Power Quality Improvement using STATCOM in PV Grid Connected System

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Abstract - *Renewable energy sources are being progressively more connected in distribution systems utilizing power electronic converters. This paper focuses on the photo voltaic (PV) grid system at the distribution level with power quality improvement features. The power quality measurements depend on the performance of the wind turbine. Active power, reactive power, variation of voltage, flicker, and harmonics are the measurements which are influenced, and these are measured according to national/international guidelines. In this paper, proposed scheme Static Compensator (STATCOM) is connected at a point of common coupling to mitigate the power quality issues. [2]*

Key Words: STATCOM, distributed generation (DG), distribution system, grid interconnection, power quality (PQ), renewable energy, International electro-technical commission (IEC).

1. INTRODUCTION

Electric utilities and end users of electric power are becoming increasingly concerned about meeting the growing energy demand. To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, and co-generation etc. The market liberalization and government's incentives have further accelerated the renewable energy sector growth. 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. The power quality is an essential customer- focused measure and is greatly affected by the operation of a distribution and transmission network. [3]

The issue of power quality is of great importance to the wind turbine. In the fixed-speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. During the normal operation, wind turbine produces a continuous variable output power. These power variations are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system. Thus, the network needs to manage for such fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. 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.

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. This proposed PV cell STATCOM control scheme for grid connected wind energy generation for power quality improvement has following objectives. [4]

- Unity power factor at the source side.
- Reactive power support only from STATCOM to wind Generator and Load.
- Simple bang-bang controller for STATCOM to achieve fast dynamic response.

1.1 POWER QUALITY ISSUES:

A. Voltage Variation:

The voltage variation issue results from the wind velocity and generator torque. The voltage variation is directly related to real and reactive power variations. The voltage variation is commonly classified as under:

- Voltage Sag/Voltage Dips.
- Voltage Swells.
- Short Interruptions.
- Long duration voltage variation.

The voltage flicker issue describes dynamic variations in the network caused by wind turbine or by varying loads. Thus the power fluctuation from wind turbine occurs during continuous operation. The amplitude of voltage fluctuation depends on grid strength, network impedance, and phase-angle and power factor of the wind turbines. It is defined as a fluctuation of voltage in a frequency 10–35

Hz. The IEC 61400-4-15 specifies a flicker meter that can be used to measure flicker directly. [6]

B. Harmonics:

The harmonic results due to the operation of power electronic converters. The harmonic voltage and current should be limited to the acceptable level at the point of wind turbine connection to the network. To ensure the harmonic voltage within limit, each source of harmonic current can allow only a limited contribution, as per the IEC-61400-36 guideline. The rapid switching gives a large reduction in lower order harmonic current compared to the line commutated converter, but the output current will have high frequency current and can be easily filter-out.

C. Wind Turbine Location in Power System:

The way of connecting the wind generating system into the power system highly influences the power quality. Thus the operation and its influence on power system depend on the structure of the adjoining power network.

D. Self Excitation of Wind Turbine Generating System:

The self excitation of wind turbine generating system (WTGS) with an asynchronous generator takes place after disconnection of wind turbine generating system (WTGS) with local load. The risk of self excitation arises especially when WTGS is equipped with compensating capacitor. The capacitor connected to induction generator provides reactive power compensation. However the voltage and frequency are determined by the balancing of the system. The disadvantages of self excitation are the safety aspect and balance between real and reactive power [5].

E. Consequences of the Issues:

The voltage variation, flicker, harmonics causes the malfunction of equipments namely microprocessor based control system, programmable logic controller; adjustable speed drives, flickering of light and screen. It may leads to tripping of contractors, tripping of protection devices, stoppage of sensitive equipments like personal computer, programmable logic control system and may stop the process and even can damage of sensitive equipments. Thus it degrades the power quality in the grid. [5]

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. [7]

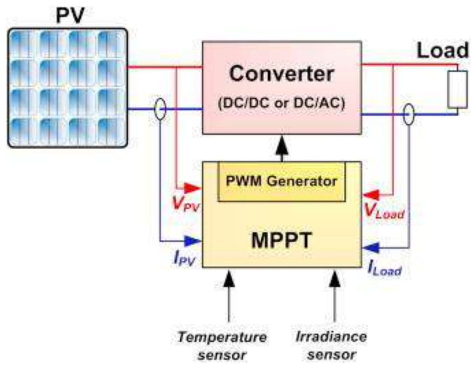

Figure 1: Block diagram of Typical MPPT system

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.

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

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terminals of the circuit are connected to the load. The current equation of the solar cell is given by:

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

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

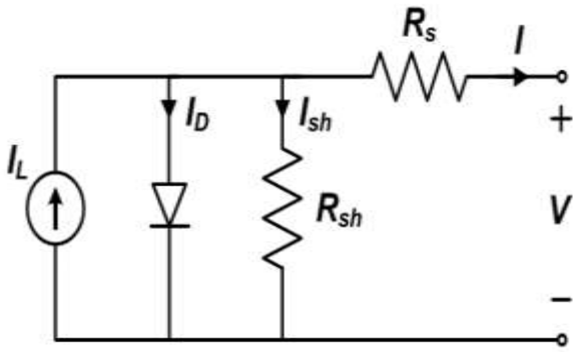

Figure 2: Equivalent Circuit of a Solar Cell

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.

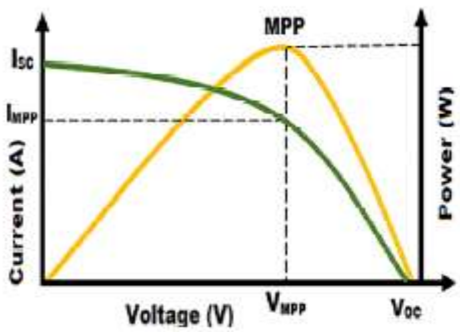

Figure 3: Output Characteristics of a PV Array

2.2 MPPT Technique:

Maximum power point tracking (MPPT) scheme is used to extract maximum power from solar PV cells. Numerous types of MPPT schemes are projected by researchers [1] namely open circuit, short circuit, perturb and observe (P&O)/hill climbing, incremental conductance, and so forth. [10]

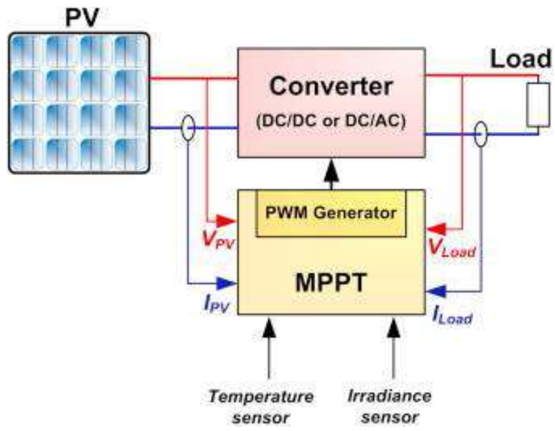

Figure 3: Block diagram of Typical MPPT system.

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.

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 figure 4.

2.2.1 Perturb and observe method:

By augmenting the estimations of duty cycle by a little proportion the voltage and current esteems will be estimated at N+1th instant. The control an incentive at Nth moment and N+1th moment will be compared. If the adjustment in the power as for the is sure then the procedure is going in the right heading, that is the positive direction. The duty cycle will be increased by a small ratio and the process will be continued for the next cycle.

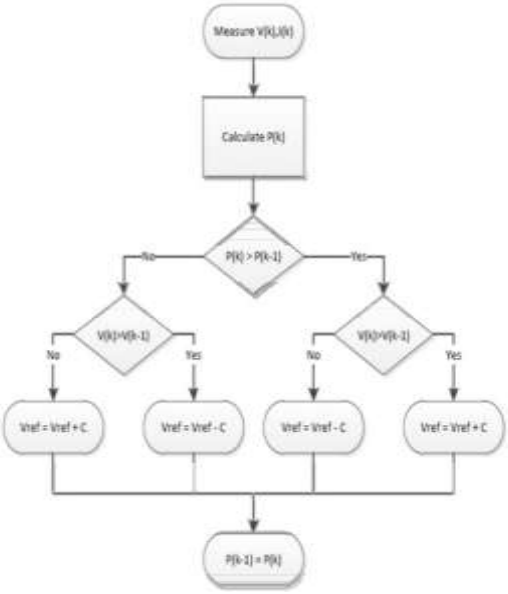

Figure 4: Flow chart of Perturb & Observe MPPT Technique

In the Perturb and Observe strategy specifically control is measured utilizing voltage and current Sensor. The control is computed from the voltage and current esteems at nth moment.

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. [8]

• 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 5 below:

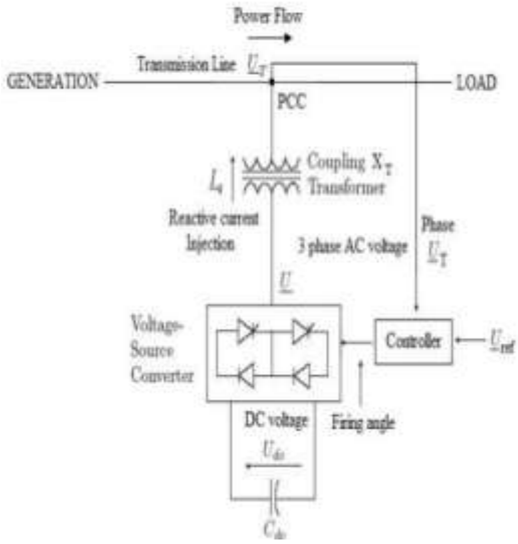

Figure 5: Statcom Operation in Power System

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, IQ is the reactive current injected by the STATCOM UT is the STATCOM terminal voltage, UEQ is 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. [9]

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.

3. Conclusions:

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. 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. [11]

Thus the proposed scheme in the grid connected system fulfils the power quality norms as per the IEC standard 61400-21.

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