Inverter topologies for photovoltaic modules with p-sim software

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Abstract

This study investigated the detail function of inverter in small scale distributed power generation, its modelling and related simulation on P-SIM software. This model can be used for photovoltaic application or especially for particular AC module. In this paper work on three basic requirements for Inverter Modelling Amplification, Inversion and Voltage regulation under change in atmospheric condition.

1. Introduction

This chapter present the overview of single-phase inverters developed for small distributed power generators. The functions of inverters in distributed power generation (DG) systems include dc–ac conversion, output power quality assurance, various protection mechanisms, and system controls. Unique requirements for small distributed power generation systems include low cost, high efficiency and tolerance for an extremely wide range of input voltage variations. These requirements have driven the inverter development toward simpler topologies and structures, lower component counts, and tighter modular design. Both single-stage and multiple-stage inverters have been developed for power conversion in DG systems. Single-stage inverters offer simple structure and low cost, but suffer from a limited range of input voltage variations and are often characterized by compromised system performance. On the other hand, multiple-stage inverters accept a wide range of input voltage variations, but suffer from high cost, complicated structure and low efficiency. Various circuit topologies are presented, compared, and evaluated against the requirements of power decoupling and dual-grounding, the capabilities for grid-connected or/and stand-alone operations [3].

2 Inverter Theory

2.1 Topology of single-phase Inverters

DG systems are usually small modular devices close to electricity users, including wind turbines, solar energy systems, fuel cells, micro gas turbines, and small hydro systems, as well as the relevant controlling/managing and energy storage systems. Such systems commonly need dc–ac converters or inverters as interfaces between their single-phase loads and sources as shown in Fig. 1, which depicts a typical renewable DG system using photovoltaic (PV) as energy source. DG inverters often experience a wide range of input voltage variations due to the fluctuations of energy sources, which impose stringent requirements for inverter topologies and controls. Functions of inverters for small DG systems can be summarized as follow [3].

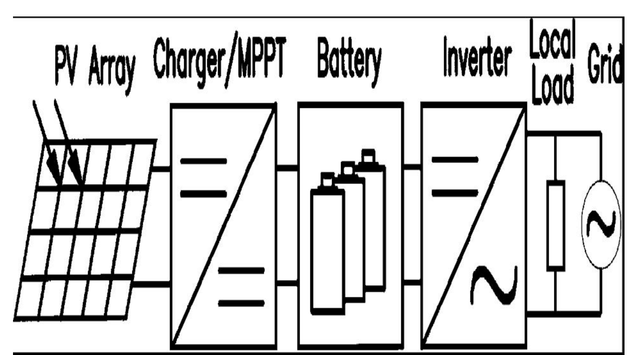

Fig. 1. Block diagram of a photovoltaic system.

1) Power conversion from variable dc voltage into fixed ac voltage for stand-alone applications or ac current output following the grid voltage and frequency for grid-connected applications. The variable dc voltage can be higher or lower than the ac voltage in one

system, which is observed normally in a wind-turbine energy system.

2) Output power quality assurance with low total harmonic distortion (THD), voltage and frequency deviation, and flickering.

3) Protections of DG generators and electric power systems from abnormal voltage, current, frequency and temperature conditions, with additional functions such as ant islanding protection and electrical isolation if necessary.

4) Control of DG systems and accomplishment of certain objectives such as maximum power extraction from wind energy, maximum power point tracking (MPPT) of PV modules, optimum efficiency for fuel cell systems, optimal energy flow control [2], etc.

Based on the electrical isolation between the input and output, inverters can be classified as isolated inverters or non isolated inverters. While electrical isolation is normally achieved using transformers, a choice can be made between using line-frequency transformers as in Fig. 2 or high-frequency transformers as in Fig. 3. The dc-link voltage of inverters for DG systems may vary over a wide range. Depending on the input dc voltage range in comparison to the output ac voltage, inverters can be buck inverters, boost inverters, or buck-boost inverters. It should be noted that although the inverters in Fig. 2 and Fig. 3 are buck inverters by themselves, the whole topologies actually represent boost or buck-boost inverters due to PWM operations and voltage step-up in either low frequency or high frequency.

Traditional full-bridge buck inverters are used in many existing high power applications with bulky and heavy line-frequency transformers. However, modern power electronic converters tend to use "more silicon and less iron." This leads to the pursuance of compact designs with wide input voltage ranges and improved overall efficiency [1].

A multiple-stage inverter is defined as an inverter with more than one stage of power conversion, in which mostly one or more stages accomplish voltage step-up or step-down or electrical isolation, and the last stage performs dc–ac conversion. In the paper, multiple-stage inverters are listed as

1) dc–dc–ac topologies;

2) dc–ac–dc–ac topologies;

3) dc–ac–ac topologies.

These topologies will also be discussed regarding the capabilities to meet certain challenging requirements of DG resource and ac utility [1].

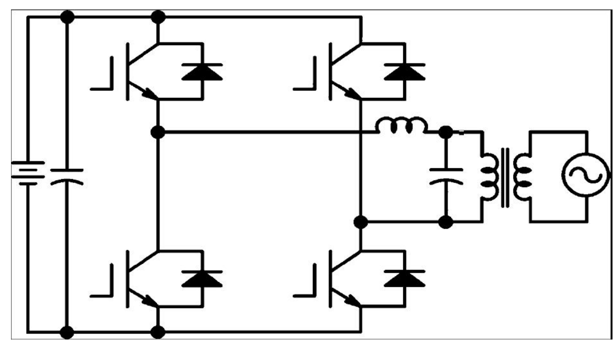

Fig. 2. Traditional buck inverter and line-frequency transformer

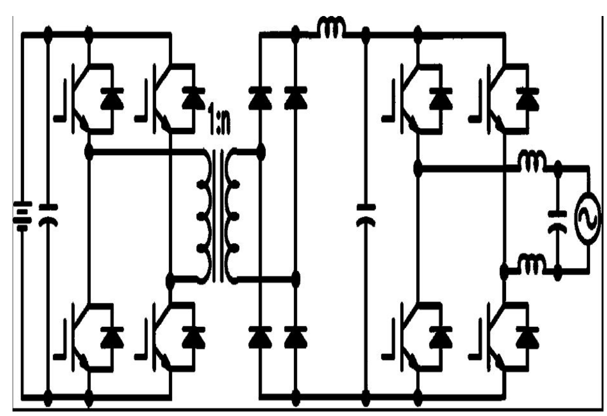

Fig. 3 Multiple-stage inverter with a high frequency transformer.

2.2 Two-Level PWM Control technique for H bridge inverter control

The H-bridge topology inverter is the most popular single-phase converter in various applications, especially in higher power rating applications. It consists of two arms fig4 and outputs a single-phase

AC output voltage, *V out* to the load. Pulse Width Modulation (PWM) techniques are used to control the switching devices on and off. During last few years, PWM technique has been the subject of intensive research and a large variety of PWM control schemes have been discussed. Sinusoidal PWM (SPWM) approach is often used in single-phase applications.

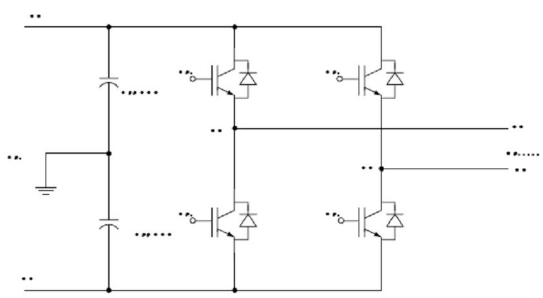

Fig.4 single-phase H-bridge inverter

Three different sinusoidal PWM switching schemes are used commonly for two-level single-phase inverter. They are bipolar PWM scheme, unipolar PWM scheme and modified unipolar PWM scheme [3] Figure 5 below shows the bipolar PWM modulation scheme. In order to generate a sinusoidal AC output with desired amplitude *Vm* and frequency *f*, a sinusoidal control signal Vcontrol at a desired frequency *f*1 is compared with a continuous triangular waveform Vcarrier as shown in Figure 5

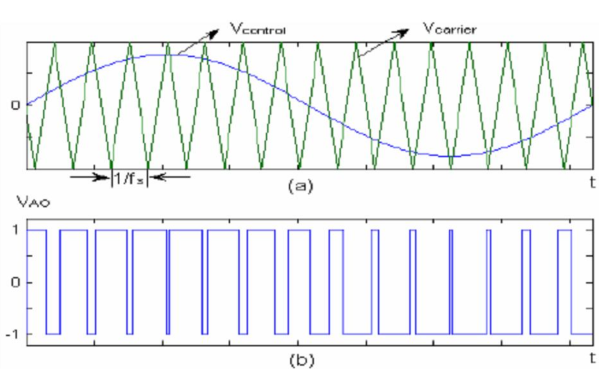

Fig.5 bipolar PWM modulation scheme

When Vcontrol is greater than Vcarrier, the PWM output is positive; otherwise the PWM output is negative. The frequency of carrier waveform Vcarrier establishes the switching frequency *s f* of the inverter. The modulation index *i m* is defined as

$$m_i = \frac{V_{cm}}{V_{crp}}$$

where Vcm is the peak amplitude of the control signal, while Vcrp is the peak amplitude of the triangle signal (carrier).

the modulation ratio is defined as:

$$m_f = \frac{f_{carrier}}{f_1}$$

where f *carrier* is the carrier frequency.

A unipolar PWM modulation scheme is shown in Figure 6 where the two switch pairs in H-bridge inverter are not always switched simultaneously as in the bipolar scheme. Instead, the switching of the two arms is controlled by two control signals. Therefore, the output voltage changes between 0 and +Vd or between 0 and - Vd in half fundamental period. Two control reference signals are used in this scheme. The output voltage from the bipolar PWM scheme does not have zero state, which means the output voltage of the inverter only changes between +Vd and - Vd. This scheme requires only one control reference signal, but the performance is poor

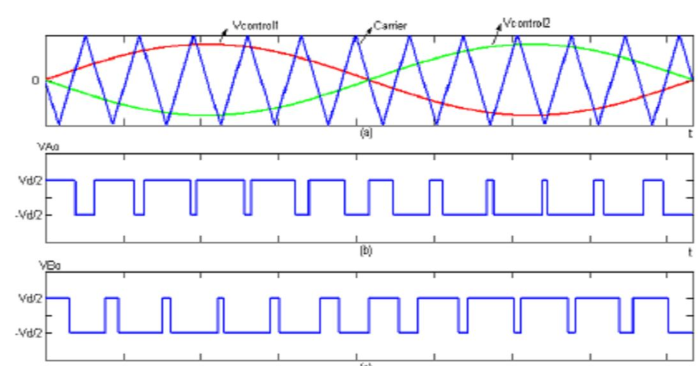

Fig. 6 unipolar PWM modulation scheme

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2.3 Overview of Solar Power Conversion System

The power conversion subsystem for a solar power system has two main tasks: one is to control the input terminal conditions to make photovoltaic (PV) modules operate at a maximum power point (MPP) and to capture the maximum power for the sun [6]. The other is to convert the output dc voltage from solar modules to a suitable ac voltage and meet the utility requirements [4] Therefore, most of the solar power conversion systems apply two-stage topology. The most common two-stage systems [5] consist of a dc-dc solar module-connected converter and dc-ac PWM inverters as shown in Figure 7.

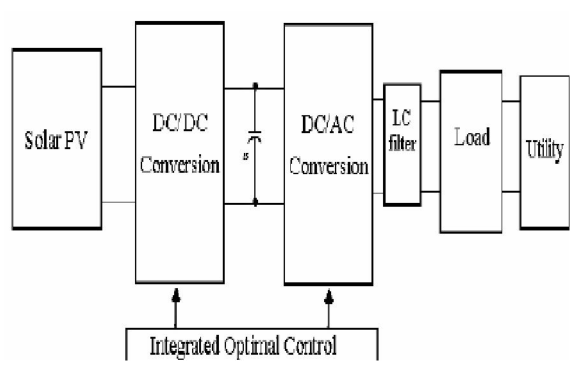

Fig 7 two-stage solar power conversion system

2.4 Simulation of single phase inverter topology

Linear regulator often plays important role in implementing power supply capable of constant voltage/current control. It always provides lost of advantage such as low ripple noise, low EMI, good regulation, easy control strategy. However due to bulky size, low efficiency switch mode technique has become inevitable development trend for raising the power density, power efficiency and dynamic performance. The full bridge converter is one of the isolated converter topology that use in high power rating. The block diagram of it is shown in fig 8. The feedback signal of voltage is given to control circuit using PI-controller block for control and protection purpose.

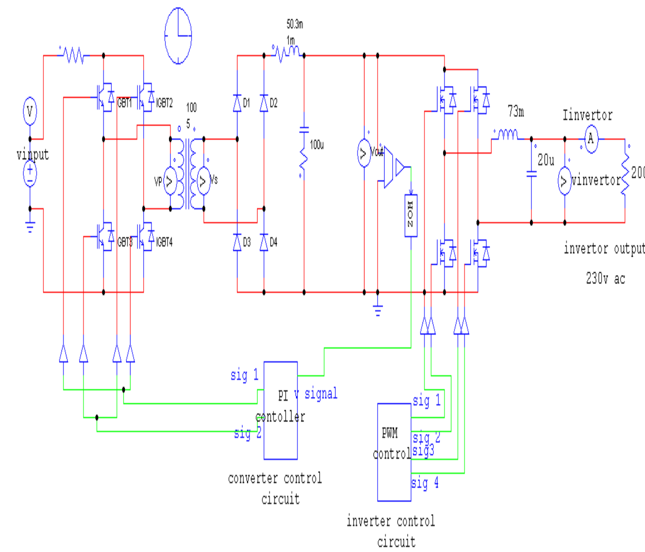

Fig. 8 Single Phase Inverter Topology with p-sim software

2.5 Closed loop converter control system

Control system should be able to adjust duty cycle in time in order to regulate the output voltage with input voltage and load variation. Voltage mode and current control mode control technique adapted to design switching power supply. As the speed of the processors increase and large load changes frequently encountered in system transition from one sleep mode to active mode, the faster transient response of DC-DC power supply has been more important. The transient response of voltage mode control technique, when the input voltage is changing because it has only one feedback loop. The input voltage varying after the variation of output voltage occurs. In fact, the transient response of voltage mode control is slow for any variation of power stage. The basic principle of following circuits in the boosting up the voltage are, charging & discharging reactive component into a load, controlling the level of charge & consequently output voltage by switching the DC supply in & out of the circuit at very high frequencies. They include a freewheeling diode to protect the switch from inductor's very reverse current and this also ensures that the generated inductor energy is applied to load capacitor are connected in parallel with load, to filter the voltage ripple & to maintain constant output voltage. Inductor is used in series with the load to filter the current ripple.

2.6 Converter control scheme using PI-controller

The control scheme essentially consisting of only one sensor with simple structure when compared with classical boost converter which requires both voltage and current sensors. Here, DC voltage of load is fed back and compared with V_{dc} reference voltage. If, there is reduced dc voltage then there is difference between ref. voltage & O/P voltage. This difference is in the form of error, which is given to PI-Controller. PI-controller stabilizes this error and give the modulated single output for PWM scheme. Signals from PI-controller is compared with high frequency signal reference signal as shown in fig9

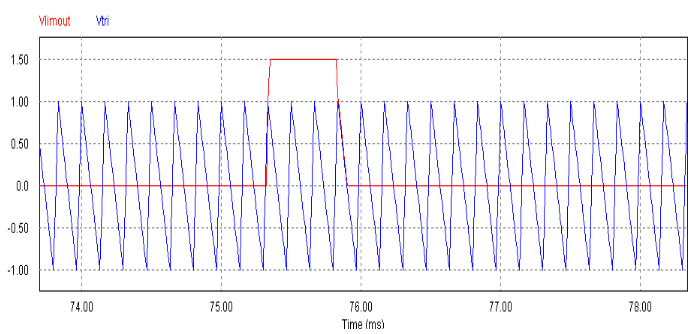

Fig 9 Comparison between Pi Output Signal and Carrier Signal

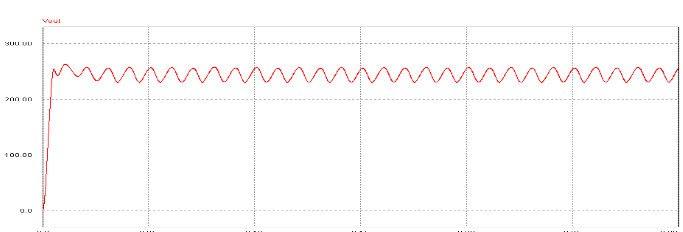

Fig 10 Converter output 230v DC

To set the gain and time-constant there are three methods given below:

(i) Analytical method
(ii) Empirical method
(iii) Trial and error method

PI-controller is designed by trial and error method for line and load regulation. Most of industries used this method for tuning of PI-controller. PI-proportional integral, where integral term yields zero steady- state error in tracing constant set point & proportional term yields output is proportional to input. Integral control filters higher frequency sensor noise; it is slow in response to current error. On the other hand, the proportional term responds immediately to the current error, yet it cannot achieve without an unacceptably large gain. PI controller reduces very high transient error. PWM technique is used for generating gate pulses of IGBTs. The duty cycle is varied according to output voltage. To increase the output voltage increases the duty ratio. Main drawback of this system is slow transient response of output voltage. If input voltage changes from 20v to 17v due to solar radiation as shown in table, the output voltage of the converter will also changes and error will generated accordingly the control circuit and this error signal after comparing with triangular wave is used for triggering the four IGBT and it will maintain the output voltage of converter to 230v dc constant. Now this 230v dc is converted to 230v AC with A unipolar PWM modulation scheme is shown in Figure6.4 where the two switch pairs in H-bridge inverter are not always switched simultaneously as in the bipolar scheme. Instead, the switching of the two arms in Fig.12 is controlled by two control signals. Therefore, the output voltage changes between 0 and +230 or between 0 and -230 in half fundamental period as shown in fig13. Two control reference signals are used in this scheme as shown in fig11. and also in table show the variation in output voltage and power using this control topology when the input supply voltage changes due to variation in solar radiation.

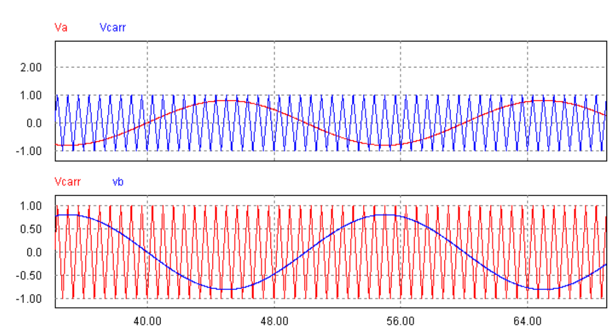

Fig 11 switching of the two arms using unipolar PWM modulation scheme

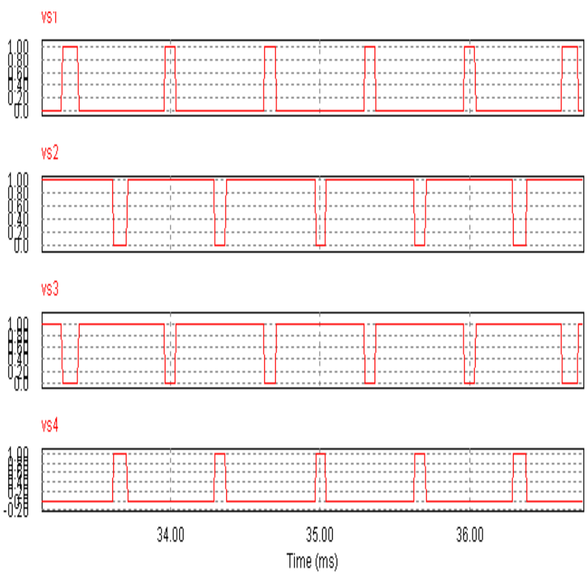

Fig. 11 Switching signal of the two arms of PWM modulation scheme

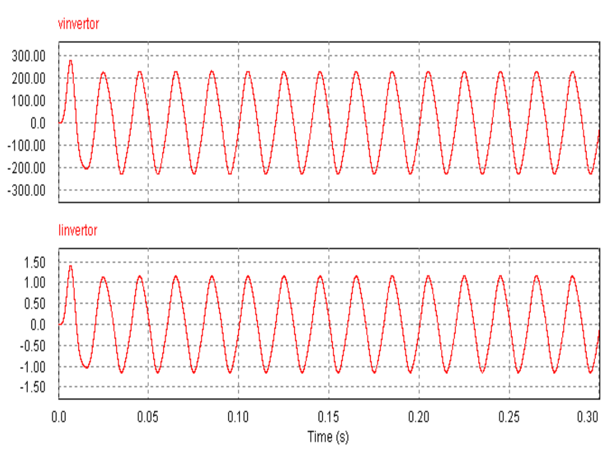

Fig 12 output current and voltage waveform of inverter in p-sim software

2.7 Simulation result and discussion

In fig 12 and table 1 show the simulation result of inverter with above topology so we can see the variation in inverter output power when there is a small variation in input supply or variation in solar panel power output due to change in solar radiation during the day.

V_{in} D.C Volt	Delta V_{in} Volt	$V_{inverter}$ A.C Volt	I_L Amp	Power (watt)	Delta $V_{inverter}$ %	Delta P %
22	10 %	259.7	1.29	335.01	12.09	25
21.5	7.5 %	252	1.26	317.52	8.87	19
21	5 %	245	1.22	298.9	5.8	12
20.5	2.5 %	237.08	1.18	280.72	2.8	5.6
19.5	2.5 %	230.39	1.15	264.94	0.0462	0.26
19	5%	229.7	1.148	263.69	0.39	0.73
18.5	7.5%	229.35	1.146	262.83	0.54	1.06
18	10 %	230.45	1.152	265.48	0.43	0.06

Table 1 variation in inverter o/p power when there is a Small variation in input supply

3. Conclusion

These inverter topologies can be used for photovoltaic applications and particular inverters for the AC-Module. The task for such an inverter is to amplify the photovoltaic-module low voltage up to the higher-level voltage of the grid and to convert it from DC into AC. and maintain it constant as there is a variation in atmospheric condition or in solar radiation during the whole day.

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