



ROLE OF POWER SEMICONDUCTOR DEVICES IN INDUSTRIAL AUTOMATION OF RENEWABLE ENERGY SYSTEMS

Dr. J. Sanjeevi Kumar* & Dr. N. Dhasarathan**

* Professor & Head, Department of EEE, PRIST University, Vallam, Thanjavur, Tamilnadu

** Associate Professor, Department of ECE, PRIST University, Vallam, Thanjavur, Tamilnadu

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Abstract:

The growing demand of energy translates into efficiency requirements of energy conversion systems and electric drives. Both these systems are based on Pulse Width Modulation (PWM) Inverter. In this paper we firstly present the state of art of the main types of semiconductor devices for Industrial PWM Inverter. In particular we examine the last generations of Silicon Carbide (SiC) MOSFETs and Insulated Gate Bipolar Transistors (IGBTs) and we present a comparison between these devices, obtained by SPICE simulations, both for static characteristics at different temperatures and for dynamic ones at different gate resistance, in order to identify the one which makes the PWM inverter more efficient. Advanced power electronic systems are deemed to be an integral part of renewable, green and efficient energy systems. Wind energy is one of the renewable means of electricity generation that is now the world's fastest growing energy source can bring new challenges when it is connected to the power grid due to the fluctuation nature of the wind and the comparatively new types of its generators. The wind energy is part of the worldwide discussion on the future of energy generation and use and consequent effects on the environment. However, this paper will introduce some of the requirements and aspects of the power electronic involved with modern wind generation systems, including modern power electronics and converters, and the issues of integrating wind turbines into power systems.

Key Words: Power Electronics, Renewable Energy, Smart Grid, Green Energy & Power Technology

1. Introduction:

The global energy consumption has been continually increasing over the last century. Official estimates indicate a 44 percent increase in global energy consumption during the period 2006-2030. It can be said that fossil fuels (liquid, coal and natural gas) have been the primary energy source for the present day world. Sustained urbanization, industrialization, and increased penetration of electricity have led to unprecedented dependency on fossil fuels. Presently, the most important concerns regarding fossil fuels are the green house gas emissions and the irreversible depletion of natural resources. Based on the official energy statistics from the US Government, the global carbon dioxide emissions will increase by 39 percent to reach 40.4 billion metric tons from 2006 to 2030. Green house gas emissions and the related threat of global warming and depleting fossil fuel reserves have placed a lot of importance on the role of alternative and greener energy sources [1].

Many renewable energy technologies today are well developed, reliable, and cost competitive with conventional generators. The cost of renewable energy technologies is on a falling trend and is expected to fall further as demand and production increases [2]. Renewable energy power systems can be a cost effective alternative for areas with high electricity connection fees. The adoption of renewable energy is being promoted as a measure to help mitigate the problem of global warming. The generated power output from renewable energy, however, is often difficult to control, and if adopted in large quantities, may cause frequency fluctuations throughout the entire power system and local voltage fluctuations may occur [4]. The power electronics technology plays an important role in the realization of a compensating high-speed high-accuracy power supply system must be used to connect renewable energy, for which the generated output power is difficult to control, to the power system.

2. 4H-SiC Step Trench Gate Power Mosfet:

2.1 An introduction about Power MOSFET and Trench Gate Structure:

In a traditional n-channel MOSFET, lateral MOSFET, the saturation drain current, I_{Dsat} , is given by the following equation:

$$I_{Dsat} = \mu_n C_{ox} W_L (V_{GS} - V_T)^2$$

Where μ_n is the electron mobility, C_{ox} is the oxide capacitance, W and L are the width and the channel length respectively, V_{GS} is the gate-source voltage and V_T is the threshold voltage. Therefore, to increase the MOSFET currents, we need to make W large and L small. On the other hand, reducing L, we have a reduction of the breakdown voltage. When the body-to-drain junction is reversing polarized, the depletion region spreads

into short channel, resulting in breakdown at relatively low voltage. This effect limits the lateral MOSFET in high voltage applications [9]. Planar MOSFET (Figure 1a), also known as DMOSFET (double diffused), has been developed to obtain short channel.

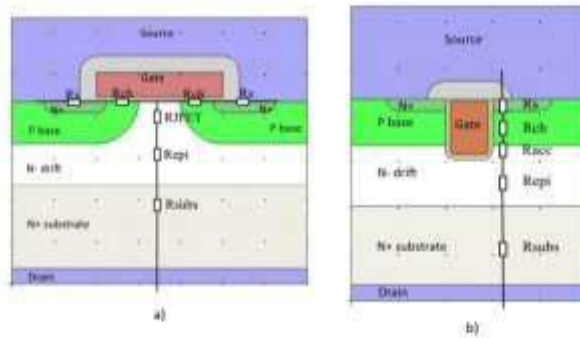


Figure 1: DMOSFET (a) and Trench Gate MOSFET (b) with R_{DS} components

2.2 The Silicon Carbide and the Newest SiC Power Mosfet:

The Silicon Carbide (SiC), as Silicon (Si), is a semiconductor material but, compared with the latter, offers: a lower intrinsic carrier concentration (9–18 orders of magnitude), a higher electric breakdown field (4–8 times) that allows a ten times reduction in drift layer thickness, a higher thermal conductivity that allows high temperature operation up to 350°C, a larger saturated electron drift velocity that allows the increasing of the switching frequency. Due to difficulty with material processing and presence of crystal defects, silicon carbide has been adopted for power devices only in the last years after the improvement of the fabrication processes. Only the 6H- and 4H-SiC poly-types are available commercially but 4H-SiC is preferred in power devices fabrication because of its high carrier mobility and its low dopant ionization energy [3].

The new generation of SiC Power MOSFET presented in [4] is developed with 4H-SiC because this material has 10X higher breakdown strength when compared to silicon, leading to realize a 10kV device. With SiC technology R_{DS} , total current per die and switching losses per chip are improved. Furthermore, trench gate technology allows better performance in matter of conduction losses.

3. Power Electronics for Wt Applications:

Wind generation has emerged as most promising among these generation technologies. Wind energy has matured to a level of development where it is ready to become a generally accepted utility generation technology. Wind exists almost everywhere on the earth, and in some places with considerable energy density. Wind turbines can make a major contribution to the production of renewable energy and it may experience large variation in its output power under variable weather conditions. When the oil crisis occurred in the 1970s in Europe, the emerging was awareness of the finiteness of the fossil fuel reserve and the adverse effects of burning those fuels for energy has made us look for alternatives. This awareness is hastening the deployment of eco-friendly wind generator systems. One method to overcome the above problem is to integrate Wind Generator with other reliable power sources [5, 6]. The wind power is starting to play (contribute in) an important role in the electric generation in several countries.



Figure 2: Different types of wind turbines

There are two types of wind turbines (WT), the horizontal axis and the vertical axis. They are both shown on Figure 2. However, the horizontal axis wind turbines are by far the most popular design.

A large number of designs are available, ranging from 50W up to 7MW size. The number of blades can vary but the most commonly seen are with 2 or 3 blades. The grid connected wind turbines are connected to the

utility grid either directly or through power electronics, feeding the produced energy to the grid. On this type of wind turbines all manufacturers are trying to increase the size and efficiency of the machines.

Figure 3 depicts a variable speed wind energy conversion system. The electrical generator popularly employed for partially variable speed wind energy conversion systems are doubly fed induction generators [7].

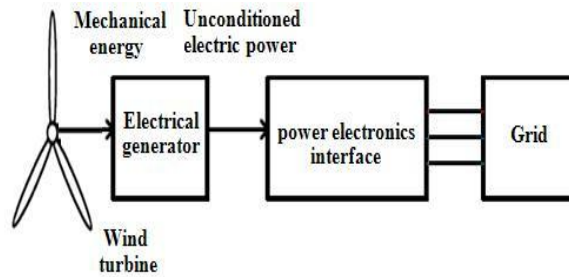


Figure 3: Variable speed of wind energy conversion system

Many studies have been made on the speed control part and on ways to reduce the cost of the unit. There are several types of inverters which are used on wind turbine installations, such as PWM-VSI converters and matrix converters. However the PWM-VSI converter is widely used. The back to back PWM-VSI is a bi-directional power converter consisting of two PWM-VSI inverters [8]. The topology of this inverter is shown in Figure 4. To achieve full control of the grid current, the DC link voltage must be boosted to a level higher than the amplitude of the grid line voltage.

The power flow of the grid side converter is controlled in order to keep the DC-link voltage constant, while the control of the generator is set to suit the magnetization demand and the reference speed.

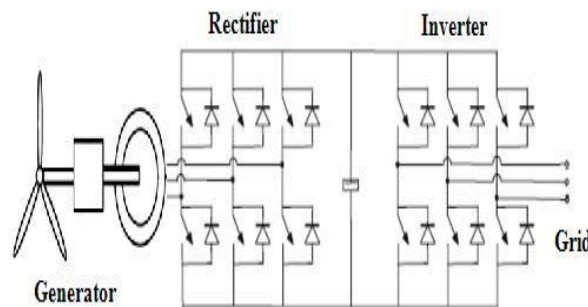


Figure 4: Topology of wind power generation system using Three-Phase Boost Rectifier

The inclusion of a boost inductance in the dc-link circuit increases the component count, but a positive effect is that the boost inductance reduces the demands of the grid side harmonic filter, and offers some protection of the converter against abnormal conditions on the grid. One of the drawbacks of the back-to-back circuit topology is the switching losses. Every commutation in both the grid inverter and the generator inverter between the upper and lower dc-link branch is associated with hard switching and natural commutation. Since the back-to-back topology consists of two inverters, the switching losses might be even more pronounced. The high switching speed to the grid may also require extra EMI-filters, as well [8]. Controlled rectifiers offer distinct advantages over typically used uncontrolled diode, or phase-controlled thyristor rectifiers in ac-dc-ac converters for variable speed drive applications. These advantages include unity power factor and greatly reduced input line current harmonic distortion due to the nearly sinusoidal input line current attainable with controlled rectifiers. There is a duty cycle factor that can be adjusted to regulate the ratio of output to input voltage, up to a maximum value. Finally, the output is passed through a filter to eliminate high frequency harmonics [9].

The PWM-VSI inverters can efficiently convert the three phase electrical output of the wind turbine to the requested electrical grid characteristics for a proper connection. They use an array of controlled bidirectional switches to convert AC power from one frequency to another. They produce a variable output voltage with unrestricted frequency. The general operation of the inverter is to convert the AC current of the wind turbine to the AC current that the utility grid demands. Wind Energy Conversion Systems are playing an increasingly important role in electricity generation. According to the way they are connected to the electricity grid, the wind energy systems can be classified as systems without power electronics, systems with partially rated power electronics and systems with full scale power electronics. Systems without power electronics use induction generators and they require reactive power compensation to operate. This reactive power can be supplied by the grid, by capacitor banks or by power electronics based reactive current injection. Systems with full scale power electronic converter use a conventional or permanent magnet synchronous generator or induction generator [10].

This design allows the wind turbine to operate in variable speed mode allowing more energy of the wind to be captured and control of torque to smooth it during abnormal operation.

4. Conclusion:

In this paper the main trends of the power electronics used in applications of the wind turbine technology are presented. Due to the high demand for renewable energy sources applications, there is a continuing research for improving the total efficiency of these applications and by improving each electronic part included. SPICE simulations for static characteristics have been evaluated at different temperatures while dynamic ones have been performed at different gate resistance, in order to identify the device which makes the PWM inverter more efficient. The development of modern power electronics has been briefly reviewed, showing that the wind turbine behavior/performance is very much improved by using power electronics. Also it can be concluded the power scaling of wind turbines is important in order to be able to reduce the energy cost.

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