Journal of Control Engineering and Technology (JCET)

Online Tracking and Mitigation of Voltage Flicker Using Neural Network

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Abstract-**This paper proposes an on-line neural network based Distributed Static Compensator (DSTATCOM) for a three-phase, three-wire grid connected distribution system to mitigate the voltage flicker. The technique is based on instantaneous tracking of the voltage envelope and phase angle using online neural network based estimator. These estimated values are used by neural controllers to compute inputs to Hysteresis current controller (HCC), which generate switching signals for DSTATCOM. On line estimation and control makes the system faster, more adaptive and more robust to the changes in system parameters and disturbances. The proposed DSTATCOM is examined by tracking and mitigating flicker produced by an unsymmetrical fault and an arc furnace load in a simple distribution system simulated in SIMULINK. Simulated results show superiority of the proposed controller over conventional PI based DSTATCOM.**

Keywords-Power Quality; DSTATCOM; Voltage Flicker; Arc furnace; Estimation

I. INTRODUCTION

Most industries and commercial establishments are affected by power quality (PQ) problems. Power quality has attracted considerable attention from both utilities and users, due to the use of many types of sensitive equipment. Voltage flicker results due to erratic variations of reactive power demands (which may be of cyclic behaviour such as electric arc furnaces or random behaviour such as motor starting and sudden load switching) leading to fluctuating voltage drops across the impedance of a distribution system. Voltage flicker is the most difficult power quality (PQ) problem from mitigation prospective, because of chaotic characteristics [1-4]. For this, use of power electronics in the form of Static Synchronous Series Compensator (SSSC), Static Compensator (STATCOM), Dynamic Voltage Restorer (DVR) and Unified Power Flow Controller (UPFC) is well-established, independent of the specific application. The use of FACTS controllers are increasing in the network for enhancing power transfer capability, dynamic voltage support and also damping of power oscillations [5]. These devices have solved the power quality problems in distribution and transmission systems by rapidly controlling reactive power [6]. DSTATCOM is a shunt connected, reactive compensation equipment, which is capable of generating and/ or absorbing reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. DSTATCOM provides operating characteristics similar to a rotating synchronous compensator without mechanical inertia and due to solid state power switching devices it provides rapid controllability of the three phase voltages, both in magnitude and phase [11]. Dynamic Voltage Restorer (DVR) offers fast response, simple control, and fewer transients. DSTATCOM has the advantage of optimized energy which the DVR does not have, because the DVRs are mostly connected to the source of energy [7-10].In this paper DSTATCOM is used for mitigation of voltage flicker.

The use of Artificial Intelligence (AI) techniques in electric power is a welcome in the electric power area and the literature on these applications has become rather huge in volume [12-15]. Artificial Neural Network (ANN) is a well established AI technique. Main applications of ANNs in power system include identification and estimating various PQ parameters [16]. In the proposed technique, an Online Neural network based estimator is designed, which tracks the envelope of the voltage flicker [23]. In offline controller data of envelope is already there and neural network controller tracks the set point while in on-line estimation and control is done simultaneously by adjusting the weights of neural network. Using online neural tracker and controller reduces calculations required as compared to traditional DSTATCOM. Neural network is made in embedded block of SIMULINK rather than standard NN toolbox. This gives more flexibility in training of the weights of neural network, thereby making the system fast. The tracked envelope is used in the Voltage Regulation technique, along with the online neural network controller. This makes the system more adaptable to change in system parameters and more robust to noise. There are two control objectives implemented in the DSTATCOM. One is the ac voltage regulation of the power system at Point of Common Coupling (PCC) and the other is dc voltage control across the capacitor inside the DSTATCOM. In the simplest DSTATCOM control strategy, both the regulators are proportional integral (PI) type controllers. Here we use neural network controller to reduce the error, by using an online correction system. It continuously evaluates the error, and manipulates the weights to give the in-phase and quadrature components of the currents [5]. To sum up in the proposed control technique for DSTATCOM first neural network estimates the voltage envelope and phase angle. They then become inputs to two online Neural controllers, the output of which are the reference currents in d and q axis respectively. Mitigation is done for voltage variations for an

DOI 10.5963/JCET0201007

open fault with linear load and for an arc furnace load which is highly non linear. The performance of this controller is compared with that of PI controller for voltage fluctuations.

The paper is organised as follows: Section II explains the system under study. Section III briefs the proposed mitigation scheme and simulated results are given in Section IV. Section V and VI give conclusion and appendix respectively.

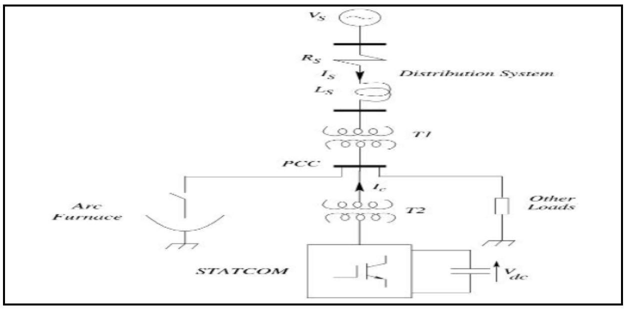

Fig. 1 The System under Study

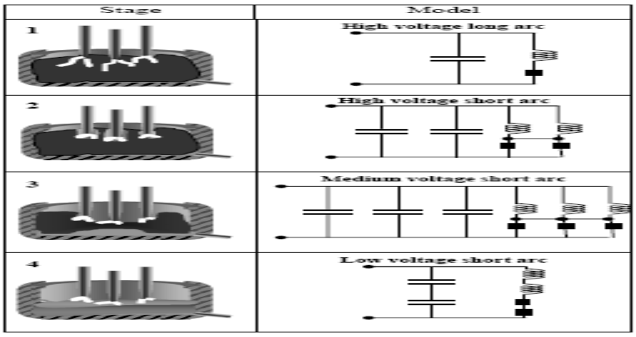

Fig. 2a Different Stages of Electric Arc Furnace Melting

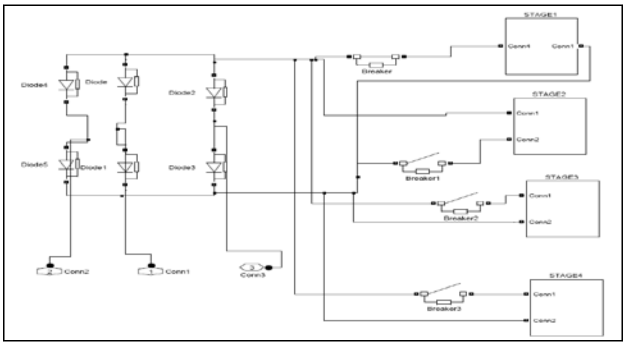

Fig. 2b Simulink Model of Arc Furnace

II. THE SYSTEM UNDER STUDY

For study purpose a power system similar to figure 1 is taken. The arc furnace is modeled as different RLC circuits for each of the initial four stages [20]. Using the Breaker models in Simulink, the different stages are introduced into the line, in the sequence in which they occur. Different stages of the welding process give a different fluctuation in the load. Details of modelling of arc furnace is not discussed as it is a well known .The equivalent circuit for various stages of arc furnace and it's simulink model are shown in figure 2a and 2b respectively. For voltage regulation problem, only linear load is taken in the system. For flicker mitigation arc furnace is taken as load (Page Layout).

III. THE PROPOSED FLICKER MITIGATION TECHNIQUE

The proposed technique for flicker mitigation can be divided into two parts:

1. Estimation of Flicker Envelope and Phase angle
2. Flicker Mitigation using DSTATCOM.

Neural networks are made in embedded block of SIMULINK and NN toolbox is not used. Use of the embedded block gives us more flexibility in training of neural networks..

A. Estimation of Flicker Envelope

The proposed technique is based on the instantaneous tracking of the low frequency envelope of the measured voltage. Then, the estimated envelope is compared to the required voltage level to produce the appropriate control action. As compared to the above-discussed methods, online envelope tracking gives a better performance due to the fact that it is an instantaneous tracking method [23].

Voltage flicker refers to the change in the envelope of the 60 Hz supply voltage. This voltage envelope is often called the instantaneous flicker level. The characteristics of the instantaneous flicker level depend on the size and type of the load that is producing the disturbance. The change in voltage magnitude can occur gradually, as in the case of arc furnace operation, or suddenly as with motor starting.

Envelope tracking has many important applications in electrical distribution systems. First step to control flicker mitigation or voltage regulation is the instantaneous tracking of the low frequency envelope of the measured voltage at point of common coupling. Then, the estimated envelope is compared to the required voltage level to produce the appropriate control action. Thus, envelope tracking is a crucial task for assessing the flicker level and evaluating the flicker severity [22-23].

The disturbed voltage waveform in distribution systems can be modelled as a variable amplitude sinusoidal waveform as follows:

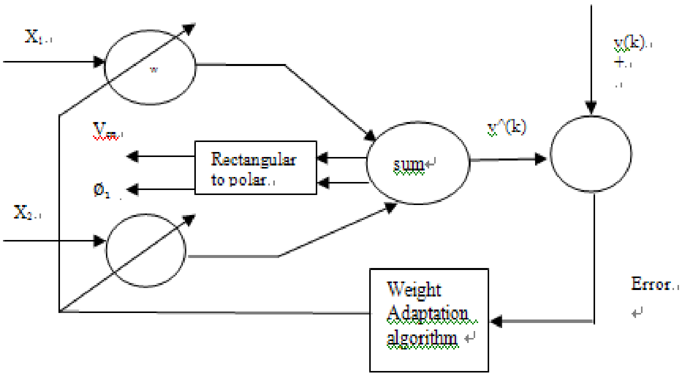

Fig. 3 Block Diagram for Estimation of Voltage Flicker Envelope and Phase Angle

$$v(t) = A(t)\sin(w_1 t + \phi_1) \qquad (1)$$

where $A(t)$ is the magnitude of the voltage under disturbance,

DOI 10.5963/JCET0201007

w_1 is the supply angular frequency, and ϕ_1 is the phase angle of the fundamental component. The shape of $A(t)$ depends on the load that produces the disturbance. The shape can be a step function to represent the switching of heavy loads, or it can be a square wave with a variable frequency and duty ratio to model the case of a resistance welder in different operating cycles.

Also, the shape can be a sinusoidal function with a frequency lower than the supply frequency as in the ac arc furnaces as follows:

$$v(t) = A_o + A_f(t)\sin(w_f t + \phi_f) \tag{2}$$

where A_o is the magnitude of the fundamental voltage , A_f is the magnitude of the voltage flicker, w_f is the angular frequency of the voltage flicker, and ϕ_f is the phase angle. To allow the proposed estimation techniques to track the envelope of the measured voltage waveform, it is written as:

$$v(t) = A(t)\{\sin w_1 t \cos\phi_1 + \sin\phi_1 \cos w_1 t\} \tag{3}$$

and in vector form, as

$$v(t) = [\sin w_1 t \quad \cos w_1 t]\begin{bmatrix} A(t)\cos\phi_1 \\ A(t)\sin\phi_1 \end{bmatrix} \tag{4}$$

$$= X(t)^{\Gamma} W(t)$$

Finally, the envelope is given by:

$$V_{en} = A(t) = \sqrt{w_1^2 + w_2^2} \tag{5}$$

and the phase angle can be calculated from:

$$\phi_1 = \tan^{-1}\left(\frac{w_1}{w_2}\right) \tag{6}$$

where and are equal to and respectively. Figure 2 is a block diagram of a general envelope tracker based on the model presented in (4)– (6). In figure 3 X1 and X2 are equal to sinw1t and cosw1t which are inputs to the neural network. The estimated voltage waveform is converted to polar form to give the tracked envelope and fundamental phase angle.

1) Simulated Results

First we examine the dynamic performance of the proposed flicker tracker with the aid of MATLAB for the above mentioned mathematical waveform. The second case deals with the mitigation of voltage flicker produced by an arc furnace.

a) Case 1

Simulated results of actual and tracked envelope for the equations of voltage flicker are shown in figure 4. The bold line shows the actual voltage and dotted one shows the tracked one. Figure 4a shows the plot of actual and estimated voltage flicker. The dotted line overlaps the bold line thus proving that the on line estimation is good. Figure 4b and 4c are the plots for plots of actual and estimated flicker envelope and fundamental phase angle. They are the plots when plot 4a is converted to polar form. Weights of neural network are trained using gradient descent and back propagation algorithms. This model can be used to detect and classify most power quality problems related to voltage, including sag, swell, flicker, and interruption.

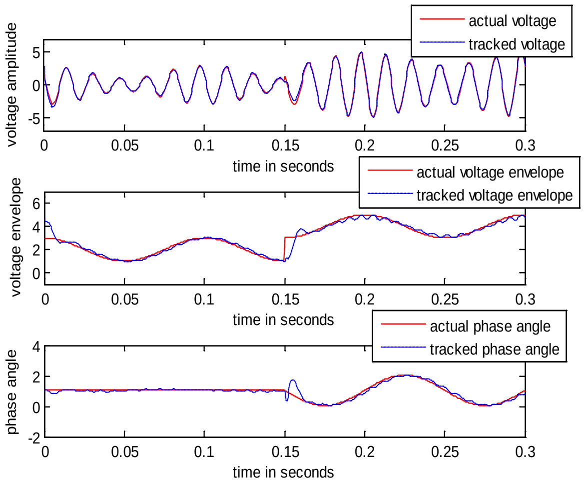

Fig. 4a Plot of Actual and Estimated Voltage Flicker
Fig. 4b Plot of actual and estimated voltage flicker enveloped
Fig. 4c Plot of actual and estimated fundamental phase angle

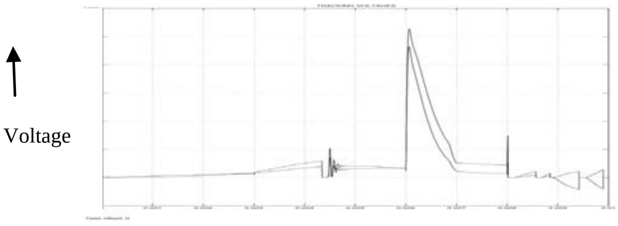

Fig. 5 Actual Voltage Waveform and Tracked Envelope with EAF as Load

b) Case 2

After testing the on line tracker for mathematical equations it is implemented on real power system as shown in figure 1.Actual and tracked voltage envelope with electric arc furnace (EAF) as load are plotted in figure 5.

B. Flicker Mitigation Using DSTATCOM.

The tracked waveforms of voltage envelope and fundamental phase angle are compared to the Modelling of DSTATCOM is done in standard MATLAB environment using Simulink and power system blockset toolboxes. Block diagram of the proposed DSTATCOM is given in figure 6a. In the proposed DTATCOM the Current Controlled Voltage Source Inverter (CC-VSI) is used which composes of six self commutated semi-conductor switches (IGBTs). Like a typical inverter, this arrangement ensures a 3 phase AC output from a DC source, the DC source in this case is the voltage across the electrolytic capacitor (Vdc), the charging and discharging of which is dependent upon the in-phase components of the supply reference currents [18-19]. Three phase reference supply currents have two components: the in-phase components and the quadrature component. While the in-phase components are required to charge the dc capacitor of the DSTATCOM to its reference dc bus voltage, the quadrature components are required for ac voltage control at the point of common coupling. These reference currents are in dq frame (id*, iq*) and are transformed to abc frame using dq_to_abc transformation. Weights of the neural network are trained on line both of tracker as well as the controller. Hystersis Current controller is used to compare these generated instantaneous reference currents to the line currents, and hence produce pulses which can trigger the Inverter IGBTs accordingly [23]. Online neural network tracks the envelope and phase angle of the instantaneous line voltage. Tracked envelope is compared with the desired envelope by an neural controller and instantaneous Vdc is regulated by another neural controller. Outputs of these controllers are reference values in d and q axis respectively. These are changed to abc frame about the tracked fundamental angle. Instantaneous values are compared with these reference values of values of currents by a hysteresis current controller, which generates switching signals for IGBT's. Thus, reactive power of the capacitor is either absorbed or consumed to make up for the voltage envelope.

To sum up first voltage envelope and phase angle are tracked online and then the estimated value is compared with the desired value to produce gate pulses for firing of the DSTATCOM using HCC.

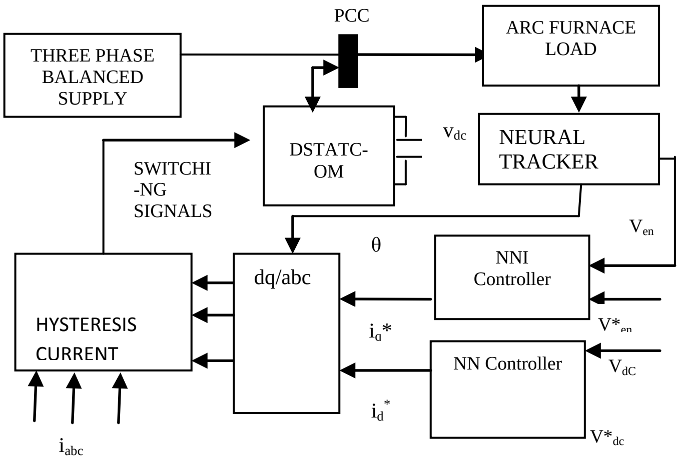

Fig. 6a Model of DSTATCOM with the Proposed Control Technique

1) *Control Scheme*

Figure 6b shows the control scheme of DSTATCOM with one online neural controllers. The One neural controller regulates the dc link voltage, while neural controller regulates the terminal voltage at point of Common Coupling (PCC). The output of the first controller over dc bus voltage is the amplitude of in phase component of supply reference currents and output of second neural controller over AC terminal voltage is the amplitude of quadrature component supply reference currents. These currents (id*,iq*) along with fundamental phase angle are used to compute instantaneous reference currents (ia*,ib*,ic*).

Once reference supply currents are generated, a carrier less hysteresis PWM controller is employed over sensed supply currents (ia,ib,ic) and instantaneous reference currents (ia*,ib*,ic*) to generate pulses for IGBT's of DTATCOM. Hysteresis current controller limits DSTATCOM currents to maintain supply currents in a band around desired reference current values. HCC generates switching signals for six IGBT's of VSI working as DSTATCOM.

2) *Simulated Results*

Voltage flicker is mitigated with the proposed technique and the results are compared with the conventional DSTATCOM with off line PI controllers. First the proposed DSTATCOM is simulated for an unsymmetrical fault on linear load and then for arc furnace as load.

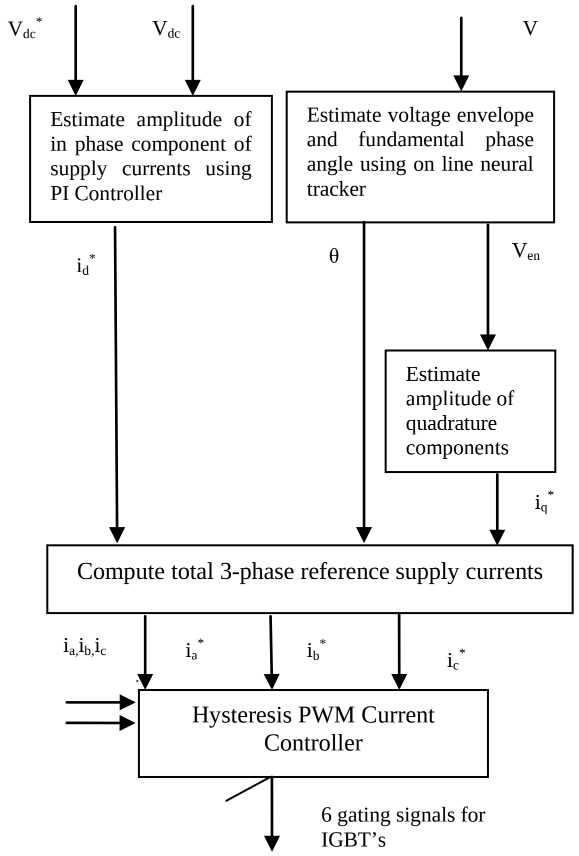

Fig. 6b Control Scheme for the Proposed DSTATCOM Desired Values to Generate Pulses for the DSTATCOM

C. *Unsymmetrical Fault*

The open fault with a star load has been simulated using a three phase series RLC Branch. The open fault is introduced from t = 0.01 sec to t = 0.02 sec. During this time period, Phase C of the supply is open circuited. As a result, the voltage transforms into a two phase voltage. The DSTATCOM control system senses this fault and generates reference currents and pulses such that the triggering of the IGBTs induces voltage into the third phase, hence making up for the fault. Figure 7 shows voltage and current at the PCC without the DSTATCOM. During the fault condition from t = 0.01 to t = 0.02 sec the value of voltage across load reaches 1500 V without DSTATCOM. Figure 8 is the plot for voltage and current at PCC with the conventional DSTATCOM with PI Controllers. From the figure 8 it is seen that PI controlled DSTATCOM opposes any increase in the voltage and keeps it

DOI 10.5963/JCET0201007

stable at 200V. There is slight glitch in voltage at the time fault starts i.e. after 0.01 sec. Figure 9 is the plot for voltage and current at PCC with the DSTATCOM of proposed scheme. NN controlled DSTATCOM opposes any increase in the voltage and keeps it stable at 200V. It is clearly seen that there is no glitch in voltage in fig. 9 which was present in fig. 8.

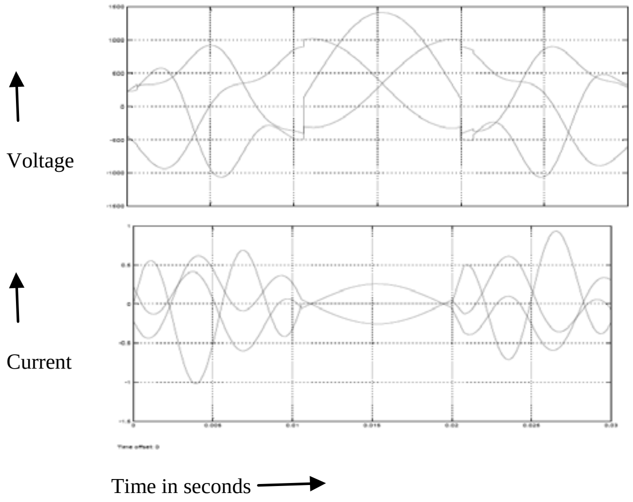

Fig. 7 Line Voltage and Current Plots at PCC without the DSTATCOM

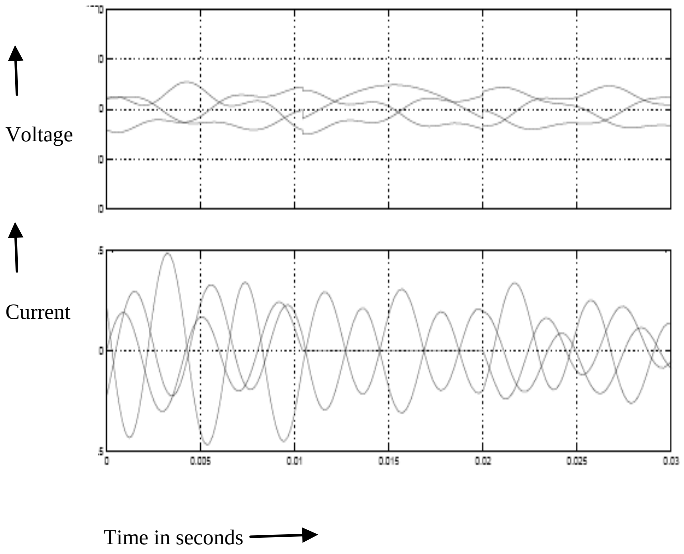

Fig. 8 Line Voltage and Current Plots at PCC with Conventional DSTATCOM with PI Controllers

As seen from the outputs, while the PI Controller gives satisfactory results, the output with the neural controller is superior

D. Arc Furnance As Load

The voltage and current variation due to an arc furnace load is very erratic and dangerous to the other peripheral devices. It produces a strong voltage flicker, which needs to be corrected for the proper and safe functioning of all loads on the distributed generation system.

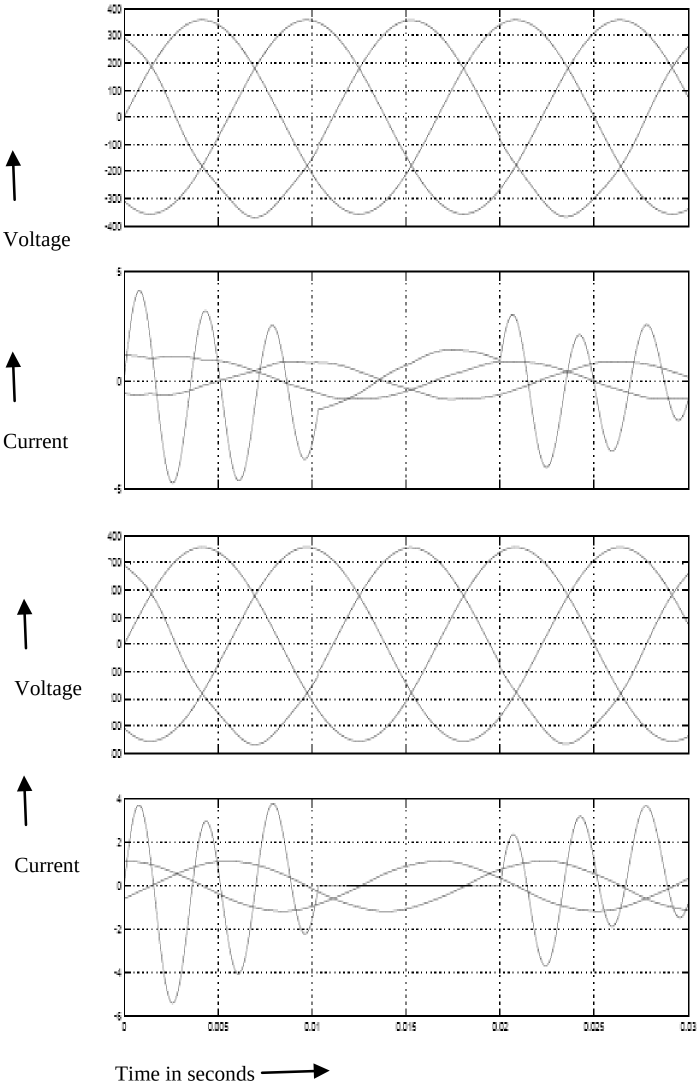

Fig. 9 Line Voltage and Current at PCC with on Line Tracker and Neural Controller DSTATCOM

1) Simulated Results

The outputs obtained without and with DSTATCOM using PI and on line NN tracker and controllers are shown in figures 10, 11 and 12 respectively.

As compared to the output without the DSTATCOM as shown in Figure 10, the flicker has been considerably removed, except for the glitch at t=0.006sec. However, the voltage transient at this time is up to 1200V in the case of an unregulated arc furnace load, whereas in the presence of a DSTATCOM, it comes down to 430V. There are certain drawbacks of using a PI Controller, such as slow response, failure to show flexibility in case of excessive fluctuations, introduction of glitches, etc. In order to overcome these, an online neural control replaces the PI Controller in the voltage regulation scheme. From figure 11 and 12 it is observed that the outputs obtained with the online neural controller overcomes the drawbacks of the PI Controller.

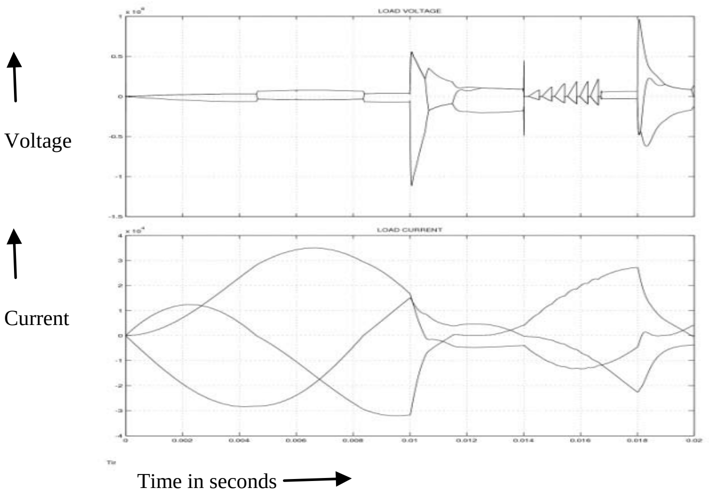

Fig. 10 Line Voltage and Current at PCC for Arc Furnace Load without DSTATCOM

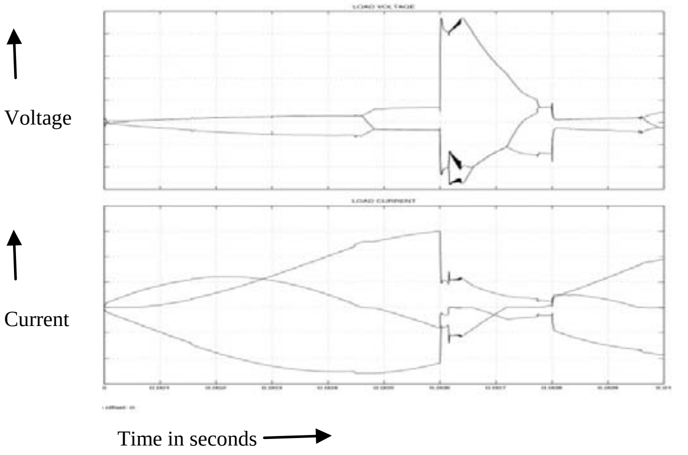

Fig. 11 Line Voltage and Current at PCC with DSTATCOM and PI Controller.

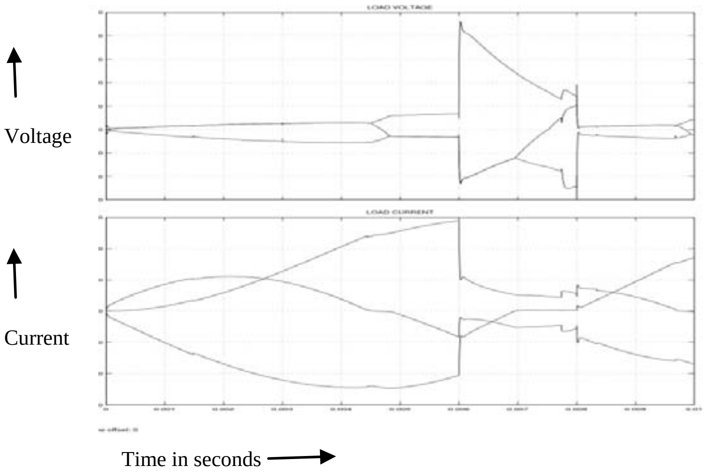

Fig. 12 Line Voltage and Current with the Proposed DSTATCOM .

The comparison between the PI Controller and the online neural Controller is listed as follows:

- At the voltage transient at time t=0.004 sec, the transition using PI Controller and Online Neural Controller is seen to be smooth, instead of the glitch as seen in Figure 10, without the DSTATCOM.
- At time t=0.006sec, Stage 3 of the Electric Arc Furnace turns on, creating a sudden voltage transient of 1200V as seen in Figure 10. This voltage transient is considerably reduced to a value of 430V, in the case of both PI Controller and Online Neural Controller.
- In the case of PI Controller, Figure 11, at time t=0.007sec, glitches are produced. These glitches are non-existent in Figure 12. Hence, this is a drawback of the PI Controller as in addition to the existing faults, the PI Controller is introducing an extra transient.
- In Figure 12, it can be seen that these glitches observed in Fig11, are missing. Not only does the Online neural Controller provide satisfactory results for voltage transients, it also provides respite from the intense voltage flicker observed at time t=0.008sec to t=0.01 sec.

Hence, as studied in the above comparison, the results of the Online Estimator coupled with an online neural Controller show better mitigation of voltage flicker as compared to existing methods.

IV. CONCLUSIONS

During the course of the study, an enhanced model of a Distributed Static Compensator (DSTATCOM) for a Three Phase, three wire distribution system was developed. The modeling of the components was carried out in MATLAB environment using Simulink and Sim Power System Blockset. DSTATCOM was designed using on-line neural estimator and online neural network controller for voltage regulation technique. The use of neural network controller in DSTATCOM gave superior results as compared to commonly used PI Controller. The on- line estimators and controllers have the advantage of being fast, more adaptive to change in system parameters and more robust to external noise. Superiority of the proposed DSTATCOM model is verified by the simulation results obtained for power quality problems such as asymmetrical fault and flicker mitigation.

The DSTACOM using neural networks for online envelope tracking along with on line controllers was implemented for voltage flicker mitigation using the electric arc furnace as the load.

APPENDIX

The values of the various parameters chosen for proper functioning of the proposed scheme are as follows:

Source: 3-phase, 3wire, 10,000 MVA, 230 kV, 50 Hz

Star load: R= 25.1ohms, L= 300e-3 H, C= 1e-6 F PI Controller: Kp=15.5, Ki=0.65.

Load: Arc Furnace Load with parametric modelling PI Controller: Kp=45, Ki=0.8.

Neural network:

Tracker: 3 layer multi feed forward network; Learning Rate=0.00001; hidden layer : 5 neurons, tansig is non linear function used; output layer: 10 neurons with puerlin activation function.

Controller: 3 layer multi feed forward network; Learning Rate=0.0001; hidden layer: 5 neurons, hardlim is non linear function used; output layer: 10 neurons with puerlin activation function.

Weights are initialized random values. Gradient descent and backpropagation are used in all the neural networks for training of weights.

REFERENCES

[1] Roger C. Dugan, Mark F. Granaghan, Surya Santoso, and H. Wayne Beaty,"Electrical Power Systems Quality, Second Edition", McGraw Hill, Professional Engineering.

[2] Amit Jain, Karan Joshi, Aman Behl and Ned Mohan ,'Voltage regulation with STATCOM: Modeling, Control and Results,' IEEE Transctions on Power Delivery, Vol. 21,, No.2, pp 726-735, April 2006.

[3] T. Larsson and C. Poumarede, "STATCOM, an Efficient Means for Flicker Mitigation," IEEE Power Engineering Society Winter Meeting, vol. 2, Jan.–Feb. 31–4, 1999, pp. 1075–1077.

[4] J. Lamoree, D. Mueller, P. Vinett, and W. Jones, 'Voltage Sag Analysis Case Studies,' IEEE Trans. Ind. Appl., vol. 30, no. 4, pp. 1083–1088, Jul./Aug. 1994.

[5] B. K. Keshavan and Nagesh Prabhu "Damping of Sub synchronous Oscillations Using STATCOM –A FACTS Controller," International conference on Power system Technology , POWERCON 2004 Singapore 21-24, November 2004.

[6] Aurelio Garcia-Gerrada, Pablo Garcia-Gonzalez, Rafael Collantes, 'Comparison of Thyristor-Controlled Reactor and Voltage Source Inverters for Compensation of Flicker Caused by Arc furnaces,' IEEE Trans power Delivery, vol. 15, pp. 1225-1231, October 2000.

[7] S. S. Chio, B. H. Li, and D. M. Vilathgamuwa,' Design and analysis of the inverter-side filter used in the dynamic voltage restorer,' IEEE Trans. Power Del., vol. 17, pp. 857–846, July 2002.

[8] Naveen Goel, R.N. Patel, Saji T. Chako.'Genetically tuned STATCOM for Voltage Control and Reactive Power Compensation,' IJCTE,vol.2, No.3, June 2010.

[9] N. H. Woodley, L. Morgan, and A. Sundaram, 'Experience with an Inverter-based Dynamic Voltage Restorer,' IEEE Trans. Power Del., vol. 14, no. 3, pp. 1181–1186, Jul. 1999.

[10] Elnady, and Magdy M. A. Salama,' Unified Approach for Mitigating Voltage Sag and Voltage Flicker Using The DSTATCOM,' IEEE Trans. Power Del., vol. 20, no. 2, pp. 992–1000, April 2005.

[11] Masand, S. Jain, and G. Agnihotri, "Distribution Static Compensator Performance under Linear and Non-Linear Current Regulation Methods", J. Electrical Systems 4-1(2008): 91-105.

[12] Mohamed Amin Eldery, Ehab F. El-Saadany, andMagdy M. A. Salama, Fellow, IEEE,' A Simple Energy Operator ComputationalMethod for Voltage Flicker Assessment,' IEEE Transactions On Power Delivery, Vol. 21, No. 3, July 2006,pp 1743-1750.

[13] Sarath Perera, , Duane Robinson, Sean Elphick, Don Geddey, Neil Browne,' Vic Smith,and Vic Gosbell, 'Synchronized Flicker Measurement for Flicker Transfer Evaluation in Power Systems' IEEE Transactions On Power Delivery, Vol. 21, No. 3, July 2006,pp 1477-1482.

[14] Araceli Hernández, Julio G. Mayordomo, Rafael Asensi, and Luis F. Beites,' A Method Based on Interharmonics for Flicker Propagation Applied to Arc Furnaces,' IEEE Transactions On Power Delivery, Vol. 20, No. 3, July 2005,pp 2334-2342.

[15] Mostafa I. Marei, Tarek K. Abdel-Galil, Ehab F. El-Saadany, and Magdy M. A. Salama,' Hilbert Transform Based Control Algorithm of the DG Interface for Voltage Flicker Mitigation,' IEEE Transactions On Power Delivery, Vol. 20, No. 2, April 2005,pp 1129-1133

[16] Elnady, Student Member, IEEE, and Magdy M. A. Salama, 'Unified Approach for Mitigating Voltage Sag and Voltage Flicker Using The DSTATCOM,' IEEE Transactions On Power Delivery, Vol. 20, No. 2, April 2005,pp 992-1000.

[17] Mostafa I. Marei, Ehab F. El-Saadany, and Magdy M.A. Salama, "Envelope Tracking Techniques for Flicker Mitigation and Voltage Regulation", in IEEE Trans. on Power Delivery, vol. 19, No. 4, October 2004.

[18] Bhim Singh, Alka Adya, A.P Mittal, and J.R.P Gupta, 'Modeling, Design and Analysis of Different Controllers for DSTATCOM", Conference on POWERCON, New Delhi, Pages: 1-8, Oct.2008.

[19] Amit Jain,Karan Joshi, Aman Behal, and Ned Mohan,' Voltage Regulation With STATCOMs: Modeling, Control and Results,' in IEEE Trans. on Power Delivery, vol. 21, No. 2,pp 726-735, April 2006.

[20] Labar Hocine, Dgeghader Yacine, Kelaiaia Mounia Samira, and Bounaya Kemal, "Closely Parametrical Model for an Electrical Arc Furnace", Proceedings of World Academy of Science, Engineering and Technology, Volume 30, Pages: 96-100, July 2008.

[21] Aurelio García-Cerrada, Member, IEEE, Pablo García-González, Rafael Collantes, Tomás Gómez, Member, IEEE, and Javier Anzola,' Comparison of Thyristor-Controlled Reactors and Voltage-Source Inverters for Compensation of Flicker Caused by Arc Furnaces,' in IEEE Trans. on Power Delivery, vol. 15, No. 4,pp 1225-1231, Oct. 2000.

[22] Adly A. Girgis,John W. Stephens,Elham B. Makram,'Measurement And Prediction Of Voltage Flicker Magnitude And Frequency ,'IEEE Transactions on Power Delivery, Vol. 10, No. 3, pp 1600-1605,July 1995.

[23] Mostafa I. Marei, IEEE, Ehab F. El-Saadany and Magdy M. A. Salama, "Envelope Tracking Techniques for Flicker Mitigation and Voltage Regulation',IEEE Transactions On Power Delivery, Vol. 19, No. 4, pp1854 -1861,Oct. 2004.

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DOI 10.5963/JCET0201007