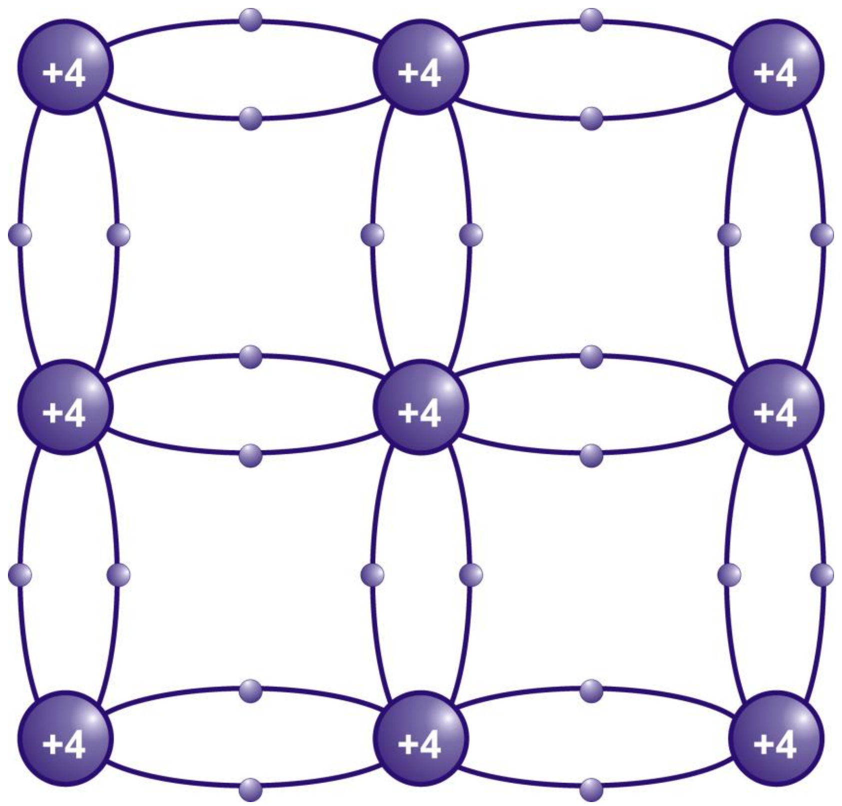
## A. Electronic Components

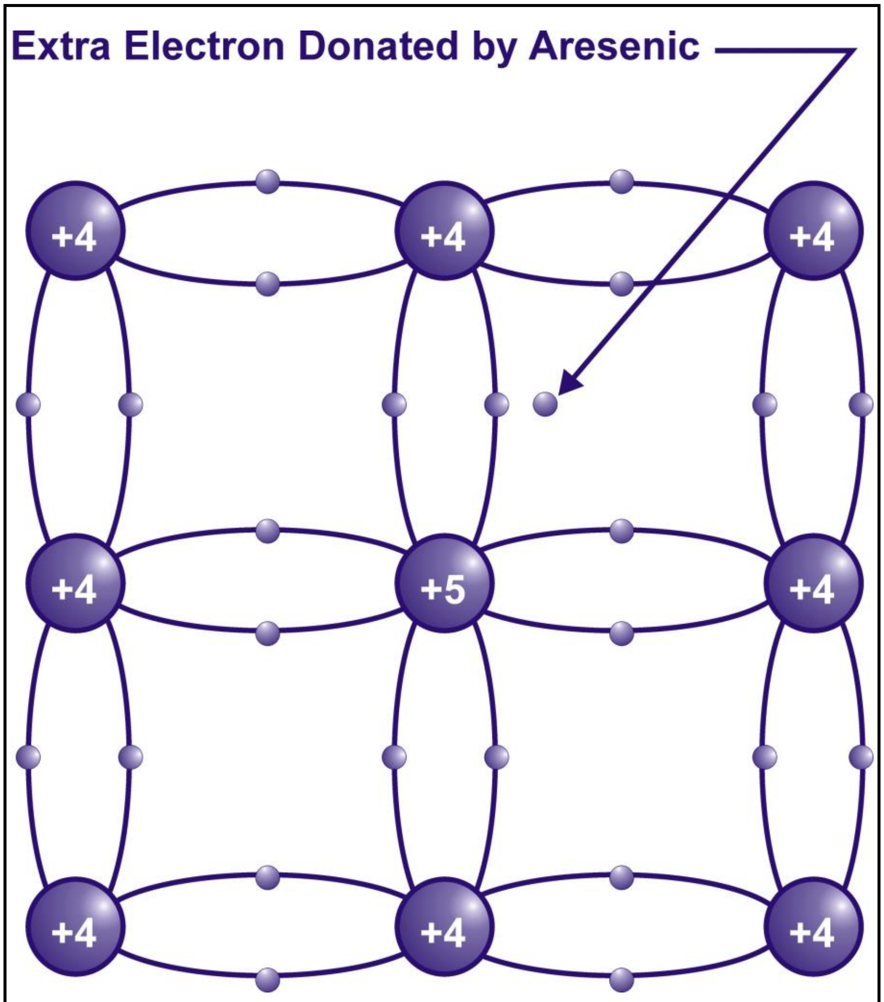
1. Semiconductors

   a. Another method of controlling current flow employs a material known as a semiconductor. In general, a semiconductor is a poor conductor of electricity unless impurities (mobile charge carriers) are added. This is called doping the material. These charge carriers can be positive or negative. Two common semiconductor materials are Germanium and Silicon. These materials will pass more current than an insulator but not as much as metal. They have 4 valence electrons in the outer shell that form a crystalline lattice (Picture 1). Each semiconductor atom shares one of its four outer electrons with neighboring atoms. This crystalline structure has no extra electrons or electron deficient atoms. (Recall that all atoms attempt to have a full outer shell of 8 electrons.) To free electrons to produce a current, high voltage would be required, but not as high as that required to produce free electrons in an insulator material.



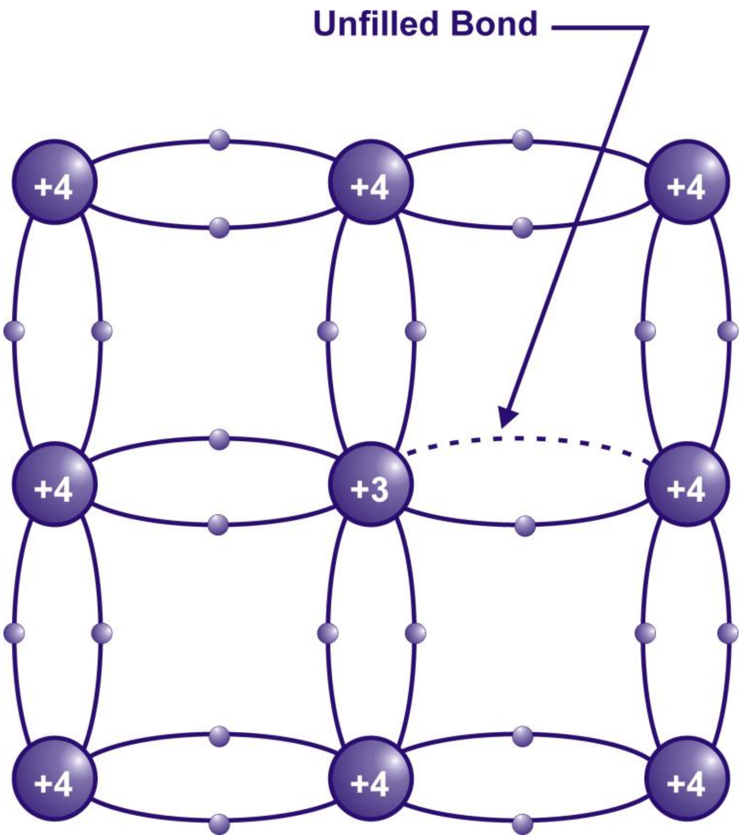

**Picture 1, Pure Semiconductor Lattice Structure**

b. By placing an impurity with five electrons in its outer shell (pentavalent material in the semiconductor material), the lattice structure has an "extra" electron in the structure (Picture 2). Voltage required to free this electron is much less than that required to free other bonded electrons. Common pentavalent elements used to dope semiconductor material are Antimony and Arsenic. Any semiconductor material doped with a pentavalent material is known as N-type material and is a source of free electrons.



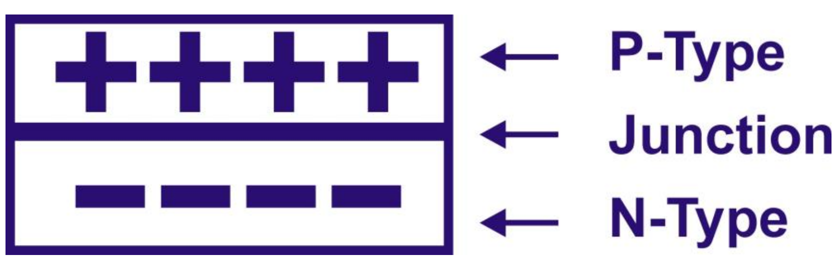

**Picture 2, N-Type Material**

c. By placing an impurity with three electrons in its outer shell (trivalent material), the lattice structure is deficient an electron (Picture 3). This causes a “hole” in the lattice structure. A semiconductor doped with a trivalent material is known as P-type material and readily accepts electrons to fill its holes. The holes appear to move opposite the direction of electron flow.



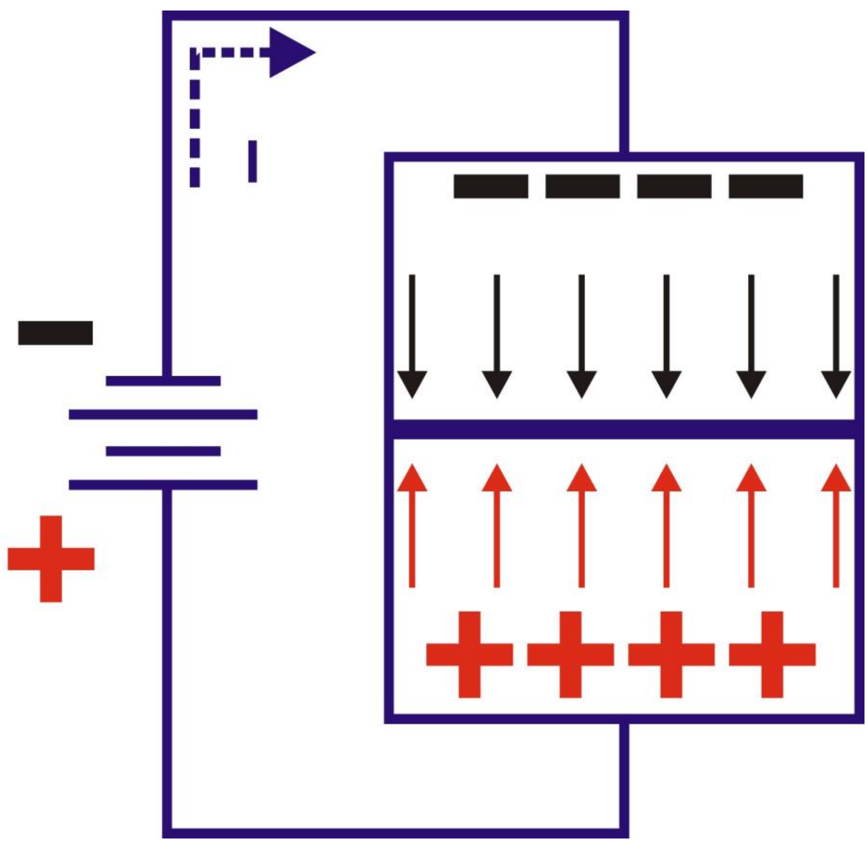
Picture 3, P-Type Material

d. By placing N-type and P-type material together (Picture 7), these characteristics can be exploited. As might be expected, when a positive (hole) and negative (electron) charge meet in a crystal, they combine and cease to exist as a mobile charge carrier. The area where N and P material meet is called a junction.



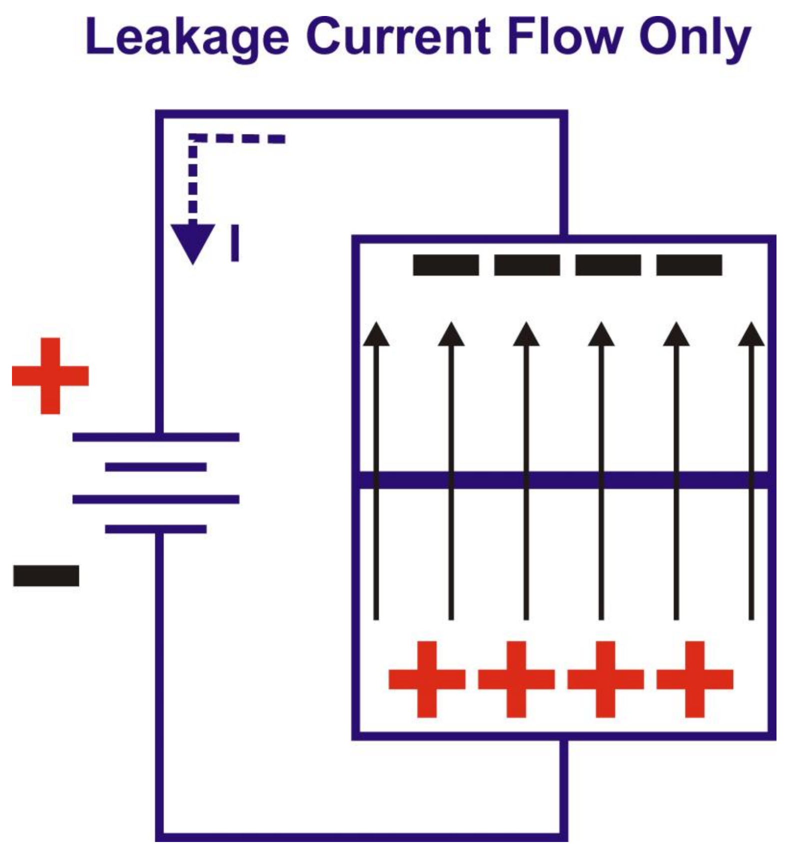
Picture 4, P-N Junction

e. By applying a negative voltage to N-type material (Picture 5), electrons will be pushed toward the junction by the negative battery voltage. The electrons and holes combine at the junction. Electrons constantly enter the crystal structure at the N-terminal to replenish electrons already combined with holes, and electrons leave the P-terminal to replenish the hole supply of the P-type portion of the crystal. This is a forward Biased P-N junction. The forward biased P-N junction offers little resistance to the current.



**Picture 5, Forward Biased P-N Junction**

f. By reversing polarity of the battery (Picture 6), connecting the P-type material to a negative voltage and N-type to positive voltage, the positive holes and negative electrons are drawn away from the junction. This leaves the section of crystal near the junction almost void of charge carriers (electrons and holes) and it blocks current. This condition is called reverse biased. A few random charge carriers do remain in the junction area allowing a minute current to pass. This current is known as leakage current and is usually a few microamperes.

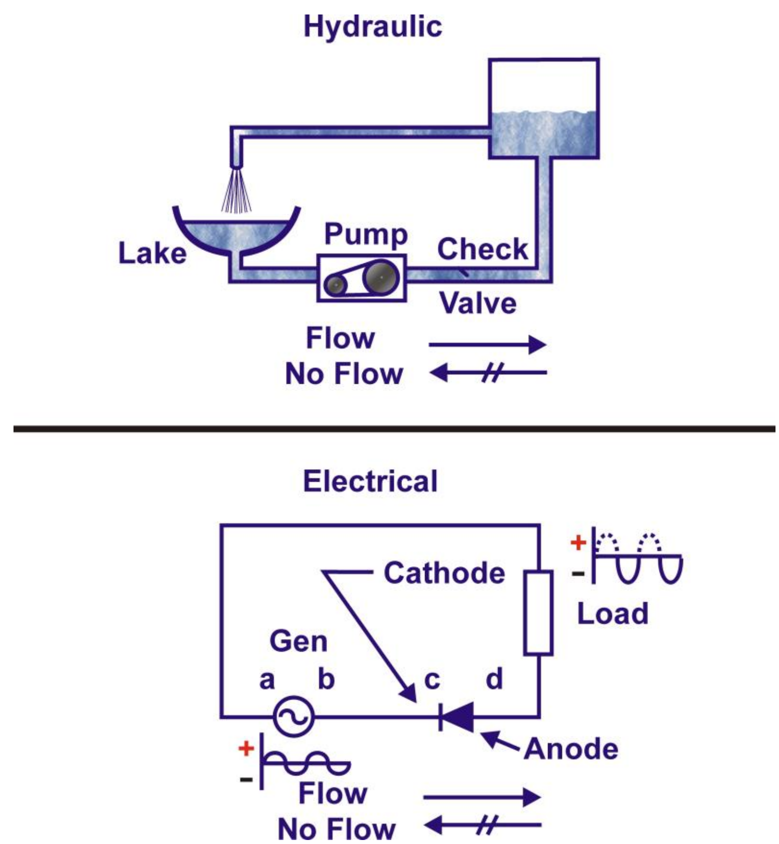



**Picture 6, Reversed Biased P-N Junction**

a) Simple P-N junction semiconductors (two active crystals) are called diodes. Semiconductor devices with two junctions (three active crystals) are called transistors and can be used, as was the triode vacuum tube, to control current flow. Some advantages of semiconductor devices over vacuum tubes are they usually cost less, take up less space, radiate less heat, and are more reliable.

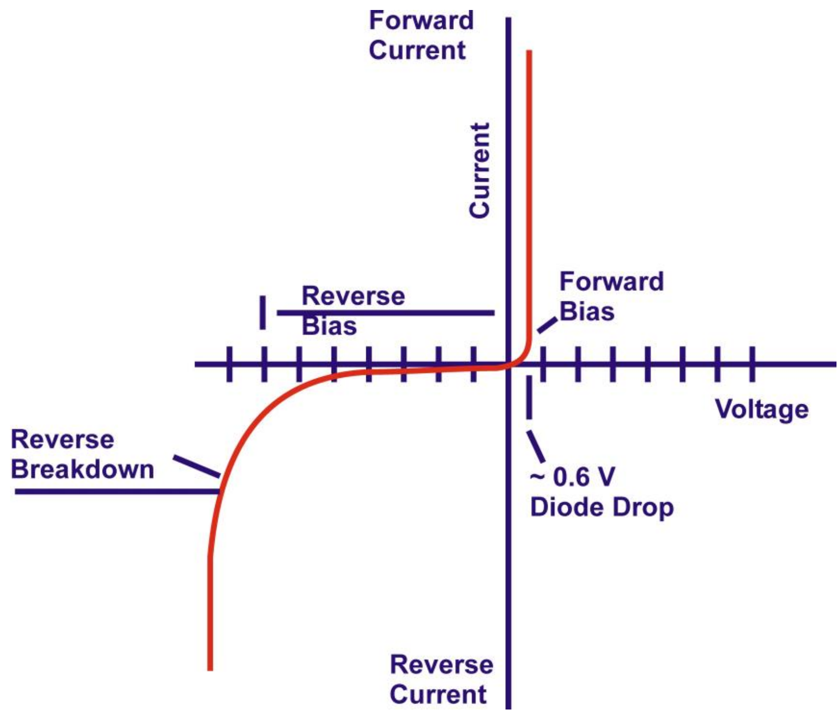
2. Semiconductor Diodes

a. Because this is the most common type of diode an operator will encounter, they will be called diodes for the rest of this text. Diodes resemble check valves in a piping system (Picture 7). In the hydraulic analogy, pump discharge pressure causes the check valve to open and water flows from pump to storage tank. If the pump discharge pressure should become lower than tank pressure the valve will shut and water flow stops. The action of the diode in the electric circuit is similar. When generator voltage is in the direction to cause current flow, cathode to the anode of the diode, (c to d), the diode conducts and current flows in the load. Current continues as long as voltage at generator terminal b is negative. When the generator voltage drops to zero to begin its alternation, the diode blocks any reverse current, as the check valve shuts when water pressure is reversed. Therefore, voltage drop across the load is in pulses and always of the same polarity.




**Picture 7, Analogy Between a Check Valve and a Diode**

b. It is quite satisfactory to consider the diode as a check valve, although it is more. Consider the characteristic volt-ampere curve for a diode (Picture 8).



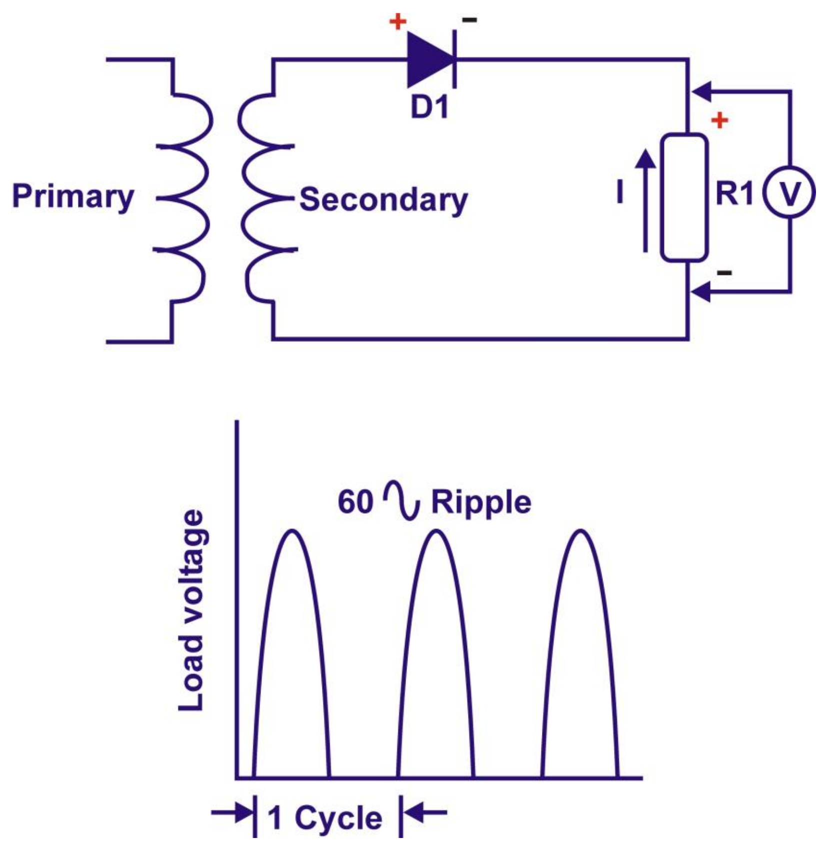

**Picture 8, Diode Characteristics**

c. When the voltage applied across the diode is of correct polarity, the diode allows current to flow. This is forward biasing the diode and allows full current conduction with a minimum voltage drop across the diode (a forward biased diode offers little resistance to current). If voltage is reversed, the diode becomes reverse biased. Very little reverse current is allowed when a diode is reverse biased. If reverse voltage becomes excessive, a point called reverse breakdown is reached. At this point the diode shorts out and is ruined.

3. Rectifiers

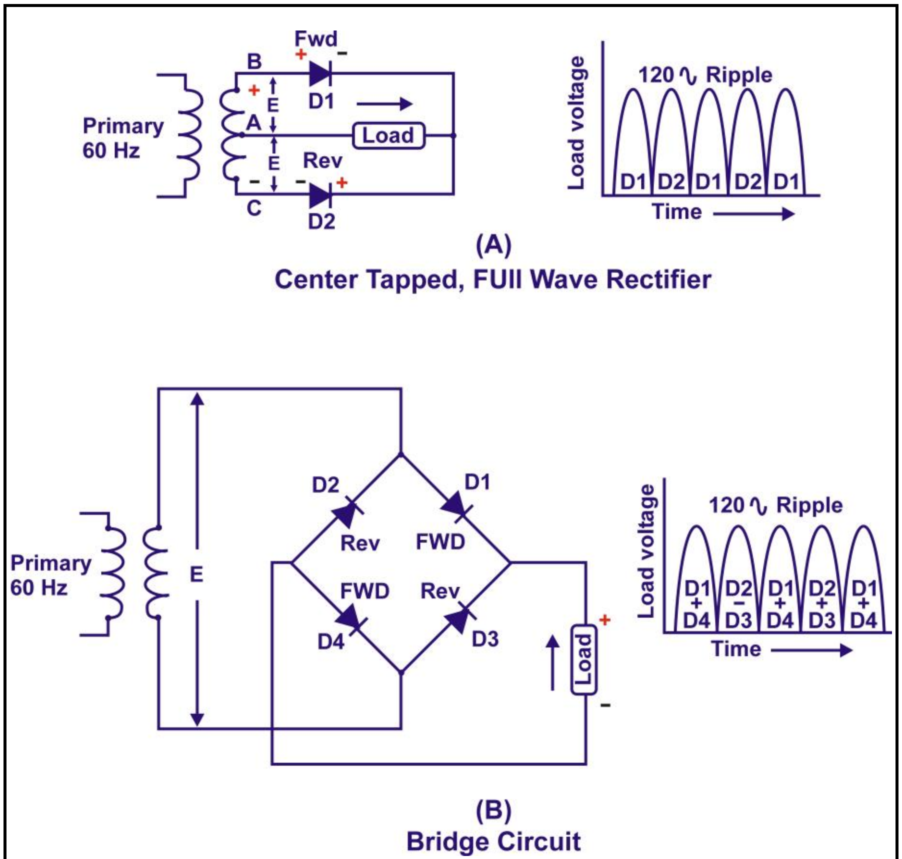
a. Previous chapters have mentioned devices called rectifiers that convert AC to DC. A rectifier is a combination of diodes connected to convert the AC to a pulsating DC.

b. In a half-wave rectifier (Picture 9), the diode rectifies AC voltage giving a pulsating DC voltage to the load with periods of zero voltage. Periods of zero voltage occur because the diode is reverse biased, preventing reverse current flow, and is therefore dropping full reverse voltage across itself. Voltage across the load is pulsating in one direction and considered a DC voltage with a 60 cycle ripple. By employing a filter circuit, ripple can be minimized to an extent but voltage will never be very steady. Note that the transformer could be any other type of AC voltage source.



**Picture 9, Simple Half-Wave Rectifier**

c. To overcome periods of zero voltage, a full-wave rectifier is used. The full-wave rectifier takes an AC signal and passes both positive and negative voltage alternations so that the pulses through the load are of the same polarity. Picture 10 shows two types of full-wave rectifiers.




**Picture 10, Full-Wave Rectifier**

d. For the center tap full-wave rectifier, the AC source must be a transformer (need a center tap). In the illustration, current flow is from center tap of the secondary winding (point A) through the load, diode D1, and back to the secondary of the transformer. Diode D2 is reversed biased and prevents current through the lower half of the circuit. When the polarity of the transformer reverses, current flow is from point A, through the load in the same direction as before, through forward biased D2 and back to the transformer. Notice that at the same time, diode D1 is reversed biased. The load sees a voltage pulse for each half of the AC sine wave.

e. Any AC source can be used with a full-wave bridge rectifier. For the first half cycle, current flows through D4, the load, D1, and back to the AC source. When source voltage reverses, current flows form the source, through D2, the load, D3, and back to the source. Once again, current flow through the load is always in the same direction. This appears as direct current with pulses 120 times a second. Therefore, a full-wave rectifier can be used to convert alternating current into direct current.

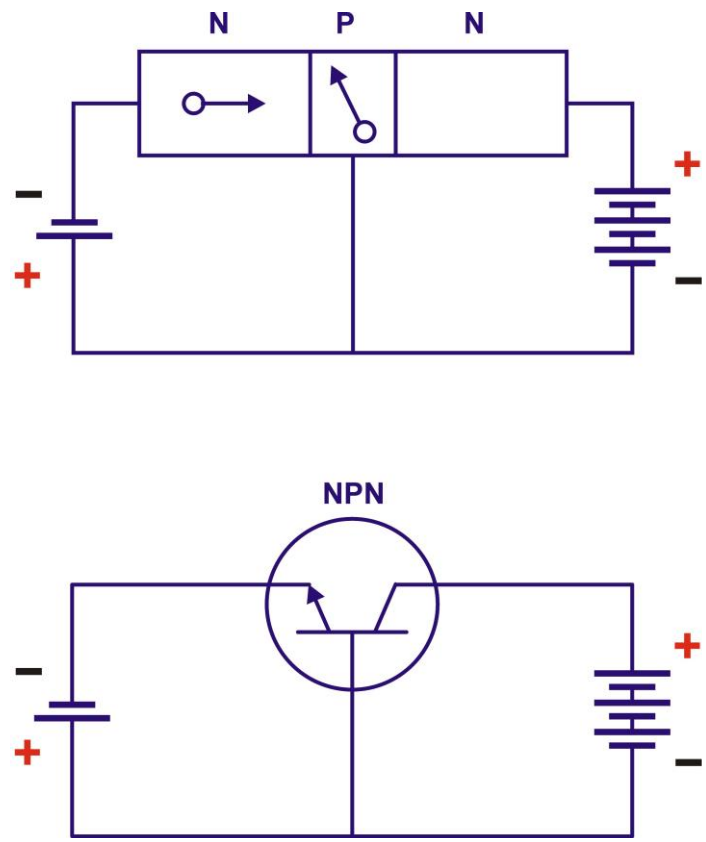
f. The advantage of the full-wave rectifier compared to the half-wave rectifier is that ripple is much easier to filter as constant DC across the load. A full-wave rectifier of high power capacity diodes is commonly used in excitation systems for large generators. It can also be found in AC battery chargers and high voltage power suppliers.

4. Transistors

a. It has been shown that semiconductors are capable of rectifying current. This is accomplished by a single junction crystal. With a second junction forming a P-N-P or N-P-N sandwich, the device is capable of amplification and is a transistor.

b. A transistor is comparable to the triode tube. The center material is very thin and is called the base (B). It controls the current in the transistor. As the grid in a triode, base current is of a relatively small value when compared to the total current of the transistor. The emitter (E) is heavily doped to supply charge carriers (holes if P material and electrons if N material the same as the cathode in an electron tube.) The collector (C) collects the charge carriers that pass through the base from the emitter the same as the anode in an electron tube.

c. For a closer look at the way a transistor works, consider the NPN circuit (Picture 11).

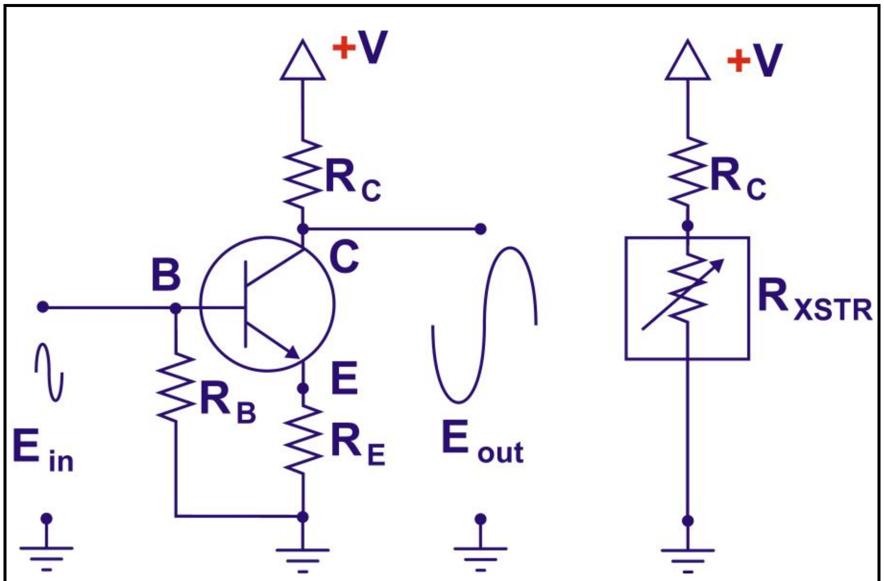



**Picture 11, NPN Transistor Operation**

d. Here the emitter-junction will pass current easily, because it is forward biased. The collector-base junction is always reverse biased. However, the collector voltage attracts the charges that pass through the base from the emitter. Because the base is very thin, most charge carriers that pass through the emitter-base junction make it to the collector. As long as a forward bias emitter-base voltage remains, current will flow from the emitter to the collector. If the base current is increased, more current will flow across the emitter-base junction and get to the collector. Thus, a relatively large emitter to collector current is controlled by a small emitter to base voltage. The electrons that enter the base but do not reach the collector, combine with holes in the base and contribute to base current, reducing the gain (amplification) of the transistor. To reduce base current, the base is kept as thin as possible, usually less than a thousandths of an inch. In a forward Biased Transistor Circuit, base current is usually less than 5% of total current through the transistor.

e. Because very little voltage (0.2 to 0.6 volts) is needed to forward bias the emitter-base junction, input power is very low. The collector output voltage can be quite high (e.g., 50 volts) with collector current almost equal to emitter current. Therefore, a relatively large amount of power can be controlled in an external load as the power gain of the transistor (power out/power in) is very high. Transistors are used in electronic control and monitoring devices such as nuclear instruments, reactor water level control, and turbine speed control circuitry.

f. The simple transistor amplifier shown in Picture 12 is an example of a Common Emitter (CE) configuration. The input to the amplifier is applied to the base which controls the forward biasing of the transistor. The output of the transistor is taken from the collector to ground. As the voltage on the base goes more positive, current flow through the transistor increases thereby increasing the voltage drop across the collector resistor ($R_c$). Because the voltage across $R_c$ increases with increased current flow, the voltage from the collector to ground must decrease (Kirchhoff's Voltage Law). In order for the voltage to decrease across the transistor with increased current through the component, resistance of that component (transistor) must decrease (Ohm's Law). Conversely as the voltage on the base decrease, the current through the transistor decrease, decreasing the voltage across $R_c$ and increasing the voltage from collector to ground. Using these analogies, it can be seen that the transistor is simply a variable resistance whose value is dependent on the potential applied across the emitter base junction.



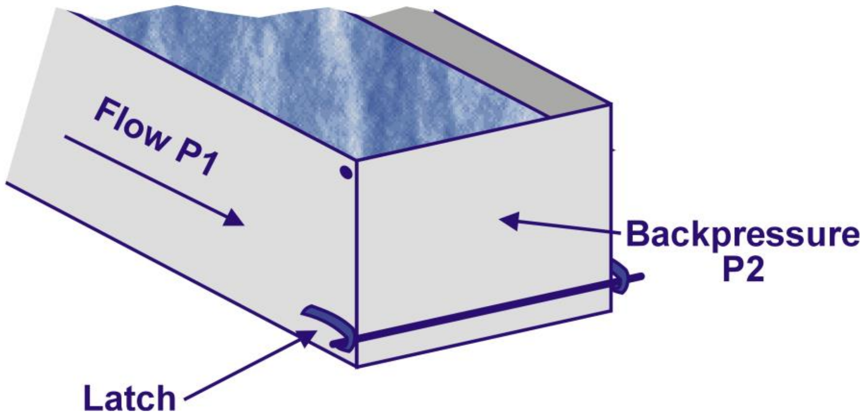

**Picture 12, Common Emitter Amplifier**

5. Integrated Circuits

   a. Many modern devices use integrated circuits. Transistors, resistors, diodes, and other circuit components are formed within one small piece of semiconductor material referred to as an IC chip and are encapsulated in various types of packages. Leads are connected to various circuit components transistors, diodes, resistors, capacitors, (etc). The advantage of integrated circuits is that the many electronic components of a circuit function in a single small chip which can be as small as ▫" in length.

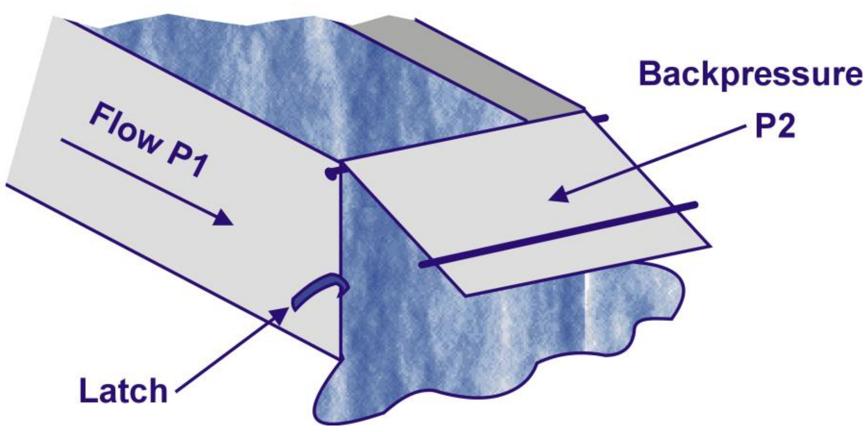
6. Silicon Controlled Rectifier

   a. A silicon controlled rectifier (SCR) or thyristor is a semiconductor diode (rectifier) whose output can be controlled by the use of a gate signal. Electrical operation of a SCR can be compared to a mechanical check valve with a holding latch (Picture 13).



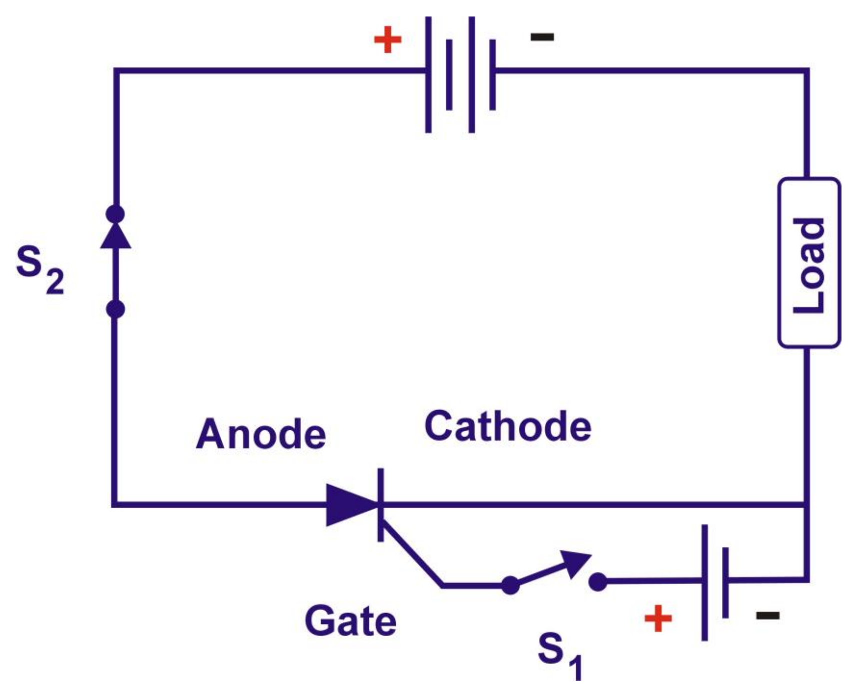

**Picture 13, Analogy of an Ungated SCR**

b. No matter how high the $P_1$ pressure gets (equivalent to forward biasing a diode), there will be no flow through the check valve until the valve is unlatched (by lifting the latch). This is equivalent to a gate signal sent to the SCR. Once started, flow will continue as long as $P^1$ pressure is greater than $P^2$ (Picture 14).




**Picture 14, Analogy of a Gated SCR**

c. In Picture 15, the ungated SCR blocks current in either direction white the voltage polarity attempts to forward bias the SCR. For an SCR, “lifting the latch” corresponds to a pulse of gate current caused by closing switch $S_1$. A pulse of gate current need only be microseconds in duration to “turn on” the SCR. Even if the gate signal is removed ($S_1$ opened) the SCR will remain forward biased and if the voltage across the SCR decreases to zero, or reverse biases, it stops conducting. Once stopped, forward bias plus a gating signal must be applied together to start conduction.



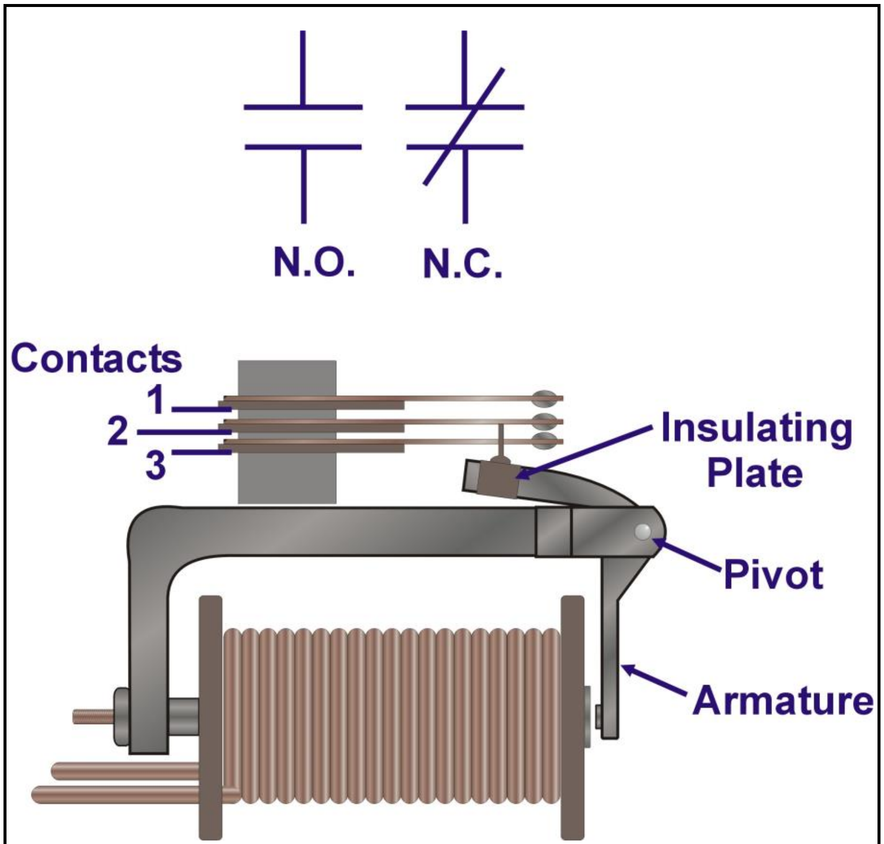
**Picture 15, Simple SCR Circuit**

## B. Electrical Components

1. Relays

   a. A relay is an electrical switching device with one or more contacts that open or close circuits. The switching device electromagnetically operates the contacts through a movable arm (called armature not to be confused with an armature in a motor or a generator). The armature is attracted when the electromagnet is energized and is released when it is de-energized. Relays can also be operated by means other than electromagnetic forces. For example, a house thermostat is a mechanical relay operated by the mechanical force created when a bimetallic strip (two pieces of dissimilar metal placed together) is heated or cooled. However, this section will concentrate on the electromagnetic device because of its wide use throughout the electrical industry.

   b. There are many complex variations in relay design. The function of a particular circuit will dictate the design. Fundamentally, however, they are all are based on the same principles. (Picture 16).




**Picture 16, Relay**

c. The relay has a coil of wire with an iron core and yoke which serves as an easy path for magnetic flux. The magnetic flux also passes through the armature to the core, attracting it to the core. To prevent the armature from sticking to the end of the core due to residual magnetism, a small separator stud made of non-magnetic material, usually brass, maintains a gap between them. Current for energizing the coil is supplied through "soldering lugs". In the relay shown, contacts (1-2) are normally opened when the coil is de-energized. When the relay is energized, the core attracts the armature, which presses the bottom contact (contact 2) up, closing the contacts 1 and 2, which allow current to flow through the external circuit. Several sets of contacts can be installed in a relay. These contacts are all simultaneously activated when the relay is energized. Contacts 1 and 3 (normally closed) open and 1 and 2 (normally open) close when the relay is energized. The relay number is usually displayed adjacent to the contact.

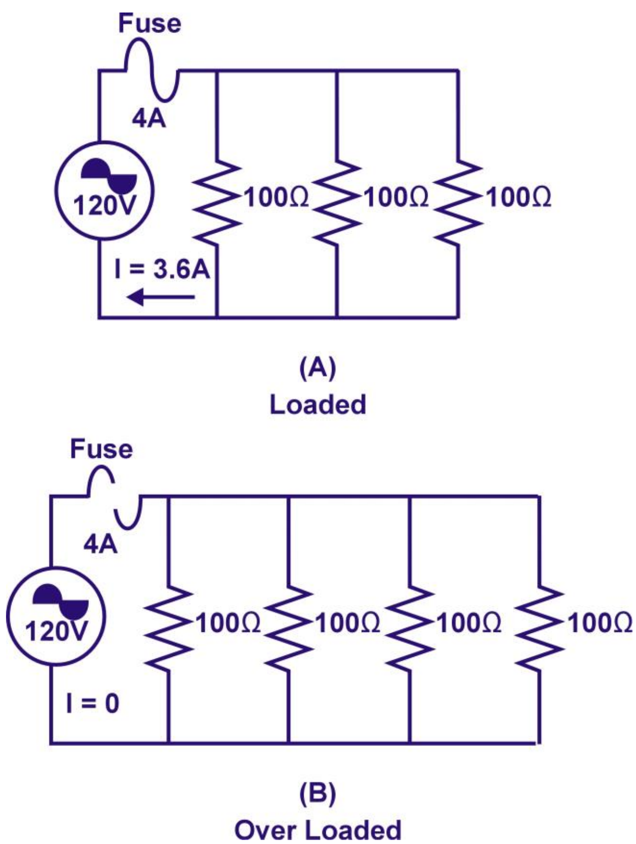
d. There are many uses for relays in a generating station. Their primary purpose is to act as an electrical switching device in a circuit. They can be found in generator protection systems, reactor protection systems, and many more systems at the plant.

2. Time Delay

a. Another type of relay which finds wide use in today's nuclear generating plant is the time delay relay. These relays delay the opening or closing of relay contacts in order to allow other prerequisite functions to occur. An oil dash pot is sometimes used to control the timing of a time delay relay. Agostat relays used widely in the plant are examples of relays of this type.

3. Fuses

a. If a short circuit develops, a large current flow can develop due to the resultant low resistance path (recall Ohm's law: $I = E/R$). This high current causes excessive heating in the circuit ($I^2R$ heating) and may result in a fire or damage to the circuit. A fuse is a simple, relatively inexpensive component, which can be placed in series with the circuit to protect it from over-current (Picture 17). The fuse is designed to open if current in the circuit becomes excessive. Excessive current could be due to either a short circuit or excessive circuit load demands. Since the fuse is in series with the circuit, an opened fuse creates an open circuit, thereby preventing current flow. If a fuse should blow (open), the circuit should be inspected for possible heat damage and short circuits. Because the rating of the fuse is based on the maximum current that the circuit can safely handle, a blown fuse should never be replaced with one of a larger rating (e.g., a 20 amp fuse should not be replaced with a 30 amp fuse).




**Picture 17, Fuse Operation**

b. In Picture 17A, the circuit current is 4.8 amps. A 5-amp fuse has been placed in the circuit, as circuit wiring has been designed to safely carry 5 amps. If an additional 100-ohm load is added in parallel to the circuit, total circuit current will rise to 6 amps. This is in excess of the 5-amp rating of the fuse and the fuse will blow (open) (Picture 17B). Now that the circuit is open, no current will flow. In other words, a low resistance will develop a very high total current and the fuse will blow, protecting the circuit.

c. Fuses come in many designs and ratings. The simplest kind of fuse is merely a length of thin wire which, in the event of excessive heating (excessive current), melts, opening the circuit.

d. To ensure a circuit is deenergized, simply removing the fuse (or fuses) will create an open circuit.

4. Circuit Breakers

a. A circuit breaker is another current interrupting device used to direct current and protect circuits from an overload. A circuit breaker consists of a set of contacts held closed by a mechanical latch. If an electromagnet or a thermal bimetallic strip generates enough force to unlatch the breaker, large tension springs rapidly force breaker contacts apart and the circuit is opened. For the operating mechanism, the breaker is initially shut by energizing the closing solenoid, which pushes upward, causing the operating linkage to be straightened out. Heavy springs are stretched (called charging springs) and the trip latch keeps the breaker closed. If too much current is sensed, the solenoid trip coil is energized. Its core plunger is pushed out of the solenoid, releasing the trigger. The large springs snap the circuit breaker contacts open, and the circuit is interrupted. Most breakers remain tripped after interrupting current (tripped free position). Some large circuit breakers, such as those used in the grid network, attempt to reclose and maintain power distribution. If the fault has not cleared, the breaker will trip and remain tripped.

b. Breaker contacts will either be normally open (a) as in the main breaker contacts, or may be normally closed (b) (used for indication, control functions, etc.). Breaker contacts are always shown in the de-energized condition. Contacts will show the appropriate breaker number in addition to the shut/ open indication.

c. When contacts of a switch or breaker separate with current through them, an arc develops. An electrical arc is the passing of electrical current through an air gap between partially separated contacts. Air at room temperature is a good insulator and will withstand very high voltages without permitting the passage of current. However, when air is heated to a few thousand degrees, air molecules become highly agitated and electrons from these atoms are more easily freed. When contacts of a breaker first separate, only a thin layer of cool air exists between the contacts. Voltage between the contacts is enough to overcome resistance of the thin layer of air and current will start to flow (arc). Current heats air between the contacts to extreme temperatures (9000 to 45,000°F in some high power breakers). This lowers resistance and allows current to continue across the gap between contacts. Eventually the contacts move so far apart that air resistance becomes to great to sustain the arc. The arc goes out and the circuit is broken (open).

d. To interrupt a DC circuit successfully, the circuit breaker must open far enough that voltage required to maintain the arc is greater than voltage existing between the open contacts.

e. Interruption of an AC circuit does not always happen the same way. In a purely resistive AC circuit, current and voltage are in phase. Therefore, the arc will quickly be interrupted when voltage passes through zero. The gap between breakers must be large enough in the next alternation to prevent reestablishment of the arc. However, most AC loads are both resistive and inductive. Interrupting a reactive load presents a greater problem because voltage and current are out of phase, because current lags voltage by some degree. Current continues to flow during the time that applied voltage passes through zero. When current finally passes through zero, applied voltage will again exist. This continues the arc. This process is referred to as inductive kick and is caused by collapsing magnetic fields generating a voltage. Therefore, contacts in the circuit breaker must open further and faster to overcome the arc.

f. Many circuit breaker are designed to extinguish the arc. The air circuit breaker (ACB) simply relies upon the air between contacts to extinguish the arc and open up the circuit. They are used extensively in low and medium voltage applications, such as switchboards, switchgear groups and distribution panels. For medium voltage ACBs, a short blast of air is used to help extinguish the arc. Most circuit breakers that are used for high current or high voltage duty are oil circuit breakers (OCB). Oil circuit breaker contacts are submerged in oil and interrupt current under oil. Oil is a much better coolant and insulator than air. For very high power, gas circuit breakers (GCB) are used. The GCB is filled with pressurized sulphur hexaflouride gas (SF) This gas is a better coolant and insulator than either oil or air.

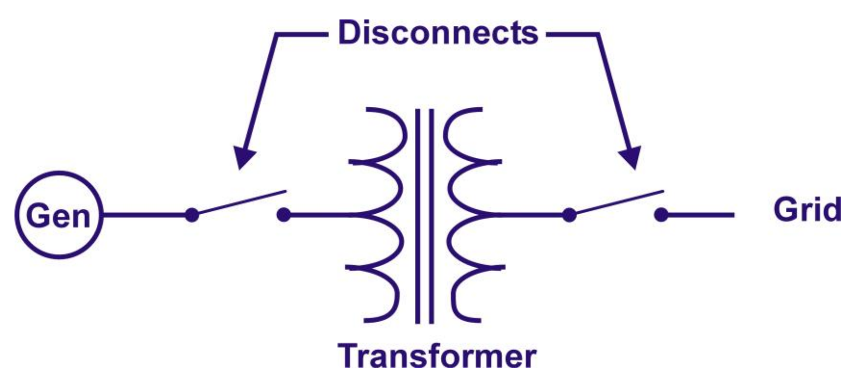
g. Undervoltage devices are also used on certain loads. Power requirements of a load remain the same regardless of the supply circuit's voltage condition. If supply voltage should drop, load will draw more current to fulfill its power demand. This increase in current may not be enough to trip the circuit. However, more current means more heat generation, which could lead to possible equipment damage.

h. Many larger electrical loads use the breaker undervoltage trips for another protective feature. If power to the breaker supply bus is interrupted, the loss of voltage is sensed and the under voltage trip coil trips the breaker open. This is done to prevent starting current surges when the bus is reenergized, if the load were still connected to the bus. If this were not done, the bus supply circuit breaker retrip immediately due to over current.

i. Large remotely operated breakers require an additional source of power to allow the breaker to cycle either on or off. This additional source of power is known as control power. Control power is usually supplied from a completely separate source than the power flowing through the main contacts. This is to ensure that the breaker can be opened or closed following a loss of main breaker power. Breaker control power is frequently supplied from the DC Bus since on a loss of all site AC, the station batteries will still be available.

5. Disconnects

a. A disconnect is a conductor that can be easily removed and replaced (Picture 18). The purpose of the disconnect is to provide an additional way of isolating equipment. Disconnects are not used to interrupt circuits. Operating action of a disconnect is quite slow when compared to a breaker. The arc that would be drawn between the contacts of a loaded disconnect could be quite large and hot, resulting in damage to equipment and possible injury to personnel. A typical use of a disconnect is to isolate equipment, such as a large transformer. This is done by installing one disconnect in series on either side of the equipment.




**Picture 18, Isolating a Transformer using Disconnects**

b. There are many types and designs of disconnects. A disconnect located indoors may be a section of hinged conductor that latches into place when closed. A knife switch is an example. Other disconnects require unbolting a section of the bus bar.

6. Circuit Switchers

a. Load breaking protective devices for outdoor use are called circuit switchers. They are similar to disconnects except they are motor operated and trip open automatically on overload. Substation transformers may have circuit switchers ahead of inputs. If a fault occurs downstream, the circuit switcher automatically opens the circuit in less than one second. A circuit breaker could do the job in a much shorter time (often in less than three cycles), but the slower circuit switcher usually provides adequate protection at far less cost. To aid in extinguishing an arc between switcher contacts, a short blast of nitrogen is commonly used. Some of the larger circuit switchers can be used to transfer switchyard distribution power.

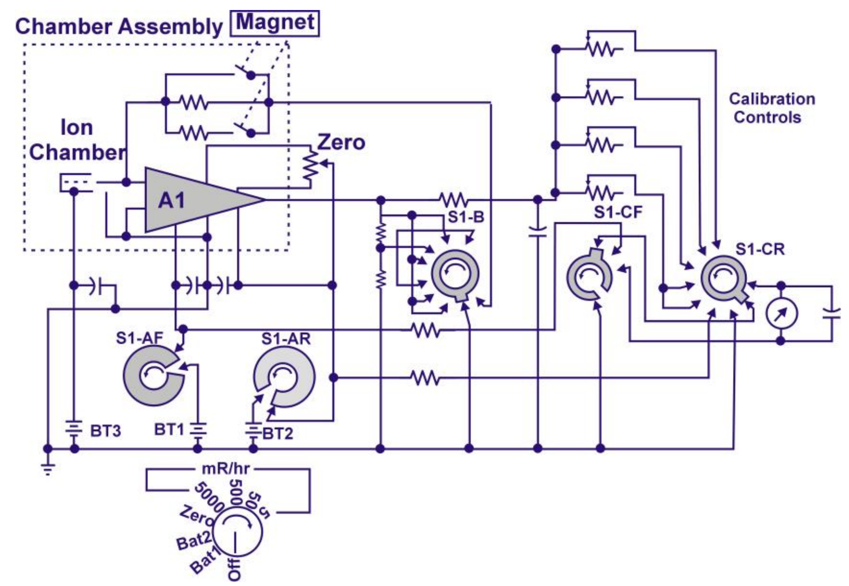
7. Switches

a. A switch enables the connection or separation of signals to various parts of the electrical or electronic circuits. A switch may be very simple in design containing only a single set of contacts, or may contain several levels (wafers) and switch positions to provide numerous single or concurrent functions. Picture 19 provides a simple schematic diagram of an instrument using rotary switches. This instrument employs 3 separate switches to enable testing and range switching of the instrument. Switch S1 is a three wafer (layer) switch with a total of 8 positions. The separate wafers S1A, S1B, and S1C all provide different functions dependent on switch position. A switch legend, located in the lower left corner of the diagram, describes the switch positioning. As the legend switch is rotated, the individual wafers will also rotate to enable different functions.

b. The functions provided by the S1AF (front) and S1AR (rear) are to connect the 2 Batteries BT-1 and BT-2 to the circuitry in all positions except the off position and to enable checking the condition of the batteries in the respective switch positions. Note that the rotations of wafer S1CR connects the meter to the appropriate battery source during the battery test functions. At the same time, wafer S1DF changes the reference point thereby changing the meter polarity when changing from BAT 1, a positive voltage to BAT 2, a negative voltage. An additional function of S1CR is to select the proper calibration resistor to be placed in series with the meter as the range of the instrument is selected.

c. The function of S1B is to change the feed back sent to the amplifier A1 as the range switch is rotated. Switches S2 and S3 are magnetically operated reed switches that are located in close proximity to the Range Switch, S1. They are operated by a magnet mechanically linked to the range switch.

# Electronic Components




**Picture 19, General Schematic**

## C. Motor Control Circuit

1. In the simple motor control circuit shown in Picture 20, operation of the motor is controlled by the positioning of a motor control switch. In addition, several overload and indication features are shown on the diagram. The switch legend included with the control diagram informs users of the condition of specific contacts associated with the control switch (42/CS). Contacts on the diagram designated by the letter "a" or "b, are auxiliary contacts providing indication.

2. With the control switch (42/CS) in the off position, the only path for current flow in the control circuit is through the green "not running" indicating light and the 42/b contact informing the operator that the motor is de-energized.

3. When the control switch (42/CS) is placed in the run position, switch contacts 42CS1-1C and 42CS 2-2C close allowing current to flow through the contactor holding coil. Energizing this holding coil shuts the three contacts found above the motor.

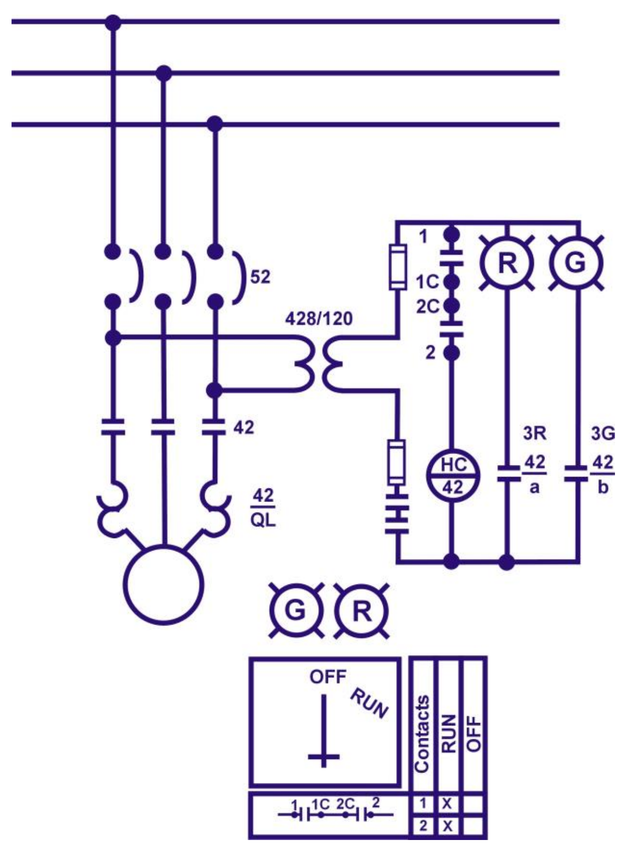
4. Power will then be supplied from the 3N 480V Bus to the motor. When the holding coil (42/HC) energizes, the 42/a contact shuts and the 42/b contact opens illuminating the red (running) light and extinguishing the green (not running) lamp.

5. Directly above the motor two motor overload devices (42/OL) are shown. These devices serve to deenergize the motor on a fault condition. Contacts in the control circuit ensure that the motor control circuit is de-energized if the motor overloads operate. Fuses in the motor control circuitry protects the supply from a fault generated in the control circuitry.

6. This type of motor, control circuit is known as a Low Voltage Release (LVR) and is designed to allow the holding coil to drop out on a loss of voltage supply or low voltage. When power is restored, the controller will

automatically reenergize, and the motor will restart.  This is accomplished by using a rotary contact snap switch in the motor control circuit.

7. On large motors, or where automatic restart of the motor is not desirable, an alternate type of motor controller is used.  This type of controller, called a Low Voltage Protect (LVP) controller, uses a momentary contact switch in either rotary or push button form to initially energize the motor.  When the holding coil is energized, it shuts a maintaining contact around the control switch.  Upon restoration of power each motor protected with this type of controller must be restarted by means of the control switch.



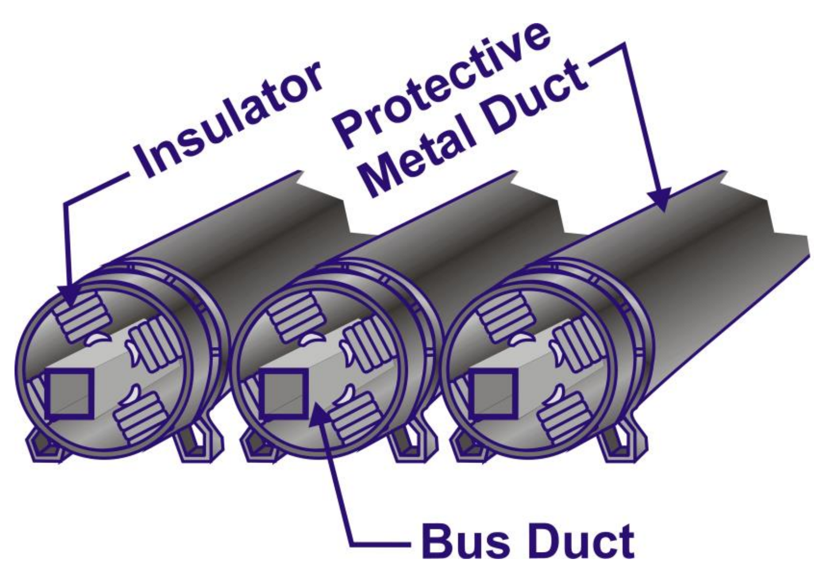

**Picture 20, Electrical Print for a Motor Controller**

## D. Bus Ducts and Buses

1. Definition of a Bus

   a. A bus is an orderly arrangement for connecting various circuits. It takes its name from the city bus which travels along the road picking up and discharging passengers at various points along a way. A bus can take a number of different forms.

   b. Isolated Phase Bus Duct. To conduct the large power output current of the main generator to its main transformer, a heavy, hollow (copper or aluminum) bus enclosed in a sheet metal pipe is used (Picture 21). This installation is called the main bus duct. There is a bus duct for each phase of the generator output. They are commonly referred to as isolated phase bus ducts. The copper or aluminum conductor (bus) is supported in the center of the metal pipe by heavy insulators. Normally, a smaller but similar bus duct branches off the main bus duct to supply the station's auxiliary (in-house) power transformer.



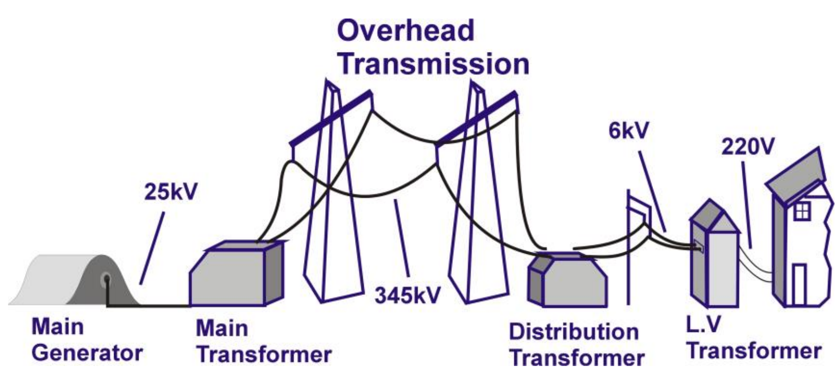

**Picture 21, Isolated Phase Bus Duct**

c. Because large currents are carried by this equipment, cooling air is forced through the bus ducts to remove heat produced by $I^2R$ losses. Also, large mechanical forces can occur during short circuit faults, so the bus must be well supported within the duct.

## E. Power Distribution

1. The Grid

a. The grid is a term used to describe the physical system used to generate and distribute electrical power. Many millions of watts are supplied to customer loads at any given second. The utility has an obligation to maintain a reliable source of power at proper voltage and frequency. The load dispatcher fulfills this obligation by determining the grid power requirements and ensuring the generating capacity matches that requirement. If a fault occurs on the grid, the load dispatcher and ground crews locate and isolate it while minimizing the power loss to that leg of the grid. A simplified diagram of a grid is illustrated in Picture 22.




**Picture 22, Simplified Grid System**

b. Station electrical loads are designated either safety related (essential) or non-safety related loads. Safety related loads are those required to minimize the consequences of an accident or those whose failure could result in a significant uncontrolled release of radioactivity to the environment. Safety related loads are supplied by the safety related electrical power boards that provide 4.16 KV power.

c. Various power and distribution panels are found in the plant. AC and DC boards supply power to the various electrical loads throughout the station. Typical power boards and their associated loads are shown below in the following table.

| Voltage | Supplied from: | Supplied to: | Typical Loads |
|---|---|---|---|
| AC Distribution | | | |
| 24/25 KV | Turbine | Generator Step-Up Transformer<br>4.16KV Transformer (U1)<br>13.8KV Transformer (U2) | 345 KV Grid<br>Station Loads<br>Station Loads |
| 115KV | Offsite | Reserve Stations Service Trnfrmrs | Station Loads |
| 13.8 KV (U2) | Normal Station Service Transformer<br>Reserve Station Service Transformer | NON-SAFETY RELATED<br>Normal Onsite AC Power System<br>Backup Onsite AC Power System | Reactor Recirculating Pumps<br>Reactor Feed Pumps<br>Circulating Water Pumps<br>Auxiliary Boiler electrodes<br>Condensate Booster Pumps<br>4.16KV Transformers<br>600V Transformers |

| | | | |
|---|---|---|---|
| 4.16KV | • T10, T101N, T101S<br>• EDGs<br><br>• Reserve Station Service Trans. (tertiary winding)<br>• Auxiliary Station Transformers<br>• EDGs | Safety and Non-Safety Related Loads | Reactor Recirculating Pumps<br>Closed Loop Cooling Pumps<br>Condensate Pumps<br>Fire Pumps<br>Control Rod Drive Pumps<br>600V Load Centers |
| 600V | Various<br>(Stub Busses) | Safety and Non-Safety related Loads (50-200 HP) | Uninterruptible Pwr Supplies (UPS)<br>Motor Control Centers |
| UPS | 600V Dist/125VDC | Safety Related Loads | RPS Trip Logic Loads<br>Primary Containment Isolation<br>Selected Lighting |
| DC Distribution | | | |
| 125V SR | Battery Chargers | Battery | Control Power<br>RPS<br>Emergency Lighting<br>Computers<br>Valve Boards |
| 125V Q | Battery Chargers | Battery | Control Power<br>Oil pumps<br>Emergency Lights |

| | | | |
|---|---|---|---|
| | | | Fire Pump Control Panel |
| 24 V | Battery Charges | Battery | SRMs, IRMs<br>Radiation Monitoring |

## F. In Summary

1. Semiconductor components are used throughout the plant. The simplest semiconductor component is the diode, which operates similar to a check valve. That is, the diode only allows current to flow in one direction. Diodes can be arranged to form a full-wave rectifier. This devices changes alternating current into pulsating direct current which can be easily filtered to supply loads requiring a constant DC voltage and current.

2. Relays and circuit switchers are used to interrupt a circuit if necessary. Some relays and circuit switchers change the circuit supplied with current. Fuses and breakers are used to protect the distribution system from overcurrent. Certain breakers utilize an undervoltage trip to protect equipment from overcurrent during undervoltage conditions and prevent excessive reenergization currents. The design of a breaker largely depends on the current-interrupting capability required by the circuit. When a breaker opens in an AC circuit, the ensuing arc is aided by an inductive kick in the circuit. Therefore, depending upon the circuit involved, a simple air circuit breaker, or the more complex oil or gas circuit breaker may be needed to extinguish the arc. Disconnects are essentially removable pieces of conductor used to isolate equipment and circuits. Disconnects should be operated when they are deenergized. If this is not done, the long operating

time may allow a very strong arc to develop, resulting in injury to personnel and damage to equipment.

3. Buses are used to provide an orderly method of connecting circuits for the purpose of transferring electrical power. Main isolated phase bus ducts are used to transfer power produced by the main generator to the main transformer. From here the power is sent to the station's switchyard. The switchyard is a large bus arrangement used to distribute power safely and reliably to connecting transmission and distribution lines. Tapping off the main isolated phase bus ducts are smaller auxiliary isolated phase bus ducts. These buses are used to take a small portion of the generator's output to supply in-house loads. The in-house power is distributed by buses located inside switchgear throughout the plant.

4. To ensure a reliable distribution system, protective devices are used throughout. They are designed to trip the closest device to a fault, safely interrupting fault current. This minimizes the number of circuits with power loss due to a fault in the distribution system. This process of isolating the fault as close as possible is called selective tripping and is accomplished through the use of fuses, circuit breakers, overload disconnects, circuit switchers, overload relays, and many other protection devices.

5. This chapter has discussed various devices and arrangements used to distribute electrical power. The equipment and arrangements actually used by a utility will depend upon many variables beyond the scope of this text. Distribution systems (both in-house and grid) were simplified to show the general philosophy used. It is important to understand the relationship of the plant to a much larger distribution network the grid. Improper operation of the generator or switchyard may jeopardize the grid’s capability to supply safe reliable power to the utilities’ customers.

**PRACTICE:**

1 What is a semiconductor?

2. What is a diode?