

Multilevel Current Source Inverter Based on Inductor Cell Topology

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ABSTRACT: This paper presents a new circuit configuration of single-phase multilevel current-source inverter (CSI). In this new topology, a basic H-bridge CSI working as a main inverter generates a multilevel current waveform in cooperation with inductor cells connected in parallel as auxiliary circuits. Each inductor cell is composed by four unidirectional power switches with an inductor across the cell circuit. The inductor cells work by generating the intermediate level of the multilevel current waveform with no additional external dc-power sources. A simple proportional integral controller is applied to control the intermediate-level currents of the multilevel output waveform. Five-level pulse width-modulation inverter configuration dc-current sources are verified through computer simulations. To generate the multilevel output-current waveform with low output harmonics by using small size of inductors without any additional external dc-power sources, which proves feasibility of the proposed strategy.

KEYWORDS: Current-source inverter (CSI), H-bridge, inductor cell, multilevel

I. INTRODUCTION

Few topologies of the multilevel CSIs have been proposed by researchers and engineers. A conventional method to generate the multilevel current waveform is by paralleling some three-level H-bridge CSIs. This topology is a dual circuit of a cascade multilevel VSI. However, the requirement of many isolated dc-current sources with their complex, bulky, and costly isolation transformers and inductors is a problem introduced by this configuration. Another topology of the multilevel CSI is obtained by applying a multi cell topology of the CSI (or multi rating inductor multilevel CSI), which is a dual converter of a flying-capacitor-based full bridge multilevel VSI. However, this topology has a drawback with its bulky intermediate inductors and complexity for balancing control of the intermediate-level currents. Some control methods have been proposed for balancing control of the intermediate-level currents, but very large in size of the intermediate inductors (100 mH) are still used.

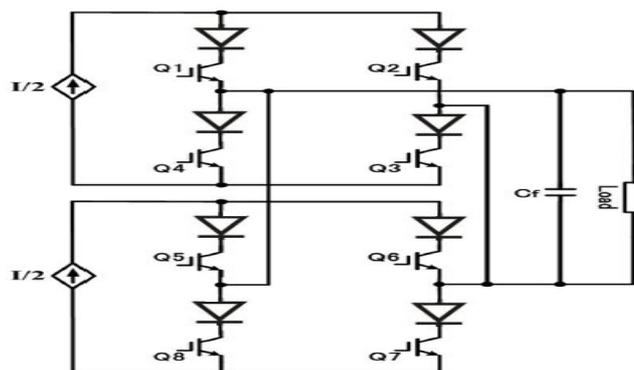


Fig 1. Parallel H-bridge five level CSI

I. BLOCK DIAGRAM:

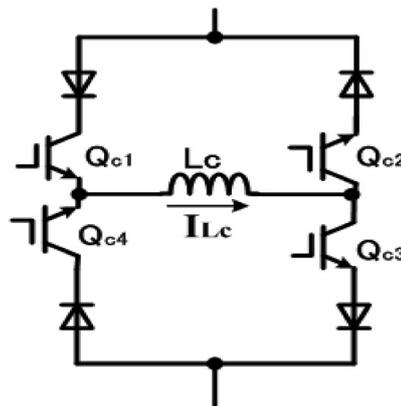
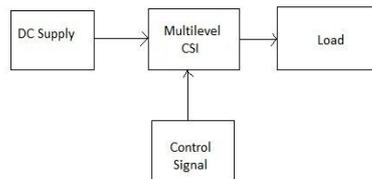


Fig 2. Proposed inductor cell Circuit

III .CIRCUIT CONFIGURATION AND OPERATION PRINCIPLE

A. Operation Principle of Proposed Multilevel CSI

Fig. 2 shows a configuration of the proposed inductor cell circuit composed by four unidirectional power switches QC 1, QC 2, QC3, and QC 4, and an inductor L_C connected across the cell circuit. The newly proposed configuration of the multilevel CSI can be obtained by connecting the H-bridge CSI in parallel with a single or more inductor cells, as shown in a schematic diagram of the proposed multilevel CSI in Fig. 3. A five-level CSI configuration is obtained by connecting a single inductor cell in parallel with the main three-level H-bridge CSI. The relation between the level number of the output-current waveform (M) and the number of the inductor cells (N) can be formulated as follows:

.For M -level CSI, if the dc-current source of the main H-bridge CSI is assumed to have amplitude I , the current flowing through the N th inductor cell (i) is expressed as follows:

$$I_{L_c(i)} = \frac{I}{2^i}$$

Where $i = 1, 2, 3 \dots N$.

The output-current levels of the Five-level CSI are $+I, +I/2, 0, -I/2,$ and $-I$. For the nine-level CSI, the output Waveform has $+I, +3I/4, +I/2, +I/4, 0, -I/4, -I/2, -3I/4,$ and $-I$ current levels.

$$M = 2(N + 1) + 1$$

IV. OPERATION MODES

The inductor cells generate intermediate-level currents of the multilevel output waveform from the basic three-level current of the H-bridge CSI. It utilizes the charging and the discharging operation modes of the inductor. The charging operation mode of the inductor L_c is conducted when the switches QC 1 and QC 3 are turned on, while the switches QC 2 and QC 4 are turned off. A current $IL_c = I/2$ flows through the power switches QC 1 and QC 3 that energizes the inductor L_c . The discharging operation mode is achieved by turning on the switches QC 2 and QC 4 and by turning off QC 1 and QC 3. The stored energy in the inductor is discharged to the load as a current $I/2$. The circulating current modes occur when the inductor cell deliver a null current to keep a constant current in the inductor cell. Similar operation modes occurred for the negative cycle of the output-current waveform. Table I lists the switch states of the proposed five-level CSI.

Power device utility and average switching frequency between QC 1, QC 2 and QC 3, QC 4 in the circulating modes of the inductor cell current is one of the considerations to use redundant switching states for I , 0 , and $-I$ output-current generation. It is also related to the heat distribution among the power switches QC 1, QC 2, QC 3, and QC 4 caused by the switching and conduction losses.

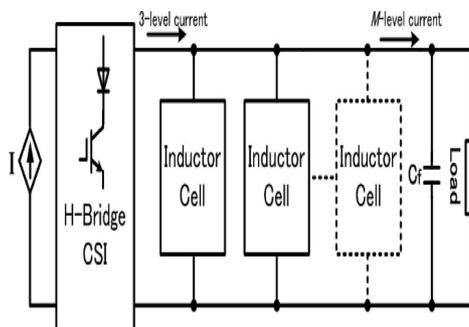


Fig 3. Basic Configuration of CSI

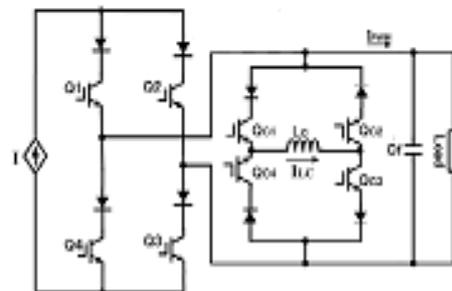


Fig 4. Proposed five level CSI

During the maximum and zero levels of the output-current generation, there is only circulating current mode, no charging and no discharging operation modes in the inductor cell. The frequency of the triangular carrier waveform determines the switching frequency of the inductor cell's power switches, which also regulates the charging and the discharging modes of the inductor cell. The discharging mode means that the inductor cell injects power to the load, and during the charging mode, the main H-bridge inverter injects power to the load.

A simple proportional-integral (PI) regulator is applied to control the dc current flowing through the smoothing inductor, which determines the amplitude of the pulse-width modulation (PWM) output-current waveform $IPWM$ simultaneously. Making the smoothing inductor current follows the reference current is an objective of this currentregulator.

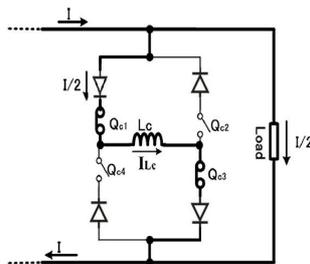


Fig5.1. charging mode. of inductor cell

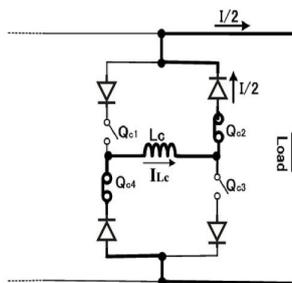


Fig5.2. Discharging mode of inductor cell

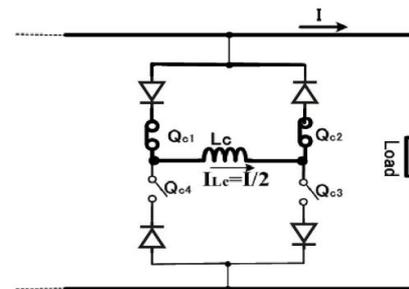


Fig5.3. Circulating mode of inductor cell.

In case of a resistive load, the inductor cell value can be found as $L_c = (I_{Lc} * R) / (f_s * \Delta I * L_c)$ where I_{Lc} is the inductor cell current (in amperes), R is a load resistance (in ohms), f_s is a switching frequency of the inductor cell circuit (in hertz), and ΔI_{Lc} is an acceptable current ripple of the inductor cell current (in amperes). The higher the switching frequency is, the higher is the frequency of the charging and discharging of the inductor cell, which results in the smaller ripple of the inductor cell current, and even a smaller size of the inductor cell can be used.

In order to achieve a lower distortion of the output-current waveform, a PWM technique is applied. In this paper, a level-shifted multicarrier-based sinusoidal PWM technique is employed to generate gate signals for the CSI power switches and to obtain the PWM current waveforms. A schematic control diagram, including the current controller of the chopper and the inductor cell for the five-level CSI, is shown in Fig.6. The control circuit of the inductor cell functions to control the operation modes, i.e., the charging, the discharging, and the circulating modes, of the inductor cell L_c . The current flowing through the inductor cell I_{Lc} is kept constant. It generates the intermediate-level currents based on the output-current waveform of the H-bridge CSI. A PI regulator is applied to zero the error between the detected current flowing through the inductor cell and the reference current to obtain stable and balanced intermediate-level currents. The amplitude of the inductor cell current is half of the dc input current I_{Li} . The output of the PI regulator is modulated by a triangular carrier to generate the control signal $i[0]$, determining the operation mode of the inductor cell.

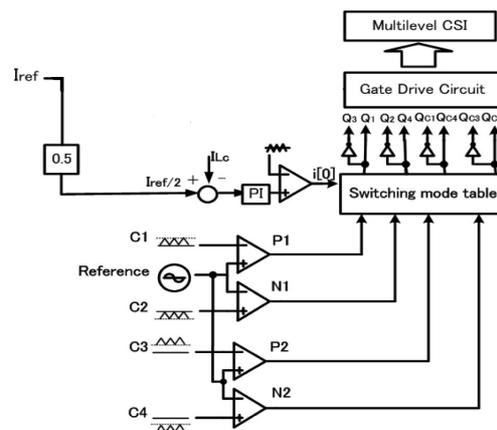


Fig6. Closed Loop Circuit.

TABLE I

Q ₁	Q ₂	Q ₃	Q ₄	Q _{c1}	Q _{c2}	Q _{c3}	Q _{c4}	Output	Operation Mode of Inductor-Cell
1	0	1	0	1	1	0	0	+1	circulating mode
1	0	1	0	0	0	1	1	+1	circulating mode
1	0	1	0	1	0	1	0	+1/2	charging of inductor-cell
1	0	0	1	0	1	0	1	+1/2	discharging of inductor-cell
1	0	0	1	1	1	0	0	0	circulating mode
1	0	0	1	0	0	1	1	0	circulating mode
0	1	0	1	0	1	0	1	-1/2	charging of inductor-cell
0	1	1	0	1	0	1	0	-1/2	discharging of inductor-cell
0	1	0	1	0	0	1	1	-1	circulating mode
0	1	0	1	1	1	0	0	-1	circulating mode

V. FILTER CAPACITOR

It is necessary to connect a capacitor across the load, because the inverter works as a current source and the load usually has an inductive component. The capacitor also functions to filter the harmonic components, e.g., switching harmonic components, of the PWM multilevel output current. The harmonic components of the PWM current will flow through the filter capacitor C_f . In general, using a higher switching frequency with its constraints, and using the higher level number of the output current, a smaller size of filter capacitor can be achieved. A proper choice of the filter capacitor is also important to minimize the heat in the filter, such as capacitors having small equivalent series resistance (ESR).

$$\omega_0 = \frac{1}{\sqrt{LC_f}} \left[\frac{R^2 C_f - L}{R^2 C_f - L} \right]^{1/2}$$

Therefore, the capacitor value that satisfies should be avoided to prevent such resonance in the circuit. In addition, as in dual property with the VSI, because the inverter behaves as a current source, a capacitive load should be connected. Hence, the total impedance connected to the CSI including the filter capacitor should be a capacitive. It is another consideration in choosing the value of the filter capacitor.

VI. SIMULATION RESULTS

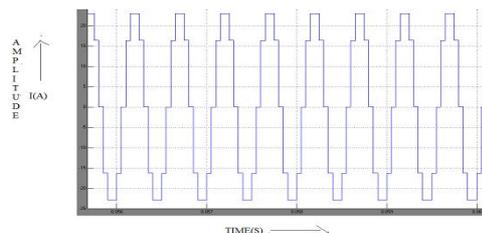


Fig7.1. Five level symmetric MLI Open loop System

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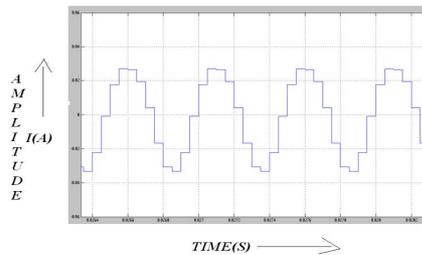


Fig 7.2 Five level Asymmetric MLI Open loop System

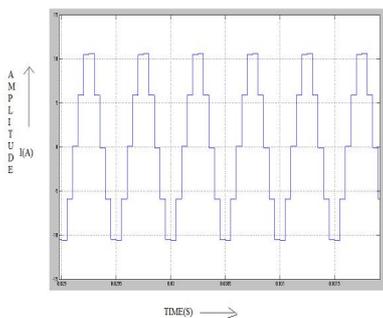


Fig.7.3. O/P Waveform of a 5-level inverter closed loop system

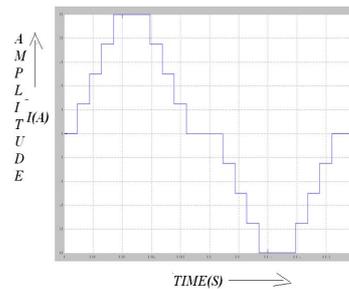


Fig.7.4. Output wave form for the nine level Open loop System of asymmetrical MLI

With the PD-PWM technique and the switching table. Through the control we get 10amp load current. In the proposed multilevel CSI, the voltage stress of the power switches is given by the maximum filter-capacitor voltage, which is determined by the amplitude of the multilevel current waveform and the load.

VII. CONCLUSION

In this paper, a new configuration of multilevel CSI, which employs inductor cells as auxiliary circuit, has been proposed. The inductor cells are connected in parallel with the main H-bridge CSI to generate multilevel output-current waveforms without additional external dc-power sources. The following are some advantages that Here we get 160V dc from source and its applied as an input to the bridge with the help of an inductor in series which forms the current source. We get the 18amp 5-level AC output from the DC source from the open loop system and a 9-level asymmetrical cascaded inverter is designed. The closed loop system is designed where the current through the inductor cell is compared can be obtained using the proposed multilevel CSI topology compared with other topologies. Compared with the conventional two-level power converter, the proposed multilevel CSI can generate multilevel output-current waveform with less distortion by connecting a single or more inductor cells across the H-bridge CSI. The control circuit of the intermediate-level current is simple, resulting in small size of the inductors.

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