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VOLTAGE UNBALANCING CORRECTION USING GRID INTERFACE INVERTER WITH DUAL FREQUENCY HARMONICS

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ABSTRACT

This paper proposes a three phase grid impedance detection method based on dual frequency harmonic current injection for islanding detection is reliable and feasible than single harmonic current injection.In this paper, the detailed control of grid-interfacing inverters supporting negative-sequence voltage correction has been presented from basic principle. Based on the voltage unbalance factor and the system's capacity, the inverter absorbs a small amount of negative-sequence current from the grid, thereby correcting the negative sequence voltage voltage at the PoC. By using many of these modules, a substantial improvement is possible. Furthermore, the improved multi-variable filter can filter out positive- and negative-sequence components accurately in case of unbalanced/distorted situations in the stationary frame. Hence the functionality and control scheme of voltage unbalance correction using interfacing inverter are verified by simulation results are shown.

I. INTRODUCTION

For practical three-phase power systems, problems of voltage unbalance exist. The problems are mainly caused by unbalanced distribution of single-phase and nonlinear loads. Together, these induce unequal voltage drops across transformers and line impedances. These negative sequence voltages are especially troublesome in practical applications, contrary to zero-sequence components which do not exist in three-wire systems. The effects of voltage unbalance are quite severe for electrical machines, power electronic converters, and drives. There are power electronic converters designed for mitigation of voltage unbalance of the utility grid that work by regulating reactive power, but this approach is not suitable for underground cables where the resistance of a cable dominates its inductance. To maintain a balanced voltage at the load terminals, an often used idea is to inject a series voltage It is straightforward to mitigate the voltage unbalance problem with such converters, but a disadvantage is that they are unused or only lightly loaded when there are no voltage unbalance problems. For dealing with other power quality problems than voltage unbalance, so-called unified power quality conditioners (UPQC) are proposed and continuously improved. However, the UPQC has no energy storage capabilities, and should be extended to cope with distributed generation (DG). Facing the emerging application of distributed generation, power electronics-based grid-interfacing inverters are playing an important role interfacing DGs to the utility grid. In addition to conventional delivery of electricity, ancillary functionality for improvement of power quality problems is being introduced into grid-interfacing inverters . In this paper, it is proposed to integrate voltage unbalance correction into the control of grid-interfacing inverters. This does not require more hardware, since the feedback variables for this control are already available. By controlling the negative-sequence currents, which induce opposite negative-sequence voltage drops on the line impedances, the objective of eliminating negative sequence voltages at the point of connection (PoC) with the grid may be achieved. To investigate the effectiveness of the proposed function, a three-phase three-wire inverter is used to control voltage unbalance correction. The employed inverter operates normally when the utility voltages are balanced, and when unbalanced, performs compensation automatically for negative-sequence voltage, based on utility voltage unbalance factor (VUF).

II. GRID-INTERFACING INVERTER WITH INTEGRATED VOLTAGE UNBALANCE CORRECTION

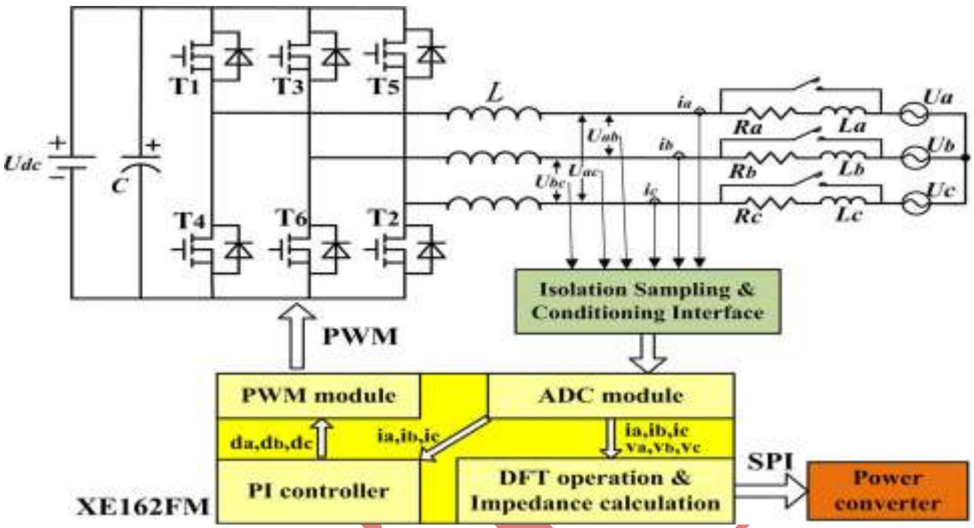

Fig 1: Block Diagram Of Grid Interfacing Inverter With Integrated Voltage Unbalanced Condition

Fig 1 shows the structure of a three-phase three-wire grid-interfacing system being connected to the utility grid at the POC through LCL filters. It normally synchronizes with the utility grid and delivers electrical energy to the grid from the DC-bus when pre-regulated distributed sources are connected. The voltage unbalance correction function is added, which intentionally regulates negative sequence currents. Note that, in order to obtain a maximum power factor, most grid-interfacing inverters deliver only positive-sequence currents under either balanced or unbalanced conditions. Therefore, the development of this proposed controller differs from the conventional one, and its design will be presented in the next sections of this paper. In view of unbalanced situations, a three-leg inverter topology is used as the circuit to eliminate zero-sequence currents. Similarly, zero-sequence voltages at the PoC can be compensated by regulating the zero-sequence currents within the system. This paper only concentrates on the correction of negative-sequence voltages, considering zero-sequence voltages do not exist in case of three wire systems. Of course, zero-sequence voltages can be isolated by transformers when needed. Furthermore, it is noted that measurements of zero-sequence components can be done simply by adding three-phase quantities, M while accurate positive- and negative-sequence components are difficult to be determined. Therefore, zero sequence voltage correction can be trivially added to the control based on the proposed control scheme for negative-sequence voltage correction and is not discussed in this paper. The equivalent line impedance is represented by Zg, the equivalent impedance of the utility grid when the line impedances of the three phases are assumed symmetrical. Accordingly, a phasor diagram showing the change for negative-sequence fundamental current is drawn in Fig.3. By changing the amplitude and phase of the negative sequence current I − s , the negative-sequence voltage V− s can be regulated through the voltage drops across the line impedance. For a given amplitude I − s , the voltage changes along the dashed circle and reaches a minimum value at the point M where θ− (the phase angle between negative sequence voltage and current) equals the negative of impedance angle of Zg’s.

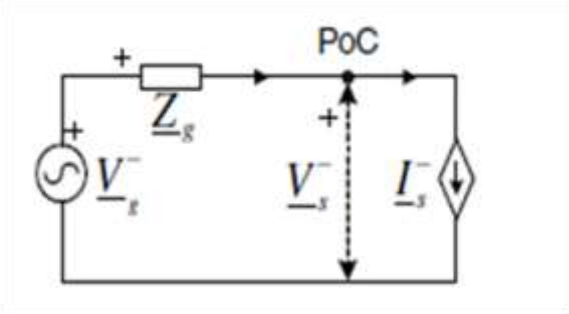

Fig. 2 Negative Sequence Equivalent Model

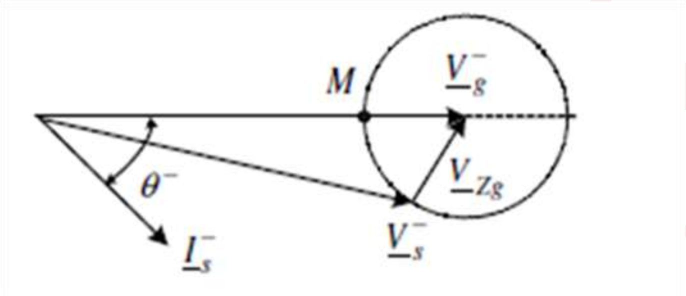

Fig. 3 Phasor Diagram of the Negative Sequence Model

III. CONTROL SCHEME

3.1 Determination of Negative-Sequence Currents

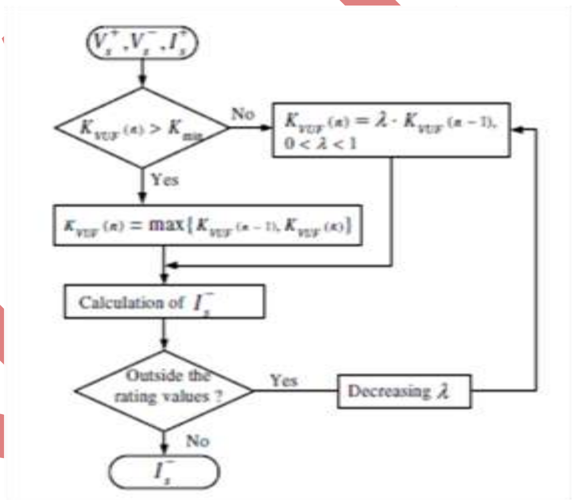

Fig. 4 Flow Chart of KVUF Determination

The factor KVUF is essential to get the amplitude of negative-sequence currents. Thus the separation of sequence voltages is central to get the value of KVUF, as well as to the synchronization with the utility grid. For unbalanced or distorted grid voltages, a multi-variable filter was introduced for detecting the positive-sequence component in the stationary frame. After modification, this filter is able to directly filter out the fundamental positive and negative-sequence vectors. The following mathematically demonstrates the multi-variable filter for symmetric sequence decomposition. For unbalanced distorted voltages, the positive- and negative-sequence components are in the $\alpha - \beta$ frame is

$$\underline{v}_{\alpha\beta}(t) = v_\alpha(t) + jv_\beta(t) = \sum_{k=1}^{\infty} \left(\underline{V}_k^{+} e^{jk\omega_1 t} + \underline{V}_k^{-\circ} e^{-jk\omega_1 t}\right), \qquad (2)$$

Where k denotes the harmonic number, ω1 denotes the fundamental radian frequency, and the superscript symbol "o" denotes conjugate. Let us look for a filter G+(t), which can damp all harmonic components of Vαβ (t) but the fundamental positive-sequence component in the stationary frame.

IV. SIMULATION AND EXPERIMENTAL RESULTS

Simulation results from PSIM7.0 are provided to enable the verification of the reference signals generation. System parameters are shown in Table I. In order to easily observe the effects of negative-sequence correction, we intentionally exaggerated the values of the line inductances to the same order as the filter inductors. Therefore, the inductors Lsa,b,c are combined with the line impedances, reducing the LCL structure to an LC one.

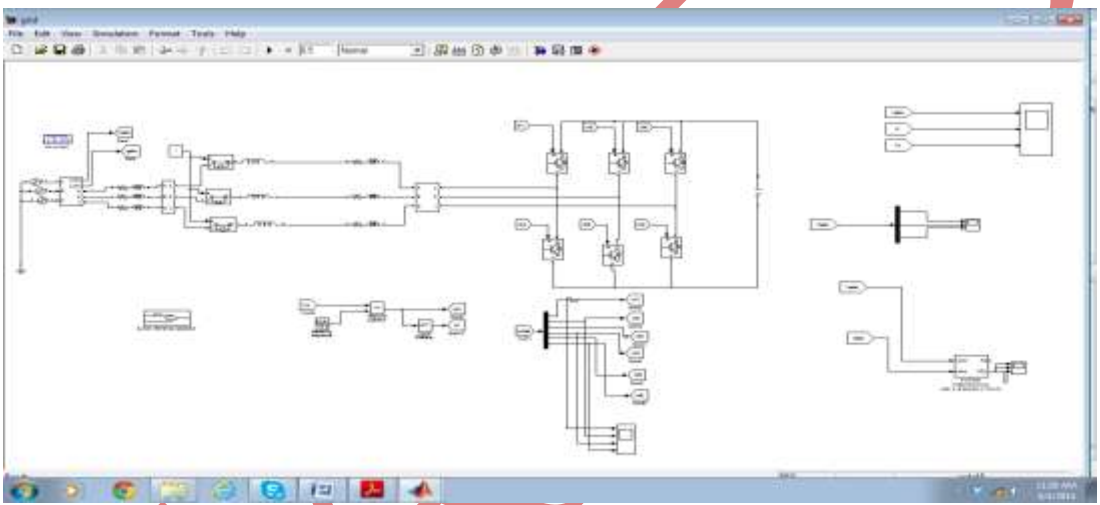

Fig 5: Block Diagram of Control Grid Connected Interfacing

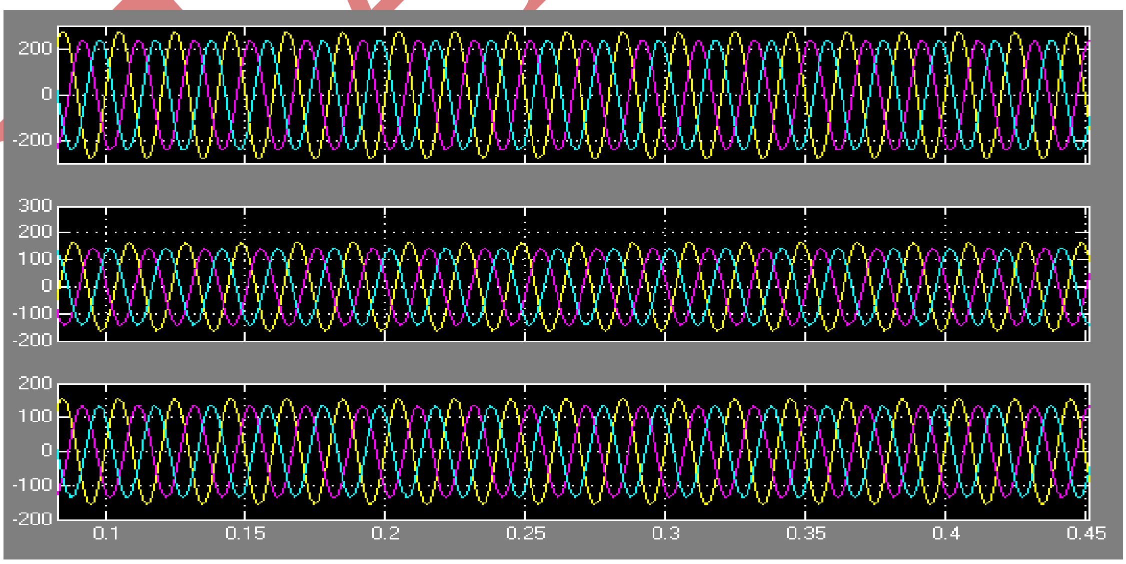

Fig 6: Grid-Interfacing Inverter With Integrated Voltage Unbalance Correction (A) Unbalanced Grid Voltages, (B) Currents Delivered By The Inverter, And(C) Voltages At The Poc

V. CONCLUSION

Hence, the three phase grid impedance detection method based on dual frequency harmonic current injection for islanding detection is reliable and feasible than single harmonic current injection.In this paper, the detailed control of grid-interfacing inverters supporting negative-sequence voltage correction has been presented from basic principle. Based on the voltage unbalance factor and the system's capacity, the inverter absorbs a small amount of negative-sequence current from the grid, thereby correcting the negative sequence voltage voltage at the PoC. By using many of these modules, a substantial improvement is possible. Furthermore, the improved multi-variable filter can filter out positive- and negative-sequence components accurately in case of unbalanced/distorted situations in the stationary frame.Hence the functionality and control scheme of voltage unbalance correction using interfacing inverter are verified by simulation results are shown.

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