B) Be Selective

As society becomes more modern, its dependence on electricity increases and sudden losses of power can have wide repercussions from a mere nuisance (Start looking for the candles) to life and death situations (Hospitals). Whether it is the utility's loss of revenue or the loss of production at a plant, the almighty dollar is the most common repercussion of electrical system interruptions. Protective relays should only operate when absolutely necessary and there should be minimum disruption to the rest of the electrical system. The following characteristics help relays meet these criteria:

i) Protective Relay Elements

In the past, protective relays were designed to operate if a certain type of electrical fault occurred. An individual relay would monitor a phase or line value and operate if a fault was detected. The most common protective relay elements are listed below along with their IEEE reference numbers. The IEEE numbers were created to provide a quick and easy reference to the relay function on electrical drawings.

- **Impedance Protection (21)** – The relay monitors system impedance and will trip if it falls within a predetermined characteristic.
- **Undervoltage Protection (27)** – If the voltage drops below a predetermined voltage, the relay will operate.
- **Reverse Power Protection (32)** – The relay monitors the direction of power flow and will operate if power flows in the wrong direction.
- **Loss of Field Protection (40)** – The relay monitors generator output impedance and will trip if it falls within a predetermined loss of field characteristic.
- **Negative Sequence Overcurrent (46)** – The relay calculates the negative sequence current and trips if it exceeds a preset value.
- **Overload Protection (49)** – The relay models the thermal characteristics of the protected equipment and measures the input current. The relay will trip if excessive current over time exceeds the thermal capacity of the relay.
- **Instantaneous Overcurrent (50)** – The relay measures current and trips if it exceeds a preset value with no intentional time delay.
- **Time Overcurrent (51)** – The relay measures current and trips if it exceeds a preset value for a period of time. The time delay can be proportional to measured current.
- **Voltage Controlled/Restrained Time Overcurrent (51V)** – The relay measures voltage and current. The relay will trip if the current exceeds a preset value for a period of time. The preset value of current varies in relation to the measured voltage.
- **Overvoltage Protection (59)** – If the voltage rises above a predetermined setpoint, the relay will operate.
- **Loss of Potential (60)** – The relay monitors system voltages and operates if it detects that a PT fuse has opened.
- **Directional Overcurrent (67)** – The relay monitors Current direction and will operate if Current flows in the wrong direction.
- **Frequency Protection (81)** – The relay monitors system frequency and will operate if an abnormal frequency is detected.
- **Differential Protection (87)** – The relay monitors current flowing in and out of a device and will operate if there is a difference between input and output current that indicates a fault inside the equipment itself.

ii) Zones of Protection

Electrical systems can be divided into five primary categories:

- Generating Plants (Generators and/or Generators with step-up transformers)
- Transformers
- Buses
- Transmission or Distribution (Transmission lines or Feeder Cables)
- End Use Equipment (Motors, MCCs, etc)

Each of these categories has their own unique characteristic and requires specialized protection. Combinations of protective elements are applied in zones surrounding the equipment within an electrical system as shown below. Zones of protection ensure the equipment in the zone receives optimum protection and the protective devices do not interfere with any other part of the electrical system. A transmission line fault should not affect bus protection and vice-versa for all different zones. Today's relays incorporate multiple protective elements and a single relay will protect an entire zone.

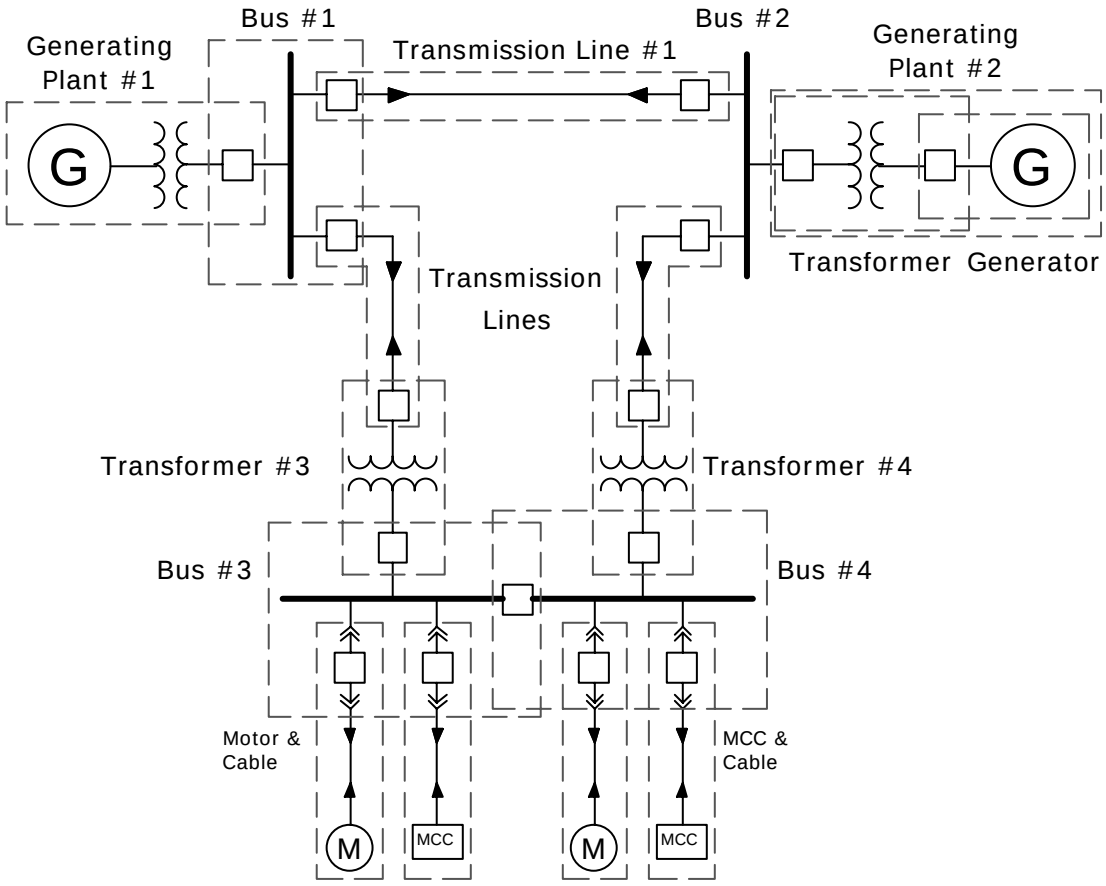

Figure 2- 1: Zones of Protection

iii) Zone Overlap

A quick review of the previous "Zones of Protection" diagram reveals that every circuit breaker is associated with at least one zone of protection. A CT input between the circuit breaker and each associated zone's protective relay is required for the protective schemes to operate. The relays can use the same CT input if they are connected in series.