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A New Design Hybrid Cascaded Multilevel Inverter for AC-DC-AC Conversion

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Abstract: ***Single-Phase AC-DC-AC converters are employed in vast of applications such as UPS Systems, Motor Drives, Yaw Drives, Traction and Micro Grids. This paper introduces an incipient topology for multilevel inverter based Single-Phase AC-DC-AC converter for different types of loads. The suggested converter consists of two phases; a full bridge rectifier that converts AC supply to DC supply and a multilevel inverter that converts DC supply to AC supply cascaded into a rectifier. For the proposed system, the multilevel inverter is chosen as it raises the voltage output level and thus diminishes the Total Harmonic Distortion (THD). The converter suggested here effectively reduces the harmonics in the output voltage and using Multilevel Inverter, reduces THD in the AC-DC-AC converter. The simulation outcomes are acquired from MATLAB®Simulink platform and a hardware prototype of the inverter is done.***

Keywords: ***Multilevel Inverter, AC-DC-AC converter, Filter Design, Total Harmonic Distortion.***

I. INTRODUCTION

Conventional AC-DC-AC converters shown in Fig.1, which are broadly utilized for power utility and drive applications, are the indirect ac-ac converters. It is important to focus on flexible speed drive. The converter associated with the source is a voltage source rectifier and the load side converter is a voltage source PWM inverter. The DC bus is provided between the rectifier and inverter components of the drive. The ripple content in the output voltage of rectifier must be expelled before any power semiconductor switches are "on". If not, this distortion will appear in the output of the load. The inverter part is comprised of group of power transistor and diode combinations. These changes over the DC supply again to AC. For every half cycle, the inverter's power semiconductor switches are turned on and off several times, resulting in a pseudo-sinusoidal current waveform.

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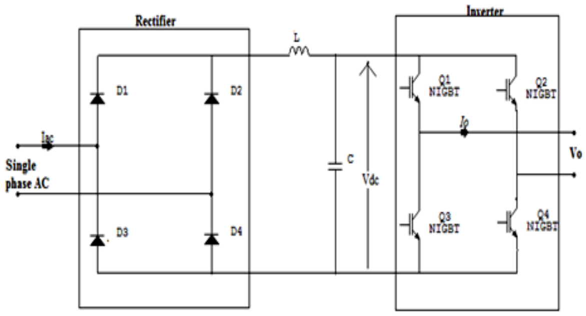

Fig. 1 Conventional Single Phase AC-DC-AC Inverter

Normally the induction motor drive with performance improved AC-DC-AC converter must have the properties like: In the Voltage Source Inverter (VSI) side, primarily it is ought to have significant torque and flux operation and maximum output torque for given range of speed operation [1]. In the rectifier fed DC side there should be bidirectional power flow, increased Total Harmonic Distortion (THD) in input and reduction of link capacitor range [3].

This method of power conversion has impediments like, it uses an IGBT PWM inverter for DC-AC conversion, in which the ac line voltage is not pure sinusoidal, and hence there may be harmonics located at high frequencies causing more THD [6]. In case if these inverters are used for Adjustable Speed Drives (ASD), then the voltage ranges used are low, this happens due to factors like:

i. The presence of increased dv/dt in the pulse width modulated ac line voltage is not tolerable in the average to maximum voltage ranges.

ii. Sharing of load power by just four switches of the inverter

There are two strategies to approximate near-sinusoidal voltage by utilizing four-switch inverter.

- Current Source Inverter (CSI) connected to a capacitive filter.
- Voltage Source Inverter (VSI), which includes an inductive (L) or combination of inductive and capacitive (L &C), filters at the load terminals.

Despite the fact that above said topologies have an advantage of producing near sinusoidal voltage waveforms, but they have a disadvantage, that load power is shared only among four power switches for a single phase inverter [7]. Therefore, it is troublesome when this converter is connected to an adjustable speed drive, since it reduces the motor performance. Hence multilevel inverter topology is used in the proposed system to reduce the dv/dt and to share load power among different switches [4].

An L-C ripple filter is intended for the proposed converter to remove the ripples in the DC output of rectifier. This paper proposes single phase diode bridge rectifier along with a new hybrid multilevel inverter [9].

II. MATERIALS AND METHODS

The new 7-level hybrid cascaded inverter shown in Fig.2 is an alternative design to conventional multilevel cascaded inverter. The term hybrid refers to the combination of one H-bridge and two auxiliary switches with the source of dc voltage [2][5]. The 7-level inverter engenders an output voltage such as: 0, $+2V_{dc}/3$, $+V_{dc}/3$, $+V_{dc}$, $-V_{dc}/3$, $-V_{dc}/3$, $-2V_{dc}$. The suggested inverter circuit design contains six power switches and three capacitors to regulate the voltage from DC supply that serves as a voltage divider.

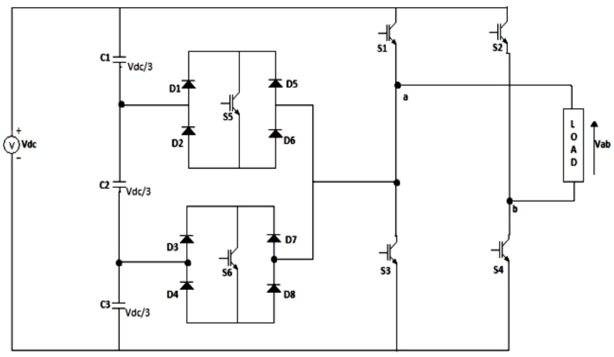

Fig. 2 Proposed Hybrid Multilevel Inverter

Table I depict the operation of new hybrid multilevel inverter with 7-level output voltages and mentioned the switch conduction to generate the different load voltage levels.

Table I Switching States

Output voltage	Conducting switches
Zero	S3-S4(S1-S2)
$V_{dc}/3$	S4-S6
$2V_{dc}/3$	S4-S5
V_{dc}	S1-S4
$-V_{dc}/3$	S2-S5
$-2V_{dc}/3$	S2-S6
$-V_{dc}$	S2-S3

The modulation strategy provided for the suggested 7-level hybrid inverter is based on multiple reference pulse width modulation technique. Three reference signals V_{ref1}, V_{ref2}, V_{ref3} are acquired in this technique by taking absolute sine wave operating at a fundamental frequency and offsetting the reference signals below zero level with a value and in phase with each other. These three carrier frequency (f_s) reference signals have same amplitude A_m. This uses one carrier wave, a triangular wave at switching frequency (f_{sw}) with A_c amplitude. The switch pattern for switches 1 to 6 is shown in Fig.3.

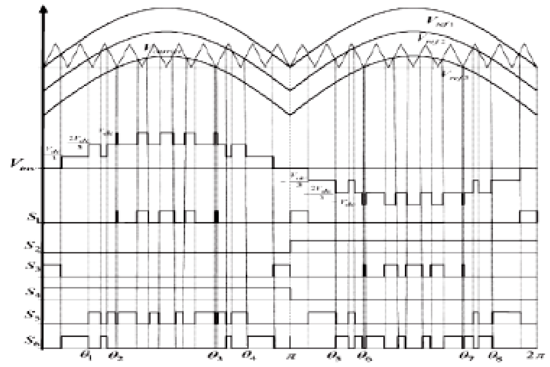

Fig. 3 Multiple Reference Modulation Technique for 1 kHz

The gate pulses are generated by means of comparing the three reference wave with a one carrier wave. When V_{ref1} crosses the peak amplitude of $V_{carrier}$, V_{ref2} will be contrasted with $V_{carrier}$ until V_{ref2} crosses the amplitude of carrier signal. From that point on, V_{ref3} claims responsibility until its amplitude crosses zero if V_{ref3} reaches zero, V_{ref2} implies liability until its amplitude crosses zero and V_{ref1} is equivalent to the carrier signal

The modulation index for a multiple reference modulation technique is given by:

$$m_a = \frac{A_m}{3A_c}$$

where,

A_m - Reference wave amplitude

A_c - Carrier wave amplitude

III. DESIGN OF LC FILTER

This filter consists of inductor L in series with load and capacitor C across the load. The dominant harmonics in the output dc voltage of rectifier is blocked by the inductor. The capacitor, which is connected in parallel to the inductor, provides an easy path to the n^{th} harmonic ripple currents. The general formula for effective filtering is given as [8],

For Voltage Ripple Factor, VRF=0.5, f=50Hz, R_L=50Ω, L & C values are calculated as,

$$C = \frac{10}{2\omega\sqrt{R^2+(2\omega L_L)^2}} = 1.59\text{mF},$$

$$VRF = \frac{\sqrt{2}}{3}\left[\frac{1}{(2\omega^2)LC-1}\right] = 0.5,\ L = 1\text{mH}$$

IV. RESULTS AND DISCUSSION

MATLAB®Simulink and Proteus 8 are used to simulate the AC-DC-AC converter.. The proposed 7-Level Inverter is simulated by generating the gating signals using multi-reference PWM technique. Then inverter is connected in cascade to diode bridge rectifier. A 230V single-phase AC input is given to diode bridge rectifier.

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A. Simulations in MATLAB® Simulink

Fig.4 demonstrates the simulation of AC-DC-AC converter with R load.

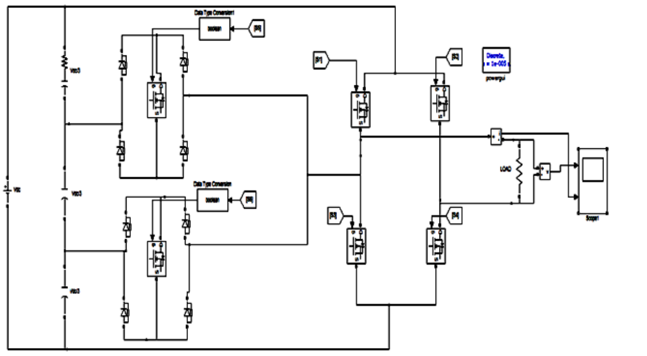

Fig.4 Simulink® realization of Proposed 7-level Multilevel Inverter

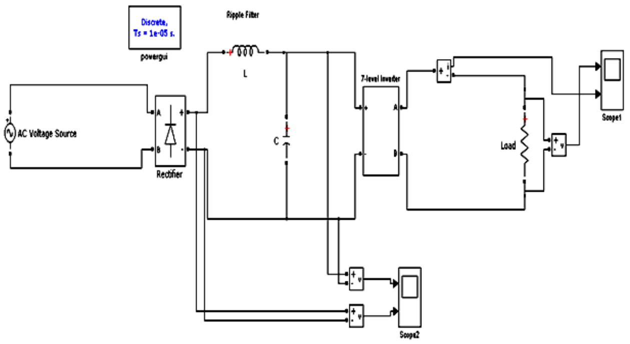

Fig.5 Simulink® realization of AC-DC-AC Converter

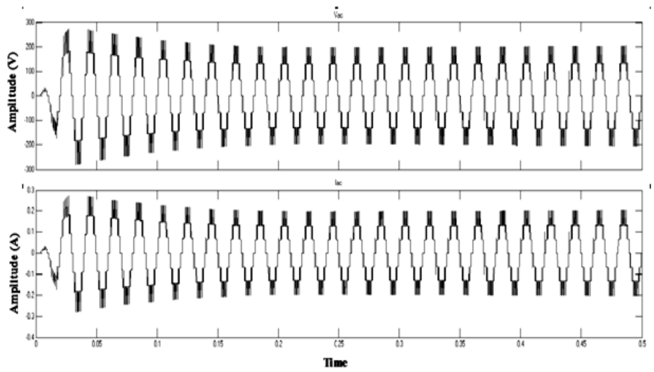

Fig. 6 Simulation Output of AC-DC-AC Converter for R-Load, R=100 ohm

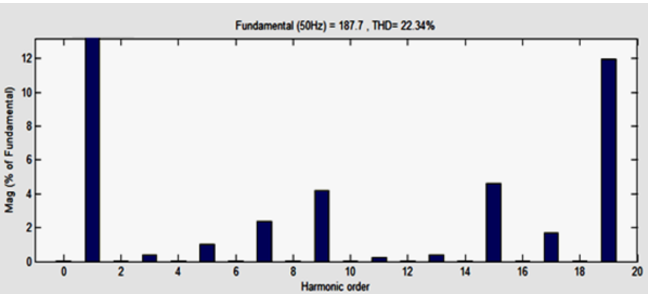

Fig. 7 FFT Analysis of output current of Converter for R-Load, R=100 ohm

B. Simulation in Proteus

Proteus 8 is a single application with many service modules offering different functionality (schematic capture, PCB layout, etc.). The suggested hybrid multilevel inverter is simulated using the real-time hardware and PIC Controller components in Proteus8 Software. The results of MATLAB® Simulink are considered to be the same.

Components utilized in the simulation are:

- IR2110- Driver IC
- PIC16F877A- Microcontroller (Loaded with.hex file for Gate pulses to MOSFET's)
- IRF540N- N-Channel MOSFET

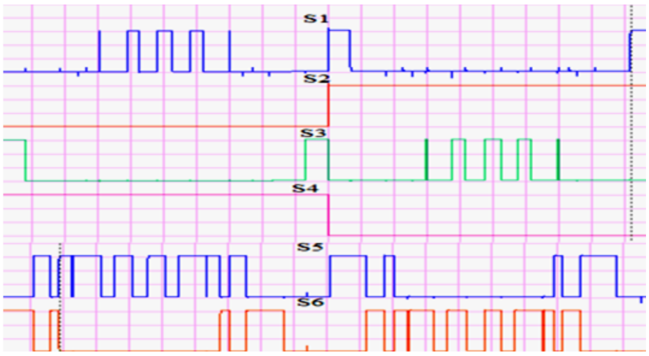

Fig. 8 Proteus based Gate Pulses from Microcontroller

Here, simulations are done with an input DC voltage of 100V, which IRF540N MOSFET can withstand; it is possible to go with higher voltages also.

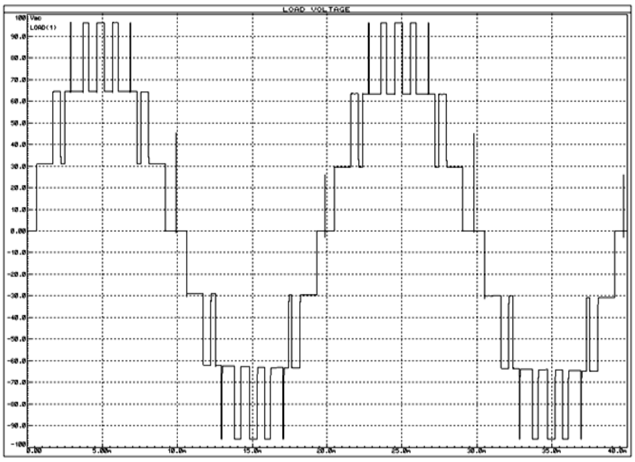

Fig. 9 Proteus based Output Voltage of Inverter

C. Practical Implementation

A prototype hardware setup of proposed multilevel inverter is developed using same components as used for Proteus software. Fig. 10 shows the consummate hardware setup. Here two single-phase 230/15V step-down transformers are fed to two separate, 5A, 230V single-phase full wave diode bridge rectifiers, both are connected to a DC capacitor discretely to smoothen the voltage. Each of that smoothened DC supply is connected to voltage regulators 7812 and 7805 respectively. These voltage regulators regulates the input DC voltage to 12V and 5V respectively and given as the supply for MOSFET driver IC IR2110.

Gate pulses to the MOSFET switches are engendered by means of a PIC controller and pulses are boosted by driver ICs. The pulses from drives ICs are given to gate terminals of MOSFET switches.

A semi-quasi H-bridge inverter consisting of 4 switches (IRFP540N MOSFET) in main circuit and two switches in auxiliary circuit is formed. The output load voltage for R Load (100ohm) is shown in Fig. 11, FFT (Fast Fourier Transform) as shown in Fig. 12 analysis on the output voltage of hardware prototype shows that THD is found to be 29.1%. The simulation and experimental results shows that the designed converter has validity and feasibility.

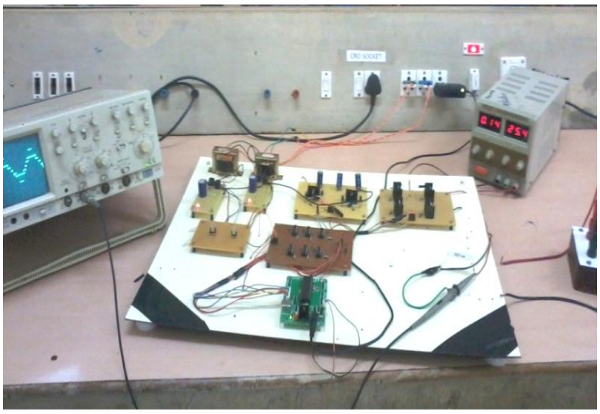

Fig. 10 Inverter Prototype with DC Input from RPS

Fig. 11 Output Voltage of Inverter

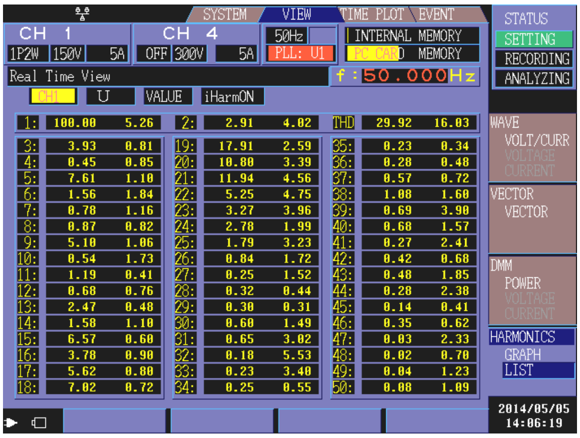

Fig. 12 FFT Analysis for output voltage of Inverter Prototype

V. CONCLUSION

Thus, an incipient configuration of AC-DC-AC converter is proposed. The proposed converter requires less number of power semiconductor switches contrasted with customary model, it likewise accomplishes less THD and the obtained output voltage is approximately, a sinusoidal wave. Calculations of LC filter to remove ripples in the output of rectifier are done. FFT analysis demonstrates that THD for output current of R load is shown. Simulations results from MATLAB®Simulink and Proteus software are also shown. In addition, a prototype of proposed inverter was made and results are shown along with FFT analysis. FFT analysis made on the Inverter output voltage shows that THD is 22.34% from MATLAB®Simulink simulation and 29.92% from hardware prototype. Therefore, the proposed converter is well suited for single phase adjustable speed drives, as if yaw drives employing single-phase motors and controls the axle of wind blade according to wind direction for traction drives and UPS Systems.

Significance Statements

- A novel AC-DC-AC converter was proposed.
- LC filter was designed to remove ripples in the rectifier output.
- Multiple reference modulation technique was used for generating the gate pulses for solid state power electronic switches.
- FFT analyses were made for both simulation and hardware prototype.
- THD is 22.34% from MATLAB®Simulink simulation and 29.92% from hardware prototype.

REFERENCES

1. P. Enjeti, A. Rahman, Jul./Aug. 1993, "A new single phase to three phase converter with active input current shaping for low cost ac motor drives", IEEE Trans. Ind. Appl., vol. 29, no. 4, pp. 806-813.
2. R. Teodorescu, F. Beaabjerg, J. K. Pedersen, E. Cengelci, S. Sulistijo, B. Woo, P. Enjeti, 1999, "Multilevel converters- A survey", Proc. European Power Electronics Conf. (EPE'99).
3. M.P. Kazmierkowski, L. Malesani,1998, "Current control techniques for three-phase voltage-source PWM converters: a survey", Industrial Electronics IEEE Transactions on, vol. 45, no. 5, pp. 691-703.
4. A. de Paula Dias Queiroz, C. B. Jacobina, N. B. de Freitas, A. C. N. Maia and V. F. M. B. Melo,2018, "Single-Phase AC–DC–AC Multilevel Converter Based on H-Bridges and Three-Leg Converters Connected in Series", in IEEE Transactions on Industry Applications, vol. 54, no. 5, pp. 4696-4706.
5. L.He and C.Cheng, 2018, " A Bridge Modular Switched – Capacitor Based Multilevel Inverter With Optimized SPWM Control Method and Enhanced Power-Decoupling Ability", in IEEE Transactions on Industrial Electronics, vol. 65, no. 8, pp. 6140-6149.
6. Gerardo Ceglia, Victor Guzman, Carlos Sanchez, Fernando Ibanez, Julio Walter, and Maria I. Gimenez Sep.2006, "A New Simplified Multilevel Inverter Topology for DC-AC Conversion," IEEE Trans.Power Electron vol. 21, no. 5, pp. 1311-1319,
7. P.S. Bimbhra, 'Power Electronics', fourth edition Khanna Publishers.
8. P.Narasimman and E.latha Mercy, 2019, "Comparison and Mitigation of Harmonics Using Different Optimization Techniques for SHE-PWM of Single-Phase Novel Symmetrical Multilevel Inverter", Journal of Electrical Engineering, Vol.19, Issue.3, pp.478-485.
9. R.Sathishkumar, V.Malathi, E.Sakthivel, "Real-Time Implementation of quazi Z source inverter Incorporated with Renewable Energy Source" Published in Elsevier Energy Procedia, Volume 117, June 2017, pp. 927-934.
10. P. Narasimman and E. Latha Mercy ,2016, " Design and Comparison of Controller for the Reduction of Conducted Electromagnetic Interference in an Inverter" Circuits and Systems, 07,pp.1167-1176.

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