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Enhancement of Power Quality Using Advanced Series Active Power Filters

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ABSTRACT: This paper presents the d various issues related to the power quality. The interest in power quality is explained in the context of a number of wider developments in power engineering such as deregulation of the electricity industry, increased customer-demand. Two power quality disturbances are discussed in detail: voltage dips and harmonic distortion. Shunt, hybrid and advanced series active power filters are described showing their compensation characteristics and principles of operation. The performance of the advanced series active power filters carried out in MATLAB/SIMULINK environment.

KEYWORDS: Power quality, voltage sag voltage Swell, series active power filters, Active filters.

I. INTRODUCTION

Power quality phenomena include all possible situations in which the waveform of the supply voltage (voltage quality) or load current (current quality) deviate from the sinusoidal waveform at rated frequency with amplitude corresponding to the rated **rms** value for all three phases of a three-phase system [1].Firstly, the voltage dips and interruptions, mostly caused by faults in the power system. These disturbances may cause tripping of “sensitive” electronic equipment with disastrous consequences in industrial plants where tripping of critical equipment can bear the stoppage of the whole production with high costs associated. Secondly, due to low quality of the current drawn by the load[8]. In this case, it is the load that disturbs the source [2].Both harmonics and unbalanced currents ultimately cause distortion [3]. The compensating devices are used for active filtering; load balancing, power factor correction and voltage regulation [4].

This paper presents that any disturbances caused in the supply voltage will result in the malfunctioning of the electrical equipment, also results in lower efficiency and also complete shutdown of the equipments[8]. Series Active power filters have been developed to overcome these problems.

II. POWER QUALITY

The Power Quality issue is defined as “any occurrence manifested in voltage, current, or frequency deviations that results in damage, upset, failure, or malfunctioning of end-use equipment”. The Power Quality (PQ) problem can be detected from one of the following several symptoms depending on the type of issue involved such as Lamp flicker, Frequent blackouts ,Sensitive-equipment frequent dropouts, Communications interference and Overheated elements and equipment[2]. Conventionally, passive filters have been used to eliminate harmonic problems. This filter consists of common devices such as inductance and capacitance[10].

There are two approaches to the mitigation of power quality problems. The first approach is called load conditioning, which ensures that the equipment is made less sensitive to power disturbances, allowing the operation even under significant voltage distortion [5]. The other solution is to install line-conditioning systems that suppress or counteract the power system disturbances.

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III. MODELING OF SERIES ACTIVE POWER FILTER

The series active filter injects a voltage component in series with the supply voltage and therefore can be regarded as a controlled voltage source, compensating voltage sags and swells on the load side[4].

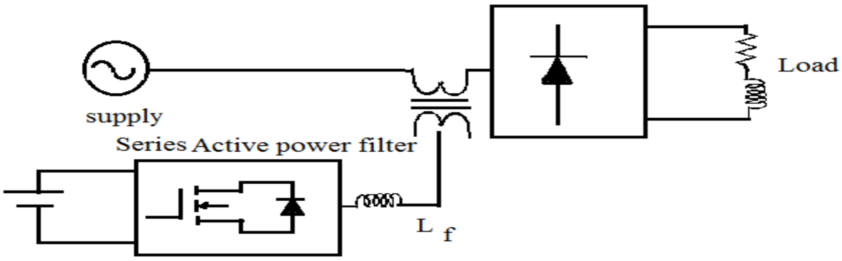

Fig.3.1: Block Diagram of Series APF

The main advantage of this scheme is that the rated power of the series active filter is a small fraction of the load KVA rating, typically 5%. However, the apparent power rating of the series active power filter may increase in case of voltage compensation [6]. The main function of a series active power filter is the protection of sensitive loads from supply voltage sags, swells and harmonics.

3.1 CONTROL SCHEME OF SERIES FILTER

A simple algorithm is developed to control the series and shunt filters [8]. The series filter is controlled such that it injects voltages (V_{ca},V_{cb},V_{cc}) which cancel out the distortions and/or unbalance present in the supply voltages **(**V_{sa},V_{sb},V_{sc}**)** thus making the voltages at the PCC (V_{la},V_{lb},V_{lc}) perfectly balanced and sinusoidal with the desired amplitude. The control strategy for the series AF is shown in Fig. 3.2.

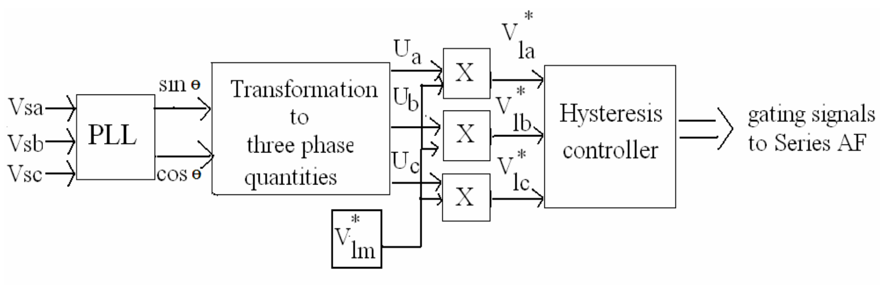

Fig.3.2: Control Scheme of Series APF

3.2 REFERENCE VOLTAGE GENERATION & HVC

Since the supply voltage is unbalanced and or distorted, a phase locked loop (PLL) is used to achieve synchronization with the supply. This PLL converts the distorted input voltage into pure three phase sinusoidal supply of RMS value of each phase equal to that of the fundamental (1 p.u).The in-phase sine and cosine outputs from the PLL are used to compute the supply in phase, 120^0 displaced three unit vectors (u_a,u_b,u_c) using eqn.(3.1) as

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \times \begin{bmatrix} Sin\theta \\ Cos\theta \end{bmatrix} \qquad (3.1)$$

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

$$\begin{pmatrix} V_{la}^* \\ V_{lb}^* \\ V_{lc}^* \end{pmatrix} = V_{lm}^* \begin{pmatrix} u_a \\ u_b \\ u_c \end{pmatrix} \qquad (3.2)$$

The hysteresis controller generates the switching signals such that the voltage at the PCC becomes the desired sinusoidal reference voltage[10]. Therefore, the injected voltage across the series transformer through the ripple filter cancels out the harmonics and unbalance present in the supply voltage.

IV. ADVANCED SERIES ACTIVE POWER FILTER

The advanced series active power filter is used to compensate the source side disturbances such as voltage sags, swells and also harmonic distortions [6]. In this configuration, the filter is connected in series with the line being compensated. Therefore the configurations are often referred to as an advanced series active filter.

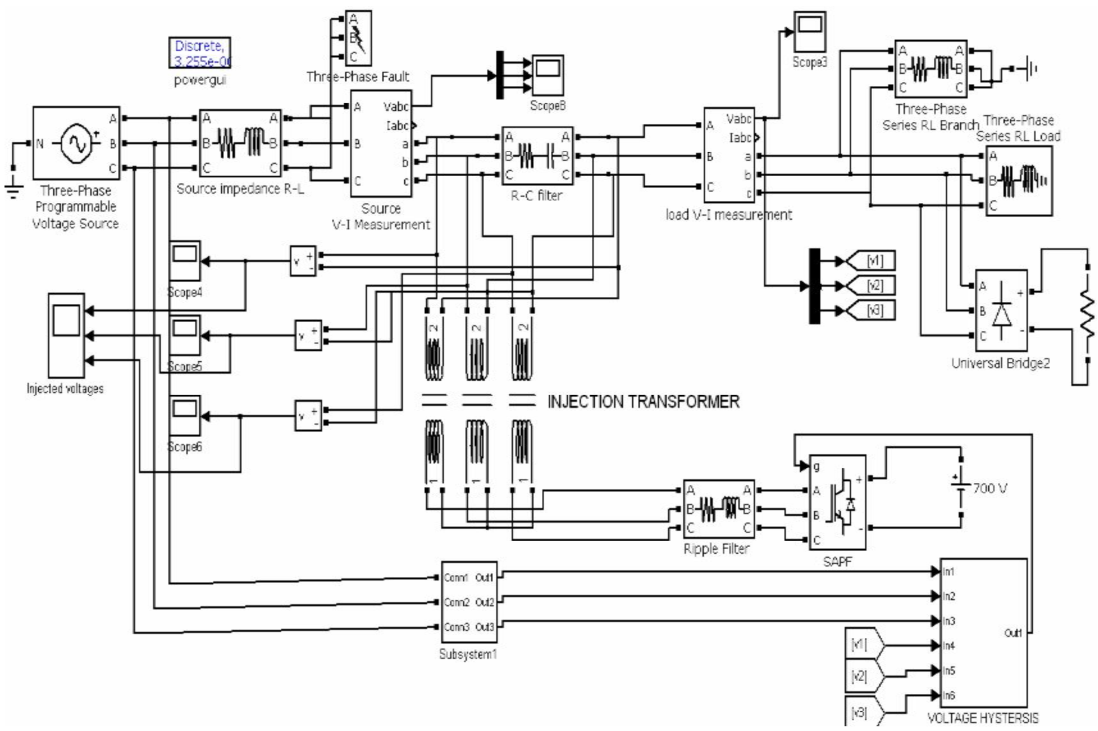

Fig. 4.1 MATLAB/Simulink model of advanced Series active power filter

Fig. 4.1 shows the source voltage in which rated 1 p.u voltage is created from 0 to 0.1 seconds, 0.8 p.u sag from 0.1 to 0.15 seconds,1 p.u voltage from 0.15 to 0.2 seconds, 1.2 p.u swell from 0.2 to 0.25 seconds , 0.8 p.u sag from 0.25 to 0.4 seconds , 1 p.u voltage from 0.4 to 0.5 seconds . A L-G fault occurs in phase A from 0 to 0.2 seconds .The load is R=10 Ω and L=1mH, a three phase diode rectifier bridge, an inductive load of power factor (p.f) 0.894 lag (active power =1000W and reactive power = 500W). The data for the Advanced Series active power filter is shown in Table 4.1., the individual three phase voltage is shown in table. 4.2 and fault in phase A shown in table 4.3.

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Utility Source	Phase voltage= 415 V(RMS) Frequency = 50 Hz Source resistance = 0.1 Ω Source inductance= 0.5 mH L-G Fault on Phase A (case 3) L-L fault on Phase B & C (case 4)
Series Active Power Filter	Ripple filter parameters= 3.35mH, 0.1Ω; Injection transformer= 1.5 KVA& 7KVA DC voltage source = 700 V RC filter= 6 Ω, 6 µF
Load	R=10 ohms and L=1 mH. R=50 ohms and L=10 mH. Inductive load of P.F 0.894 lag. Three phase Diode bridge rectifier.

Table 4.1 System parameters for Series APF

Time(seconds)	Voltage (p.u)	Load
0 to 0.1	1	R=10 Ω &L=1mH, three phase diode rectifier bridge, inductive load of power factor (p.f) 0.894 lag
0.1 to 0.15	0.8	
0.15 to 0.2	1	
0.2 to 0.25	1.2	
0.25 to 0.4	0.8	
0.4 to 0.5	1	

Table 4.2: Source Voltage parameters 3-phase (line-Ground)

Time (seconds)	Phase A	Phase B	Phase C
0 to 0.2	L-G fault	-	-

Table 4.3: Fault in Phase A

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The Source voltages in 3-Phases A, B & C are shown as follows.

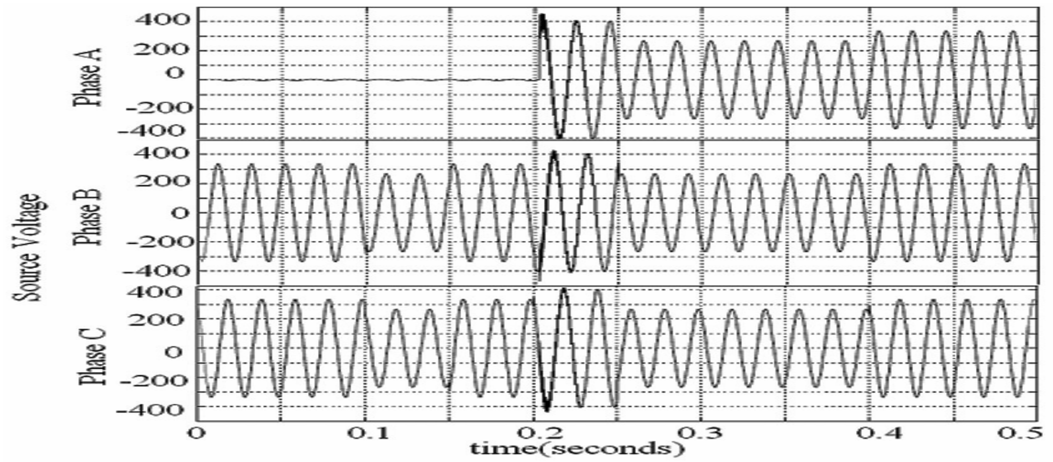

Fig. 4.2 Source voltages in 3-Phases A, B & C

Fig. 4.3 shows the compensated voltage injected by each phases to cancel the source side disturbances present in the system. The approach was based on the principle of injecting voltage in series with the line through the injection transformer to cancel the source side voltage disturbances and thus it made the load side voltage sinusoidal. finally the source side voltage disturbances is cancelled and got ripples free source voltage

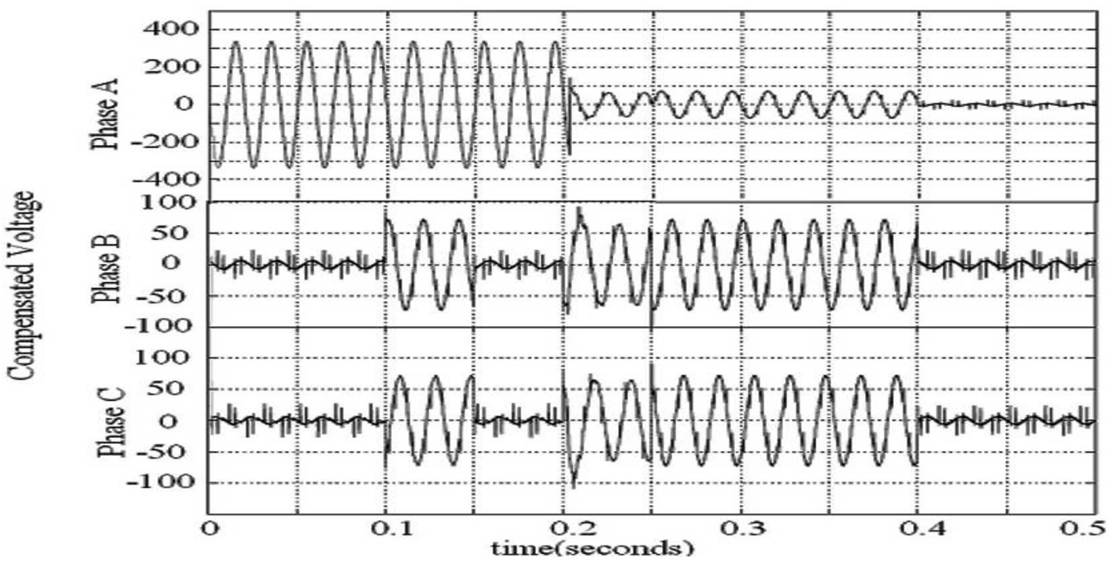

Fig. 4.3 Compensated voltages injected for each phases

Due to the injection of the above voltages through the injection transformer in series with the line the load voltage is sinusoidal as shown in the Fig. 4.4

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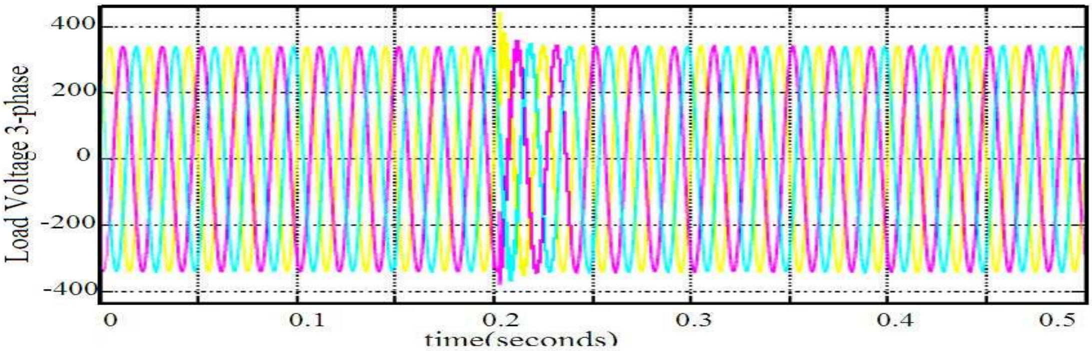

Fig. 4.4: 3-Phase load voltage (Line-Ground)

Active filters able to compensate for harmonics without fundamental frequency reactive power concerns. This means that the rating of the active power can be less than a conquerable passive filter for the same nonlinear load and the active filter will not introduce system resonances that can move a harmonic problem from one frequency to another and got ripple free line voltage. The Total harmonic distortion of source voltage is 3.52% and load voltage is 1.09 % as shown in fig 4.5 and fig 4.6 respectively.

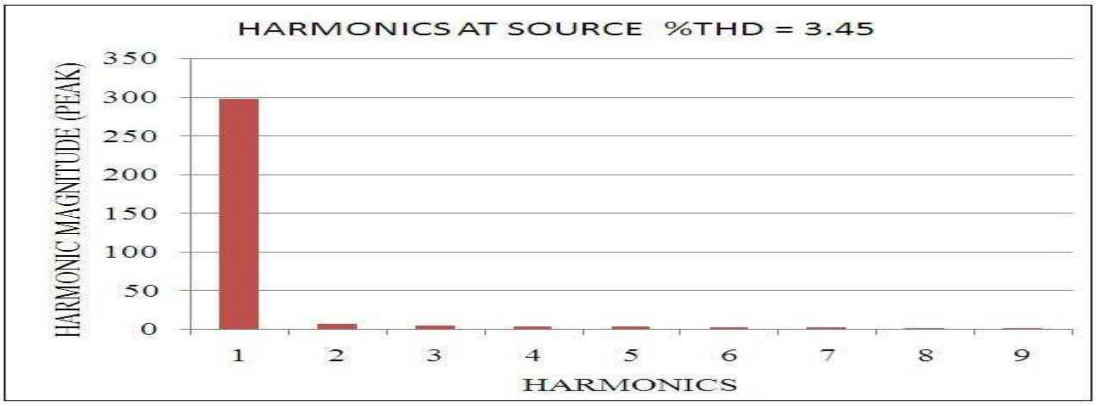

Fig. 4.5 Source voltage harmonic spectrum

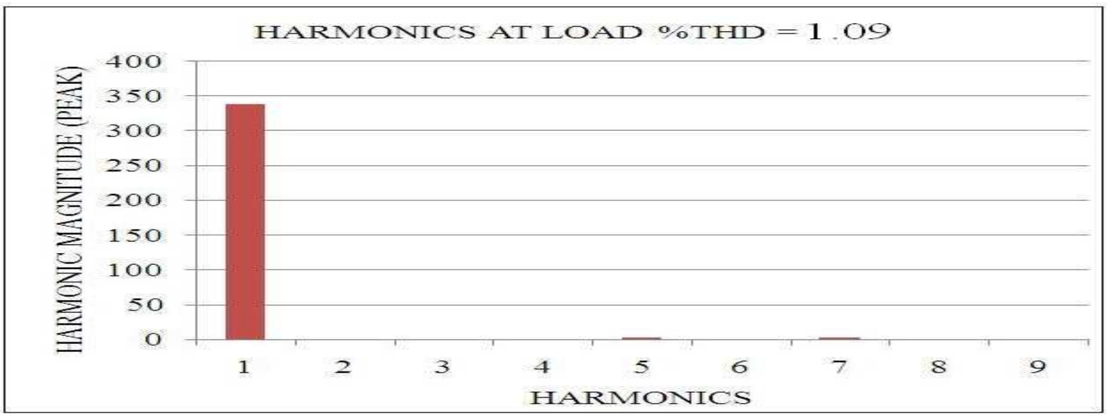

Fig. 4.6: load voltage harmonic spectrum

The information regarding the harmonic spectrum, generated by a nonlinear load which is supplied to the reference-current/voltage estimator together with information about other system variables. The reference signal from the current

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estimator, as well as other signals, drives the overall system controller. The SAPF is simulated with interruptions in the form of Sag, Swell, LG fault in the input side on phase A & the performance of SAPF is analyzed by taking the FFT analysis of the Source and load Voltages**.** Finally the harmonic magnitudes are suppressed.

V. CONCLUSION & FUTURE SCOPE

Hysteresis controller based Series active power filter is implemented for harmonic and voltage distortion compensation of the non-linear load. The Simulation is even extended for abnormal faults occurring on the power system like L-G & L-L faults. The simulation results of series active power filter has shown the ability to compensate voltage sag, swell and harmonics present at input source side. The THD of the load voltage is below 5%, the harmonics limit imposed. The performance of the above mentioned Hysteresis controller based Series active filter can be improved by fuzzy logic controller.

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