Shunt Active Power Filter with 3 Level 4 Leg FCC for Power Quality Improvement

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ABSTRACT: This paper presents the various causes of poor power quality, their effects and solutions are proposed with respect to present nonlinear load patterns of the power system. It also presents the new implementation of the system ,which includes shunt active power filter with three level four leg flying capacitor converter which is solution for compensating current into the distribution line by using residual current, The three main issues regarding the algorithm development are described and the solutions are proposed. The first is addressed to modelling of the four-wire system, the second relates to the control of FCC(Flying Capacitor Converter), i.e., a proper interpretation of the FCC switching states and control of flying capacitor (FC) voltages, which was moved from the prediction loop.This paper develops mathematical modelof shunt active powerfilter with three level flying capacitor converter in which current waveforms are presented with the help MATLAB–Simulink.

KEYWORDS: Four-leg converter, multilevel converter, power quality, predictive control, shunt active filters (SAPFs.
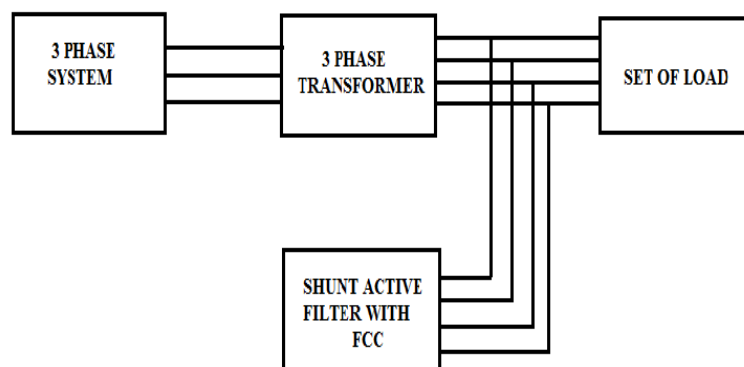
I.INTRODUCTION

Fig.Basic block diagram of proposed system

The electricity has been widely used in various application such as motors, resistive heating and incandescent lighting. Nowadays, with the wide application of the non-linear loads and electronic equipment in distribution systems such as switch-mode power supplies, light controllers, interruptible power supplies, electric furnaces, AC voltage regulators, Domestic loads, Adjustable Speed Drives (ASD), etc… the problem of power quality has become increasingly serious. Most of the international standards define power quality as the physical characteristics of the electrical supply provided under normal operating conditions that do not disturb the consumer's processes. Therefore, a power quality problem exists if any voltage, current or frequency deviation results in a failure or in bad operation of customer's equipment. These modern devices are becoming widely adopted due to their energy efficient operation. The generalization of static converters in industrial activities and by consumers leads to an increase in harmonic injection in the network and a lower power factor. These large increasing of non-linear loads results in a deterioration of the quality

of voltage /current waveforms and affects the reliability of power electronic equipment's. Although the effects of harmonic currents and voltages in power systems are varied, the result is that harm is often caused to other equipment connected to the same power system.

The active Power filters (APF) are a highly flexible solution to the problem of harmonic pollution in power networks and also solution to this problem is to install active filters for each nonlinear load in the power system network. Although presently very uneconomical, the installation of active filters proves essential for solving power quality problems in distribution networks such as harmonic current compensation, reactive current compensation, voltage sag compensation, voltage flicker compensation and negative phase sequence current compensation. Ultimately, this would ensure a polluted free system with increased reliability and quality

II.SYSTEM MODEL AND ASSUMPTIONS

The figure 1 shows systematic diagram of shunt active power filter with three level four leg FCC which is connected to the grid (PCC) i.e. point of common coupling, the three level four leg flying capacitor converter which is acting as a shunt active power filter having a combination of IGBT's is connected to the distribution system. The load which is used into the system is nonlinear load due to this load there is a problem of harmonic injection into the system so this system is also deals with total harmonic distortion.

The main objective of this system is to compensate the current into the line by using the residual current it is nothing but most of the electronic gadgets like Computers TVs etc. convert AC power into DC for actual functioning such process of conversion taking place inside the instruments when you put off the instrument such converted power will be therefor few seconds/minute or hours in a coils this is called static power or residual current It is also important to noted that in case of full compensation of load neutral wire current, the shunt active power filter also operates as a load a symmetry compensator which may require a higher output
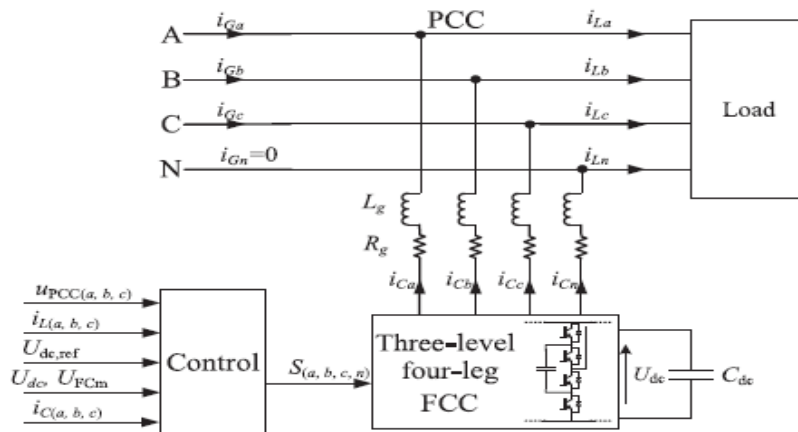

Fig.1. schematic diagram of the suggestedthree level-four leg FCC acting as a shunt active power filter

III.DESIGN OF SAPF's WITH FCC

The Design of Shunt Active Power filter includes the number of IGBTs, fig 2 shows available switching states for single leg of FCC(Flying Capacitor Converter),Let us consider two of possible types of transitions between states :
A) State 2 (1100) ↔State 0 (0011)B) State 1a (1010) ↔State 1b (0101)

It is clearly seen that transitions types A and B will cause a simultaneous switching of all transistors in considered leg leading to high voltage shock on the power component and increase switching losses. Therefore, these undesirable conditions should be avoided to improve the robustness of the converter. This task can be handled by the

control algorithm.Elimination of the transitions A and B is a step in FS-MP optimization, which provides a further reduction in the computational demand at every sampling period
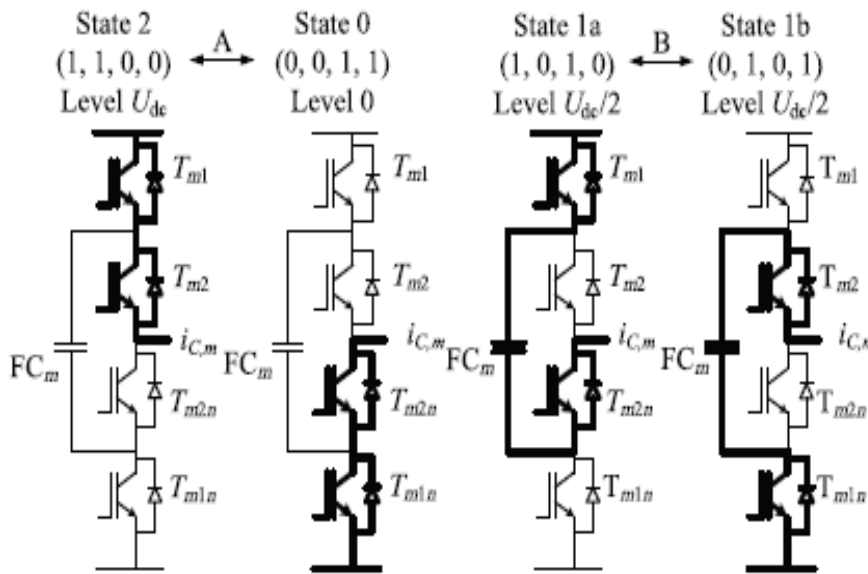

Fig. 2Available switching states for single leg of FCC.

The developed approach is based on the comparison of the switching state selected in the previous sampling time and the state considered in the actual run of the prediction loop. If the undesirable transition is detected in any of converter

Leg, one of the two actions is chosen:

1) Action 1: the state is eliminated if transition A would occur; the prediction is skipped.

2) Action 2: if transition B would occur the prediction runs normally with a condition that the state will not change

Nevertheless, Action 2 can influence the dynamics of FCs voltages control. This can be avoided, by adding the absolute values of the respective FCs voltages errors to the cost function. Thanks to that the FCs voltages fluctuations are insignificant, while elimination of step changes of converter's output voltage considerably reduces switching losses and current ripples.This section will be focused on some specific aspects regarding FCC control with FS-MPC.The three-level FCC contains one FC for each leg and the required voltage level is half of the dc voltage.The operation of the SAPF system requires ac mains to supply real power needed to the load and some losses (switching losses of devices, losses in the reactor, and dielectric losses of dc capacitor) in the SAPF. The reference source currents are used to decide the switching of the SAPF.The system parameter is shown in table I.

Table 1. System Parameters

	Parameters		Value
Source	Voltage	Vs abc	400 VP-P rms
	Frequency	f	50/60 Hz
	Source Resistance	Rs abc	0.0287 Ω
	Source Inductance	Ls abc	0.2047 mH
Load (Diode Bridge Rectifier)	3-Phase ac Line Inductance	LL abc	2.5 mH
	3-Phase dc Inductance	L_{dc}	5mH
	3-Phase dc Resistance	R_{dc}	25 Ω
dc-link	Voltage	VDC	700 V
	Capacitor	CDC	2000 μF
Shunt APF	ac Line Inductance	LCabc	4.25 mH
	Filter Resistor	RCabc	5 Ω
	Filter Capacitor	FCabc	10 μF

IV. CONTROL STRATEGY

Instantaneous Reactive Power (IRP) Theory

The method offers the technique tocalculate the real and reactive power requirements of the load instantaneously. Themethod is mostly applied to calculate the reference current of the SHUC or shunt active filter.The transformations involved are given in equations (2.1)-(2.8). Three phaseto two-phase transformation is applied on measured voltages and currents using equations (2.1) and (2.2) where T is the transformation matrix.A new definition of instantaneous reactive power is presented. This definition has a clear physical meaning that includes both the conventional instantaneous reactive power and the instantaneous power of a zero-phase component. A simple control algorithm for the active filter derived from the new definition is described. Simulations verified the control algorithm. This theory is based on the transformation of three-phase quantities to two-phase quantities in α–β frame and the calculation of instantaneous active and reactive power in this frame..The systematic use of active power filters, APF, to compensate non-linear loads, has extended the use of the instantaneous reactive power theory. Originally, p–q theory appeared; it obtained constant instantaneous power in the source side after compensation. Later, other formulations have been developed. They have allowed different compensation objectives to be obtained. Nevertheless, all of them can only be applied to three-phase systems .This paper presents a new approach which can be applied to multi-phase power systems. Thus, a new product is introduced that allows an operative definition of the instantaneous reactive power tensor and the derived instantaneous reactive current component. According to these expressions, different compensation strategies can be defined in multi-phase systems.

The powers and currents expressions derived from the formulations presented up now can be obtained applying this new approach. In this work, original p–q and modified p–q formulations expressions are derived in the new approach framework. In addition, a series of practical examples has been included to improve the understanding of the proposed formulationThe transformations involved are given in equations (2.1)-(2.8). Threephaseto two-phase transformation is applied on measured voltages and currents usingequations (2.1) and (2.2) where T is the transformation matrix. The instantaneous real and reactive power can be calculated by transformed voltages and currents using equation (2.3). The calculated instantaneous power has both DC and AC components (2.4 and 2.5). The AC components of the powers originate from harmonics and negative sequence components. Therefore a high pass filter can be applied to separate the AC components and the compensator reference current can be calculated using equations (2.6), (2.7) and (2.8). T1 is the reverse transformation matrix.

$$\begin{bmatrix} i & v_\alpha \\ i & v_\beta \end{bmatrix} = T \begin{bmatrix} i & v_a \\ i & v_b \\ i & v_c \end{bmatrix} \tag{2.1}$$

$$T = \sqrt{2/3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & \sqrt{3}/2 \end{bmatrix} \tag{2.2}$$

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & -v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_a \\ i_b \end{bmatrix} \tag{2.3}$$

$$P = \bar{p} + \overline{p} \tag{2.4}$$

$$q = \bar{q} + \overline{q} \tag{2.5}$$

$$\begin{bmatrix} i_{ref\alpha} \\ i_{ref\beta} \end{bmatrix} = \frac{1}{V^2_{\alpha} + v^2_{\beta}} \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \tag{2.6}$$

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = T' \begin{bmatrix} i_{ref\alpha} \\ i_{ref\beta} \end{bmatrix} \tag{2.7}$$

$$T' = \frac{2}{3} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \tag{2.8}$$

IV. SIMULATION AND RESULTS

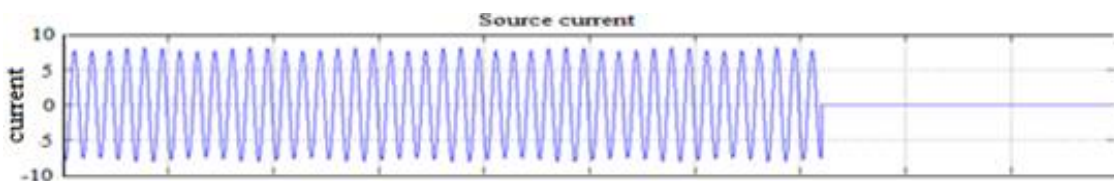### Results obtained for the source, injected, load current waveform

fig 1 Simulation result for source current

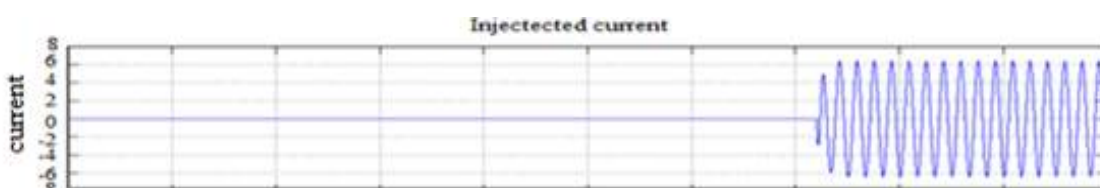fig 2 Simulation Result for Injected Current

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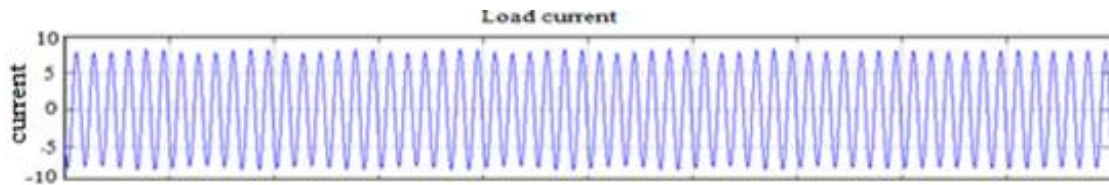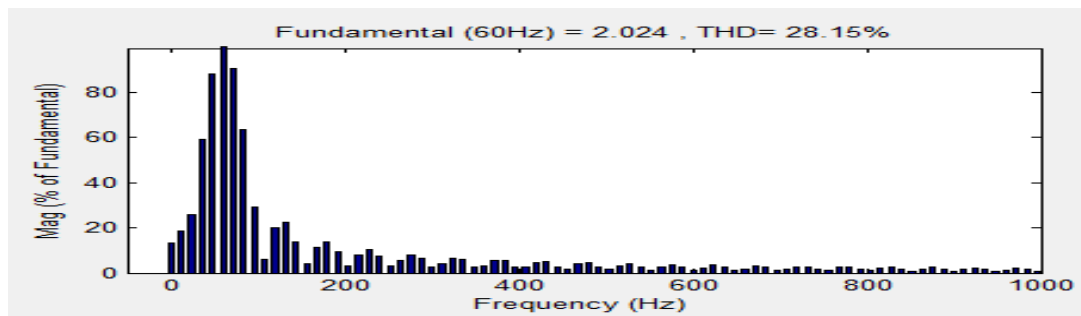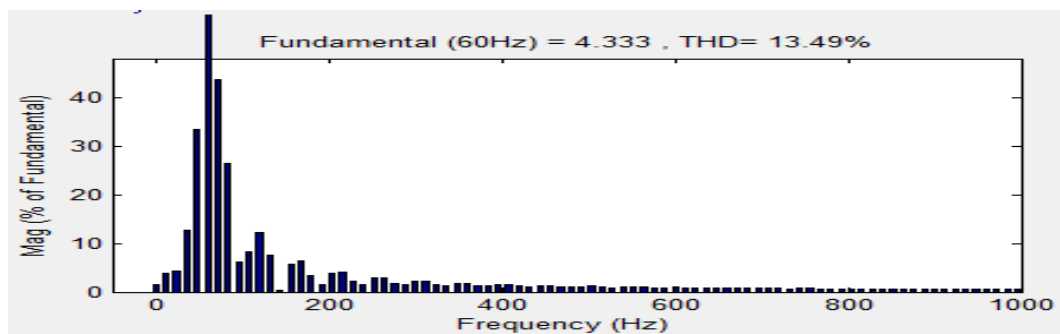fig 3Simulation result for Load Current

Above fig shows the MATLAB Simulation results for current waveform, Fig 1 shows the input waveform for source current Vs time and when any fault occurs in a Distribution System the continuity of supply is not maintained. Fig 2 shows Injected current, this waveform represent Injection of current by using residual current at that point where supply is cut off. Fig 3 showsoutput load current Vs time waveform this shows continuity supply is maintained.

Fig 4 Shows FFT Analysis for total harmonic distortion in which harmonic obtained for input 1shows harmonic present in source is around 28.15%.Input 2 shows value of total harmonic distortion after injecting current is 13.49. Input 3 shows load side total harmonic distortion which is reduced and value is 0.19%

Harmonics obtained for input 1

Harmonics obtained for input 2
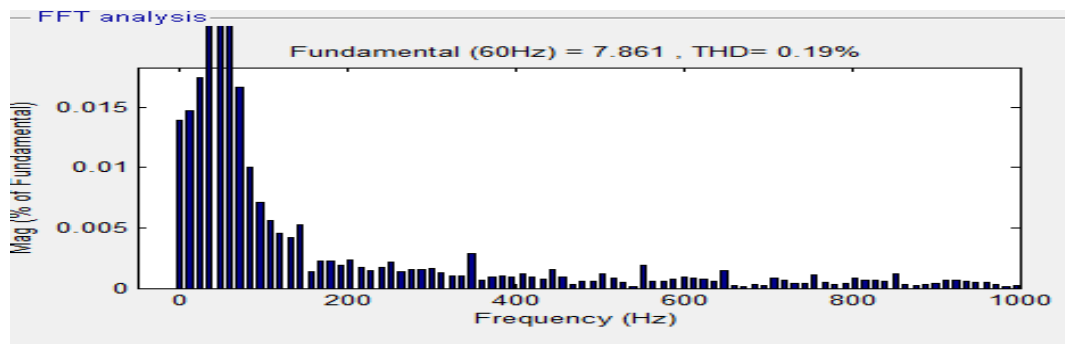
Harmonics obtained for input 3

Fig.4 FFT Analysis for total harmonic distortion

VI.CONCLUSION

In thispaper reference current generation by using IRP (Instantaneous Reactive Power) has been proposed. The mathematical derivation of the IRP, theory has been employed to Simulated results have verified the effectiveness of these control algorithms. The simulation results showed that the proposed control algorithm has good performance in the harmonic compensation and performance under distorted supply voltage condition.

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BIOGRAPHY

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