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JOURNAL

Adaptive FLC Based UPQC in Distribution Power Systems for Power Quality Problems

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Key words: UPQC, adaptive FLC, voltage sag/swells, active power filter MATLAB/Simulink

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Page No.: 149-157
Volume: 15, Issue 6, 2020
ISSN: 1816-9155
Agricultural Journal

Abstract: This study proposes UPQC to enhance all Power Quality issues. The UPQC is outlined by consolidating a series APF and shunt APF. The adaptable FLC together with Series APF controls the voltage distortion. Shunt APF's operation is controlled by d-q axes current from load current and DC-interface voltage is maintained through adaptable FLC. The stationary and transient action of controller circuit in various load current and variable voltage conditions is discussed. A versatile FLC is planned for the plant when its parameters are changing. The UPQC is used with static and switching nonlinear burdens. It can reduce voltage sag/swell, voltage variations and eliminates harmonics and so on. The proposed controller is implemented by using MATLAB.

INTRODUCTION

Power Quality (PQ) has become an important concern at utility point of view. The Nonlinear load equipment's have a substantial influence on the feature of electric power source[1]. The nonlinear loads/equipment such as SMPS, lamps, Arc-wielding etc. produce harmonics and hence, infect the power distribution system. In such conditions maintaining the quality of electric power is very difficult at both the ends[2]. Some customers need a basic level of P.Q. than the level provided by modern electric networks, but some require very high level of P.Q. than the level provided. According to system structure, APFs may be categorized into Series APF and/or Shunt APF[3]. The Series APF controls the voltage distortion and shunt APF controls current based distortion and these two combined with common DC-interface capacitor is called as UPQC. The UPQC mitigates the two power quality issues at the same time and independently[4]. It is an all-inclusive device that can compensate all P.Q. issues. The impact of a swell can be most dangerous at that point list. Because of sudden change of line current through the source impedance the swell will be exhibited in the system. The state investigation of UPQC amid voltage sag/swells on the framework is one of the highest notches by Mukassir *et al*.[5].

To continue the supply voltage at load to be sinusoidal and to deliver a stream of genuine and receptive power under these conditions, UPQC is arranged with two converters (VSC) consecutively through a typical DC interface capacitor. Series and shunt APF are used for minimizing distortions. For receptive power compensated and maintain DC-interface capacitor, shunt.

APF is utilized and is controlled by d-q axis segment of load current[6]. Reference current is utilized for producing exchanging beats of Shunt Compensator to manage the DC-interface capacitor voltage. PI Controlleris employed to hold the VDC at the reference

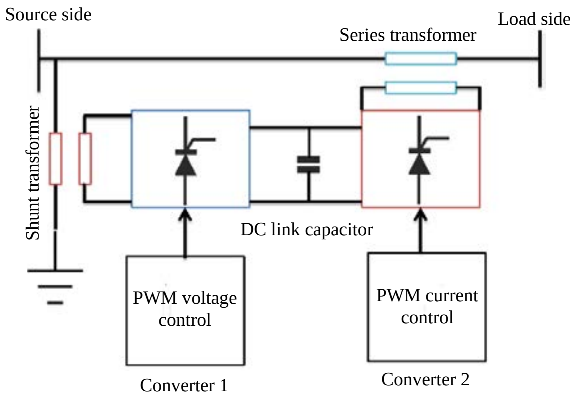

Fig. 1: Block diagram of UPQC

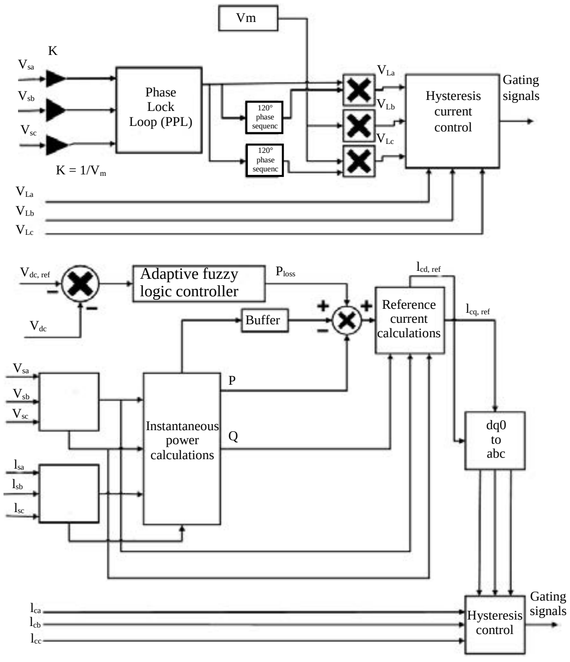

Fig. 2: Series APF configuration and shunt APF configuration

level. To defeat the moderate dynamic reaction with PI-Controller in DC-interface voltage, a superior versatile FLC is proposed[7]. The DC-interface capacitor voltage is sustained with the utilization of FLC. The arrangement of APF which is implemented for voltage sag/swell is done by using FLC[8] (Fig. 1).

Series APF control algorithm: The series APF is created on the concept of Unit Vector Model (UVM) as proposed by Woo *et al*.[9]. The UVM is extracted from the deformed supply. The natural process and control algorithm is shown in Fig. 2.

Shunt APF control algorithm: p-q theory used for controlling the active power filters. Transformation of 3-φ voltages currents from abc to dq coordinates by utilizing these modeling equations. The natural process and control algorithm is shown in Fig. 2:

$$\begin{bmatrix} \upsilon_0 \\ \upsilon_d \\ \upsilon_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \upsilon_{s,a} \\ \upsilon_{s,b} \\ \upsilon_{s,c} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_0 \\ i_d \\ i_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{s,a} \\ i_{s,b} \\ i_{s,c} \end{bmatrix} \quad (2)$$

P and Q components are obtained by the give relation in Eq. 3. Where P and Q components are function of load current and Phase voltages:

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} \upsilon_d & \upsilon_q \\ -\upsilon_q & \upsilon_d \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} \quad (3)$$

$$P_0 = V_0 \times I_0 \quad (4)$$

$$P = \bar{P} + \tilde{P} \quad (5)$$

$$\begin{bmatrix} I_{cd,ref} \\ I_{cq,ref} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} V_\alpha & -V_\beta \\ V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} -\bar{P} + P_0 + \overline{P_{loss}} \\ -Q \end{bmatrix} \quad (6)$$

where, I_{cd-ref} and I_{cq-ref} are reference currents of shunt-APF in d-q coordinates. These currents are changed to 3-φ system as shown in Eq. 7:

$$\begin{bmatrix} i_0 \\ i_d \\ i_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{cd,ref} \\ i_{cq,ref} \end{bmatrix} \quad (7)$$

The reference current in 3-phase system (Ica, ref, Icb, ref, Icc, ref) are measured in direction to alter neutral", harmonic and reactive current at the load. Hysteresis band current control algorithm[10] is used to produce switching signal by comparing actual signal with reference signal, depending on speed and accuracy of reference signal the performance of UPQC can be improved.

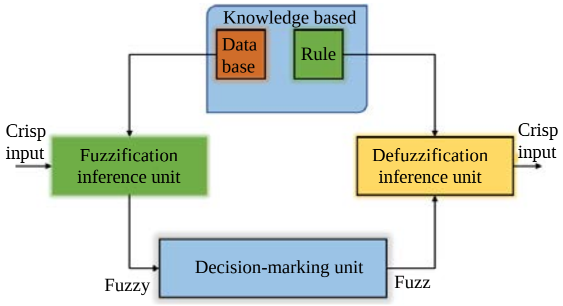

Fig. 3: Block diagram of fuzzy inference system

MATERIALS AND METHODS

The design procedure for a adaptive FLC contains four parts: defining the i/p and o/p; intellectual of fuzzification and fuzzy logic; defuzzification and parameters operational self-tuning of PI controller (Fig. 3).

Defining input and output: The inputs of the FLC are the error E (E = V_{dcref}-V_{dc}) and the error rate is EC. The inputs are incessantly monitored and designed by the FLC, so the PI controller parameters are attuned online via the fuzzy logic rules to obtain optimal parameters.

Since, the FLC inputs in the adaptive FLC, ‘E’ and ‘C’ may fulfill the PI self-calibration requirements at various times. The input and output consist of seven membership functions respectively. These membership functions of the variables is shown in Fig. 4 and 5. The membership functions of K_p and K_i are designed as shown in Fig. 5.

The fuzzy set field ranges of input and output variables are attained by simple design of standardization. The fuzzy set field of input variables is set as E, ΔE = {-3, -2, -1, 0, 1, 2, 3} and the fuzzy set field of outputs ΔKP, ΔKi are set as {-0.6, 0.6} and {-0.06, 0.06}, respectively (Fig. 6).

Learning part: The learning part of the adaptive FLC includes performance feedback where the performance index works nearby conveying a recognition or recompence to discrete control activities that gives to the existing performance and produces an optimal state[11].

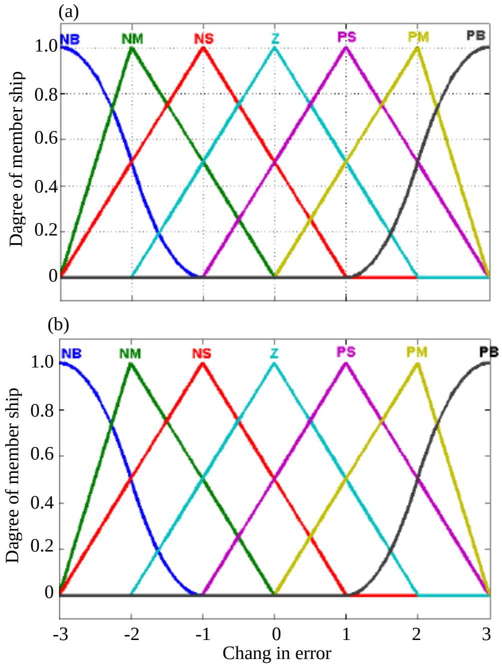

Fig. 4(a, b): Membership functions of input variables: (a) E and (b) ΔE

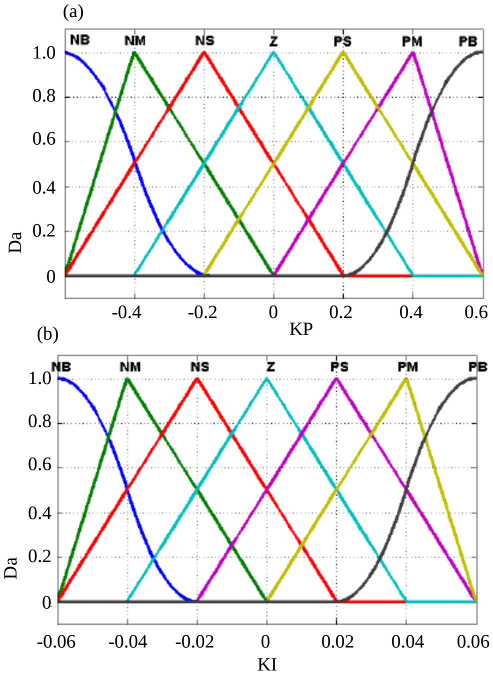

Fig. 5(a, b): Membership functions of output variables: (a) ΔKP and (b) Δki

To produce an optimal constraint state constructed on the fuzzy inference, collection of an output control signal[11] such as Power loss (in practice, parameters of the plant vary: harmonics voltage distortions and current distortions etc...) is required. Same membership functions may be used for these variables as in the previous case by adjusting the implication table of FLC to continue voltage and current at sending end and delivery end sides. The projected adaptive FLC based UPQC is put into provision to mitigate both voltage sag and load current harmonics. The determined value of the reference currents is calculated by altering the DC interface voltage. The

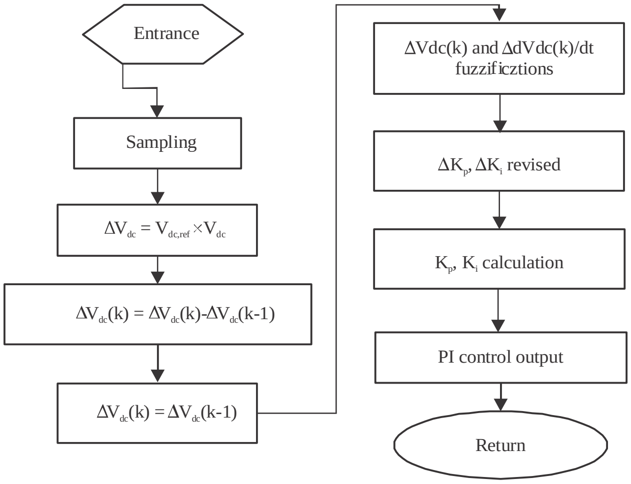

Fig. 6: Flow chart of parameters online regulation

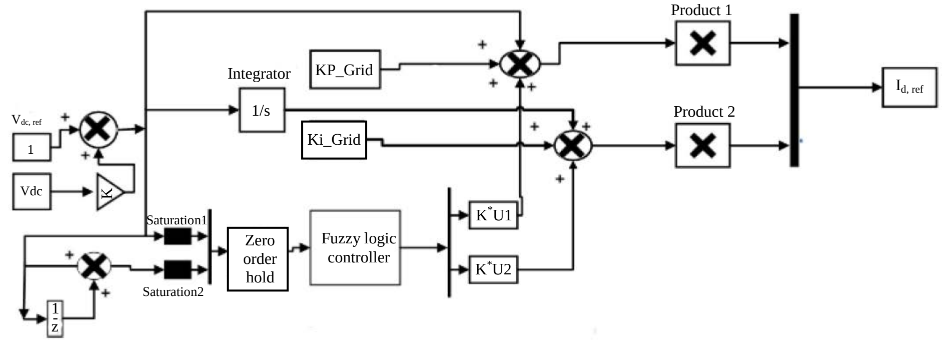

Fig. 7: Proposed adaptive FLC

Table 1: Rule table

Error/Change in error	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

voltage on the current capacitor is related with a reference value. The error signal is at that moment managed through an FLC which underwrites to a constant error of zero signals tracking of the signal. To sustain constant DC interconnection voltage, FLC is supplementary to the d-axis under d-q0 to govern the active current component. The FLC controls this minor quantity of active current and the current regulator then adjusts the current to continue the DC interface voltage. Figure 7 shows the fuzzy systems have been working effectively in the adaptive control problems of nonlinear systems. It is exposed that the properties of estimated errors and exterior disturbance can be reduced to a specific reduction level using the proposed adaptive FLC structure. We syndicate the features of fuzzy systems, the performance of feedback linearization, the adaptive control structure and Optimal Control theory with goal to explain the tracking controller strategy problem for nonlinear systems with limited unknown or undefined parameters and external disturbance[12] (Table 1).

RESULTS AND DISCUSSION

Figure 8 shows that after the execution of adaptive based UPQC, the input current goes to sinusoidal. It is successfully mitigating the current harmonics. The simulation is carried out for a period of 0.0-0.5 sec and 0.5-1.0 sec as shown in Fig. 8 and 9. The adaptive fuzzy based UPQC recompenses the sag/swells in voltage successfully as shown Fig. 8 and 9. After applying adaptive FLC based UPQC, the sag/swell is not affected. In Fig. 8, first wave form shows grid voltage with swell, affected and then injected voltage is shown in third wave form and both combined together, the compensated load voltage is shown in second waveform. Figure 10a-c shows

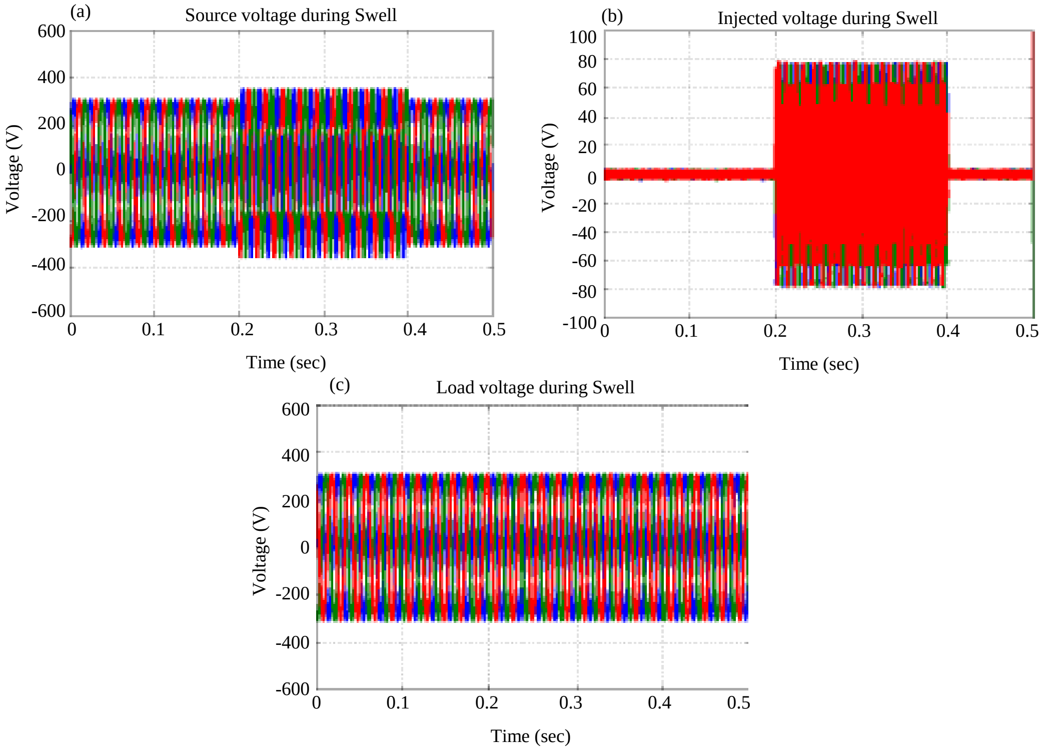

Fig. 8(a-c): Simulation results for V_{source}, V_{inj} and V_{load} during swell

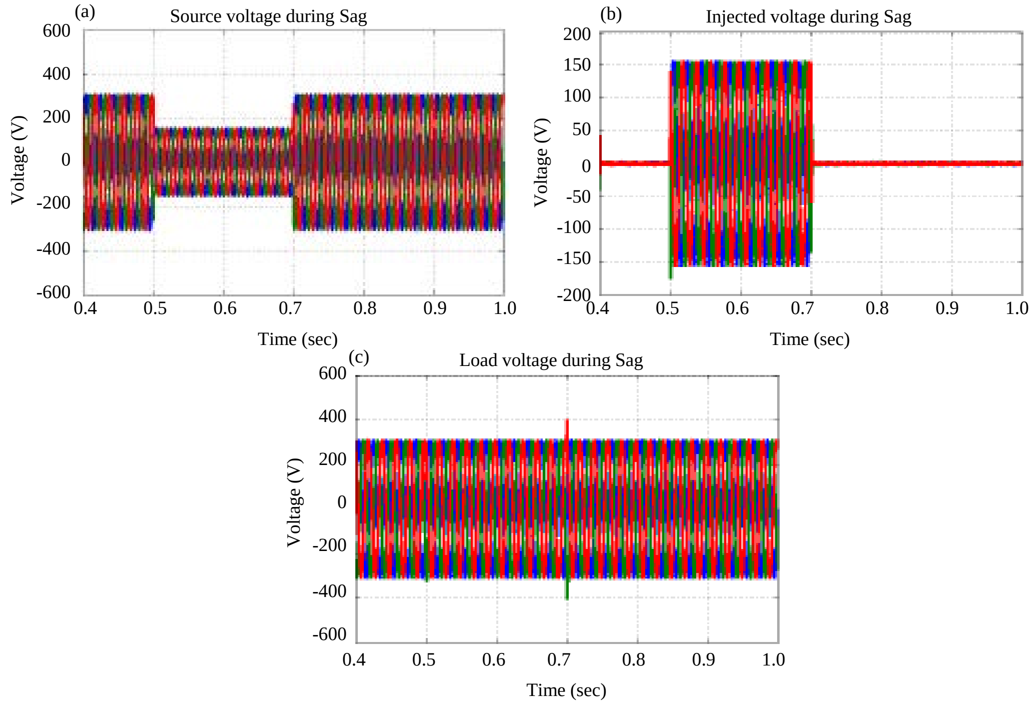

Fig. 9(a-c): Simulation results for V_{source}, V_{inj} and V_{load} during sag

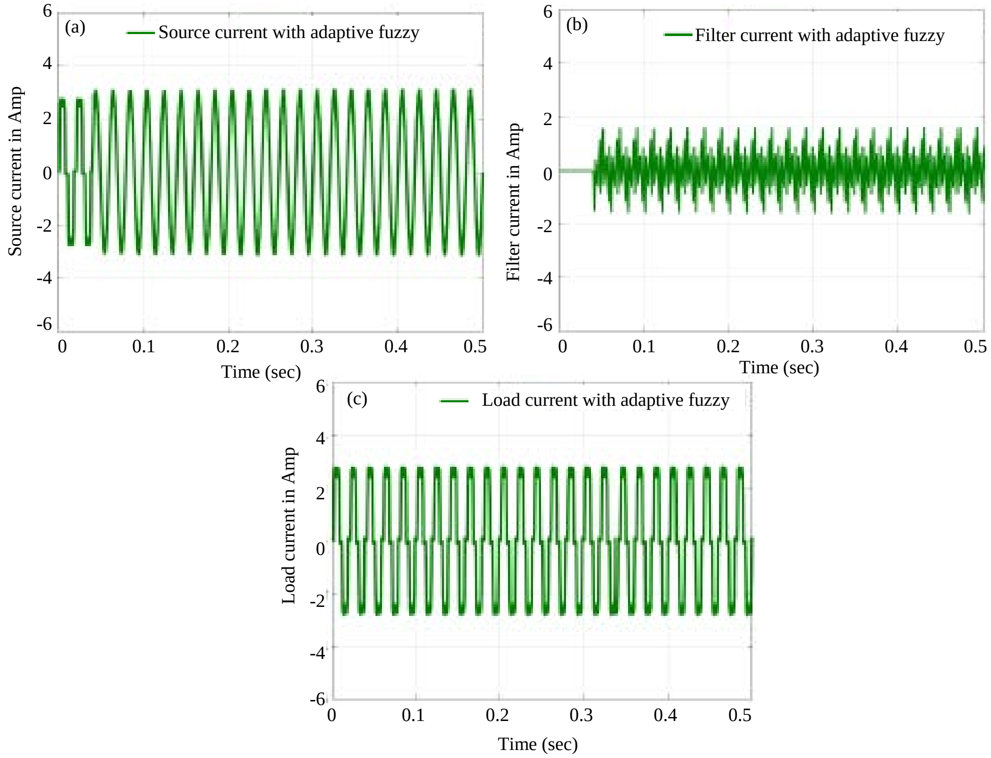

Fig. 10(a-c): Simulation result for I_{source}, I_{filter} and I_{load}

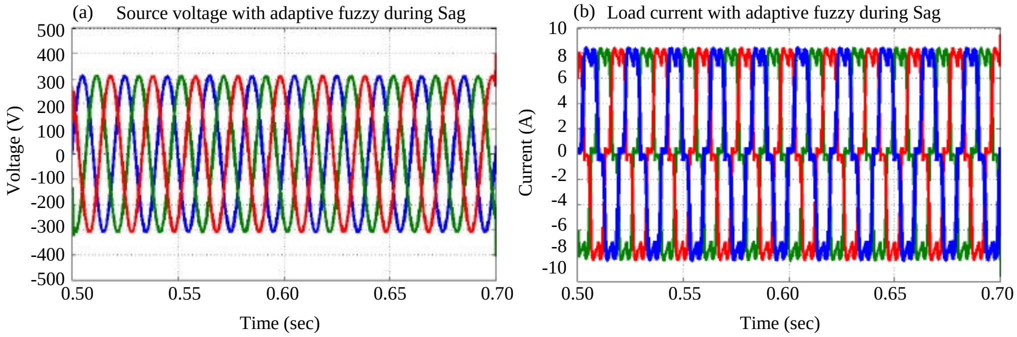

Fig. 11(a, b): Simulation result for V_{source} and I_{load}

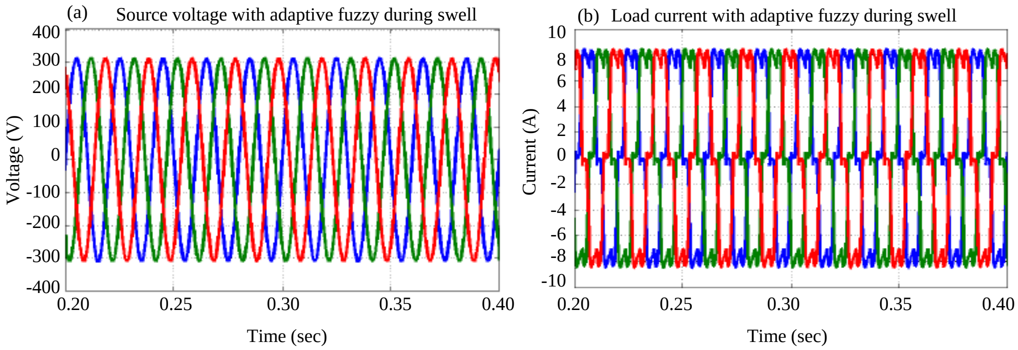

Fig. 12(a, b): Simulation result for V_{source} and I_{load}

the I_{source}, I_{Filter} and I_{Load}, respectively. Simulation results for source voltage and load current is shown in Fig. 11a, b and 12a, b, respectively during the sag/swell after implementation of adaptive FLC. THD for grid and load current, grid and load voltage” is shown in Fig. 13a, b, 12b and 14a, respectively (Table 2).

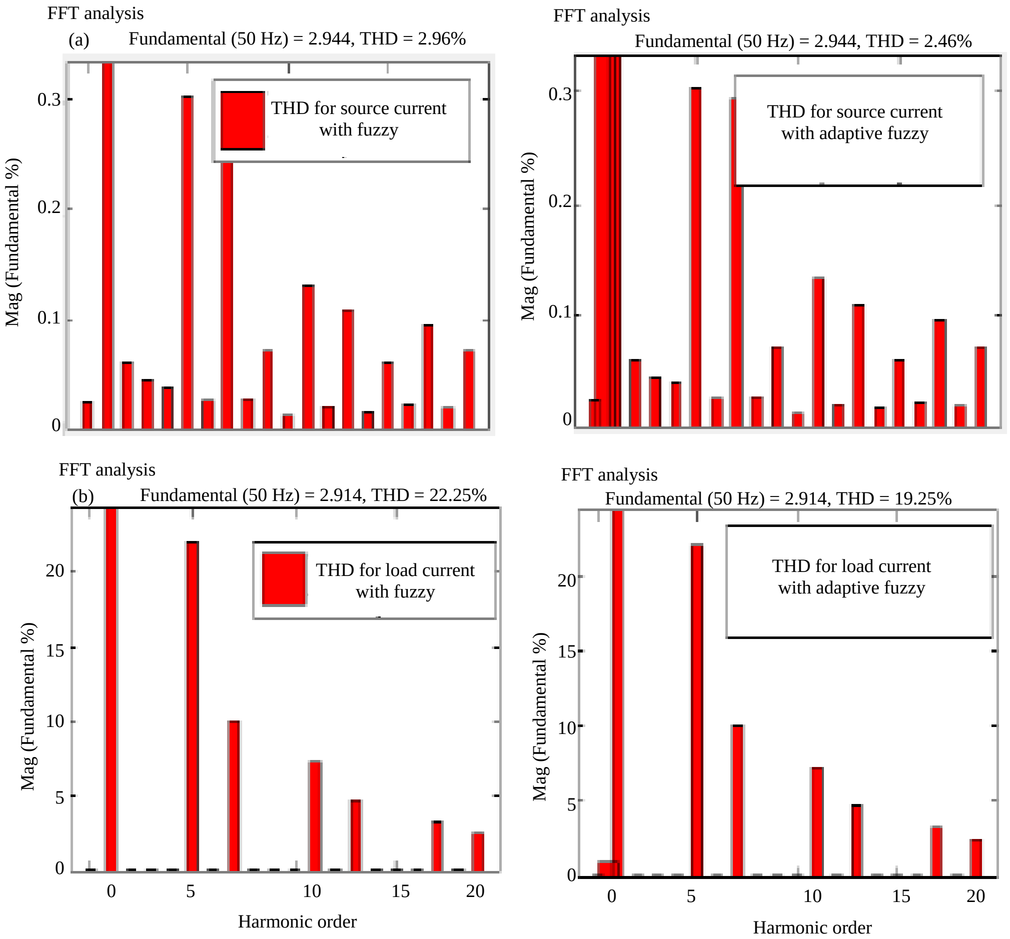

Fig. 13(a, b): THD for I_{source} and I_{load} with fuzzy and adaptive fuzzy

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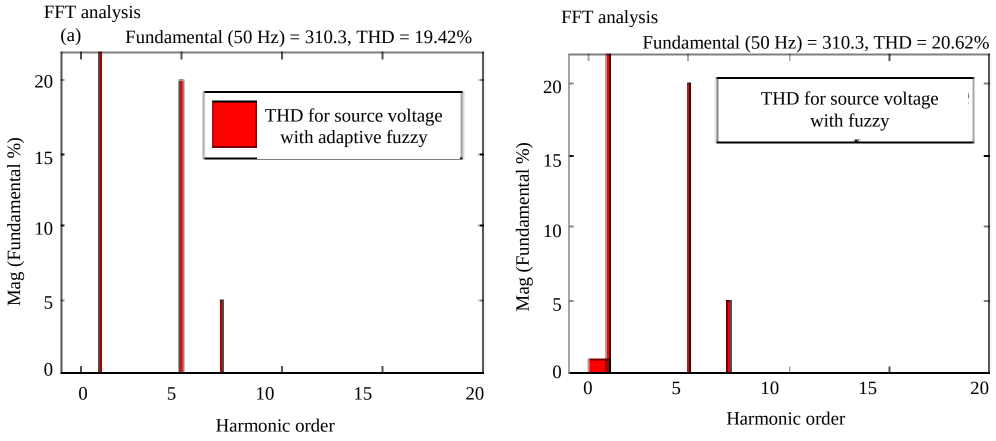

Fig. 14(a, b): Continue

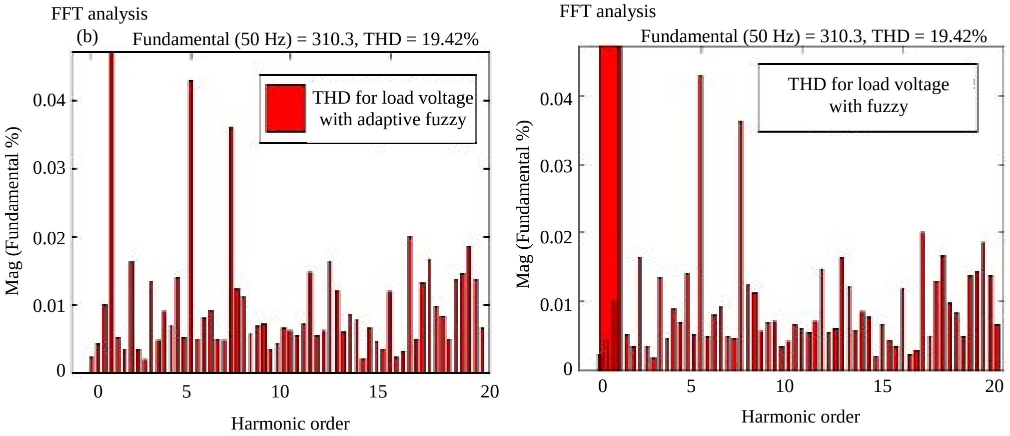

Fig. 14(a, b): THD for V_{source} and V_{load} with fuzzy and adaptive fuzzy

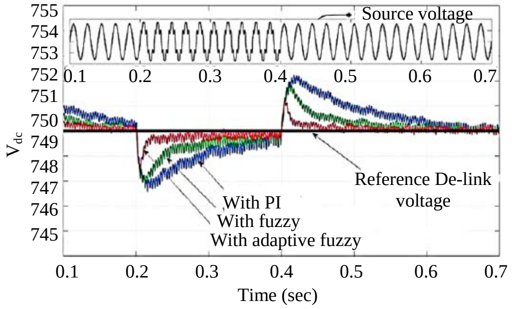

Fig. 15: Regulation of DC-link voltage with PI, fuzzy and adaptive fuzzy

Table 2: Comparison THD with fuzzy and adaptive fuzzy

	THD (%)			
Controller	Source current	Load current	Source voltage	Load voltage
With fuzzy	2.96	20.55	20.62	0.79
With adaptive fuzzy	2.46	19.25	19.42	0.49

CONCLUSION

The UPQC is designed by combining a series and shunt-APF. Adaptive FLC controls voltage distortions with the Series-APF. The operation of the APF bypass is well-ordered by the dc current of the load current and the intermediate circuit voltage is maintained through the adaptive FLC. The stationary and dynamic operation of the control circuit under different current and/or voltage conditions are studied by the simulation and results are tabulated. Performance of the proposed system is compared with the customary UPQC without adaptive fuzzy. By proposed controller it achieved, at nominal load, reactive power compensated and harmonic components of the load currents give rise to UPF. Almost UPF is retained at any load. Stable voltage regulation has been obtained during voltage distortion. Losses in VSI and power supply are considerably decreased. Simulation results show that the proposed system with UPQC has got the ability to solve the various PQ issues (related to voltage and current). The UPQC is tested with static and non-linear switching loads. It is able to reduce sag/swell, voltage fluctuations, eliminate harmonics, current distortions, etc.

REFERENCES

01. Xiao, Y., Y.H. Song, C.C. Liu and Y.Z. Sun, 2003. Available transfer capability enhancement using FACTS devices. IEEE. Trans. Power Syst., 18: 305-312.
02. Krishna, D., M. Sasikala and V. Ganesh, 2017. Mathematical modeling and simulation of UPQC in distributed power systems. Proceedings of the 2017 IEEE International Conference on Electrical, Instrumentation and Communication Engineering (ICEICE'17), April 27-28, 2017, IEEE, Karur, India, pp: 1-5.
03. Khadkikar, V., 2012. Enhancing electric power quality using UPQC: A comprehensive overview. IEEE Trans. Power Electron., 27: 2288-2297.
04. Modesto, R.A., S.A.O. Da Silva, A.A. De Oliveira and V.D. Bacon, 2015. A versatile unified power quality conditioner applied to three-phase four-wire distribution systems using a dual control strategy. IEEE. Trans. Power Electron., 31: 5503-5514.
05. Mukassir, S.M., S.M.M. Mudassir, S. Sultana and D. Giribabu, 2017. The new trend in power conditioning using Multi-Converter Unified Power-Quality Conditioning (MC-UPQC) for multi feeder system. Proceedings of the 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS'17), August 1-2, 2017, IEEE, Chennai, India, pp: 3356-3361.

06. Senapati, R., R.K. Sahoo, R.N. Senapati and P.C. Panda, 2016. Performance evaluation of sinusoidal current control strategy unified power quality conditioner. Proceedings of the 2016 International Conference on Electrical, Electronics and Optimization Techniques (ICEEOT'16), March 3-5, 2016, IEEE, Chennai, India, pp: 1404-1408.
07. Khonde, S.S., S.S. Dhamse and A.G. Thosar, 2014. Power quality enhancement of standard IEEE 14 bus system using unified power flow controller. Int. J. Eng. Sci. Innovative Technol., 3: 323-334.
08. Titus, S., B.J. Vinothbabu and I.M.A. Nishanth, 2013. Power system stability enhancement under three phase fault with FACTS devices TCSC, STATCOM and UPFC. Int. J. Sci. Res. Publ., Vol. 3, No. 3.
09. Woo, S.M., D.W. Kang, W.C. Lee and D.S. Hyun, 2001. The distribution STATCOM for reducing the effect of voltage sag and swell. Proceedings of the 27th Annual Conference of the IEEE Industrial Electronics Society (IECON'01) (Cat. No. 37243'01), November 29-December 2, 2001, IEEE, Denver, Colorado, USA., pp: 1132-1137.
10. Muni, B.P., S.E. Rao and J.V.R. Vithal, 2006. SVPWM switched DSTATCOM for power factor and voltage sag compensation. Proceedings of the 2006 International Conference on Power Electronic, Drives and Energy Systems, December 12-15, 2006, IEEE, New Delhi, India, pp: 1-6.
11. Bigand, A. and K. Messaadi, 1996. State observers fuzzy controller for real-time process. Proceedings of the 1996 IEEE International Conference on Systems, Man and Cybernetics: Information Intelligence and Systems (Cat. No. 96CH35929'96), October 14-17, 1996, IEEE, Beijing, China, pp: 2564-2568.