Used of Single Phase Shunt Active Power Filter for Power Quality Improvement

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Abstract- The advance use of power electronic devices introduces harmonics in the supply system which creates a problem in the quality of power delivered. Good Power Quality is very much important for our day to day use of appliances in both industrial and domestic sectors. With the proliferation of power electronics devices used for industrial, commercial and residential purposes have led to the deterioration of supply current and voltage wave forms, and this caused power quality problems within the supply system. Traditional passive filter was the earliest solution for mitigating harmonics produced by non-linear loads, but passive filter have the disadvantages of series and parallel resonances with the supply source impedance and it's heavy in size. Due to these problems in passive filter, it applications becomes very limited. With the introduction of shunt active power filter, harmonics mitigations of the current and voltage distortion wave forms can therefore be suppressed.

I. INTRODUCTION

In industries and domestic usage we are having large numbers of single phase loads which employs solid state control which requires the attention to the problem of harmonics occurring due to its usage. These solid state controllers try to convert and also control ac power fed to many loads and thereby increase efficiency of the system and in this process they also introduce harmonic components in the lines which create several problem which need to be solved. A simple figure to depict the operation of single phase APF is shown below:

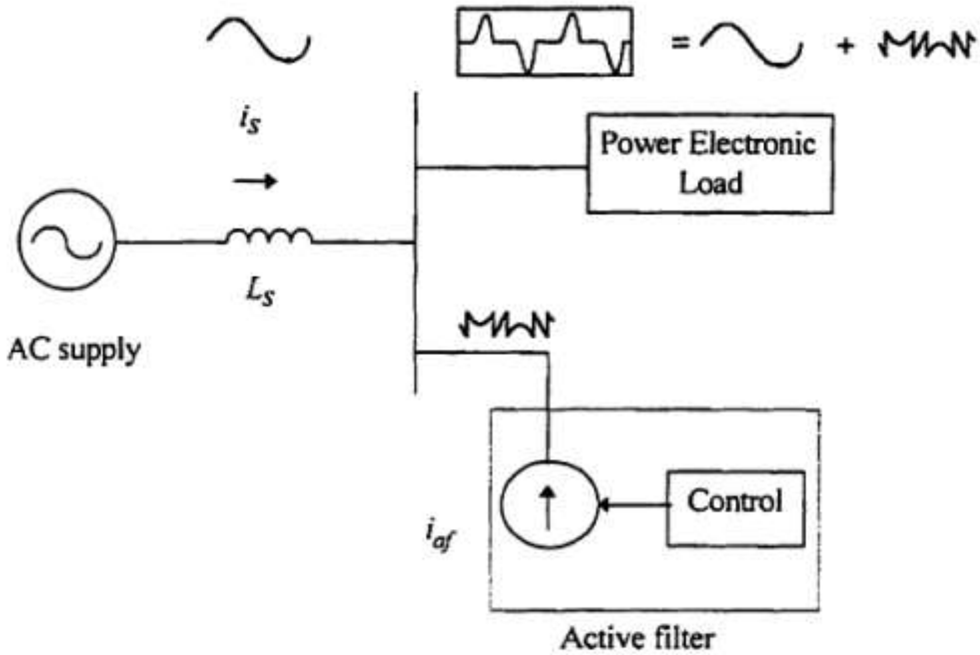

Fig 1.1 Principle of Single phase shunt active power filter.

II. Design of the system

The idea used here is to produce harmonic current having components which has 180° phase shift to the components of harmonic current which are generated by the use of nonlinear loads. The concept is totally based on injecting harmonic current in the ac system similar in amplitude but opposite in phase when compared with load current waveform harmonics.The following is the discussion based on **[2]**. In normal conditions, the source is assumed as a perfect sinusoidal voltage i.e

$$V_s(t) = V_m \sin(\omega t) \qquad (2.1)$$

Now we apply a non-linear load and as discussed above, the load current will have both fundamental component and also harmonics of higher order. This current we represent as:

$i_l(t) = \sum^{\infty} n=1\ I_n \sin(n\omega t + \theta_n)$

(2.2)

Now, the load power is expressed as:-

$p_l(t) = (t)(t) = I_1 V_m \sin^2(\omega t)\cos\theta_1 + I_1 V_m \sin(\omega t)\cos(\omega t)\sin\theta_1 +$

$\sum$ ∞ $n{=}2$

$V_m \sin(\omega t)\ I_n \sin(n\omega t + \theta_n)$

$= p_s(t) + (t)$ (2.3)

In eqn. (2.3) the we define $p_s(t)$ as real power given by utility source, and (t) as the reactive power and the harmonic power, i.e.

$p_s(t) = I_1 Vsm\ \sin^2(\omega t)\cos\theta_1$ **&**

$p_s(t) = I_1\ \sin(\omega t)\cos(\omega t)\sin\theta_1 + \sum^{\infty}{}_{n=2} Vsm \sin(\omega t)\ I_n \sin(n\omega t + \theta_n)$ (2.4)

By discussion above we know that APF will provide the reactive and harmonic power $p_c(t)$, the current supplied by source is given as :-

$$i_s(t) = \frac{p_s(t)}{V_s(t)} = I_1 \cos\theta_1 \sin(\omega t) = I_s \sin(\omega t) \quad (2.5)$$

The current (t) is and utility voltage is seen to be in phase and pure sinusoidal. At this time, the APF will provide the following compensation current in the circuit:

$$(t) = (t) - (t) \quad (2.6)$$

III. Voltage Controller

One kind of voltage controller namely P-I (proportional-integral) controller has been utilised here for the purpose of regulating voltage across dc bus capacitor in the APF. The voltage across the dc bus capacitor (V_{dc}) is noted here using a voltmeter and then compared with reference constant voltage (V_r). The resulted error in voltage ($_{(n)}$) at a particular sample say nth has been expressed as following :

$$(n) = (n) - V_{dc(n)} \quad (2.7)$$

The error is passed through the PI voltage controller and the output $_{(n)}$ at the nth sample interval is given by:-

$$(n) = (n{-}1) + [V_{e(n)} - V_{e(n-1)}] + K_{ii} V_{e(n)} \quad (2.8)$$

Here, K_{ii} and K_{pp} are defined as integral gain constant & proportional gain constant and in PI controller. $_{(n-1)}$and $V_{e(n-1)}$ are the controller output & error in voltage at (n - 1)th sampling instant. This output $_{(n)}$ of the PI controller has been limited to safe permissible value then this limited output is considered as maximum value of utility or supply current I^*_{sm}.

sm

IV. Reference Current Generation

From the assumed supply voltage $(t) = V_m \sin(\omega t)$ **,** unit vector template is calculated by the following equation :

$$(t) = \frac{(t)}{V_{sm}} = \sin(\omega t) \quad (2.9)$$

We then multiply his unit vector with estimated peak value of source current I^*_{sm} . This resulting signal is now considered as the reference source current signal as:

$$i_s^*(t) = I_{sm}^* * u(t) = I_{sm}^* \sin(\omega t) \qquad (2.10)$$

The reference source current and actual source current is the passed via a hysteresis carrier less PWM current controller to achieve the gating signals for the MOSFETs operation which hasbeen used in the APF.

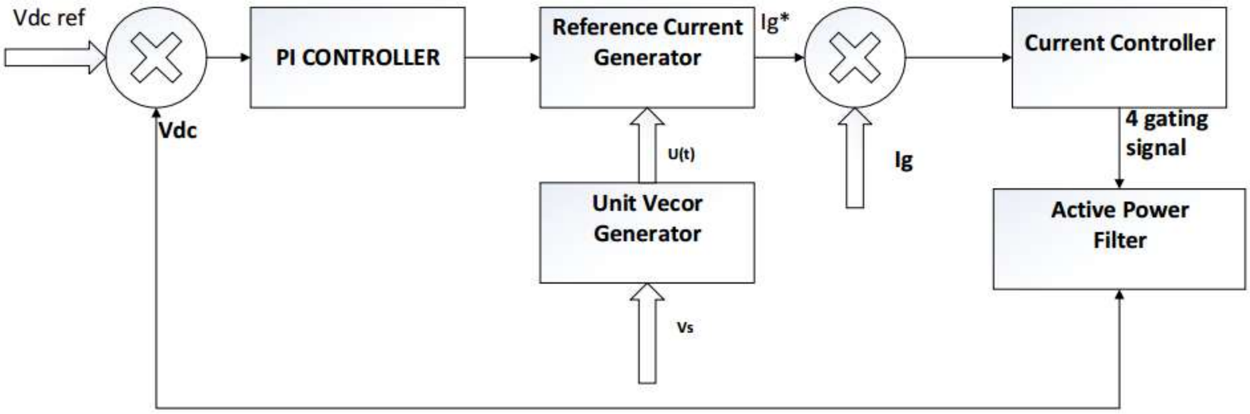

Fig 1.2:- Unit vector Control scheme for shunt APF

In simple words from Fig 1.2 we can say that in order to run the Shunt APF and achieve the above mentioned task the voltage across the dc link is sensed and compared with the reference dc link voltage. This error is then processed by a PI controller. The resultant signal from PI controller is then multiplied with unit vector templates of equation (2.9) giving reference source current signals. The actual source current must be equal to this reference signal. In order to follow this reference current signal, the three phase source current is also sensed and compared with above calculated reference current signals. The error generated is then processed by a hysteresis current controller with a definite particular range of band, generating gating signals for shunt APF.

V. Results

In Shunt APF "p-q theory" and hysteresis current controller was used for getting simulation results. In Series APF "dq0 transformation" and hysteresis voltage controller were used for getting simulation results. Shunt APF is used to remove problems due to current harmonics. So it makes current drawn from source completely sinusoidal which is effected by load current harmonics. . In Table-4.1 system parameters of shunt APF are given

Table-4.1 System Parameters used for Shunt APF

Supply Voltage	400 V
Line impedance	R_s= 0.01 Ω , L_s= 1 μH
DC Voltage	850 V
DC capacitor	500 μF
Load impedance	R_L=0.0001 Ω , L_L=1 μH
Line frequency	50 Hz

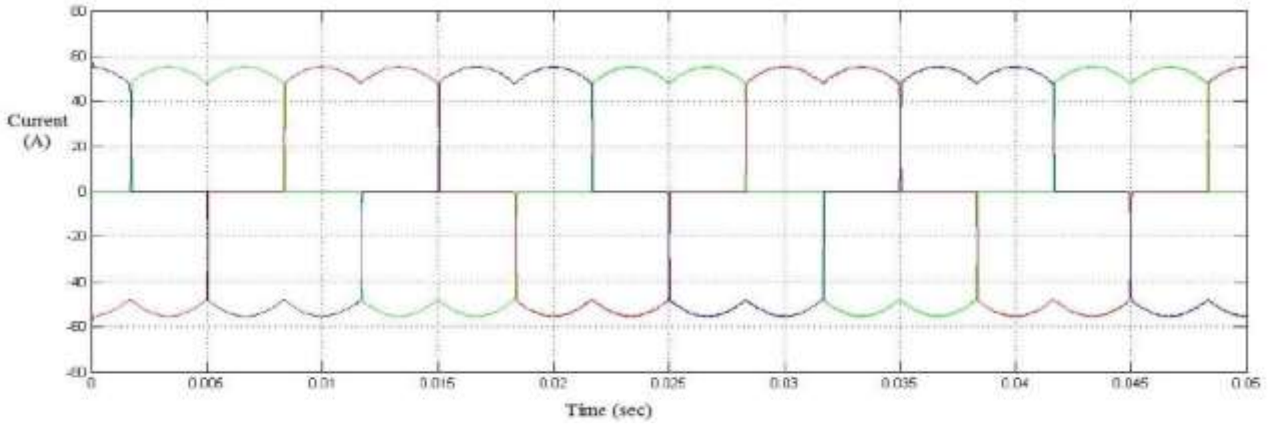

Fig. 1.3 Load current of Shunt APF

In fig.1.3 the waveform of load current of shunt APF is given and they are not sinusoidal due to presence of non-linear loads. This is non-linear waveform. They are Non-linear due to presence non-linear loads like diode etc.

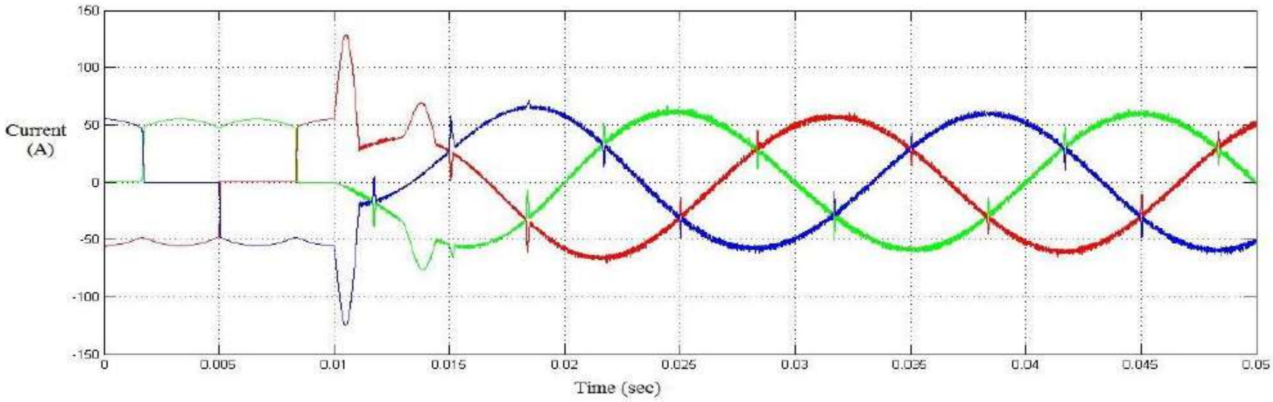

Fig. 1.4 Source current of Shunt APF

Fig. 1.4 shows source current of shunt APF. The source current contains harmonics till 0.01 sec as up to this time shunt APF is not in operation. After 0.01 sec shunt APF starts operating in a system. So after 0.01 sec the harmonics are removed from source current. The time of operation of shunt APF is controlled by circuit breaker.

VI. Conclusions

A single phase shunt active power filter based on indirect control technique is used in this paper.Using this control strategy reference signal is generated successfully.The shunt active power filter is found effective in injecting harmonic compensating current and thereby reducing the source current THD and improves the power factor of the line.The THD is reduced from 38.90% to 9.65% after compensation. It is also noticed that a constant voltage appears across the DC-link capacitor which helps the smooth functioning of the voltage source inverter.

VII. Refrence

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