International Journal of Electrical Engineering.
ISSN 0974-2158 Volume 9, Number 1 (2016), pp. 51-56

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Synchronization and Smooth Connection of Solar Photovoltaic Generation to Utility Grid

Srinivasan M.
Department of EEE, Adhiyamaan College of Engineering, Hosur - 635109, Tamilnadu, India.

Ravikumar R.
Department of EEE, Adhiyamaan College of Engineering, Hosur - 635109, Tamilnadu, India.

Abstract

This paper presents the interconnection of distorted solar photovoltaic (PV) generation to a utility grid, which requires the synchronization between PV and grid voltage. The voltage imbalance due to harmonic content in PV due to power electronic devices results in over currents and unwanted protection tripping. The control structure, which includes voltage control loop and current control loop and filter design for smooth interconnection.
Index terms- voltage control loop, current control loop, phase locked loop and power system interconnection.

I. INTRODUCTION

Increasing utilization of electric energy made renewable energy as predominant source, synchronization of renewable energy sources like solar and wind energy to the grid network has several challenges due to harmonic distortion and voltage unbalance (due to discontinuous in availability) in renewable energy generations.

Distributed power generation unit is connected to the utility grid [1]-[7].In the grid connected scheme, the voltage magnitude and phase are set by the grid at the point of common coupling (PCC), the distributed power generation (DPG) synchronize with the PCC voltage.

The grid measurements such as voltage magnitude, phase angle and frequency will be the main objective for stable synchronization operation .The practical connection between utility grid and DPG is realized [8]-[9],for smooth interconnection the DPG and grid voltage should be of same, but it is not guaranteed in distorted solar photovoltaic generation.

In the proposed system, the synchronization and interconnection of grid network to distorted solar photovoltaic generation is analysed, with the goal of rectifying the harmonic distortion and voltage mismatch at the point of common coupling.
This paper is organized as follows: Section II reviews the control structure for interconnection of grid network to distorted PV generation. Section III presents the simulation result of proposed system. Finally, Section IV presents the conclusions.

II. CONTROL STRUCTURE FOR THE INTERCONNECTION OF GRID NETWORK TO DISTORTED PV GENERATION

Fig. 1 shows the control block diagram of proposed system with voltage control loop and current control loop respectively.
It consist of inner control loop and outer control loop, the inner current control loop controls the output current of the voltage source inverter (VSI) and the outer voltage control loop controls the output of filter voltage. In the voltage control loop, the proportional and integral (PI) controller is used at solar photovoltaic generation to control voltage and current. The phase locked loop (PLL) is used to analyse the three phase grid voltage respectively. The proposed system eliminates the overcurrent due to voltage mismatch between PV generation and grid, the magnitude of over current depends upon the voltage difference between PV and grid respectively

The frequency and phase angle of grid voltage is transformed from abc to dq quantities using (1) and (2),

$$`F_{dq}=2/3(f_a + f_b e^{j*2*\pi/3} + f_c e^{j*4*\pi/3}) e^{-j*\varphi} \quad (1)$$

$$\Phi = \int \omega \, dt \quad (2)$$

Where, Φ is phase angle and ω is frequency of grid voltage respectively.

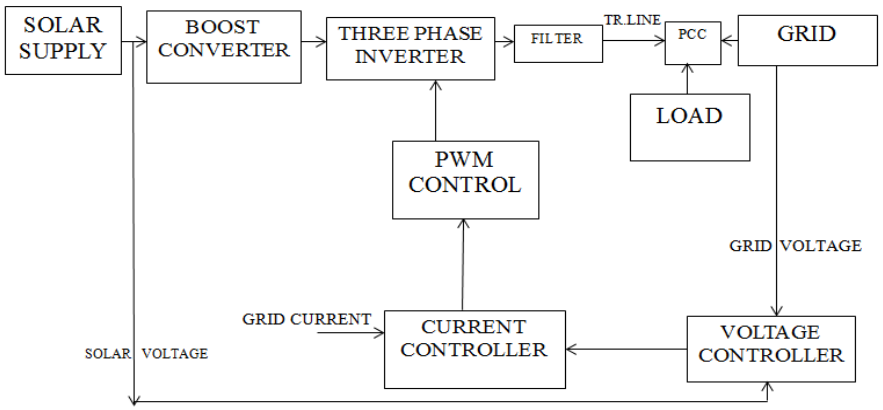

Fig. 1. Controller block with voltage and current control loop.

A. Connection of Distorted DPG To Grid Network Through LC Filter

Fig. 2 shows the circuit diagram of three Phase voltage source converter connected to the grid network through LC filter. The inductance of transmission line and filter are given by (L_{TL} and L_i) ,capacitance C with a series resistance R_C and the equivalent resistance is given by (R_{TL} and R_C) respectively,

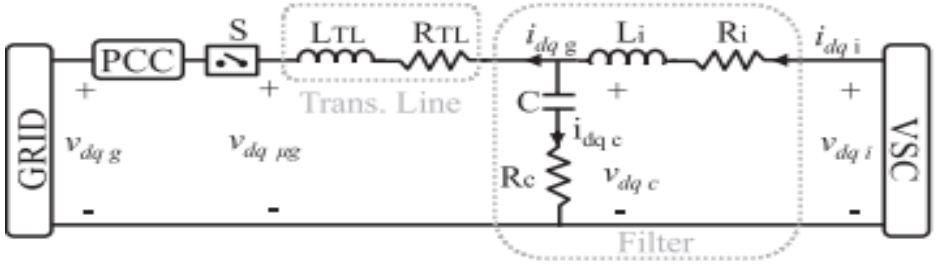

Fig. 2.VSC connected to grid network

The transfer function between harmonic current and harmonic voltage given in (3), based on which the filter values has been designed.

$$i_{dqh} / v_{dqh} = (s/L) / (s^2 + s.R/L + 1/LC) \quad (3)$$

The filtering circuit has been designed for 5^{th} order harmonics.

III. SIMULATION RESULTS OF PROPOSED SYSTEM

The proposed method has been tested by simulation, the three phase programmable ac source is used to emulate the grid voltage. The DPG is represented by solar photovoltaic (PV) generation followed by boost converter, which is used to boost the solar voltage and fed into the voltage source inverter followed by filter design and transmission line, the pulses for the voltage source inverter is generated by the control structure, which consist of voltage and current control loop based on which the VSI is triggered. The output of the VSI consist of harmonics due to the presence of power electronic devices, which are removed by enabling filter and transmission Line design and the synchronization is achieved at the point of common coupling.

The output waveform of voltage source inverter which consist of harmonics, due to which the synchronization becomes complex is shown in the Fig.3(a) and Fig.3(b) shows the waveform at the PCC respectively,

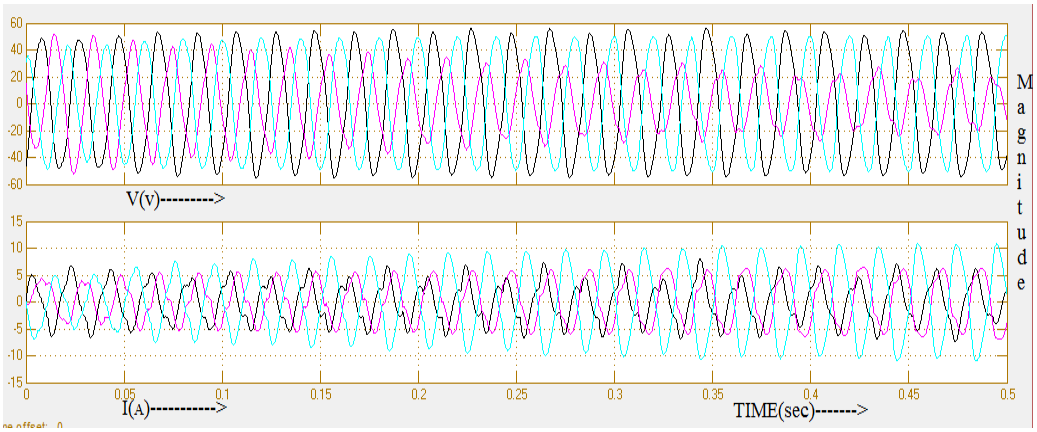

Fig. 3(a)

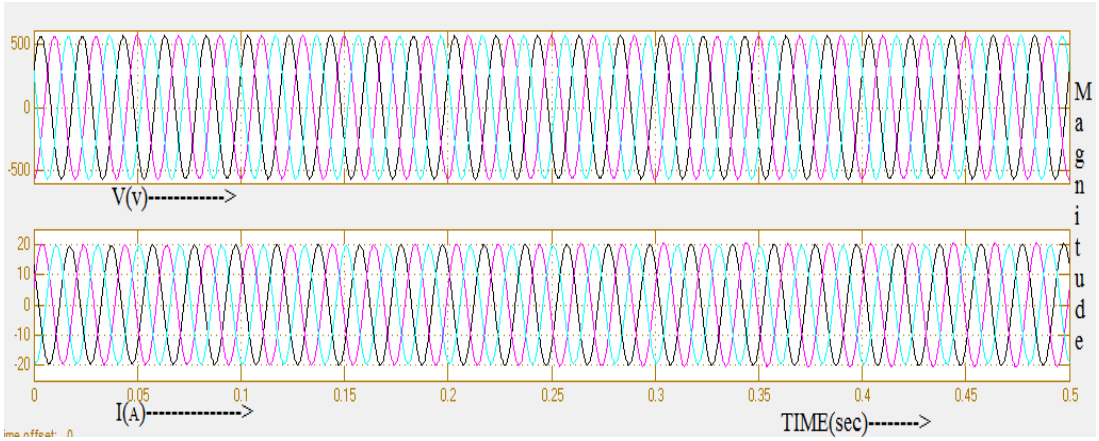

Fig. 3(b)

Fig. 3(a) and 3(b) shows the snapshot of output waveform at VSI and at PCC.

A. Total Harmonic Distortion Calculation

The mathematical expression for Total Harmonic Distortion (THD) is given by the equation (4),

$$THD = \frac{\sqrt{\sum_{n=2}^{\infty} h_n^{\,2}}}{h_1} \tag{4}$$

Where, h_1 is the amplitudes of the fundamental component, whose frequency is w_o and h_n is the amplitude of n^{th} harmonics at frequency nw_o respectively, the values of THD at VSI is 29.33 and at PCC the value of THD is 0.40% and the wave form representation of THD is shown in the Fig.4(a) and 4(b) respectively,

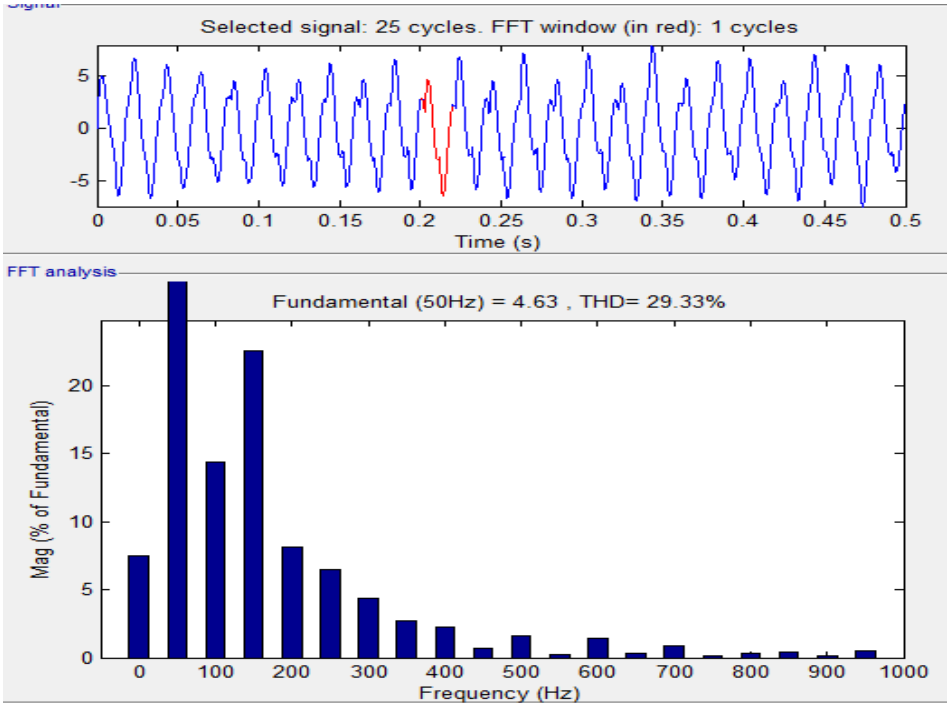

Fig. 4(a)

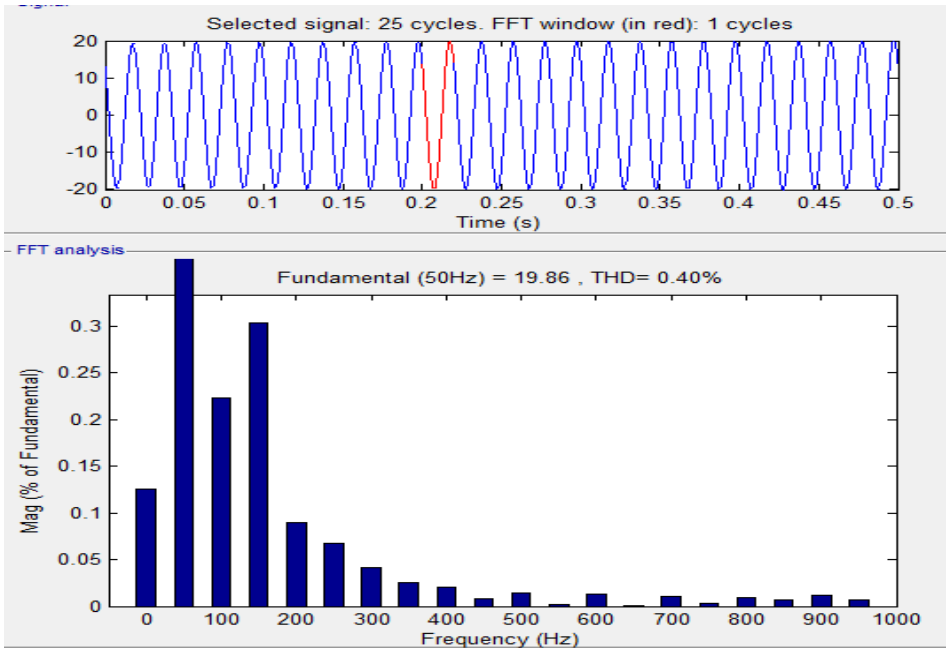

Fig. 4(b)

Fig. 4(a) and 4(b) shows the value of THD at VSI and at PCC.

CONCLUSION

In this paper, synchronization between the distorted distributed power generation and utility grid has been proposed, which results in rejection of harmonics, unwanted protection tripping, transient overcurrent due to voltage mismatch between DPG and utility grid and power electronic damage.

Performance of the proposed system is demonstrated using simulation results.

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