Active Power Filter for Power Quality Improvement using Hysteresis Controller

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Abstract - *Some distribution loads are extremely sensitive to voltage changes at the input. When electrical equipment is supplied with contaminated or distorted voltage, its performance suffers. To reduce harmonics, increase power factor, and avoid electrical resonance, a variety of solutions are available in today's practice, including power factor correction systems with detuned filters, capacitor banks, and series reactors. Even though they have fixed compensation and the risk of resonance, passive filters are nevertheless widely utilized*

There are two methods to solve these problems: one is to modify the system's architecture to decrease the problem, and the other is to discover a solution for the present system. The various loads are categorized based on the difficulties they cause and the numerous practical remedies that can help solve them to a large extent.

The modeling and analysis of Custom Power Devices are the subject of this dissertation paper (SAPF). The models for the Series Active Power Filter (SAPF) are given using MATLAB/Simulink. Because of its ease of implementation, hysteresis band voltage control PWM is a common choice among PWM methods. This well-known approach does not need any knowledge of system characteristics. The SAPF is simulated for various voltage changes at the input provided by the three phase programmable source, with the results being displayed.

Key Words: *Active Power Filter, Power Quality, PWM*

1. INTRODUCTION

For all three phases of a three-phase system, power quality phenomena include any situation in which the waveform of the supply voltage (voltage quality) or load current (current quality) deviates from the sinusoidal waveform at rated frequency with amplitude corresponding to the rated rms value [1]. Power quality disturbances encompass a wide variety of abrupt, short-duration changes, such as impulsive and oscillatory transients, voltage sags, and brief interruptions, as well as steady-state aberrations like harmonics and flicker. Disturbances related to the quality of the supply voltage and those related to the quality of the current absorbed by the load can also be distinguished based on the cause [2].

The first class includes voltage dips and interruptions, which are often caused by power system problems. These disruptions may induce tripping of "sensitive" electronic equipment, which can have severe effects in industrial operations, where tripping of vital equipment might force the entire production to stop, resulting in enormous expenses. One may argue that the source is the one causing the load to be disrupted in this situation. Industrial clients frequently elect to install mitigation equipment to safeguard their operations against such disturbances in order to avoid recurring financial losses.

The second group of occurrences is caused by low-quality current drawn by the load. The source is disrupted in this situation by the load. Current harmonics generated by disruptive loads such as diode rectifiers, or unbalanced currents pulled by unbalanced loads, are two examples. Customers do not suffer any direct production losses as a result of these power quality problems. However, poor quality current taken by a large number of consumers would eventually result in poor quality electricity provided to other customers [3].

Both harmonics and unbalanced currents result in voltage distortion and, correspondingly, imbalance. As a result, suitable criteria are established to restrict the amount of harmonic currents, imbalance, and/or flicker introduced by a load. Customers are frequently required to install mitigation devices in order to comply with standard limitations.

Custom Power is a phrase that represents the value-added power that electric utilities and other service providers will supply in the future to their consumers. An integrated solution to current problems, with a prominent feature being the application of power electronic controllers to utility distribution systems and/or at the supply of many industrial and commercial customers and industrial parks, will improve the level of reliability of this power in terms of reduced interruptions and less variation.

2. MODELLING OF ACTIVE FILTER

2.1 Principal of operation

Active power filter is a highly important technology for improving the electrical distribution network's power quality. A series active power filter's principal purpose is to protect sensitive loads from supply voltage sags, swells, and harmonics. Three single phase transformers link the supply and load terminals of the series filter. The primary windings of these transformers are linked in series with the three-phase supply, while the secondary windings are connected in star configuration. These transformers filter the switching ripple of the series active filter in addition to injecting voltage.

To remove the large switching ripple content in the series active filter injected voltage, a small capacity rated RC filter [1] is connected across the secondary of each series transformer. IGBTs are used to build the voltage source inverters for both active filters (Insulated Gate Bipolar Transistors).

Figure 1 depicts the overall construction of the active power filter under investigation. The 3-phase voltage source converter, Lf, Cf filter to reduce switching ripples, and series transformers that inject the compensatory voltage to the line make up the series active power filter.

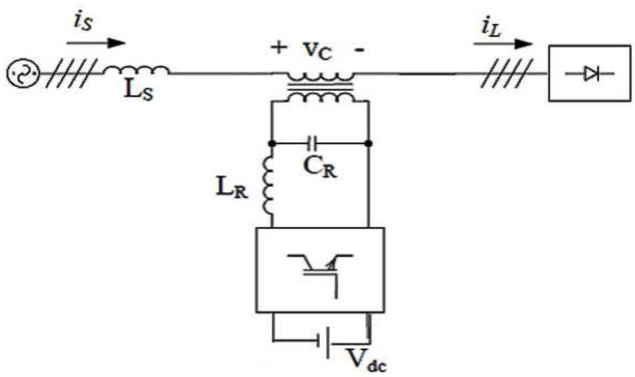

Fig-1: Schematic diagram of series active filter

The dynamics of the modulation technique used to control the switches, as well as the mechanism utilised to calculate active filter voltage references, will influence the Series Active Power Filter's performance. The disturbance detection block and the voltage control are the two major blocks in the control scheme of a series active power filter. A robust PLL system is utilized in this approach to identify voltage references. Because of its ease of implementation, hysteresis band current or voltage control PWM is a common choice among PWM methods. This well-known approach does not need any knowledge of system characteristics.

2.2 Control Scheme of Series Filter

To regulate the series and shunt filters, a simple algorithm is created. The series filter is programmed to inject voltages (Vca, Vcb, Vcc) that cancel out the distortions and/or imbalance present in the supply voltages (Vsa, Vsb, Vsc), resulting in precisely balanced and sinusoidal voltages at the PCC (Vla, Vlb, Vlc). In other words, the required voltage at the load terminals is equal to the sum of the supply voltage and the injected series filter voltage. Figure 2 depicts the control method for the series AF.

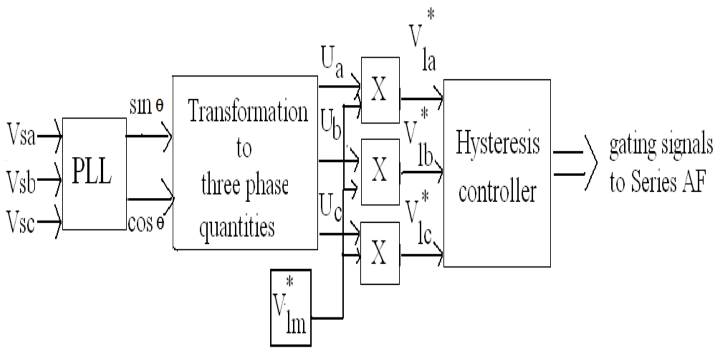

Fig-2: Control Scheme of Series APF for transient stability improvement of power system

2.3 Hysteresis Controller

A phase locked loop (PLL) is utilized to achieve synchronization with the supply because the voltage is imbalanced and/or distorted. This PLL transforms a distorted input voltage into a pure three-phase sinusoidal supply with each phase's RMS value equal to the fundamental voltage (1 p.u). The PLL receives three phase distorted/unbalanced source voltages and produces two quadrature unit vectors (Sin,Cos).

Before being sent into the PLL, the detected supply voltage is multiplied by an appropriate gain value. Using eqn.(1) and the in-phase sine and cosine outputs from the PLL, the supply in phase, 120 degree displaced three unit vectors (ua, ub, uc) are computed.

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \times \begin{bmatrix} Sin\theta \\ Cos\theta \end{bmatrix} \quad \ldots\ldots\ldots\ldots (1)$$

The computed three in-phase unit vectors are then multiplied with the desired peak value of the PCC phase voltage (Vlm*), which becomes the three-phase reference PCC voltages as

$$\begin{pmatrix} V_{la}^{*} \\ V_{lb}^{*} \\ V_{lc}^{*} \end{pmatrix} = V_{lm}^{*} \begin{pmatrix} u_a \\ u_b \\ u_c \end{pmatrix} \quad \ldots\ldots\ldots\ldots (2)$$

The highest value of the PCC phase voltage is thought to be 338V (= (415* 2)/3). The hysteresis controller receives the calculated voltages from eqn. (2) as well as the sensed three-phase PCC voltages. The hysteresis controller outputs switching signals to the six VSI switches in the series AF. The switching signals are generated by the hysteresis controller so that the voltage at the PCC becomes the required sinusoidal reference voltage. As a result, the ripple filter cancels out the harmonics and imbalance in the supply voltage by injecting voltage across the series transformer.

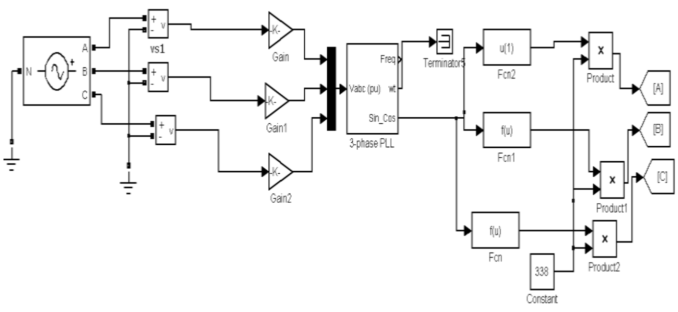

Fig-3: Reference voltage generator for SAF for transient stability improvement

The error signal is transmitted through the Relay block after the reference voltages are compared to the load voltage. Gating pulses (Fig. 4) are created and delivered to IGBTs to correct for system disruptions based on comparison of reference voltages with load voltages in a voltage hysteresis controller (Fig. 5).

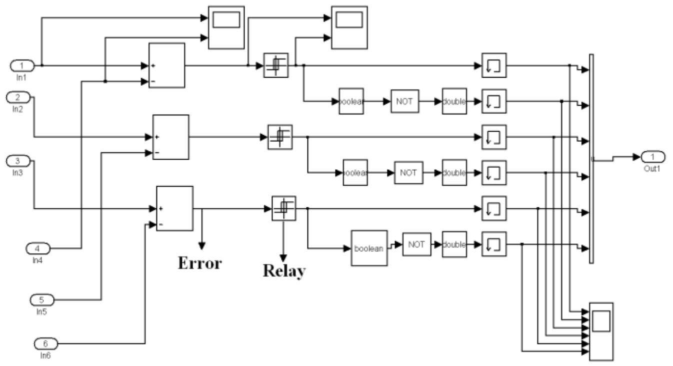

Fig-4: Hysteresis voltage controller

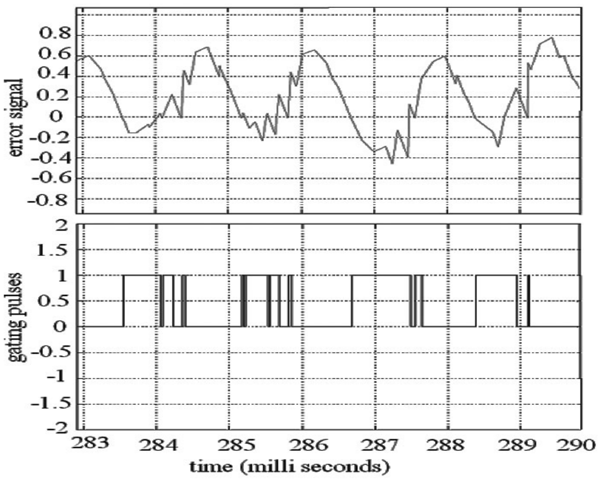

Fig-5: Error signal & PWM pulses generated for the 1st top leg of SAPF

3. SIMULATION MODEL

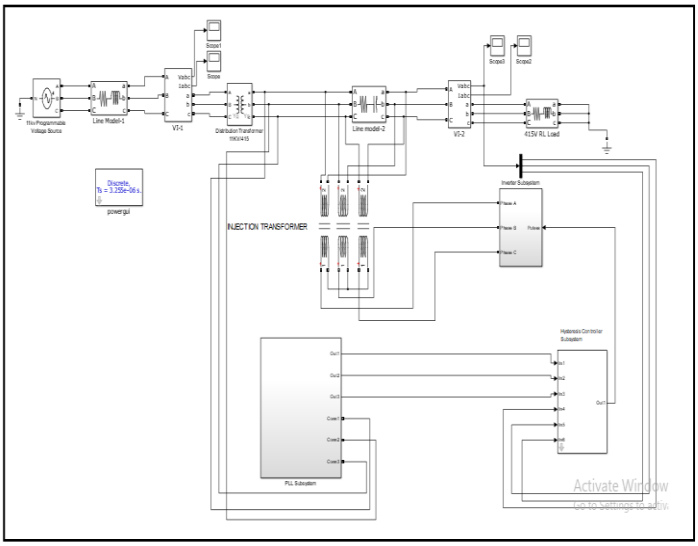

Fig-6: Proposed complete matlab simulation model

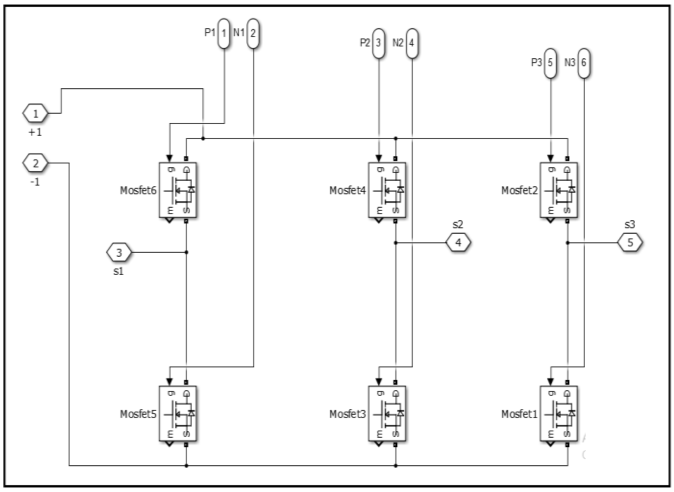

Fig-7: Three phase six pulse inverter subsystem matlab simulink model

Fig. 6 shows the MATLAB/ Simulink model of designed system. The main components of the below system are as follows.

- Mains supply
- Nonlinear load
- Active Power Filter
- Voltage source inverter
- Interface reactor
- Reference voltage generator
- Hysteresis voltage controller

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4. SIMULATION RESULTS

4.1 Voltage sag

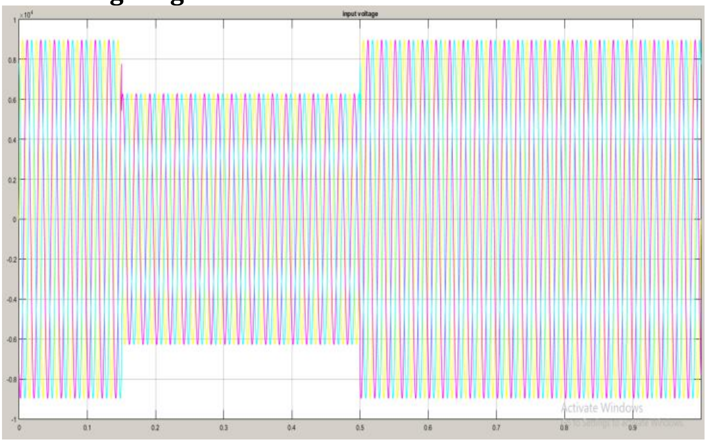

Fig-8: Three phase transmission line send end voltage or source side voltage during voltage sag

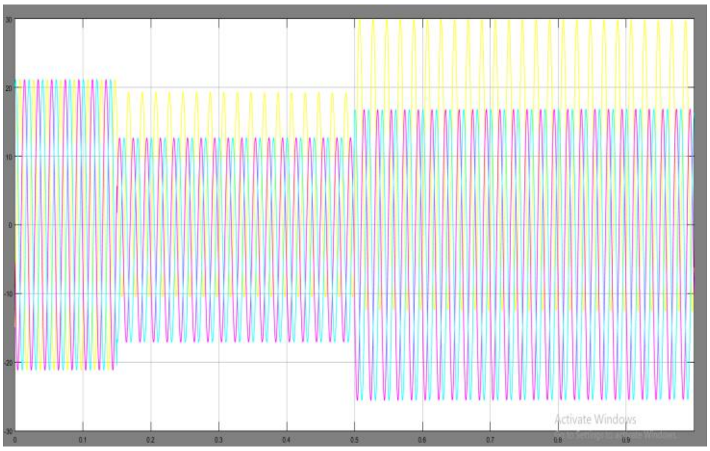

Fig-9: Three phase transmission line sending end current or source side current during voltage sag

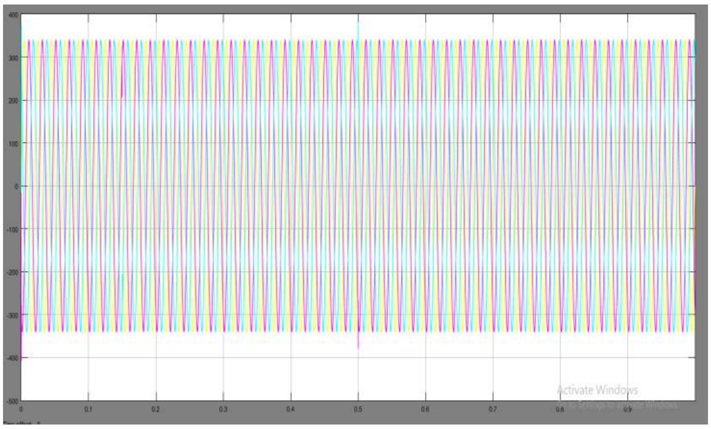

Fig-10: Three phase transmission line receiving end voltage or load side voltage during voltage sag

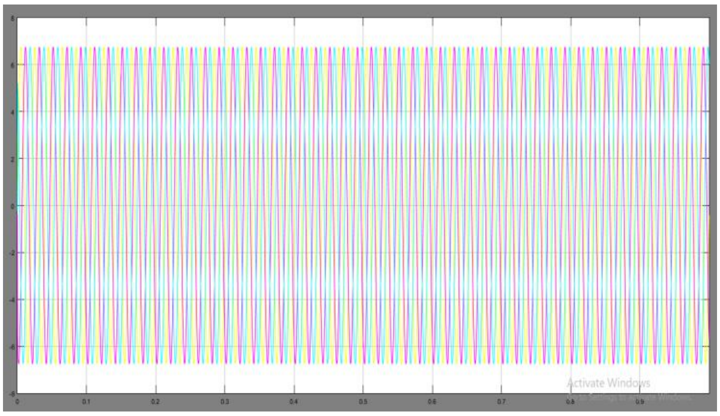

Fig-11: Three phase transmission line receiving end current or load side current during voltage sag

4.2 Voltage Swell

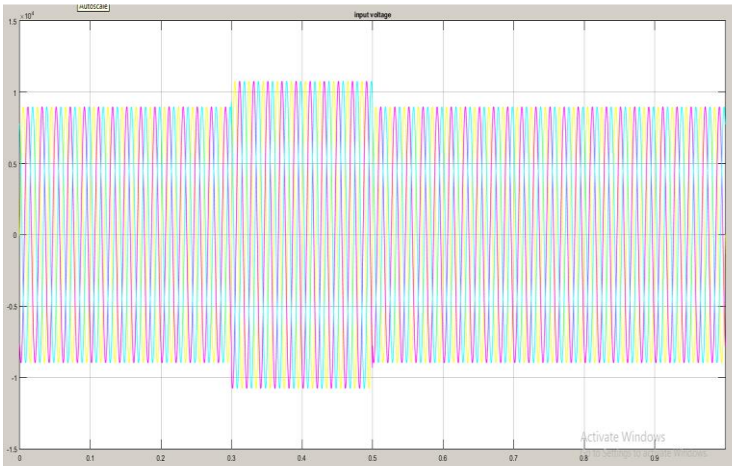

Fig-12: Three phase transmission line send end voltage or source side voltage during voltage swell

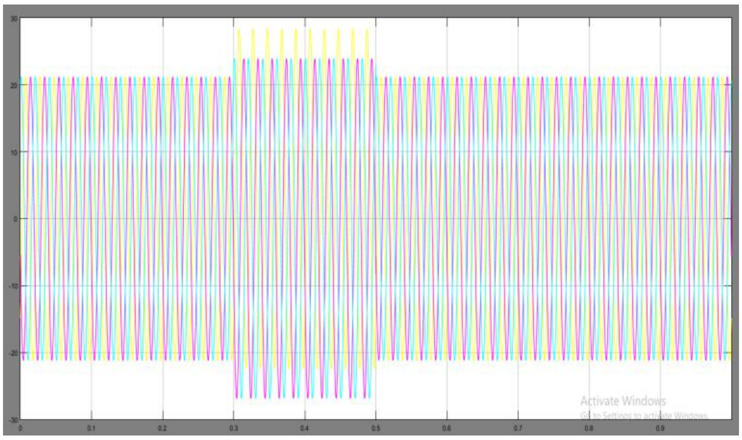

Fig-13: Three phase transmission line receiving end current or source side current during voltage swell

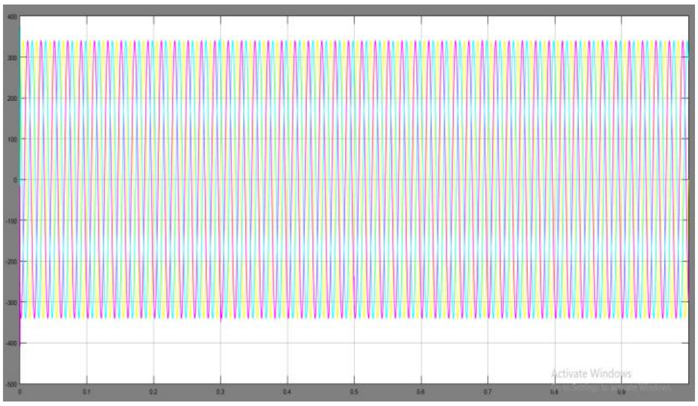

Fig-14: Three phase transmission line receiving end voltage or load side voltage during voltage swell

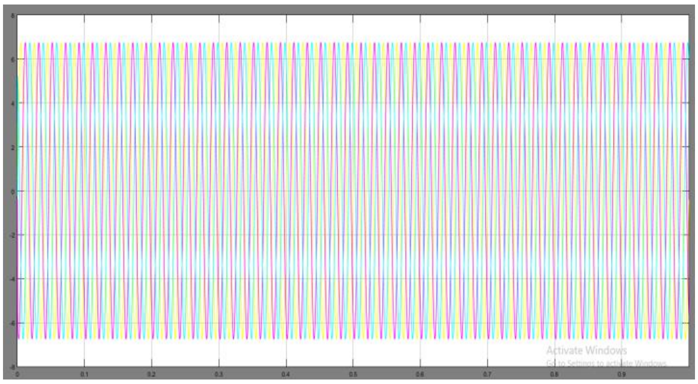

Fig-15: Three phase transmission line receiving end current or load side current during voltage swell

4. CONCLUSIONS

The proposed active power filter using Hysteresis PWM controller result analysis conclude that:

- In matlab simulation software, a series active power filter phase lock loop system for reference voltage generation was created.
- In a matlab simulation, a hysteresis PWM based controller for an inverter system was created.
- In matlab simulation software, a three phase six pulse Mosfet based inverter system was designed.
- The voltage sag, swell, and short duration of fault conditions were investigated using the results of the entire system analysis.
- Voltage sag, swell, and short duration LG faults were investigated at the transmission line transmitting and receiving ends, i.e. load side voltage.
- On the transmission line load side, simulation results were analysed for two situations. The RL load on the transmission line and the rectifier load or power electronics load are the two situations.
- The use of a series active power filter to improve power quality has been studied. To evaluate the system's performance, various simulations are run. Harmonic and voltage distortion correction of the non-linear load is done using a Hysteresis controller based Series active power filter. The simulation is also expanded to include anomalous failures in the power system, such as L-G and L-L faults.
- The simulation findings of a series active power filter showed that it can correct for voltage sag, swell, and harmonics at the input source. The suggested SAPF is appropriate for connecting at the PCC of industrial drives that are particularly susceptible to Sags, Swells, and harmonics because of these functions. The THD of the load voltage is less than 5%, which is the IEEE standard's harmonics limit.

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