Enhancement of Shunt Active Power Filters by Harmonic Detection Schemes

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Abstract- *In this strategy, the DC link voltage is regulated by a hybrid control technique mixed with a standard PI and a sliding mode (SM) control in Shunt active power filters (SAPF). Sliding Mode(SM) control strategy and Feedback Linearization based control strategy have been applied considering their ease of implementation and robustness under external disturbances. That means chattering is due to the SM scheme is reduced by a transition rule that fixes the controller gains when steady state condition is reached. In this method a band pass filters used for calculating the reference source current which makes source current Total Harmonic Distortion (THD) independent of source voltage THD. The three phase voltages are applied by three pairs of semiconductor switches with amplitude, frequency and phase angle by control of SVPWM. A PR controller has much in common with a common PI controller. The differences consist only in the way the integration action takes part. The integrator will only integrate frequencies very closed to the resonance frequency and will not introduce stationary error or phase shift. So the PR controller reduces the steady state error and improving power quality.*

Keywords- Shunt active power filters (SAPF), used control stagiest

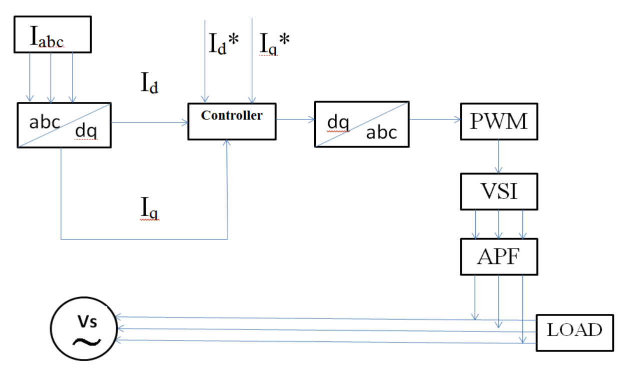
I. INTRODUCTION

Now a day's people are extremely dependent on use of nonlinear loads . All the power electronic devices can be considered as nonlinear loads. Controlled /uncontrolled rectifiers, inverters, uninterruptable power supplies, switched mode power supplies are some examples of nonlinear loads.

The use of nonlinear loads causes harmonic distortion. Harmonics of a sinusoidal wave form are sinusoidal wave having frequency integral multiple off frequency. Of the original sinusoidal waveform. In electrical engineering, voltage and current wave forms plays an important role in there liability of electrical devices. The presence of these harmonic sin voltage or current wave forms is known as harmonic distortion. There are several problems caused due to voltage and current harmonic distortion ,such as:overheating of motors, transformer and capacitors, increase in conduction losses and eddy current losses, damage of electrical equipment, important data loss from computers used in offices, meter readings with higher percentage of error, etc. Therefore mitigation of harmonics from voltage and current waveforms has become a major concern of power and control researchers. Including harmonic distortion, there are also several other factors, such as voltage sag, voltage swell, voltage flicker, etc., which hampers the power quality.[1]

II. SYSTEM DESCRIPTION WITH BLOCK DIAGRAM

The dc-link voltage is regulated by a DSM -PI controller is done by generating the reference current iesd, which determines the system active power component. The phase angle of the power grid voltage vectors is determined by using a PLL. Thus, the dq reference phase currents in a stationary reference frame dqs can be obtained by issd=iesdcos(s) and issq = iesdsin(s), respectively. The reference current ie sdis defined to guarantee the active power balance of the SAPF system. The phase currents of the power grid are indirectly regulated by two DSCs, in which the IMP is employed to avoid reference frame transformations.



The DSCs generate proper active filter phase voltages vsfd and vsfq. These DSC current controllers will be described next. The unmodeled dis- turbances Isedq and Isrdq can be estimated and introduced into the algorithm of DSC current controllers. However, theoretical studies and experimental essays have shown that this control scheme has the ability of compensating such unmodeled disturbances. Block xsdq/123 performs the orthogonal transformation from the dqs reference frame to the three-phase system, i.e., from vsfdq to vf123. Based on these reference voltages, a suitable PWM strategy determines the duty cycle of VSI power switches.

NOMENCLATURE

PWM	Pulse Width Modulation
VSI	Voltage Source Inverter
APF	Active Power Filter
PR	Proportional Resonant
SM	Sliding Mode
PI	Proportional Integral
SVPWM	Space Vector Pulse Width Modulation
Vs	Voltage Source
DSM	Dual Sliding Mode
DSM-PI	Dual Sliding Mode- Proportional Integral

A. Shunt Active Filter

Shunt Active Power Filter is connected in parallel at the Point of Common Coupling (PCC) in between source and mostly connected to nonlinear load. Main focus of shunt APF design is to compensate current harmonics caused by nonlinear load by supplying equal amount of harmonics at PCC but with opposite polarity.

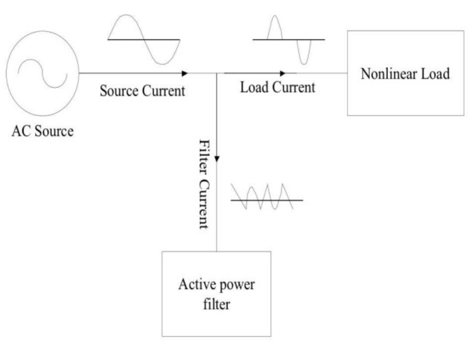


Fig. No. 1 Single Line Diagram of Shunt APF

APF is an inverter with some controlled switches. In this Paper SVPWM control strategy used. The design of the APF circuit mainly includes the following factors:

1. Choosing controlled switches
2. Selecting the Value of DC link filter capacitor
3. Choosing the value of coupling inductor
4. Taking a reference DC capacitor voltage.

The voltage and current rating of the switches must be higher than peak DC link Filter capacitor voltage and peak coupling inductor current respectively. The peak of coupling inductor current can be determined easily by knowing nonlinear load model. Coupling inductor current is for a single phase shunt APF,[4]

$$I_L = I_{Source} - I_{load}$$

Where*IL* is the coupling inductor current. *ISource* can be calculated as follows:

$$I_{Source} = \frac{\sqrt{2}P_{load}}{V_{rms}}\sin(\omega t)$$

P_{load} is real power consumed by nonlinear load and ωt is the instantaneous phase of the source voltage. The current rating of the APF semiconductor switches is taken higher than the maximum value of the inductor current considering inductor current ripples and other factors. The smaller is the inductor, the higher is the ripple and vice versa. But inductor with high inductance does not allow the compensating current to flow with in it. Considering these two aspects, the value of inductor is chosen suitably. To shape the line current at any instant of time, the reference DC capacitor voltage must be higher than the peak of the source voltage for a single phase shunt APF [1].

Similarly for a three phase shunt APF the reference DC capacitor voltage must be greater than two times to that of source voltage as per [3]. As this DC reference capacitor voltage does not have any impact on THD of source current, it can be taken randomly satisfying the above said conditions.

B. PR controller

The PR controller is in essence a grouping of a proportional kp and resonant controller discussed earlier, which results in an ideal controller transfer function GAC(s),

$$G_{AC}(S) = K_P + \frac{SK_i}{S^2 + \omega^2}$$

Where, ω is the AC frequency and ki is a constant that is carefully selected to shift the controller's magnitude response vertically. The ideal PR controller has an infinite gain at the AC frequency and no phase shift and gain at other frequencies. The simulated module is given in the Figure.A. The controller's infinite gain may cause stability problems and due to practical limitations of signal processing systems that implements it, a non-ideal transfer function GAC (s),

$$G_{AC}(S) = K_P + \frac{2SK_i\omega_C}{S^2 + 2S\omega_C + 2\omega^2}$$

With the practical PR transfer function, its gain is infinite, but it is still relatively high for enforcing a small steady-state error. The controller's bandwidth can be widened by setting c appropriately, which helps to reduce sensitivity towards slight frequency variations.

PI controller, develops the Proportional resonant (PR) controller for reference tracking in the stationary frame. Interestingly, the same control structure can also be used for the precise control of a single-phase converter. In brief, the basic functionality of the PR controller is to introduce an infinite gain at a selected resonant frequency for eliminating steady-state error at that frequency, and is therefore conceptually similar to an integrator whose infinite DC gain forces the DC steady-state error to zero.

The resonant portion of the PR controller can therefore be viewed as a generalized AC integrator (GI). With the introduced flexibility of tuning the resonant frequency, attempts at using multiple PR controllers for selectively compensating low-order harmonics have also been reported in for three-phase active power filters, in for three-phase uninterruptible power supplies (UPS) and in for single-phase photovoltaic inverters. Based on similar concept, various harmonic reference generators using PR filters have also been proposed for single-phase traction power conditioners and three-phase active power filters. Where GAC(s) represents the equivalent stationary frame transfer function. Therefore, for the ideal and non-ideal integrators of,

$$GAC\ (s) = Ki/S\ \&\ GDC = (Ki/1+s/\omega c)$$

(Ki and ωC << ω represent controller gain and cut Off frequency respectively), the derived generalized AC integrators GAC(s) are expressed as, frequency respectively), the derived generalized AC integrators GAC(s) are expressed as,

$$G_{AC}(S) = \frac{Y(S)}{E(S)} = K_P + \frac{2SK_i\omega_C + \omega_c^2}{S^2 + 2S\omega_C + (\omega_C + \omega_c^2)}$$

3. Proportional Integral

The proportional integral controller is about the most common and useful algorithm in control system engineering. The proposed PR Controller simulation is represented in Figure A. The feedback loops are controlled using PI algorithm. Feedback is very important in systems in order to attain a set point irrespective of disturbances or any variation in characteristics of any form. PI controller is designed to correct error between the measured process value and a particular desired set point in a system. The Proportional (P) and Integral (I) controls the system S, using the controller C where the controller efficiency depends on P and I parameters.

1. A PI speed controller has been chosen with gain parameters Kp and Ki.
2. The speed of the motor compared with the reference value and the error in speed is processed by the speed controller.
3. The output of the PI controller at any instant is the reference torque given by

$$T_{ref} = K_p + K_i = sW_{ref} \quad W_r$$

Where T_{ref} is the reference torque Kp is the proportional gain of the PI controller. Ki is the integral gain of the PI controller. Wref is the reference speed in rad/sec. Wr is the actual speed in rad/sec. The actual value of current or speed is sensed from the output and sent to proportional and integral terms which contains the proportional term with gain and integral term with gain . The outputs are summed using a Sum block and the output is sent to saturation block for saturation purpose and output from this block gives the error between the reference value and actual value of the motor.

In PI controlled PMBLDC motor starting speed is greater than reference speed while in no load and on load condition. The time taken for speed to settle at reference speed after load is applied is less. Speed drop is less when load is applied. The time taken for torque to settle at reference torque after load is applied is low.

PI controllers have a simple control structure, inexpensive cost. However, when the system is nonlinear and when bounded uncertainties present in the system, PI controllers are not perfectly able to stabilize the system, particularly, when the nonlinearity is very high or the bound of uncertainty is large. In many practical problems, almost perfect disturbance rejection or control performance is required. It is also sensitive to parameter variations and external load torque.

D. Sliding Mode Technique

SM control is one of the nonlinear control strategies. It is mostly applicable to variable structure system. The basic principle for applying SM control strategy is to design as lading surface or switching function. Then the switches of power electronic device are controlled in such away that the system trajectory will be directed towards the sliding surface, slide as long the surface and eventually reach the equilibrium point [3].The sliding surface taken is given by,

$$S = \alpha_1 p_1 + \alpha_2 p_2 + \alpha_3 p_3$$

$T_{ref} = K_p + K_i = sW_{ref} \quad W_r$

Where α1, α2, α3 are positive constant and

$$S = (\frac{d}{dt} + \rho)(x - x_d)$$

*p*1, *p*2, *p*3 are state variable of the DC-DC converter. The sliding surface is given by, Where x*d* is the error between state variable to be controlled and desired reference variable. After designing of the sliding surface, the next step is to define a control law based on three conditions. These conditions are given as follows:

(1)Rea1chingcondition or hitting condition
(2)Existence condition
(3)Stability condition.

E. *SVPWM Method*

The main objectives of space vector pulse width modulation technic to generated gate pulse. With the advance technology in microprocessor the SVPWM has been playing a pivotal and viable role in power conversion. It uses a space vector concept to calculate the duty cycle of the switch which is imperative implementation of digital control theory of PWM modulators. The main advantageous to use of this technic is to minimize the harmonics analysis in power converter. With the application of Fourier analysis the harmonic content of any waveform can be determined.

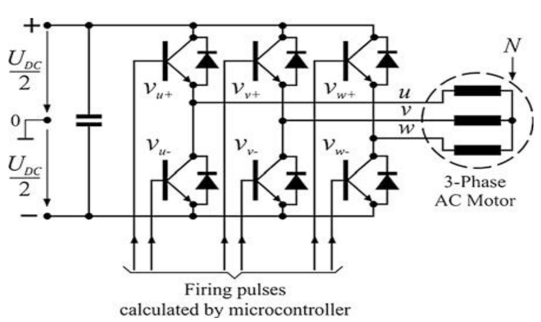


Fig. No.2 Principle Circuit of the VSI Inverter

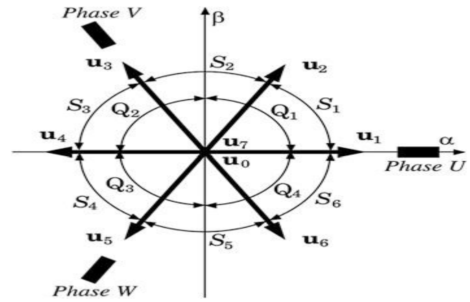


Fig. No. 3The standard voltage vectors u0, u1… u7 formed by the three transistor pairs (Q1… Q4: quadrants,S1… S6: sectors)

SV-PWM is actually just a modulation algorithm which translates phase voltage (phase to neutral) references, coming from the controller, into modulation times/duty-cycles to be applied to the PWM peripheral. It is a general technique for any three-phase load, although it has been developed for motor control. SV-PWM maximizes DC bus voltage exploitation and uses the "nearest" vectors, which translates into a minimization of the harmonic content. The classical application of SV-PWM is vector motor control, which is based on the control of currents' projection on two orthogonal coordinates (direct and quadrature, dq), called Field Oriented Control (FOC). For induction machines, the most common choices for the direct axis is to align it to the rotor field (rotor FOC) or to the stator field (stator FOC). The basic concept is that with a known motor and known voltage output pulses you can accurately determine rotor slip by monitoring current and phase shift. The controller can then modify the PWM "sine" wave shape, frequency or amplitude to achieve the desired result. For example the desired speed is 200 rpm and the control senses there is 2 rpm of slip so it increases the frequency slightly to bring the speed up. Since torque can also be determined it can also be controlled. SVPWM just does a lot of sampling, calculating and wave form manipulation. The specific algorithms and deciding what the best output solution is for different situations could fill up several books. SV means space vector, as in space vector modulation. SVM basically allows a 3-phase bridge PWM drive to supply about 15% higher peak voltage to a motor than the standard sine-triangle modulation scheme by allowing the neutral point of the motor to move away from the nominal 1/2 of the supply rail (it will look like a triangle wave). The characteristic voltage output of an SVM-modulated sine wave is a sine wave with a double-hump on the peaks. To be more precise, SVM output about 15% more "non over-modulated" voltage than the traditional carrier based PWM. That is the maximum voltage before over-modulation happens. The shape of the phase voltage has a double-hump as mentioned (similar to a standard PWM + third harmonic addition). The line-to-line voltage will not show the humps though. Therefore the SVPWM technique is used to generate the gate pulse and help to reduce steady state error. This method used to mitigate harmonics for PWM inverter.

III. CONCLUSION

This paper deals with significant gains in the Shunt APF based on the sliding mode control strategy with SVPWM Control. A effectiveness of the proposed control strategy even during system load variation while provide simultaneously system reactive power compensation and harmonic mitigation. If we give high gain to the system the stability is distributed so to overcome that problem the PR controller can be made on-ideal by introducing damping and achieves zero steady state error.

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