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Simulation Study and Implementation of Non-Direct Current Controlled Shunt Active Power Filter for Power Quality Enhancement

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Abstract:
This article presents indirect Hysteresis Current Controlled (HCC) single phase Shunt Active Power Filter (SAPF) for power quality enhancement. In this SAPF consists of two control loops namely inner current loop and outer voltage loop. Here, FLC is acts as outer voltage loop for regulating D.C bus voltage of SAPF, while HCC is chosen as inner current loop for regulating/shape the supply current and reduce the harmonics. In existing control loop for SAPF, the reference current generation is derived from P-Q theory or D-Q theory and other computational methods, but in this designed control techniques reference current is derived from D.C link capacitor voltage of SAPF. The fuzzy rules are framed based on the SAPF performance. The performance designed model is validated at various load conditions by making the model over Proportional Integral (PI) controller. The responses are presented to show proficient of the designed model.

KEYWORD: Shunt Active Power Filter (SAPF), PI controller, Fuzzy Logic Controller (FLC), Harmonics, Hysteresis Current Controller (HCC).

I. INTRODUCTION

Total Harmonic Distortion (THD) is main issues in power systems. Distortions produced in the power supply due to non-linear loads such as un-controlled diode rectifier or controlled rectifier and inductive loads. The occurrence harmonics in power supply that may leads to transformer heating, damage of power semiconductor device, and EMI issue. Therefore, it is compulsory to suppress the dominant harmonics less than 5% as specified in IEEE 519-1992 harmonic standard [1-3]. These issues can be solved many different approaches like passive filters (PF) and Active Power Filter (APF). Among these AFC is best choice because has faced problems of filter size, instability and resonance [4-5]. In this article, Shunt APF is designed for increasing power parameters in the power systems. The various controls for APF have been reported [6-10]. Therefore, in this article proposes a FLC plus HCC SAPF for power quality improvements at various load operating conditions.

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II. OPERATION OF SHUNT ACTIVE POWER FILTER

The VSI of a FLC plus HCC SAPF is illustrated in Fig.1. The actual bi-directional power flows of the VSI. Using suitable working of Fig. 2, a compensating voltage V_{comp} having a fundamental component V_{comp1} is produced at the output of the VSI. Current leading, lagging and unity depending on the V_{comp1} and V_{source}.

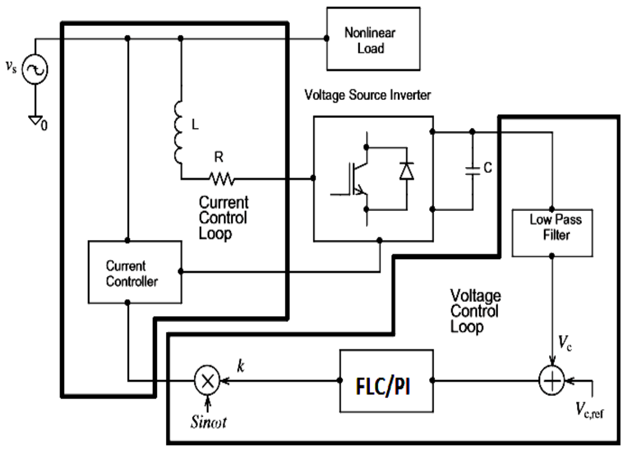

Fig .1 FLC plus HCC for SAPF

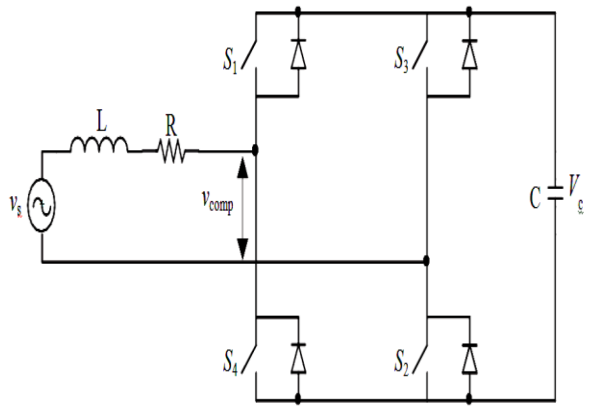

Fig .2 Circuit diagram of VSI

The state space of equations the converter is based on the switching operation of it (refer Fig.2).

II. CONTROLLER OF SAPF

A. HCC

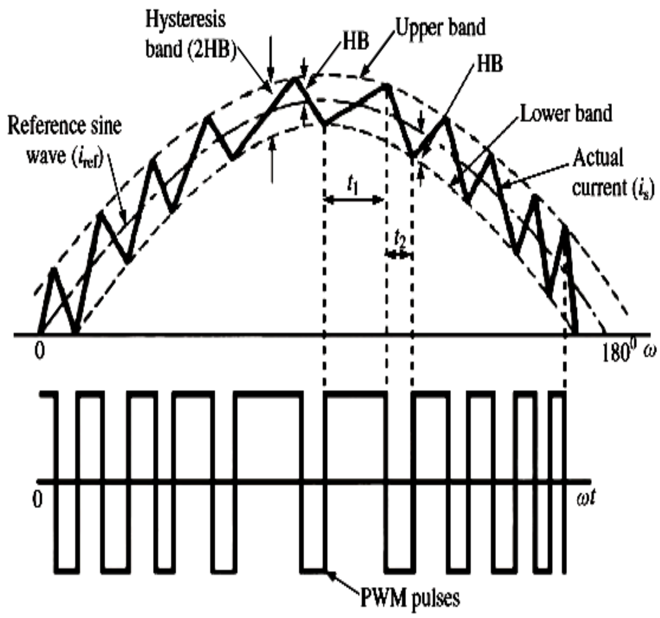

Fig .3 Graphical representation of HCC

The HCC is depicting in Fig.3. Using this method, the switching of VSI is arrived.

B. Design of classical controller

A classical PI controller is selected for providing the excellent load voltage modulating and suppressed fixed state error for the SAPF. In this case, the PI controller parameters of this converter are computed with help of the tuning method (K_p= 0.6 and K_i=50) [10-11].

C. Design of fuzzy logic controller

The main merits of the FLC over linear controller are that it does not require any complex mathematical models, which are always needed for highly complex non-linear models. The FLC use the heuristic reasoning ability based on the human experience of the model [12-13]. The FLC for SAPF is depicting in Fig. 4. In this study, the sugeno-method FLC is utilized as an outer voltage loop to regulate the power switches of the VSI. The applied inputs and output of the FLC for the converter is depict in Fig. 4 (a) to (c). The voltage

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error (e) and its change in error (ce) of this VSI is applied as a input the FLC and the output is o (mark the control signal for the power switches of the VSI). For convenience, the arithmetic values of the inputs as well as the output of the FLC can be standardized and expressed in Figs.4a, 4b and 4c case, 49 rules are framed (see the Table 1).

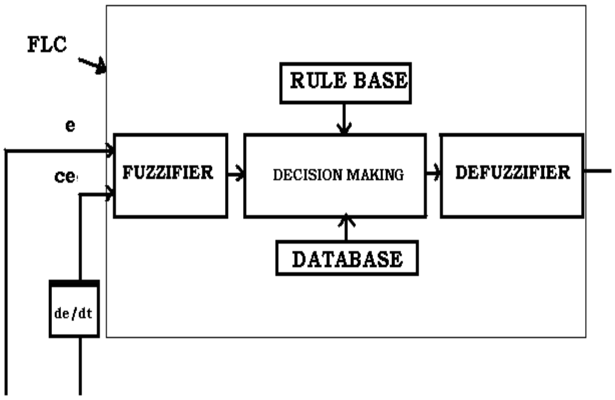


Fig.4. Structure of FLC for SAPF block diagram.

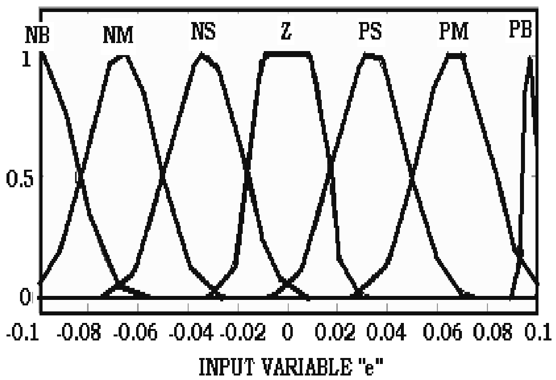


Fig. 4a. “e”.

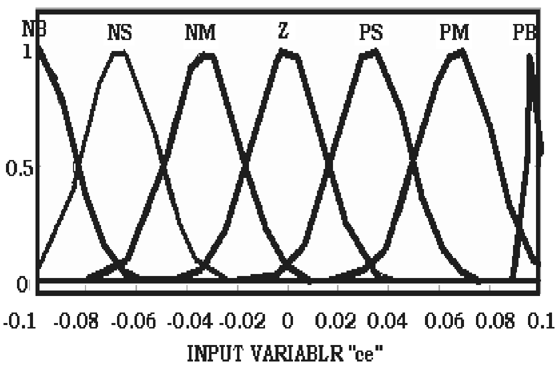


Fig. 4b. “ce”.

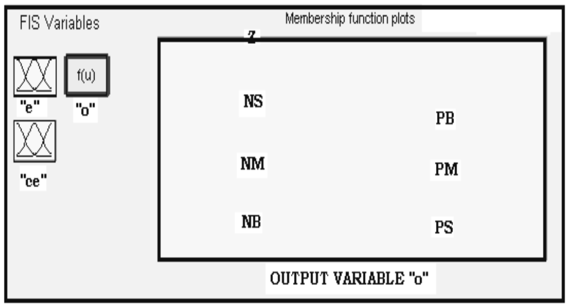
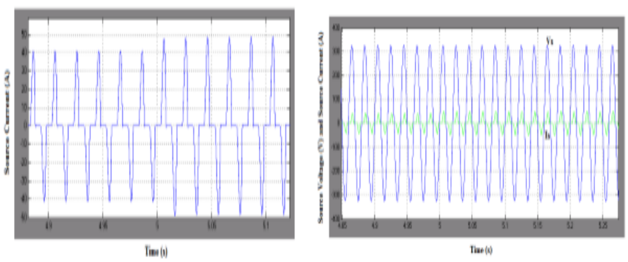


Fig. 4c. “o”.

VI. SIMULATION RESULTS

This section deals about the SAPF with controllers at different load conditions. The model (see Fig. 6) for SAPF in both single/three phase circuit) with parameters follows;

Fig. 5 indicates results of various parameters sample power system without SAPF (non-linear diode rectifier R-L load). From this figure , it is found that the THD is 70.6% for system without SAPF. Figs.6, 9 and 10. model of designed system with controlles. Figs. 7 to 8 showed excellent performance for designed FLC plus HCC at different operating conditions (THD=2.91% (FLC plus HCC) THD=6.49% (PI plus HCC).



(a) (b)

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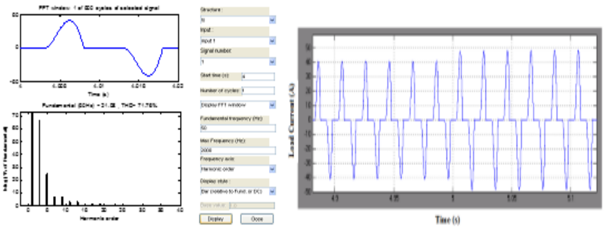


(c) (d)

Fig.5 . Results of designed syatem.

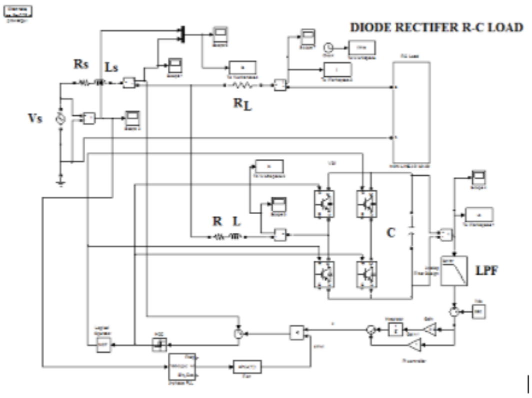
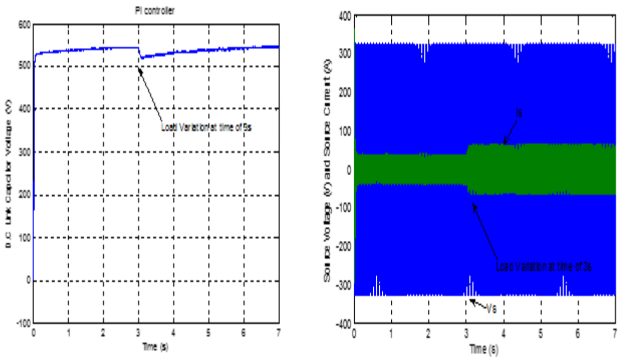
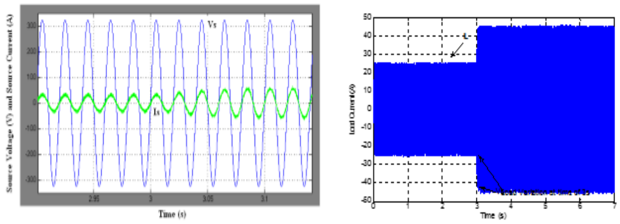


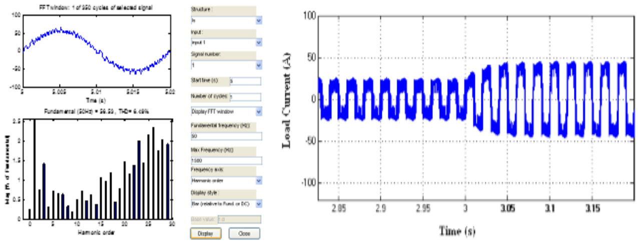
Fig.6 . Model of designed system.



(a) (b)

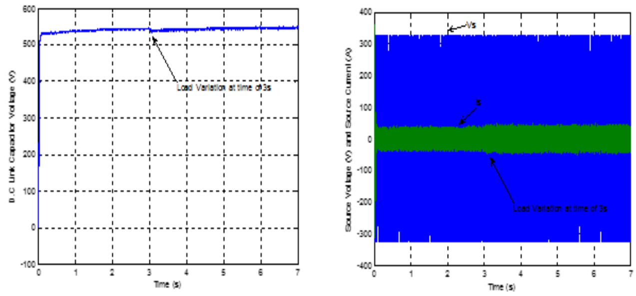


(c) (d)

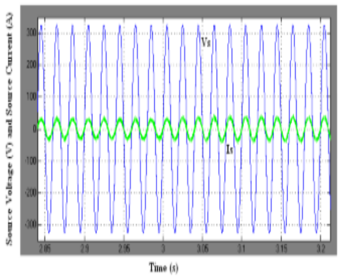


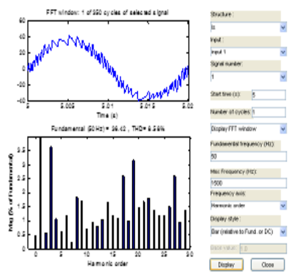
(e) (f)

Fig.7. Results of designed system using PI controller plus HCC with R-L Load.



(a) (b)





(c) (d)

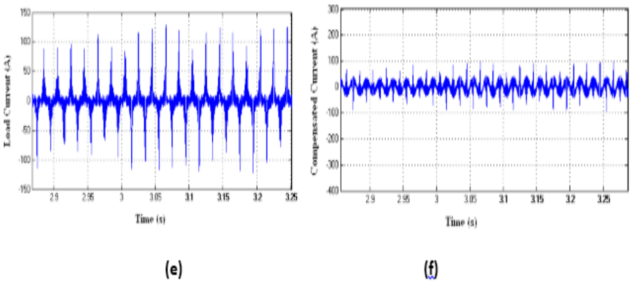


Fig.8. Responses of designed system with PI controller plus HCC with R-C Load.

V. CONCLUSIONS

Thus the FLC plus HCC for SAPF in sample power system has been successfully demonstrated. The SAF was simulated and its performance was analyzed in a sample power system with a source and a non linear load. The controller with SAPF is verified at various load conditions. At the end, the simulation results of developed controller have produced proficient performance in comparison with tradition controller.

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