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Synchronous Reference Frame Theory for Active Power Filter

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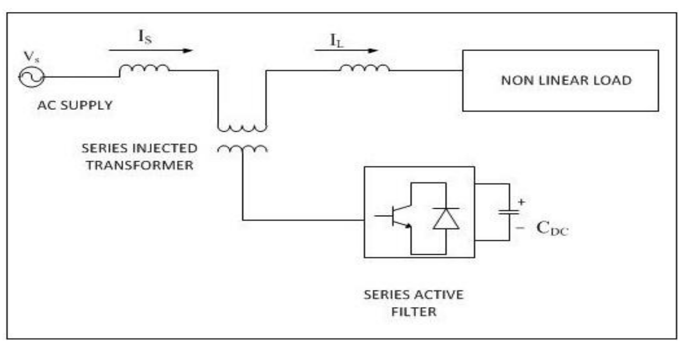
Abstract:
Today major voltage related problem in the electrical industry is voltage sag. Due to the increasing number of non linear load had dropped a serious power quality problem known as disturbance in power system. This paper deals with modeling and simulation of a Series Active Filter (SAF) for mitigation of voltage sag. In this paper a three-phase three- wire series active filter under distorted load conditions, the power quality problems are compensate through a synchronous reference frame (SRF) and hysteresis controller based control method. The proposed SAF system can improve the power quality at the point of common coupling (PCC).Key Words: Series Active Filter (SAF), Synchronous Reference frame (SRF), Power quality

I. INTRODUCTION

Modern power system is a complex network where many generating station and load centers are interconnected through long power transmission and distribution network. Nowadays distribution system is facing poor power quality at the load ends. Today industrial processes are based on a large amount of power electronics devices such as programmable logic controllers, adjustable speed drives. A power electronics converters behaves as a non linear load and very sensitive to disturbance. Due to increasing number of highly nonlinear load such as computer power supplies, furnaces, power converters at domestic, commercial and industrial level which produce undesirable effect in the power system. Poor power quality may result into leads to low power factor, low efficiency, overheating of transformer and so on. Voltage disturbance become very expensive for the industrialists in terms of loss of production, loss of raw materials, and damage of material. The most common form of power quality disturbance is the voltage sag, which accounts 70% of all power quality disturbances. Voltage sags that occurs during the operation of the equipment will causes a reduction in life span and equipment will causes a reduction in life span and efficiency of the devices. Typical distribution system the wide spread use of non-linear loads results in a drop of the quality of a voltage waveforms at the point of common coupling of various loads. The weakening quality of electric power is mainly because of current and voltage harmonics due to wide spread application of power electronics converters, zero and negative sequence components originated by the use of single phase and unbalanced loads, voltage sag, voltage swell, voltage interruption etc. Voltage sag is the most occurring power system problem today that can cause electrical equipment to fail or shut down. The power generated at the generating station is a purely sinusoidal in nature. Conventional power quality mitigation equipment use passive elements and do not always respond correctly as nature of power system condition change. Therefore, it is very important to maintain a high standard of power quality. A number of topologies have been proposed [1]. The latest generation of power semi-conductor devices Active Power Filter is used. With improvements in power and control circuits, active filters are appropriate a good alternative to passive filters. Active power filters as an efficient and economical way of eliminating harmonics in the power system. One modern solution that deals load supply voltage imperfections is the Series Active Filter (SAF). Series Active Power Filter was introduced by the end of the 1980 and operates mainly as a voltage regulator. The series connected filter protects the consumer from an inadequate supply voltage quality. The series active filter is modeled in the stationary abc frame and then the model and then the model is transformed to the rotating dqo frame with the aim of reducing the control complexity.

II. SERIES ACTIVE FILTER

The series active filter injects voltage components in series with the supply voltage and therefore can be regarded as a controlled Compensating voltage sags and swells on the load side. The Series Active Filter is connected series with the mains, using a suitable transformer. The main purpose of a SAF is to compensate for supply voltage power quality issues such as, sags, swells, and unbalance.



LINE DIAGRAM OF SERIES ACTIVE FILTER
Figure shows a system arrangement of a single-phase or three-phase series active filter is mainly used for compensate various

types of voltage related problems. The series activeis controlled on the basis of the following manner: The controller detects the instantaneous supply current is. The series active filter applies the compensating voltage VAF across the primary of the series injection transformer. This compensating voltage is significantly reducing the supply harmonic current Ish when the feedback gain K is set to be enough high [3].

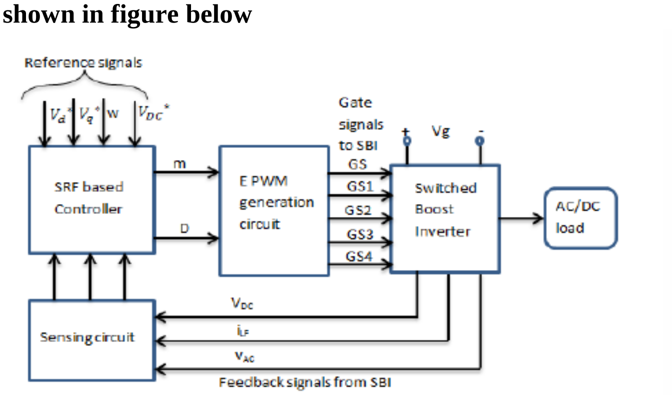
II. CONTROL STRATEGY OF SHUNT ACTIVE FILTER

The proposed control strategy is aimed to compute mainly the three phase reference voltage at the load terminal. The series active filter based on SRF method can be used to solve the voltage related power quality problems such as, voltage sag, voltage swell and voltage harmonics. The SRF method is used in series active filter for generating reference voltage signal. The supply voltages $V_S$abc are transforming into d-q-0 which is given in equation below.

$$\begin{bmatrix} Vd \\ Vq \\ V0 \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} \cos(wt) & \cos(wt-2\pi/3) & \cos(wt+2\pi/3) \\ -\sin(wt) & -\sin(wt-2\pi/3) & -\sin(wt+2\pi/3) \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix}\begin{bmatrix} Vsa \\ Vsb \\ Vsc \end{bmatrix} \quad (1)$$

Whereωt is the transformation angle and V denotes voltages. In the SRF wt is a time varying angle that represents the angular position of the reference frame which is rotating at constant speed in synchronism with the three phase ac voltage. Synchronous Reference Frame method (SRF) is one of the most common and probably it is the best method.

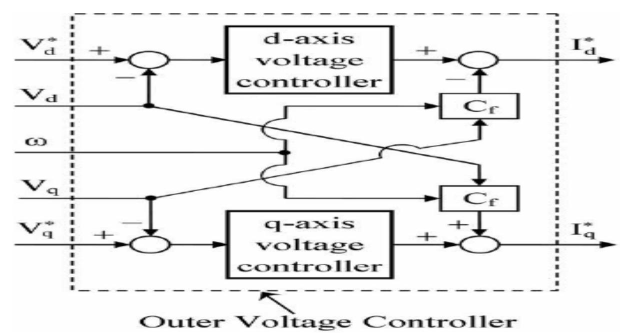
The block diagram of the proposed SRF control theory is shown in figure below



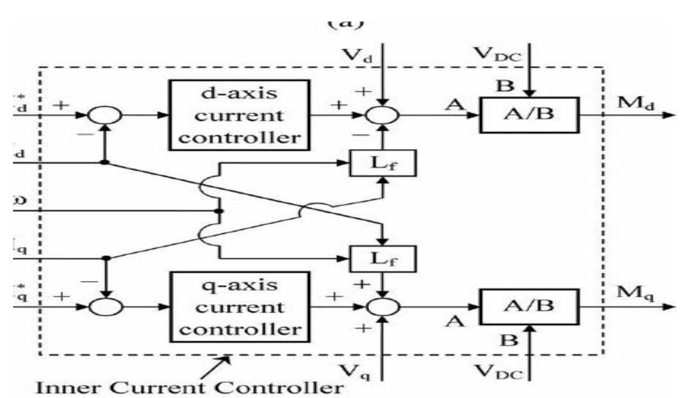
The inverse park transformation is used for generating reference voltage signal which is given in equation below is convert the reference load voltage ($V_L$abc) are transform d-q-0 into a-b-c.

$$\begin{bmatrix} V'La \\ V'Lb \\ V'Lc \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} \cos(wt) & -\sin(wt) & 1/\sqrt{2} \\ \cos(wt-2\pi/3) & -\sin(wt-2\pi/3) & 1/\sqrt{2} \\ \cos(wt+2\pi/3) & -\sin(wt+2\pi/3) & 1/\sqrt{2} \end{bmatrix}\begin{bmatrix} Vd \\ Vq \\ V0 \end{bmatrix} \quad (2)$$

After generating reference load voltage (V*Labc) are compared with sensed load voltage ($V_L$abc) in sinusoidal pulse width modulation technique. This comparison between reference load voltage and sensed load voltage in sinusoidal PWM technique generate gating signals for series voltage source converter. In series voltage source converter as a switching device use insulated gate bipolar transistor (IGBT) which can compensate all voltage related problems, such as voltage sag, voltage swell and voltage harmonics The closed loop control of the SBI using SRF theory The control loop consists of feedback path which senses the voltages and current from the SBI and is fed to the controller. The controller generates a modulating wave „m" and „D" which is given to PWM module to generate thePWM pulses. These pulses turn the the switches of SBI ON/OFF for predetermined duration to drive the AC/DC loads connected. „D" is the shoot through interval of the switches. The reference signals are given to the controller along with the sensed signal from the DC bus, SBI (AC current and Voltage) The signals Vd and Vqare directly given to the controller; this reduces the computational burden on the processor used. The dq transformation from αβ is obtained using the equations 1 and 2. There are two voltage control loops one to control the DC voltage VDC and other to control the AC voltage vAC. The DC controller is a linear controller which varies the value of „D" in proportional to the error from the feedback sensing circuit. The DC control loop is not shown in the figure1, while is implemented in the controller. The linear controller is implemented using the Proportional Integrative (PI) controller, which is beyond the scope of this paper. The controller has inner and outer loop to control current and voltage respectively. The sensed coefficients use PI controller to reduce the non-linearity and local dqcouplings. The control block for inner current loop and outer voltage loop is as shown in figure bellow. The d-axis and q-axis voltage controller are derived using PI controller. Since DC signals are used as reference to control the AC values, simple linear controller can be used to restrict the sensed value to be within the limits nearer to the reference value.



(A) OUTER VOLTAGE CONTROL LOOP



(B) INNER CURRENT CONTROL LOOP.

Block diagram of AC bus controller (a) Outer voltage control loopv(b) Inner current control loop is shown. The cross coupling of the terms between dqcomponents results in cancelling of active and reactive components along with the non-linearity's. This control scheme has been verified to have high performance along with tracking accuracy at a dynamic state [7]. C. AC Current and Voltage controller the equations for the controller is developed using the equivalent circuit of SBI

$$\frac{d}{dt}\begin{bmatrix} I_d \\ I_q \end{bmatrix} \equiv \begin{bmatrix} \frac{R_{Lf}}{L_f} & w \\ -w & -\frac{R_{Lf}}{L_f} \end{bmatrix} \begin{bmatrix} I_d \\ I_q \end{bmatrix} + \frac{1}{L_f} \cdot \begin{bmatrix} V_{invd} - V_d \\ V_{invq} - Vq \end{bmatrix} \quad (3)$$

The equation (3) represents the current controller Equation, while equation (4) represents the voltage controller equation.

$$\frac{d}{dt}\begin{bmatrix} V_d \\ V_q \end{bmatrix} \equiv \begin{bmatrix} \frac{1}{R_{AC}.C_f} & w \\ -w & -\frac{1}{R_{AC}.C_f} \end{bmatrix} \begin{bmatrix} V_d \\ V_q \end{bmatrix} + \frac{1}{C_f} \cdot \begin{bmatrix} I_d \\ Iq \end{bmatrix} \quad (4)$$

The resistance RAC is the equivalent value of load resistance. The above equations are used to generalize and design the controller for voltage control and current control.

IIIADVANTAGES OF SRF THEORY

1. The number of voltage equations are reduced. 2. The time – varying voltage equations become time – invariant ones. 3. Performance of power systems and electric machines can be analysed without complexities in the voltage equations. 4. Transformations make it possible for control algorithms to be implemented on the DSP 5. With aid of this technique, many of the basic concepts and interpretations of these general transformations are concisely established.

IV. CONCLUSION

This paper describes a SRF based control strategy used in SAF, which mainly compensate voltage related power quality problems. The series active filter mitigated the voltage sag of the circuit.The investigation of series active filter with compensation technique based on SRF and hysteresis based theory. It was observed that the proposed control scheme of the SAF has a fast response and is able to maintain the voltage level. A voltage compensation technique based on SRF technique had been studied for series active power filters.

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