

Design & Simulation UPQC with Minimum VA Rating for Power Quality Improvement

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Abstract: — *The Unified Power Quality Conditioner (UPQC) is a versatile device which could function as both series filter and shunt filter. The main concern in this paper is to introduce a new concept of UPQC for mitigating different power system problems. This paper deals with “unified power quality conditioners” (UPQCs) which aim to integrate series active and shunt active filters. The main purpose of a UPQC is to compensate for voltage flicker/imbalance, reactive power, negative sequence current and harmonics. It protects the consumer at the load end from supply voltage sag, and provides unity power factor condition at the utility for different values of load power factor. During the unbalanced voltage sag/swell at the input side, the DVR maintains the rated voltage at the load side. It regulates the load voltage with minimum VA loading of the overall UPQC by an optimum voltage angle injection. Computer simulation by MATLAB/SIMULINK has been used to support the developed concept.*

Keywords: Power Angle Control (PAC); power quality; reactive power compensation; Active power filter (APF); unified power quality conditioner (UPQC); voltage sag and swell compensation; PSO (Particle Swarm Optimization).

I. INTRODUCTION

Power Quality (PQ) related issues are of most concern nowadays. Electrical Power quality is the degree of any deviation from the nominal values of the voltage magnitude and frequency. From the customer perspective, a power quality problem is defined as any power problem manifested in voltage, current, or frequency deviations that result in power failure or disoperation of customer of equipment [1]. The waveform of electric power at generation stage is purely sinusoidal and free from any distortion. Many of the Power conversion and consumption equipment are also designed to function under pure sinusoidal voltage waveforms. However, there are many devices that distort the waveform. These distortions may propagate all over the electrical network. The widespread use of electronic equipment, such as information technology equipment, power electronics such as adjustable speed drives (ASD), programmable logic controllers (PLC), energy-efficient lighting, led to a

complete change of electric loads nature. These loads are simultaneously the major causers and the major victims of power quality problems.

Mainly there are different power quality problems. Voltage sag, voltage swell, harmonics, very short interruptions, long interruptions, voltage spike, noise, voltage unbalance these are the main PQ problems in power system. A wide diversity of solutions to power quality problems is available for both the distribution network operator and end user. The measure of power quality depends upon the needs of the equipment that is being supplied. Custom Power devices are a better solution for these Power Quality related issues in distribution system [2]. Out of these available power quality enhancement devices, the UPQC has better sag/swell compensation capability. It is the control strategy which decides the efficiency of a particular system. The efficiency of a good UPQC system solely depends upon its various used controlling algorithm. [2]The UPQC control strategy determines the current and voltage reference signals and thus, decides the switching times of inverter switches, so that the expected performance can be achieved. In this proposed work Particle Swarm Optimization is used as the control algorithm and the effect of this controlling method based UPQC in a 14 bus test systems is presented. In the proposed control method, load / source voltages and source voltage /current are measured, analyzed, and tested under unbalanced and distorted load conditions.

At distribution level UPQC is the most attractive solution to compensating many power Quality problems. The term active power filter (APF) is a widely used in the area of electric power quality improvement. APF s have the ability to mitigate some of the major power quality problems effectively. The UPQC is one of the APF family members where shunt and series APF functionalities are integrated together to achieve superior control over several power quality problems simultaneously. The system configuration of a UPQC is shown in Fig.1.

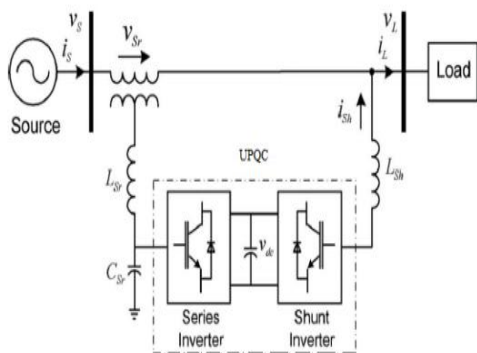


Fig.1. System Configuration of UPQC

II. PROPOSED TOPOLOGY – UPQC MINIMUM VA METHOD

A. Basic phasor diagram of the proposed minimum VA Method :

In this paper, In this method the injected voltage (V_{inj}) from the Series active filter is in quadrature with the postsag source voltage (V_{s2}). So the angle between the injected voltage and the postsag source current (I_{s2}) will be 90° as shown in figure.2. From this it can identify that the active power requirement will be zero in this method [4]. But the reactive power requirement will be more. Though it takes zero active power, the magnitude of injected voltage will be more. That is the main drawback of this method. Hence, the minimum VA method is used to overcome the drawbacks of both the UPQC P and the UPQCQ method.

In this minimum VA method the voltage injection will be based on an optimum angle α . α is an angle between the postsag source voltage and the load voltage shown in figure.3. Optimum angle is an angle in which the VA requirement of the UPQC will be minimum[5]. Based on this optimum angle, the magnitude of injected voltage and the injection angle will be derived. In that particular magnitude of injected voltage and an injection angle, the active power requirement of the UPQC will be less than the UPQC-P method and the reactive power requirement of the UPQC will be less than the UPQC-Q method. So the total VA requirement of the UPQC will be less compare to the other two methods. And also the magnitude of injected voltage will be less than the UPQC-Q

method. So the minimum VA method is one of the very efficient method. The injected voltage and the power limitation in the minimum VA method (V, P, Q and S indicates injected voltage, real, reactive and apparent power and subscripts such as I_n , Quad, Min indicates UPQC-P, UPQC-Q, Minimum VA method) will be,

$$\begin{aligned} V_{In} &< V_{Min} < V_{Quad} \\ P_{Quad} &< P_{Min} < P_{In} \\ Q_{In} &< Q_{Min} < Q_{Quad} \\ S_{Min} &< S_{In} < S_{Quad} \end{aligned}$$

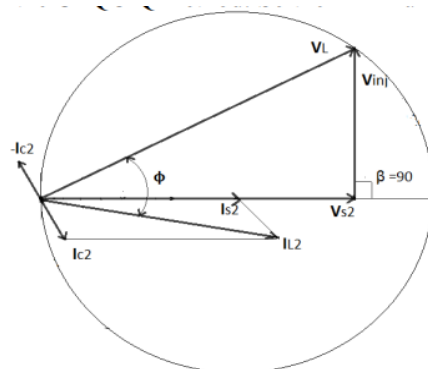


Fig.2. Phasor diagram of Quadrature compensation method

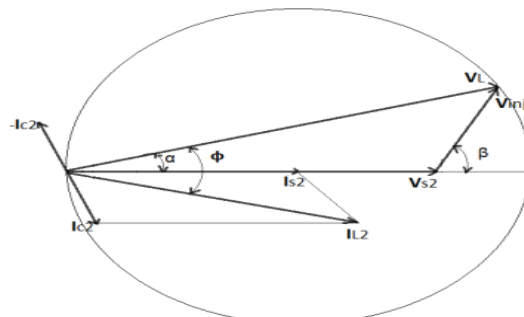


Fig.3. Detailed power conversion circuit

B. Design and Minimum VA Calculation the Proposed System :

The total VA requirement of the UPQC (S_{Upqc}) from is depending on the VA requirement of both the series (SSr) and shunt active filter (SSH) [5]. By considering the presag source voltage and the postsag load voltage (V_L) are 1 p.u, we can write the total VA requirement is in terms of the load displacement power factor ($\cos \phi$), the sag in p.u, and an optimum angle. Here, R_s , L_s is series resistance and inductance respectively. Active pass filter and shunt pass filter values are given in Appendix section

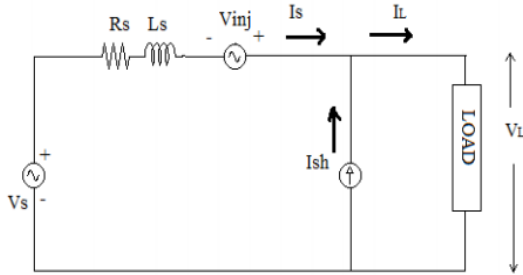


Fig.4. Equivalent circuit of UPQC

C. Minimum VA Calculation Algorithm :

- Step (1): Initialize $\alpha=0$ and $T_{VA1}=100$
- Step (2): Get input values of sag and p.f. angle
- Step (3): Check $\alpha \leq \text{p.f. angle}$,
if it is true go to step(4),
if it is false go to step(7)
- Step (4): find the value of new T_{VA}
- Step (5): Check $T_{VA1} < T_{VA}$
- Step(6): If (5) is false, assume $T_{VA1}=T_{VA}$, and then increase the α by 1 and go to step(3). If (5) is true go to step(7)
- Step(7): find the values of V_{inj} and β for corresponding optimum angle $\alpha-1$ and print the result.

III. MATLAB BASED SIMULATION & RESULTS

To verify the feasibility of the proposed system a simulink model is developed with modular five-level cascaded converter which gives three phase 1kV rms as output. Fig.5, Fig.6 & Fig.9 shows the sub system in the simulink model.

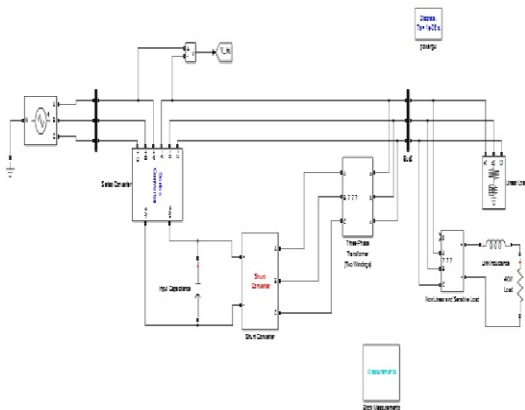


Fig.5. MATLAB based simulation diagram of proposed system with masked diagrams

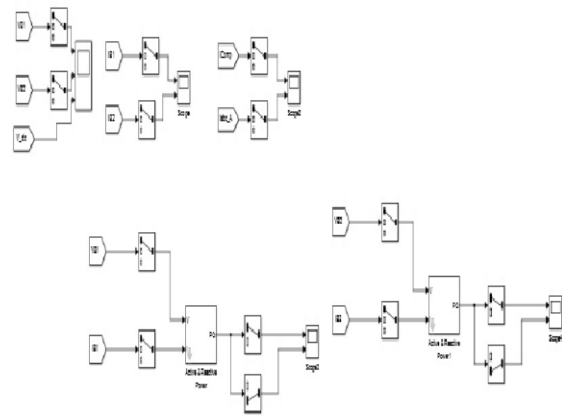


Fig.6. MATLAB based simulation diagram of proposed system with masked blocks

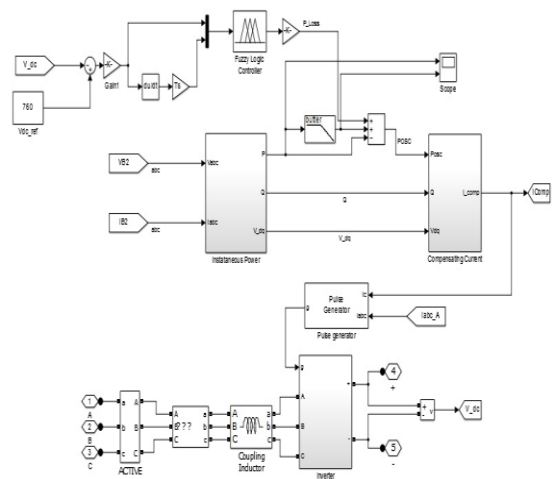


Fig.7. MATLAB based simulation diagram of proposed system with masked blocks

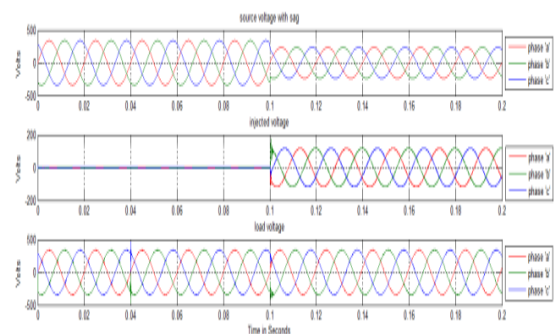


Fig.8. MATLAB based simulation of Source, series active filter and load voltages with minimum VA method

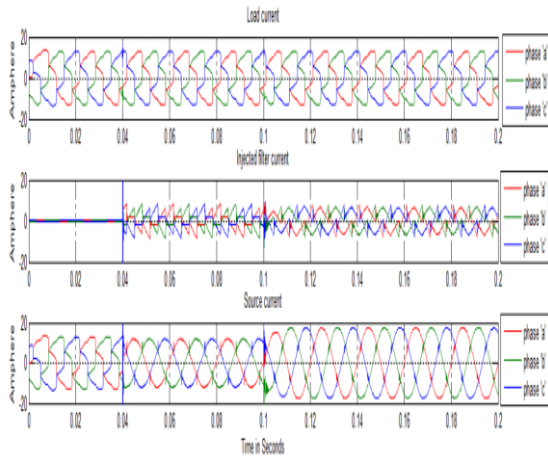


Fig.9. MATLAB based simulation of Load, shunt active filter and source currents with minimum VA method

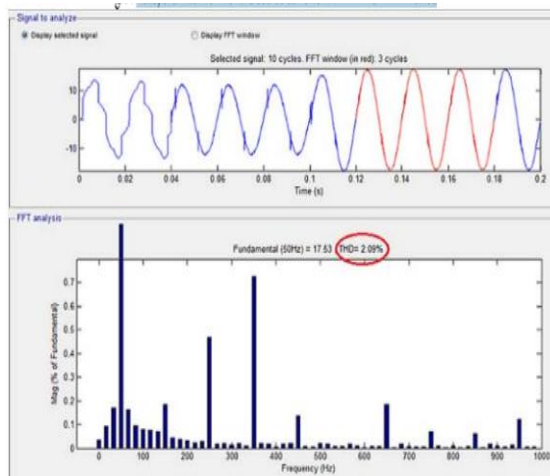


Fig.10. THD analysis of source current

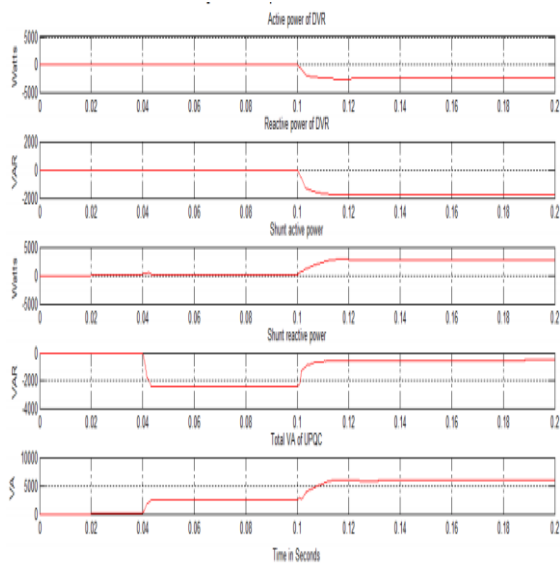


Fig.11. Power handled by UPQC in minimum VA method

Table.III shows the simulation parameters for the proposed system

TABLE.I.SIMULATION SPECIFICATIONS

Parameter	Rating
Series Injection Transformer rating	7.5 kVA 350V/350V
DVR LC Filter	L=3.5mH,C=15 uF
Frequency	50Hz
DC Link Voltage	760
DC Link Capacitance	5000uF
DVR Switching Frequency	10kHz
Non Linear load : Full Bridge Rectifier with RL load on DC side	4 kW
Synchronous Link Inductance	2.5 mH
Sag (s)	0.3 p.u
Optimum Phase Angle α	12°
Angle of Voltage Injection β	36.78°

CONCLUSION

Voltage compensation method both for supply voltage sag and swell also shows a very good performance. The power factor is improved at unity by compensation. The load voltage is maintained at its reference value. UPQC operates in the minimum VA optimization mode; the optimized operation can result not only in reduced overall size, but also in the increased efficiency. From the experimental results, one can say that the proposed control methods have good compensation characteristics and the proposed UPQC system can have an important role for power quality improvement.

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