VARIOUS OPTIMIZATION STRATEGIES OF CONTROLLER UTILIZED ON THE SHUNT ACTIVE POWER FILTERS

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Abstract— The application of various controllers to a three-phase shunt active power filter is described in this paper. The results are compared. The controllers used for comparison are the PI (proportional-integral) controller, FUZZY LOGIC controller, genetic controllers, PI-VPI controllers. These controllers are used to improve power quality, such as reactive power and harmonic current compensation. The harmonics are produced when the source is linked to nonlinear loads. To render the supply currents sinusoidal, the payment is made. Those controllers control the dc capacitor voltage and generate reference source currents. A comparative assessment of the three-phase shunt active power filter's simulation results was carried out using various controllers.

Keywords- Shunt active power filter (SAPF), Fuzzy logic, genetic algorithm, PI-VPI controller, PI controller nonlinear load, harmonic current compensation

1. INTRODUCTION

In modern distribution systems, nonlinear loads, such as adjustable speed drives, electric arc welders and uninterruptible power supplies, are increasingly used. These nonlinear loads generate harmonics. These harmonics are responsible for specific power quality problems, such as distortion of voltage, increasing power loss, electromagnetic interference, operating failures, etc. As they are small in size and less in cost, LC filters are used for harmonic compensation. There are certain disadvantages to LC filters, and so APF is used for harmonic balance. In polarity, the APF is switched to inject equal but opposite to harmonic load-drawn currents and inject it to the point of standard coupling. The controller is an essential part of the shunt active power filter, and it extracts the fundamental load current component. Various forms of controls may be used. SPF can compensate for the harmonics generated by several forms of nonlinear loads and provide a fast response to load variations.

Fig 1 illustrates the general block diagram of the harmonic compensation using the shunt active power filter[1-11].

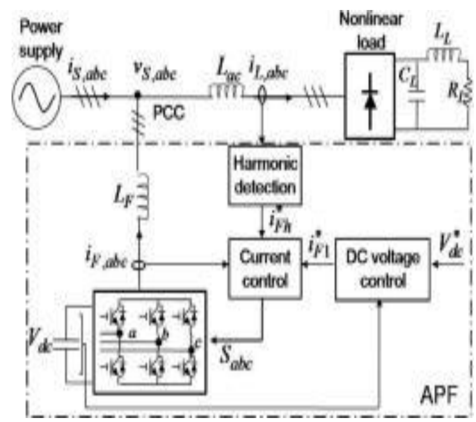

Fig 1 Block diagram of shunt active power filter

The results of APF design using different controllers are compared, and the results are discussed.

2. DESIGN OF SHUNT ACTIVE POWER FILTERS

In industrial AC drives, three-phase diode bridge rectifiers are often used as loads. In the processing of harmonics, these nonlinear loads are responsible. Because of these harmonics, severe problems that deteriorate the power quality are caused[1] to prevent all these problems. Active control filters have been developed to compensate for the harmonic currents and thereby increase the efficiency of the power.The APF illustrated in Fig1 is commonly considered a three-phase voltage source inverter connected in parallel to the load at the point of standard coupling. It has been previously mentioned that the APF should generate harmonic currents to compensate for the harmonics generated by nonlinear loads and to make the supply voltage sinusoidal.

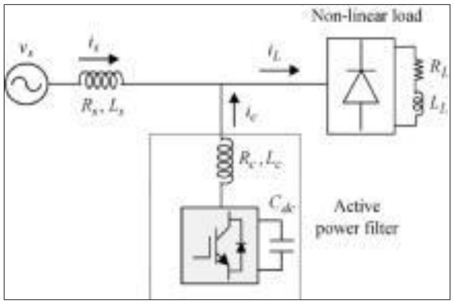

Fig 2 Basic block diagram

Fig 2 illustrates the basic current compensation using SAPF. From the figure, the instantaneous current is given by

Is(t)=i1(t)-ic(t)   (1)
The source voltage is given by
Vs=Vm sin wt   (2)

When the nonlinear load is applied, the load current will have a fundamental component and harmonic components. Using SAPF, these harmonic currents are removed. In this paper, the simulation results of various control algorithms have been discussed and compared.

3.PI CONTROLLER

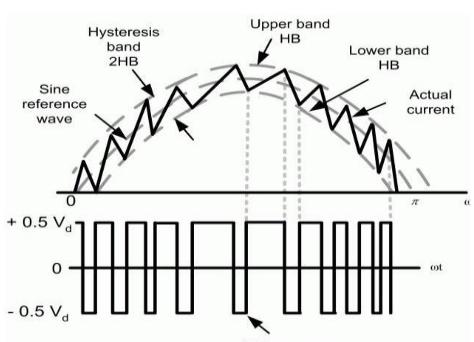

Fig 3. Compensating currents

The block diagram of the SAPF PI control scheme is shown in Fig 3. The capacitor's voltage on the DC side is sensed, and this sensed voltage is contrasted with the reference voltage. The methods of reference voltage estimation can be applied as time-domain control and frequency domain control.

The frequency-domain regulation technique is based on the Fourier relation of the distorted voltage or to derive compensating current/voltage.

PDF control methods in the time domain are based on the instantaneous derivation of distortion or harmonic voltage or current signal compensating commands. The time-domain algorithms are the reactive power algorithm (p-q), the fictitious power compensation algorithm and the algorithm for synchronous flux detection instantaneously. Using hysteresis, PWM, multi resonant control, the switching signals for the solid-state devices of APF are produced. Instantaneous reactive power theory (PQ method) is used for harmonic detection in this proposed control scheme to measure the active power filter's reference currents.

4. CONTROL OF COMPENSATING CURRENT USING HYSTERESIS METHOD

The compensating current influence using the approach to hysteresis is shown in Fig 3. The hysteresis band (HB) is the potential boundary of the compensating current(ic) according to figure 4. This current oscillates between the upper and lower limits of hysteresis. Depending on the pattern switch of IGBT within the APF, the compensating current can be increased or decreased. When IGBT turns on, ic will be boosted before the upper limit of hysteresis is reached.

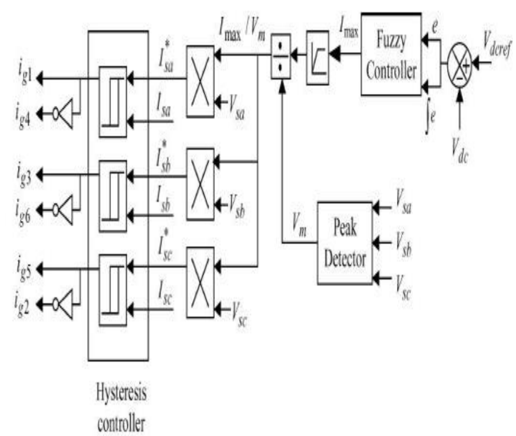

Fig 4 Fuzzy logic control of SAPF

IGBT will be shut off automatically at this point to reduce the compensating current. If wind falls to the lower limit, the IGBT will turn on again automatically to raise the compensating wind. Therefore, after the current reference ic, the recent compensating swings within HB. By PQ harmonic detection, the reference current can be identified.

5.FUZZY CONTROLLER

In PI controllers, which are hard to obtain, linear mathematical models are required. Fuzzy controls that do not need any mathematical model are used to solve the disadvantage. Mamdani fuzzy control[3] is the fuzzy controller that provides the best result for APF control. Still, it has a large number of fuzzy sets. For real-time applications with short sampling time, it can not be used. Over Mamdani controllers, the TS fuzzy controllers have the following advantages[2].

- The number of laws that should be used
- Number of optimized coefficients
- For input fuzzification, the number of fuzzy sets used
- Calculation Time

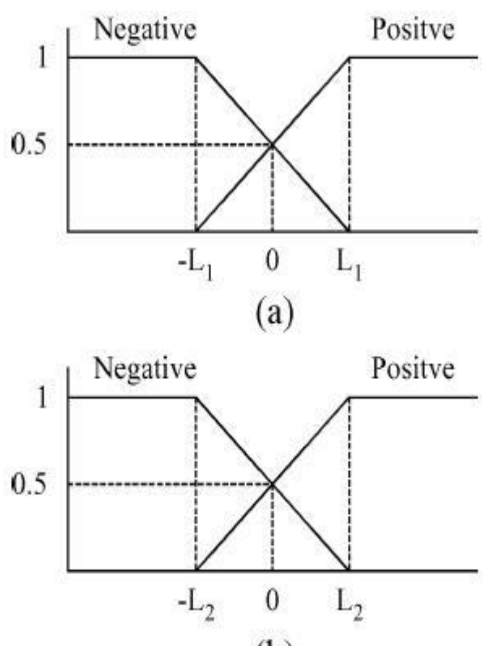

Fig 5 Membership functions

The block diagram of SAPF fuzzy logic control is illustrated in Fig 4. The acquired error signal and the incorporation of error signals are used as ambiguous inputs[2] in fuzzy logic control. The output will be considered as the peak reference voltage. The currents obtained by comparing the draft of the real source and the reference currents generate switching signals. Using the TS fuzzy controller, an infinite number of gain variation properties are obtained. In the dc capacitor voltage's fuzzification, two input fuzzy sets (positive set and negative set) are used. To control the inverter's switches to maintain the current inside the inverter, a hysteresis current controller (Fig. 4) is introduced.

Fig 5a and 5b illustrates the membership functions for x1 and x2.L_1 and L_2 values are chosen based on the maximum value of error and its integration.

6. GENETIC ALGORITHM

Stochastic approaches that imitate the metaphor of natural biological evolution are evolutionary algorithms. To generate better alternatives to a solution, evolutionary algorithms work on a population of possible solutions applying the fittest survival theory. The following description summarizes the genetic algorithm

The algorithm starts with random population creation.

- The algorithm then generates a series of new populations. GA conducts the following steps to establish new communities.
- By computing its fitness value, each number of the present population scores.
- To change them into a more usable range of values, the raw fitness score scales
- Chooses fitness-based members called parents.
- Selects members called parents based on appropriateness.
- Some of the individuals in the present population that have lower fitness are chosen as elite
- produces children from the parent
- replaces the current population with the children to form the next generation

The algorithm stops when one of the discontinuing criteria is met

APF is controlled using a GA controller. A fitness function executes it for suppressing the harmonics. The reference currents are obtained from the PQ theory.

7.VPI CONTROLLERS

The control scheme can be streamlined, and an advanced control strategy using VPI controllers improves APF's accuracy. The APF block diagram operated by a VPI controller is illustrated in Fig 6. In the fundamental reference frame, the VPI current controller is constructed. The current controller outputs are added along with the feed-forward supply voltage and then converted into the stationary reference frame. The transfer feature in the s-domain of VPI controllers is

$$G_{PI-VPI} = K_{p1} + \frac{K_{il}}{s}\sum_{h=6.....30} 2\,\frac{K_{ph}s^2+K_{rh^8}}{s^2+(h\omega_s)^2}$$

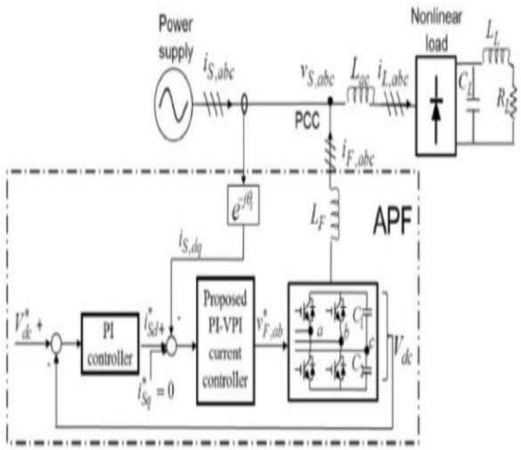

Fig 6. Block diagram of PI-VPI controllers

Without the need for current calculation and harmonic detector, the harmonic currents are compensated, which increases APF accuracy.

As follows, the transfer function of PI controllers plus VPI controller

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$$G_{PI-R} = K_{p1} + \frac{K_{il}}{s}\sum_{h=6,12,18.....} K_{ph}\frac{2K_{rh^8}}{s^2+(h\omega_s)^2}$$

The simulation results are obtained and, compared with other controllers, it is found to be the best. As PI-VPI controllers are used, the per cent THD value gets reduced to the lowest value.

8. SIMULATION RESULTS AND DISCUSSIONS

MATLAB/SIMULINK is used to investigate the outcomes of proposed PI, GA and fuzzy controllers. Machine parameters are voltage (Vs) 230 Vrms, system frequency (f) 50 Hz, RS source impedance, LS 0.1mH, Rc filter impedance, Lc 1; 2.7 mH, RL load impedance, LL diode rectifier RL load in steady state: 200 mH and Transient: 10 100 mH, DC link capacitance (CDC) 1600 F, reference voltage (VDC) 400 V and IGBT/Diode control devices used. Table 1 provides comparison of different controllers.

Table 1 comparison of performance of different controllers

CONTROLLERS	**%THD**
PI controller	5.57
GA controller	2.66
TS fuzzy controller	1.74
VPI controller	1.65

9.CONCLUSION

The harmonic distortions in the line of the power system are of significant concern. APF is being used to address this problem. Using various controllers, APF's can be monitored, and the controllers' simulation results are compared. This allows the power quality parameters to be improved. After compensation, the THD of the source current is less than 2 per cent of the harmonic limit set by the IEEE-519 standard. The VPI controller seems to be an appropriate candidate for an active power filter to solve power quality problems. Also, under distorted conditions, the supply current is made sinusoidal and in-phase with the supply voltage.

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