

# Simulation and Implementation of Single Phase Eleven Level Inverter with Simple Control Strategy Using MATLAB

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**ABSTRACT:** The Multilevel Inverter is a promising power electronics topology for high power applications because of its low electromagnetic interference (EMI) and high efficiency with low-switching-frequency control method. The various topologies of MLI are diode-clamped, flying capacitors and cascaded H-bridges inverter. Amongst these topologies, the multilevel cascaded inverter was introduced in static VAR compensation and drive systems. This report proposes the simulation and the hardware implementation of hybrid cascaded multilevel inverter using single phase inverter. Traditionally, each phase of a cascaded multilevel inverter requires  $n$  DC sources for  $2n+1$  level. The proposed HCMLI inverter scheme focuses on using a single dc power source and the remaining with  $(n-1)$  dc sources being capacitors with reduced number of switches to obtain a eleven level output. The topology used in this project reduces the number of DC sources and switching elements. The PWM strategy for multilevel inverter used in this project ensures efficient voltage utilization and gives a better harmonics spectrum and is done using MATLAB/SIMULINK software Simulation results using MATLAB/SIMULINK R2013a software are reported. The cascaded eleven level inverter is implemented in hardware using PIC microcontroller and hardware results are compared with the simulation results.

**KEYWORDS:** Multilevel Inverter, HCMLI inverter.

## I. INTRODUCTION

The emergence of multilevel inverters has been in increase since the last decade. These new types of inverters are suitable for high voltage and high power applications due to their ability to synthesize waveforms with better harmonics spectrum. Numerous topologies have been introduced and widely studied for utility and drive applications. The multilevel sources inverter's unique structure allows them to reach high voltages with low harmonics without the use of transformers or series connected synchronized switching devices, a benefit that many contributors have trying to appropriate for high voltage, high power applications. This article aims to implement Hybrid cascaded H-bridge multilevel inverter using only one single DC power source and  $(n-1)$  dc source being capacitors to obtain eleven level.

## II. MULTILEVEL INVERTER

A bridged and compact version of voltage inverter, aimed to obtain a quality output waveform with minimum amount of ripple content, without the limitation of operating at high frequency, devoid of switching losses and constraints of device ratings is the ideal of power industry. The unique structure of multilevel voltage source inverter allows them to reach high voltages with low harmonics without the use of transformers or series connected synchronized switching devices.

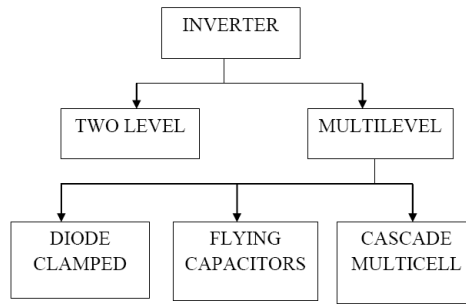


Figure 1.1 Inverter classification

**2.1 EXISTING SYSTEM OF NINE LEVEL INVERTER**

In multilevel inverters with a fundamental frequency switching strategy, the switching angles can be selected so that the output THD is minimized. The output voltage will have fundamental and the associated harmonics. These harmonics produce additional heating in the system, when the output voltage of the inverter is fed to the load. Therefore in order to reduce the losses in the form of heat, harmonics reduction is necessary.

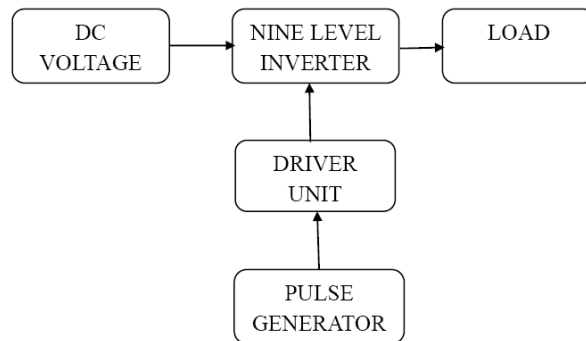


Fig 2.1. Configuration of the system

**2.2 CALCULATING THE SWITCHING ANGLES**

The switching angles  $\alpha_1, \alpha_2, \alpha_3,$  and  $\alpha_4$  are of the multilevel inverter are considered as variables and should be determined.  $V_{dc}$  is the voltage of the DC sources which are shown in Figure 4.2 Here; it is supposed that the voltages of all of the DC sources are equal. Each full-bridge inverter produces a three level waveform  $+V_{dc}, -V_{dc}$  and the number of levels (L) is calculated by  $L = 2S+1$ . S is the number of DC sources that is equal to number of switching angles.

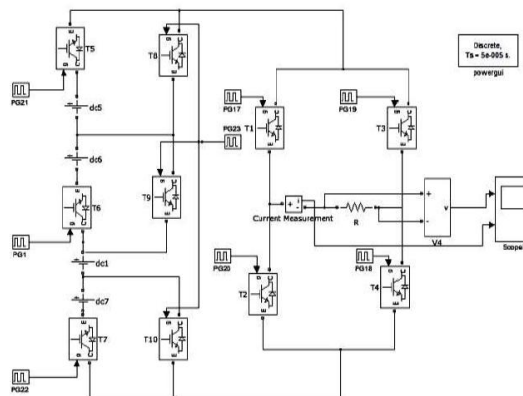


Figure 2.2 Simulation diagram for cascaded H-bridge nine level cascaded inverter

**4.4 OUTPUT WAVEFORM FOR NINE LEVEL INVERTER**

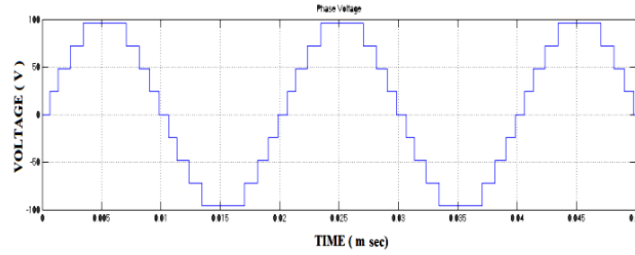


Figure 3.3 Output voltage waveform of nine level inverter

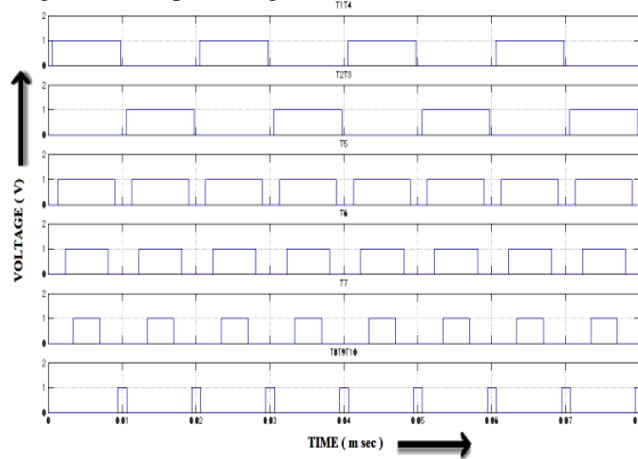


Figure 2.5 Gate pulse of switching devices

**III. IMPLEMENTATION OF ELEVEN LEVEL INVERTER**

The general block diagram of an eleven-level cascaded multilevel inverter fed by pulse generator is shown in Figure 5.1. The AC supply is fed to a rectifier which converts alternating current (AC) to direct current (DC). The DC supply sends the gate pulses to the driver circuit through a pulse generator. The battery source is fed to the cascaded multilevel inverter and load.

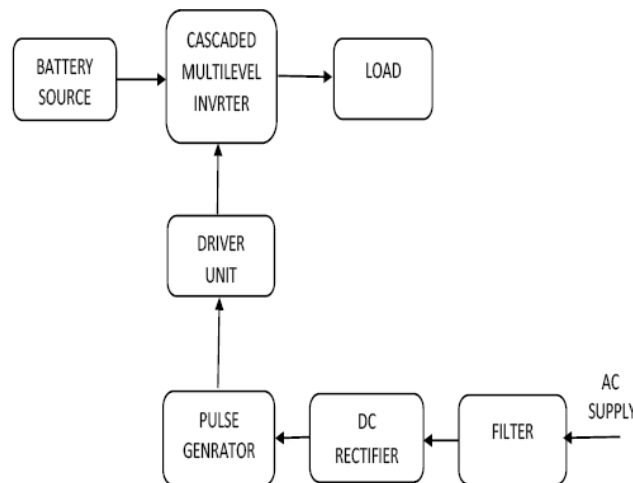


Figure 3.1 Block Diagram of Proposed System

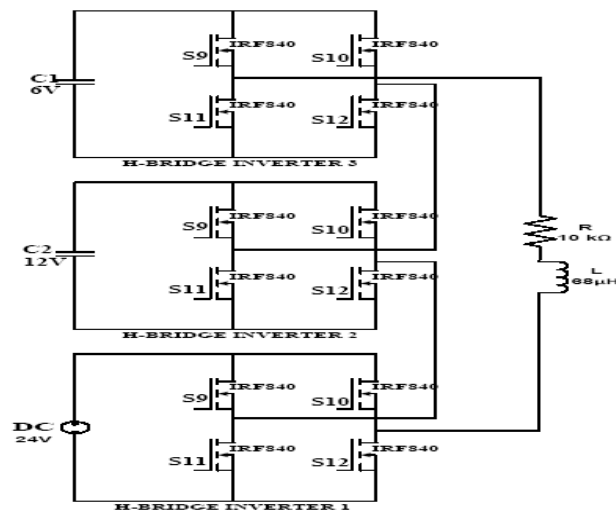


Figure 3.2 Eleven level cascaded H-bridge multilevel inverter

#### IV. SIMULATION AND RESULTS

##### 4.1 INTRODUCTION

This chapter deals with the simulation and hardware diagram of a eleven level cascade multilevel inverter with implementation of dc source reduction scheme. The circuit has been simulated using MATLAB R2013a software with Simulink toolbox. Simulink is a software package for modeling, simulating and analyzing dynamic systems. It supports linear and non-linear systems, modeled in discrete time, continuous time, sampled time or a hybrid of above. Simulink includes a comprehensive block library of sinks, source, linear and nonlinear components and connectors. The hardware was fabricated using a printed circuit board. The hardware contains power supply as transformer, rectifier, filter and regulator for converting for dc supply. The hardware results obtained from PIC microcontroller. The hardware output is taken from power supply, Mosfet, Optocoupler, RL Load and PIC microcontroller.

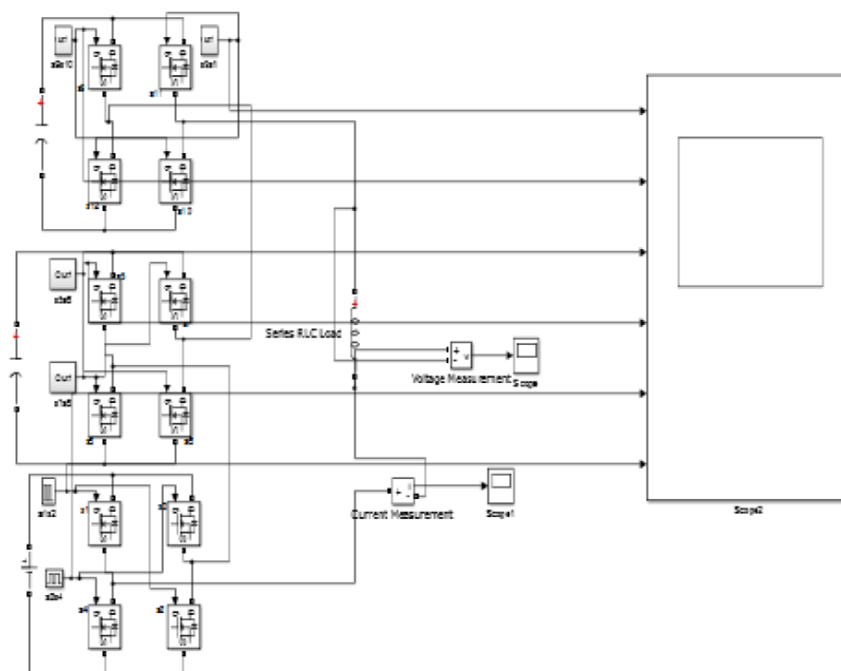


Figure 4.1 Circuit Diagram for eleven level cascaded inverter

MODES	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
MODE 0&10	0	0	0	0	0	0	0	0	0	0	0	0
MODE 9&1	1	1	0	0	1	1	0	0	1	0	0	1
MODE 8&2	1	1	0	0	1	0	0	1	1	1	0	0
MODE 7&3	1	1	0	0	1	0	0	1	1	0	0	1
MODE 6&4	1	0	0	1	1	1	0	0	1	1	0	0
MODE 5	1	0	0	1	1	1	0	0	1	1	0	0
MODE 11&19	0	0	1	1	0	0	1	1	0	1	1	0
MODE 12&18	0	0	1	1	0	1	1	0	0	0	1	1
MODE 13&17	0	0	1	1	0	1	1	0	0	1	1	0
MODE 14&16	0	1	1	0	0	0	1	1	0	0	1	1
MODE 15	0	1	1	0	0	0	1	1	0	1	1	0

Table 4.1 Modes of operation in switch

Angle	degree	TIME(ms)
$\theta_1$	9	5.004
$\theta_2$	27	15.012
$\theta_3$	45	25.02
$\theta_4$	63	35.028
$\theta_5$	81	45.036

Table 4.2 Angle degree

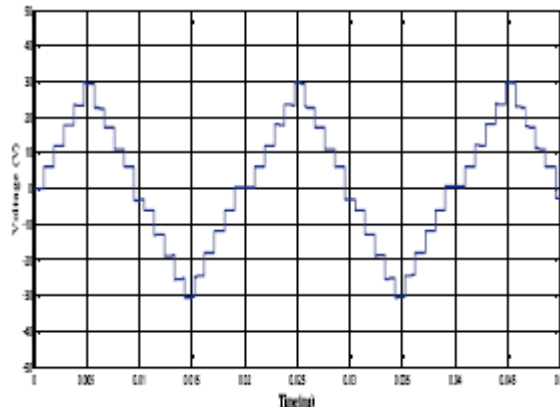


Figure 4.2. Output voltage waveform of eleven level cascaded inverter

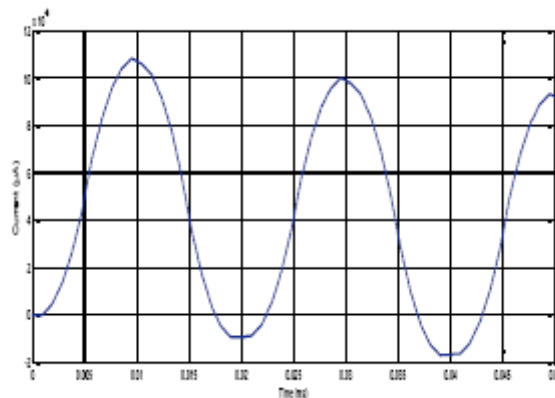


Figure 4.3. Output current waveform of eleven level cascaded inverter



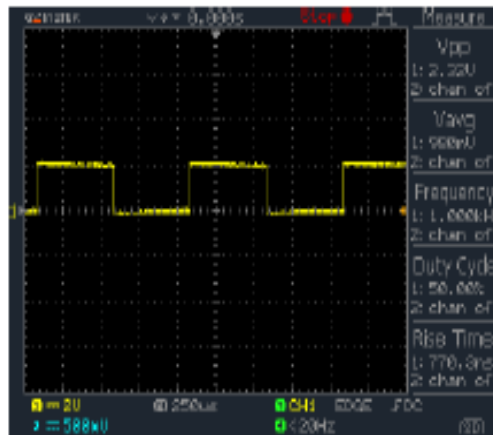


Figure 5.2. Gate pulse for single bridge  
 [X-Axis – 1div = 250µs, Y-axis – 1div = 2V]

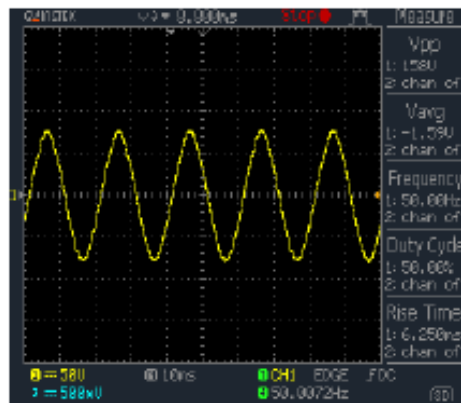


Figure 5.3 The input voltage waveform of eleven level cascaded H-bridge multilevel inverter  
 [X-Axis – 1div = 10ms, Y-axis – 1div = 50V]

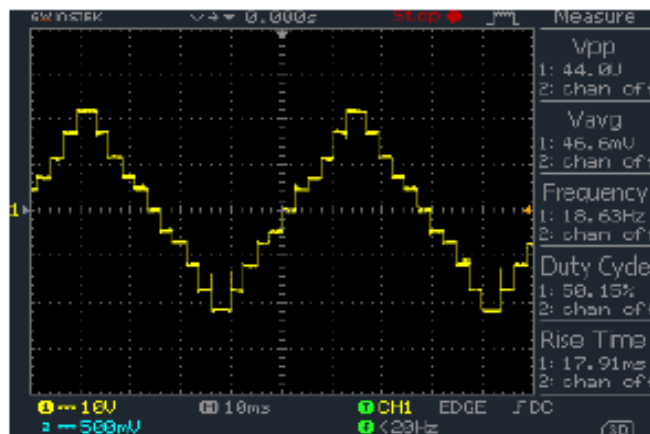


Figure 5.4. The output voltage waveform of eleven level cascaded multilevel inverter

## VI. CONCLUSION AND FUTURE SCOPE

The cascaded H-bridge multilevel inverter was designed. The simulation was demonstrating the proposed cascaded bridge multilevel inverter using MATLAB Simulink version R2013a. The simulation results shows that simultaneous operation of block diagram is possible to give a constant output. The eleven level cascaded multilevel inverter was implemented in hardware using PIC microcontroller and hardware results are compared with the simulation results. The main advantage of this topology is it reduces the switching components by 40% than the conventional cascaded

multilevel inverter. By controlling the modulation index, the desired number of levels of the inverter output voltage is achieved. The reduced number of components reduce the complexity of the system and hence the cost of the circuit. From the cascaded H-bridge inverter eleven level output voltage was achieved. In this proposed method only PIC microcontroller can be used for cascaded H-bridge multilevel inverter to get an eleven level output voltage. DSP controller can be used in future for cascaded H-bridge multilevel inverter. Multilevel inverter with fuel cell in place of dc sources has a greater scope in applications involving electrical vehicles.

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