FACTS in Voltage Profile Improvement of open-loop Traction system

Lalit G. Patil

Assistant Professor, Department of Electrical Engineering,
The Maharaja Sayajirao University of Baroda, Gujarat, India

ABSTRACT

This paper deals with voltage profile improvement in railway traction system and it describes a concept of static variable compensator which is a fact device. Static variable compensator is composed of TSC and TCR [9]. Locomotives on railway track is powered from substation and Substation is capable of delivering power to only fix number of locomotives. When any locomotive is moving in particular range of substation, at that time a substation is capable to operate particular number of locomotives only. When number of locomotives increase in substation there may be a reduction in voltage profile of power delivered to the locomotive motors due to load on substation. Harmonics may generate and this may cause tripping of circuit breaker without any fault. A concept of Static variable compensator overcomes this low voltage profile problem.

Keyword: - *facts devices, static variable compensator, fault analysis, harmonic reduction, traction system.*

1. INTRODUCTION

Railway is called a life line of country for transportation of goods and citizen's as well healthy and timely operation is always in demand. A technical issues need to be solved and it should not affect again and again and need to be improved. This paper describes a concept of railway traction system when variable number of locomotives move in particular substation. A substation is capable of delivering 25kV to each locomotive and itself have a capability of 220kV. As locomotives increase in particular SS, then tripping may occur without any fault due to low voltage and this may disrupt the operation of locomotives. A static VAR compensator is be used for voltage stability. Statcom typically exhibit higher losses and may be more expensive than SVC, so SVC technology is more widespread. Static variable compensator is a concept which improves voltage profile of railway traction system [3]. The basic pi circuit consist of horizontal inductor and vertical capacitors with two resistances parallel to it for energy consumption purpose. This is also called as medium transmission line pi section and this pi section is used in railway network to feed power.

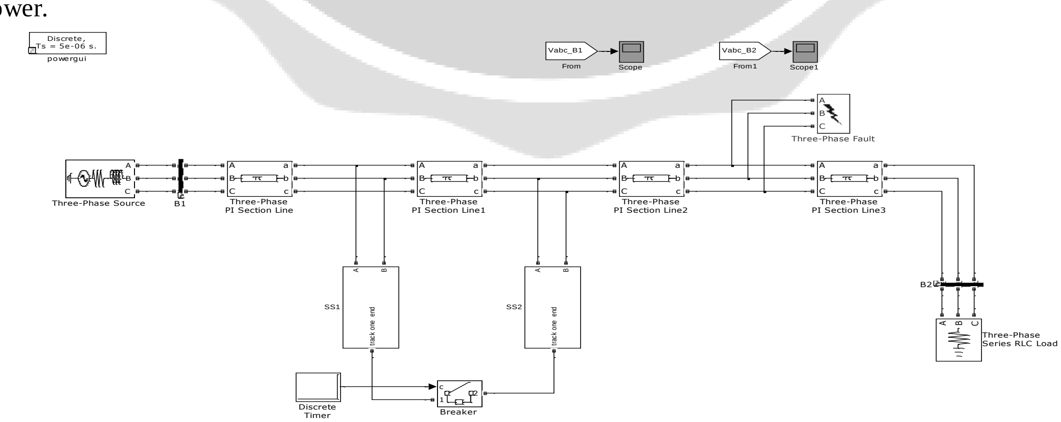

Fig 1: Electrical Railway traction feeding system

Figure 1 shows a typical arrangement for railway feeding system. Here a three phase source is connected at main source and a kilometers of long line is distributed. After several kilometers of long distance say 40-50km there is a substation, and each substation is capable of generating 220kv. Here in simulation we have considered two substations and each substation is capable to drive locomotives of 25kv each as well we have considered two sub stations and two locomotives in each substation. After several kilometers of line we have shown a three phase fault, and there is a deviation in voltage profile. So, this may cause unwanted tripping of locomotives without any fault, and to overcome this problem SVC concept is introduced.

2. COMPONENTS OF SYSTEM

2.1 Static Variable Compensator (Facts)

SVC is popular in traction system because of Expansion and growth in electrical utility, Transmission stability and thermal limit, Quality of power deliver, Optimum and profitable operation in generation, transmission and distribution and efficient utilization and control of the existing transmission system. SVC provides as an infrastructure for this advantages. Improved utilization of the existing power system is provided through the application of advanced control technologies like SVC, Power electronics based equipment, or Flexible AC Transmission Systems, provide proven technical solutions to address these new operating challenges being presented today. SVC technology allow for improved transmission system operation with minimal infrastructure investment, environment impact, and implementation time compared to the construction of new transmission lines. FACTS technologies provide advanced solution as cost-effective alternatives to new transmission line construction. The potential benefits of SVC equipment are now widely recognized by the power systems engineering.
While discussing the creation, movement, and utilization of electrical power or energy, it can be separated into three areas, which traditionally determined the way in which electric utility companies has been organized.

- Generation
- Transmission
- Distribution

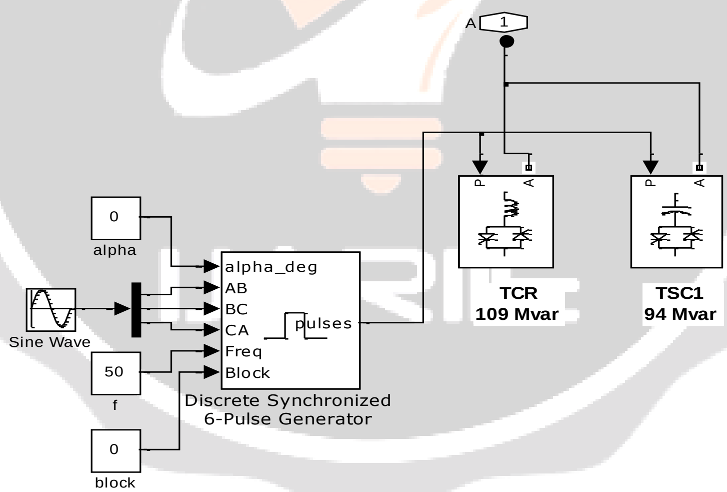

Fig 2: SVC

Figure 2 shows a basic model of SVC which includes TCS and TCR [9]. SVC used to inject reactive power in line when fault occurs and brings a stability in voltage profile [7].
There are various controlling methods for enhancing the power control system like Static Synchronous Compensator, Static Variable Compensator, Unified Power Flow Controller, Convertible Series Compensator, Inter-phase Power Flow Controller, and Static Synchronous Series Controller. Each of the controller impacts voltage, impedance, and/or angle (and power).

2.2 Locomotive design

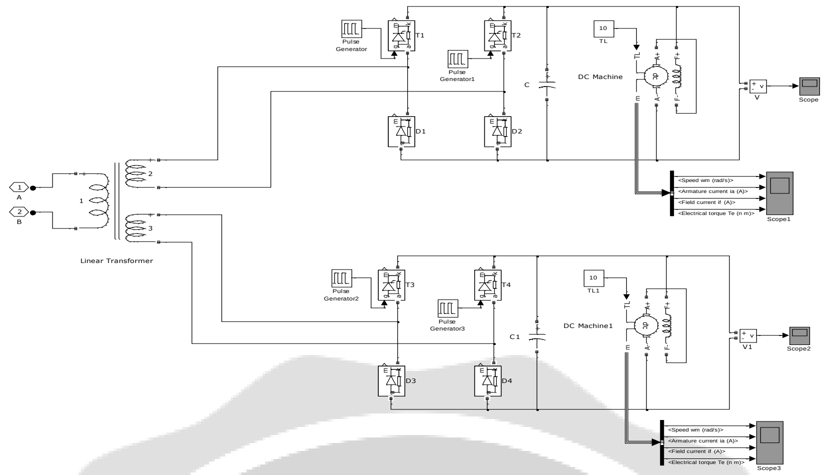

Fig 3: Locomotive Design

Figure 3 shows a basic simulation model of a Locomotive. The model have a thyristor diode bridge rectifier, each having parameters of Ron = 0.001 Ohms Forward voltage = 0.8Volt and snubber resistance = 500 Ohms. In real there are several locomotives which are connected in series to drive wagons.

3. RESULT ANALYSIS

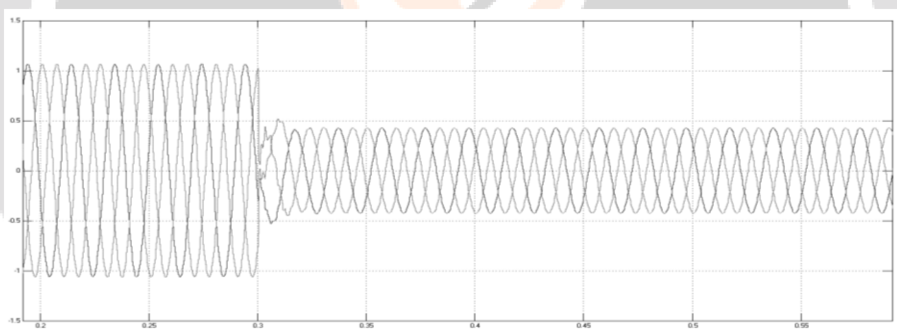

Fig 4: Grid voltage with LLLG fault

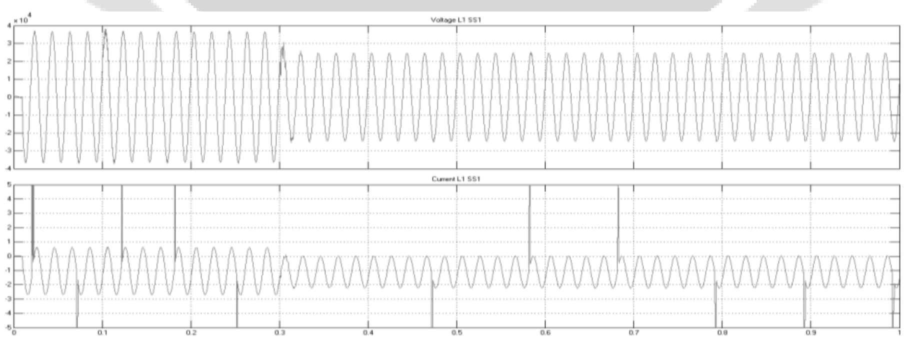

Fig 5: Voltage profile of Locomotive 1 in Substation 1 without SVC

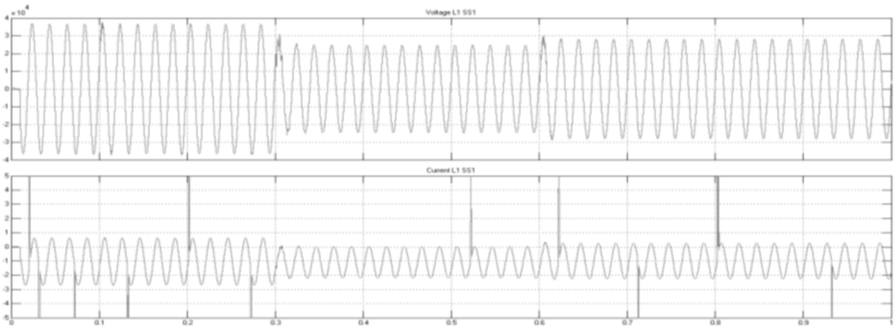

Fig 6: Voltage and current profile of Locomotive 1 in Substation 1 with SVC

From the waveforms it can be observed that during period of 0 to 0.6 SVC is off and in distribution line fault occurs at 0.3, so during period of 0.3 to 0.6 time this fault remains and voltage profile is weak during this period. As SVC becomes on at 0.6 time, it injects reactive power in line, and voltage profile starts to improve and this is shown in graphs clearly.

If we keep SVC continuous on then following voltage profile is obtained which helps in getting stable voltage profile and less harmonics [2].

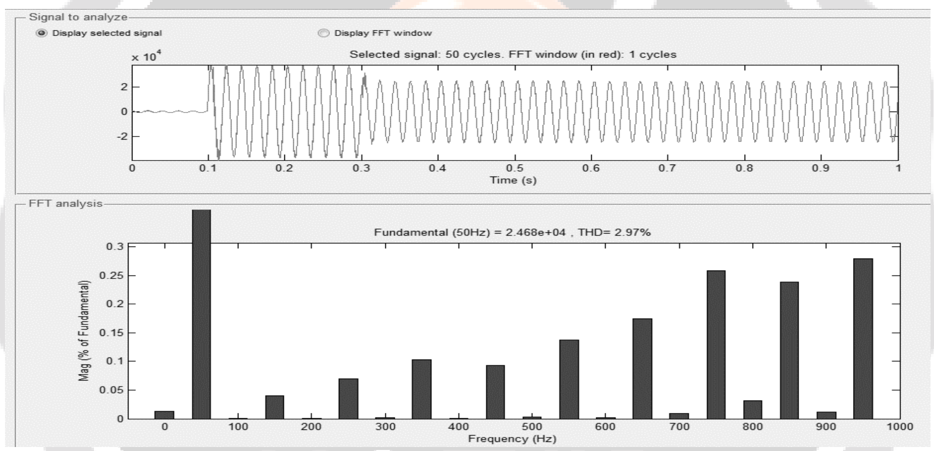

Fig 7: THD of voltage before SVC (during fault)

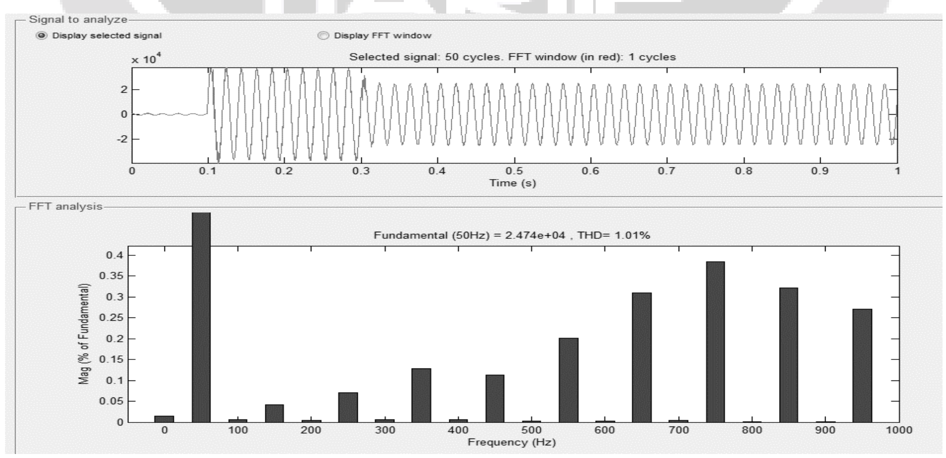

Fig 8: THD voltage after SVC (during fault)

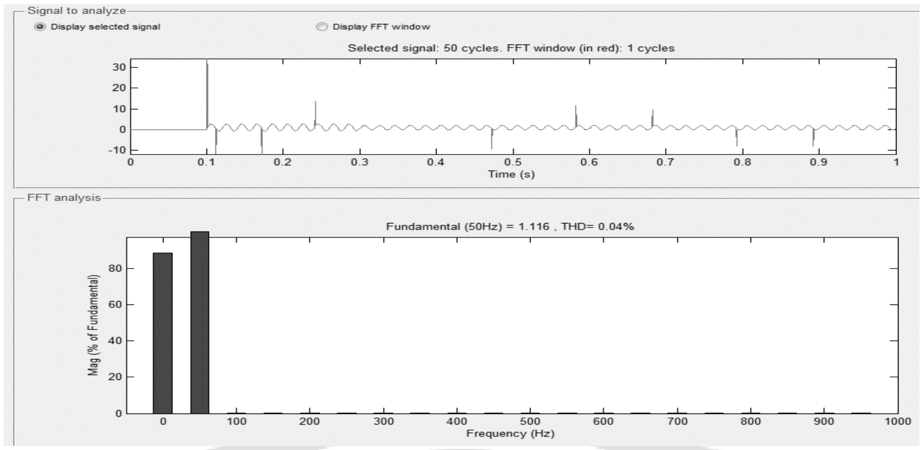

Fig 9: THD of current before SVC (during fault)

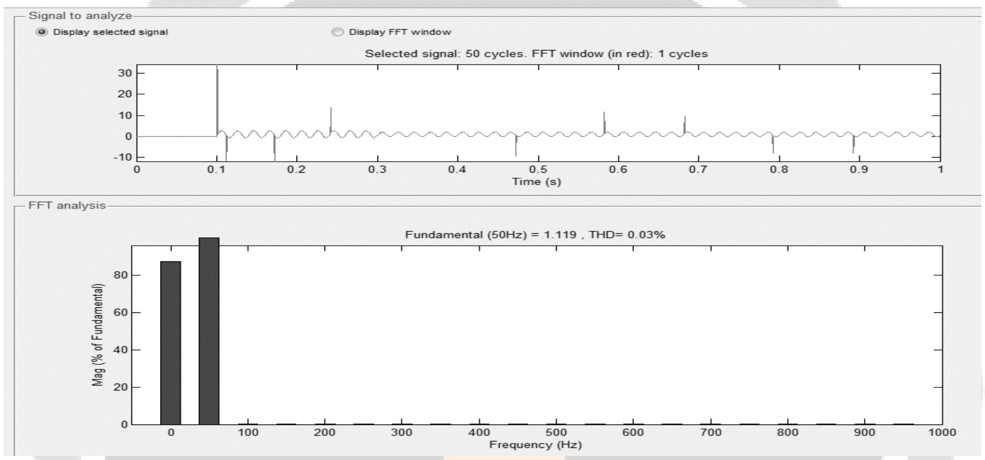

Fig 10: THD of current after SVC (during fault)

From the analysis of harmonics, it can be seen that harmonics are suppressed using SVC. In voltage profile of locomotive without using SVC, THD = 2.97%, and with SVC, THD = 1.01% of fundamental component.
In current profile of locomotive without SVC, THD = 0.04%, and with SVC, THD = 0.03% of fundamental component.

4. CONCLUSION

SVC is used for Increased Loading and More Effective Use of Transmission Corridors, Added Power Flow Control, Improved Power System Stability, Increased System Security, Increased System Reliability, Added Flexibility in Sitting New Generation, Elimination of the Need for New Transmission Line.

The following conclusions are drawn from implemented simulation.

1. SVC improves voltage profile when tripping occurs due to excessive loading of locomotive on substation and decreases harmonics in converter while driving DC motors of locomotives. It improves power quality in converter as well in distribution line because of moving load, as moving load is challenging task for substations.
2. SVC prevents false operation of circuit breaker due to excessive flow of line current because of multiple locomotives on same section of transmission line.
3. From the harmonic analysis it can be seen that harmonic distortion is less in voltage profile of locomotives while using SVC.

5. REFERENCES

[1] Zhu Guiping; Chen Jianye; Liu Xiaoyu "Compensation for the negative-sequence currents of electric railway based on SVC", *Industrial Electronics and Applications, 3rd IEEE Conference on*, on page(s): 1958 – 1963, 2008

[2] Tokio Matsuhashi, Kazutaka Itako, Takeaki Mori and Susumu Ohya, "Reduction method of high harmonic currents on the AC side of the diode rectifier circuits in the AC electric railways", *Industry Application Society Annual Meeting*, vol.2, pp.1343-1350, 4-9 Oct., 1992

[3] Kenji Hawahara, Shin-iche Hase, Yoshifumi Muchinaga and Yasuji Hisamizu, "Compensation of voltage drop using static Var compensator at sectioning post in electric railway system", *Power Conversion Conference - Nagaoka*, 1997, Proceeding of the Volume 2, 3-6 Aug. 1997, pp955-960

[4] K.H.Yuen, M.H.Pong, W.C.Lo and Z.M.Ye, "Modelling of electric railway vehicle for harmonic analysis of traction power-supply system using Spline interpolation in frequency domain", *Applied Power Electronics Conference and Exposition*, Vol.1, pp458-463, 14-18 March 1999

[5] R. Cella, G. Giangaspero, A. Mariscotti, A. Montepagano, P. Pozzobon, M. Ruscelli, and M. Vanti, Measurement of AT Electric Railway System Currents at Power-Supply Frequency and Validation of a Multiconductor Transmission-Line Model, *IEEE Transactions On Power Delivery*, vol 21, no3, July 2006.

[6] Singh, B.; Singh, B.N.; Chandra, A.; Al-Haddad, K.; Pandey, A.; Kothari, D.P. "A review of single-phase improved power quality AC-DC converters", *Industrial Electronics, IEEE Transactions on*, On page(s): 962 - 981 Volume: 50, Issue: 5, Oct. 2003

[7] Ma Jianzong; Wu Mingli; Yang Shaobing, "The application of SVC for the power quality control of electric railways", *Sustainable Power Generation and Supply, International Conference on*, On page(s): 1-4; 6-7 April 2009

[8] Chi Meidan; Wu Mingli; "The switching transient simulation of SVC used in electric railway traction substation", *Sustainable Power Generation and Supply, International Conference on*, On page(s): 1-5; 6-7 April 2009

[9] Dan Wang ; Chaoying Yang ; Xin Zhang ; Jinhao Wang ; Gengyin Li, "Research on application of TCR+FC typed SVC in power quality integrated management for power traction system" , *Sustainable Power Generation and Supply, International Conference on*, On page(s): 1-5; 8-9 Sept. 2012

[10] A. Dán, P. Kiss: “Advanced Calculation Method for Modelling of Harmonic Effect of AC High Power Electric Traction”, *12th International Conference on Harmonics and Quality of Power, Cascais*, 1-5. October 2006.