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Unified Power Quality Conditioner for Power Quality Enhancement of Distribution System Using Space Vector Pulse Width Modulation Based Fuzzy Controller

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ABSTRACT

In this editorial, the quality of power is enhanced by using diverse configurations of Unified Power Quality Conditioner (UPQC) specifically UPQC-L (Left shunt) and UPQC-R (Right shunt). Evaluation is made to categorize the superior performing of UPQC. Fuzzy Logic Controller (FLC) is implemented with Space Vector Pulse Width Modulation (SVPWM) technique for different non-linear loads. Results of both the techniques are compared with (SPWM) Sinusoidal Pulse-Width Modulation. This editorial demonstrates that UPQC-R configuration with FLC based on SVPWM technique provides enhanced performance and lower Total Harmonic Distortion (THD) values.

Key words: UPQC-R, UPQC-L, SVPWM, SPWM, FLC, voltage sag, voltage swell, PQ.

1. INTRODUCTION

In modern era, there's a pervasive usage of non-linear loads, made from power electronics. Non-linear loads are both origin and fatalities of PQ concerns. The PQ issues include voltage sag, voltage swell, harmonics, transients and several other troubles. If the PQ issues aren't mitigated, then it escorts to many difficulties like breakdown, augmented electricity bills, interference with communication systems and even packs up of entire plant.

In order to diminish this issue, in this editorial author uses a compensating device called UPQC. Two different configurations of UPQC, specifically UPQC-L shunt and UPQC-R shunt considered to diminish voltage sag and swell for two non-linear load cases. Finally, SPWM and SVPWM techniques are executed with FLC and results acquired.

[1] gives the detailed information about UPQC and different types/ configurations of UPQC. [2] provides the information about UPQC-R and UPQC-L. The authors of [3] provide information about PQ and the different PQ issues that are being a raised in the DS. The authors of [4] provide information about the FLC. Author uses Fuzzy Logic technique with different controllers such as PWM and PI controller for various types of loads, and the results acquired and compared in these articles. The various control strategies outlined in [5]. Article [6] and [7] investigated the details of PWM techniques and PI controllers respectively.

In this article, UPQC-L and UPQC-R operated with FLC based SVPWM technique, and the outputs obtained are compared with FLC based SPWM technique for the better results.

Section II explains about the UPQC, section III and IV provides detailed analysis about the different configurations of UPQC, i.e., UPQC-L and UPQC-R. Further in section V control of UPQC is explained briefly. The proposed method in this editorial is clearly explained in section VI and SVPWM technique, which was used, is explained in detail in section VII. Simulation and results are exhibited in VIII and finally editorial concludes in the section IX.

2. UPQC

In recent times, countless research endeavors are done by utilizing UPQC to decipher PQ tribulations in DS or industrial systems [1] [2]. UPQC amalgamates together the series & shunt VSC's coupled B-B-C with a same dc link. The shunt part of UPQC makes amends for I_l associated issues were as the series part can amends for all Vs associated issues [1]. Two diverse configurations are made to get enhanced performance of UPQC. The 2 probable ways to attach the UPQC to the DS are UPQC-R which is placed on the right side of series VSC that is to load side of DS while UPQC-L placed on the left side of series VSC that is on the source side of DS. Both structures of UPQC have same characteristics. Nevertheless, the distinctiveness of UPQC-R is highly preferable as it can work in zero power addition/ amalgamation modes

3. UPQC-L

The UPQC-L is essential custom equipment, which reimburses both I and V allied troubles, concurrently. The structure of UPQC-L is analogous to UPFC. Similar to UPQC, UPQC-L also consists of two VSIs that associated to a same dc link. Shunt/ series compensation accomplished simultaneously by UPQC-L in power DS. However, a UPFC only necessitates as long as shunt and/or series compensation is under balanced state. On the opposite hand, an influence DS may consist of, distortion, and unbalances both in V and I. The most intent of a UPQC-L is to atone:

1. PQ issues of V_s like sag /swells, unbalance, harmonics, etc.
2. PQ issues of I_l like harmonics, distortions, etc.

Figure.1 illustrates a one-line diagram of UPQC. The focal apparatuses of this configuration.
1) Two B-B-Converters- shunt APF is one among them, which associates across the load of DS. While series APF associated in series to transmission network.
2) Shunt Coupling-inductor (L_{sh}) - This helps to link the shunt converter to the system. It even assists to facilitate current waveform to get smoother.
3) Dc link- This is created through employing a capacitor. The dc link consists of a capacitor which bridges both the converters, and it also continues own-supplying dc bus voltage across it.
4) L-C filter- This is LPF. It uses to eradicate harmonics of raised frequency on output voltage of the converter.
5) *Series injected Transformer*- Series VSC connected to DS through the transformer. A proper turn's ratio is usually deemed to condense I or V rating of the series inverter. [1] [2]

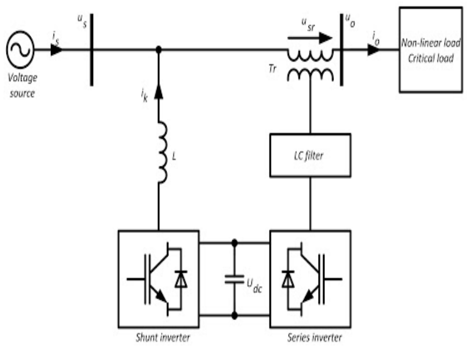


Figure 1: UPQC-L shunt configuration

4. UPQC-R

The UPQC-R consists of two B-B-C; which was divided into several categories depending on assignment of shunt VSC w.r.t series VSC. Figure 1 illustrates UPQC-L pattern, while Figure. 2 UPQC-R pattern. In these two arrangements, the UPQC-R is highly recommended than UPQC-L because the current flows from series injected transformer is preferably sinusoidal. UPQC R configuration is similar to that VSI UPQC.

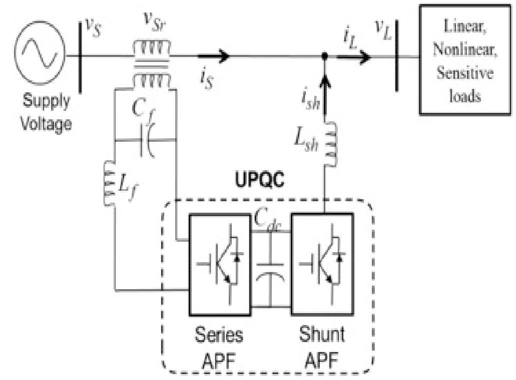


Figure 2: UPQC R shunt

Table 1: Parameters and variables

		UPQC-L shunt	UPQC-R shunt
Description	**Parameter**	**Value unit**	**Value unit**
Rated power	Sa	10KVA	10KVA
Source voltage	V_s	300V	300V
Frequency	F	60Hz	60Hz
DC reference link voltage	Vdc ref	700V	500V
Dc capacitor voltage	Vc	20µF	20µF
Shunt VSC resistance	Rp	1000Ω	1000Ω
Shunt VSC inductance	Lp	1mH	1mH
Shunt VSC capacitance	Cp	1µF	1µF
Series VSC inductance	Ls	1.7mH	1.7mH
Series VSC capacitance	Cs	1µF	1µF
PI control parameters	Kp Ki	0.0001 0.0001	0.0001 0.0001
Chopping frequency of SVPWM technique	Fc	2000Hz	2000Hz
Carrier frequency for PWM technique	fc'	1080Hz	1080Hz

5. CONTROL OF UPQC

Control of UPQC is usually carried out in three steps.
Step1: The voltage of the Dc link will be sensed. The Voltage of any kind of UPQC (UPQC-L shunt/ UPQC-R shunt) changes if any fault occurs. Hence the most important and primary step to improve power quality using UPQC is to preserve the Dc link voltage.
Step2: Derive the compensating instructions in terms of V and I level through FLC.

Step3: Once the compensating commands generated, they are given to the semiconductor switches of UPQC in the form of gating signals. This can be achieved by using SPWM technique and SVPWM technique.

6. FUZZY LOGIC CONTROLLER

The fuzzy control is fundamentally a non-linear and adaptive which gives the vigorous performance in the cases where parameter variation of the controller is present. In FLC, the PI controller pooled with the clever and addictiveness of FLC system. FLC operates in three modes namely fuzzification decision making and defuzzification.

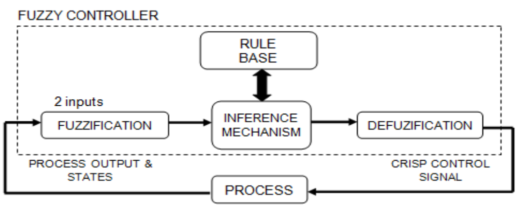


Figure 3: FLC block diagram.

fuzzification: In FLC, basic control action works on the liguistic rules. In FLC, basic control action works on the linguistic rules. As the arithmetic variables are transformed into linguistic, no arithmetic model is essential. In order to translate into linguistic terms the fuzzy levels selected in this paper are Negative (N), Positive (P) and Zero (Z). Membership functions like trapezoidal and triangular are applied as the input of FLC. This process of translating crisp into linguistic variables is called as fuzzification. Figure 3 gives the basic block diaram of FLC.

Decision making: In Mamdani method, the output of membership functions may be trapezoidal/ triangular/ gaussian, etc. The fuzzy inter fence system uses if-then rule base. Table 2 shows the assessment table for FLC rule base. Every input of the fuzzy system is allocated to three membership functions. Hence, it consists of nine rules. The accuracy can be enhanced by increasing the number of rules, but this increases the data size, execution time and complexity of system[7].

Table 2: fuzzy rules

E/ΔE	**N**	**Z**	**P**
N	N	Z	Z
Z	N	Z	P
P	Z	P	P

Defuzzification: The method of converting linguistic outputs into crisp solution for control of the system is called as Defuzzification.

7. SVPWM TECHNIQUE

The key motive of this technique is to attain fewer switching losses, fewer current losses, etc. To reduce the switching losses the switching operation must be reduced, this can be achieved by using SVPWM and hence it is found advantageous over SPWM. In SVPWM technique the 3φ quantity is reduced to two phase quantity (α-β) by synchronously rotating frame or stationary frame.

Consider the 3 phase voltages:

Va= VmSinωt (1)

Vb=VmSin(ωt-2π/3) (2)

Vc=VmSin(ωt-4π/3) (3)

To implement the SVPWM technique, the equations in abc frame must be converted into α-β axes or d-q frame. With the help of the figure the voltage along α-axis and β-axis is given below respectively:

$$V\alpha = Van - Vbn * cos60° - Vcn * cos60° \quad (4)$$

$$V\beta = 0 + Vbn * cos30° - Vcn * cos30° \quad (5)$$

Therefore,

$$\begin{bmatrix} V\alpha \\ V\beta \end{bmatrix} = 2/3 \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3/2} & -\sqrt{3/2} \end{bmatrix} \quad (6)$$

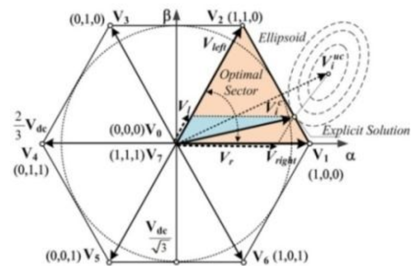


Figure 4: Basic switching vectors and sectors

The upper switches of the inverter are named 1, 3 and 5 whereas the lower switches if the inverter are numbered as 2, 6 and 4. If the upper switches are ON (all together or individual) it is represented with 1. If the lower switches are ON (individual or all together) it is represented with zero. They are opposite to the upper switches, therefore the feasible combinations of these switches are 000,001,010,011,100,101,110 and 111 and these are shown in figure 4. The state's 000 and 111 are called as zero states as the switches are short circuited under these states. The other states such as 100, 101,110,011,010,001 are known as active states. The radian of the hexagon is equal to the voltage space vector structure for the two level inverter i.e., all the active voltages lie along the radii of the hexagon. Hence, it takes 6 steps to take one complete revolution

Max radii of the hexagon is given as

$V_{dc} * cos30° = \sqrt{3}/2V_{dc}$……………………... (7)

Voltage second balance along α-axis

$V_1T_1 = (V_2 * cos60°)T_2 = V_sT_s * cos \propto$ ……... (8)

Voltage second balance equation along β-axis

$0 + (V_2 * sin60°)T_2 = V_sT_s * sin \propto$………….. (9)

Solving the above two equations we get

$T_1 = T_s * \frac{V_s}{V_{dc}} * [\sin(60° - \alpha) / sin60°]$ (Since $V_{dc} = V_1 = V_2$)…………………………………….... (10)

$T_2 = T_s * \frac{V_s}{V_{dc}} * \frac{2}{\sqrt{3}} * sin\alpha$…………………...... (11)

Therefore in a sector α varies from $0°$ *to* $60°$.

Hence by selecting the appropriate values of T_1 and T_2 for a particular V_s i.e., the reference space vector of particular amplitude and alpha for different frequencies of operation we can obtain different amplitudes.

8. SIMULATION AND TEST RESULTS

Case 1: 3 Phase Rectifier Load

Table 3: Load considered in case study 1

Description	Parameters	Value
Resistance	R_l	60Ω
Inductance	L_l	0.1H

1.1 Without UPQC

Initially considering the 3phase rectifier load the THD of the system without compensating device is calculated. The source values are given Table 1. The load parameters of case study 1 are given in table 3. The load voltage (V_l) and load current (I_l) waveforms as given in Figure 5 and their corresponding THD values are mentioned in table 5.

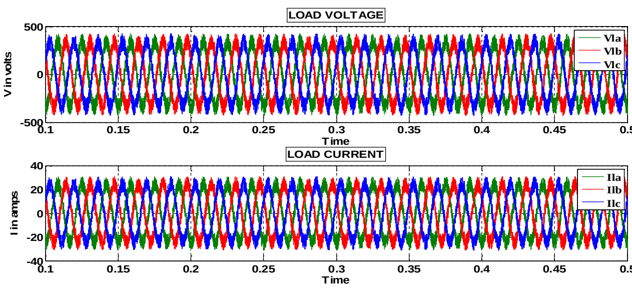


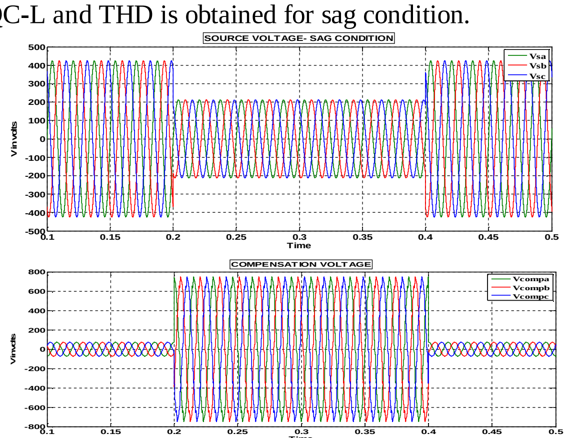
Figure 5: waveforms of V_l and I_l for the system without UPQC

1.2 With UPQC-L shunt

Here, Compensating device UPQC of UPQC-L shunt category is inserted to diminish THD of 3phase rectifier load. Different conditions have been studied with both PWM & SVPWM with FLC.

1.2.1 Sag condition- SVPWM technique

Here, FLC based on SVPWM technique is implemented on UPQC-L and THD is obtained for sag condition.



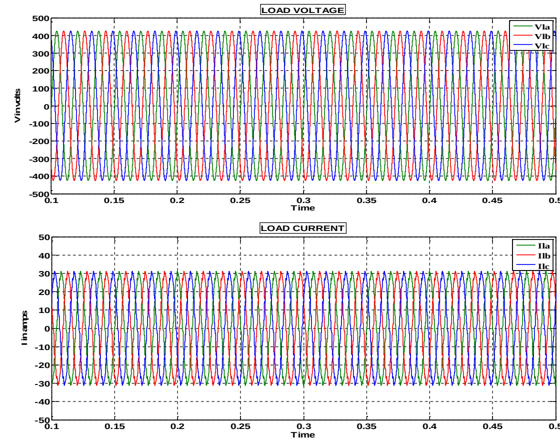
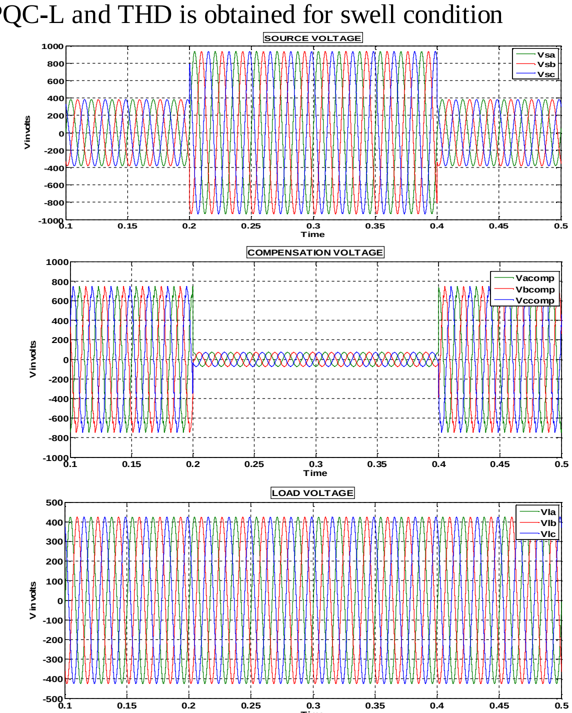


Figure 6: Source, Compensating voltages, V_l & I_l of UPQC-L with sag condition SVPWM technique in case-1

A sag condition for the supply voltage is applied to the system from 0.2 seconds to 0.4 seconds. UPQC-L shunt supply's voltage to compensate the sag of the wave. This compensating voltage is applied from 0.2 seconds to 0.4 seconds. Once the sag is minimized, the output of the V_l wave is obtained. The distortion-free voltage is now given to the load. The Source, Compensating voltages, V_l & I_l waveforms of UPQC-L with sag condition SVPWM technique for the case-1 of the system is given in Figure 6.

1.2.2 Swell condition- SVPWM technique

Here, FLC based on SVPWM technique is implemented on UPQC-L and THD is obtained for swell condition



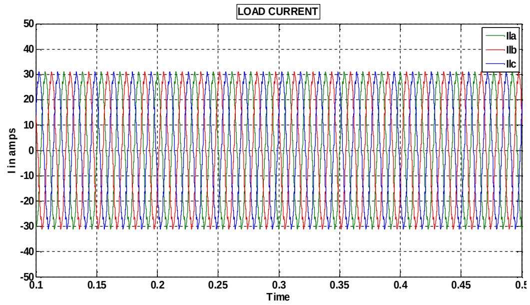


Figure 7: Source, Compensating voltages, Vls & Il of UPQC-L with swell condition SVPWM technique in case1

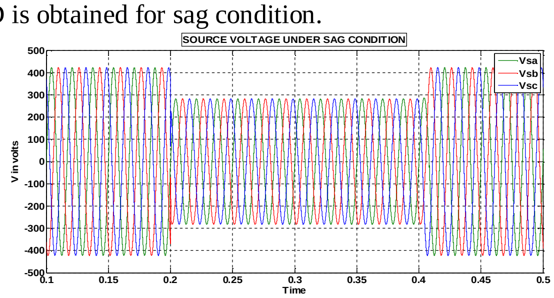
A swell condition for the supply voltage is applied to the system from 0.2 seconds to 0.4 seconds. UPQC-L shunt compensates the swell of the wave from 0.2 seconds to 0.4 seconds. Once the swell is minimized, the output of the Vl wave is obtained. The distortion- free voltage is now given to the load. The Source, Compensating voltages, V_l & I_l waveforms of UPQC-L with swell condition of SVPWM technique for the case-1 of the system is given in Figure 7.

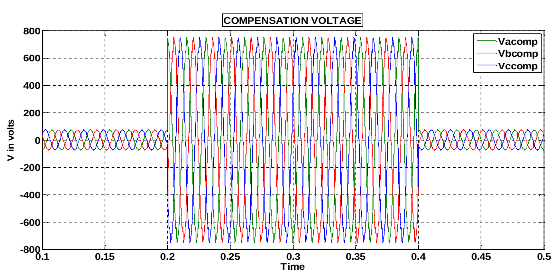
1.3 With UPQC-R shunt

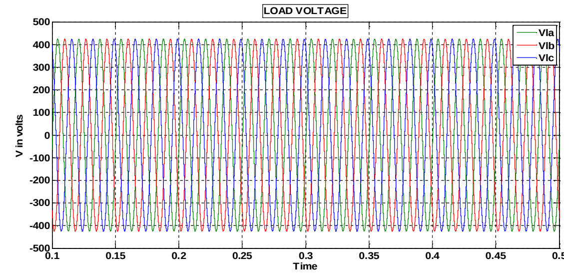
Here, Compensating device UPQC of UPQC-R shunt category is inserted to diminish THD of 3phase rectifier load. Different conditions have been studied with both PWM & SVPWM with FLC.

1.3.1 Sag condition- SVPWM technique

Here, FLC based on SVPWM technique is implemented and THD is obtained for sag condition.







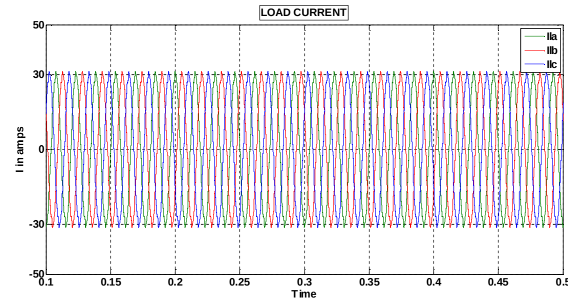
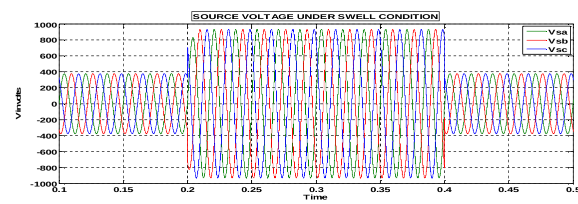


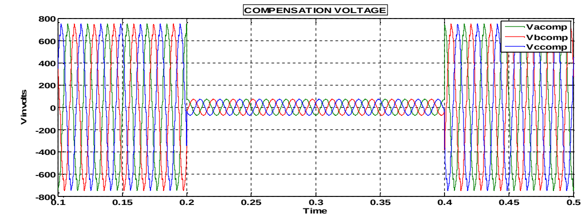
Figure 8: Source, Compensating voltages, V_l & I_l of UPQC-R with sag condition SVPWM technique in case1

A sag condition for the supply voltage is applied to the system from 0.2 seconds to 0.4 seconds. UPQC-L shunt supply's voltage to compensate the sag of the wave. This compensating voltage is applied from 0.2 seconds to 0.4 seconds. Once the sag is minimized, the output of the Vl wave is obtained. The distortion-free voltage is now given to the load. The Source, Compensating voltages, V_l & I_l waveforms of UPQC-R with sag condition SVPWM technique for the case-1 of the system is given in Figure 8.

1.3.2 Swell condition- SVPWM technique

Here, FLC based on SVPWM technique is implemented and THD is obtained for swell condition.





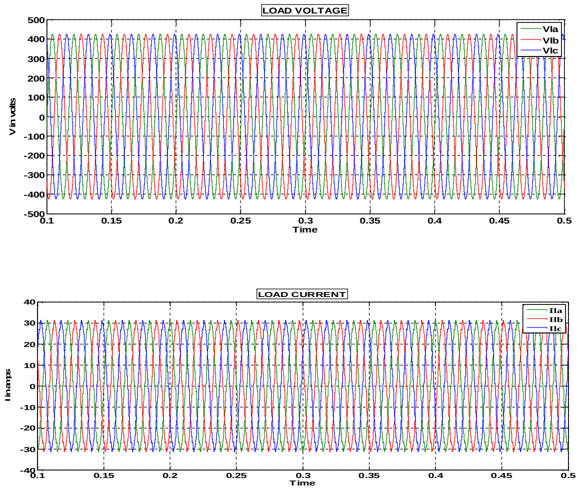


Figure 9: Source, Compensating voltages, V_l & I_l of UPQC-R with swell condition SVPWM technique in case1

A swell condition for the supply voltage is applied to the system from 0.2 seconds to 0.4 seconds. UPQC-L shunt compensates the swell of the wave from 0.2 seconds to 0.4 seconds. Once the swell is minimized, the output of the Vl wave is obtained. The distortion-free voltage is now given to the load. The Source, Compensating voltages, V_l & I_l waveforms of UPQC-R with swell condition of SVPWM technique for case-1 of the system is given in Figure 9.

Case2: Three-Single Phase Rectifier Load

Table 4: parameters of load in case study 2

Description	Value unit
RL load for phase a	Resistance, R=8.1Ω Inductance, L=38Mh
RL load for phase b	Resistance, R=10.12Ω Inductance, L=346mH
RL load for phase c	Resistance, R=13.5Ω Inductance, L=357mH

2.1 Without UPQC

Initially considering three single phase rectifier load the THD of the system without inserting compensating device is calculated. The load parameters are given the table 4. The source voltage, V_l and source, I_l wave forms as given in Figures 10, 11 and their corresponding THD values are mentioned in table 6.

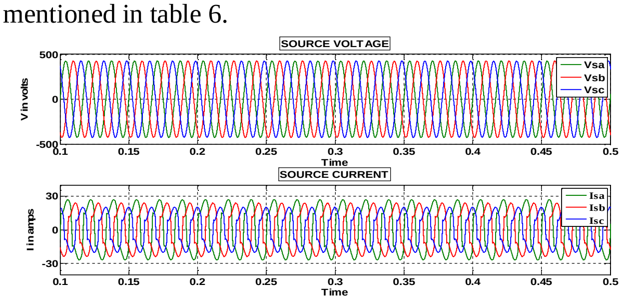


Figure 10: Source Voltage and Source Current waveforms of case-2 without UPQC

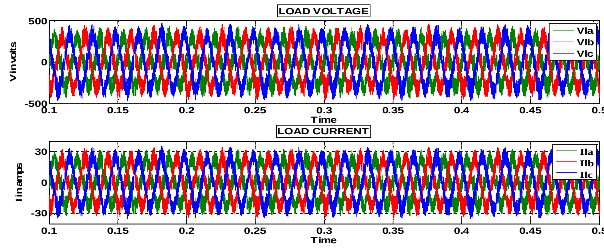


Figure 11: Vl and Il waveforms of case-2 without UPQC

2.2 With UPQC L shunt

Here, Compensating device UPQC of UPQC-L shunt category is inserted to diminish THD of three single phase rectifier load. Different conditions have been studied with SVPWM with FLC.

2.2.1 Sag Condition- SVPWM Technique

Here, FLC based on SVPWM technique is implemented and THD is obtained for sag condition

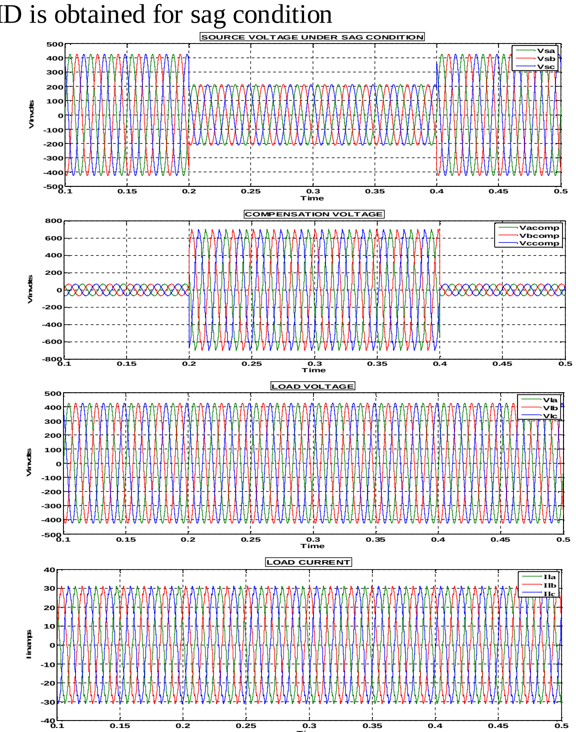


Figure 12: Source, compensating voltages, V_l & I_l of UPQC-L with sag condition SVPWM technique in case2

A sag condition is applied to the source voltage from 0.2 seconds to 0.4 seconds. UPQC-L shunt supply's voltage to compensate the sag of the wave. This compensating voltage is applied from 0.2 seconds to 0.4 seconds. Once the sag is minimized, the output of the V_l wave is obtained. The distortion-free voltage is now given to the load. The Source, compensating voltages, V_l & I_l waveforms of UPQC-L with sag condition SVPWM technique for the case2 is given in Figure12.

2.2.2 Swell condition- SVPWM technique

Here, FLC based on SVPWM technique is implemented and THD is obtained for swell condition

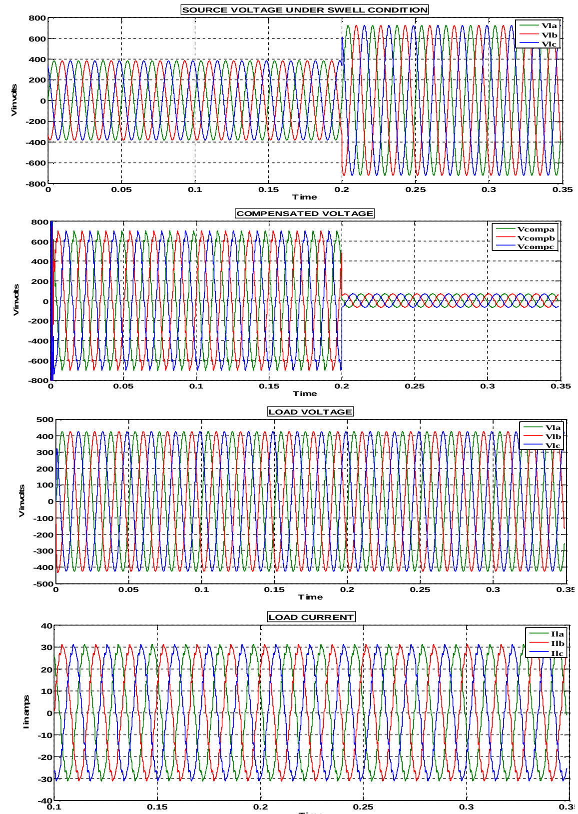


Figure 13: Source, compensating voltage, V_l & I_l of UPQC-L with swell condition SVPWM technique in case2

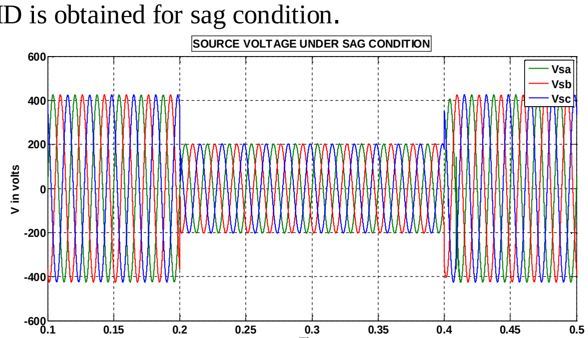
A swell condition is applied to the system source voltage from 0.2 seconds to 0.35 seconds. UPQC-L compensates the swell of the wave. The compensation is applied from 0.2 seconds to 0.4 seconds. Once the swell is minimized the output of the load waveform is obtained. The distortion-free voltage waveform obtained is given to load. Source, compensating voltages, V_l & I_l waveforms of UPQC-L with swell condition SVPWM technique for the case2 is shown in figure13.

2.3 With UPQC R-shunt

Here, Compensating device UPQC of UPQC-R shunt category is inserted to diminish THD of three single phase rectifier load. Different conditions have been studied with SVPWM with FLC

2.3.1 Sag condition- SVPWM technique

Here, FLC based on SVPWM technique is implemented and THD is obtained for sag condition.



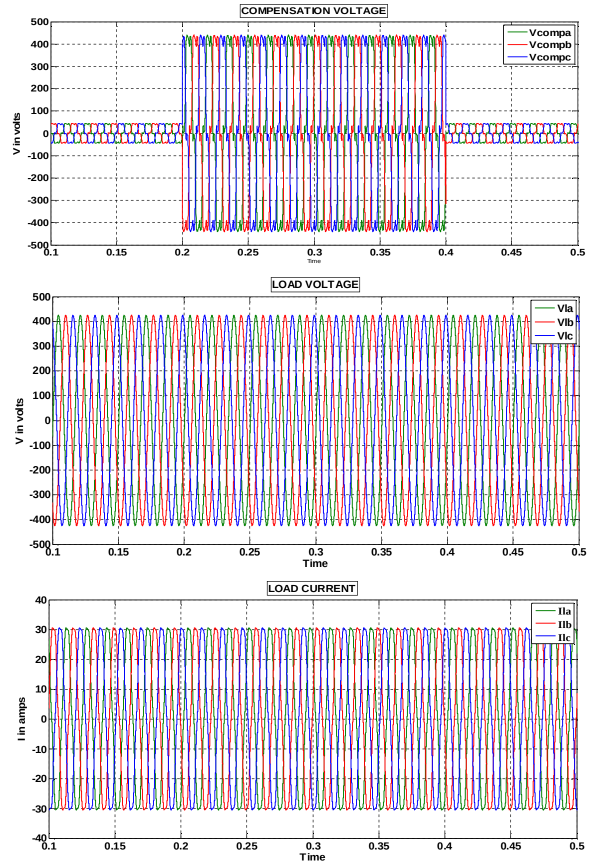
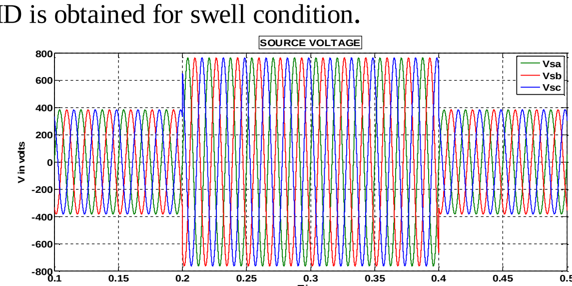


Figure 14: Source, compensating voltages, V_l & I_l of UPQC-R with sag condition SVPWM technique in case2

A sag condition is applied to the source voltage from 0.2 seconds to 0.4 seconds. UPQC-R shunt supply's voltage to compensate the sag of the wave. This compensating voltage is applied from 0.2 seconds to 0.4 seconds. Once the sag is minimized, the output of the V_l wave is obtained. The distortion-free voltage is now given to the load. The Source, compensating voltages, V_l & I_l waveforms of UPQC-R with sag condition SVPWM technique for the case2 is given in Figure14.

2.3.2 Swell condition- SVPWM technique

Here, FLC based on SVPWM technique is implemented and THD is obtained for swell condition.



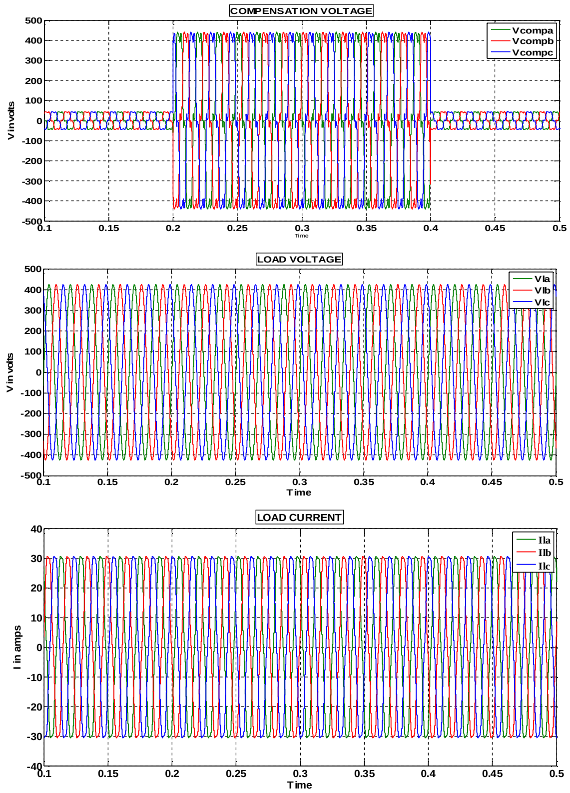


Figure 15: Source, compensating voltages, V_l & I_l of UPQC-R with swell condition SVPWM technique in case2

A swell condition is applied to the system source voltage from 0.2 seconds to 0.35 seconds. UPQC-R compensates the swell of the wave. The compensation is applied from 0.2 seconds to 0.4 seconds. Once the swell is minimized the output of the load waveform is obtained. The distortion free voltage waveform obtained is given to load. Source, compensating voltages, V_l & I_l waveforms of UPQC-R with swell condition SVPWM technique for the case2 is shown in figure15.

3. THD Comparison

Table 5: Case (a): 3phase Rectifier load (UPQC-L)

Parameters	Without UPQC	With UPQC-L			
		Sag		Swell	
		Fuzzy SPWM	Fuzzy SVPWM	Fuzzy SPWM	Fuzzy SVPWM
V_l	45.1	2.59	2.27	2.59	2.27
I_l	45.1	29.86	27.17	29.86	27.17

Table 6: Case (a): 3phase Rectifier load (UPQC-R)

Parameters	Without UPQC	With UPQC-R			
		Sag		Swell	
		Fuzzy SPWM	Fuzzy SVPWM	Fuzzy SPWM	Fuzzy SVPWM
V_l	45.1	2.16	1.93	2.16	1.93
I_l	45.1	26.99	24.46	26.99	24.46

Table 7: Case (b): Three 1phase rectifier load

Parameters	Without UPQC	With UPQC-L (Fuzzy SVPWM)		With UPQC-R (Fuzzy SVPWM)	
		Sag	Swell	Sag	Swell
V_l	31.52	2.22	2.22	1.91	1.91
I_l	31.52	26.99	26.99	19.36	19.36

THD of V_l and I_l of various cases is calculated. Table 5, Table6 gives the THD comparison of SVPWM, SPWM techniques with FLC for both UPQC-L & UPQC-R of 3phase load. Similarly, table 7 gives the THD comparison of SVPWM technique with FLC for both UPQC-R & UPQC-L of three 1phase loads. From the table 5, 6 clearly SVPWM based FLC technique provides lower THD compares to SPWM.

4. CONCLUSION

This document provides the work investigation for UPQC-L shunt with fuzzy SPWM technique, fuzzy SVPWM technique, UPQC-R shunt with fuzzy SPWM technique and fuzzy SVPWM technique**.** Evaluating the outcome, we discover that the UPQC-R shunt with FLC based on SVPWM gives the enhanced results compared to UPQC-L with SVPWM technique for both sag and swell conditions for different nonlinear loads. From simulation analysis, SVPWM technique gives better results when compared to SPWM technique as the switching losses are reduced.

REFERENCES

[1]. B. S. Mohammed, K. S. Rama Rao, R. Ibrahim, N. Perumal Department of Electrical and Electronic Engineering **Performance Evaluation of R-UPQC and L-UPQC Based on a Novel Voltage Detection Algorithm** 2012 IEEE symposium on industrial electronics and applications (ISIEA2012) September 23 26, 2012, bandung Indonesia. https://doi.org/10.1109/ISIEA.2012.6496621

[2]. Amit Kumar Yadav, Sachin Tiwari and Kaushik Kumar Pandey **Power Quality Improvement Using Left Shunt Unified Power Quality Conditioner** Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 4, Number 5 (2014), pp. 429-436 © Research India Publications.

[3]. Mojtaba Yavari, Sayyed Hossein Edjtahed, Seyed Abbas Taher **A non-linear controller design for UPQC in distribution systems** Alexandria Engineering Journal (2018) 57, 3387–3404 hosted by Elseveir. https://doi.org/10.1016/j.aej.2018.02.002

[4]. Rajesh Kumar Patjoshi , Kamalakanta Mahapatra **Resistive optimization with enhanced PLL based nonlinear variable gain fuzzy hysteresis control strategy for unified power quality conditioner**

Electrical Power and Energy Systems 83 (2016) 352–363 Elseveir
https://doi.org/10.1016/j.ijepes.2016.03.040

[5]. Vinod Khadkikar, Member, **IEEE Enhancing electric Power quality Using UPQC: A comprehensive review** IEEE transactions on power electronics, vol 27 No 5, may 2012
https://doi.org/10.1109/TPEL.2011.2172001

[6]. Yashaswini H N, Dr. S.G.Srivani **Performance Analysis of a Non-inverting DC-DC Buck-Boost Converter with PI Controller** International Journal of Emerging Technologies in Engineering Research (IJETER) Volume 7, Issue 5, May (2019)

[7]. M. Sowmiya, Dr. D. Murali **Performance Analysis of a Non-inverting DC-DC Buck-Boost Converter with PI** Controller International Journal of Emerging Technologies in Engineering Research (IJETER) Volume 7, Issue 7, July (2019)