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SOFT-SWITCHING ACTIVE POWER FILTER FOR REDUCING HARMONIC CURRENT IN SYSTEM WITH NON-LINIER LOAD

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ABSTRACT

This paper presents the design of an active power filter (APF) with soft switching. APF used for compensating the power factor harmonic and harmonic current, but usually switching losses is increased when APF operates at high frequency. The switching losses can be reduced by soft switching technique. The proposed soft switching losses can be reduced by soft switching technique. The proposed soft switching APF includes the combination of the boost converter with auxiliary resonant. By using an auxiliary resonant circuit, switching losses of APF is reduced and the circuit forces voltage or current to zero for the duration switching. The advantages of proposed design improve efficiency, reduced voltage stress, and greatly reduced harmonic current of voltage source. The proposed soft switching APF rated at 500 W and operated at 10 kHz. It can achieve a sinusoidal line current and near unity power factor. In order to verify the proposed design a simulation model using Matlab/ Simulink was developed. The results show that the proposed APF can significantly reduce the total harmonic distortion (THD) and improve the power factor.

Keywords: soft switching, active power filter, total harmonic distortion, power factor.

INTRODUCTION

The modern technology use nonlinear load to connect the electronic devices such as; personal computer (PC), smart phone, microwave oven, variable speed drive, battery charger, and industrial electronic equipment with power system [1],[2], [3], which cause significant increase of line losses, in stability, and voltage distrotion. It is drawn non-sinusoidal current from the supply and voltage distortion which led to the harmonic [4].

Recently, the harmonic become a very important field to be explored because the problems of harmonics are serious, such as overheating, low power factor, data losses, malfunction of the grid component, wiring failure, an excessive neutral return current in the neutral current conductor and blackout system [5]

Now, there are some methods to reduce harmonic current that have been used by previous researchers i.e. passive filter and active filter [6]. Passive filter has been used to restrict the harmonic current flow in a distribution system. However, the passive filter still possesses many disadvantages such as tuning problem, parallel and series resonance with source voltage harmonics, dimensions and weight of the device are big [6], [7], [8].

The generally shunt APF is designed to reduce the THD which reducing harmonic current and improve the power factor closed in the unity harmonic. The compared with the Passive Filter, APF is being avoidable for potential resonance, flexible control, accurate in parametric design, and small in size and effective to press all of the harmonic systems [9], [10]. In order to the switching losses can be reduced by soft switching technique [11] . This proposed use APF need soft switching is to adder resonant of boost converter.

In this paper, the compared an APF conventional with APF proposed, to reducing THD current source and improve power factor.

MATERIAL AND METHOD

In this section, an APF conventional and APF with soft switching with charging battery (non- linear load) discussed.

APF conventional concept

The active power filter (APF) is consist of four MOSFETs by bridge single phase method where a capacitor connected with series inductor L_f in the ac side and the dc capacitor C_{dc} in the dc side as Figure-1. The operation filter of the filter is providing the harmonic compensation current, but APF has capable [12], [13], of compensating for all the harmonic produced by nonlinear load. The main function of the APF is the current harmonic reduce and the reactive compensation of the load. The active filters draw the compensating current to cancel harmonic current produced by the nonlinear load.[14], [15].

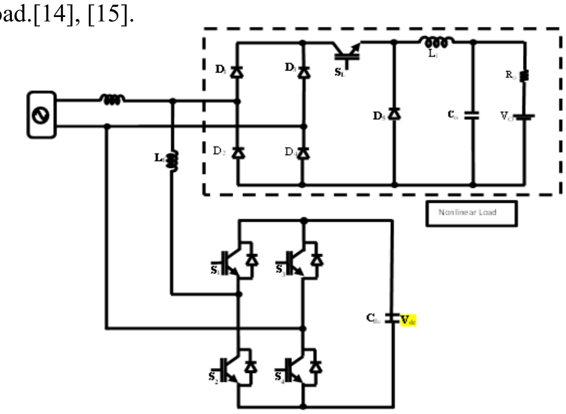

Figure-1. APF conventionally connected to the grid with nonlinear load.

To compensate effective, the APF design is an important. In order to implement the APF the reference signal.

$$i^* = i_L - i_{L1} \qquad (1)$$

Where i_L and i_{L1} are the load current distorted by the non-linear load and fundamental component of the load current.

The single APF compensating current is regulated by a deadbeat current controller, such that the current drawn by the APF from the utility AC power source is equal to the harmonics and reactive current required for the nonlinear load and PI controller is necessary to keep the capacitor on the DC side of the single-phase APF constant [16].

If the voltage supply, Vin for system is an ideal sinusoidal waveform, the value of instantaneous can be is:

$$i_f = i_L - i_s \qquad (2)$$

Soft switching APF proposed

The APF soft switching proposed using an auxiliary resonant circuit is as Figure-3. It consist of APF with an additional auxiliary circuit such as three switch (S_1, S_{r1}, S_{r2}), two resonant inductor $((L_r, L)$, three resonant capacitor $((C_r, C_{rp})$ and two diodes $((D_r, D_o)$.

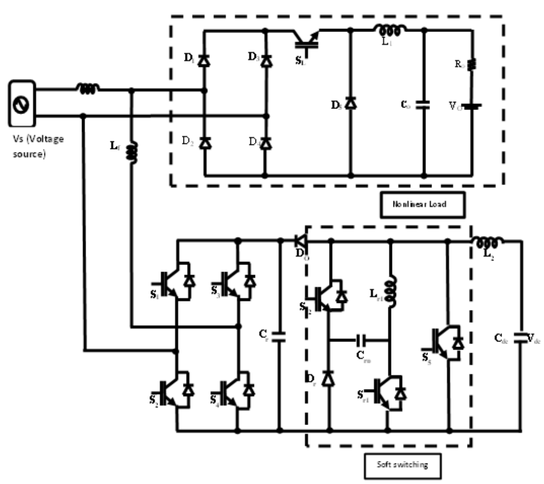

Figure-2. APF Proposed connected to the grid with non-linear load.

The principle of APF proposed as boost converter concept.

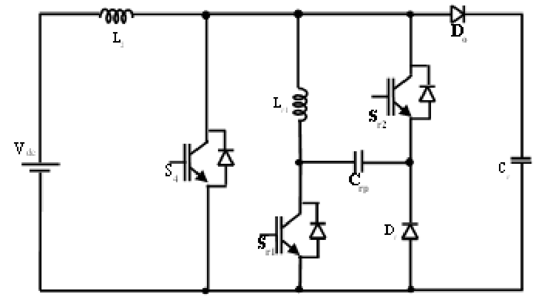

Figure-3 Proposed soft switches APF.

The operational principle of this APF proposed can be divided into eight operation modes in detail below:

The 1st operation mode ($t_o \leq t \leq t_1$) is assumed that switch S_1on and switch S_2 off, as well as D_1 and D_2 off. The current cannot flow through switch S_1 and S_2. The current which flow through D_1 and D_2 is i_{Ld} (t)=0 with V_{cr}(t) =0. Therefore, the main inductor energy in load transfer is shown in equation 2 and equation 3.

$$V_L(t) = V_{si} - V_o \qquad (3)$$

$$i_L(t) = \frac{1}{L}\int V_L(t).dt \qquad (4)$$

$$i_L(t) = \frac{V_{si} - V_o}{L}(t - to) \qquad (5)$$

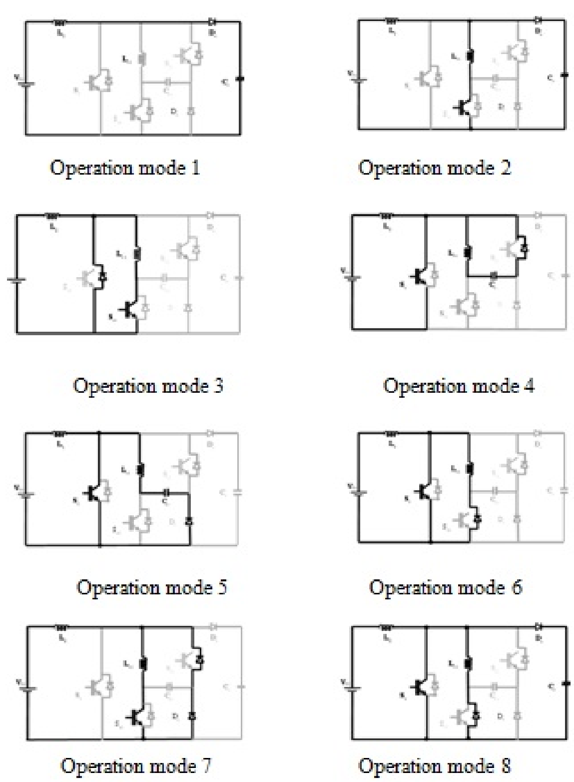

Figure-4. Operation soft switching APF.

During this resonant inductor current is zero (0), charged resonant capacitor equal to the output voltage.

The 2nd mode operation is ($t_1 \leq t \leq t_2$). There are two current loops where switch S_2 is turned off. Therefore, resonant inductor current is increased linearly from zero. The current resonant inductor is shown in equation 6.

$$i_{Lr}(t) = \frac{V_o}{Lr}(t - t_1) \quad (6)$$

The 3th operation mode is ($t_2 \leq t \leq t_3$). The main diode D_0 is turned off. Resonance capacitor and resonant inductor led to the current flowing to resonant inductor which are produced by combination between main inductor current and resonant capacitor current.

While the resonant period, the voltage of the resonant is equal to zero. Therefore, the equation 7 and equation 8 show the frequency and impedance calculation.

$$\omega_r = \frac{1}{\sqrt{L_r C_r}} \quad (7)$$

$$Z_r = \sqrt{\frac{L_r}{C_r}} \quad (8)$$

Where: ω_r, Z_r, L_c and Cr are angular speed, resonant impedance, resonant inductor and resonant capacitor.

The 4th Operation mode ($t_3 \leq t \leq t_4$) is this mode when the switch S_1 turn on and then the voltage of a resonant capacitor (C_r) is zero. Therefore, main voltage (C_r) and resonate capacitor C_{r2} equal to zero (0). The main inductor is calculated based on equation 9.

$$i_L(t) = i_{\min} + \frac{V_{si}}{L}(t - t_3) \quad (9)$$

The 5th Operation mode is ($t_4 \leq t \leq t_5$). In this mode switch S_r turn on, and auxiliary diode D_{r1} and D_{r2} are not connected which produce zero voltage. When the resonant inductor is L_r and C_{r2} have been fully charged. The following resonance as:

$$Z_x = \sqrt{\frac{L_r}{C_{r2}}} \quad (10)$$

$$\omega_x = \frac{1}{\sqrt{\frac{L_r}{C_{r2}}}} \quad (11)$$

Where resonant impedance and angular frequency is Z_x and ω_x.

The 6th Operation mode is ($t_5 \leq t \leq t_6$). The voltage C_{rp} has reached zero when auxiliary switch turn on. The freewheeling path current is turned off on the diode resonant inductor. Therefore, the current resonant inductor is calculated by using equation 12.

$$i_{Lr} = \frac{V_{si}}{L}(t - t_3) + i_{\min} \quad (12)$$

The 7th Operation mode is ($t_6 \leq t \leq t_7$). The diode (D_r) is turned on and switch S_{r2} is turned off. These conditions led to resonant capacitor voltage become zero. Resonant inductor current is separated by main inductor current and auxiliary diode current.

The 8th mode operation is ($t_7 \leq t \leq t_8$). The zero voltage of main diodes is observed when the resonant capacitor (C_r) is discharged.

SIMULATION RESULT

A soft switching APF topology is chosen for simulation study, consists of a single phase. To verify the proposed converter performance, simulation of 500 W APF, with boost converter is listed followed:

Table-1. Parameter of the proposed APF.

Parameter	Value
Input voltage	240 V
V out load	48 V
Switching frequency	20 kHz
Fundamental frequency	50 Hz
Resonance inductor	33.25 uh
Resonance conductor (Crp)	750 nF
Resonance conductor (Cr)	1 nF
Output boost conductor	1 uF

From Figure-5 to 6 show simulation result of the conventional APF connected with non-linear load, the waveform of current source almost in sinusoidal from it, improve based on percentage of total harmonic distortion (THD) and power factor are 27.31% and 0.964.

By using the main switch (S_1) and auxiliary switch (S_{r1}), (S_{r2}). And resonant inductor and resonant capacitor, and switching frequency are 20 KHz constant.

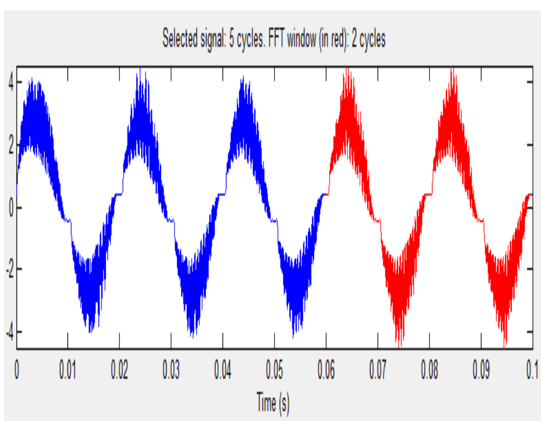

Figure-5. Current source APF conventional.

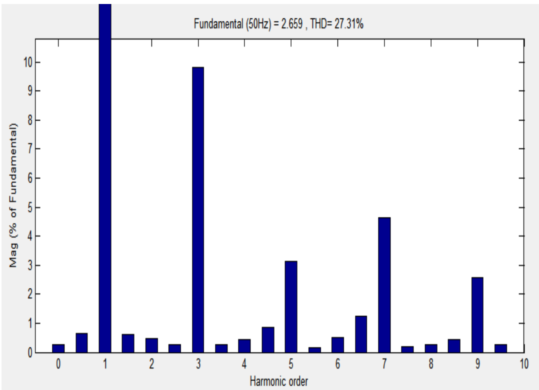

Figure-6. THD current source APF conventional.

Once in compensation with APF proposed current source pure sinusoidal wave had a more visible form, as in the picture Figure-7 and Figure-8 can be significantly lower total harmonic distortion of 8.83% and improve power factor 0.996.

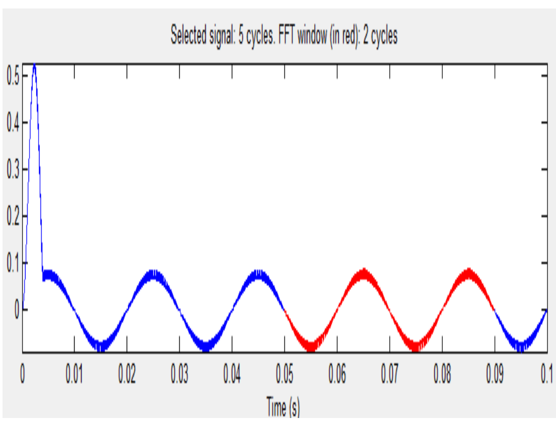

Figure-7. Current source APF proposed.

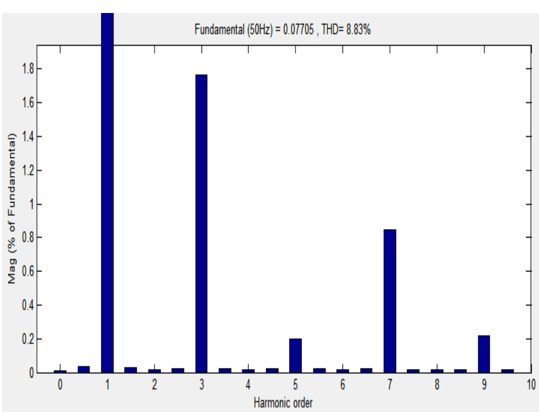

Figure-8. THD current source APF proposed.

The comparative result of the system with APF conventional and APF proposed performs well as gives the lowest THD current source and the best improvement of power factor as follows Table-2.

Table-2. The compare THD current and power factor.

Parameter	APF conventional	APF proposed
Total harmonic distortion (THD)	27.31%	8.83%
Power factor	0.964	0.996

CONCLUSIONS

This paper has presented the power shunt APF for harmonic compare current source THD with APF conventional and APF proposed. This project has been attached with non-linear load and single phase APF developed using Matlab/Simulink. The APF proposed harmonic distortion can be reduced and power factor of the supply system has improved as well.

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