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Modified Seven Level Inverter Integrated With Boost Converter

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ABSTRACT: Energy demand is increasing day by day. In order to meet this energy demand renewable energy sources have to be incorporated. Renewable energy sources like fuel cells, pv cells etc. produces DC voltage. But most of the house hold and industrial purpose require AC voltage. So this DC (direct current) voltage has to be converted into AC (alternating current) voltage. For this power electronic inverters can be used. Multilevel inverters has got wide spread acceptance as it can synthesis almost sinusoidal wave form. This paper presents an inverter which can give a seven level AC output without variation in its voltage amplitude, from a variable DC source. Here a boost converter is introduced as a front-end stage. This DC-DC conversion helps to stabilize the output voltage. A new class of multilevel inverter with coupled inductor was introduced in the second stage to get a seven level AC as output. The working principle of DC-DC converter and the inverter are explained. The circuit is tested with different DC voltage and found to give the same output voltage waveform. The circuit has been simulated using MATLAB/Simulink tool and a prototype is made to verify the validity and performance of the circuit.

KEYWORDS: Multilevel inverters (MLI), Total harmonic distortion (THD), neutral point clamped (NPC) inverters.

I.INTRODUCTION

The birth of semiconductor technology and its widespread acceptance and applications fuelled the design of various power converter topologies. Numerous industrial applications have begun to require higher power apparatus in recent years. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power inverter structure has been introduced as an alternative in high power and medium voltage situations. Multilevel inverters (MLIs) are finding increased attention in industries as a choice of electronic power conversion for medium voltage and high-power applications, because improving the output waveform of the inverter reduces its respective harmonic content and hence, the size of the filter used and the level of electromagnetic interference generated by switching operation. The output of conventional two-level inverter is in the form of square wave ac power which usually contains undesirable harmonics. When this output is fed to an electrical device such as an electrical motor it causes heating which in turn causes increased losses and finally resulting in decreased efficiency. This is caused by high harmonic contents. These harmonics increases the total harmonic distortion value which is responsible for reducing the quality of output. The harmonics has to be removed in order to attain a proper sine wave. The harmonics in the output side of the inverter can be eliminated using multilevel inverter structures. A multilevel inverter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photo-voltaic, and fuel cells can be easily interfaced to a multilevel inverter system for a high power application.

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Basically multilevel inverter topologies can be classified into two types: Type I and Type II. Type I uses multiple DC voltage sources and Type II uses multiple (split or clamping) DC voltage capacitors. As the level increases, the required number of DC sources also increases in Type I. This made the use of Type I a limited one. Type II is limited mainly by the balancing of the capacitor voltages. So the most desirable topology may be, a multilevel inverter with single source and no split capacitor. . The inverter used in this paper can synthesis an AC voltage with seven levels from a single DC source. Besides in this inverter, no voltage split capacitors are used.

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II.SINGLE PHASE FIVE LEVEL INVERTER USING COUPLED INDUCTORS

The proposed topology is the single-phase five-level inverter using coupled inductors and the common three-arm power module. For this inverter, only one dc voltage source is needed and split of the dc voltage capacitor is also avoided, which eliminates the problem of dc capacitor voltage balancing with the other multilevel inverter topologies. Meanwhile, six power switches with the same voltage stress and only one set of coupled inductors are adopted Figure 1.1 shows the circuit of the single-phase five level inverter. In Figure, E is the dc-link voltage and L_1 and L_2 are the two coupled inductors. The mutual inductance of thetwo inductors is M and the output terminals of this inverter are 1 and 2. Obviously, this topology is very simple and can be constructed simply by adding two coupled inductors to a conventional three-arm inverter bridge.

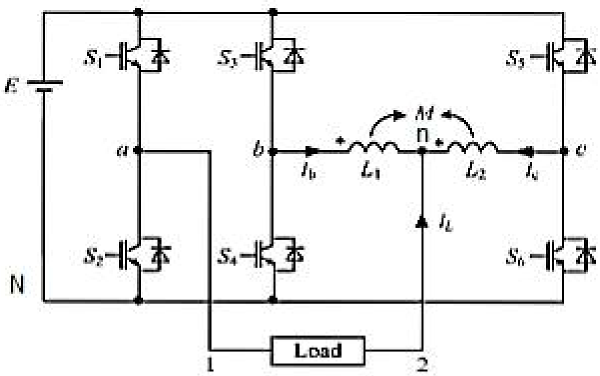

Fig.1.1 Single phase five level inverter

III.ROLE OF COUPLED INDUCTORS

It is, in fact, the adoption of the coupled inductors that makes it possible to output five-level voltage with only one dc voltage source. So the role of the coupled inductors have to beanalyzed first. Two coupled inductorswith the same number of turns are considered. The leakage inductances of the two inductors are L_{K1} and L_{K2}, respectively and M is the mutual inductance between the two inductors. Since the number of turns are equal, self and leakage inductance of the two inductors are the same (ie. $L_1 = L_2 = L$ and $L_{k1} = L_{k2} = L_k$). The voltage equations of the coupled inductors can be expressed as follows:

$$Vbn = Vb - Vn = L\frac{dib}{dt} - M\frac{dic}{dt} = (M + Lk)\frac{dib}{dt} - M\frac{dic}{dt} \qquad -(1)$$

$$Vcn = Vc - Vn = L\frac{dic}{dt} - M\frac{dib}{dt} = (M + Lk)\frac{dic}{dt} - M\frac{dib}{dt} \qquad -(2)$$

According to Kirchhoff's current law, at node n,

$$ib + ic - iL = 0 \qquad -(a)$$

solving these equations we will get,

$$Vn = \frac{Vb + Vc - Lk\left(\frac{diL}{dt}\right)}{2} - (3)$$

Indeed leakage inductance is very small and can be safely neglected in most cases. Then equation (5) becomes

$$Vn = \frac{Vb + Vc}{2} \qquad -(4)$$

This result shows that the coupled inductors will perform as an adder of the two input voltages at the non-common connected terminals with the common connected terminal as the output.

The switching states of the five level inverter can be summarized by the table 1.1.

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S1	S2	S3	S4	S5	S6	v_{12}
1	0	0	1	0	1	+E
1	0	0	1	1	0	+E/2
1	0	1	0	0	1	+E/2
1	0	1	0	1	0	0
0	1	0	1	0	1	0
0	1	0	1	1	0	-E/2
0	1	1	0	0	1	-E/2
0	1	1	0	1	0	-E

Table.1.1 Switching states of the five level inverter

IV.MODIFIED SEVEN LEVEL INVERTER INTEGRATED WITH BOOST CONVERTER

For delivering premium electric power in terms of high reliability and power quality, from PV cells, fuel cells etc.an interface is needed to boost up and to convert the low voltage variable DC voltage to a constant amplitude AC . For this a cascaded converter-inverter topology is used. A boost converter is introduced as the front end stage. As the name implies, output voltage of this converter is always greater than the input voltage. This dc-dc conversion helps to stabilize the output voltage. Second stage is a single phase seven level inverter using coupled inductors.

In single phase five level inverter, there are redundant switching states. The redundancy is because the coupled inductors are having equal no of turns. If the turn's ratio is changed to 1:2, we can increase the number of levels. Thus the modified seven level have the same power circuit as shown in 1.1, but have coupled inductors with turn's ratio N1:N2 as 1:2.Consider an unbalanced coupled inductor with turn's ratio with turn's ratio N1:N2 as 1:a.The self-inductance and mutual inductance are as follows. Assuming coe□cient of coupling k=1 we can obtain various equations as follows

$$L1 = \frac{N1\emptyset 1}{i1} = \frac{N1\left(\frac{N1i1}{R}\right)}{i1} = \frac{N_1^2}{R} = L \qquad -(5)$$

$$L2 = \frac{N2\emptyset 2}{i2} = \frac{N2\left(\frac{N2i2}{R}\right)}{i2} = \frac{N_2^2}{R} = a2L \qquad -(6)$$

$$M = k\sqrt{L1L2} = aL \qquad -(7)$$

$$Vbn = Vb - Vn = L\frac{dib}{dt} - aL\frac{dic}{dt} \quad -(8)$$

$$Vcn = Vc - Vn = a2L\frac{dic}{dt} - aL\frac{dib}{dt} \qquad -(9)$$

Solving equation (8) and (9),

$$Vn = \frac{aVb + Vc}{1 + a} - (10)$$

If a=2 then,

$$Vn = \frac{2Vb + Vc}{3} \qquad -(11)$$

Now voltage across the load becomes

$$Vload = Van - \frac{2Vbn + Vcn}{3} \qquad -(12)$$

The switching states of the five level inverter can be summarized by the table 1.2

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S1	S2	S3	S4	S5	S6	V_{ab}
1	0	0	1	0	1	+E
1	0	0	1	1	0	+2E/3
1	0	1	0	0	1	+E/3
1	0	1	0	1	0	0
0	1	0	1	0	1	0
0	1	0	1	1	0	-E/3
0	1	1	0	0	1	-2E/3
0	1	1	0	1	0	-E

Table.1.2 Switching states of the five level inverter

V. RESULT AND DISCUSSION

The simulation diagram of single phase five levelinverter is shown in figure 1.2.The input given to the inverter is 50V. The switches in a leg are switched in a complementary fashion

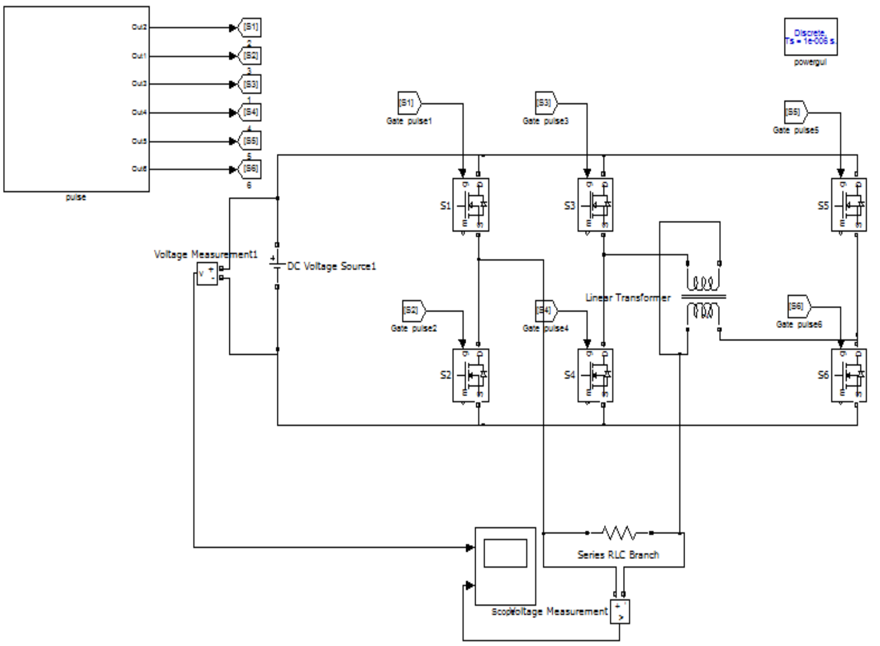

Fig.1.2 MATLAB/Simulink model of single phase five level inverter

Figure 1.3 gives the input- output voltage waveforms of the single phase five level inverter.

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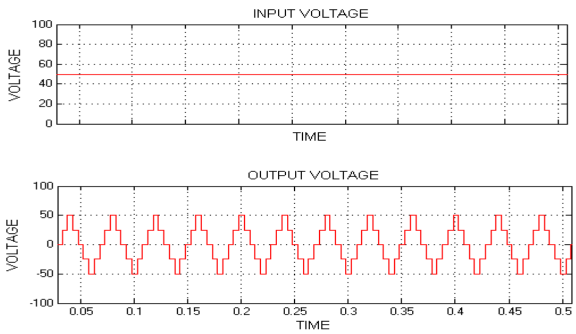

Fig. 1.3Input-Output Voltage waveforms of single phase five level inverter

The simulation diagram of modified seven level inverter integrated with boost converter is shown in figure 1.4. Output of the boost converter is 50 V even if the input is varied from 12 to 24 V. The control strategy of boost converter is implemented by using a PI controller. The PI controllers used here have a proportional gain of 0.01 and an integral gain of 120.Simulation is done with 12 V and 24V dc input.

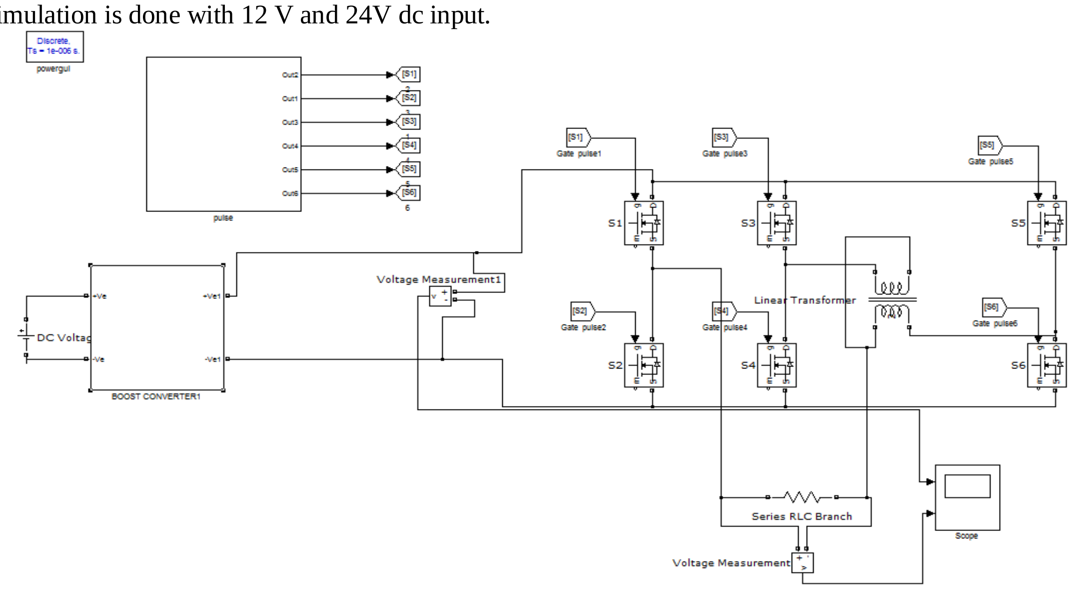

Fig. 1.4 MATLAB/Simulink model of modified seven level inverter integrated with boost converter

Figure 1.5 gives the input-output voltage waveforms of boost converter and inverter for 12 dc input. Output is 50V AC.

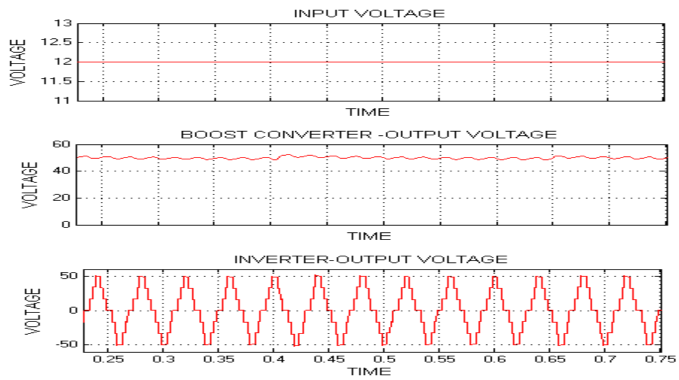

Fig.1.5Input-output voltage waveforms for 12V input

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Figure 1.6gives the input-output voltage waveforms of boost converter and inverter for 24dc input. Output is 50V AC

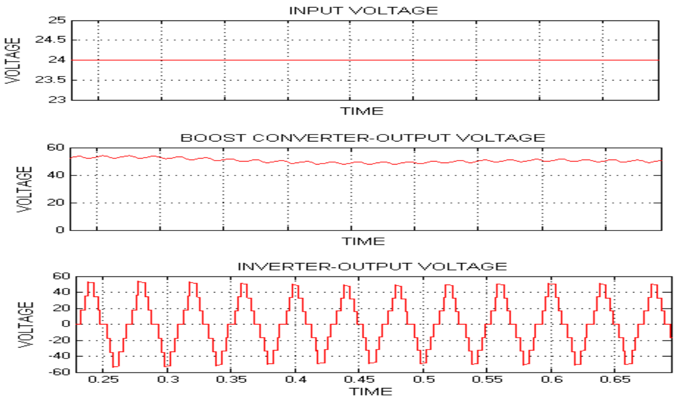

Fig.1.6Input-output voltage waveforms for 24V input

That is, in both cases of input voltage, output is a regulated 50 V AC.

VI.CONCLUSION

Simulated and fabricated a circuit for the regulated seven level inverter. The input to this circuit is a low voltage DC and a boosted, regulated AC is the output. This circuit can be used for converting the low voltages from PV panels or from fuel cells to a boosted AC voltage, capable of using in micro grid system. This inverter can give a seven level AC output from a single source and no split capacitors are required. Proposed topology completely eliminates the voltage balancing problem in conventional inverters. The importance of this innovation lies within using minimum number of elements and PE switches, while increasing number of voltage levels.

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