A Hybrid Series Active Filter Approach for Enhancing Power Quality in Single-Phase Networks

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Abstract: **Power quality degradation is significant issue in electrified systems, particularly those with substantial nonlinear loads. To mitigate these problems the paper suggests the hybrid series active filter device without transformer. The THSeAF designed to tackle the power quality problems in systems with large nonlinear loads. This method enhances the power quality by reducing harmonics and stabilizing voltage levels. This Paper deals with control of energy as well as power quality problems. The proposed control scheme focuses on mitigating current harmonics generated by nonlinear load and improving the systems power factor. Additionally it tackles the various problems affecting the power quality like voltage sag, voltage swell are reduced by using this system. In this the external voltage is injected in to the supply line using H-bridge converter to overcome the power quality problem. The paper includes simulation results demonstrating the effectiveness of the proposed method in improving power quality. The results likely show the reduction in harmonics and improvement in voltage stability, validating the methods performance.**

Keywords- Harmonics, Power Quality, THSeAF, Single Phase system, Nonlinear load, Sensitive load.

I. INTRODUCTION

In modern power system the harmonics are generated by nonlinear loads, such as electric vehicle chargers, pose significant challenges which affects on the voltage level of the system. As we know various problems like voltage sag, voltage swell, are generated due to the nonlinear loads. As a results the power quality deteriorates, leading to increased heating and losses in electrical equipment, ultimately reducing the system efficiency [1]. Nonlinear loads introduce harmonics that disrupt the power system by altering the maximum and RMS value of current. This disturbance not only decrease the efficiency of electrical equipment but negatively impact on the power quality of the system [2].

To address these issues and enhance the power quality, the Hybrid Series Active Filter (THSeAF) has been designed [5]. THSeAF are designed to mitigate the current harmonics, generated by nonlinear loads, while also improving the power factor of the system [3], [9].

This paper explores the application of THSeAF in cleaning the source-side electrical equipment from harmonics arising due to unbalanced loads. A key advantage of the THSeAF is its capability to individually control each phase without disrupting the others. This precise control allows for optimal compensation of harmonics across different phases, enhancing voltage stability and power quality [7].

The effective use of an H-bridge converter for voltage injection provides an effective means of real time compensation for power quality issues. By effectively controlling the switching operations, the hybrid strategy ensures the more stable output voltage. Stability of voltage is critical for maintaining power quality as voltage fluctuation can lead to various power quality issues [4], [6].

The hybrid nature of the converter combines the benefit of both active and passive filtering techniques, allowing the better performance in reducing the harmonic distortion compared to traditional methods. The ability of this H-bridge converter is to generate high quality output voltage and current waveforms which results in lower Total Harmonic Distortion, which is critical measure of power quality [8].

The subsequent sections will detail the simulation diagram and control scheme of the THSeAF, demonstrating its effectiveness in voltage restoration, power factor improvement, and reduction of voltage distortion.

II. BLOCK REPRESENTATION OF THSeAF.

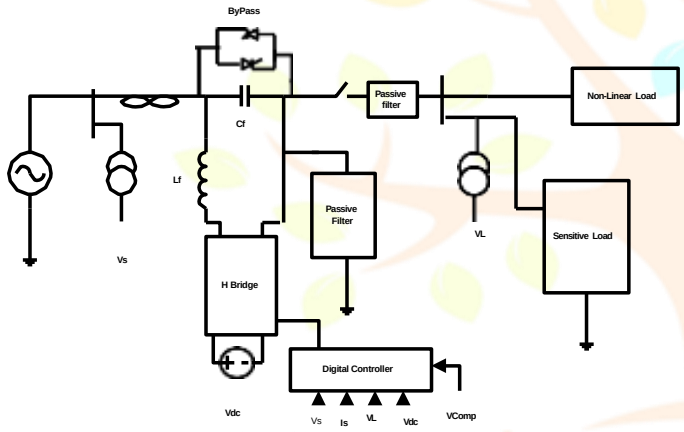

Fig. 1 Block diagram for THSeAF.

In this block diagram THSeAF described is a transformerless H-bridge converter connected in series between Source side and load side depicted in fig.1. It uses a shunt capacitor to filter current harmonics and can inject power during voltage sags via a dc auxiliary source. Designed for is having H-bridge converter connected in between them in series. The shunt type passive capacitor is also taken to filter current harmonics and inject power during voltage sags via DC auxiliary source. The THSeAF compensates the voltage by injecting it directly into the grid without the need for a bulky transformer, making it a cost-effective solution for mitigating current harmonics and voltage distortion.

III. OPERATING STRATEGY

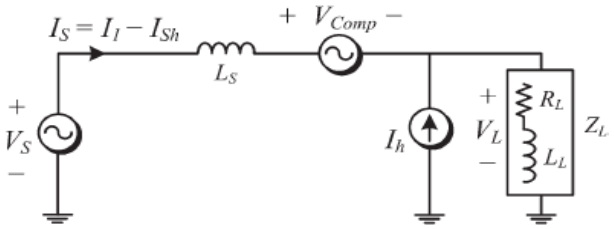

Fig. 2 Equivalent Circuit for THSeAF.

The fig.2 shows the equivalent circuit diagram of THSeAF. The source voltage (V Comp), (G) is the Gain which is directly Proportional to the current harmonics (Ish) flowing to the grid (Vs).

The SeAF represents a controlled voltage source (VSI). In order to prevent current harmonics *iLh* to drift into the source, this Fig2. THSeAF equivalent circuit for current harmonics. series source should present low impedance for the fundamental component and high impedance for all harmonics as shown in Fig. 2 The use of a well-tuned passive filter is then mandatory to perform the compensation of current issues and maintaining a constant voltage free of distortions at the load terminals. The behavior of the SeAF for a current control approach is evaluated from the phasor's equivalent circuit shown in above fig. The nonlinear load could be modeled by a resistance representing the active power consumed and a current source generating current harmonics. Accordingly, the impedance *ZL* represents the nonlinear load and the inductive load. The SeAF operates as an ideal controlled voltage source (*V* comp) having a gain (***G***) proportional to the current harmonics (*Ish*) flowing to the grid (*Vs*)

$$Vcomp = G.Ish - Vlh \ldots\ldots (1)$$

This allows having individual equivalent circuit for the fundamental and harmonics. The toltal source voltage is the sum of the fundamental voltage Vs1 and the harmonic voltage component Vsh. This equation simply states that the load voltage remains same.

$$Vsource = Vs1 + Vsh, Vl1 + Vlh \ldots\ldots (2)$$

The source harmonic current could be evaluated

$$Vsh = -Zs.Ish + Vcomp + VLh \ldots\ldots\ldots (3)$$

This Equation shows how the harmonic voltage component Vsh is affected by source impedance Zs, Vcomp and Vlh.

$$Vlh = Zl(Ih - Ish) \ldots\ldots\ldots (4)$$

Combining (3) and (4) leads to (5)

$$Ish = Vsh/(G - Zs) \ldots\ldots (5)$$

If gain G is sufficiently large (G→∞), the source current will become clean of any harmonics (Ish → 0). This will help improve the voltage distortion at the grid side. In this approach, the THSeAF behaves as high-impedance open circuit for current harmonics, while the shunt high-pass filter tuned at the system frequency creates a low-impedance path for all harmonics and open circuit for the fundamental; it also helps for PF correction.

The simulation of the THSeAF is processed using Matlab.Fig.3 is having the various blocks for controlling the harmonics in the system. The current harmonics are controlled by using PID controller. Mainly this system is working on AC Supply. The simulation shown above is done on MATLAB 2016. The result of THD are shown below.

IV. SIMULATION DIAGRAM

The graphs shown in fig. 4 the Total Harmonic Distortion without THSeAF is 76.73% is relatively. The THD value of 76.73% is relatively high, indicating that signal contains a substantial amount of harmonic distortion, which could impact the quality of the power signal and after using THSeAF we are getting it reduced to 24.54% as shown in fig.5 which is much lower showing that the signal has less harmonic distortion. Due to decrease in THD the system is highly efficient.

V. WAVEFORMS OF LOAD SIDE AND SOURCESIDE VOLTAGE AND CURRENT

The Fig. 6 show the source side voltage and current waveform have some distortion or ripple due to presence of harmonics. The THSeAF aims to clean the power supplied to the load by reducing the distortion and harmonics as evident from more sinusoidal nature of load side voltage and current compared to source.

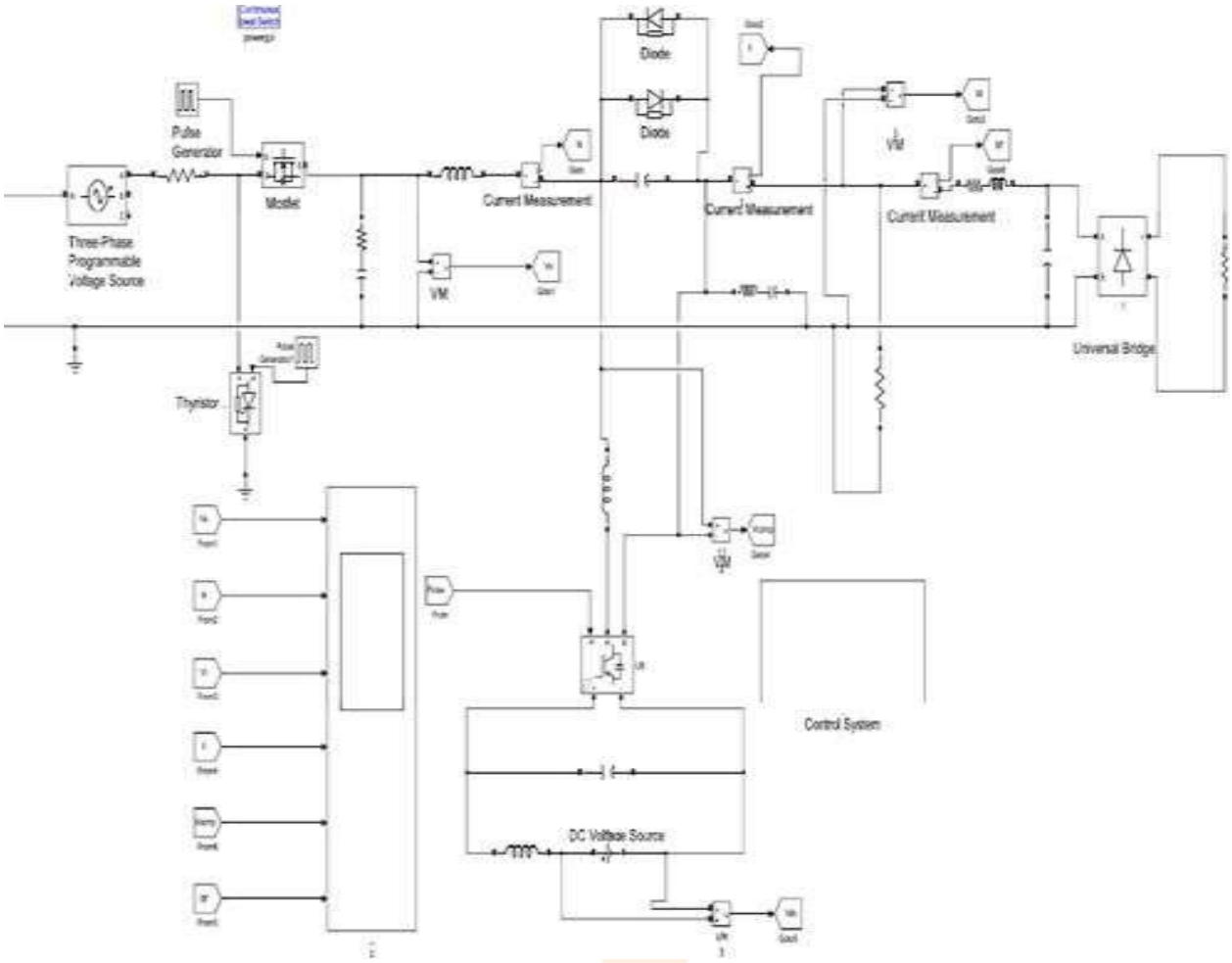

Fig. 3 Simulation diagram for THSeAF.

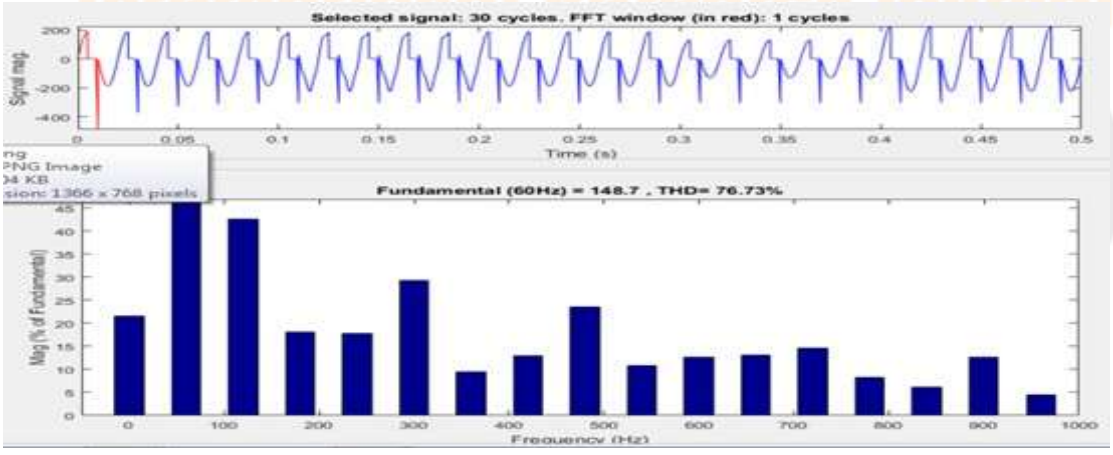

Fig. 4 Input THD without THSeAF

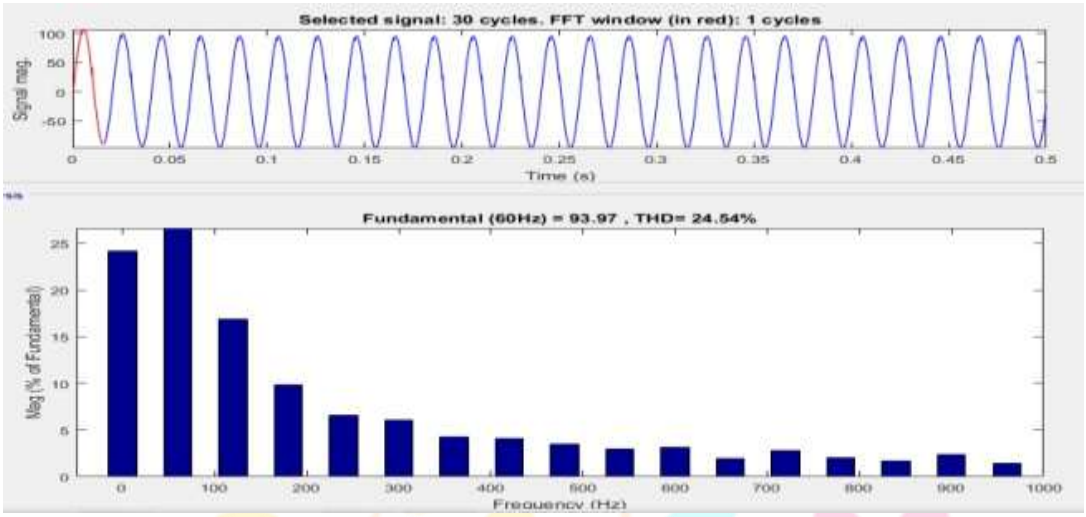

Fig. 5 Output THD with THSeAF.

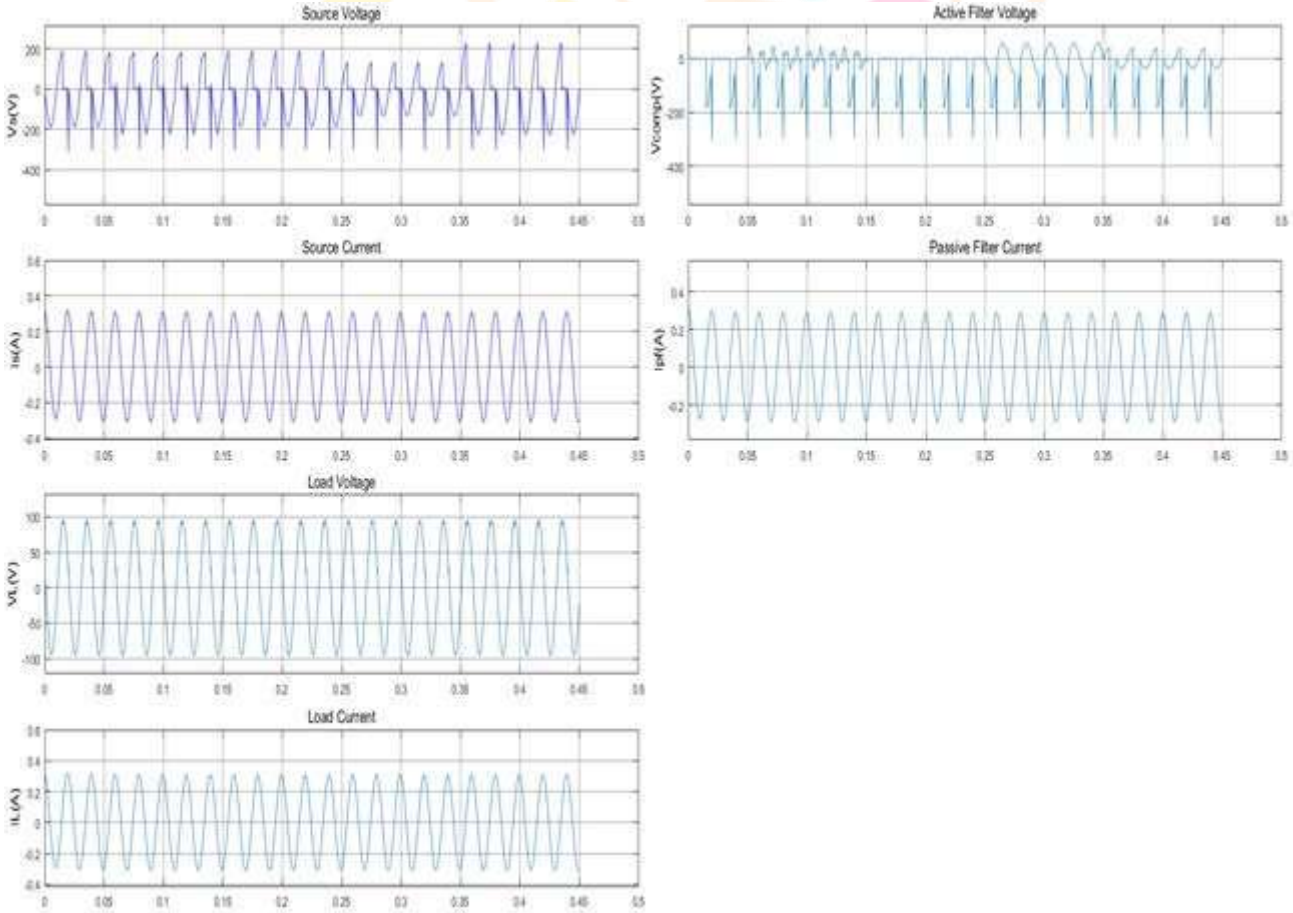

Fig. 6 Waveforms of load and source side voltage and current.

VI. VI. CONCLUSION

The paper deals with improving power quality in single-phase systems through the use of a Hybrid Series Active Filter (THSeAF). This device particularly effective in reducing the current harmonics on both the load and source sides. A key finding of research is that the Total Harmonics Distortion (THD) on input side decreases significantly from 76.73% without THSeAF to just 24.54% with it. This substantial reduction in THD demonstrates the effectiveness of the THSeAF in mitigate current harmonics. Additionally the paper highlights that THSeAF system is not only highly efficient but also simpler and more cost-effective compared to other harmonic compensation devices. These characteristics make the THSeAF a promising solution for enhancing power quality in single-phase systems.

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