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Enhancement of Harmonics by Shunt Active Filter by I_d-I_q Method

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Abstract**—** *This manuscript deals with plan, simulation testing of a shunt active power filter (SAPF) to develop power quality. Due to a huge amount of non-linear power electronic equipments, and variable loads (such as that of arc furnace, heavy merchant mill etc), troubles of power quality have become increasingly serious with each passing day. It is identified from the fact that Harmonic Distortion is one of the major power quality troubles often encountered by the utilities. As a effect Shunt Active power filter (SAPF) gains much added attention due to outstanding harmonic compensation. Here active and reactive current method (i_d-i_q) is used to alter the Shunt active power filter. I_d-I_q technique gives away an excellent performance under any voltage conditions (balanced, un-balanced, balanced non sinusoidal and balanced sinusoidal). Wide-ranging simulations were carried away; Simulation results authorize the superior performance of active and reactive method (i_d-i_q). Simulation is completed in Matlab/simulink software and the results shows that Total Harmonic Distortion (THD) is decreased significantly when compared with further methods.*

Key words**—** *Harmonic compensation, Shunt Active filter, hysteresis controller, i_d-i_q control approach.*

1. INTRODUCTION

Several social and economic actions depend on electrical energy superiority and efficiency. Mutually industrial and commercial users are involved in guaranteeing the electrical waveform Quality , which supply their different systems. The nonlinear load can create current harmonics and voltage harmonics, which makes decrease the quality of power. As a result, these harmonics must be removed. In sequence to achieve this, series or parallel configurations or combinations of active and passive filters have been designed depending on the application. Conventionally, a passive *LC* power filter is used to remove current harmonics when it is linked in parallel with the load. This compensation equipment has some drawback mostly related to the look of series or parallel resonances because of which the passive filter cannot provide a entire solution.

In current years, single-phase electronic equipments have been broadly used in domestic, educational & commercial appliances. These equipments comprises of computers, communication equipments, electronic lighting ballasts etc., Moreover, a large number of computers are switched on at the similar time. Every computer and its linked devices have a diode rectifier to transfer AC electricity to DC. In other words, those equipments depict non-sinusoidal currents which spoil the utility line due to the current harmonics generate by the variable loads. [1] [5]

While the beginning of the 1980s, active power filters (APFs) have roll into one of the most common compensation methods. APF can be linked either in parallel or in series with the load. The shunt connection APF is the mainly studied topology. Though, the costs of shunt active filters are comparatively high for major system and are difficult to use in high-voltage grids.[7] In toting up, their compensating performance is enhanced in the harmonic current source load type than in the harmonic voltage source load . The first of these were proposed by Akagi moreover known as Instantaneous P-Q-theory can be efficient only when the supply voltages are balanced. [9]

Two main categories of APFs be present: shunt filters, also called parallel filters, and series filters. [2][3] The earlier are effective for those variable loads, which can be calculated as current harmonic sources (e.g., phase-controlled rectifiers with large Dc inductance). As a result Shunt filters are used to generate harmonic currents to compensate load harmonic currents. Series filters are effective to create harmonic voltages to compensate load harmonic voltages. [11] [12]

Three-phase APFs have previously drawn more attention. In this crate, three “optimal” compensation targets can be addressed by APF controller, from which three control strategies derive:

1) Constant instantaneous source power control;
2) Sinusoidal current control;
3) Generalized Fryze current control.

This document describes the principle of id-iq detection method. The id-iq detection technique assumes that system three-phase voltage is full elemental positive sequence voltage. [4] [6] This is not well-known when three-phase voltage is asymmetric. According to the errors of conventional method, this document presents a improved id-iq detection technique which structures practical symmetrical three-phase voltage by using one-phase voltage to eradicate detection errors brought by voltage asymmetric [8][10]. This enhanced method is simulated, and the real-time and precision of this method is proved.

2. OUTLINE OF ACTIVE POWER FILTER

To stop the harmonics and balance the reactive power Active Power Filter is the suitable solution. The APF idea is to use an inverter to infuse currents or voltages harmonic components to cancel the load harmonic components. The more common configuration is a shunt APF to infuse current harmonics into point of common coupling (PCC). The APF can be installed in a low voltage power system to compensate one or extra loads; thus, it avoid the spread of current harmonics in the system. The developments of different control strategy give APF to a new position. As Active Power Filter compensates the reactive power and cancels the harmonics, it is also called as active power line conditioners (APLC). The three main aspect of an active power conditioner are:

- The arrangement of power converter
- The control strategy (the computation of APLC control reference signals)
- The control method used (how the power inverter follows the control orientation).

The topology of active power filter is classify into three types.

- Series active power filter
- Shunt active power filter
- Hybrid active power filter

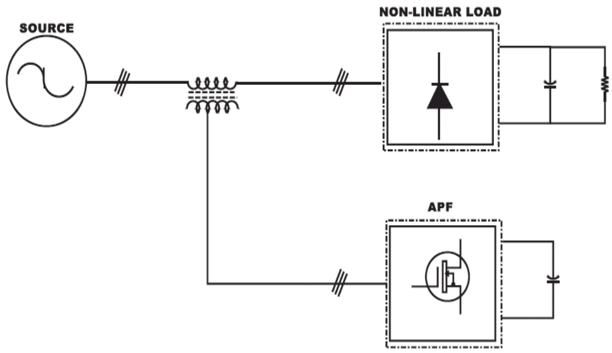

FIG.1 Series Scheme

The link scheme of a series APLC is as shown in the following diagram. It is related to the power system through coupling transformer. The compensation voltage is used to stop the voltage harmonics of load.

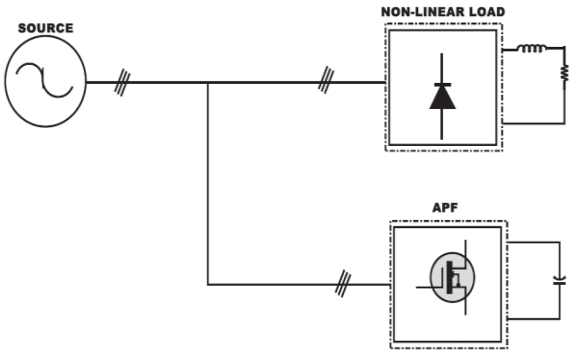

Fig.2 Shunt scheme

The 3 phase shunt active power filter is a three-phase current controlled "voltage source inverter" (CCVSI) with a mid-point earthed, split capacitor in the dc bus & inductors in the ac output.

Traditionally, a shunt Active Power Filter is controlled in such a way that to inject harmonic & reactive compensation currents based on calculated reference currents. Injected currents are destined to "cancel" the harmonic and reactive currents pinched by the non-linear loads. Though, the reference current to be injected has to be determined by extensive calculations with natural delays, errors and slow transient reaction.

An input component of this system is the added series inductance X_L which is similar in size to the efficient grid impedance, Z_S. Exclusive of this inductance (or a series active filter), load harmonic voltage sources would generate harmonic currents through the grid impedance, which could not be compensated by a shunt active power filter. Currents from the APF do not considerably change the harmonic voltage at the loads. As a result there are still harmonic voltages across the grid impedance, which persist to produce harmonic currents.

The grid current is sensed & directly restricted to follow symmetrical sinusoidal reference signals in phase with the grid voltage. Consequently, by putting the current sensors on the grid side, the grid current is enforced to behave as a sinusoidal current source and the grid appears as a high-impedance circuit for harmonics. Through forcing the grid current to be sinusoidal, the APF robotically provides the harmonic, reactive, negative and zero sequence currents for the load, following the basic current summation rule

$$i_{GRID} = i_{APF} + i_{LOAD} \quad 1$$

The sinusoidal grid current reference signal is given by:

$$i_{REF} = k\, v_{GRID}\text{-}1 \quad 2$$

where v_{grid}-1 is the fundamental component of the grid voltage, and k is obtained from an outer control loop regulating the CC-VSI dc-bus voltage.

3. ACTIVE FILTER DESIGN BY I_D-I_Q TECHNIQUE

This manuscript presents a new detection method called i_d–i_q detection. It has been applied to a shunt active power filter the next assumption made in calculating the three phase compensating current by the same current distribution method of synchronous detection algorithm. The basic design is forming rotary coordinate by using practical symmetrical three-phase system synthetic voltage vector system. This method do not need PLL, so it eliminate the adverse effects generated by PLL. Here we visualize that

- Voltage is not distorted.
- Loss in neutral line is negligible.
- The equivalent current d-q theory method shows a improved profile of source side line current after compensation.

The average power

$$P_{av} = P_a + P_b + P_c \quad 3$$

By rearranging

$$P_a = \frac{V_{am}}{V_t} P_{av} \quad 4$$

$$P_b = \frac{V_{bm}}{V_t} P_{av} \quad 5$$

$$P_c = \frac{V_{cm}}{V_t} P_{av} \quad 6$$

where

$$V_t = V_{am} + V_{bm} + V_{cm} \quad 7$$

Imagine the peak values of source currents are balanced after compensation

$$I_{am} = I_{bm} = I_{cm} = I_m \quad 8$$

In the filter current sub-block three phase supply is given as a input shown in fig 3. From that we measure the current using current measurement block. Then the phases are converged using multiplexer and we generate the filter current I_{fabc}. Then the neutral current are converged and given as a input to the hysteresis block.

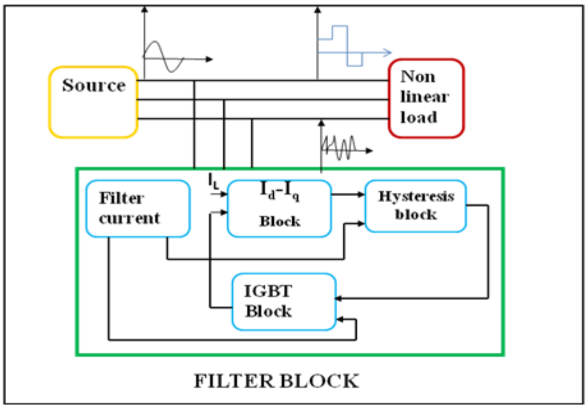

Fig.3 SAPF tuned with id –iq method

Fig.4 shows the block diagram of i_d-i_q method. First the three phase current is given as a input to the ABC to DQ conversion block. Inside this we convert the three phase into two phase i.e., d & q component. D represents sin component & Q represents cos component. By using the phase angle difference i.e., (0,-120,120) we convert this into DQ component.

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And then the D component alone passes through a low pass filter and then compared with signal got from the IGBT block. The Q component is directly given as an input to the DQ to ABC conversion block.

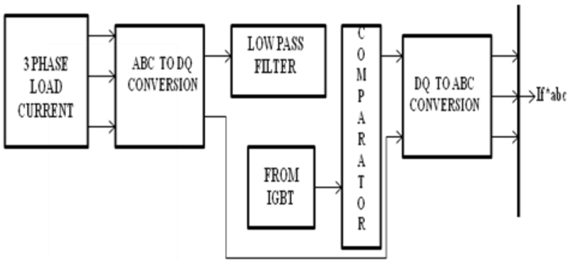

Fig.4 id–iq Block diagram

Another input for the DQ to ABC conversion block is from the comparator. And then again we convert the DQ component into ABC component i.e., two phase to three phase & generate the filter current If^*_{abc}.

The Butterworth filter is a kind of signal processing filter designed to have as even a frequency response as possible in the pass band. It is also referred to as a maximally flat magnitude filter. "An ideal electrical filter should not only completely reject the unwanted frequencies but should also have uniform sensitivity for the wanted frequencies". Such an filter cannot be achieved but Butterworth shows that sequentially closer approximations were obtained with rising numbers of filter elements of the right values.

4. SIMULATION RESULTS

The shunt active power filter which is linked to a voltage source type variable load is simulated by using MATLAB/SIMULINK . The system is first simulated without any filter to find out the THD of supply current. Then it is simulated with filter tuned with i_d-i_q method to observe the variation in THD of supply current. Simulation is also carried out with hysteresis controller to find out the comparative study of the THD of the supply current.

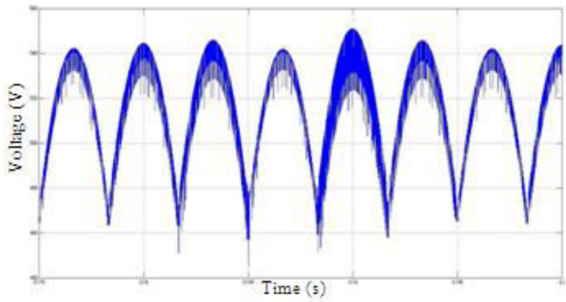

FIG.5 Non linear load voltage waveform

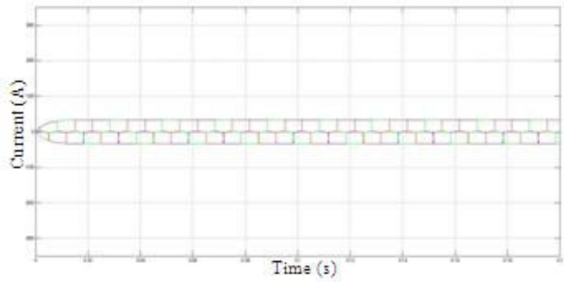

FIG.6 Source Current Waveform before filtering

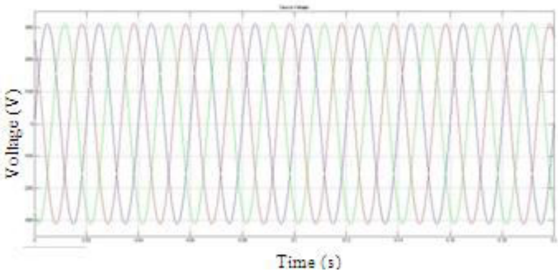

Fig.7 Source Voltage Waveform before Filtering

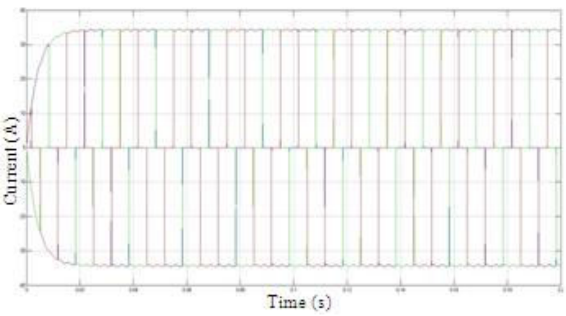

FIG.8 Load Current Waveform before Filtering

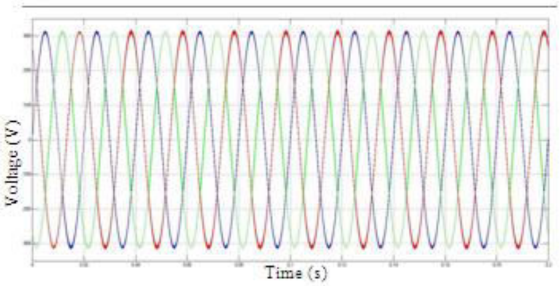

FIG.9 Load Voltage Waveform before Filtering

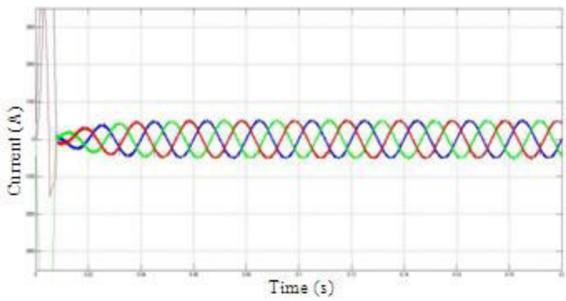

FIG.10 Source Current Waveform after Filtering

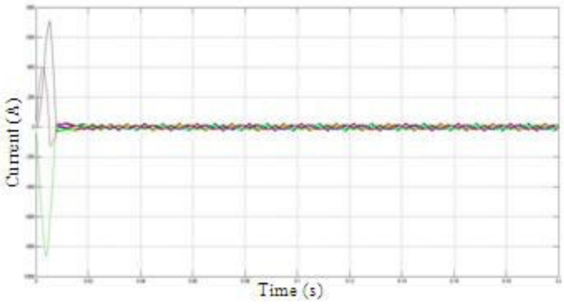

FIG.11 Filter Current Generated Waveform

5. CONCLUSION

In this paper i_d-i_q control strategy is developed & verified with three phase four wire system. It is experiential that i_d-i_q method gives always improved results under un-balanced & non-sinusoidal voltage conditions compare with other methods. In this method, angle 'θ' is calculated directly from main voltages & thus enable the method to be frequency independent. Large number of synchronization problems with un-balanced and non-sinusoidal voltages is also prevented. By using this technique the source side THD is reduced from 43% to 6% i.e., (86.2% efficiency). This efficiency is achieved without including LCL filter. While using Shunt active filter, it is very difficult task to minimize THD at the load side due to the existence of Non-linear load. But this method effectively reduces the load side THD from 43% to 30%.

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APPENDIX

- Phase voltage & frequency = 230v(rms) & 50Hz
- Line resistance & inductance = 0.0000001(ohms) & $0.1*10^4$ (henry)
- Non-Linear Load resistance & inductance = 15(ohms) & $60*10^3$(henry)
- Universal bridge rectifier resistance & capacitance = $1*10^5$ (ohms)& $5*10^{-5}$(farad)
- Butterworth low pass filter order & pass band edge frequency = 2 & 2*π*2(rad/sec)
- GTO resistance & inductance = 0.001(ohms) & $1*10^{-6}$(henry)
- Ideal DC source for IGBT = 800(Volt)
- Relay switch ON & switch OFF time = 0.05 & -0.05