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STUDY OF MULTILEVEL INVERTERS FOR RURAL ELECTRIFICATION USING RENEWABLE SAPS SYSTEM

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Abstract— Multi-level inverters play an important role in today's interconnected grid systems with renewable energy sources. Power electronics devices which converts DC input power to AC at required output level of voltage and frequency are known as inverters. They are used for high voltage and high power applications, with the improved advantages of low switching stress and reduced total harmonic distortion (THD), hence they reduce size of the passive filters. This paper provides a review on various types of multilevel inverters. Multilevel inverter has three different major topologies: Cascaded H-bridges converter(CMLI), Diode clamped(DMLI), and Flying capacitor multilevel inverter(FCMLI). Therefore with less number of switches in the circuit, there will be reduction in the gate driver circuits, weight and reduces the THD.

Keywords— Multi-Level Inverter, Topologies, CMLI, DMLI, FCMLI.

INTRODUCTION

Power-electronic based inverters are becoming popular for various industrial drives applications. A multilevel inverter is a power electronic system that synthesizes a desired output voltage from several levels of dc voltages as inputs [1]. The attractive feature of this technology is mainly in the range of medium to high voltage application and offers a number of advantages when compared to the conventional two-level inverter. Multilevel inverters are used in power conversion system due to improved voltage and current waveforms [2]. It is recently emerged as very important alternatives in high power medium voltage applications because of their additional advantage over the conventional inverters and their capability to reduce the undesirable harmonics. The aim of introducing the concept of multilevel inverter is to reduce switching losses and to obtain the output with multiple steps voltage to achieve the improved power quality and higher voltage capability [3].

The smaller output voltage step is the main advantages of multilevel inverters, which results in high voltage capability, lower harmonic components, lower switching losses, better electromagnetic compatibility, and improved power quality. Also it can be operated at both fundamental switching frequency and high switching frequency PWM. The three major topologies of multilevel inverters have been proposed here: cascaded multi cell with separate dc sources, diode-clamped (neutral-clamped) and capacitor-clamped (flying capacitors) [4]. Each of these topologies has a different mechanism for providing the voltage level. The first topology introduced was the series H-bridge design but several configurations have been obtained for this topology as well. As the topology consists of series power conversion cells, the power and voltage levels may be scaled easily. The H-bridge topology was followed by the diode-clamped inverter that utilized a bank of series capacitors. The flying-capacitor topology followed diode-clamped after few years. Instead of series connected capacitors, this topology uses floating capacitors to clamp the voltage levels. H-bridge inverters consists of isolation transformers to isolate the voltage source but they does not need either clamping diode or flying capacitor inverters. One main disadvantage of multilevel power conversion is the requirement of great number of power semiconductor switches. Another disadvantage of multilevel power inverters is that the small voltage steps are typically produced by isolated voltage sources or a bank of series capacitors. Isolated voltage sources may not always be readily available and series capacitors require voltage balance [5].

TYPES OF MULTILEVEL INVERTERS

In today's world, multilevel inverters are widely used in power industries. It starts from three level inverter. Voltage unbalance problem is one of the major issue in working of multilevel inverter. The multilevel inverters are classified as follows:

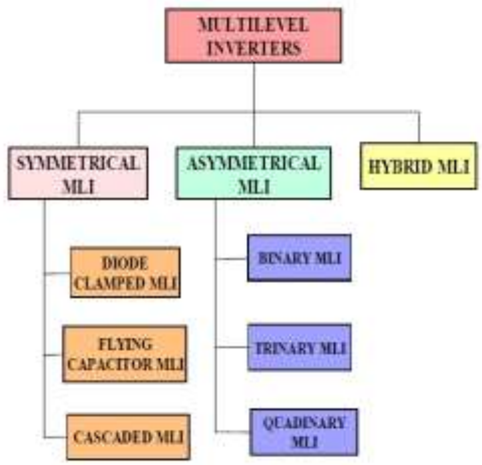

Fig.1: Types of multilevel Inverters

TOPOLOGIES OF MULTILEVEL INVERTERS

The multilevel inverter topology is broadly classified as symmetrical , asymmetrical and hybrid inverters ,but in this paper our study will only focus on symmetrical multilevel inverters.

Symmetrical Multilevel Inverters

Symmetrical multilevel inverter is those inverters which have equal amplitude of voltage sources. Its major types are diode clamped multilevel inverter, flying capacitor based multilevel inverter & cascaded H-bridge multilevel inverter.

Diode clamped multilevel inverter

This inverter mainly use diodes to limit the power devices voltage stress. The voltage over each capacitor and each switch is V_{dc}. An m level inverter needs (m-1) voltage sources, (m-1) capacitors,2(m-1) switching devices and (m-1) (m-2) diodes per leg [6].

To produce a staircase-output voltage, let us consider only one leg of the five –level inverter. The dc rail 0 is the reference point of the output phase voltage. The steps to produce the five level voltages are as shown:

1. For an output voltage level v_{a0} = V_{dc}, turn on all upper-half switches Sa1 through S_{a4}.
2. For an output voltage level v_{a0} = $V_{dc}/2$, turn on two

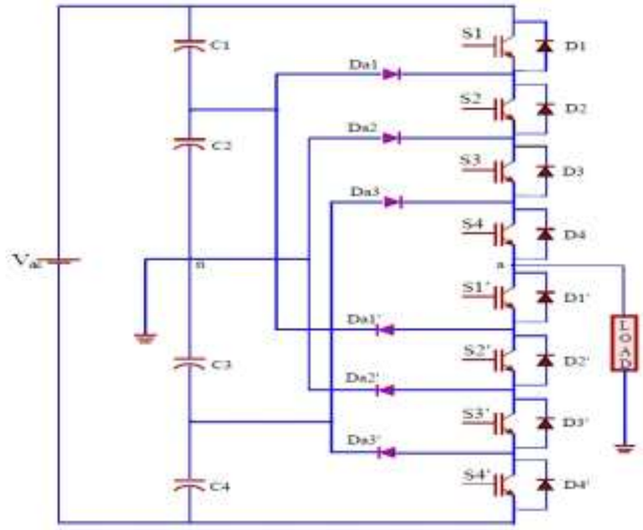

Fig.2: Five level diode clamped multilevel inverter

TABLE 1
DIODE CLAMPED INVERTER -SWITCH STATES AND OUTOUT VOLTAGE LEVELS

Switch state								Output
S1	S2	S3	S4	S1'	S2'	S3'	S4'	V_{an}
1	1	1	1	0	0	0	0	$+V_{dc}/2$
0	1	1	1	1	0	0	0	$+V_{dc}/4$
0	0	1	1	1	1	0	0	0
0	0	0	1	1	1	1	0	$-V_{dc}/4$
0	0	0	0	1	1	1	1	$-V_{dc}/2$

upper switches S_{a3} through S_{a4} and two lower switches S'_{a1} and S'_{a2}.

3. For an output voltage level v_{a0} = 0, turn on all lower half switches S'_{a1} through S'_{a4}.

State 1 is known as ON condition ,and state 0 is known as OFF condition. It is mentioned that each switch is turned on only one time per cycle and there are four complementary switch pairs in each phase. The pairs for one leg of the inverter are (S_{a1}, S'_{a1}), (S_{a2}, S'_{a2}), (S_{a3}, S'_{a3}) and (S_{a4}, S'_{a4}). Thus, if one of the complementary switch pairs is turned on, the other switch of the same pair must be off. The line voltage consists of the positive phase- leg voltage of terminal *a* and the negative phase-leg voltage of terminal *b* .Each phase-leg voltage tracks one-half of the sinusoidal wave. The resulting line voltage is a five-level staircase wave. This implies that an m-level converter has an m-level output phase-leg voltage and a (2m-1) level output line voltage. The switching angles should be calculated in such a way that the

THD of the output voltage becomes as low as possible [7].

Features

1. High-voltage rating required for blocking diodes.
2. Unequal device rating.
3. Capacitor voltage unbalance.

Advantages

1. It possess high efficiency.
2. There is no need of filters for reducing harmonics.
3. Reactive power flow can be altered.
4. The control method is very simple.

Disadvantages

1. For high levels, more number of diodes are required.
2. Real power flow control for individual converter is difficult.

Flying capacitor multilevel inverter

This inverter uses capacitors to limit the voltage of the power devices. The configuration of the flying capacitor multilevel inverter is like a diode clamped multilevel inverter except that capacitors are used to divide the input DC voltage. The voltage over each capacitor and each switch is Vdc. Figure 3 shows the flying capacitors based multilevel inverter topology. It requires (m-1) capacitors on dc bus form level converter.

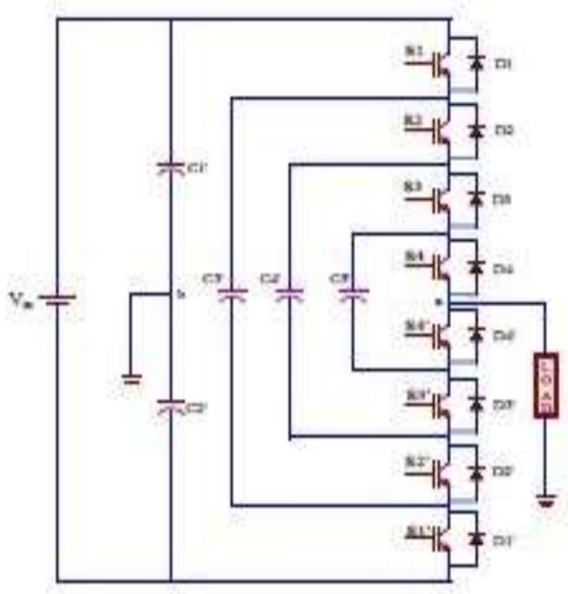

Fig.3: Five level flying capacitor based multilevel inverter

TABLE 2
FLYING CAPACITOR INVERTER-SWITCH STATES AND OUTPUT VOLTAGE LEVELS

S1	S2	S3	S4	C3'	C4'	C5'	V_o
1	1	1	1	NC	NC	NC	$+V_d/2$
1	1	1	0	NC	NC	!	$+V_d/4$
1	1	0	1	NC	+	-	
1	0	1	1	+	-	NC	
(	1	1	1	-	NC	NC	
(	0	1	1	NC	-	NC	0
(	1	0	1	-	+	-	
(	1	1	0	-	NC	!	
1	0	0	1	+	NC	-	
1	0	1	0	+	-	+	
1	1	0	0	NC	+	NC	
1	0	0	0	+	NC	NC	$-V_d/4$
(	1	0	0	-	+	NC	
(	0	1	0	NC	-	!	
(	0	0	1	NC	NC	-	
(	0	0	0	NC	NC	NC	$-V_d/2$

Features

1. It consists of large number of capacitors.
2. It has balancing capacitor voltages.

Advantages

1. Phase redundancies are available for balancing the voltage levels of the capacitors.
2. The flow of Real and reactive power can be controlled.
3. The large number of capacitors enables the inverter to ride through short duration outages and deep voltage sags.

Disadvantages

1. Control is complicated to track the voltage levels for all of the capacitors. Also, recharging all of the capacitors to the same voltage level is complex.
2. Switching utilization and efficiency are poor for real power transmission.
3. The large numbers of capacitors are both more expensive and bulky than clamping diodes in multilevel diode-clamped converters. Packaging is also more difficult in inverters with a high number of levels.

Cascaded multilevel inverter

The concept of this inverter is based on connecting H-bridge inverters in series to get a sinusoidal voltage output. The output voltage is the sum of the voltage that is generated by each cell. The number of output voltage levels are (2*n*+1), where *n* is the number of cells. The switching angles can be chosen in such a way that the total harmonic distortion is minimized. One of the advantages of this type of multilevel inverter is that it needs less number of components comparative to the Diode clamped or the flying capacitor, so the price and the weight of the inverter is less than that of the two former types [8].

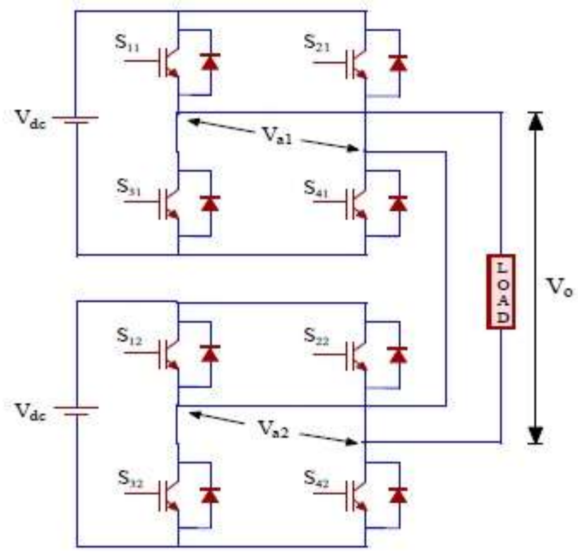

Fig.4: Five level cascaded multilevel inverter

TABLE 3
SWITCH STATES AND VOLTAGE LEVELS OF FIVE LEVEL CASCADED INVERTER

S_{11}	S_{21}	S_{12}	S_{22}	Output (V_o)
1	0	1	0	$+2V_{dc}$
1	0	0	0	$+V_{dc}$
1	0	1	1	$+V_{dc}$
0	0	1	0	$+V_{dc}$
1	1	1	0	$+V_{dc}$
0	0	0	0	0
1	1	1	1	0
1	0	0	1	0
0	1	1	0	0
0	0	1	1	0
1	1	0	0	0
0	1	1	1	$-V_{dc}$
0	1	0	0	$-V_{dc}$
1	1	0	1	$-V_{dc}$
0	0	0	1	$-V_{dc}$
0	1	0	1	$-2V_{dc}$

Features

1. Separate dc source are fuel cell, photovoltaic, and biomass.
2. Back-to-back fashion between two converter is not possible.

Advantages

1. The number of possible output voltage levels is more than twice the number of dc sources (m = 2s +1).
2. The series of H-bridges makes for modularized layout and packaging. This will enable the manufacturing process to be done more quickly and cheaply.

Disadvantages

1. Separate DC sources are required for the real power conversion.

COMPARISON OF MULTILEVEL INVERTERS

All three inverter types have the potential for application in high voltage applications. The diode clamped inverter is most suitable for the back to back intertie system operating as a unified power flow controller, other two are also applicable for the same but they would require more switching per cycle . All devices are assumed to have same voltage ratings but not necessarily same current ratings.

The cascaded inverter uses full bridge in each level as compare to the half bridge versions in other two types. The cascaded inverter requires the least number of components and has the potential for utility interface applications because of its capabilities for applying modulation and soft switching techniques [9][10].

TABLE 4
COMPARISON OF COMPONENTS REQUIRED FOR VARIOUS TOPOLOGIES

S. No.	DCMLI (5-Level)	FCMLI (5-Level)	CMLI (5-Level)
Main Switching Devices	8	8	8
Clamping Diode	12	0	0
Balancing Capacitor	0	12	0
DC Bus Capacitor	4	4	2
Main Diodes	8	8	8

CONCLUSION

In this paper various types of multilevel inverter topologies are discussed and compared. Cascaded multilevel inverter requires minimum number of components when compared will other types. So it produces an increased stepped output with less number of semiconductor switches [11]. Today, more and more commercial products are based on the multilevel inverter structure, and more and more worldwide research and development of multilevel inverter-related technologies is occurring. Through this paper we want to provide detailed knowledge about the concept. With fewer switches, controlling the overall circuit becomes less complex, the size and installation area reduces. Whenever the demand increases it is met out by adding additional H-bridge in cascaded inverter. Also the various new topologies for cascaded inverter are available to decreases the switching devices. Thus after this study we found that cascaded inverter is the better choice when we compare the reliability, modulation scheme and switching techniques with other topologies [12].

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