DESIGN AND ANALYSIS OF HIGH GAIN CHOPPER WITH DIFFERENT LEVELS OF INVERTER

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Abstract

This voltage multiplier increases the converter voltage to a significant level by a PWM switching technique. The duty cycle in the PWM controller controls the step-up converter operation and maintains the required output level. An inverter inverts the boost converter DC output to AC power and fed to the induction motor (IM). The operation of the IM is mainly based on the suitable choice of converter-inverter system. Inverter operation is controlled by a PWM switching technique. This paper mainly deals with the photovoltaic (PV) integration of Voltage Doubler converter and an inverter (DC-AC) fed IM drive for water pumping applications. Solar energy from the renewable resource is the primary source for this paper because of its availability. The electrical equivalent of available solar power is 77000 TW, and PV technology is adapting to convert solar energy into electrical. In renewable energy applications, a new high step-up converter is using to boost up the input variable low-voltage. Converter doubles the input voltage by using a voltage multiplier circuit. The proposed model is designed in MATLAB and the output waveforms are plotted.

Keywords: High step-up converter; Induction motor; PV cell; Renewable energy sources; Voltage multiplier module.

I. Introduction

The Voltage Doubler circuit mainly uses the principle of the Boost converter in closed-loop since it yields better efficiency for the considered system. During the DC-AC conversion process, multi-level inverters [I,II,VIII] will reduce the harmonics. Nowadays, from medium level to high power level implementations the multilevel inverters [III,IV,V,VI,VII,IX,X,XI] are the best choice to reduce harmonics in the system by increasing the inverter levels. Presently, Photovoltaic (PV) system of solar energy is one of the alternative resources to provide the electrical energy to the system. The major disadvantage of the PV system is its installation cost. To improve the efficiency of the system and to reduce the installation cost, a PE interface is required. This paper mainly deals with the effective operation of the high step-up converter fed IM using different levels of inverter operation. In this modern developing world the demand for power is increasing every year by 2%. The demands have to compensate, by moving towards a renewable form of power generation. Grid integration is necessary for all stand-alone operations as the sustainable energy resources are not producing continuous power to the load due to nature. Direct current generator sources are numerous available and they produce power at different frequencies and at

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different voltage levels. In a wind turbine, solar and fuel cells are found some disparity. So, for needs of standard value, some necessary power and frequency conversions are required and they should be compatible with commercial and domestic power supply. A power conditioner is required to fulfill this power conversion.

II. Voltage Doubler with converter technology

The voltage multiplier circuit with Boost converter topology is shown in Fig. 1. The voltage multiplier is also called as voltage doubler circuit or voltage coupled inductor.

This voltage multiplier is using in boost converter circuit as it can yield high voltage gain. By using soft-switching technique, we can decrease the stress in the switches and also diminish the switching losses. So the output voltage gain of the system also increases. A voltage multiplier with a coupled inductor increases the overall gain of the system. To compensate the losses in the inductor the soft-switching techniques are used and these techniques also improves the voltage gain of the converter and decreases the converter losses.

III. Implemented Converter Technology

The implemented converter topology explains the photovoltaic (PV) integrated high step-up converter with cascade H-bridge multilevel inverters for three-level, five-level, seven-level, nine-level, and eleven-level topologies for single phase IM drive for water pumping applications. In present days the key sources are the renewable energy sources for PV integrated step-up converter, with multilevel inverters to improve the number of levels to get the inverter voltage impure sinusoidal form and increases the given input voltage by step up converter. The converter output gain improves by voltage doubler circuit. The step-up converter voltage is given as input to the single-phase 3-level cascade H-bridge multilevel inverter to converter the source voltage from DC-AC for single phase IM drive applications. The major advantage of the cascaded H-bridge multilevel inverter consists of less number of components, the size of the circuit is small, and PWM control technique is applied. The output voltage level of the 3-level inverter switching sequence is shown in Table 1.
Table 1: Three-level cascade H-bridge multilevel inverter switching sequence operation

| Output voltage levels | Switching sequence operation |
|-----------------------|------------------------------|
|                      | $T_a$ | $T_b$ | $T_c$ | $T_d$ |
| $V_{dc}$              | 1     | 1     | 0     | 0     |
| 0                     | 1     | 0     | 1     | 0     |
| $-V_{dc}$             | 0     | 0     | 1     | 1     |

The PV integrated high-step-up DC-DC converter with 5-level cascade H-bridge multilevel inverter fed IM is obtained by connecting two inverters in series. The step-up converter voltage is given to the 5-level inverter. The 5-level multi-level inverter consists of two input voltage sources which are fed by the independent voltage sources. The voltage in the 5-level inverter is the sum of the individual voltages of the voltage sources. The 5-level inverter total voltage value is given by equation (1)

$$V = \frac{V_{dc}}{2} + \frac{V_{dc}}{2}$$

Table 2: Switching operation of 5-level H-bridge multilevel inverter

| Output voltage levels | Switching sequence operation |
|-----------------------|------------------------------|
|                       | $T_a$ | $T_b$ | $T_c$ | $T_d$ | $T_a'$ | $T_b'$ | $T_c'$ | $T_d'$ |
| $\frac{V_{dc}}{2}$    | 1     | 1     | 0     | 0     | 0      | 0      | 0      | 0      |
| $V_{dc}$              | 1     | 1     | 0     | 0     | 1      | 1      | 0      | 0      |
| 0                     | 1     | 0     | 1     | 0     | 1      | 0      | 1      | 0      |
| $-\frac{V_{dc}}{2}$   | 0     | 0     | 1     | 1     | 0      | 0      | 1      | 1      |
| $-V_{dc}$             | 0     | 0     | 1     | 1     | 0      | 0      | 0      | 0      |

The first inverter voltage is represented by $\frac{V_{dc}}{2}$ and another multilevel inverter voltage value is also represented by $\frac{V_{dc}}{2}$. The output voltage level sequence of the 5-level inverter consists of five output voltage levels such as $\frac{V_{dc}}{2}$, $V$, 0, $-V$, $-\frac{V_{dc}}{2}$ and the switching sequence operation is given in Table 2.

To obtain 7-level H-bridge multilevel inverter, connect three multilevel inverters in series. Three different voltage levels are operated at three different voltage sources. The 7-level inverter overall voltage is represented by the equation (2).

$$V = \frac{V_{dc}}{3} + \frac{V_{dc}}{3} + \frac{V_{dc}}{3}$$

(2)
Table 3: The operating sequence of the 7-level inverter.

| Output Voltage Levels | Switching Sequence Operation |
|-----------------------|-----------------------------|
| \(\frac{2V_{dc}}{3}\)  | \(T_a\) 1 \(T_b\) 1 \(T_c\) 0 \(T_d\) 0 \(T_a'\) 1 \(T_b'\) 0 \(T_c'\) 1 \(T_d'\) 0 \(T_b''\) 1 \(T_c''\) 0 \(T_d''\) 1 |
| \(\frac{V_{dc}}{3}\)    | \(T_a\) 1 \(T_b\) 1 \(T_c\) 0 \(T_d\) 0 \(T_a'\) 1 \(T_b'\) 0 \(T_c'\) 1 \(T_d'\) 0 \(T_b''\) 1 \(T_c''\) 0 \(T_d''\) 0 |
| \(-\frac{V_{dc}}{3}\)   | \(T_a\) 1 \(T_b\) 1 \(T_c\) 0 \(T_d\) 0 \(T_a'\) 1 \(T_b'\) 0 \(T_c'\) 1 \(T_d'\) 0 \(T_b''\) 1 \(T_c''\) 0 \(T_d''\) 0 |
| \(-\frac{2V_{dc}}{3}\)  | \(T_a\) 0 \(T_b\) 0 \(T_c\) 1 \(T_d\) 0 \(T_a'\) 1 \(T_b'\) 0 \(T_c'\) 1 \(T_d'\) 0 \(T_b''\) 1 \(T_c''\) 0 \(T_d''\) 1 |
| \(-V_{dc}\)            | \(T_a\) 0 \(T_b\) 0 \(T_c\) 1 \(T_d\) 0 \(T_a'\) 1 \(T_b'\) 0 \(T_c'\) 1 \(T_d'\) 0 \(T_b''\) 1 \(T_c''\) 0 \(T_d''\) 1 |

The three different voltage sources of the inverter are represented by \(\frac{V_{dc}}{2}\). The voltage level of the 7-level inverter consists of seven output voltage levels those seven levels are denoted by \(V_{dc}, \frac{2V_{dc}}{3}, \frac{V_{dc}}{3}, 0, -\frac{V_{dc}}{3}, -\frac{2V_{dc}}{3}, -V_{dc}\) and the switching sequence operation of 7-level inverter is given in Table 3.

The 9-level inverter is obtained by connecting four inverters in cascade. The overall voltage of the 9-level inverter is the sum of all the individual voltage levels. The output voltage value of the 9-level inverter is given by equation (3)

\[
V = \frac{V_{dc}}{3} + \frac{V_{dc}}{3} + \frac{V_{dc}}{3}
\]

When comparing the 3-level and 11-level inverters the THD is decreased, the harmonics also reduced and the pure sine wave is obtained. Five inverters are connected in cascade to obtain the 11-level inverter.

IV. Results and Discussion

The PV panel output voltage is shown in Fig. 1. The output value of the PV panel voltage is 48V. This voltage is given as input to the converter.
The converter output voltage with the coupled inductor is shown in Fig. 3. The converter voltage value is 230V. Fig. 4 shows the simulation waveform of the inductor primary voltage $V_{N_1}$. The value of the primary voltage multiplier is 48V.

![Converter output voltage waveform](image)

**Fig. 3** Converter output voltage waveform

![Voltage multiplier primary voltage $V_{N_1}(V)$](image)

**Fig. 4** Voltage multiplier primary voltage $V_{N_1}(V)$

The output waveform of the secondary side voltage multiplier is shown in Fig. 5. The inductor voltage value is 144V.

![Output voltage value of the secondary side voltage multiplier $V_{N_2}$](image)

**Fig. 5** Output voltage value of the secondary side voltage multiplier $V_{N_2}$. 

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Fig. 6 Output voltage value of the 3-level inverter

The output voltage waveform of the 3-level inverter is shown in Fig. 6. The voltage value of the 3-level converter is 230V.

Fig. 7 Output current of the 3-level inverter

The current waveform of the 3-level inverter is shown in Fig. 7 and the IM speed, torque and current waveforms are shown in Fig. 8. The THD plot of the 3-level inverter is shown in Fig. 9. The output THD value for the 3-level inverter is 52.37%.
Fig. 8 Output waveforms of speed, torque, and current.

Fig. 9 Three-level inverter THD

The output voltage and current waveforms of the 5-level inverter are shown in Fig. 10 and Fig. 11 respectively. The output voltage value of the inverter is 230V.
Fig. 10 Output voltage of the 5-level inverter.

Fig. 11 Output current of the 5-level inverter

Fig. 12 Output waveforms of speed, torque, and current.
Fig. 13 THD plot 5-level H inverter source current

The IM speed, torque, and current waveforms are shown in Fig. 12 for five-level inverter. The THD plot of the 5-level inverter is shown in Fig. 13. The THD value of 5-level inverter is 26.4%. When compared to the 3-level inverter, %THD value reduces in 5-level inverter.

Fig. 14 Seven-level inverter output voltage

The voltage and current output waveforms of the 7-level inverter are shown in Fig. 14 and Fig. 15 respectively. The voltage value of inverter is 230V.
Fig. 15 Seven-level inverter output current

Fig. 16 Output waveforms of speed, torque, and current.

Fig. 17 THD plot of 7-level H-bridge multilevel inverter
The waveforms of the IM speed, torque and current are shown in Fig.16 and the %THD plot for 7-level H-bridge multilevel inverter is shown in Fig.17. The THD value of the 7-level inverter is 16.99%. The 7-level H-bridge inverter %THD value is decreased when compared to the %THD value of 3-level, 5-level H-bridge inverters.

Fig.18 Nine-level Inverter output voltage

Fig.19 Output waveforms of speed, torque, and current at different loading conditions

Fig.20 Source current THD plot for 9-level inverter
Fig. 21. Output voltage waveform for 11-level inverter.

Fig. 22. Output waveform for Speed, Torque and Current at different loading conditions.

Fig. 23. Eleven-level inverter source current THD plot.
Fig. 24: Graphical representation of source current THD at different levels.

Fig. 25: Graphical representation of %torque ripple at different loading condition with different levels.

Fig. 26: Representation of speed at different loading conditions with different multilevel inverters.
Table 4: The %THD comparison of different multilevel inverters

| S.no | Type of inverter | %THD  |
|------|------------------|--------|
| 1    | 3-level          | 52.37  |
| 2    | 5-level          | 26.47  |
| 3    | 7-level          | 16.99  |
| 4    | 9-level          | 12.2   |
| 5    | 11-level         | 11.9   |

Table 5: %THD comparison of different multilevel inverters (3, 5, 7, 9 and 11-level inverters) and torque ripples at different loading conditions

| Type Of Inverter | % current THD | 25% | 50% | 75% |
|------------------|---------------|-----|-----|-----|
| 3-level          | 52.37         | 85% | 72% | 60% |
| 5-level          | 26.47         | 43.3% | 30% | 6% |
| 7-level          | 16.99         | 30.3% | 18% | 5.3% |
| 9-level          | 12.15         | 18.7% | 11.9% | 4.9% |
| 11-level         | 9.58          | 8% | 6.2% | 2.3% |

Table 6: The %THD comparison of different multilevel inverters fed induction motor speed

| Type Of Inverter | Speed Change at different Loading conditions |
|------------------|---------------------------------------------|
|                  | No Load | 25%  | 50%  | 75%  |
| 3-level          | 1500    | 1460 | 1440 | 1420 |
| 5-level          | 1500    | 1460 | 1440 | 1420 |
| 7-level          | 1500    | 1460 | 1440 | 1420 |
| 9-level          | 1500    | 1460 | 1440 | 1420 |
| 11-level         | 1500    | 1460 | 1440 | 1420 |

V. Results and Discussion

The proposed converter is flexible to use as PV based step-up converter for multilevel inverter fed single phase IM drive applications. In this paper the simulation analysis of the proposed converter with different multilevel inverter topologies are discussed and the output waveforms are plotted. The Simulation analysis of PWM
control based DC-DC converter integrated with 3, 5, 7, 9, and 11-level inverter’s feeding a single-phase IM drive for water pumping applications is also presented. The THD analysis of the different multi-level inverter topologies are shown in simulation results and also shown that the THD is reduced even though the disturbances are increasing.

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