Soft Computing Approach for Reactive Power Compensation with Solar Photovoltaic System

S. S. Khule[1], S. W. Mohod[2]

Abstract- *Environment friendly nature of renewable energy sources (RES), specially of Photovoltaic (PV) system and technological developments of power electronics have motivated in harnessing renewable energy. Photovoltaic Modules are related under standard condition to determine the Watt- Peak rating which can be used with insolation to get the expected output. The paper presents a solar PV system designed and integrated through a three phase shunt active filtering soft computing algorithm based on real component of load current IcosΦ has been proposed and implemented in novel manner. The STATCOM is used as a reactive power compensator and for real power exchange for the load. The implementation of soft computing algorithm maintain the power factor nearly to unity. The irradiance effects are studied with the soft computing algorithm which also compensate irradiance effect. The response of soft computing algorithm proves the effectiveness of proposed control technique.*

Keywords- Solar Photovoltaic, IcosΦ Algorithm, STATCOM.

I. INTRODUCTION

Due to ever increasing energy consumption and global climate change problems, renewable energy technologies have been received more and more attention to solve the global issues. Because of rapid growth in power electronic techniques, the photovoltaic (PV) power generation system has been developed worldwide. By changing the duty cycle, the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer maximum power. Therefore MPPT techniques are needed to maintain the PV arrays operating at its Maximum Power Point. There are many MPPT techniques like Perturb and Observe (P&O), Incremental Conductance (IC), Fuzzy Logic, etc.

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A unique step-by-step procedure for the simulation of photovoltaic modules with Matlab -Simulink has presented in[1].This mathematical modelling procedure serves as an aid to induce research and gain a closer understanding of I-V and P-V characteristics of PV module. I cos Φ algorithm has been applied to a three-phase shunt active filter to provide harmonics and reactive power compensation as demanded by the non-linear reactive load. This algorithm is very simple and easy to implement so that it is necessary for the source to supply only the real power demanded by the load [2] Three-phase four-wire shunt active filters can compensate power quality problems and can also interface renewable energy sources with gird. The inverter stage of the active filter is based in two-level four-lag inverter and its control is based in the theory of instantaneous reactive power (p-q Theory). The filter is capable of compensating power factor, unbalance, and current harmonics. Additionally it can also make the interface between renewable energy sources and the electrical system injecting balanced, practically sinusoidal currents (with low THD) [3]. Overview of the Maximum Power Point Tracking methods for Photovoltaic (PV) inverters has been presently reported in the literature. The most well-known and popular methods, like the Perturb and Observe (P&O) These methods, especially the P& O, have been treated by many works, which aim to overcome their shortcomings, either by optimizing the methods, or by combining them.[4].

In the paper the most popular of MPPT technique Perturb and Observe method has been implemented The utilization efficiency can be improved by employing this hill-climbing MPPT technique. This is a simple algorithm that does not require previous knowledge of the PV generator characteristics or the measurement of solar intensity and cell temperature and is easy to implement with analog and digital circuits. The algorithm perturbs the operating point of the PV generator by increasing or decreasing a control parameter by a small amount (step size) and measures the PV array output power before and after the perturbation. If the power increases, the algorithm continues to perturb the system in the same direction; otherwise the system is perturbed in the opposite direction. The number of perturbations made by the MPPT algorithm per second is known as the perturbation frequency or the MPPT frequency.

II. MATHEMATICAL MODEL OF PHOTOVOLTAIC

A photovoltaic PV module consist of number of Ns solar cells in series and the equivalent circuit of the physical model of the solar cell is given in Fig. 1.

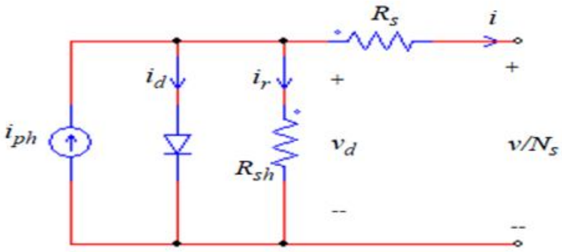

Figure 1. Equivalent circuit diagram of solar cell

The Solar cells are made from semiconductors cells and are usually arranged in modules. There are different types of solar cells available in the market and are under development as sensitized nand-crystalline cells for high efficiency and low cost. The datasheet parameters of physical PV module are shown in Table I.

Table 1.Specifications of photovoltaic module

Sr. No.	Electrical Characteristics	Value
01	Product Code	SLP011-12
02	No. of Cell	36
03	Standard light intensity So	1000
04	Ref. temperature Tref	25°C
05	Maximum Power Pmax	11W
06	Voltage at Pmax	17.6V
07	Current at Pmax	0.63A
08	Open-Circuit Voltage Voc	21.1V
09	Short-Circuit Current Isc	0.68A
10	Temperature Coeff. of Voc	-(80±10)mv/°C
11	Temperature Coeff. of Isc	±0.015%/° C
12	Operating Temperature	-40°C to 85°C

The solar cell describes the inverse relationship between current and voltage and the equations that describes a solar cell as (1).

$$i = i_{ph} - i_d - i_r \quad (1)$$

$$i_{ph} = I_{sc\,o} \cdot \frac{S}{S_o} + C_t \cdot (T - T_{ref}) \quad (2)$$

$$i_d = I_o \cdot \left[e^{\frac{q\, v_d}{Ak}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)} \right] \quad (3)$$

$$i_r = \frac{v_d}{R_{sh}} \quad (4)$$

$$v_d = \left(\frac{v}{N_s} + i \cdot R_s \right) \quad (5)$$

Where q is the electron charge (q =1.6*10-19C) ; k is the Boltzmann constant (k=1.3806505*10-23) ; s is the intensity

Input ; Ta is the ambient temperature input ; v is the voltage across the entire solar module ; and i is the current flowing out of the positive terminal of the solar module.

The photovoltaic module provides power to the load which often operates away from the maximum operating point of module. The characteristics curves for solar cell simulated module as shown in Fig.2.

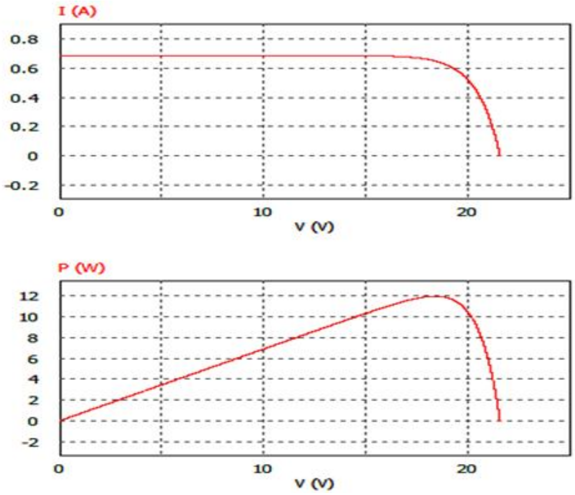

Figure 2. Characteristics of Current verses Voltage and Power verses Voltage

III. STATCOM MODEL

The STATCOM is a very efficient power electronics system to transfer the power to the grid. Many types of the power electronics interfaces topologies are available. The main control objective is to track dc power and transfer the maximum power to the grid. The major parameter which is sensitive to the power flow across the dc link is the dc bus voltage. This requires being constant to operate the voltage source inverter satisfactorily. The dc bus voltage can be maintained constant by regulating the MPPT. The demand of load as when it is increased or decrease can be felt by change in the dc bus voltage. This is incorporated in the control to regulate the photovoltaic power. This enables the system to support the varying real power of the load demand. The voltage source inverter is operated in current control mode.

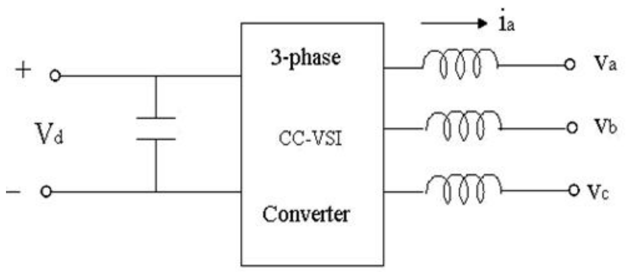

Figure 3. Voltage Source Inverter Model

The three phase inverter model with Thyristor /IGBT switches are built using Power System Block Set of SIMULINK. The dc bus capacitor rating is chosen to withstand the circulating currents while operating with more of reactive power support. The interface of the inverter with the grid is through the transformer. This is represented as equivalent inductor in the simulation

IV. SOFT COMPUTING ALGORITHM

The Icos∅ algorithm generates reference compensation currents for the three-phase shunt active filter based on the real part of the load current. This ensures that the current drawn from the supply mains is purely sinusoidal with no reactive component i.e. at unity power factor. The three-phase system includes a three-phase balanced supply connected to a thyristors-controlled converts feeding a resistive load. Firing of the thyristors is adjusted to 0-60 so that the load currents are highly non-linear and reactive. A three-phase voltage source inverter with a self- supporting

DC bus capacitor generates the required harmonics and reactive power compensation. Fig.6 shows the block diagram representation of the Icos∅ control scheme

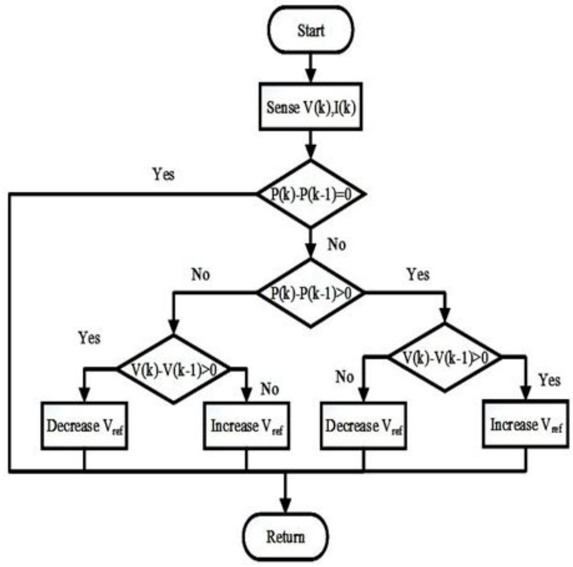

Figure 4. An Algorithm of Perturb and Observe Method

V. PROPOSED SCHEME

The STATCOM based current control voltage source inverter injects the current into the grid in such a way that the source current are harmonic free and their phase-angle with respect to source voltage has a desired value. The injected current will cancel out the reactive part and harmonic part of the load and induction generator current, thus it improves the power factor and the power quality. To accomplish these goals, the grid voltages are sensed and are Synchronized in generating the current command for the inverter. The proposed system is implemented for reactive power support, power quality improvement at point of common coupling (PCC), as shown in Fig. 5.

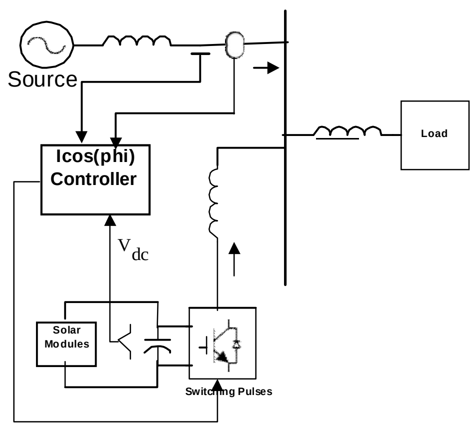

Figure 5. Grid-Solar PV Module

V. CONTROL STRATEGY

The load currents in the three phases are sensed and the amplitude of the active part alone is detected using second order low pass filters. This forms the amplitude IcosØ of the desired source currents in the three phases. The fluctuation in the dc bus voltage is used to calculate the corresponding power loss occurring in the switching devices of the active filter and/or the interface transformer. The amplitude of the current equivalent to the power loss is added to the IcosØ component in each phase to arrive at the required magnitude of the source circuit.

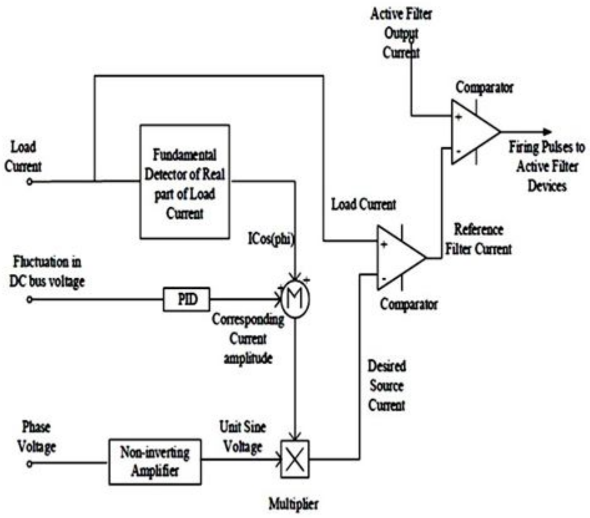

Figure 6. Block Diagram of IcosØ Algorithm

The three-phase mains voltages are used as templates to generate unit amplitude sine waves in phase with the mains voltages. The product of the two i.e. the amplitude IcosØ of the reference source current and the unit sine wave gives the desired source current waveform in each phase.

VI. SIMULATION RESULTS

The simulation of the three phase grid system supplying linear inductive-load and STATCOM interface for renewable energy source has been done using MATLAB Simulink. The STATCOM acts as an effective interfacing link between the renewable energy source and grid system. The STATCOM unit performs regular role of delivering the required amount of reactive power and power factor correction, which works with the gating pulses generated to merely being an, interfacing unit another imperative function of a STATCOM is the ability of real power exchange from renewable energy source to load and grid. Fig. 7 shows the load voltage and current which is constant for all irradiation From Fig. 8 & Fig. 9 we can observe that the rms value of source current is increasing as the irradiation decreases from 1000W/m2 to 0W/m2

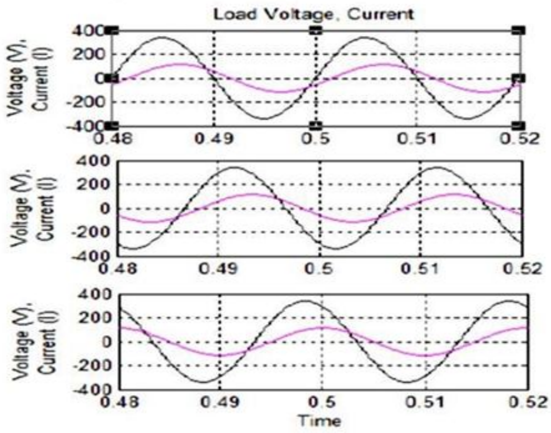

Figure 7. Load Voltage and Current

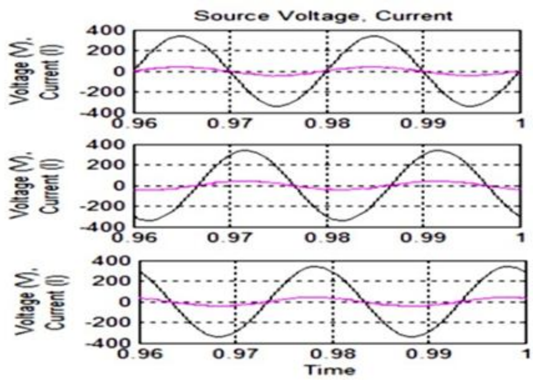

Figure 8. Source Voltage and Current at 1000W/m2 Irradiation

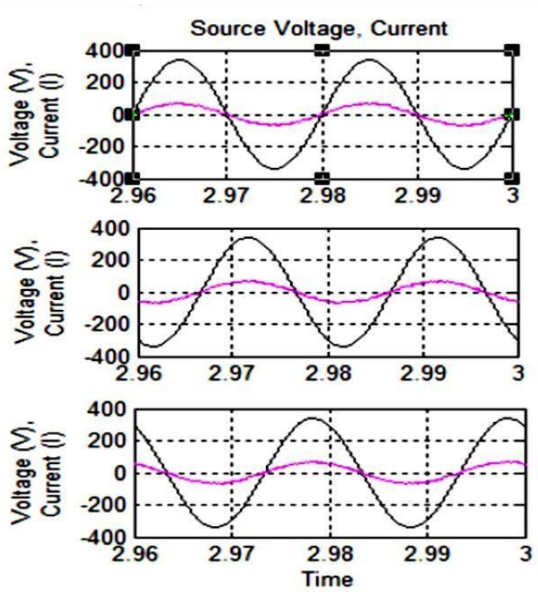

Figure 9. Source Voltage and Current with 0 W/mˆ2 Irradiation

Table 2. Simulation Analysis of STATCOM with Solar PV System

	Irradiation (W/m2)	Voltage (V)	Current (A)	Active Power (kW)	Reactive power (kVar)	Power Factor
Source	1000	$240\angle 0°$	$29.69\angle 1.2°$	21.3	-0.45	0.999Lead
Load		$240\angle 0°$	$81.12\angle -30.95°$	50.0	30.0	0.857Lag
STATCOM		$282.1\angle 7.7°$	$58.26\angle 46.70°$	28.7	30.45	
Source	800	$240\angle 0°$	$38.53\angle 0.9°$	27,7	-0.40	0.999Lead
Load		$240\angle 0°$	$81.12\angle -30.95°$	50.0	30.0	0.857Lag
STATCOM		$281.0\angle 6°$	$52.46\angle 53.65°$	22.3	30.40	
Source	600	$240\angle 0°$	$46.52\angle 0.6°$	33.4	-0.35	1
Load		$240\angle 0°$	$81.12\angle -30.95°$	50.0	30.0	0.857Lag
STATCOM		$280.3\angle 4.5°$	$48.08\angle 61.35°$	16.6	30.35	
Source	400	$240\angle 0°$	$53.38\angle 0.4°$	38.3	-0.30	1
Load		$240\angle 0°$	$81.12\angle -30.95°$	50.0	30.0	0.857Lag
STATCOM		$279.3\angle 3.5°$	$45.04\angle 68.95°$	11.7	30.30	
Source	200	$240\angle 0°$	$61.66\angle 0.3°$	44.3	-0.25	1
Load		$240\angle 0°$	$81.12\angle -30.95°$	50.0	30.0	0.857Lag
STATCOM		$279.3\angle 1.5°$	$42.77\angle 79.25°$	5.7	30.25	
Source	0	$240\angle 0°$	$69.65\angle 0.2°$	50	-0.20	1
Load		$240\angle 0°$	$81.12\angle -30.95°$	50.0	30.0	0.857Lag
STATCOM		$279.3\angle 0°$	$42.00\angle 90°$	0	30.20	

VII. CONCLUSION

Implementation of soft computing algorithm I cosØ algorithm for reactive power compensation with solar PV has been presented in this paper. Integration of Solar PV with STATCOM improves the power quality of source supply where sensitive loads are connected. The scheme also reduces transmission lines losses as the source is free from reactive power supply and also power transfer capacity of system get improved and thus improve the stability of receiving end.

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