Simulation of Solar Power System IGBT Based Inverter Transition to IGCT to Increase Output Performance

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Abstract: ***This paper also proposes a Solar power energy system consisting of a IGCT Inverters for converting boost DC supply of converter to controlled AC Supply at input of load, a combined structure of photovoltaic source, dc to dc step up booster and a four IGCT based inverter unit designed to supply continuous AC power to the load. A simple and economic control with dc-dc converter is used for maximum power extraction from the photovoltaic array. Due to the control intermittent nature of both the converter and inverter photovoltaic energy sources is added to the system for the purpose of ensuring regulated continuous power flow. In industrial applications, the Insulated Gate Bipolar Transistor (IGBT) is favorable. The IGBT is a voltage controlled device, hence it requires less gate drive power, thus simplifies the gate driver design. Due to the non-latched transistor operation, the IGBT has Shorter storage time therefore pushes the IGBT to higher switching frequency. However, the large conduction voltage drop limits the popularity of IGBT at high voltage. Today, only 600A device is available at 6.5kV. On the other hand, improved GTO devices emerge. Hard-driven and MOS-assisted technologies are used in the Integrated Gate Commutated Thyristor (IGCT) and Emitter Turn-Off (ETO) thyristor. These two devices use unity gain turnoff technique to cut the storage time of GTO by ten times, thus increase the switching performance close to that of the IGBT. The low conduction loss and rugged structure make IGCT and ETO more favorable than IGBT. The latest IGCT and ETO devices have reached the same power level of GTO. The Integrated Gate-Commutated Thyristor, or IGCT, is an advanced high-power semiconductor switch for power conversion which sets new performance standards with regards to power, reliability, speed, efficiency, cost, weight and volume. Despite these major simultaneous improvements on several fronts, IGCTs are eminently manufacturable and available today.***

Keywords: MOSFET, Diode, Power Converter, Power Inverter, IGBT, IGCT

1. Introduction

With the rising cost and limited availability of fossil fuels, much attention has been focused on the use of renewable energy sources for electrical power generation. Renewable Energy Sources are those energy sources which are not destroyed when their energy is harnessed. Human use of renewable energy requires technologies that harness natural phenomena, such as sunlight, wind, waves, water flow, and biological processes such as anaerobic digestion, biological hydrogen production and geothermal heat. Among these, solar energy with Solar cell appears to be the most promising basic source of renewable energy. Solar energy conversion systems are used to capture the energy available in sun light to convert into electrical energy. The power electronics is changing the characteristic of the solar cell from being an energy source to be an active power source.

Photovoltaic (PV) power-generation systems are becoming increasingly important and prevalent in distribution and generation systems. An conventional type of PV array is a serial connection of numerous panels to obtain higher dc-link voltage for main electricity through a dc–ac inverter. The total power generated from the PV array is sometimes decreased remarkably when only a few modules are free from shadow effects to overcome this problems several necessary steps are taken. Interactive inverter is individually mounted on PV module and operates so as to generate the maximum power from its corresponding PV module. The power capacity range of a single PV panel is about 100W to 300W, and the maximum power point (MPP) voltage range is from 15V to 40V, which will be the input voltage of the ac module; in cases with lower input voltage, it is difficult for the ac module to reach high efficiency. However, employing a high step-up dc– dc converter in the front of the inverter improves power-conversion efficiency and provides a stable dc link to the inverter. The micro inverter includes dc–dc boost converter, dc–ac inverter with control circuit as shown in fig. The dc–dc converter requires large step-up conversion from the panel’s low voltage to the voltage level of the application. The dc-input converter must boost the 48 V of the dc bus voltage to about 380– 400 V. Generally speaking, the high step-up dc–dc converters for these applications have the following common features: 1) High step-up voltage gain. Generally, about a step-up gain is required. 2) High efficiency. 3) No isolation is required.

2. Photovoltaic Energy Conversion System

Photovoltaic energy systems consist of arrays of solar cells which create electricity from irradiated light. The yield of the photovoltaic systems (PV) is primarily dependent on the intensity and duration of illumination. PV offers clean, emission-less, noise-free energy conversion, without involving any active mechanical system. Since it is all electric it has a high life time (> 20 years). Figure 2.1 shows a PV system.

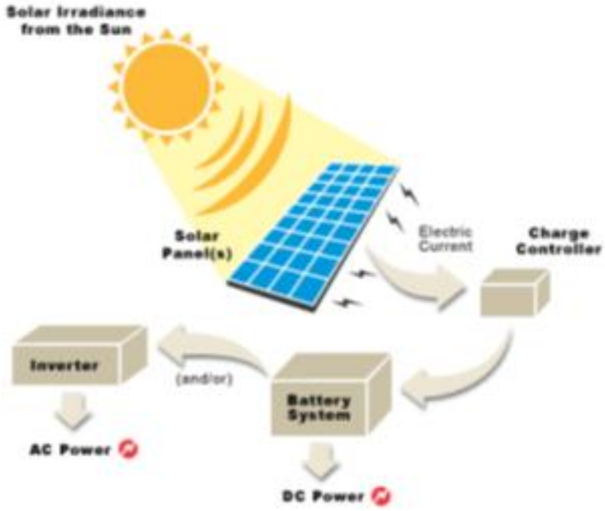

Figure 2.1: Photovoltaic system

A lot of work is being done to enhance the efficiency of the solar cell which is the building block of PV. In this regard the focus is mainly on electro-physics and materials domain. Some of the existing PVs and their efficiencies are:

1. Crystalline and multi-crystalline solar cells with efficiencies of ~11 %.
2. Thin film amorphous Silicon with an efficiency of ~10%.
3. Thin-film Copper Indium Dieseline with an efficiency of ~12%.
4. Thin film cadmium telluride with an efficiency of ~9%.

PV panels are formed by connecting a certain number of solar cells in series. Since the cells are connected in series to build up the terminal voltage, the current flowing is decided by the weakest solar cell, Parallel connection of the cells would solve the low current issue but the ensuing voltage is very low (< 5 V). These panels are further connected in series to enhance the power handling ability. The entire PV system can be seen as a network of small dc energy sources with PE power conditioning interfaces employed to improve the efficiency and reliability of the system. The role of PE is mainly twofold:

I. To interconnect the individual solar panels – two solar panels cannot be identical hence a dc-dc converter interfacing the two will help maintain the required current and voltage, and with regulation improve the overall efficiency. Several non-isolated dc-dc converters have been employed for this purpose. Buck, buck-boost, boost, and Cook topologies with suitable modifications can be employed for this purpose.

II. To interface the dc output of the PV system to the grid or the load - This includes the topics of dc-dc-ac and dc-ac-ac conversion.

3. DC-DC Boost Converter

There are two major factors related to the efficiency of a high step-up dc–dc converter: large input current and high output voltage. Fig.3.1 shows the solar energy through the PV panel and micro inverter to the output terminal when the switches are OFF. When installation of the ac module is taking place, this potential difference could pose hazards to both the worker and the facilities. A floating active switch is designed to isolate the dc current from the PV panel, for when the ac module is off-grid as well as in the non -operating condition.

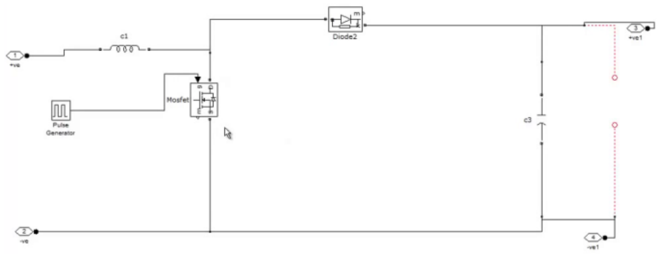

Figure 3.1: Simulation Circuit of boost converter

a) High intensity lamp ballast b) dual -input front –end converters As an example for a high intensity discharge (HID) lamp ballast used in automotive head lamps in which the start-up voltage is up to 400V,an another example diagram shows the convergence of computer and telecommunications industries in that the dc-input converter must boost the 48V of the dc bus voltage to about 380-400V. The main aim here is to attain the maximum output as much we can get from the dc input similarly in this paper from the pv panel we can the dc voltage as output before connecting the output to grid the voltage from the pv panel is not more sufficient since in between the pv panels and the grid interface we are going for micro inverter which consists of boost converter and inverter. The simulation result uses 160 V input to the boost converter and attains 320 V as the output voltage respectively.

3.1 Simulation of Boost Converter

Simulation diagram and the simulation output results separately shown for the boost converter as well as inverter .The parameter values is shown below Vs=160 V, L=1e-3 H, C1 = C2 = 47e-6 F, C 3= 220e-6 F R load = 400 ohms, Vo = 320 V. The main concern of this project is to design and Construct a DC to DC converter which is one of the main module in the solar PV system that shown in Figure. The main principle of the DC to DC converter is based on boost type. The purpose of the project is to develop DC to DC converter (boost type) that converts the unregulated DC input to a controlled DC output with desired voltage level. The main objectives of this project are designing and constructing a DC to DC converter (boost type) circuit practically with input voltage, 120 V and the output voltage, 320 V.

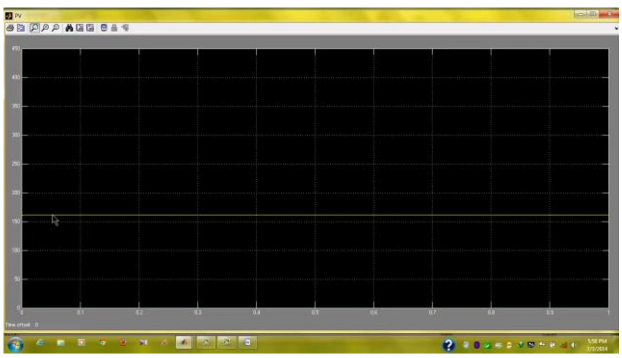

Figure 3.2: Input waveform for Boost converter from Solar energy source

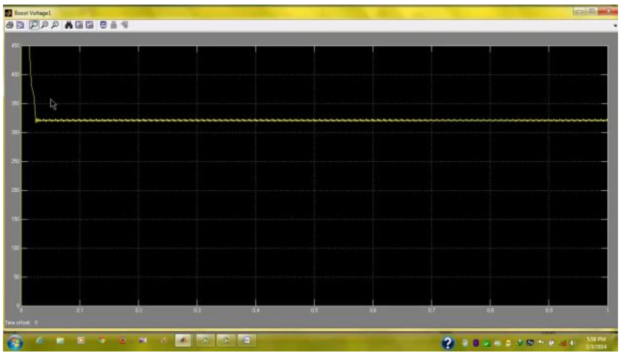

Figure 3.3: The output voltage waveform Boost converter

4. Insulated-Gate Bipolar Transistor

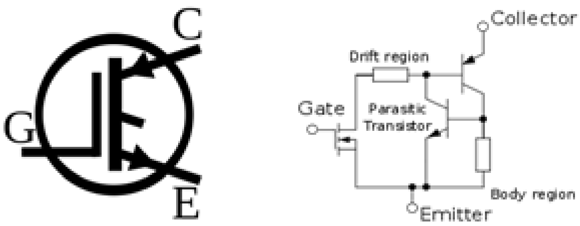

Figure 4.1: Electronic Symbol for Depletion-Mode IGBT and Equivalent circuit for IGBTs

The insulated-gate bipolar transistor (IGBT) is a three-terminal power semiconductor device primarily used as an electronic switch which, as it was developed, came to combine high efficiency and fast switching. It switches electric power in many modern appliances: variable-frequency drives (VFDs), electric cars, trains, variable speed refrigerators, lamp ballasts, air-conditioners and even stereo systems with switching amplifiers. Since it is designed to turn on and off rapidly, amplifiers that use it often synthesize complex waveforms with pulse width modulation and low-pass filters. In switching applications modern devices boast pulse repetition rates well into the ultrasonic range—frequencies which are at least ten times the highest audio frequency handled by the device when used as an analog audio amplifier.

The IGBT combines the simple gate-drive characteristics of MOSFETs with the high-current and low-saturation-voltage capability of bipolar transistors. The IGBT combines an isolated gate FET for the control input, and a bipolar power transistor as a switch, in a single device. The IGBT is used in medium- to high-power applications like switched-mode power supplies, traction motor control and induction heating. Large IGBT modules typically consist of many devices in parallel and can have very high current handling capabilities in the order of hundreds of amperes with blocking voltages of 6000 V, equating to hundreds of kilowatts.

The first-generation IGBTs of the 1980s and early 1990s were prone to failure through such modes as latch up (in which the device will not turn off as long as current is flowing) and secondary breakdown (in which a localized hotspot in the device goes into thermal runaway and burns the device out at high currents). Second-generation devices were much improved, and the current third-generation ones are even better, with speed rivaling MOSFETs, and excellent ruggedness and tolerance of overloads.

The extremely high pulse ratings of second- and third-generation devices also make them useful for generating large power pulses in areas including particle and plasma physics, where they are starting to supersede older devices such as triggered spark gaps. Their high pulse ratings, and low prices on the surplus market, also make them attractive to the high-voltage hobbyist for controlling large amounts of power to drive devices such as solid-state Tesla coils and coil guns.

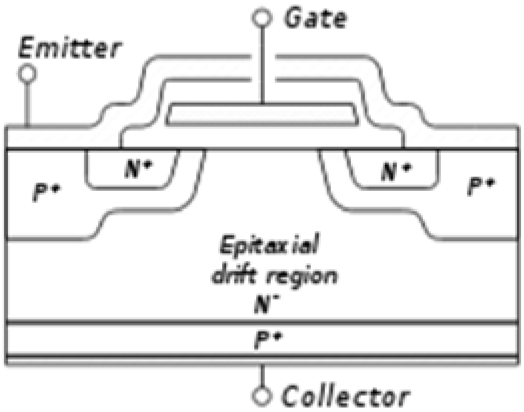

Figure 4.2: Cross section of a typical IGBT cell

Cross section of a typical IGBT showing internal connection of MOSFET and Bipolar Device An IGBT cell is constructed similarly to a n-channel vertical construction power MOSFET except the n+ drain is replaced with a p+ collector layer, thus forming a vertical PNP bipolar junction transistor. This additional p+ region creates a cascade connection of a PNP bipolar junction transistor with the surface n-channel MOSFET. IGBTs are important for electric vehicles and hybrid cars.

4.2 Static Characteristic of an IGBT

The IGBT is a semiconductor device with four alternating layers (P-N-P-N) that are controlled by a metal-oxide-semiconductor (MOS) gate structure without regenerative action.

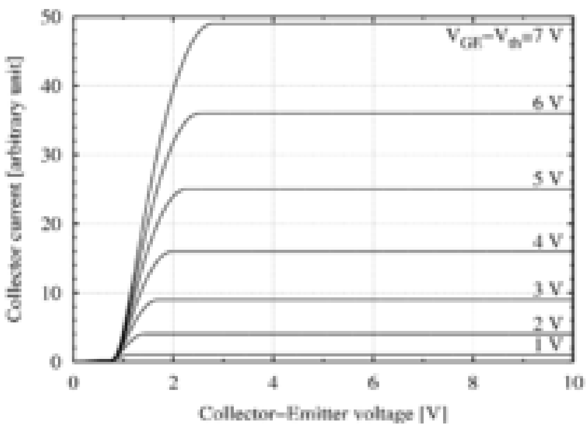

Figure 4.3: Static characteristic of an IGBT

5. Simulation Model and Results

5.1 Simulation of Single Phase Full Bridge Inverter Using IGBT

Figure 5.1 shows the simulation of Single phase full bridge Inverter using Mat lab Simulink, When the S1 and S2 conducts the load voltage is Vs whereas the S3 and S4 conducts the load voltage is –Vs . Frequency of the output voltage can be controlled by varying the periodic time T. The circuit connected with the RL load, in the circuit there are 4 IGBTs. The basic working principle of the inverter is to converts the dc power into ac power at desired output voltage and frequency. The inverters are mainly classified into two types 1) voltage source inverters 2) current source inverters. In the above circuit it uses voltage source inverters. The voltage source inverters is the one in which the dc source has small or negligible impedance. In other words, voltage source inverters has stiff dc voltage source at its input terminals. The output voltage and output current waveforms are shown in figure. & figure.

The parameter values is shown below Vdc = 320 V Pulse generator: Amplitude = 1V Period (sec) = 0.02 sec Pulse width (% of period) = 50% Phase delay (sec) =0 Load: R load =1 ohms L load = 10e-3 H

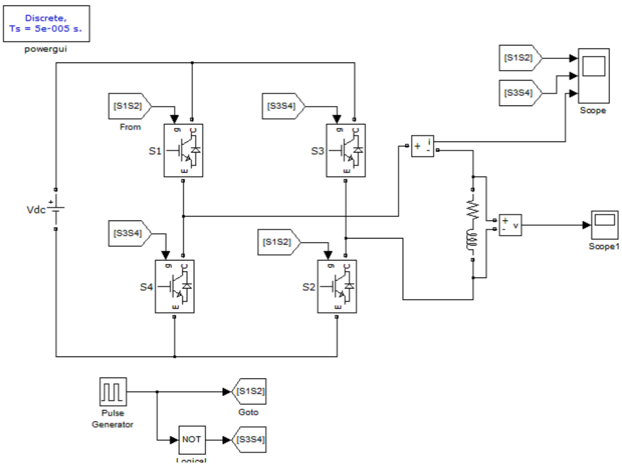

Figure 5.1: Simulation of Single Phase Full Bridge Inverter using Matlab/Simulink

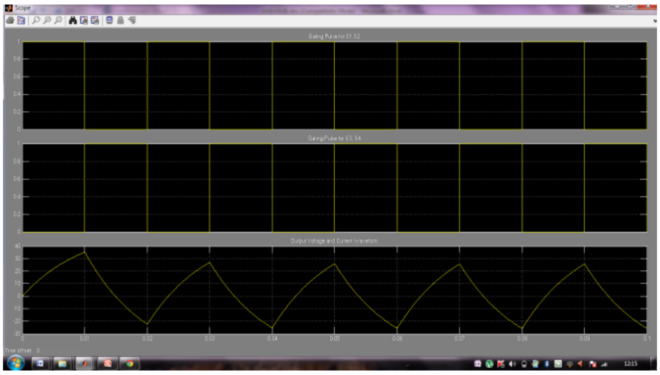

Figure 5.2: Pulse voltage and Output Current waveform for Single Phase Full Bridge Inverter

Figure 5.3: Output Voltage waveform for Single Phase Full Bridge Inverter

5.2 Modeling and Simulation of the PV Panel using Matlab/ Simulink

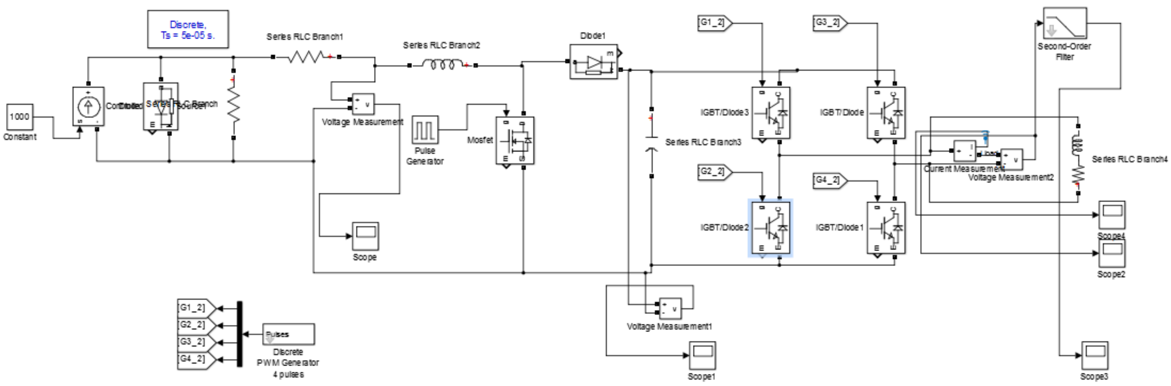

Figure 5.4: Simulation of the PV panel using MATLAB/SIMULINK

It is to be known that the PV cell current is purely dependent on the solar radiation. Because we applied constant voltage supply which is providing uniform supply to whole system but in practical case parameter will change and system get irregular supply due non uniformity if sun radiation which is cause by cloudy season.

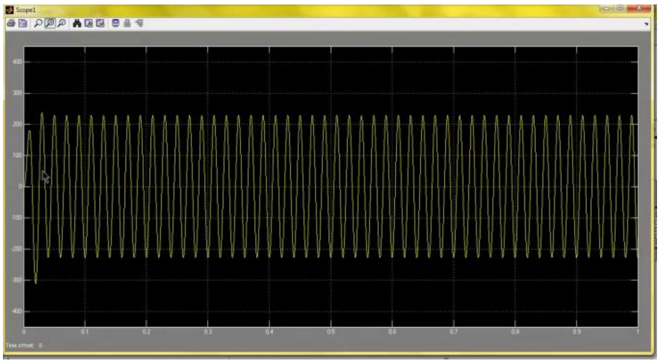

Figure 5.5: output waveforms of PV panel using Matlab/Simulink

It is to be known that the PV cell current is purely dependent on the solar radiation. Because we applied constant voltage supply which is providing uniform supply to whole system but in practical case parameter will change and system get irregular supply due non uniformity if sun radiation which is cause by cloudy season.

Fig. showing us output waveform which we get finally after fully control supply of inverter by reducing harmonics and ripple of inverter output supply. Inverter IGBT switch usually produce harmonic due to large switching activity during operation of system .and this constraint will overcome by implementing IGCT in place of IGCT in inverter circuit .because IGCT have established themselves as the power semiconductor of choice at medium voltage levels within the last few years because of their low conduction and switching losses. The trade-off between these losses can be adjusted by various lifetime control techniques and the growing demand for these devices is driving the need for standard types to cover such applications as Static Circuit Breakers (low on-state) and Medium Voltage Drives (low switching losses). The additional demands of Traction (low operating temperatures) and Current Source Inverters (symmetric blocking) would normally result in conflicting demands on the semiconductor. This paper will outline how a range of power devices can meet these needs with a limited number of wafers and gate units. Some of the key differences\ between IGCTs and IGBTs will be explained and the outlook for device improvements will be discussed.

6. Conclusion

The state-of-the-art high power devices are studied in this paper. A behavioral loss model is developed and implemented in SABER to evaluate these devices. This methodology is used in a pulse application design. The comparison basis is power losses and thermal handling capability of the devices. The result data show that the IGCT and the ETO have better performance than the IGBT device in the intended application.

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