Investigation of PCC Point Harmonics in a Grid Connected Photovoltaic System

Nilesh Deotale[1], Prof. D. B. Waghmare[2]
[1]*M. Tech. Student, Electrical Engineering Department, Shri Sai College of Engineering and Technology Bhadravati, India*
[2]*Assistant Professor, Electrical Engineering Department, Shri Sai College of Engineering and Technology Bhadravati, India*

Abstract- **This paper presented an integration of Photovoltaic (PV) system to utility grid. PV system is connected to grid via a DC-DC boost converter and three-phase three-level voltage source converter (VSC). The maximum power point tracking (MPPT) is implemented in the boost converter using incremental conductance+ integral regulator technique. This paper work presents analysis and harmonic measurement at point of common coupling (PCC) when Photovoltaic (PV) system is connected to utility grid. THD measurement of the different possible cases of PV system integrated to grid at PCC has been carried out in MATLAB/Simulink environment. Finally, harmonic mitigation and power quality improvement at PCC using passive filter and control technique of complete system is proposed and proved by different simulation results.**

Index terms- MPPT, Power Quality (PQ), Renewable Energy Sources (RES), THD Measurement, Utility Grid.

I. INTRODUCTION

Due to the critical condition of industrial fuels which include oil, gas and others, the development of renewable energy sources is continuously improving. This is the reason why renewable energy sources have become more important these days. Few other reasons include advantages like abundant availability in nature, eco-friendly. Many renewable energy sources like solar, wind, Hydro and tidal are there. Among these renewable sources solar and wind energy are the world's fastest growing energy resources. With no emission of pollutants, energy conversion is done through wind and PV cells[1].

Day by day, the demand for electricity is rapidly increasing. But the available base load plants are not able to supply electricity as per demand. So these energy sources can be used to bridge the gap between supply and demand during peak loads[2]. This kind of small scale stand-alone power generating systems can also be used in remote areas where conventional power generation is impractical.

In order to exchange power with the grid certain requirements must be met to ensure the quality and stability of the power system. The standards for connecting distributed resources with an electric power system are defined in IEEE Std. 1547 [3] and standards for Power Quality are defined in IEEE Std. 1159 [3]. The harmonic content standards are taken from standard known as IEEE Std. 519- 1992 [3]. Passive filters are one of the classic methods to solve harmonics problems.

II. PV SYSTEM

A. PV Modeling

A detail and complete model of 100 kW PV array connected to 25 kV Grid as shown in Fig.1. Maximum power is obtained at 1000 W/m2 sun irradiance and temperature of 250C at PV array module. Boost converter of 5 kHz increased the voltage from 272V DC to 500V DC with the help of MPPT controllers which use the technique of incremental conductance plus integral regulator. MPPT used for optimized switching frequency. Voltage source converter converts the 500V DC to 260V AC with unity power factor. Capacitor bank of 10 KVAR used for suppression of harmonics due to VSC. The transformer of three phase 100 KVA 260V/25kV is used with utility grid at B1 and load is connected at B2 shown in Fig.2.

The general diode expression is given by

$$Id= Ist [\exp(Vd/Vt) - 1] \quad (1)$$

VT= kT / (q*Qd*Nc) (2)

Where,

Vd : diode voltage.

Id : diode current.

Ist : diode saturation current.

Vt: temperature voltage.

Qd: diode quality factor.

q: electron charge.

k: Boltzmann's constant.

Nc: number of series connected cells per module.

The photo current DC generated by the single PV cell is represented by Iph and it is proportional to solar irradiance on module surface and number of parallel module string. 66 parallel string (Npr) with of 5 modules (Nsr) each of the PV array. Due to this the generated equation diode become

Idary = Istary[exp(Vd/Vtary) - 1] (3)

This value with generated current DC Iphary is calculated as

Istary = Istary × Npr (4)

Vtary = Vtary × Nsr (5)

Iphary = Iphary × Npr (6)

From the table I and values of each parameter, single PV array maximum power is given by

Pary = Npr × Nsr × Pmp (7)

and its value from equation (7) is 100.5 kW.

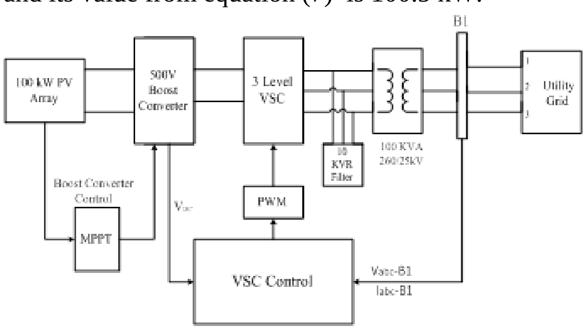

Fig.1: Grid Tied PV Model

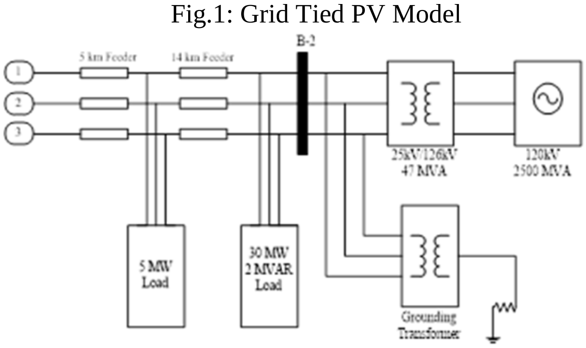

Fig.: Utility Grid Model

B. DC to DC Converter

It is a power electronic converter which is use to convert fixed DC to variable DC based on the operation of chopper in the circuit. Based on the constant switching operation the output of converter depends. Boost converter is used so as to achieve the maximum power from the solar by controlling the electrical load seen by the solar plant.

In the boost converter MOSFET is used as control switch, where by giving controlled gate signal it is possible to control the output of the boost converter. Switching duty cycle is optimized by MPPT controller that uses Incremental conductance with Integral Regulator method.

C. DC to AC converter

The power generated by solar is in DC form. To convert the DC power to AC power converters are required. Power electronic converters are used for this purpose. These converters require proper gate pulse. Three phase three level inverter is used to improve power quality of system [7]. But control of three level inverter is more complicated. For generating gate pulses there are various literature on control algorithms which are used for generating gate Pulse.

The control of 3-phase system is much complicated procedure. Hence by transforming 3-phase system to 1-phase this complication can be avoided. This can be done by Clarke's transform. where by generating reference wave and pulses are provided using PWM technique) After finding error in actual and reference it is required to convert the single phase controlled signal to 3-phase controlled signal. For this inverse Clarke transform of the controlled signal is taken.

D. Passive filter

Because of use of power electronics devices power quality of system deteriorates. AC power from inverter will be having harmonics in it because of constant switching operation of converter. Hence for improving the power quality and mitigating the harmonics filter is needed to be designed. 10 kVAR Filter is consider in this system.

III. SIMULATION ANALYSIS

The performance of PV system is analyzed under changes of solar irradiation. PV array surface temperature is taken to be constant at 25°C during the complete simulation time duration. The change of irradiation shows that the injected active power from PV system varies with its solar irradiance which is shown in Fig.3. Fig.4 shows PV Array voltage. Fig.5, Fig.6 shows power, voltage and current at bus B1 respectively. Fig.11 and Fig.12 shows voltage and current at bus B2 respectively. Fig.7 and Fig.8 shows Inverter output voltage with and without filter. Measured THD without filter is 14.9% and with filter it comes to 1.59% which is shown in Fig.9 and Fig.10. THD bus B1 and B25 is shown in Fig.10 and Fig.13.

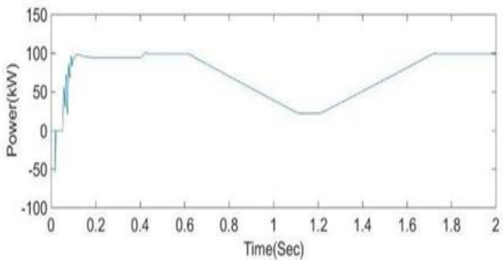

Fig.3: PV Array Power

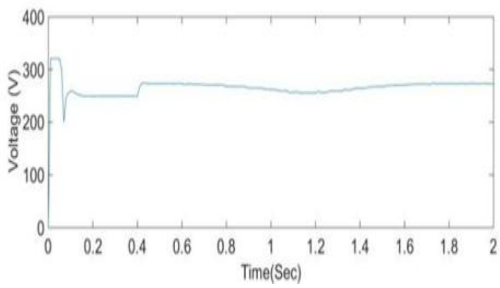

Fig.4: PV Array Voltage

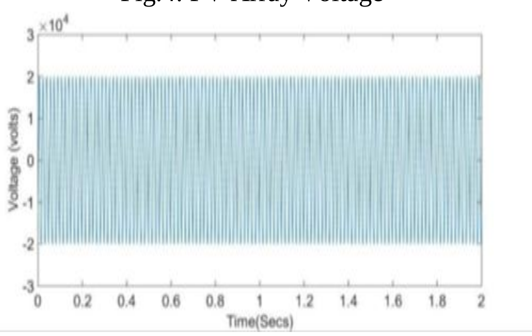

Fig.5: Voltage at B1

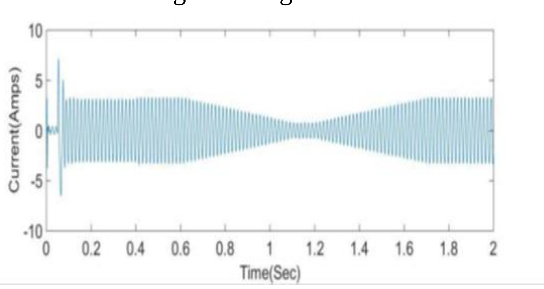

Fig.6: Current at B1

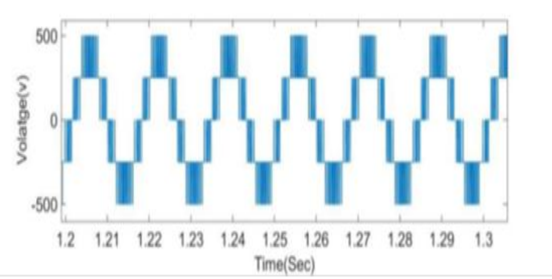

Fig.7: Inverter output Voltage without filter

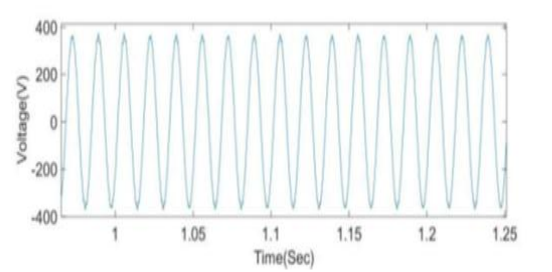

Fig.8: Inverter output Voltage with filter

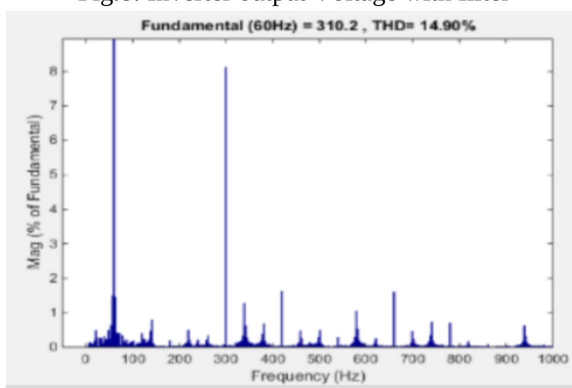

Fig.9: THD without filter

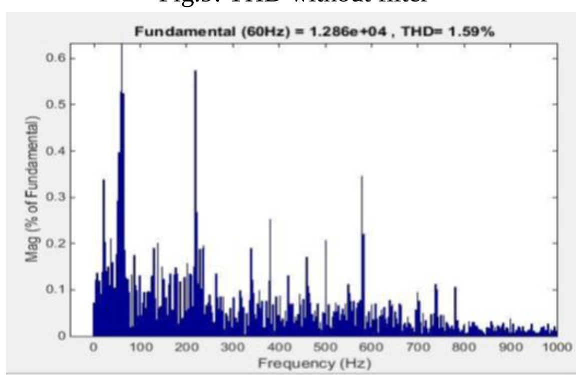

Fig.10: THD with filter

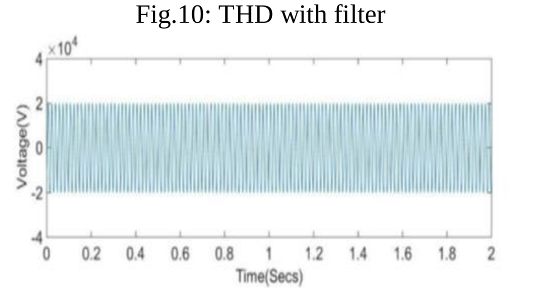

Fig.11: Voltage at Bus B2

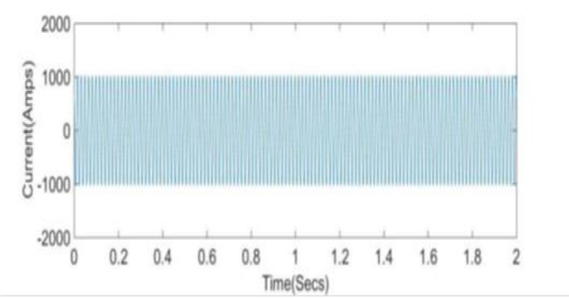

Fig.12: Current at Bus B2

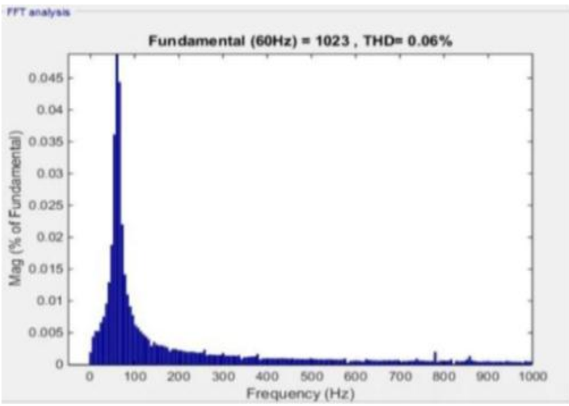

Fig.13: THD at Bus B2

IV. CONCLUSION

This paper proposes the design of a PV system in MATLAB and maximizes the power extraction using DC-DC converter with proper control technique. Further for integrating solar power to utility grid a control technique is proposed using which proper gate pulses could be provided to the inverter, so as to convert the generated DC power to AC power. This project shows effect of power electronics equipment on power quality. Power quality improved using passive filter. For harmonics analysis measured THD without filter is 14.9% and it comes to 1.59% with installation of Filter. This paper proposes the complete implementation of a PV system to utility grid with its analysis on MATLAB.

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