International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 10, Issue 7 (July 2014), PP.51-57

Power Quality Enhancement using Different "FACTS" Devices.

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Abstract:- Improvement of Power Quality has a positive impact on sustained profitability of the distribution utility on the one hand and customer satisfaction on the other. Flexible AC Transmission Systems (FACTS) controllers have been used in power systems since the 1970s with the objective of improving system dynamic performance. Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Sensitive power electronic equipment and non-linear loads are widely used in industrial, commercial and domestic applications leading to distortion in voltage and current waveforms. Due to the environmental, right-of-way, and cost problems in both bundled and unbundled power systems, many transmission lines have been forced to operate at almost their full capacities worldwide. FACTS controllers enhance the static performance viz. increased loading, congestion management, reduced system loss, economic operation, etc., and dynamic performance viz. increased stability limits, damping of power system oscillation, etc. In this paper, an overview of FACTS controllers is explained. Various FACTS controller several devices in FACTS family are also discussed.

Keywords:- Power quality, SVC, STATCOM, SSSC

I. INTRODUCTION

Electrical power is perhaps the most essential raw material used by commerce and industry today. It is an unusual commodity because it is required as a continuous flow - it cannot be conveniently stored in quantity - and it cannot be subject to quality assurance checks before it is used. It is, in fact, the epitome of the 'Just in Time' philosophy in which components are delivered to a production line at the point and time of use by a trusted and approved supplier with no requirement for 'goods in' inspection. For 'Just in Time' (JIT) to be successful it is necessary to have good control of the component specification, a high confidence that the supplier can produce and deliver to specification and on time, and a knowledge of the overall product behavior with 'on limit' components.

The situation with electricity is similar; the reliability of the supply must be known and the resilience of the process to variations must be understood. In reality, of course, electricity is very different from any other product – it is generated far from the point of use, is fed to the grid together with the output of many other generators and arrives at the point of use via several transformers and many kilometers of overhead and possibly underground cabling. Where the industry has been privatized, these network assets will be owned, managed and maintained by a number of different organizations. Assuring the quality of delivered power at the point of use is no easy task – and there is no way that sub-standard electricity can be withdrawn from the supply chain or rejected by the customer.

1. FACTS

FACTSare defined by the IEEE as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability."

Flexible AC Transmission Systems, called FACTS, got in the recent years a well-known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice. Even more concepts of configurations of FACTS-devices are discussed in research and literature.

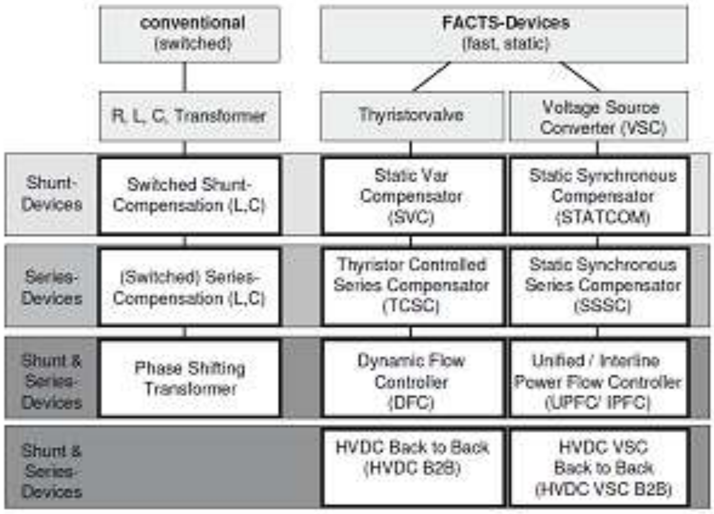

Fig1.Overview of major FACTS-Devices [5]

SVC

Electrical loads both generate and absorb reactive power. Since the transmitted load varies considerably from one hour to another, the reactive power balance in a grid varies as well. The result can be unacceptable voltage amplitude variations or even a voltage depression, at the extreme a voltage collapse. A rapidly operating Static Var Compensator (SVC) can continuously provide the reactive power required to control dynamic voltage oscillations under various system conditions and thereby improve the power system transmission and distribution stability. Installing an SVC at one or more suitable points in the network can increase transfer capability and reduce losses while maintaining a smooth voltage profile under different network conditions. In addition an SVC can mitigate active power oscillations through voltage amplitude modulation. SVC installations consist of a number of building blocks. The most important is the Thyristor valve, i.e. stack assemblies of series connected anti-parallel Thyristors to provide controllability.

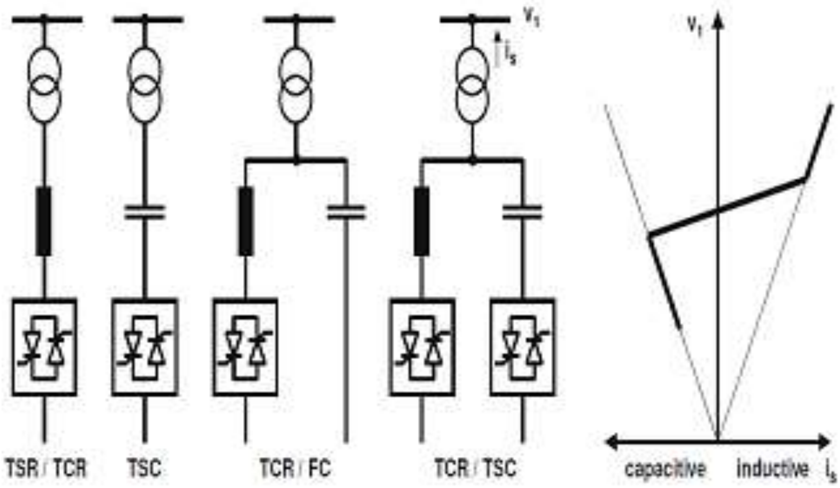

Fig.2.SVC building blocks and voltage/current characteristic [5]

Air core reactors and high voltage AC capacitors are the reactive power elements used together with the Thyristor valves. The step-up connection of this equipment to the transmission voltage is achieved through a power transformer. The Thyristor valves together with auxiliary systems are located indoors in an SVC building, while the air core reactors and capacitors, together with the power transformer are located outdoors. In principle the SVC consists of Thyristor Switched Capacitors (TSC) and Thyristor Switched or Controlled Reactors (TSR / TCR). The coordinated control of a combination of these branches varies the reactive power as shown in Fig 2. The first commercial SVC was installed in 1972 for an electric arc furnace. On transmission level the first SVC was used in 1979. Since then it is widely used and the most accepted FACTS-device.

STATCOM

In 1999 the first SVC with Voltage Source Converter called STATCOM (Static Compensator) went into operation. The STATCOM has a characteristic similar to the synchronous condenser, but as an electronic device it has no inertia and is superior to the synchronous condenser in several ways, such as better dynamics, a lower investment cost and lower operating and maintenance costs. A STATCOM is build with Thyristor with turn-off capability like GTO or today IGCT or with more and more IGBTs. The structure and operational characteristic is shown in Figure 3.4 where V_1 is the voltage and I_S is the source current. The static line between the current limitations has a certain steepness determining the control characteristic for the voltage. The advantage of a STATCOM is that the reactive power provision is independent from the actual voltage on the connection point. This can be seen in the diagram for the maximum currents being independent of the voltage in comparison to the SVC in Fig 3.3.

This means, that even during most severe contingencies, the STATCOM keeps its full capability. In the distributed energy sector the usage of Voltage Source Converters for grid interconnection is common practice today. The next step in STATCOM development is the combination with energy storages on the DC-side. The performance for power quality and balanced network operation can be improved much more with the combination of active and reactive power.

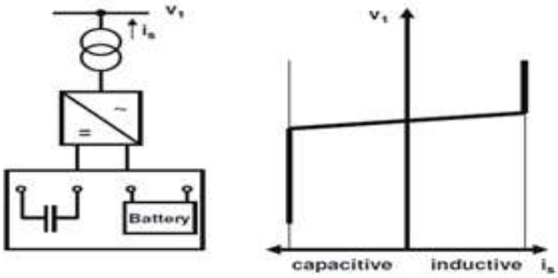

Fig.3. STATCOM structure and voltage / current characteristic [5]

SSSC

While the TCSC can be modeled as a series impedance, the SSSC is a series voltage source. The principle configuration is shown in Figure 3.6, which looks basically the same as the STATCOM. But in reality this device is more complicated because of the platform mounting and the protection. A Thyristor protection is absolutely necessary, because of the low overload capacity of the semiconductors, especially when IGBTs are used. The voltage source converter plus the Thyristor protection makes the device much more costly, while the better performance cannot be used on transmission level. The picture is quite different if we look into power quality applications. This device is then called Dynamic Voltage Restorer (DVR). The DVR is used to keep the voltage level constant, for example in a factory in feed. Voltage dips and flicker can be mitigated. The duration of the action is limited by the energy stored in the DC capacitor. With a charging mechanism or battery on the DC side, the device could work as an uninterruptible power supply.

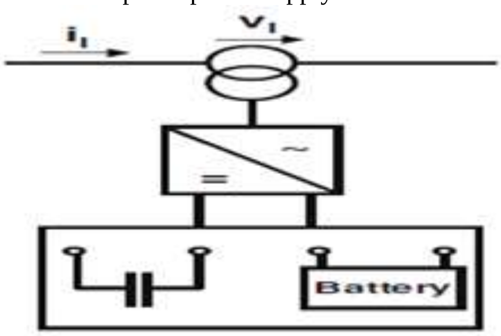

Fig. 4. Principle setup of SSSC [5].

II. MATLAB SIMULINK MODEL FOR FACTS DEVICES SYSTEM

Static Var Compensator (SVC)

Static Var Compensator (SVC) is used to regulate voltage on a 500 kV, (3000 MVA & 2500 MVA system). When system voltage is low the SVC generates reactive power (SVC capacitive). The SVC is rated +200 Mvar capacitive and 100 Mvar inductive. The Static Var Compensator block is a a phasor model representing the SVC static and dynamic characteristics at the system fundamental frequency. The SVC is set in voltage regulation mode with a reference voltage Vref=1.0 pu. The voltage droop is 0.03 pu/ 200MVA. A good approximation of the maximum frequency range represented by the PI line model is given by the following equation:

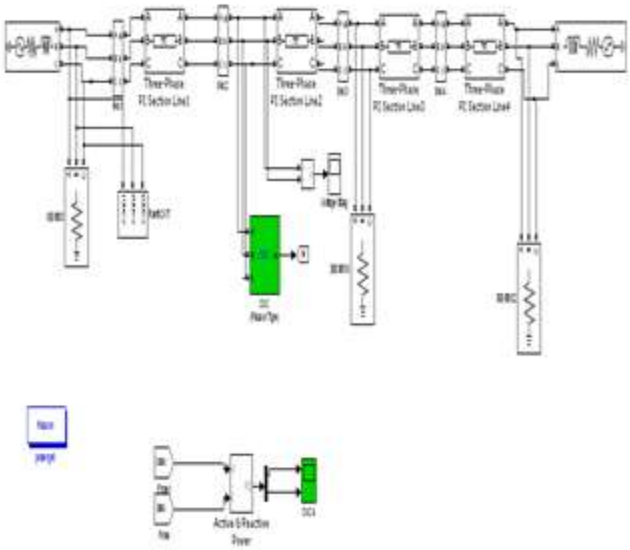

Fig 5 MATLAB Simulink Model of SVC System

Static Synchronous Compensator (STATCOM)

The Static Synchronous Compensator (STATCOM) is one of the key FACTS devices. Based on a voltage-sourced converter, the STATCOM regulates system voltage by absorbing or generating reactive power. Contrary to a thyristor-based Static Var Compensator (SVC), STATCOM output current (inductive or capacitive) can be controlled independent of the AC system voltage.The power grid consists of two 500-kV equivalents (respectively 3000 MVA and 2500 MVA) connected by a 3000-km transmission line.On the AC side, its total equivalent impedance is 0.22 pu on 100 MVA. This impedance represents the transformer leakage reactance and the phase reactor of the IGBT bridge of an actual PWM STATCOM.

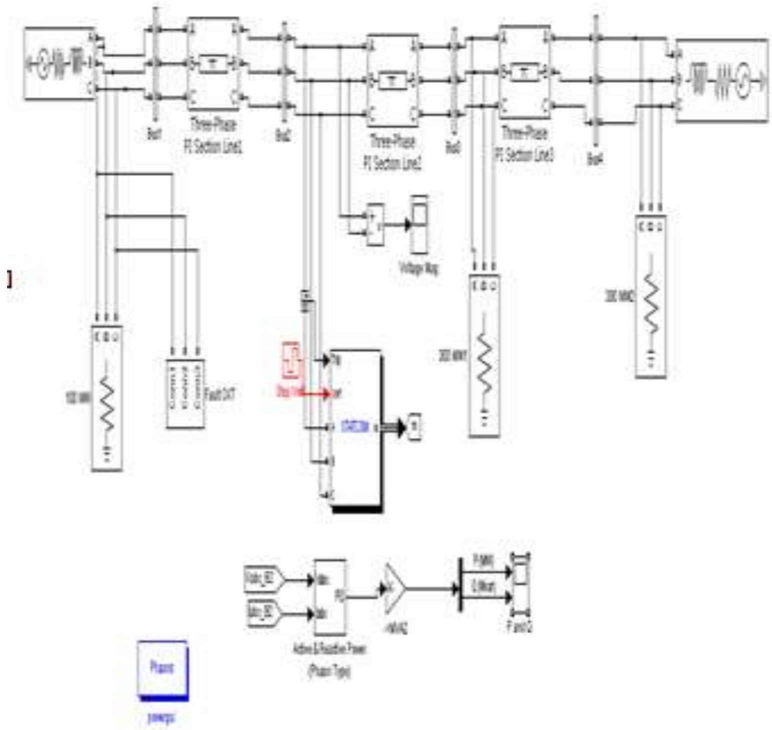

Fig.6. MATLAB Simulink Model of STATCOM Syst

III. STATIC SYNCHRONOUS SERIES COMPENSATOR (SSSC),

The Static Synchronous Series Compensator (SSSC), one of the key FACTS devices, consists of a voltage-sourced converter and a transformer connected in series with a transmission line. The SSSC injects a voltage of variable magnitude in quadrature with the line current, thereby emulating an inductive or capacitive reactance. This emulated variable reactance in series with the line can then influence the transmitted electric power. In our demo, the SSSC is usedto damp power oscillation on a power grid following a three-phase fault. The power grid consists of two power generation substations and one major load center at bus B3. The first power generation substation (M1) has a rating of 3000 MVA, and second 2500 MVA.

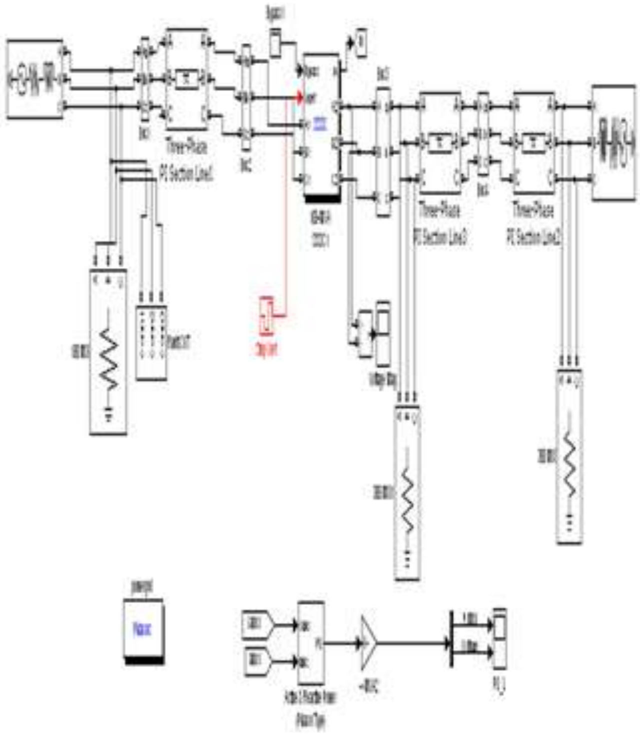

Fig 7.MATLAB Simulink Model of SSSC System

IV. COMPARSION

Issue	STATCOM	SVC	SSSC
V/I characteristic	good under voltage performance Current source	good overvoltage performance Impedance	good under voltage performance Voltage source
Control range	Symmetrical otherwise Hybrid solutions	freely adjustable to any range by TCR/TSR /TSC branches	Symmetrical
Modularity	Same converter usable for various applications (STATCOM, UPFC, CSC, B2B etc) Redundancy no degraded mode	TCR/TSR/TSC branches used in SVC and TCSC/TPSC Redundancy Degraded mode operation	Same converter usable for various applications UPFC, SSSC configurations are used in the CSC
Investment costs	120 to 150 %	100 %	130 %
Response time	1 to 2 cycle	2 to 3 cycle	3 to 4 cycle
Transient behavior	Self protecting at critical system faults	Available before, during and after critical system conditions	Self protecting at critical system faults
Space requirements	40 to 50 %	100 %	60 to 70 %
Availability	96 to 98 %	> 99 %	90 to 92 %

V. RESULTS

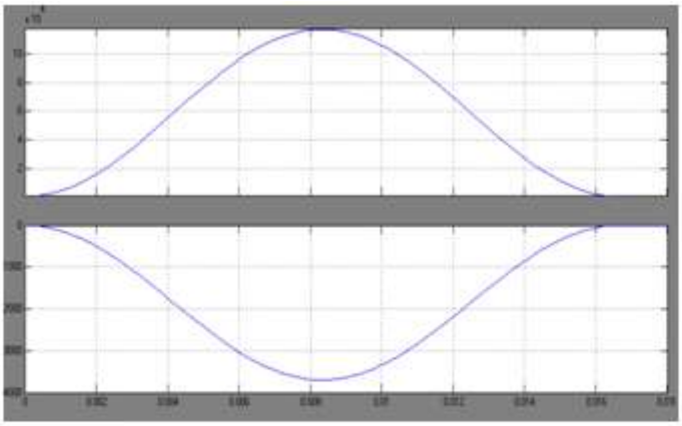

Fig.8. Power profile without fault SVC System

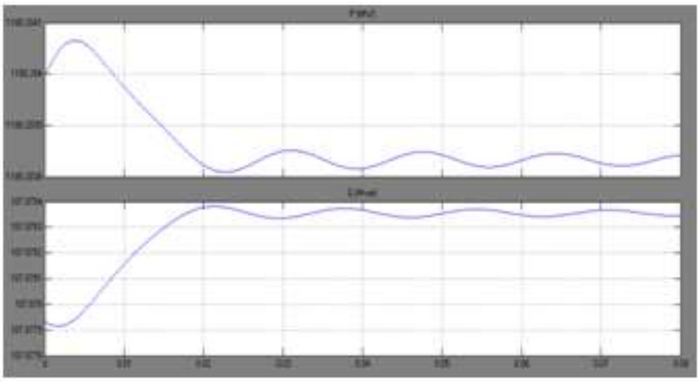

Fig.9. Power profile without SVC fault System

Fig.10. Power profile without fault SSSC System

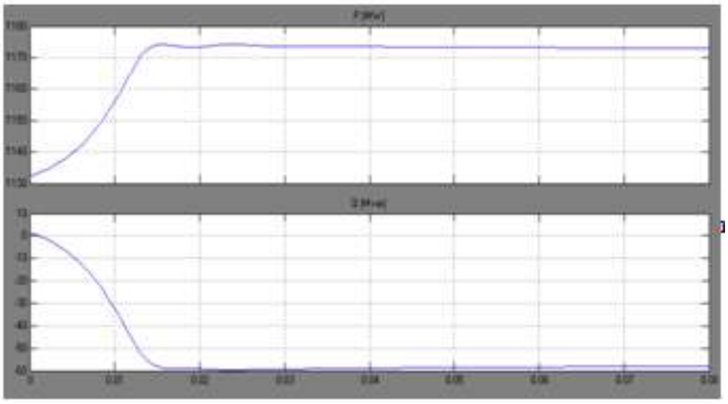

Fig.10. Power profile without fault STATCOM System

VI. CONCLUSIONS

The paper explains various power quality problems and the FACTS controllers that are used to mitigate the power quality problems. The standard FACTS controller for a particular type of problem is also given. The simulation results give the clear observation of how the FACTS devices improve the power quality. The simulation work is done on Static Var Compensator (SVC) and Static Synchronous Compensator (STATCOM) Static Synchronous Series Compensator (SSSC).

SVC, STATCOM and SSSC are providing better power quality under variation of source voltage and when the system is suddenly loaded. The thesis includes the simulation results of the SVC, STATCOM and SSSC only. The future work given as the simulation results of the systems for various power quality problems with all remaining FACTS devices. Then it can be very easy to find an exact FACTS device for a particular type of power quality problem.

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