

# Power electronics assignment



Power Electronic Controllers \* The control and conversion of electric power is performed with the help of power electronic controllers \* Power electronic system consists of controllers The power electronic controllers are also called as power electronic converters Advantages \* Fast dynamic response due to static devices \* High efficiency of conversion \* Compact size and light weight of the controllers \* Increased operating life and reduced maintenance \* Highly flexible-PECC uses digital or microprocessor based controls electromagnetic interference and acoustic noise is reduced.

Disadvantages \* The \* PECC generate harmonics, these affect the performance of other loads \* The power factor of some power electronic controllers is very low. Hence power factor correction is necessary to reduce reactive power \* Power electronic converters are costly for the simple requirements The Four Main Forms of Conversion Example \* Conversion of electric power Other names for electric power converter: -Power converter - Converter -Switching converter -Power electronic converter -Power electronic converter The electric energy in one form is given at the input

Example is AC to DC conversion Power Electronic Systems \* Assembly of components that are connected together to form a functioning machine or an operational procedure. Assembles next general building blocks: \* AC/DC Converters- rectifiers that transform AC to dc with adjustment of voltage and current \* DC/AC converters- inverters that produce AC of controllable magnitude and frequency particular with galvanic isolation via a transformer AC/AC converters- AC frequency, phase, magnitude and power converters, both without and with an intermediary dc link \* DC/DC converters- linear

regulators ND switching choppers Generic structure of a power electronic system \* The power source can be AC mains, generator or batteries.

The power controller converts the input power which is suitable for the load \*

The sensing and feedback circuits monitor the load conditions \* The control unit consists of drive circuits of the power controller. The drives of the switches are adjusted according to feedback and the reference settings \*

The control unit adjusts the drives whenever there is difference between feedback (actual) speed and reference speed. The control unit also accepts commands from the user. These commands are given for the proper functioning of the power electronic system and the load.

History \* 1882- French physicist J. Jasmine discovered a phenomenon of semiconductor and proposed this effect used for AC rectifying \* 1892- German researcher L. Aaron invented the first mercury arc vacuum valve \* 1901- P. C. Hewitt developed the first valve in 1901 in USA and he also patented the mercury rectifier \* 1906-John Ambrose Fleming Position and Significance in the Human Society of Power Electronics \* Electric power is used in almost every part and everywhere of modern human society.

Electric power is the major form of energy source used in modern human society. \* The objective of power electronics is right on how to use electric power, and how to use it effectively and efficiently, and how to improve the quality and utilization of electric power. \* Power electronics and information electronics make two poles of modern technology and human society: information electronics is the brain, and power electronics is the muscle.

Areas of Application of Power Electronics Areas of Application of Power Electronics High frequency power conversion Power Transmission HAVE - DC/DC, inverters Low frequency power conversion - HAVE Power quality - Power factor - Line rectifiers Distributed power - Harmonic reduction Power devices Passive filtering Active filtering Applications \* Heating and lighting control \* Induction heating \* Uninterruptible power supplies (UPS) \* Fluorescent lamp ballasts: Passive; Active \* Electric power transmission \* Automotive electronics \* Electronic ignitions \* Motor drives \* Battery chargers \* Alternators \* Energy storage \* Electric vehicles \* Alternative power sources: Solar; Wind; Fuel Cells And more! Industrial applications Motor drives Electrolysis Electroplating Induction heating Welding Arc furnaces and ovens Lighting \* Other Applications Nuclear reactor control Power systems for particle accelerators Environmental engineering \* Trends \* It is estimated that in developed countries now 60% of the electric energy goes through some kind of power electronics converters before it is finally used. Power electronics has been making major contributions to -better performance of power supplies and better control of electric equipment - energy saving -environment protection Reduction of energy consumption leads to less pollution \* Reduction of pollution produced by power converters \* Direct applications to environment protection technology Power Electronic Devices Comparative diagram of power ratings and switching speeds of semiconductor electronic devices Theorists \* Another name: SCAR?? silicon controlled rectifier \* Theorists Opened the power electronics era -1956, invention, Bell Laboratories -1957, development of the 1st product, GE - 1958, 1st commercialese product, GE -Theorists replaced vacuum devices in almost every power processing area. \* 4- rarer, 3-Junction pan device \* Has 3

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terminals: anode, cathode and gate \* Turn ON: applying a short pulse across the gate and cathode, once turn on, the gate loses its control to turn off the device \* Turn OFF: applying a reverse voltage across the anode and cathode  
Still in use in high power situation. Thyristors still has the highest power-handling capability.

Two Classifications of Thyristors \* Converter grade thyristors \* Slow type and are used in natural commutation(or phase controlled) applications \* Inverter grade thyristors \* Used in forced commutation applications  
b Appearance and symbol of thyristors Structure and equivalent circuit of thyristors \* Other methods to trigger thyristors ON \* High voltage across anode and cathode?? avalanche breakdown rate of anode voltage \* High Junction temperature \* Light activation \* Static characteristics of thyristors \* High rising \* Blocking when reverse biased, no matter if there is gate current applied. \* Conducting only when forward biased and there is triggering current applied to the gate. Once triggered on, will be latched on conducting even when the gate current is no longer applied. \* Physics of thyristors operation Unilateral Switching Devices \* Shockley Diode Invented by William Shockley \* A two-terminal four-layer thyristors diode thyristors. \* Can be turned ON through the application of sufficient voltage between anode and cathode \* Can be turned off through the reduction of the applied voltage to a much lower point where there is too little current to maintain transistor bias Shockley Diode: Basic Operation \* If a positive voltage is applied from anode-to-cathode; Junctions 1 & 3 will be forward biased and Junction 2 will be reversed biased.

Thus, the two transistors  $I_Q$  &  $S_Q$  will be operating on the active region. \* At low values of bias voltages, the two transistors are barely forward biased,

therefore very little current flows. \* OFF State. If the bias voltage applied is very low, transistor currents are also very low, thus,  $\alpha$ 's will also be very low. With this,  $r_{AK}$  will be very small (usually in  $\Omega$ ) and the resistance will be very high. (usually in  $M\Omega$ ). \* ON State. If the bias voltage applied is increased,  $\alpha$ 's also increases until their sum becomes equal to 1. With this the diode current is maximum (both transistors are saturated) and its resistance will be very low (approximately  $0\Omega$ ).

Ways of Increasing dc \* increasing device temperature increasing the bias voltage \* incident light energy \* Important Parameters and Specifications: \* Forward Breaker (or Switching) Voltage [ $V_s$  or  $V_{ERB}$ ] - the voltage at which the Shockley diode enters the forward conduction region. \* Switching Current [ $I_s$ ] - the value of diode current at which switching occurs. \* Holding Current [ $I_H$ ] - the current needed to hold the diode on, or the current below which the Shockley diode switches from forward conduction region to forward blocking region. \* Special terms applied to Shockley diode: \* Latch \* Breaker \* Critical rate of voltage rise \* Characteristic Curve . Over-voltage Indicator. The Shockley diode is used to protect the sensitive load from possible damage due to excessive voltage.

2. Relaxation Oscillator Operation: 1.

Capacitor is initially uncharged, diode is OFF. 2. When the switch S is closed, diode still OFF, the capacitor will begin to charge to  $V_s$ . The voltage across the capacitor is given by: 3.  $V_C$  increases and reaches a value equal to  $V_s$ ; that is at  $t = T$ , the diode turns ON (short circuit). The capacitor discharges to the diode. 4. When the diode current falls below the holding current  $I_H$ , the diode turns OFF again and capacitor will again charge to  $V_s$ . 5. Sequence is repeated. Sharp positive pulse output that occurs a certain time delay

after the application of input voltage. The time delay will be essentially the capacitor charge-up time given by Equation 1. Summary \* Shockley diodes are 4-layer PAN semiconductor devices. They have as a pair of interconnected PAN and NP transistors. \* Shockley diodes tend to stay ON once they've been turned on and stay once they've been turned off \* There are two ways to latch a Shockley diode: exceed the anode-to cathode breaker voltage, or exceed the anode to cathode critical rate of voltage rise. There is only one way to cause a Shockley diode to stop conducting and that is to reduce the current going through it to a level below its low-current dropout threshold. Power Diodes \* They are mainly used as uncontrolled rectifiers to convert single-phase or three- phase AC voltage to DC. They are also used to provide a path for the current flow in inductive loads. \* Typical types of semiconductor materials used to construct diodes are silicon and germanium. \* Power diodes are usually constructed using silicon because silicon diodes can operate at higher current and at higher Junction temperatures than germanium diodes. Symbol and Structure \* PAN Junction \* The diode is constructed by joining together two pieces of semiconductor material?? a p-type and an n-type?? to form a pan-junction. \* When the anode terminal is positive with respect to the cathode terminal, the pan-junction becomes forward-biased and the diode conducts current with a relatively low voltage drop. When the cathode terminal is positive with respect to the anode terminal, the pan - junction becomes reverse-biased and the current flow is blocked \* The arrow on the diode symbol in shows the direction of conventional current flow when the diode inducts \* Examples of commercial power diodes Silicon Controlled Rectifier (SCAR) \* A four-layer (pan) device similar to the Shockley diode except that it has a third terminal

called gate. \* SCAR is a switching device for high voltage and current \* It's a four layer device with three terminals, anode, cathode, and gate. Operations. \* In off state, it act ideally as an open circuit between A and K, and high resistance. In on state it's act as short between A and K and small forward resistance. \* Some application are motor control, time delay, heater control, relay control and phase control. Operates on the principle of current conduction when the break over voltage is reached or gate triggering even though the break over voltage is not reached. \* SCAR Waveforms \* The popular terms used to describe how an SCAR is operating are conduction angle and firing delay angle. \* Conduction Angle is the number of degrees of an AC cycle during which the SCAR is turned ON. \* The firing delay angle is the number of degrees of an AC cycle that elapses before the SCAR is turned ON.

Equivalent Circuit \* When the gate current, ' G, is zero, the device acts as diode in the off state when he very high resistance between the anode and can be approximated by an open switch. \* When a positive pulse of current (trigger) is applied to the gate, both transistors turn on (the anode must be more positive than the cathode). \* Then, 182 turns on SQ, providing a path for BIB into the SQ collector, turning on IQ. \* The collector current of IQ provides additional base current for SQ so that SQ stays in conduction after the trigger pulse is removed from the gate. \* Through such regenerative action, SQ sustains the saturated conduction of IQ by providing a path for 181.

IQ, in turn, sustains the saturated conduction of SQ by providing 182. \* The device stays on (latches) once it is triggered on and the very low resistance



between the anode and cathode can be approximated by a closed switch. -

running the SCAR ON 1. Gate Triggering \* When  $V_G = 0$ ;  $V < V_{\text{VERB}}$ ; SCAR OFF \* When a pulse is applied at the gate;  $V_G > V_{\text{VERB}}$ , SCAR turns ON 2. Increasing the bias voltage \*  $V_S < V_{\text{VERB}}$ ; SCAR OFF \*  $V_S > V_{\text{VERB}}$ ; SCAR turns ON \* Like the 4-layer diode, an SCAR can also be turned on without gate triggering by increasing the anode-to-cathode voltage to a value exceeding the forward-breaker voltage. \* The forward-breaker voltage decreases as  $V_G$  is increased above 0 V. Eventually, a value of  $V_G$  is reached at which the SCAR turns on at a very low anode-to-cathode voltage. \* The gate current controls the value of forward breaker voltage required for turn-on. \* Although anode-to-cathode voltages in excess of the forward breaker voltage will not damage the device if current is limited, this situation should be avoided because the normal control of the SCAR is lost. \* The SCAR should normally be triggered on only with a pulse at the gate. -running the SCAR OFF 1 .

Anode Current Interruption . Series Switching (Figure 1. 7) b. Parallel Switching (Figure 1. 8) \* When  $V_G$  returns to 0 V after the trigger pulse is removed, the SCAR cannot turn off. \*  $I_A$  must drop below the value of  $I_H$  for it to turn off. 2.

By Forced Commutation \* Requires momentary forcing the current through the SCAR to flow in a direction opposite to the forward conduction so that the net forward current is reduced below the holding value. \* This method requires momentarily forcing current through the SCAR in the direction opposite to the forward conduction so that the net forward current is reduced below  $I_H$ . While SCAR is conducting, the switch is open. \* To turn off the SCAR, the switch is closed, placing the battery across the SCAR and

forcing current through it opposite to the forward current. (Typical turn-off times: few as to about 30 AS. ) Regions of Operation 1. Forward Conduction Region (FCC)- region that corresponds to the ON state of the SCAR where there is forward current from anode-to-cathode. 2.

Forward and Reverse Blocking Regions (FRR and RIB) - regions corresponding to the OFF condition of the SCAR where the forward current from anode-to-cathode is blocked. Characteristic Curve Important Parameters and Specifications 1. Forward Breaker Voltage (VERB) - voltage at which the SCAR enters the forward conduction region. 2. Holding Current (AH) - value of anode current below which the SCAR switches from forward conduction region to the forward blocking region. 3. Gate Trigger Current [voltage] (KIT, VGA)- value of gate current [voltage] needed to trigger the SCAR from forward blocking region to the forward conduction region under specified condition. 4.

Average Forward Current (FIVE) - maximum continuous DC anode current that the device can withstand in the conduction state under specified indentation. 5. Reverse Breakdown Voltage (BAD) - parameter that specifies the value of reverse voltage from cathode to anode at which the device breaks into the avalanche region and begins to conduct heavily. 6. Average Gate Power Dissipation (PAGAN) - maximum value of average power dissipated between gate and cathode. 7. Instantaneous " on" voltage (IF)- voltage drop between anode and cathode in " on" state at a given current level. Typical Packages \* Other types of transistors are found in the same or similar packages.

The Silicon-controlled Switch (CSS) \* Has similarities with the SCAR in terms of construction Has two gate terminals: a. Cathode gate b. Anode gate \* Can be turned on and off using either of the gate terminals in any of the following ways: \* 1. Reducing its anode current below  $I_H$  \* Can be turned OFF pulse at the anode gate (GA) \* Available in power ratings lower than those of the SCAR \* a four-terminal thyristor that has two gate terminals used to trigger the device on and off \* has schematic symbol and terminal identification as shown above Basic Operation \* Assuming  $I_Q$  and  $S_Q$  are off, the CSS is not conducting. \* A (+) pulse on GO drives  $S_Q$  into conduction, providing a path for  $I_Q$  base current.

When  $I_Q$  turns on, its ICC provides B for  $S_Q$ , sustaining the "on" state of the device. \* The CSS can also be activated with a (-) pulse on the GA. \* The said (-) pulse drives  $I_Q$  to conduct, providing B for  $S_Q$ . \*  $S_Q$  provides a path for  $I_Q$  base current, sustaining the "on" state. \* The CSS can be turned off by applying a (+) pulse to GA. \* This makes the B-E Junction of  $I_Q$  reverse-biased, thus turning  $I_Q$  off. \*  $S_Q$  cuts off and the CSS ceases conduction \* It can also be turned off by applying a (-) pulse on GO. \* The CSS typically has a faster turn-off time than the SCAR. \* Other Methods for Turning Off a CSS These are switching methods to reduce the  $I_A$  below  $I_H$ . The BSTJ acts as a switch. CSS Applications \* CSS and SCAR are used in similar applications. \* CSS has the advantage of faster turn-off with pulses on either gate terminals, but it is more limited in terms of maximum current and voltage ratings. \* CSS is sometimes used in digital applications: counters, registers, and timing circuits. Gate Turned-Off switch (GTO) \* Major difference from conventional thyristors: \* The gate and cathode structures are highly interdigitated, with

various types of geometric forms being used to layout the gates and cathodes. Physics of GOT operation \* The basic operation of GOT is the same as that of the conventional theorists.