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Analysis of Passive Line Impedance Stabilization Network Filter to Reduce Harmonics at DC- DC Converter

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Abstract—The study aimed to develop a passive LISN filter capable of reducing total harmonic distortion of current (THDi) and voltage (THDv) in a DC-DC converter system, and to evaluate its effectiveness in improving overall system efficiency. The focus of this review is to assess the methodology, results, strengths, and weaknesses of the study in the context of recent literature on harmonic mitigation and EMI/EMC techniques in power electronic systems. Additional literature is also reviewed concerning input filter design, LISN characteristics, and EMI mitigation in power converters. Through an experimental approach, the study demonstrated a reduction of THDi by 25–30% and THDv by about 0.5%, although the results did not fully meet the IEEE 519-1992 harmonic standards. This review compares those findings with recent works on input filter design, harmonic mitigation methods, and LISN applications for electromagnetic compatibility (EMC). The analysis concludes that a passive LISN filter is effective as an initial stage for harmonic mitigation but requires a more complex (multi-stage or hybrid active-passive) design for optimal attenuation and better stability against variations in grid impedance.

Keywords: **LISN, harmonics, DC-DC converter, EMC, passive filter**

I. INTRODUCTION

Electrical harmonics are a major issue in modern power systems, particularly in semiconductor-based power conversion devices such as DC-DC converters. These devices operate using a switching principle, where rapidly oscillating current and voltage create high-frequency spectra that distort the fundamental AC waveform. This phenomenon leads to increased power losses, reduced efficiency, and electromagnetic interference (EMI) that can disturb nearby electronic devices.

In this context, the Line Impedance Stabilization Network (LISN) plays a crucial role—both as a measurement tool to isolate source impedance variations and as a filter element to suppress harmonics and stabilize the test system (Equipment Under Test).

According to Rashid (2004), input filters in converters serve to block high-frequency disturbances from entering the power network. Similarly, Johannesson and Fransson (2008) found that proper filter design can reduce electromagnetic emissions by up to 60%. Samapta et al. (2015) proposed LISN as a low-cost and simple passive solution to reduce current and voltage harmonics in single-phase DC-DC converter systems. However, with the emergence of modern harmonic mitigation methods such as active filters, hybrid filters, and random pulse-width modulation (RPWM), the effectiveness of passive LISNs must be reevaluated to meet today's performance and stability demands in power systems.

II. THEORETICAL BACKGROUND

2.1 *Electromagnetic Compability* (EMC)

Electromagnetic Compatibility (EMC) refers to the ability of an electronic system to operate properly within its electromagnetic environment without causing interference to other systems, and to withstand external disturbances without malfunctioning. According to Rashid (2004), EMC has two main aspects: *electromagnetic emission* and *electromagnetic immunity*. Emission describes a device's ability to limit electromagnetic noise radiated into the environment, while immunity describes its ability to resist external disturbances.

In power converters such as DC-DC converters, the main source of electromagnetic disturbance is the rapid switching of current and voltage, which produces high-frequency spectra known as Electromagnetic Interference (EMI). These disturbances can propagate through conductors (*conducted emission*) or via radiation (*radiated emission*). Thus, EMC control in power systems requires careful design to address noise propagation, grounding systems, layout optimization, and the use of filters to suppress harmonic and high-frequency components.

2.2 *Electromagnetic Interference* (EMI)

Electromagnetic Interference (EMI) refers to unwanted electromagnetic disturbances generated by intentional or unintentional sources that disrupt the operation of other electronic equipment. In power systems, EMI commonly arises from transients, current surges, or fast switching in semiconductor devices.

According to Bhattacharyya (2022), EMI can be classified into two main types: *common-mode noise* and *differential-mode noise*. Common-mode noise occurs on both conductors in the same direction relative to ground, whereas differential-mode noise occurs between two conductors with opposite directions.

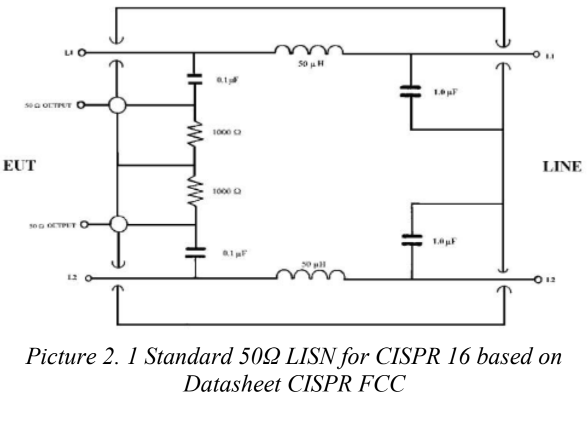
In DC-DC converters, EMI results from current variations in the inductor and switching transistors. The harmonic components generated are multiples of the switching frequency, reaching kilohertz to megahertz ranges. Excessive EMI can cause sensor malfunction, digital communication errors, and decreased system reliability. Therefore, EMI filters or LISNs are used to control conducted noise and maintain test stability according to EMC standards such as CISPR-16 and FCC Part 15.

2.3 *Line Impedance Stabilization Network* (LISN)

A Line Impedance Stabilization Network (LISN) is a passive device that provides a standardized and stable impedance between a power source and the Equipment Under Test (EUT). Its main function is to isolate source impedance variations during noise measurements and to direct disturbance signals to the measurement port (e.g., a spectrum analyzer or EMI receiver).

According to Fischer (2011), a standard LISN provides a 50 Ω impedance at the test frequency, complying with CISPR 16-1-2 specifications.

In addition to measurement purposes, LISN can also function as a low-pass filter that prevents high-frequency noise from feeding back into the power grid. In Samapta et al. (2015), the LISN was placed at the transformer input side to reduce current and voltage harmonics generated by nonlinear loads. Typically, LISN components include inductors, resistors, and capacitors configured to produce low impedance at low frequencies and high impedance at high frequencies, effectively blocking high-frequency harmonic currents while allowing accurate noise measurement.



Picture 2. 1 Standard 50Ω LISN for CISPR 16 based on Datasheet CISPR FCC

2.4 EMI Filters and Input Power Filters

EMI filters are one of the main solutions for mitigating electromagnetic disturbances. They reduce noise amplitude propagating through conductors, in both common and differential modes. The main components of an EMI filter are combinations of inductors (L) and capacitors (C) arranged in low-pass, high-pass, or band-stop configurations depending on the required attenuation.

Baranowski et al. (2021) reported that passive LC or π filters can reduce conducted emissions by up to 40 dB above 150 kHz. In DC-DC converter systems, input filters serve dual functions maintaining converter stability and reducing harmonics fed back to the grid. However, filter design must ensure dynamic stability. As Middlebrook (1976) explained, power converters can exhibit negative input impedance regions at certain frequencies, leading to oscillations if connected to undamped passive filters. Therefore, modern filter designs often include damping resistors or multi-stage LC configurations to achieve smoother frequency responses and prevent resonance.

2.5 Harmonics and Total Harmonic Distortion (THD)

Harmonisa are periodic waveforms whose frequencies are integer multiples of the fundamental frequency. When current or voltage waveforms deviate from pure sinusoids, harmonic components exist. Nonlinear loads—such as rectifiers, inverters, and DC-DC converters—are primary harmonic sources, causing additional power losses, transformer overheating, interference with digital kWh meters, and reduced system power factor.

The magnitude of harmonic distortion is expressed by the Total Harmonic Distortion (THD) parameter. For voltage, THD is formulated as:

$$THD_v = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots}}{V_1} \times 100\%$$

while the current is expressed as:

$$THD_i = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \cdots}}{I_1} \times 100\%$$

Where V_1 and I_1 are the fundamental components, while V_2, V_3, and so on are the second- and third-order harmonics, respectively. According to the IEEE 519-2014 standard, the maximum THDv limit for a distribution system is 3%, and the THDi for individual loads should not exceed 20% of the fundamental component. In a study by Samapta et al. (2015), the THDi value in a DC-DC converter system without a filter reached 109.6%, while after the installation of a LISN, it decreased to approximately 51.47%. While this reduction is significant, it is still above the permissible limit, requiring improved filter design or additional active filters to meet international standards.

2.6 DC-DC Converter

A DC-DC converter is an electronic circuit that converts DC voltage from one level to another. Based on its operation, it can be categorized into linear and switching types, with switching converters being more popular due to higher efficiency and smaller size. Common types include buck (step-down), boost (step-up), and buck-boost converters.

Switching converters produce pulsating current waveforms at the transistor's switching frequency, which are rich in harmonic components. According to Johannesson and Fransson (2008), a DC-DC converter operating at 100 kHz can generate harmonics up to 10 MHz, potentially causing severe interference in sensitive systems such as wireless communication or digital control devices. Thus, input and output filters are crucial to suppress harmonics and ensure stable DC output.

2.7 Rectifier

A rectifier converts alternating current (AC) into direct current (DC). Rectifier circuits can be half-wave, full-wave with a center-tap transformer (CT), or bridge configurations. In DC-DC converter systems, rectifiers serve as the initial stage before the switching process, but they also introduce harmonics because diodes conduct only during part of the AC cycle, distorting the current waveform.

Cahyani (2014) showed that a single-phase rectifier with resistive load can produce dominant 3rd, 5th, and 7th harmonics. Therefore, combining a rectifier filter with LISN is often used to stabilize current waveforms and reduce THD. In Samapta et al. (2015), a full-wave rectifier using a CT transformer provided DC input to the converter, with the LISN placed before the transformer to mitigate harmonics from the source side.

2.8 Testing Standard and Harmonic Regulations

In EMC and power quality testing, several international standards are applied to ensure measurement consistency, including CISPR-16, IEEE 519-1992/2014, and IEC 61000-3-2. CISPR-16 defines LISN characteristics and noise measurement procedures, IEEE 519 specifies harmonic limits for voltage and current in power systems, and IEC 61000-3-2 sets harmonic emission limits for residential and light industrial equipment.

In Samapta et al.'s study, measured THDv and THDi values after applying the LISN were 3.8% and 51.47%, respectively—still above IEEE 519 limits. This indicates that while LISN effectively reduces harmonics, additional filters are required to achieve compliance with international power quality standards.

III. METHODOLOGY

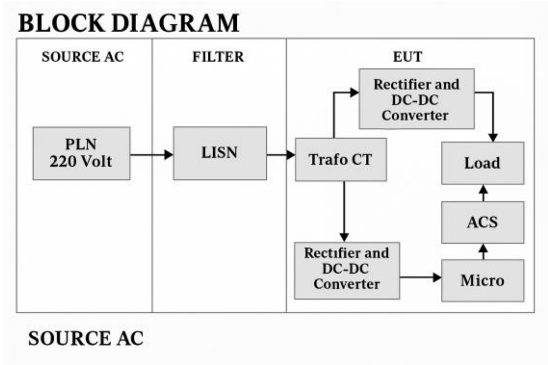
The reviewed study used an experimental laboratory approach. The test system consisted of a single-phase 220 V/50 Hz AC source, a 36 V step-down transformer, a full-wave rectifier (CT), a DC-DC converter, and a resistive lamp load. A passive LISN filter was placed on the transformer input side, and measurements were taken before and after filter installation.

Measured parameters included THDv (%), THDi (%), and power efficiency (%). Tests were conducted at several phase angles (90°, 110°, 130°, 150°, and 180°). Before filtering, THDv reached 4.2% and THDi ranged from 70.8% to 109.6%. After installing the LISN, THDv decreased to 3.7–3.8%, and THDi to 51.47–85.14%. System efficiency improved from 17–31% to about 45% under some conditions. Despite significant harmonic reduction, the results still failed to meet IEEE 519-1992 standards (THDv < 3%, THDi < 20%).

The LISN used was a simple passive configuration (single inductor and capacitor) without damping stages, frequency analysis, or simulation support, focusing purely on empirical observations rather than optimized filter design.

A. Measurement LISN

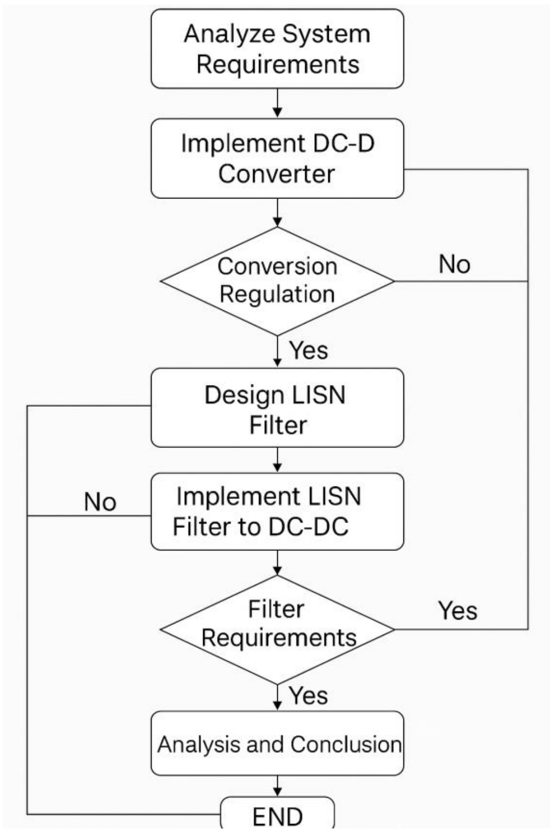
The system input is 220 volts alternating current at 50 Hz from the state electricity company (PLN). This input then enters a DC-DC converter circuit. The use of a non-linear load, such as the converter itself, can generate harmonics, distorting the original PLN waveform, distorting it, thus distorting it as a pure sine wave, potentially introducing interference or noise. To reduce the impact of these harmonics and noise, a passive LISN filter is installed after the single-phase AC source from PLN. This filter functions to filter harmonics and noise, which can be reduced to this level. The following is a system design block diagram.



Picture 3.1 System block diagram

B. Design Flowchart

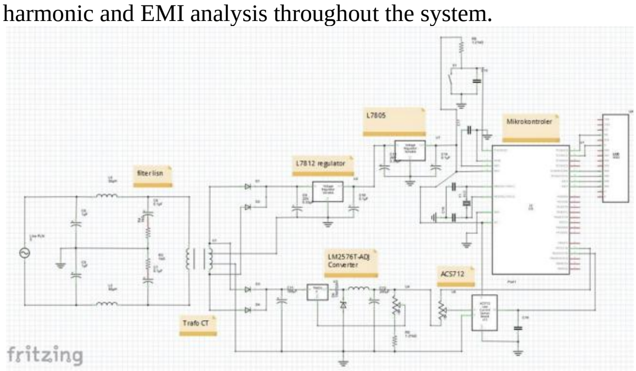
The following is a flowchart of the design of the DC-DC Converter and LISN filter in this research:



Picture 3. 2 Flowchart

C. System Circuit

Figure 3.3 illustrates the complete schematic of the LISN and EUT system, which begins with an AC power source of 220 V at 50 Hz passing through a Line Impedance Stabilization Network (LISN) that functions to reduce and measure conducted harmonics before entering the Current Transformer (CT). The CT isolates and distributes power to two main blocks: the rectifier and the DC–DC converter stage. The rectifier converts AC to DC, while the LM2576T-ADJ switching regulator provides efficient adjustable DC output, and linear regulators (L7812 and L7805) ensure stable 12 V and 5 V supplies for the microcontroller and sensors. The ACS712 current sensor monitors load current, which is processed by the microcontroller that also controls the load operation and displays data via the LCD. Each block, particularly the rectifier and DC–DC converter, introduces nonlinear characteristics that generate harmonics, making the LISN essential for filtering and providing a standardized impedance for harmonic and EMI analysis throughout the system.

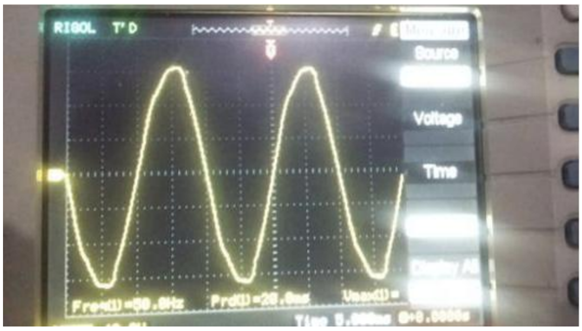


Picture 3.3 LISN and EUT Circuit Schematic

IV. TESTING AND RESULTS

4.1 Voltage Source Testing

The results of the voltage source test are displayed on the oscilloscope device and can be seen as in the following image.



picture 4.1 Transformer Signal Output as a Power Circuit Voltage Source

The oscilloscope waveform shown in Figure 4.1 displays the output signal of the step-down transformer, which is nearly sinusoidal with a frequency of approximately 50 Hz. Based on the horizontal time scale of 1 ms/div, one full cycle is about 20 ms, corresponding precisely to a 50 Hz power frequency. With a vertical scale of 5 V/div and an observed amplitude consistent with the 36 VAC transformer specification (RMS value), the peak voltage can be estimated as $36 \times \sqrt{2} \approx 50.9$ V, giving a peak-to-peak voltage of about 101.8 V, which matches the measured waveform amplitude on the oscilloscope. The waveform appears generally clean and stable, though slight rounding at the waveform peaks and minimal distortion can be observed, likely due to nonlinear loading on the transformer or the high-frequency response limitations of the probe and oscilloscope. This indicates the presence of minor harmonic components, while the main power remains concentrated at the 50 Hz fundamental frequency. Overall, the measurement confirms that the transformer output meets its design specifications (≈36 VAC RMS, 50 Hz) and functions properly as the voltage source for the power circuit. For more detailed harmonic analysis, it is recommended to record the waveform using an isolated or differential probe and perform FFT analysis to quantify harmonic distortion while ensuring proper grounding and probe connection techniques.

4.2 DC-DC Converter System Testing Before Passive LISN Filter Installation

Testing the DC-DC converter output before installing the passive LISN filter by connecting a resistive load such as a lamp is performed to determine the power efficiency of the EUT block with the resistive load. Furthermore, this test is performed to measure the amount of voltage and current harmonics generated by the nonlinear load, such as the rectifier and DC-DC converter.

Table 4.1 DC-DC Converter Test Results Before Filter Installation With Lamp Load

Phase angle	Measured input power (Watt)	THDi (%)	THDv (%)	Vdc (V)	Idc (A)	Efficiency (%)
90	2	70,8	4,2	19,55	0,12	31
110	1,4	106	4,2	11,4	0,032	22
130	1	109,6	4,2	5,2	0,016	17
180	0	101,4	4,2	0	0	0

4.3 DC-DC Converter System Testing After LISN Filter Installation

The converter output and filter on the input side were tested by connecting a load. This test was conducted to determine the power efficiency of the converter after the filter was installed. Furthermore, this test was conducted to measure the extent to which the LISN filter could reduce the voltage and current harmonics generated by the non-linear load, the dc-dc converter, before the filter was installed. The measuring instruments used in this test were the same as those used in the previous power circuit test.

Table 4. 2 DC-DC Converter Test Results After Filter Installation With Lamp Load

Phase angle	Measured input power (Watt)	THDi (%)	THDv (%)	Vdc (V)	Idc (A)	Efficiency (%)
90	1,2	51,47	3,8	16,91	0,11	45
110	0,4	85,14	3,7	9,86	0,042	10
130	0,1	77,4	3,8	4,7	0,017	11
180	0	76,6	3,8	0	0	0

4.4 ANALYSIS

The study demonstrated that a passive LISN effectively reduces harmonics and improves system efficiency. The 25–30% THDi reduction indicates suppression of low-order harmonics, while the 0.5% THDv decrease suggests limited ability to isolate source-side voltage harmonics.

This aligns with literature noting that single LC filters are often insufficient to attenuate higher-order harmonics. Comparative studies by Cahyani (2014) and Bhakti (2013) reported that multi-stage or LC + damping resistor configurations can reduce THDi below 30%. Martin (2011) of Texas Instruments highlighted the importance of *insertion loss* and *Bode plot* analyses to ensure filters do not introduce new resonances that worsen harmonics at certain frequencies.

Methodologically, Samapta et al.'s work lacked numerical simulations (e.g., MATLAB/PSIM) to validate experimental results or analyze filter-system impedance interactions. The tests used only resistive loads, whereas nonlinear loads (e.g., motors or other converters) generate different harmonic spectra. Grounding conditions also significantly influence measurements, with deviations up to 3 dB (Kwon et al., 2018).

Compared to modern methods, passive LISNs are simple and cost-effective but less flexible than active filters. Bhattacharyya (2022) showed that Active EMI Filters (AEF) can reduce THD by up to 80% without significant power loss, especially when combined with random PWM or spread-spectrum modulation.

V. KONCLUSION

The reviewed research successfully demonstrated that passive LISN filters can reduce current and voltage harmonics in DC-DC converter systems. A reduction of THDi by 25–30% and THDv by around 0.5% demonstrates the basic effectiveness of LISNs in attenuating harmonic interference. However, these results do not meet applicable harmonic standard limits and still indicate potential resonance and limitations in filter design.

For further development, several aspects can be improved. First, the filter design needs to be modified to a multi-stage or hybrid active-passive design to expand the attenuation frequency and avoid resonance. Second, numerical simulations are needed to analyze the frequency response and harmonic behavior of each order and compare them with experimental results. Third, testing should involve various types of loads (linear and nonlinear) for more representative results. Fourth, harmonic measurement methods need to comply with the latest standards (CISPR 32 or IEC 61000-3-2) for more accurate and industrially relevant results.

By pursuing these developments, similar future research can make a stronger contribution to the fields of electromagnetic compatibility and energy efficiency. LISN filters continue to have important value, both as measurement devices and as fundamental EMI mitigation elements, especially when integrated with active filter technology and intelligent switching control.

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