IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 11, Issue 1 Ver. IV (Jan. – Feb. 2016), PP 05-09
www.iosrjournals.org

A Novel Control Strategy of Shunt Active Filters

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Abstract: *A shunt active filter injects a suitable non-sinusoidal current (compensating current) into the system at the point of common coupling and makes the source current sinusoidal. This paper presents a performance comparison of different methods of estimating reference-compensating current for a three-phase shunt active power filter. The control strategy considers the presence of harmonics in the system voltage and load current simultaneously. The shunt active filter provides current compensation, such that the compensated current drawn from the network is sinusoidal and balanced, corresponding to the fundamental positive-sequence component of the load current, plus an additional fundamental positive sequence component to cover losses in the power circuit of the shunt active filter. Simulation results are presented to validate the control strategy. Simulation results have determined that the Fast Fourier Transform method provides good steady state and transient responses for active filters in unbalanced systems.*

Keywords*: Current Compensation, Fast Fourier Transform, Harmonic and Reactive power compensation, Instantaneous Active and Reactive Power, Harmonic Elimination etc.*

I. Introduction

In industry, harmonics cause excess heating in motors and transformers and can lead to overloading of neutral conductors in power lines [1]. This is because harmonics that are a multiple of three (the triplens) will add, rather than cancel, in the neutral wire. The neutral current will only be zero if the three phases are each carrying exactly the same current (ie. the phases are balanced) and there are no triplens. Having the three phases balanced is unusual for light industrial and commercial loads where each of the three phases are treated as independent supplies. Shunt active filters were initially proposed in 1971 by Sasaki and Machida [2] as a means of removing current harmonics. Recent advances in semiconductor technology have produced high-speed, high-power devices suitable for constructing active filters [3]. The shunt active filter provides current compensation, such that the compensated current drawn from the network is *sinusoidal and balanced*, corresponding to the fundamental positive-sequence component of the load current, plus an additional fundamental positive sequence component to cover losses in the power circuit of the shunt active filter. Simulation results are presented to validate the control strategy.

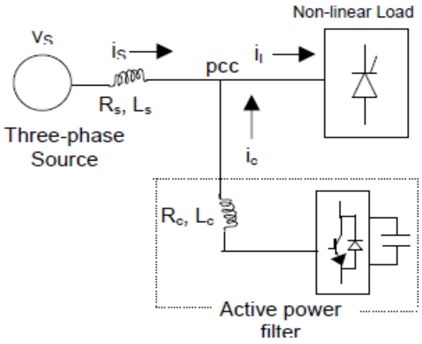


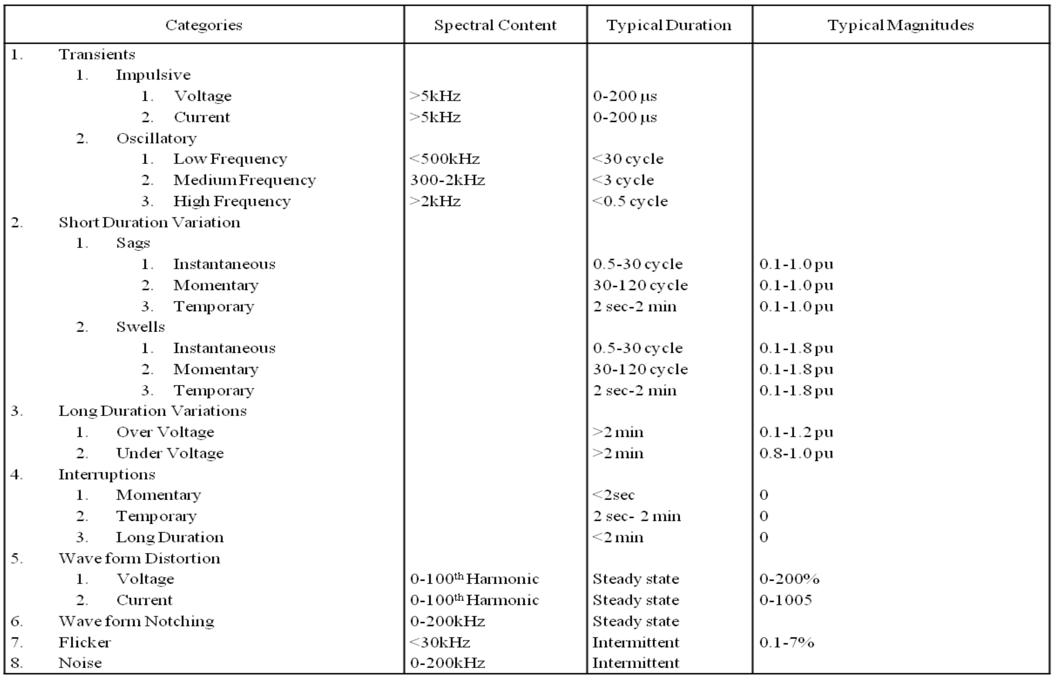
Figure. 1 Basic compensation principle of SAPF

Harmonic Determination Methods

A number of methods exist for determining the harmonic content of a current waveform. Two common methods are notch filtering of the fundamental [4] and Instantaneous Reactive Power Theory [5]. Two common methods are notch filtering of the fundamental [4] and Instantaneous Reactive Power Theory [5]. Less common methods include the Synchronous Reference Frame [6], Fast Fourier Transforms (FFTs) and a novel method using the subtraction of a synthetic fundamental from the load current [3]. Each of these methods is described with attention to the case of unbalanced load currents. The effectiveness of each method was quantitatively determined by calculating the Total Harmonic Distortion (THD) of the resulting supply current and response of the controller to step changes in load. An expression for THD is given in Eqn. (1), where *In*(*rms*) is the root-mean-square current of the *n*th harmonic.

$$THD = \frac{\sqrt{\sum_{n=2}^{\infty} I_{n(rms)}^{2}}}{I_{1(rms)}} \times 100\% \tag{1}$$

Categories Of Power Quality Variation



Categories	Spectral Content	Typical Duration	Typical Magnitudes
1. Transients			
1. Impulsive			
1. Voltage	>5kHz	0-200 µs	
2. Current	>5kHz	0-200 µs	
2. Oscillatory			
1. Low Frequency	<500kHz	<30 cycle	
2. Medium Frequency	300-2kHz	<3 cycle	
3. High Frequency	>2kHz	<0.5 cycle	
2. Short Duration Variation			
1. Sags			
1. Instantaneous		0.5-30 cycle	0.1-1.0 pu
2. Momentary		30-120 cycle	0.1-1.0 pu
3. Temporary		2 sec-2 min	0.1-1.0 pu
2. Swells			
1. Instantaneous		0.5-30 cycle	0.1-1.8 pu
2. Momentary		30-120 cycle	0.1-1.8 pu
3. Temporary		2 sec-2 min	0.1-1.8 pu
3. Long Duration Variations			
1. Over Voltage		>2 min	0.1-1.2 pu
2. Under Voltage		>2 min	0.8-1.0 pu
4. Interruptions			
1. Momentary		<2sec	0
2. Temporary		2 sec- 2 min	0
3. Long Duration		<2 min	0
5. Wave form Distortion			
1. Voltage	0-100th Harmonic	Steady state	0-200%
2. Current	0-100th Harmonic	Steady state	0-1005
6. Wave form Notching	0-200kHz	Steady state	
7. Flicker	<30kHz	Intermittent	0.1-7%
8. Noise	0-200kHz	Intermittent	

Table : Categories of Power Quality Variation [7]

Frequency Domain Method

1. FFT method [8] [9]

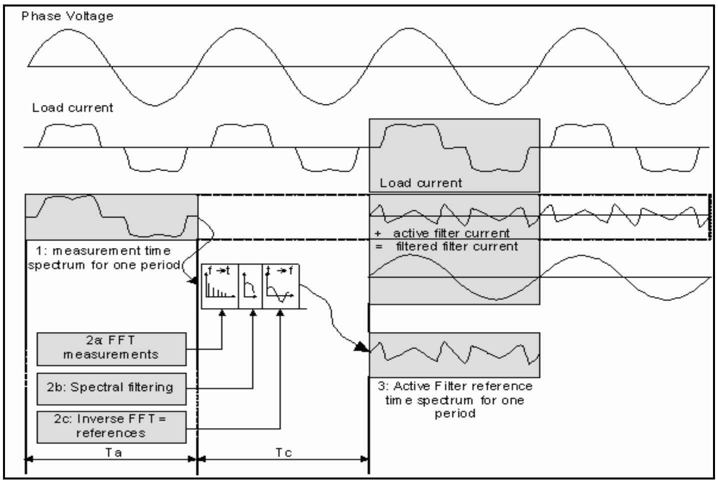


Figure 2: operating principle of FFT algorithm for harmonic mitigation.

2. FFT Algorithm [8] [9]

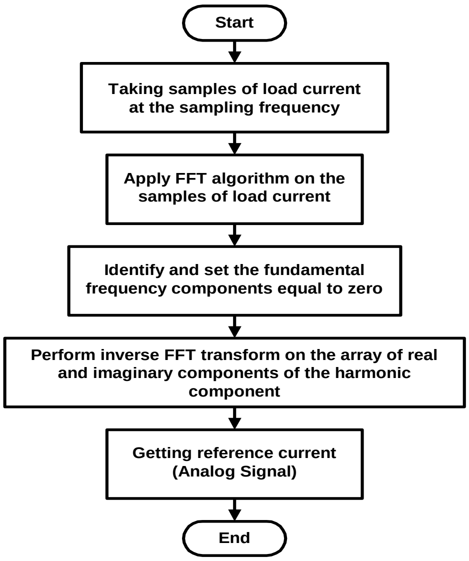


Figure 3 : Flow chart for the calculation of compensating current using FFT algorithm

Simulation Of Shunt Active Filter Based On Fft Algorithm

Simulation Of Shunt Active Filter Based On Fft Algorithm For Unbalanced Supply Voltage Condition

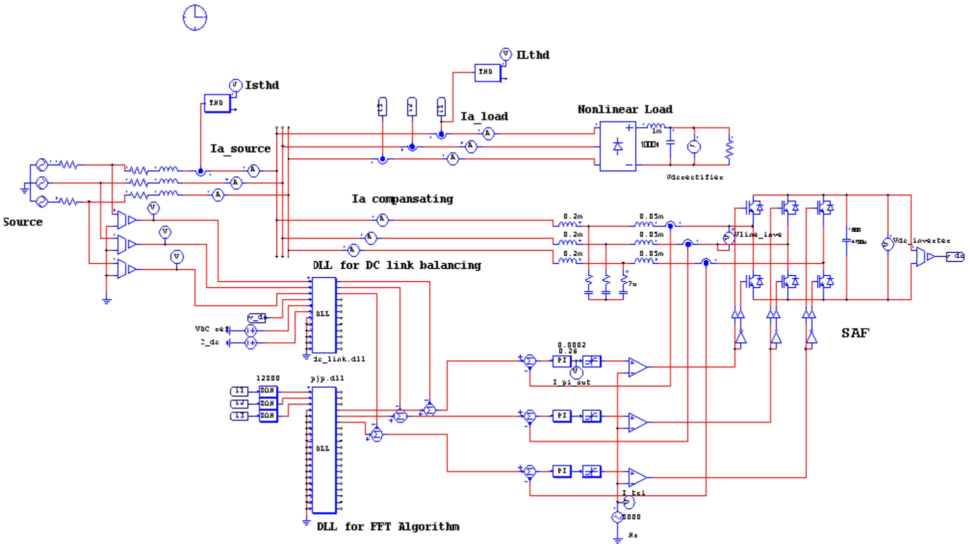


Figure 4 : Simulation Diagram of Shunt Active Filter Based on FFT Algorithm for Unbalanced Supply Voltage Condition

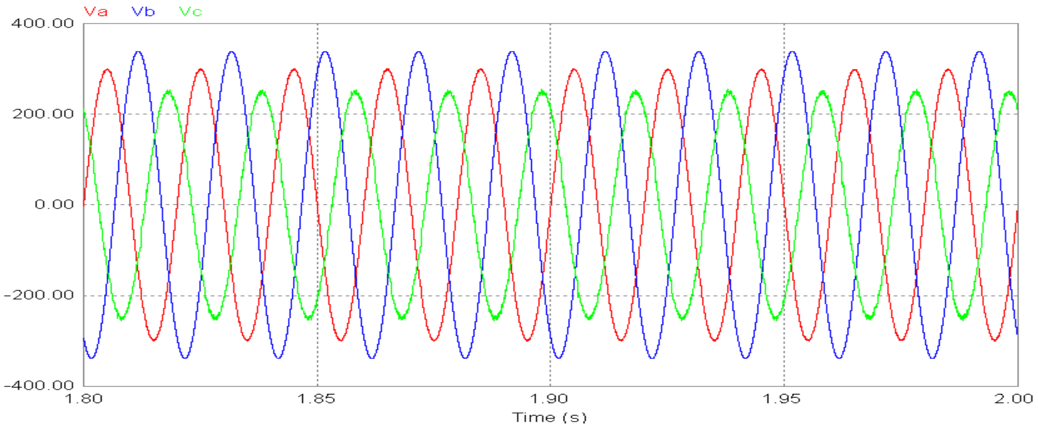


Figure 5 : Three Phase Supply Voltage

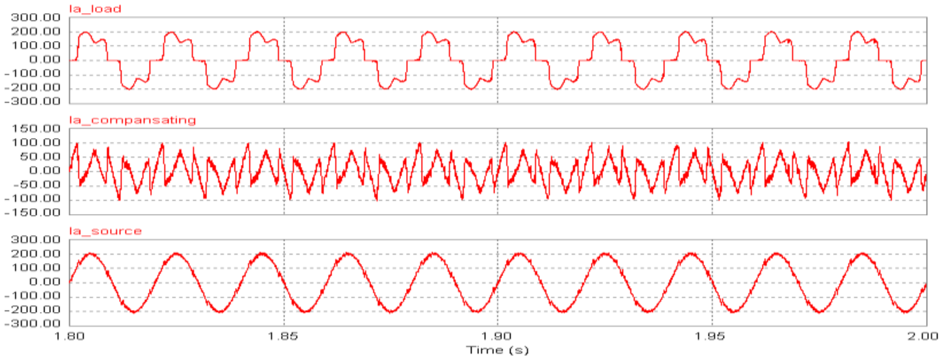


Figure 6 : waveforms of phase-A (a) distorted load current (b) compensating current by filter (c) source current after compensation

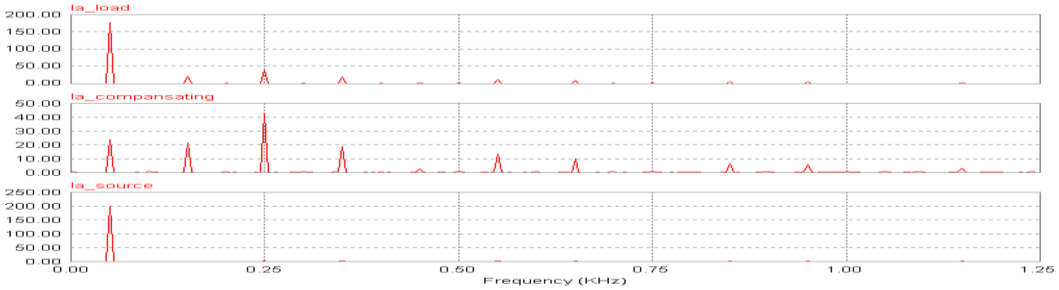


Figure 7 : Harmonics spectrum of phase-A (a) distorted load current (b) compensating current by filter (c) source current after compensation

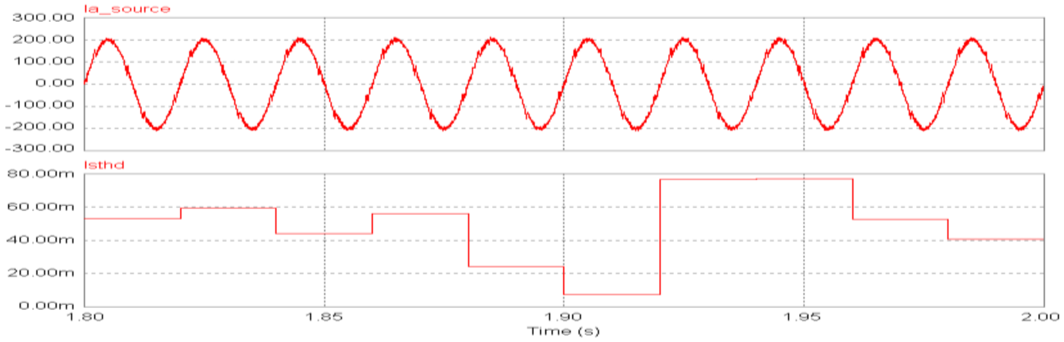


Figure 8: Wave Forms of (a) Compensated Source Current in Phase-A, and (b) THD of Source Current(4.91%)

II. Conclusion

In unbalanced supply voltage condition the performance of the P-Q theory is not effective, while because of the important characteristic of treating each phase individually FFT can effectively compensate harmonics in the unbalanced supply voltage condition From Figure 8, it is observed that for all the five methods, THD of the source current is reduced well below 5% and meets IEEE-519 standards

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