# Generalized Multicell Impedance Source Inverter for Drives: A Comparative Analysis

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***Abstract**: A voltage-source inverter exists for one primary purpose. It performs voltage step-down operations. When voltage-type Z-source inverter first appeared, researchers added boosting capabilities while keeping the steady number of semiconductors constant. The new inverter generation demonstrates improved resistance to electromagnetic noise disturbances. The spectrum performance along with boosting ability suffers due to component stresses which causes poor performance at low modulation index ratios. Actual implementation shows their boosting capabilities remain restricted. The performance review of the generalized switched-inductor Z source inverter using PWM and SPWM techniques confirmed additional boosting capabilities and other benefits during simulation analysis and experimental testing enabling their adoption to overcome these constraints.*

***Keywords**: Z-source inverter, multicell, switched inductor, PWM, and SPWM techniques*


## I. Introduction

Modern electrical systems including industrial drives power conditioners and distributed generators have created an increased demand for properly conditioned energy through dc–ac inverters. Although widely used today popular inverter topologies need further development work. Their fixed operating voltage and current conversion parameters represent one of their main issues [3-4]. The current voltage-source inverters (VSI) function as they were designed to reduce voltage output levels. The attachment of suitable dc–dc converters transform traditional inverters into devices which provide greater flexibility with their voltage and current steps. The simple nature of this design makes it the most market-ready solution. The Z-source inverter technology finds applications in electric vehicles where drive voltage requirements and control system performance are main design factors [4].

Z-source inverter research shows rapid progress through ongoing investigations about modulation [2] and modelling [3] control [4][5] component sizing as well as applications [5]. Current investigations focus on developing solutions to enhance the Z-source inverters' operational conversion limitations. Z source inverters with intelligent control linked to renewable energy sources for obtaining maximum output have become a research focus [1]. The theoretical infinite change capabilities of Z-source inverters face performance restrictions in real applications which produce elevated semiconductor load stresses and inadequate spectra quality. The limitations of Z-source inverters stem directly from the trade-off they must make between modulation ratio and time spent in the shoot-through state.
Each approach contains favorable elements which enhance its usability for particular applications. The selection process depends on three factors: which issues need addressing and personal choices combined with professional evaluations. The idea could have inspired researchers to develop numerous dc–ac inverters which appear in academic literature. The voltage Z-source inverter displayed in Figure 1 [1] stands as the most popular inverter type in the present research context.

This device offers bilateral energy transfer capabilities alongside clean sinusoidal waveforms free of subharmonics and minimal high order harmonic content and operates using the ST state to deliver buck or boost modes from its Z-network arrangement containing two capacitors and two inductors which connects to the traditional three phase bridge as shown in Figure 1. When both high and low switches in each phase leg are gated simultaneously the ZSI utilizes ST states for dc-link voltage elevation. When a ST state occurs due to electromagnetic interference (EMI) noise the circuit remains intact. This power conversion design produces an improved single stage converter which operates dependably as either a boost or buck converter stage [3].

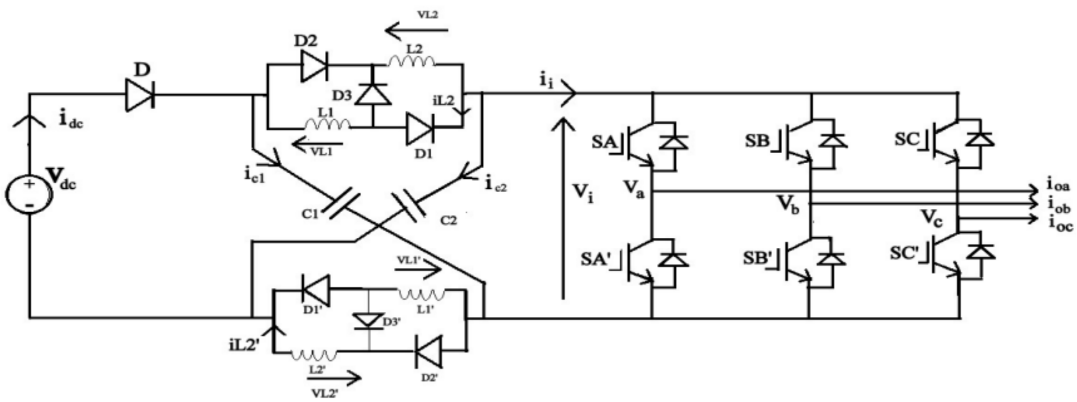

Fig 1: Topology of voltage type SL Z-Source Inverter

## II. Multicell SL Topology Generalized

Figure 2 shows the generic cell represented in the lower right section that models the SL topology. The nth cell of this formation includes $D_{3n-1}$, $D_{3n-2}$, and $D_{3n}$ diodes together with an $L_n$ inductor. The linked cell from Figure 2 supports a replication pattern of 2N times which distributes identical content equally throughout the high and low dc rails. The inductors $L_{2N+1}$ and $L_{2N+2}$ exist outside the generic cell structures. They operate as the fundamental inductors that build the traditional voltage-type Z-source inverter system shown in Figure 1. As the generic cell formation process occurs the generalized SL topology provides additional cells to the initial two inductors rather than replacing them completely [2]. The shooting-through operation of these cells requires parallel connections between inductors while they need serial inductor arrangements during discharging operation [4].

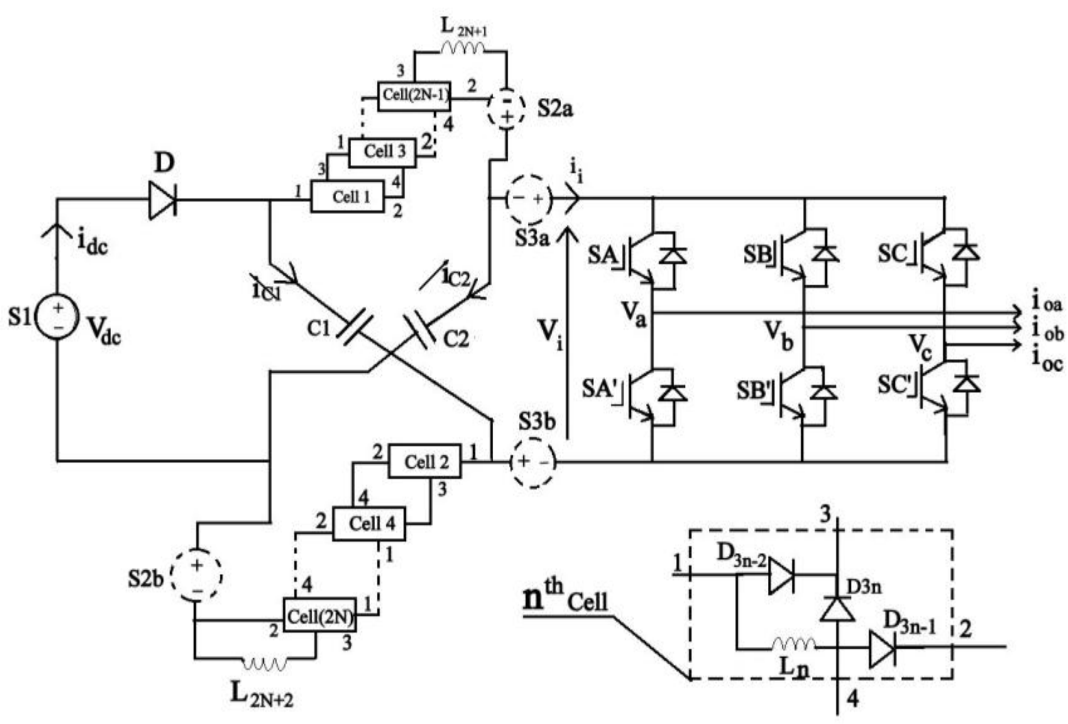

Fig 2: Topology of generalized voltage type SL Z-Source Inverter

## III. Voltage Source Inverter Three Phase

The circuit schematic in Figure 3 illustrates the three-phase VSI design and shows its eight distinct switch state configurations. A short circuit across the dc link voltage supply would form when switching together $S_1$ and $S_4$, $S_3$ and $S_6$, or $S_5$ and $S_2$ in any inverter leg. This phenomenon matches the behaviour of single-phase VSIs. The inverter's VSI and resulting ac output line voltages experience undefined behaviour whenever the switches of any single leg are operated simultaneously [3-4]. Manufacturing voltages using line currents leads to outputs whose values depend on the individual lines' polarities. During states 7 and 8 the ac current freewheels using the higher or lower component thus generating zero-line voltages on the ac output. States other than 7 and 8 generate nonzero output voltages that appear in the inverter's ac output. The inverter requires specific switching states to generate voltage waveform requirements. The ac output line voltages of Figure 4 consist of discrete levels including $V_s$, 0V, and -Vs. The modulating approach defines the set of states which will be valid for operation. Our system uses this behaviour in several distinct expressions.

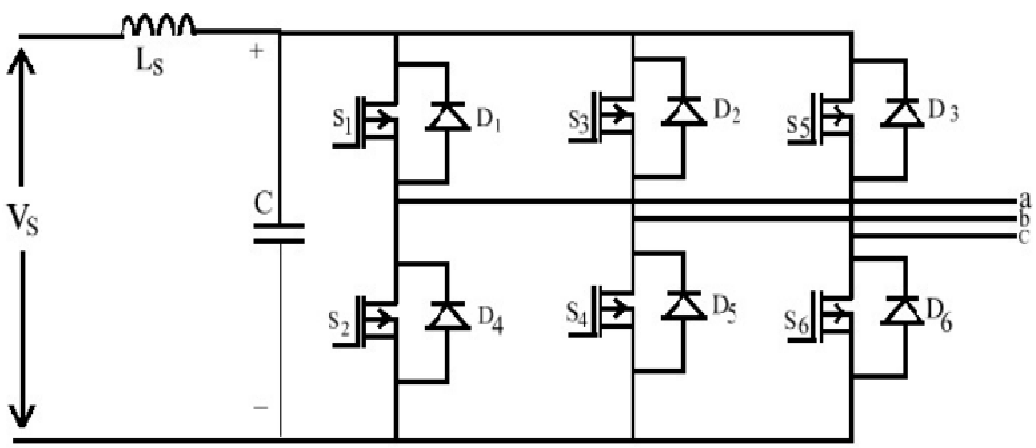


Fig 3: Circuit diagram for Voltage Source Inverter

## IV. Pulse Width Modulation

PWM delivers electrical power with outstanding performance during states of partial on and complete off operation. Standard power switches operating in the on position deliver complete power to the system. Electronic power switches have revolutionized PWM communication into a recent technology [3].

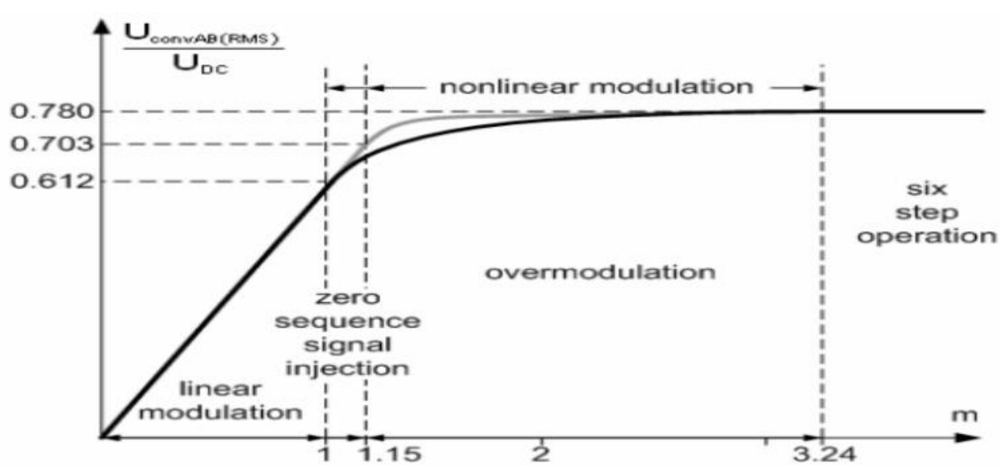


Fig 4: PWM for the DC line side converters

Additional information exists about the correlations between modulation index values and DC-link voltage measurements along with converter input voltages as presented in Figure 4. The modulation bandwidth function shows linear and nonlinear operational regions which remain distinct from each other. Proper operation of PWM rectifiers depends on maintaining the modulation region within the linear operating boundaries. For optimal dynamic performance during transients the synchronous rectifier requires operation in the over modulation range [4]. The non-linear nature of this technology produces line current distortions which makes it inappropriate for DC converter applications that enhance electrical power quality. This paper presents an in-depth analysis of fundamental PWM approach modulation index and modulation range issues in the subsequent sections.

## V. Simulation Results

A comparison between PWM and SPWM through the use of MATLAB/Simulink models shows differences in motor load THD performance.

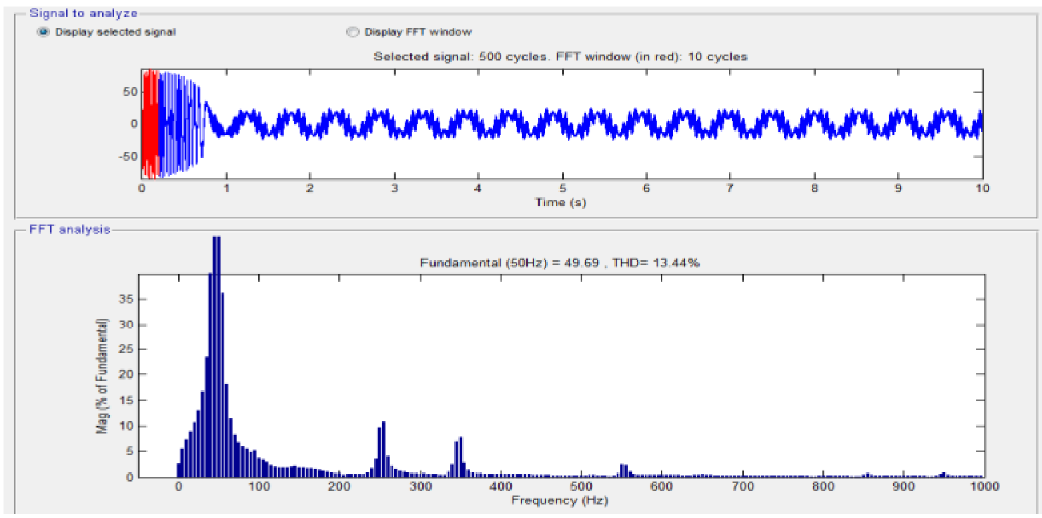


Fig 5: THD for Rotor current with PWM Technique

Simulation analysis through THD revealed that PWM Technique produces an 11% rotor current.

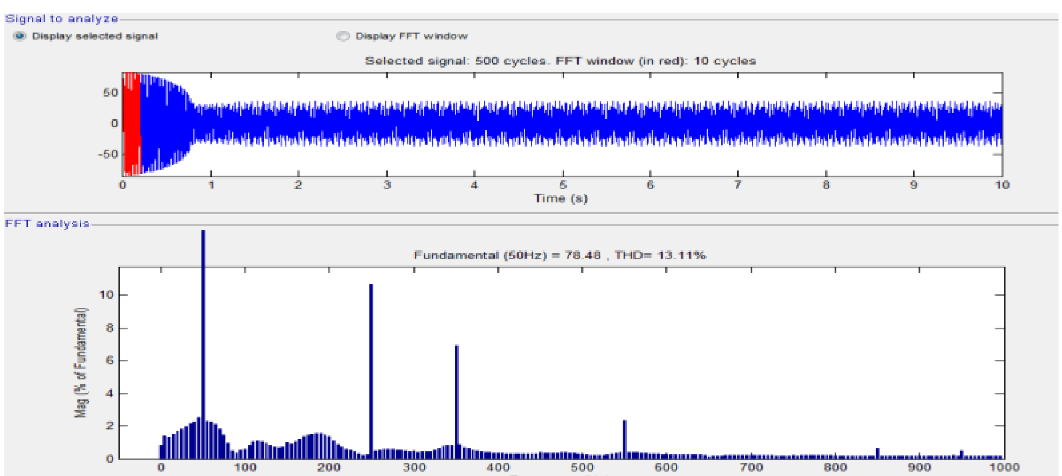


Fig 6: THD for Stator current with PWM Technique

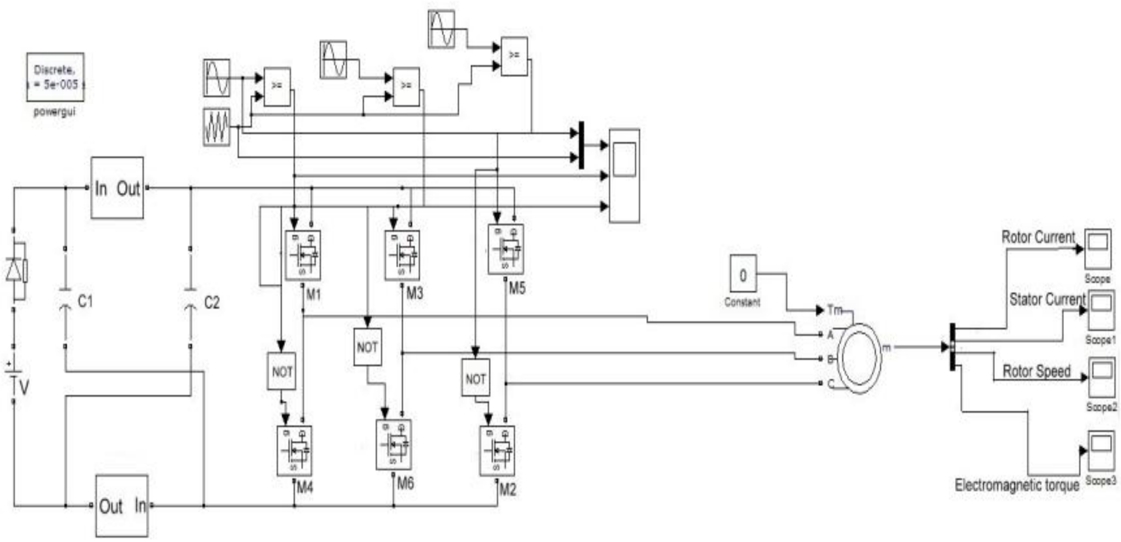


Fig 7: Simulation for Motor load with SPWM Technique

The analysis tools in THD determine the simulation output data for PWM Technique operation when the stator current runs at 15% power. The sinusoidal PWM approach functions through the three-phase inverter to drive an induction motor as shown in Figure 8. The upcoming sections present research results for these investigations. The PWM method stands as the unique difference between these two circuits. Sinusoidal PWM serves as the principle method to reduce harmonics in power systems. Better performance results from the application of this approach to induction motors. The graphical display shows rotor current per phase and harmonic content measurement provides investigation of stator current harmonics.

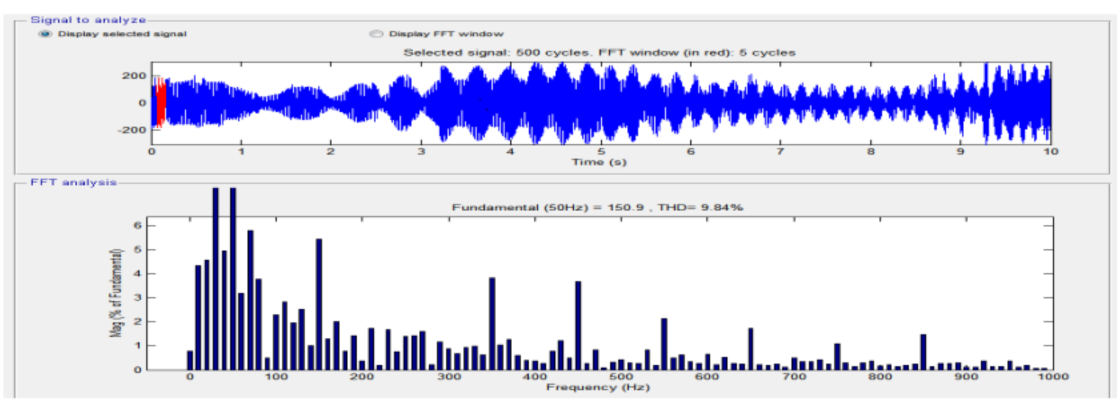


Fig 8: THD for Rotor Current with SPWM Technique

## VI. Conclusion

This research investigates the Z-Source inverter multicell approach for driving three-phase induction motors. The PWM method achieved maximum efficiency standards through the reduction of operational commutations. A comparison of PWM and SPWM approaches against the proposed solution method occurred in this research. Using PWM generates higher harmonic levels. The SPWM technique addresses this shortcoming by delivering effective harmonic reduction together with superior control over switching losses when compared to standard PWM technology. Simulation data are generated to evaluate the Multicell Z-Source inverter with PWM and SPWM control resulting in system stabilization improvement.

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