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Improvement of Transformer-less Inverter Output Voltage Using 7-Level Single Phase Inverter and LCL Filter

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Abstract-The system is designed for transformer-less inverter which has harmonic distortion present in their output voltage due to power electronic switching. Total Harmonic Distortion present within the output voltage may be minimized by using 7-level cascaded H-Bridge inverter rather than previous multilevel inverter. An LCL filter with damping resistor is proposed which might be used between the inverter and therefore the load. In the recent days the renewable energy sources has increased rapidly, as these individuals power sources are getting increased throughout the years. Power electronics are getting great at controlling and having a great advantage to process the power. Inverters are one of these power electronic devices used in the process of conversion of DC to AC power. The transformer-less inverter has an excellent efficiency, also not having a transformer the device is compact, have less weight and cheaper. Harmonics is one of the power quality problem and need to eradicate at the proper time to reduce significant power losses thus multilevel inverters are receiving more attention in industrial application and renewable energy system. The DC link capacitor is used to reduce the fluctuation of the DC voltage. These harmonic distortion are generated because of power electronic switching, Using Mat lab /Simulink software the 7-level cascaded H-Bridge multilevel inverter is simulated. This system will help in securing the loads and reducing the loss due to heating caused by unwanted harmonics in the voltage

Keywords – Multilevel Inverter, Harmonics, Switching, Filter, Transformer-less

I. INTRODUCTION

The utilization of renewable energy source has increased rapidly because of its cleanliness and inexhaustible source of Sun rays, PV power system are being significantly developed throughout recent years. As these individual power sources are becoming increased in numbers. Power Electronics are becoming great part at controlling and having an excellent advantage to process the facility from these renewable sources. Inverters are one in all these power electronics devices. PV cells have very low efficiency (around 20%) and the obtained energy shouldn't be wasted. Highly efficient inverters are used in order that less energy is lost within the process of conversion of electricity DC to AC.

There are mainly two kinds of inverters supported having in its construction or working mechanism. Inverters with line frequency transformers are bulky in size and high frequency transformers are complex in operation. They are not efficient enough because it has low power density and high cost. On the other hand transformer-less inverters has an excellent efficiency like above 95%, also not having a transformer the device is compact. The transformer-less inverter are a standard choice for commercial use due to its less weight and cheaper. Nowadays, Multilevel Inverters are receiving more attention in Industrial application and renewable energy system.

The cascaded multilevel inverter is the greatest choice in the field of renewable energy management system to reduce the harmonic distortion which may increase in output voltage and efficiency of the system. The voltage output of single-phase inverter without a filter has a lot of harmonic distortion.

II. RELATED WORKS

A. Power Supply

A power supply is a device that supplies power to an electrical load. The first function of an influence supply is to convert electrical phenomenon from a source to the proper voltage, current, and frequency to power the load. As a result, power supplies are sometimes said as wattage converters. Some power supplies are separate standalone pieces of kit, while others are built into the load appliances that they power. Samples of the latter include power supplies found in desktop computers and consumer electronics devices. Other functions that power supplies may perform include limiting this drawn by the load to safe levels, shutting off this within the event of an electrical fault, power conditioning to stop electronic noise or voltage surges on the input from reaching the load, power-factor correction, and storing energy so it can still power the load within the event of a brief interruption within the source power (uninterruptible power supply).

B. DC Power Supply

An AC-to-DC power supply operates on an AC input voltage and generates a DC output voltage. Depending on application requirements the output voltage may contain large or negligible amounts AC frequency components known as ripple voltage, related to AC input voltage frequency and the power supply's operation. A DC power supply operating on DC input voltage is called a DC-to-DC converter. This section focuses mostly on the AC-to-DC variant.

C. Boost Stage Converter

DC-DC Converter is also known as chopper. Here we have a look at the step up or boost converter which increases the input DC voltage to a specified DC output voltage. A typical boost converter is shown in fig 1.

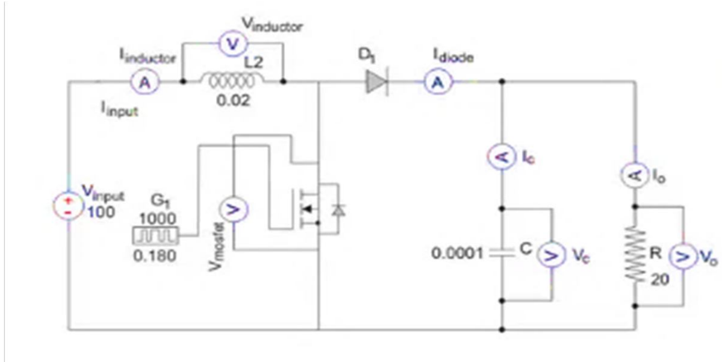

Fig 1. Circuit diagram of boost converter

D. 7-Level Cascaded H-Bridge Multilevel Inverter

In order to meet the requirement from the industries demand aimed at a free-harmonics and high power rating source is remarkably increased in past few years. An inverter which a device or electric circuit that convert direct current to alternating current is one of the electronic devices that give concern to researchers for improvement of generating a neat power source. The inverter can be categorized into a single level and multilevel inverter. As compared to single level inverter, multilevel inverter offers minimum harmonic distortion and higher power output. This paper presents a model of multilevel inverter using 7-level Cascaded H-Bridge of multilevel DC-AC inverter to reduce total harmonic distortion with different sinusoidal pulse width modulation such as phase disposition and phase opposition disposition.

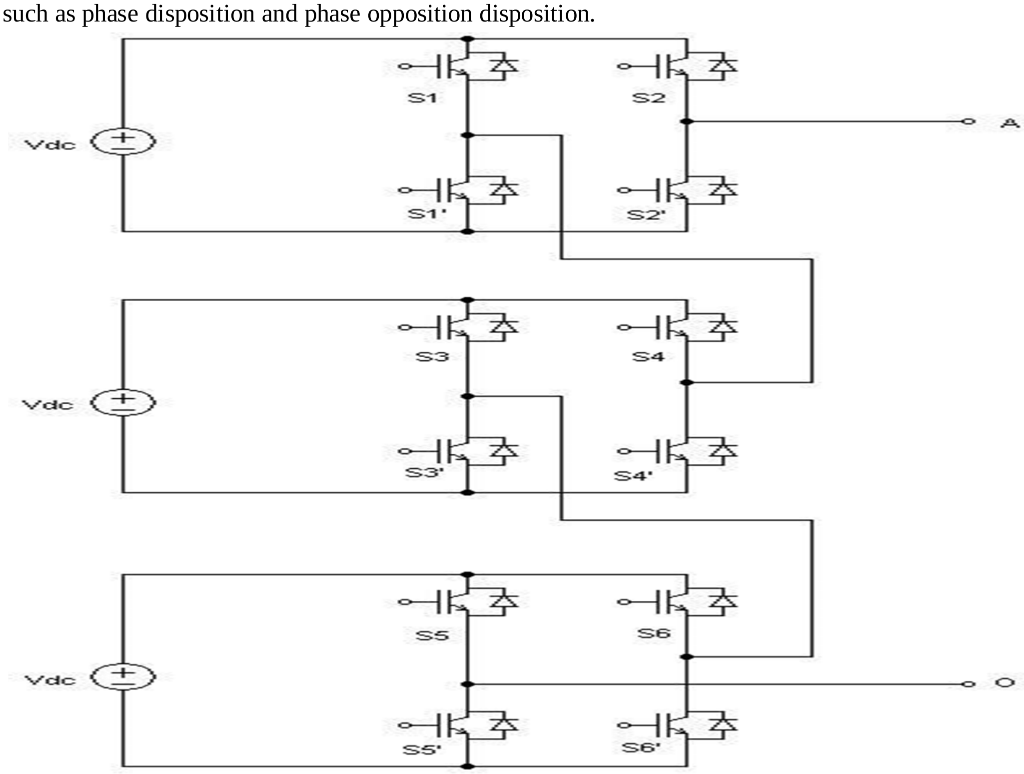

Fig 2 7-Level cascaded H-Bridge multilevel inverter

The usual two or three levels inverter does not significantly eliminate the unnecessary harmonics in the output waveform. Therefore, we are using multilevel inverter instead of traditional Pulse width modulation inverters. In this technique, the number of phase voltage levels at the converter terminals is 2N+1, where N is the dc link voltages or number of cells. In this arrangement, every cell has a separate dc link capacitor and the voltage through the capacitor may vary among the cells. So, every power circuit needs only a single dc voltage source. The quantity of dc link capacitors depends on the number of phase voltage levels .Every cell of H-Bridge can have positive, negative or zero voltage. Voltage at the output is the sum of all voltages of H-bridge cell and with respect to neutral point it is symmetric, so the voltage levels are odd in number. Cascaded H-bridge multilevel inverters usually have IGBT switches. Such switches have low block voltage and high switching frequency.

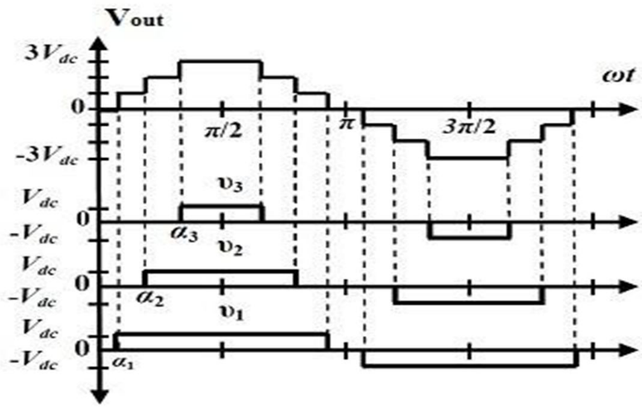

Fig 3 Output waveform of inverter

The output of AC voltage waveform is the summation of all converter outputs. Cascaded multilevel inverter has a peculiar and fascinating topology such as structure simplicity, usage of less components etc. Its main benefit is that it can produce output voltages with very low distortion and very low voltage stresses (dv/dt). It can work with a lower switching frequency. Cascaded Multilevel Inverter has many H-bridge Inverter units. Every bridge will be fed from a different DC source which can be taken from batteries, fuel cells, or solar cells. The work of this multilevel inverter is to obtain a desired voltage from various Dc Sources (SDCSs).The ac terminal voltages of multi-level inverters are connected in series. Each level of inverter can produce voltage outputs in three levels $+V_{dc}$, 0, and $-V_{dc}$ by connecting the dc source to the ac output by four different combinations of switches, S1, S2, S3, and S4. In order to obtain $+V_{dc}$, switches S1 and S4 are turned ON whereas for obtaining $-V_{dc}$, we can turn ON switches S2 and S3. If we turn ON, S1 and S2 or S3 and S4, the output voltage is 0. The ac output of each of every full-bridge inverter level is connected in series so that the voltage waveform generated will be the summation of all the inverter output voltages.

E. LCL Filter

1) *LCL Filter Design for Grid-Connected Inverter System:* In grid-connected inverters for PV applications, filters are essential elements. The filter incorporated in such systems should offer high harmonic attenuation. The simple inductor L filter provides only low harmonic attenuation, and the voltage drop across it is very high. The L filter is also so bulky that it consumes more space, which is a demerit. LCL filters are a good alternative, as they offer all the merits that are not present in the L and LC filters. The LCL filter effectively smooth, the inverter current output, and the filtered harmonic-free current is supplied to the grid. The advantages of LCL filters are high attenuation, improved performance, cost-effectiveness, and less weight and size. The LCL filter offers good harmonic elimination with low values of inductors and capacitors.
2) *LCL Filter Design Consideration:* When designing an LCL filter for grid-connected applications, you need to consider characteristics such as filter size, current ripple, and switching ripple attenuation. The damping is another requirement when the filter is interfacing with the grid. When the inverter system is integrated into the grid, the capacitance may undergo resonance. Active or passive damping is needed to suppress the resonance. The inclusion of a series resistor with the filter capacitor is a kind of damping used in LCL filters.

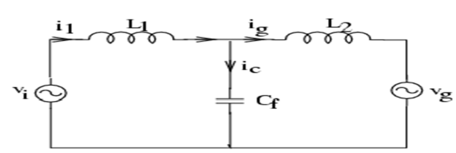

Fig 4 Circuit Diagram of LCL Filter

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LCL filter design starts by taking system parameters such as inverter output voltage, rated active power, grid frequency, switching frequency, and resonance frequency into consideration.

$$L = \frac{Z}{2\pi f c}$$

$$C = \frac{2}{LWc\text{^}2}$$

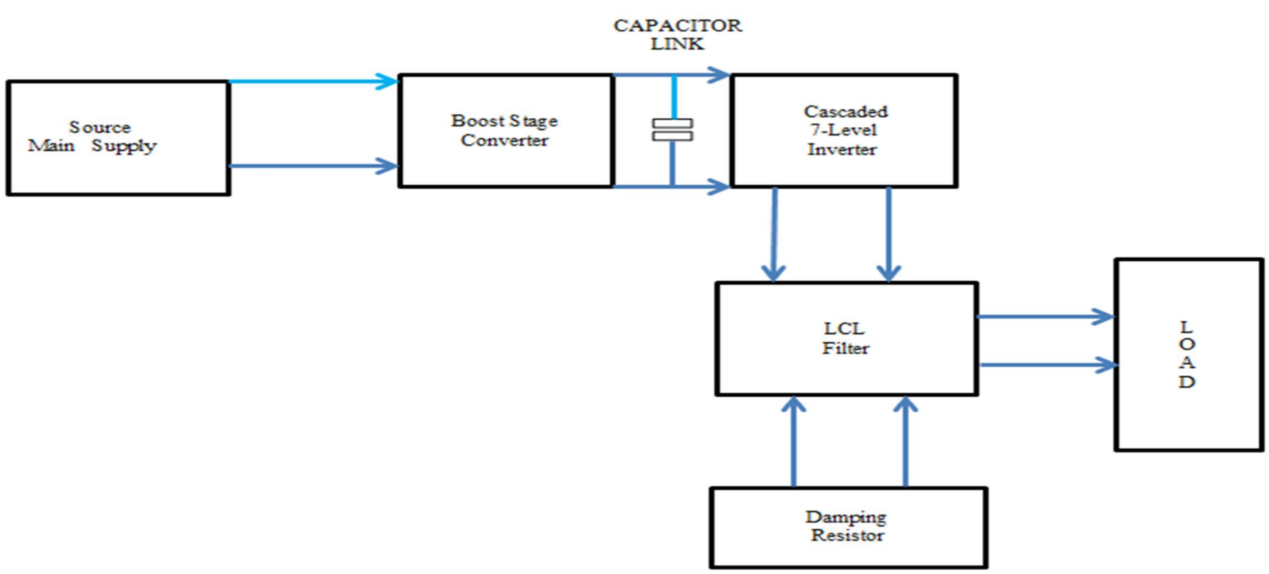
The rest of the procedure in the LCL filter design involves mathematical calculations. The base impedance and base capacitance are calculated. The capacitance C_f is taken as a certain percentage (usually 5%) of base capacitance. The inverter side inductor L_1 value is inversely proportional to the current ripple. By fixing the required current ripple value, the inductor L_1 is designed. The grid side inductor L_2 is determined by providing an attenuation factor.

$$Wc = 2\pi f c$$

With the calculated LCL values, the resonance frequency of the filter should be greater than 10 times the grid frequency, and less than 0.5 times the switching frequency. If this condition is not satisfied, the inductor L_2 is redesigned until it gets satisfied.

3) *Dc Capacitor Link:* In electric vehicle applications, the DC link capacitor is used as a load-balancing energy storage device. The capacitor is placed parallel to the battery, which maintains a solid voltage across the inverter. The device helps protect the inverter network from momentary voltage spikes, surges and EMI. The DC-link capacitor's purpose is to provide a more stable DC voltage, limiting fluctuations as the inverter sporadically demands heavy current. A design can use different technologies for DC-Link capacitors such as aluminum electrolytic, film, and ceramic types.
4) *Damping Resistor:* A resistor that is placed across a parallel resonant circuit or in series with a series resonant circuit to decrease the Q factor and thereby eliminate ringing. Damping resistors are used to avoid negative effects on the grid of power systems. A series resonant circuit at the inlet of the medium voltage feed consisting of a series connection of capacity and inductance act as a loader on the harmonic waves, thus damping them.

III. RESULTS AND DISCUSSION



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A. Comparison Of 5-Level And 7-Level Inverter

Factor	5-Level	7-Level
Output Current	Sinusoidal	Sinusoidal
Filter	L:7mHx2 C:2200µF	L:5mHx2 C:2200µF
Power Factor, pf	0.861 (Lagging)	0.913 (Lagging)
THD	1.876%	1.175%
Efficiency	**67.9%**	**88.5%**

Fig 5 Comparison Table

IV. CONCLUSION

The results of simulations done in MATLAB/SIMULINK software, it has been made clear that the proposed 7-level cascaded H-bridge Inverter and LCL Filter Combination topology has the lowest Total Harmonic Distortion present at the output voltage among all the circuits the proposed inverter has performed best in reducing the THD present at the output voltage. This circuit will help in securing the loads and reducing the loss due to heating caused by unwanted harmonics in the voltage. Thus the output voltage of the inverter has been improved more than the previous inverter.

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