ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A Novel Multilevel Ac–Dc-Ac Converters with Improved Efficiency

Punati Mallika
M.Tech Student,
HITAM Engineering College.

Mr.T.Sreenivas
Assistant Proffessor,
HITAM Engineering College.

Abstract:

Multilevel inverter technology has emerged recently as a very important alternative in the area of high power medium-voltage control and also for improving the total harmonic distortion by reducing the harmonics. Generally, the poor quality of voltage and current of a conventional inverter fed induction machine is obtained due to the presence of harmonics and hence there is a significant level of energy losses. The nine level inverter and seven level inverter are used to reduce the harmonics. So, this paper presents the simulation of three phases nine level inverter. In inverters by increasing the number of steps it generates the very high quality of the output voltage and current. This paper presents a nine level multi-level inverter and these can follow a voltage reference with accuracy and with the advantage that the generated voltage can be modulated in amplitude instead of pulse-width modulation. To operate effectiveness of proposed topologies, a level-shifted pulse width modulation (LS-PWM) technique is presented and simulation results are verified for the operating stages of the proposed &9L converter. And a novel multilevel ac/dc/ac converter with reduced number of semiconductor devices to achieve light weight, efficiency, and better input currentquality. Comparative studies are conducted to analyze the performances of the two proposed front-end rectifiers and simulation results are presented by using Mat lab/Simulink environment.

Keywords:

9 level Multiple-Pole Converter, Reduce Number of Semiconductor Devices, Transformer Less drive.

I. Introduction:

The general function of this multilevel inverter [4-7]. Power electronic devices contribute with an important part of harmonics, such as power rectifiers, thyristor converters and static var compensators. Even updated pulse-width modulation (PWM) techniques used to control modern static converters such as machine drives, power factor compensators, do not produce perfect waveforms, which strongly depend on the semiconductors switching frequency [8]. A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency Pulse Width Modulation (PWM).Staircase waveform quality: Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems can be reduced [9].

Multilevel inverters have drawn tremendous interest in the power industry. They present a new set of feature that are well suited for use in reactive power compensation. Multilevel inverters will significantly reduce the magnitude of harmonics and increases the output voltage and power without the use of step-up transformer. A multilevel inverter consists of a series of H-bridge inverter units connected to three phase induction motor. The general function of this multilevel inverter is to synthesize a desired voltage from several DC sources. The AC terminal voltages of each bridge are connected in series [10].

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II. OPERATING PRINCIPLES OF AC/DC/AC TOPOLOGIES:

This section presents the operating principles of three different ac/dc/ac PWM converters based on the classical MDCC and the proposed M2DCC approaches. The derivation of the proposed M2DCR and M2SCR topologies are explained here

A. Classical Bidirectional Front-End -MDCR With Rear-End MDCI Topologies:

The classical-MDCC ac/dc/ac is a back-to-back (BTB) configuration based on a frontend bidirectional rectifier (see Fig. 2) and a rear-end diode clamped inverter. A total of 16 insulated-gate bipolar transistors (IGBTs) and 12 diodes in each phase leg is required in this topology to synthesize the input and output voltage waveforms (see Fig. 3 for the proposed front-end unidirectional rectifier). The voltage stepped waveform is obtained with the switching positions based on a single-pole circuit configuration, as shown in Fig. 4. It can be observed directly that the phase voltage levels are achieved across the point Va to the neutral point m.

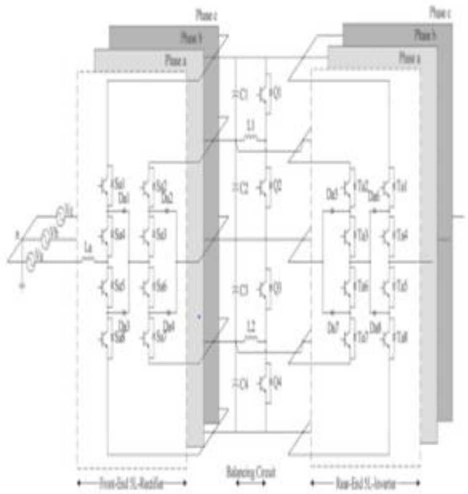

Fig. 1. Proposed bidirectional ac/dc/ac drive based on multiple-pole multilevel diode-clamped converter approach.

1. Proposed Bidirectional Front-End M 2DCR With Rear-End Topologies:

The proposed-M2DCC ac/dc/ac drive presented in Fig. 1 consists of a front-end bidirectional -M2DCR and a rear-end M2DCI. This BTB topology requires only eight power diodes in each phase leg to achieve the same input and output quality as the classical -MDCC. However, when the

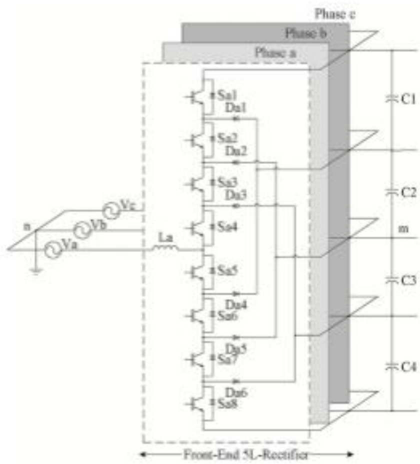

Fig. 2. Classical front-end bidirectional rectifier

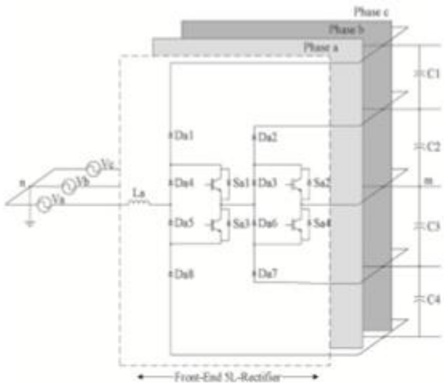

Fig.3. Proposed front-end unidirectional rectifier

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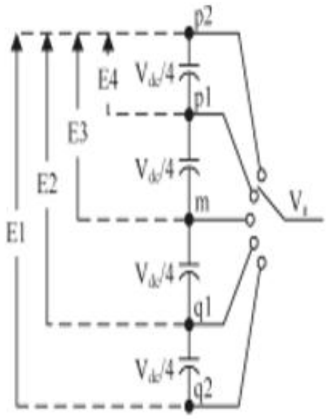

Fig.4. Circuit diagram of per phase leg single-pole classical MDCCtopology with switching position.

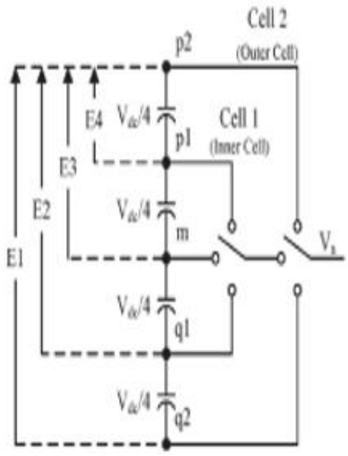

Fig.5. Circuit diagram of per phase leg multiple-pole 2DCC topology with switching position

TABLE I: Switching Logic for Respective IGBT in M2dcc Topology

Vom / Switch	Vdc/2 (Sector II)	Vdc/4 (Sector I & III)	0 (Sector I, III, IV & VI)	-Vdc/4 (Sector IV & VI)	-Vdc/2 (Sector V)
Sa1, Ta1	1	0	0	0	0
Sa2, Ta2	1	1	0	0	0
Sa3, Ta3	1	1	1	0	0
Sa4, Ta4	1	1	1	1	0
Sa5, Ta5	0	1	1	1	1
Sa6, Ta6	0	0	1	1	1
Sa7, Ta7	0	0	0	1	1
Sa8, Ta8	0	0	0	0	1

1: on and 0: off

2. Proposed Unidirectional Front-End M 2SCR with Rear-End M 2DCI Topology

A bidirectional power flow in the front-end rectifier is not required for certain ac/dc/ac drive applications such as propulsion, compressor, or any non-Regenerative braking system. Thus, a proposed transformerless front-end unidirectional rectifier is reconstructed in Fig. 3 with the arrangement of the semiconductor devices in the bidirectional M2DCR configuration (see Fig. 1). Hence, the unidirectional rectifier in Fig. 3 is named as multiple-pole multilevel switch-clamped rectifier (M2SCR) instead. Each phase leg of the proposed unidirectional-M2SCR also requires two cells, as shown in Fig. 5, to achieve input voltage stepped waveform. The states selection of the top and bottom diodes of a M2SCR is dependent on 1-Sa1 and 1-Sa2 for the outer cell and similarly for the inner cell. Hence, only two switching devices are required in each cell, with four series diodes connected to the terminals of the capacitors in the dc link. In Fig. 3, the two switching devices (Sa3 and Sa4) of the inner cell are connected directly to the neutral-point clamped of the four dc-link capacitors, whereas the other two switching devices (Sa1 and Sa2) of the outer cell are clamped to the output terminals of the inner cell. Due to lesser number of switches needed, higher power efficiency is achieved with lesser switching and conduction losses.

3. General Characteristic of the Classical and Proposed AC/DC/AC Converters

The front-end rectifier and the rear-end inverter of ac/dc/ ac drives are operated independently with same levelshifted PWM (LS-PWM). The LS-PWM requires a reference signal and a set of four 1-kHz triangular carriers to achieve the desired switching signals for the

$$\begin{cases} S_{a1}(t) = T_{a1}(t) = 2m_a \sin\omega t - 1 \\ S_{a2}(t) = T_{a2}(t) = 2m_a \sin\omega t \\ S_{a3}(t) = T_{a3}(t) = 2m_a \sin\omega t + 1 \\ S_{a4}(t) = T_{a4}(t) = 2m_a \sin\omega t + 2 \end{cases} \quad (1)$$

Where ma is the ratio of two times the fundamental component of pole voltage to the dc-link voltage.

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Under the condition of steady state and balanced dclinkvoltage, the general incremental output pole voltage equation is expressed as

$$V_{xm}(t) = \frac{V_{dc}(t)}{n-1}\left(\sum_{i=1}^{n-1} T_{xi} - \frac{n-1}{2}\right) \quad \textbf{(2)}$$

Where x represents phase ―a,‖ ―b,‖ and ―c;‖ and n is the number of voltage level. Txiis the switching states of each switching device depicted in the inverter side. The voltage transfer ratios of the converters system between the dc bus voltage to the input and output voltage are defined as

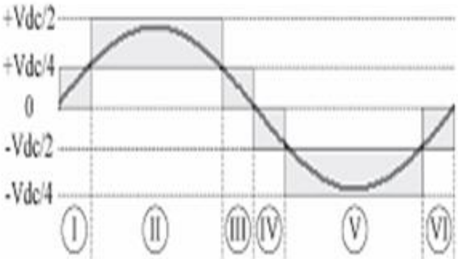

Fig.6. Incremental input and output voltage stepped waveform of a BTB ac/dc/ac drive.

III. HIGH-POWER-FACTOR OPERATION OF THREE-PHASE M2DCR AND M2SCR RECTIFIERS:

A. Semiconductors Voltage And Current Stresses

Voltage and current stresses are the dominant factors considered in the converter design, so that the converter can achieve optimum performance with higher reliability. Proper selection of device rating for the proposed front-end rectifiers is determined based on the global stress analysis. The voltage and current stress expressions for the respective front-end rectifiers are derived with the switching function in (1) and based on the following factors: 1) high-power-factor operation; 2) current and voltage ripple free; 3) constant switching frequency; 4) balanced dc-link capacitors voltage; and 5) zero voltage dropped across boost inductors (Lx). The maximum voltages across the power devices of unidirectional-M2SCR and bidirectional -M2DCR are respectively expressed in the following:

B. SRF Current Control Scheme:

The proposed control algorithm with power factor correction technique is shown in Fig.7. Two control loops, i.e., synchronous-reference-frame (SRF) current control and constant switching frequency modulation, are implemented to regulate the dc-link voltage and mitigate the current distortions. Due to the simplicity of the control strategy, lowcost integrated control circuit can be designed. The balancing control for the dc–dc balancing circuit is presented. The unity power factor controller for the front-end rectifiers (M2DCR or M2SCR) designed in Fig.7.is based on the SRF current control with the LS-PWM technique. The detailed analyses of the outer-loop dc-link voltage control and the inner-loop current control are both presented. SRF controller

TABLE II: Number of Components Used In the Front End Rectifier Topologies

Devices	Topologies				
	Unidirectional Rectifier			Bidirectional Rectifier	
	Classical 9L-MDCR (ref. to Fig. 6 of [1])	Classical 9L-MDCR (ref. to Fig. 7 of [1])	Proposed 9L-M²SCR	Classical 9L-MDCR	Proposed 9L-M²DCR
Diode	24	24	24	18	12
IGBT/MOSFET	18	18	12	24	24
Capacitors	4	4	4	4	4
Complementary Switch	0	9	0	12	12
Isolated Gate Driver	18	18	12	24	24
Cost (USD)	$7472.72	$8943.56	$5698.07	$6616.08	$7410.76
Efficiency (%)	77.37	80.44	85.42	80.99	82.30
Weight (kg)	8.01	9.63	6.17	7.14	7.91

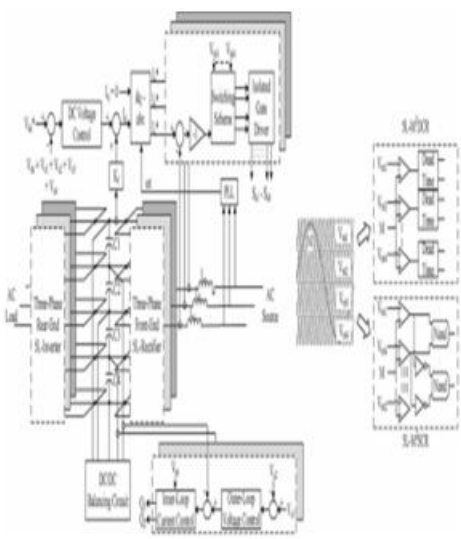

Fig. 7. Proposed front-end rectifier controller for the 9L ac/dc/ac converter.

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V.SIMULATION RESULTS:

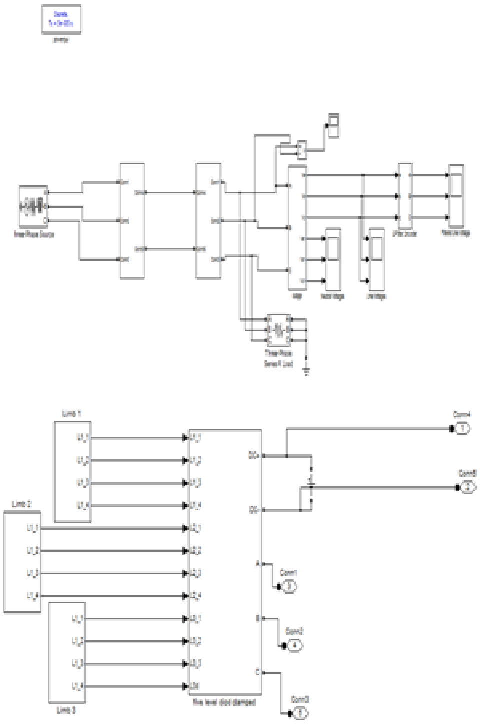

Fig 8. Circuit diagram

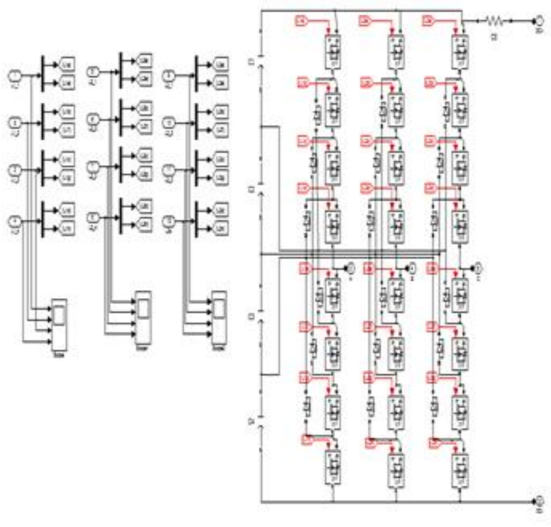

Fig 9.Subcircuits

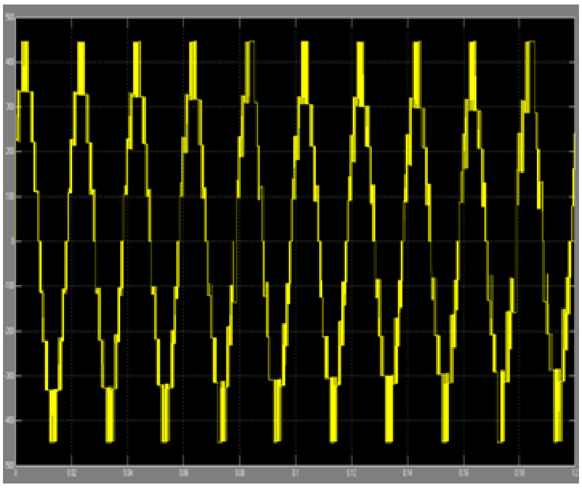

Fig 10.9-level output voltage

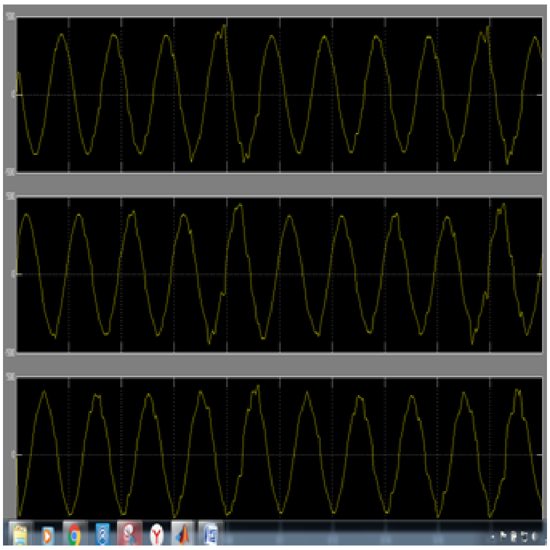

Fig 10.Output currents

VI. CONCLUSION:

A new generation of front-end unidirectional -M^{2}SCR, 9L-M^{2}SCR and bidirectional -M^{2}DCR topologies has been introduced in this paper to reduce the number of semiconductor devices compared with the conventional converters. The agreement between the theoretical analysis is validated and has proven the feasibility of the two proposed ac/dc/ac topologies. Excellent performance and low input current distortion with high power factor is achieved with low operational switching frequency of 1 kHz without the aid of any bulky LC passive filter.

In addition to that, the reduction of component counts allows the proposed converters to achieve low voltage/current stress and low switching losses. The total harmonic distortion is very low compared to that of classical inverter and nine level inverter. The simulation result shows that the harmonics have been reduced considerably. The nine level inverter has been successfully simulated and the results of voltage waveforms, current waveforms. The inverter system can be used for industries where the adjustable speed drives are required.

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Author Details:

Punati Mallika Received B.Tech degree from Pulipati Prasad institute of technology and sciences, Ammapalem(V), Konijerla(m), Khammam(D), Telangana in 2014 and currently pursuing M.Tech in Power electronics and electrical drives at Hyderabad institute of technology and management, Gowdavelly(V), Medchal(M), Ranga Reddy(D). Her area of interest in Power electronics field.

Mr.T.Sreenivas Obtained his B.TECH degree from Jntuk, kakinada in 2009, M.Tech from Andhra university college of engineering, vizag in 2012. He has been working as a Asst., Prof., in Dept of EEE at HITAM Hyderabad since 2013.His area of interest include power systems, HVDC, FACTS.