International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

Fuzzy Logic Controlled Three-Phase Improved Power Quality Converter for Disturbed AC Mains

Deepak Sharma[1], Abdul Hamid Bhat[2], Aijaz Ahmad[3]
[1, 2, 3]National Institute of Technology, Department of Electrical Engineering Srinagar, Jammu and Kashmir, India
Email address: [1]deepaksmail99@yahoo.com, [2]bhatdee@nitsri.net, [3]aijazahmad45@gmail.com

Abstract**—** This paper presents Fuzzy Logic control approach for better performance of Three-phase Improved Power Quality Converters (IPQC) with distorted and unbalanced AC Mains. Space vector modulation (SVM) algorithm has been used for the control of the Converter. The trajectory of reference vector of SVM technique plays an very important role to obtain exact switching times under distorted and unbalanced ac mains. Due to disturbed supply, trajectory of reference vector gets affected which results in low input power factor, high input current THD and high ripple factor of the DC output voltage. Our Proposed control approach implements Fuzzy Logic control for three-Phase Improved Power Quality Converter to retransformation of Clarke Transformation for disturbed supply. At the time of any disturbance, an error signal is generated which is processed by controller based on Fuzzy Logic theory to adjust the switching times for each devices in each legs of the converter in such a way so as to balance the current in all the phases with nearly unity input power factor, low input current THD and reduced ripple factor of the regulated DC output voltage. Three-Phase, IPQC system along with proposed control scheme is modeled in MATLAB/Simulink environment. Simulated results are presented to demonstrate the effectiveness of the new proposed control technique. Simulation results shows that the proposed implementation of Fuzzy Logic controller in Three-Phase IPQC displays better performance with nearly unity input power factor, low input current THD and reduced ripple factor of the regulated DC output voltage with distorted and unbalanced AC Mains, which are regularly uncounted in practical environment..

Keywords**—** Power quality, improved power quality converters, multilevel converters, harmonics compensation, unbalanced AC mains.

I. INTRODUCTION

SVPWM technique is very much in use as it gives nearly sinusoidal waveform for source currents at near unity power factor. It also increases the voltage by 15% for same modulation index. It also results in low switching frequency for same performance as compared to SPWM. Three-phase IPQC, as shown in Fig.1provides smooth powering and regeneration capability with 6 semi conductor power switches. Its current regulators can control the power factor close to unity and the boost inductance L limits the magnitude of the input current ripple, thus reducing harmonics and it also serves as an energy-storage device to allow the overall converter circuit to act as a boost rectifier. Fig.2 shows the overall control scheme of the converter. The outer-loop PI voltage controller controls the magnitude of the reference space vector. Voltage control loop of the converter and the inner-loop PI current controllers controls the d and q components of the source current, resulting in the unity power factor operation of the converter. Under unbalanced AC mains, the trajectory vector is disturbed resulting in deviations of source and load side parameters beyond acceptable limits. These non- ideal supply conditions are regularly encountered in practical operating conditions resulting in the deteriorating performance of converter in real time applications. The stable operation of the IPQC under disturbed mains condition is a burning issue and has been a topic of intensive international research.

In the literature, limited work has been reported on the effects of the unbalanced voltage disturbances on converters. Most related work is based on detection and classification of the unbalanced supply in power system. There are some schemes reported in the literature [1-5] to overcome the problem of unbalance supply by providing insensitivity towards supply disturbances within certain limited ranges. The scheme is based on providing insensitivity towards supply disturbances using inverse Clarke Transformation. But no compensation technique is reported for optimizing the performance of the converter using SVPWM under unbalanced main condition. This problem can be solved by applying the artificial fuzzy logic technique.

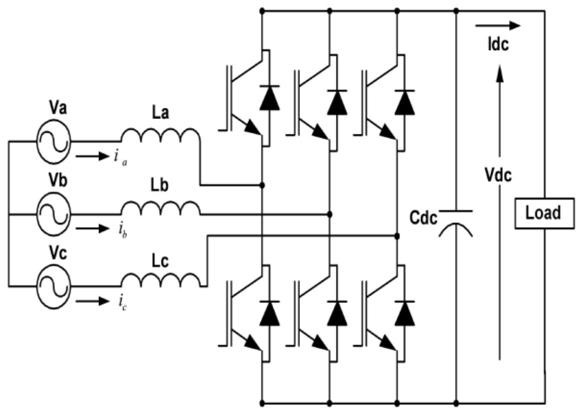


Fig. 1. Bi-directional three-phase boost converter.

Fuzzy set theory in 1965 forms the basis of Fuzzy logic control; where transition occurs between membership and non membership function. Thus, limitation of fuzzy sets can be undefined and ambiguous; FLCs are an excellent choice when precise mathematical formula calculations are not possible. Fuzzy logic theory is considered as a mathematical approach which combines multi-valued logic, probability theory, and artificial intelligence to represent the human approach so as to reach the solution of a specific problem by means of

Deepak Sharma, Abdul Hamid Bhat, and Aijaz Ahmad, "Fuzzy logic controlled three-phase improved power quality converter for disturbed AC mains," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 4, pp. 1-6, 2016.

ISSN: 2454-1532

approximate reasoning relating different data sets and making decisions. The performance of Fuzzy Logic Controllers is well implemented in the field of control theory because it provides robustness to dynamic system parameter variations as well as improved transient and steady state performances. In this paper an attempt has been made to minimize the effect of disturbed ac supply and to maintain source and load parameters within acceptable limits i.e. nearly unity input power factor, low input current THD and reduced ripple factor of the regulated DC output voltage using a fuzzy logic controller.

II. Mathematic Modeling of Reference Voltage Vector

The reference voltage vector 'Vs' is obtained by mapping three phase output voltages (line to neutral) in the (d-q) frame through the Clarke transform given by,

$$\begin{bmatrix} v_d \\ v_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & \frac{1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} v_{AN} \\ v_{BN} \\ v_{CN} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} I_d \\ I_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & \frac{1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} I_a \\ Ib \\ I_c \end{bmatrix} \quad (2)$$

Under balanced three phase sinusoidal voltages, Vs is a vector rotating, forming a circular trajectory in shape in the complex (α - β) plane at constant amplitude with fundamental angular speed. This circular trajectory is sampled instantly in each 600 in order to have 6 active vectors sector for two level three-phase rectifiers. There are two more non active sectors .So there are eight basic space vectors defined for the combination of the switches.Proposed fuzzy logic controller is used to form a required reference space vector trajectory for particular unbalanced magnitude in respective phase(s) by modifying current vector of Clarke Transformation in order to minimize the effect of unbalanced voltage disturbances as shown in fig 2.

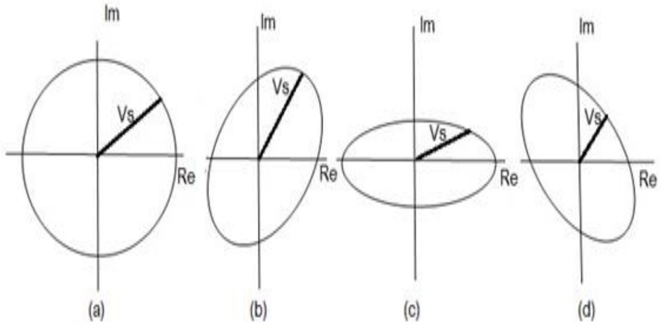


Fig. 2 Require shape of the space vector trajectory for better performance of IPQC a) Under balanced condition. b) Sag in phase A. c) Sag in phase B. d) Sag in phase C.

Modified reference space vector will modify modulation index, so as to vary duty cycle ratio of each leg of the IPQC. In order to have modified modulation in each sector, it is required to generate the reference vector Vs for that particular sector. Time average of the associated basic space vectors is required for each sector, which is synthesized as a linear combination of the two adjacent space vectors, Ux and Uy which form any sector.

Vs= TaUx + TbUy + ToUz (3)

where Ux, Uy are the active vectors and Uz is the zero vector, Ta, Tb and To are the respective duty ratios .

The sum of duty ratios for a PWM period is always constant i.e.

Ta + Tb + To = constant value (4)

and the magnitude of the Vs depends on the duty ratio of active vectors only as zero vectors makes no effect on the IPQC voltage but are used for balancing the voltage.

From equation (1), Vs magnitude in respective sector affects the duty ratios Ta, Tb, To will change accordingly but the total sum of the duty ratios in the each sector will remain same (i.e. Ta + Tb + To = Constant value). Therefore switching time for a switching state can be increased or decreased according to requirement.

Vs=MVmax=TaUx+TbUy+ToUz (5)

where M is the modulation index and Vmax is the maximum value of the desired dc voltage

III. Proposed Algorithm

In many developing modern technologies demand for Fuzzy Logic controlled applications has increased. In various cases, the mathematical model of the control process is very difficult to implement with respect to computer processing power and memory and a system based on factual rules may be morel adequate. Furthermore, fuzzy logic is perfectly suited to low cost implementations based on less-resolution A/D converters, cheap sensors and 4-bit or 8-bit one-chip microcontroller chips. To enhance performance or add new attributes, new rules can be easily added in such type of systems. Fuzzy logic control can be used to improving the existing conventional controller systems by an additional layer of intelligence to the current control method. Fuzzy logic controller is chosen over the conventional PI and PID controller due to its robustness to system parameter variations during operation and it being simple in its implementation. There are two types of fuzzy models generally used i.e. Mamdani Fuzzy models as well as sugeno fuzzy models. Mamdani method is widely accepted for capturing expert knowledge. It allows us to describe the expertise in more intuitive, more human-like manner. In this paper Mamdani type fuzzy model is used.The basic theory of the proposed controller is form a particular trajectory of the space vector under undisturbed/disturbed ac mains. The proposed fuzzy logic controllers as shown in fig 3.

Deepak Sharma, Abdul Hamid Bhat, and Aijaz Ahmad, "Fuzzy logic controlled three-phase improved power quality converter for disturbed AC mains," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 4, pp. 1-6, 2016.

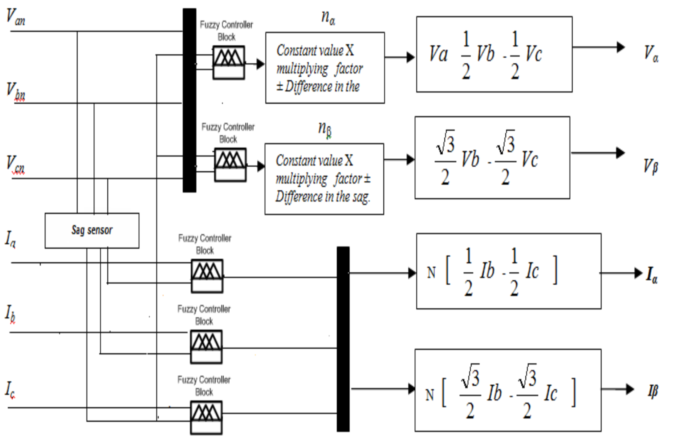
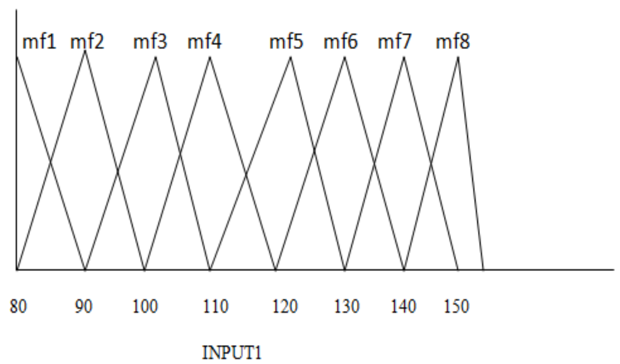


Fig. 3. Basic block diagram proposed fuzzy logic controller for retransformation of Clarke Transformation.

retransform the Clark Transformation for improving the power quality of IPQC under disturbed supply by making use of adjustable suitable weight at the input power side of converter. Weights at input supply sides for current vector are adjusted linearly in proportional to variation till same current flows in all the phases by the fuzzy logic controller.

The main inconvenience in already proposed algorithms is reported in the literature that they need consistent details of exact measurements of error at each step till iteration process stops. This is not practical in real time applications where system cannot wait even for the completion of one cycle for the generation of error. So there is desperately a need of an algorithm for deriving estimates only from whatever available data. This is achieved by retransformation of Clarks Transformation with the help of fuzzy logic controller for whatever data is available. The fuzzy logic based control scheme makes decision can be divided into three main functional blocks namely Fuzzification, Decision Making and Defuzzification. The fuzzy set representing the controller output in linguistic labels has to be converted back into a Crisp solution variable before it can be used to control the system. This is attained by using a defuzzifier. Several methods of defuzzification are available. One of the most common methods selected for Defuzzification is ‘sugeno’s wtaver (weighted average) method. Reference Fuzzy Sets is shown in Fig. 4a for Valpha and Vbeta and Fig.- 4b for Ia and Ib



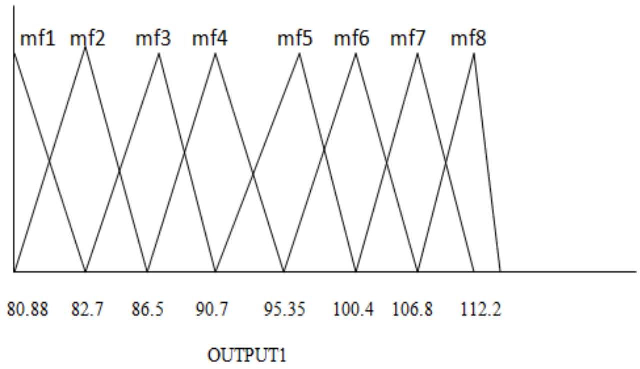


Fig. 4 a) Reference Fuzzy Sets for Valpha and Vbeta

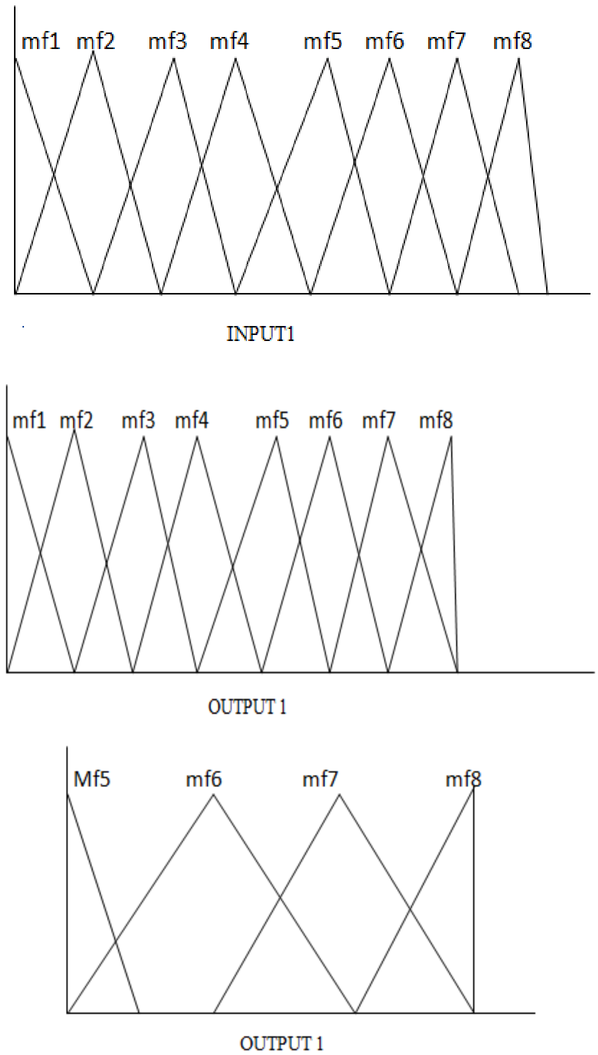


Fig. 4 b) Reference Fuzzy Sets for Ia and Ib.

IV. PERFORMANCE EVALUATION

The performance of traditionally controlled IPQC and proposed Control of IPQC under unbalanced condition converter is evaluated using MATLAB/Simulink and SimPower System environment. For Three-Phase, bidirectional rectifier, the system parameters are: Peak Input Phase Voltage =155.6 V, 50Hz.Boost inductance = 1mH, operating frequency

Deepak Sharma, Abdul Hamid Bhat, and Aijaz Ahmad, “Fuzzy logic controlled three-phase improved power quality converter for disturbed AC mains,” *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 4, pp. 1-6, 2016.

ISSN: 2454-1532

is 5 KHz. The desired DC-link voltage of the proposed rectifier is set at 400 V. Traditionally Control IPQC and Modified Control IPQC under disturbed supply condition.

At t=0.5 sec, the controller is tested by introducing voltage magnitude unbalance of peak input phase voltage 40 V in phase C and peak input phase voltage 155.6 V in phase A and B with injected harmonics up to 9th order. Comparative results from fig: 5 reveal that under unbalanced mains condition, there is low input power factor, high input current THD without controller. With proposed controller the maximum THD of the source currents Ia, Ib, Ic reduced to just 4.62%, 4.72%, 4.77% from 9.10%, 7.24%, 7.24% respectively, which is well within acceptable limits. Further with the proposed algorithm, there is no reduction in DC bus voltage and ripple content is negligible.

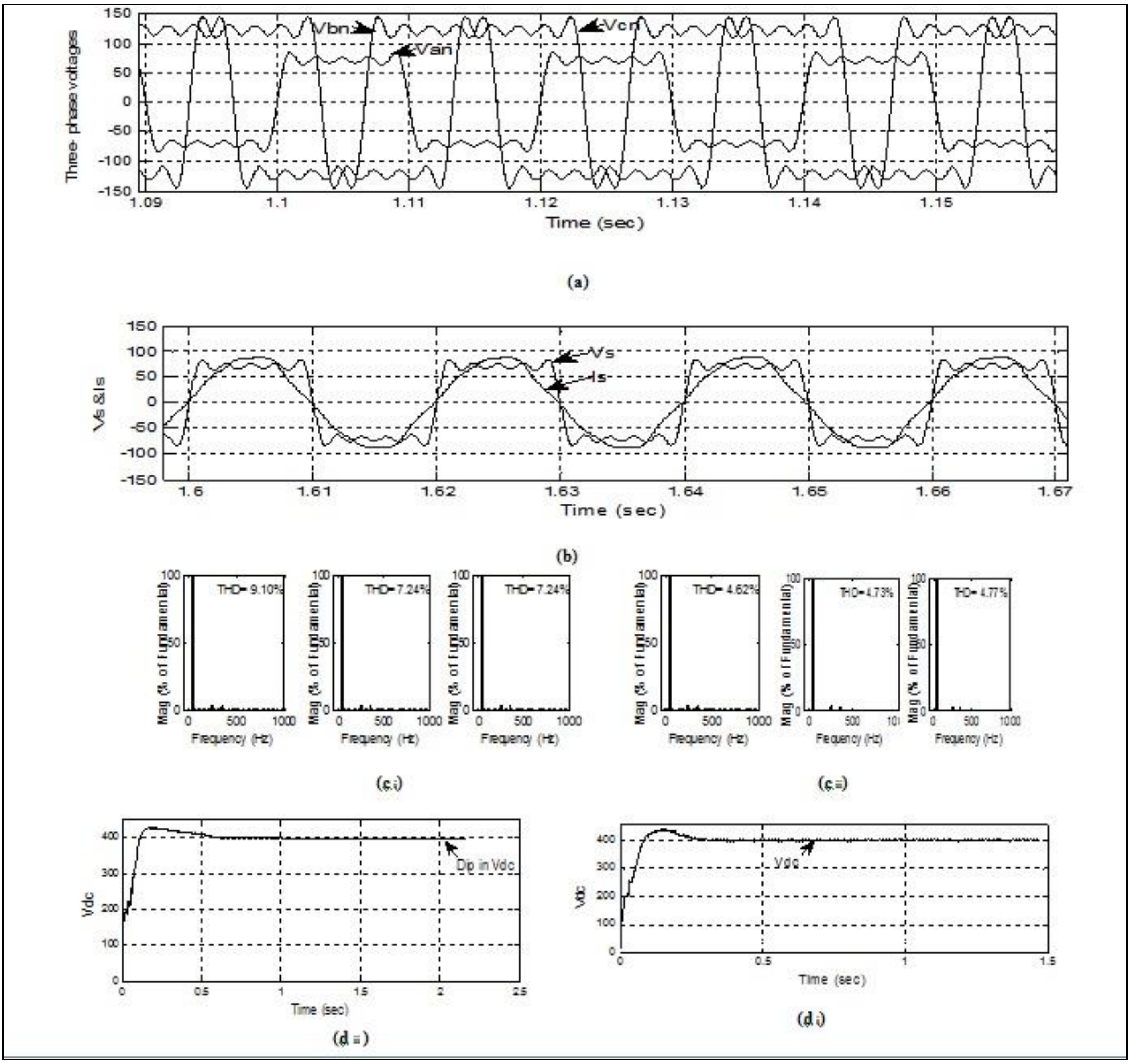


Fig. 5. Three-phase disturbed supply voltages.

a)Input phase voltage 40 V in phase C and peak input phase voltage 155.6 V in phase A and B with injected harmonics up to 9^{th} order.
b) Source voltages & currents with unity input supply power factor
c i) High THD of source currents Ia, Ib, Ic
c ii) Low THD of source currents Ia, Ib, Ic
d i) Less ripple with regulated V_{dc}

Deepak Sharma, Abdul Hamid Bhat, and Aijaz Ahmad, “Fuzzy logic controlled three-phase improved power quality converter for disturbed AC mains,” *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 4, pp. 1-6, 2016.

d ii) Less ripple with regulated V_{dc}

V. Conclusion

In this paper, a new technique based on Clarke transformation is proposed for unbalanced conditions and analysis is also done to mininise the effects on the balanced/ unbalanced voltage disturbances in the conventional SVPWM. Simulation results are explored using Matlab/Simulink software. Relevant figures and graphs have been shown to understand the conclusive results for the simulation model. The source current harmonics are compensated very effectively by using the new proposed technique and also at the same time maintaining unity input power factor, low input current THD and regulated DC output voltage. The proposed control algorithm proves to be very effective in addressing the voltage sags (balanced and unbalanced) which are practically encountered in real power system.

VI. References

[1] v. ignatova, p. granjon, s. bacha, and f. dumas, "classification and characterization of three phase voltage dips by space vector methodology," presented at the fps conf., 2005.

[2] A. H. Bhat and P. Agarwal,"Three-phase, power quality improvement AC-DC converters,"Elsevier Electric Power Systems Research, pp. 276-289, 2008.

[3] Saribulut, L. ; Tumay, M. "A robust SVM technique to minimize the effects of unbalanced voltage disturbances " Electrical and Electronics Engineering, 2009. ELECO 2009. International Conference on Publication Year: 2009 , Page(s): I-283 - I-287.

[4] Nitin Langer, Abdul Hamid Bhat Supply Perturbation Compensated Control Scheme for Three-Phase IPQC rectifier International journal of Electrical Power and Energy Systems Vol:54,p:17-25,2014.

[5] Deepak Sharma, Abdul Hamid Bhat and Aijaz Ahmad, "Performance evaluation of a three-phase improved power quality converter under unbalanced mains conditions", Journal of Scientific and Technical Advancements, Volume 1, Issue 3, pp. 17-21, 2015.

Deepak Sharma, Abdul Hamid Bhat, and Aijaz Ahmad, "Fuzzy logic controlled three-phase improved power quality converter for disturbed AC mains," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 4, pp. 1-6, 2016.

Deepak Sharma, Abdul Hamid Bhat, and Aijaz Ahmad, "Fuzzy logic controlled three-phase improved power quality converter for disturbed AC mains," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 4, pp. 1-6, 2016.