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Measurement and Investigation of PCC Point Harmonics in a Grid Connected Photovoltaic System

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***Abstract*- This paper work presents analysis and harmonic measurement at point of common coupling (PCC) when Photovoltaic (PV) system is connected to utility grid. Use of power electronic convertors while integrating PV to grid may introduce harmonics, due this power electronic convertor deteriorates power quality. Photovoltaic (PV) system is connected to grid via 3-phase 3-level voltage source converter (VSC). The maximum power point tracking (MPPT) is implemented using incremental conductance technique (IC). An AC/DC/AC IGBT based SPWM converter is considered for study. 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

In recent years, due to the deficiency of fossil fuel and greenhouse effect, Renewable Energy Sources (RES) have gained importance. Since solar and wind energy are freely available in nature, efforts have been made to use their potential for electricity generation. Because of the intermittent nature of both sources, instead of operating individually they should operate together as hybrid PV and wind energy system giving higher reliability of continuous power to the end users [1]. The power conversion devices are playing a vital role in order to integrate PV and wind renewable energy system to the utility grid, which injects harmonics to the AC grid side. Hence the presence of harmonics at point of common coupling (PCC) will deteriorates power quality [2]. This will affect operation of sensitive loads and results in higher system losses.

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 method to solve harmonics problems.

The presentation of this paper shows the simulation analysis, THD measurement of the integrated PV system connected to utility grid using different advanced power electronic based device and different control algorithm strategy at PCC.

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/m^2 sun irradiance and temperature of 25^{0}C 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

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

These value with generated current DC Iphary is calculated as

$Istary = Istary \times Npr$ (4)

$Vtary = Vtary \times Nsr$ (5)

$Iphary = Iphary \times Npr$ (6)

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

$Pary = Npr \times Nsr \times Pmp$ (7)

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

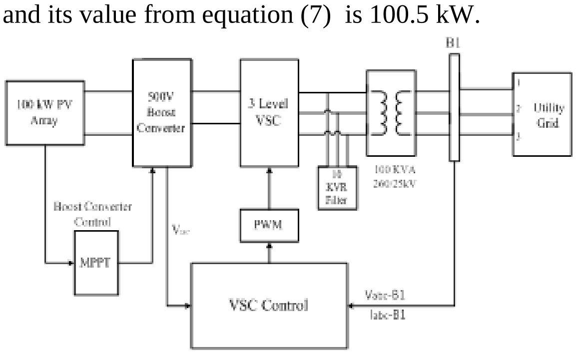

Fig.1: Grid Tied PV Model

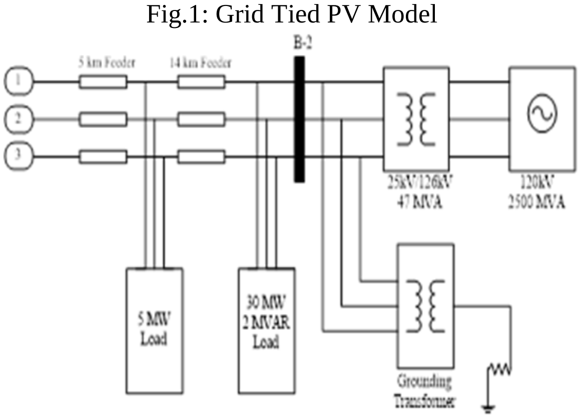

Fig.: Utility Grid Model

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.

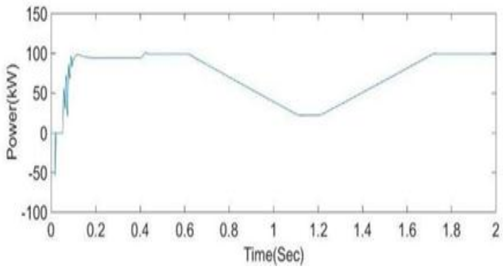

Fig.3: PV Array Power

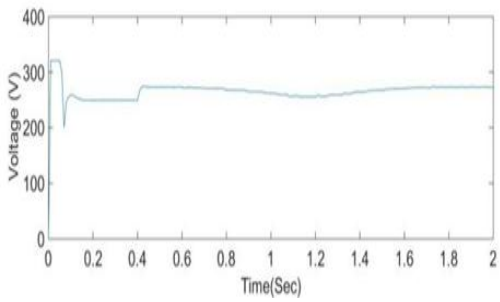

Fig.4: PV Array Voltage

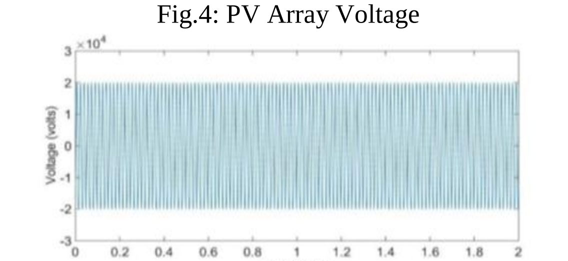

Fig.5: Voltage at B1

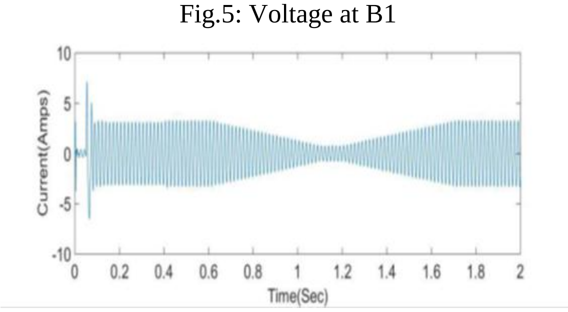

Fig.6: Current at B1

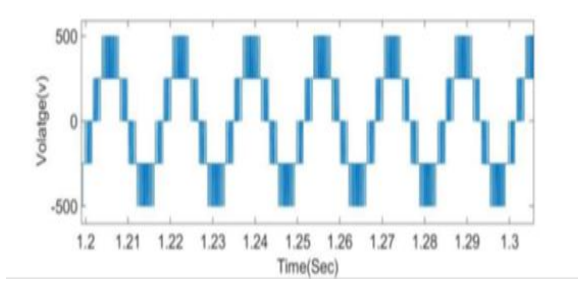

Fig.7: Inverter output Voltage without filter

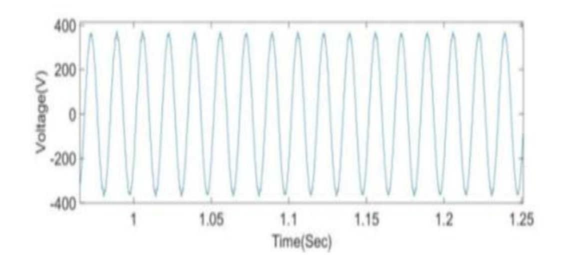

Fig.8: Inverter output Voltage with filter

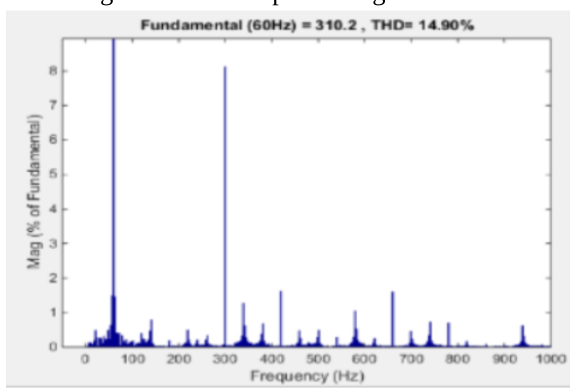

Fig.9: THD without filter

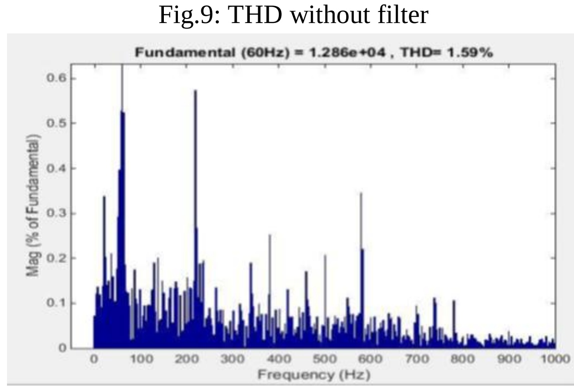

Fig.10: THD with filter

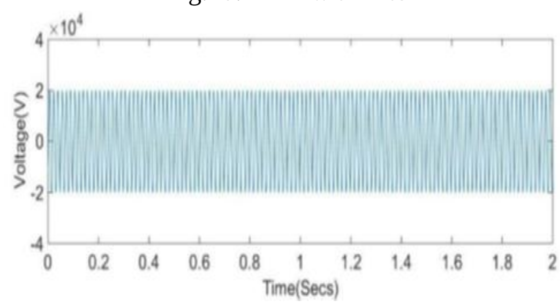

Fig.11: Voltage at Bus B2

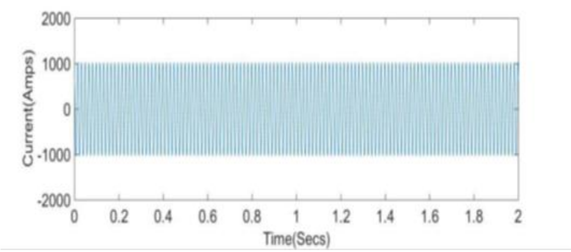

Fig.12: Current at Bus B2

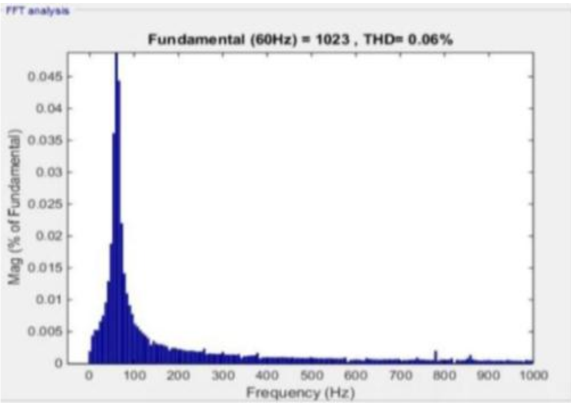

Fig.13: THD at Bus B2

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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