

A novel shunt active filter algorithms for a three phase system with unbalanced and distorted source voltage wave forms feeding to adjustable speed drive

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Abstract— This paper presents the simulation of Shunt Active Power filter by using two different control schemes, indirect current control technique and ANN control technique. These two controllers are working under both balanced and unbalanced three phase voltage sources while it is feeding to adjustable speed drive. Indirect current control technique is implemented under dynamic load condition and load balanced condition. ANN control technique theory is used here to calculate the three phase compensating currents to be provided by the active filter.

Index Terms - Power Quality, Shunt active filter, indirect current control, ANN control

I. INTRODUCTION

The wide use of non-linear loads such as uninterrupted power supplies (UPS), adjustable speed drives (ASD), furnaces, and single phase computer power supplies etc cause power quality problems such as harmonic currents, poor power factor and voltage sag/swell increase in reactive power. There are several shunt active filtering algorithms published in the literature. Indirect control algorithm of the Active filter, the three-phase reference supply currents are obtained using a closed loop PI controller. A Hysteresis PWM current controller is employed over the reference and sensed supply currents to generate gating pulses of IGBT's of the Active filter. ANN based theory can work effectively under balanced as well as unbalanced source and load conditions because the compensating currents are calculated taking into account the magnitudes of per phase voltages. By using two control methods the THD values are compared and torque and speed variations for an adjustable speed drive with balanced and unbalanced voltage source are presented here. In this paper, simulation results of indirect current control technique and ANN control techniques are presented.

II. INDIRECT CURRENT CONTROL

Above fig: 1 shows the basic control scheme of the AF using indirect current control. Three-phase voltages at PCC along with dc bus voltage of the AF are used for implementation of control scheme.

Comparison of Average value of DC bus voltage (V_{dc}) and reference value of dc bus voltage (V_{dc}^*) of the AF results in a voltage error, which is fed to a PI controller as shown in figure.

$$V_{dcerror} = V_{dc}^* - V_{dca}$$

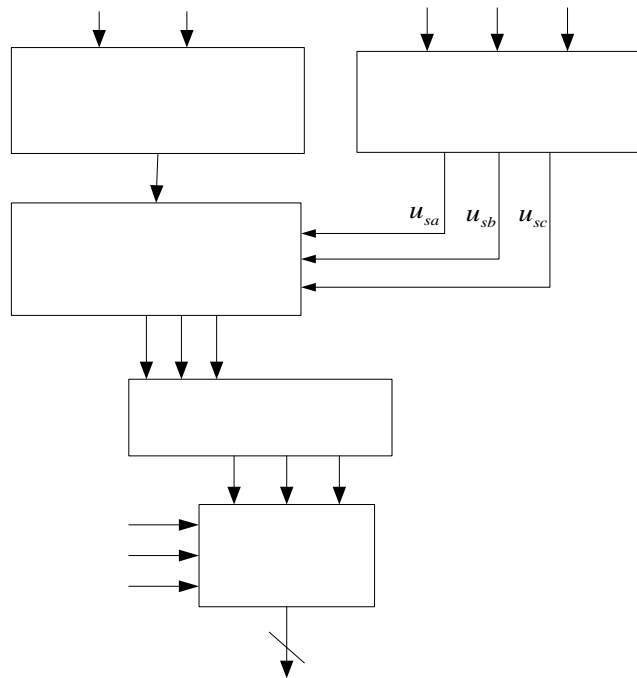
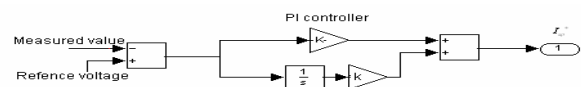
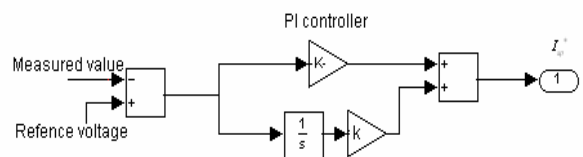


Fig: 1 Control algorithm for indirect current control



Here, proportional (K_p) and integral gains (K_i) are so chosen, such that a suitable DC bus voltage response is achieved. The output of PI controller is taken as amplitude (I_{sp}^*) of the reference supply currents.

Now, Three-phase in-phase components of the reference supply currents are computed using their amplitude and in-phase unit current vectors derived in-phase with the supply voltages, and are given by

$$i_{sa}^* = I_{sp}^* \cdot u_{sa}$$

$$i_{sb}^* = I_{sp}^* \cdot u_{sb}$$

$$i_{sc}^* = I_{sp}^* \cdot u_{sc}$$

Where u_{sa} , u_{sb} and u_{sc} are in-phase unit current vectors and are derived as,

$$u_{sa} = v_{sa} / V_{sp}$$

$$u_{sb} = v_{sb} / V_{sp}$$

$$u_{sc} = v_{sc} / V_{sp}$$

Where V_{sp} is the amplitude of supply voltage and it is computed as

$$V_{sp} = \left\{ 2/3(v_{sa}^2 + v_{sb}^2 + v_{sc}^2) \right\}^{1/2}$$

Hence from the above procedure, the three phase reference supply currents are computed.

Now the three-phase reference supply currents and sensed supply currents are given as inputs to hysteresis current controller which generates gating signals for IGBT's of the AF.

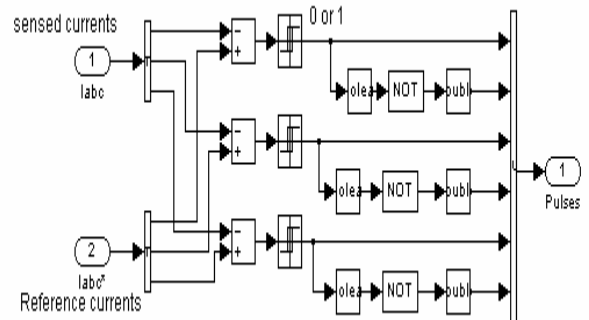
A. Implementation of hysteresis based current controller Hysteresis band PWM control is basically an instantaneous feedback current control method. The sine reference current wave is compared with the actual phase current wave. When the current exceeds a prescribed hysteresis band, the upper switch in the inverter bridge is turned off and the lower switch is turned on, and the current starts to decay. As the current crosses the lower band limit, the lower switch is turned off and the upper switch is turned on.

Hence the conditions for switching the devices are,

Upper switch on: $(i^* - i) > HB$.

Lower switch on: $(i^* - i) < -HB$.

The model of hysteresis controller, which is implemented in MATLAB for the current control purpose, is shown in below figure



Simulation model for the indirect current control is shown in fig: 2. The input inductor, Dc bus capacitor used in AF is $L_c = 3.35\text{mH}$, $C_{dc} = 1500\mu\text{F}$.

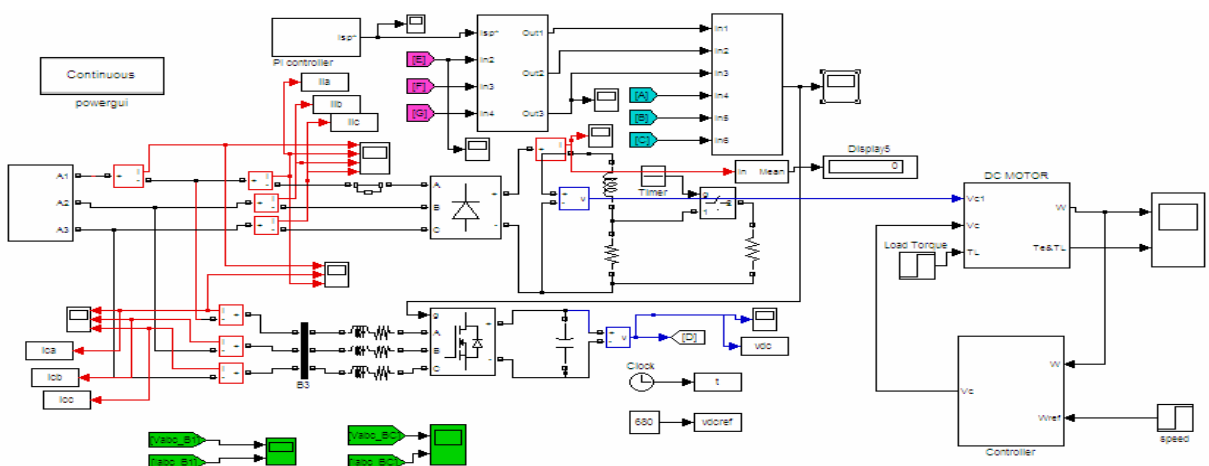


Fig: 2 Simulation model for Indirect current control scheme in SIMULINK environment.

III. ANN CONTROL TECHNIQUE

By using ANN block the three phase line currents and voltages monitored. Procedure for generating the ANN block is explained below.

Training Data generation : For the extraction of sequence currents the required inputs are three phase currents, and the corresponding outputs. The required inputs and outputs are generated in MATLAB program. In the program the input Currents are initialized to zero, and incremented in steps. By taking one thousand samples in a cycle and arranging them in a vector of three rows, outputs also arranged in required vector size depends on the no of the outputs. The input vector size and output vector size must have same no of columns. The training data is generated for both balanced and unbalanced conditions. The number of the data required is depending on the network architecture and required error tolerance.

Training the Network : The training of the network was done with MATLAB program. The training data required the number of epochs, error and min_gradient. The number of epochs depends on the error, and architecture of the network. First, the weights are initialized to random numbers. After training the first data the weights are adjusted to the required outputs. The training is done for both balanced and unbalanced conditions. After training, the network is simulated with trained inputs. If the network errors are within the predefined range then the architecture is suitable, otherwise the network architecture must be changed. After successful training the network can also give the required outputs with unknown inputs. After training the architecture is converted to simulink block.

By using ANN block monitoring the line currents and voltages, the average power is determined and distributed proportionally among the three phases according to their instantaneous phase voltage. From this power value, instantaneous current is calculated and subtracting it from the measured current, compensating component is determined.

Assume the peak values of source currents are balanced after Compensation:

$$I_{am} = I_{bm} = I_{cm} = I_m$$

Peak values of active current in each phase after compensation are

$$I_{am} = \frac{2P_a}{V_{am}}, I_{bm} = \frac{2P_b}{V_{bm}}, I_{cm} = \frac{2P_c}{V_{cm}}$$

Where Pa, Pb and Pc are real powers from each of the phases

and Vam, Vbm and Vcm are peak values of phase voltages in the three phases.

From the above equations

$$\frac{2P_a}{V_{am}} = \frac{2P_b}{V_{bm}} = \frac{2P_c}{V_{cm}}$$

Then

$$P_b = \frac{V_{bm}}{V_{am}} P_a$$

$$P_c = \frac{V_{cm}}{V_{am}} P_a$$

The total average power

$$P_{av} = P_a + P_b + P_c$$

By rearranging

$$P_a = \frac{V_{am}}{V_t} P_{av}$$

$$P_b = \frac{V_{bm}}{V_t} P_{av}$$

$$P_c = \frac{V_{cm}}{V_t} P_{av}$$

The reference active source currents are calculated as

$$i_{acc}(t) = \frac{2P_{av}}{V_{am} * V_t} v_{an}(t)$$

$$i_{bcc}(t) = \frac{2P_{av}}{V_{bm} * V_t} v_{bn}(t)$$

$$i_{ccc}(t) = \frac{2P_{av}}{V_{cm} * V_t} v_{cn}(t)$$

Where

$$V_t = V_{am} + V_{bm} + V_{cm}$$

The compensating current is obtained as

$$i_{can}(t) = i_{an}(t) - i_{acc}(t)$$

$$i_{cbn}(t) = i_{bn}(t) - i_{bcc}(t)$$

$$i_{ccn}(t) = i_{cn}(t) - i_{ccc}(t)$$

The generation of training data and training the neural network is done in using the neural network toolbox commands. The neural network structure is converted into simulink diagram using the command gensim, to interface with the other power system blocks. The fig:3 shows the 3 layers of the neural

network and the fig:4 shows the inside view of a layer. The fig:5 shows the no of the neurons of a layer. Simulation model for the ANN control technique is shown in fig: 6.

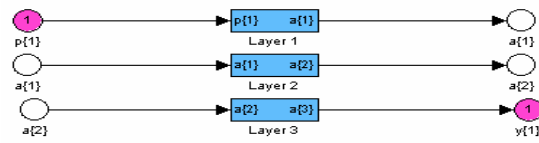


Fig: 3 3Layer Feed-forward Neural Network

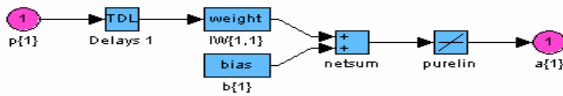


Fig: 4 view of single Layer

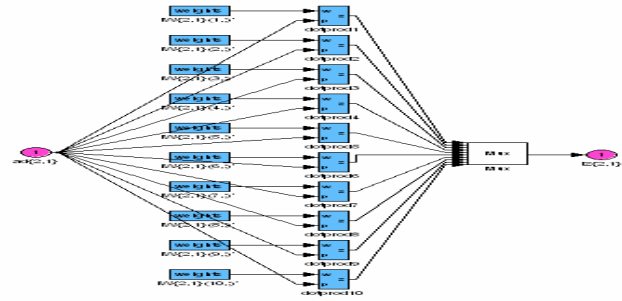


Fig: 5 View of Weights of the layer one

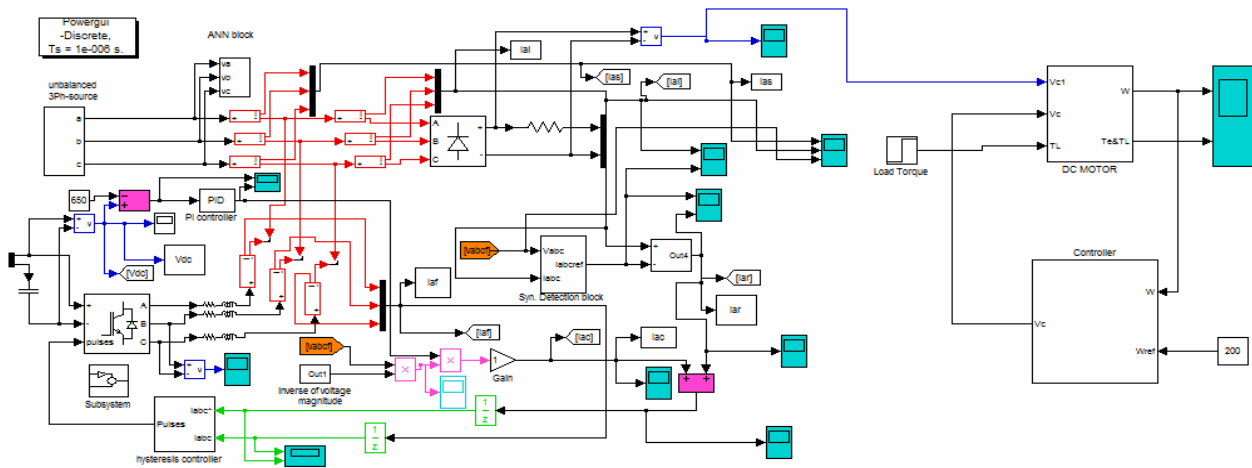


Fig: 6 Simulation Model for Shunt active Filter for proposed ANN method

IV. SIMULATION RESULTS

The simulation results of the shunt active power filter is carried in MATLAB/SimPowerSystems environment. The simulation results are shown below. As can be seen from the figure, the non-linear load is a three-phase bridge rectifier feeding an adjustable speed drive. The simulation is done for various source and load conditions for providing harmonic compensation, load balancing and reactive power compensation. It can be clearly seen that by using ANN control technique THD value is less compared to indirect current control technique.

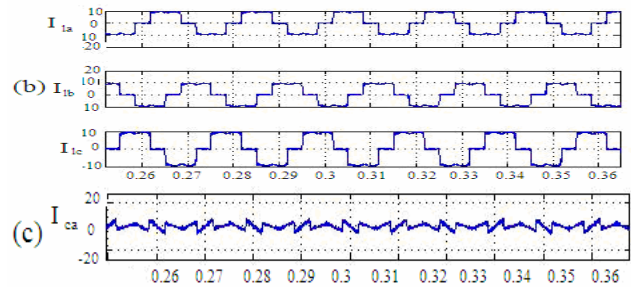
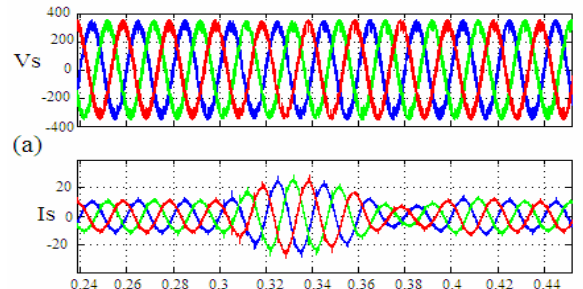
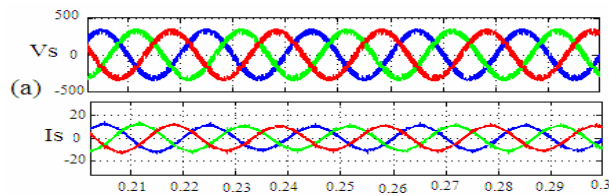


Fig: 7 Indirect current control wave forms of three phase
(a) Supply voltage & current (b) load current (c) filter current



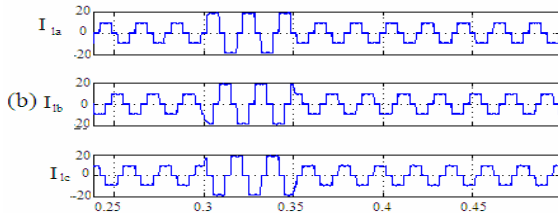


Fig: 8 Indirect current control wave forms under dynamic

Load condition. Three phase (a) supply voltage & current (b) Load current

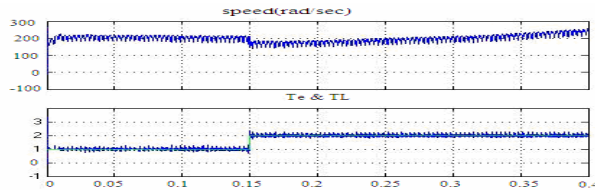


Fig: 9 speed & torque wave forms for Indirect current control

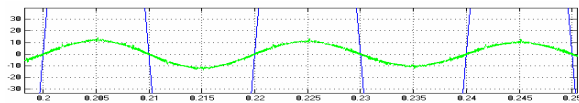


Fig: 10 supply voltage & current waveform PF is unity

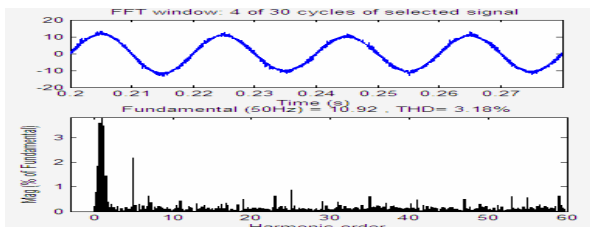


Fig: 10 Indirect control FFT analysis for supply current

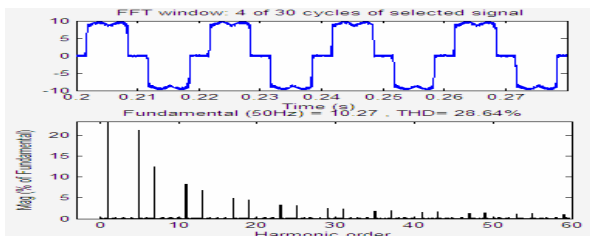


Fig: 11 Indirect control FFT analysis for load current & filter current

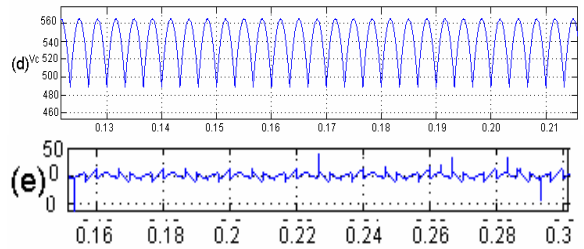
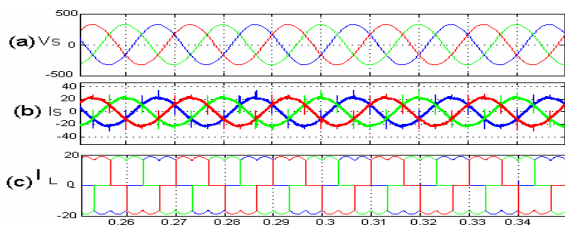


Fig: 12 ANN control wave forms under balanced voltage. Three phase (a) supply voltage (b) supply current (c) Load current (d) output voltage (e) filter current

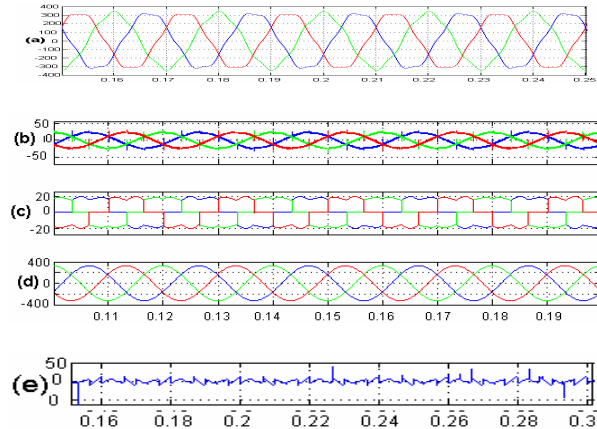


Fig: 13 ANN control wave forms under unbalanced voltage. Three phase (a) supply voltage (b) supply current (c) Load current (d) supply voltage after balancing (e) filter current

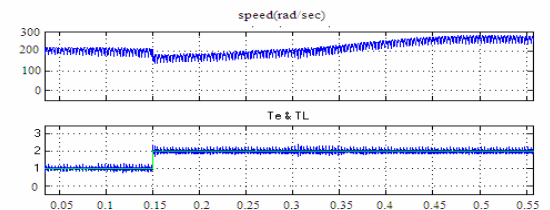


Fig: 14 speed & torque wave forms (ANN)

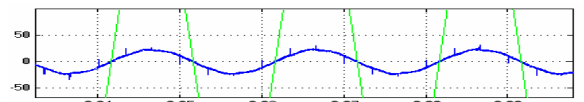


Fig: 15 supply current & voltage PF is unity

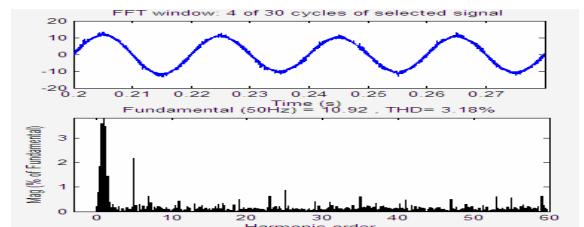


Fig: 16 FFT analysis for supply current (ANN)

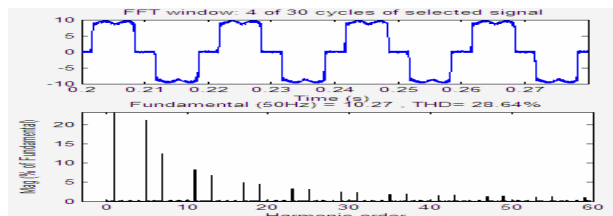


Fig: 17 FFT analysis for load current, filter current (ANN)

V. CONCLUSIONS

In this paper, indirect current control and ANN control methods using equal current division technique has been applied to a shunt active power filter to compensate for reactive and harmonic currents under balanced and unbalanced source voltage conditions. The simulation has been carried out in MATLAB/SIMULINK environment and power factor is unity for supply voltage, current.

VI. REFERENCES

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