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A Review on a Digital Active Power Filter Controller for current compensation in a Power System

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Abstract: *With the extensive use of power electronics equipment such as rectifier, inverter etc. in power system generates major difficulty related to power quality. One of such difficulties is creation of current and voltage harmonics producing distortion of load waveform, voltage fluctuation, voltage drop, heating of equipment etc. Harmonic current sources, such as computer power supplies, fluorescent lamps with electronic ballasts, elevator drives, and electronic devices using Switch mode power supplies, are commonly found in commercial, institutional, and medical buildings. Active power filters (APF) are the most practical method for harmonic reduction and can be utilised in a variety of situations. In this study, a digital active power filter is used to eliminate harmonics in the source current in a grid system with a non-linear demand. Nonlinear loads are an important component of any power system. With the advent of power electronics, switching elements now account for a significant portion of the electrical load. These constituents cause discontinuities in lines, which increases line losses while lowering power quality as well as sin wave purity. Passive filters are effective in removing harmonics at specific frequencies that are specified in the design. Active filters, on the other side, operate in accordance with the harmonics that are now in play.*

Keywords: *Active Power Filter, Instantaneous Power Theory, Harmonics, Non-Linear Load, MATLAB Simulink and FFT analysis tool, PI Controller, Fuzzy logic Controller.*

1. Introduction

Early technology was built to tolerate disturbances like lightning, short circuits, and abrupt overloads without incurring additional costs. If current power electronics (PE) equipment was constructed with the same resilience, prices would be significantly higher. Nonlinear loads such as transformers and saturation coils have polluted power systems, but the rate of disturbance has never reached the current levels.[1] PE is responsible for the majority of pollution problems due to its nonlinear properties and rapid switching. The nonlinear properties and quick switching of PE are responsible for the majority of environmental problems. PE processes around 10% to 20% of today's energy; this percentage is expected to rise to 50% to 60% by 2010, owing to the rapid increase of PE capability. On the one side, there is a race between rising PE pollution & sensitivity, while on the other hand, there is a race among innovative PE-based corrective devices that can mitigate the concerns caused by PE. Increased non-linearity results in a variety of unfavourable characteristics, including low system efficiency and a low power factor. It also creates annoyance to other customers and communication network interference in the area. Within the next few years, the impact of such non-linearity could be significant. As a result, overcoming these negative characteristics is critical.

Shunt passive filters, which are made up of tuned LC filters and/or high passive filters, are traditionally used to eliminate harmonics and power capacitors are used to enhance power factor. However, they have fixed compensation, are huge in bulk, and can cause resonance situations. [2]

To compensate for harmonics as well as reactive power requirements of non-linear loads, active power filters are now viewed as a feasible alternative to traditional passive filters. The goal of active filter is to alleviate these issues by integrating it with significantly reduced ratings of the required passive filters.

However, the conventional PI controller was used for the generation of a reference current template. The PI controller requires precise linear mathematical models, which are difficult to obtain and fails to perform satisfactorily under parameter variations, nonlinearity, load disturbance, etc. [3]

1.1 Power Quality

"Any incident manifested in voltage, current, or frequency variations that leads in damage, upset, breakdown, or mis-operation of end-use equipment," according to the PQ definition. In practically every part of commercial, home, as well as industrial use, all PQ difficulties are strongly tied to PE. Residential appliances such as televisions and computers, business and office equipment such as copiers and printers, including industrial equipment such as programmable logic controllers, variable speed drives, rectifiers, inverters, CNC machines, and so on all use power electronic devices. Based on the type of concern, one or more of the following symptoms can be used to diagnose a Power Quality (PQ) problem. [6]

Lamp flicker
Frequent blackouts
Sensitive-equipment frequent dropouts
Voltage to ground in unexpected
Locations
Communications interference
Overheated elements and equipment.

Harmonics, inter harmonics, dips, as well as neutral currents are all caused by PEs. Rectifiers, ASDs, soft starters, electrical ballast for discharge lamps, switched-mode power supply, and HVAC employing ASDs all generate harmonics. Transformers, motors, wires, interrupters, as well as capacitors are all impacted by harmonic (resonance). Converters are the primary source of notches, which have a significant impact on electrical control systems. Equipment that uses switched-mode power sources, including as PCs, printers, photocopiers, as well as any triplets generator, generate neutral currents. Neutral currents have a significant impact on the temperature of the neutral conductor as well as the transformer's capabilities. Static frequency converters, cyclo-converters, induction motors, and electric current devices all generate inter harmonics. [7]

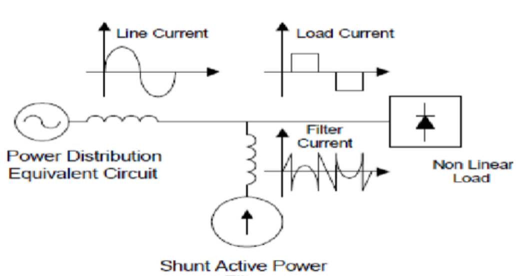

Figure 1. Power Quality Improvement

There are two techniques to addressing power quality issues. The first method is known as load conditioning, and it assures that the equipment is rendered less sensitive to power disturbances, enabling it to operate even when the voltage is significantly distorted. Installing line-conditioning equipment to minimize or counteract power system disturbances is another option. [8] the most prevalent method of limiting the flow of harmonic currents in distribution networks has been to use passive filters. They are normally made to order for the specific use. Furthermore, their performance is restricted to a few harmonic, and they can cause power system resonance. Active power filters have shown to be a significant and adaptable choice for compensating for voltage and current fluctuations in power distribution systems, among the various new technical options opportunities to facilitate power quality. The concept of active filters isn't new, but it's only just become a reality thanks to advancements in power electronics as well as microcomputer control tactics, and also the lower electronic component costs. Active power filters are quickly gaining market share as their costs fall below those of passive power filters. The active filter provides current or voltage components using power electronics that eliminate the harmonic components of nonlinear loads or supply lines, accordingly. Various active power filter topologies have been developed, and several of them are now commercially available [9].

2. Literature Review

The suggested system's primary goal is to provide a low-priced universal PV battery charger that may be used for electric car applications. The suggested system includes a slope-compensated current controller for regulating the charging current at the highest power point of the PV module. The suggested system uses a buck converter as an interface converter to regulate charging current flow and determine the PV array's MPP's reference current Iref. The state of charge (SOC) of the battery is employed to create the battery management circuit, and the battery's properties are monitored using an LCD display. E-vehicles may benefit from this suggested system since it is a clever and efficient PV battery charger[1].

This research presents an inverter-based analysis of the effects of harmonic content in 3-phase induction motor (IM) current generated by "sinusoidal pulse-width modulated (SPWM) and space vector pulse-width modulated (SVPWM) drives." The IM drive's topology and circuit are introduced, followed by its operational basics and the waveform it produces [2].

The load-control process, including the 3-phase IM model fed from the grid, is also covered in detail, as are the characteristics of its operation. This thesis makes use of the MATLAB/Simulink simulation software package to model the operation of a three-phase IM connected to a pulse-width-modulated (PWM) inverter. The IM stator current is monitored while switching between SPWM and

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SVPWM inverters at different modulation indices in order to compare their performances. The Fast Fourier transform is used to do a spectral analysis of the IM current and reveal its harmonic content [3].

Non-linear loads generate harmonic current in power system. These harmonics currents can produce various type of effect that is harmful to the power system. A system required to filter out these harmonics. Design and assessment of shunt active power filter (SAPF) for harmonics elimination using intelligent control controller (fuzzy logic) present in this paper. Generally, conventional phase-locked loop (PLL) technique are used for eliminate harmonics. In PLL technique based system contains more harmonic. This paper compared without filter versus with filter at different loads. Results shows that intelligent control controller based system contain minimum harmonic contain as compared to conventional controller [5].

3. Control Techniques

3.1. Instantaneous Real and Reactive Power Theory

The "Generalized Theory of the Instantaneous Reactive Power in Three-Phase Circuits," also referred as instantaneous power theory or p-q theory, was proposed by researchers in 1983. An algebraic conversion (Clarke transformation) of the three-phase currents and voltages in the a-b-c variables to the —0 coordinates is accompanied by the computation of the p-q theory instantaneous power components. It is based on current and voltage values of the power system at any given time. It is valid for Steady state as well as transient condition. The Clark transformation of voltage is given as: [4]

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \qquad (1)$$

Also, three phase instantaneous line currents ia, ib, ic can be transformed on αβ0 axes as:

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \qquad (2)$$

The compensating current of each phase can be derived by using the inverse orthogonal transformations as shown below in equation

$$\begin{bmatrix} i_{ca}^* \\ i_{cb}^* \\ i_{cc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix} \qquad (3)$$

Because the harmonics detecting phase's reaction is delayed, this method gives stronger harmonics compensations. In quick reaction current controlled inverters like active power filters, the current control approach is crucial.

3.2 Synchronous Reference Frame Theory

The fundamental reference current component of the load current is extracted using the synchronous reference frame theory by transforming iLa, iLb, and iLc into the d-q frame of reference. The translation of coordinates from a three-phase a-b-c stationary coordinate system to the 0-d-q rotational coordinate system is known as reference frame transformation. This transformation is significant because it occurs in the 0-d–q reference frame, which allows the signal to be regulated efficiently to obtain the appropriate reference signal. A synchronization system known as a phase-Locked loop (PLL) is utilized to accomplish the SRF approach. [46]

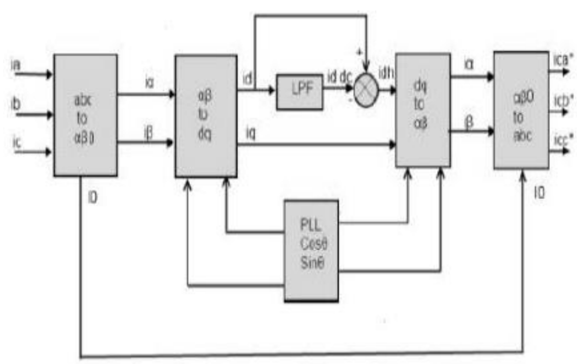

Figure 2 Block Diagram of SRF Algorithm

As a result, the SRF theory is effective in extracting different components in the load currents. By adjusting the VSI using different control schemes like hysteresis current controller as well as sliding mode controller, the source current is adjusted to match these reference fundamental positive sequence currents.

4. Proposed Methodology

4.1 Fuzzy Logic Controller

The fuzzy controller is made up of four primary parts: The knowledge in the form of a collection of rules outlining the optimal way to manage a system is stored in the rule-base. To measure knowledge, membership functions are being used. The inference system determines which control rules are applicable at this time and then determines which plant input must be activated. The inputs are modified by the fuzzification interface so that they may be understood and matched to the rules in the rule-base. The defuzzification

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interface converts the plant's inputs into the conclusions derived by the inference engine. A circuit illustration of a fuzzy logic controller is shown in fig.

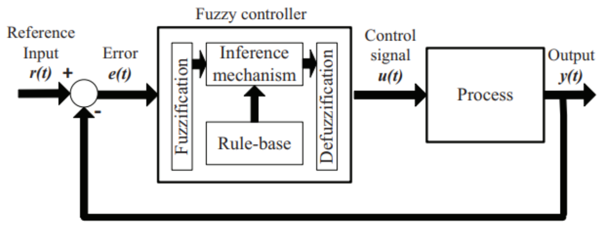

Figure 3 Scheme of a fuzzy logic controller

4.2 Description of fuzzy logic tools

Unlike Boolean or crisp logic, fuzzy logic deals with situations that are unclear, uncertain, or imprecise, and employs membership functions with values ranging from 0 to 1. A graphical block diagram of a fuzzy inference system or fuzzy controller is shown in Figure.
It is made up of the following working blocks.
Fuzzification Interface
Knowledge base
Decision making logic
Defuzzification
A fuzzy controller should have proportional integral control effects because it is a two-dimensional fuzzy control. To get the best performance in a practical situation, an entire action is usually required.

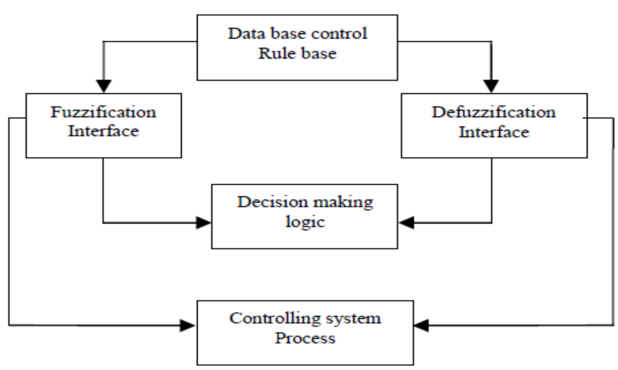

Figure: 4 Fuzzy Inference System

5. Conclusion

The harmonics mitigation is achieved when the grid system with non-linear load is connected with digital active power filter. Here, the combination of Park's transformation and digital PI controller, this varying PWM signal is generated. These PWM signals are control signals to a voltage source inverter (VSI) which injects the harmonics of same magnitude at 180-degree shift to cancel the effect of harmonics or distortion in power line. The DC link voltage with FIS controller is more accurate with 740V generation at DC link as compared PI controller.

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