# PERFORMANCE EVALUATION OF UPQC USING PI CONTROLLER UNDER UNBALANCED AND DISTORTED LOAD CONDITION

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**ABSTRACT-**This paper is proposed to control the UPQC under the sag and swell mitigation using PI (proportional and integral controller) controller. The proportional plus integral is controller device that produces an output signal consisting of two terms, one proportional to input signal and other proportional to the integral of signal. In this, the optimal Hysteresis pulse width modulation technique has been found to perform the evaluation of UPQC. The simulation result is carried out by the use of Matlab/simulink software.

**Keywords:** PI controller, UPQC, power quality sag and swell.

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## I-INTRODUCTION

Power electronics is playing an important role in transmission and utilization of electrical power due to its capability of processing electric power in most efficient and cost-effective way. However, the nonlinear characteristics of power electronic devices give rise to two important limitations; they generate harmonics and draw lagging current from the utility. In recent years unified power quality conditioner (UPQC) is being used as a universal active power conditioning device to compensate both harmonics as well as reactive power. UPQC is an advanced version of unified power flow controller (UPFC). The performance of UPQC mainly depends upon how quickly and accurately compensation signals are derived. The UPQC mitigates harmonics and provides reactive power to the power systems network so as to improve the power factor close to unity [1].

The UPQC is a combination of shunt active and series active power filters connected through a dc bus. The shunt active filter of UPQC acts as a current source for injecting compensating current through a shunt transformer, whereas, the series active filter acts as a voltage source for feeding compensating voltage through a series transformer. The proposed UPQC system can improve the power quality at the point of common coupling on power distribution systems under Power quality problem conditions. The PI controller is used to stabilize DC link Voltage and balance the active power between the shunt and series inverters. The capacity of series and shunt inverters is calculated through loading calculations of these inverters applying phasor diagram to increase the design accuracy.

## II-RELATED WORK

In this paper many investigations in the area of UPQC of shunt and series active power filter interconnected system have been reported in the past and a number of control strategies have been proposed to achieve improved performance. The proportional plus integral (PI) control and integral control approach is successful in achieving zero steady start error in the UPQC of the system. Several APF and UPQC application works presented in the literature are about improving the performance of the compensator [2],[7],[8],[9]-[11]. but it exhibits relatively poor dynamic performance as evident by large load and sag/swell. Moreover the transient settling time is relatively large. In the application of optimal control technique, the controller design is normally based on fixed parameter model of the system delivered by a linearization process. The nature of the UPQC PI control problem makes it difficult to ensure stability for all operating points when an integral (or) PI Controller is used by O.I.Elgerd and Mc Graw-Hill in [14].

## III-PROPOSED WORK

A three phase Unified Power Quality Conditioner (UPQC), capable of compensating for both supply voltage and load current imperfections have to be analyzed. This work deals with PI controller design development of 3 Phase UPQC for both load current and supply voltage imperfections with PI control algorithms for improved performance. LC or/and LCL filters are used for interfacing the shunt inverter in order to prevent switching frequency currents entering into the grid. In the presence of such a filter, a hysteresis-controlled shunt inverter fails to follow the reference, if it attempts to track the current injected into the grid. (Present) In voltage control mode the current injected by the shunt active filter is controlled indirectly by controlling the voltage generated by the shunt inverter. First the shunt active filter reference current is determined, and then the reference voltage for the shunt inverter is calculated. Knowing the shunt inverter reference voltage, the switching pulses are generated with the most well known PWM method, which compares the reference signal with a triangular carrier signal.

A three-phase three-wire UPQC has been investigated using the simulation model described and the simulation results are presented in the following. The UPQC is connected at 0.02 s. In Fig.1 the supply currents are shown for the case when there is no filter capacitor connected in parallel with the load and the shunt VSI is

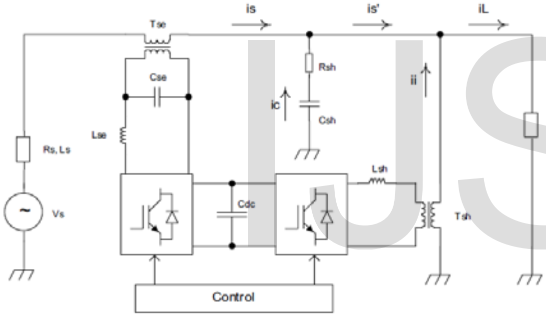

Fig.1. Diagram of system under consideration

The reference supply current is compared with the actual supply current and the error is passed through a hysteresis controller. The hysteresis control strategy has the advantage of simple practical implementation; that is why it is so attractive and preferable in many cases. As mentioned above, in order to prevent the switching frequencies generated by the shunt inverter entering into the grid, an LC/LCL filter is used for interfacing the shunt VSI with the distribution network. In order to divert the switching harmonic currents, a filter capacitor Csh (see Fig.1) is connected in parallel with the load in each phase. If the supply current (see Fig.1) is chosen as the feedback variable, the hysteresis controller will fail to maintain the system stability.

However, if the "not filtered" supply current is chosen as the feedback variable, the system is stable using the hysteresis controller. Thus, in order to assure the system stability, the hysteresis controller is tracking the "not filtered" supply current is. In this section a control approach for avoiding the stability problem while using the hysteresis control technique is proposed with application to the shunt component of the UPQC incorporating an LCL filter. It is shown that if the output inverter current is tracked, rather than the current into the grid after the filter capacitor, stability is maintained using the hysteresis controller. Therefore, the control goal (keeping the grid current and load voltage THDs within the limits prescribed by standards) is achieved using a hysteresis controller, which is simple to implement. The shunt inverter is controlled in such a way that the supply current is sinusoidal and in phase with the supply voltage.

The "not filtered" (containing switching harmonics) supply current (see Fig.1) is used as the feedback variable. Since the waveform and phase of the supply current are known, only its magnitude needs to be determined to get the reference feedback variable. The magnitude of the reference supply current is determined using the control approach proposed. The average DC capacitor voltage is compared with the reference value and the voltage error is processed by a proportional integral (PI) controller. The average DC capacitor voltage is maintained constant and the output of the PI controller is the magnitude of the reference supply current. By properly changing the magnitude of the supply current, the average DC capacitor voltage is maintained constant. Applying this concept the control circuit can be simplified and the number of current sensors reduced.

The design and practical implementation of an LQR controller is not a trivial task. Simple control strategies (for example hysteresis band control), which are reliable with first order systems, are usually unstable when applied to the second and higher order systems. Hysteresis current controller fails to track the reference if the current injected into the distribution grid is tracked. An analysis of control stability when using the third order filter is presented. It has been shown that using the current injected into the grid as the feedback variable in the control circuit, results in unstable operation of the power circuit. Instead, if the inverter output current is used as the feedback control variable the operation is stable. Thus, the hysteresis current control technique can be applied in the second and higher order systems without having stability problems if the feedback control variable is the inverter output current.

## IV. DESIGN OF PI CONTROL

Many industrial processes are non-linear and are thus complicated to be described mathematically. However, it is known that a good many non-linear processes can satisfactorily be controlled using PID controllers provided the controller parameters are tuned well. Practical experience shows that this type of control has a lot of sense since it is simple and based on three basic behavior types or modes: Proportional (P), Integral (I) and Derivative (D). Instead of using a lesser number of complex controllers, larger number of simple PID

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controllers can be used to control complex processes in an industrial assembly in order to automate such processes. Controllers of different types such as P, PI and PD are today basic building blocks in control of various processes.

In spite of simplicity, they can be used to solve even a very complex control problem, especially when combined with different functional blocks, filters (compensators or correction blocks), selectors etc. A continuous development of new control algorithms insure that the PID controller has not become obsolete and that this basic control algorithm will have its part to play in foreseeable future. It can be expected that it will be a backbone of many complex control systems. While proportional and integral modes are also used as single control modes, a derivative mode is rarely used in control systems. PI controller forms the control signal u(t) from the error signal e(t) between desired or expected output and actual output. u(t) is defined as

$$u(t) = K_p \left[ e(t) + \frac{1}{T_i} \int_0^t e(\tau) d\tau \right]$$

Where $K_p$ and $T_i$ are PI controller settings. The tuning of this controller is done using the reaction curve method as follows. The corresponding PI controller settings $K_p$ and $T_i$ are designed using Ziegler-Nichols tuning technique based on the converter's open loop step responses with above loads. Controller tuning involves the selection of the best values of $K_p$ and $T_i$. This is often a subjective procedure and is certainly process dependent. Error in output voltage ($V_e$) and updated converter switching frequency updating signal are respectively the input and output of the PI controller for UPQC.

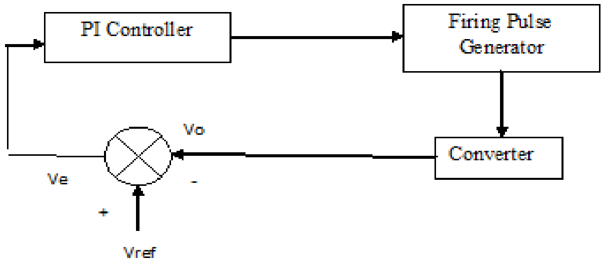

Fig. 2 Design of PI controller

## IV-RESULTS AND DISCUSSIONS

### A-WITHOUT UPQC SYSTEM

The three phase supply is connected to the load using transmission line. Here UPQC system is not connected.

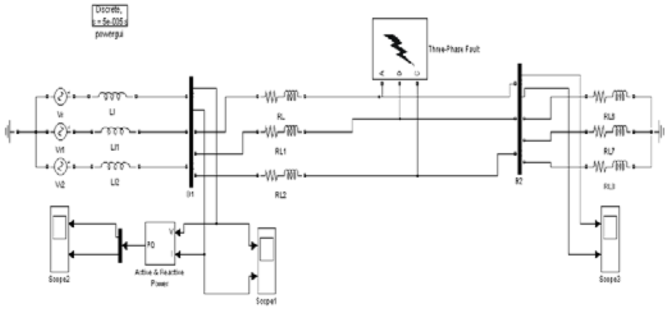

Fig 3 Without UPQC system

The three phase fault is created in the transmission line. Due to this fault the Sag, Swell, Active and Reactive distortion is occurred. The circuit is drawn by the use of MATLAB/SIMULINK. The output of without UPQC system is shown below

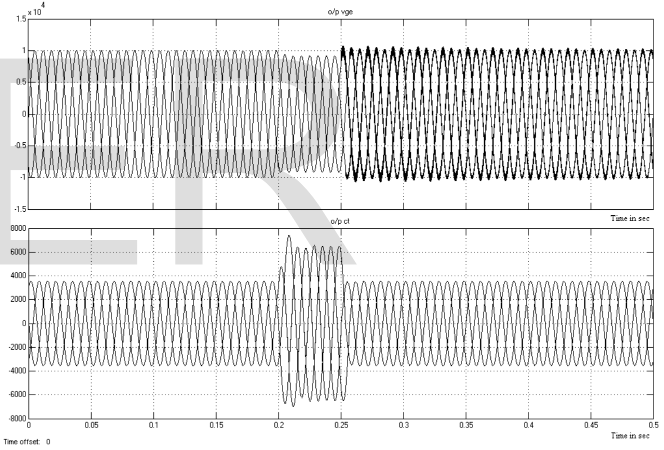

Fig 4 Without UPQC system Sag, Swell output

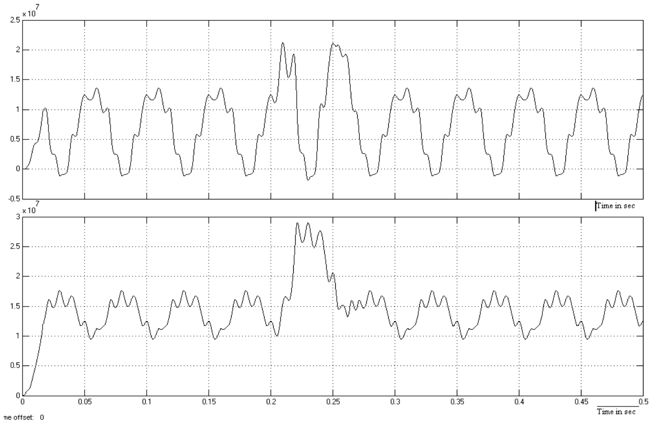

Fig 5 Active and Reactive power wave forms

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The Fig.4 and Fig.5 shows the output result of without UPQC system for Sag, Swell, Active and Reactive distortion.

## B-WITH UPQC SYSTEM SIMULINK DIAGRAM

The without UPQC system is taken, and then we can add the UPQC system with PI controller is connected to this without UPQC circuit. The actual signal is taken from the source side, this signal is transformed abc to dqo form. Then this signal is compared with reference signal it then the error signal. The error signal is given to the PI-controller; the controller gives signal the corresponding switch will be turned on. Depending upon the controller gain value the output will be varied.

The without UPQC system contain Sag, Swell, Active and Reactive power output by using this with UPQC system we can eliminate this Sag, Swell, Active and Reactive power for the use of proper Proportional Integral (PI) controller.

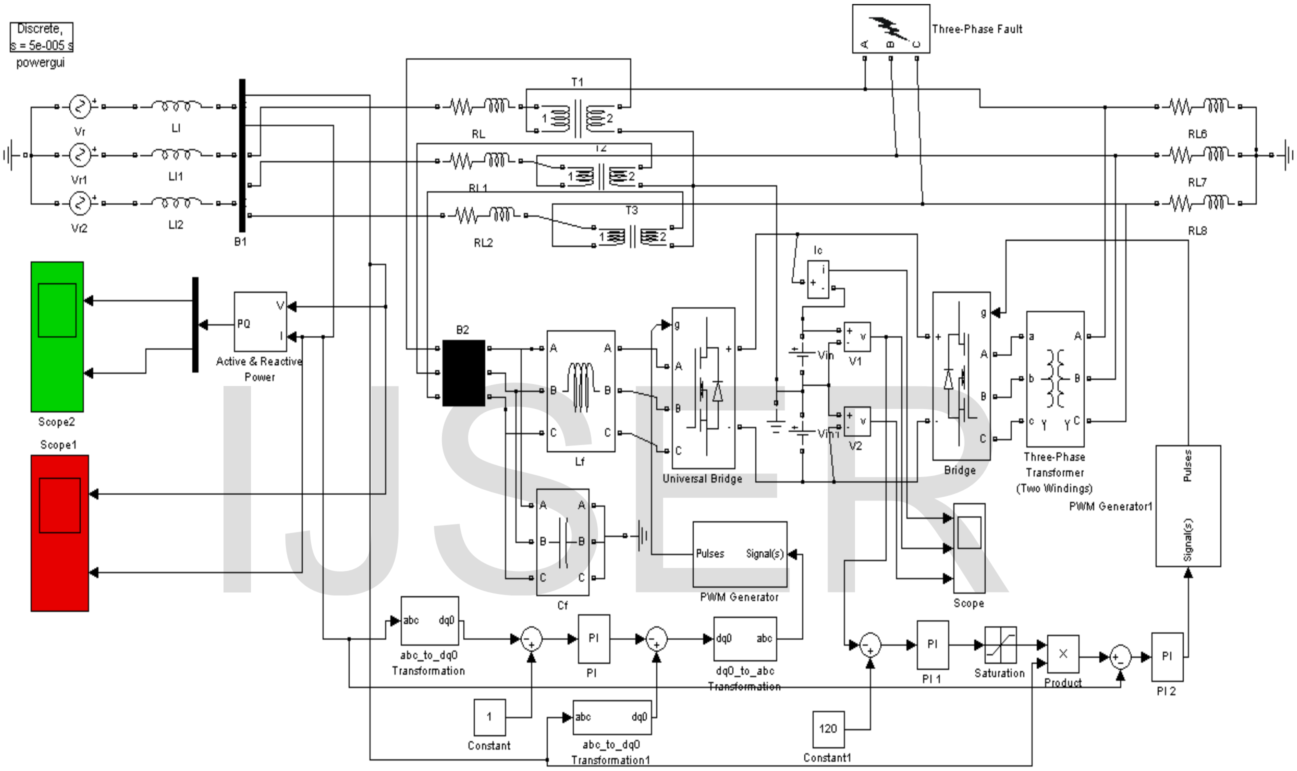

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Fig 6 With UPQC system

The Fig.6 shows the Matlab/Simulink diagram of UPQC system with PI controller. Here two converter, series transformer and shunt transformer is used.

To run this simulation we get this simulation output result. Here the Sag, Swell, Active and Reactive power is mitigated.

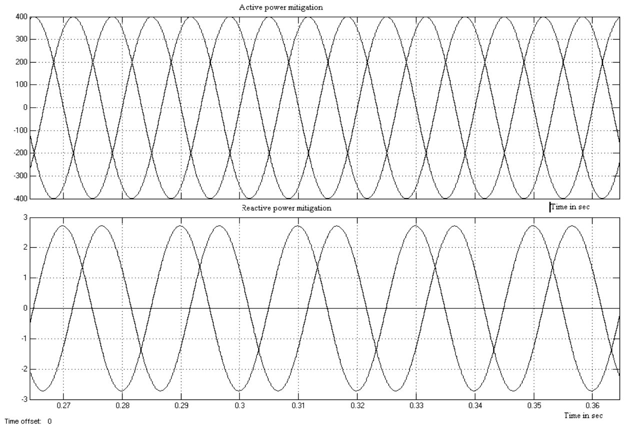

Fig 7 With UPQC mitigation of fault distortion

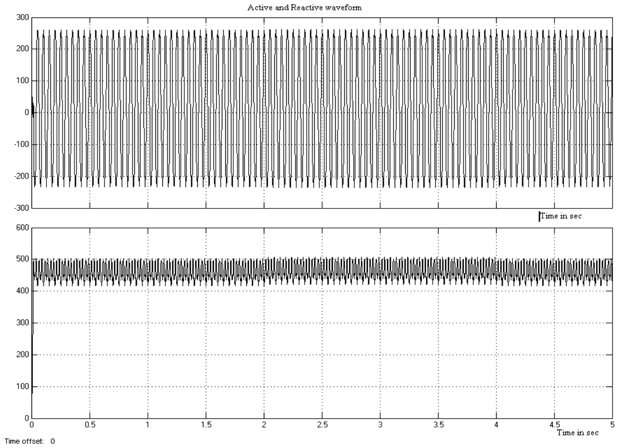

Fig.8.With UPQC system active and reactive power compensation

## CONCLUSION

This paper describes a PI-based control strategy used in the UPQC, which mainly compensates the reactive power along with voltage and current harmonics under non-ideal mains voltage and unbalanced load-current conditions. The without UPQC contain sag, swell, active and reactive power distortion. So we can mitigate this problem UPQC system is proposed, to mitigate this problem by the use of PI control and Pulse Width Modulation (PWM) technique. The simulation results show that, when under sag, swell, active and reactive power distortion under fault condition, the PI control algorithm eliminates the impact of distortion on supply voltage and unbalance of load current on the power line, making the power factor unity. Meanwhile, the series APF isolates the loads and source voltage in unbalanced and distorted load conditions, and the shunt APF compensates reactive power, and provides three-phase balanced and rated currents for the mains. Simulation results obtained by the use of Matlab/simulink software to mitigate the power quality problems effectively by the use proper PI controller of UPQC.

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