ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Implementation of Single-Phase Rectifier for Reduction of Input Current Harmonic Distortions by Using Fuzzy Logic Controller

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Abstract:
In this paper, the problem of controlling AC-DC full bridge converter is considered. The control objectives are two, one is guaranteeing a regulated voltage for the connected load and second one is enforcing power factor correction (PFC) with input current sinusoidal. Power factor correction of PWM converter is done by using fuzzy control technique. Power Factor Correction (PFC) provides well-known benefits to electric power systems. These benefits include power factor correction, poor power factor penalty utility bill reductions, voltage support, release of system capacity, and reduced system losses. The PFC strategy uses PI controllers to correct the input current shape and fuzzy controller to control the output voltage. A model for Power Factor Correction has been formed by using the MATLAB software. The produced model has also been simulated by using fuzzy logic tools. The simulation results show that the fuzzy controller for output voltage can achieve better dynamic response than its PI counterpart under lager load disturbance and plant uncertainties.

*Keywords-****AC-DC Converters, Harmonic Reduction, Power-Factor Correction, Fuzzy Logic Controller.***

I. INTRODUCTION

In the attempt to meet standard requirements (like IEC 555-2), many rectifier topologies and control techniques have been proposed, which provide almost unity power factor. In most solutions, however, the main effort is dedicated to improve the quality of the input current waveform, while dynamic response of the output voltage is sacrificed [3]. In fact, due to input power fluctuation, the output voltage contains a low frequency ripple at twice the line frequency, which must be outside the voltage loop bandwidth in order to avoid input current distortion.

In the attempt to overcome this limitation, average current control, which allows improved response to the detriment of a higher input current distortion, was proposed in [4], while other techniques, aimed to remove the low-frequency ripple from the feedback signal, were analyzed in [5]. Also the Fuzzy Logic Control (FLC) seems very powerful for this purpose: in fact, fuzzy control rules can be written so as to allow low-distorted and m-phase line current during normal operation and fast dynamic response during transient conditions.

In particular, in PFP's application the fuzzy logic may overcome the voltage loop bandwidth limitation provided that some input current distortion is accepted (with the limits posed by the standards). From this point of view, fuzzy logic is a powerful tool because, by properly weighting the input current and the output voltage errors, it can provide an optimal trade-off between the needs for improving dynamic response and reducing input current distortion. Another advantage of the FLC approach is its generality, since almost the same control rules can be applied to several pre-regulator topologies; however, some scale factors must be tuned according to converter topology and parameters [6-11].

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II. MODELLING

A. Design of Inductance and Capacitance

The proposed single phase high power factor rectifier is shown in fig .l. To achieve unity power factor in both the directions choose fundamental component of V AB i.e. Vr such that transformer draws current nearly sinusoidal and in phase with the mains voltage Vs. When power draws from source to the load input current 'Is' should be positive and load is reverse current should be negative then it acts as a generator which passes the power from load to source. The phasor diagram for it is shown in fig.2.

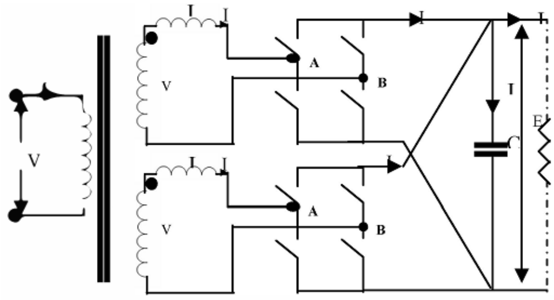

Fig.1. Proposed Single-phase PWM controlled Active rectifier.

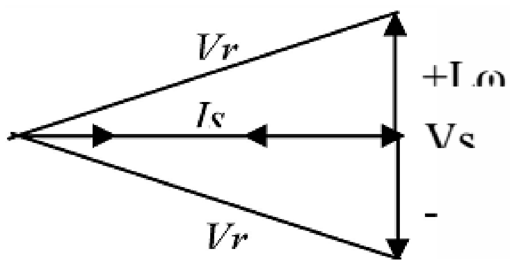

Fig.2. phasor diagram of HPFR

Fundamental component of VAB is given by

$$Vr = \sqrt{(Vs)\ 2 + (L\omega Is)^{2}}$$

Where L is inductor, co is angular frequency (21ft) and f is mains frequency. In practical applications to avoid the over modulation 80% of output DC voltage Eo. The modulation index is given by

$$m = Vc/Vm$$

The average input current in a switching period Ts is given by

$$Is = \sqrt{(m^2 - Vs^2)} / L\omega$$

The inductance can be found

$$L = \sqrt{(m^2 - Vs^2)} / \omega^2 Is^2$$

The ripple current IL contains DC part and ripple part. It goes through capacitor. The ripple in the current should be as small as possible. Here it is consider as 5% of DC voltages Eo. The input power is equal to the output power

$$V_r\ (t) * Is\ (t) = E_o * I_L$$

The phasor diagram for it is shown in fig.3

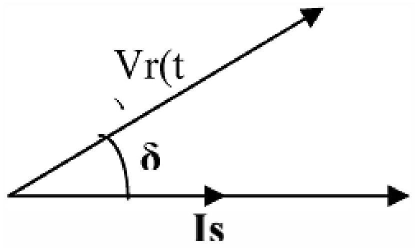

Fig.3. phasor diagram of transformer side

Vr(t) is given by

$$V_r(t) = V_r \sin(\omega t - \delta) * Is \sin \omega t$$

Net current is

$$I_L = \frac{Vr\ Is \sin(\omega t - \delta) * \sin \omega t}{Eo}$$

The consist of DC part i.e and fluctuating part. This part is going through capacitor; its ripple pick is give by

$$\frac{I_L}{2\omega C} \leq 0.05\ Eo$$

Using this equation the capacitor value can be derived as

$$\frac{I_L}{2\omega C} \leq 0.05\ Eo$$

B. Controller Design of Single Phase HPFR

The sinusoidal signal of fundamental component of VAB (Vr*) coming from the current controller compared with the fixed amplitude triangle signal. Where V c is amplitude of triangular signal and Vr* is amplitude of sinusoidal signal The delay Tr is appear between the two comparison. It can be shown using first order lag

$$\text{First order lag} = 1/(1+STr)$$

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For the PWM converter the control block is

$$PWM\ converter = G / (1+STr)$$

Where Tr is triangular period = l/f In order to reduce the harmonics fundamental components of leg A and leg B can be added and are controlled independently because each having their own harmonics (fc and sidebands) hence here is two degree of freedom (DOF) one is at leg A and second is at leg B.

C. Current Controller Design

Vr is the actual fundamental voltage of V AB obtained from controller. Actual source current 'Is' is the integral of difference between Vr and Vs.

$$Is = 1/L\ (Vr-Vs)\ dt$$

Current controller gain is given by

$$K1 = L/ (ki*G*T)$$

Where $G = Vrpeak/8$ and $T=2Tr$

To control it PI controller is used. This is show in fig .3.

D. DC Voltage Regulator

IL is the load current. Here the resistive load is used for the simulation purpose. 10 is the DC output current. The DC output voltage Eo is obtained by taking the integral of difference of Io and IL which is given by

$$Eo = 1/C\ (Io- I_l)\ dt$$

The control block is show in fig.4.

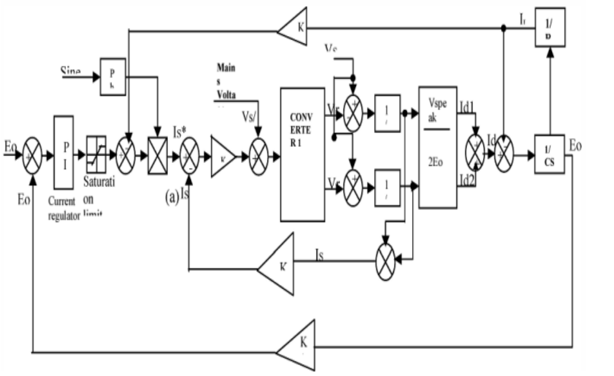

Fig. 4 Proposed control scheme for Active Rectifier.

III.FUZZY LOGIC CONTROL

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to power system [5]. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of converter. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of compensator.

The basic scheme of a fuzzy logic controller is shown in Fig .5. and consists of four principal components such as: a fuzzy fication interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

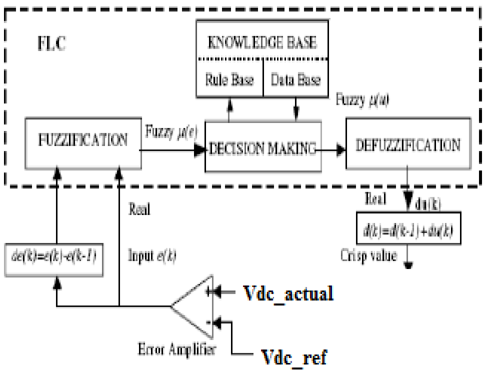

Fig.5.Block diagram of the Fuzzy Logic Controller (FLC) for Proposed Converter.

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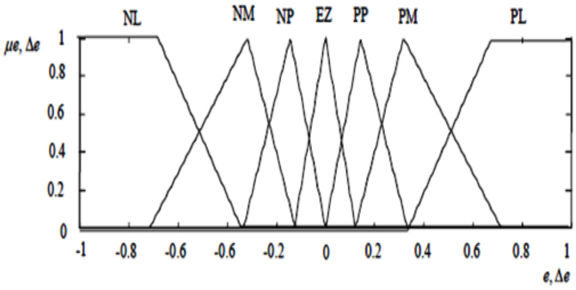


Fig.6. Membership functions for Input, Change in input, Output.

Rule Base:

The elements of this rule base table are determined based on the theory that in the transient state, large errors need coarse control, which requires coarse input/output variables; in the steady state, small errors need fine control, which requires fine input/output variables. Based on this the elements of the rule table are obtained as shown in Table, with 'Vdc' and 'Vdc-ref' as inputs

IV.MATLAB/SIMULINK RESULTS

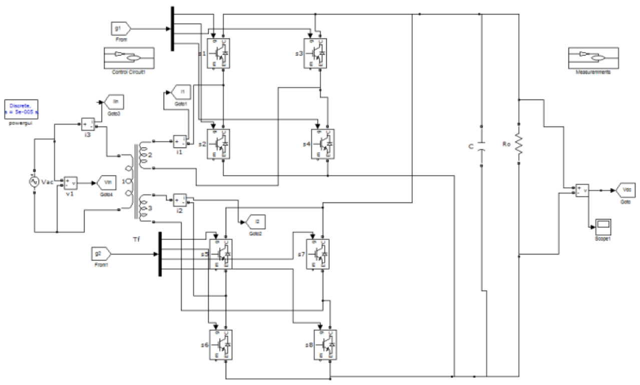
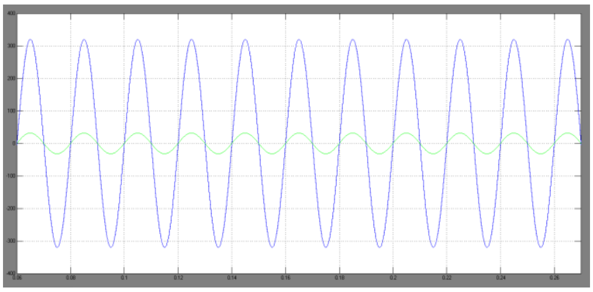
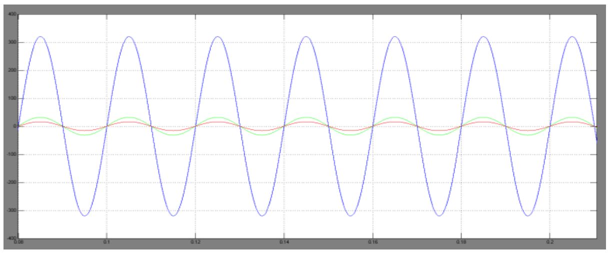


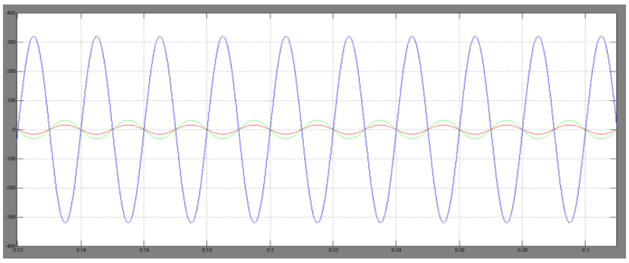
Fig.7.Matlab/Simulink Model of Single-phase PWM Controlled Active Rectifier.



a

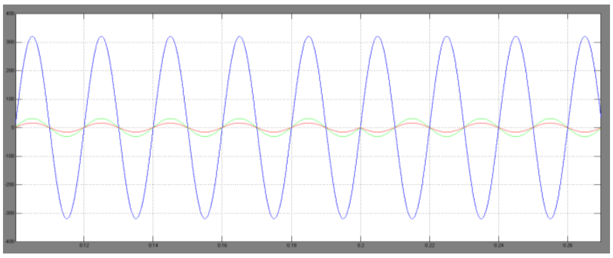


b

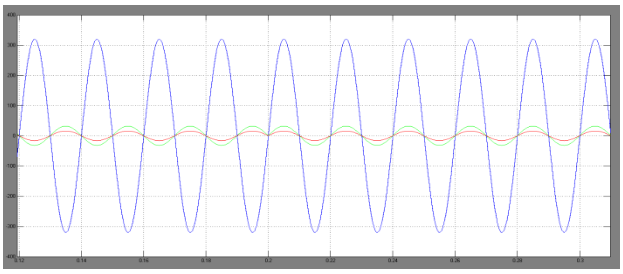


c

Fig. 8. Simulated Results: Oc link voltage (400 V/div.), Input mains voltage (230VIdiv.), Input current (6A/div.), sets of converter currents (a) input mains voltage (230V/div.) and input current (6A/div.) are in phase nearly unity power factor (b) load is positive, (c) load is reverse.

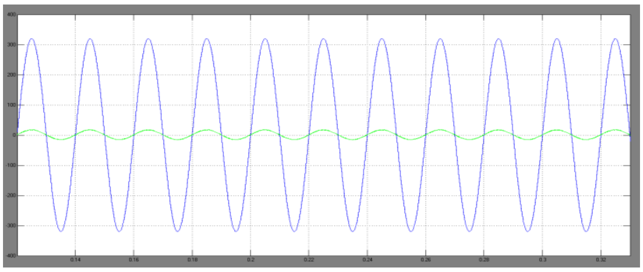


a

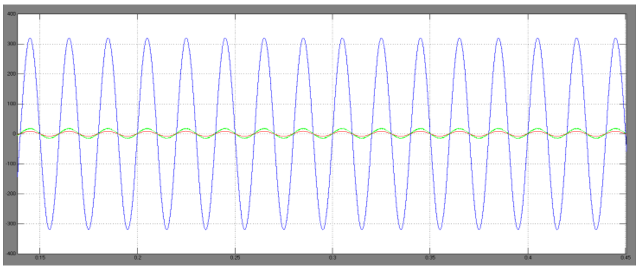


b

Fig.9. Simulated Results: Oc link voltage (400 V/div.), Input mains voltage (230V/div.), Input current (6A1div.), sets of converter currents (a) load transition from positive to negative, (b) load transition From negative to positive.



a



b

Fig. 10. Simulated Results: (a) No load, oe link voltage (400 V/div.), Input mains voltage (430V/div.), Input current (OA/div.), sets of converter currents (b) Load is 50%, oe link voltage (380 V/div.), Input mains voltage (230V/div.), Input current (6A/div.), sets of converter currents,

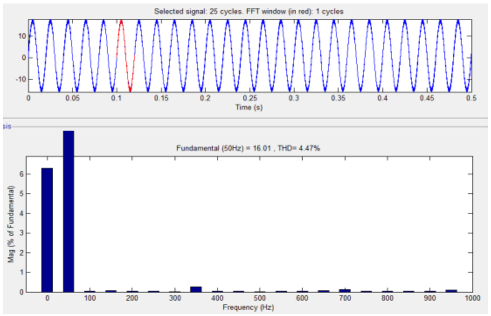


Fig.11.THD for Line current.

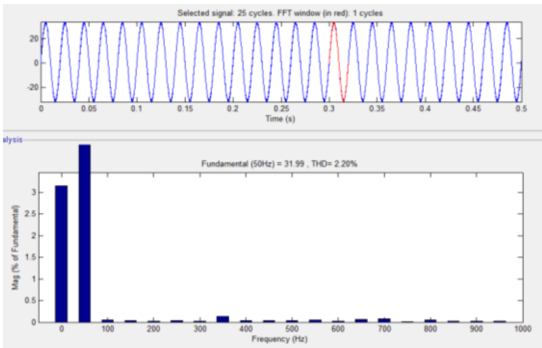


Fig.12.THD for PI controller.

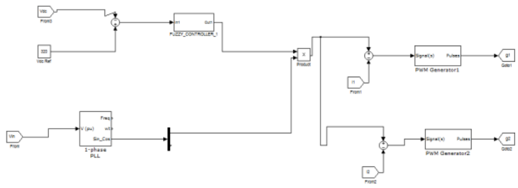


Fig.13.Control Diagram of Fuzzy Logic Controller.

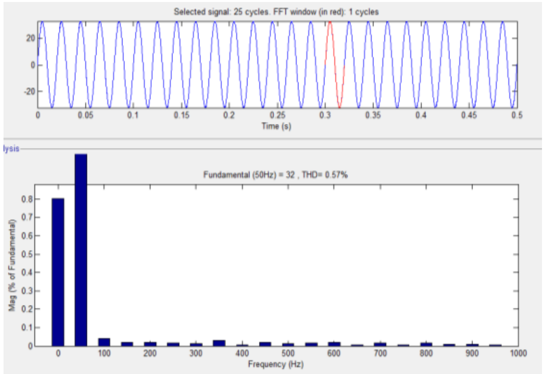


Fig.14.THD for Fuzzy logic controller.

V. CONCLUSION

Analysis, design and simulation of a single-phase proposed converter are carried out. The proposed single-phase converter offers many advantages such as unity power factor operation, low THD, low EMI and low switch stresses. The soft switching of the devices decreases the switching losses thereby increasing the efficiency. It can be concluded that fuzzy controller has a better transient response compared to a conventional PI controller, and the steady state performance of the fuzzy controller is comparable to the PI controller. The performance of the different control techniques compares, the fuzzy control is better to compare with PI controller and the settling time of the fuzzy controller.

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