Power quality and Reliability improvement in Distributed Generation system using SVC

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***Abstract*— The global requirement for sustainable energy provisions will become increasingly important over the years as the environmental effects of fossil fuels become more apparent and detrimental. Distributed Generation (DG) based schemes on Renewable Energy Technologies (solar, wind, hydro and biomass) are becoming a more important energy option for the future generation system. A common challenge faced by modern electric utilities is to determine how variable generation plants (wind and solar) affect the power system and subsequently on the power quality and thereby adversely affecting the reliable operation of the electric grid. Poor power quality of any utility distribution network are detrimental to sensitive industrial loads and disrupt critical commercial operation due to various type of outages, equipment failures and service interruptions, resulting in significant financial losses .This paper throws light on how SVCs can be used to improve the power quality (i.e.) related to non-standard voltage, current and frequency at the consumer side which make the system more reliable.**

***Index Terms*—Distributed Generation; Static VAR Compensator(SVC) ; Harmonics; power quality; voltage stability**

I. INTRODUCTION

In today's open energy market, Distributed energy systems have an increasingly important role. Traditionally, electricity has been generated in large power stations, located near resources or at logistical optima; it is transported through a high-voltage transmission grid and is locally distributed through medium-voltage distribution grids. DGs aim to add versatility of energy sources and also ensure reliability of supply and reduction of greenhouse emissions .DGs can also contribute to the reduction of transmission losses and help introduce new developments such as fuel cells and super-conducting devices.

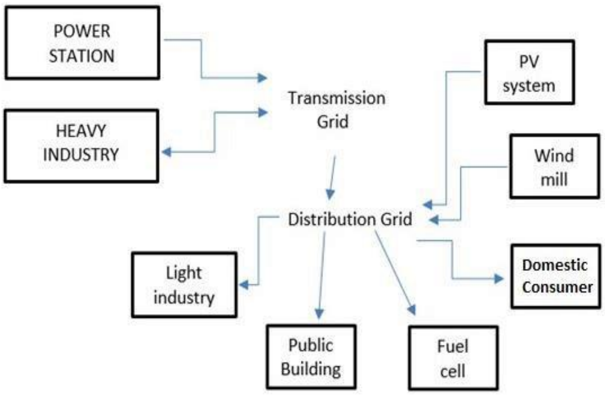

Figure 1: Distributed generation schematics

Most of the DG units available are not continuous generators of energy and inherently make use of solid state power devices as convertors. This obvious inconsistent and nature-dependent generation causes problems related to voltage stability and also the convertors used tend to inject Harmonics and cause harmonic distortion in the power system. These problems deteriorate the overall power quality of the system and have adverse effects on the connected utility. To overcome this problem related to the power quality, custom power devices are introduced. A number of Power quality problem solutions are provided by custom devices. At present, a wide range of flexible AC controllers which are capitalized on newly available power electronic components are emerging for custom power applications. Among these Static VAr Compensator (SVCs) has been focused upon in this present work. The distribution system losses and power quality problems are increasing nowadays due to more and more penetration of DGs and consequent injection of harmonics from various power electronic controllers. The main advantages of SVCs are high speed control of reactive power to provide voltage stabilization and also its acts as a shunt Harmonic filter.

II. STATIC VAR COMPENSATOR

SVCs provide an excellent source for rapidly controllable reactive shunt compensation for dynamic voltage control through its utilization of high-speed thyristor switching/controlled devices. A SVC is typically realized by a coupling Transformer, Thyristor valves, Reactors, and Capacitance (often tuned for harmonic filtering). Fig. 2 illustrates a TCR/FC static VAr compensator. The control objective of SVC is to maintain the desired voltage at a particular high voltage bus. In steady- state, the SVC will provide some steady- state control of voltage to maintain the highest voltage bus at the pre-defined voltage level. If the bus

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voltage begins to fall below its set point range, the SVC will inject reactive power (Qnet) into the system (within its control limits), thereby increasing the bus voltage back to its desired voltage level. If bus voltage increases, the SVC will inject less (or TCR will absorb more) reactive power (within its control limits), and the result will be to achieve the desired bus voltage. Static Var Compensators (SVC) are composed of capacitor /filter banks and air-core reactors connected in parallel. The air-core reactors are series connected to thyristors. The current of air-core reactors can be controlled by adjusting the firing angle of thyristors. The air-core reactor in Static VAr Compensator has high stability and linearity. It is used to absorb reactive power under the control of thyristors. Usually the air-core reactor is series connected to the thyristor valve in delta-connection and then to power grid. The capacitor/filter banks can supply sufficient capacitive reactive power to power grid and filter the unwanted harmonics. The filter is composed of capacitors, reactors and resistors, providing capacitive reactive power to the entire system. In practical applications, the capacitor/filter banks are divided into several sub-banks which can be switched-in/switched-off by mechanical breakers or other electrical switches according to the demands of an actual situation.

Advantages of SVC:-

- Stabilized voltage at the receiving end of long lines.
- Increased productivity as stabilized voltage means better utilized capacity.
- Reduced Reactive power consumption, which gives lower losses and improved tariffs.
- Balanced Asymmetrical loads reduce system losses and enable lower stresses in rotating machinery
- –Enables better use of equipment (particularly transformers and cables)
- Reduced voltage fluctuations and light flicker
- decreased Harmonic Distortion.

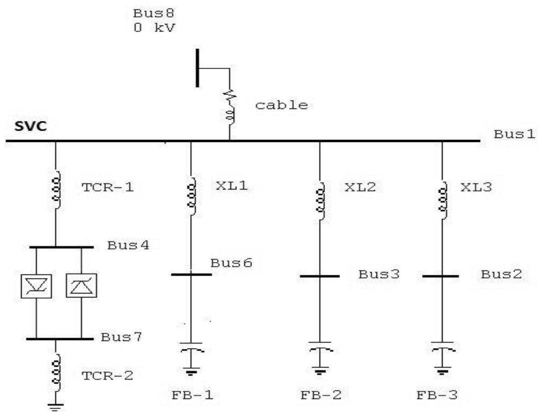

Figure 2:Static VAr Compensator schematics

III. HARMONIC FILTER DESIGN

The IEEE 1531[14] “IEEE Guide for Application and Specification of Harmonic Filters” clearly specify and guide for harmonic filter design. In SVC a single tuned shunt filter can be used as a capacitive reactive power generator. Single Shunt filters are made up of two components, capacitor and inductor. The capacitor must be capable of withstanding the arithmetic sum of the peak voltage of the fundamental and harmonic voltage drop across the capacitor. The current as seen by the filter is the voltage impressed on the filter divided by the total reactance of the tuning inductor and the capacitor. Since the total reactance is less than the capacitive reactance (the inductive reactance has an opposite sign to the capacitive reactance so that the total is the difference of the two values), the fundamental current into the filter will be larger than into the capacitor without the tuning reactor. The harmonic voltage across the capacitor is the voltage, due to the harmonic current, to which the filter is tuned that is available from the system times the reactance of the capacitor at the tuned frequency. In addition to harmonic filtering, the filter equipment will provide the system with capacitive reactive power that will improve the power factor and help maintain voltage during heavy loads. The capacitive reactive power requirements for power factor and voltage control generally determine the effective KVAr size of the harmonic filter. The effective KVAr of the harmonic filter is always less than the nameplate KVAr of the harmonic filter capacitor because of the subtractive effect of the filter reactor. The reactance of the harmonic filter capacitor is determined by the VAr size of the harmonic filter. The inductive reactance is selected to create a series resonance with the harmonic filter capacitor at the tuned frequency. The series resonance provides a low impedance path to neutral for the harmonics of the system.

$$X_C = \left(\frac{h^2}{h^2-1}\right) X_{eff} \qquad (1)$$

Where

$$X_{eff} = \frac{kVLLsys^2}{Q_{eff}\ (Mvar)} \qquad (2)$$

A simple equation to calculate the inductive reactance at power frequency is Equation (3)

$$X_L = \frac{X_C}{h^2} \qquad (3)$$

Where,
Xeff is the effective reactance of the harmonic filter,
Qeff is the effective reactive power (MVAr) of the harmonic filter,
VLLsys is the nominal system line-to-line voltage,
XC is the capacitive reactance of the harmonic filter capacitor at the fundamental frequency,
XL is the inductive reactance of the harmonic filter reactor at the fundamental frequency, h is the harmonic number.

By selecting the tuning frequency ,the reactor and capacitor values can be determined. The values obtained from equation (1) and (3) shall be used to design the harmonic filter.

IV. DG SYSTEM MODELLING

In general terms, Distributed Generation (DG) is any type of electrical generator or static inverter producing alternating current that has the capability of parallel operation with the utility distribution system, or is designed to operate separately from the utility system and can feed a load that can also be fed by the utility electrical system. In here we consider a system where a solar power plant is connected to the utility which is having other small distributed generators along with it. The fluctuating nature of the typical solar power plant from measurements are considered for the study and the parameters considered are as presented in Figure 3 to 6.

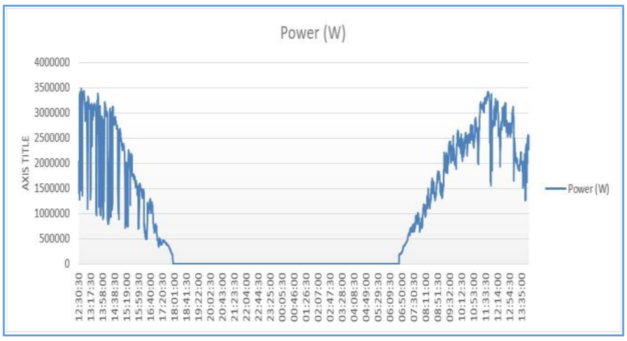

Figure 3: Typical power fluctuation from solar power plant

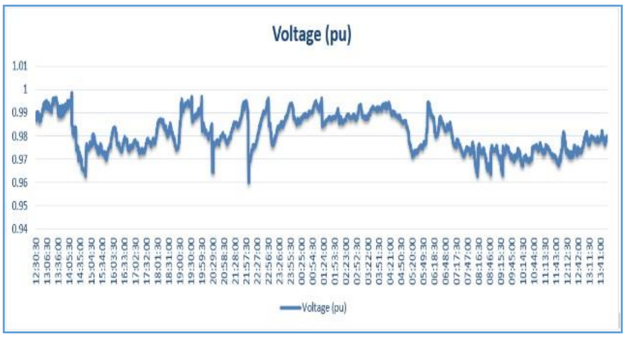

Figure 4: Typical voltage fluctuation at PCC of solar power plant in pu

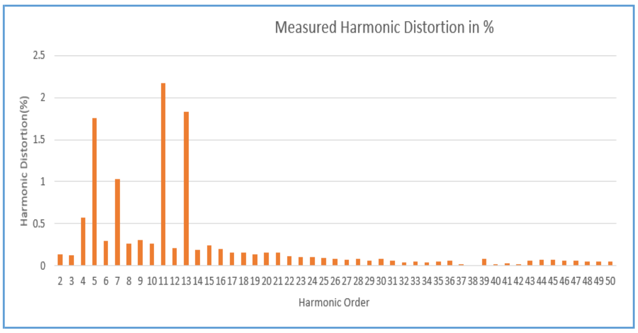

Figure 5: Typical voltage harmonic distortion at PCC of solar power plant in pu

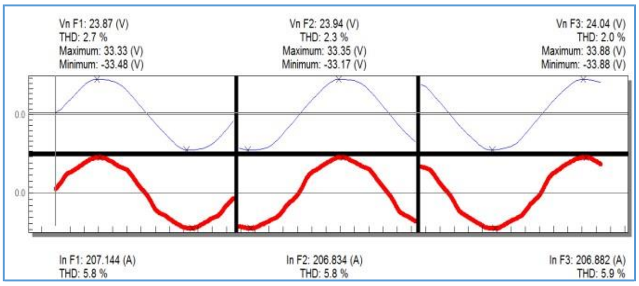

Figure 6: Typical voltage and current waveform at Bus-6 (415V).

The SVC is modelled with 5th, 7th and 11th order Single Tuned filters as static capacitor and a TSR with a control unit which controls reactive power based on the voltage feedback from SVC connected bus. The lumped utility load is considered at 11kV with 33/11kV interconnecting transformers. All together it is connected to a 132kV Transmission system.

V. SIMULATION AND RESULTS

Simulation of simple distributed generation system with and without SVC is carried out and the results with observation are presented below.

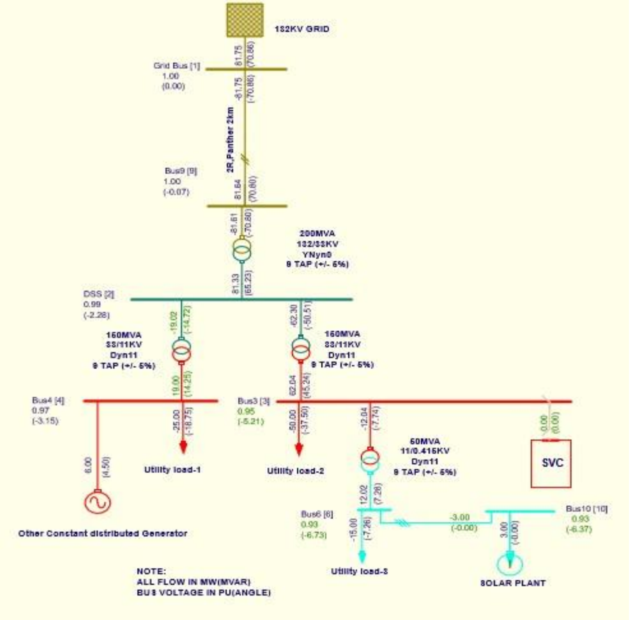

Figure 7: Sample DG system without SVC connected.

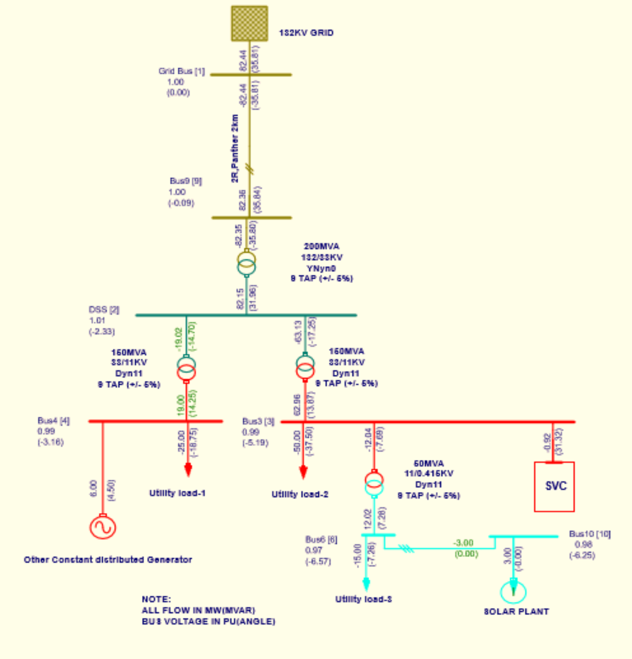

Figure 8: Sample DG system with SVC connected.

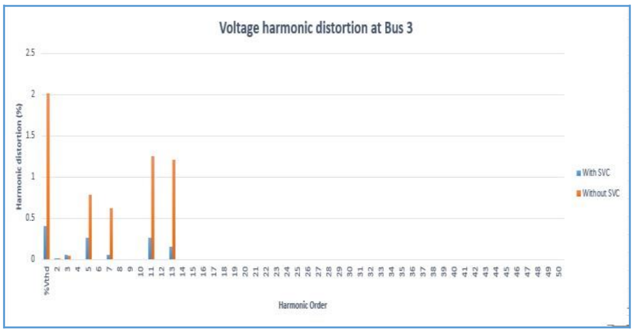

Figure 9: voltage Harmonic distortion at bus-3 for with and without SVC connected.

TABLE 1: VOLTAGE PROFILE AT DIFFERENT LOCATION IN SYSTEM

Sl No.	Location	Voltage in Pu	
		without SVC	With SVC
1	Bus 6	0.93	0.97
2	Bus 4	0.97	0.99
3	Bus 3	0.95	0.99
4	Bus 2	0.99	1.01

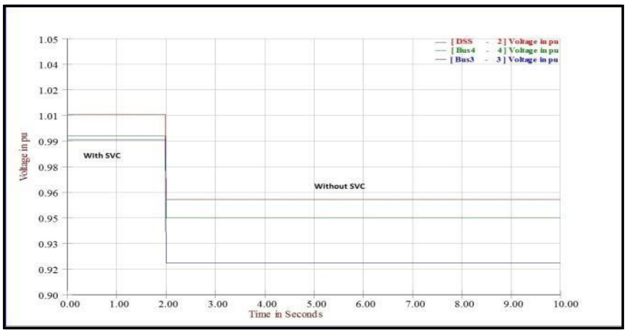

Figure 10: Voltage profile at different bus of the system.

Figure 11: Impedance plot at bus-3 for with and without SVC.

From the simulations we can observe the voltage profile at different buses in the system are enhanced by using a SVC in the network (Refer figure 2 and 3). The harmonic distortion caused due to convertors used in distributed generation system is also reduced by using SVC. IEEE 519[13] standard "IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems" specify the permissible harmonic limits for different voltage levels. Simulated Harmonic distortion results of sample system are presented in below table for with and without SVC in the system.

TABLE 2: HARMONIC DISTORTION COMPARISON WITH IEEE-519 STANDARD

Location	Bus voltage (kV)	IEEE 519 permissible limit (%)	% VTHD	
			without SVC	With SVC
Bus 6	0.415	5	1.86	0.38
Bus 4	11	5	4.14	3.54
Bus 3	11	5	2.90	0.40
Bus 2	33	5	2.45	1.49

CONCLUSION

In this paper, the basic structure of an SVC and its operation has been discussed. Also its impact on power quality and subsequent power quality improvement are presented. A simple distributed generation system with a typical solar plant is modelled with its characteristics and simulated. The results are analyzed and compared with IEEE standards. From all the observations made after the simulations we can clearly conclude that use of SVCs in Distributed Generation systems will enhance the quality and the reliability of power.

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