A MULTISOURCE FIVE LEVEL INVERTER FOR GRID CONNECTED SYSTEMS

WITH AN IMPROVED PWM SCHEME USING PI CONTROLLER

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Abstract- **This paper presents a single-phase multisource five-level inveter topology for grid-connected systems with an improved pulse width-modulated (PWM) scheme. A PV panel, an AC source and a DC source are cascaded together in parallel configuration and connected to a five level inverter to produce an output voltage in five levels. Two reference signals that were identical to each other with an offset were used to generate PWM signals for the switches. Digital Proportional-Integral Current Control Algorithm is used to implement this PWM switching scheme.**

Keywords- Grid-connected, multilevel inverter, photovoltaic (PV), pulsewidth-modulated (PWM), inverter, proportional-integral (PI) current control.

I. INTRODUCTION

Renewable Energy Sources, particularly solar and wind energy, have become very popular and demanding as the world is concerned with fossil-fuel exhaustion and environmental problems caused by conventional power generation. PV sources have the advantage of being maintenance and pollution free. Due to decreasing costs and prices, Solar-electric-energy demand has grown consistency by 20%-25% per annum over the past 20 years. This decline has been driven by mainly three factors: 1) an increasing efficiency of solar cells; 2) improvements in manufacturing-technology; 3) economics of scale. An inverter, which is an important element in the system, is used to convert dc power from the sources into ac power to be fed into grid.

This paper presents a multisource five-level inverter. In this, a PV panel, an AC source and a DC source are interfaced with their own dc-dc converter to a common dc-ac inverter. This is beneficial compared with the centralized system, because every source can be controlled individually. Further enlargements are easily achieved because a new source with a dc-dc converter can be added into the existing system. A High efficiency is thereby achieved with a flexible design. A five level inverter have great advantages such as improved output waveforms, smaller filter size and lower electromagnetic interference.

In this paper, a single phase multisource five level inverter is presented. It consists of a PV panel, an AC source and a DC source connected to their own dc-dc boost converter. A modified PWM control scheme is presented to generate PWM switching signals for the switches and to produce five output-voltage levels. In this, two reference signals are used instead of one to generate PWM signals for the switches. V_{ref1} and V_{ref2} are the two reference signals and are identical to each other.

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.2, Pages : 112-117 (2013)
Special Issue of NCRTECE 2013 - Held during 8-9 February, 2013 in SMK Fomra Institute of Technology, OMR, Thaiyur, Kelambakkam, Chennai
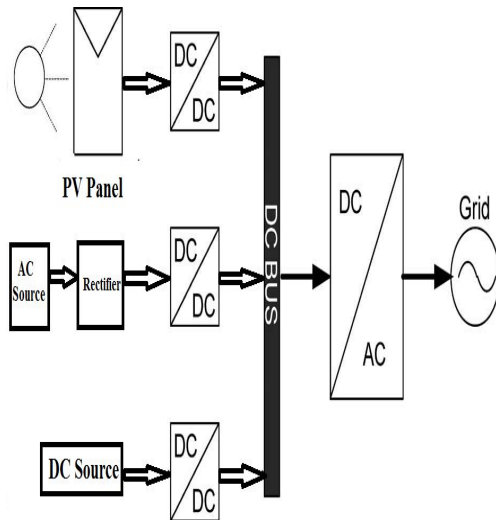
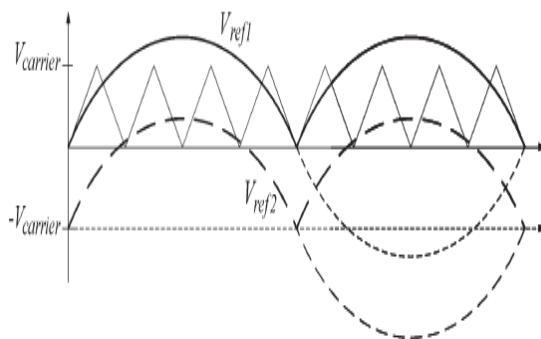Fig.1. Configuration of multisource inverters.

Fig.2. Carrier and reference signals.

A Proportional-Integral Current Control Scheme is employed since the inverter is used in PV system in order to keep the output current sinusoidal and to have high dynamic performance under Simulation and experimental results are presented to validate the proposed configuration.

II. MULTISOURCE FIVE-LEVEL INVERTER TOPOLOGY

The single phase multisource five-level inverter topology is shown in fig. 3. It consists of a PV panel, an AC source and a DC source connected to a common
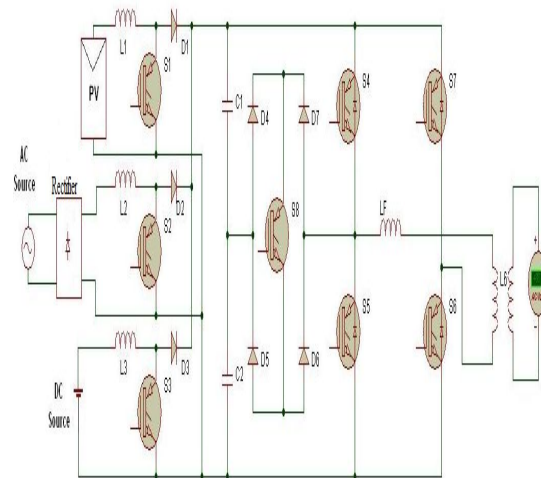

Fig.3. Single-phase multisource five-level inverter topology.

dc bus, an auxiliary circuit and a full bridge inverter configuration. Input sources, PV panel, AC source and DC source are connected to the inverter via the dc-dc boost converters. The utility grid is used instead of a load since the inverter is used in a grid-connected system. To track the Maximum Power Point [MPP] independently and to step up inverter output voltage, the dc-dc boost converters are used. A Step-up transformer with a ratio of 1:2 is used.

DC-DC converter can perform MPP tracking [MPPT] for the PV panel. An advantage of using Multisource approach in parallel configuration is that the mixing of different sources becomes possible, i.e., existing PV sources can be extended by adding new higher output sources without comprising the overall system reliability or performance. It also have the advantage of greater safety during installation and maintenance. Each converter module may be able to isolate its connected power source so that wiring of series or parallel connection of these sources can be performed safely depending on the design. A safe low voltage connection is used for power-source-converter connection.

To avoid high dc-dc voltage, the dc-dc boost converters are connected in parallel which will eventually increase the size of capacitors and the inverter's cost. Therefore, as the dc bus, only two capacitors with equal capacitance rating are used and the other dc-dc boost converters are connected to this dc bus as shown in fig. 3.

To filter the current injected into the grid, a filtering inductance is used. The current injected into the grid must be sinusoidal with low harmonic distortion. In order to generate sinusoidal current, a sinusoidal PWM is used because it is one of the most effective methods. A sinusoidal PWM is obtained by comparing a high frequency carrier signal with a low-frequency sinusoid signal, 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.

Fig.1 Inverter Output Voltage (V_{inv}) and switching pattern for the single-phase five-level inverter.

III. OPERATING PRINCIPLES OF MULTISOURCE FIVE-LEVEL INVERTER

Combinations of PV panel, AC source and DC source are used as the input voltage sources. Voltages across the input sources are boosted by dc-dc converters to exceed grid voltage. The proposed inverter produces five output voltage levels. An auxiliary circuit is used which consists of four diodes and a switch connected between the dc-bus capacitors and the full bridge inverter. A five level of input supply voltage is generated by the proper switching control of the auxiliary circuit.

V_{ref1} and V_{ref2} are the two reference signals which will take turns to be compared with the carrier signal at a time.
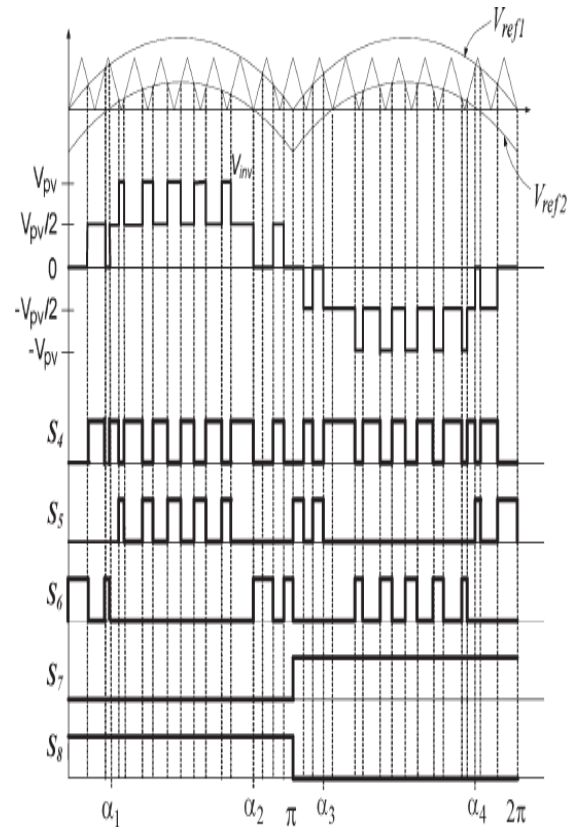
TABLE 1
INVERTER OUTPUT VOLTAGE
DURING S_4-S_8 SWITCH ON AND OFF

S_4	S_5	S_6	S_7	S_8	V_{inv}
ON	OFF	OFF	OFF	ON	$+V_{pv}/2$
OFF	ON	OFF	OFF	ON	$+V_{pv}$
OFF	ON or OFF	OFF or ON	ON or OFF	OFF or ON	0
ON	OFF	OFF	ON	OFF	$-V_{pv}/2$
OFF	OFF	ON	ON	OFF	$-V_{pv}$

V_{ref2} will be compared with the carrier signal until it reaches zero when V_{ref1} exceeds the peak amplitude of carrier signal $V_{carrier}$. A switching pattern shown in fig.4 is obtained. Switches S_4-S_6 will be switching at the rate of the carrier signal

ISSN 2278-3091

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frequency whereas Switches S_7 and S_8 will operate at fundamental frequency. Table 1 shows inverter output voltage level V_{inv} during S_4-S_8 switch on and off.

Since dc-dc boost converters are connected in parallel, if one of the sources is disconnected from the dc bus, the operation of the other dc-dc boost converters will not be affected. Expansion of sources is possible by adding a dc-dc boost converter.

IV. CONTROL SYSTEM ALGORITHM

The main problem in PV generation systems is that the amount of electric power generated by the solar arrays is always changing with weather conditions, i.e., the intensity of solar radiation. An MPPT method or algorithm has quick response characteristics and is able to make good use of the electric power generated in any weather. This method is needed to solve the aforementioned problem.

The perturb-and-observe algorithm is used in this paper to extract the maximum power from the PV arrays and deliver it to the inverter. PI algorithm is used as controller for the feedback controller. The grid current I_g, which is the current injected into the grid is sensed and fed back to the comparator, which compares it with the reference current I_{ref}.

The instantaneous current error is fed to a PI controller. The integral term in the PI controller improves the tracking by reducing the instantaneous error between the reference and the actual current. The resulting error signal is used to control the pulse-width modulation for the switches. Below the minimum power condition or above the maximum power condition, the inverter should not operate to ensure the safety of the PV panel.
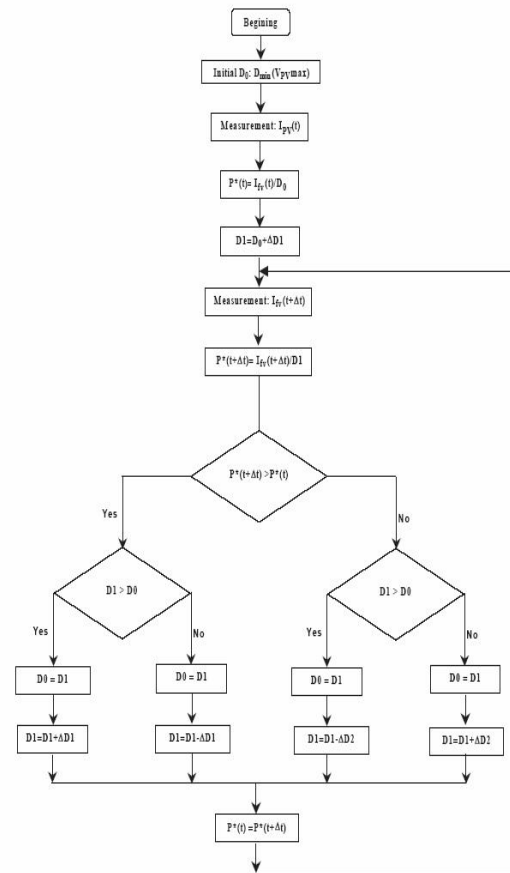

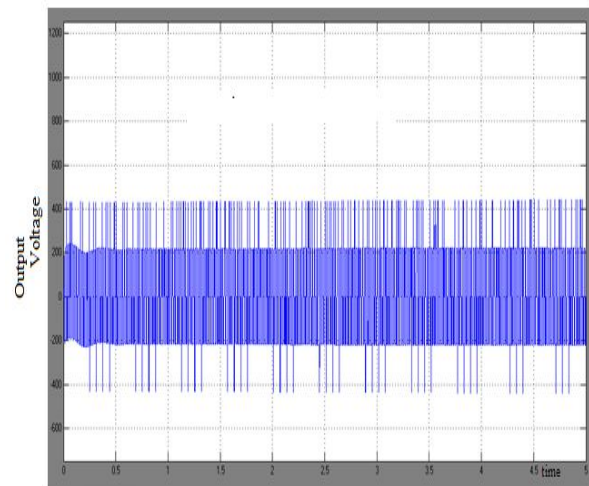Fig.4 MPPT Flow Chart.

V. SIMULATION RESULT

Fig.5 Output Voltage of Multisource Five-Level Inverter.

VI. CONCLUSION

This paper proposes a multisource five level inverter for grid connected system. A modified PWM control scheme with two reference signals and a carrier signal has been used to generate the PWM switching signals. The circuit topology, control algorithm and the operating principle of the proposed inverter have been analyzed in detail. The configuration is suitable for PV application and later expansion is possible. A five level output Voltage is obtained. This proposed system uses renewable power and can operate in absence of sunlight also.

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