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POWER QUALITY IMPROVEMENT IN A GRID BY AN IMPROVED UNIFIED POWER QUALITY CONDITIONER USING ANN WITH HYSTERESIS CONTROL

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ABSTRACT

The quality of the Electrical power is effected by many factors like harmonic contamination, due to non-linear loads, such as large thyristor power converters, rectifiers, voltage and current flickering due to arc in arc furnaces, sag and swell due to the switching of the loads etc. One of the many solutions is the use of a combined system of shunt and active series filters like improved unified power quality conditioner (IUPQC) This device combines a shunt active filter together with a series active filter in a back-to-back configuration, to simultaneously compensate the supply voltage and the load current or to mitigate any type of voltage and current fluctuations and power factor correction in a power distribution network. The present work study the compensation principle and different control strategies used here are based on ANN controller of the IUPQC in detail. The control strategies are modeled using MATLAB/SIMULINK. The simulation results are listed in comparison of different control strategies and for the verification of results.

1. INTRODUCTION

The power electronic devices due to their inherent non-linearity draw harmonic and reactive power from the supply. In three phase systems, they could also cause unbalance and draw excessive neutral currents. The injected harmonics, reactive power burden, unbalance, and excessive neutral currents cause low system efficiency and poor power factor. In addition to this, the power system is subjected to various transients like voltage sags, swells, flickers etc.[1]-[2] These transients would affect the voltage at distribution levels. Excessive reactive power of loads would increase the generating capacity of generating stations and increase the transmission losses in lines. Hence supply of reactive power at the load ends becomes essential.[3-5].Power Quality (PQ) mainly deals with issues like maintaining a fixed voltage at

the Point of Common Coupling (PCC) for various distribution voltage levels irrespective of voltage fluctuations, maintaining near unity power factor power drawn from the supply, blocking of voltage and current unbalance from passing upwards from various distribution levels, reduction of voltage and current harmonics in the system.[6-7].'This paper presents a novel method for derivation of compensation signals in IUPQC using neural network with hysteresis control. The performance of the system is verified by extensive simulation on Matlab/SPS environment.

2. SYSTEM CONFIGURATION

Basic block diagram of IUPQC is shown in Figure.1, where as the overall control circuit is shown in the Figure.2. The voltage at PCC may be or may not be distorted depending on the other non-linear loads connected at PCC. Here the assumption of the voltage at PCC is distorted. Two voltage source inverters are connected back to back, sharing a common dc link.[8-10]

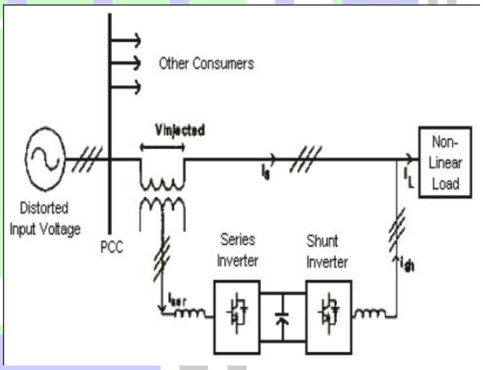


Figure.1 Basic Block Diagram of IUPQC

One inverter is connected parallel with the load. It acts as shunt APF, helps in compensating load harmonic current as well as to maintain dc link voltage at constant level. The second inverter is connected in series with utility voltage by using series transformers and helps in maintaining the load voltage sinusoidal.[11-12]

As for the shunt active filter of the IUPQC it is represented by $\frac{V_{dc}}{2}u_2$ with l_{sh} as the first order low-pass interfacing filter and r_{sh} as the losses of the shunt VSI. $\frac{V_{dc}}{2}u_2$ represents the switched voltage across the shunt VSI output of the IUPQC. The injection current of the shunt active filter is denoted by both u_1 and u_2 take the value of either -1 or 1 depending on the switching signal of the hysteresis control.

In Figure.2 the instantaneous current of the nonlinear load i_L is expanded into 3 terms. The first term i_{Ljp} is the load Reference currents and voltages are generated using Phase Locked Loop (PLL).

3. OVERALL CONTROL CIRCUIT CONFIGURATION OF IUPQC

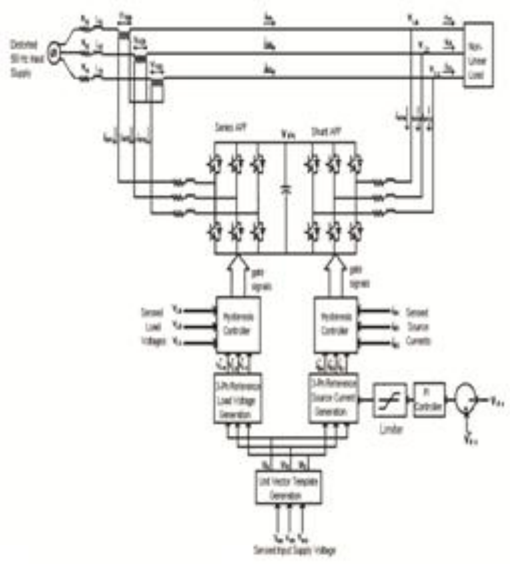


Figure.2 Overall Control Circuit Configuration of IUPQC

The control strategy is based on the extraction of Unit Vector Templates from the distorted input supply. These templates will be then equivalent to pure sinusoidal signal with unity (p.u.) amplitude. The extraction of unit vector templates is

$$\left.\begin{aligned} U_a &= \sin(wt) \\ U_b &= \sin(wt-120) \\ U_c &= \sin(wt+120) \end{aligned}\right\} \quad (1)$$

Multiplying the peak amplitude of fundamental input voltage with unit vector templates of equation (1) gives the reference load voltage signals,

$$V^{*}_{abc} = V_m . U_{abc} \quad (2)$$

The error generated is then taken to a hysteresis controller to generate the required gate signals for series APF. The unit vector template can be applied for shunt

Figure.3 Extraction of Unit Vector Templates and 3-Φ Reference Voltages shown in the Figure.3.The unit vector templates are generated APF to compensate the harmonic current generated by non-linear load. The shunt APF is used to compensate for current harmonics as well as to maintain the dc link voltage at constant level [13-14]. To achieve the above mentioned task.

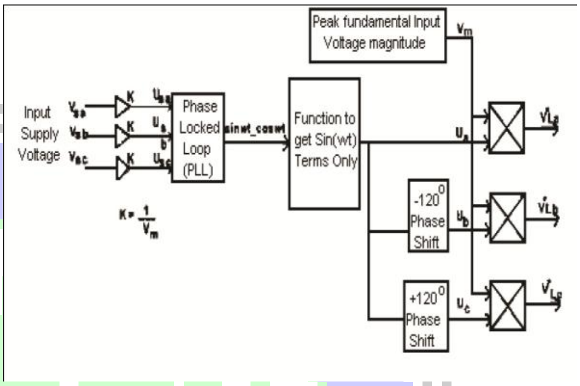


Figure.3 Extraction of Unit Vector Templates and 3-Φ Reference Voltages

the dc link voltage is sensed and compared with the reference dc link voltage. A PI controller then processes the error. The output signal from PI controller is multiplied with unit vector templates of equation (1) giving reference source current signals. The source current must be equal to this reference signal. In order to follow this reference current signal, the 3-phase source currents are sensed and compared with reference current signals. The error generated is then processed by a hysteresis current controller with suitable band, generating gating signals for shunt APF. The IUPQC uses two back-to-back connected three phase VSI"s sharing a common dc bus. The hysteresis controller is used here to control the switching of the both VSI's.

4. CONTROL STRATEGY OF IUPQC

IUPQC consists of series compensator and shunt compensator. The shunt compensator is controlled by a PWM current control algorithm, while the series converter is controlled by a PWM voltage control algorithm. According to the adopted control scheme, these two parts of IUPQC have different functions as follows:

4.1 Static Shunt Compensator

In Figure.2 the instantaneous current of the nonlinear load i_L is expanded into 3 terms. The first term i_{Ljp} is the load functions sent from PLL (Phase Locked Loop) in accordance with equation.(3)

$$I_{Ldq0} = T_{abc}^{dq0} i_{Labc}$$
(3)

By this transform, the fundamental positive sequence components are transformed into dc Quantities in d and q axes, which can easily be extracted by low-pass, filter (LPF).

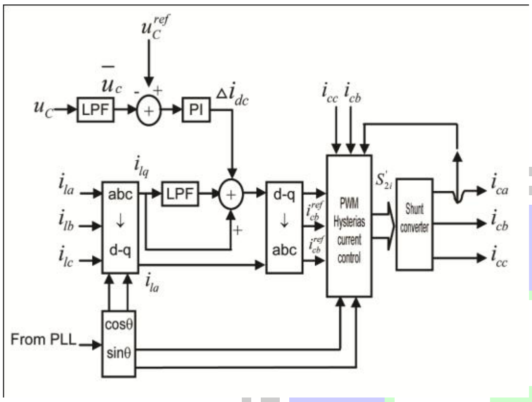


Figure.4 Control of the shunt Converter of the IUPQC

All harmonic components are transformed into ac quantities with a fundamental frequency shift.

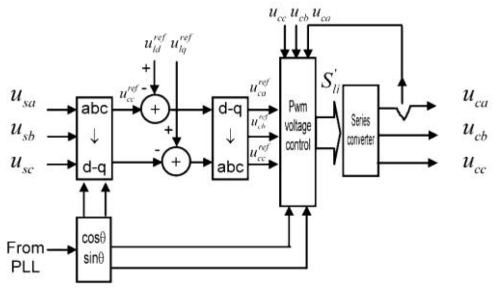
$$I_{Lq} = \bar{i}_{Lq} + \tilde{i}_{Lq} \qquad (4)$$

Since $i_L = i_s + i_c$ (5)

This means there is no harmonic and reactive components in the system currents. The switching loss can cause the dc link capacitor voltage to decrease. Other disturbances, such as unbalances and sudden variations of loads can also cause this voltage to fluctuate. In order to avoid this, in Figure 4. a PI controller is used. The input of the PI controller is the error between the actual capacitor voltage and the desired value, its output then added to the reference current component in the d-axis to form a new

4.2 Static Series Compensator

The system side voltage may contain negative-zero-sequence as well as harmonics components which need to be eliminated by the series compensator [15-16]. The control of the series compensator is shown in Figure.5. The system voltages are detected then transformed into synchronous dq-0 reference frame using equation (6).



$$U_{sdq0} = T_{abc}^{dqo} U_{sabc} = U_{sLp} + U_{sLn} + U_{sL0} + U_{sh}$$

Figure.5 Control block diagram of the series converter of the IUPQC

5. DESIGNING & TRAINING OF ANN

An ANN is essentially a cluster of suitably interconnected non-linear elements of very simple form that possess the ability of learning and adaptation. These networks are characterised by their topology, the way in which they communicate with their environment, the manner in which they are trained and their ability to process information [18]. Their ease of use, inherent reliability and fault tolerance has made ANNs a viable medium for control. An alternative to fuzzy controllers in many cases, neural controllers share the need to replace hard controllers with intelligent controllers in order to increase control quality [19]. A feed forward neural network works as compensation signal generator. This network is designed with three layers. The input layer with seven neurons, the hidden layer with 21 and the output layer with 3 neurons. Activation functions chosen are tan sigmoidal and pure linear in the hidden and output layers respectively.

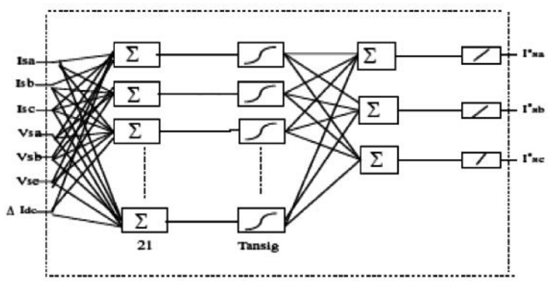


Figure.6 Network Topology of ANN

The training algorithm used is Levenberg Marquardt back propagation (LMBP). The Matlab programming of ANN training is as given below:

net=newff(minmax(P),[7,21,3],

```
{'tansig', 'tansig', 'purelin'}, 'trainlm');
net.trainParam.show = 50;
net.trainParam.lr = .05;
net.trainParam.mc = 0.95;
net.trainParam.lr_inc = 1.9;
net.trainParam.lr_dec = 0.15;
net.trainParam.epochs = 1000;
net.trainParam.goal = 1e-6;
[net,tr]=train(net,P,T);
a=sim(net,P);
gensim(net,-1);
```

The compensator output depends on input and its evolution. The chosen configuration has seven inputs three each for reference load voltage and source current respectively, and one for output of error (PI) controller. The neural network trained for outputting fundamental reference currents [20]. The signals thus obtained are compared in a hysteris band current controller to give switching signals. The block diagram of ANN compensator is as shown in Figure 7.

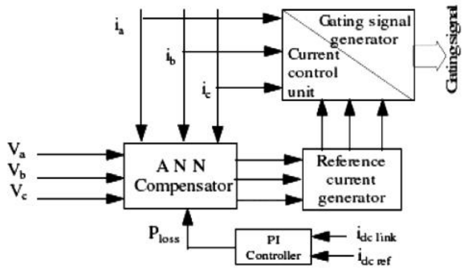


Figure.7 Block diagram of ANN-based compensator

6. SIMULATION RESULTS

The harmonic content of input and output of the Bridge converter are shown in Figure 8. (three phase voltages) and Figure 9. (three phase currents). due to non-linear loads, such as large thyristor power converters, rectifiers, voltage and current flickering due to arc in arc furnaces, sag and swell due to the switching of the loads etc. One of the many solutions is the use of a combined system of shunt and active series filters like unified power quality conditioner (IUPQC) .

This device combines a shunt active filter together with a series active filter in a back-to-back configuration, to simultaneously compensate the supply voltage and the load current or to mitigate any type of voltage and current fluctuations and power factor correction in a power distribution network. The control strategies used here are based on PI & ANN controller of the IUPQC in detail. The control strategies are modeled using MATLAB/SIMULINK. The simulation results are listed in comparison of different control strategies are shown in figures.

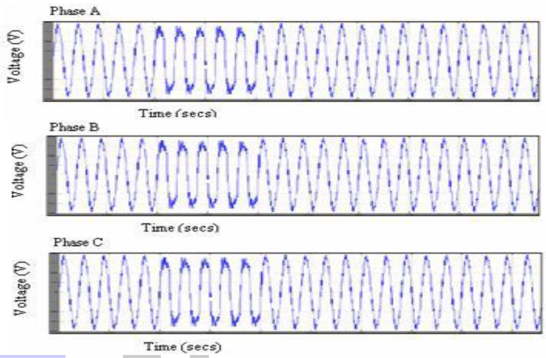


Figure.8 Wave form of 3-Φ load voltages without IUPQC for Phase A, Phase B and Phase C

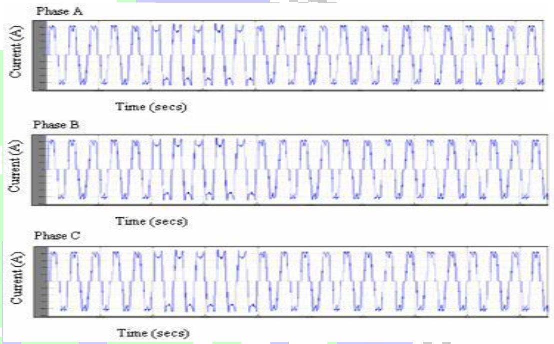


Figure. 9 Wave form of 3-Φ Source currents without IUPQC for Phase A, Phase B and Phase C

The simulation results are shown in the Figure 10. load voltages & Figure 10. Source currents of both the series and shunt APF"s and they are put into the operation at different time instant.

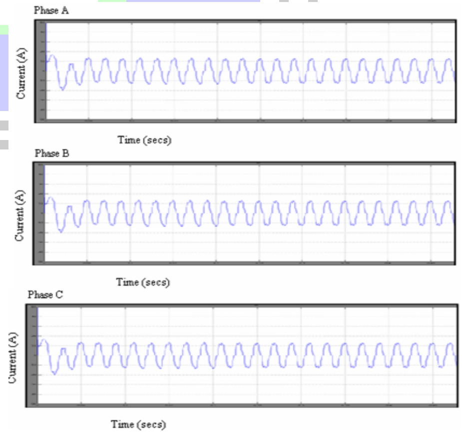


Figure. 10 Wave forms of 3-Φ Source Currents with IUPQC for Phase A, Phase B and Phase C

The shunt APF is put into the operation at instant '0.2 sec'. Within the very short time period the shunt APF maintained the dc link voltage at constant level as shown in Figure.10. In addition to this the shunt APF also helps in compensating the current harmonics generated by the nonlinear load. It is evident that before time '0.1 sec', as load voltage is distorted, As soon as the series APF put in to operation at '0.1 sec' the load current profile is also improved. Before time '0.2 sec', the source current is equal to load current. But after time '0.2 sec', when shunt APF starts maintaining dc link voltage it injects the compensating current in such a way that the source current becomes sinusoidal .Current injected by the shunt APF is shown in Figure.12. model of the IUPQC has been developed with different shunt controllers (PI and ANN) and simulated results.

Table.1 Voltage and current harmonics (THD‟s) of IUPQC

Order of harmonics	WITHOUT IUPQC utility side voltage	WITHOUT IUPQC utility side current	IUPQC with PI controller utility side voltage	IUPQC with PI controller utility side current	IUPQC with ANN controller utility side voltage	IUPQC with ANN controller Utility side current
3rd &5th	4.2	24.2	2.99	2.99	1.2	1.2
5th & 7th	4.2	24.6	3.42	3.42	1.19	1.19
7th &9th	4.2	24.6	2.18	2.18	1.3	1.3

7. CONCLUSIONS

The closed loop control schemes of direct current control, for the proposed IUPQC have been described. A suitable mathematical have been described which establishes the fact that in both the cases the compensation is done but the response of ANN controller is faster and the THD is minimum for the both the voltage and current which is evident from the plots and comparison Table.1. Proposed model for the IUPQC is to compensate input voltage harmonics and current harmonics caused by non-linear load. The work can be extended to compensate the supply voltage and load current imperfections such as sags, swells, interruptions, voltage imbalance, flicker, and current unbalance. Proposed IUPQC can be implemented using simple analog hardware, because it is having PLL and Hysteresis blocks.

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