Scientific Journal Impact Factor (SJIF): 1.711

International Journal of Modern Trends in Engineering and Research

IJMTER

ISSN (ONLINE) : 2349 - 9745

ISSN (PRINT) : 2393 - 8161

Mitigation of Voltage Flickers using Shunt FACTS device

P Gopi[1], D Gurunadh[2]

[1] *Electrical & Electronics Engineering, PBR Viswodaya Institute of Technology & Science,*

[2] *Electrical & Electronics Engineering, PBR Viswodaya Institute of Technology & Science,*

Abstract—Voltage flicker is considered as one of the most severe power quality problems, especially in loads like electrical arc furnaces and mush attention has been paid to it. Due to the latest achievements in the semiconductors industry and consequently the emergence of the compensators based on voltage source converters, FACTS devices has been gradually noticed to be used for voltage flicker compensation. This paper covers the contrasting approaches; dealing with the voltage flicker mitigation in three stages and assessing the related results in details. Initially, the voltage flicker mitigation using FCTCR (Fixed Capacitor Thyristor Controlled Reactor) was simulated. Secondly, the compensation for the static synchronous compensator (STATCOM) has been performed. In this case, injection of Harmonics into the system caused some problems which were later overcome by using 12-pulse assignment of STATCOM and RLC filters. The obtained results show that STATCOM is very efficient and effective for the flicker compensation.

Index Terms— Power Quality, Voltage Flicker, Static Synchronous Compensator (STATCOM)

I. INTRODUCTION

Power quality is the combination of voltage quality and current quality, thus power quality is concerned with deviations of voltage and or current from ideal. Power quality (PQ) related issues are of most concern nowadays. The widespread use of electronic equipment and Electrical equipment susceptible to power quality or more appropriately to lack of power quality [2] would fall within a seemingly boundless domain. All electrical devices are prone to failure or malfunction when exposed to one or more power quality problems. The electrical device might be an electric motor, a transformer, a generator, a computer, a printer, communication equipment, or a household appliance.

The relationship between power quality and distribution system has been a subject of interest for several years. The concept of power quality describes the quality of the supplier voltage in relation to the transient breaks, falling voltage, harmonics and voltage flicker. Voltage Flicker [1] is the disturbance of lightning induced by voltage fluctuations. Very small variations are enough to induce lightning disturbance for human eye for a standard 230V, 60W coiled-coil filament lamp. The disturbance becomes perceptible for voltage variation frequency of 10 Hz and relative magnitude of 0.26%. Huge non-linear industrial loads such as the electrical arc furnaces [9], pumps, welding machines, rolling mills and others are known as flicker generators.In this respect, the quality of supplied voltage is significantly reduced in an electrical power system and the oscillation of supplied voltage appears to be a major problem. Voltage variation at the common point of supply to other consumers. The relative voltage drop is expressed by equation (1):

$$\frac{\Delta U}{U_n} = \frac{R\Delta P + X\Delta Q}{U_n^2}$$

Where ΔP and ΔQ are the variation in active and reactive power; U_n is the nominal voltage and R and X are short circuit resistance and reactance. Since R is usually very small in comparison to X, ΔU is proportional to Q (reactive power).Therefore, voltage flicker mitigation depends on reactive

Volume 02, Issue 07, [July– 2015] ISSN (Online):2349–9745 ; ISSN (Print):2393-8161

power control. Two types of structures can be used for the compensation of the reactive power fluctuations that cause the voltage drop: A: shunt structure [7]: in this type of compensation, the reactive power consumed by the compensator is kept constant at a sufficient value.B: series structure: in this type, all the efforts are done to decrease the voltage drop mentioned above, and finally the reactive power is kept constant despite the load fluctuations by controlling the line reactance.

In addition to the aforesaid procedures for the compensators, the active filters are used for the

Voltage flickers mitigation as well. Furthermore, the mitigating devices based on Static VAR Compensator (SVC) such as Static Synchronous Compensator (STATCOM) is the most frequently used devices for reduction in the voltage flickering. SVC devices achieved an acceptable level of mitigation, but because of their complicated control algorithms, they have problems such as injecting a large amount of current harmonics to the system and causing spikes in voltage waveforms.

A new technique based on a novel control algorithm, which extracts the voltage disturbance to suppress the voltage flicker as well as Total Harmonic Distortion, is presented in this paper. The technique is to use STATCOM [8] along with a harmonic filter for voltage flicker compensation as well as harmonic distortion to overcome the aforementioned problems related to other techniques. The concept of instantaneous reactive power components is used in the controlling system.

A two-bus system is exploited to fulfill the investigation of the presented procedure. All the simulations are done according to the usage of MATLAB software. The related compensation was performed first by 6-pulse VSC STATCOM [8]. Afterwards, a 12-pulse voltage-source converter STATCOM [8] was used to compensate for the voltage flicker. With respect to the harmonic problem in this stage, a 12-pulse voltage-source converter STATCOM along with a Harmonic filter was designed to isolate load harmonics and mitigate the propagation of voltage flicker to the system in the next stage. The obtained results clearly confirmed the efficiency of the 12-pulse STATCOM to complete the voltage flicker mitigation and the harmonic filter reduces the total harmonic distortion at minimum possible value.

II. CONTROLLING SYSTEM

The concept of instantaneous reactive power is used for the controlling system. Following this, the 3-phase voltage upon the use of the park presented by Akagi has been transformed to the synchronous reference frame (Park or dq0 transformation). This transformation leads to the appearances of three instantaneous space vectors: V_d on the d-axis (real or direct axis), V_q on the q-axis (imaginary or quadrature axis) and V0, from the 3-phase voltage of V_a, V_b and V_c. The related equations of this transformation, expressed in the MATLAB software, are as follows:

$$V_d = \frac{2}{3}\left(V_a \sin(\omega t) + V_b \sin\left(\omega t - \frac{2\pi}{3}\right) + V_C \sin(\omega t + \frac{2\pi}{3})\right) \quad (2)$$

$$V_q = \frac{2}{3}\left(V_a \cos(\omega t) + V_b \cos\left(\omega t - \frac{2\pi}{3}\right) + V_c \cos(\omega t + \frac{2\pi}{3})\right) \quad (3)$$

$$V_0 = \frac{1}{3}(V_a + V_b + V_c) \quad (4)$$

A dynamic computation shows that the voltage oscillations in the connecting node of the flicker generating load to the network are created by 3 vectors: real current (i_p), imaginary current (i_q) and the derivative of the real current with respect to time di_p/dt. In general, for the complete voltage flicker compensation, the compensating current (i_p) regarding the currents converted to the dq0 axis is given as [3]:

$$i_c = j(i_q + i_p \frac{R}{X} f + \frac{1}{\omega}\frac{di_p}{d\omega} f + k) \quad (5)$$

Where R and X are the synchronous resistance and reactance of the line and f is the correcting coefficient. The constant k is also used to eliminate the average reactive power of the network [3]. If the compensation current of the above equation is injected to the network, the whole voltage flicker existing in the network will be eliminated. Regarding the equation ,related to the dq-transformation of the 3-phase-voltages to the instantaneous vectors, it is obvious that under the conditions of accessing an average voltage flicker, V_d and V_0, the obtained values are close to zero and V_q is a proper value adapting to the voltage oscillation of the network.

III. COMPENSATIG SYSTEM

In this project a two bus system is considered to investigate the voltage flicker compensation using STATCOM. This configuration block diagram is illustrated in fig:1 which consists of 3Ø programmable voltage source and STATCOM [1]. The voltage oscillation is produced by the programmable voltage source which is connected to the main bus-bar, by specifying the amplitude of modulation the signal increments and decrements with respect to unit value.
Two 6-pulse bridges are connected in parallel, forming a 12-pulse converter for a complete voltage Flicker compensation design. In this case, the first converter is connected with a wye-wye transformer and the second one with a wye-delta transformer. These are linked together using a three winding transformer. Moreover, the delta-connected secondary of the second transformer must have √3times the turns compared to the wye-connected secondary and the pulse train to one converter is shifted by 30 degrees with respect to the other.
Three-phase harmonic filters are shunt elements that are used in power systems for decreasing voltage distortion. Nonlinear elements such as power electronic converters generate harmonic currents or harmonic voltages, which are injected into power system. The resulting distorted currents flowing through system impedance produce harmonic voltage distortion. Harmonic filters [8] reduce distortion by diverting harmonic currents in low impedance paths. Harmonic filters are designed to be capacitive at fundamental frequency, so that they are also used for producing reactive power required by converters and for power factor correction.

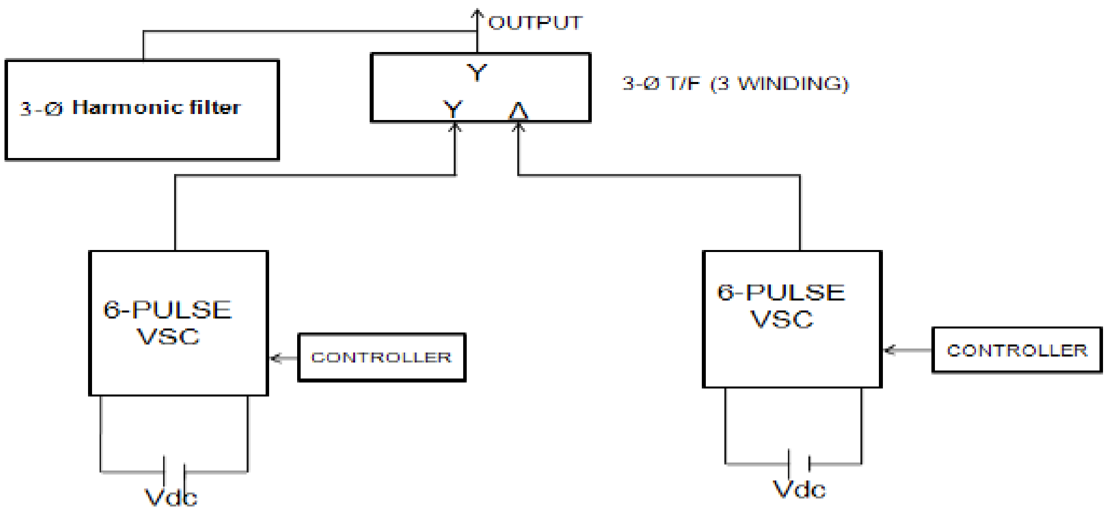


Figure 1. Block diagram of 12-pulse voltage source converter STATCOM with harmonic filter

IV. RESULTS AND ANALYSIS

In order to investigate the influence of the STATCOM as an effective mitigating device for voltage flicker, three types of compensators are simulated in MATLAB.

4.1. Compensating using FCTCR

The simulation circuit is shown in the Fig 2 . The output voltage waveform shown in the Fig 3 controlled by FCTCR that this technique achieves a reasonable level of mitigation but is incapable to be perfectly successful. Furthermore, in spite of using snubber circuit to eliminate voltage spikes caused by the huge TCR reactor switching, there are still distortions in the output waveform.

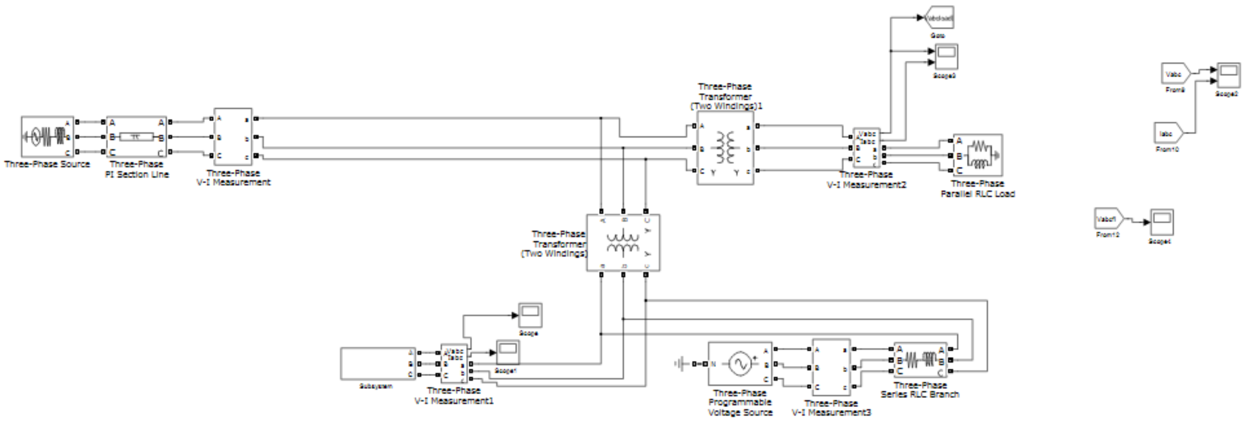


Figure 2. Simulink diagram for Compensation using FCTCR

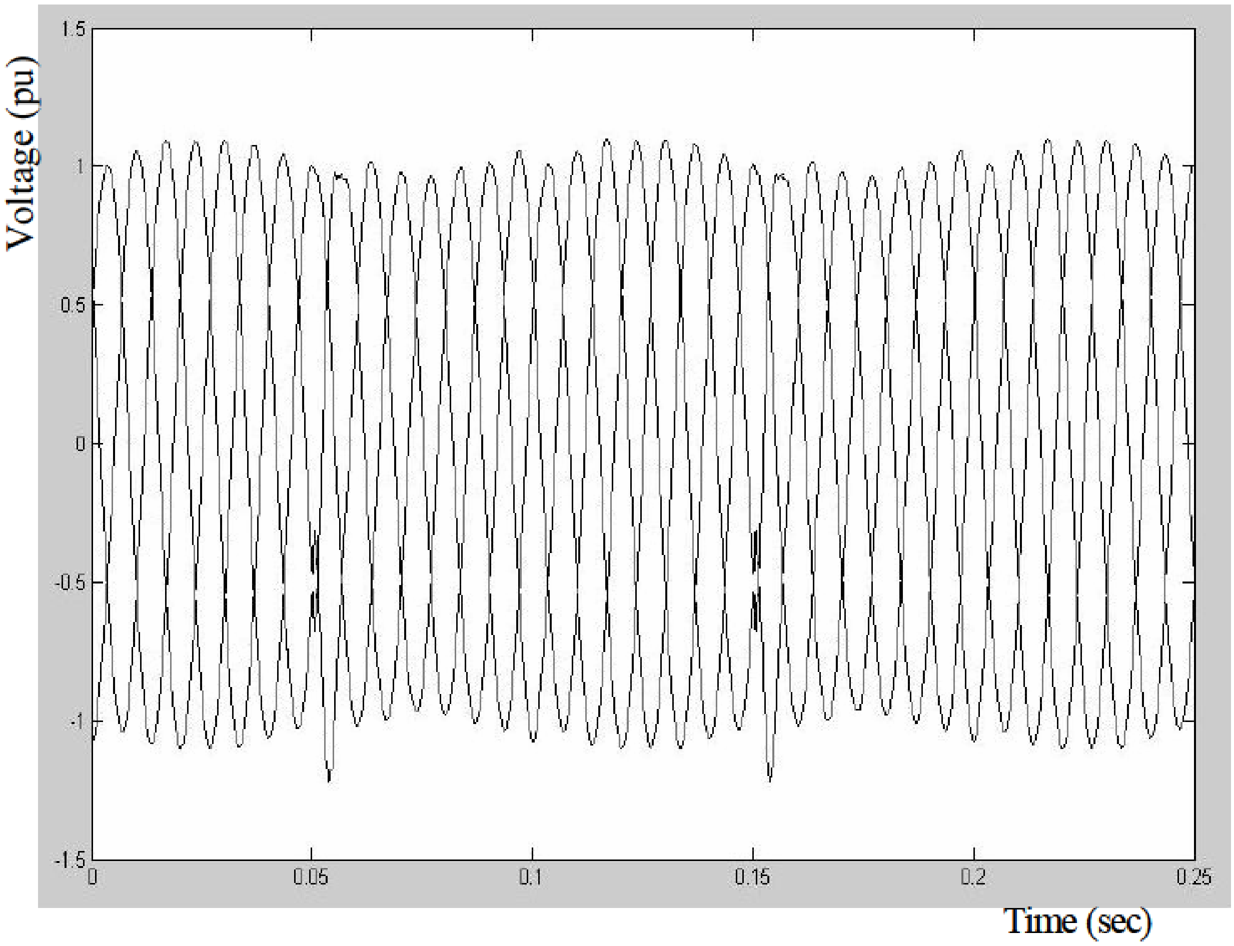


Figure 3. Output waveform for Compensation using FCTCR

4.2. Compensating using 6-pulse voltage source converter STATCOM

The Simulink model of a three-phase 6-pulse voltage source converter STATCOM is shown in fig 4. Six valves compose the converter and each valve is made up of a GTO with a diode connected antiparallel. In this type of STATCOM, each GTO is fired and blocked one time per line voltage cycle. In this case, each GTO in a single branch is conducted during a half-cycle (180 degree) of the fundamental period. The combined pulses of each leg have a 120 degrees phase difference to produce a balanced set of voltages. By adjusting the conducting angle of the GTOs, the generated voltage and then the injected or absorbed power of the STATCOM are controlled. In this respect, the compensated output voltage by 6-pulse voltage-source converter STATCOM is presented in fig 5.

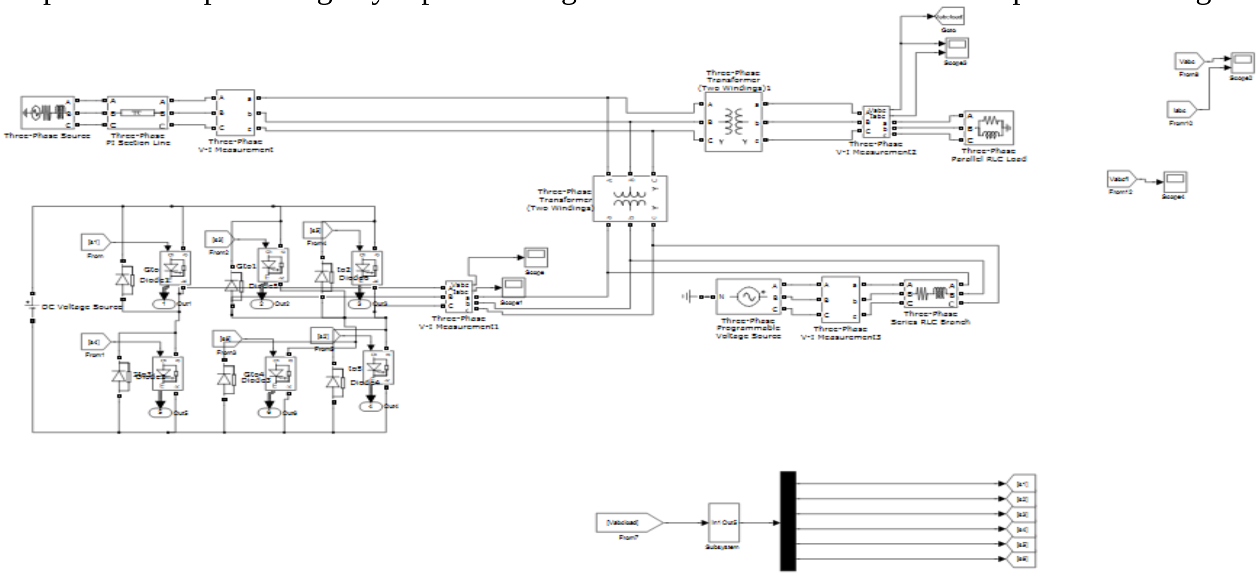


Figure 4. Simulink diagram for Compensation using 6-pulse voltage-source converter STATCOM

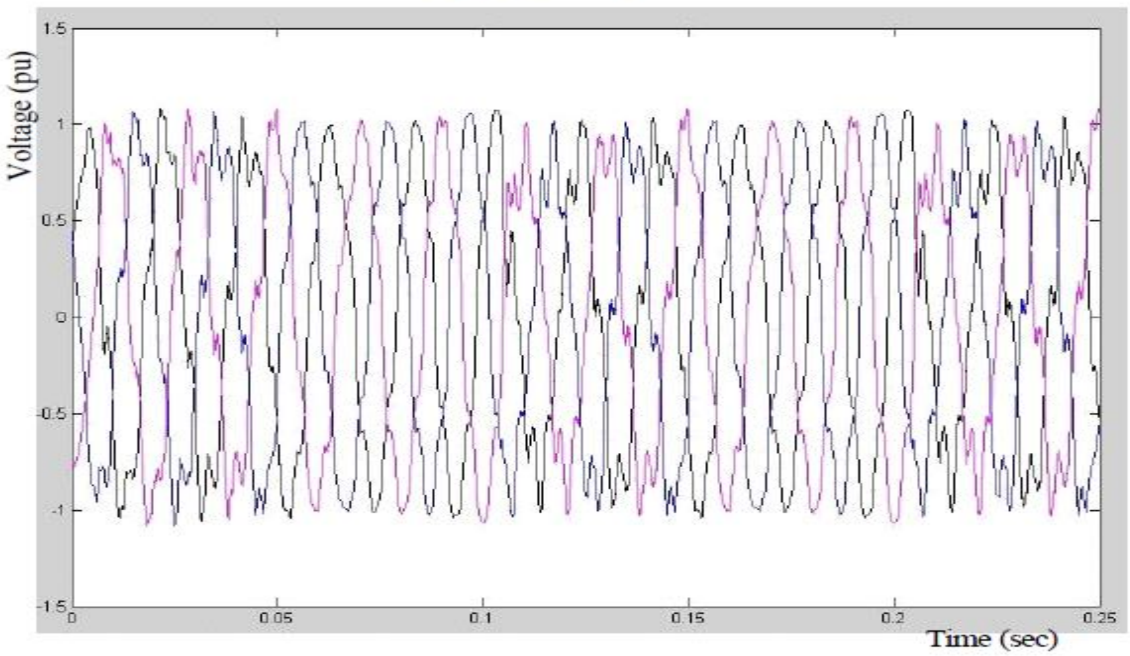


Figure 5. Output waveform for Compensation using 6-pulse voltage-source converter STATCOM

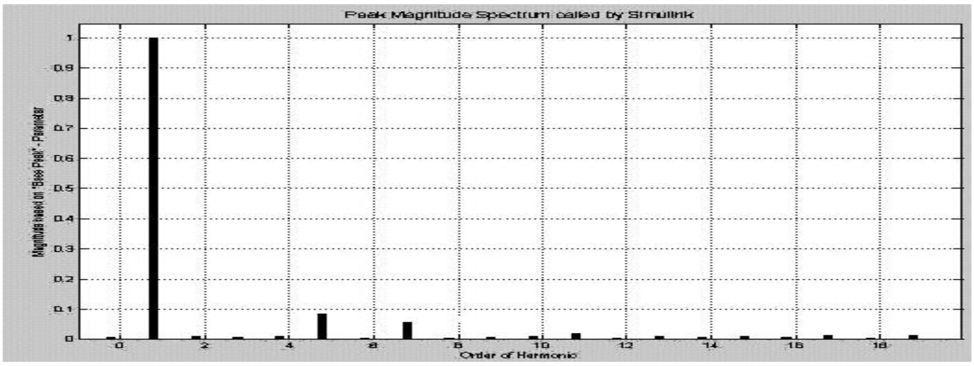


Figure 8 . The Harmonic spectrum of the compensated output voltage using 6-pulse voltage-source converter STATCOM

It can be seen that the mitigation effects of this compensator is better than that of FCTCR and effectively mitigate the voltage flicker, but the output waveforms some considerable harmonics, that can be eliminated using 12-pulse voltage-source converter STATCOM.

3.3. Compensating using 12-pulse voltage source converter STATCOM

In order to reduce the harmonic contents at the output voltage, the number of pulses can be increased, forming a multi-pulse configuration. Multi-pulse converters are composed by n, where n is the number of pulse bridges connected in parallel on the same DC bus and interconnected in series through transformers on the AC side. Depending on the number of pulses, these transformers and their configurations can be become very complex

Two 6-pulse bridges are connected, forming a 12-pulse converter for complete voltage flicker compensation design. In this case, the first converter is connected with Y-Y transformer and the second one with Y-delta transformer. Moreover, the delta connected secondary of the second transformer must have √3 times the turns compared to the Y-connected secondary and the pulse train to one converter is shifted by 30 degrees with respect to the other. The 12-pulse voltage-source converter STATCOM circuit diagram is shown in fig:6

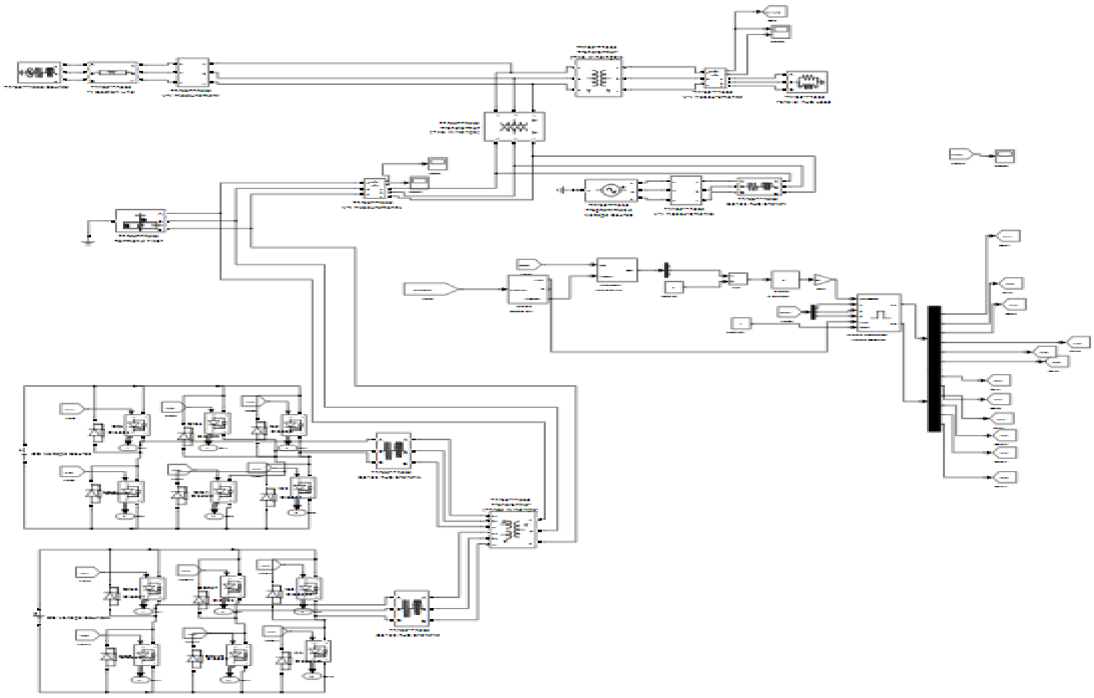


Figure 6. Simulink diagram for Compensation using 12-pulse voltage-source converter STATCOM

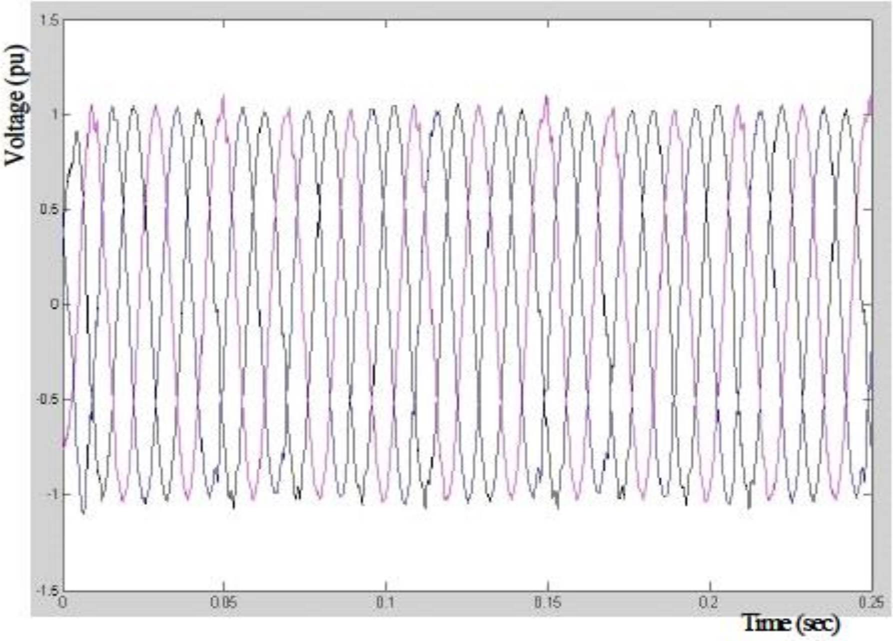
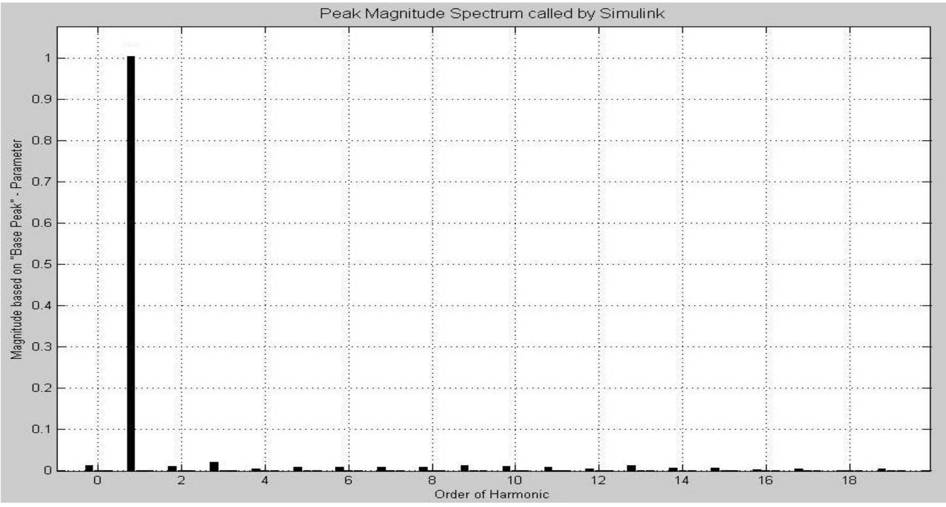


Figure 7. Output waveform for Compensation using 6-pulse voltage-source converter STATCOM



Figur9 . The Harmonic spectrum of the compensated output voltage using 6-pulse voltage-source converter *STATCOM*

V. CONCLUSION

The design and application of STATCOM technology based on voltage-source converters for voltage flicker mitigation is discussed in this paper. Mitigation is done in three stages and the results are compared and contrasted. First, FCTCR is used to compensate for the voltage flicker, then a 6-pulse voltage-source converter STATCOM and finally a 12-pulse STATCOM based on voltage-source converter equipped with an RLC filter are designed for complete voltage flicker compensation without harmonics.

All the simulated results which have been performed in MATLAB show that a 6-pulse STATCOM is efficiently effective in decreasing the voltage flicker of the generating loads. However, there is injection of the harmonic from STATCOM into the system which can be improved with the increase of the voltage source converters of STATCOM using a 12-pulse STATCOM equipped with an RLC filter. The obtained results clearly demonstrate that 12-pulse STATCOM equipped with an RLC filter can reduce the voltage flickercaused by nonlinear loads such as electric arc furnaces.

REFERENCES

[1] T. Larsson, C. Poumarede, "STATCOM, an efficient means for flicker mitigation" IEEE Power Engineering Society Winter Meeting, Vol.2, (Jan-4Feb 1999), pp. 1208-1213.

[2] R. Mienski, R. Pawelek, I. Wasiak "Shunt Compensation for Power Quality Improvement using a STATCOM controller: Modelling and simulation", IEE Proc.-Gener. Transm. Distrib. No.2, Vol.151, (2004), pp. 274-280.

[3] Z. Zhang, N. R. Fahmi, W. T. Norris, "Flicker Analysis and Methods for Electric Arc Furnace Flicker (EAF) Mitigation (A Survey)", IEEE Power Tech Proceedings, Vol.1, (10-13 Sept. 2001).

[4] Y. Hamachi, M. Takeda, "Voltage Fluctuation Suppressing System Using Thyristor Controlled Capacitors", 8^{th} U.I.E.Congress, (1976).

[5] C. S. Chen, H. J. Chuang, C. T. Hsu, S. M. Tscng, "StochasticVoltage Flicker Analysis and Its Mitigation for Steel Industrial PowerSystems", IEEE Power Tech Proceedings, Vol.1, (10-13 Sept. 2001).

[6] J. Dolezal, A. G. Castillo, V. Valouch, "Topologies and control of active filters for flicker compensation", International Symposium on Industrial Electronics, IEEE Proceedings, Vol.1, (4-8 Dec, 2000), pp. 90-95.

[7] L. Gyugi, A. A. Otto, "Static Shunt Compensation for Voltage Flicker Reduction and Power Factor Correction", American Power Conference (1976), pp. 1272-1286.

[8] Mahamood joorabian, Davar Mirabbasi, Alireza Sina, "Voltage Flicker Compensation using STATCOM" IEEE proceedings, 2009.

[9] Le Tang, Sharma Kolluri, Mark F.McGranaghan, "Voltage flicker prediction for two simultaneously operated ac arc furnaces", IEEE Transactions on Power Delivery, Vol. 12, No. 2, April 1997.

[10] R.C. Seebald, 9.F. Buch, and D.J. Ward, "Flicker Limitations of Electric Utilities, "IEEE Transactions on PowerApparatus and Systems, Vol. PAS-104, No. 9, September 1985.