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Power Quality Improvement by Suppression of Current Harmonics Using Hysteresis Controller Technique

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Abstract*— Recently wide spread of power electronic equipment has caused an increase of the harmonic disturbances in the power systems. The nonlinear loads draw harmonic and reactive power components of current from ac mains. Current harmonics generated by nonlinear loads such as adjustable speed drives, static power supplies and UPS. Thus a perfect compensator is required to avoid the consequences due to harmonics. To overcome problems due to harmonics Shunt Active Power Filter (SAPF) has been considered extensively. SAPF has better harmonic compensation than the other approaches used for solving the harmonic related problems. The performance of the SAPF depends upon different control strategies. This paper presents the performance analysis of SAPF under most important control strategy namely instantaneous real active and reactive power method (p-q) for extracting reference currents of shunt active filters under unbalanced load condition. Detailed simulations have been carried out considering this control strategy and adequate results were presented. These simulation results validate the significance of instantaneous real active and reactive power (p-q) control strategy in achieving an effective harmonic compensation under unbalanced load conditions. In this paper, harmonic control strategy is applied to compensate the current harmonics in the system. A detailed study about the harmonic control method has been used using shunt active filter technique.

***Index Terms*— Hysteresis Current control, Instantaneous power (p–q) theory, PI Controller, Shunt Active Power Filter.**

I. INTRODUCTION

Since the rapid development of the semiconductor industry, power electronics./these power electronics devices have benefited the electrical and electronics industry, these devices are also the main source of power harmonics in the power system. These power harmonics are called electrical pollution which will degrade the quality of the power supply. As a result, filtering process for these harmonics is needed in order to improve the quality of the power supply. Thus, active power filter seems to be a viable alternative for power conditioning to control the harmonics level in the power system nowadays.

The voltage at different buses of power system network is getting distorted and the utilities connected to these buses are not operated as designed. The power harmonics caused by the saturated devices which are mainly due to the operating modes of the transformers and machines are usually laid on the iron core saturation curve.

On the other hand, the current distortion caused by the florescent lamp is related to the arc and the magnetic ballasts. Both currents of these devices are peaked and rich in third order harmonics. As for the power electronic devices, these loads control the flow of power by supplying the voltages and currents in certain intervals of the fundamental period. Thus, the current drawn by the load is no longer sinusoidal but appears chopped or flattened [1].

Active power filters which are more flexible and viable have become popular nowadays. The basic compensation principles of the active filter were proposed around 1970 by Bird, B. M. *et al.* in 1967 and Gyugyi, L. *et al.* in 1976. These active power filters are able to compensate harmonics continuously, regardless of the changing of the applied loads [2]. However, active power filters configurations are more complex and require appropriate control devices to operate. As there are various topologies of active power filter, researches are done in order to design and develop better control strategies and filter configurations [3], [4]

II. POWER QUALITY ISSUES

Power Quality (PQ) related issues are of most concern nowadays. The widespread use of electronic equipment, such as information technology equipment, power electronics such as adjustable speed drives (ASD), programmable logic controllers (PLC), energy-efficient lighting, led to a complete change of electric loads nature. These loads are simultaneously the major causers and the major victims of power quality problems. Due to their non-linearity, all these loads cause disturbances in the voltage waveform

Along with technology advance, the organization of the worldwide economy has evolved towards globalisation and the profit margins of many activities tend to decrease. The increased sensitivity of the vast majority of processes (industrial, services and even residential) to PQ problems turns the availability of electric power with quality a crucial factor for competitiveness in every activity sector.

2.1 Power Quality Problems:

The AC and DC variable speed drives utilized on board container cranes are significant contributors to total harmonic current and voltage distortion. Whereas SCR phase control creates the desirable average power factor, DC SCR drives operate at less than this. In addition, line notching occurs when SCR's commutate, creating transient peak recovery voltages that can be 3 to 4 times the nominal line voltage depending upon the system impedance and the size of the drives.

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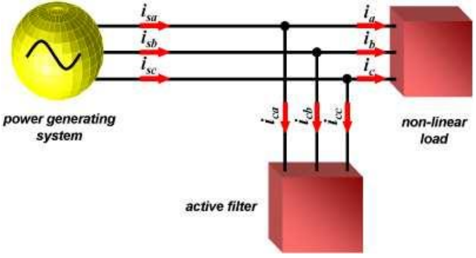
Power factor will be lowest when DC drives are operating at slow speeds or during initial acceleration and deceleration periods, increasing to its maximum value when the SCR's are phase on to produce rated or base speed. Above base speed, the power factor essentially remains constant. Unfortunately, container cranes can spend considerable time at low speeds as the operator attempts to spot and land containers.

Poor power factor places a greater KVA demand burden on the utility or engine-alternator power source. Low power factor loads can also affect the voltage stability which can ultimately result in detrimental effects on the life of sensitive electronic equipment or even intermittent malfunction.

III. SHUNT ACTIVE FILTER

The shunt active power filter (APF) is a device that is connected in parallel to and cancels the reactive and harmonic currents from a nonlinear load. The resulting total current drawn from the ac main is sinusoidal. Ideally, the APF needs to generate just enough reactive and harmonic current to compensate the nonlinear loads in the line. In an APF depicted in Fig. 1, a current controlled voltage source inverter is used to generate the compensating current (ic) and is injected into the utility power source grid. This cancels the harmonic components drawn by the nonlinear load and keeps the utility line current (is) sinusoidal.

A variety of methods are used for instantaneous current harmonics detection in active power filter such as FFT (fast Fourier technique) technique, instantaneous p-q theory, synchronous d-q reference frame theory or by using suitable analog or digital electronic filters separating successive harmonic components. In this paper, the synchronous d-q-0 reference frame theory based algorithm is proposed.

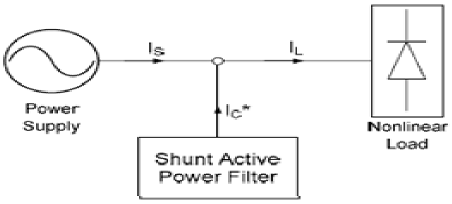


Shunt Active Power Filter

Shunt active power filter compensate current harmonics by injecting equal but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic Components generated by the load but phase shifted by 180°

IV. ACTIVE POWER FILTER TOPOLOGIES

The main purpose of the active power filter installation by individual consumers is to compensate current harmonics or current imbalance of their own harmonic-producing loads. Besides that, the purpose of the active power filter installation by the utilities is to compensate for voltage harmonics, voltage imbalance or provide harmonic damping factor to the power distribution systems.



Basic Principle of Current Harmonic Compensation

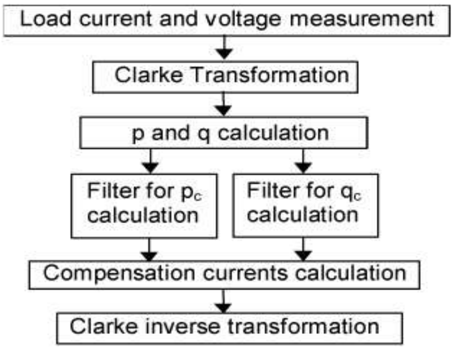
The harmonic current compensations by the active power filter are controlled in a closed loop manner. The active power filter will draw and inject the compensating current, I_C* to the line based on the changes of the load in the power supply system. The source current is equal to the load and filtering current and is given by the following equation as:

$$I_l + I_f = I_s$$

V. INSTANTANEOUS REAL AND REACTIVE POWER THEORY

In 1983, Akagi et al. [1, 2] have proposed the "The Generalized Theory of the Instantaneous Reactive Power in Three-Phase Circuits", also known as instantaneous power theory , or p-q theory. The p-q theory consists of an algebraic transformation (Clarke transformation) of the three-phase voltages and currents in the a-b-c coordinates to the α-β-0 coordinates, followed by the calculation of the p-q theory instantaneous power components.

The clarkes transformation is shown in figure 2 below:



Clarke transformation

The relation of the transformation between each component of the three phase power system and the orthogonal coordinates are expressed in space vectors shown by the following equations in terms of voltage and current as shown in equation 1.

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

The three phase coordinates a-b-c is mutually orthogonal. As a result, the conventional power for three phase circuits can be derived by using the above equations. The instantaneous active power of the three phase circuit, p, can be calculated as shown in equation 2.

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

The instantaneous real power is defined as follows in equation 3.

$$p = v_a i_a + v_b i_b + v_c i_c$$

From these equations, the instantaneous power can be rewritten as shown in euation 4.

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

As the compensator will only compensate the instantaneous reactive power, the real power is always set to zero. The instantaneous reactive power is set into opposite vectors in order to cancel the reactive component in the line current. From the equation 2 & 3, yields equation 5.

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}^{-1} \begin{bmatrix} p \\ q \end{bmatrix}$$

By deriving from these equation, the compensating reactive power can be identified. The compensating current of each phase can be derived by using the inverse orthogonal transformations as shown below in equation 6.

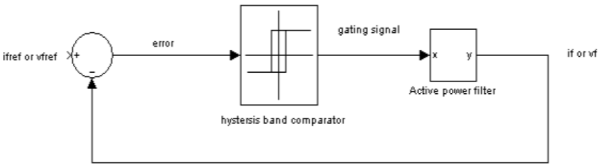
$$\begin{bmatrix} i_{Ca}^* \\ i_{Cb}^* \\ i_{Cc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{C\alpha} \\ i_{C\beta} \end{bmatrix}$$

This instantaneous reactive theorem performs instantaneously as the reactive power is detected based on the instantaneous voltages and currents of the three phase circuits. This will provide better harmonics compensations as the response of the harmonics detection phase is in small delay.

The current control strategy plays an important role in fast response current controlled inverters such as the active power filters. There are several types of current controllers such as three independent hysteresis controllers, three dependent hysteresis controllers, ramp comparison controllers and predictive controllers. However, the hysteresis current control method is the most commonly proposed control method in time domain. This method provides instantaneous current corrective response, good accuracy and unconditioned stability to the system. Besides that, this technique is said to be the most suitable solution for current controlled inverters [5], [6].

VI. HYSTERESIS CONTROLLER METHOD

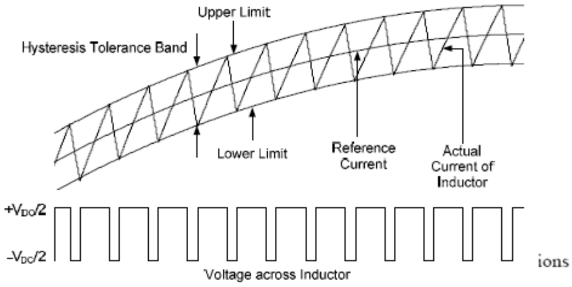
Hysteresis current control is a method of generating the required triggering pulses by comparing the error signal with that of the hysteresis band and it is used for controlling the voltage source inverter so that the output current is generated from the filter will follow the reference current waveform is shown in Figure below



Hysteresis Control

This method controls the switches of the voltage source inverter asynchronously to ramp the current through the inductor up and down, so that it follows the reference current. Hysteresis current control is the easiest control method to implement in the real time.

Figure 4 illustrates the ramping of the current between the two limits where the upper hysteresis limit is the sum of the reference current and the maximum error or the difference between the upper limit and the reference current and for the lower hysteresis limit, it is the subtraction of the reference current and the minimum error. Supposing the value for the minimum and maximum error should be the same. As a result, the hysteresis bandwidth is equal to two times of error [7].

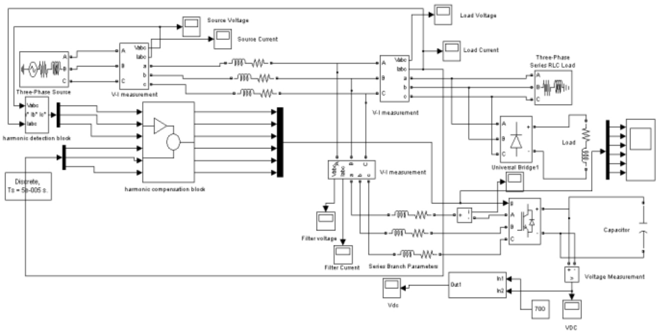


Hysteresis Band

According to the operating principle of the inverter, the output voltages of each phase are significant to the switching pulses of the switches in each leg. As a result, the switching gates for the active power filter can be obtained. The voltage across the inductors show the frequency of the switching and the frequency can be altered by adjusting the width of the hysteresis tolerance band.

VII. SIMULATION RESULT

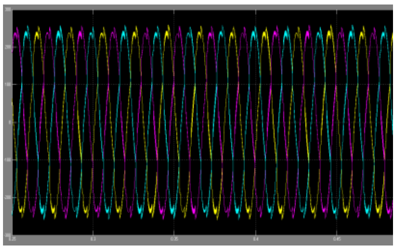
In order to verify the results, the simulation is done in a **MATLAB/SIMULINK** environment. The\model of proposed method is shown in Figure 5 and corresponding waveforms are obtained. The system parameters are given below.



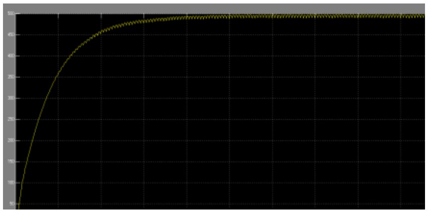
Simulation Model of Hysteresis Current Control

The various waveforms for the hysteresis control method are shown in Figure 6 -11. Figure 6 shows AC source voltage, while Figure 7 shows the load voltage and current waveforms. In order to reduce the harmonic level in the system, within the standard, the proposed algorithm based SAF is introduced in the system. Figur8 shows the distorted line currents produced by the algorithm for the filtering purpose and the actual filter current is shown in the Figure9.

By injecting the required amount of current to the system the source current become sinusoidal as shown in Figure 10. With the proposed control algorithm the source current improves with the THD of 2.09% which is well within the standard. In order to perform the above task the capacitor voltage should have to be maintained, and must be regulated by the algorithm. The proposed algorithm can properly regulate the capacitor voltage.



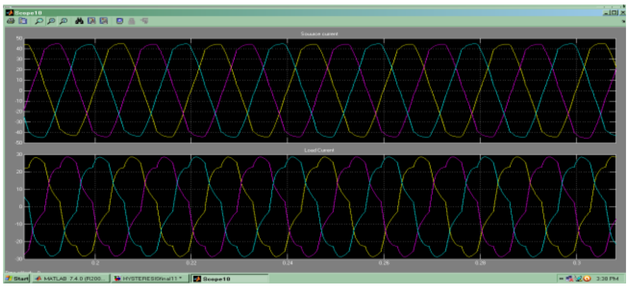
Source Voltage Waveform (a ,b ,c)



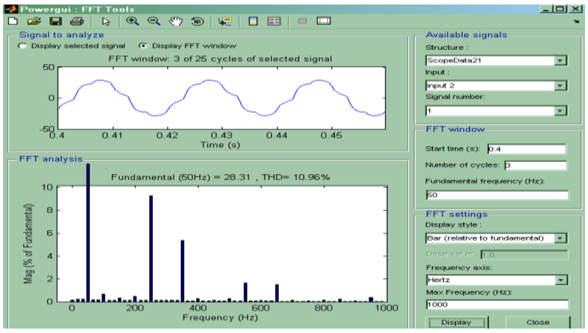
D.C. Capacitor Voltage

CASE-1 Non-Linear Load

Balanced Non- Linear Load with 0.5 power factor : In balanced Non- Linear load condition, the active power of 12KW and reactive power of 2KW with Power Factor of 0.5 as shown below



Balanced Non-Linear Load and Source current

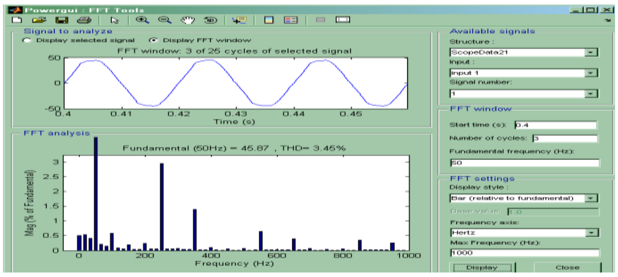


FFT window: 3 of 25 cycles of selected signal

Fundamental (50Hz) = 28.31 , THD= 10.96%

Structure : ScopeData21
Input : input 2
Signal number: 1
Start time (s): 0.4
Number of cycles: 3
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Frequency axis: Hertz
Max Frequency (Hz): 1000

THD of balanced Non- Linear load is 10.96% at t = 0.4s**.**



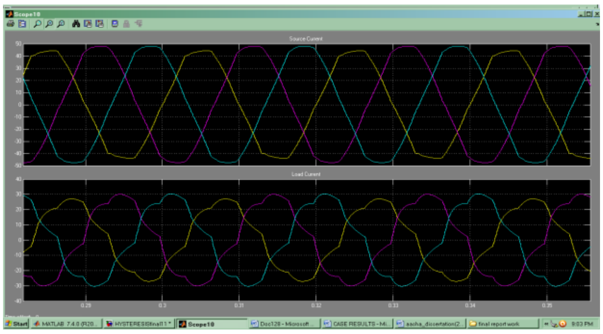
FFT window: 3 of 25 cycles of selected signal

Fundamental (50Hz) = 45.87 , THD= 3.45%

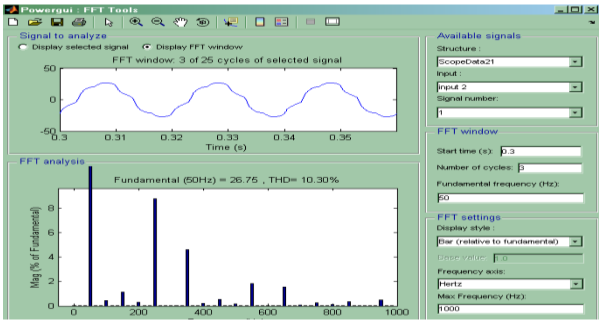
Structure : ScopeData21
Input : input 1
Signal number: 1
Start time (s): 0.4
Number of cycles: 3
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Frequency axis: Hertz
Max Frequency (Hz): 1000

THD of balanced Source Current is 3.45% at t = 0.4s.

(ii) Unbalanced Non –Linear Load with 0.5 power factor: In Unbalanced Non- Linear load condition, we have active power of 12KW and reactive power of 2KW with Power Factor of 0.5 as shown



Unbalanced Non-Linear Load and Source current

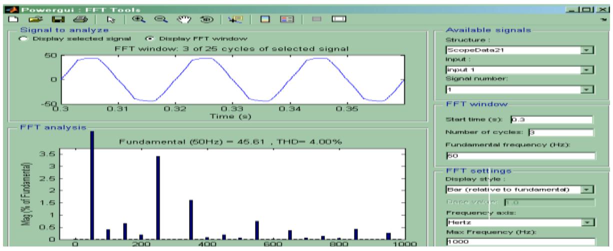


FFT window: 3 of 25 cycles of selected signal

Fundamental (50Hz) = 26.75 , THD= 10.30%

Structure : ScopeData21
Input : input 2
Signal number: 1
Start time (s): 0.3
Number of cycles: 3
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Frequency axis: Hertz
Max Frequency (Hz): 1000

THD of Unbalanced non-linear load current is 10.30% at t =0.3s



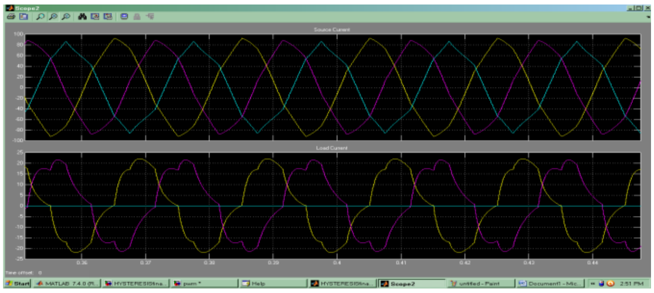
FFT window: 3 of 25 cycles of selected signal

Fundamental (50Hz) = 45.61 , THD= 4.00%

Structure : ScopeData21
Input : input 1
Signal number: 1
Start time (s): 0.3
Number of cycles: 3
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Frequency axis: Hertz
Max Frequency (Hz): 1000

THD of Unbalanced Source current is 4.00% at t =0.3s.

(iii) Unbalanced Load with 0.9power factor (By opening of one phase): In this case, the unbalancing is done by keeping the one line open whose results are shown in figure 5.14 (a) to 5.14(c). The proposed system reduces the load current harmonics, as a result the source current becomes more sinusoidal with less harmonics present in the system which is depicted in fig 5.14(b). The source current balances itself in such a way that our total harmonic distortion becomes 2.91% from 9.66%.



Non-linear load current and sinusoidal source current

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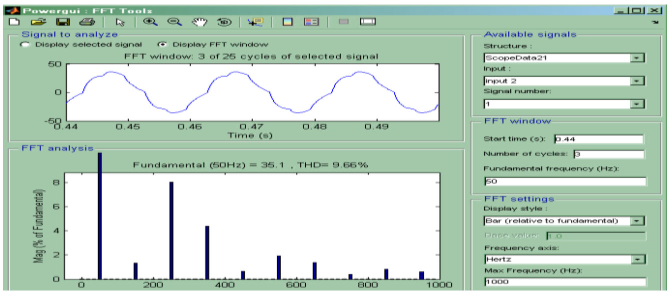
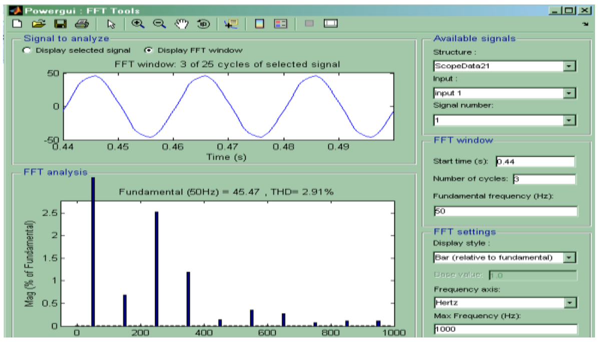


Structure : ScopeData21
Input : input 2
Signal number: 1
Start time (s): 0.44
Number of cycles: 3
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Frequency axis: Hertz
Max Frequency (Hz): 1000
Fundamental (50Hz) = 35.1 , THD= 9.66%

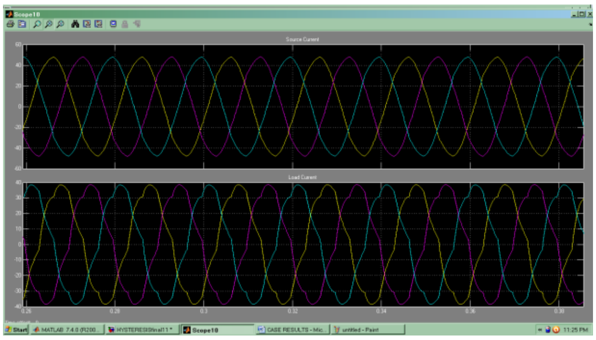
THD of Non-Linear Load current is 9.66% at t= 0.44s



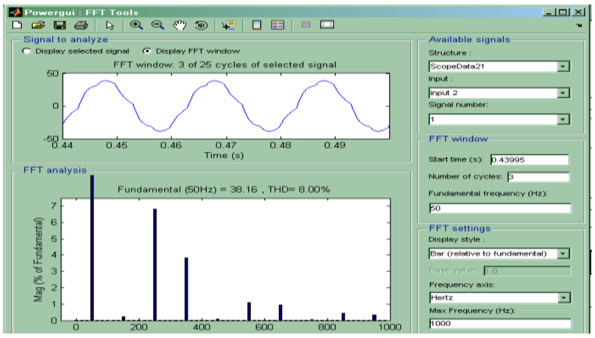
Structure : ScopeData21
Input : input 1
Signal number: 1
Start time (s): 0.44
Number of cycles: 3
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Frequency axis: Hertz
Max Frequency (Hz): 1000
Fundamental (50Hz) = 45.47 , THD= 2.91%

THD of source current is 2.91% at t= 0.44s.

(iv) At Different Load (24KW): The simulation result at different loads is calculated as shown below**:**

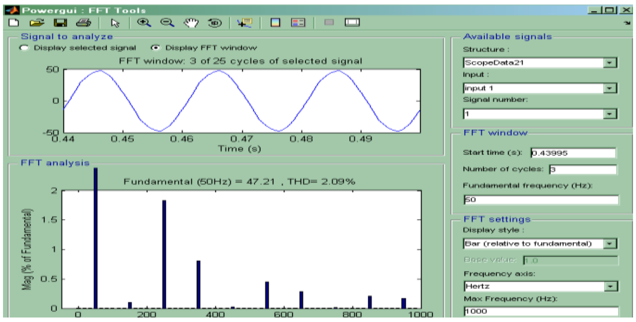


Scope showing Non-Linear Load and Source current.



Structure : ScopeData21
Input : input 2
Signal number: 1
Start time (s): 0.43995
Number of cycles: 3
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Frequency axis: Hertz
Max Frequency (Hz): 1000
Fundamental (50Hz) = 38.16 , THD= 8.00%

THD Non-Linear Load is 8.00% at t=0.439s.



Structure : ScopeData21
Input : input 1
Signal number: 1
Start time (s): 0.43995
Number of cycles: 3
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Frequency axis: Hertz
Max Frequency (Hz): 1000
Fundamental (50Hz) = 47.21 , THD= 2.09%

THD of Linear Source current is 2.09% at t=0.439s.

The frequency of the hysteresis controller is kept 50Hz. These results show that source always remains sinusoidal and lower than the load currents. It is evident from Figure 8 that even if the load resistor is been changed, the proposed algorithm is capable of coping with the change in the load and the transient performance of the Active filter with the scheme is very good. The THD of the existing method has been reduced to 2.09%.

It is observed that the THD of the given system reduced and it can also be observed from the harmonic spectrum of currents that, the proposed algorithm is effective to meet the standard recommendations on harmonic level in unbalanced current source conditions, as well as during load variation conditions. The proposed algorithm also compensates the reactive power requirements of the load and it improves the power factor of the system

VIII. RESULT AND DISCUSSION

The objectives of this paper have been achieved by reducing the harmonic components that exist in a power system with a chosen nonlinear load. This system is able to compensate the harmonics caused by a three phase uncontrolled diode rectifier and it provides positive results by reducing the percentage of THD of the line current. The validity in terms of eliminating instantaneous reactive theory in terms of eliminating harmonics and power factor improvement is confirmed from low THD source current which is in phase with source voltage. However, the system can be improved to increase its flexibility and the robustness in compensating harmonics cause by different kinds of nonlinear loads

IX. FUTURE WORK

As instantaneous reactive theory can be implemented in three-phase with excellent results in terms of THD, transient response, reference current generation. The work on extending use of these theory in APF is being done **[9].** Switching required in APF is very high in order of 10 kHz resulting in appreciable amount of power. Thus, one can further work on to reduce switching frequency and to switching losses. For future work, we intend to extend our study to the hybrid structure of series and shunt active power filters and the application of the fuzzy and neural networks to these structure.

X. CONCLUSION

In this paper we are able to compensate the harmonics caused by a three phase uncontrolled diode rectifier and it provides positive results by reducing the percentage of THD of the line current. In fact, the distortion of the power supply current was diminished to a satisfactory level with THD = 2.09%. As a conclusion, the objectives of this paper have been achieved by reducing the harmonic components that exist in a power system with a chosen nonlinear load.

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

REFERENCES

1. Akagi.H, 1996. "New Trends in Active Filters for Power Conditioning", IEEE Transaction on Industrial Applications, vol. 32, No 6, Dec., pp 1312-1322.
2. Akagi.H, 2006. "Modern active filter and traditional passive filters", Bulletin of the polish academy of sciences technical sciences vol.54.No.3
3. Ali Ajami and Seyed Hossein Hosseini, 2006. "Implementation of a Novel Control Strategy for Shunt Active Filter", ECTI Transactions on Electrical Eng., Electronics, And Communications Vol.4, No.1
4. Akagi, Hirofumi. Active Filters for Power Conditioning. In Timothy L.Skvarenina. The Power Electronics Handbook: Industrial Electronics Series. United State of America: CRC Press. Chap. 17:30-63. 2002.
5. Peng, F. Z., Akagi, H. and Nabae, A. A Novel Harmonics Power Filter.IEEE Transactions on Power Electronics Specialists Conference. April 11-14. PESC '88 Record: IEEE. 1988. 1151-1159.
6. Grady, W. M., Samotyi, M. J. and Noyola, A. H. Survey of Active Line Conditioning Methodologies. IEEE Transactions on Power Delivery.1990. 5 (3): 1536-1542.
7. Bhattacharya S. and Divan D., "Synchronous frame based controller implementation for a hybrid series active filter system," IEEE Conf. On Industry applications, vol.4,(1995):pp. 2531–2540
8. Lin C. E., Su W. F., Lu S. L, Chen C. L., and Huang C. L., "Operation strategy of hybrid harmonic filter in demand-side system," IEEE-IAS Annul. Meeting, Industry applications, (1995):pp. 1862–1866.
9. Dahono P.A, "New hysteresis current controller for single-phase bridge inverters" IET journal on [10] Power electronics, vol.2 (2009):pp. 585-594
10. Casaravilla, G, Salvia, A., Briozzo, C. and Watanabe, E. Control Strategies of Selective Harmonics Current Shunt Active Filter. *IEE Proc.- Generation, Transmission and Distribution.* 2002. 149 (6): 689-694.
11. Grady, W. M., Samotyi, M. J. and Noyola, A. H. Survey of Active Line Conditioning Methodologies. *IEEE Transactions on Power Delivery*.1990. 5 (3): 1536-1542.
12. Bhattacharya S. and Divan D., "Synchronous frame based controller implementation for a hybrid series active filter system," IEEE Conf. On Industry applications, vol.4,(1995):pp. 2531–2540
13. Lin C. E., Su W. F., Lu S. L, Chen C. L., and Huang C. L., "Operation strategy of hybrid harmonic filter in demand-side system," IEEE-IAS Annul. Meeting, Industry applications, (1995):pp. 1862–1866.
14. Dahono P.A, "New hysteresis current controller for single-phase bridge inverters" IET journal on Power electronics, vol.2 (2009):pp. 585-594.
15. Hongyu Li., Fang Zhuo, Zhaoan Wang, Lei W. and Wu L., "A novel time domain current detection algorihm for shunt active power
16. Buso S., Malesani L., Mattavelli P. and Veronese R., "Design and fully digital control of parallel active filter for thyristor rectifier to comply with ICE 1000-3-2 standard" IEEE Trans. Ind. Applicat., vol. 34, (1998):pp. 508-517

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