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A Multi Level Inverter for Reducing Switching Power Loss When Deployed in Solar Power Generation System

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Abstract:

The Demand for renewable energy has increased significantly over the years because of shortage of fossil fuels and greenhouse effect. Among various types of renewable energy sources, solar energy has become very popular and demanding due to advancement in power electronics techniques. In this paper, a multilevel inverter is developed and applied for injecting the real power of the renewable power intothe grid to reduce the switching power loss, harmonic distortion, and electromagnetic interference caused by the switching operation of power electronic devices. Here a dual buck configuration with full bridge inverter is used for the MLI implementation. The input of the dual-buck converter is dc capacitor voltage sources. The output voltage of the dual-buck converter supplies to the full-bridge inverter. The power electronic switches of the full-bridge inverter are switched in low frequency synchronous with the utility voltage to convert the output voltage of the dual-buck converter to a multilevel ac voltage. The output current of the multi-level inverter is controlled to generate a sinusoidal current in phase with the utility voltage to inject into the grid. Five level and nine level topologies are developed to verify the performance of the developed renewable power generation system. The simulation results show that the developed renewable power generation system reaches the expected performance with the help of proposed topology.

Keyword:

Five level inverter, Solar energy, Switching power loss, Power electronics, dual-buck converter.

Introduction:

Human activity is overloading our atmosphere with carbon dioxide and other global warming emissions, which trap heat, steadily drive up the planet's temperature, and create significant and harmful impacts on our health, our environment, and our climate.Increasing the supply of renewable energy would allow us to replace carbon-intensive energy sources and significantly reduce global warming emissions. Generating electricity from renewable energy rather than fossil fuels offers significant public health benefits. The air and water pollution emitted by coal and natural gas plants is linked to breathing problems, neurological damage, heart attacks, and cancer. Replacing fossil fuels with renewable energy has been found to reduce premature mortality and lost workdays, and it reduces overall healthcare costs.Solar power generation has emerged as one of the most rapidly growing renewable sources of electricity. Solar power generation has several advantages over other forms of electricity generation:

- Solar energy production does not require fossil fuels and is therefore less dependent on this limited and expensive natural resource.

- Solar energy can effectively supplement electricity supply from an electricity transmission grid, such as when electricity demand peaks in the summer.

- Solar power production facilities can be installed at the customer site which reduces required investments in production and transportation infrastructure.

PV inverter, which is the heart of a PV system, is used to convert dc power obtained from PV modules into ac power to be fed into the grid. 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 (EMI) generated by switching operation of the inverter. In recent years, multilevel inverters have become more attractive for researchers and manufacturers due to their advantages over conventional three level PWM Inverters. They offer improved output waveforms, smaller filter size and lower EMI, lower Total Harmonic Distortion (THD). The three common topologies for multilevel inverters are as follows:

1) Diode clamped (neutral clamped),
2) Capacitor clamped (flying capacitors),
3) Cascaded H-bridge inverter.

In addition, several modulation and control strategies have been developed or adopted for multilevel inverters, including the following multilevel sinusoidal (PWM), multilevel selective harmonic elimination, & Space Vector modulation.

A typical single phase three-level inverter adopts full-bridge configuration by using approximate sinusoidal modulation technique as the power circuits. The output voltage then has the following three values: zero, positive (+Vdc), and negative(-V dc) supply dc voltage (assuming that Vdc is the supply voltage). The harmonic components of the output voltage are determined by the carrier frequency and switching functions. Therefore, their Harmonic reduction is limited to a certain degree.

To overcome this limitation, this paper presents a five-level PWM inverter whose output voltage can be represented in the following five levels: zero,+1/2Vdc, Vdc, , -1/2V dc , and -V dc . As the number of output levels increases, the harmonic content can be reduced. This inverter topology uses two reference signals, instead of one reference signal, to generate PWM signals for the switches. Both the reference signals V ref1 and Vref2 are identical to each other, except for an offset value equivalent to the amplitude of the carrier signal Vcarrier, as shown in Figure below.

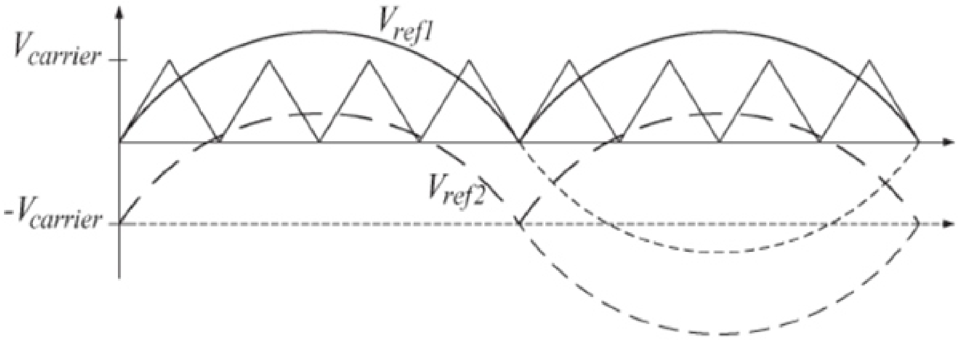

Fig: Carrier and reference signals

Because the inverter is used in a PV system, a Fuzzy control scheme is employed to keep the output current sinusoidal and to have high dynamic performance under rapidly changing atmospheric conditions and to maintain the power factor at near unity. Simulation results are presented to validate the proposed inverter configuration.

Five Level Inverter Topology:

The proposed single phase five level inverter topology is shown in Fig.2. The inverter adopts a full-bridge configuration with an auxiliary circuit. PV arrays are connected to the inverter via a dc–dc Boost converter.

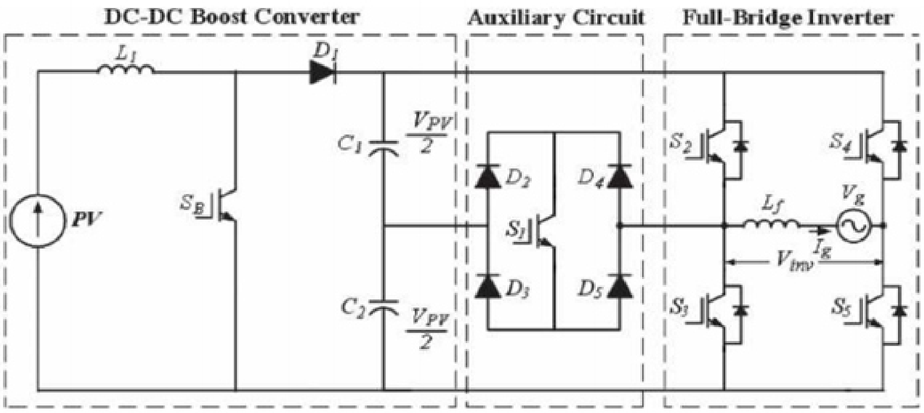

Fig: Single Phase Five Level Inverter Topology

Because the proposed inverter is used in a grid-connected PV system, utility grid is used instead of load. The dc–dc boost converter is to be used to step up inverter output voltage Vin to be more than 2 of grid voltage Vg to ensure power flow from the PV arrays into the grid. A filtering inductance Lf is used to filter the current injected into the grid. The injected current must be sinusoidal with low harmonic distortion. In order to generate sinusoidal current, sinusoidal PWM is used because it is one of the most effective methods. Sinusoidal PWM is obtained by comparing a high frequency carrier with a low frequency sinusoid, which is the modulating or reference signal. The carrier has a constant period; therefore, the switches have constant switching frequency. The switching instant is determined from the crossing of the carrier and the modulating signal.

Operational Principle Of The Proposed Inverter : Because PV arrays are used as input voltage sources, the voltage produced by the arrays is known as Varrays. Varrays boosted by a dc–dc boost Converter to exceed 2Vg.The voltage across the dc-bus capacitors is known as V pv. The operational principle of the proposed inverter is to generate five level output voltage, i.e., 0, +Vpv/2, +Vpv , -Vpv /2, and -Vpv . Proper switching control of the auxiliary circuit can generate half level of PV. Supply voltage, i.e., +Vpv/2, +V pv, -Vpv /2.

Two reference signals V ref1 and V ref2 will take turns to be compared with the carrier signal at a time. If V ref1 exceeds the peak amplitude of the carrier signal Vcarrier, V ref2 will be compared with the carrier signal until it reaches zero.

At this point onward, V ref1 takes over the comparison process until it exceeds Vcarrier. This will lead to aswitching pattern, as shown in Fig. below. Switches S1–S3 will be switching at the rate of the carrier signal frequency, whereas S4 and S5 will operate at a frequency equivalent to the fundamental frequency. Table I illustrates the level of Vinv during S1–S5 switch on and off.

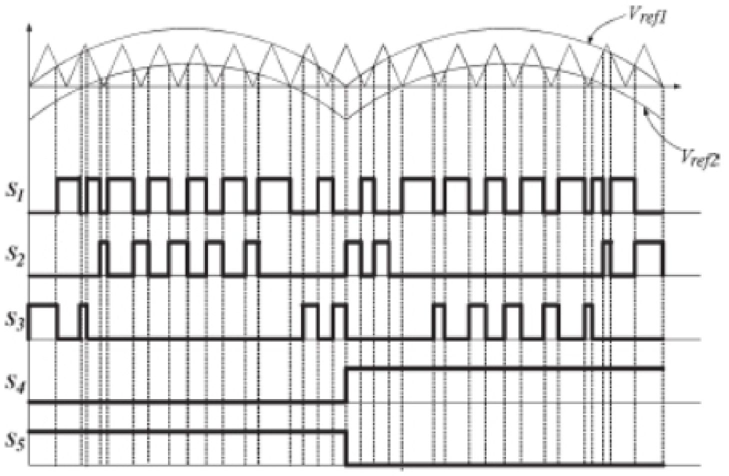

Fig: switching pattern for the single-phase five-level inverter

Control System Algorithm And Implementation:

The feedback controller used in this application utilizes the PID algorithm. As shown in Fig., the current injected into the grid, also known as grid current Ig, is sensed and fed back to a comparator which compares it with the reference current Iref . Iref is obtained by sensing the grid voltage and converting it to reference current and multiplying it with constant m. This is to ensure that Ig is in phase with grid voltage Vg and always at near-unity power factor. One of the problems in the PV generation systems is the amount of the electric power generated by solar arrays always changing with weather conditions, i.e., the intensity of the solar radiation.

A maximum power point tracking (MPPT) method or algorithm, which has quick-response characteristics and is able to make good use of the electric power generated in any weather, is needed to solve the aforementioned problem. Constant m is derived from the MPPT algorithm. The perturb and observe algorithm is used to extract maximum power from PV arrays and deliver it to the inverter.

The instantaneous current error is fed to a PID controller. The integral term in the PID controller improves the tracking by reducing the instantaneous error between the reference and the actual current. The resulting error signal u which formsVref1 and Vref2 is compared with a triangular carrier signal and intersections are sought to produce PWM signals for the inverter switches.

Inverter Output Voltage during S1-S5 Switch ON and OFF

S1	S2	S3	S4	S5	Vinv
ON	OFF	OFF	OFF	ON	+Vpv/2
OFF	ON	OFF	OFF	ON	+Vpv
OFF	OFF	OFF	ON	ON	0
ON	OFF	OFF	ON	OFF	-Vpv/2
OFF	OFF	ON	ON	OFF	Vpv

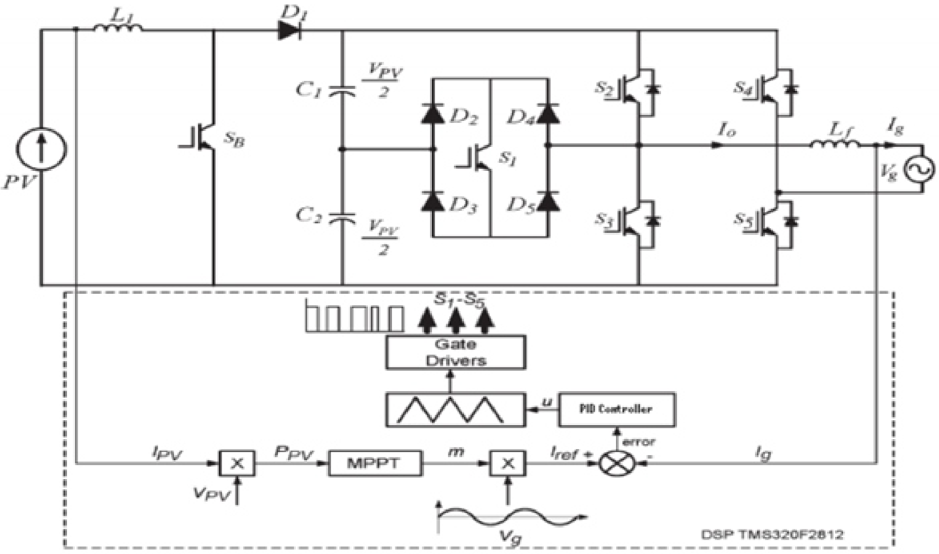

Fig: Five level inverter with control algorithm

Simulation Results:

In order to verify that the proposed inverter can be practically implemented in a PV system, simulations were performed by using MATLAB SIMULINK. It also helps to confirm the PWM switching strategy which then can be implemented. It consists of two reference signals and a triangular carrier signal. Both the reference signals are compared with the triangular carrier signal to produce PWM switching signals for switches S1–S5. Note that one leg of the inverter is operating at a high switching rate equivalent to the frequency of the carrier signal, whereas the other leg is operating at the rate of fundamental frequency (i.e., 50 Hz). The switch at the auxiliary circuit S1 also operates at the rate of the carrier signal. As mentioned earlier, the modulation index M will determine the shape of the inverter output voltage Vinv and the grid current Ig. Fig.7 shows Vinv and Ig for different values of M.

Conclusion:

Fossil fuel deposits are scattered and finite. Fossil fuels must be burned to produce electricity. Burning them creates unwanted byproducts that can create air and water pollution and release huge amounts of greenhouse gasses into the atmosphere. When in use, solar panels produce power without waste or emissions, and do so through a natural process called photovoltaics.5 level inverter sourced by a PV panel was simulatedand necessary waveforms were obtained.The circuit topology, modulation law, and operational principle of the proposed inverter were analyzed in detail. The switching losses will be less when compared to conventional topologies since less number of power electronic switches are used .Thus as a whole the newly developed 5 level inverter is found to have good performance under grid connected application.

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