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A Novel Method for Power Quality Improvement of SRM Drive Fed Three-Phase Three-Wire DG System

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Abstract: Electric power produced by the use of ordinary fuels will produce toxic gasses like carbon dioxide, carbon monoxide, nitrogen dioxide etc. Which will causes environment contamination and as a result cause to global warming. This bring to the use of renewable energy sources. A Solar Photovoltaic (SPV) system, along with Maximum Power Point Tracking (MPPT), catenated to a three phase grid which feeding a switched reluctance motor is introduced. The catenation of solar photovoltaic system to the grid arise through two stages of operations, which is through a DC/DC boost converter via a current controlled Voltage Source Inverter (VSI). The Maximum power point tracking algorithm used is Perturb & Observe (P &O) algorithm, which is applied to the boost converter. Also reference reimbursement current has been generated by using I cos Φ algorithm. Adaptive hysteresis band current controller is used for switching pulse generation in current controlled VSI. Employing adaptive control, the Total Harmonic Distortion (THD) of supply current is reduced to 0.22% from 28.20%. There by the power factor is increased to a value 0.976%.

Keywords: Distributed generation (DG), power quality, switched reluctance motor (SRM), voltage source inverter (VSI).

I. INTRODUCTION

The load interest is increasing regularly and it's become an immense dare for power plans. In order to encounter this growth in load interest, the electric power generation must be improved. Electric power produced with the use of ordinary fuels will causes the emission of toxic gasses like carbon dioxide, carbon monoxide, nitrogen dioxide etc. It will leads to environment contamination and as a result global warming were takes place. This led to the use of renewable energy sources like wind, solar etc. The electrical energy produced by these renewable energy sources does not produce any type of greenhouse gases. And also they are freely available from the environment [1]. The electrical power produced from the renewable energy sources must be served to the grid. Producing electric power from the renewable energy source and conveying the power to an extensive distance is not reasonable. The distributed generation (DG) can be defined as the make use of renewable energy sources and integrating them at distribution level. But distributed generation may perhaps cause a number of difficulties like power quality issues, stability issues, reactive power issues and voltage regulation etc. Distributed generation can be adequately controlled for harmless process of the power system improving power quality due to the advancements in power electronics. But due to the large scale use of power electronics components in the electric circuits may led to harmonics in the power system [3-8]. By the use of passive filters or active filters the power quality problems can be resolute. Passive filters can filter out the harmonics effectively regulated for which, functioning in resonance and they departure residual terms in the source current. These disadvantages can be conquer using active power filters. To regulate the harmonics the active filter will persuade reimbursing currents in towards the system [9].In this paper the voltage source inverter consumes two goals, one stands to invert the output from the renewable energy source and further is to perform as a filter. And solar photovoltaic system stays as the renewable energy source. Due to limited life span and high initial cost of photovoltaic array creates it essential for the consumer to excerpt maximum power from the solar PV system. The grid connected solar photovoltaic system is turn out to be very prevalent since they do not want battery back up to confirm MPPT. This paper also proposes to enhance the Total Harmonic Distortion (THD) of the source current by adaptive hysteresis current controller and also it optimize switching frequency of grid connected photovoltaic inverter. For mining maximum power from photovoltaic system Perturb & Observe (P & O) algorithm is used [9-12].

Working performance of the voltage source inverter is established on the technique used for the generation of reference current. In this paper the reference current generation is realized using IcosΦ algorithm. And also the switching pulse generated for this power stage is comprehended by using Adaptive Hysteresis Band Current Control. The Switched Reluctance Machines are receiving significant attention from industries, because of its inexpensive manufacturability, simple structure and reliability make it superior to other electric machines. The system performance was verified with the presence of Switched Reluctance Motor (SRM) drive system at load side.

II. BLOCK DIAGRAM DESCRIPTION

The fig.1 shows the block diagram of system with distributed generation integration to grid. In this paper it deliberated about the voltage source inverter established three phase grid connected inverter along with control circuit.

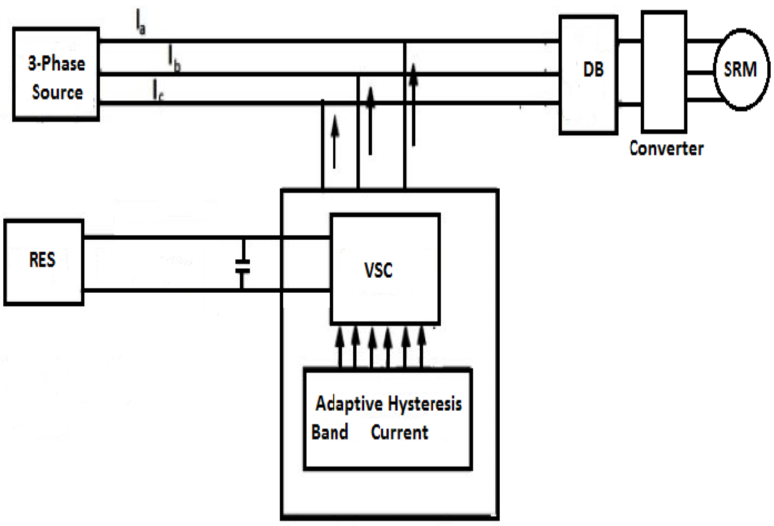

Fig. 1. Block diagram of system with distributed generation integration to grid

Also it perform as a Shunt Active Power Filter (SAPF) and is linked in parallel through the load which produces harmonics on the Point of Common Coupling (PCC). SAPF produces a current which is identical and conflicting towards that of the harmonic current drained by the load and then it injects the current at the point of common coupling, also creating the source current sinusoidal. The features of harmonics reimbursement is decided by the calculation of load current harmonics. The abandoning of harmonics by current wave form is attained by Voltage Source Inverter (VSI) and interfacing inductor. The smoothening and separation of high frequency components are delivered by the inductor. Actual filter current or desired current wave form is gained by guiding the swapping of switches in the inverter. The switching frequency of inverter and accessible driving voltage through interfacing inductors will limits the control of wave shape.

A. *The Shunt Active Filter Using Icos Φ Algorithm*

The control stratagem used here is the I Cos Φ algorithm. The control algorithm for a shunt active filter determine the reference reimbursement currents to be shoot up. Therefore the choice of the control stratagem is resolves the accuracy and response time of the filter. In order to make the control circuit squeezed the scheming phases involved in the control procedure consume to be nominal. The reimbursement for the harmonic and reactive quota of the three-phase load current, and intended for some imbalance in the three-phase load currents are expected to provide by the shunt active filter. This will assure that the balanced current will be drained from the mains which will be virtuously sinusoidal and in phase with the mains voltage. Subsequently the mains is mandatory to supply the active portion of the load current. That is, in I cos Φ, "I" is the amplitude of the fundamental load current and cos Φ is the load displacement power factor. Accordingly the anticipated algorithm is named as "I cos Φ" algorithm [2].

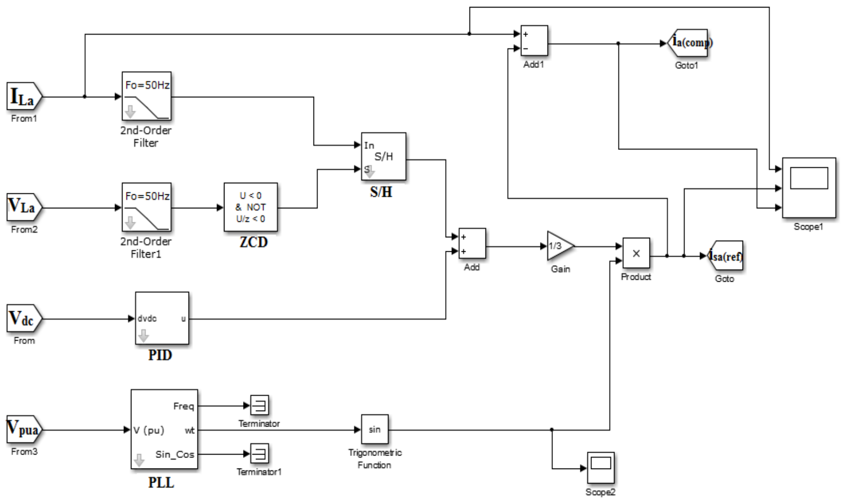

Fig. 2. Comprehension of the IcosΦ algorithm

That is which perform as lowpass, highpass, and bandpass filters [16]. The second-order lowpass filter is used here. The negative going zero crossing of the corresponding phase voltage is detected by a zero crossing detector (ZCD). By using a lowpass filter afore being served to the ZCD the fundamental component of the phase voltage is haul out to sort it invulnerable to any alterations in the inward voltage. The zero crossing detector has been intended through an acceptance of 5%. The "sample" input is the phase-shifted fundamental current and the output pulse of the zero crossing detector is the "hold" input to the "sample and hold" circuit and the magnitude is the output of it. By means of a summing amplifier having a gain of 1/3 the average of these values in the three phases is determined. The MATLAB diagram of the control circuit of one of the three phases is set in the Fig. 2. It is obviously describes in what way the reference reimbursement currents are produced.

B. *Adaptive Hysteresis Band Current Control*

A number of current control methods for grid linked inverter has been described in literature. The widest approval of Hysteresis band current control method provides rapid current controllability, fast reaction, inherent peak current controlling capability, and simplicity of implementation. For this there is no need of data about system constraints. The major drawbacks of conventional hysteresis controller is the variable switching frequency and high switching losses due to control of the 6 switches of inverter. In the case of a modified hysteresis controller, only 2 switches remain controlled at high frequency at any time. In adaptive control the pulses to the controller is produced by using adaptive control by modifying pulses [4]. In a 3-wire system, it is adequate to control current only in two phases. The harmonic current has to be inserted into the grid from the inverter in order to reimbursing harmonic current at the source side. A comprehensive switching procedure is established with respect to grid voltage and inserted current polarities to inject harmonic current. For control purpose phases consuming identical polarity of voltage is carefully chosen. This will results easier control. The three phase voltages are given the notation Ua, Ub and Uc. From the selected phases, based on the current polarity controlling switches are selected. In respectively 60° period of line cycle the accomplishment of the controlled bridge is illuminated based on the polarity of injected current and source voltage.

The switching sense for an inverter leg is set beneath,

If IL < (ILref –HB), in this condition the upper switch of inverter is off and at the same time lower switch of inverter become turned on for a particular leg.

If IL > (ILref + HB), in this condition the upper switch of inverter is on and lower switch of inverter is turned off. Where IL is the actual filter current and ILref is the line reference current.

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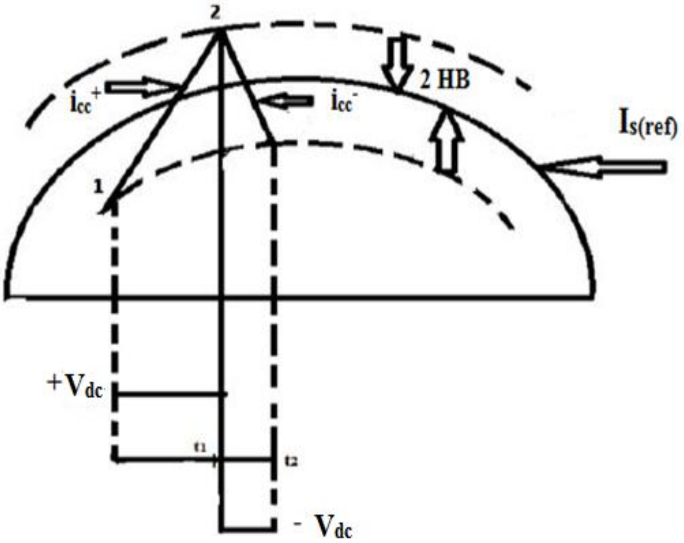

Fig. 4. Concept of adaptive hysteresis current control

$$\text{Hysteresis band} = \{\frac{0.25V_{dc}}{f_c}[1 - \frac{L^2}{V_{dc}^2}(\frac{V_{La}}{L} + m)^2]\} \qquad (1)$$

The hysteresis band expression is given by the equation (1). Where fc is modulation frequency, m is the slope of reference current. Vdc is the DC- link capacitor voltage, L is the line interface inductance, VLa is the phase voltage. The Fig.4 shows pulse width modulated current and voltage for phase c. When the current icc- reaches the lower hysteresis band at the point 1, then the upper switches of inverter leg “c” become switched on. When the current icc+ reaches the upper band of hysteresis band at the point 2, then the lower switches of inverter leg “c” become switched on.

III.MODELLING OF PHOTOVOLTAIC MODULE

The photovoltaic system can generate direct current electricity when it is exposed to sunlight. The elementary construction block of PV module is the solar cell, which is ultimately a p-n semiconductor junction. The V-I characteristic of a solar cell is shown by Eq. (2)

$$I = I_{ph} - I_s [\exp(\frac{q(V+I_{rs})}{kT_cA}) - 1] - \frac{V+I_{rs}}{R_{sh}} \qquad (2)$$

Iph : Photocurrent function
k : Boltzmann’s constant,(1.38*10-23J/K)
Trf : Reference temperature
Tc : Actual temperature
Irs : Reverse saturation current
q : electron charge (1.6*10-19 C)
k : Temperature coefficient
V : Terminal voltage
A : Ideal factor

In this paper the P & O (perturb and observe) MPPT algorithm has been simulated along with boost converter for maximum utilization of available power as shown in Fig. 5.

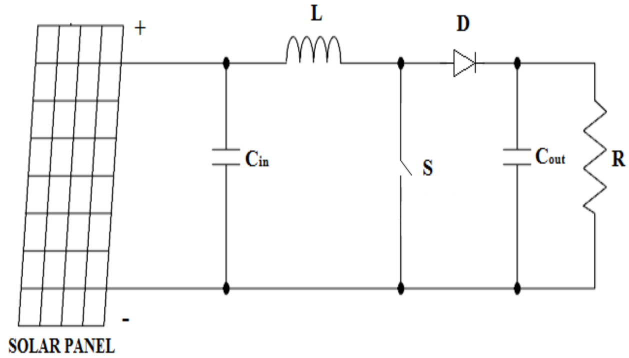

Fig. 5. Boost converter

Maximum power point tracking (MPPT) is a control technique to regulate the terminal voltage of PV panels in order to extract maximum power. The MPP may possibly varies due to external factors such as temperature, light conditions etc. Main dependent factor of MPPT is temperature and irradiance.

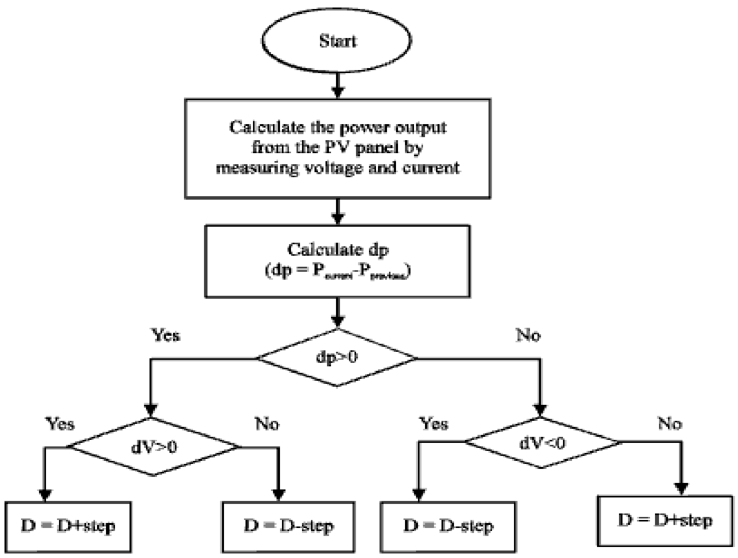

Fig. 6. Flow chart of P&O MPPT

It is also mentioned as hill climbing or P & O method, since it depends on the rise of power against voltage which is below the maximum power point, and the drop above that particular point. Perturb and observe method possibly will result in top-level efficiency.

TABLE I SPECIFICATION OF SIMULATED PV MODULE

Peak power(Pm)	648 W
Open circuit voltage(Voc)	90 V
Short circuit current(Isc)	7.2 A
Operating temperature	$25^{\circ}C$

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IV. MATLAB/SIMULINK RESULTS AND DISCUSSIONS

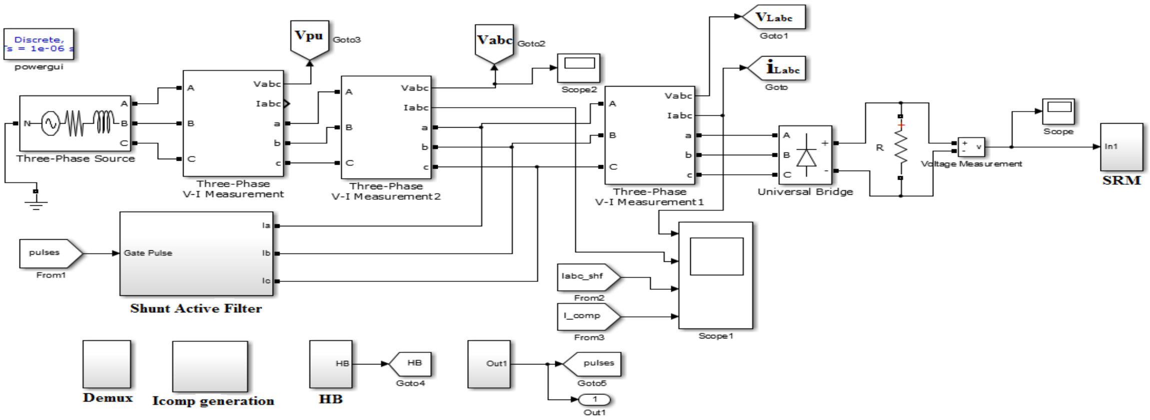

Fig. 7. Overall simulation circuit model of the proposed system

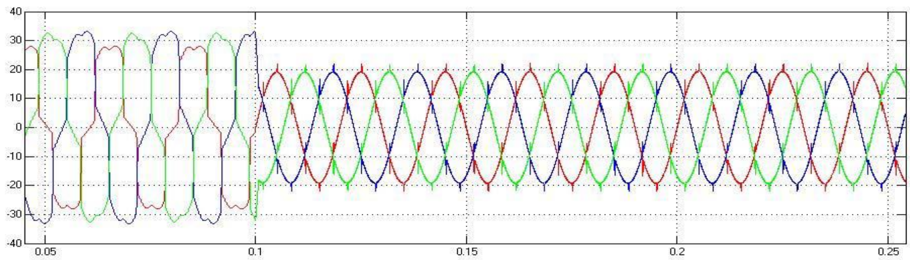

Fig. 8. Simulation output of source current

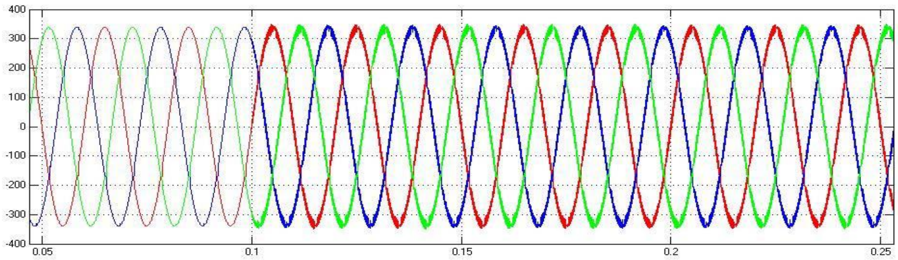

Fig. 9. Simulation output of source voltage

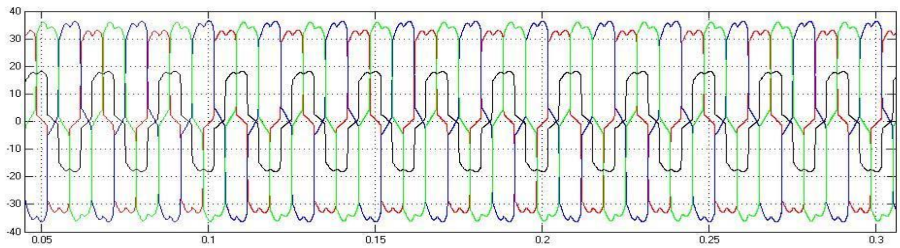

Fig. 10. Simulation output of load current

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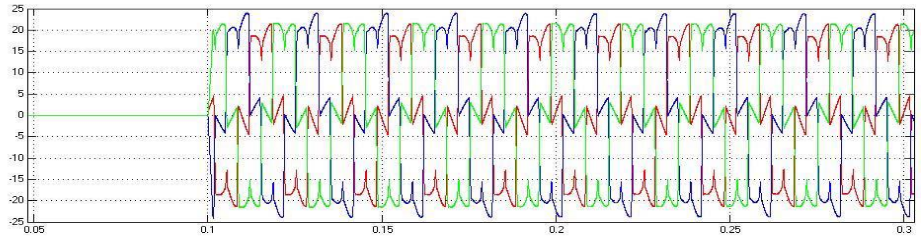

Fig. 11. Simulation output of inverter current

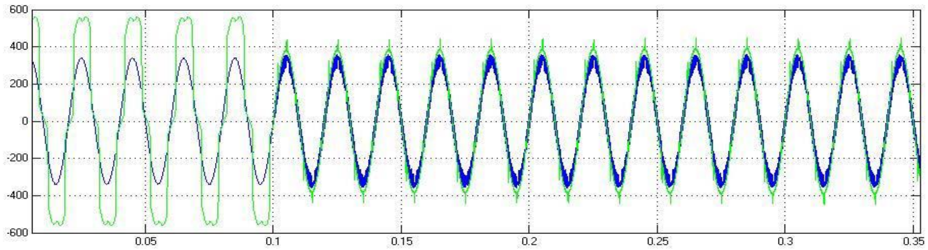

Fig .12. Simulation output showing power factor

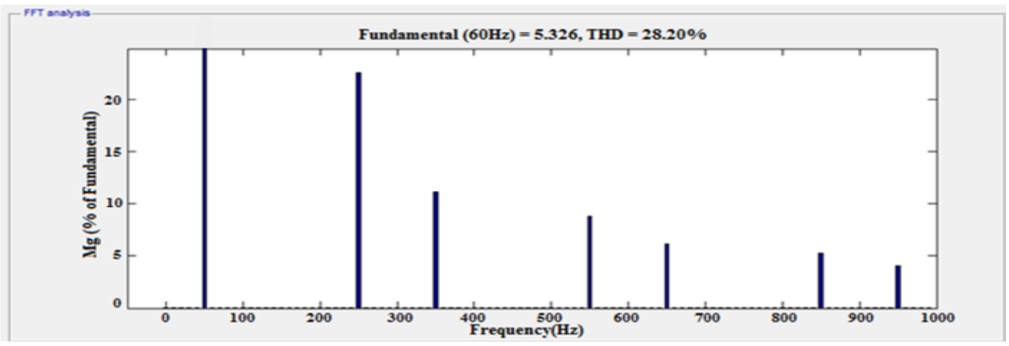

Fig .13. Uncompensated Source Current THD

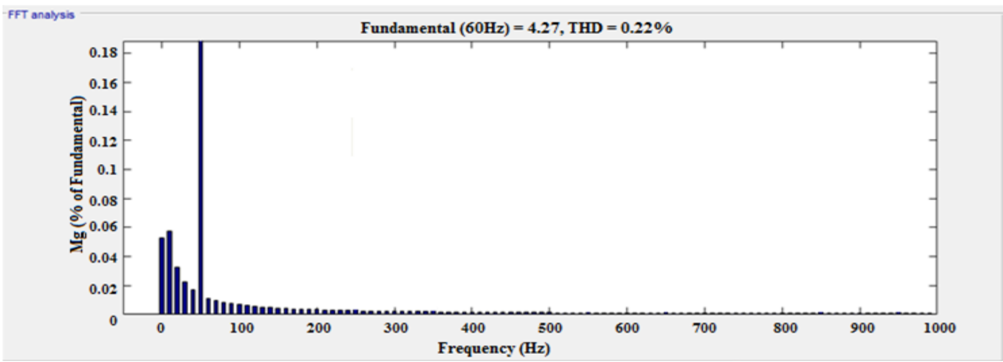

Fig .14. Compensated Current THD

Fig. 7 shows the MATLAB model of grid system with unbalanced non-linear SRM load. Fig. 8 and figure 9 shows the output results of source currents and source voltages. Fig. 10 shows the simulation result of load current and fig. 11 shows the inverter currents which are fed to grid. Since the load is linear the source current consists of much disturbances and at this time the inverter delivers the power to the grid and conditions the power keeping THD in nominal values. Fig. 12 shows the power factor of the system. Fig. 13 and fig. 14 shows the FFT analysis of uncompensated source current and compensated source current for the system.

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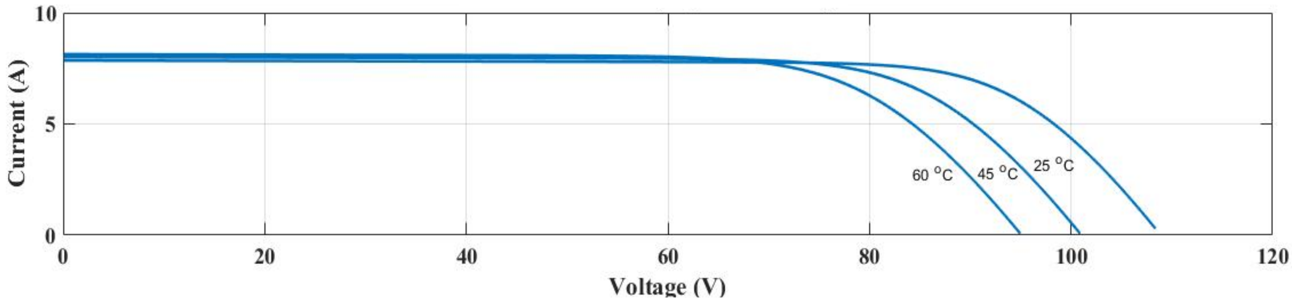

Fig.15. V-I characteristics at 25°C

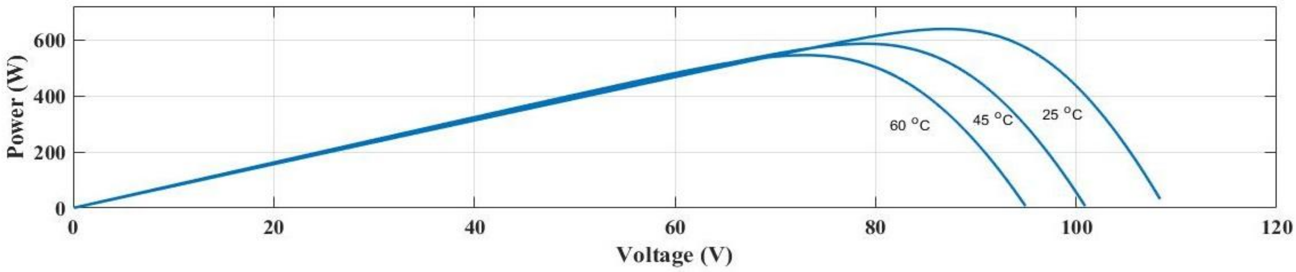

Fig.16. P-V characteristics at 25°C

The above figures Fig.15 and Fig.16 shows the V-I and P-V curves of PV at 25°c.

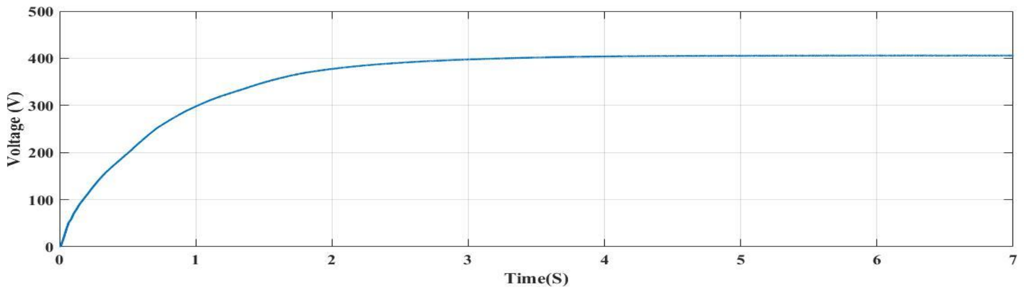

Fig. 17: Output Voltage of Boost Converter

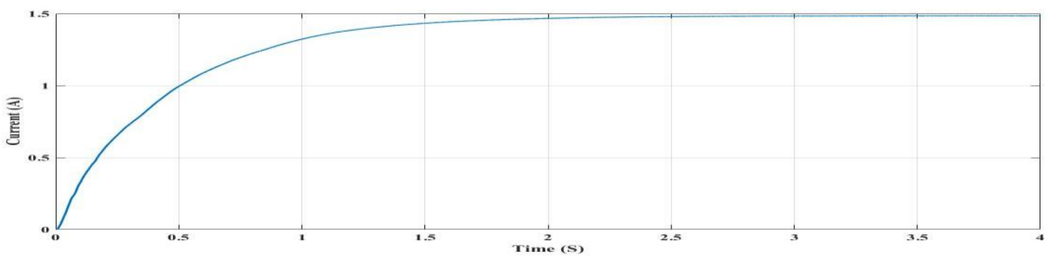

Fig. 18: Output Current of Boost Converter

Fig. 17 and Fig. 18 shows the output voltage and current wave forms of the boost converter.

V. CONCLUSION

Power produced with the usage of ordinary fuels will releases toxic gasses like carbon dioxide, carbon monoxide, nitrogen dioxide etc. It will causes environment contamination and as a consequence leading to global warming. This led to the usage of renewable energy sources. A three phase source feeding switched reluctance motor has been simulated and obtained waveforms for distorted source current. Also reference current has been generated by using IcosΦ algorithm and waveforms are obtained through MATLAB Simulation. By the use of minimally switched grid connected photo voltaic inverter with adaptive control, in which switching losses are reduced can be magnificently used for creating the switching frequency of the VSI approximately constant. By this means overwhelming the drawback of conservative and modified hysteresis controller which consumes variable switching frequency. Employing adaptive control, the THD of supply current is condensed to 0.22% from 28.20%. In this paper it is clear by using FFT analysis that the THD of the source current is minimum (that is 0.22%) by the use of shunt active filter there by the power factor is increased to a value 0.976%.

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