International Journal of
Scientific Engineering and Technology Research

ISSN 2319-8885
Vol.03,Issue.11
June-2014,
Pages:2338-2343

www.semargroup.org,
www.ijsetr.com

Review and Utility of FACTS Controller for Traction System

PRASHANT SINGH RAJPOOT[1], SHARAD CHANDRA RAJPOOT[2], DURGA SHARMA[3]

[1]PG Scholar, Dept of EEE, Dr. C. V. Raman Institute of science & Technology, Kargi Road Kota Bilaspur, Chhattisgarh, India, Email: prashantrajpoot141@gmail.com.

[2]PG Scholar, Dept of EEE, Dr. C. V. Raman Institute of science & Technology, Kargi Road Kota Bilaspur, Chhattisgarh, India, Email: ms.sharad90@gmail.com.

[3]Asst Prof, Dept of EEE, Dr. C. V. Raman Institute of science & Technology, Kargi Road Kota Bilaspur, Chhattisgarh, India, Email: drgshrm@gmail.com.

Abstract: This paper provide an overview of power electronics based controller and focuses on the issues and benefits of applying FACTS controller in traction system. Threshold of Power Electronics Revolution leads to development of electronics based controller an emerging and improved technology for enhancing reliability & power flow control, this paper focus on basic circuit, characteristic of several FACTS controller like STATCOM & SVC and how they utilised for traction purpose.It is also important that with FACTS controller in the traction system, adequate power quality can be achieved with in at lower voltages than would otherwise be possible. This paper provides a framework for comparing the advantages of STATCOM over SVC in traction.

Keywords: Flexible AC Transmission System(FACTS), Power Electronics Equipment, Power Quality, Transmission Expansion Planning.

I. INTRODUCTION

Flexible AC Transmission Systems, called FACTS, is a well known term for higher controllability in power systems by means of power electronic devices. FACTS-devices are widely used in traction system for reducing harmonics and sag mitigation result in improved power quality and enhancing the reliability of traction system worldwide. Railway exerts a heavy load to the grid. They required large amount of power to be taken from power grid result in derating of power quality and grid suffer from phase unbalance, voltage unbalance, and fluctuation and harmonics distortion. Railway load is connected between two phases, therefore they must be confined in magnitude and prevented from spreading through the grid to other parts of the system and it is necessary to control the harmonics and voltage fluctuation. FACTS enable connection at lower voltage and fulfil the grid code. FACTS-devices provide a better adaptation through varying operational conditions and improve the usage of existing installations.

The usage of lines for active power transmission should be ideally up to the thermal limits. Voltage and stability limits shall be shifted with the means of the several different FACTS devices .with growing line length, the opportunity for FACTS devices gets more and more important. The influence of FACTS-devices is achieved through switched or controlled shunt compensation, series compensation or phase shift control. These devices basically work as fast current, voltage or impedance controllers. The power electronic allows very short reaction times down to far below one second. FACTS-devices can equally be static and dynamic. FACTS-devices posses more advanced technology of voltage source converters mainly based on Insulated Gate Bipolar Transistors(IGBT) or Insulated Gate Commutated. Thyristors (IGCT). With the help of Voltage Source Converters free controllable voltage in magnitude and phase due to a pulse width modulation of the IGBTs or IGCT obtained. High modulation frequencies result in low harmonics in the output signal and compensate disturbance coming from the network.

Fig1. Connection diagram of railway through grid.

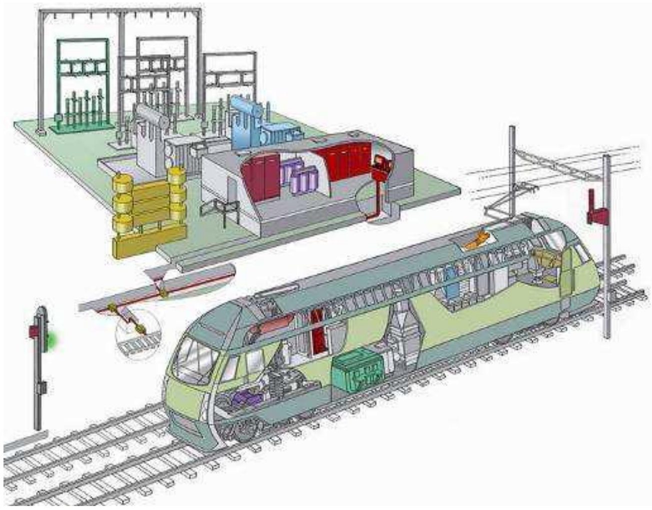

Fig2. Layout of railway with substation.

These series and shunt controller where widely used in railways In order to improve the power for Trains taking power from the catenary supply voltages must be stable and do not sag. use of STATCOM ensure balanced supply and help in sag mitigation and result in improved power quality .power taken between two phases causing substantial imbalance between phases in networks originally not at all built for this kind of operation. Due to increase demand in traction system some of the line being overloaded. Conventional scheme of power transmission based on impedance says that power transfer is inversely related to impedance of the line i.e .line having less impedance will transfer more power.

Therefore healthy feeder gets faulty due to overload. Use of FACTS controller help in improving power transfer capability and improving the reliability of the system. Heavy and varying consumption of reactive power by locomotives result in sagging and fluctuating catenaries voltage. This is overcome by means of dynamic voltage support of catenaries, thereby maintaining heavy traction capability despite weak feeding, and avoiding harmful voltage drops along the catenaries. Use of FACTS controller result In time as well as money saving by implementing FACTS in existing systems rather than investing in costly and time-consuming reinforcement of the railway feeding infrastructure, for example, by building new transmission or sub-transmission lines, and/or building new substations and feeding points. SVC, SVC light and STATCOM are the controller which is widely used in traction system to fulfill this requirement.

II ABBREVIATIONS AND ACRONYMS

Following acronyms are used in this paper
F.A.C.T.S-Flexible AC Transmission system
S.V.C.-Static var compensator
STATCOM-Static compensator
T.C.R.-Thyristor controlled reactor
T.S.R-Thyristor switched reactor
F.C/T.C.R.-Fixed capacitor/thyristor controlled reactor
I.G.B.T-Insulated gated bipolar junction transistor

III CONTROLLER USED IN TRACTION SYSTEM

There are mainly three controllers which are widely used in traction system for reducing harmonics and result in improved power quality. These controllers are Static var compensator SVC, static shunt compensator STATCOM and SVC light.

A. Static VAR Compensator (SVC)

It acts like a variable shunt reactor, which either injects or absorbs reactive power in order to regulate voltage level at the connected point.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. 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

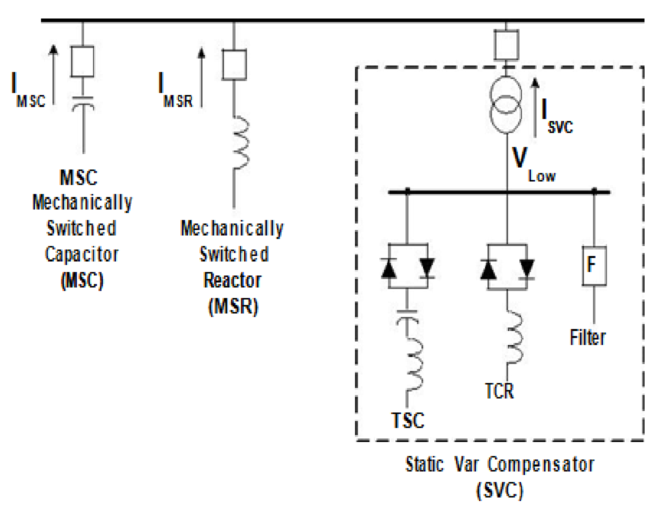

Figure3. Circuit for a Static Var Compensator.

SVC is a type of series controller it can be a variable impedance, variable reactor and capacitor

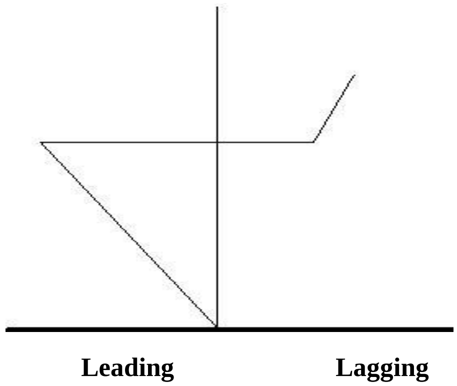

Fig 4 .V-I characteristics of a SVC.

SVC is a type of series compensator they provide the variable impedance active power increases but they required injection of large reactive power

B. Static Synchronous Compensator (Statcom):

In principle, it is similar to the SVC to perform the voltage regulation but it operates with an advanced energy storage element SVC with Voltage Source Converter called STATCOM (STATicCOMpensator) went into operation. The STATCOM has 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 Thyristors with turn-off capability like GTO or today IGCT or with more and more IGBTs. The structure and operational characteristic. 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

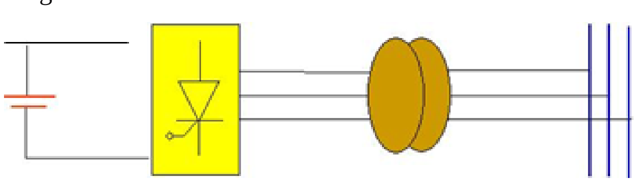

Fig5.Circuit for a Static Synchronous Compensator (STATCOM).

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. Usage of Voltage Source Converters In distributed energy system becom common .for grid interconnection. The performance for power quality and balanced network operation can be improved much more with the combination of active and reactive power STATCOM.

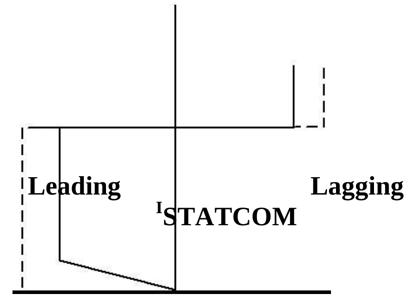

Fig6. V-I characteristics of a STATCOM.

C. SVC LIGHT

When VSC and insulated gate bipolar transistor (IGBT) technologies are brought together they create a highly dynamic and robust system which has a high bandwidth known as SVC Light, in power conditioning tasks in grids and beyond. Using pulse width modulation (PWM), an AC voltage almost sinusoidal in shape can be produced without the need for harmonic filtering. Use of SVC Light result in both technically and economically advantageous .in svc light Light is used to dynamically balance the asymmetry between phases caused by the mode of traction feeding. In these cases, the thyristor locomotives are fed power from two phases of a three-phase grid. SVC light has with ability to generate voltages of any amplitude and phase angle, therefore they are capable to play the role of load balancer dynamic voltage support and power factor correction. The major part of SVC Light can be made container based, assembled and tested in the factory, which facilitates and speeds up work on site, thereby contributing to the installation coming on line faster. For un-sectionalized, substation i.e. where the load is always connected to the same phase pair of the feeding transformer generate negative phase sequence in one direction (quadrant) only, the SVC Light rating can be cut in half proved to be very cost effective and this is realized by offsetting the dynamic range by means of inductive and capacitive branches in the remaining phase pairs.

1. SVC Light:

Some salient design feature - Design of SVC depends on three-level VSC design, through IGBTs (insulated-gate bipolar transistors) as switching elements and a controlling is govern through pulse width modulation. On PWM. The ZPSS SVC Light is rated at 35 kV, 0-164 Mvar continuously variable over the entire range. SVC Light are built through the VSC, rated at -/+ 82 Mvar, an air-core phase reactor which provide coupling for VSC to the 35 kV bus, and an array of parallel harmonic filters rated together at 82 Mvar. harmonic perform multiple task like offsetting the operating range of the SVC filtering low-order harmonic of the EAF; and filtering high-order harmonics from the VSC.VSC has four IGBT valves and two diode valves in each phase leg. The valves are made up of stacked devices with interposed coolers and with external pressure applied to each stack .we connect the One side of the VSC is to a capacitor bank which acts as a DC voltage source. The converter work as inverter convert the input DC voltage in corresponding AC voltage produces by connecting the positive pole, the neutral, or the negative pole of the capacitor bank directly to any of the converter semiconductors are series connected. IGBT and diode component is built up in a modular housing comprising a number of submodules (in this installation six), each containing a number of semiconductor chips in order to provide mechanically robust series connection and to limit requirements on flatness tolerances, each of the submodules is equipped with a system of spring assemblies for each individual chip.

Fig7. SVC Light

2. Control and protection:

Open loop control scheme is provided in order to control the voltage fluctuation.. It compensates the entire reactive part of the furnace loads, in addition also modifies the reactive current reference in order to minimize the effects on flicker caused by active load fluctuations .This load unbalance is also compensated for by the SVC Light. It is achieved by "wheeling" active power between phases.

IV. FACTS CONTROLLER FOR HARMOICS REDUCTION

FACTS controller plays an important role for harmonics reduction in traction system result in improved power quality and increased reliability for traction system. In this article we compare how different controller where utilized for traction system and their contribution for overall improvement of traction system.

A. Reduction of Harmonic THROUGH SVC

SVC dynamically supports the sagging catenaries voltage there by mitigating the harmonics. TCR and the secondary windings of the step-down transformer are arranged in delta connection to reduce the triplex harmonics and with the help of series reactor capacitor bank are tuned for fifth harmonics ,seventh and higher order harmonics as a high pass filter The capacitor banks with the help of series reactors are tuned to filter fifth, seventh, and other higher-order harmonics as a high-pass Filter .These do not have a short-time overload capability because the reactors are usually of the air-core type. In application requiring overload capability, TCR must be designed for short-time overloading, or separate thyristor -switched overload reactors must be employed.

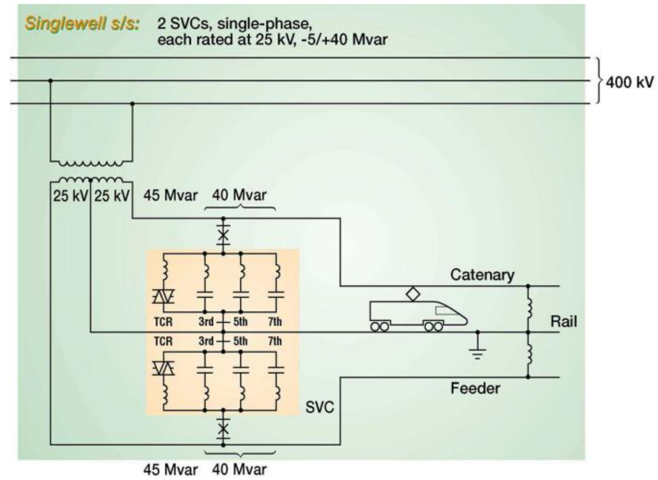

Fig8. Application of 2 SVC in traction system.

B. Harmonics Reduction through STATCOM

In STATCOM if two-phase structure are used four-phase control of active and reactive power, can be obtained providing two supply arms of power substation with dynamic reactive compensation and, regulate active flow of two supply arms, so as to dynamically balance the loading .STATCOM is usually supported by DC voltage provided by capacitor on DC side, it can't provide continues active power. But if change a power supply on DC side, STATCOM, served as voltage source inverter, can exchange energy with system In contrast with SVC, STATCOM has its advantages of fast speed, gat loading rate high work efficiency, and small output harmonic content. STATCOM is frequently used for mitigation of voltage flicker.SVC also provide mitigation of voltage flicker but they have complex algorithms injecting large harmonics current on the other hand STATCOM have novel control algorithms exerts the voltage disturbance and suppress the voltage flicker reduces the voltage flicker to the acceptable low level at PCC also helpful in reduction of total harmonics distortion .use of STATCOM reduces the voltage flicker to the factor 7.they provide negative phase sequence compensation through flicker compensation.

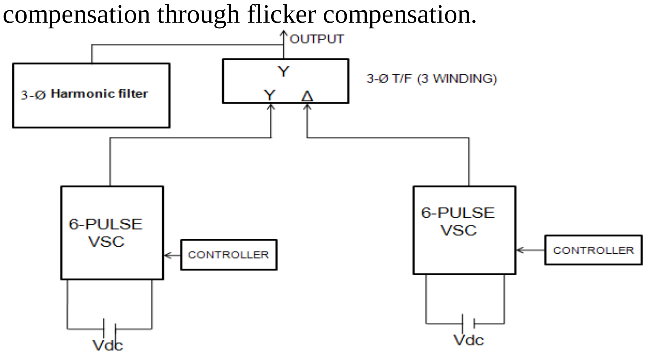

Fig9. Block diagram of 12-pulse voltage source converter STA TCOM with harmonic.

C. Harmonics Reduction through SVC Light

Active filtering is obtained by generating harmonic currents in the SVC Light in phase opposition to the currents from the load. This is obtained by modulating the converter terminal fundamental voltages by higher frequencies. Filtering performance depends upon the switching frequency of the convertor Typically, the active filtering is effective up to and including the 9th harmonic .this is better understand by example suppose two SVC Light are operated in the French railway system fed from the national power grid, one at 90 kV and one at 63 kV sub-transmission levels. At both sites, SVC Light is utilized for dynamic balancing of asymmetry between phases caused by single-phase take-off of power from the three-phase grid. The SVC Light also performs the task of active filtering of harmonics generated by thyristor locomotives, enabled by the high dynamic response inherent in SVC Light. With the SVC Light, the grid code at the 90 kV and 63 kV points of common connection is fulfilled. With the use of SVC Light following benefit are obtained in traction system

- Flicker mitigation
- Productivity improvement
- Load balancing

Above mentioned points are the main advantages of applying SVC light in traction system there by enhancing the reliability and improving the power quality of traction system.

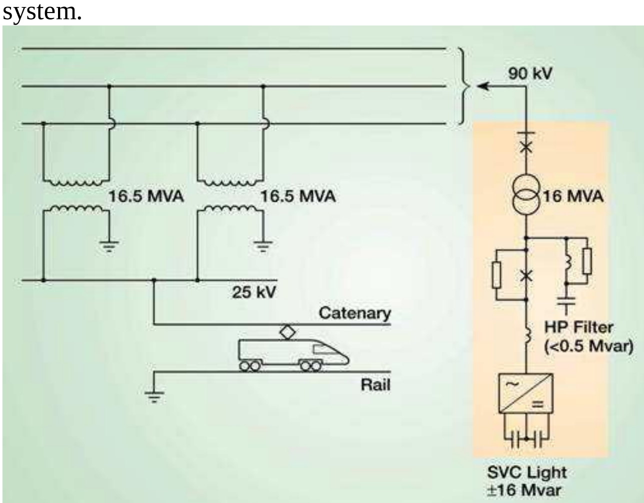

Fig10. SVC Light for 90 kV, 16 MVA.

V. BENEFITS OF APPLYING FACTS CONTROLER IN TRACTION

FACTS controller Keep the catenaries voltage high at all times for sufficient loco power following are the possible benefit of applying controller in traction system.

A. Load Balancing through FACTS

Traction loads, Pload, tend to be relatively large. These loads create imbalances in the supply system voltage as they are connected between two mains phase result in the negative phase sequence voltage resulting from an unbalanced load. In many cases the traction system is relatively far from strong high-voltage transmission lines, while weaker sub-transmission lines may run somewhere in the vicinity of the rail. These lines can be used to supply the rail in case the imbalance caused by the traction .Use of FACTS controller provide the load balancing as we all know in traction system 2 phase supply in available there by this feature is essential otherwise result in large harmonics current sag and load fluctuation.

- Maximum power transfer capability
- Maximum availability
- Minimum environmental impact
- Minimum transmission costs
- Minimum investment costs
- Minimum maintenance costs

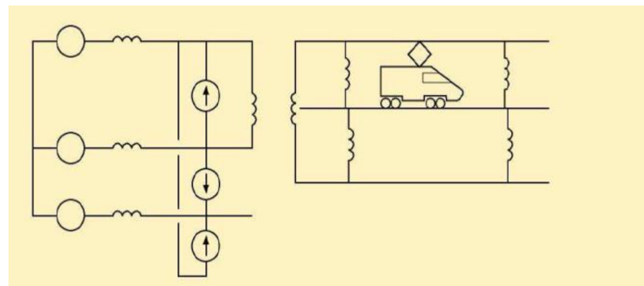

Fig11. Dynamic voltage support.

With increase in train loads high and stable catenaries voltage becomes an issue for maintaining traction efficiency. Rather than having to reinforce the feeding infrastructure, SVC Light offers a cost and time effective means for voltage support. And vice versa, in green-field projects, it can minimize the required number of feeding substations. result in overall reduction in cost thereby enhancing the overall efficiency.

B. Power quality improvement

Because of large load and two phase supply there is large Voltage fluctuations and imbalance between phases these are the main power quality issue both for railway and grid from which traction system is taking supply they generate large current and voltage harmonics, emanating from thyristor and diode locomotives must be trapped and confined, lest they spread out into the power system feeding the railway and become a nuisance to others. The ability of SVC Light to act as an Active Filter opens up for efficient harmonic filtering.

C. Power factor improvement

High power thyristor locomotives are operated at relatively low power factors, typically 0.7 – 0.8. The result is reactive power consumption, leading to transmission losses as well as higher than necessary power tariffs. With the use of FACTS controller providing reactive power compensation. power factor is improved through SVC Light, the power factor can be kept high and stable, regardless of load fluctuations,use of STATCOM help in obtained constant voltage at feeding point without any back feed of reactive power to the grid Energy storage. Use of SVC light provide the storing facility which enables the energy to be stored during low traffic periods at night and low load period when power and prices are low on the traction system. This energy can then be discharged into the rail way system during peak periods, mostly in the morning and late afternoon, when power and prices usually are high. The result will be a gain on the electricity bill. Energy storage off the power peak due to high traffic

D. Cost reduction

Large load on traction system required the installation of new transmission line FACTS controller enhances the power transfer in existing line there by increases the power transfer limit and reduces the cost for installation of new transmission line result in reduced cost.

VI CONCLUSION

This paper provide the information for use of FACTS controller in traction system use of controller with energy storage increases the traffic intensity enable facility for energy storage during light load period and increases the power quality by reduction in voltage flicker, sag mitigation and harmonics reduction, SVC light is proved to be very cost effective and STATCOM gives better result for sag mitigation through shunt compensation.

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