CONTROL SCHEME FOR IMPLEMENTATION FOR SHAPF USING FUZZY (P-Q Theory) UNDER UNBALANCED CONDITIONS

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ABSTRACT

A shunt Active power Filter (APF) may be a device that's connected in parallel to cluster of hundreds. APF cancels the reactive power and harmonic current drawn by the load thus on create provide current curving. Active Power Filter is explored for death penalty totally different power acquisition operate at the same time beside harmonic elimination thanks to increase in nonlinear and unbalanced load, at the purpose of common coupling. The aim of gift treatise is to review totally different management methods for Active Power Filter victimisation Fuzzy abstract thought system. a lot of significantly to review instant power theory based mostly Shunt Active Power Filter that preponderantly utilized in gift state of affairs. The shunt active power filter is investigated through Mat lab/Simulink simulation below load conditions. typically within the power systems causation finish voltage constant. Whereas the receiving finish voltage (or) load voltages undergoes variations relying upon the magnitude of the load and power issue of the load. The voltage variation at the node is a sign of the unbalance between the reactive powers generated and consumed by load Power physics hundreds. These issues will overcome by victimisation Fuzzy system quick response and doctorate of the system is additionally shown higher

KEYWORDS: A Shunt Active power Filter (APF), Fuzzy System Quick Response, Mat lab/Simulink Simulation

INTRODUCTION

With the proliferation of nonlinear power physics masses, the matter of harmonic is severity, that influences the facility quality of power system. Passive power filter may be a ancient harmonic restraint technique. The passive filtering may be a easy thanks to eliminate the harmonic currents. However, it doesn't enable to fully eliminating all of them and has several drawbacks like series or parallel resonance with the system electric resistance Active filter is employed, these last years, to enhance power quality on the load aspect from the grid current, by injecting compensating currents The performance of a full of life filter chiefly depends on the reference current generation strategy, technique management, topology of the filter electrical converter. A common answer for harmonic compensation in massive B industrial plants is to mitigate the harmonic currents at the purpose of common coupling, by mistreatment either passive or active strategies. As a passive technique might produce issues with uncontrolled resonances between the electrical device and also the existent supply electric resistance, a a lot of economical manner is by mistreatment active filtering strategies. chiefly, the look of any SAF system have 3 necessities criteria: power electrical converter topology, current managemententler and strategy control. instant power theory is wide utilized in totally different analysis work, this method give sensible results beneath totally different voltage supply conditions however gift some drawbacks such North American country a way calculations range, necessitate complicated mathematical transformation and tough implementation in apply The controller is that the main a part of the active power filter operation and has been a topic of the many researches in recent years. The p-q theory or “Instantaneous Power Theory”, with the objectives of Applying it to the management of active power filters
techniques are projected for prime power or medium-voltage applications like reactive power compensation and elimination of harmonics.

The preference of p-q theory to enhance the APF performances there’s an excellent tendency to use intelligent management techniques, significantly fuzzy controller. The benefits of this controller it's primarily based in instant values, permitting glorious dynamic response will work with inexact inputs and settle for non-linearity. During this paper, formal logic and current management area unit projected to regulate the three-phase three-wire shunt active filter with 2 totally different control methods on fuzzy controller.

The performances of shunt active filter supported this controller are evaluated mistreatment MATLAB-Simulink and power grid Block Set tool chest beneath balanced voltage conditions and additionally unbalanced conditions. The obtained results show that the projected shunt active filter supported these controllers turn out a curved provide current with acceptable low harmonic distortion.

![Figure 1: Block Diagram of Power System with apf](image)

**The p-q theory and Mathematical Model**

The p-q theory or “Instantaneous Power Theory”, was developed by Akagi et al with the objectives of Applying it to the management of active power filters, at the start it absolutely was developed just for three-phase systems with or while not neutral wire. This theory relies on Time-Domain, that makes it valid for operation in steady-state or impermanent regime, also as for generic voltage and current grid waveforms, permitting to manage the active power filters in period of time. Another necessary characteristic of this theory is that the simplicity of the calculations, that involves solely algebraical calculation (exception done to the necessity of separating the mean and alternated values of the calculated power components). The p-q theory performs a metamorphosis (known as “Clarke Transformation”) of a stationary coordinate system of coordinates a - b - c to a coordinate system of coordinates α - β - zero, additionally stationary the calculation of the p-q theory instantaneous power components

\[
\begin{bmatrix}
  v_a \\
  v_\alpha \\
  v_\beta \\
\end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix}
  \frac{1}{\sqrt{2}} & 1 & 0 \\
  -\frac{1}{\sqrt{2}} & \frac{1}{2} & \frac{\sqrt{3}}{2} \\
  -\frac{1}{\sqrt{2}} & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\
\end{bmatrix} \begin{bmatrix}
  v_a \\
  v_b \\
  v_c \\
\end{bmatrix} \quad \begin{bmatrix}
  i_a \\
  i_\alpha \\
  i_\beta \\
\end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix}
  \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\
  1 & -\frac{1}{2} & \frac{1}{2} \\
  0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\
\end{bmatrix} \begin{bmatrix}
  i_a \\
  i_b \\
  i_c \\
\end{bmatrix}
\]

(1)

Where the voltages and currents can be calculated from following mathematical model equations
\[
\begin{align*}
\mathbf{v}_a(t) &= \sqrt{2} V \cos(\omega t + \phi), \\
\mathbf{v}_b(t) &= \sqrt{2} V \cos(\omega t + \phi - \frac{2\pi}{3}), \\
\mathbf{v}_c(t) &= \sqrt{2} V \cos(\omega t + \phi + \frac{2\pi}{3}), \\
\mathbf{i}_a(t) &= \sqrt{2} I \cos(\omega t + \phi), \\
\mathbf{i}_b(t) &= \sqrt{2} I \cos(\omega t + \phi - \frac{2\pi}{3}), \\
\mathbf{i}_c(t) &= \sqrt{2} I \cos(\omega t + \phi + \frac{2\pi}{3}).
\end{align*}
\]

\( p_0 = v_o i_o \) \hspace{1cm} \text{instantaneous Zero-sequence power} \hspace{1cm} (3)

\( p = v_o i_o + v_o i_o + v_o i_o \) \hspace{1cm} \text{instantaneous Real power} \hspace{1cm} (4)

\( q = v_o i_o - v_o i_o \) \hspace{1cm} \text{instantaneous Imaginary power power} \hspace{1cm} (5)

Figure 2: Three Phase to Two Phase Transformation

The power components \( p \) and \( q \) are related to the same \( \alpha-\beta \) voltages and currents, and can be written together

\[
\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} \mathbf{v}_\alpha & \mathbf{v}_\beta \\ -\mathbf{v}_\beta & \mathbf{v}_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}
\]

(6)

Where “–” represents the typical and “~” represents the oscillatory parts of every power. The typical parts are often extracted through low-pass filters, because it are often noted in many management algorithms for change compensators. These quantities are illustrated in Fig. for an electrical system described in a-b-c coordinates and have the following physical that means

**Instantaneous Zero-Sequence Power \((p_0)\)**

\[
P_0 = V_o i_o = \overline{P} + \overline{P}
\]

\( P_0 \) – Mean value of the instantaneous zero-sequence power. It corresponds to the energy per time unity that is transferred from the power source to the load through the zero-sequence components of voltage and current.

\( \overline{P}_o \) – Alternating value of the instantaneous zero-sequence power. It means the energy per time unity that is exchanged between the power source and the load through the zero-sequence components of voltage and current.

Current. The zero-sequence power exists only in three-phase systems with neutral wire. Moreover, the systems must have both unbalanced voltages and currents, or the same third order harmonics, in both voltage and current, for at least one phase. It is important to notice that \( p_0 \) cannot exist in a power system without the presence of \( \overline{P}_o \). Since \( \overline{P} \) is
clearly an undesired power component (it only exchanges energy with the load, and does not transfer any energy to the load), both \( p_0 \) and \( \bar{p} \) must be compensated.

**Instantaneous Real Power (p)**

\[
P_0 = V_x i_x + V_y i_y = \bar{p} + \tilde{p}
\]

\( p \) - Mean value of the instantaneous real power. It corresponds to the energy per time unit that is transferred from the power source to the load, in a balanced way, through the \( a-b-c \) coordinates (it is, indeed, the only desired power component to be supplied by the power source).

\( \bar{p} \) - Alternating value of the instantaneous real power. It is the energy per time unit that is exchanged between the power source and the load, through the \( a-b-c \) coordinates. Since \( \bar{p} \) does not involve any energy transfer from the power source to load, it must be compensated.

**Instantaneous Imaginary Power (q)**

\[
q = V_x i_x - V_y i_y = \bar{q} + \tilde{q}
\]

\( q \) - Mean value of instantaneous imaginary power.

\( \bar{q} \) - Alternating value of instantaneous imaginary power. The instantaneous imaginary power, \( q \), has to do with power (and corresponding undesirable currents) that is exchanged between the system phases, and which does not imply any transference or exchange of energy between the power source and the load. Rewriting equation in \( a-b-c \) coordinates the following expression is obtained

\[
q = \frac{\sqrt{3}}{2} \left[ (V_a - V_b) i_a + (V_b - V_c) i_b + (V_c - V_a) i_c \right]
\]

This is a acknowledge expression utilized in standard reactive power meters, in power systems while not harmonics and with balanced curving voltages. These instruments, of the electro dynamic sort, show the mean of equation. The fast imagined power differs from the traditional reactive power, as a result of within the 1st case all the harmonics in voltage and current area unit thought of. within the special case of a balanced curving voltage provide and a balanced load, with or while not harmonics, letter is up to the traditional reactive power

\[
q = 3 \cdot V \cdot I \sin \varphi
\]

\( \tilde{q} \) - Alternating value of instantaneous imaginary power. The instantaneous imaginary power, \( q \), has to do with power (and corresponding undesirable currents) that is exchanged between the system phases, and which does not imply any transference or exchange of energy between the power source and the load. Rewriting equation in \( a-b-c \) coordinates the following expression is obtained

\[
q = \frac{\sqrt{3}}{2} \left[ (V_a - V_b) i_a + (V_b - V_c) i_b + (V_c - V_a) i_c \right]
\]

It is also important to note that the three-phase instantaneous power (p3) can be written in coordinates systems, \( a-b-c \) and \( \alpha-\beta-\gamma \), assuming the same value.

**Figure 3: p-q Theory Power Component**

The p-q theory is one among many strategies which will be utilized in the management active filters It presents some fascinating options, namely:
• it’s inherently a three-phase system theory;
• It are often applied to any three-phase system (balanced or unbalanced, with or while not harmonics in each voltages and currents)
• it’s primarily based in fast values, permitting glorious dynamic response;
• Its calculations are unit comparatively straightforward (it solely includes algebraically expressions which will be enforced exploitation normal processors)

It permits 2 management strategies: constant fast provide power and curving provide current one advantage of applying the αβ0 transformation is separate zero-sequence parts from the abc-phase parts. The α and β axes create no contribution to zero sequence parts. No zero-sequence current exists in a very three-phase, three-wire system, io are often eliminated from the higher than equations, so leading to simplification shown figure(4)

\[
\mathbf{\frac{1}{V^2}} = \frac{1}{\mathbf{V}^2 + \mathbf{V}^2} \begin{bmatrix} \mathbf{V}_\alpha & \mathbf{V}_\beta \\ \mathbf{V}_\beta & -\mathbf{V}_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \tag{12}
\]

HYSTERESIS BAND CURRENT CONTROLLER

The actual active power filter line currents square measure monitored instantly, then compared to the reference currents Generated by the management rule. so as to induce precise fast current management, the present management methodology should provide fast current controllability, so fast response. For this reason, physical phenomenon band current management for active power filter line currents may be enforced to come up with the switch pattern the electrical converter. There square measure numerous current management strategies planned for such active power filter configurations, however in terms of fast current managementability and straightforward Implementation physical phenomenon band current management methodology has the best rate among alternative current control strategies like curving PWM shown in Figure(5), physical phenomenon band current management is that the quickest management with minimum hardware and code however even switch frequency is its main drawback.

The physical phenomenon band current management theme, used for the management of active power filter line current, is shown in Figure 5, composed of a physical phenomenon round the reference line current. The reference line current of the active power filter is named as I^c and actual line current of the active power filter is named as Ic. The
physical phenomenon band current controller decides the switch pattern of active power filter

$$I^*_c + I_c^-$$

Figure 5: Hysteresis Current Control Technique

The switching logic is formulated as follows:

If $I_{ca} < (I^*_{ca} - HB)$ upper switch is OFF and lower switch is ON for leg “a” ($SA = 1$).

If $I_{ca} > (I^*_{ca} + HB)$ upper switch is ON and lower switch is OFF for leg “a” ($SA = 0$).

The switch functions $SB$ and $SC$ for phases “b” and “c” square measure determined equally, exploitation corresponding reference and measured currents and physical phenomenon information measure (HB). In order to get the reference compensation currents within the a-b-c coordinates the inverse of the transformation given in expression is

$$\begin{bmatrix}
  1 & \sqrt{2}/3 & 0 \\
  \sqrt{2}/3 & 1 & \sqrt{2}/2 \\
  1 & -1/2 & -\sqrt{3}/2
\end{bmatrix}
\begin{bmatrix}
  i_{ca}^* \\
  i_{cb}^* \\
  i_{cc}^*
\end{bmatrix}
= \begin{bmatrix}
  i_{c0}^* \\
  i_{ca}^* \\
  i_{cβ}^*
\end{bmatrix}$$

(13)

Basic P-Q Control THEORY with (P,1) Control Scheme

Figure 6: Calculation for the Constant the Switching Supply Voltage Power

Where the powers from source to load deliver and this could be the conversion of powers to be transferred

$$v_a i_a + v_b i_b + v_c i_c = \frac{2}{3} (v_a i_a^* + v_b i_b^* + v_c i_c^*)$$

$$p_{abc} = \frac{2}{3} p_{ab}$$

(14)

Three phase power is equals to 2/3 times of two phase system Power equation calculation
Control Scheme for Implementation for SHAPF Using Fuzzy (P-Q Theory) under Unbalanced Conditions

\[
P_3 = v_a i_a + v_b i_b + v_c i_c = P_a + P_b + P_c
\]
\[
P_3 = v_a i_a' + v_b i_b' + v_c i_c' = p + p_0
\]

The sinusoidal supply current control strategy must be used when the voltages are distorted or unbalanced and sinusoidal currents are desired. The block diagram presents the calculations required in this case. When this Approach is used the results, illustrated are:

- The phase supply currents become sinusoidal, balanced, and in phase with the fundamental voltages
- The neutral current is made equal to zero (even 3rd order current harmonics are compensated)
- The total instantaneous power supplied (\(p3S\)) is not made constant, but it presents only a small ripple (much smaller than before compensation)

![Figure 7: Control Scheme Algorithm of the System](image)

**PROPOSED SCHEME**

In this projected theme mistreatment of artificial intelligent neural network controller, during this from purpose[ the purpose] to point calculations area unit mechanically done by mistreatment the principles and from the predefined given values that the response of the system with intelligent neural network technique wherever within the P and that i controller the gains area unit in fastened points. an excellent more practical methodology to boost quick response for not solely reactive power dominant and additionally eliminating of harmonics supported this fuzzy abstract thought system

In following half we'll contemplate unbalanced/balanced system of the road voltages and currents. Reference is that the most significant a part of APF management. In Figure(8) is shown diagram and reference current calculation relies on the pq- theory. Inputs of the calculations area unit part voltages (va vb vc) and part load currents (iLa, iLb, iLc). once transformation (abc \(\rightarrow\) \(\alpha\beta\)), \(\alpha\beta\) elements of the voltage and cargo currents area unit the inputs of the block of instant active and reactive power calculation outlined by pq- theory equations explained before, each of instant powers contain DC and AC elements. Shunt APF with Fuzzy ought to inject to the nonlinear load current that consists of each harmonics on the far side active a part of elementary current element. In power expression it suggests that all power on the far side DC element of instant active power. during this case would be necessary to applied high pass filter on p(t). except for AC element of p(t) it'd be mean your time delay, which might cause an error for reference current calculation. Compensation of now delay, during this case the time delay won't occur as a result of DC element. we are able to use multiplication by zero for instant fanciful power q(t) filtering. Back transformation for \(\alpha\beta\) current elements. once the inputs of back transformation are solely the DC a part of instant active power (active power of elementary harmonic) and \(\alpha\beta\) element. Definitive reference current elements is obtained by subtraction \(\alpha\beta\) current elementary elements for completeness sake of reference current calculation is critical to contemplate the DC bus voltage control(keeping constant voltage on capacitor). Charging
and discharging of electrical device is ensured by active power flow, during this case painted by active a part of current elementary element. For DC bus management is employed Fuzzy controller. Worth from the output of Fuzzy controller ∆PDC bus is added of DC element PDC of instant active power

![Figure 8: Compensation Control Scheme by Using Fuzzy System](image)

Reference current is again is transformed (αβ → abc) to abc reference frame. The input 3-phase voltage 415v 50Hz R_s 0.1Ω, L_s 0.9e-3H and load uncontrolled load L_L 30e-3H R_L 60Ω. The Hysteresis band controller is used for the current control. The reference current wave is compared with the actual phase filter current wave form. As the error exceeds a prescribed hysteresis band, by its upper and lower switches the signals can be produced and given to gating pulse.

**SIMULATION OF A TEST SYSTEM**

![Figure 9: Source Voltage and Current Before Compensation](image)

![Figure 10: Source Voltage and Current After Compensation](image)
Control Scheme for Implementation for SHAPF Using Fuzzy (P-Q Theory) under Unbalanced Conditions

Figure 11: Total Harmonic Distortion for System before Compensation

Figure 12: Total Harmonic Distortion for System after Compensation by APF with PI Controller

Figure 13: Harmonics Currents

Figure 14: Source Voltage after Compensation Using Fuzzy Inference
CONCLUSIONS

Active filters are an up-to-date answer to power quality issues. Shunt active filters enable the compensation of current harmonics and unbalance, along with power issue correction and might be a far higher answer...
than the traditional approach (capacitors for power issue correction and passive filters to make amends for current harmonics). This paper presents the p-q theory as an appropriate tool to the analysis of non-linear three-phase systems and for the management of active filters. supported this theory, 2 management ways for shunt active filters were delineate, one resulting in constant instant provide power and therefore the alternative to curved provide current. The implementation of active filters supported the p-q theory ar efficient solutions, by victimisation higher simulating results by fuzzy controller technique permitting the employment of enormous variety of low-power active filters within the same facility, near every problematic load (or cluster of loads), ThD of system is additionally beneath 3%(that is two.50%which is beneath 3%), avoiding the circulation of current harmonics, reactive currents and neutral currents through the ability power lines.

REFERENCES
