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POWER QUALITY IMPROVEMENT USING HYBRID ANN-CORRELATION CONTROL SCHEME BASED UPQC

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Abstract - The quality of power to the customers plays significant role in utility distribution system due to day to day rapid increase in usage of non-linear loads. This paper proposes hybrid ANN-correlation control scheme based Unified Power Quality Conditioner (UPQC) to enhance the power quality . The UPQC is the one of the custom power device consists of shunt and series voltage source converters with common dc link capacitor. The propoded neuro-correlation control method generates refernce voltage and current switching pulses for UPQC to enhance power quality profile. This approach mitigates all power quality issues. The performance of correlation-ANN approach is studied through MATLAB/Simulink. The performance analysis of this ANN- correlation control scheme based UPQC is studided and were satisfactory for time varying and abnormal load cases.

Keywords- Correlation scheme; back propagation algorithm; Voltage sag; Unified Power Quality Conditioner; total harmonic distortion; load balancing.

I.INTRODUCTION

The distribution system network pollutes with many power quality issues due to day to day rapid increse in non-linear load usage. The performance of sensitive electronics equipment gets affected due to this small duration diturbances. Hence little enhancement of power quality within standard IEEE 519 (<5%) [1] has major impact on quality of the system. Unified Power Quality Conditioner is a custom power device that provides shunt and series compensation which exhibhits the functions of distribution STATCOM and dynamic voltage restorer. The application of recent developed control schemes for compensating devices to enhance quality of power in the distribution network using soft computing schemes [2] like ABC algorithm, artificial neural networks (ANN), genetic algorithm (GA), fuzzy logic, ABC algorithm etc. The power quality in distribution system means the consumer equipment operates in the absence of mal function through out their life period especially sensitive electronic equipment [3]-[4]. In [5] proven to be the multi period pseudo random binary signal (PRBS) better than traditional control method with fast convergence speed and one computational operation using correlation approach. The DSP based ANN control scheme is introduced for series passive filter and the performance of the this system was better as compared to conventional PI control scheme [6]. In [7], synchronous

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reference theory (SRFT), SRF theory and I cosα theory has proved to be better. The distribution system presents poor quality due to increase in non linear loads. The noval algorithm with dynamic performance has been introduced to mitigate voltage sag and compared with PI controller and proven to be better. In [8], comparative study on DSTATCOM with LMS based improved adaptive non-linear system and neural network. The harmonics present in distribution system due non-linear load as harmonic currents and distributed as voltage through load and line impedance drops [9]. The study of harmonic detection with neural network was presented in [10].

II.SYSTEM CONFIGURATION AND PRINCIPLE

The schematic diagram of Basic three-phase distribution system configuration is shown in figure 1. This configuration consists of three phase source fed to the three phase non-linear load with UPQC device to mitigate power quality issues. UPQC consists of shunt and series VSCs. series VSC is used to mitigate power quality issues like voltage sag, and load imbalances etc. by compensating voltage. The compensating voltage Source Converter (VSC) connects in parallel to the electrical power system to mitigate current disturbances. The series VSC is fed through injection transformers at PCC. The DC capacitor is dc link common for both shunt and series converter devices. Correlation based back propagation controller can regulate this dc voltage.

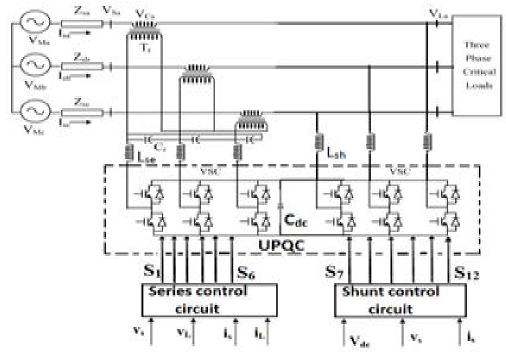

Fig. 1 Basic three-phase distribution system configuration.

III.HYBRID ANN-CORRELATION CONTROLLER

A.Series controller design

The input source voltages, load voltages and load currents are the reference input vectors to generate reference switching pulses to the series VSC as shown in fig. 2. Park's transformation is used to transform three phase voltages to dq0 as:

$$V_{sq} = \frac{2}{3}\left[cos\emptyset * V_{sa} + \cos\left(\emptyset - \frac{2\pi}{3}\right) * V_{sb} + \cos\left(\emptyset + \frac{2\pi}{3}\right) * V_{sc}\right] \quad \text{.........(1)}$$

$$V_{sd} = \frac{2}{3}\left[sin\emptyset * V_{sa} + \sin\left(\emptyset - \frac{2\pi}{3}\right) * V_{sb} + \sin\left(\emptyset + \frac{2\pi}{3}\right) * V_{sc}\right] \quad \text{.........(2)}$$

$$V_{so} = \frac{1}{3}[V_{sa} + V_{sb} + V_{sc}] \quad \text{.........(3)}$$

The dq0 load voltages are inputs for back-propagation based correlation control and V_{qr} is the system response of the controller expressed by (4) and (5) and (6).

$$V_q^* = V_{sq} - V_{qr};\ V_d^* = V_{sd} - V_{dr};\ V_0^* = 0 \quad \text{...........(4)}$$

The three phase reference voltages can be estimated for series VSC using reverse Park's transformation are:

$$V_{sea} = \left[cos\emptyset * V_q^* + sin\emptyset * V_d^* + V_0\right] \quad \text{.........(5)}$$

$$V_{seb} = \left[cos\left(\emptyset - \frac{2\pi}{3}\right) * V_q^* + sin\left(\emptyset - \frac{2\pi}{3}\right) * V_d^* + V_0\right] \quad \text{.........(6)}$$

$$V_{sec} = \left[cos\left(\emptyset + \frac{2\pi}{3}\right) * V_q^* + sin\left(\emptyset + \frac{2\pi}{3}\right) * V_d^* + V_0\right] \quad \text{.........(7)}$$

The calculated reference voltages (7), (8) & (9) are subtracted from source reference

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voltages and fed to reference pulse generator for producing gating pulses for series VSC of UPQC as S1, S2, S3, S4, S5 and S6.

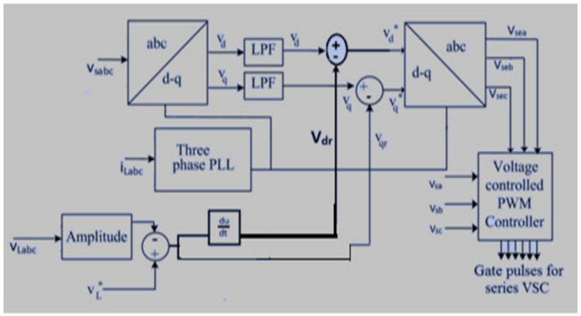

Fig. 2 Series control scheme

B.Shunt control design

The load voltages (vLabc), source currents (isabc) and load currents (iLabc) are the reference input vectors to generate reference switching pulses to the shunt VSC. The reference gating pulses are estimated using back-propagation based correlation controller as shown if figure 4. The PCC voltage by using reference input source voltages is given by

$$v_p = \sqrt{\frac{2}{3}} * \sqrt{v_{sa}^2 + v_{sb}^2 + v_{sc}^2} \quad \text{.......(8)}$$

The real power components of unit voltage are calculated as:

$$e_{ap} = \frac{v_{sa}}{v_p};\ e_{bp} = \frac{v_{sb}}{v_p};\ e_{cp} = \frac{v_{sc}}{v_p} \quad \text{.......(9)}$$

The reactive power components of three-phase unit voltage are estimated as:

$$e_{aq} = \frac{(-e_{bp}+e_{cp})}{\sqrt{3}};\ e_{bq} = \frac{(3e_{ap}+e_{bp}-e_{cp})}{2\sqrt{3}};\ e_{cq} = \frac{(-3e_{ap}+e_{bp}-e_{cp})}{2\sqrt{3}} \quad \text{.......(10)}$$

The instantaneous real power component of balanced source voltages are displaced by 120° and expressed as

$$v_{spa} = V_{maxa}\sin wt;\ v_{spb} = V_{maxb}\sin\left(wt - \frac{2\pi}{3}\right);\ v_{spc} = V_{maxc}\sin\left(wt + \frac{2\pi}{3}\right) \quad \text{.......(11)}$$

The non-linear load currents, which are including harmonics under study, given by

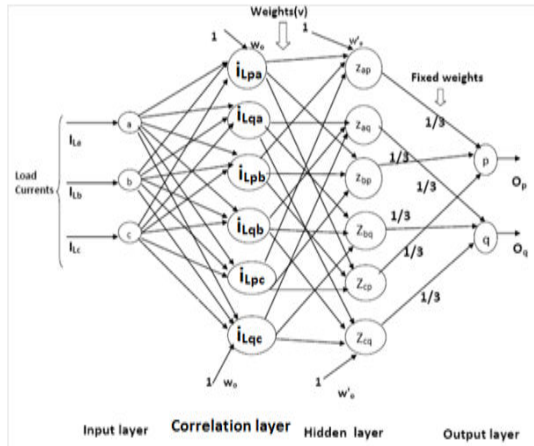

Fig. 3 Back-propagation network

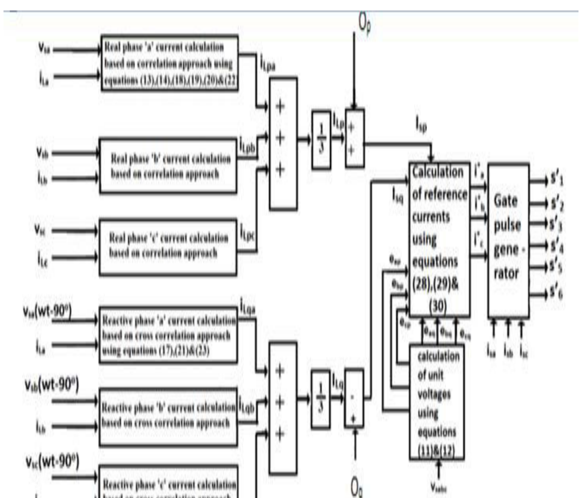

Fig. 4 Shunt controller for VSC of UPQC

$$i_{La} = I_{maxa1}\sin(wt - \emptyset_{a1}) + I_{maxa3}\sin(3wt - \emptyset_{a3}) + I_{maxa5}\sin(5wt - \emptyset_{a5}) + - \quad \text{...(12)}$$

$$i_{Lb} = I_{maxb1}\sin(wt - \emptyset_{b1}) + I_{maxb3}\sin(3wt - \emptyset_{b3}) + I_{maxb5}\sin(5wt - \emptyset_{b5}) + - \quad \text{...(13)}$$

$$i_{Lc} = I_{maxc1}\sin(wt - \emptyset_{c1}) + I_{maxc3}\sin(3wt - \emptyset_{c3}) + I_{maxc5}\sin(5wt - \emptyset_{c5}) + - \quad \text{...(14)}$$

The instantaneous reactive power component of balanced source voltages (with90° delay) are given by

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$$v_{sqa} = V_{maxa} \sin\left(wt - \frac{\pi}{2}\right); v_{sqb} = V_{maxb} \sin\left(wt - \frac{7\pi}{6}\right); v_{sqc} = V_{maxc} \sin\left(wt + \frac{\pi}{6}\right) \quad \ldots\ldots\ldots(15)$$

The positive Root Mean Square value of source voltage (v_{sa}) and Root Mean Square value of load current (i_{La}) are:

$$\|v_{sa}\| = \sqrt{\frac{1}{T}\int_0^T v_{sa}^{\ 2}\, dt} \quad \ldots\ldots\ldots(16)$$

$$\|i_{La}\| = \sqrt{\frac{1}{T}\int_0^T i_{La}^{\ 2}\, dt} \quad \ldots\ldots\ldots(17)$$

Here 'T' is periodic time.

The correlation coefficient (c_p) and cross correlation coefficient (c_p) using equations (16), (17), (18) and (19) are estimated as:

$$c_p = \left[\frac{(v_{sa}).\,(i_{La})}{(\|v_{sa}\|).(\|i_{La}\|)}\right] \quad \ldots\ldots\ldots(18)$$

Here $(v_{sa}).\ (i_{La}) = \frac{1}{T}\int_0^T (v_{sa}.\ i_{La})\, dt$

Here $(v_{sa}).\ (i_{La}) = \frac{1}{T}\int_0^T (v_{sa}.\ i_{La})\, dt$

$$c_q = \left|\frac{(v_{sqa}).\,(i_{La})}{(\|v_{sqa}\|).(\|i_{La}\|)}\right| \quad \ldots\ldots\ldots(19)$$

The active power component of phase 'a' load current is

$$i_{Lpa} = c_p * \frac{v_{spa}}{\|v_{spa}\|} * \|i_{La}\| \quad \ldots\ldots\ldots(20)$$

The other phase's real power components $(i_{Lpb} \& i_{Lpc})$ can be obtained in similar manner, represented by equation (23) and (24) as:

$$i_{Lpb} = c_p * \frac{v_{spb}}{\|v_{spb}\|} * \|i_{Lb}\| \quad \ldots\ldots\ldots(21)$$

$$i_{Lpc} = c_p * \frac{v_{spc}}{\|v_{spc}\|} * \|i_{Lc}\| \quad \ldots\ldots\ldots(22)$$

Similarly, the quadrature load currents are estimated using equations (16), (17), (18) & (19) as

$$i_{Lqa} = c_q * \frac{v_{sqa}}{\|v_{sqa}\|} * \|i_{La}\| \quad \ldots\ldots\ldots(23)$$

The other phase's reactive power components $(i_{Lqb} \& i_{Lqc})$ can be obtained in similar manner, represented by equation (26) and (27) as:

$$i_{Lqb} = c_q * \frac{v_{sqb}}{\|v_{sqb}\|} * \|i_{Lb}\| \quad \ldots\ldots\ldots(24)$$

$$i_{Lqc} = c_q * \frac{v_{sqc}}{\|v_{sqc}\|} * \|i_{Lc}\| \quad \ldots\ldots\ldots(25)$$

IV.RESULTS AND DISCUSSIONS

The performance of the test system of three phase distribution system of 230Vph, 50 Hz, supplying a non-linear load with UPQC compensation is carried using hybrid correlation based back-propagation control approach. The results of power quality are analyzed using MATLAB/SIMULINK.

A. Sag

The performance of hybrid correlaion-back propagation algorithm based UPQC under voltage sag condition in short duration is analyzed is shown in figure 5. There is a 20% voltage sag of of nominal voltage from 3.7 sec to 3.8 sec. This has been mitigated using hybrid correlaion-back propagation algorithm based UPQC as shown in figure 6 and its dynamic performance of source voltage, current, load currents, dc voltage, load balancing as shown in figure

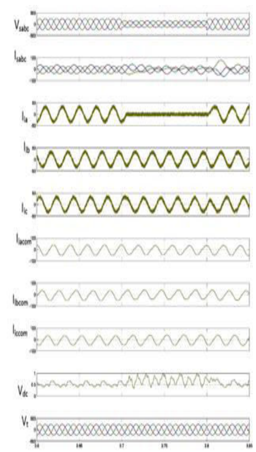

Fig. 5 Dynamic performance of correlation-back propagation based UPQC

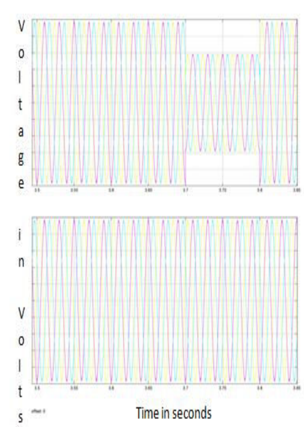

Fig. 6 Voltage Sag and its mitigation using correlation-back propagation based UPQC

B.Total Harmonic Distortion

The UPQC mitigates the current and power quality issues that presents in the electrical power system due to non-linear loads. The load harmonics and the vars can be compensated by shunt VSC. The Total

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Harmonic Distortion (THD) of load current is 24.91% as shown in figure 7. The FFT analysis of PCC voltage, the total harmonic distortion and its waveform for compensation using correlation-back propagation method is shown in figure 10. From figures 10, it is concluded that the PCC voltage has THD of 1.06% using correlation-back propagation approach and source voltage and source current respectively of 0.74% and 2.34% as shown in fig. 9 and fig. 8. The performance of correlation-back propagation approach based UPQC is tabulated in table 1.

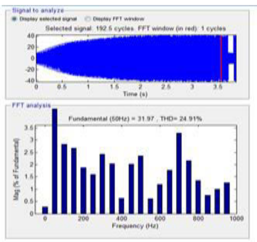

Fig. 7 Load current Harmonic Distortion

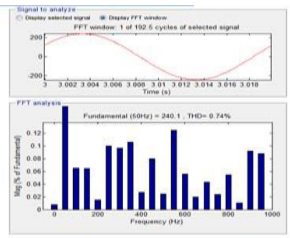

Fig. 9 Source voltage and THD

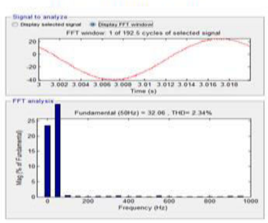

Fig. 8 Source Current and THD using correlation-ANN based UPQC

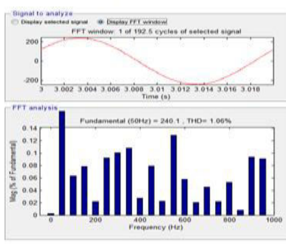

Fig. 10 PCC voltage and THD with ANN-correlation based UPQC

Table1. Performance of correlation-ANN based UPQC

Parameter	Magnitude	Total Harmonic Distortion (%)
Load current	31.97 A	24.91
Source Current	32.06 A	2.34
Source Voltage	240.1 V	0.74
PCC Voltage	240.1 V	1.06

V.CONCLUSION

UPQC mitigates the power quality issues like harmonics, sag and swell etc. The THD of load current that injected into the distribution system is 24.91%. The harmonics enter at load terminals due to non-linear loads as harmonic currents, and this harmonics has been suppressed to 2.34% at source end in currents and 0.74% in voltage. At PCC it reduces to 1.06% with correlation-back propagation control scheme based Unified Power Quality Conditioner. The UPQC DC capacitor bus voltage can be controlled by using correlation control scheme and load voltage can be stabilized with proposed correlation – back propagation controller. The correlation-back propagation control method estimates switching gate pulses for shunt and series VSCs of UPQC.

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