

Frequency Domain-Control Strategies of Active Filters

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Abstract: Commencing with incandescent light bulbs, every load today creates harmonics. Unfortunately, these loads vary with respect to their amount of harmonic content and their response to problems caused by harmonics. The prevalent difficulties with harmonics are voltage and current waveform distortions. In addition, Electronic equipment like computers, battery chargers, electronic ballasts, and variable frequency drives, and switching mode power supplies generate perilous amounts of harmonics. Issues related to harmonics are of a greater concern to engineers and building designers because they do more than just distort voltage waveforms, they can overheat the building wiring, cause nuisance tripping, overheat transformer units, and cause random end-user equipment failures. Thus power quality is becoming more and more serious with each passing day. As a result, active power filters (APFs) have gained a lot of attention due to their excellent harmonic compensation. However, the performance of the active filters seems to have contradictions with different control techniques.

Keywords: Active power filter and Passive power filter, Fundamental frequency, FFT(Fourier Analysis Method), Harmonics, Harmonic Mitigation Techniques.

I. Introduction

Shunt active power filters (SAPF) represent a feasible solution to the problems caused by the non-linear loads. These loads draw non-sinusoidal currents from the 3-phase sinusoidal, balanced voltages which are classified as identified and unidentified loads. The SAPF can compensate for the harmonics, correct the power factor and work as a reactive power compensator, thus providing enhancement of power quality in the system [1, 2]. The control scheme of a SAPF must calculate the current reference waveform for each phase of the inverter, maintain the dc voltage constant, and generate inverter gating signals. The current reference circuit generates the reference currents required to compensate the load current harmonics and reactive power, and also try to maintain constant the dc voltage across the capacitor [3]. Most of the industrial applications need current harmonic compensation, so the shunt active filter is popular than series active filter. The shunt active power filter has the ability to keep the mains current balanced and sinusoidal after compensation regardless of whether the load is non-linear and balanced or unbalanced [8-12].

In the generalized instantaneous reactive power theory [2], transformation of a-b-c axes to $d-q$ synchronous reference frame is done for harmonic and reactive power compensation. However, the synchronous reference frame (SRF) strategy [3] only computes the sinusoidal fundamental components of the load currents; the reactive power compensation and a null neutral current thus cannot be achieved if the load imbalance at the fundamental frequency occurs. Among different PWM methods, hysteresis is one of the most popular PWM strategies [6- 10] and widely applied in SAPF for current quality compensation, owing to its advantages such as ease of implementation, fast dynamic response and current limiting capability.

II. State Of The Art

The AF technology is now mature for providing compensation for harmonics, reactive power, and/or neutral current in ac networks. It has evolved in the past quarter century of development with varying configurations, control strategies, and solid-state devices. AF's are also used to eliminate voltage harmonics, to regulate terminal voltage, to suppress voltage flicker, and to improve voltage balance in three-phase systems. This wide range of objectives is achieved either individually or in combination, depending upon the requirements and control strategy and configuration which have to be selected appropriately.

This section describes the history of development and present status of the AF technology. The active power filter (APF) is a popular approach for cancelling the harmonics in power system. The main component in the APF is the control unit. The control unit is mainly divided into two parts as follows.

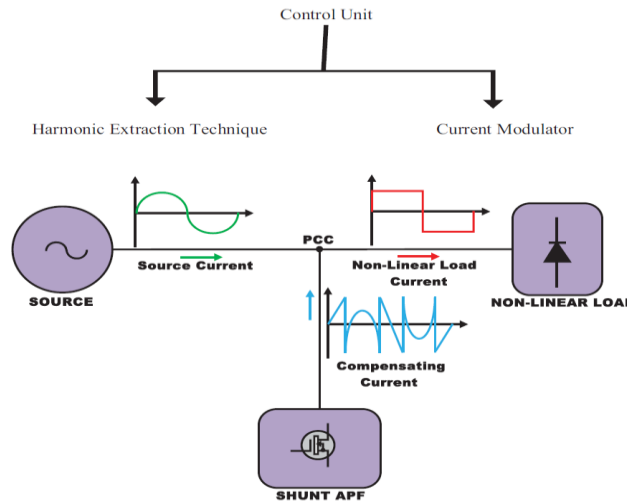


Fig.1 Shunt Active Power Filter

Harmonic extraction is the process in which, reference current is generated by using the distorted waveform. Many theories have been developed such as p-q theory (instantaneous reactive power theory), d-q theory, frieze controller, PLL with fuzzy logic controller, neural network etc.. Out of these theories, more than 60% research works consider using p-q theory and d-q theory due to their accuracy, robustness and easy calculation.

Current Modulator (Gate control signal): Current modulator is mainly used to provide the gate pulse to the active power filter (Inverter). There are many techniques used for giving the gating signals to PWM VSI such as sinusoidal PWM, triangular PWM, hysteresis current controller, adaptive hysteresis current controller, space vector modulation and space vector with hysteresis current controller etc.

III. Effects Of Harmonics

The voltage or current distortion limit is determined by the sensitivity of loads (also of power sources), which are influenced by the distorted quantities. The least sensitive is heating equipment of any kind. The most sensitive kind of equipments are those electronic devices which have been designed assuming an ideal (almost) sinusoidal fundamental frequency voltage or current waveforms. Electric motors are the most popular loads which are situated between these two categories. An example classification of the effects of the presence of high harmonics is given in Table 1

TABLE 1 Effects of current and Voltage Harmonics:

| Classification of Criterion | Type of Effect | Comments |
|---|-------------------------|---|
| Period | Very short-term effects | These effects are associated with a failure, malfunction or inoperative state of equipment exposed to high harmonics, such as control and instrumentation equipment, electronic equipment, IT equipment, etc. |
| | Long-term effects | Mainly of thermal nature. The thermal effect (causing accelerated ageing of insulation) is a function of many variables, of which the most important are the values and orders of harmonics. |
| Physical Nature Of The Distorted Quantity | Current effects | Related to the instantaneous or time-averaged current value (overheating of electric machines, capacitor fuses blowing, increased losses in transmission lines, unwanted operation of relays, etc.). Harmonics in power supply systems are the main cause of temperature rise in the equipment and shortening of in-service time. |
| | Voltage effects | Related with the peak, average or RMS value of distorted voltage. |

Comparison between Shunt Active Filter and Series Active Filter

| | Shunt Active Filter | Series Active Filter |
|----------------------------------|---|---|
| Power Circuit of Active Filter | Voltage fed PWM inverter with current minor loop | Voltage fed PWM inverter without current minor loop |
| Active filter acts as | Current Source: i_{AF} | Voltage Source: v_{AF} |
| Harmonic producing load suitable | Diode/Thyrister rectifiers with inductive loads and cycloconverters | Large capacity diode rectifiers with capacitive loads |
| Additional Function | Reactive power compensation | AC voltage regulation |

Simulation Of Shunt Active Filter Based On Fft Algorithm

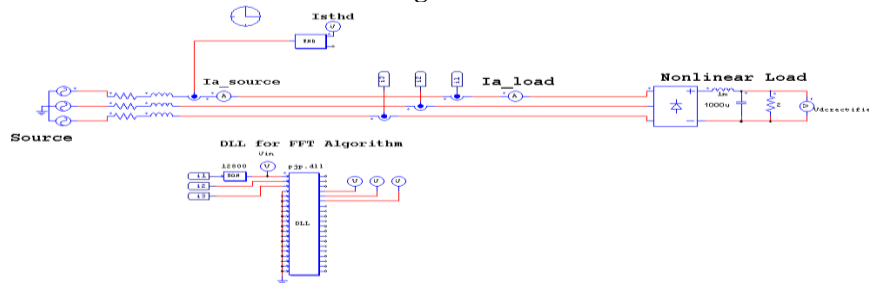


Figure : Simulation Diagram for Verification of FFT Algorithm in Balanced Supply Connected to the Constant Nonlinear Load

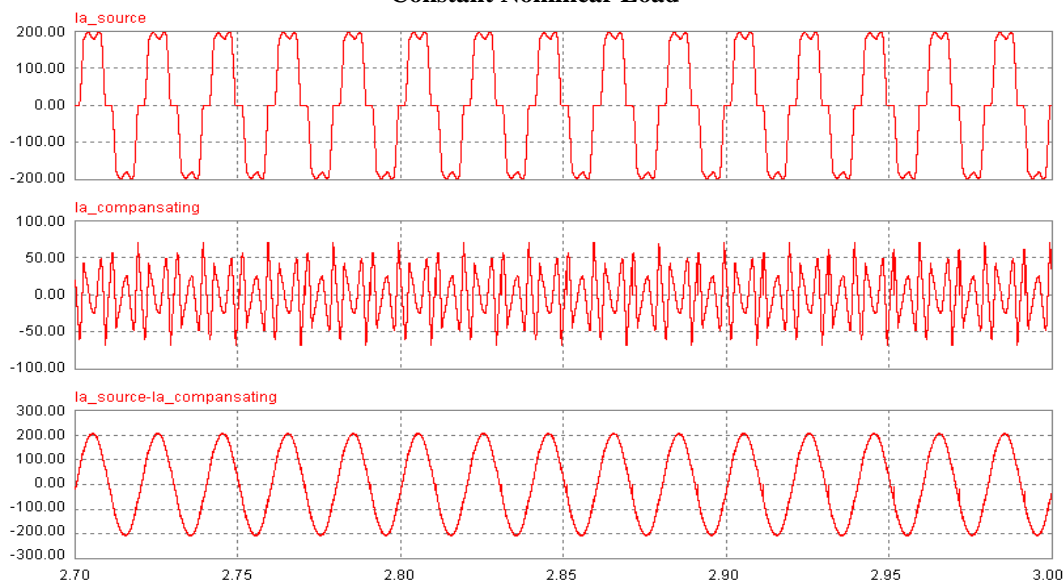


Figure : Wave Forms For Verification of FFT Algorithm (a) Distorted Source Current (b) Compensating Current (c) Source Current After Compensation of Phase-A

Simulation Of Shunt Active Filter Based On Fft Algorithm For Steady State Condition

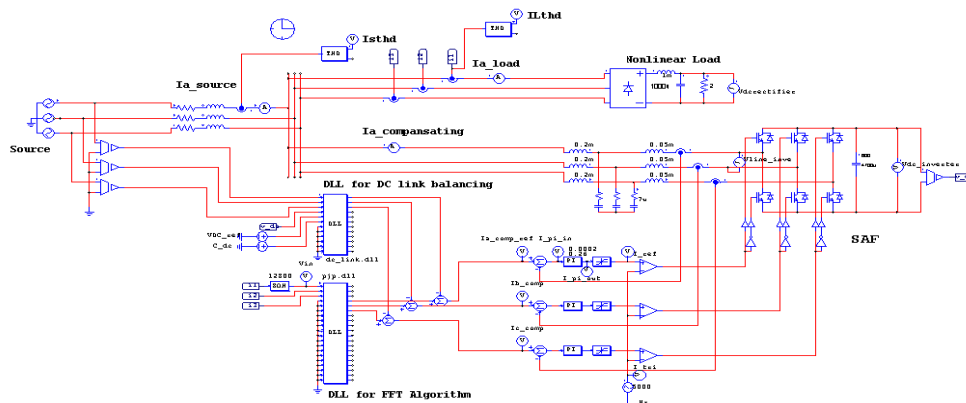


Figure : Simulation Diagram of Shunt Active Filter Based On FFT Algorithm for Steady State Condition

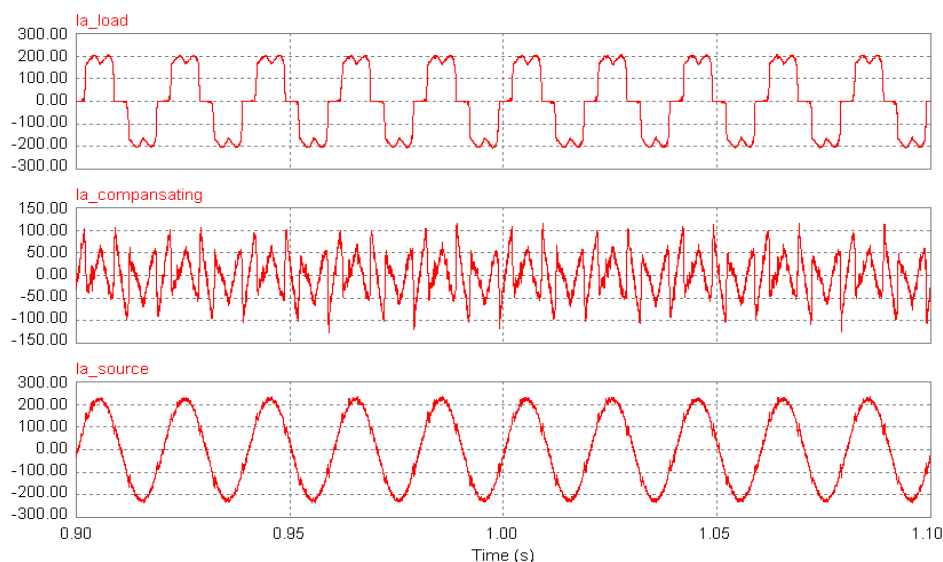


Figure : waveforms of phase-A (a) distorted load current (b) compensating current by filter (c) source current after compensation

IV. Conclusion

From the simulation of shunt active power filter working on p-q Theory and FFT algorithm the following results have been obtained. Balanced supply voltage and constant load condition -THD in source current before compensation is 27.59% and THD in source current after compensation is 5.52% .

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