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COMPENSATION OF POWER QUALITY ISSUES IN GRID CONNECTED SOLAR ENERGY SYSTEM USING STATOM – A REVIEW

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ABSTRACT

The renewable energy is a naturally available source and can be used as a standalone system or as grid connected system. This paper focuses the behaviour of the photovoltaic solar system and the power quality issues connected with the system. Power quality is the combined effect of voltage and current quality. Power quality issues are the significant deviations from the ideal characteristics. Voltage flicker and the harmonics are the main issues. The harmonics are created by the switching phenomenon of the power electronic circuit. The output causes damage to power equipment on the utility side and sensitive loads on the customer side. Voltage flicker and harmonics are considered as the most severe power quality problems. A Literature survey on various mitigation solutions for the above power quality problems has been studied. The voltage flicker disturbances reduced using 12 pulse Static synchronous compensator STATCOM and harmonics compensation through RLC filter(three phase harmonic filter) are studied and it can be adopted for the Grid connected solar energy system.

Keywords: Power quality, Voltage flickers, STATCOM, harmonics, Total Harmonic Distortion.

I. INTRODUCTION

The most important commodity of this modern day is the Electrical Power. With increased industrialization, depletion in fossil fuel option for the source of power is renewable energy. The renewable energy - solar is the most preferred as it is available in nature in plenty. Government promotes the renewable energy sources and has led to several large scale solar power plants in India. India receives daily an average solar energy incident from 4 to 7 kWh/m^2 for 300 to 330 days (depending on the location) in a year. For example, assuming the efficiency of PV modules as low as 10%, the energy produced from solar in India is less than 1% of the total energy demand.

Renewable energy generation units, if properly controlled and designed can improve the power flow management on the grid and reduce the probability of grid faults. It's important to evaluate the possible power quality issues. All electrical devices are prone to failure or malfunction when exposed to one or more power quality problems. The electrical device might be an electric motor, a transformer, a generator, a computer, a printer, a communication equipment, or a household appliance. The stability and quality of power can be maintained by proper design and management of renewable energy units both in grids connected and stand-alone configurations.

II. SOURCES OF ENERGY

Photovoltaic array model

Solar panel is used to convert solar energy into electrical energy. The semi conductor material of panel absorbs the available solar beam and emits the electrons from the bounded atoms. This activates the current and the electricity is induced.

The output power of solar panel is

$$P_{solar} = f'_{solar} Y_{solar} (I_T/I_S) \qquad (1)$$

Where f'_{solar} is conversion efficiency of solar panel in %;

Y_{solar} is capacity of solar panel kW; I_T Incident solar flux kW/m^2; I_S is 1kW/m^2

The maximum conversion efficiency of a solar cell is given by ratio of the maximum useful power to the incident solar radiation. Thus

$$\eta_{max} = \frac{Im\ Vm}{It\ Ac} = \frac{FF\ Isc\ Voc}{It\ Ac} \qquad (2)$$

Where, I_t is Incident solar flux, FF is Fill Factor and Ac is Area of cell.

The grid connected solar system is shown in the Figure 1 and the control blocks for the solar system connected to the grid system is shown in the Figure 2.

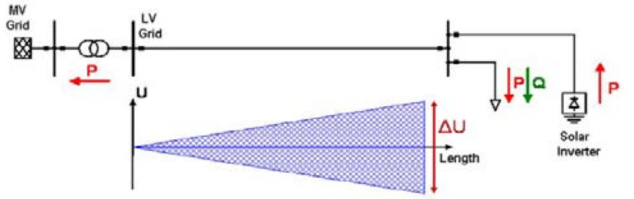

Figure 1: Grid connected solar system.

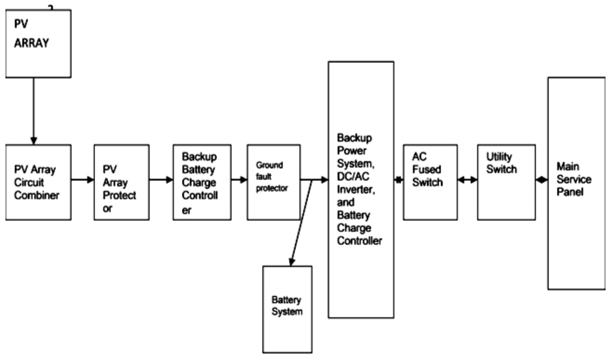

Figure 2: Control blocks of grid connected solar system

III. ISSUES OF POWER QUALITY (PQ)

The solar energy generated is fed to the grid system. 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 effect of disturbances and behaviour 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.

Over Voltages and Voltage Dips: Over voltage on the low voltage grid can only be generated by faults or environmental phenomena (lightning) 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.

Voltage drop is

$$\frac{\Delta U}{U_n} = \frac{R\Delta P + X\Delta Q}{U_n^2}$$

Where ΔP and ΔQ are the variation in active and reactive power; U_n is the nominal voltage and R and X are short circuit resistance and reactance. Since R is usually very small in comparison to X, ΔU is proportional to Q (reactive power). Therefore, voltage flicker mitigation depends on reactive power control [1]

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 present due to regulator malfunctioning or due to harmonic components at frequency lower than the cut off frequency of the power bus regulator flicker compensation using STATCOM.

IV. LITERATURE SURVEY

D. Czarkowski et al [3] have analysed about the voltage flicker compensation using STATCOM in their paper "Voltage Flicker Mitigation Using PWM-Based Distribution STATCOM". The authors concluded that the concept of power quality describes the quality of the supplier voltage in relation to the transient breaks, falling voltage, harmonics and voltage flicker.

J. Mckim et al [4] have analysed about voltage flicker compensation using STATCOM in the paper "The UIE Flicker-meter Demystified”. The authors concluded that the concept of the disturbance becomes perceptible for voltage variation frequency of 10 Hz and relative magnitude of 0.26%.

R.Collantes-Bellido et al [5-6] have analysed in their paper about the Identification and Modeling of a Three Phase Arc Furnace for Voltage Distribution Simulation.”.The authors concluded that the concept of huge non-linear industrial loads such as the electrical arc furnaces, pumps, welding machines, rolling mills and others are known as flicker generators.

M. Zouiti et al [7-10] have analysed about the Electronic Based Equipment for Flicker Mitigation in their paper dealing with the voltage, a furnace reactance (included connection cables and busses) and a variable resistance which models the arc. The authors concluded that the concept of the voltage flicker mitigation depends on reactive power control.

J. R. Clouston et al [11-17] have analysed about the reactive power consumed by the compensator in their paper "Field

Demonstration of a Distribution Static Compensator used to Mitigate Voltage Flicker"

M. W. Marshall [18] have analysed about the sing Series Capacitors to Mitigate Voltage Flicker Problems in his paper. In this type, all the efforts are done to decrease the voltage drop mentioned above, and finally the reactive power is kept constant despite the load fluctuations by controlling the line reactance.

J. Dolezal et al [19] have analysed about the voltage flicker compensation using STATCOM, in their paper" Topologies and control of active filters for flicker compensation". In addition to the aforesaid procedures for the compensators, the active filters are used for the voltage flickers mitigation.

L. Gyugi et al[20] have analysed on voltage flicker compensation using STATCOM in their paper "Static Shunt Compensation for Voltage Flicker Reduction and Power Factor Correction". Furthermore, the mitigating devices based on Static VAR Compensator (SVC) are the most frequently used devices for reduction in the voltage flickering.

Y. Hamachi et al [21] have analysed about compensation using STATCOM" in their paper "Voltage Fluctuation Suppressing System Using Thyristor Controlled Capacitors". They concluded that the mitigating devices based on Thyristor Switched Capacitors TSC are the most frequently used devices for reduction in the voltage flickering.

F. Frank et al [22] have analysed about the voltage flicker compensation in their paper "TYCAP, Power Factor Correction Equipment Using Thyristor Controlled Capacitor for Arc Furnaces". They have stated that the mitigating devices based on FCTCR are the most frequently used devices for reduction in the voltage flickering.

In this respect, the FACTS devices based on voltage source converters have been able to improve the problems related to SVC. However a new technique based on novel control algorithm in STATCOM is used for voltage flicker compensation to overcome the problems related to other techniques.

V. COMPENSATION USING STATCOM

The voltage flicker compensation is considered using two bus system [23] and shown in the figure (3). In this, two 6 pulse (12 pulse) bridges are connected in parallel. The first converter is connected with wye-wye transformer and the second one is connected with wye-delta transformer. These are linked using three winding transformer. Pulse train to one converter is shifted by 30° with respect to the other.

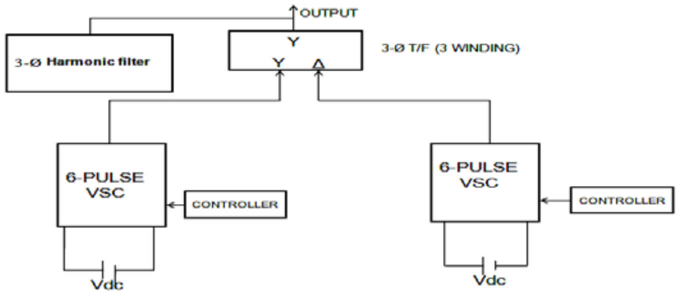

Figure 3: Block diagram of 12 pulse voltage source converter STATCOM with harmonic filter

The controlling system used [23] is

$$V_d = \frac{2}{3}\left(V_\alpha \sin(\omega t) + V_b \sin\left(\omega t - \frac{2\pi}{3}\right) + V_C \sin\left(\omega t + \frac{2\pi}{3}\right)\right)$$

$$V_q = \frac{2}{3}\left(V_\alpha \cos(\omega t) + V_b \cos\left(\omega t - \frac{2\pi}{3}\right) + V_C \cos\left(\omega t + 2\pi 3\right.\right.$$

$$V_0 = \frac{1}{3}(V_\alpha + V_b + V_C)$$

$$i_c = j(i_q + i_p \frac{R}{X} f + \frac{1}{\omega}\frac{di_p}{d_\omega} f + k\ \ (+V_b + V_C)$$

The nonlinear elements for example, power electronic devices generate harmonic currents or harmonic voltages. These disturbances are injected into power system. The harmonic filters are the shunt elements used in power system to reduce the voltage distortion. These harmonic filters reduce the distortion by diverting harmonic current into low impedance paths. The filters are capacitive at fundamental frequency, so that they are used for producing power required by converters and for power factor correction.

Where R and X are the synchronous resistance and reactance of the line and f is the correcting coefficient. The constant k is also used to eliminate the average reactive power of the network [3]. If the compensation current of the above equation is injected to the network, the whole voltage flicker existing in the network will be eliminated. Regarding the equation, related to the dq-transformation of the 3-phase-voltages to the instantaneous vectors, it is obvious that under the conditions of accessing an average voltage flicker, V_d and V_0, the obtained values are close to zero and V_q is a proper value adapting to the voltage oscillation of the network.

To eliminate the lowest order harmonics such as 11^{th} and 13^{th} harmonic, double tuned band pass filter is connected across the 12 pulse voltage source converter output. Fig 4 shows SIMULINK diagram of 12 pulse voltage source converters STATCOM with 3Ø harmonic filter connected to the power system. The output load voltage mitigated by 12-pulse voltage-source converter STATCOM with 3Ø harmonic filter and its harmonic spectrum is shown in figures 4 and 5 respectively. In this respect, the voltage flicker is completely removed from the output load voltage and a sinusoidal waveform is obtained. It can be observed from the harmonic spectrum that THD is 2.30% [23].

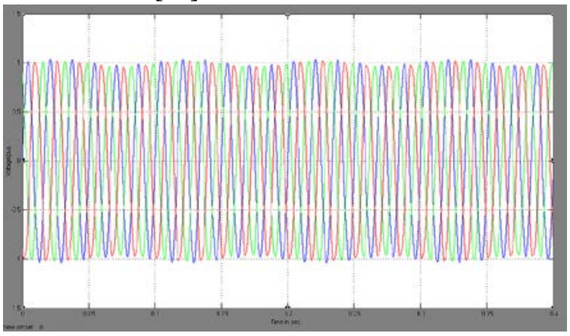

Figure 4. Output load voltage mitigated by 12-pulse voltage source converter STATCOM with 3Ø harmonic filter

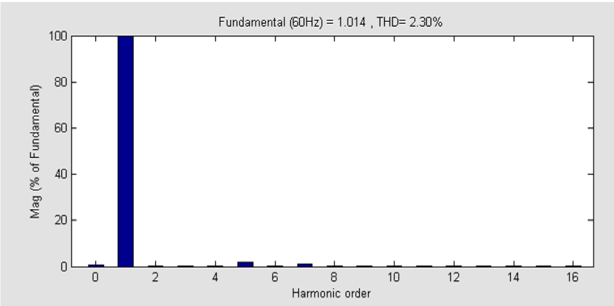

Figure 5. Harmonic spectrum of the output load voltage mitigated by 12-pulse voltage-source converter STATCOM equipped with a harmonic filter.

Voltage flicker mitigation using 6 pulse voltage source converters STATCOM, 12 pulse voltage source converters STATCOM, and 12 pulse VSC STATCOM with 3Ø harmonic filter are simulated. The output load voltage without STATCOM and with STATCOM is obtained and compared.

The results obtained are as follows:

I. Without STATCOM

The output load voltage is 1.3 Pu (maximum value).The voltage flicker existing in the output load voltage (exerted to the system) is 0.3 Pu (30%).

II. With STATCOM

TABLE I: COMPARISON OF VOLTAGE FLICKER MITIGATION AND THD VALUE OF STATCOM COMPENSATORS

Compensator	Compensated output load voltage	Voltage Flicker	THD
6 pulse VSC STATCOM	1.15 pu	Existing is 0.15 pu (15%) (or) Mitigated by 50%	8.95%
12 pulse VSC STATCOM	1.0 pu	Completely mitigated	4.47%
12 pulse VSC STATCOM with 3Ø harmonic filter	1.0 pu	Completely mitigated	2.30%

VI. CONCLUSION

This paper has provided a summary about solar energy and the power quality issues in the grid connected power system. Power quality issues are created due to the power electronic devices connected in generation of solar energy and the load connected in the grid. Various mitigation solutions using FACTS controllers have been studied through literature survey. Based on the study, it is suggested that the STATCOM is suitable for the power quality issues in solar energy system connected to the grid both economically and technically.

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