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A STATCOM Controller for Grid Connected Photo Voltaic Energy System to Improve Power Quality

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ABSTRACT

Renewable energy sources are being increasingly connected in distribution systems utilizing power electronic converters. This paper focuses on the photo voltaic (PV) system integrated to a three phase four wire system at the distribution level with power quality improvement features. The photo voltaic panel is modelled based on associated equations. The influence of the wind turbine in the grid system concerning the power quality measurements are-the active power, reactive power, variation of voltage, flicker, harmonics and electrical behavior of switching operation and these are measured according to national/international guidelines. This paper demonstrates the power quality problem due to installation of solar panel with the grid. In this proposed scheme Static Compensator (STATCOM) is connected at a point of common coupling to mitigate the power quality issues. The STATCOM control scheme for the grid connected PV energy system for power quality improvement is simulated using MATLAB/SIMULINK in power system block set. The STATCOM is controlled on the basis of hysteresis control of statcom. Thus with such a control, a balanced linear load appears at the grid with the combination of STATCOM and 3-phase 4-wire linear/non-linear unbalanced load

KEYWORDS: STATCOM, distributed generation (DG), distribution system, grid interconnection, power quality (PQ) and renewable energy.

I. Introduction

Electric utilities and end users of electric power are becoming increasingly concerned about meeting the growing energy demand. Seventy five percent of total global energy demand is supplied by the burning of fossil fuels. But increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution. Since the past decade, there has been an enormous interest in many countries on renewable energy for power generation. The market liberalization and government's incentives have further accelerated the renewable energy sector growth. Renewable energy source (RES) integrated at distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of intermittent Resin distribution systems as it may pose a threat to network in terms of stability, voltage regulation and power-quality (PQ) issues. Therefore, the DG systems are required to comply with strict technical and regulatory frameworks to ensure safe, reliable and efficient operation of overall network. With the advancement in power electronics and digital control technology, the DG systems can now be actively controlled to enhance the system operation with improved PQ at PCC. However, the extensive use of power electronics based equipment and on-linear loads at PCC generate harmonic currents, which may deteriorate the quality of power.

The non-linear load current harmonics may result in voltage harmonics and can create a serious PQ problem in the power system network.The causes of power quality problems are generally complex and difficult to detect when we integrate a photo voltaic system to the grid. Technically speaking, the ideal AC line supply by the utility system should be a pure sine wave of fundamental frequency (50/60Hz). We can therefore conclude that the lack of quality power can cause loss of production, damage of equipment or can even be detrimental to human health. It is therefore imperative that a high standard of power quality is maintained. This paper demonstrates that the power electronic based power conditioning using custom power devices like STATCOM can be effectively utilized to improve the quality of power supplied to the customers.Here, the main idea is the maximum utilization of inverter rating which is most of the time underutilized due to intermittent nature of RES. It is shown in this paper that the grid-interfacing inverter can effectively be utilized to perform following important functions: 1) transfer of active power harvested from the solar panel; 2) load reactive power demand support; 3) current harmonics compensation at PCC; and 4) current unbalance and neutral current compensation in case of 3-phase 4-wire system. Moreover, with adequate control of grid-interfacing inverter, all the four objectives can be accomplished either individually or simultaneously. The PQ constraints at the PCC can therefore be strictly maintained within the utility standards without additional hardware cost.

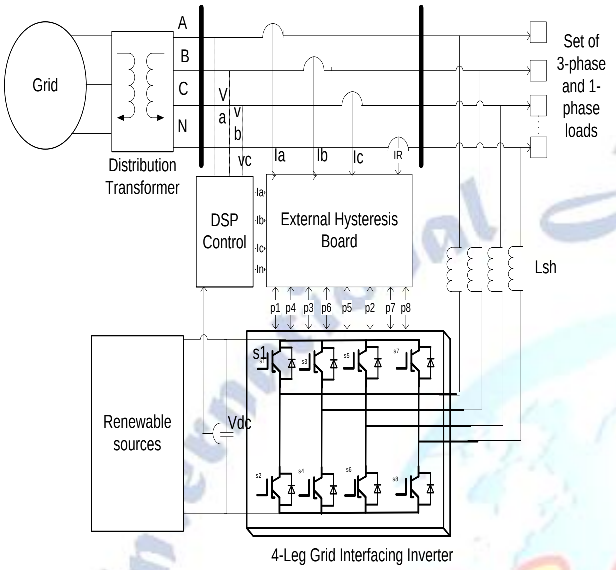

Fig 1: Schematic of proposed renewable based distributed generation system.

The paper is arranged as follows: Section II describes the system under consideration and the controller for grid-interfacing inverter. A simulation study is presented in Section III. Extensive experimental results are discussed in Section IV and, finally, Section V concludes the paper.

2. Grid Interconnection of Photo Voltaic System

Recently grid connected photovoltaic system have been spreading in residential areas and in industrial areas. So we have to find a suitable MPPT technique that gives a better power output when connected is to find out. For a grid connected system there are certain factors that have been considered such that DC-AC conversion with highest output power quality with the proper design of filters System main controlling factors like MPPT.Grid interface inverters which transfers the energy from the photovoltaic module to the grid by just keeping the dc link voltage which is to be maintained constant. For a grid connected system the utility network mainly demands for better power quality and power output. In the case of voltage fluctuations control of grid parameters is very difficult. So for a PV system that is connected to a grid first stage is the boosting stage and the second stage is DC-AC converter. An output filter is usually employed which reduces the ripple components due to switching problems.The problem associated with the grid connected system is that the dc link voltage that must be oscillates between the two levels which depends on the operating climatic conditions (ambient temperature & irradiance) in which inverter which acts us a power controller between the dc link and the utility. Dc link is generally used to isolate between the grid side and the inverter side so that we can control both PV system and grid separately. All the available power that can be extracted from the photovoltaic system is transferred through the grid. In the case of a distributed power generation system that is connected to a grid the grid frequency and the grid voltage that can be controlled by simply adjusting the active and reactive power.

2.1 Solar Panel:

A solar cell is the most fundamental component of a photovoltaic (PV) system. The PV array is constructed by many series or parallel connected solar cells to obtain required current, voltage and high power. Each Solar cell is similar to a diode with a p-n junction formed by semiconductor material. When the junction absorbs light, it can produce currents by the photovoltaic effect. The equivalent circuit of a solar cell is the current source in parallel with a diode of a forward bias which represents dark current. The output terminals of the circuit are connected to the load. The current equation of the solar cell is given by:

$$I = I_{ph} - I_D - I_{sh}$$

$$I = I_{ph} - I_0[\exp(\frac{qV_D}{nkT})] - \frac{V_D}{R_{SH}}$$

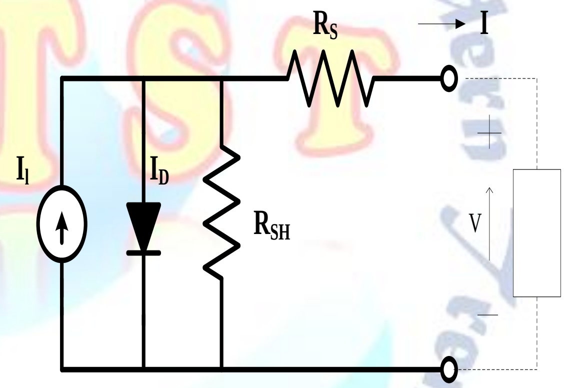

Fig 2: Equivalent Circuit of a Solar Cell

A typical PV characteristic of a solar cell is shown in figure based on varying solar irradiation and temperature changes.It can be seen that a maximum power point exists on each output power characteristic curve. A solar cell is modelled based on the equivalent circuit.

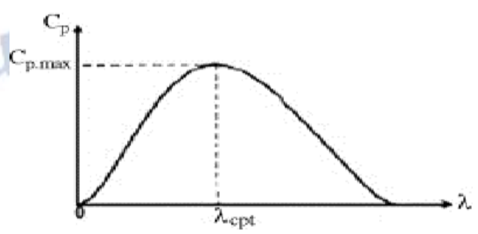

Fig 3: Output Characteristics of a PV Array

2.2 **MPPT Technique**:

Maximum power point tracker (or MPPT) is a high efficiency DC to DC converter that presents an optimal electrical load to a solar panel or array and produces a voltage suitable for the load.

For a grid connected for a grid connected PV system the first stage is the boosting stage in which the input voltage from the PV panel is boosted. Basically a dc-dc converter which acts us an interface between the load and the PV module. The maximum power point tracking is basically a load matching problem in which our basic requirements are obtained. In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle) that is tracking the maximum power, a DC to DC converter is basically required. Due to more flexibility, better performance and ease of implementation a boost converter is generally used for PV grid connected systems. In the case of a buck converter the current is not flowing constantly and it is continuously varying. Compared to other type of converters boost converter which provides maximum efficiency.

MPPT techniques are commonly used to find out the voltage and current at which maximum power point of a PV module occurs. Using MPPT techniques with solar panel which have clear advantages such that initial investment is much smaller because smaller panel wattage power is required. Maximum power point of a particular solar photovoltaic module lies about 0.75 times which is greater than its open circuit voltage. Maximum amount of power that can be extracted from a panel which depends on certain factors like SOLAR IRRADINCE: It is the measure of how much solar power that we have obtained from a particular area and also it depends on certain natural factors. TEMPERATURE: It mainly depends on panel operating point at which maximum power is obtained.

There are different techniques used to track the maximum power point. The choice of the algorithm depends on the time complexity of the algorithm to track the Maximum power, Implementation cost, Simplicity, Ability to track maximum power under varying atmospheric conditions. Here the technique of PERTURB AND OBSERVE (P&O) METHOD is used. It is the simplest method and is widely used. In this technique we generally use only one sensor, that is the voltage sensor, to sense the PV module voltage and hence the cost of implementation is less and hence easy to implement without any complexity. The algorithm for P&O method is given in fig: 4.

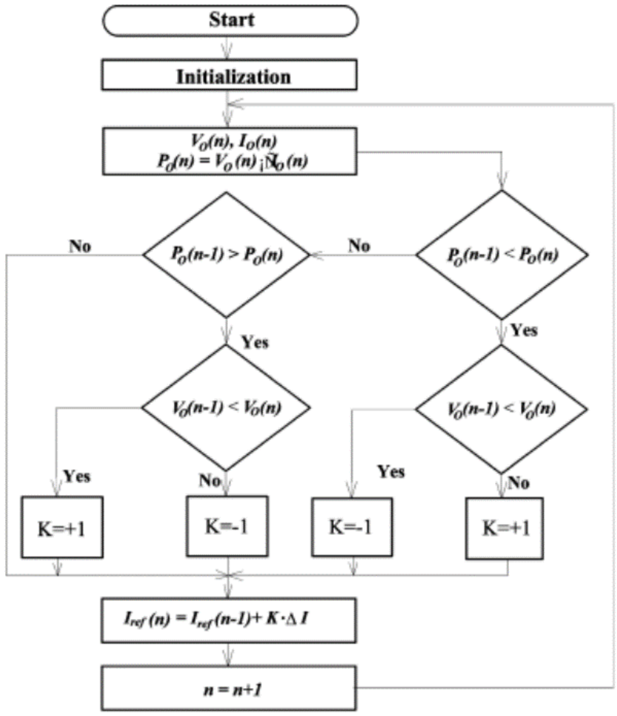

FIG 4: FLOWCHART OF P&O METHOD

2.3 STATCOM and its Control Technique:

A STATCOM is built with Thyristors with turn-off capability like GTO or today IGCT or with more and more IGBTs.A STATCOM based control technology has been proposed for improving the power quality which can technically manages the power level associates with the commercial photo voltaic system. The proposed Solar based STATCOM control scheme for grid connected photo voltaic energy generation for power quality improvement has following objectives.

• Unity power factor at the source side.

• Reactive power support only from STATCOM to wind Generator and Load.

• The Dc voltage is obtained for STATCOM is generated from Solar Cells.

A STATCOM is a controlled reactive-power source.The STATCOM is connected to the power system at a PCC (point of common coupling), through a step-up coupling transformer, where the voltage-quality problem is a concern.It provides voltage support by generating or absorbing reactive power at the point of common coupling without the need of large external reactors or capacitor banks. Using the controller, the VSC and the coupling transformer, the STATCOM operation is illustrated in Figure below:

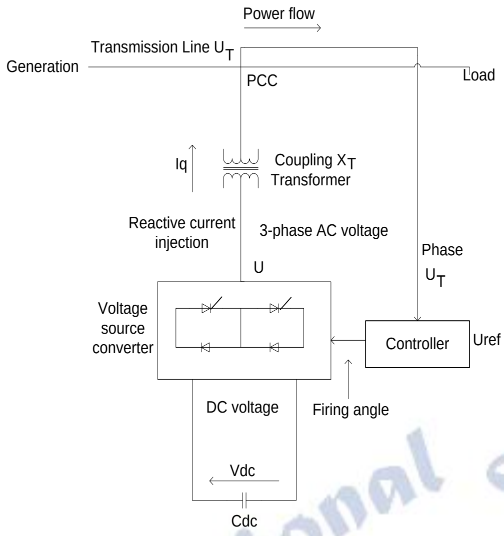

Fig 5: STATCOM OPERATION IN POWER SYSTEM

The charged capacitor C dc provides a DC voltage, U_{dc} to the converter, which produces a set of controllable three-phase output voltages, U_{in} synchronism with the AC system. The synchronism of the three-phase output voltage with the transmission line voltage has to be performed by an external controller. The amount of desired voltage across STATCOM, which is the voltage reference, U_{REF}, is set manually to the controller. The voltage control is thereby to match UT with U_{REF} which has been elaborated. This matching of voltages is done by varying the amplitude of the output voltage U, which is done by the firing angle set by the controller. The controller thus sets U_T equivalent to the U_{REF}.

The reactive power exchange between the converter and the AC system can also be controlled. This reactive power exchange is the reactive current injected by the STATCOM, which is the current from the capacitor produced by absorbing real power from the AC system. Where, I_Q is the reactive current injected by the STATCOM U_T is the STATCOM terminal voltage, UEQis the equivalent Thevinin's voltage seen by the STATCOM, XEQ is the equivalent Thevinin's reactance of the power system seen by the STATCOM. If the amplitude of the output voltage U is increased above that of the AC system voltage, U T, a leading current is produced, i.e. the STATCOM is seen as a conductor by the AC system and reactive power is generated. Decreasing the amplitude of the output voltage below that of the AC system, a lagging current results and the STATCOM is seen as an inductor. In this case reactive power is absorbed. If the amplitudes are equal no power exchange takes place. A practical converter is not lossless. In the case of the DC capacitor, the energy stored in this capacitor would be consumed by the internal losses of the converter. By making the output voltages of the converter lag the AC system voltages by a small angle, δ, the converter absorbs a small amount of active power from the AC system to balance the losses in the converter.

The control scheme approach is based on injecting the currents into the grid using "bang-bang controller." The controller uses a hysteresis current controlled technique. Using such technique, the controller keeps the control system variable between boundaries of hysteresis area and gives correct switching signals for STATCOM operation.

The control system scheme for generating the switching signals to the STATCOM is shown in Fig. 6.The control algorithm needs the measurements of several variables such as three-phase source current $I_{saac,}$ DC voltage v_{dc}, inverter current $i_{iabc,}$ with the help of sensor. The current control block, receives an input of reference current $i^*_{sabc,}$ and actual current i_{sabc} are subtracted so as to activate the operation of STATCOM in current control mode .In three-phase balance system, the RMS voltage source amplitude is calculated at the sampling frequency from the source phase voltage (V_{sa}, V_{sb}, V_{sc}) and is expressed, as V_{sm}, sampled peak voltage, as in (a).

$$V_{sm}= \{2/3(V^2_{sa}+V^2_{sb}+V^2_{sc})^{1/2}\} \quad \text{.................. (a)}$$

The in-phase unit vectors are obtained from AC source—phase voltage and the RMS value of unit vector U_{sa}, U_{sb}, U_{sc} as shown in (b)

$$Usa = \frac{Vsa}{Vsm} Usb = \frac{Vsb}{Vsm} Usc = \frac{Vsc}{Vsm} \quad \text{.................. (b)}$$

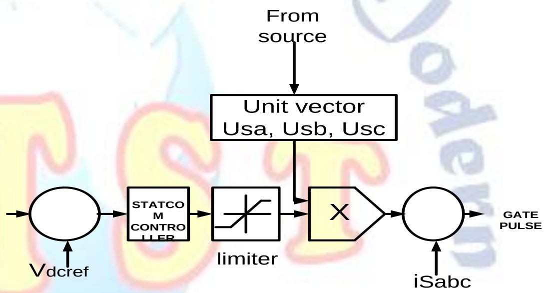

Fig 6: Control Diagram

3. SIMULATION STUDY

The proposed control scheme is simulated using SIMULINK in power system block set. The main block diagram of the system operational scheme is shown in Fig. 1. The simulation is done based on the fig 1, as shown in figure 7 and the obtained power quality is shown below.

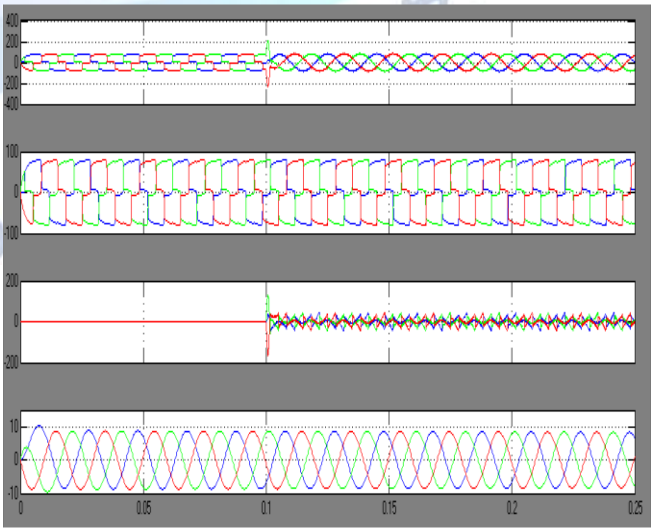

Fig 7: Over All Circuit Diagram in Simulation with Sub Systems

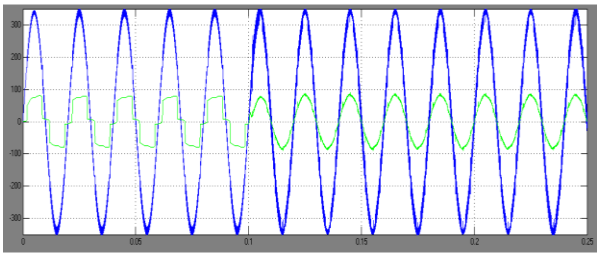

Fig 8: simulation result for load voltage and current for power factor.

CONCLUSION

The paper presents the STATCOM based control scheme for power quality improvement in grid connected photo voltaic energy system along with PV Cell and with non-linear load. The power quality issues and its consequences on the consumer and electric utility are presented. The operation of the control system developed for the STATCOM-PV in MATLAB/SIMULINK for maintaining the power quality is simulated. It has a capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in-phase and support the reactive power demand for the solar panel and load at PCC in the grid system, thus it gives an opportunity to enhance the utilization factor of transmission line. The integrated grid and STATCOM with PV have shown the outstanding performance.

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