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Simulation of one cycle control based active power filter for harmonic reduction using fuzzy controller

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Abstract:

Harmonics produced due to non linear loads will affect the source currents which leads to aging of generation equipment. To reduce this effect we have to design an active power filter. The active power filter consistes of an inverter and a dc link. The inverter can be controlled by using one cycle control scheme. To reduce the error and to produce the controller firing singnal we have to use controllers.the controllers used here is pi. And by modifying and designing a fuzzy controller and it is replaced and compared with pi controller. The work is done in matlab simulation tool.

Index Terms:

Nonlinear loads, Active Power Filter (APF), Harmonic current estimation method, Dual -Boost converter, One-Cycle control, fuzzy logic controller.

I.INTRODUCTION:

Since the rapid development of the semiconductor industry, power electronics devices have gained popularity in our daily used electrical house-hold appliances. Although 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. Power system normally operates at 50 or 60 Hz.

However, saturated devices such as transformers, arching loads such as florescent lamp and power electronic devices will produce current and voltage components with higher frequencies into the power line. These higher frequencies of current and voltage components are known as the power harmonics. The harmonics disturbances in the power supply are caused by the nonlinearity characteristic of the loads. Due to the advantages in efficiency and controllability of power electronic devices, their applications can be found in almost all power levels.

The ac power system harmonic problems are mainly due to the substantial increase of non-linear loads due to technological advances, such as the use of power electronics circuits and devices, in ac/dc transmission links, or loads in the control of power systems using power electronic or microprocessor controllers. Such equipment creates load-generated harmonics throughout the system. In general, sources of harmonics are divided into:(a) Domestic loads (b) Industrial loads (c) Control devices.

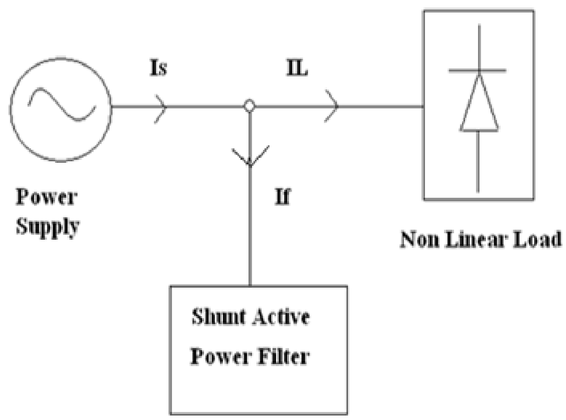

Fig.1 Basic principle of harmonic currents compensations

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The one-cycle control method eliminates the need of calculating the current reference as well as the use of multipliers in the control loop. The control circuitry is simple and reliable. In pulse width-modulation (PWM) active power filter, all switches are triggered with switching frequency; therefore, the switching losses are relatively higher than that of the vector operated active power filters. In this project, a three-phase APF with six-switch bridge voltage-source converter with vector operation is presented.

The different of the shunt and series active filter is the compensating harmonic injection method and the type of compensating harmonic. The compensating voltage, VC* of the series power filter is added into the phase supply voltage to cancel the harmonic voltage in each phase. Both shunt and series active power filter carry different role for the harmonic compensation. The shunt and series active filters act as a current source with If and a voltage source with VC* respectively in order to compensate the harmonics currents or voltages occurred in the distorted line.

II.PARALLEL CONNECTED DUAL BOOST CONVERTER:

A.Principle of operation:

The three-phase voltage waveforms Va, Vb and Vc of the grid is shown in Fig..2 During each 60 region in Fig.2, the voltage-source converter in Fig.1 can be decoupled into a parallel-connected dual-boost converter.

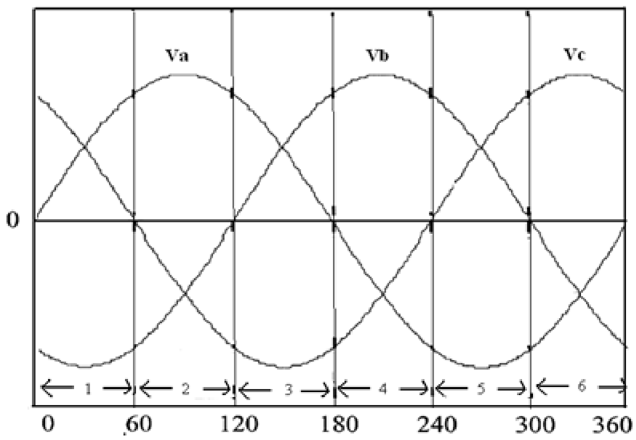

fig 2 three phase waveform

Here the total 3600 region is divided into six regions as shown in Fig.2. In each region two voltages are either positive or negative, one voltage is either negative or positive, and depending on this condition the total 3600 region is divided into six regions. In each region the voltage-source converter is operated as a dual-boost converter as explained in the next section.

In the region (0~600) , the phase voltage Vb is the lowest. In this case, switch Sbn is kept on and switch Sbp is kept off during the whole 600 region, while switches in the other two branches such as San,Sap and Scn,Scp are controlled complementally (with negligible dead time in between) at the switching frequency. For example, during each switching cycle, if switch Sap is ON, switch San will be OFF and vice versa. Here switching frequency is much higher than the line frequency. Here Switching frequency is 50 KHZ and Line frequency is 60 HZ.

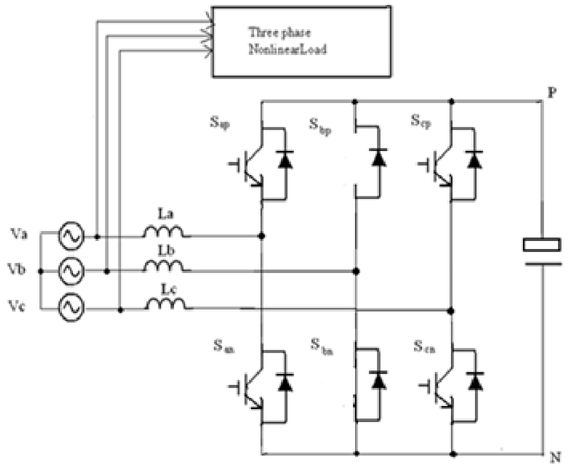

Fig.3 Power stage of the three-phase APF during 0 _ 600 regions.

B.Characteristics of proposed converter:

For the dual-boost converter shown in Fig.4 or 5, four switching states are available for the two switches Tp and Tn . The four switching states and inductor voltages are shown in Table 1. Where

$$\begin{bmatrix} V_p^* \\ V_n^* \\ V_t^* \end{bmatrix} = \begin{bmatrix} \frac{2}{3} & \frac{-1}{3} \\ \frac{-1}{3} & \frac{2}{3} \\ \frac{1}{3} & \frac{1}{3} \end{bmatrix} \cdot \begin{bmatrix} V_p \\ V_n \end{bmatrix} \quad \text{----------} (1)$$

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For a three-phase APF with a constant switching frequency, only two switching sequences are possible, i.e., I, II, IV (condition dp >dn , dp , dn are the duty ratios of switches , Tp, Tn respectively) or I, III, IV (condition dp <dn) during each switching cycle, if trailing-edge modulation is performed. The voltage waveforms across inductors Lp, Ln, Lt are shown in Fig.6 for the first switching sequence (dp >dn). Based on the assumption that switching frequency is much higher than the line frequency, the inductor voltage-second balance is approximately valid, that is

$$\left.\begin{aligned} V_p^* d_n + \left(V_p^* + \tfrac{1}{3}E\right)\cdot(d_p - d_n) \quad \left(V_p^* - \tfrac{1}{3}E\right)\cdot(1-d_p) &= 0 \\ V_n^* d_n + \left(V_n^* - \tfrac{2}{3}E\right)\cdot(d_p - d_n) + \left(V_n^* - \tfrac{1}{3}E\right)\cdot(1-d_p) &= 0 \\ V_t^* d_n + \left(V_t^* - \tfrac{1}{3}E\right)\cdot(d_p - d_n) + \left(V_t^* - \tfrac{2}{3}E\right)\cdot(1-d_p) &= 0 \end{aligned}\right\} \text{-------------} (2)$$

The following equation is true for a symmetrical three-phase system:

$$Vp^* + Vn^* - Vt^* = 0 \qquad \text{-------------------} (3)$$

From (2) and (3) with further simplification we will get

$$\begin{bmatrix} (1-d_p) \\ (1-d_n) \end{bmatrix} = \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \cdot \begin{bmatrix} \dfrac{V_p^*}{E} \\ \dfrac{V_n^*}{E} \end{bmatrix} \quad \text{-------------} (4)$$

It has been verified that this equation is valid for the other switching sequence I, III, and IV (dp<dn) as well. Equation (4) gives an inherent relationship between the duty cycle and the input, output voltage for the parallel-connected dual-boost converter.

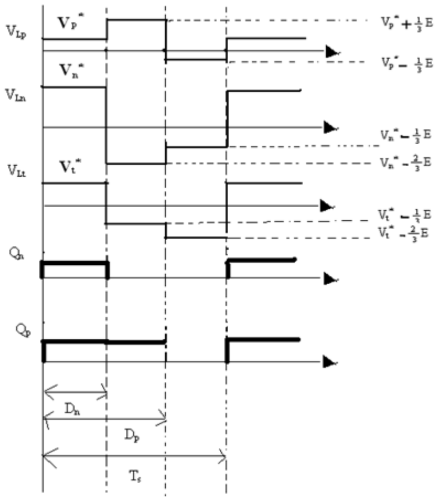

Fig.6 Inductor voltage waveforms for the converter under the condition dp > dn

In Fig.6 VLp, VLn, and VLt represents the voltage across inductors Vp , Vn , and Vt , respectively. Qp and Q n are driving signals for switches T p and Tn respectively.

III.PROPOSED ONE-CYCLE CONTROLLER FOR THREE-PHASE APF:

For the unity-power-factor three-phase APF, the control goal is to force the grid line current in each phase to follow the correspondent sinusoidal phase voltage, i.e.,

$$\left.\begin{aligned} V_a &= Re \cdot i_a \\ V_b &= Re \cdot i_b \\ V_c &= Re \cdot i_c \end{aligned}\right\} \text{-----------------} (5)$$

where Re is the emulated resistance that reflects the real power of the load. This control goal can be realized by controlling the equivalent currents ip and in to follow the voltages Vp* and Vn* The control goal of three-phase APF can be rewritten as

State	T_p	T_n	$\overline{T_p}$	$\overline{T_n}$	V_{Lp}	V_{Ln}	V_{Lt}
I	ON	ON	OFF	OFF	V_p^*	V_n^*	V_t^*
II	ON	OFF	OFF	ON	$V_p^* + \frac{1}{3}E$	$V_n^* - \frac{2}{3}E$	$V_t^* - \frac{1}{3}E$
III	OFF	ON	ON	OFF	$V_p^* - \frac{2}{3}E$	$V_n^* + \frac{1}{3}E$	$V_t^* - \frac{1}{3}E$
IV	OFF	OFF	ON	ON	$V_p^* - \frac{1}{3}E$	$V_n^* - \frac{1}{3}E$	$V_t^* - \frac{2}{3}E$

$$\left.\begin{aligned} V_p^* &= Re \cdot i_p \\ V_n^* &= Re \cdot i_n \end{aligned}\right\} \text{-------------} (6)$$

Substituting (6) into (4) and considering the switch is ON for the entire 60 region, it is obtained that

$$\left.\begin{bmatrix} (1-d_p) \\ (1-d_n) \end{bmatrix} = \frac{Re}{E\,Rs} \cdot Rs \cdot \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \cdot \begin{bmatrix} i_p \\ i_n \end{bmatrix}\right\}_{d_t=1} \text{-------------} (7)$$

Define

$$Vm = \frac{E\ Rs}{Re} \quad \text{-------------} (8)$$

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where the signal Vm can be generated from the output voltage feedback compensator, which is used to regulate the output capacitor voltage E of the voltage source converter according to the load level; Rs is equivalent current sensing resistance and it is fixed constant. Combining of the two equations 7,8 and the control key equation is derived as

$$V_m \cdot \begin{bmatrix} (1-d_p) \\ (1-d_n) \end{bmatrix} = R_s \cdot \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \cdot \begin{bmatrix} i_p \\ i_n \end{bmatrix} \Bigg\} \quad d_k = 1 \qquad \text{------------- (9)}$$

The above equation indicates that three-phase power factor can be achieved by controlling the duty ratios of switches so that first-order polynomial equation (9) is satisfied. This can be realized by the one-cycle control core as shown in Fig.7. The operation waveforms are shown in Fig.8.

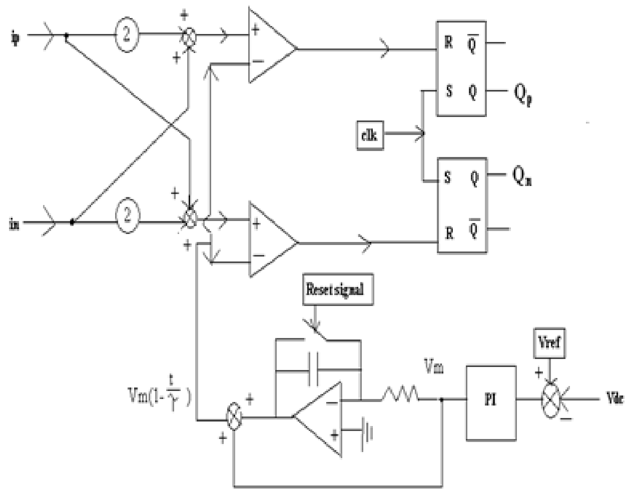

Fig.7 One- cycle control logic

In the beginning of each switching cycle, the clock pulse sets the two flip-flops. The currents ip and in from the current selection logic is linearly combined to form an input to each of the two comparators. At other input of the two comparators is the value of Vm minus the integrated value of Vm. Signal Vm(1-t/Ts) is compared with Rs(2 ip+ in) in the upper comparator and is compared with Rs(ip+2 in) in the lower comparator as shown in Fig.7. When the two inputs of a comparator meet as shown in Fig.8, the comparator changes its state, which resets the correspondent flip-flop. As a result, the correspondent switch is turned off. Therefore, the duty ratios dp and dn are determined for the correspondent switch in each switching cycle.

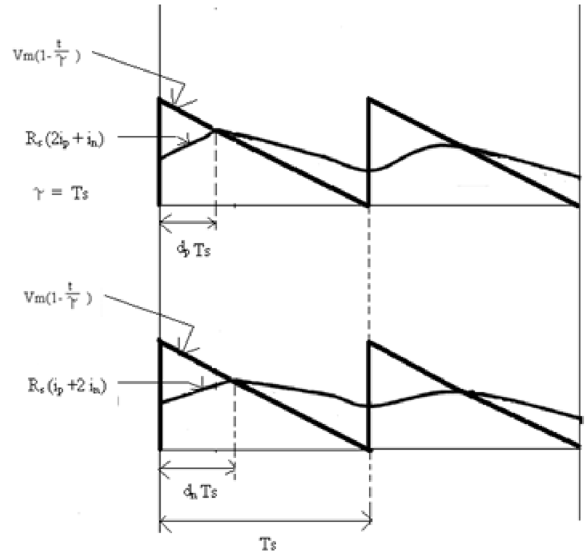

Fig.8 Operation waveforms of One-cycle controlled APF controller

The Presented One-Cycle Control Approach has the Following Features:

Three-phase unity-power-factor and low total harmonic distortion (THD) are achieved by one integrator with reset as well as several logic and linear components. It is simple and reliable.Only ac mains current and voltage zero-crossing points are sensed. No sensors for the load current and the APF inductor current are required. There is no need to calculate the reference for APF inductor current so that complicated digital computation is eliminated.No multipliers are required.Constant switching frequency, which is desirable for industrial applications, is achieved.For the three-phase bridge converter, only two switches are operated in high frequency, and switching losses are reduced compared to PWM-operated ones.

IV.DESIGN CONSIDERATION:

Dc-Link Capacitor Design :

The output dc-link capacitor of voltage source converter is determined by the output voltage ripple. The equation is given by

$$c \geq \frac{P_o}{2 * f_{line} * (V^2_{omax} - V^2_{omin})} \qquad \text{---------- (10)}$$

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For example, suppose the power is 7000 W; APF and output voltage is 400 V with 2% ripple. The line frequency is 60 Hz. The capacitance is calculated as 4800μF.

V FUZZY CONTROLLERS:

5.1 INTRODUCTION TO FUZZY LOGIC:

The logic of an approximate reasoning continues to grow in importance, as it provides an in expensive solution for controlling know complex systems. Fuzzy logic controllers are already used in appliances washing machine, refrigerator, vacuum cleaner etc. Computer subsystems (disk drive controller, power management) consumer electronics (video, camera, battery charger) C.D. Player etc. and so on in last decade, fuzzy controllers have convert adequate attention in motion control systems.

As the later possess non-linear characteristics and a precise model is most often unknown. Remote controllers are increasingly being used to control a system from a distant place due to inaccessibility of the system or for comfort reasons. In this work a fuzzy remote controllers is developed for speed control of a converter fed dc motor. The performance of the fuzzy controller is compared with conventional P-I controller.

VI SIMULATION RESULTS:

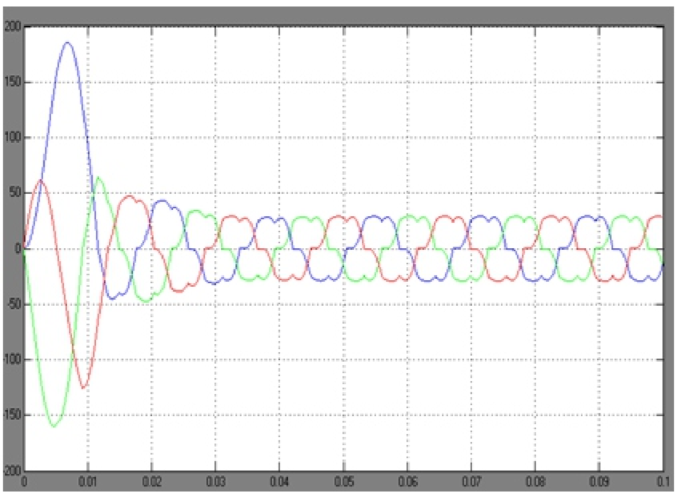

Fig 9 Source current without APF

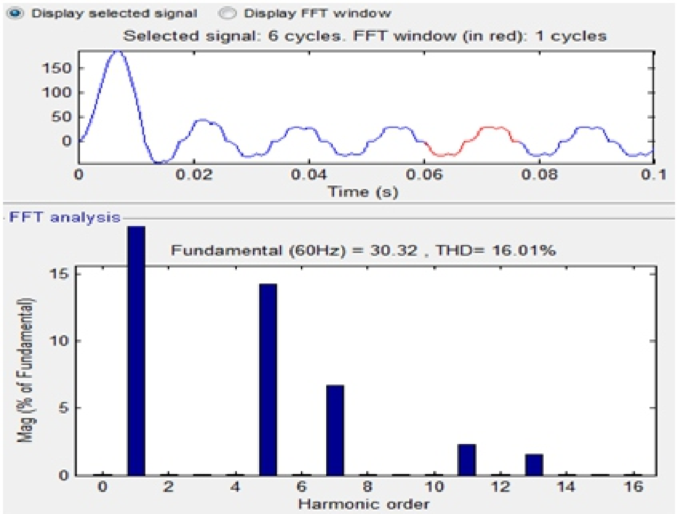

Fig 10 THD without APF.

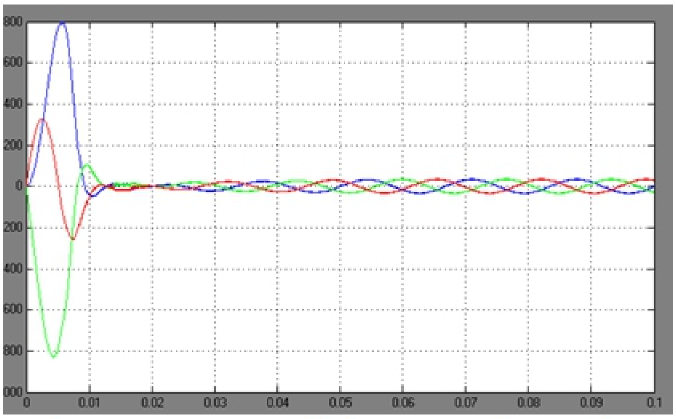

Fig 11 Source current with fuzzy one cycle control.

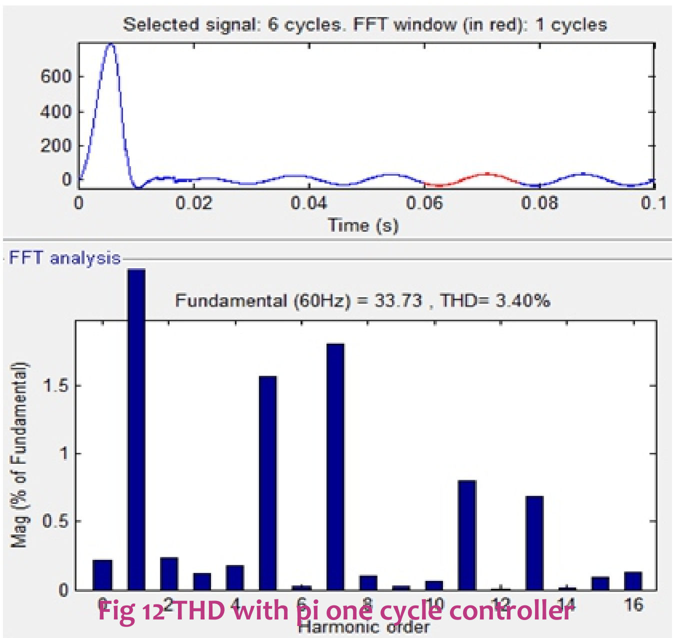

Fig 12 THD with pi one cycle controller

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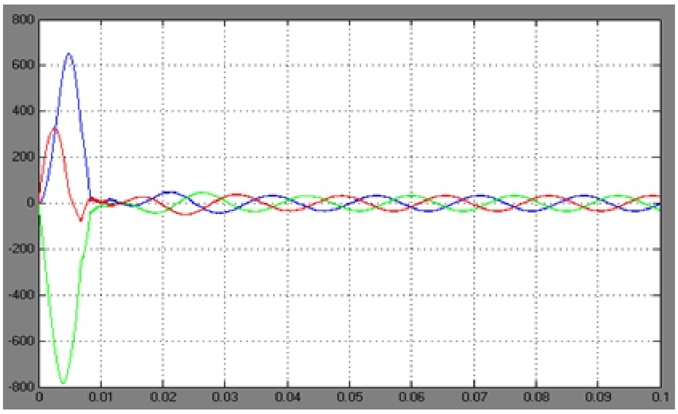

Fig 13 Source current with fuzzy one cycle control

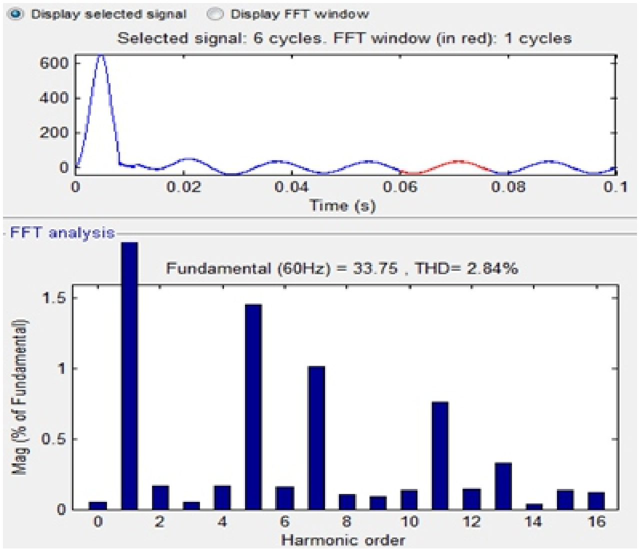

Fig 14 THD with fuzzy one cycle controller.

VII CONCLUSION:

In this paper, a three-phase APF with fuzzy one-cycle control has been designed.Here one new One-Cycle controlling method is introduced with some extra reliability and fast harmonic compensation capability. The proposed control approach senses only the mains current and the zero crossing of grid voltage. Furthermore, there is no need to calculate the reference for APF inductor current so that the intensive digital computation is eliminated. A non linear load is connected to a distribution system which produces harmonics in the source. In order to reduce the harmonics a fuzzy logic one cycle control APF is connected in parallel to the system. The total harmonic reduction without APF - 16.1% and with PI - 3.40% and with Fuzzy – 2.84%. hence the harmonics are reduced using fuzzy logic controller APF.

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