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Mitigation of Voltage Flicker and Reduction in THD by using STATCOM

S. Chandrasekhar*, J. Brahmmam, M. Srinu***
* Departement of Electrical and Electronics Engineering,Anurag Engineering College, AP, INDIA
** Departement of Electrical and Electronics Engineering,Anurag Engineering College

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ABSTRACT

Voltage flicker is considered as one of the most severe power quality problems (especially in loads like electrical arc furnaces) and much attention has been paid to it lately. Due to the latest achievements in the semiconductors industry and consequently the emergence of the compensators based on voltage source converters, FACTS devices have 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 reduction in total harmonic distortion 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 six-pulse as well as 12-pulse 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 SATCOM and RLC filter (three phase harmonic filter). The obtained results show that STATCOM is very efficient and effective for the flicker compensation as well as harmonic sprectrum. All the simulations have been performed on the MATLAB Software.

Corresponding Author:

M.Srinu,
Departement of Electrical and Electronics Engineering,
Anurag Engineering college,
Kodad, AndhraPradesh, India.
Email: srinumudusu@gmail.com

1. 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 appropriatelyto 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 ormore power quality problems. The electrical device might be an electric motor, atransformer, a generator, a computer, a printer, communication equipment, or ahousehold 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 voltagevariation 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.Voltagevariation at the common point ofsupply to otherconsumers. The relative voltage drop is expressed by equation(1):

$$\frac{\Delta U}{U_n} = \frac{R\Delta P + X\Delta Q}{U_n^2} \quad (1)$$

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

Two types of structures can be used for the compensationof 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 mitigatingdevices based on Static VAR Compensator (SVC) such as Static Synchronous Compensator (STATCOM) is the most frequentlyused devices for reduction in the voltage flickering.SVCdevices achieved an acceptable level of mitigation, butbecause of their complicated control algorithms, they haveproblems such as injecting a large amount of currentharmonics to the system and causing spikes in voltagewaveforms.

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.

2. COMPENSATION

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 $\sqrt{3}$times 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.

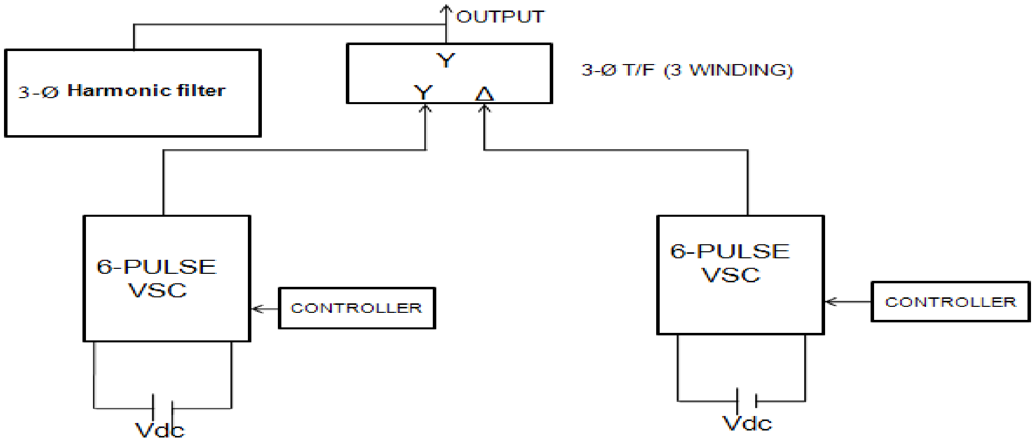

Figure 1. Block diagram of 12-pulse voltage source converter STATCOM with harmonic filter

3. 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 V_0, 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:

$$V_d = \frac{2}{3}(V_a \sin(\omega t) + V_b \sin\left(\omega t - \frac{2\pi}{3}\right) + V_C \sin(\omega t + \frac{2\pi}{3})) \quad (2)$$
$$V_q = \frac{2}{3}(V_a \cos(\omega t) + V_b \cos\left(\omega t - \frac{2\pi}{3}\right) + V_c \cos(\omega t + \frac{2\pi}{3})) \quad (3)$$
$$V_0 = \frac{1}{3}(V_a + V_b + V_c) \quad (4)$$

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 equationis injected to the network, the whole voltage flicker existing inthe network will be eliminated. Regarding the equation,related to the dq-transformation of the 3-phase-voltages to theinstantaneous vectors, it is obvious that under the conditions ofaccessing an average voltage flicker, V_d and V_0, the obtainedvalues are close to zero and V_q is a proper value adapting tothe voltage oscillation of the network.

4. RESULTS AND ANALYSIS

In this project 69kv 3Ø voltage source, 100 km 3-Ø∏section power system line are used and are connected to the step-down 3Ø transformer, which supplies a 3Ø parallel RL load. 3Ø programmable Voltage source is used to produce voltage flicker or voltage fluctuation into the system. Block parameters of 3Ø programmable voltage source are as follows, amplitude of modulation is 0.3 pu, frequency of the modulation is 10 HZ, Variation timing is 0 to 0.4 sec. with these specified parameter values, the variation in the output load voltage is shown in the Fig. 4 SIMULINK diagram of a two bus power system without STATCOM is shown in the Fig. 3.

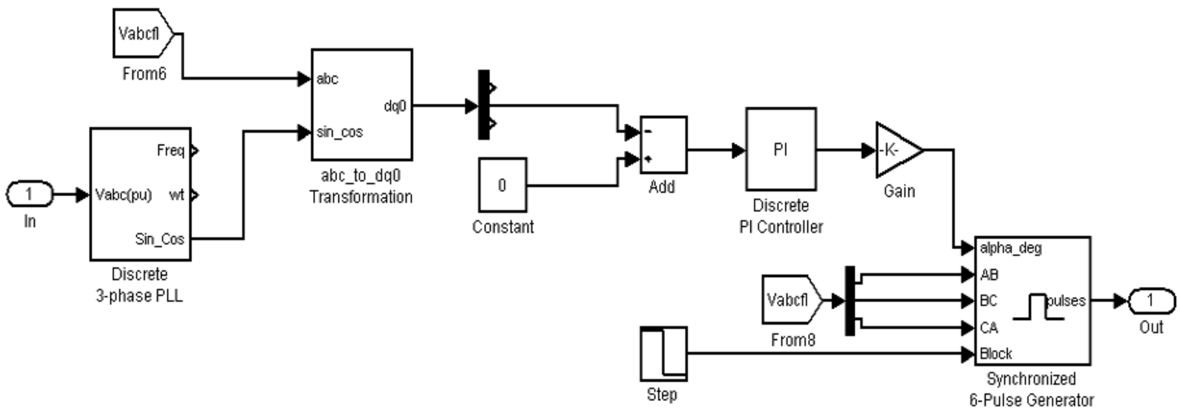

Figure 2. Control circuit

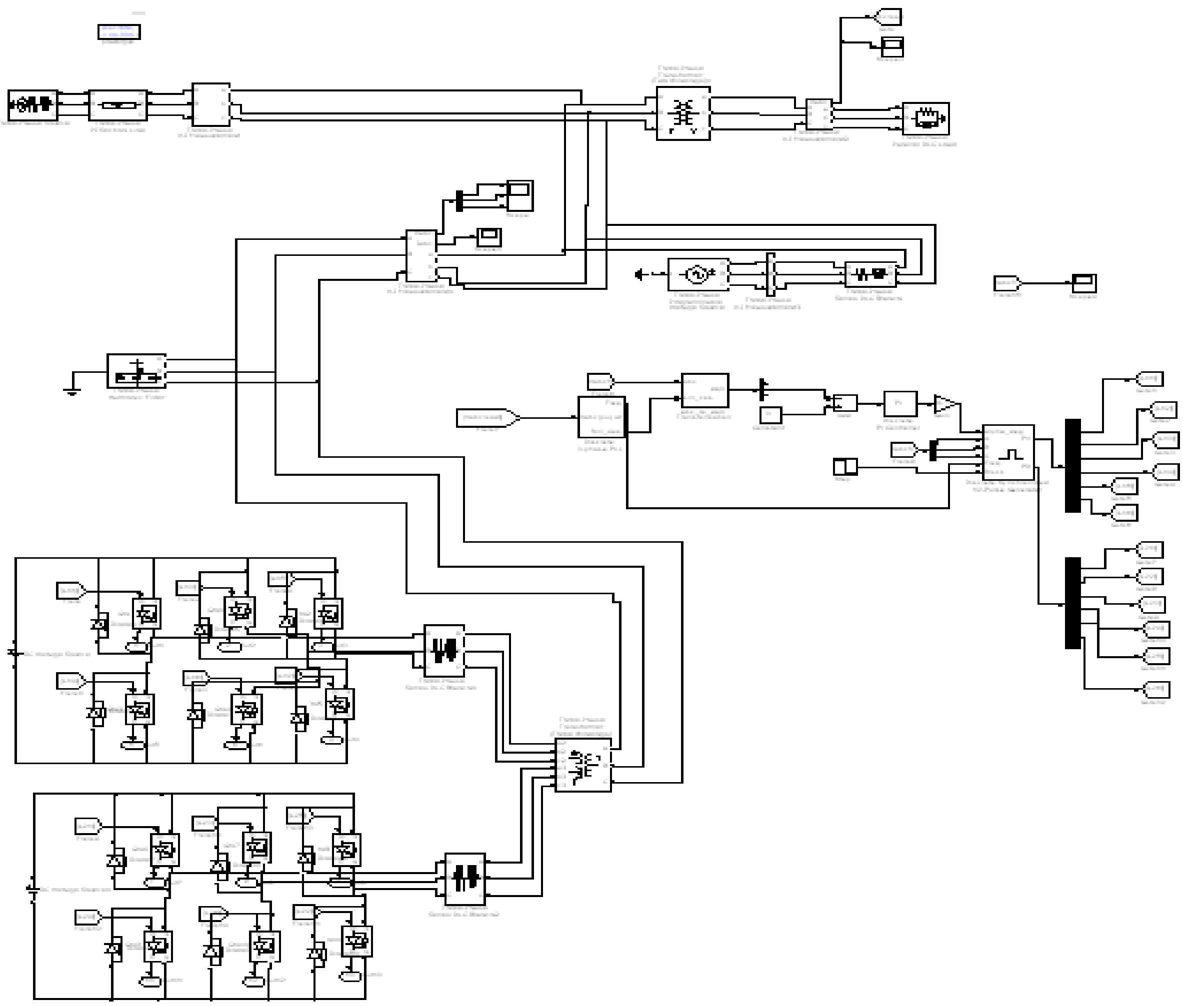

Figure 3. SIMULINK diagram of 12 pulse Voltage source converter STATCOM with
3Ø harmonic filterconnected to the power system.

To eliminate lowest order harmonics such as 11th and 13th harmonic, double tuned band pass filter is connected across the 12 pulse voltage source converter output.Fig 4 shows SIMULINK diagram of 12 pulse voltage source converters STATCOM with 3Ø harmonic filter connected to the power system.The output load voltage mitigated by 12-pulse voltage-source converter STATCOM with 3Ø harmonic filter and its harmonic spectrum is shown in figures 4 and 5 respectively. In this respect, the voltage flicker is completely removed from the output load voltage and a sinusoidal waveform is obtained. It can be observed from the harmonic spectrum that THD is 2.30%.

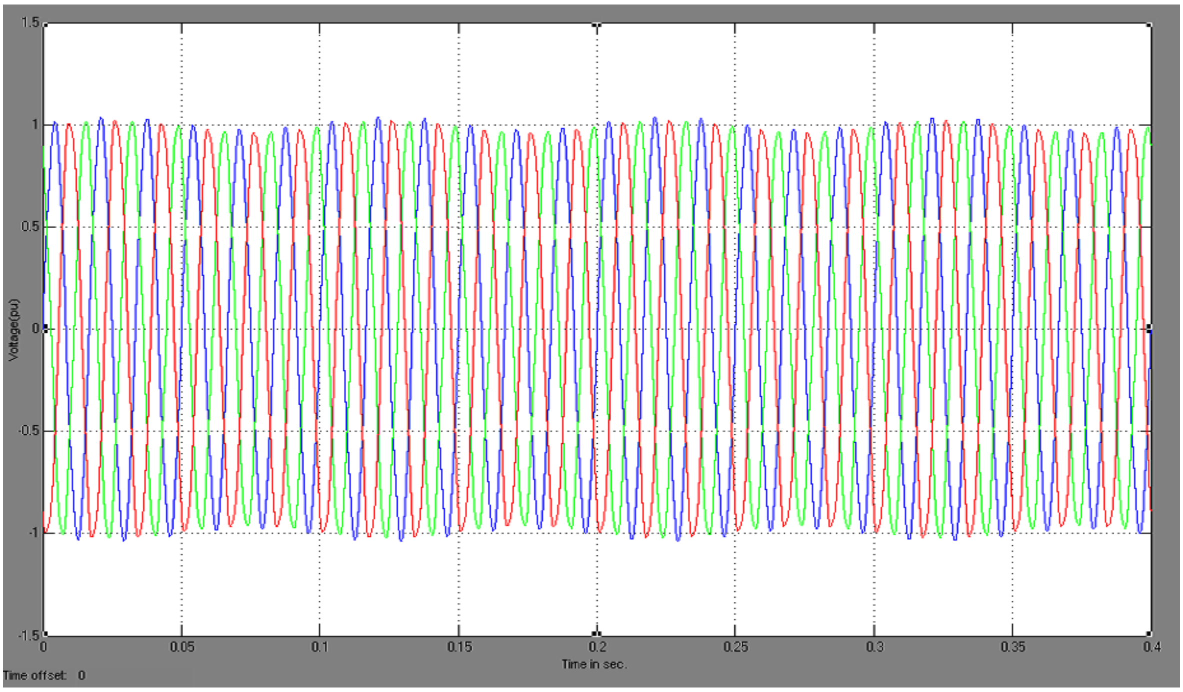

Figure 4. Output load voltage mitigated by 12-pulse voltage source converter STATCOMwith 3Ø harmonic filter

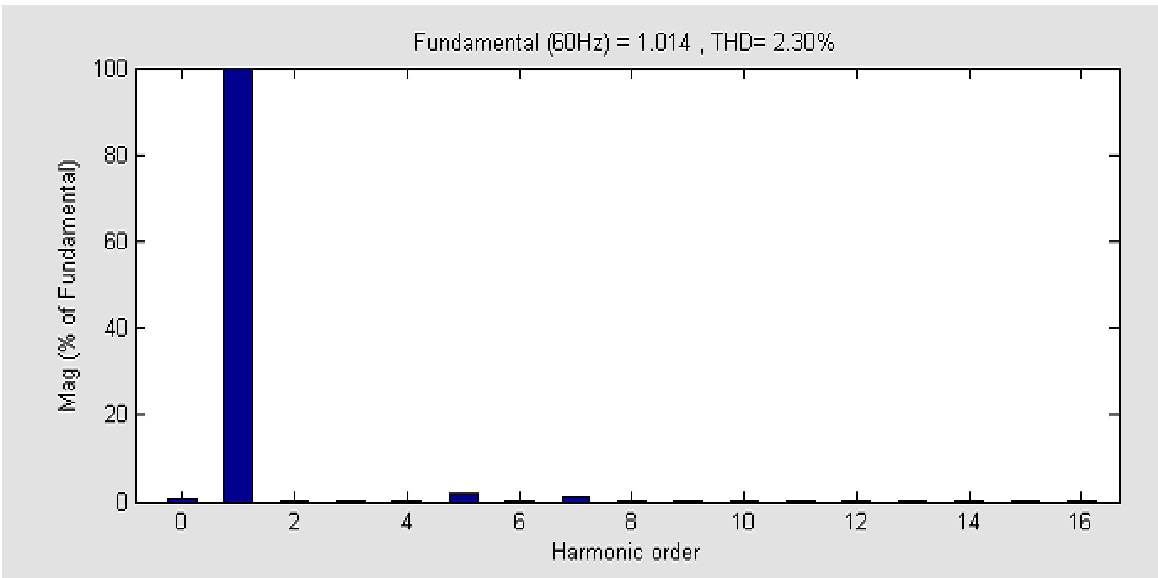

Figure 5. Harmonic spectrum of the output load voltage mitigated by 12-pulse voltage-sourceconverter STATCOM equipped with a harmonic filter.

Voltage flicker mitigation using 6 pulse voltage source converter STATCOM, 12 pulse voltage source converter STATCOM, and 12 pulse VSC STATCOM with 3Ø harmonic filter are simulated. The output load voltage without STATCOM and with STATCOM is obtained and compared.

The results obtained are as follows:

I. Without STATCOM:

The output load voltage is 1.3 Pu (maximum value).The voltage flicker existing in the output load voltage (exerted to the system) is 0.3 Pu (30%).

II. WithSTATCOM:

Table 1. Comparison of voltage flicker mitigation and THD value of STATCOM compensators.

Compensator	Compensated output load voltage (maximum value)	Voltage Flicker	THD
6 pulse VSC STATCOM	1.15 pu	Existing is 0.15 pu (15%) (or) Mitigated by 50%	8.95%
12 pulse VSC STATCOM	1.0 pu	Completely mitigated	4.47%
12 pulse VSC STATCOM with 3Ø harmonic filter	1.0 pu	Completely mitigated	2.30%

5. CONCLUSION

In this thesis, theapplication of STATCOM technology based on voltage-source converters for voltage flickermitigation has been investigated and simulation results emphasized its significant effect. A 6-pulseSTATCOM is decreasing the voltage flicker by 50%. However, there is injection of the harmonic from 6-pulseSTATCOM into the system which can be improved with theincrease of the voltage source converters of STATCOM using a 12-pulse STATCOM equipped with a harmonic filter. The obtained results clearly demonstrate that 12-pulse STATCOM equipped with a harmonic filter can reduce the voltage flicker completely and the output is obtainedwith minimum THD Value.

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", *8th 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 Power Apparatus and Systems,* Vol. PAS-104, No. 9, September 1985.

BIOGRAPHIES OF AUTHORS

Mr. S. Chandrasekhar was born in 1978. He received his M.Tech (High Voltage Engineering) degree in Electrical and Electronics Engineering from Jawaharlal Nehru Technological University, Kakinada. Presently he is working as assistant professor in Anurag engineering college, Kodad. He is guiding both undergraduate and post graduate student projects. His area of interest includes High voltage transmission, Power Electronics and Drives.
E-mail: hod.eee@anurag.ac.in

Mr. J. Brahmmam was born in 1986. He is persuing his M.Tech in Power electronics and electrical drives in Anurag Engineering College, Kodad. Received Bachelor degree in Electrical and Electronics Engineering from Jawaharlal Nehru Technological University, Hyderabad. His area of interest includes Power Electronics and Drives, power systems.
E-mail: brahma550@gmail.com

Mr. M. Srinu was born in 1983. He received his M.Tech (Power and Industrial Drives) degree in Electrical and Electronics Engineering from Jawaharlal Nehru Technological University, Kakinada. Presently he is working as assistant professor in Anurag engineering college, Kodad. He is guiding both undergraduate and post graduate student projects. His area of interest includes Power Electronics and Drives, Control systems.
E-mail: srinumudusu@gmail.com