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Improvement of Power Quality using a Hybrid Series Active Power Filter with Fuzzy Logic Controller

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ABSTRACT

In this paper a hybrid active power filter is introduced for harmonic filtration in a transmission system with sources and loads. The harmonics which are generated by non-linear loads (diode bridge rectifier) are introduced into the source voltage and currents which could also be injected into other loads connected to the system. These harmonics are eliminated using a series active power filter which is connected to the transmission line through series transformers which eliminates harmonics in the source voltage and currents. Along with the series active power filter a passive filter is also connected to eliminate lower order harmonics, whereas the series active power filter eliminates lower order harmonics. The controller of the series active power filter is updated with fuzzy logic controller for faster Response rate to the transients caused in the proposed system. A harmonics comparative analysis is carried out on the source current with PI and fuzzy logic controllers using FFT analysis tool in MATLAB Simulink software. All the results are presented with THD values compared in a table.

Keywords: Fuzzy logic controller PI, Shunt active power filter, Series Active Power Filter.

INTRODUCTION

Electrical power quality has been a developing concern because of the proliferation of the nonlinear loads, which causes significant increase of line losses, instability and voltage distortion [1]. With injection of harmonic current into the system, those nonlinear loads additionally motive low electricity component. The ensuing unbalanced current adversely affects each component inside the energy system and equipment. This outcome in terrible power aspect, increased losses, excessive neutral currents and reduction in standard efficiency. Passive power filters have been utilized as a remunerating gadget, to repay mutilation produced by consistent non-straight loads. These filters [2] are intended to give a low impedance way to harmonics and keeping up great power quality with a most straightforward structure and ease. Notwithstanding, latent filters have a few faults like mistuning, reverberation, reliance on the states of the power supply system and huge estimations of detached segment that prompting cumbersome usage.

II.PROPOSED METHODOLOGY

2.1INTRODUCTION

Fig. 2.1 demonstrates the schematic diagram of the control and power circuit of 3-stage HSAPF. The SAPF comprises of a voltage source inverter associated with the matrix through a LC filter and a three-stage direct transformer.

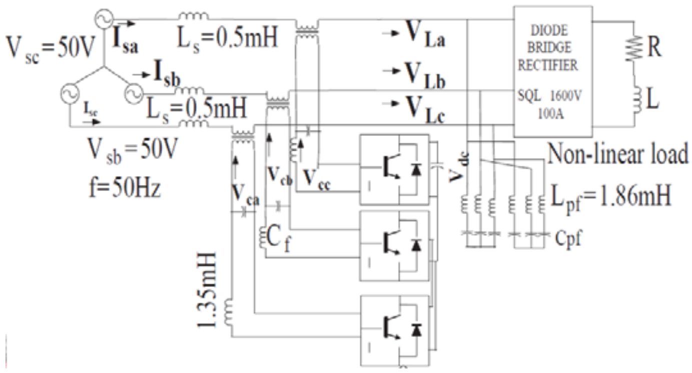

Fig 2.1: Proposed topology of HSAPF.

The topology of HSAPF is made out of an arrangement associated active power filter (SAPF) and a shunt associated latent power filter (PPF). PPF associated in parallel with the load. The PPF comprises of fifth, seventh tuned LC filter of rating (L_{pf}= 1.86mH and C_{pf}= 60µF) for the pay of consonant current on load side. The SAPF associated in arrangement with the source through a coordinating transformer of turn proportion 1:2 to guarantee galvanic seclusion. SAPF comprises of three sections, for example, three stage IGBT based SEMIKRON inverter, a DC-connect capacitor of 2200µF and a three-stage high recurrence LC filter of impedances (C_f= 60µF, L_f= 1.35mH). The high recurrence LC filter is connected to dispose of high recurrence changing swells from the remunerating voltage provided by the inverter. A non-direct load involving a three stage diode connect rectifier (ABC 100V 100A) with RL-load (i.e. resistor of 8.5A, 100 and inductor of 40mH) is considered.

2.2MODELLING OF THE HSAPF

The arrangement obstruction of the inductors is dismissed. Where u_a , u_b and u_c are the obligation cycle of the inverter legs in an exchanging period, while V_{ca}, V_{cb}, V_{cc} are the yield voltage of arrangement active filter for three stages are appeared in Fig. 2.2 and I_{ca}, I_{cb}, I_{cc} are known as the three stage current yield of active filter, V_{aN} , V_{bN} , V_{cN} are the stage voltages for three stages, Isa, Isb, Isc are known as the three stage source current, V_{nN} is the unbiased voltage.

By averaging the inverter legs in the circuit chart, the entire found the middle value of model [13] of the inverter in three stages are acquired as appeared in Fig. 2.3. From this circuit diagram, the dynamic model of the HSAPF under a synchronous reference frame can be expressed by the following differential equations:

$$\frac{d\,i_{cd}}{dt} = \frac{V_{cd}}{L_f} + w\,i_{cq} - \frac{u_d V_{dc}}{L_f} \quad (2.1)$$

$$\frac{di_{cq}}{dt} = \frac{V_{cq}}{L_f} + wi_{cd} - \frac{u_q V_{dc}}{L_f} \quad (2.2)$$

$$\frac{dV_{cd}}{dt} = wV_{cq} - \frac{i_{cd}}{C_f} + \frac{i_{sd}}{C_f} \quad (2.3)$$

$$\frac{dV_{cq}}{dt} = -wV_{cd} - \frac{i_{cq}}{C_f} + \frac{i_{sq}}{C_f} \quad (2.4)$$

$$\frac{dV_{dc}}{dt} = \frac{2}{3C_{dc}} (u_d i_{cd} + u_q i_{cq}) \quad (2.5)$$

Where, V_{cd} and V_{cq} are the d_q-axis remunerating voltages, u_d and u_q are the d_q-axis obligation proportion.

To encourage the controller plan, the HSAPF system model can be defined as pursues:

$$x = f(x) + g(x)\,u \quad (2.6)$$

$$y = h(x) \quad (2.7)$$

Where x = [i_{cd}, i_{cq} , V_{cd}, V_{cq} , V_{dc}]T is defined as the state vector, vector u = [u_d , u_q]T represents system control factors, vector y = [y_1, y_2]T = [V_{cd}, V_{cq}]T presents the system yields. It must be seen that the accomplished multi-input multi-output (MIMO) system is non-straight due to presence of augmentation terms of the state factors and control factors. And furthermore, the state factors are strongly consolidated to one another. These two difficulties can be precisely constrained by the plan of sliding mode controller, which straightforwardly inspect the connection between the control factors and the system yields.

The reference pay voltage of the HSAPF system receiving half and half control approach based synchronous reference outline strategy are communicated as:

$$V_c^* = K\,I_{sh} - V_{Lh} \quad (2.8)$$

This half and half control approach at the same time identify both source current I_s just as load voltage V_L to acquire their consonant parts. The age of reference repaying signal v_c^* utilizing the consolidated load voltage and source current recognition conspire together with receiving cross breed control approach based synchronous reference outline strategy for HSAPF system can be acquired as (8) and (9). The acknowledgment circuit for producing v_c^* is appeared in Fig. 3.2

$$u_d = K\, I_d - V_d \quad (2.9)$$

$$u_q = K\, I_q - V_q \quad (2.10)$$

The age of reference repaying signal utilizing the consolidated load voltage and source current recognition conspire [14] is appeared in Fig. 2.2, the mistake between the reference and the real DC-connect voltage of DC-interface capacitor of three stage PWM inverter fed from the air conditioner system is first gone through a PI controller and afterward it is subtracted from the oscillatory part in d-pivot. Since the additional crucial segments are added to symphonious parts individually. Along these lines the reference remunerating voltages are likewise communicated as:

$$V_{ca}^* = K\, I_{sah} - V_{Lah} + \Delta V_{caf} \quad (2.11)$$

$$V_{cb}^* = K I_{sbh} - V_{Lbh} + \Delta V_{cbf} \quad (2.12)$$

$$V_{cc}^* = K\, I_{sch} - V_{Lch} + \Delta V_{ccf} \quad (2.13)$$

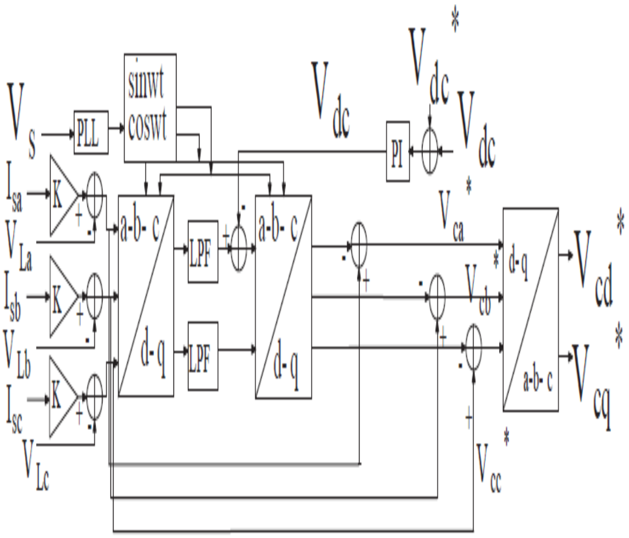

Fig 2.2: Reference Generation Scheme (HSRF).

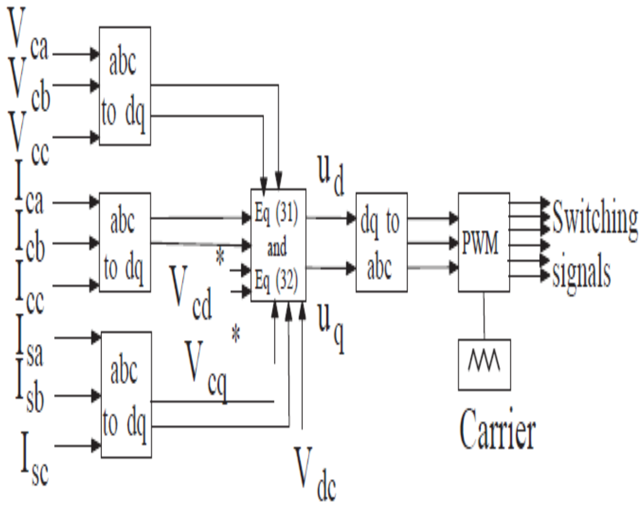

Fig 2.3: Pulse Generation from Controller.

In this proposed control approach the control signal satisfies all the above conditions, with the goal that the state directions are moved towards the exchanging surface. Consequently, amid the activity of this proposed controller, the HSAPF system accomplishes quick reaction, great power and disposable aggravations successfully.

2.3 Design of Fuzzy Control Rules

The fuzzy control rule design involves defining rules that relate the input variables to the output model properties. As fuzzy logic controller is independent of system modal, the design is mainly based on the intuitive feeling for, and experience of, the process. The rules are expressed in English like language with syntax such as If {error e is A and change of error Δeis B} then {control output is C}For better control performance finer fuzzy petitioned subspaces(NL, NM, NS, ZE, PS, PM, PB) are used, and summarized in table 5.1. These seven membership functions are same for input and output and characterized using triangular membership functions.

2.4 Advantages of Fuzzy Control

The advantages of fuzzy control over the adaptive control can be summarized as follows the linguistic, not numerical; variables make the process similar to that of human think process. It relates output to input, without understanding all the variables, permitting the design of system more accurate and stable than the conventional control system. The fuzzy controller uses two input membership variables error E and change in error dE. There is only one output for the fuzzy function. The function considered is 'mamdani' function with seven membership functions in each variable. The input membership functions have gauss format and are shown below.

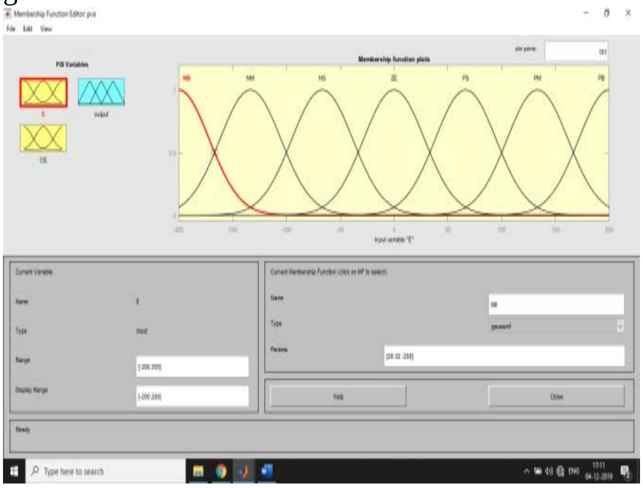

Fig 2.4: Error input membership function.

III SIMULALTION RESULT AND DISCUSSION

3.1 INTRODUCTION

In this paper, various waveforms of fuzzy logic controller model are simulated in MATLAB Simulink and various input and output waveforms for the different conditions are shown below.

Working of the model

The simulation is connected with a three phase source connected to impedance. A non-linear load is connected which has diode bridge rectifier connected to RL load. The series active power filter is connected at point of common coupling using series transformers. Each single-phase inverter is controlled individually using feedback controller. The controller comprises of fuzzy logic controller with voltage and current feedback. The complete simulation is run for 1sec with and without active power filter.

The fuzzy logic controller uses for the series active power filter to react faster to the disturbances caused by the non-linear load. An FFT analysis is carried out from powerful block and compared with response time between PI and fuzzy logic controllers.

3.2 PROPOSED SIMULATION MATLAB MODEL

Case: 1 Improvement of Power Quality by using Hybrid Series Active Power Filter using conventional pi controller. The proposed simulation model is shown in fig. no. 3.1

Fig. No. 3.1 show the Matlab/Simulink power circuit model of HAPF. It consists of five blocks named as Ac source block, nonlinear load block, control block, HSAPF block and measurements block.

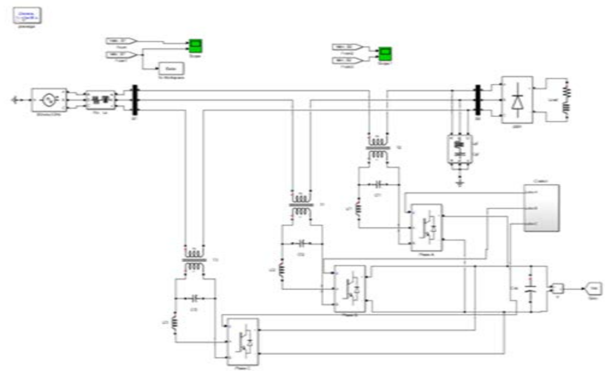

Fig 3.1: Simulink model of test system PI Model with HSAPF.

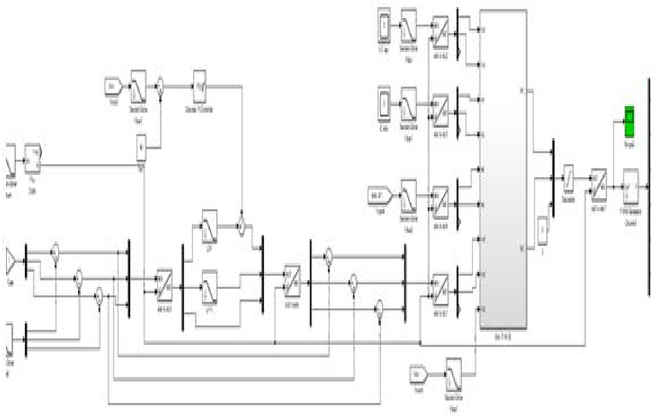

Fig 3.2: Internal sub sytem of SM- PI controller.

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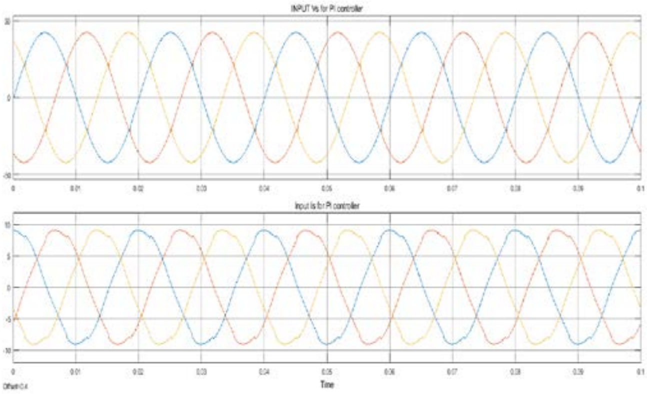

Fig 3.3: Input Waveforms, V_S and I_S for PI controller.

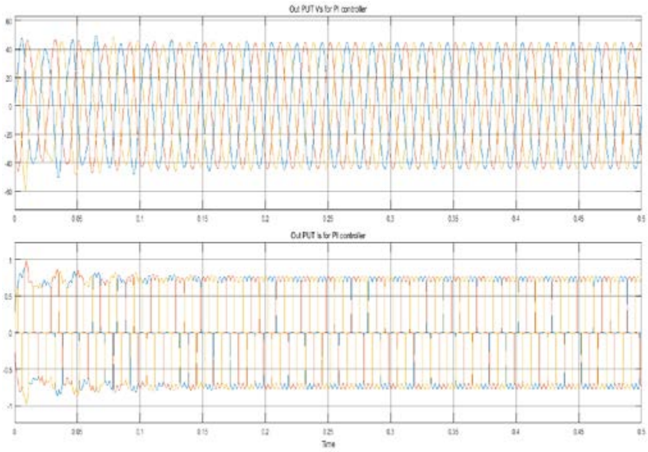

Fig 3.4: Out Put Waveforms, V_S and I_S for PI controller.

3.4 Harmonics analysis of Hybrid Series Active Power Filter using conventional pi Controller.FFT Analysis:

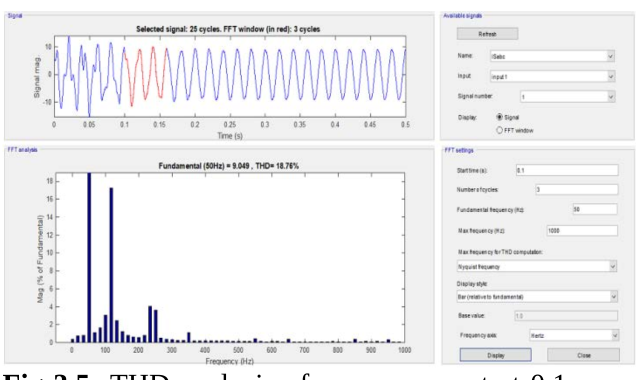

Fig 3.5: THD analysis of source current at 0.1sec with PI controller.

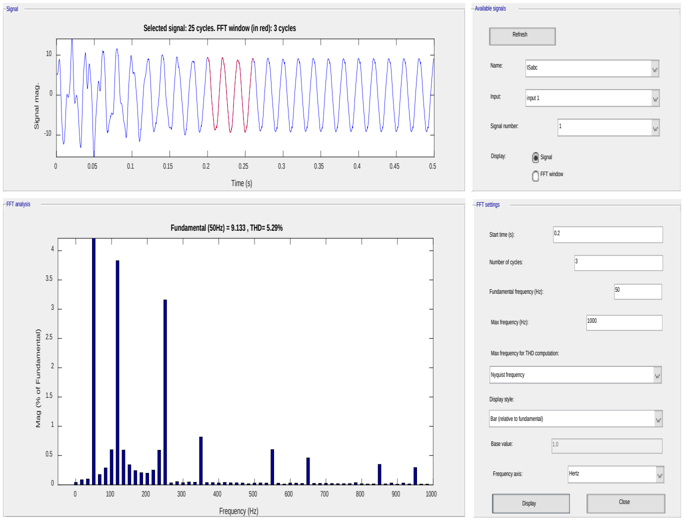

Fig 3.7: THD analysis of source current at 0.2 sec with PI controller.

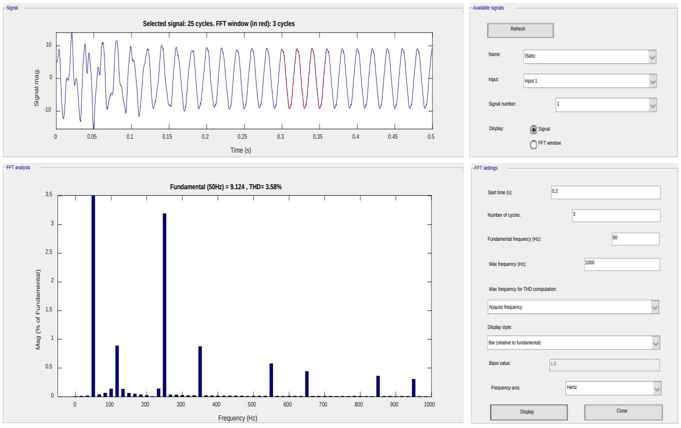

Fig 3.8: THD analysis of source current at 0.3 sec with PI controller.

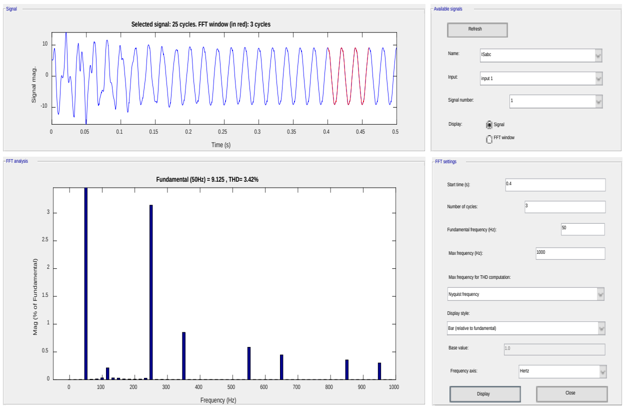

Fig 3.9: THD analysis of source current at 0.4 sec with PI controller.

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Case ii: Improvement of Power Quality by using Hybrid Series Active Power Filter using conventional fuzzy controller. The proposed simulation model is shown in fig. no. 3.10. Fig. No.3.10 show the Matlab/Simulink power circuit model of HAPF. It consists of five blocks named as Ac source block, nonlinear load block, control block, Fuzzy Logic controller HSAPF block and measurements block.

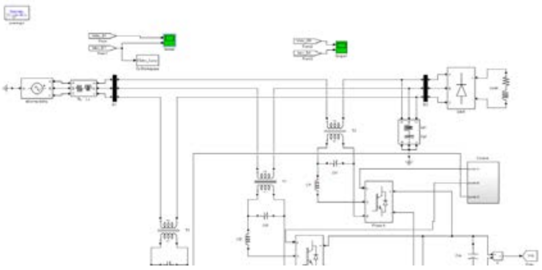

Fig 3.10: Simulink model testsystem Fuzzy controller with HSAPF.

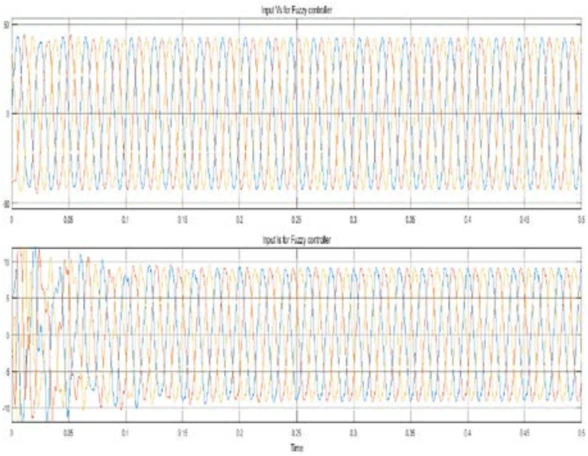

Fig 3.11: Input Waveforms, V_S and I_S for Fuzzy controller.

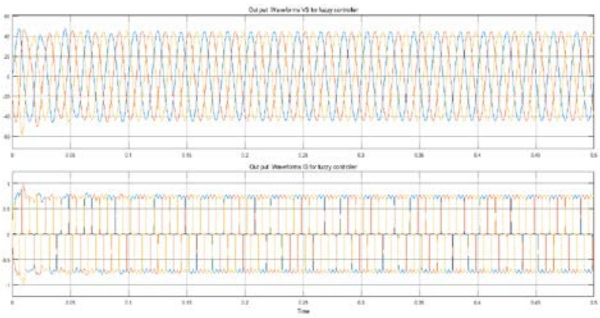

Fig 3.12: Output Waveforms, V_S and I_S for Fuzzy controller.

3.4 Harmonics analysis of Hybrid Series Active Power Filter using conventional Fuzzy Controller.
FFT Analysis:

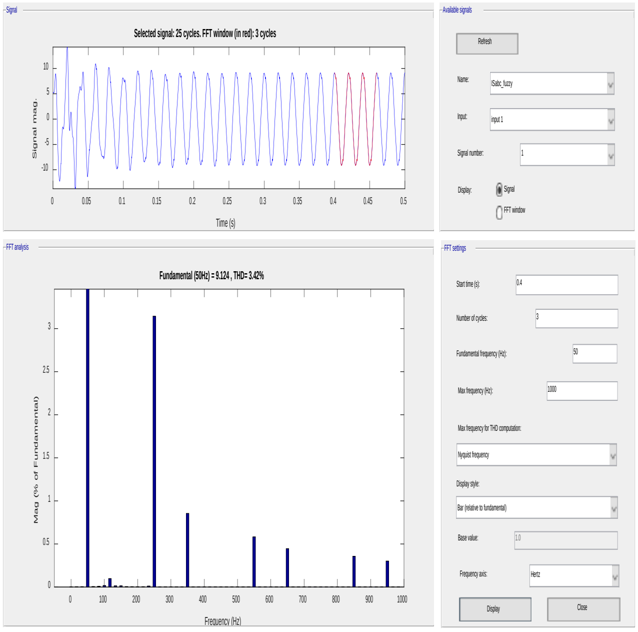

Fig 3.13: THD analysis of source current at 0.4sec with Fuzzy controller.

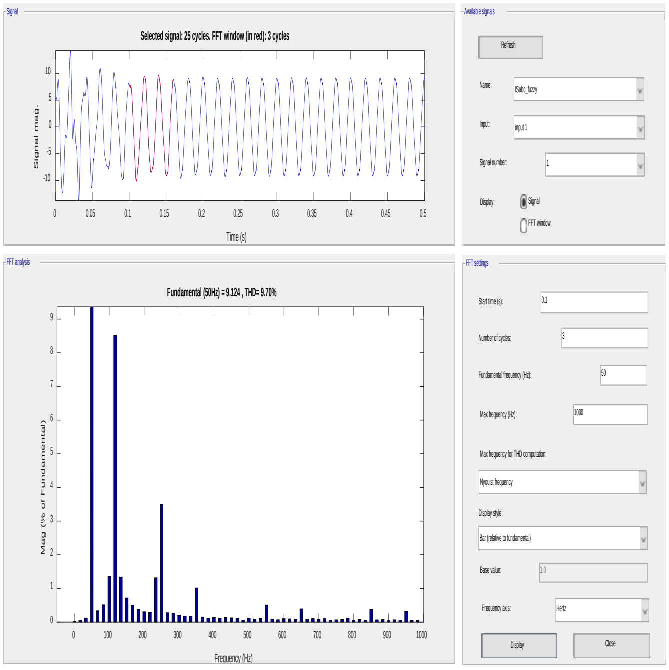

Fig 3.14: THD analysis of source current at 0.1sec with Fuzzy controller.

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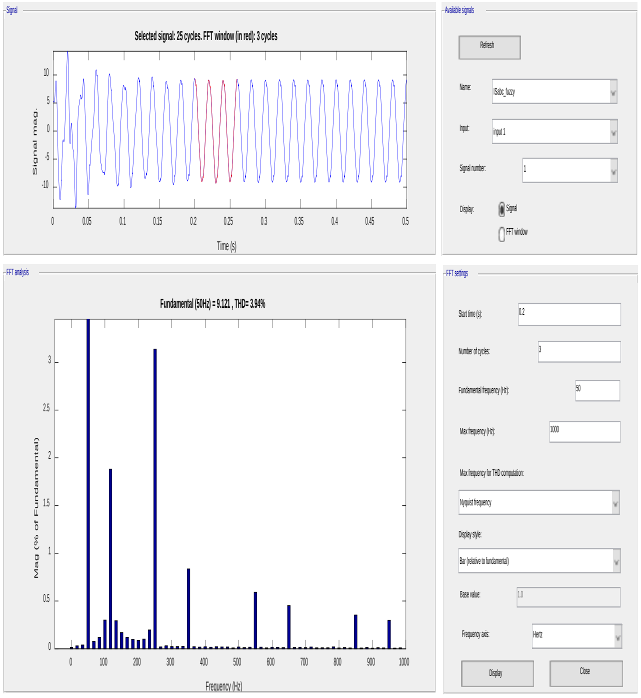

Fig 3.15: THD analysis of source current at 0.2sec with Fuzzy controller.

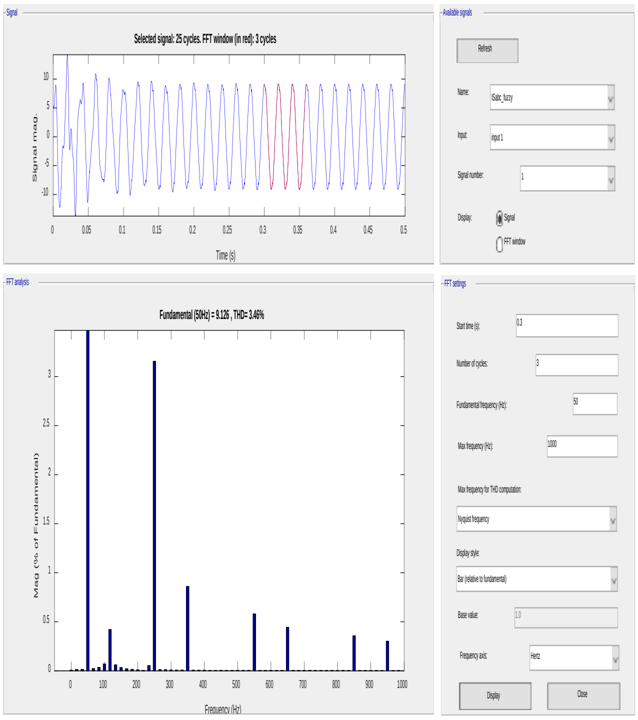

Fig 3.16: THD analysis of source current at 0.3 sec with Fuzzy controller.

3.5 THDCOMPARISIONS

THD Comparisons of PI and Fuzzy controller are compared below.

TIME(Sec)	PI (%)	Fuzzy (%)
0	57.03	43.99
0.1	18.76	9.70
0.2	5.29	3.94
0.3	3.58	3.46
0.4	3.42	3.42

IV CONCLUSION NAD FUTURE SCOPE

With the comparison of the above given results the THD of the source current is less at transient state when the controller of the series active power filter is updated with fuzzy logic controller. The fuzzy uses nearest value generation with respect to the 7 membership functions given in the inputs and output. However the THD will be same after the source current settles at specific time. The THD reduction is done at transient state when the active power filter is connected to the test system. A comparison table is given with THD percentage at different intervals of time with simulation run for 0.5sec. The controller of the series active power filter can be further updated with sliding mode controller or any optimization controllers for better response on source current. The series active power filter can be connected to multi bus system with multiple loads reducing harmonics at different buses.

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