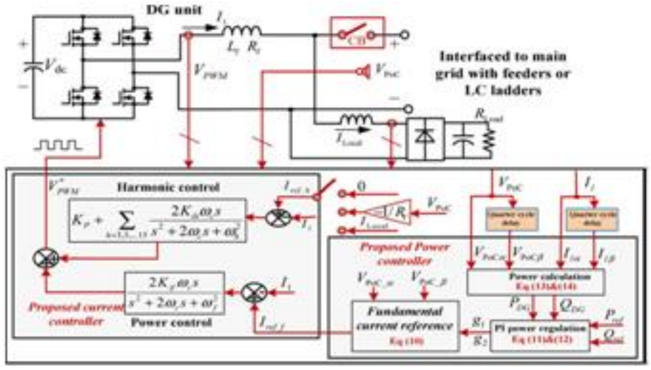
and the delayed-signal-cancellation-based detection in [11]. Nevertheless, harmonic extraction process substantially increases the computing load of DG unit controllers. For a cost-effective DG unit with limited computing ability, complex harmonic extraction methods might not be acceptable. Alternatively, an interesting harmonic detection less method was proposed in [6] and [1]. It shows that the main grid current can be directly controlled to be sinusoidal, instead of regulating DG output current to absorb local load harmonics. In this scenario, local load current is essentially treated as a disturbance in the grid current regulation loop. It should be noted that DG system normally has smaller stability margin when the direct control of grid current is employed. In addition, for the shunt active harmonic filtering via point of connection (PoC) harmonic voltage detection (also named as resistive active power filter (R-APF) in [12] and [2]), the control techniques in [9] and [15] cannot be used. Alternatively, the recently proposed hybrid voltage and current control method (HCM) [3] also allows the compensation of local load harmonics without using any harmonic detection process, where the well-understood droop control scheme [2] is adopted to regulate the output power of the DG unit. Further considering that droop-control-based DG unit often features slow power control dynamics [1] and current-controlled DG units are more widely installed in the distribution system, developing a robust current-control-based harmonic compensation method without using any system harmonic detection is very necessary.

PROPOSED CONTROL BLOCK DIAGRAM:



CIRCUIT DIAGRAM:



DG UNITS WITH HARMONIC COMPENSATION

In this section, a DG unit using the compensation strategies in the conventional active power filters is briefly discussed. Afterward, a detailed discussion on the proposed control strategy is presented.

A. Conventional Local Load Harmonic Current Compensation

The Figure illustrates the configuration of a single-phase DG system, where the interfacing converter is connected to the distribution system with a coupling choke (Lf and Rf). There is a local load at PoC. In order to improve the power quality of grid current (I2), the harmonic components of local load current (ILocal) shall be absorbed through DG current (I1) regulation.

The DG unit control scheme is illustrated in the lower part. As shown, its current reference consists of two parts. The first one is the fundamental current reference (Iref f), which is synchronized with PoC voltage (VPoC) as

$$I_{ref\_f} = \frac{\cos(\theta) \cdot P_{ref} + \sin(\theta) \cdot Q_{ref}}{E^*} \quad (1)$$

where θ is the PoC voltage phase angle detected by PLL,Pref and Qref are the real and reactive power references, and E∗ is the nominal voltage magnitude of the system.

However, the current reference generator in (1) is not accurate in controlling DG power, due to variations of

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the PoC voltage magnitude. To overcome this drawback, an improved power control method with consideration of PoC voltage magnitude fluctuations [11] was developed as shown in Section II-B.

First, the fundamental PoC voltage VPoCα f and its orthogonal component VPoCβ f (quarter cycle delayed respect to VPoCα f) are obtained by using SOGI [15] as

$$V_{\mathrm{PoC}\alpha\_f} = \frac{2\omega_{D1}s}{s^2 + 2\omega_{D1}s + \omega_f^2} \cdot V_{\mathrm{PoC}} \qquad (2)$$

$$V_{\mathrm{PoC}\beta\_f} = \frac{2\omega_{D1}\omega_f}{s^2 + 2\omega_{D1}s + \omega_f^2} \cdot V_{\mathrm{PoC}} \qquad (3)$$

where ωD1 is the cutoff bandwidth of SOGI and ωf is the fundamental angular frequency.

For a single-phase DG system, relationships between the power reference and the fundamental reference current can be established in the artificial stationary α − β reference frame as follows:

Pref = ½ · (VPoCα f · Irefα f + VPoCβ f · Irefβ f) (4)

Qref = ½ · (VPoCβ f · Irefα f − VPoCα f · Irefβ f) (5)

where Irefα f and Irefβ f are the DG fundamental current reference and its orthogonal component in the artificial α − β reference frame. Similarly, VPoCα f and VPoCβ f are PoC fundamental voltage and its orthogonal component, respectively.

According to (4) and (5), the instantaneous fundamental current reference (Iref f) of a single-phase DG unit can be obtained as

$$I_{\mathrm{ref}\_f} = I_{\mathrm{ref}\alpha\_f} = \frac{2(V_{\mathrm{PoC}\alpha\_f} \cdot P_{\mathrm{ref}} + V_{\mathrm{PoC}\beta\_f} \cdot Q_{\mathrm{ref}})}{V_{\mathrm{PoC}\alpha\_f}^2 + V_{\mathrm{PoC}\beta\_f}^2} \qquad (6)$$

Moreover, to absorb the harmonic current of local nonlinear load, the DG harmonic current reference (Iref h) is produced

$$I_{\mathrm{ref}\_h} = G_D(s) \cdot I_{\mathrm{Local}} = \sum_{h=3,5,7,9,\ldots} \frac{2\omega_{D2}s}{s^2 + 2\omega_{D2}s + \omega_h^2} \cdot I_{\mathrm{Local}} \qquad (7)$$

where GD (s) is the transfer function of the harmonic extractor.

To realize selective harmonic compensation performance [2],[5], GD (s) is designed to have a set of band pass filters with cutoff frequency ωD2 .

With the derived fundamental and harmonic current references, the DG current reference is written as Iref = Iref f +Iref h . Afterward, the proportional and multiple resonant controllers[12], [8]–[2] are adopted to ensure rapid current tracking

$$V_{\mathrm{PWM}}^* = G_{\mathrm{cur}}(s) \cdot (I_{\mathrm{ref}} - I_1) = \left(K_p + \sum_{h=f,3,5,\ldots,15} \frac{2K_{ih}\omega_c s}{s^2 + 2\omega_c s + \omega_h^2}\right) \cdot (I_{\mathrm{ref}\_f} + I_{\mathrm{ref}\_h} - I_1) \qquad (8)$$

where V_P* is the reference voltage for pulsewidth modulation (PWM) processing, Kp the proportional gain of the current controller Gcur (s),Kih the resonant controller gain at the order h, ωc the cutoff frequency of the resonant controller, and ωh is the angular frequency at fundamental and selected harmonic frequencies.

B. Conventional Feeder Resonance Voltage Compensation

It should be pointed out that the objective of local load harmonic compensation is to ensure sinusoidal grid current I2 in above Figure. In this control mode, DG unit should not actively regulate the PoC voltage quality. As a result, the PoC voltage can be distorted especially when it is connected to the main grid through a long underground cable with nontrivial parasitic capacitance [8], [3]. In this case, the feeder is often modeled by an LC ladder [12], [6]. To address the resonance issue associated with long underground cables, the R-APF concept can also be embedded in

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the DG unit current control. Compared to the DG harmonic current reference in this case is modified as

$$I_{ref\_h} = \left(-\frac{1}{R_V}\right) \cdot \left(G_D(s) \cdot V_{PoC}\right) \quad (9)$$

where RV is the virtual damping resistance at harmonic frequencies.

SOFTWARE REQUIREMENTS:

- MATLAB – SIMULINK
- Or cad / PSpice

HARDWARE REQUIREMENTS:

- passive components,mosfet,PIC

ADAVANTAGES:

- Low harmonics distortion
- Accurate power control
- Efficiency is high

APPLICATION:

- MICRO GRID
- LED
- DG –GRID INTEGRATION
- VARIABLE SPEED DRIVES

SIMULATION RESULTS

Simulation Diagram:

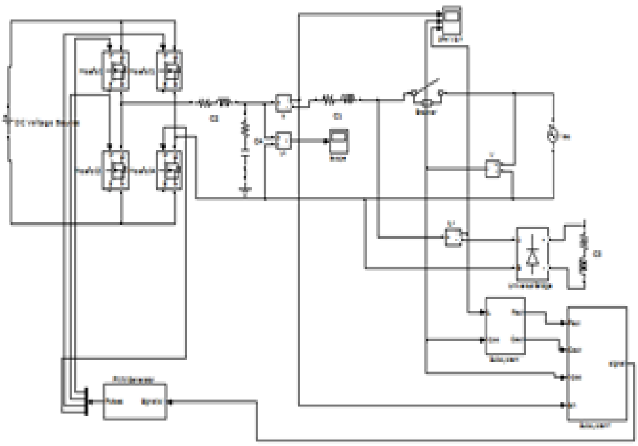
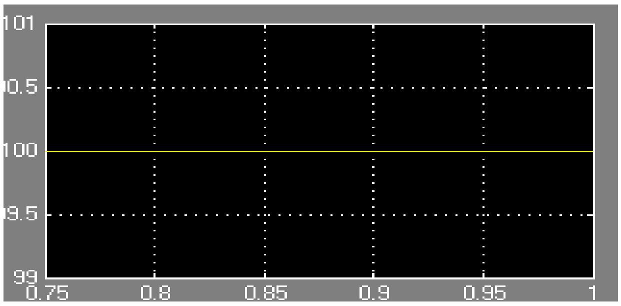
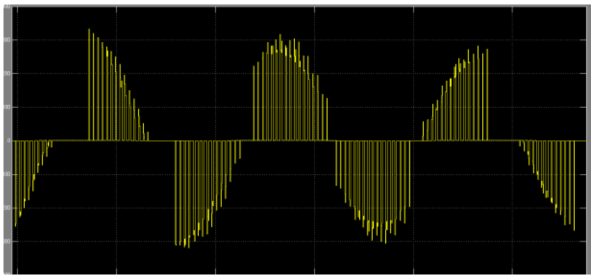


Fig:simulation circuit diagram for active harmonic compensator for DG connected unit.

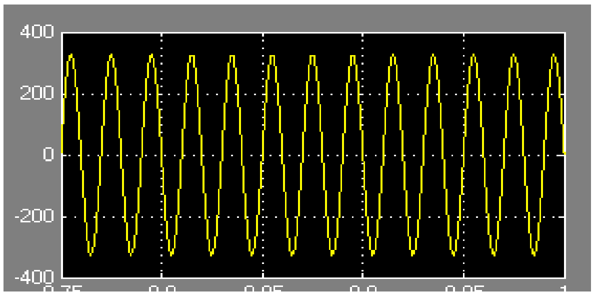
DC Link Voltage Across The Capasitor



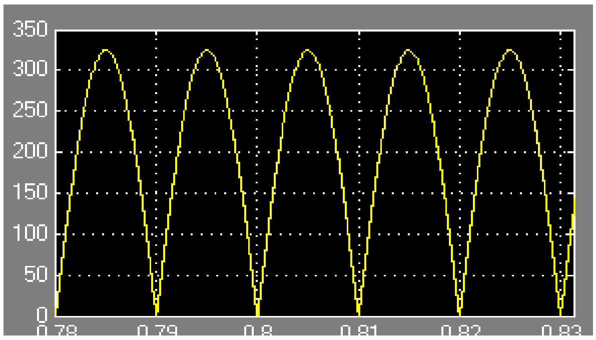
Currents



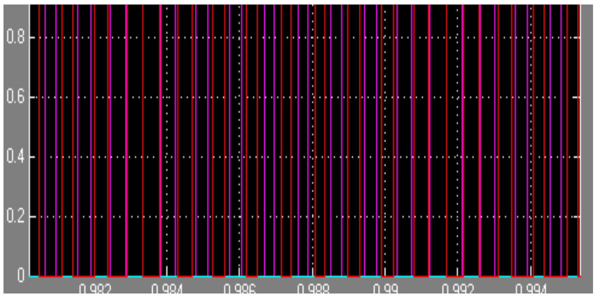
POC voltage



Voltage across Non linear load



PWM pulses



CONCLUSION

In this paper, a simple harmonic compensation strategy is proposed for current-controlled DG unit interfacing converters. By separating the conventional proportional and multiple resonant controllers into two parallel control branches, the proposed method realizes power control and harmonic compensation without using any local nonlinear load harmonic current extraction or PoC harmonic voltage detection. Moreover, the input of the fundamental power control branch is regulated by a closed-loop power control scheme, which avoids the adoption of PLLs. The proposed power control method ensures accurate power control even when harmonic compensation tasks are activated in the DG unit or the PoC voltage changes. Simulated and experimental results from a single-phase DG unit verified the feasibility of the proposed strategy.

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BIOGRAPHIES

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