Comparison of Five Level Inverters as Series Active Power Filters for Minimizing THD in a Non-Linear System

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Abstract
Background: A series hybrid Active Power Filter has been focused more to improve the power quality. The harmonics produced by the non linear loads are filtered out by the passive filters and the filtering property of it is improved by active filter. The filter is developed to inject voltage in series and also for harmonic isolation. Current harmonics are eliminated by controlling the APF with the P-Q theory based control strategy. The system produces voltage of same amplitude but opposite to load harmonic voltage to nullify the harmonics injected into the system. For current harmonics, the system produces voltage proportional to the current and offers high impedance path to the current harmonics. Objective: The hybrid filter is designed and implemented with three phase five level inverter as active filter and LC filter connected in parallel with power lines acting as passive filter to analyze the harmonic distortion. The five level inverter acting as active filter to compensate the harmonics voltage and current producing loads. Results: A performance comparison between the conventional cascaded five level inverter and the simplified five level inverter with passive filter when used as hybrid filter is analyzed. The validity of the control scheme is verified by simulation using MATLAB/SIMULINK and comparative analysis is carried out with help of simulated values to obtain the harmonic values within standard values. Conclusion: We have reported the total harmonic distortion of the system when connected with both type of inverters. It is noticed that the THD of the proposed simplified inverter produces reduced magnitude of harmonic distortion when compared to the conventional cascaded five level inverter.

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INTRODUCTION

The increase in use of power electronic components in today’s energy conversion system lead to the increasing power quality problems particularly power system harmonics. The harmonics introduces many malfunctions in equipments, overvoltage, heating and these cause harmonic impedance which affect system power quality. These harmonic current sources seems to be well identified, such as in industrial, commercial and residential facilities are exposed to well known patterns of waveform distortion. Non linear loads have been characterized into two types of harmonic sources as current source type and voltage source type harmonic sources. Their corresponding operating condition, features, applications issues, and adaptive harmonic sources of filters have been presented (Fang Zeng Peng, 1999).

Different non linear loads produce different harmonics but identifiable harmonic spectra. Various configurations of filters for elimination of harmonics produced by non linear load such as active and passive filters are discussed. These harmonics can be easily abated by use of filters such as passive filters which provides lower impedance to the tuned harmonic frequency than the source impedance to reduce harmonics flowing into the system. However it suffers from few disadvantages like parallel and series resonance and the effect of filtering characteristics get affected by supply impedance. They are also bulky, not suitable for variable loads and tuning frequency gets reduced with ageing, deterioration and temperature change.

This increasing austerity of harmonics in power system which made development of the equipment called as active filter which is also known as active power line conditioners. Several topologies of active filters are
proposed (Fang Zeng Peng, 1999; Peng, F.Z., 2001), and they have been surveyed based upon the types of non linear loads (Grady, W.M., et al., 1996). The active power line conditioners are classified as shunt and series, the use of these active filters for improvement of quality of power and their distinction is made (Singh, B., et al., 1999). Mostly shunt active filters have been implemented which compensates the harmonic current. Thus it acts as controlled current source for harmonic current produced due to non linear loads. However shunt active filters are expensive due to its large rating i.e. power capacity of filter increase with increase in load current to be compensated.

The emerging series filters can act as an active filter; this is capable of compensating voltage producing as well as current producing harmonics loads. The series active filter is better suited for harmonic voltage source such as diode rectifiers with dc smoothing capacitors (Salmeron, P., S.P. Litran, 2010). The series active filter acts as sinusoidal current source in phase with mains of voltage was developed (Alexander Varschavsky et al., 2010). This paper deals the filter used as hybrid i.e. in conjunction with passive filter.

The hybrid filter is used to mitigate source current harmonics as well as to regulate load voltage so as to compensate for abnormal utility voltages. Active filters can be implemented with Voltage Source Inverters (Dixon, J.W., et al., 1997) but it possesses some disadvantages like high switching losses and high harmonic noise.

The multilevel inverter finds its own advantages (Mariusz Malinowski, K. Et al., 2010) such as capability of producing cleaner voltage with low current distortion, operates with low switching frequency which drastically can reduce switching losses, Elimination of transformer by providing required voltage levels which results in faster response, simple structure and reduces voltage stress on power electronic devices.

For higher number of inverter levels there is the more complicated problem of maintaining capacitor voltage balance while retaining good filtering performances. To obtain efficient performance, it is important to obtain proper reference voltage generation. Major development in control strategy took place by (Akagi, H., et al., 1984) who introduces instantaneous power theory and another important technique by Synchronous Reference frame theory.

In this paper, the performance comparison of a hybrid filter using conventional cascaded H-bridge five level inverter and simplified five level inverter as an active filter and LC filter as passive filter. The advantage of using the simplified inverter structure is to obtain the same five level output with reduced number of switches when compare to the conventional one. Hence, the switching loss, complexity in designing the control circuit is reduced. The use of reduced number of switches naturally improves conversion efficiency. Similar method of active filter is implemented in paper (Alexander Varschavsky, et al., 2010) which uses nine level topology with transformers. The nine level inverter which makes the control circuit complex to control eight switches. This comparison study explains harmonic distortion in the input voltage and current with and without filters of the system. It overcomes the disadvantages by eliminating the use of transformer and reduces the switching losses.

**System Description:**

**System Configuration:**

The configurations of a hybrid filter connected into a non linear system using CCHBMLI and simplified multi level inverter is shown in Fig.1 and Fig.2. In this, a three phase source is connected to a non linear load which produces the voltage type harmonics. The hybrid filter consists of shunt passive filter connected to the load and series active filter in series and parallel to the load. A three single phase series connected transformer is not only to inject voltage into the system but also isolate the inverter from source side and also match the current and voltage of the inverter to the system specifications.

![Fig. 1: Hybrid Series Filter Configuration using CCHB Five Level Inverter](image-url)
Operation Principle:

The operating principle of series active filter is different from shunt active filter. The series active filter is considered as controlled voltage source which generates compensation voltage for injection into the system. The active filter consists of three main circuits, namely control circuit for generation of compensation voltage, generation of gating pulse to the inverter and the inverter main circuit.

The control circuit produces reference voltage and the pulse generation circuit produces gating pulses to control the inverter for compensation. Fig. 3 shows the single phase equivalent circuit of series active filter, where \( v_s \) is the source voltage with source impedance \( z_s \) and current \( i_s \) is the source current. The voltage across load is denoted as \( v_l \); \( v_{Af} \) denotes the compensated voltage by active filter. Current or Voltage signals contains fundamental as well as harmonic content which is denoted as: \( v_{sf} \) and \( v_{sh} \) for source voltage respectively, \( i_{sf} \) and \( i_{sh} \) for source current respectively. Similarly the load voltage is described as \( v_{lf} \) and \( v_{lh} \) for its fundamental and harmonic content.

Reference voltage is generated by detecting source current harmonics \( i_{sh} \), and it generates reference voltage which is \( K \) times proportional to source harmonic current (i.e. \( K \cdot i_{sh} \)). Thus the series active filter is represented as resistor which has the value of \( K \); the series active filter has value of zero for \( K \), while it is \( K \) ohms for harmonic components. The reference voltage to each phase is

\[
V_{Af} = K \cdot i_{sh} + v_{AFf}
\]

From Fig 3 the harmonic current content is directly derived as

\[
I_{sh} = \frac{V_{af} - V_{hf}}{Z_s + K}
\]

The series active filter offers high impedance path to the current harmonics and also acts as damping resistance, eliminating harmonic sinks problems which is an ingrained problem of shunt passive filter. (Alexander Varschavsky, et al., 2010)

The series active filter is mostly used as controlled voltage source which is operated with shunt passive filter to compensate voltage producing harmonics. The load current is made to circulate mainly through passive
filter rather than power system. This technique is recommended for voltage unbalance and voltage sags from AC system and low power system. The filter is installed at PCC of the distribution line (Hirofumi Akagi, 1994). The active filter injects current to a radial distribution system at PCC (Tien-Ting Chang, Hong-Chan Chang, 2000) which determines the spectra of harmonics and location of injection by suitable method.

**Multilevel Inverter:**

*Conventional CCHB and Simplified Multilevel Inverter Topologies:*

![Fig. 4: Basic Switching Circuitry of Five level Inverter: a) Cascaded Inverter b) Simplified Inverter](image)

The multi level inverter topologies used in this system are shown in Fig.4 a) and b). The conventional topology requires eight power switches to connected such a manner to produce five levels of voltage where as the other topology requires only six switches which drastically reduces power circuit complexity with simple design. The switching to the inverter is based on Phase Disposition PWM technique to produce five level output -2Vs to +2Vs. The strategy used two carriers and only one reference to produce the switching pulses.

For the Conventional CCHB MLI, the maximum positive voltage \((V_{s1}+V_{s2}) = 2V_s\) is obtained when the switches \(S_{11}, S_{24}, S_{21}\) and \(S_{14}\) are ON. The maximum negative output voltage \(- (V_{s1}+V_{s2}) = -2V_s\) is obtained when the switches \(S_{13}, S_{22}, S_{23}\) and \(S_{12}\) are ON. The first level positive voltage \(V_{s1}\) is obtained when the switches \(S_{11}, S_{21}\) and \(S_{23}\) are ON and \(V_{s2}\) is obtained when the switches \(S_{13}, S_{22}, S_{21}\) and \(S_{14}\) are ON. Similarly \(-V_{s1}\) is obtained when the switches \(S_{13}, S_{22}, S_{23}\) and \(S_{12}\) are ON and \(-V_{s2}\) is obtained when the switches \(S_{23}, S_{12}, S_{13}\) and \(S_{22}\) are ON. The zero voltage is obtained when all the switches are OFF.

For the Simplified MLI, the maximum positive voltage \((V_{s1}+V_{s2}) = 2V_s\) is obtained when the switches \(S_{12}, S_{21}\) and \(S_{23}\) are ON. The maximum negative output voltage \(- (V_{s1}+V_{s2}) = -2V_s\) is obtained when the switches \(S_{11}, S_{13}\) and \(S_{22}\) are ON. The first levels of both positive and negative voltages are \(V_{s1}\) or \(V_{s2}\) and \(-V_{s1}\) or \(-V_{s2}\) are obtained when the switches \(S_{23}, S_{13}\) and \(S_{21}\) and \(S_{11}, S_{22}\) and \(S_{23}\) are ON. The zero voltage is obtained when all the switches from any one right or left leg are turned ON.

**Modulation Strategy:**

In general, inverters are modulated by pulse width modulation or pulses are generated by comparison of a modulated signal with carrier. The index of modulation is represented in two indices signal.

Amplitude Modulation \((m_a) = \frac{A_m}{(m-1)A_c}\) (3)

Frequency Modulation \((m_f) = \frac{F_c}{F_m}\) (4)

The carrier signals are defined with same frequency \(F_c\) and amplitude \(A_c\). The index of modulation is shown in (3) and index of frequency is shown in (4) which is ratio of frequency of carrier with respect to the modulator. This is always greater than one.

**Table-1: Switching Sequence of CCHB Five Level Inverter**

<table>
<thead>
<tr>
<th>(V_{s1})</th>
<th>(S_{11})</th>
<th>(S_{12})</th>
<th>(S_{13})</th>
<th>(S_{14})</th>
<th>(S_{21})</th>
<th>(S_{22})</th>
<th>(S_{23})</th>
<th>(S_{24})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>((V_{s1}+V_{s2}))</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(-V_{s1})</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(-V_{s2})</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 2: Switching Sequence of Simplified five Level Inverter

<table>
<thead>
<tr>
<th>Voltage levels</th>
<th>S11</th>
<th>S12</th>
<th>S13</th>
<th>S21</th>
<th>S22</th>
<th>S23</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_s$</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$(V_s+V_s)$</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$-V_s$</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$-(V_s+V_s)$</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1 and 2 lists the switching combination that generates the required five level output. The carrier and reference signals for pulse generation are shown in Fig.5.

Fig. 5: Comparison of Carrier and Reference signals

Harmonic Elimination:
Output voltage $V(t)$ of MLI can be expressed in Fourier series as

$$V(t) = \sum_{n=1}^{\infty} (A_n \sin n \alpha + B_n \cos n \alpha)$$

(5)

Due to the quarter wave symmetry of output voltage the even harmonics are absent ($B_n = 0$) and only odd harmonics are present (Wanmin Fei, Xinbo Ruan, Bin Wu, 2009). The amplitude of $n^{th}$ harmonic $A_n$ is expressed only with first quadrant switching angle $\alpha_1, \alpha_2, \ldots, \alpha_n$

$$A_n = \frac{dV_{dc}}{dn} \sum_{k=1}^{n} \cos nk$$

(6)

For any odd harmonics $A_n$ can be expressed up to $k^{th}$ term. Multilevel inverters are mainly employed in three-phase medium and high-voltage systems in which all the triplen harmonics are absent in output voltage because triplen harmonics can be automatically cancelled in line-line voltages for a balanced three phase system. The low order non triplen harmonics in the line-to-neutral voltages are to be eliminated.

Control Scheme:
The reference voltage generator and controller circuit are mainly used in harmonic elimination and PQ theory is employed for the purpose of generation of reference voltage. The controller for reference voltage generation is shown in Fig.6 which is based on PQ theory discussed in following section.

Instantaneous power theory:
The appropriate voltage is used as reference by use of generalized instantaneous power theory (Akagi, H., et al., 1984) also called as PQ theory. The PI controller is used to maintain constant DC voltage across the dc link capacitor. According to this theory, three phase sinusoidal source voltages and distorted line currents are considered for reference generation. Instantaneous quantities of voltages are $V_a, V_b, V_c$ and the currents are $i_a, i_b, i_c$ of a three phase system are considered. The a-b-c co-ordinates are to be transformed into $\alpha-\beta$ coordinates as orthogonal system by Clarke’s transformation as follows.
The conventional instantaneous power \( P_{ac} \) on the three phase circuit can be defined as follows:

\[
P_{ac} = V_a i_a + V_b i_b + V_c i_c = V_{\alpha} i_{\alpha} + V_{\beta} i_{\beta}
\]  

**(9)**

Instantaneous real power is passed through second order butterworth filter (50Hz Low Pass Filter) which eliminates higher order thereby permitting only fundamental component which is denoted by \( P_{ac\text{loss}} \).

The conventional instantaneous reactive power on the three phase circuit is

\[
Q = V_{\alpha}^* i_{\alpha} + V_{\beta}^* i_{\beta}
\]  

**(10)**

The power components \( P \) and \( Q \) are related to the same \( \alpha-\beta \) voltages and currents, they can be written as

\[
\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} V_a & V_b \\ V_b & V_c \end{bmatrix} \begin{bmatrix} i_a \\ i_b \end{bmatrix}
\]  

**(11)**

The instantaneous real power is calculated from AC component of real power loss \( P_{ac\text{loss}} \) and DC power loss which is denoted by \( P_{dc\text{loss}} \). The DC power component is obtained by comparing dc link capacitor voltage of H bridge inverter and reference voltage. The PI controller determines the dynamic response and settling time of dc capacitor

\[
P_{dc} = [V_{dc,\text{ref}} - V_{dc}] k_p + k_i/s
\]  

**(12)**

Instantaneous voltage on \( \alpha-\beta \) divided into real power loss and reactive power loss. The proposed controller computes only real power loss and reactive power loss is taken as zero

The reference voltage generation

\[
\begin{bmatrix} V_{\alpha}^* \\ V_{\beta}^* \end{bmatrix} = \begin{bmatrix} 1 & -1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} i_a - i_b \\ i_b \end{bmatrix} \begin{bmatrix} P_{dc} + P_{o} + P_{ac\text{loss}} \end{bmatrix}
\]  

**(13)**

Where

- \( P_{dc} \) is average component of instantaneous real power
- \( P_{o} \) is zero sequence power
- \( P_{ac\text{loss}} \) is power loss in the system.
The reference voltage generation for compensation in a-b-c coordinates can be obtained by inverse Clarke’s transformation

\[
\begin{bmatrix}
V_a^* \\
V_b^* \\
V_c^*
\end{bmatrix}
= \sqrt{2}
\begin{bmatrix}
\frac{1}{\sqrt{2}} & 1 & 0 \\
\frac{1}{\sqrt{2}} & \frac{1}{2} & \frac{\sqrt{3}}{2} \\
\frac{1}{\sqrt{2}} & \frac{1}{2} & -\frac{\sqrt{3}}{2}
\end{bmatrix}
\begin{bmatrix}
V_{ca} \\
V_{cp} \\
V_{co}
\end{bmatrix}
\]

\(V_{ca} = -V_o\) \hspace{1cm} (15)

The instantaneous real and reactive power theory has several advantages such as it can be inherently applied to a three phase system which can be balanced or unbalanced, with or without harmonics in case of both current and voltage. The system with PQ controller has very good dynamic response. This includes only algebraic expressions which are relatively simple.

**Simulation Results:**

The proposed hybrid filter is implemented using MATLAB/SIMULINK for 2 kVA, 440V and 50Hz system using multilevel inverters as series active filter. From the above discussed equations the compensating voltage is obtained by taking the source current and voltage. Hybrid filter simulation model is tested for compensating voltage source producing harmonic load. Since the power supply is a voltage source, the series active filter tries to control the load voltage. But the load current depends on it terminal voltages. The voltage that the series instantaneous active filter wishes to inject depends on the current of the load, and the current of the load depends on its voltage.

The non linear diode rectifier with R-C load acts as voltage producing harmonic load and the cascaded MLI as active filter in series at PCC for injection of anti harmonics. Elimination of harmonics in the system is done by computing load voltage and source current. The series active filter is more suitable for voltage harmonics non linear loads such as diode rectifiers with smoothing capacitors and SMPS. The harmonic spectra and THD for load voltage and source current are analyzed. It uses system with no filter, with passive filter and with hybrid filter are analyzed for the source current and source voltage of a three phase system in this section.

![Fig. 7: Simulated output for three phase Uncompensated System (a) Source Voltage (b) Source Current](image)

The compensated voltage is injected into the system with help of three single phase matching transformers. Fig.7 shows the source voltage and source current waveforms of the system when there is no compensation for the harmonics is made. The harmonic spectra of the system with presence of harmonic contents are shown in Fig.8. These distorted components have to be compensated rather than isolating by use of filters.

![Fig. 8: Harmonic Spectra of Uncompensated System (a) Source Voltage (b) Source Current](image)
When the active filter is offline it does not inject the compensating voltage into the system instead it shows anticipated waveforms. The shunt passive filters reduces the harmonic level to certain extent further reduction in harmonics will introduce resonance problems with increase in component value. The system with the use of passive filter can mitigate the harmonic to the level which is shown in Fig.9 and their harmonic content is shown in Fig.10.

Fig. 9: Simulated output for three phase System with passive filter Source Voltage (b) Source Current

However smaller harmonic distortion still remains at source current due to presence of distorted components in the system voltage. The use of passive filters will eliminate harmonic content in the source voltage from 5.24% to 3.29% and source current from 35.78% to 9.31%. The voltage that the series active filter injects depends on the current of the load, and the current of the load depends on its voltage. The use of active filter will eliminate the oscillating component of the real power.

The controller used is based on PQ theory by producing voltage reference to produce gate pulses. The voltage source injects the voltage to eliminate the harmonics. The compensated voltage is to be injected into the system through series transformer is shown in Fig.11 a) and b). Considerable amount of fundamental voltage appears across the terminals of the active filter, which is due to resistive loss at AC side of the filter transformers. By introducing hybrid filter the line current becomes sinusoidal than the expected outcome compared to the use of LC filter alone.

Fig. 10: Harmonic Spectra with Passive filters Source Voltage (b) Source Current

Fig. 11: Active filter Voltage generated by a) Cascaded Five level inverter b) Simplified Five level Inverter
Cascaded Five level Inverter as active filter:
The cascaded h-bridge five level inverter as active filter injects the required amount of injection voltage into the system for harmonic elimination and the source becomes almost sinusoidal as shown in Fig.12. The line current THD is drastically improved by use of hybrid filters from 9.31% to 0.98% and also the source voltage is reduced from 3.29% to 0.21% where almost all the harmonics goes to zero level which is shown in Fig.13.

Fig. 12: Simulated output for three phase system with Hybrid filter (CCHB) (a) Source voltage (b) Source Current

Fig. 13: Harmonic spectra of System with Hybrid Filter (CCHB) (a)Source Voltage (b) Source Current

Simplified Multilevel Inverter as active filter:
The simplified five level inverter as active filter injects the required amount of injection voltage into the system for harmonic elimination and the source becomes purely sinusoidal as shown in Fig.14. The line current THD is drastically improved by use of hybrid filters from 9.31% to 0.53% and also the source voltage is reduced from 3.29% to 0.13% where almost all the harmonics goes to zero level which is shown in Fig.15.

The level of harmonics further reduces the source voltage harmonics and hence all harmonics go to zero with less harmonic content.

Fig. 14: Simulated output for Three phase system with Hybrid filter (SFLI) (a) Source voltage (b) Source Current
Fig. 15: Harmonic spectra of System with Hybrid Filter (SFLI) (a) Source Voltage (b) Source Current

Improvement of voltage source harmonic depends upon utility stiffness if is the system is strong voltage is not affected by harmonic currents flowing from loads and action of APF cannot be seen clearly. Alternatively if the system is weak, line currents affect the source voltage and performance of APF can be understood clearly. From the above discussions, the FFT analysis of the hybrid filter indicates that the THD of source current is brought less than 5% as compliance of standards such as IEEE 516, IEC 61000-3.

The passive filters used in the system are shown in Table 3 and Table 4 shows performance of THD of source current and source voltage of the system before compensation and series hybrid filter connected to it.

**Table 3: List of Passive Filters**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>C(µF)</th>
<th>L(mH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250Hz</td>
<td>32.88</td>
<td>12.32</td>
</tr>
<tr>
<td>350Hz</td>
<td>32.88</td>
<td>6.29</td>
</tr>
</tbody>
</table>

**Table 4: Harmonics of the system input voltage and current**

<table>
<thead>
<tr>
<th>SL.No</th>
<th>Type of Inverter used for Hybrid Filter</th>
<th>Description</th>
<th>Type of Compensator</th>
<th>%THD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>Source Voltage</td>
<td>Without Filter / Uncompensated System</td>
<td>5.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Source Current</td>
<td></td>
<td>37.58</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>Source Voltage</td>
<td>With Passive Filter</td>
<td>3.29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Source Current</td>
<td></td>
<td>9.31</td>
</tr>
<tr>
<td>3</td>
<td>Cascaded H Bridge Five level Inverter</td>
<td>Source Voltage</td>
<td>With Hybrid Filter</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Source Current</td>
<td></td>
<td>0.98</td>
</tr>
<tr>
<td>4</td>
<td>Simplified Five Level Inverter</td>
<td>Source Voltage</td>
<td></td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Source Current</td>
<td></td>
<td>0.49</td>
</tr>
</tbody>
</table>

Fig. 16: Graphical Representation of Harmonic spectra of System (SFLI) (a) Source Voltage (b) Source Current

**Conclusion:**

Thus series active filter not acts as harmonic compensator rather as harmonic isolator. A hybrid series active power filter based on five level inverter acting as high impedance path for voltage producing harmonic
loads. The effect nonlinear loads on the power quality of the system are analyzed. The control strategy is to obtain almost sinusoidal voltages and currents using the conventional cascaded multilevel inverter and simplified multilevel inverter as an active filters. The controller used in this paper for compensation of harmonics. The Hybrid filter compensates harmonic voltage source generated by contaminating loads. The THD comparative analysis is made for both the type of inverters used as an hybrid filters along with the passive filters and the Simplified five level inverter produces less harmonic distortion.

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