

ANALYSIS OF HARMONIC GENERATION OF SVC IN VFD LOAD SYSTEM

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Abstract- In this paper, the harmonic content and overall performance of a system including both a VFD and a SVC will be studied and analyzed. Specifically, the cases of Variable Frequency Drive (VFDs) and power electronic based static VAR compensation are examined. Static VAR Compensator and Induction Motor Drives Systems are modeled and simulated using a Matlab/Simulink environment. Simulation is carried out and results are compared with the IEEE standard limits. The simulation results were performed and tested to simulate a system which contained both fixed and power electronic based harmonic generating loads. The performance of system was determined by total harmonic current and voltage distortions, true power factor, and RMS current levels at different points in the system. The simulation results shows that a Total Harmonic Distortion (THD) is reduced from 16.38% to 0.36% for current and Total Harmonic Distortion is reduced from 6.99% to 0.26% for voltage in worst scenario, which is below 5% limits of Institute of Electrical and Electronics Engineers (IEEE) standard. In addition to that the system power factor is improved from 0.94 to 0.98.

Keywords: IM, Harmonics, PQ, SVC, THD, VFD, MATLAB/ SIMULINK.

1. INTRODUCTION

In any industrial application, the primary challenge is how to maximize the output production while minimizing the input costs. From a power perspective, this means accomplishing the required output task at the minimum input power and current requirements. In induction motor applications, the use of power factor correction and variable frequency drives (VFDs) are two methods to maximize the efficiency of the system. By providing power factor support to the system the input current is minimized for the same amount of real power. This can result in fewer line losses and smaller, and thereby cheaper, circuit breakers. With the advent of power electronics, flexible AC transmission systems (FACTS) now provide a means to dynamically adjust the power factor as the load requirements of the system change. Another product of power electronics, VFDs, allow for the speed of the induction motor to easily be changed to ensure the motor is running at the optimal level for the required task. The downside is VFDs and FACTS are based on switching power electronics and thereby produce harmonics which can be dangerous in power systems. To protect against this the Institute of Electrical Engineers (IEEE) has created a standard, IEEE Std 519-1992, which outlines the recommended practices and requirements for harmonics in a power system. Specifically, the standard sets the acceptable distortion limits a consumer can reflect back to the utility. This paper examines the harmonics and overall system effects of applying static VAR compensation to a node which contains VFD controlled and fixed speed induction motor loads. In general, it is not practical to apply conventional capacitive power factor correction to a VFD load. Since a VFD draws current in phase with the voltage, any power factor correction applied to a VFD should be in the form of a line filter to mitigate its harmonics and reduce its distortion power factor [1]. However, this work attempts to look at the more universal situation of providing power factor support at a single node which supplies many different loads. In this case the specific loads connected to the node may be unknown, such as a utility, or the number of loads may be enough so that it is not practical to provide individual power factor correction.

2. REVIEW OF HARMONIC GENERATION OF SVC SYSTEM

The reviews related to this work are as Karuna Nikum, & et al [1]. This paper proposes a combined system of harmonic filters and thyristor-controlled reactors (TCRs) for PF improvement and reactive power compensation with new economical design of static VAR compensator (SVC). Generally, the SVC requires high-voltage switching of capacitors and inductors at very high cost. In the new concept, the voltage is stepped down to 600 V for reactors and divides into 32 parallel TCRs to handle high current in steps by switching without continuous control of firing angle. This technique makes system reliable and cost-effective. Ivana Damjanovic & et al [2]. In this paper, harmonic performance analysis of SVC equipped with TCRs is presented. SVCs utilizing TCRs generate harmonic currents and determine the effect of harmonics generated by the SVC on the power system and its elements. This includes interaction of the SVC with the system, the SVC performance under balanced and unbalanced operating conditions and finally, evaluation of countermeasures such as installation of harmonic filters. Harmonics generated by SVCs are largely dependent on the operating point within the SVC characteristic. The results of harmonic performance analysis are important for appropriate design of SVC. Harmonic performance analysis related to SVC application which are presented in this paper. E. V. Liberado, & et al [3]. This paper describes a harmonic analysis methodology for the SVC, considering non-ideal source voltages, in order to determine harmonic power terms that may be used to design and also control harmonic power filters are presented and the operation of an experimental SVC prototype is also analyzed. S. Sujatha & et al [4]. Main objective of the paper is to study the impact of SVC on stability and

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enhancing the power quality for a real time industrial system. Modified RK method is used for transient stability analysis and detailed frequency modeling is used for harmonic analysis. Karsten Kahle & et al [5]. This paper presents the Particle accelerators, and in particular synchrotrons, represent large cycling non-linear loads connected to the electrical distribution network. Shadab Shakee & et al [6]. This paper investigates the use of a Static VAR Compensator (SVC) used along with wind farms and solar for the purpose of proper stabilizing the grid voltage after grid-side disturbances such as a temporary trip of a wind solar generation and sudden load changes. SVC has capacity to absorb or inject volt-ampere reactive (VAR) or Reactive power at faster rate. SVC has rehabilitation to control or stabilize the voltage sag after drastic disruption through voltage source converter. It absorbs or injects reactive power at greater rate as compared to other devices. Rekha T & et al [7]. In this paper discussed the different power quality phenomena that can appear such as voltage fluctuation, voltage and current distortion, voltage sag, voltage transient, voltage and current unbalances. All of the power quality phenomena appear due to the presences of nonlinear loads. Also he analyzed the system and the power quality problems generated different scenarios. M. Jafar & et al [8]. This paper investigates the utilization of a transformer less arrangement associated responsive/harmonic compensator. The compensator is connected to remunerate the high receptive power/harmonic request of a 12-beat line-commutated HVDC rectifier terminal. Simulation comes about uncover that the proposed system remunerates the responsive power and harmonics of the HVDC converter attractively. Manjulata Badi [9]. This paper provide framework for issue like harmonics, voltage sag, voltage unbalance, poor power factor and flicker which cause poor power quality. In this paper propose integration of Static Var Compensator and harmonic filter in the Rectifier traction substation for improving power quality. S. H. Hosseini & et al [17]. This paper proposed hybrid filter structure with new and simple control techniques is used for power quality improvement of the DC distribution system feeding the DC electrified railway systems.

3. WORKING PRINCIPLE SVC FOR PROPOSED SYSTEM

For the purpose this work, induction motor was fed by a 220 V_{L-L} 3 Φ 50Hz source through a Delta-Wye grounded transformer. The Δ -Y connection was used based on the recommended grounding system by the VFD as shown in figure 1. Additionally, the configuration is popular in distribution and commercial systems. The Δ -Y connection offers the benefits of a grounded secondary, a 30⁰ phase shift to help keep voltages balanced, and a delta primary to protect the source against harmonics [21] [4]. The transformer supplied the power to motor with their rated voltage. In this work both a distortion and a displacement power factor less than unity will be present when no compensation is applied. If VFD controlled motor was used the displacement power factor would be unity regardless of the loading conditions required Static Var Compensation (SVC).

To best match of this work for the real world, the VFD motor had its load and speed stepped to match a variable torque load. A variable torque load is one whose torque demand increases with its speed, usually proportionally to the speed squared [1]. This load characteristic is common to variable flow applications which can include fans, centrifugal pumps or blowers, propeller pumps, turbine pumps, agitators, and axial compressors. Since the torque increases proportional to the square of the speed, VFDs provide the greatest cost savings for this type of load [16]. This made the variable torque load profile the best choice of work. A Static VAR Compensator was placed between each secondary phase and ground. When the SVC was used, its firing angle was adjusted until the minimum achievable value of VARs being sent from the source and all measurements will assume a balanced system so that the measurements of phases A, B and C are of the same magnitude.

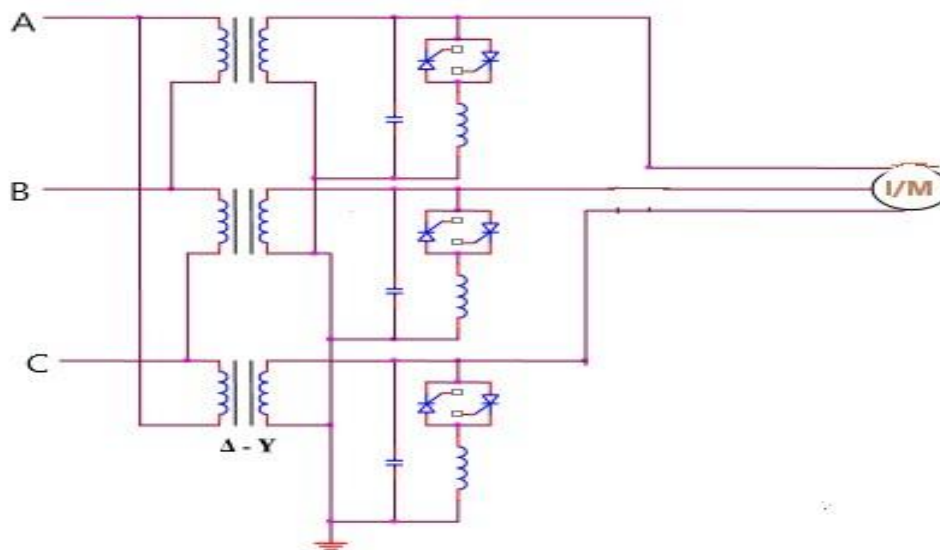


Fig. 3.1 Static VAR Compensation Schematic

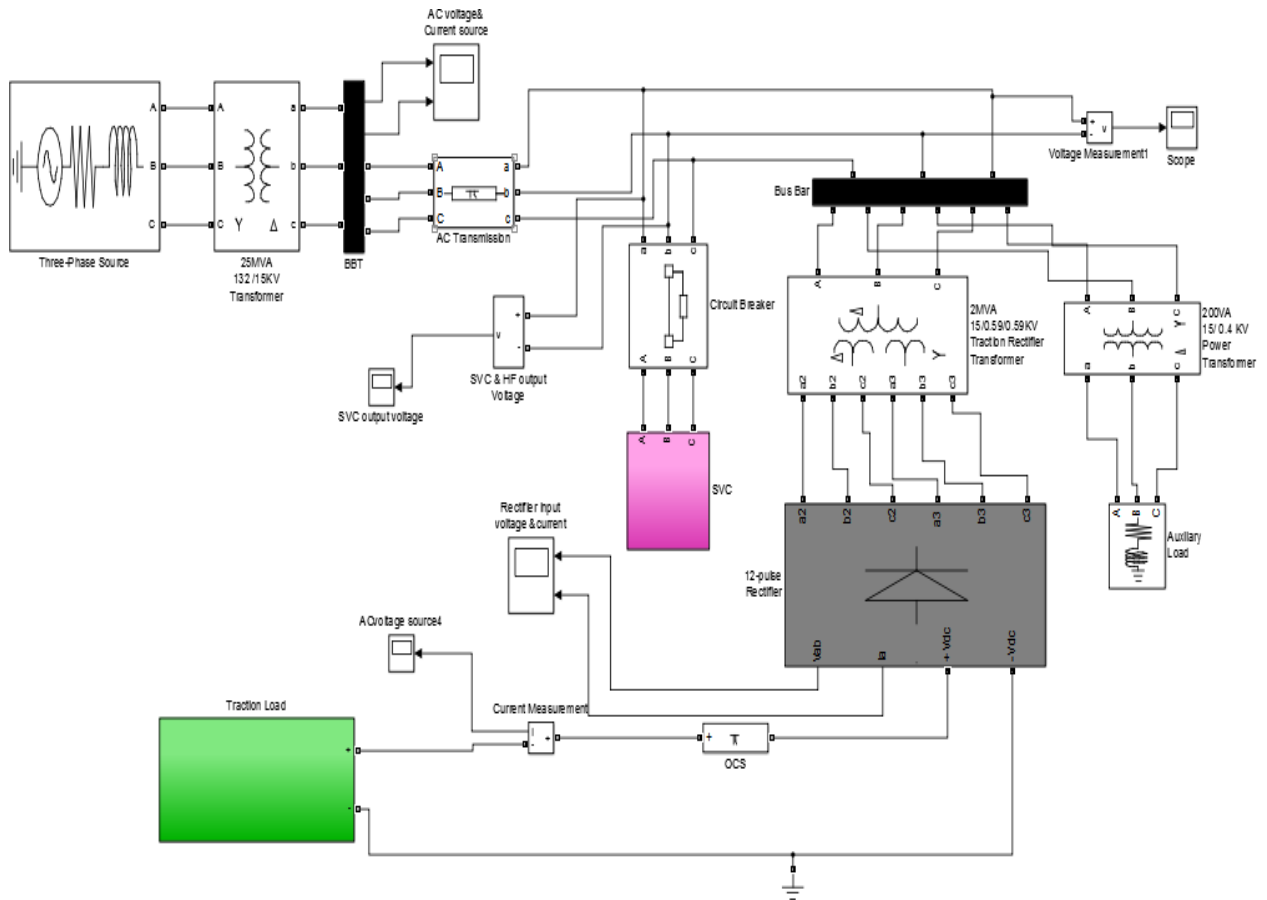


Fig. 4.2 Simulation Model System with SVC and Harmonic Filter

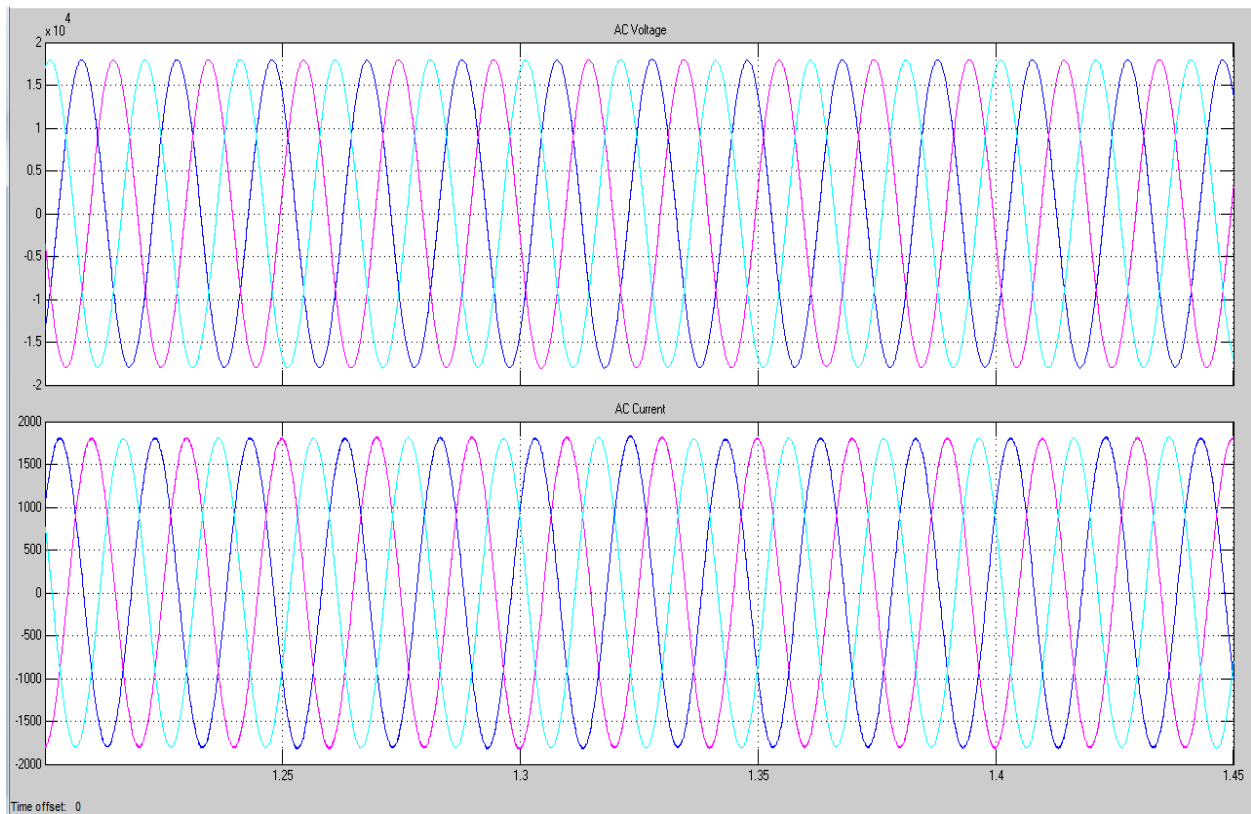


Fig. 4.3 AC Voltage and Current Waveform with SVC & Harmonic Filter

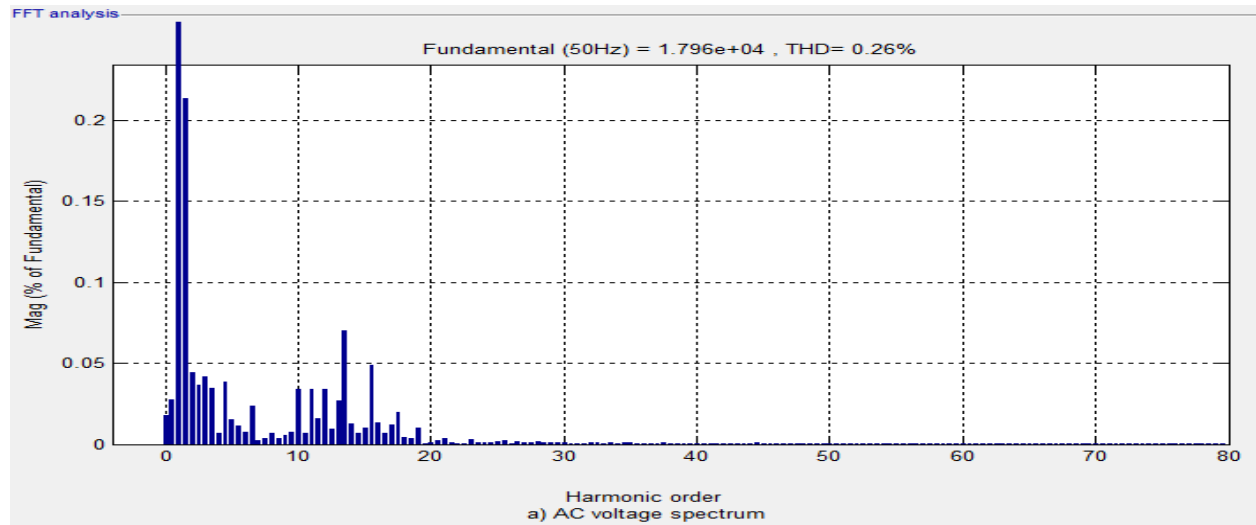


Fig. 4.4 AC Voltage Harmonic Spectrum with SVC and Harmonic Filter

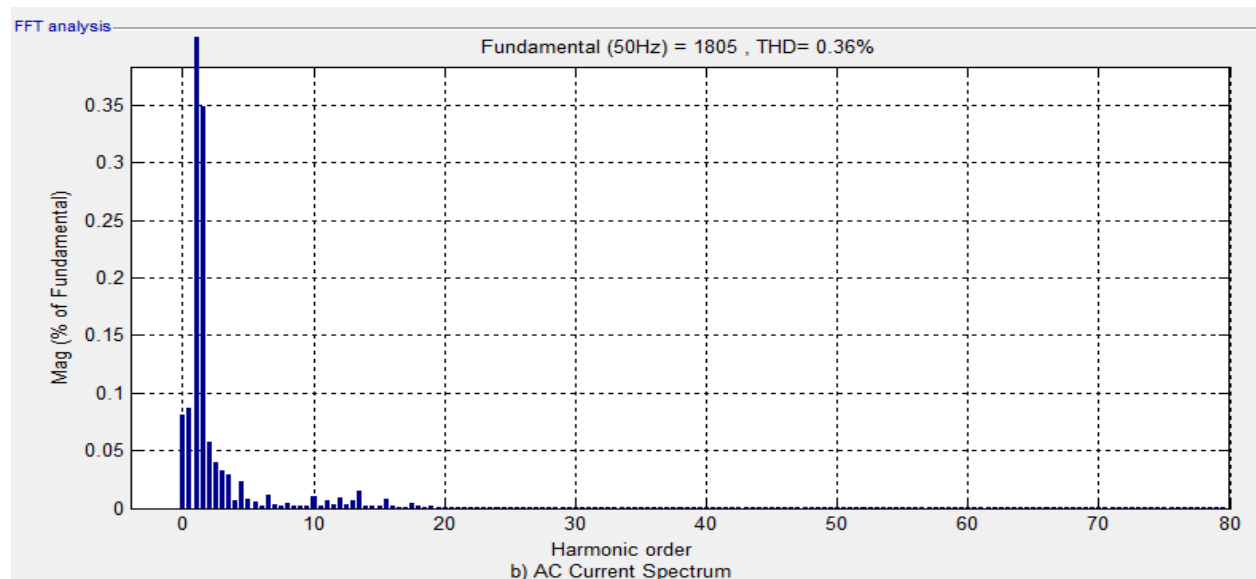


Fig. 4.5 AC Current Harmonic Spectrum with SVC and Harmonic Filter

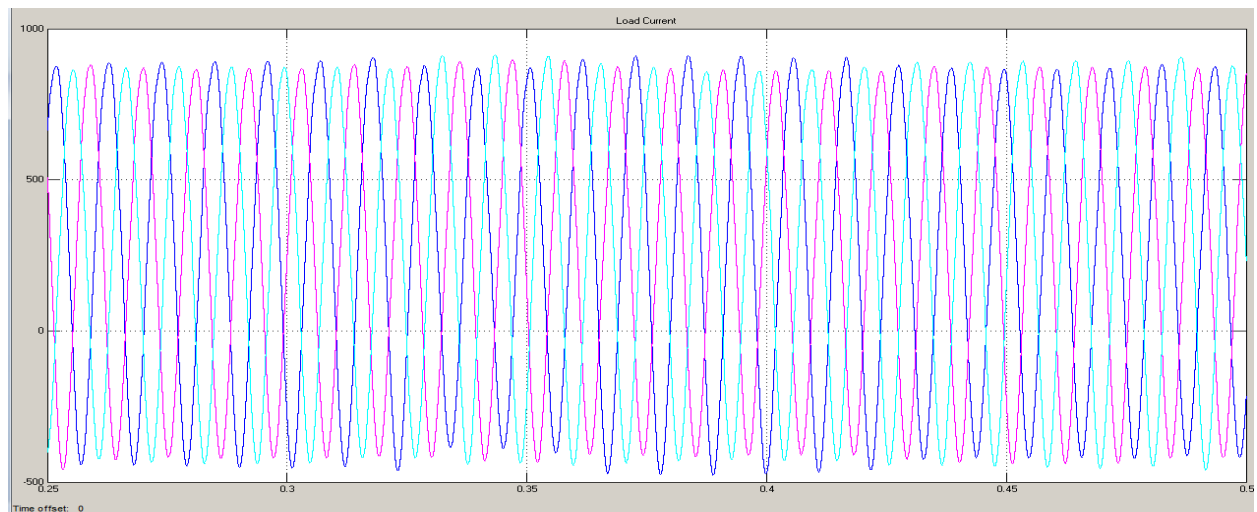


Fig. 4.6 Load Current Waveform with SVC and Harmonic Filter

In above case, it is seen that the voltage THD decreases while the current THD increases with increases the load.

Table-4.1 Total Harmonic Distortion (THD) Level with SVC and Harmonic Filter.

Load (%)	THD of Voltage (%)	THD of Current (%)	Pf
50%	0.28	0.28	0.98
60%	0.28	0.29	0.98
70%	0.27	0.31	0.98
80%	0.27	0.32	0.98
90%	0.27	0.35	0.98
100%	0.26	0.36	0.98

CONCLUSION

In this work, the various power quality issues are discussed. It mainly gives solutions to harmonic distortion and power factor using SVC and harmonic filter. Here, investigations are carried out with SVC and harmonic filter and it is clear the results that load has increased the total harmonic distortion in feeding bus. In general, current and voltage distortion have been varied accordance with nature of load characteristics. From the simulation result, it can be concluded that the % THD of current increase as the load increase. During simulation in worst case scenario for voltage distortion THD of 6.99% was observed, which 28.45% above the recommended limit of IEEE (5%). In addition to this, individual current distortion of the most dominant harmonic orders is high and violates the recommended limit of IEEE 519. Finally, % THD of voltage and current is 0.26 % and 0.36% respectively. Integration of SVC and Harmonic filter has the advantage of improving the power factor of system. It is shown that the power factor is improved from 0.94 to 0.98 by controlling the harmonic distortion of the system.

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