Fuzzy Logic based PWM Switching Scheme for Shunt APF under Adverse Supply and Load Conditions

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Abstract. This article discusses the SSPF's design and development success with the updated controller. The aim of this SAPF was to compensate for three-phase harmonics and reactive power (3P3W). Shunt APF performance, heavily affected by DC link voltage stabilization. The DC-link voltage is reactive to load impedance changes that contribute to the system overtaking and carrying out. The DC-like voltage will experience huge conditions as charging and voltage distortions change. The PI controllers are known to regulate the DC connection voltage at their benchmark. In such situations, the optimisation of PI control gain parameter tuning can be achieved by means of an improved fuzzy logic control algorithm. In addition, PWM control techniques improves the switching action which enhances the shunt APF. The Fuzzy logic based PWM scheme is developed by MATLAB/Simulink. The controlling algorithm output is obtained by removing the current harmonics under adverse supply voltage and load conditions.

1. Introduction

In the modern electrical system, power electronics plays an important role. Direct application of electronic electronic electronic power equipment in commercial and residential applications, aerospace applications, manufacturing applications etc. In comparison, the electronics pollute with harmonic current injection the electrical delivery system. The machine is therefore of a degraded power standard (PQ). Many scientists and electrical engineers work to overcome these issues [1-2]. Many machine PQ issues are solved in Custom Power Devices (CPDs) [3]. SAPFs are a CPD designed to alleviate many harmonic problems associated with the current situation. In order to address these PQ issues, the Shunt Software uses control technology. In our publication we give many control techniques including enhanced power balance theory, synchronous SRF theory, etc. (EPLL), unit template technique, instantaneous reactive power theory). [4-6] The voltage and load conditions of supply are heavily affected by these control techniques. Because of their simple implementation and versatile control, many researchers and industries use PI controllers. Tuning PI parameters is therefore a major meeting for the researchers. The SISO function is the tuning of PI controller values that boost the functioning of APF shunt [6-8].

The following sections categorize this article. Section 2 is about constructing the shunt APF's framework in real time. The current measurement of reference is modelled by generalized p-q theory and explained in Section 3. Section 4 depicts and follows assumptions on design and production of shunt APF using updated controls.

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2. System Architecture

Figure 1 displays the block diagram of SAPF. A appropriate harmonic compensation, reactive power and real power are supplied with a voltage source inverter (VSI) on the DC side with an electrolytic condenser during load transportation. This VSI is connected to the grid through some fluid inductors at the interface point (PoI) (Lf). This fluoridation inductor function is to supply the electricity from the VSI to the grid and to remove the ribs from the countervailing streams. The AC main grid has a rectifier load. This bridge rectifier incorporates harmonics into the grid in the dominant third order.

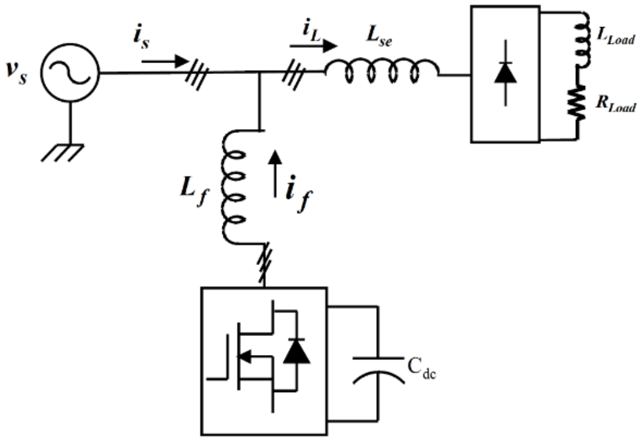


Figure 1. Block diagram of hardware implementation of shunt APF

3. Modified Generalized P-Q Theory

A modified control scheme is implemented to mitigate PQ problems with shunt APF. There are many control technique are available in the literature to generate reference currents. The generalized *p-q* control technique invented by *H. Akagi* et. al in 1983 [4] is simple and effective solution for generation of reference currents. In *p-q* theory, first the a-b-c coordinates are converted to two-phase system coordinates using parks transformation as follows:

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \tag{1}$$

The load currents in orthogonal components are i_α and i_β, as follows:

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \tag{2}$$

The instant actual AC power can be calculated as follows:

$$P_{ac} = v_\alpha i_\alpha + v_\beta i_\beta \tag{3}$$

The low-pass filter (LPF) used for extracting AC and DC powers as follows:

$$\mathrm{P_{dc(loss)}} = \left[\mathrm{V_{dc,ref}} - \mathrm{V_{dc}} \right] \left[\mathrm{K_p} - \frac{\mathrm{K_i}}{\mathrm{s}} \right] \tag{4}$$

The total power is shown as follows:

$$P = \overline{P}_{ac} + P_{dc(loss)} \tag{5}$$

$$\begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \end{bmatrix} = \frac{1}{u_\alpha^2 + u_\beta^2} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} p \\ 0 \end{bmatrix} \tag{6}$$

From above Eq. (6), the $i_{s\alpha}$ and $i_{s\beta}$ currents are used for calculating the reference currents as follows:

$$\begin{bmatrix} i_{sa}^* \\ i_{sb}^* \\ i_{sc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \end{bmatrix} \tag{7}$$

The actual and generated reference currents are compared and error will be generated. This error will be goes through the hysteresis controller for switching pulse generation for power electronic switches of SAPF

Details of the Proposed Technique

With input membership functions and output membership functions, as well as specific rules, fuzzy logic improves the efficiency and reliability of particular membership functions (MFs). Traditional FLC models are divided into two categories: mamdani FLC and Takagi-Sugeno FLC. Takgi-Mamdani Sujino's FLC is instinctive and widely known. As a result, mamdani FLC is taken into account, and the input MFs are created using switching moments calculated offline using the Newton-Raphson method for various mi values. This serves as a sort of look-up table. MFs such as triangular, Gaussian, bell-shaped, trapezoidal, and monochromatic are commonly tempered as standard MFs. A singleton output MFs, a closed input MFs with sharp edges, and an input MFs for accepting gate pulses. Although trapezoidal and triangular MFs meet the input MFs requirement, pulse patterns are difficult to visualise. As a result, a custom MFs entry is provided, together with step-by-step design details.

A. Calculations with different magnitudes

According to the SHE method, a minimum ‘q' firing angle of the old MLI waveform is required to eliminate 'n' harmonics and provide a ‘2q+1' level of output waveform. For example, to minimise the two harmonics in a 7-level symmetric CHB MLI, three firing angles are required (5th and 7th). The non-linear equations for the relevant non-linear equations are shown in 1-3.

(1) - (3) demonstrate the related nonlinear equations, and the obtained firing angles are translated to the magnitude of switching using a chosen mi (4). Switching angles with larger values are obtained, as indicated in Table I.

$$COS(\beta_1) \pm COS(\beta_2) \pm COS(\beta_3) = \frac{QV_{dc} \times n_i \times \pi}{4} \tag{8}$$

$$COS(5\beta_1) \pm COS(5\beta_2) \pm COS(5\beta_3) = 0 \tag{9}$$

$$COS(7\beta_1) \pm COS(7\beta_2) \pm COS(7\beta_3) = 0 \tag{10}$$

$$where(Q) = 1,2,3$$

$$y_i = n_i \times \sin(\beta_i) \tag{11}$$

It is necessary to adapt the switching scheme to the magnitude value in the proposed switching scheme. The appropriate switches will transition (on / off) when the input reference measure (sinusoidal) is attained. FLC will support the lookup table if the proposed scheme does not include one.

4. Matlab Results and Discussion

The three step shunt APF efficiency parameters with changed p-q. Figure 2 indicates the sinusoidal voltage of the SAPF perforce. The supply currents are distorted by non-linear loads by inserting current harmonics and drawing reactive power from the device. Figure 3 (a) is the THD source current before SAPF ON, which was successfully implemented to boost shunt APF operation with enhanced control algorithm with the optimum tuning of PI gaining parameters. The reduced THD percent of a phase-a-source current using a modified control algorithm is shown in Figure 3(b). Furthermore, Figure 4 shows the analyzed output using complex load changes and distorted supply voltage. Figure 5 demonstrates the DC link voltage stabilisation. It can be concluded that the proposed SISO tool provides better results in the search of optimal PI gain values that increase reliability, performance and control algorithm complexity.

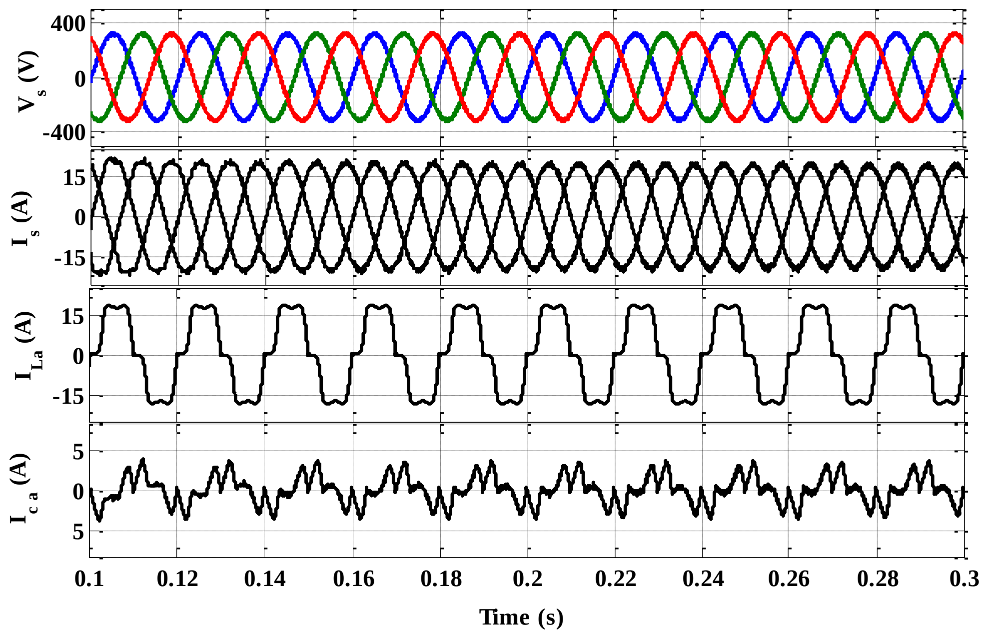
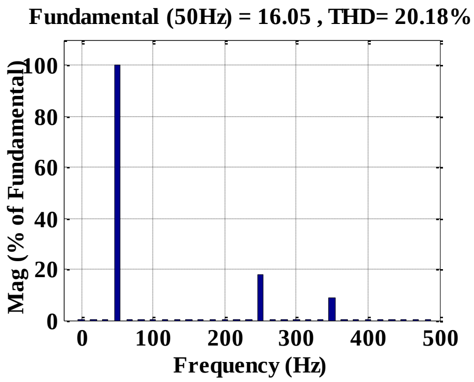
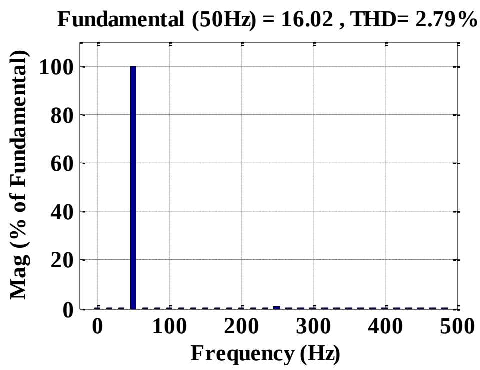


Figure 2. Performance of SAPF under sinusoidal supply voltage



(a)



(b)

Figure 3. %THD of source current: (a) With SAPF OFF (b) after SAPF ON

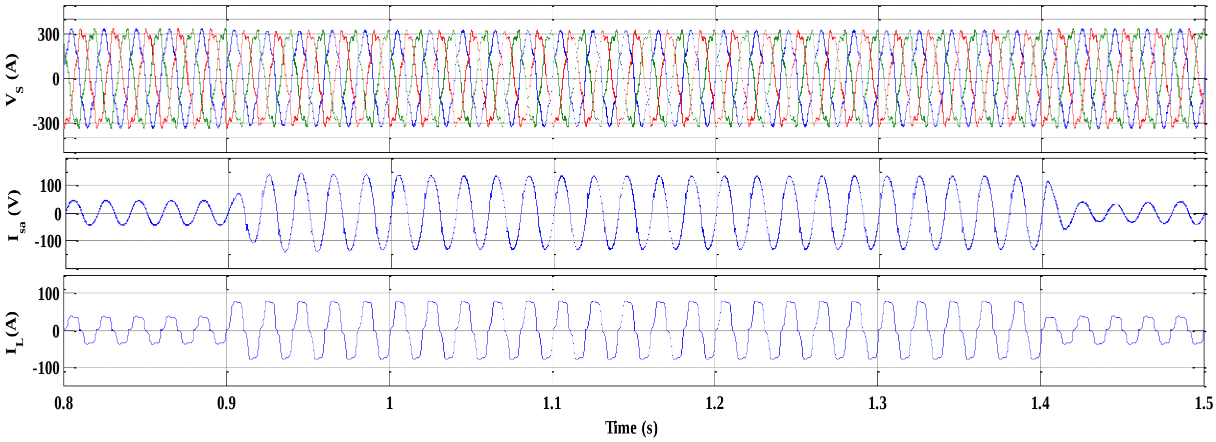


Figure 4. Simulation dynamic load changing condition and SAPF performance

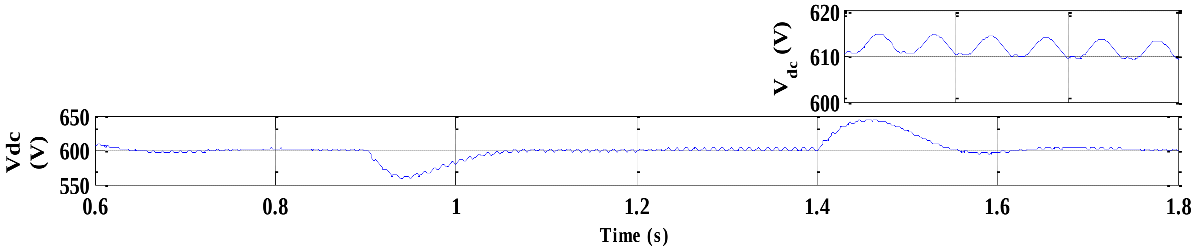


Figure 5. DC-link voltage under dynamic load condition

Table 1. Simulation Performance of proposed control algorithm under different supply voltage conditions

	Sinusoidal Power supply with Diode bride rectifier with R-L Load			Distorted Power supply with Diode bride rectifier with R-L Load			Under distorted and Unbalanced Power supply with Diode bride rectifier with R-L Load		
	Phase-a	***Phase-b***	***Phase-c***	***Phase-a***	***Phase-b***	***Phase-c***	***Phase-a***	***Phase-b***	***Phase-c***
i_s (A)	16.52	16.52	16.52	16.47	16.47	16.47	16.26	16.27	16.26
v_s (V)	230	230	230	230	230	230	230	212.5	252.6
Supply voltage % THD	0	0	0	12.33	12.33	12.33	12.76	10.76	12.89
%THD of i_s (A) before compensation	20.18	21.12	21.53	26.24	26.31	26.44	26.52	27.31	26.44
%THD i_s (A) afetr compensation	2.79	2.79	2.79	3.36	3.38	3.41	4.12	4.22	4.12
5th Harmonic Component	1.594	1.594	1.594	1.547	1.547	1.547	1.547	1.594	1.547
7th Harmonic Component	1.138	1.138	1.138	1.113	1.113	1.113	1.113	1.138	1.113
11th Harmonic Component	0.724	0.724	0.724	0.697	0.697	0.697	0.697	0.724	0.697
13th Harmonic Component	0.613	0.613	0.613	0.585	0.585	0.585		0.613	0.585

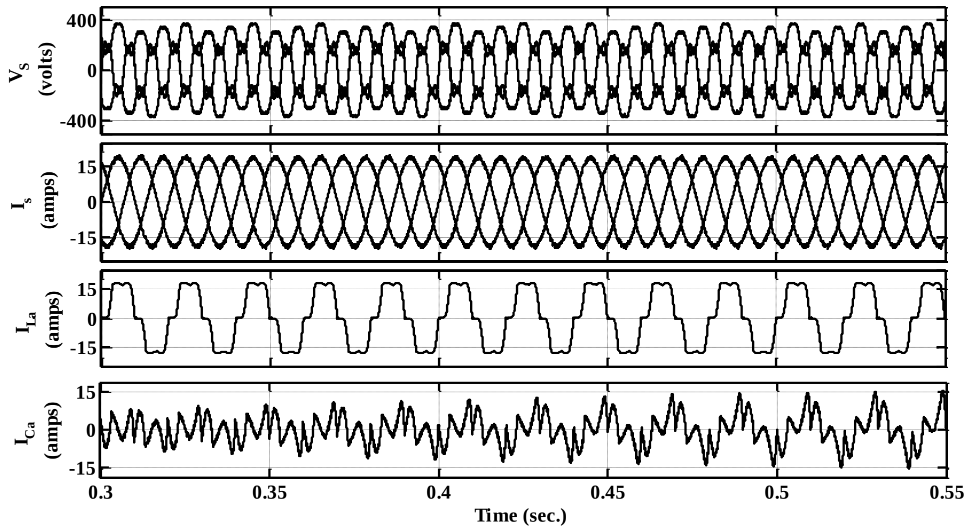


Figure 6. Performance of interleaved SAPF under distorted and unbalanced supply voltage

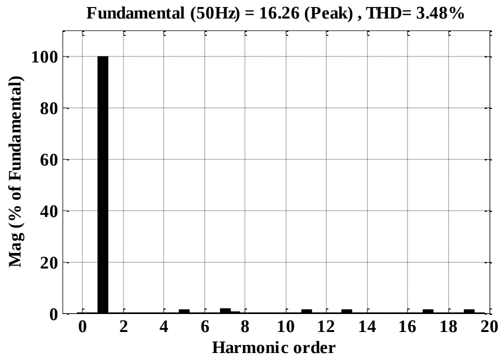


Figure 7. THD of source current after compensation

Unbalanced and supply voltage conditions display the perfromance part of the proposed control algorithm. In synchronizing and minimizing current Harmonic from source currents, the proposed control algorithm is efficient. The THD of source current remains therefore sinusoidal and complies with IEEE-519. Table 1 summarizes a full performance of the control technology.

5. Conclussions

This paper presented the hardware implementation of three-phase shunt APF using modified p-q controller. The PI controller tuning is big challenge for the investigators which highly affect the performance of the shunt APF. In this paper, a generalized *p-q* theory used for the reference current generation and tuning of PI controller is achieved by the advanced feature in the MATLAB using SISO tool box. Also, the fuzzy logic based PWM techniqe give better performance in operation of shunt APF. The performance of the shunt APF using modified controller shows that the proposed controller is ease of implementation and better compensation results under adverse condition of supply and load.

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