Electric Arc Furnace Voltage flicker alleviation by Unified Power Quality Conditioner using PSCAD/EMTDC

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Abstract— **Electric Arc furnaces (EAF) are intensive distressing, unbalanced, stochastic, time varying, non-linear loads which are used in steel industry. Their non linearity and dynamic characteristics produce harmonic problems and fluctuation of voltage. Advanced control strategy based Custom Power Device such as Unified Power Quality Conditioner (UPQC) is designed to provide significant reduction in voltage flicker on the power system. Moreover, to estimate the severity of fluctuations, IEC flicker meter is simulated. The modeling and simulation of the UPQC has been demonstrated using the electromagnetic transient simulation program PSCAD/EMTDC.**

I.INTRODUCTION

The voltage fluctuations in the electrical networks is mainly caused by the electric arc furnace used in production of steel which leads to the flicker effect [1].

Due to random arc length variations during scrap drilling, melting and reheating gives the voltage fluctuations in the frequency range 0.5-35 Hz [2].

SVC comprises both Thyristor controlled Reactor (TCR) and Thyristor Switched Capacitor (TSC). TCR absorbs the reactive power thereby reducing the voltage for maintaining the appropriate value if the applied load is capacitive in nature. TSC injects the reactive power thereby increasing the voltage for maintaining the required voltage if the applied load is inductive in nature. But disadvantage of this device which cannot capture the fast varying voltage flicker and less response time [7]-[9].

DSTATCOM is a parallel connected, Custom Power Device which minimizes the voltage flicker due to induction furnace. DSTATCOM controls the reactive-power flow by either injecting or absorbing it from the electric line.[10]-[12].

UPQC can have the capability to inject current in parallel and voltage in series in a dual control mode. UPQC control provides improved performance for mitigating voltage flicker due to Arc Furnace operation. Particularly, the contributions of this paper are:

i) To model the voltage flicker due to the availability of EAF
ii) To design the UPQC control
iii) To alleviate voltage flicker by the application of UPQC

II.SYSTEM CONFIGURATION

A. Mitigating device structure

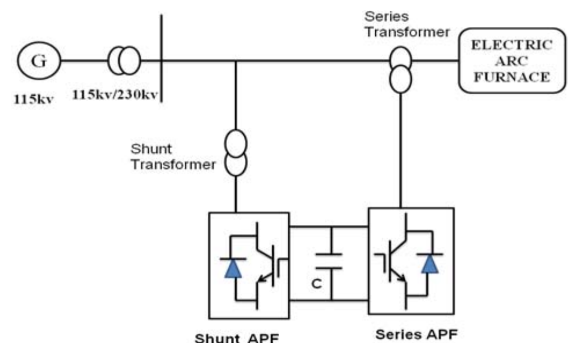

Fig.1. Schematic diagram of EAF using UPQC

Fig.1. shows the Schematic diagram of the electrical distribution system connected with an Electric Arc furnace. The test system has a 115-kV generator and an impedance connected at th PCC (Point of Common Coupling) through step up transformer (115/230KV). The Custom Power Device (CPD) is the UPQC which is connected to the system to alleviate the power quality disturbances. The electrical arc furnace load is not sinusoidal and fluctuating in nature.

B. Nonlinear, time varying arc model

Electric arc furnaces are used in melting the steel and it induces random harmonic currents. An aperiodic waveform is generated to produce the variations to the RMS waveform by

$$R(t) = R_O + a_L \cos(\omega_L t + \theta_L) + a_H \cos(\omega_H t + \theta_H)\ \Omega$$

Where ω_L and ω_H are randomly generated frequencies in the range of concern and a_L and a_H are the positive scalars which are generated randomly.

$\omega_L = 2\pi(1 + \rho 8)$ where $\rho \in [0,1]$ is a random number
$\omega_H = 2\pi(10 + \rho 30)$
a_L=50ρ

α_H=10ρ
R_O=130Ω (phase a, b), R_O=80Ω (phase c)
:

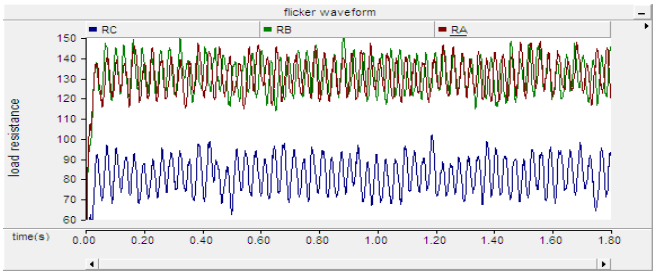

Fig.2. Flicker Waveform

III.Control Strategies

The control scheme of UPQC consists of Shunt Active Power filter and Series Active Power Filter controllers. The required gate signal is generated by comparing these signals in the PWM controller [14].
The required gate signals for IGBT switches are generated by comparing the obtained error signals with the hysteresis controller.

A .Control Algorithms for SHUNT APF of UPQC

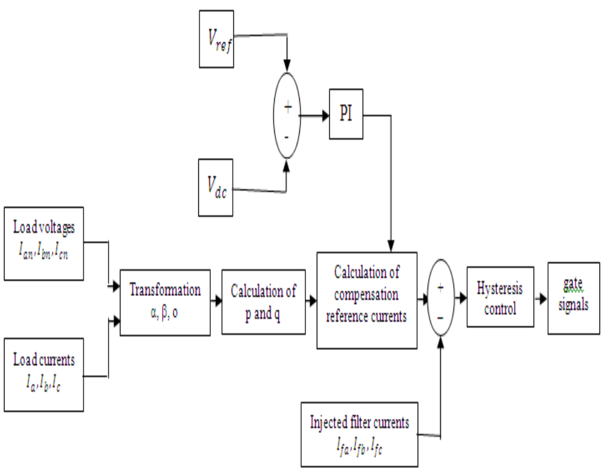

Fig.3. Control system of shunt APF

The reference currents (Ia, Ib and Ic) are the outputs of the control system.

B.Control Algorithms for SERIES APF of UPQC

The PI controller needs two proportional and integral gains for optimal results if the operating point changes.

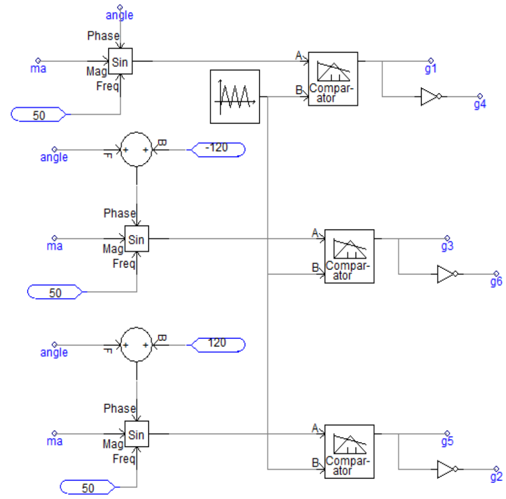

Fig.4.Controller diagram for the Series APF

It can be seen in Fig.4. that the control implementation is kept very simple in the control scheme using voltage only as the feedback variable.

B.The IEC Flicker measurement method

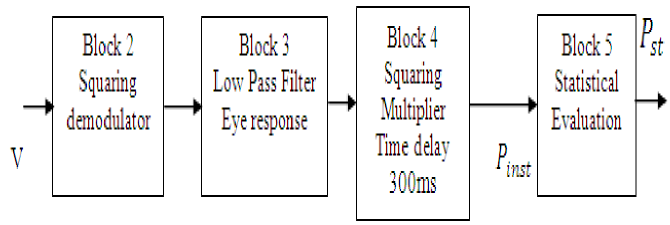

Fig.5.Block diagram of flicker meter

The block diagram of the flicker meter specified is seen in Fig.5. To measure flicker, a flicker meter is used. This is modeled in PSCAD.

IV.Results and Discussion

The Performances of the UPQC control has been analyzed and evaluated by using several quantitative assessments. Their performances are evaluated in i) balancing of voltage between phases ii) Maintaining the RMS voltage iii) Voltage flicker mitigation iv) Total Harmonic Distortion (THD) reduction.

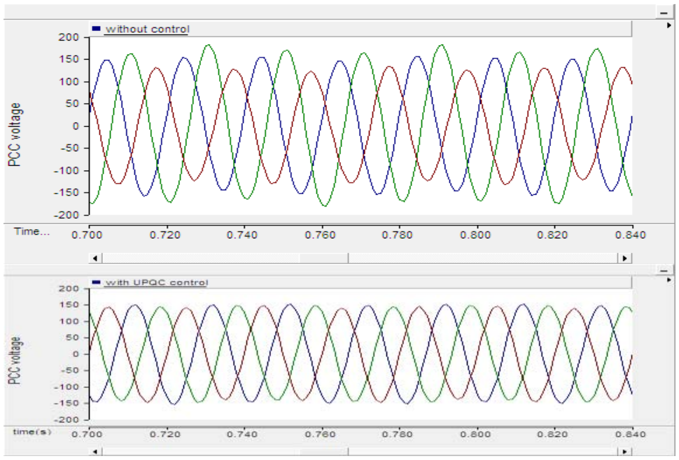

Fig.7. ThreePhase voltages at PCC without and with UPQC control

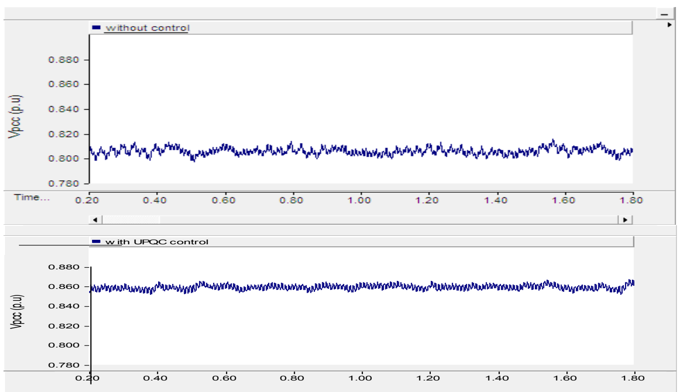

Fig.8.Voltage (RMS) at PCC without amd with UPQC control

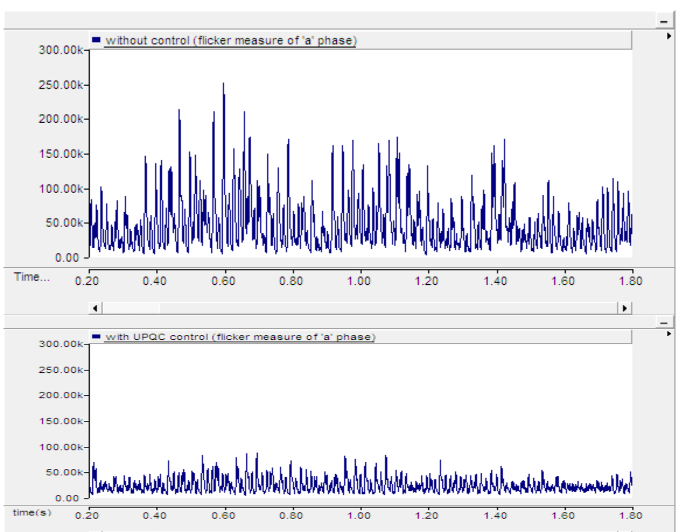

Fig.9.Flicker measure at PCC without and with UPQC

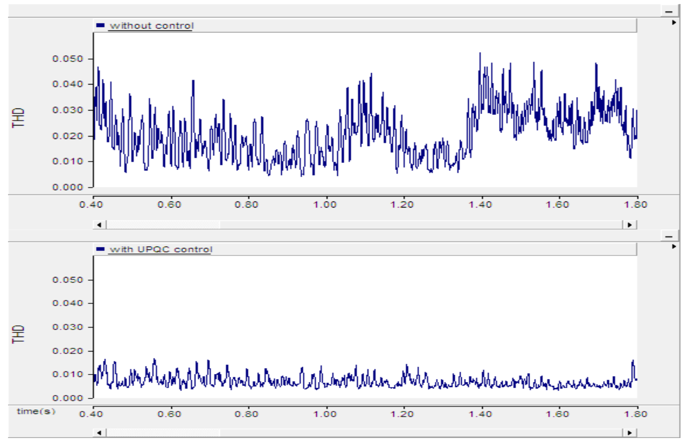

Fig.10. Voltage THD at PCC without and with UPQC

A. Voltage Balancing

Fig. 7 shows the three phase voltage waveform in which the magnitude of the voltages are not equal due to presence of EAF load. By the application of UPQC which provides reactive power compensation and voltage controls, it effectively mitigates the imbalance in voltage.

B. RMS voltage

The RMS voltage at PCC under balanced and unbalanced EAF load condition is demonstrated in Fig. 8. The UPQC control significantly improves the RMS voltage to 0.86 p.u. from 0.81 p.u

C. Flicker Measurement of PCC voltage

The Flicker measurement of voltages at PCC is seen in Fig.9. It is noted that UPQC control reduces drastically than without control.

D. Total Harmonic Distortion (THD)

The voltage THD without and with UPQC control is shown in fig.10. THD is measured by using THD module in PSCAD. THD value has been calculated for Phase ‘a’ is shown in fig.10. And rest of the phases ‘b’ and ‘c’ are similar in quality even though they are different in quantity. It is noted that UPQC control reduces the voltage THD from 3.7% to 0.9%. The maximum voltage distortion at the PCC is provided by IEEE 519 that is listed in Table [15]. The UPQC control mitigates effectively the voltage fluctuations to 0.9 % of voltage THD and lies within the IEEE 519 standard.

IV.CONCLUSION:

In this research work, the performances of Unified Power Quality Conditioner (UPQC) has been analyzed for the flicker compensation caused by Electric arc furnaces. The Arc furnace load is randomly varying and unbalanced. The UPQC control shows improved control for RMS voltage and harmonics reduction. In addition, UPQC control provides reduction of total harmonic content, flicker, and phase imbalance. The UPQC control produced enhanced results which enhances the productivity of the Electric Arc Furnace.

REFERENCES

[1] Timothy J.E.Miller.JohnWiley & Sons, Reactive power control in electric systems. Inc.1982.ISBN 0-471-86933-3.

[2] Atousa Yazdani, Mariesa L. Crow and J. Guo, "An Improved Nonlinear STATCOM Control for Electric Arc Furnace Voltage Flicker Mitigation" Institute of Electrical and Electronics Engineers transactions on power delivery, vol. 24, no. 4, pp.2284-2290, October 2009.

[3] S. M. Halpin, R. Bergeron, T. Blooming, R. Burch, L. Conrad, and T. Key, IEEE Power Engineering Society Flicker Task Force—P1453, "Voltage and lamp flicker issues: Should the IEEE adopt the IEC approach?," Institute of Electrical Electronics Engineers transactions on power delivery, vol. 18, no. 3, pp. 1088–1097, Jul.2003.

[4] Jin-Lung Guan, Jyh-Cherng Gu and Chi-Jui Wu, "A Novel Method for Estimating Voltage Flicker" Institute of Electrical Electronics Engineers transactions on power delivery, vol. 20, no. 1, pp.242-247, January 2005

[5] Amit K. Jain, Aman Behal, Ximing T. Zhang, "Nonlinear Controllers for Fast Voltage Regulation Using STATCOMs" Institute of Electrical Electronics Engineers transactions on control systems technology, vol. 12, no. 6, pp.827-842, November 2004

[6] A.Pandiyarajan, S.Latha, "Performance comparison of D-STATCOM and SVC for mitigation of voltage flicker in Electric Arc Furnace using PSCAD/EMTDC", published in springer, Power Electronics for Renewable Energy Systems,pp.163-176, ISBN:978-81-322-2118-0

[7] Tsu-Hsun Fu and Chi-Jui Wu,"Load Characteristics Analysis of ac and dc Arc Furnaces Using Various Power Definitions and Statistic Method", Institute of Electrical Electronics Engineers transactions on power delivery, vol. 17, no. 4, pp.1099-1105, october 2002.

[8] Aurelio García-Cerrada, Pablo Garcia Gonzalez, Rafael Collantes, Tomás "Comparison of Thyristor-Controlled Reactors and Voltage-Source Inverters for Compensation of Flicker Caused by Arc Furnaces" Institute of Electrical and Electronics Engineers transactions on power delivery, vol. 15, no. 4, pp.1225-1231, October 2000

[9] C. Sharmeela, G. Uma, M.R. Mohan and K.Karthikeyan, "Voltage Flicker Analysis and Mitigation- Case Study in AC Electric Arc Furnace Using PSCAD/EMTDC" " Institute of Electrical Electronics engineers International conference on industrial Technology, pp.207-212, 2004

[10] Chong Han, Zhanoning Yang, Bin Chen, Alex Q. Huang, "Evaluation of Cascade-Multilevel-Converter-Based STATCOM for Arc Furnace Flicker Mitigation" Institute of Electrical Electronics Engineers transactions on industry applications, vol. 43, no. 2, pp.378-385, March/April 2007.

[11] Olimpo Anaya-Lara and E. Acha, "Modeling and Analysis of Custom Power Systems by PSCAD/EMTDC" Institute of Electrical Electronics Engineers transactions on power delivery, vol. 17, no. 1, pp.266-272, January 2002.

[12] R. Mienski, R. Pawelek, and I. Wasiak, "Shunt compensation for power quality improvement using a STATCOM controller: Modelling and simulation," Proc. Inst. Elect. Eng., Gen. Transm. Distrib., vol. 151, no. 2, Mar. 2004.

[13] A. Elnady, W. El-khattam, and M. M. A. Salama, "Mitigation of AC Arc Furnace Voltage Flicker Using the Unified Power Quality Conditioner" Institute of Electrical Electronics engineers International conference on industrial Technology, pp.735-739, 2002

[14] Vinod Khadkikar, and Ambrish Chandra, "A Novel Structure for Three-Phase Four-Wire Distribution System Utilizing Unified Power Quality Conditioner (UPQC)" Institute of Electrical Electronics Engineers transactions on power delivery, vol. 45, no.5, pp.1897-1902, September 2009

[15] C.Sankaran, "Power Quality" CRC Press Baca Raton London New York Washington D.C.