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IMPROVING QUALITY OF POWER USING TRY CONVERTER UNIFIED POWER QUALITY CONDITIONER (T-UPQC)

Pappula Sampath Kumar[1] and M. Sushama[2]
[1]Department of Electrical and Electronics Engineering, Jawaharlal Nehru Technological University, Kakinada, Kakinada, Andhra Pradesh, India
[2]Department of Electrical and Electronics Engineering, Jawaharlal Nehru Technological University, Kukatpalli, Hyderabad, India
E-Mail: pappulasampathkumar@gmail.com

ABSTRACT

Electric power systems needs pure sinusoidal output voltage and current without any interruptions at desired value. T-UPQC consists of combined shunt and two series converter based through filters for improving the quality of power in load side as well as source side. This paper deals with an implementation of a T-UPQC using two control techniques one is PI and other one is mamdani fuzzy controlling technique for mitigation of different distorted load conditions. They are maintained and manage the power into the T-UPQC. The model and the proposed control technique are discussed in d-q coordinates and the performance of this scheme is evaluated. Simulation results demonstrate satisfactory performance of the proposed new smart technique for the control of T-UPQC under varying loads using MATLAB-Simulink environment. The improvement of quality of power is analysed by comparing with two smart techniques use of the T-UPQC.

Keywords: fuzzy, PI controller, sinusoidal pulse width modulation (SPWM), T-UPQC, VSC.

1. INTRODUCTION

The increasing different ON and OFF of the capacitor bank switches and active, passive loads in distribution systems causes lack of quality of power. Such as imbalances sag, swell, flickers, reactive power variations and harmonic disturbances. These are the serious issues in addition that, lightning also causes less quality of power at user end. But in case of sensitive loads, in industry process control requires less disturbances [1]. So that to overcome this PQ problems now a days we adapt some compensation devices with high level control modern technique. Those are either converter based filters or passive rectified devices [2]-[4]. In present days FACTS controlling techniques are most useful compensating devices to improve the quality of power in distribution systems. In that series compensation is for improve voltage profile, shunt compensator for nullified negative load in the circuit. Multi line controllers those are like interline power flow controllers (IPFC), generalized power flow controller are also preferred to improve the performance and transfer capability of the power [5]-[11]. A unified power quality conditioner (UPQC) is shown in Figure-1.

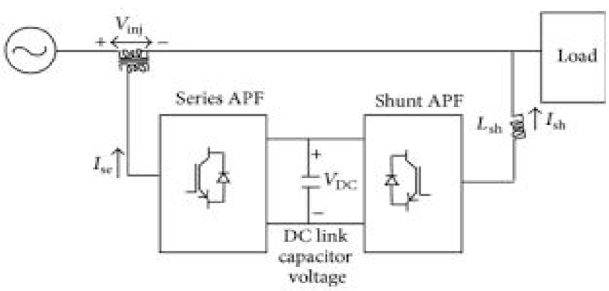

Figure-1. Single-line diagram of a distribution system with an UPQC.

In this paper, a new configuration of a UPQC called the try unified power quality conditioner (T-UPQC) is proposed. Here in this system added by two series and one shunt converters which are to be connected to common DC link capacitance. To compensate the voltage and current profile in both the lines. Here by sharing the power between the two distribution lines which are connected through the FACTS device? Figure-2 shows the line diagram of new proposed T-UPQC system.

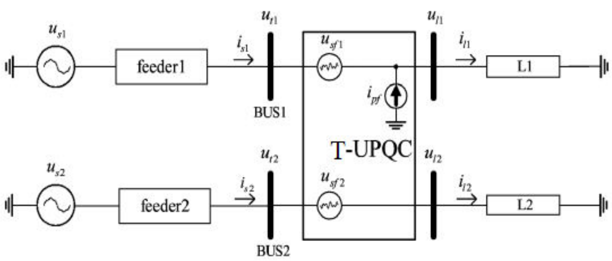

Figure-2. Equivalent circuit for distribution system with T-UPQC.

Here the paper proposes the new mamdani fuzzy controller with SPWM is used to generate the pulses to converters which are connected to the distribution lines simultaneously with respect to maintain the desired values. However the performance of the T-UPQC is justified by using different control techniques first running the system without controller next run with PI controller. Finally run the total system with mamdani fuzzy technique. At the end compare with all the controlled techniques by seeing the total harmonic distortion parameter.

2. PROPOSED T-UPQC SYSTEM

2.1 Basic circuit model

Already shown in the Figure-2 the basic diagram of T-UPQC. Here two distribution lines are connected to two different loads L2, L1 through the converters. Having the voltage sources are U_{s1}, $U_{s2,}$ where feeder 1, feeder 2 the currents passing through these are i_{s1}, i_{s2}. Bus voltages are U_{t1}, U_{t2}. The shunt part of the T-UPQC is connected the feeder1. Where U_{l1}, U_{l2} are the load voltages and are i_{l1}, i_{l2} are the load currents respectively. Loads L_1 is nonlinear load whereas L_2 is the more sensitive load. In distribution system 1 we observe the sag, swell variations in different time periods but in case system 2with load 2 not only sag, swell creating the fault for some time and observe the line condition. But this type of variations in voltage will became maximum problem in power system which may results loss of men.

2.2 Structure of T-UPQC

The total structure of T-UPQC is shown in Figure-3. In this three converters are used to mitigate the power quality problems. Where converter 1 and converter 3 are for voltage controllers. Converter 2 is for current controller which is connected in parallel to the feeder.

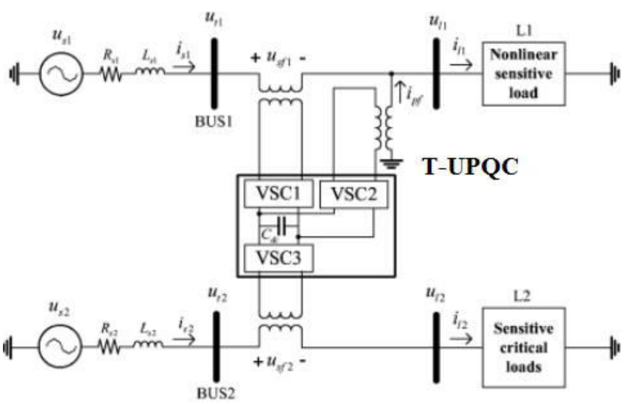

Figure-3. Typical T-UPQC used in a distribution system.

In all of the converters are connected to the line through the RC filters to prevent the switching losses in the system. These filters are connected to the converter terminals with commutating reactors as shown in Figure-4. The main purpose of this try converter UPQC is to compensate the load voltages at bus 1 and 2. And main important thing is to regulate the voltage level and reduce the harmonics at nonlinear loads. So that the way of connections of three converters are making the connection as two are for voltage controllers one for current controller.

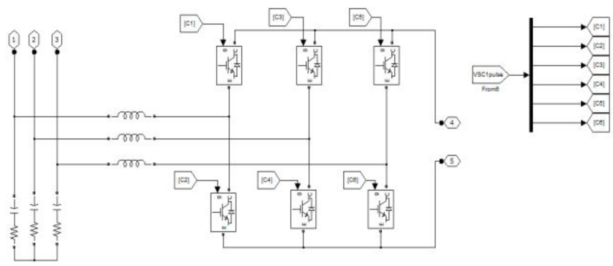

Figure-4. Voltage source converter.

Here in this voltage source converter the DC link voltage is maintained always constant here one capacitor is used as input of the converter.

3. CONTROL STRATEGY

In the Figure-3 shows that there are total three converters are used. Two series and one shunt converter is used.

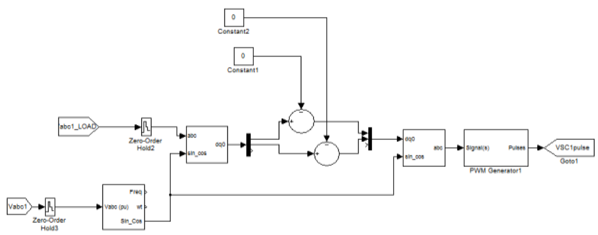

Figure-5. Control circuit for voltage source converter.

These converters are controlled by sinusoidal pulse width modulation SPWM technique it is to be performed by d-q method. The control circuit is shown in Figure-5. The purpose of this controller is to regulate the commonly connected DC link capacitor voltage, maintain the voltage profile at feeders.

By synchronous reference frame theory using this current three phase is first converted to two phases again it is to be fed to the three currents to the load. By using this theory.

$$V_d = 2/3(V_a * \sin Wt + V_b * \sin(Wt - 2pi/3) + V_c * \sin(Wt + 2pi/3)) \quad (1)$$

$$V_q = 2/3(V_a * \cos Wt + V_b * \cos(Wt - 2pi/3) + V_c * \cos(Wt + 2pi/3)) \quad (2)$$

$$V_0 = 1/3(V_a + V_b + V_c) \quad (3)$$

Using the transformation matrix the load currents is easy to analyze here. The functions of shunt voltage source converters are given below. Figure-5 shows circuit diagram of controller the load current is to be measured by transforming three phase to two phase by dq theory.

$$i_{ac-dqo} = T_{abc}^{dqo} i_{ac-abc} \quad (4)$$

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$$T_{abc}^{dqo} = 2/3 \begin{pmatrix} \cos(wt) & -\sin(wt) & 0.5 \\ \cos(wt-120) & -\sin(wt-120) & 0.5 \\ \cos(wt+120) & -\sin(wt+120) & 0.5 \end{pmatrix}^T \quad (5)$$

Here the matrix is shown in equation (5) that is with respect to three phase transforms represented in terms of dq0 theory. All the harmonic components are in ac components and the d and q axes expressed to low pass filter. With a fundamental frequency are given below:

$$i_{ac-d} = i_{dc-d}^{-} + i_{ac-d}^{:} \quad (6)$$

$$i_{ac-q} = i_{dc-q}^{-} + i_{ac-q}^{:} \quad (7)$$

Where i_{ac-d} and i_{ac-q} are the ac currents in terms of dq theory i_{sh-d}^{r} , i_{sh-q}^{r} are the shunt reference currents of dq components. The feeder current components are represented as in dq quantities. i_{f-d} , i_{f-q} where it is fed to the distribution lines from the converters.

$$i_{sh-d}^{r} = i_{ac-d}^{:} \quad (8)$$

$$i_{sh-q}^{r} = i_{ac-q}^{:} \quad (9)$$

The feeder currents are take it as in dq components. Where this value shows that zero that means there is no harmonics and there is no voltage drops.

$$i_{f-d} = i_{ac-d}^{:} \quad (10)$$

$$i_{f-q} = 0 \quad (11)$$

In the circuit shows that PI controlling method where the error is created by comparing the reference to the actual signal obtained from the distribution load side.

$$i_{sh-abc}^{r} = T_{dqo}^{abc} i_{sh-dqo}^{r} \quad (12)$$

The reference currents are given to SPWM module which generates the total pulses to the converters.

In case of series connection of the converter the fallowing equations are derived. Where u_{b-dqo} is the sum of all positive, negative and zero sequence values of feeder.

$$u_{b-dqo} = T_{abc}^{dqo} u_{b-abc} = u_{b+1} + u_{b-1} + u_{b01} + u_{te} \quad (13)$$

Here series compensator function is that to mitigate the voltage sags and swells, reduce the harmonics, improves the voltage profile.

$$\begin{aligned} u_{b+1} &= \begin{pmatrix} u_{b+1-d} & u_{b+1-q} & 0 \end{pmatrix}^T \\ u_{b-1} &= \begin{pmatrix} u_{b-1-d} & u_{b-1-q} & 0 \end{pmatrix}^T \\ u_{b01} &= \begin{pmatrix} 0 & 0 & u_{00} \end{pmatrix}^T \end{aligned} \quad (14)$$

With respect to the T-UPQC the aim is to maintain the load voltage is sinusoidal even the some disturbances are occurred in the system.

$$u_{b-abc}^{\exp} = \begin{pmatrix} u_m \cos(wt) & u_m \cos(wt-120) & u_m \cos(wt+120) \end{pmatrix}^T \quad (15)$$

By conversion of dq theory to abc generalized form that it is given to feeder through PWM controlling technique with loop.

The power rating of the new proposed system that is T-UPQC is power improvement is in cost. Here two models are proposed one is in quadrature T-UPQC and another one is in phase T-UPQC. By using quadrature compensation which is used to compensate the voltage ratings in series when sag is accrued in the line here the main advantage with this is there is no active power consumption using this method. This series compensator involves to compensate reactive power in shunt also. So the power rating of the shunt is to be reduced. Fig.6 shows that reactive power is not given to the line so that it is the way the series injecting voltage is zero. Here the shunt injects the VSC into the line so that the power factor maintained unity. Total harmonic distortion is also reduced.

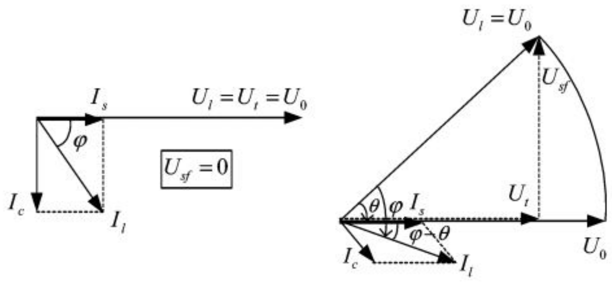

Figure-6. Quadrature compensation Phasor diagram with and without voltage sag.

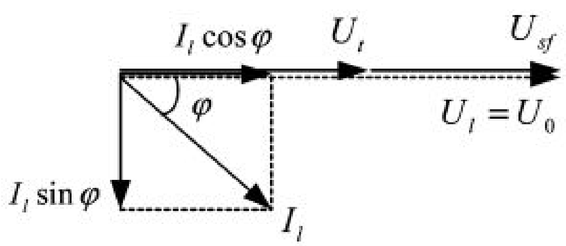

Figure-7. Supply voltage sag phasor diagram in phase diagram.

In Figure-6a there is no reactive power injection but in 6b for sag compensation need reactive power injection. Such that the active power drawn from the utility which is maintained unity power factor. When the supply is balanced the phase voltages are equal. Figure-7 explains that in case of voltage sag how the device reacts. If the VAR demand is very low then T-UPQC reactive component is lower that of T-UPQC active power component. It is less than or equal to 0.9. The power in series is more than power rating in shunt connected system.

The power rating of T-UPQC is calculated by taking suffix 1, 2 for feeders 1, 2 respectively. Here assumptions taking that load voltages and load currents are initially take it as constant.

$$u_{t1}i_{s1} = u_{t1}i_{s1}\cos\theta_1 + u_{sf2}i_{l2}\cos\theta_2 \quad (16)$$

$$(1-x_1)u_0 i_{s1} = u_0 i_{01}\cos\theta_1 + x_2 u_0 i_{02}\cos\theta_2 \quad (17)$$

$$(1-x_1)i_{s1} = i_{01}\cos\theta_1 + x_2 i_{02}\cos\theta_2 \quad (18)$$

$$i_{s1} = \frac{i_{01}\cos\theta_1}{(1-x_1)} + \frac{x_2 i_{02}\cos\theta_2}{(1-x_1)} \quad (19)$$

The feeder currents can be found by from the above three equations. The voltage injected by bus 1 and in bus 2 reactive power is compensated. From Equation 20 to Equation 23 series voltage injected in feeder 1 is multiplied by current we get power at feeder 1. Power at feeder 2 calculated by the fallowing equation.

$$u_{sf1} = u_0(1-x_1)\tan\theta \quad (20)$$

$$s_{vsc1} = 3u_0(1-x_1)\tan\theta \times \left(\frac{i_{01}\cos\theta_1}{(1-x_1)} + \frac{x_2 i_{02}\cos\theta_2}{(1-x_1)}\right) \quad (21)$$

$$i_{c1} = \left(i_{l1}^2 + i_{s1}^2 - 2i_{l1}i_{s1}\cos(\theta_1 - \varphi)\right)^{0.5} \quad (22)$$

$$s_{vsc2} = 3u_0\left(i_{c1}^2 + (x_2 i_{02}\cos\theta_2)^2\right)^{0.5} \quad (23)$$

4. IDEA TO DESIGN CONTROLLER

The direct current linking capacitor regulated voltage by PI with fuzzy technique. Whenever load changes DC capacitor voltage is also changes which may causes the compensation i.e which increase the harmonics in this line. In linked DCstorage device if the load increased the DC link voltage is increased vice versa. For better operation always we need to maintain DC link capacitor voltage constant irrespective of the quantity of the Kd and Kp the voltage across the capacitor consumes 6 to 8 cycles for settling. In any period using PI, Fuzzy the DC link voltage is maintained constant.

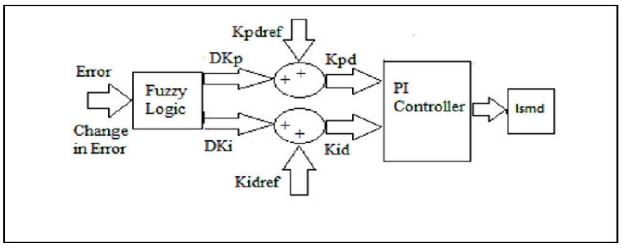

Figure-8. A mamdani based fuzzy logic based PI controlleris designed using DC voltage error and power factor.

Here in Figure-8 the fuzzy controller the change in error, error compared with each and gives the 2 outputs DKp, DKi using these two variables find resultant values. Those values cangetwhile compared with reference values of proportional and integral constants finally with these and PI controller the pulse will generated. This pulse controls the T-UPQC so the power quality is improved. In controller by Fuzzy logic the change in Direct current link potential is difference between $V_{DC}^{ref} - V_{DC}(i)$. The change in error is the difference between error (i)-error(i-1). In the Fuzzy change in the values of two constants those are $K_p = K_{pchref} + \Delta K_p$ and $K_i = K_{ichref} + \Delta K_i$ this equations are outputs of controlled technique in fuzzy. In this paper the error membership are triangular functioned based given in Table-1. Those are seven member shipped triangular type are selected. Where NL is (Negative Large), NM (Negative Medium), NS (Negative Small), EZ for (Equal Zero), PS (positive Small), PM (Positive Medium) and PL (Positive Low) respectively and for error E (error) and CE (change in error).

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Table-1. Fuzzy controller rule base.

E/CE	NL	NM	NS	EZ	PS	PM	PL
NL	PL	PL	PM	PM	PS	PS	NS
NM	PL	PM	PM	PS	PS	EZ	NS
NS	PM	PM	PS	EZ	EZ	NS	NS
EZ	PM	PS	PS	EZ	NS	NS	NM
PS	PS	PS	EZ	NS	NS	NM	NM
PM	PS	EZ	NS	NS	NM	NM	NL
PL	EZ	NS	NS	NM	NM	PL	NL

Defuzzification means the method of converting fuzzy to its crisp action; here the type is centre of gravity technique is preferred in this paper. From Figure-9 to Figure-11 shows the input and output membership functions with P and I controller actions.

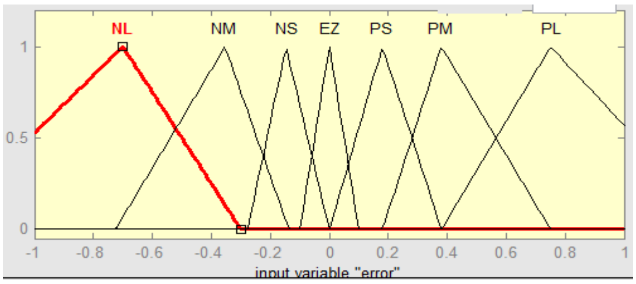

Figure-9. Input member ship function 1 error.

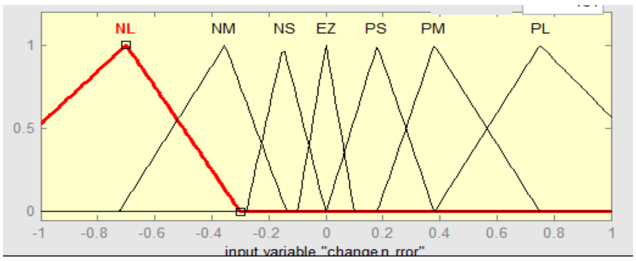

Figure-10. Input member ship function 2 change in error.

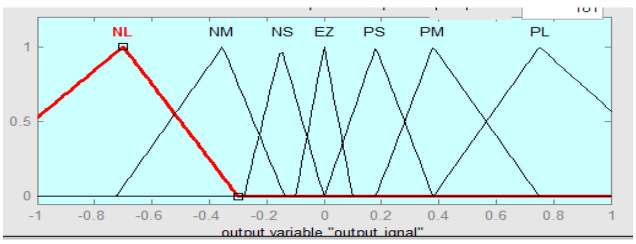

Figure-11. Output membership function.

The main identified points are included when it is programmed in the file. The rules are as follows:

a) If the error is negative large and the error change is also negative large then angle is positive large.

b) If the error is negative small and the change in error is Equal to zero then value is Positive small.

c) If the error is positive medium and error change is positive small then value is negative medium.

d) If the error is positive large and changing error is positive medium then value is negative large.

5. SIMULATION RESULTS

In this article mamdani based control of Fuzzy with PI Controller is devolved. From the simulation diagrams Figure-12 to Figure-14 Here fortune of proportional and integral constants fuzzy is used, the input voltages are taken that balanced in direct current link potential is controlled by Fuzzy irrespective of that the load conditions.

In the converter circuit IGBT is used here for protect the converters snubber circuit is used with rating of $1X10^5$ ohms, infinite capacitance. Here through the filter the converter is connected to the feeder. So the filter rating resistance is 0.1 ohms, capacitance is $100X10^{-6}$ F. with K_p, K_i values are 1 and 2 with the sample time period of $50X10^6$.

Here the input is per unit value with phase displacement of 120deg and fixed frequency of 50Hz for bus 1 and for bus 2 it is taken as frequency is 60Hz. Consider two three phase systems shown in Figure-3. Where voltage is taken in per unit system, the feeder 1 contains 7^{th} order harmonic and 2^{nd} bus contains 5^{th} order harmonics with 22% and 35% respectively. Bus 1, KVA rating of transformer is $10X10^3$VA, 50Hz. The input voltage is 20V, output voltage is 200V, resistances offered in primary and secondary is 80micro ohms and 0.008 respectively the inductances are offered is 10.086micro henry and 0.0010186 respectively. In this same transformer the no load resistance and reactance are 500, 500 ohms.

Bus 2 consisting of the transformer rating with 10KVA, 60Hz and having winding parameters are input voltage is 20rms and output voltage is 200rms. Resistance of primary and secondary are 0.002, 0.002ohms respectively. The inductances offered are 0.08. On bus 1 shown in Figure-15 sag is created in the period from 0.1sec to 0.2sec with 75% reduction in actual value and

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swell is created in the period of 0.2sec to 0.3sec. 20% more than its value. Total time taking to complete this operation with in the 0.3 sec. From Figure-16, Figure-17 we can observe the series injected voltage and load voltage at bus 1 is maintained constant.

In case of bus 2 that is Feeder 2 the sag and swell are 35% and 30% respectively with the total time period of 0.3 sec. in steps of 0.15 shown in Figure-18. From Figure-19, Figure-20 we can observe that the series injected voltage and load voltage at bus 2 is maintained constant. Even here after swell in bus 2 at the time period of 0.1sec fault is created that is from 0.3 to 0.4sec load voltage is maintained constant. With this the outputs indifferent conditions are absorbed.

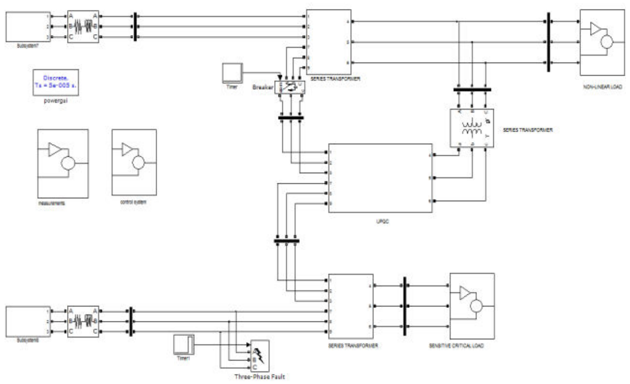

Figure-12. Simulation/ Matlab model for typical new T-UPQC used in distribution system.

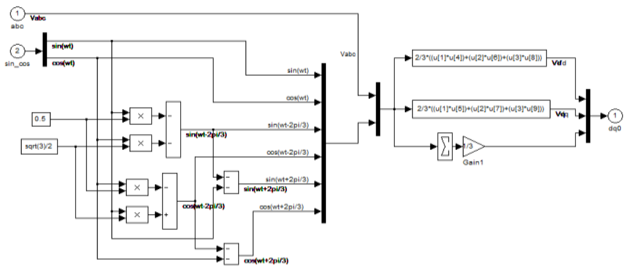

Figure-13. pq conversion simulation circuit.

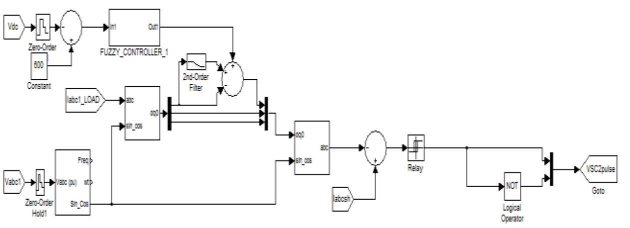

Figure-14. PWM generating controlled circuit.

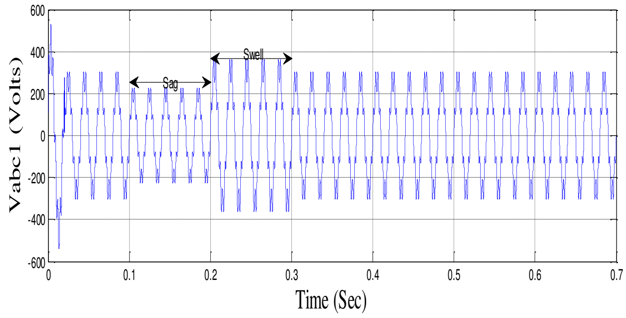

Figure-15. Vabc at bus1 with different disturbances.

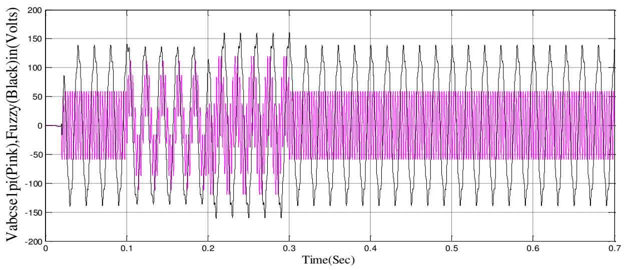

Figure-16. Series injected voltage at bus1 using PI, fuzzy controller.

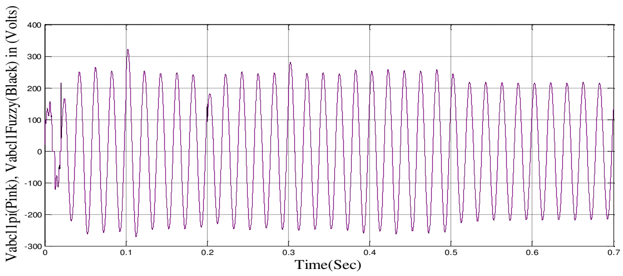

Figure-17. Load voltage at bus1 using PI, fuzzy controller.

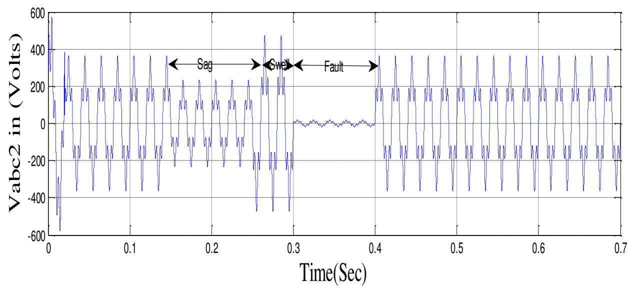

Figure-18. Vabc bus2 voltage at different disturbances.

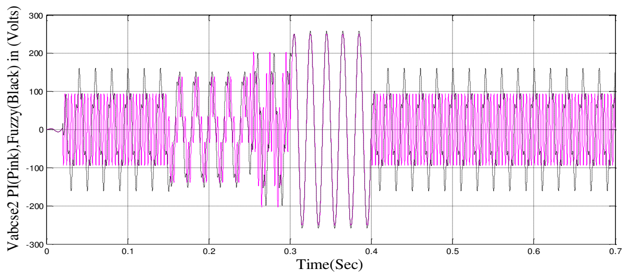

Figure-19. Series injected voltage at bus 2 using PI, fuzzy controller.

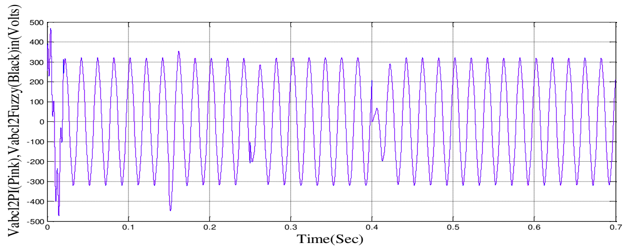

Figure-20. Load voltage at bus2 using PI, fuzzy controller.

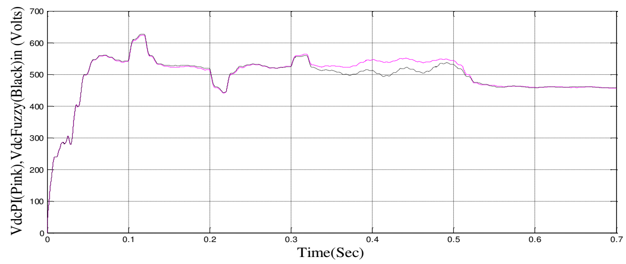

Figure-21. DC link voltage using PI, fuzzy controller.

In Figure-21 shows that the DC capacitor voltage using Fuzzy controller which settles very faster than PI controller. And it is maintained constant voltage.

Table-2. THD comparision.

Power quality parameter	Comparison of THD with controllers			
	Quantity to be improved	Without controller	PI controller	Mamdani fuzzy technique
THD	Total harmonic distrotion	30.83	5.27	2.46

By comparing the different controllers in above table shows that the total harmonic distortion is comparatively reduced by using mamdani fuzzy technique in T-UPQC system than PI controller.

6. CONCLUSIONS

This paper introduced a new configuration for at time compensation of voltage and current in feeders in distribution system using T-UPQC. Compared to a conventional UPQC system the THD value is reduced effectively. By using new proposal of T-UPQC, the performance of T-UPQC is evaluated by different disturbances finally the advantages are obtained power transferred with compensations in sag and swell times also. Without battery systems compensation in two feeders are obtained. Sharing of power is effectively be obtained even both are internally connected one other.

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