ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 10, Iss 3, 2021

Shunt active Power Filter Performance Evaluation Using Artificial Neural Networks and 6-Switch 2-Leg Inverter with PI/Fuzzy Logic Controlled Transformerless

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ABSTRACT: Background/Objective: To improve the power quality in distribution networks, this study proposes a Transformer less Shunt Hybrid Power Filter (TSHPF) employing a 6-Switch 2-Leg Inverter (SSTL). Statistical Analysis/Methods: The TSHPF is made up of a passive filter and an SSTL inverter connected at a Point of Common Coupling (PCC). Shunt Active Filter (SAF) is a function of this SSTL inverter. SSTL inverter's DC bus voltage is maintained using a PI/Fuzzy controller. Inverter switching pulses are produced using a linear control approach. Here, a TSHPF integrated with a fuzzy controller is created, and comparisons are drawn with a traditional PI controller. Findings: For both control techniques, the suggested system is simulated in MATLAB/ SIMULINK. According to simulation studies, adding a fuzzy controller increases the overall harmonic distortion compared to PI From 8.64% to 3.40% less harmonic distortion is produced. Because an explicit mathematical model is required, improvement: The PI controller cannot be implemented. As a result, TSHPF based on fuzzy controllers is substantially more effective in improving power quality.

Keywords: Harmonic Currents, Hybrid Power Filter (HPF), Non-Linear Loads, Power Quality, Total Harmonic Distortion (THD)

1. Introduction

At present almost all household and industrial appliances are equipped with electronics. These electronics are causing nonlinearity on the power system network thereby affecting its healthiness and sensitivity. Hence, IEEE519 standards1 are recommended to restrict the current harmonics2.

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Passive filters have been employed to pacify distortions due to current harmonics. It comprises of R, L and C components [1]. Usage of passive filters is restricted in low frequency systems due to cost effectiveness and bulk in size.

Active filters3–5 have been introduced to wipe out the problems of the passive filters. It comprises of R and C components [2]. The practice of active filter is uneconomical due to huge initial investment and high-power losses.

On economical reasons to stamp out the problems caused by both passive and active filters, hybrid power filters6 were introduced in the present power applications [3]. It comprises of both passive and active components. Usage of HPFs is still restricted due to several passive components and transformers causing its weight and size.

To overcome these problems Transformerless Shunt Hybrid Power Filter7–10 was introduced in this paper. The TSHPF comprises of SSTL inverter and passive filter coupled to Point of Common Coupling. Voltage rating of APF is considerably reduced by introducing SHAF design. Several control methods have been practiced so far, in time and frequency domain [4]. Methods introduced under frequency domain is Fast Fourier Transformation (FFT); under time domain are: 1) Instantaneous reactive power or P-Q theory, 2) Synchronous reference frame or D-Q theory and 3) Sliding mode control. Among them P-Q and D-Q theories are widespread due to reduced computational burden. To generate switching pulses in inverter linear control method is used [5].

To regulate DC bus voltage and harmonics, conventional PI controllers are used [6]. Presently, evolution of fuzzy logic controller has created enormous interest in various applications over PI controllers. The benefits of fuzzy over conventional controllers are explicit mathematical model is not required; can manage nonlinearity and more feasible than conventional controllers.

2. Proposed System Design

Figure 1 shows the fundamental circuit topology for TSHPF using SSTL for suppression of harmonics. The SHPF consists of SSTL inverter acting as an active power filter which is in series connection with passive filter [7]. This passive filter is adjusted to prevailing harmonic content for harmonic removal. APF circuit mainly composes of SSTL inverter with a DC bus capacitor. This APF retains a very low fundamental current and voltages of grid; hence the rated capacity of APF is being drastically reduced. Due to these advantages, the combined topology is very effective for compensating the current harmonics in power system network [8].

2.1 6-Switch 2-Leg Inverter

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Figure 2 shows SSTL inverter evolved from a 9-switch inverter. 9-switch inverter is obtained by joining 3-semi conductor switches per phase which leads to a total of 9-switches in all 3-phases. Elimination of a phase among the three viz. removal of three semiconductor switches in the third phase leads to a SSTL inverter [9]. These six switches are powered by a common DC bus capacitor. The SSTL inverter looks like two 3-ø inverters with passive filters in series thereby two sets of 3-ø outputs can be obtained. The two inverter units are treated as upper and lower inverters. ABC represents the output of upper inverter unit with passive filter adjusted to 7th harmonic and is capable for elimination of harmonic pair of 5th and 7th. Similarly XYZ represents the output of lower inverter unit with LC passive filter regulated to 13th harmonic and is capable for elimination of 11th and 13th order harmonic [10]. Both inverters in SSTL inverter topology are powered by a common DC side capacitor. To generate output from both upper and lower inverter units a minimum value of voltage across DC link is sufficient. Hence, HPF formed by series combination of SSTL inverter with LC passive filter would ensure low voltage requirement compare to conventional APFs [11].

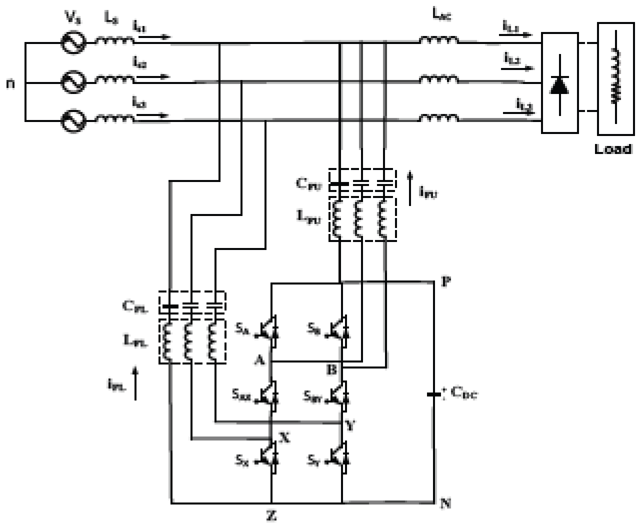

Figure 1. Configuration of proposed Transformerless HPF.

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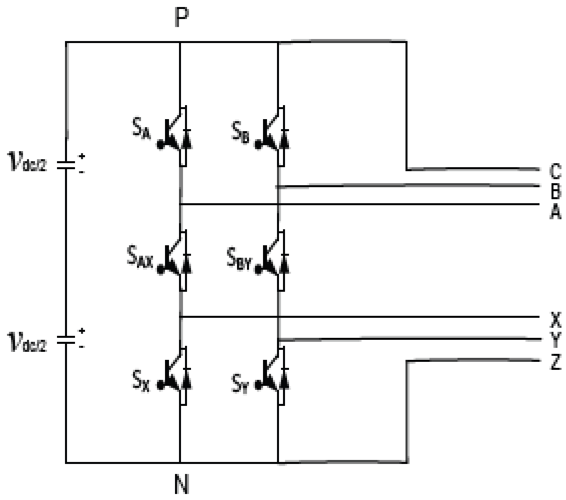

Figure 2. SSTL inverter configuration.

3. Hybrid Power Filter Modeling

3.1 Active Filter

Voltage across DC side capacitor (dc V):

The voltage across DC side capacitor for SSTL inverter can be calculated from the following equation:

$$V_{dc} = \frac{V_{dc\,refre}}{\sqrt{2}} \quad (1)$$

Capacitor (DC side) (C_{dc}):

The significance of capacitor (CDC side) is:

Under steady state condition, DC voltage is maintained with small ripples.

During transient state, the source and load real power variations can be met, by acting as energy storage component.

4. Control Strategy of Active Filter

The proportional controller is mainly responsible to control the harmonic component of source current. Hence in order to calculate its real time value, a fast algorithm is required. The greater response time of frequency domain algorithms made them inoperative. So, time domain algorithms are used; among them frequently accepted are instantaneous power theory and synchronous rotating reference frame method. The compensating command signals are acquired from d-q theory after performing transformation from 3-ø currents into 2-ø currents in stationary reference frame. The main difference

ISSN PRINT 2319 1775 Online 2320 7876

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of d-q theory and p-q theory is phase synchronization. The absence of phase synchronization in d-q theory made it more practical than p-q theory thereby avoiding problems associated with zero detection.

In this paper the controlling of filter is performed through synchronous rotating reference frame method11 and PLL loop. The presence of phase lock loop eliminates the zero detection problems.

4.1 Upper Inverter

4.1.1 Feedback Mechanism

Figure 3 represents upper inverter unit feedback mechanism. The transformation from abc to d-q converters three phase current source currents is1, is2, is3 into two phase currents id1 and iq1.

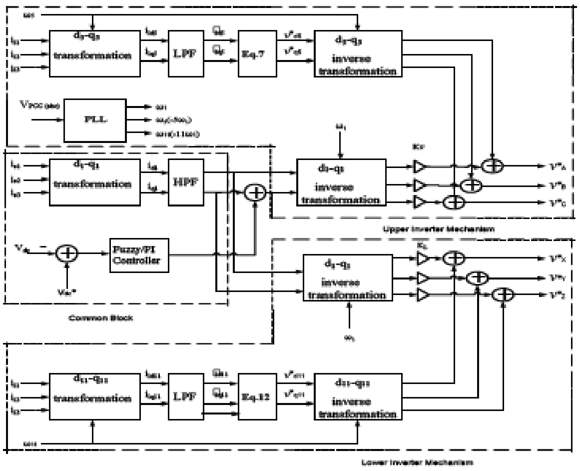

Figure 3. Control strategy of active power filter.

5. Simulation Diagram and Results

The simulation diagram for proposed Transformerless Hybrid Power Filter is shown in Figure 6 below: MATLAB environment is used to examine the complete system. Table 2 specifies the parameters of the system. The passive filters are tuned at 7th and 13th harmonic order respectively. The grid voltage amplitude is taken as 220V and dc-side voltage reference is 120V. Simulation results without filter with PI and fuzzy based controllers are projected in the following diagrams: 7, 8 and 9 respectively.

Table 1. Fuzzy decision table.

Error→ Change in error ↓	**VS**	**S**	**Z**	**B**	**VB**

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Research paper UGC CARE Listed (Group -I) Journal Volume 10, Iss 3, 2021

VS	VS	VS	VS	B	B
S	VS	S	Z	B	Z
Z	VS	Z	Z	B	VB
B	S	S	S	B	B
VB	VS	VB	VB	B	VB

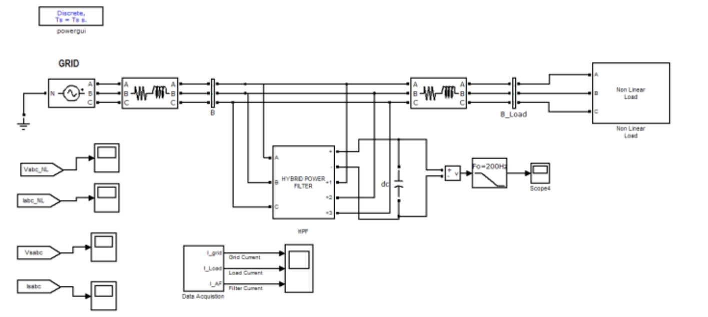

Figure 6. MATLAB model for TSHPF using SSTL inverter.

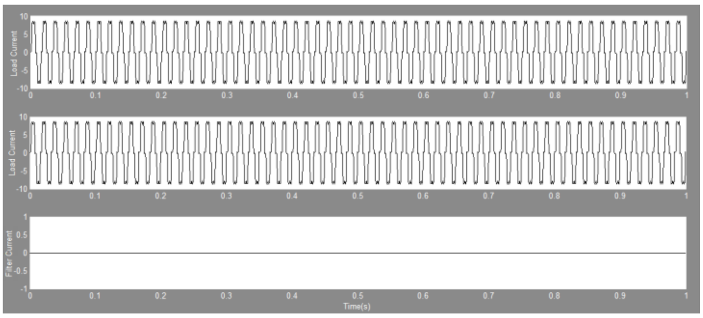

Figure 7. Simulation results without filter.

The results obtained from Figures 7, 8 and 9 demonstrate the usage of fuzzy controller incorporated in TSHPF using SSTL inverter, the supply current turn out to be almost sinusoidal from the distortion wave.

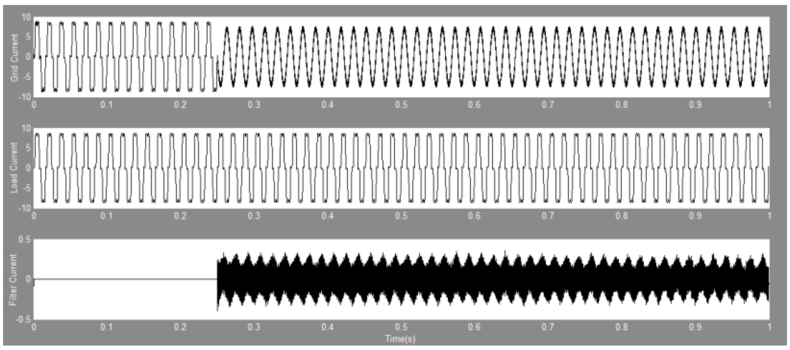

Figure 8. Simulation results with PI controller.

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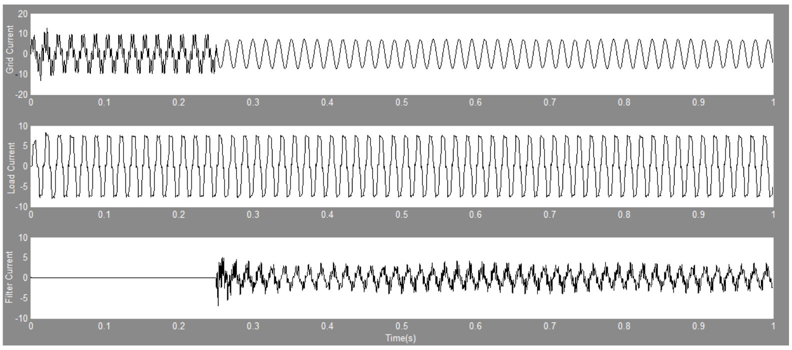

Figure 9. Simulation results with FUZZy logic controller.

Table 2. System parameters

PARAMETER	SYMBOL	VALUE
Seventh order harmonic tuned Upper capacitor	CFU	30.7 µF
Thirteenth order harmonic tuned Upper inductor	LFU	5 mH
Seventh order harmonic tuned Lower capacitor	CFL	61.2 µF
Thirteenth order harmonic tuned Upper inductor	LFL	0.8 mH

Table 3. Comparison of %THDs

TYPE OF CONTROLLER	% THD VALUES
Without filter	23.15
Transformer less HPF with PI controller	8.64

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Transformer less HPF with Fuzzy controller	3.40

Following Table 3 specifies the comparison of THDs for grid current with various controllers.

From the Table 3 it can be seen using the PI controller based Transformerless HPF, the grid current total harmonic distortion reduced to 8.64% from 23.15%. When the fuzzy controller is incorporated in the Transformerless HPF, the grid current total harmonic distortion is reduced to 3.40% from 23.15% which is in the allowable range as per the IEEE standards. Hence it can be observed that the proposed fuzzy based controller exhibits much better performance than the conventional PI controller.

6. Conclusion

Power quality is dependent on the load operating well with the least amount of maintenance and the greatest amount of care by preventing malfunctions of the other loads connected to the system. Hybrid power filters have been chosen as the optimum choice for nonlinear load correction in order to overcome the drawbacks of active and passive filters. Transformerless Hybrid Power Filters are recommended for the distribution system in the suggested plan. The performance of the controller with source current that is close to sinusoidal is enhanced by the fuzzy logic-based Transformerless Hybrid Filter, according to an absolute comparison between PI and fuzzy-based power in this work. Because it does not require extensive mathematical modelling and is very effective at stabilising dc link voltage, the suggested fuzzy control approach.

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