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Power Quality Enhancement using A Unified Power Quality Conditioner (UPQC)

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***Abstract:** This project proposes effective work to increase the power quality in the power system by using a Unified Power Quality Conditioner (UPQC) The advanced use of power electronic devices introduces harmonics in the power system which creates a problem in the quality of power delivered. Although several methods are there for improving power quality standards, including the use of active and passive filters, and Hybrid filters have been developed, these methods face issues and are ineffective due to the growing number of applications. The UPQC is an advanced technique for mitigating voltage and load current supply fluctuations. In this project the combination of series active filter and shunt active filter is studied. UPQC is used to reduce the power quality issues like harmonics and sag. The shunt active filter and series active filter performs the simultaneous elimination of current and voltage problems. The project work presents the working of the UPQC filter in such a way that the harmonics are reduced.*

***Keywords**: Active power filter (APF), Harmonics, Passive Power Filter, Power Quality, Series active filter, Shunt active filter, Unified Power Quality Conditioner.*

I. INTRODUCTION

The combination of current and voltage quality is known as power quality [1]. Power quality issues can be defined as the difference between the quality of power required and the quality of power supply for the continuous operation of the load equipment. With the increase in the use of sensitive loads and by an increase in the number of electronic devices and the growth of Renewable energy resources, the power quality issues raised [1, 2]. The advanced use of power electronic devices introduces harmonics in the power system which creates a problem in the quality of power delivered [2]. Better Power Quality is very much important for our day-to-day use of appliances in both domestic and industrial sectors [3]. Poor quality of electric supply to the equipment is normally caused by power line disturbances such as transients, momentary interruptions, notches, voltage swell and sag, under-voltages, over-voltage, and harmonic distortions. We are using filters to better the power quality [4]. People demand quality power continuously for their appliance's operation. The performance of the consumer end equipment is heavily dependent on the quality of power supplied to it. But the quality of power delivered to the consumer is affected by various internal and external factors, like voltage and frequency variations, faults, outages, etc. [4]. These power quality problems reduce the lifetime and efficiency of the equipment. Thus, to enhance the performance of the consumer equipment and the overall performance of the system these problems should be mitigated. The solution to overcome these problems is to reduce harmonics [5]. For this purpose, there are many filter topologies present in the literature. Active power filters can solve the shortcomings of passive filters, but they are difficult to control and implement [6, 7]. So, a hybrid filter is chosen which works effectively to the quality of power. The series active filter with a shunt active filter is the best option among the many hybrid filters [8, 9].

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II. INTRODUCTION TO UNIFIED POWER QUALITY CONDITIONER (UPQC)

Electrical energy is the most efficient and popular form of energy where the modern society is heavily dependent on the electric supply. Without electricity, life would be impossible to imagine. At the same time, the quality of the electric power delivered is important for the proper operation of end-user equipment [10, 11].

The Unified Power Quality Conditioner combines the Shunt Active Power Filter with the Series Active Power Filter, sharing the same DC Link, to compensate for both voltages and currents [12]. UPQC will allow for the reduction of voltage and current disturbances that might affect sensitive electrical loads while compensating the load reactive power [13]. UPQC can compensate for both voltage and current problems, such as voltage harmonics, voltage sags, and swells, voltage flicker for voltage, reactive power compensation, power factor correction, current harmonics, and load unbalance compensation for current [14]. The shunt active filter and series active filter performs the simultaneous elimination of current and voltage problems [8].The series converter can mitigate the voltage-related problems and the shunt converter can mitigate the harmonics [9].

Series Active Power Filter

- This filter is connected in series with the line through a matching transformer. The compensatory voltage is injected in series with the supply voltage via this filter.
- It compensates for current system distortion caused by non-linear loads.
- It acts as a controlled voltage source and can compensate for all voltage-related problems such as voltage harmonics, voltage sags & swells, voltage flicker, etc. [8]

Shunt Active Power Filter

- It is connected in shunt at the Point of common coupling. It injects an equal and opposing current to the harmonic current.
- It compensates for current harmonics by injecting equal-but- opposite harmonic compensating current.
- Shunt APF is connected across the load to compensate for all current related problems such as current harmonics, power factor correction, reactive power compensation load unbalance compensation [9].

III. CIRCUIT TOPOLOGY AND WORKING PRINCIPLE

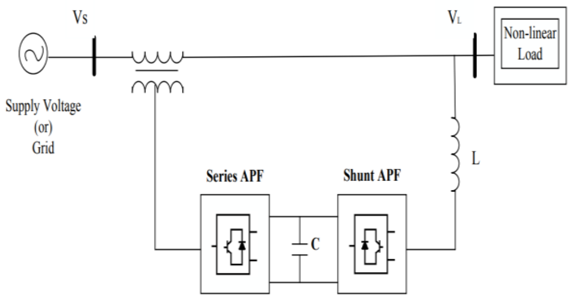

Fig. 1 Circuit topology for UPQC system

The general configuration of UPQC is, it consists of two filters series of active power filters and shunt active power filters. Series active power filter connected in series with the power system and shunt active power filter connected in parallel with the power system. The series APF is used for mitigating the voltage disturbance and harmonic in the power system by injecting the voltage.The shunt APF is used for compensating the reactive power in the power system by injecting the current and it is used for regulating DC link voltage for both filters [15, 16].

Table 1 Circuit parameters

Source voltage	400 V
Frequency	50 Hz
RL Load parameters	R=60Ω and L=0.1*10^{-3} H
Transformer rating	Nominal power= 4000 W, f=50Hz
Coupling Capacitor	100*10^{-6} F
PI Controller	Proportional gain Kp= 10, Integral gain Ki= 0.1

IV. SIMULATION RESULTS

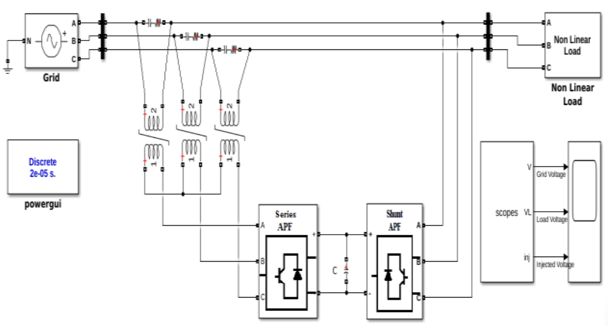

Fig. 2 MATLAB circuit of UPQC

Harmonic: First, we will check voltage mitigation in the power system by the means of UPQC, initially there is no injected voltage (UPQC is not working) to mitigate the voltage problem in the power system. In Fig.3 in the first graph, the Hamonic's generated in the source from time 0.3 to 0.4 and magnitude change is one per unit to 1.3 per unit in Fig.3 to mitigate this UPQC started working. Because of this UPQC injection voltage load voltage is maintained constant.

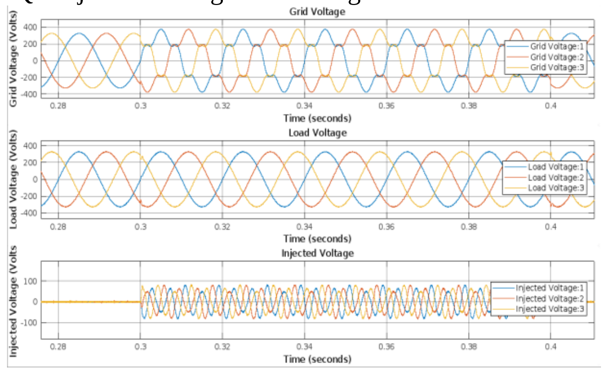

Fig.3 Harmonics generated in the source and UPQC injected voltage from 0.3 to 0.4

Voltage Sag: In Fig.4 in the first graph Voltage Sag was generated in the source from time 0.9 to 1.0 and the magnitude change is one per unit to 0.7 per unit in Fig.4 to mitigate this UPQC started working. Because of this UPQC injection voltage load voltage is maintained constant.

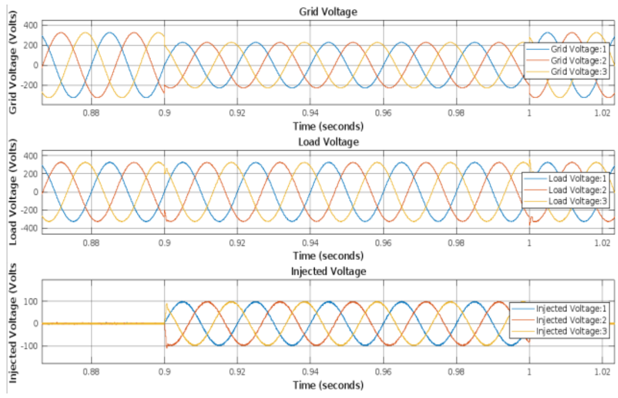

Fig.4 Voltage Sag is created from 0.9 to 1 per unit and UPQC injected voltage

Voltage Swell: In the below Fig.5 in the first graph Voltage Swell generated in the source from time 1.6 to 1.7 and magnitude change is one per unit to 1.3 per unit in Fig.5 to mitigate this UPQC started working. Because of this UPQC injection voltage load voltage is maintained constant.

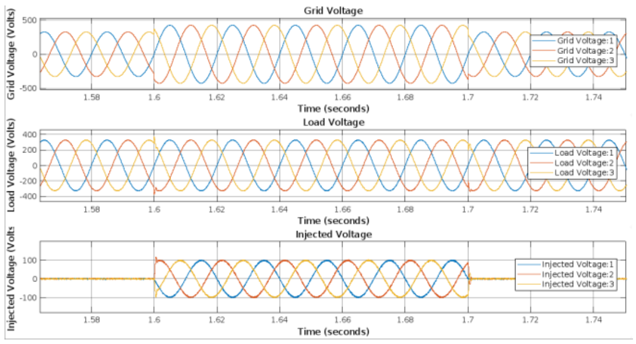

Fig.5 Voltage Swell is created from 1.6 to 1.7 and UPQC injected voltage

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Source current on shunt APF compensates reactive power and improves power quality on the source side to make current quality improvements, near to sinusoidal waveform.
The waveforms of time and current is shown below.

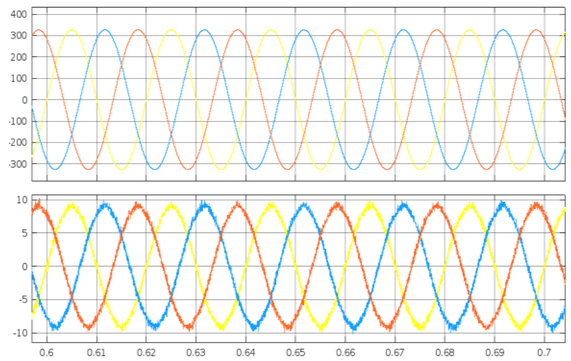

Fig.6 Source current on Shunt active filter

Earlier when there is no filter used the THD is 22.22%, so after the addition of UPQC we reduced harmonics and the THD is decreased to 2.68%.

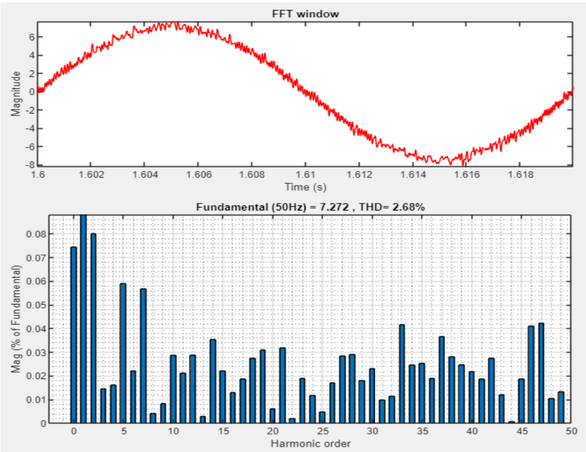

Fig.7 THD of UPQC

V. CONCLUSION

In this paper, the combination of Shunt active power filter and Series active power filter topology is proposed which is called UPQC. Shunt active power filter of UPQC removes all the current related harmonic problems in the system and series connected active power filter of UPQC system removes all voltage harmonics, simultaneously mitigating the sag and swell, which come up due to the use of nonlinear load. When there is no filter used the THD is 22.22%, so after the addition of UPQC we reduced harmonics and the THD is decreased to 2.68%. The proposed UPQC design using both filters can mitigate the power quality problems. Thus, power quality is increased using UPQC.

FUTURE SCOPE

The work done in this project can be further extended such new improvements can be found. The feasible options are

- To simulate the proposed control strategy with grid faults and study the behavior of APF in power quality improvement
- To implement the control strategy using Artificial Intelligence (AI) techniques.

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