Abstract —The use of renewable energy sources either as distributed generators in public AC networks or as isolated generating units supplying is one of the new trends in power-electronic technology. The main objective of this paper is to identify the problems associated with grid connected solar power system. The main objective of this work is to study of the behaviors of the solar PV systems and the power quality issues in converters and inverter. Harmonics are created by the switching system of the power electronic circuit and can cause damage to power equipment on the utility side and sensitive loads on the customer side. This paper presents studies of anti-islanding control and protection and capacitive control and also focused on application of electrochemical capacitor in power quality.

Index Terms: Power Quality, Solar Energy, Harmonics, Inverter.

I. INTRODUCTION

Government promotion of renewable energy sources has led to several large scale solar power plants in India. India receives solar energy in the region of 5 to 7 kWh/m² for 300 to 330 days in a year. This energy is sufficient to set up 20 MW solar power plants per square kilometer land area. With about 300 clear, sunny days in a year, India’s theoretical solar power reception, on only its land area, is about 5 Petawatt-hours per year (PWh/yr) (i.e. 5 trillion kWh/yr or about 600 TW). The daily average solar energy incident over India varies from 4 to 7 kWh/m² with about 1500–2000 sunshine hours per year (depending upon location), which is far more than current total energy consumption. For example, assuming the efficiency of PV modules were as low as 10%, this would still be a thousand times greater than the domestic electricity demand (in India) projected for 2015. The amount of solar energy produced in India is less than 1% of the total energy demand. The grid-interactive solar power as of December 2010 was merely 10 MW.

Government-funded solar energy in India only accounted for approximately 6.4 MW-yr of power as of 2005. However, as of October 2009, India is currently ranked number one along with the United States in terms of installed solar power generation capacity. Renewable distributed generation units, if properly controlled and designed can improve the power flow management on the grid and reduce the probability of grid faults, so increasing the power quality of the energy supply. It’s important to evaluate also the possible drawbacks of the increasing number of renewable energy sources on the power-supply stability and quality, both in grid connected and stand-alone configurations, in order to prevent possible problems with a proper design and management of this generation unit.

II. POWER QUALITY (PQ)

Power Quality describes the quality of the power exchanged at the point of connection and depends on the quality of the voltage and current. The distortion of the voltage level may not differ much from the ideal sinusoidal waveform, fundamental harmonic 50Hz. Due to the power system impedance, any current or voltage harmonic will result in generation and propagation of voltage and currents harmonics and affects the entire power system. The classifications for PQ are not identical for each issue and they are categorized in different guidelines e.g. IEC61000-2-5. The effect of disturbances and behavior of appliances on PQ cannot be solved completely but it should be decreased to normal proportions. The quality of the main voltage depends on the electromagnetic compatibility (EMC) which depends on the electromagnetic interference (EMI). The EMI is
defined as a disturbance signal that can lead to unacceptable working proportions. EMC is defined as the ability of the equipment or system to work in a proper way in the electromagnetic environment.

III. POWER QUALITY DISTURBANCES

*Over Voltages and Voltage Dips:* Over voltage on the low voltage grid can only be generated by faults or environmental phenomena (lightening) on the grid. Due to the reduced extension of the grid, these events are very rare and can be reduced by carefully designing and installing the grid components. The considerations about the over voltages can be extended also for voltage dips (sags). The main cause of voltage dips on grid connected loads is the fast reclosing action of switches in order to eliminate transient faults.

*Flickers:* Flickers are fast variations of the voltage supplied to the loads. These voltage oscillations are generated by repetitive load connection and disconnection or by their discontinuous current absorption.

*Harmonics:* High frequency harmonic components in the electric system can affect the grid current and the grid voltage too. Due to the impedances of the system, current harmonic components can produce voltage harmonics, and vice versa. Anyway, the primary causes of voltage and current harmonics are quite different. The harmonic components in grid current are produced by the loads equipped with electronic devices that absorb high frequency current components. These harmonic components can be reduced only by acting directly on the loads. The voltage harmonic components are introduced in the system by the interface converter and are produced mainly by the switching of electronic components. Voltage harmonics can also be presents due to regulator malfunctioning or due to harmonic components at frequency lower than the cut off frequency of the power bus regulator.

IV. POWER QUALITY IMPROVEMENT ISSUE

*Converter:* A boost converter is a DC-DC converter with an output voltage greater than the source voltage. The aim is to analyze and design the high efficient modified converters to extract maximum power from solar PV. For effective DC-DC conversion we should use chopper with input filter. The chopper can also be used for switching mode voltage regulator and for transferring energy between two dc source. However, harmonics are generated at the input and load side of the chopper, and these harmonics can be reduced by input and output filter. An input filter out the chopper generated harmonics from the supply line. The rms value of the nth harmonic component in the supply can be calculated from

\[ I_{ns} = \sqrt{1+(2nfLc)^2} \cdot I_{nh} \]

Where \( I_{ns} \) is supply current and \( I_{nh} \) is harmonic current. A high chopping frequency reduced the sizes of input filter element.

\[ V = V_s \left( \frac{\beta}{\pi} \right) \]

\[ V_a = \sum_{n=1,3,5}^{n} \frac{2V_s}{nm} \sin nwt \]

\[ V_b = \sum_{n=1,3,5}^{n} \frac{2V_s}{nm} \sin (\omega t - \beta) \]

\[ V_{ab} = \sum_{n=1,3,5}^{n} \frac{4V_s}{nm} \sin \frac{n\beta}{2} \cos (\omega t - \frac{\beta}{2}) \]

From equation (1) indicate that the nth harmonics can be eliminated by a proper choice of displacement angle \( \beta \), if

\[ \sin \frac{n\beta}{2} = 0 \]

\[ \beta = \frac{360}{n} \]
and the third harmonic will be eliminated if $\beta = \frac{360}{3} = 120^\circ$.

![Gating Signal Generation Diagram](image)

**Fig. 4. Gating Signal Generation Diagram**

A pair of unwanted harmonics at the output of single phase Inverter can be introducing a pair of symmetrical placed voltage notches. If some voltage harmonics still remain on the power bus and are transferred to the grid voltage, a solution to eliminate these can be the reducing of the cut off frequency of the inverter regulator, in order to make it able to compensate these lower harmonic components, too. Anyway, the cut off frequency of the interface inverter regulator should not be less at least one decade of the grid frequency.  

**Controller:** The embedded controller will fetch the input from the sensor and give command to the motor to run in order to tackle the change in the position of the sun. And also controller monitors the various electrical parameters and generates the control signal to solve the power quality issues.  

**Virtual Grid Flux Oriented Control:** Virtual grid flux vector control of grid connected Pulse Width Modulated (PWM) converter has many similarities with vector control of an electric machine. In fact grid is modeled as a synchronous machine with constant frequency and constant magnetization [2]. A virtual grid flux can be introduced in order to fully acknowledge the similarities between an electric machine and grid. In space vector theory, the virtual grid flux becomes a space vector that defines the rotating grid flux oriented reference frame. The grid flux vector is aligned along d-axis in the reference frame, and grid voltage vector is aligned with q-axis. Finding the position of grid flux vector is equivalent to finding the position of the grid voltage vector. An accurate field orientation can be expected since the grid flux can be measured. The grid currents are controlled in a rotating two-axis grid flux orientated reference frame. In this reference frame, the real part of the current corresponds to reactive power while the imaginary part of the current corresponds to active power. The reactive and active power can therefore be controlled independently since the current components are orthogonal. Accurate field orientation for a grid connected converter becomes simple since the grid flux position can be derived from the measurable grid voltages.

**V. ANTI-ISLANDING CONTROL AND PROTECTION**

In Grid Link mode of operation, when the output power of the inverter matches with the total load on the grid, the failing of grid does not create any change in voltage or frequency. The inverter continues to support the load. This condition is not safe. It is mandatory for power exporting inverters to detect grid failure and stop exporting power to the grid within 2 seconds. There are two types of anti-islanding control techniques:  

**Passive:** The voltage and/or the frequency change during the grid failure is measured and employs a positive feedback loop to push the voltage and/or the frequency further away from its nominal value. Frequency or voltage may not change if the load matches very well with the inverter output or the load has a very high quality factor (reactive to real power ratio). So there exists some Non Detection Zone (NDZ).  

**Active:** Injects some error in frequency or voltage. When grid fails the error accumulates and pushes the voltage and/or frequency beyond the acceptable range.

**VI. CAPACITIVE COUPLING**

The region between PV modules and PV structure essentially acts as an insulator between layers of PV charge and ground. Most shunt capacitive effects that may be ignored at very low frequencies cannot be neglected at high frequencies for which the reactance will become relatively small due to the inverse proportionality with frequency and, therefore, a low impedance path is introduced between power elements and ground. This effect is present in PV installations because of the high frequency switching carried out by the converters stage, which arises different capacitive coupling between modules and ground? Thus, the capacitive effect must be represented as a leakage loop between PV arrays, cables and electronic devices and the grounding system. By means of this leakage loop, capacitive currents are injected into the grounding system creating a GPR along the PV installation which introduces current distortion, electromagnetic interference, and noise and Unsafe work conditions. For this reason, an accurate model of these capacitive couplings is required for PV installations.

![Resonance Frequency of the PV Installation without Capacitive Coupling](image)

**Fig 5. Resonance Frequency of the PV Installation without Capacitive Coupling (Dashed Line) and Considering Capacitive Couplings (Solid Line) [3]**

**VII. THE APPLICATION OF THE ELECTROCHEMICAL CAPACITORS IN POWER QUALITY**

The simplified scheme of using of EC in systems with the primary photoelectric source and secondary low-voltage batteries is given at figure.
In all these cases EC (Electrochemical capacitor) energy store is calculated according to the covering of 75 – 85% of energy that is required in the high-power discharge. It means that batteries are protected from overloads and are discharged in long and middle modes. Besides, the presence of the high-voltage capacitor before the DC/AC converter improves the power quality in consumer’s AC grid.

VIII. CONCLUSION

This paper has provided a brief summary of solar PV systems and power quality issues in grid connected power system. This paper has also presents a summary of converts and inverters in solar power system and its power quality issues. Suitable control techniques are also discussed briefly. The intention of the authors was simply to provide groundwork to readers interested in looking back on the evolution of power quality issues in PV systems, and to consider where to go from here.

REFERENCES