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Intelligent Technique Based Shunt Active Filter To Reduce Harmonics In Power Systems

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Abstract

This paper studies a Fuzzy Logic Control Based (FLCB) Shunt Active Filter (SAF) capable of reducing the total harmonics distortion (THD) in Power System (PS). SAF is one of the key controllers in Flexible Alternating Current Transmission System (FACTS) to control the transmission line voltage and can be used in PS to enhance the power transmission capacity and extend the transient stability. In order to improve the power factor, compensate the reactive power and suppress the total harmonic distortion (THD) drawn from a Non-Linear Diode Rectifier Load (NLDRL) of SAF, we propose a Hierarchical neuro-fuzzy current control scheme for a shunt active power filter for the Pulse Width Modulation technique which is used as control for the switches of the Voltage Source Inverter (VSI) or SAF. The synchronous reference D-Q frame theory is used to detect the harmonic currents and to generate the reference compensating currents for SAF. A fuzzy logic based control is developed to regulate the voltage of the DC capacitor. The system with control scheme is implemented in Mat lab/Simulink.

Keywords: Neuro-fuzzy logic, shunt active power filter

Introduction

In recent years there has been an increasing interest in the subject of harmonic generation and its effects on power systems. The effects of harmonics are becoming a growing problem facing the utilities now and in the future. This is attributed to extensive use of nonlinear power electronic devices and power plant components which are capable of producing considerable harmonic distortion in the network. As the tendency in the use of more and more nonlinear power components increases, the need for a reliable method of harmonic mitigation becomes an important matter in power system planning, analysis and operation. The active power filter appears to be a viable solution for eliminating harmonic currents as well as for reactive power compensation. Fuzzy logic and neural network techniques are now being increasingly applied to power electronics. In this paper a hierarchical neuro-fuzzy current control scheme for a shunt active power filter is presented. In this paper first a single fuzzy controller based active power filter is presented. In order to improve the performance of the single fuzzy controller system an increase in the number of inputs and membership functions was necessary. A neuro-fuzzy controller, which we call hierarchical neuro-fuzzy control, is connected hierarchically to the output of the first fuzzy logic controller to improve the performance. Since standard fuzzy logic controllers suffer from exponential increase in the number of rules with the number of input variables, we opt to employ hierarchical fuzzy systems that are known to reduce the computational burden.

Here, the main work is to detect the harmonics level and to generate the reference current to suppress it. The performance of the proposed control scheme is evaluated through computer simulations under steady state and transient conditions. The harmonic elimination and reactive power compensation ability of the SAPF under non-ideal grid voltages is investigated.

Control of Shunt Active Filter

The typical components of an active power filter system are the mains supply, a nonlinear load, a reference current estimator, a PWM current controller and a voltage source inverter with an interface reactor. The information regarding the harmonic current generated by a nonlinear load is supplied to the reference current estimator together with information about other system variables. The reference signal from the current estimator, as well as the other signals provides the control for the PWM current controller. The output of the PWM current controller controls the voltage source inverter via a suitable interface Reactor.

The main components of an active power filter system with the proposed hierarchical neuro-fuzzy current controller are shown in Fig. 1.

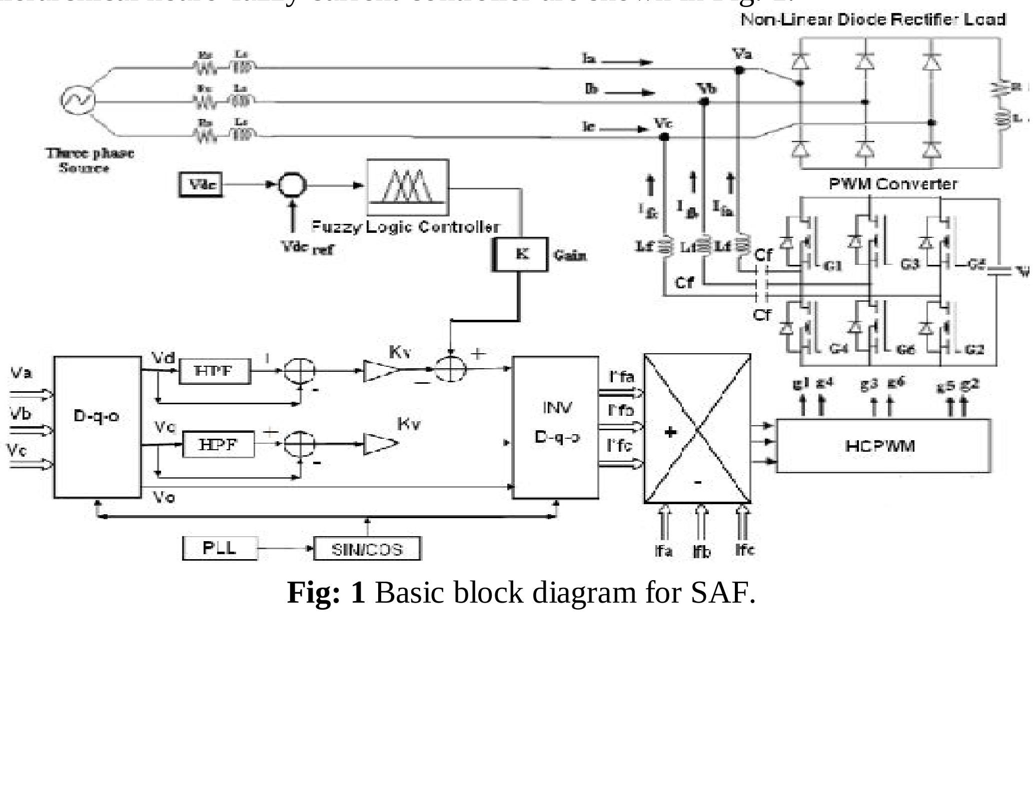


Fig: 1 Basic block diagram for SAF.

The fuzzy controllers for the single fuzzy controller scheme are characterized as follows:
3 fuzzy sets for each of the 2 inputs.
3 fuzzy sets for the output.
Triangular and trapezoidal membership functions.
Implication using the "min" operator.
Mamdani fuzzy inference.
Defuzzification using the "centroid" method.

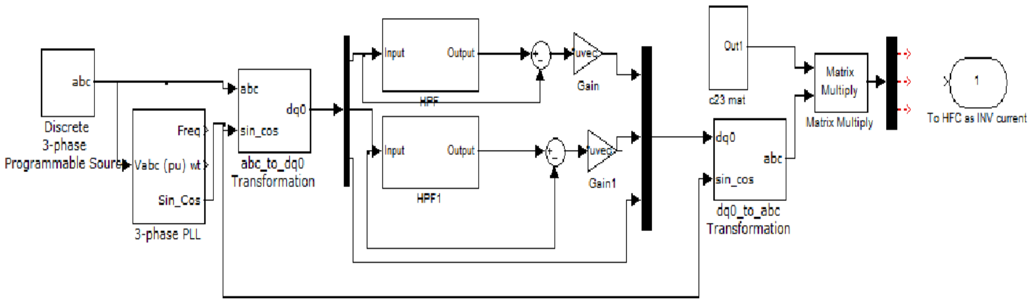


Fig 2: Getting Ia, Ib, Ic currents for HFCPWM input.

The performance of the active filter mainly depends on the methodology adopted to generate the reference current and the control strategy adopted to generate the gate pulses.
The control strategy is implemented in three stages.
The essential voltage signals are measured to gather accurate system information.
Compensating currents are derived based on synchronous reference D-Q theory.
The gating signals for the solid-state devices are generated using HFCWM control method.

There are several methods to extract the harmonic components from the detected three-phase waveforms. Among them, the so-called D-Q theory based on time domain has been widely applied to the harmonic extraction circuit of SAF. The detected three-phase voltage is transformed into the D-Q-0 co-ordinates as shown in Fig.2.

Two first order digital high pass filters (HPF's) with the same cut off frequency as 20 Hz extract the dc component Vhd*, Vhq* and V0 which corresponds to the fundamental frequency in the coordinates. The line voltage regulation part is performed by a feedback control. Two co–ordinates Vd and Vq is compared with harmonic extracted voltage Vhd* and Vhq*. A gain KV amplifies and to produce current references for harmonic damping Ihd, Ihq, and I0 as shown in equations 1,2, and 3. The current reference for the voltage source inverter is the sum of the current references from the three parts, as follows:

$$I^*fd\,(s) = Kv\,(Vdc^* - V\,dc) \qquad (1)$$
$$I^*fq(s)=Kv(Vhq^*-Vq) \qquad (2)$$
$$I^*0(s)=1/3(Va+Vb+Vc) \qquad (3)$$

Fuzzification of Inverter Current with Reference Load Current

The fuzzy logic controller (1) has two inputs, named error and error rate and one output named actuatingsig. Error is the difference between voltage source inverter current data and reference current data for each phase.

Error = Iinv – Iref

The linguistic rules for the fuzzy logic controller) are as follows:

1. If error is big and error rate is high then actuating sig is dec.
2. If error is zero and error rate is high then actuating sig is dec.
3. If error is small and error rate is high then actuating sig is inc.
4. If error is big and error rate is zero then actuating sig is dec.
5. If error is zero and error rate is zero then actuating sig is constant.
6. If error is small and error rate is zero then actuating sig is inc.
7. If error is big and error rate is low then actuating sig is dec.
8. If error is zero and error rate is low then actuatingsig is inc.
9. If error is small and error rate is low then actuatingsig is inc.

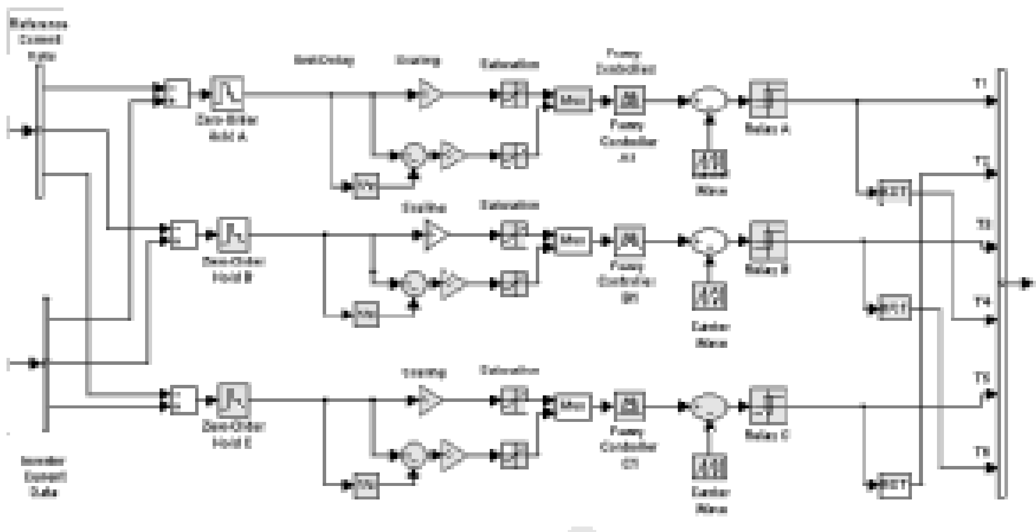


Fig 3. Circuits with two Fuzzy controllers (1 & 2) to regulate the switching signals (T1 – T6) for converter.

Triggering of Mosfet's with (T1-T6) Controlled By FLC

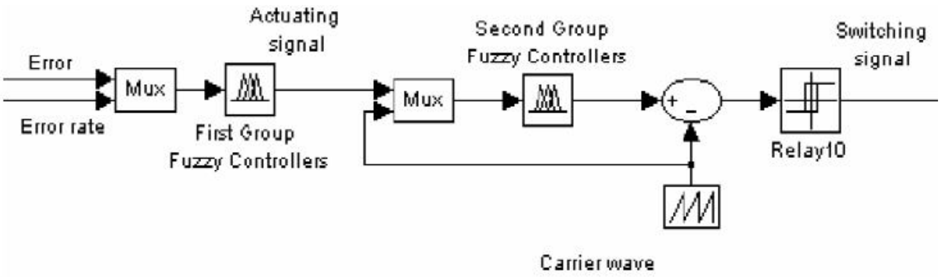
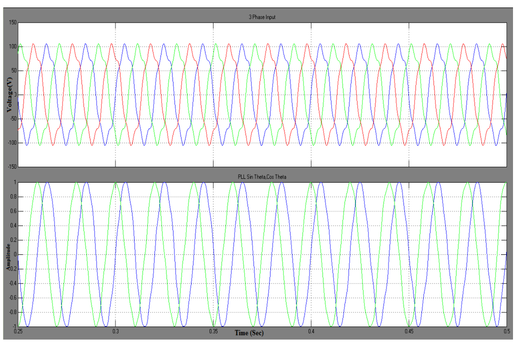


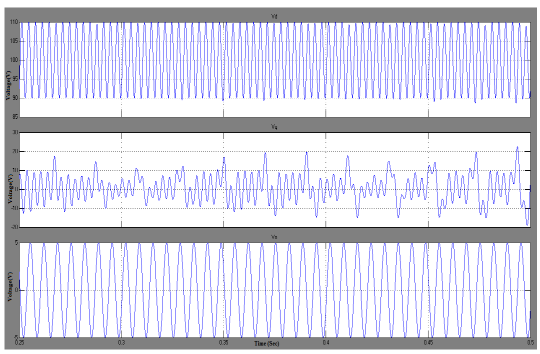
Fig 4: FLC (2) giving switching signals.

Fig. 4 explains the generation process of switching signals in the model. The output of the fuzzy controller is the actuating signal and this output is compared with a carrier signal. The relay element is set to give output when the input of itself is greater than 0. The output of the fuzzy controller is set to take values between –0.622 to 0.622. The carrier signal is set to take values between –0.55 to 0.55.

The important point here is that the second group controllers employed in the model are Adaptive Neuro Fuzzy Inference Systems. They are developed by using the ANFIS tool of the MATLAB Fuzzy Logic Toolbox. They are employed to correct error points of the first group controllers. As explained before, without controlling the carrier signal, it may not be known, what the switching signals are, if the error or error rate is not high enough to make the output value high enough to pass the carrier signal. To correct this, a training data has been developed that includes the input/output data pairs of the neuro-fuzzy controllers in the second group. This training data is based on the input-output characteristics of the first group fuzzy controllers. In this training data, at the error points, by using the reference signal input, the correct output values are trained to neuro-fuzzy controllers.

Simulation and Its Results In MATLAB/SIMULINK.





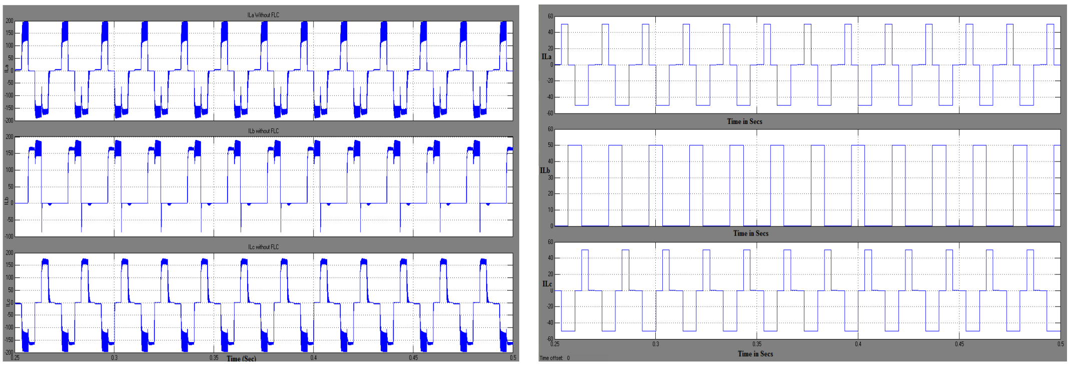


Fig 5: (A) Shows the Input 3 phase voltage values with constant Sin/Cos waves.
(B) Shows the converted of Vd, Vq, and V0.
(C) Shows the Currents ILa, ILb, and ILc with harmonic content, without FLC.
(D) Shows the Currents ILa, ILb, ILc without harmonic content, with FLC.

Parameter Values

Source Impedance = 0.1ohm and 0.03mH
Load impedance = 10ohm, 1mH and 1microF
Rp = 0.01ohm
Lp = 0.07e-6H
Lf = 1.26e-3
Cf = 21.5 e-6

Conclusion

This paper focused on applying a hierarchical neuro-fuzzy current control scheme to shunt active power filter. Problems faced on performance improvement of the single fuzzy control scheme are overcome by developing an ANFIS based neuro-fuzzy controller connected hierarchically to the first fuzzy controller. Combining neural-nets and fuzzy logic, the ANFIS controller minimizes system cost by optimizing the number of rules and membership functions, reduces memory requirements and creates fuzzy solution in the form of if-then rules, which is more robust and reliable and can work well under a wider range of operating conditions. Simulation results show that proposed method provides a superior current tracking capability and an improved filtering performance to reduce the harmonics in supply lines during transmission.

References

[1] Pawel Z. Grabowski, Marian P. Kazmierkowski, Bimal K. Bose and Frede Blaajberg, “A Simple Direct –Torque Neuro-Fuzzy Control of PWM-Inverter-Fed Induction Motor Drive”, IEEE Transactions On Industrial Electronics, Vol. 47, No. 4, August 2000, pp. 863-870.

[2] S. K. Jain, P. Agrawal and H. O. Gupta, “Fuzzy Logic Controlled Shunt Active Power Filter for Power Quality Improvement”, IEEE Proc. Electr. Power Appl. Vol.149, No.3, September 2002, pp. 317-328.

[3] E.E.EL-Khoy,A.EL-Sabbe, A.El-Hefnawy, and Hamdy M.Mharous,Three phase active power filter based on current controlled voltage source inverter, Electrical Power and Energy Systems, 28 (2006), 537-547.

[4] S.K.Jain, P.Agrawal and H.O.Gupta, Fuzzy Logic controlled shunt active power filter for power quality improvement, IEEE proceedings in Electrical Power Applications, Vol 149, No.5, September 2002.

[5] V.Agelidis, M. Calais, Application specific harmonic performance evaluation of multicarrier PWM techniques, IEEE-PESC’98 Conference Record, pp. 172-178, 1998.G. Carrara, S. Gardelta, M. Murchison, A new multilevel PWM method: theoretical analysis, IEEE Trans. On power electronics Vol. 7. No. 3, July, pp.497-505, 1992.

[6] Mikko Routimo, Mika Salo and Heikki Tuusa, “A Novel Simple Prediction Based Current Reference Generation Method for an Active Power Filter”, IEEE 2004 35th Annual IEEE Power Electronics Specialists Conference.

[7] Hsiung Cheng Lin “Intelligent Neural Network-Based Fast Power System Harmonic Detection”, IEEE transactions on industrial electronics, vol. 54, no. 1, February 2007.

[8] Rachid.Dehini, Abdesselam.Bassou, Brahim.Ferdi “Artificial Neural Networks Application to Improve Shunt Active Power Filter”, International Journal of Computer and Information Engineering 3:4 2009.

[9] Rachid Dehini, Abdesselam Bassou, Brahim Ferdi “The harmonics detection method based on neural network applied to harmonics compensation”, International Journal of Engineering, Science and Technology Vol. 2, No. 5, 2010, pp. 258-267.

[10] Avik Bhattacharya, and Chandan Chakraborty, “A Shunt Active Power Filter With Enhanced Performance Using ANN-Based Predictive And Adaptive Controllers”, IEEE Transactions On Industrial Electronics, Vol. 58, NO. 2, February 2011