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Improved Harmonic Compensation Performance through Simulation-Based Transform Less HPF Using SSTL Inverter

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Abstract: Modern trends place a significant deal of attention on power quality and stability in distribution networks. The main cause of the PQ issue is the nonlinear loads, which result in current harmonics. It causes noise on the regulating and control circuit, which leads to incorrect operation of such equipment, and it causes considerable interaction with communications circuits along with AC Power line. This is one of the main problems with electricity quality. Using HPF in conjunction with the SSTL inverter, this power quality trouble can be reduced. HPFs can be connected straight to grid without the need for matching transformers by using smaller rating inverters and LC filters as part of their HPF design. Conversely, employing two converters results in a greater quantity of switches. The system is dependable, easy to use, and cost-effective when Transformer-less HPF with SSTL inverter is used to improve harmonic compensations in addition to harmonic compensation.

Keyowrds: Harmonic,HPF,PQ,SSTL.

1. Introduction*:*

In the current trends, power quality and stability in distribution networks are highly emphasized. The development of industrial drives and production systems necessitates a distribution system with a power supply that is both reliable and high-quality. PQ is defined as "The concept of powering and grounding sensitive electronic equipment in a manner suitable for that equipment's operation" by IEEE1100, an IEEE standard. When maximum electrical drives are subjected to PQ issues, malfunctions are inevitable. The majority of electrical equipment, including computers, household appliances, electric motors, transformers, and generators. Depending on how severe the issues are, this campaign and others may be a negative response to the PQ problem.

"Power quality is a set of electrical limits that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy" is a potentially clearer and more concise definition. The term illustrates both performance and life expectancy. Voltage swell/sag, voltage flicker, harmonic distortion, impulsive transients, and interruption are among the many phenomena covered by PQ problems. Since the price of the tools has a significant impact on power quality, the customer's perspective must be taken into consideration while evaluating power quality. Therefore, it is necessary to have solutions tailored to a specific client with extremely sensitive loads since a quick response from the VG regulator is required.

In both residential and commercial distributions, the characteristic of current harmonics must be synthesized. Power electronics are a major component of many household and commercial appliances. Because of these devices, there is a noticeable influence on the voltage supplied quality. The electricity system suffers from additional losses. In contemporary commercial and industrialized application, power quality has becomean increasingly important concern. In both residential and commercial distributions, the characteristic of currentharmonics must be synthesized.

The nonlinear loads that produce current harmonics are the major reasons of the PQ issue.Because of its impact on delicate loads and the electrical distribution system, harmonic contaminations have become a major worry for power system specialists. Power system losses are increased by harmonic current components. Increased power loss, overheating, and hazy current waveforms are present in transformers that are operating at saturation.The reversal of the DC currents components injected or absorbed by electric loads or grid-associated converters coupled at the same PCC is implied by the certainty that a DC current components causes a small DC voltage component at the "point of common coupling" (PCC). "IEEE 519 defines current harmonics." Since it is advised to have control over the harmonics, steps are taken to normalize the harmonic currents.Due to their low cost, shunt passive filters—which include high passive filter and tuned LC filter for harmonic compensation—were traditionally employed. The main mechanism of the shunt APF are "Voltage source inverters" (VSI) and a sizable DC link capacitor, which reduce current harmonicss to the required standard.

Higher power rated components are used by the shunt APFs to offset high peak harmonic currents.As analternative, the HPF is employed to combine PF and AF with the goal of reducing cost. The idea behind how HPFs work is to enhance filtering properties and p revent undesired grid resonance. However, HPF uses a lotof passiveparts in addition to the transformer, which make the filter heavier and larger. HPF inverters" (VSI) was connected to the PCC through the LC filters without matching transformers in to reduce filter components.

2. Objectives

IEEE 519 defines current harmonics, and is advised to have control over the harmonic current that nonlinear loads inject into the grid. An improvement in power-semiconductor device reliability spurred The distribution system is directly coupled to the customer and is situated at the ending of the reliability daily. However, because the customer demands high-quality power, the distribution system'sreliability needs to be increased. The following are the main goals of the suggested work:

Using HPF and SSTL inverters to cut down on the amount of power electronics switches'.

- To mitigate current harmonics.
- To bypass the matching transformer.
- The process to be simple, efficient and economical. Results in better harmonic compensation when compared with the existing method.

3. Literature Review

Giampaolo Buticchi and Luca Consolini [1] discussed aboutthe causes regarding grid connected converters and non-linear-loads which cause current harmonics in the grid current,a DC current component injection. The DC current component causes saturation to the magnetic core of "distributed power transformers (DPT). Transformers operating over saturation conditions present improved power losses, overheating and fuzzy current waveforms. Since a DC current section causesa small DC voltage element crash across the parasitic resistance of the distribution grid c0nductors, canceling the DC voltage component at the "Point of Common Coupling" (PCC) implies the reparation of the DC current component injected/absorbed by electric loads or grid connected converters connected at the same PCC.

Mohammed Qasim , Parag Kanjiya and Vinod Khadkikar [2] has reported that it is probable to have houses with non- linear loads occupying 80% or additional than that of the total loads. In accumulation, many engineering devices are nonlinear or become non-linear when combine with additional control-circuits. For illustration, most "induction motors" (IM), which are linear in nature, act as a nonlinear load when prepared with variable speed drives (VSD's). As a consequence, the power networks have become contaminated with harmonics at both distribution and transmission levels. Power converter, variable speed drive, cycloconverters, arc furnaces, battery chargers, large power supplies are some of the example of nonlinear loads [2]. Not only do these nonlinear currents increase the harmonics in the system but they also increase the reactive power demand. Conventionally, passive-filters were used to suppress harmonics.

"Author discussed that [3] the ever-increasing demand of power- electronics-based non-linear loads has increased several PQ problems. The irregular distribution of vigorously changing single-phase-loads gives rise to the supplementary troubles ofexcessive neutral current and current unbalance (UB). The combined effects of the above on today's power distribution systems effect in increased current and voltage distortions, disturbed supply voltages, extreme neutral currents, increasedlosses, reduced overall efficiency and poor power factor.

Qian Liu, Yong Kang and Li peng has described [4] a SAPF is a power-electronic device used to mitigate current harmonics from the polluted sources. It is connected near the PCC or near harmonic source.

The prime aim of SAPF is to identify the current-harmonics and to nullify them out leaving behind only the fundamental current at the utility side. The converters PWM technique in ASPF which will cause greater harmonic-pollution at the grid. This multiple switching frequency disturbs the supply voltage of the other sensitive load connected to the grid.

Ambrish Chandra, Bhim singh and Kamal AL-Haddad discussed that [5] furnaces, VSD's asynchronous ac-dc-ac- links uses large number of thyristors and other semiconductor-devices. These devices behaves as a non- linear loads to the supply and causes harmonic pollution, poor voltage regulation, lower PF. The unbalance at the load side affects the performance of other sensitive devices connected to it. They presented control algorithms of a APF for harmonic elimination at the PCC.

Hirofumi Akagi [6] has described the objective of shunt- active-filter to damp the harmonic contamination, which is resulting from the harmonic-resonance between capacitor for PF correction. Harmonic mitigation is a byproduct of SAF for damping the harmonic-propagation.

According to Patricio Salmeron and Salvador P. Litran [7], passive LC-power filters were typically employed to reduce current harmonics, and they were coupled in parallel to the load. The fundamental disadvantage of this compensating technique was that it couldn't provide a complete solution due to parallel and series resonance. APFs, which are primarily employed to attenuate any harmonic current from the source, are utilized to solve this issue.

Syed Karimulla and V.Arun Kumar [8] discussed the nonlinear loads associated to energy distribution networks create harmonic pollution. Such nonlinear-loads deplete currents with unstable degree of harmonic contents. The harmonic-current component does not signify useful active- power due to frequency variance with the grid voltage. However, the movement of harmonic currents through the feeders and protective network components produces Joule losses and electromagnetic-emissions that may obstruct with other devices coupled to the distribution network. This affects the performances of communication systems control and involved with the shielding elements. Control strategy is much simpler to implement than conventional strategies.

A three phase APF was proposed by Rogel R. Wallace [9] it employs VSI and PWM it has two important features. Firstly it can compensates current-harmonics the reactive power from nonlinear load and secondly it operates at fixed switching- frequency. Current-harmonic compensation is done in time domain and reactive power compensations is achieved without sensing and computing the reactive-component of load current.

."An advanced control strategy to improve performance of shunt active power filter (APF)" was proposed by Quoc-Nam Trinh [10]. The Proposed controlled method requires only two current sensors towords the supply side and does not require a harmonic detector. To build the supply currents purely sinusoidal, an effective method of harmonic compensation is developed with the support of a conventional proportional-integral (PI) and vector PI controllers. The lack of harmonic- detector it not only simplifies the control scheme but also appreciably improves the exactness of the APF, since the control performance is no longer exaggerated by the performance of the harmonic tracking process. Moreover, the total rate to implement the proposed APF becomes lesser, owing to the minimized current sensors and the use of a four-switch three-phase inverter the performance of APF is enhanced extensively compared to the conventional control scheme.

The author [11] explains that In power quality assessment, one of its most vital tasks is to monitor voltage harmonics. An important factor in the accuracy attained is the instrument transformer. Its frequency response function is usually measured in order to assess its harmonic measurement performance. Nonlinearities, however, may have a significant effect on measurement uncertainty; this is the case, for instance, when taking into account inductive voltage transformers. Author explains, a straightforward method for compensating for the largest nonlinear effect the harmonic distortion cause by the large fundamental primary voltage is proposed. Numerical simulations are used to derive and introduce the method before a suitable experimental setup is used to put it into practice.

Li, W. Lu, S. Yan and Z. Zhao, "Improving Dynamic Performance of Boost PFC Converter Using Current-Harmonic Feed forward Compensation in Synchronous Reference Frame," [12] the harmonic distortion of the reference current is suppressed by using a current-harmonic feedforward compensation way in synchronous reference frame. Finally, a 225-W experimental prototype is built with digital implementation, and the experimental results show a more than 68% improvement of the dynamic response for the case with the proposed scheme as compared with the traditional LPF scheme, along with a high-quality controlled current.

Wu, L. Ding, C. Xue and Y. W. Li, "Model-Based Closed-Loop Control for High-Power Current Source Rectifiers Under Selective Harmonic Elimination/Compensation PWM With Fast Dynamics,"[16]. . To significantly decrease low-frequency current harmonics, in this paper author proposes a novel active disturbance rejection repetitive control scheme used for current loops, in which two improvements for the ESO are presented. One is the introduction of a low-pass filter (LPF) as an alternative of the conventional integrator, and that can enhance the disturbance observation capability.

4. Proposed Work

The HPF, shown in Figure 5.1, is built on the new SSTL inverter, which is a two-leg version 5n of the nine-switch inverter [12]. Two passive low-pass filters that are tuned to distinct harmonic frequencies are connected in series with the SSTL inverter, which is comprised of two three-phase inverter units. The top part, which has outputs ABC-is connected to the PCC via LC filters that are tuned roughly to seventh harmonic component. This eliminates the fifth and seventh harmonic pair and keeps the required value of the dc-link voltage constant. Likewise, the bottom-unit represented by the outputs RST—is linked to PCC via LC filter that are

adjusted to center about the 13th harmonics component. This allows the bottom unit to compensate for the 11th and 13th harmonic pair. Because the SSTL inverter has the similar number of switche as a traditional three-phase VSI, the projected topology aims to achieve greater compensation capabilities compared to conventional HPFs without raising the number of switches in the active filter.

There are two anomalies to be aware of, given that the SSTL inverter is a derivative of the nine-switch inverter with a nonconventional topology. First, if one of the nine-switchs inverter legs is removed and connected to the terminal "O" in Figure 3.1, there may be a dc_link voltage imbalance.

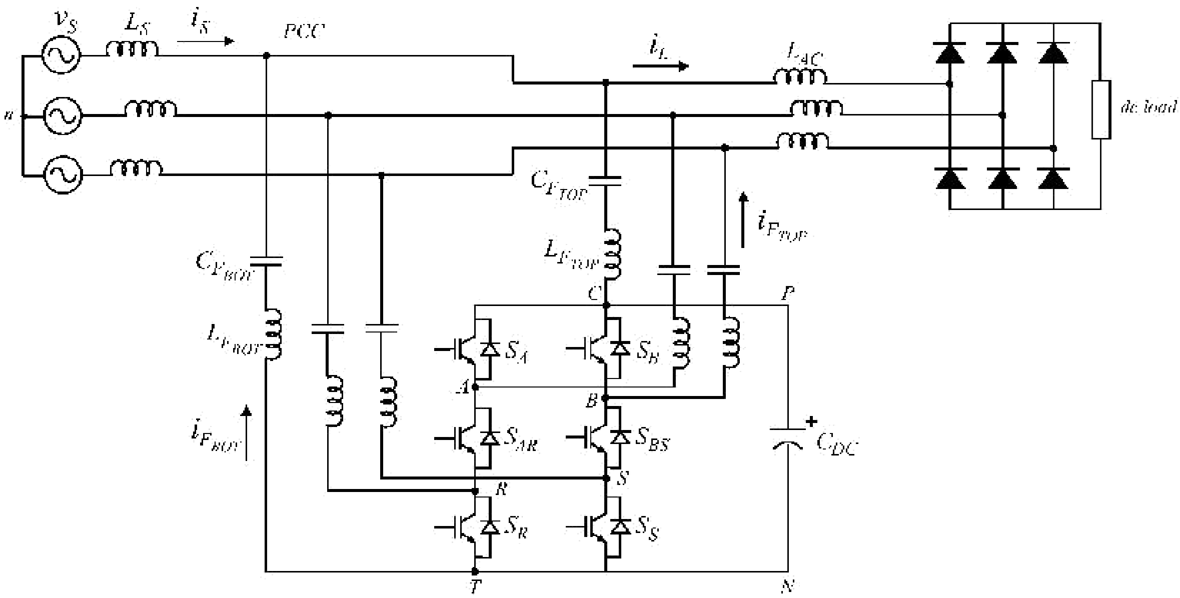

Fig 3.1: Proposed transformerless HPF based on SSTL inverter

4.1 SSTL inverter:

The resolution is to join the left overphase to the negative/ positive pole of dc -link. This method would guide to a dc voltage-injection in the network if the capacitors of *LC* filter (C_{FTOP} & C_{FBOT}) be not located between the dc- link pole & the PCC.

Furthermore, a dc circulation across phases ABC and RST may be naturally generated by the connection between the two inverter units and the PCC. Again, the passive LC filters' capacitors prevent the flow of dc current, preventing a short circuit in dc link.

Second, since the SSTL units split the same dc-link voltage, it's critical to keep dc-link voltage at a minimum high enough to provide the total of the two output voltages. However, when compared to traditional APFs, the series connection of the inverter with the passive filter in HPFs ensures a substantially lower voltage obligation at the inverter's output.Therefore, in the suggested topology, there is no problem with the dc-link 3 voltage level.

The SSTL inverter be analyzed, and a specific modulation- techniques are presented. then, the intend guidelines forthe *LC* passive filters are carried out.

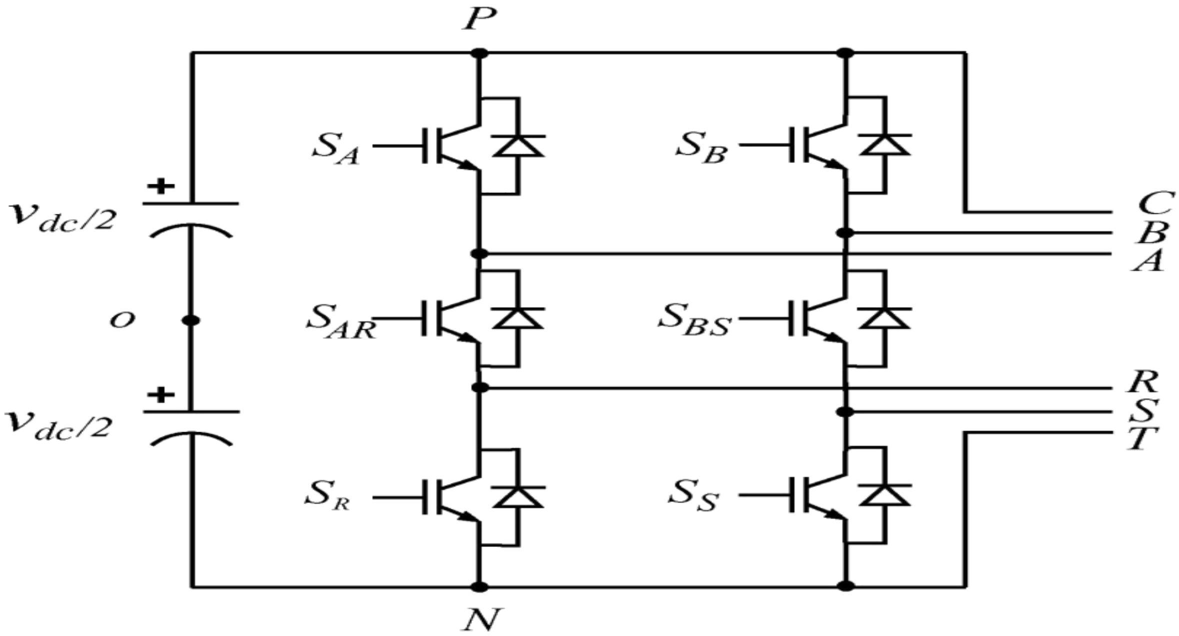

Fig 3.2: SSTL inverter

5. Simulation Results

Fig.4.1 shows the three phase source voltage and fig.4.2. shows the load side voltage without any harmonics.

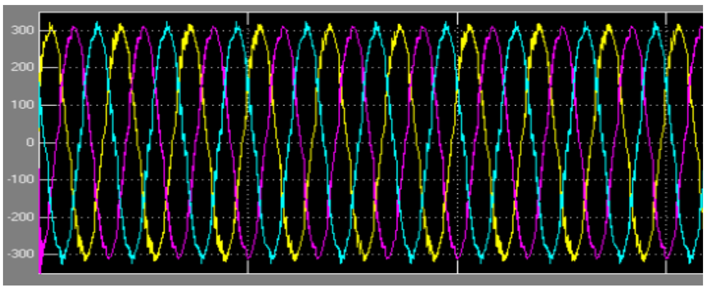

Fig 4.1: Source voltage

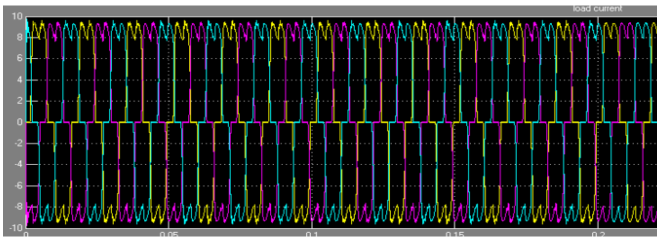

Fig 4.2: Load voltage without any harmonics

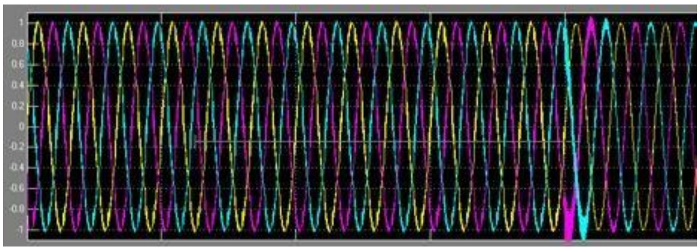

Fig 4.3: Balanced three phase source current

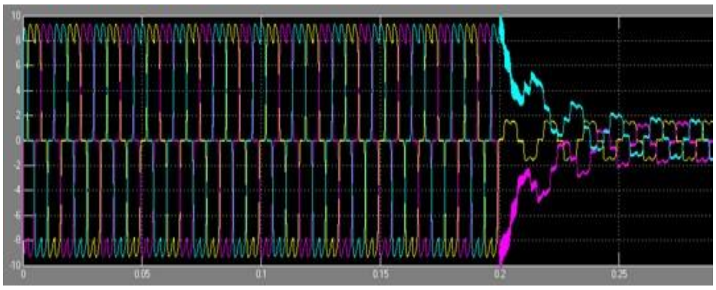

Fig 4.4: Load current with harmonic contents.

The Simulink control circuit form of the controller is as shown in the fig 4.5. The controller is tuned with fundamental, 3rd harmonic and 5th harmonic as shown in fig 4.6, 4.7 and 4.8 respectively.

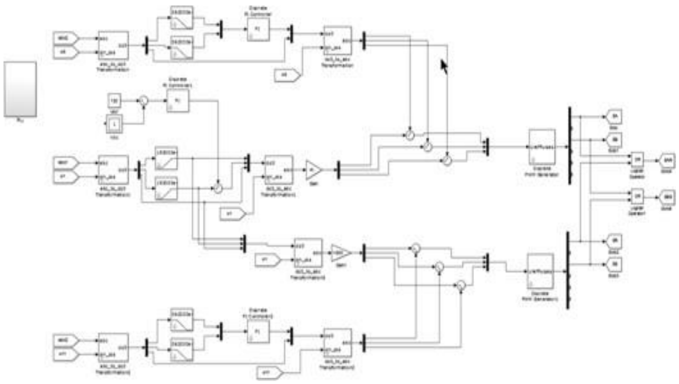

Fig 4.5: simulink control module

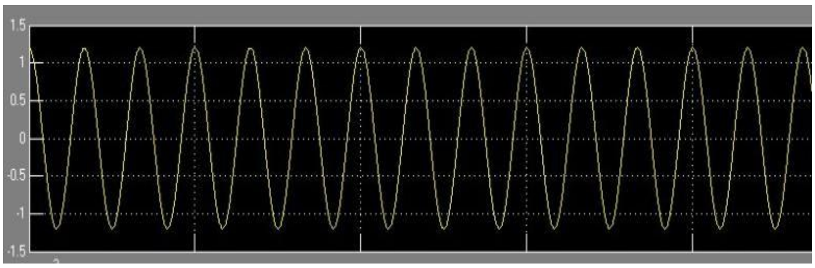

Fig 4.6: fundamental component

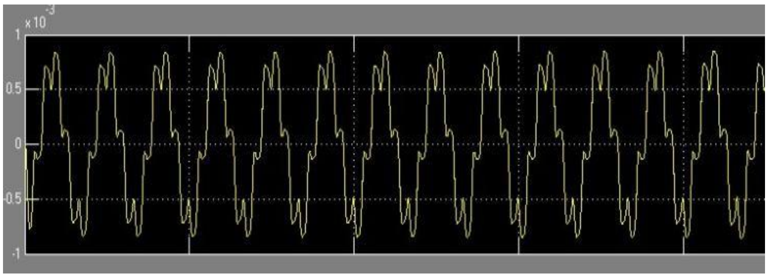

Fig 4.7: Third harmonic component

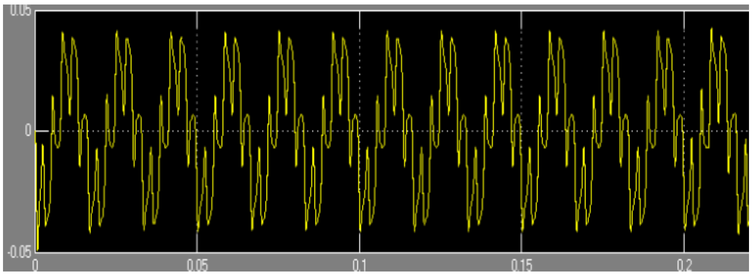

Fig 4.8: Fifth harmonic component

5.1 Comparison of THD with and without HPF

Table 1: THD before connecting filter

Sl no	THD(before connecting filter)	6.44
1.	H5	2.91
2.	H7	1.62
3.	H11	1.9
4.	H13	1.14

Table 2: THD after connecting filter

Sl no	THD(After connecting filter)	1.14
1.	H5	0.5
2.	H7	0.31
3.	H11	0.38
4.	H13	0.26

6. Conclusion

In this proposed work a Transformer less-HPF topology based on a SSTL inverter is confer. The projected inverter is divided in two part, which is connected in series with two passive-L*C* filters tuned for different harmonic frequencies, resulting an enhancement in the harmonic-compensation presentation with the compact number of switches comparing to that of other methods.

A complete scrutiny of both inverters and passive-filters, with the rule necessary to design HPF, is presented. The controlalgorithm of the proposed-system improves the performance of both passive-filters through feedback & feed forward compensations and it also controls the dc-link- voltage.

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