# Series Active Power Filter with UVTG Technique for Voltage Sag and Swell Compensation

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***ABSTRACT**: The drastically increase in usage of Power Electronics based equipment has produced a significant impact on quality of electric power supply. Conventional power quality mitigation equipment is providing to be inadequate for an increasing number of applications. One modern and very promising solution that deals with both load current and supply voltage imperfections is the Unified Power Quality Conditioner (UPQC). This paper deals with a three-phase series active power filter is used to eliminate voltage sag and swell compensation on distribution network. The simulation results based on MATLAB simulink are discussed in detail to support UVTG controller based control method presented in this paper.*

**Keywords - Active power filter (APF), Power quality (PQ), Unified Power Quality Conditioner (UPQC), Voltage sag and swell compensation, Unit Vector Template Generation (UVTG).**

## 1. INTRODUCTION

The term "Power Quality"(PQ) are most important facets of any power delivery system today. Low quality power affects electricity consumers in many ways. The lack of quality power can cause loss of production, damage of equipment or appliances, increased power losses, interference with communication lines and so forth. The widespread use of power electronics based equipment has produced a significant impact on quality of electric power supply by generating harmonics in voltages and currents. Therefore, it is very important to maintain a high standard of power quality [1].

Conventional power quality mitigation equipment use passive elements and do not always respond correctly as nature of power system condition change. The term active power filter (APF) is a widely used terminology in the area of power quality improvement. One modern solution that deals with both load current and supply voltage imperfections is the UPQC. The UPQC is one of the APF family members [2,3].

The UPQC is a combination of series and shunt active filters connected in cascade via a common DC link capacitor. The main purpose of a UPQC is to compensate for supply voltage power quality issues such as, sags, swells, unbalance, flicker, harmonics, and for load current power quality problems such as, harmonics, unbalance, reactive current and neutral current [4].

## 2. BASIC CONFIGURATION OF SERIES APF

UPQCs consist of combined series and shunt APFs for simultaneous compensation of voltage and current. The series APF inserts a voltage, which is added at the point of common coupling (PCC) such that the load end voltage remains unaffected by any voltage disturbance, whereas, the shunt APF is most suitable to compensate for load reactive power demand and unbalance, to eliminate the harmonics from supply current, and to regulate the common DC link voltage [2].

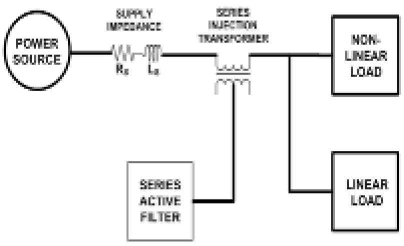


Fig.1 Block diagram of the series APF

The series PWM converter of the UPQC behaves as a controlled voltage source, that is, it behaves as a series APF.

The series active power filter can compensate the supply voltage related problems by injecting voltage in series with line to achieve distortion free voltage at the load terminal. The series inverter of the UPQC can be represented by following equation:

$$V_{inj}(\omega t) = V_L(\omega t) - V_S(\omega t) \qquad (1)$$

Where $V_{inj}(\omega t)$, $V_L(\omega t)$, and $V_S(\omega t)$ represent the series inverter voltage, load voltage, and actual source voltage, respectively.

## 3. SIMULATION MODEL OF SERIES APF

The series active filter shown in figure 2 is a voltage controlled voltage source inverter (VSI), which is connected in series with series injection transformer. Series active power filters are used to compensate the voltage related problems

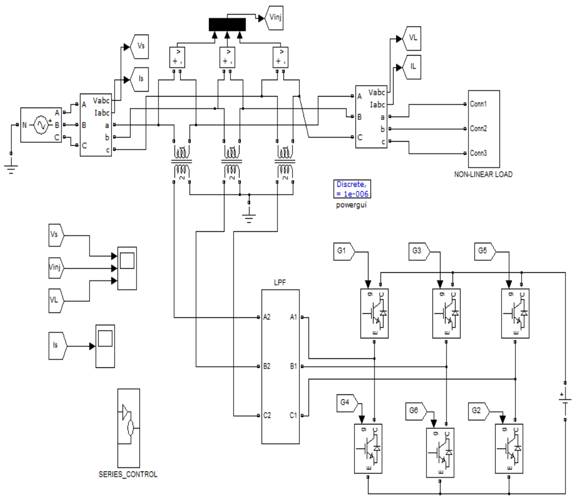


Fig. 2 Series APF simulink model

## 4. PROPOSED CONTROL STRATEGY OF SERIES APF

There are various types of control techniques used in series active power filter. UVTG technique is used to control the series active power filter in this paper [7,8]. In series active power filter, the reference voltage signal generation for series active power filter is shown in figure 3.

In this figure 3 the phased locked loop (PLL) is used to achieve synchronization with supply voltage. The extraction of three-phase voltage reference signal for series active power filter is based on unit vector template generation (UVTG) is achieved by using phased locked loop (PLL) is given by equation[8]:

$$U_a = \sin(\omega t)$$
$$U_b = \sin(\omega t - 120^{\circ}) \qquad (2)$$
$$U_c = \sin(\omega t + 120^{\circ})$$

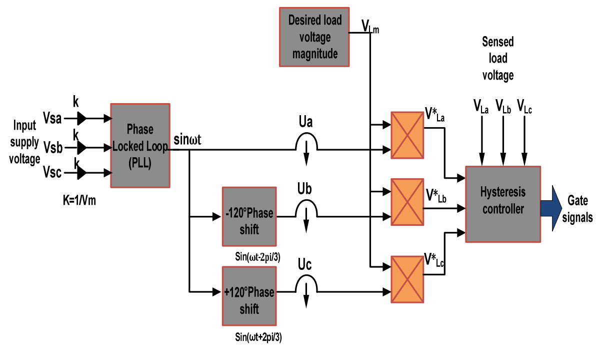


Fig. 3 Control block diagram of series APF

After gating the extraction of three-phase voltage reference signal ($U_{abc}$) with multiplying the peak amplitude of fundamental input voltage with unit vector template generation (UVTG) of equation (1) gives the reference load voltage signals which is given by equation:

$$V^*_{Labc} = V_m * U_{abc} \qquad (3)$$

The sensed load voltage ($V_L$) and reference load voltage ($V^*_L$) are compared in hysteresis controller to generate switching signals to the switches of series active power filter.

## 5. SIMULATION RESULTS

To validate the proposed control technique, the series APF has been simulated using Simpower system block set in MATLAB/SIMULINK. The simulation results for series active power filter are obtained by applying parameter and values shown in TABLE-1.

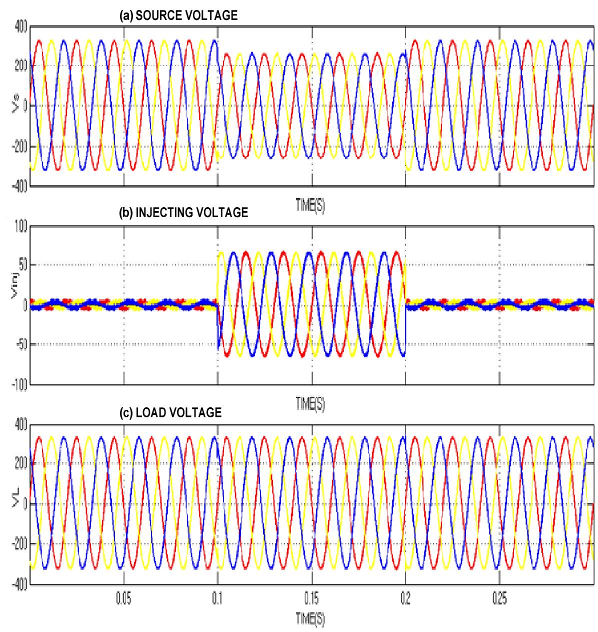


Fig.4 Simulation results with UVTG theory (with 20% voltage sag)

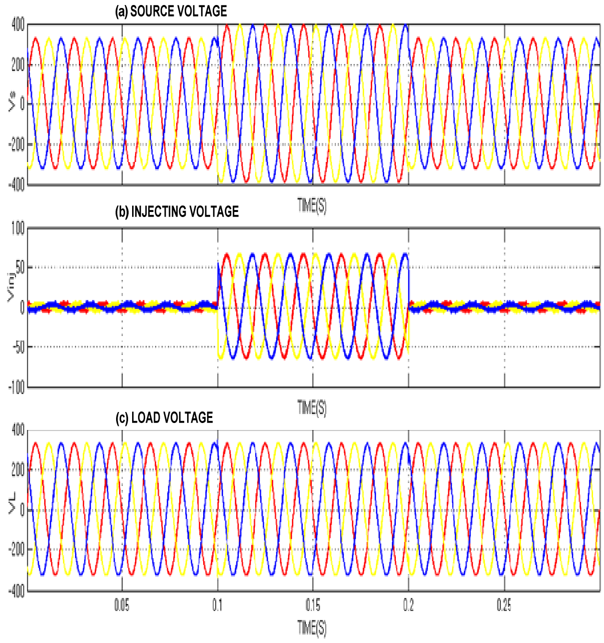


Fig.5 Simulation results with UVTG theory (with 20% voltage swell)

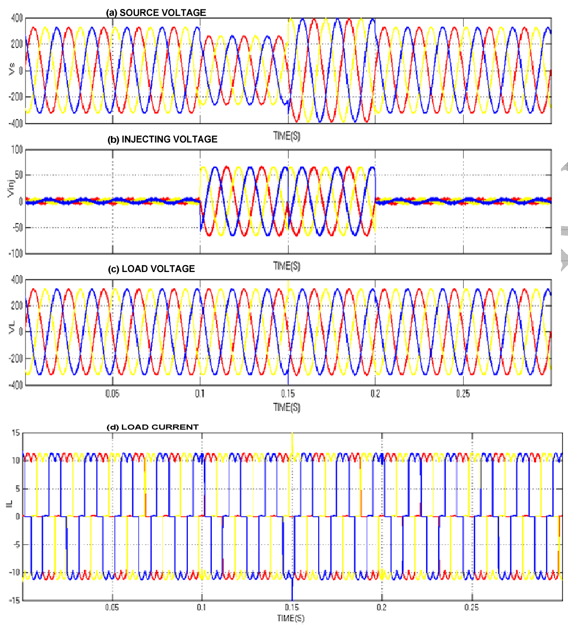


Fig.6 Simulation results with UVTG theory (with 20% voltage sag & swell)

In figure 4 results shows series APF effectively compensates voltage sag and maintains load voltage constant. In figure 5 results shows series APF can compensate voltage swell and maintains load voltage constant. In figure 6 results shows series APF can compensate voltage sag & swell and maintains load voltage constant. Simulation results have shown in figure 6(d) presents load current which is same in during voltage sag, voltage swell and combination of both.

TABLE-1:VARIOUS PARAMETER APPLIED TO SERIES ACTIVE POWER FILTER

| System parameter | Value |
|---|---|
| AC voltage supply (phase-phase rms) | 230*sqrt(3) |
| Line frequency | 50Hz |
| Series transformer | 10 KVA, 1:1 turns ratio |
| DC voltage | 700V |
| Voltage sag | 20% |
| Voltage swell | 20% |
| Load (Diode rectifier with RL Load) | R=50Ω L=1Mh |
| Series LPF | Lse=1mH, Cse=20µF |

## 6. CONCLUSION

This paper presents control technique based on unit vector template generation (UVTG) for series APF. A simulink model has been prepared. The simulation results show that the voltage sag & swell can be compensated by proposed control strategy. The load voltage waveforms are constant during voltage sag and swell conditions. This is verified by taking 20% voltage sag & swell.

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