EEE340 Protective Relaying

Lecture 1 – Introduction

Module Code, Title and Guider

Module Code: EEE340

Module Title: Protective Relaying

Module Guider: Fei Xue

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Reference Books

Reference Books:

- –“Protective Relaying: Principles and Applications”, J. Lewis Blackburn, Thomas J.Domin, Taylor & Francis.
- – “Power System Protection”, P. M. Anderson, Wiley Press
- – “电力系统继电保护（第二版）”, 张保会等, 中国电力出版社.

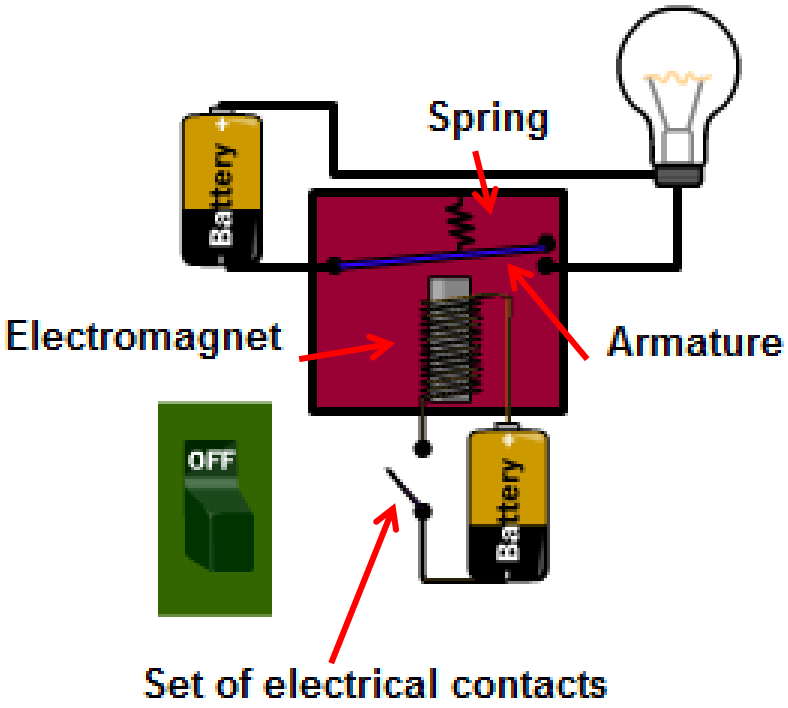
What are Relays

- A relay is an electromagnetic switch operated by a relatively small electric current that can turn on/off a much larger electric current.
- A relay is an electrically operated switch.
- A relay is a special kind of switch.
- A device that responds to a small current or voltage change by activating switches or other devices in an electric circuit.
- An electrical switch that opens and closes a circuit. Relays can open or close one or many sets of contacts.
- ……
- Relays are one of the oldest, simplest, and yet, easiest and most useful devices.

Relay Constructions

There are four basic parts in a relay:

- Electromagnet
- Armature that can be attracted by the electromagnet
- Spring
- Set of electrical contacts



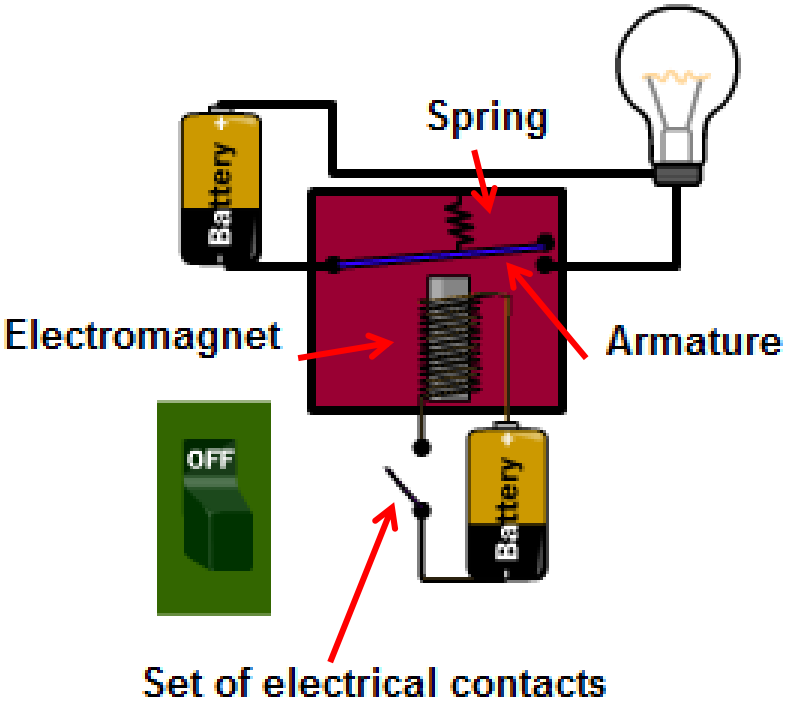
Electromagnet: the electric coil, which is powered by AC or DC current.

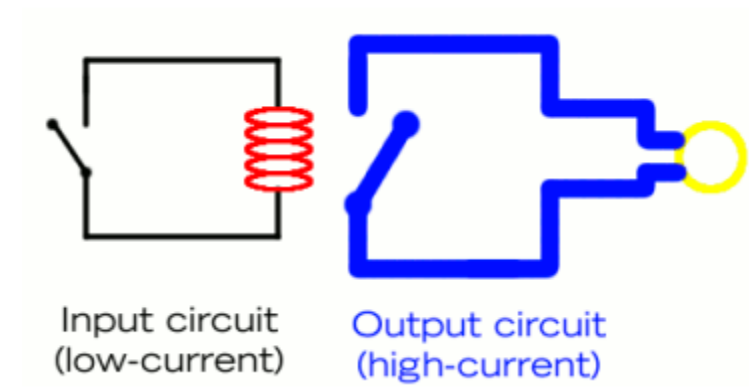
A relay consists of two separate and completely independent circuits:

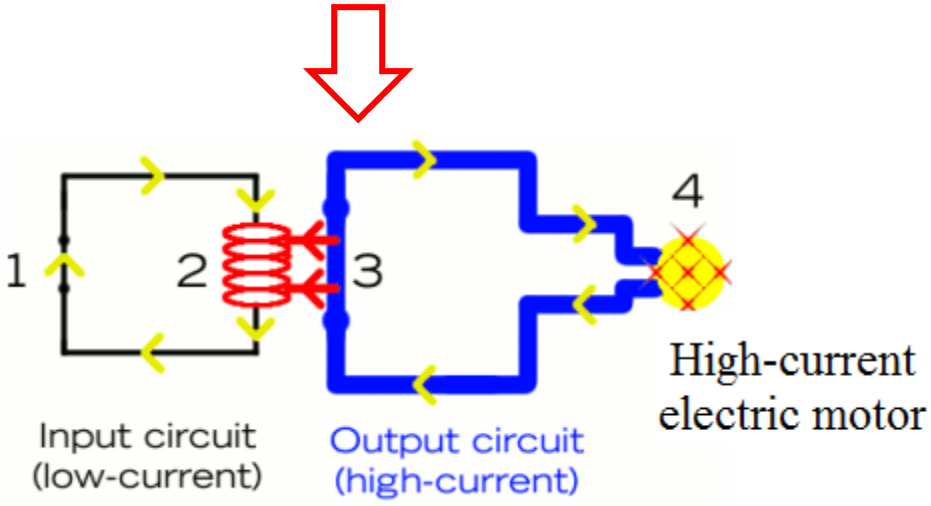
The first circuit is called the control circuit; the second is called the load circuit.

How Relays Work

Closely related with: solenoid
Action like: Switch







Applications

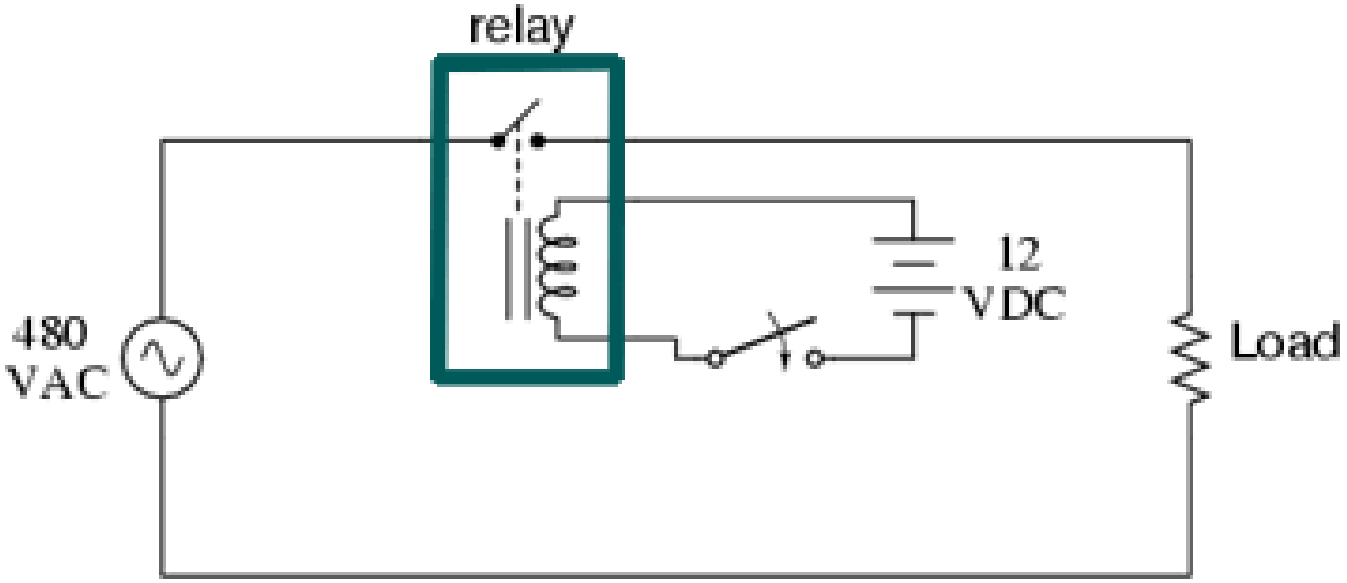
Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

Relays are used in a wide variety of applications throughout industry, such as in telephone exchanges, digital computers and automation systems. Highly sophisticated relays are utilized to **protect electric power systems** against trouble and power blackouts as well as to **regulate and control** the generation and distribution of power.

In the home, relays are used in refrigerators, washing machines and dishwashers, and heating and air-conditioning controls,…

Why Relays

- Like remote control switches
- Use small power to control big power
- The relative simplicity, long life, and proven high reliability



Types of Relays (1)

Classification can be done by different ways, such as by input, operating principles , function, …

- By input: such as, current, voltage, power, frequency and temperature relays
- By operating principles; such as, electromechanical, solid-state
- By function: such as, protective, regulating, reclosing, monitoring, and auxiliary relays

Types of Relays (2)

By operating principles:

Two basic classifications: Electromechanical and Solid-State.

Electromechanical relays: have moving parts

Advantages: lower cost, no heat sink is required, multiple poles are available, and they can switch AC or DC with equal ease.

Solid state relay (SSR): a solid state electronic component that provides a similar function to an electromechanical relay but does not have any moving components, increasing long-term reliability.

An SSR based on a single MOSFET, or multiple MOSFETs in a paralleled array, works well for DC loads.

Compared to electromagnetic relays, they may be falsely triggered by transients.

Types of Relays (3)

IEEE Power System Relay Collection:

Power system relaying standards concentrate on the application, design, construction and operation of protective, regulating, monitoring, reclosing, synch-check, synchronizing and auxiliary relays.

This includes items used in the operation of relays and relaying systems in the transmission, generation, distribution and utilization of electrical energy and their effect on system operation.

Types of Relays (4)

By functions :

1) Protective relays:

used to detect faults and to initiate switching (i.e. send a signal to the breakers to open)

Examples: overcurrent relays, impedance relays, etc.

They are applied to all parts of the power system; generates, distribution lines, motors, loads, …

2) Regulating relays:

used to detect a departure from a predetermined quantity and to initiate corrective action to get the quantity back to its limits.

Examples: frequency relays, voltage relays used for voltage regulation, etc

Types of Relays (5)

3)Reclosing, synchronism check, synchronizing relays:

Relays of this type are used in energizing or restoring lines to service after an outage and in interconnecting pre-energizing parts of the systems.

4) Monitoring relays:

Voltage monitoring relay, current monitoring relay, ….

5) Auxiliary relays:

used to assist other relays or devices to perform their function.

Examples: timing relays, interposing relays, etc.

Protective Relays (1)

- The main purpose of protection relay is **to detect** a problem during its initial stage: such as overload, short-circuits, and other faults in electrical apparatus and transmission lines, **to eliminate** or significantly reduce damage to personnel and or equipment.

- Relays can identify problems **by deviation in current, voltage, resistance or temperature,** as the problem started to develop severely such as insulation breakdown, overheating or over voltage, the protective relay will **interrupt** power to the faulted equipment.

- Therefore, protection relay will **isolate** the faulted equipment and avoid the entire network to fail or cause more damages to personnel or equipment.

Protective Relays (2)

- In electrical engineering, a protective relay is a complex electromechanical apparatus, often with more than one coil, designed to calculate operating conditions on an electrical circuit and trip circuit breakers when a fault is detected.

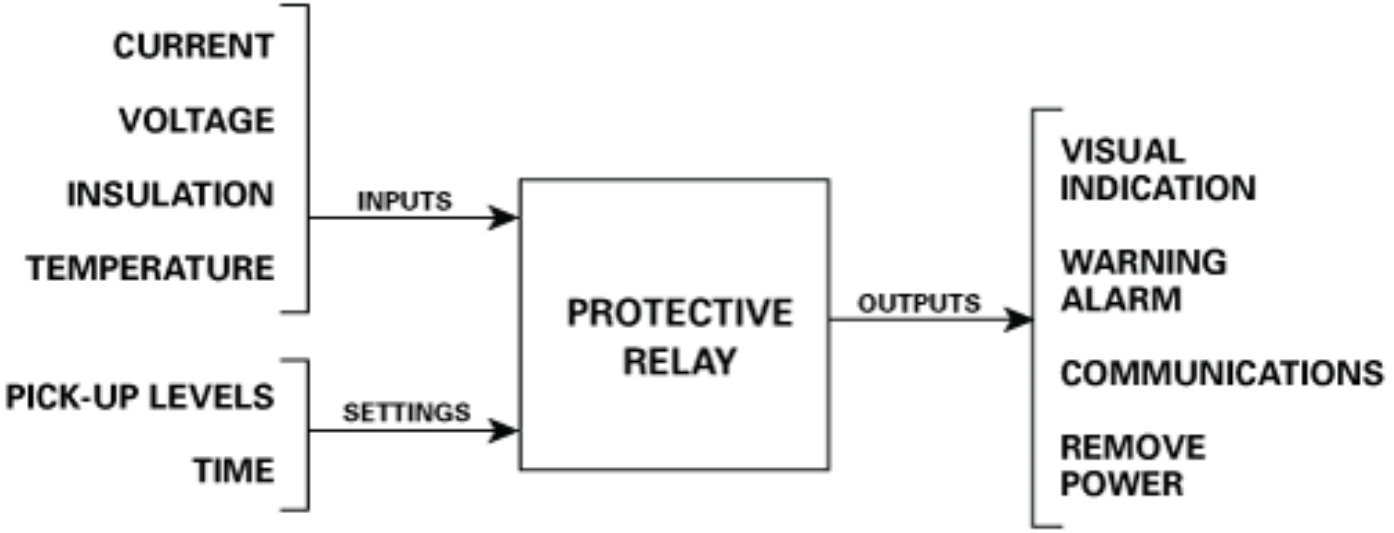
- Protection relays respond to such conditions as over-current, over-voltage, reverse power flow, over- and under-frequency.

- Distance relays trip for faults up to a certain distance away from a substation.

- An important transmission line or generator unit will have cubicles dedicated to protection, with many individual electromechanical devices.

Protective Relays (3)

- A protection relay receives inputs, compares them to set points, and provides outputs.
- Inputs can be current, voltage, resistance, temperature, ….
- Outputs can include visual feedback in the form of indicator lights and/or an alphanumeric display, communications, control warnings, alarms, and turning power off and on.



Protective Relays (4)

Inputs

A relay needs information from the system to make a decision. These inputs can be collected in a variety of ways:

- connected directly to the relay,
- additional devices converts the measured parameters to a format that the relay can process: such as, current transformers, potential transformers, tension couplers, or other devices.

Settings

The user programs settings (pick-up levels) that allow the relay to make a decision. The relay compares the inputs to these settings and responds accordingly.

Protective Relays (5)

Processes

Once the inputs are connected and the settings are programmed, the relay compares these values and makes a decision.

Outputs

The relay has several ways of communicating that a decision has been made:

Operating a switch to indicate that an input has surpassed a setting,

Providing notification through visual feedback, such as a meter or LED.

One advantage of electronic or microprocessor relays is an ability to communicate with a network or a PLC.

Components of Electrical Power Systems

Primary equipment

- To generate, transform, transmit and make use of power ;
- Be connected to the primary side of PT and CT.

Secondary device

- To measure and transmit information for monitoring, control and protection;
- Be connected to the secondary side of PT and CT.

Normal operating conditions

- All equality constraints for real time active power and reactive power are true.
- Power generation and consumption must be balanced in real time.
- All inequality constraints for parameters of power quality and equipment operation are true.
- Through automatic or manual control, power systems should operate at normal conditions as much as possible.

Abnormal operating conditions

- All equality constraints for real time active power and reactive power are still true.
- Part of parameters of power quality and equipment operation are out of limit without any fault.
- Such as out-of-limit in current, voltage, frequency and power swing.
- It could be harmful for equipment and reduces power quality to impact on customer usage.
- Necessary to detect abnormal operating states and to alarm or cut related components with time delay.

State of Fault

- Short circuit & Disconnection fault.
- Short circuits are more common and dangerous.
- The fault current may damage components of faulted equipment.
- The power quality may be decreased and normal usage of customers may be impacted.
- Stable operation of power system may be damaged with large-scale blackout.

Operating States of Power System

Fault of Transformer

Functions of Relay Protection

Unavoidable Faults

- Nature factors.
- Factors of manufacture.
- Human factors.

Fast fault-clearing

- Reduce transient process.
- Benefit for equipment restoration.
- Benefit for system stable operation.

Relay protection is a set of automatic devices which can detect faults or abnormal operation of power system and give alarm or trigger breakers to clear the faults.

Basic Tasks for Relay Protection

- To automatically cut off the faulted components from the system with reliability, selectivity, speed, economy and simplicity.
- To stop damages on the faulted components and to rapidly restore non-faulted components to normal operation.
- To detect the abnormal operating conditions of power system and make alarm or trigger breakers according to operation and maintenance conditions.

Design Criteria for System-Protection

- *Reliability*: Operate dependably when fault conditions occur, even after remaining idle for months or years. Failure to do so may result in costly damages.
- *Selectivity*: Avoid unnecessary, false trip.
- *Speed*: Operate rapidly to minimize fault duration and equipment damage. Any intentional time delays should be precise.
- *Economy*: Provide maximum protection at minimum cost.
- *Simplicity*: Minimize protection equipment and circuitry.

Basic Principles of Relay Protection

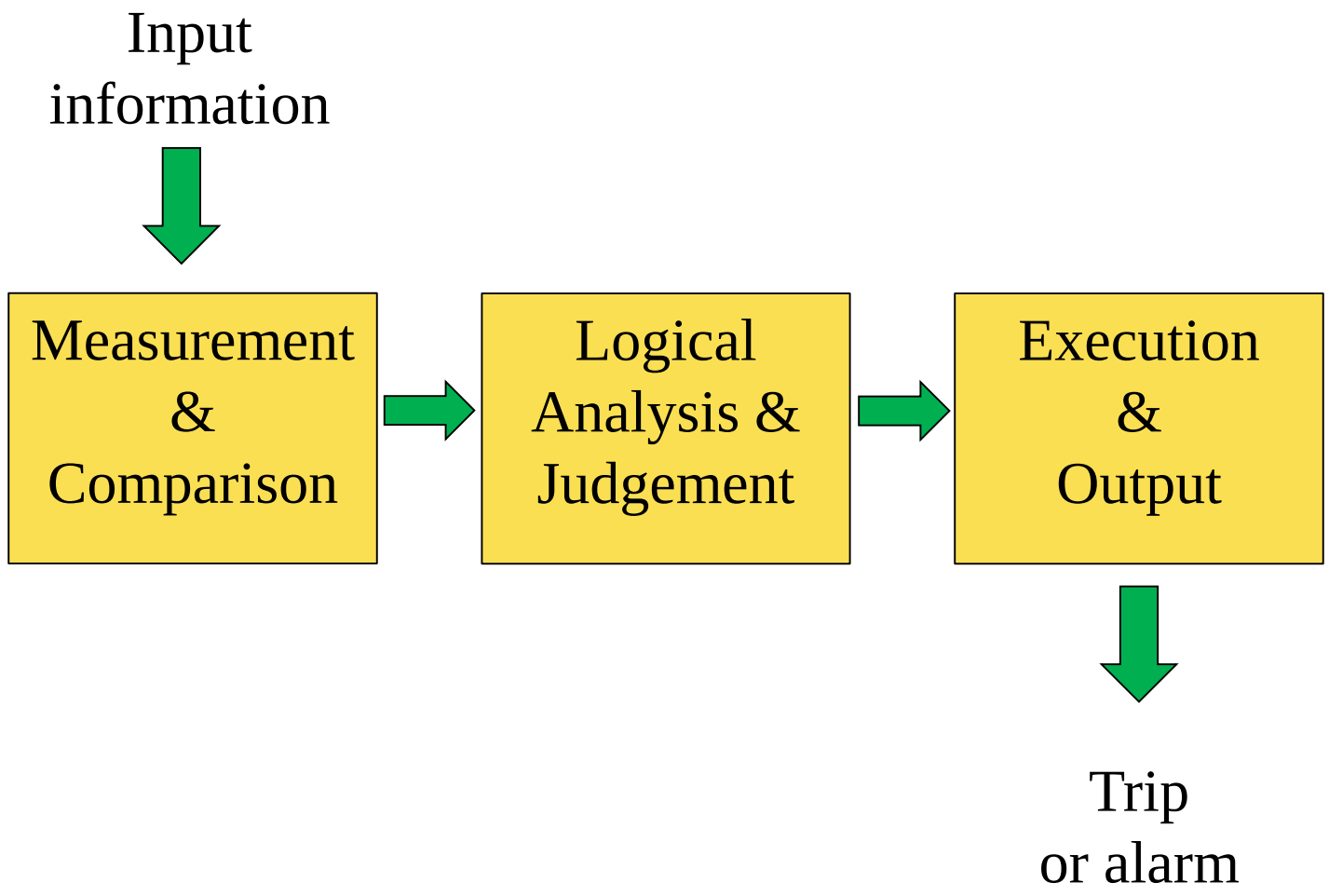
- By analysis on characteristics and difference of parameters from the protected equipment under normal, abnormal and faulted states of power system, corresponding protecting solutions can be developed.

- Judging criterion: current, voltage, power, phase angle, sequence components, impedance and direction.

Common Principles

Characteristics of Faults	Principles
• Increased current	• Over current relay
• Increased or decreased voltage	• Over/under voltage relay
• Decrease of U/I	• Impedance/distance relay
• Kirchhoff's current law	• Differential relay
• Direction of power	• Directional relay
• Sequence components	• Sequence protection

Elements of Relay Protection



Elements of Relay Protection

- ***Measurement & Comparison*:** To make measurement on related parameters (such as current, voltage) of the protected equipment and to compare with the presetted values.

- ***Logical Analysis & Judgement*:** According to the comparison results, to judge the type and scope of faults and make decisions on control strategies (to trip, alarm or no response).

- ***Execution & Output*:** According to the control strategies, to send out corresponding instructions for implementation.

Working Circuits of Relay Protection

- ***AC circuit*:** PT and CT which transform the primary voltage and current to secondary parameters, as well as their connected cables.

- ***Control circuit*:** Tripping devices for breakers and connected cables, as well as information circuit to indicate the working state of protection system.

- ***DC power supply circuit*:** To supply power for devices of protection, tripping and information circuits.

The proper operation of replay protection systems depends on the proper working of all related working circuits and connected cables.

Coordination of Relay Protection

- Every set of protection has a zone of protection to minimize the blackout scope due to faults clearance. This set of protection will only clear the faults inside the zone and does not respond to the faults outside the zone.

- To identify the zones of protection, a fault of any component must be reliably cleared with minimum blackout scope or minimum impacts on system operation
- The locations of breakers are often considered as reference to identify protection zones.
- Neighboring zones must be overlapped to guarantee a fault of any location is included in at least one zone. But the overlapped part should be as small as possible.

Zones of Protection

- General power system configurations can be divided into protective zones.
- If a fault occurs anywhere within a zone, action will be taken to isolate that zone from the rest of the system.
- Zones are defined for: generators, transformers, buses, transmission and distribution lines, and motors.

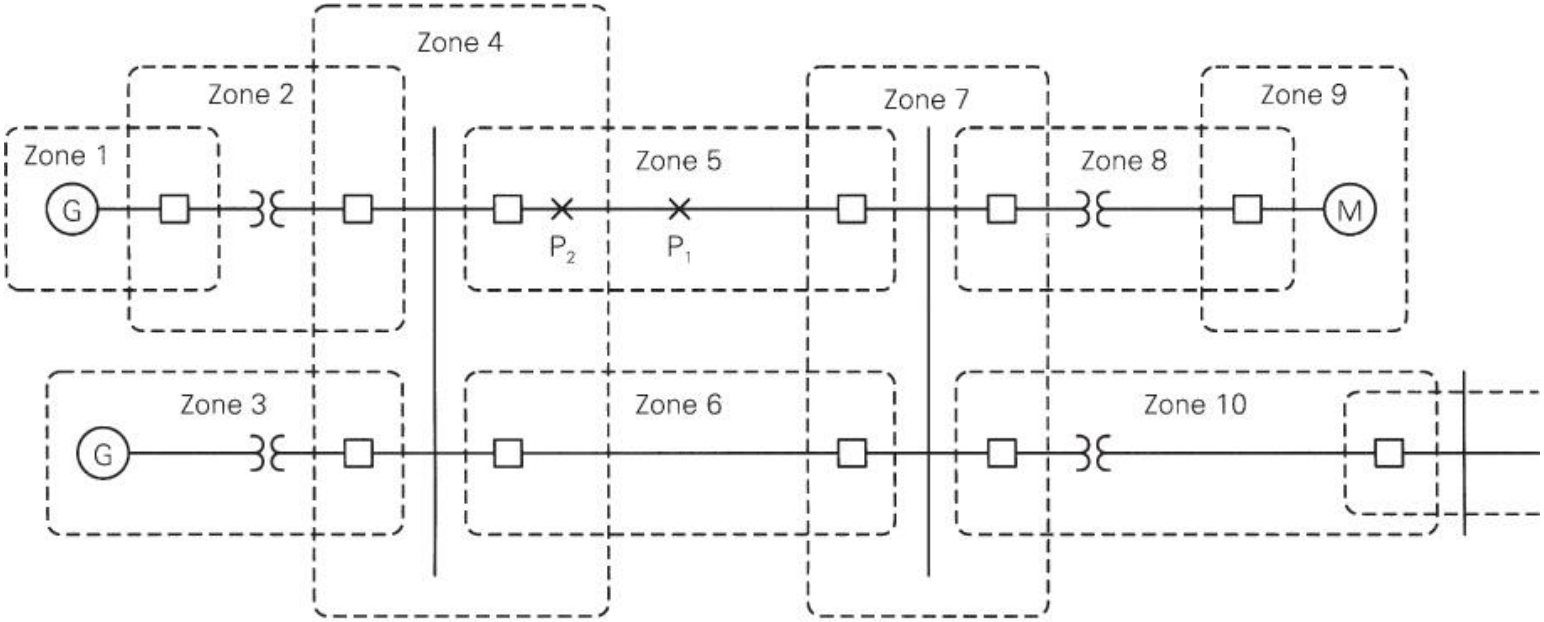


FIGURE 10.23 Power system protective zones

Zones of Protection

- Protective zones have the following characteristics:
- Zones are overlapped.
- Circuit breakers are located in the overlap regions.
- For a fault anywhere in a zone, all circuit breakers in that zone open to isolate the fault.

Neighboring zones are overlapped to avoid the possibility of unprotected areas.

Breakers should be inserted between equipment in a zone and each connection to the system.

If a fault occurs within an overlap region, two zones will be isolated. To minimize this possibility, overlap regions are kept as small as possible.

Coordination of Relay Protection

- The configuration of protection for a component mainly depends on how important it is, how the economy is and related regulations.

- Normally, an important component should have two sets of protection: **Primary Protection** and **Back-up Protection**.

Next Lecture

Symmetrical faults &
Symmetrical components

Thanks for your attendance