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Harmonics Analysis of Inverter with Load Variation Using Matlab Similation

Suraj Kumar Vaishnav
Roshan Kashyap
Rajesh Gond
Department Electrical and Electronics Engineering
Choukeshey Engineering Collage, Lal Khadan, Masturi Road,NH-49, Bilaspur C.G.
Corresponding Author: Richa Dubey

ABSTRACT: *Inverters, crucial components in various applications from renewable energy integration to electric vehicles, are not ideal AC sources. Their switching operation introduces harmonics, distorting the output waveform and impacting power quality. This paper delves into the harmonics analysis of inverters, exploring their generation mechanisms, effect on input and output circuits, and potential mitigation strategies. Through circuit diagrams and simulations, we gain insights into minimizing harmonic content and designing efficient and compliant inverters.*

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I. INTRODUCTION

The ubiquitous rise of power electronics technologies has propelled inverters to the forefront of modern electrical systems. Inverters convert DC power into AC, enabling diverse applications like photovoltaic grid integration, electric vehicle propulsion, and industrial motor drives. However, their idealized sinusoidal output is often marred by harmonics, sinusoidal components at integer multiples of the fundamental frequency. These harmonics pose significant challenges to power system stability, equipment performance, and overall efficiency. Their switching operation introduces harmonics, distorting the output waveform and impacting power quality. This paper delves into the harmonics analysis of inverters, exploring their generation mechanisms, effect on input and output circuits, and potential mitigation strategies. Through circuit diagrams and simulations,

II. MATERIAL AND METHODS

Phase I: PWM Control
Pulse-width modulation (PWM) is the most common inverter control technique, employing rapid switching of power semiconductor devices to synthesize the desired AC waveform. The switching transitions, though ideally instantaneous, create non-sinusoidal voltage and current waveforms, rich in harmonics.

Phase II: Non-Linear Loads
Many devices connected to inverters exhibit non-linear characteristics, drawing distorted currents that further contribute to harmonic pollution. Rectifiers, choppers, and variable-speed drives are common examples.

Phase III: Commutation
The switching of power devices, particularly in bridge configurations, results in commutation overlap periods where multiple devices conduct simultaneously. This creates short-duration voltage spikes and dips, enriching the harmonic spectrum.

Phase IV: Increased Losses
Higher-order harmonics generate additional heat losses in inductors, capacitors, and conductors, compromising component efficiency and reducing overall system output

Phase V: Derating
Harmonic currents can overload transformers and neutral conductors, necessitating derating to ensure thermal limits are not exceeded.

Phase VI: Equipment Malfunction
Sensitive electronic equipment can malfunction due to harmonic interference, disrupting communication, control systems, and data acquisition.

Phase VII: Resonance
Harmonic currents can interact with system impedances, creating resonant conditions that amplify specific harmonic components and exacerbate their adverse effects.ss

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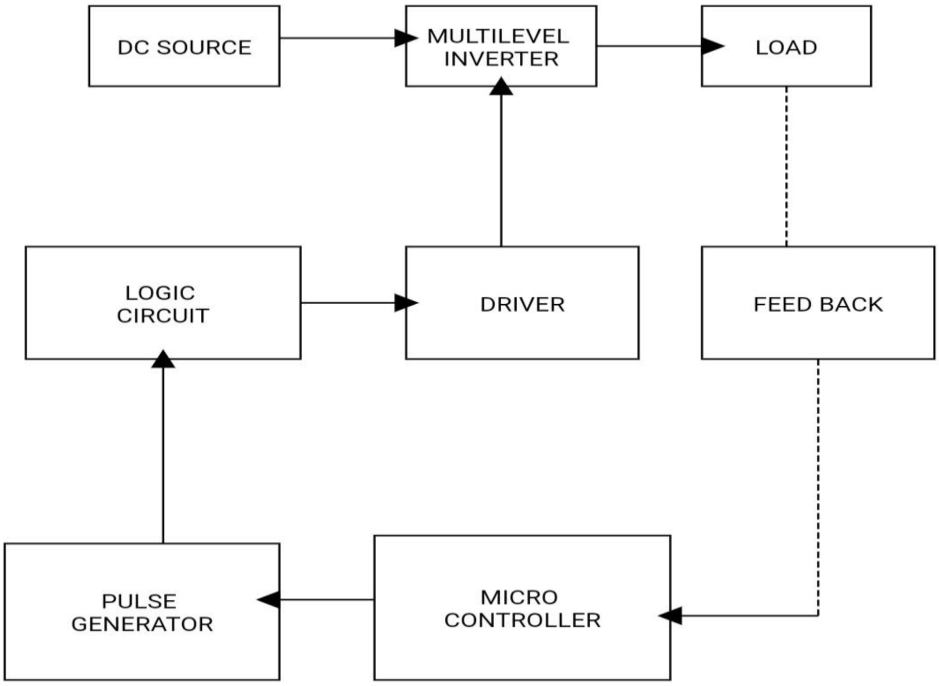

Figure 1: Block Diagram of Harmonics

III. HARMONICS MITIGATION STRATEGIES

Several strategies can be employed to mitigate harmonics in inverters:

Phase I: PWM Optimization
Modifying the PWM switching pattern, such as employing multi-level waveforms or space-vector modulation, can reduce the harmonic content injected into the output.

Phase II: Harmonic Filters
Passive filters using inductors and capacitors can attenuate specific harmonic frequencies, but they suffer from bulky size and limited tuning flexibility.

Phase I: Active Filters
These employ power electronic devices to actively cancel out harmonic currents by injecting currents with opposite phase and amplitude. They offer dynamic control and wider bandwidth filtering compared to passive filters.

Phase I: Control System Design
Implementing closed-loop control algorithms incorporating harmonic feedback enables dynamic mitigation and compensation for variations in load and operating conditions.

IV. CHARECTERIZATION OF HARMONICS

4.1. Frequency Domain Analysis:
The most common characterization technique involves analyzing the harmonic content of the voltage and current waveforms using tools like Fast Fourier Transforms (FFTs). This provides insights into the dominant harmonic frequencies, their amplitudes relative to the fundamental, and the Total Harmonic Distortion (THD) as a measure of overall distortion.

4.2. Time Domain Analysis:
Time-domain analysis methods study the transient behavior of inverter voltages and currents. Oscilloscopes and power analyzers can capture switching waveforms, revealing details about rise times, fall times, and overshoot voltages, all contributing to harmonic generation.

4.3. Simulation Tools:

Computer-aided software packages, like SPICE and MATLAB/Simulink, enable detailed modeling of inverter circuits. These tools allow engineers to predict harmonic spectrum based on circuit parameters and control strategies, facilitating optimized design and mitigation techniques.

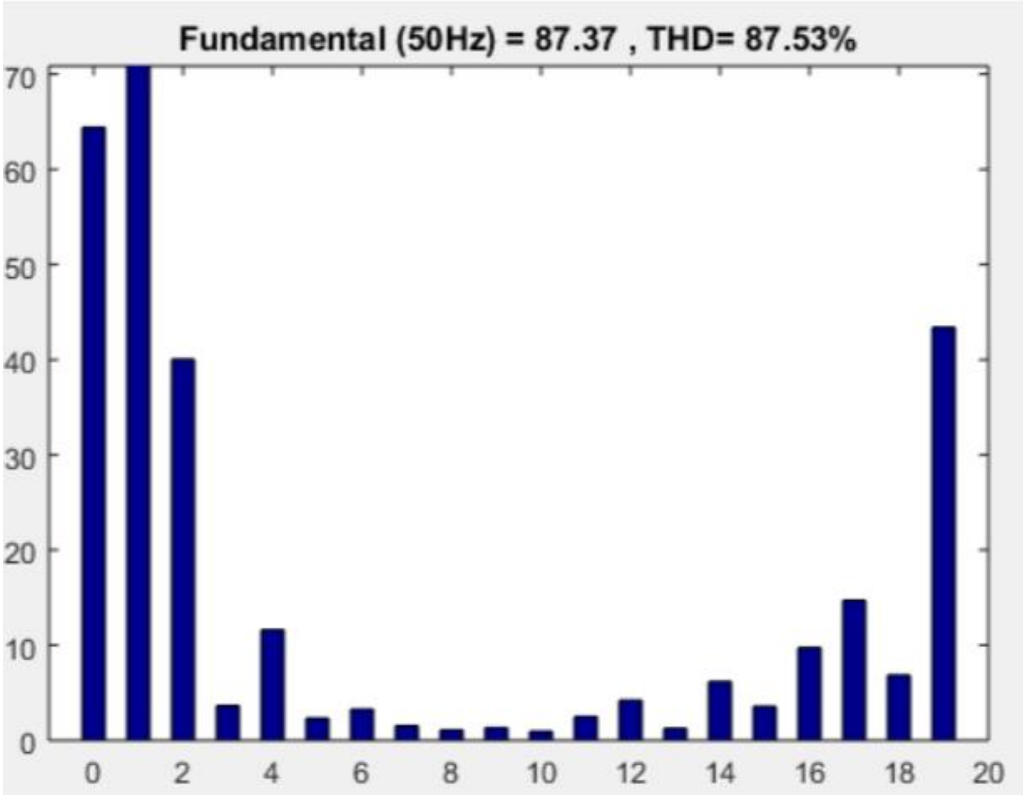

Figure 2: Variatin Table of RL Load

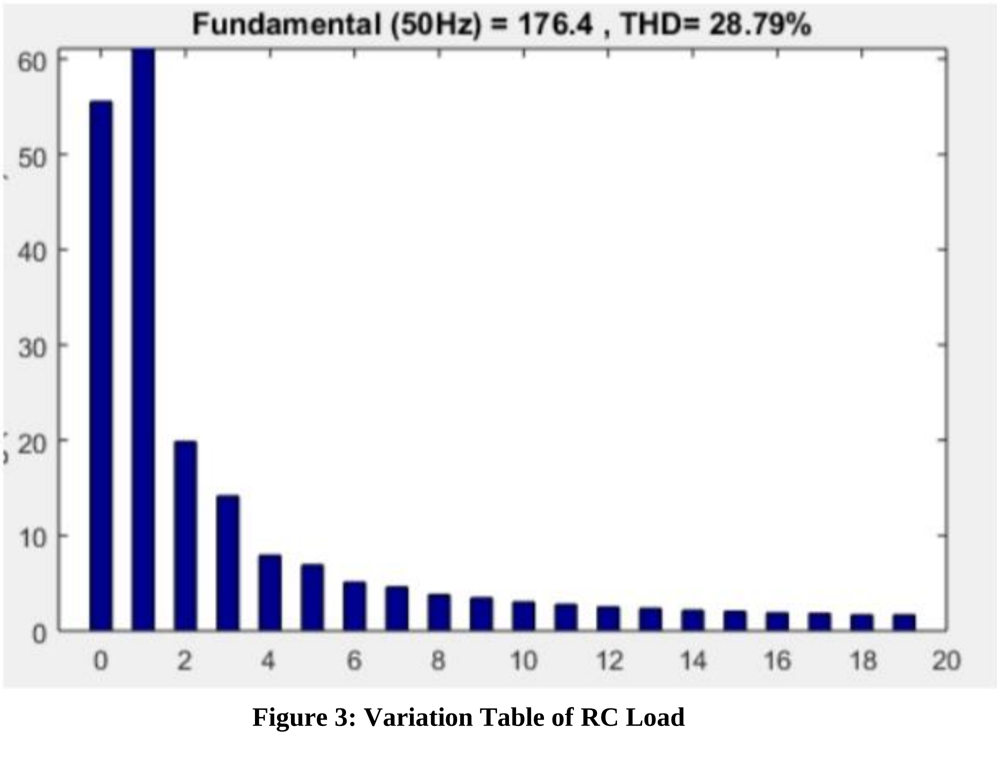

Figure 3: Variation Table of RC Load

V. DIAGRAM AND SIMULATION ANALYSIS

To elucidate the impact of harmonics and the effectiveness of mitigation strategies, detailed net diagrams of specific inverter topologies (e.g., full-bridge, half-bridge) can be presented. Simulation tools like SPICE or MATLAB/Simulink can be used to model the inverter circuits and analyze the harmonic content of the output waveform under different operating conditions and with various mitigation techniques applied. This helps to quantify the effectiveness of each approach and guide optimal design choices.

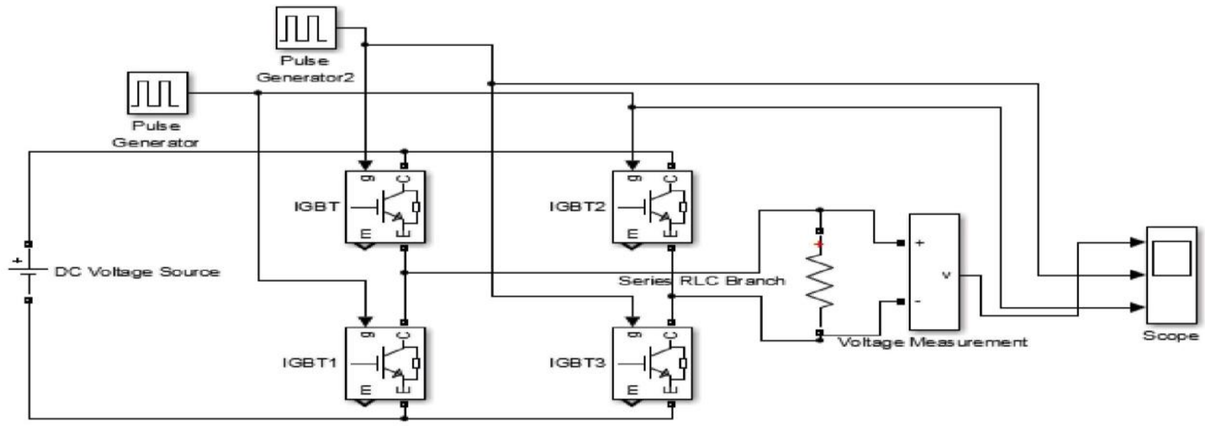

Figure 4: Input Circuit

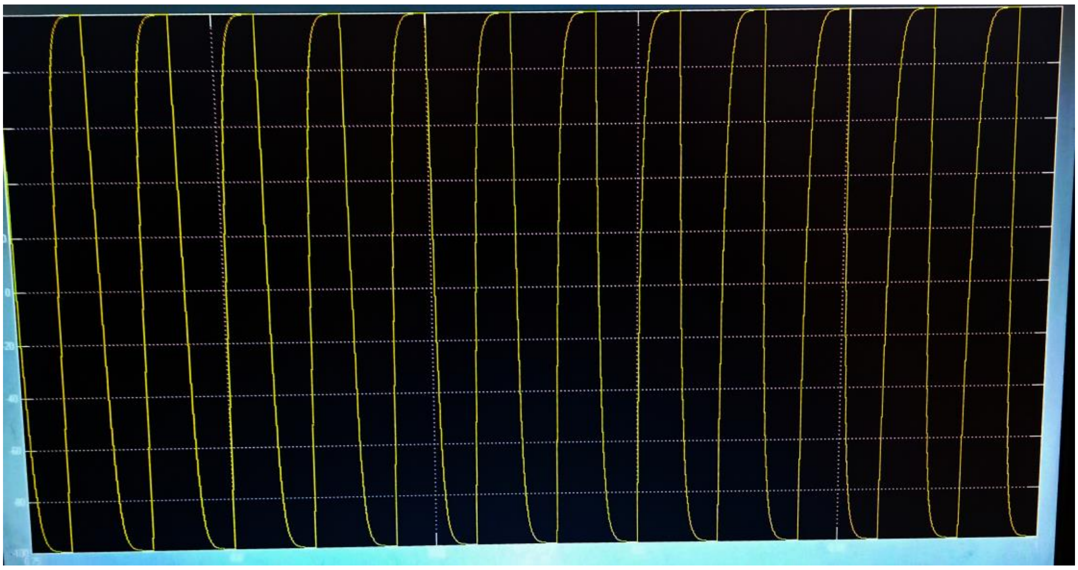

Figure 5: Inverter Output with RC Load

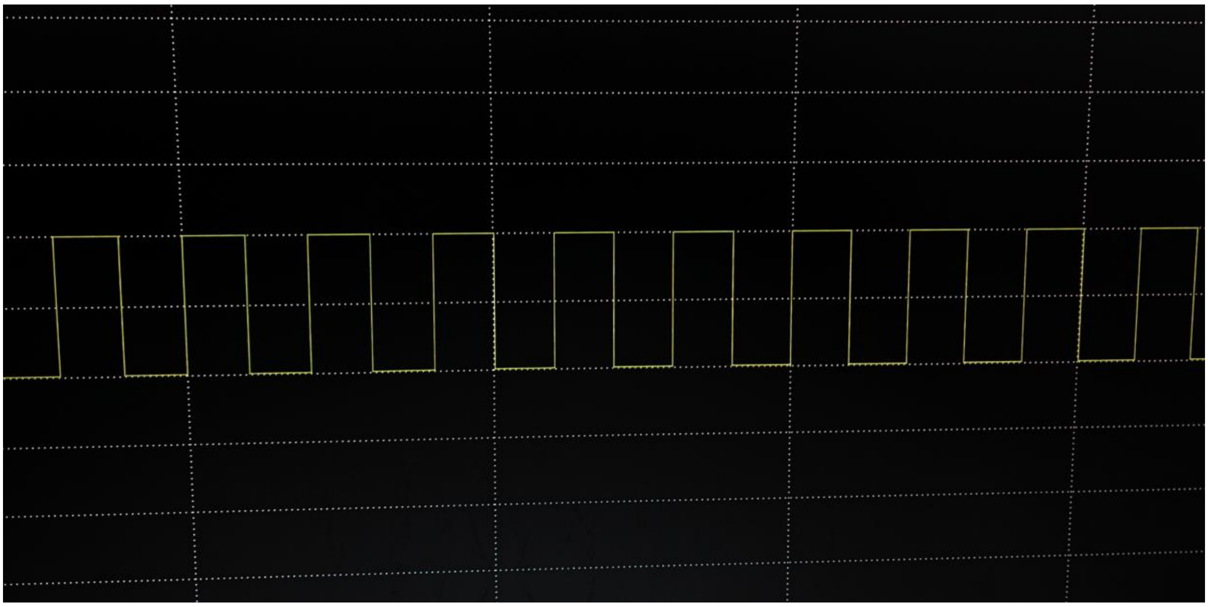

Figure 6: Inverter Output with RL Load

VI. CONCLUSION

This study deals with the harmonics analysis of a single phase inverter. It includes both a simple and practical inverter. The Simulink model for both simple and practical inverter has been simulated in MATLAB. In order to find the harmonics content and THD, FFT analysis is used using MATLAB Simulink software. It is hown that the performance of the inverter circuit with the harmonics filtering circuit having a THD value of 28.79% is better than the inverter circuit without the harmonics filtering circuit having a THD value of 87.53%. If the carrier triangular wave angular frequency ωc as a benchmark to get another Fourier series expansion. Actually no matter in what form, the output of the inverter harmonic should contain kωr and nωc these two kinds of harmonic. The carrier triangle wave angular frequency ωc average value of 1Khz-15Khz. Due to the carrier frequency value is relative taller, it easily eliminated by filter. Because of inverter harmonic interference, in short, the public power grid and electric equipment to produce all kinds of hazards. Widely used in all kinds of frequency converter, we must pay attention to the inverter harmonic interference. Be suppressed by using reasonable technology.

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