International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 08 | August - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

HARMONIC CANCELLATION IN POWER SYSTEM USING MULTIPULSE AC-DC CONVERTERS

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Abstract - Power quality issues have become a prominent concern within modern electrical systems due to the escalating reliance on sensitive electronic equipment and the integration of renewable energy sources. Sources contributing to these disturbances, encompassing power grid irregularities, switching activities, and nonlinear loads, are thoroughly explored.

Using various ideas and techniques, a lot of effort has been done in recent years to reduce total harmonic distortion. Filtering or cancellation are two techniques for harmonic treatment. In this section, we discuss employing a multi-pulse AC to DC conversion strategy to reduce total harmonic distortion. Power quality can be enhanced using multiple pulse converters, and in this research, 6, 12, 18, 24 pulse converters have been simulated and modeled using the MATLAB/Simulink programme. Each one of these converters produces 6-pulse AC to DC conversion, so consistent phase-shift is needed to build many sets of 6-pulse system. As a result, 12-, 18-, 24-, and 30-pulse systems have been created with the necessary phase-shifting angle. Total harmonic distortion (THD) in current supply and ripples present in DC type voltage are reduced, improving the performance of multi-pulse converters[5].

Keywords: Multi-Pulse converters , Total Harmonic Distortion (THD), Harmonics, Ripple Content , Power Quality.

I.INTRODUCTION

Within the framework of a power system, harmonics denote the additional frequency components that emerge within the waveforms of current voltage or as integer multiples of the fundamental frequency. The fundamental frequency constitutes the primary operating frequency of the power system, such as 50 Hz or 60 Hz, and harmonics manifest as frequencies that are whole-number multiples of this fundamental frequency. Harmonics are generally engendered by nonlinear loads, encompassing electronic devices and equipment[9][11]. These loads draw current in patterns that deviate from the sinusoidal nature of the supplied power. In contrast to linear loads, which consume current proportionate to the supplied voltage, nonlinear loads can introduce deformations in voltage and current waveforms, thereby introducing harmonic components[2].

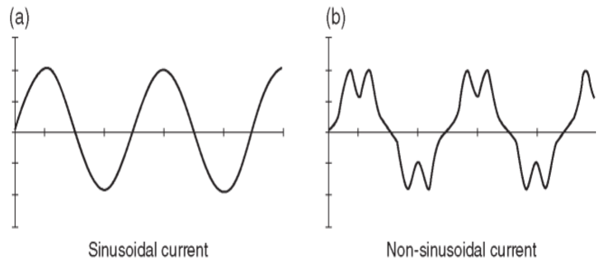

Fig. 1 Harmonic or nonlinear loads current waveform

Even though there is a clear visual difference between the waveforms in the aforementioned examples, a power engineer must often look beyond graphical appearance while analyzing the consequences of non-sinusoidal loading upon a power network.. The term "Fourier series" refers to one way to describe the non-sinusoidal waveform.

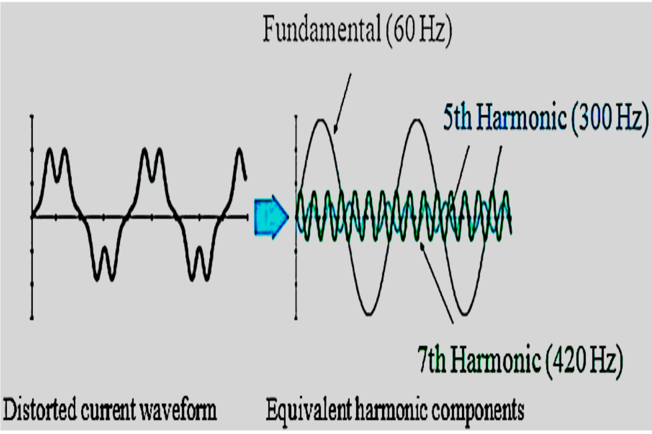

Fig. 2. An electronic variable-speed drive's current waveform

With the aid of the Fourier series, which is a mathematical technique, periodic functions are represented as a collection of series of sinusoid with varying frequencies, amplitudes, and phases. The core idea is to break down a complex periodic waveform into simpler sinusoidal components, making it easier to analyze and understand.n power systems, non-sinusoidal waveforms often emerge because of the existence of harmonics caused by unsteady loads [3]. These nonlinear loads, like electronic devices and equipment, draw current in non-sinusoidal patterns from the power supply.In power systems, the Fourier series is particularly useful for power quality analysis. By applying the Fourier series to voltage and current waveforms, engineers can determine the extent of harmonic distortion, identify the specific harmonic frequencies present, and assess their impact on system stability, equipment performance, and electromagnetic interference.

.II. HARMONICS-RELATED PROBLEMS

Harmonics in a power system refer to unwanted frequency components which are multiples by integers of the power supply's fundamental frequency. Depending on the area, the standard frequency is commonly 50 or 60 Hz. [2]. Harmonics are primarily resulting from loads that are not linear and devices in the power network, such as computers, variable frequency drives, fluorescent lights, and other electronic equipment. These non-linear loads draw currents that are not sinusoidal and contain harmonic components.

The following disadvantages caused by harmonics are as follows :

Power Quality Concerns: Harmonics introduce voltage and current distortions, degrading power quality and reducing efficiency.

Interference Problems: Harmonics disrupt the functioning of sensitive electronic devices and communication systems.

Equipment Overheating and Damage: Harmonics contribute to equipment overheating and premature failure.

Elevated Energy Expenses: Harmonics lead to increased energy consumption and higher utility costs.

Transformer Overload Risk: Harmonics can result in transformer overheating and decreased capacity.

Resonance Hazards: Harmonics may cause hazardous voltage or current amplification through resonance.

Compatibility Challenges: Harmonics create operational disturbances in connected equipment.

Regulatory Non-Compliance: Failure to meet harmonic standards can lead to regulatory penalties.

Electromagnetic Interference (EMI): Harmonics produce interference affecting nearby electronic devices.

To tackle these concerns, approaches like utilizing harmonic filters and designing systems thoughtfully are employed.

III. IMPLEMENTATION REFERENCE FOR ADDRESSING HARMONICS ISSUES:

Harmonics, which manifest as unwarranted distortions in power system waveforms, present notable challenges due to their detrimental impacts on equipment operation and grid integrity. This synopsis delves into diverse strategies for mitigating harmonics within power systems. The investigation encompasses both passive and active harmonic filtering methodologies, multi-pulse converter applications, and active front-end converter solutions. Each approach's fundamental principles, merits, and limitations are scrutinized. By critically evaluating these harmonic mitigation tactics, this abstract contributes to an enriched comprehension of available techniques, enabling engineers and researchers to discern and adopt the most fitting strategies for augmenting power system efficiency and dependability.

Passive Filters: These methods are straightforward and cost-effective for mitigating harmonics.Drawbacks: Passive filters are designed to address particular harmonics, making them inadequate for managing a broad range of harmonic frequencies.

Active Filters: Active filters employ power electronics to generate counteractive harmonic currents that cancel out unwanted harmonics present in the load current. Drawbacks: Active filters are more intricate and expensive compared to passive filters due to the need for power electronics components and control systems.Inadequate design and control can result in active filters introducing their own harmonics.Maintaining and calibrating active filters can be demanding.

Tuned Passive Harmonic Filters: These filters are devised to target specific harmonic frequencies. They utilize a combination of capacitors, inductors, and resistors to form resonant circuits that mitigate particular harmonics.Drawbacks:Alterations in system conditions, such as fluctuations in load impedance, can impact the filter's effectiveness.Incorrect tuning or design can lead to the amplification of certain harmonics.

Variable Frequency Drives (VFDs): VFDs regulate the speed of electric motors by adjusting the input power frequency. They also aid in harmonic reduction as they convert incoming AC power to DC and then back to AC with a controlled waveform.Drawbacks:VFDs themselves can be sources of harmonics and might necessitate additional measures to mitigate their impact on other equipment.Installing and maintaining VFDs can be intricate and demand skilled personnel.

Switching Frequency Modification: Adjusting the switching frequency of power electronics devices can impact the harmonic content in such equipment.Drawbacks:Modifying the switching frequency might lead to elevated switching losses and reduced overall efficiency.Proper care and design are crucial to avoid unintended repercussions on equipment performance.

Multi-pulse converters are specialized devices within power electronics that find application in electrical systems to mitigate harmonic distortion and enhance overall power quality. These converters offer several merits that make them a valuable option for rectifying harmonic challenges and boosting system performance.Multi-pulse converters contribute to an improved power quality by alleviating these problems, leading to smoother and more dependable operation of connected devices[10]. Multi-pulse converters are purpose-built to diminish the presence of harmonics within an electrical setup. By employing multiple converter units in parallel with phase shifts, they effectively counteract specific harmonics, resulting in cleaner voltage and current waveforms.

According to this idea, the input voltage is phase-shifted into a number of pulses.The input's harmonic content and total harmonic distortion (THD) both decline as the pulse count rises. This system relies heavily on application of a six-pulse diode based bridge rectifier .The size of the filtering element can be decreased by utilising multi-pulse converters. A multi-pulse converter is an appropriate arrangement to achieve large power ratings and good quality output waveforms as well.The fundamental building block for AC-DC conversion is the bridge rectifier, while half--wave and full-wave rectifiers are also utilized the ratings upto 120 kW . . Here, we discuss the use of a multipulse AC/ DC conversion technique to reduce overall harmonic distortion.

IV. ELIMINATION OF THE TOTAL HARMONICS USING MULTI PLUSE CONVERTORS

In order to address the three-phase converter system's harmonic problem, the current work analyses various multipulse AC- DC converters are describe in following Fig. 5 [6]

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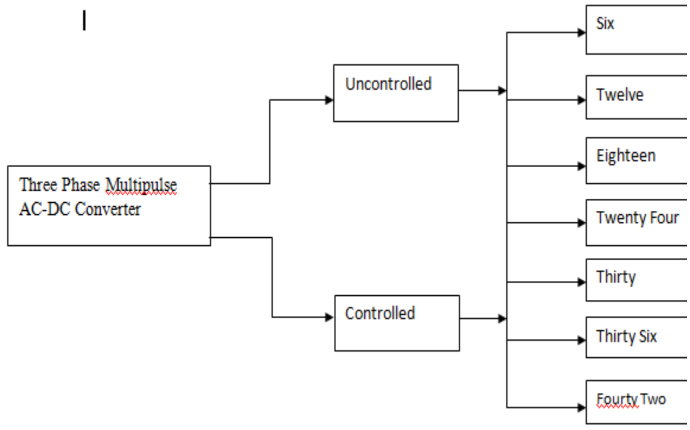

Fig. 5. Multiple-pulse converter arrangements

V. UNCONTROLLED MULTI-PULSE CONVERTER SIMULATION

1. Six-Pulse Converter : Fig. 6 depicts Rectification, in which electrical power moves from the alternating current (AC) portion towards the DC side and Inversion, in which the opposite occurs ,are both carried out using the fundamental converter unit of HVDC transmission (Fig. 6 and 7)[10].

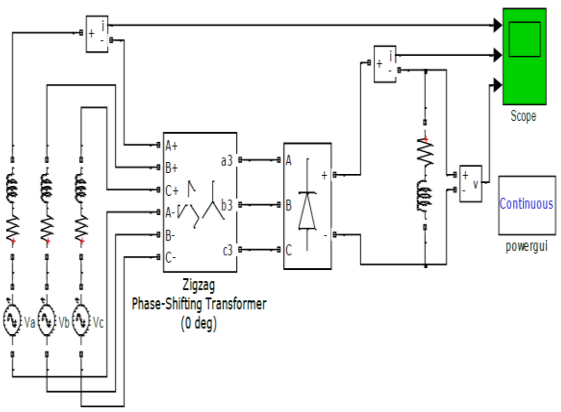

Fig. 6. Uncontrolled : six-pulse converter

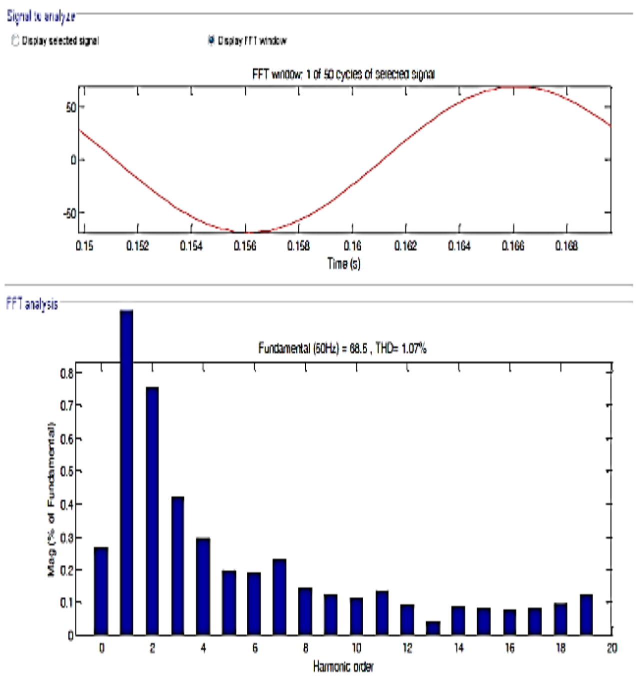

Fig. 7. THD for the uncontrolled six-pulse converter's input current

2. Twelve Pulse Converter: Two 3-phase systems are required for the 12-pulse converter, in which two completely controlled 6-pulse converter bridges are connected in series.. These systems must be spaced apart from one another by 30 electrical degree(Fig 8 and 9).

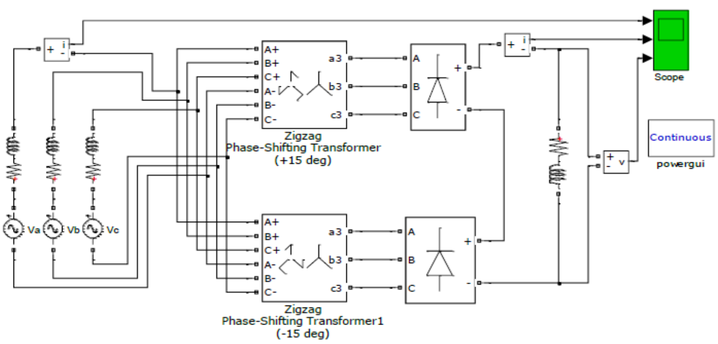

Fig. 8. Uncontrolled twelve-pulse converter

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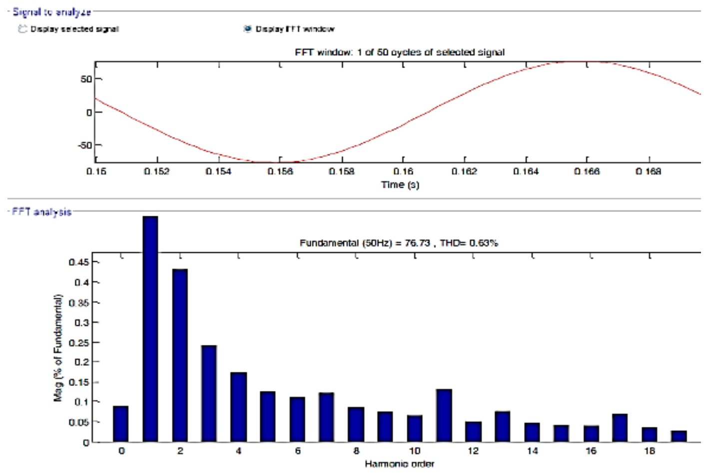


Fig. 9. THD for the uncontrolled 12-pulse converter's input current

3. Eighteen Pulse Converter The 18-pulse architecture uses the same circuit configuration as a 6-pulse converter. As a result, this structure is considered to be more favored [13]. All three of the phase shift transformers with star connected secondary have been given with a 20° phase shift (Fig. 10 and 11).

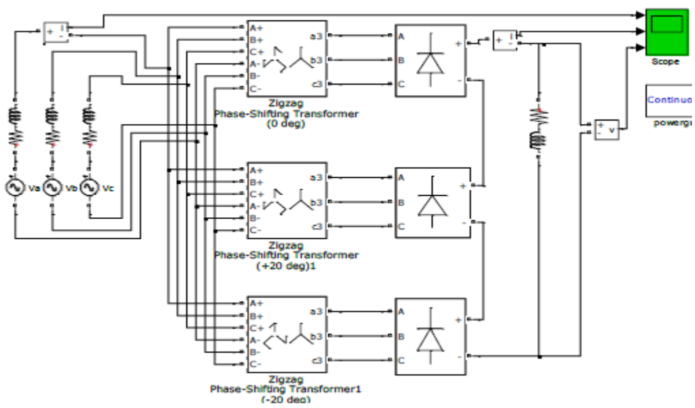


Fig. 10. Uncontrolled eighteen-pulse converter

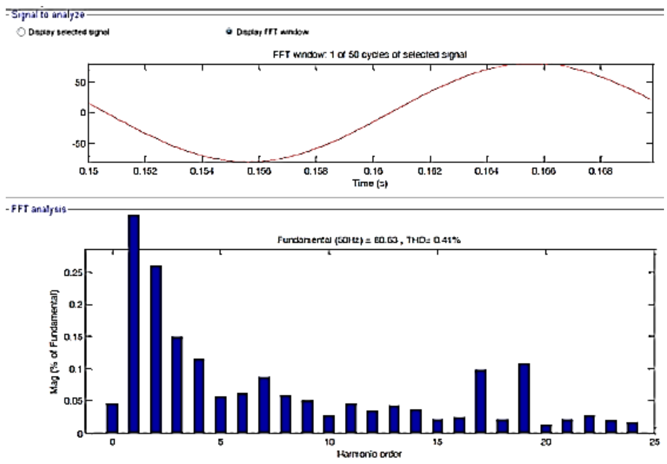


Fig. 11. THD for the uncontrolled 18-pulse converter's input current

4. Twenty-Four Pulse Converter

Fig. 12 depicts the 24-pulse converter connector with accompanying combination. In order to offer twenty-four pulse rectification, four-six pulse converters must be phase-shifted apart with 15 degrees [5]. Obviously, this results in significantly reduced harmonics present on both the DC side as well as and AC sides. Its output AC voltage would have (24 n ± 1) order of harmonics, or the 23 rd, 25 th, 47 th, and 49 th order harmonics, having phase shifts that were 1/23rd, 1/25th, 1/47th, and 1/49th, respectively.

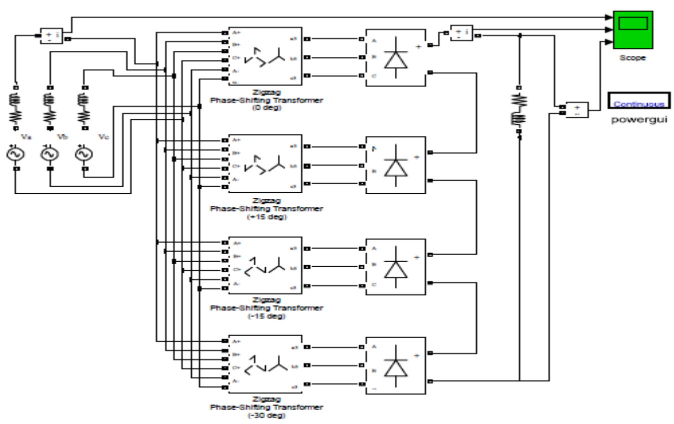


Fig. 12. Uncontrolled twenty-four pulse converter

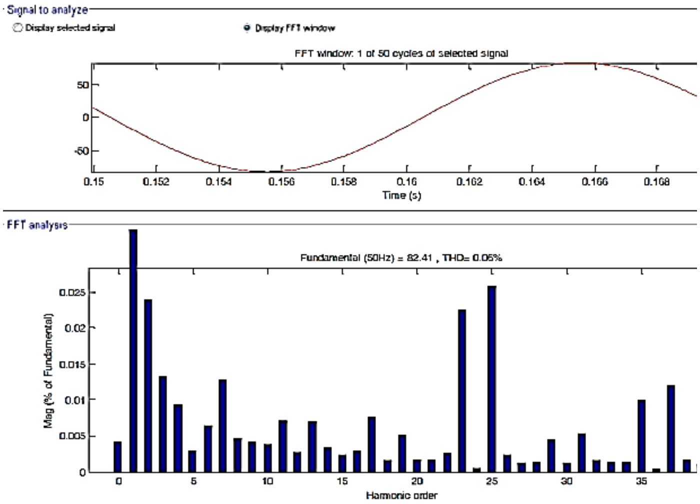


Fig. 13 THD for the uncontrolled 24-pulse converter's input current

Regarding the effectiveness of AC to DC converters, the impact raising the total amount of pulses has been studied.Using a phase-shifting transformer and a three-phase, the three-phase multi-pulse AC to DC conversion system converts AC to DC. To create more sets of 6-pulse systems, a consistent phase-shift is required for each of these converters, which each produce a 6-pulse AC to DC conversion. As a result, 12-, 18-, 24-, and 30-pulse systems have been created using the correct phase-shifting angle. Total harmonic distortion (THD) in DC voltage ripples and supply current are reduced, improving the efficiency of multi-pulse converters.

Results are obtained for converters that are regulated and uncontrolled for RL loads. Thyristors have been used for controlled conversion whereas diodes have been favoured for uncontrolled conversion. The simulation findings that were given demonstrate the supply side's reduced THD. Multiple converters are coupled in multi-pulse methods so that the harmonics produced by one converter are combined with harmonics produced by other converters[1]. By doing this, specific harmonics connected to the quantity of converters are removed from the power supply. Regarding the influence the converter has on the power system, the reduction of AC inputline current harmonics is crucial in multi-pulse converters.

V. SIMULATION : CONTROLLED MULTI-PULSE CONVERTERS

1. Six-Pulse Converter : Instead of using a diode bridge to simulate controlled multi-pulse converters, we utilise a thyristor bridge, and the relevant pulses are provided (Fig. 20).

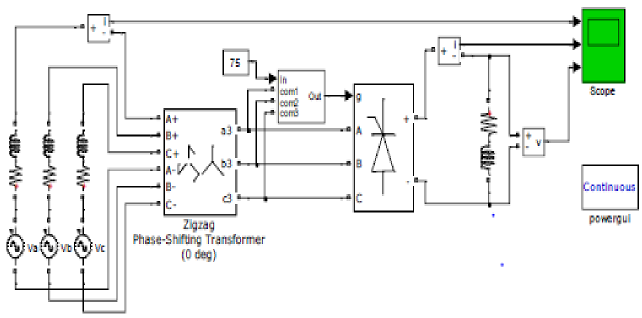


Fig. 20. Controlled : six-pulse converter

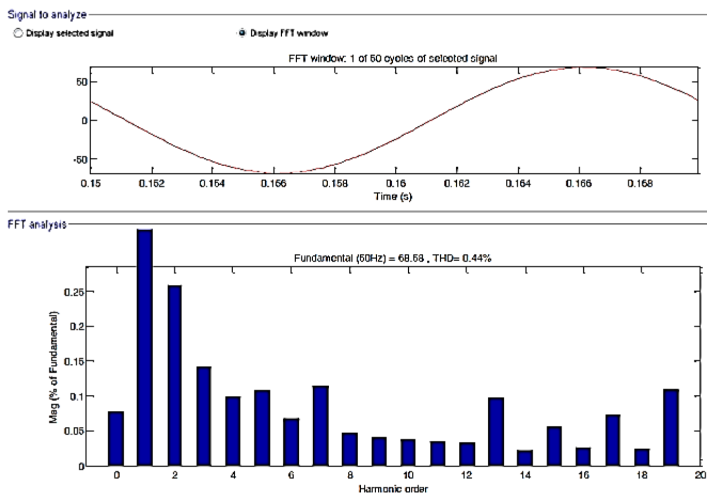


Fig. 21. THD for controlled : six-pulse converter's input current

B. Twelve-Pulse Converter (Fig. 22)

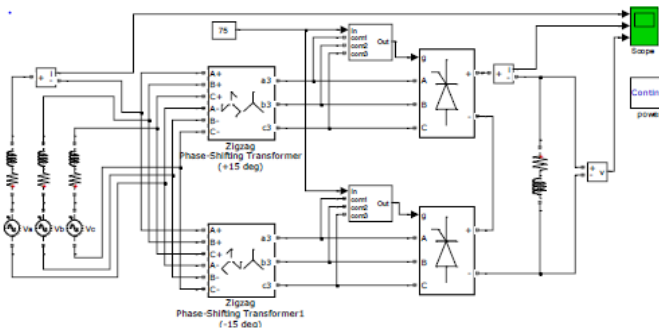


Fig. 22. Controlled : twelve-pulse converter

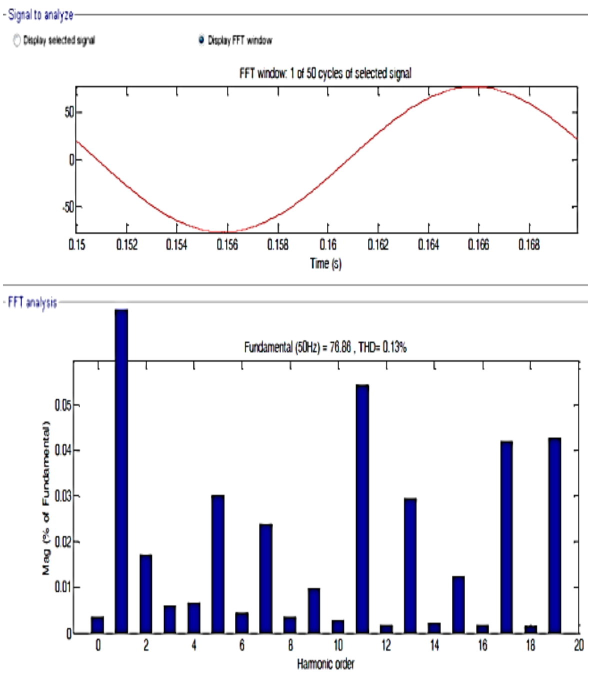


Fig. 23. THD for the : twelve-pulse converter's regulated input current

C. Eighteen-Pulse Converter (Fig. 24)

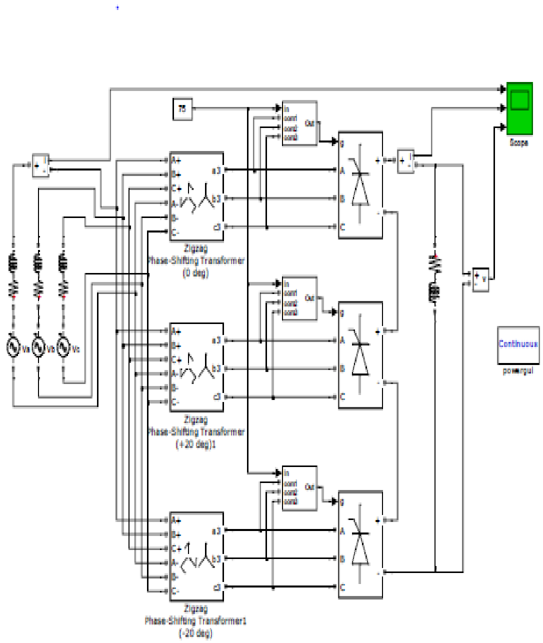


Fig. 24. Controlled : Eighteen-pulse converter

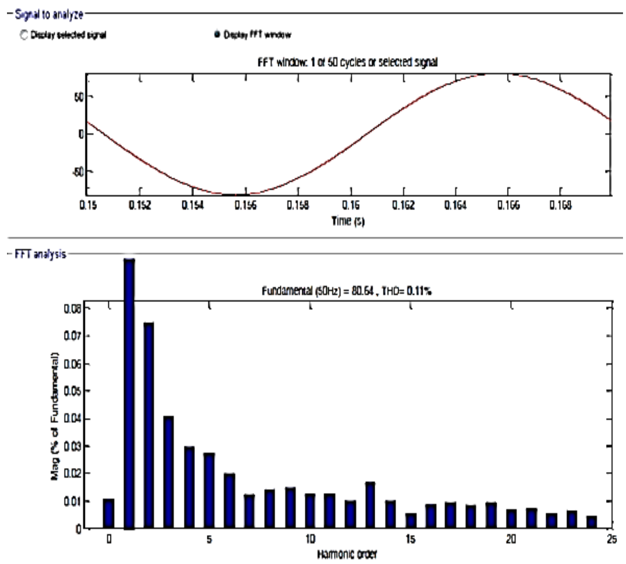


Fig. 25. THD for the regulated : Eighteen-pulse converter's input current

D. Twenty Four-Pulse Converter (Fig. 26)

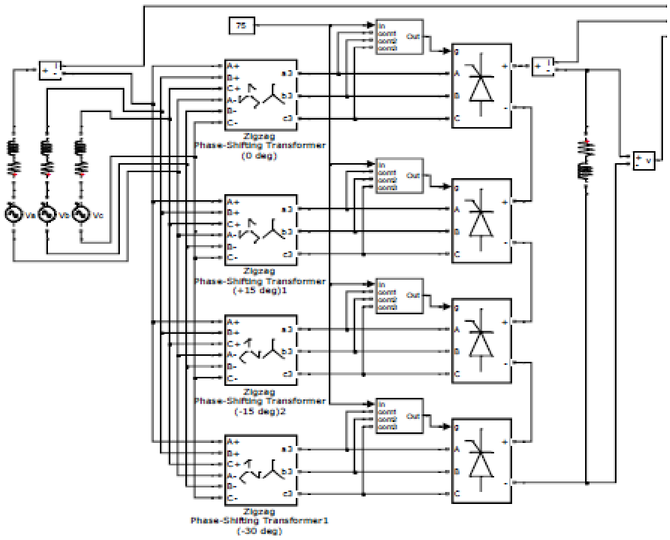


Fig. 26. Controlled : Twenty four-pulse converter

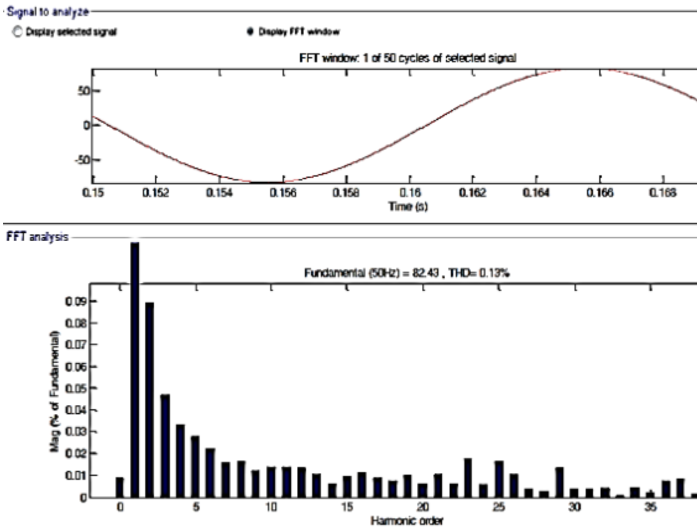
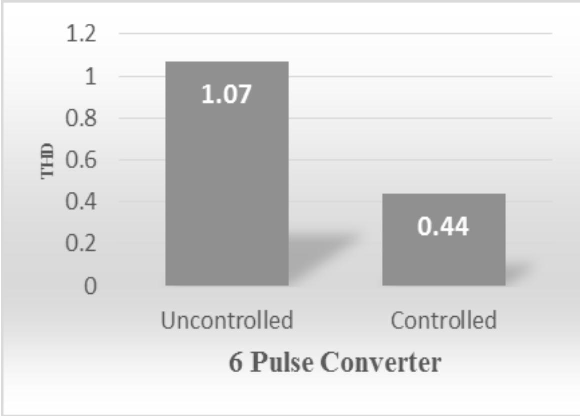


Fig. 27. THD for the regulated : 24-pulse converter's input current

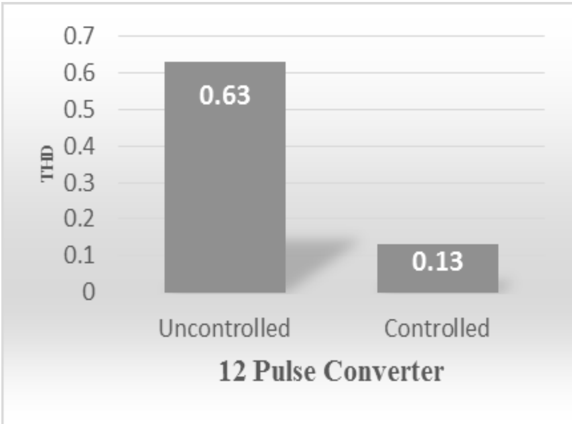
VI. SIMULATION RESULTS

To make it easier to compare parameters taken into account, such as ripple content, THD, and between regulated multi-pulse converters and uncontrolled multi-pulse converters, all the information received following simulation with the previously described models having MATLAB/Simulink has been compiled here.

Total Harmonic Distortion (THD) (Fig. 34)



A) Six-pulse converter



b) Twelve-pulse converter

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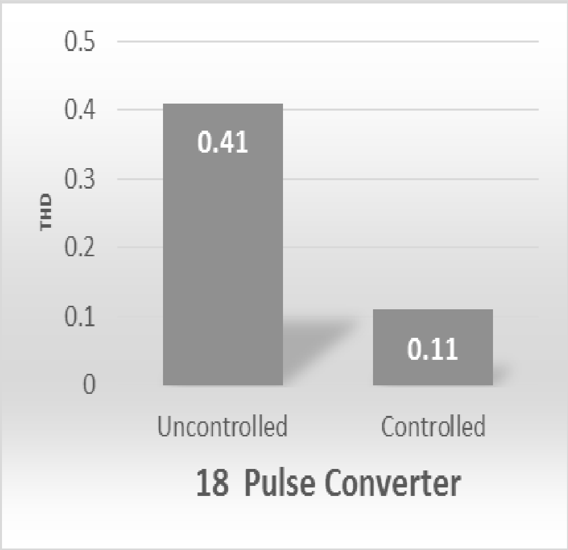
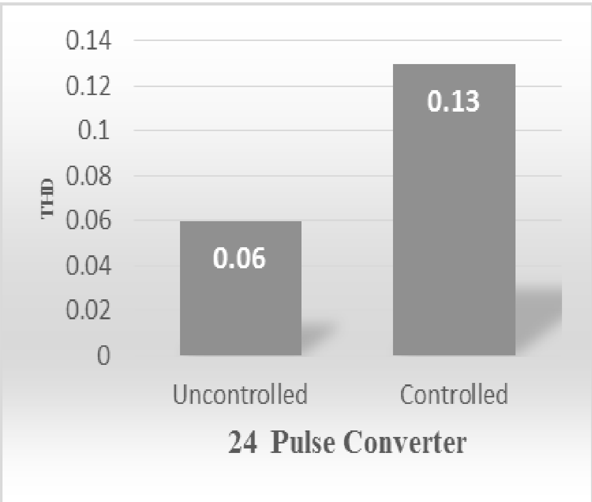


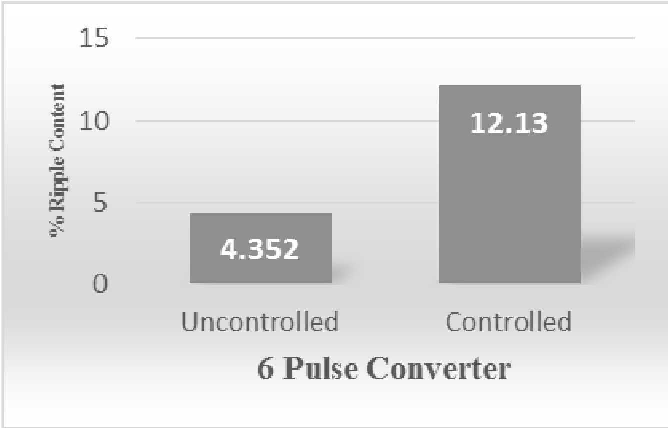
c) Eighteen-pulse converter



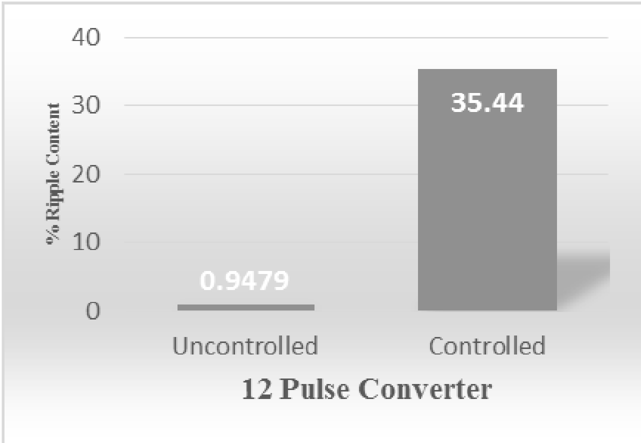
d) Twenty four-pulse converter

Fig. 34. Percentage THD for RL load (a) six-pulse converter, (b) twelve-pulse converter, (c) eighteen-pulse converter, (d) twenty four pulse converter

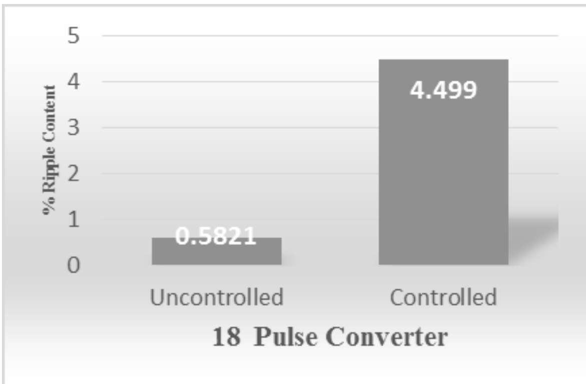
Percentage Ripple Content (Fig. 35)



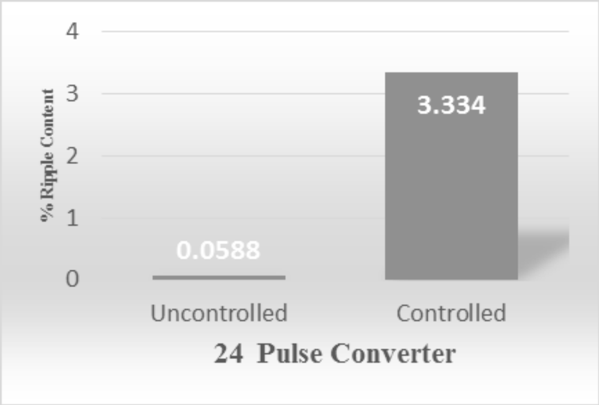
A) six-pulse converter



B) Twelve-pulse converter



C) Eighteen-pulse converter



D) Twenty four-pulse converter

Fig. 35. Percentage ripple content for RL load, (a) six-pulseconverter, (b) twelve-pulse converter, (c) eighteen-pulse converter, (d)twenty four-pulse converter

VII. CONCLUSIONS

The ongoing work goal is to compare the effectiveness of multi-pulse converters that are regulated and those that are not. These converters are investigated in terms of the ripple content, overall harmonic distortion, and harmonic spectrum of the AC supply current.Therefore, it can be determined that the working criteria of such converters are generally significantly enhanced as the number of pulses increases in the multi-pulse situation.To make it easier to compare the elements taken into account, such as THD and ripple contents between uncontrolled and controlled multi-pulse converters, here is a compilation of all the data generated by simulating the earlier discussed models using MATLAB/Simulink.

We may therefore conclude with certainty that THD becomes better as the quantity of converter pulses grows and that is within IEEE-acceptable bounds. As a higher pulse number converter is employed and a good quality output DC current wave is created, the ripple in the input current waveform reduces.

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