A COMPARATIVE STUDY OF POWER ELECTRONICS DEVICES INTEGRATION

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Abstract

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. Power Electronics is a branch which combines Power (electric power), Electronics and Control systems. Power engineering deals with the static and rotating power equipment for the generation, transmission and distribution of electric power. Electronics compromise with the study of solid state semiconductor power devices and circuits for Power conversion to meet the desired control objectives (to command the output voltage and output power). Power electronics may be defined as the subject of applications of solid state power. Power electronics deals with the study and design of Thyristorised power controllers for many of application like Heat control, Light/Illumination control, and Motor control - AC/DC motor drives used in industries, High voltage power supplies, Vehicle propulsion systems, High voltage direct current (HVDC) transmission. Semiconductor devices (Thyristors) for the control and conversion of electric power.

Keywords: Electric Power, Control System, Semiconductor.

1. INTRODUCTION

The first Power Electronic Device invented was the Mercury Arc Rectifier during the year 1900. Then the other Power devices like metal tank rectifier, grid controlled vacuum tube rectifier, ignitron, phanotron, thyratron and magnetic amplifier, were invented & used gradually for power control applications until 1950. The first SCR (silicon controlled rectifier) or Thyristor was found and developed by Bell Lab's in 1956 which was the first PNPN transistor. The second electronic revolution began in the year 1958 with the development of the commercial grade Thyristor by the General Electric Company (GE). Thus the new area of power electronics was born. After that many different types of power semiconductor devices & power conversion methods have been introduced. The power electronics innovation is giving us the ability to convert shapes and control large amounts of power.

1.1. POWER ELECTRONIC APPLICATIONS

DOMESTIC APPLICATIONS:

Lighting, Cooking Equipments, Personal Computers, Entertainment Equipments, UPS, Heating, Air Conditioners, Refrigerators & Freezers.

COMMERCIAL APPLICATIONS:

Lighting, Computers and Office equipments, Uninterruptible Power Supplies (UPS), Heating Systems Ventilating, Air Conditioners, Central Refrigeration, Elevators, and Emergency Lamps.

INDUSTRIAL APPLICATIONS

Pumps, induction furnaces, lighting control circuits, industrial lasers, induction heating, compressors, blowers and fans, Machine tools, arc furnaces, welding equipments.

AEROSPACE APPLICATIONS:

Satellite power systems, aircraft power systems, Space shuttle power supply systems,.

TELECOMMUNICATIONS

Mobile cell phone battery chargers, Battery chargers, power supplies (DC and UPS).

TRANSPORTATION

Electric locomotives, street cars, trolley buses, Traction control of electric vehicles, battery chargers for electric vehicles, automobile electronics including engine controls.

UTILITY SYSTEMS

Alternative energy sources (wind, photovoltaic), fuel cells, High voltage DC transmission (HVDC), static VAR compensation (SVC), , energy storage systems, induced draft fans and boiler feed water pumps.

1.2. Modern power electronics

Power Electronics is an interdisciplinary field, which combines power, electronics and control theory for the control and conversion of electric power. It can be viewed as a branch of system engineering. Power Electronics has already found an important place in the modern technology and it is now being used in great variety of high power products. The rapid growth of the power electronics revolution has been caused due to the numerous benefits of power electronics for power control and processing of industrial applications [1]. This presentation reviews the chronological development of power electronic circuits and identifies the commonly used converters for renewable energy. The power-electronic technology plays an important role in distributed generation and in integration of renewable energy sources into the electrical grid, and it is widely used and rapidly expanding as these applications become more integrated with the grid-based systems [3].

2. POWER SEMICONDUCTOR DEVICES

The power semiconductor devices are handled as on-off switches in power control circuit. These devices are classified as follows.

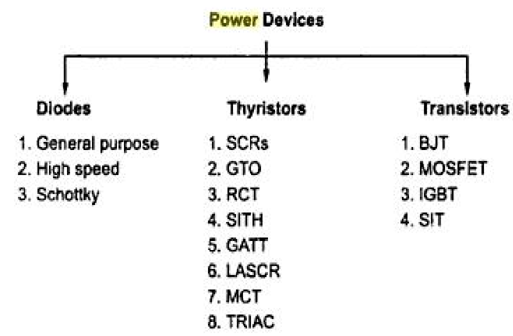

Fig.1: Structure of Power semiconductor devices

2.1. Power Diode

Silicon Power diodes are the replacement of Selenium rectifiers having significantly improved forward characteristics and voltage ratings. The minority carriers in the diodes require finite time - t_{rr} (reverse recovery time) to recombine with opposite charges and neutralize. Large values of Q_{rr} =(Q_1 + Q_2) - the charge to be dissipated as a negative current when the and diode turns off and t_{rr} (= t_2 - t_0) - the time it takes to regain its blocking features, impose capable current stresses on the controlled device in series. A 'snappy' type of recovery of the diode effects high di/dt voltages on all associated power device in the converter because of load or stray inductances available in the network.

2.2. Silicon Control Rectifier

The Silicon Controlled Rectifier is the most famous of the thyristor family of four layer regenerative devices. It is normally turned on by the application of a gate pulse when a forward bias voltage is available at the main terminals. However, being artistic or 'latching', it cannot be turned off via the gate terminals especially at the extremely high amplification factor of the gate.

2.3. MOSFET

The Power MOSFET technology has largely reached maturity and is the most famous device for SMPS, lighting ballast type of application where high switching frequencies are desired but operating voltages are low. Being a voltage fed, majority carrier device (resistive behavior) with a typically rectangular Safe Operating Area, it can be conveniently utilized. Utilizing shared manufacturing processes, comparative costs of MOSFETs are low. For low frequency applications, where the currents drawn by the similar capacitances across its terminals are small, it can also be forced directly by integrated circuits. These capacitances are the main hindrance to operating the MOSFETS at speeds of several MHz. The resistive characteristics of its main terminals allow easy paralleling externally also. At high current low voltage applications the MOSFET offers best conduction voltage specifications as the $R_{DS(ON)}$ specification is current rating dependent. However, the lesser features of the inherent anti-parallel diode and its higher conduction losses at power frequencies and voltage levels limited its wider application.

2.4. THE IGBT

It is a voltage controlled four-layer device with the benefits of the MOSFET driver and the Bipolar Main terminal. IGBTs can be classified as punch-through (PT) and non-punch-through (NPT) structures. In the punch-through IGBT, a superior trade-off between the forward voltage drop and turn-off time can be achieved. Punch-through IGBTs are available up to about 1200 V. NPT IGBTs of up to about 4 KV have been exposed in literature and they are more robust than PT IGBTs particularly under short circuit conditions. However they have a higher forward voltage drop than the PT IGBTs. Its switching times can be controlled by suitably shaping the drive signal.

3. BASE/GATE DRIVE CIRCUIT

All discrete controlled devices, regenerative have three terminals. Out of them two are the Main Terminals. One of the Main Terminals and the third form the Control Terminal. The amplification factors of all the devices (barring the now practically obsolete BJT) are quite high, though turn-on gain is not equal to turn-off gain. The drive circuit is required to amuse the control terminal characteristics to efficiently turn-on each of the devices of the converter, turn them off, if possible, again optimally and also to protect the device against faults, mostly over-currents. Being driven by a common controller, the drives must also be separated from each other as the potentials of the Main Terminal which doubles as a Control terminal are different at various locations of the converter. Gate-turn-off-able devices require precise gate drive waveform for optimal switching. This necessitates a wave-shaping amplifier. This amplifier is located after the isolation stage. Thus separate isolated power supplies are also required for each Power device in the converter (the ones having a common Control Terminal - say the Emitter in an IGBT - may require a few less). There are functionally two types of isolators: the pulse transformer which can transmit after isolation, in a multi - device converter, both the un-shaped signal and power and optical isolators which transmit only the signal. The former is acceptable for a SCR without isolated power supplies at the secondary. The latter is a must for practically all other devices.

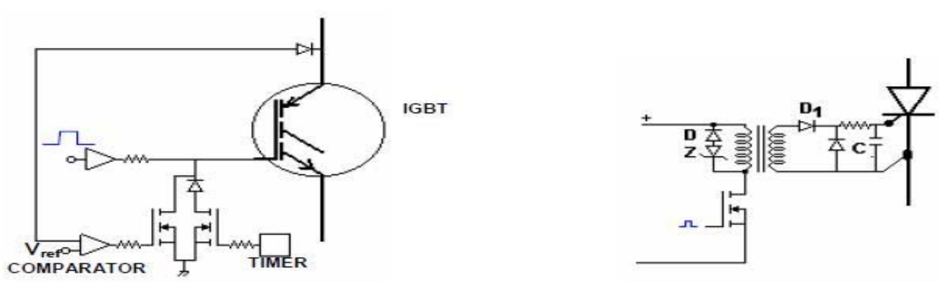

Fig.2: Simple gate-drive and protection circuit for a stand-alone IGBT and a SCR

4. POWER CONVERTER TOPOLOGIES and CHARACTERISTICS

A Power Electronic Converter processes the available form to another having a different frequency and/or voltage magnitude. There can be four basic types of converters depending upon the function performed.

4.1. STATIC CHARACTERIZATION

The transfer characteristics at various V_{CE}/V_{DS} using 10 Ω gate resistance at the junction temperature of 125 °C. Solid lines with square symbols show IGBT characteristics (I_C vs V_{GE}) and dashed lines with "x" symbols show

MOSFET characteristics (I_D vs V_{GS}). Figure 7 shows the output characteristics at various gate bias using 10 Ω gate resistance at the junction temperature of 125 °C.

4.2. DYNAMIC CHARACTERIZATION

The dynamic characteristics of the simulated IGBT are shown in Figures 8 and 9. In particular in Figure 8 we have highlighted the turn-on behavior, while in Figure 9 the turn-off behavior is highlighted. Top graphs present the driving voltage as dashed line and V_{GE} as solid line. In middle graphs collector current is shown and bottom graphs present the V_{CE}. The driving pulse had 2 μs pulse and a 4 μs period at the junction temperature of 125 °C.

5. CONCLUSION

Thus we have studied some power electronics devices like DC to Dc Converter, DC to AC converter, AC to AC converter and AC-AC Converter. Electronics compromise with the study of solid state semiconductor power devices and circuits for Power conversion to meet the desired control objectives (to command the output voltage and output power). 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. 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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