Power Quality Improvement of Grid Connected Solar System using Neutral Point Clamped MLI

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Abstract— Multi-functionality in converters are drawing attention of researchers, since it is the main link of grid tied solar system. A lot of ongoing research has been reported in literature for auxiliary services on power quality improvement through multi-functional grid-tied (MFGT) converters. These converters can perform dual work of interfacing solar system with the grid and also conditions the power at point of common coupling. The state-of-the-art of the converter is its design feature which optimally achieve the multi-functionality, hence presents a cost effective solution to power quality issues. A Grid connected solar system for radial distribution system is designed, which is capable of injecting active power into the grid with its inherent advantages to mitigate the Power Quality Issues.

Keywords: Solar Panel, Maximum Power Point Tracking, Multi-Functional Grid-Tied (MFGT) Converters, Power Quality Issues, Single Stage, Dual Stage

I. INTRODUCTION

As the conventional energy sources are rapidly depleting and the demand of the electricity is increasing day by day as the world is moving towards advancement, this leads to develop alternatives for fulfilling the energy requirement. Hence the most promising solution is the use of renewable energy sources.

Most reliable type of the renewable energy i.e. Solar Energy is utilized for powering utility in the proposed work of this thesis. Using Solar Photovoltaic Array as the primary source, a model is developed and simulated in the MATLAB-Simulink, extracting the solar energy in the form of electrical energy. Output of the array is interfaced to the conventional dc-ac converter to get the AC voltage.

For feeding the single phase utilities, a two level voltage source inverter is interfaced at the output terminals of the PV array to get the pure sinusoidal output voltage, but the low Total Harmonic Distortion (THD) generated is not within the standard limits. To reduce THD filter is used with two level voltage source inverter. On the other hand multilevel is first choice because it gives low THD AC output voltage without the use of filter.

Many efforts has done to improve the performance of the system with minimum losses, distortion and as possible as the maximum efficiency by using different topologies of multilevel inverter and with different levels.

In this paper a MFGT inverter is designed the system is integrated to grid and to mitigate various power quality issues like voltage regulation, harmonic reduction, real and reactive power management etc. has been discussed.

II. SOLAR ENERGY GENERATION SYSTEM

The smallest element of solar energy generation system is Photo cell. Solar cell (Fig-1) is basically a semiconductor look like thin film or disc which is when exposed to sunlight produces voltage or current. When solar cells are laminated between a clear super-strate (glazing) and encapsulating substrate, they are termed as solar panel or module and the combinations of more than one module in series or parallel is called as solar array [13,14].

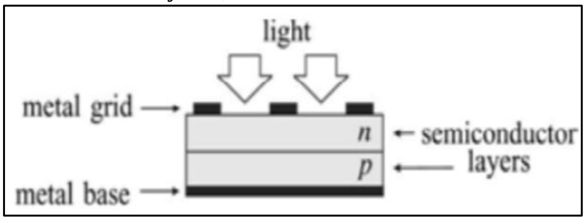

Fig. 1: solar cell

The power produced by the PV array can be given as;

$$Ppv = VpvIpv + VdcIpv$$

Where Ppv solar output power, Vpv Solar output voltage, Ipv solar output current, Vdc DC bus voltage. The generated power from solar cell is directly depend upon solar irradiations and hence is not constant always. When sun is visible it will produce energy and at evening time and morning g time when rays are less electricity will be reduced. In literature various MPPT techniques are available which helps is stabilizing the Dc output power of the solar system.

III. GRID-TIED SOLAR SYSTEM

The two important issues of GTIs are efficiency and low cost are. They are broadly two type of GTIs namely; single-stage (SS) and multiple-stage. Because the more stages reduce the efficiency of a GTI much more, a multiple-stage GTI mainly has two stages. In SS single converter (Fig. 2) take care of both DC/DC as well as DC/AC conversion. While two-stage GTI is comprised of a DC/DC stage and a DC/AC stage, as depicted in Fig. 3. SS and DS GTIs have their own advantages and disadvantages, so it is hard to say which is better.

They are all implemented in different suitable occasions. Generally, small-capacity-scale grid-connected systems are more like to use DS GTIs due to their flexible feature. However, big-capacity-scale systems mainly uses SS GTIs for their high efficiency and reliability.

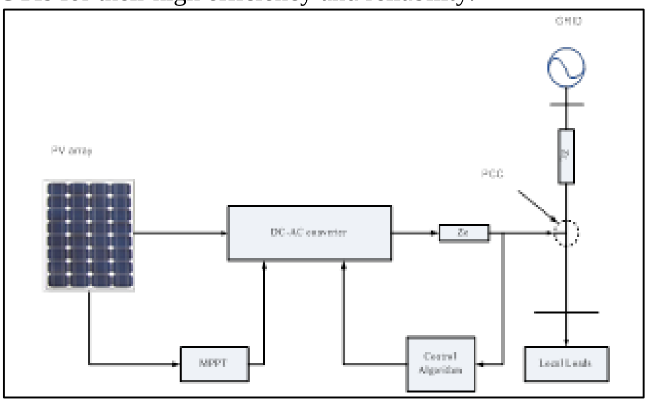

Fig. 2: Grid tied Single-Stage solar system

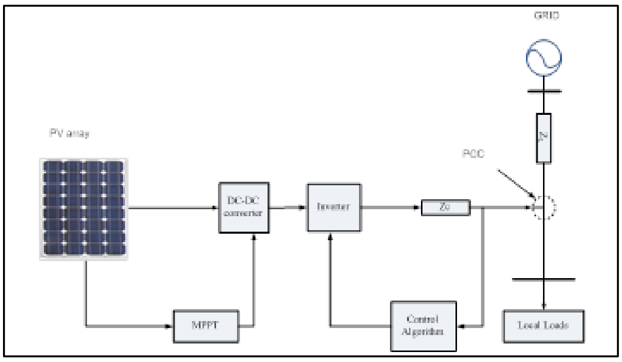

Fig. 3: Grid tied Dual-Stage solar system

The choice of MPPT technique depends upon the application whether grid connected or stands alone system, efficiency of the technique control variables, and cost of implementation.

IV. PROPOSED WORK

A PV system is designed, 50 parallel strings and 10 Series-connected modules. The rated capacity of the PV panel is 100 KW. To obtain the constant DC output from Solar system a DC-DC boost converter is designed with switching frequency 3Khz. The output voltage of the boost converter is approx. 720 V.

To integrate the PV system with the grid a DC/AC inverter is simulated. The inverter is designed using 5-level Neutral Point Clamped Multilevel Inverter (NPC-MLI) which is synchronized using PLL and PI controller.

A matlab simulink model of the solar panel with 10KW rating has been developed whose DC output is regulated using DC-DC boost converter.

To design a DC/AC converter a 5 level inverter is designed whose pulse width modulation technique is designed using level shifted carrier modulation technique.

One side of the converter is connected to the synchronized AC output of the PV system and other side to the grid.

The system is synchronized with the grid using PI controller and Phase Lock Loop.

The parameter considered in designing the proposed system is presented in table 1.

Parameter	Values
DC-DC converter parameter	
Input voltage	400 volts
Output voltage	720 volts
R	0.5 ohm
Switching frequency	5kHz
C_{dc}	12000e-6 F
L1	5e-3 H
Inverter parameter	
Effective nominal voltage of the utility (RMS) VS	415 V
Nominal utility grid frequency fS	50Hz
Switching frequency of the converters fch	30khz
inductance of filter	100e-3 H
Series resistance converter	0.01 ohms
Capacitances of the parallel filters	1000e-6F
Resistances of the converter filter	0.01 ohms
dc-bus voltage Vdc	720V
PI gains	Kp = 0.04; Ki = 500

Table 1: System parameters for 10 KW solar system with converter Parameters

V. RESULT AND DISCUSSION

The system designed is varyfied for two loading conditions namely unbalanced linear loa and unbalanced nonlinear load. Firstly the output voltage waveform of the single phase5 level inverter is presented in Fig. 4. The output voltage and current waveform of inverter with PI control is presented in Fig. 5. Fig. 6 shows the output of Solar system with proposed topology and it can be seen from the figure that at norml operating condition the solar system designed with the proposed topology is synchronized with the grid. Fig. 7 shows the output Voltage and current waveform for linear unbalanced loading at Grid side. Fig. 8 presents Voltage and current waveform Grid side for Non-linear loading with the proposed topology. The THD analysis for all the operating conditions is presented in Table 2 and 3. FFt analysis shows that the proposed topology havebetter results as compared to the conventional topoloies.

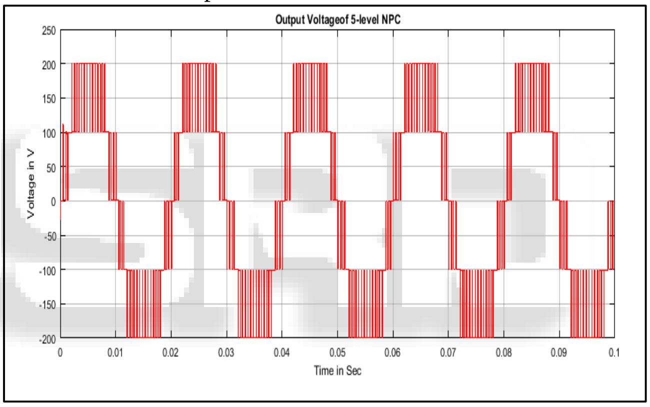

Fig. 4: Output Voltage of 5-level single phase NPC-MLI

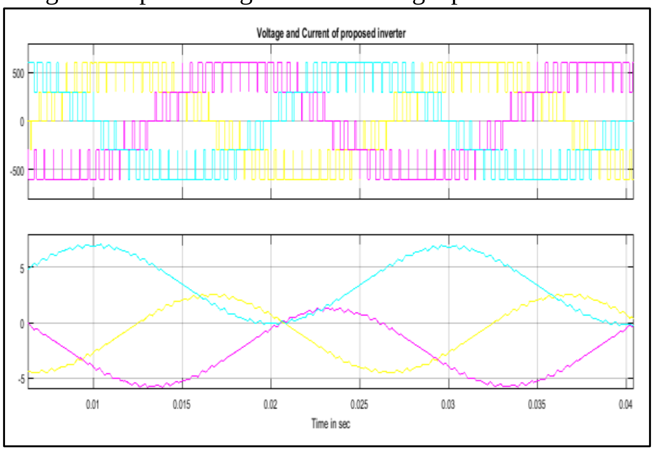

Fig. 5: Output Voltage and current of 5-level three phase NPC-MLI

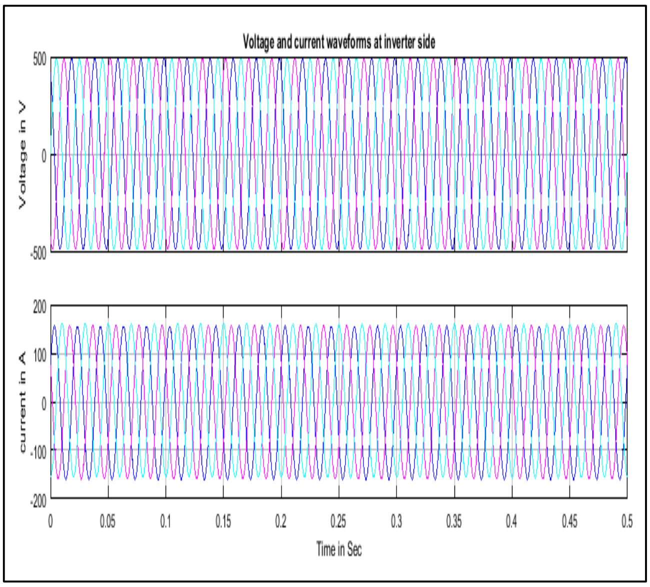

Fig. 6: Output of Solar system with proposed topology

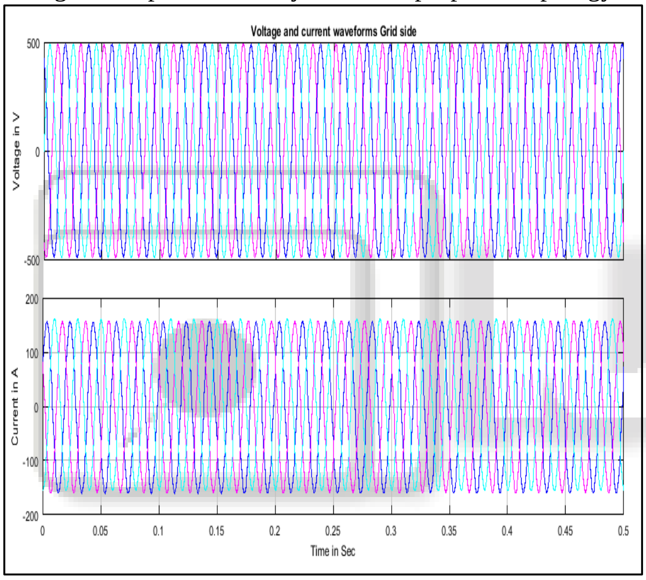

Fig. 7: Voltage and current waveform for linear unbalanced loading at Grid side

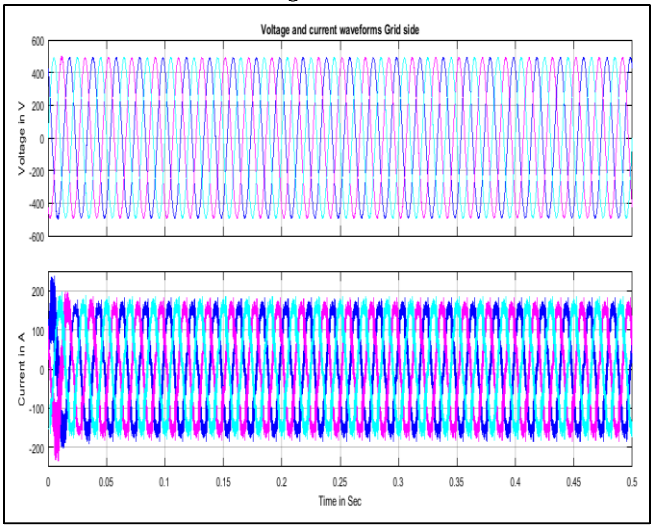

Fig. 8: Voltage and current waveform Grid side for Non-linear loading with the proposed topology

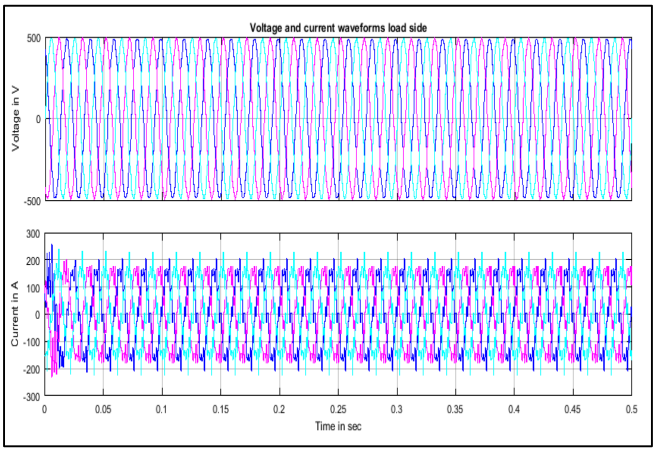

Fig. 9: Voltage and current waveform load side for Non-linear loading with the proposed topology

THD analysis of	Proposed work	Conventional topology
Supply	0.00	3.6
Load current	0.37	2.4
Inverter current	0.04	3.1

Table 2: Comparison of THD for unbalanced linear loading

THD analysis of	Proposed work	Conventional topology
Supply	0.11	4.2
Load current	25.09	27.6
Inverter current	1.54	10.8

Table 3: Comparison of THD for balanced non-linear loading

VI. CONCLUSION

Inverters are the important link between RES and utility grid interface. There are several task that a properly stimulated inverter can perform like power quality improvement, battery back-up etc. this paper presents an overview on such functionalities of inverter and its application in modern power system. A three-phase two stage SPV energy conversion system has been implemented in MATLAB.

Static and dynamic performances of the system were evaluated under various modes of operation of grid voltage conditions.

The performance of the multifunctional VSC has been demonstrated for harmonic elimination.

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