

Presented by:

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Content

- **Introduction**
  - Overview (electrical Energy systems & Types of Protection)
  - Relays & Evaluation of Relays
  - Circuit breaker
- **Apparatus protection Schemes**
  - Overcurrent protection
  - Differential protection
  - Distance protection
- **Desirable attributes of protection**
- **System Protection**
  - Under frequency and rate of change of frequency relays
  - Under voltage and reverse power flow relay
  - Lightening protection

Content

- **Instrument Transformer**
  - CTs
  - PT/CVT/CCVT
- **Technological development & its application in power system protection**

Introduction

Overview

- Electrical energy generated at few kV through synchronous generators and stepped up to transmit it for a long distance.
- Transmission of electrical energy through AC or HVDC lines.
- Stepped down at distribution level and distributed at load center.
- Electrical apparatus operates at various voltage levels and may be enclosed or placed in open. Under abnormal operating conditions protection is necessary for
  - Safety of electrical equipment.
  - Safety of human personnel.
  - In power system based on functional charactersics two types of protection schemes are used: 1) Primary and 2) Secondary protection

Introduction

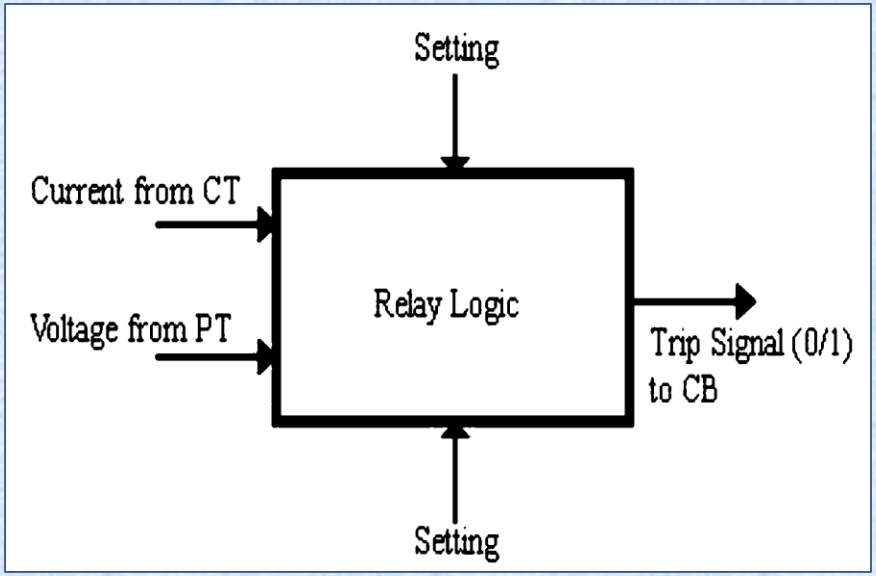
Types of protection

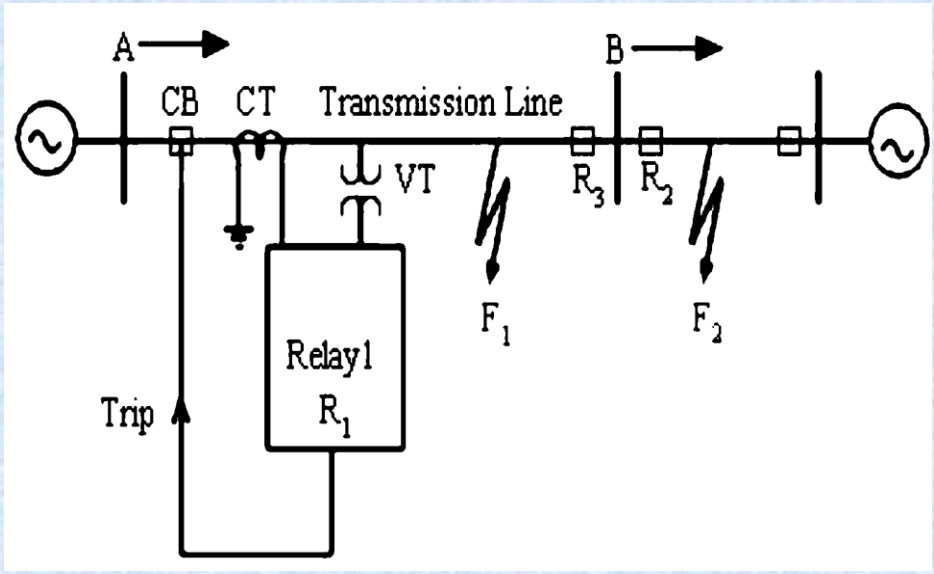
- Apparatus protection
  - Transmission line protection.
  - Transformer protection
  - Generator protection
  - Motor protection
  - Bus bar protection
- System protection
  - Out of step protection
  - Under frequency relays
  - Islanding system
  - Rate of change of frequency relay
  - Under voltage relay
  - Reverse power flow relay

Introduction

What is a Relay

- A relay is a logical element which process the inputs from the system and issues a trip decision, if a fault within its zone of protection, it detects and send a trip decision to a circuit breaker. In a common practice input to the relays are current from current transformer and voltage from a voltage transformer.





Introduction

Evolution of Relay

- In a present context we can realize three generation of relays
  - 1st Generation: Electromechanical Relays
  - 2nd Generation: Solid state relays
  - 3rd Generation: Numerical or Digital relays
- Electromechanical relays uses the principle of electromechanical energy conversion. Its operation is immune to electromagnetic interference and rugged. Different types of such relays are:
  - Solenoid type
  - Induction disk type
  - Balanced beam type etc.

Introduction

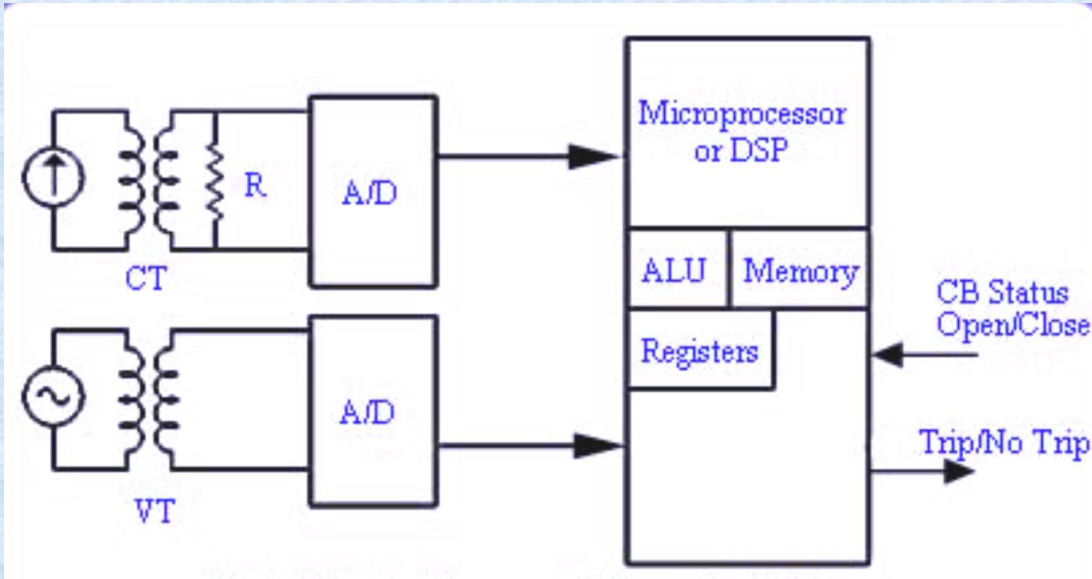
Solid state Relay

- With the advancement in transistor and amplifier technology such relays are realized. Their functionality is through various operation like adder, subtractor and comparator etc. Their advantages compared to electromechanical relays are:
  - More flexible
  - Self checking facilities
  - Less power consumption and low burden
  - Improved dynamic performance characteristics
  - High seismic withstand capacity
  - Reduced panel space

Introduction

Numerical or digital Relay

- Operation of numerical or digital relays involves, analog to digital conversion of current and voltage obtained from CTs and VTs. Furthermore, this signals are fed to the microprocessor or DSP, where the protection algorithms process these signals and necessary decision are taken. Its advantages are:
  - Maximum flexibility
  - Provide multiple functionality
  - Self checking and communication facility
  - It can be made adaptive



Introduction

Comparison

	Numerical or Digital Relay	Solid State Relay	Electromag-netic Relay
Cost	✓	✓	✓
Self Checking and Reliability	✓	✓	☒
System integration and Digital Environment	✓	☒	☒
Functional Flexibility and Adaptive Relaying	✓	☒	☒

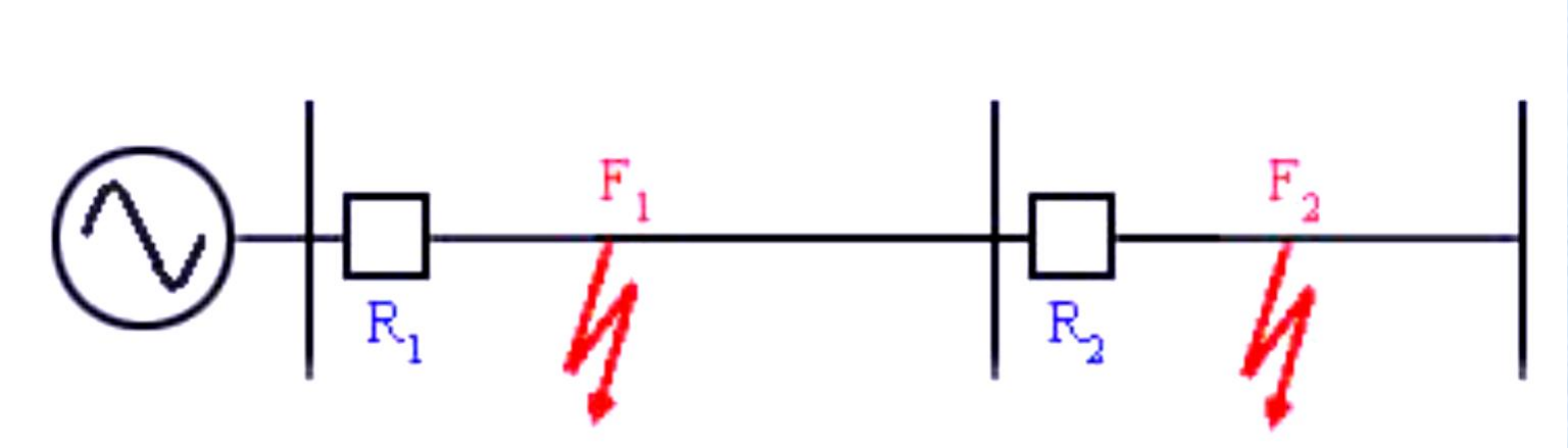
Introduction

Circuit breaker

- Basically circuit breaker is a switch to interrupt the flow of large current. The functional characteristics of the circuit breaker consists :
  - It opens on relay command
  - It has to handle large voltage and currents
  - The inductive nature of power system results in arcing between the terminals of a circuit breaker.
  - Circuit breakers are categorized based on the interrupting medium used, such as :
    - Air blast circuit breaker
    - Oil circuit breaker
    - Vaccume circuit breaker
    - SF6 circuit breaker

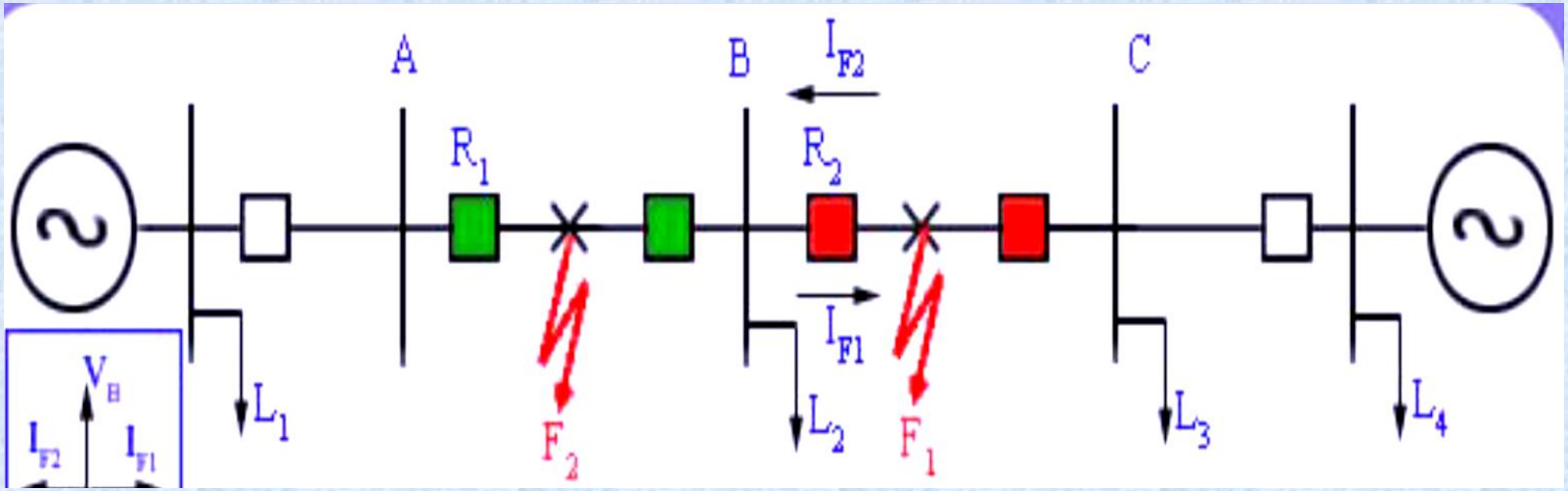
Overcurrent protection

- When the current in the system exceeds a predetermined value, it indicates the presence of fault.
- Relaying decision is based on the magnitude of current.
- Mainly used in radial distribution system and for backup protection.
- Fuse and overcurrent relay uses this this principle.



Directional Overcurrent protection

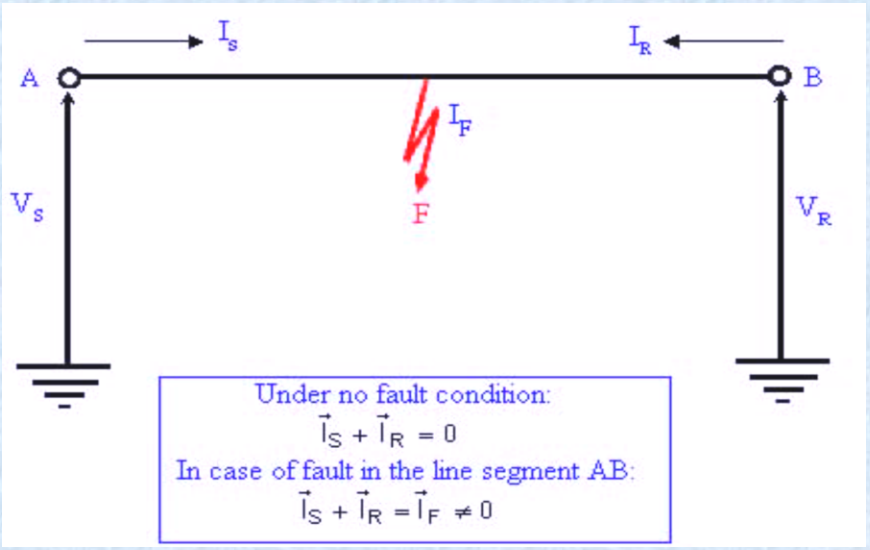
- Relaying decision is based on both magnitude of current and phase angle information for decision making.
- Mainly used in radial distribution system with source at both ends for primary and for backup protection.



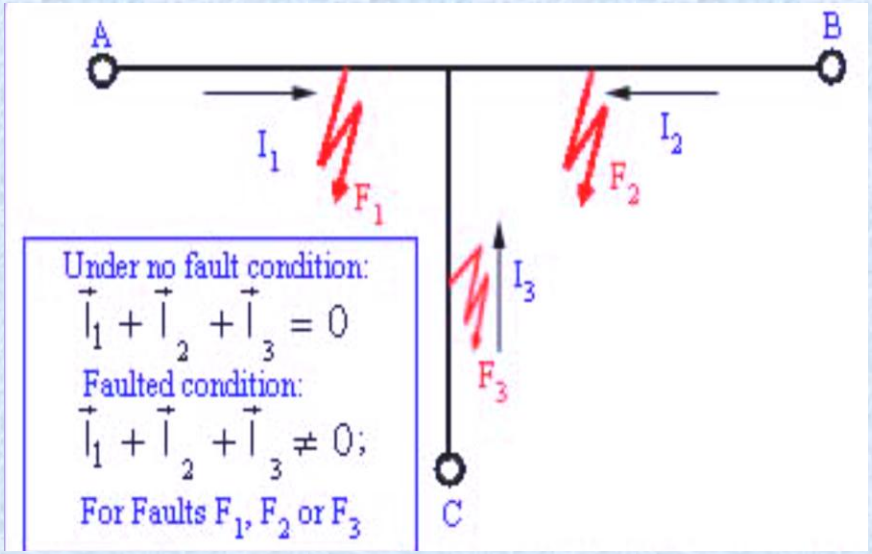
Differential protection

- Principle of differential protection is based on Kirchhoff's current law.
- Mainly used in radial distribution system with source at both ends for primary and for backup protection.
- By comparing the current magnitude or phase or both fault can be determined.
- It is an attractive option if both the ends of the apparatus located at near each other.
- For differential protection of transmission line it requires communication channel.

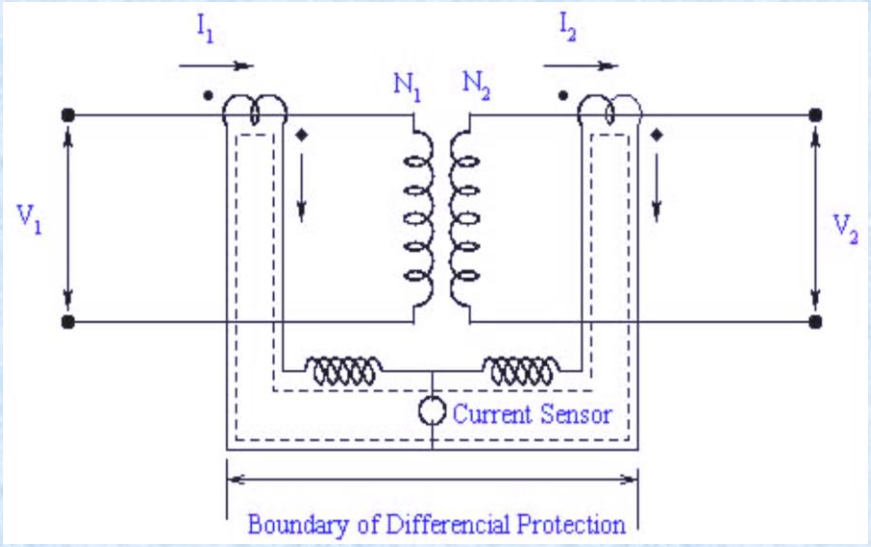
Differential protection



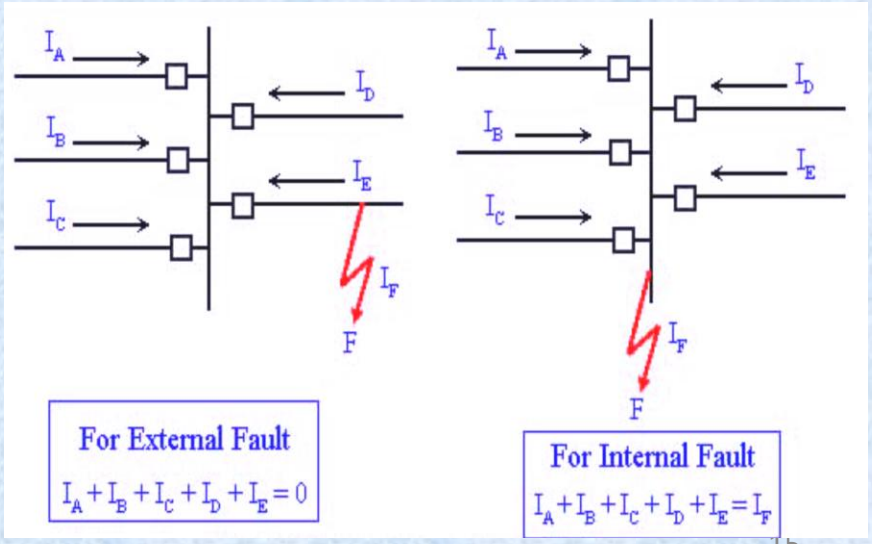
Differential protection of Transmission line



Differential protection for tapped line



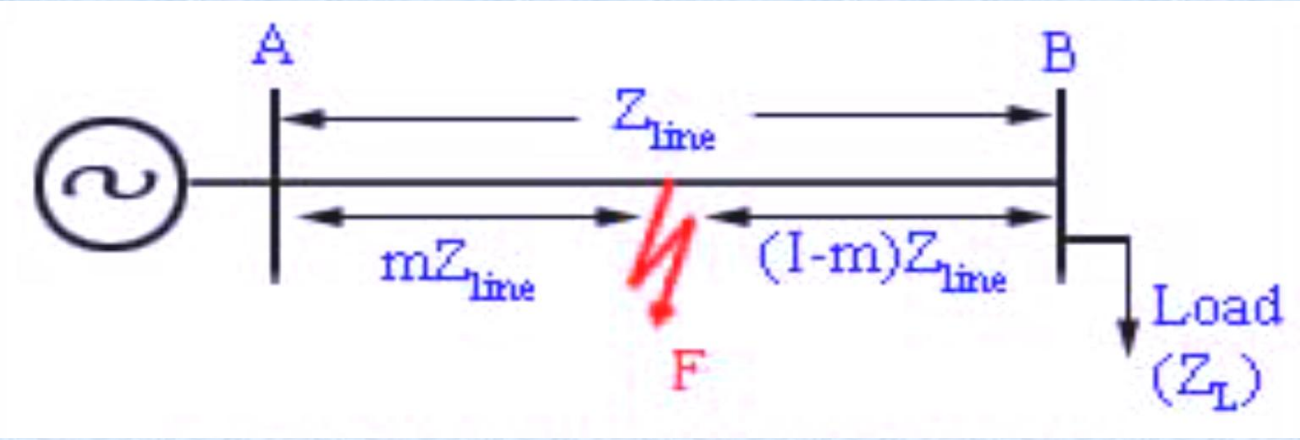
Differential protection of Transformer



Differential protection of Busbar

Distance protection

- Principle of distance protection is that the apparent impedance seen by the relay reduces drastically in case of short circuit fault.
- If the ratio of apparent impedance to the positive sequence impedance is less than unity, it indicates a fault.
- This protection scheme is inherently directional.
- Mainly applied in transmission line as impedance and mho relay.



Distance protection

Impedance Seen by distance relay

Sr. No.	Type of fault	Z_{app}	Sr. No.	Type of fault	Z_{app}
1	a - g	$\frac{V_a}{I_a+mI_0}$	6	c - a - g	$\frac{V_c}{I_c+mI_0}$, $\frac{V_a}{I_a+mI_0}$
2	b - g	$\frac{V_b}{I_b+mI_0}$	7	a - b	$\frac{V_a-V_b}{I_a-I_b}$
3	c - g	$\frac{V_c}{I_c+mI_0}$	8	b - c	$\frac{V_b-V_c}{I_b-I_c}$
4	a - b - g	$\frac{V_a}{I_a+mI_0}$, $\frac{V_b}{I_b+mI_0}$	9	c - a	$\frac{V_c-V_a}{I_c-I_a}$
5	b - c - g	$\frac{V_b}{I_b+mI_0}$, $\frac{V_c}{I_c+mI_0}$	10	a - b - c	$\frac{V_a-V_b}{I_a-I_b}$, $\frac{V_b-V_c}{I_b-I_c}$, $\frac{V_c-V_a}{I_c-I_a}$

Desirable Attributes of protection

- The desired attributes of protection system are:
  - Dependability
  - Sensitivity
  - Security
  - Selectivity
  - Reliability

Dependability

- A relay is said to be dependable if it trips only when it is expected to trip.
- Dependability is the degree of certainty that the relay will operate correctly.
- Dependability can be improved by increasing the sensitivity of the relaying scheme.

$$\%Dependability = \frac{No.\ of\ correct\ trippings \times 100}{Total\ No.\ of\ desired\ trippings}$$

Desirable Attributes of protection

Sensitivity

- It is the ability of the relay to pick up even on small-est possible faults.

Security

- Security is a property used to characterize false trippings.
- A relay is said to be secure if it does not trip when it is not expected to trip.
- It is the degree of certainty that the relay will not operate incorrectly.
- Security can be improved by improving selectivity of the relaying scheme.

$$\%Security = \frac{No.\ of\ correct\ trippings \times 100}{Total\ No.\ of\ trippings}$$

Desirable Attributes of protection

Selectivity

- It is the ability to correctly locate and classify the fault.
- A relay should be able to discriminate whether the fault is in its jurisdiction or not.
- This jurisdiction of a relay is called zone of protection.
- Protection zones are classified into primary and backup zones.
- Selectivity is usually provided by Time discrimination, overcurrent and distance relays use this principle.
- Applying differential protection principle. In the case of differential protection, the CT location provides crisp demarcation of zone of protection.

Desirable Attributes of protection

Reliability

- It is the ability to ’not to fail’ in its function.
- It can be achieved by redundancy.
- Redundancy in protection depends on the criticality of
- the apparatus.
- Reliability can be improved by providing backup protection.

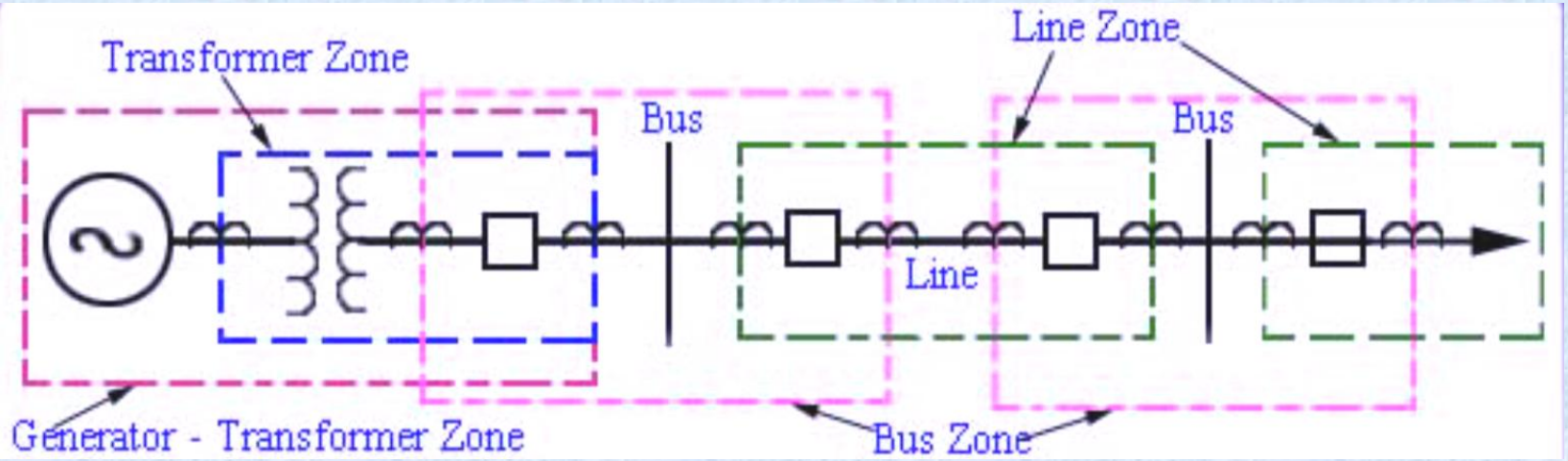
$$\%\ Reliability = \frac{No.\ of\ correct\ trips \times 100}{No.\ of\ desired\ trips + No.\ of\ incorrect\ trips}$$

- Number of desired tripping can be greater than or equal to number of correct trippings.

Desirable Attributes of protection

Zone of Protection

- A relay's zone of protection is a region which defines its jurisdiction.
- It is shown by demarcating the boundary.
- It is essential that primary zones of protection should always overlap so that no portion of the system ever remain unprotected.



System Protection Relays

- Following relays are used to detect system disturbances and for enhancing system stability.
  - Under frequency and over frequency relays.
  - Rate of change of frequency relays.
  - Under voltage relays.
  - Reverse power flow relays.
  - Vector shift relays.
- For example, consider a voltage distribution system with local generation which is synchronized with the grid. During grid disturbances, the local plant generators have to be isolated from the grid.
- The most commonly used devices for protection against lightning are:- Shielding by earth wires, Proper earthing of transmission towers, and Surge Arrestors.

Current Transformer

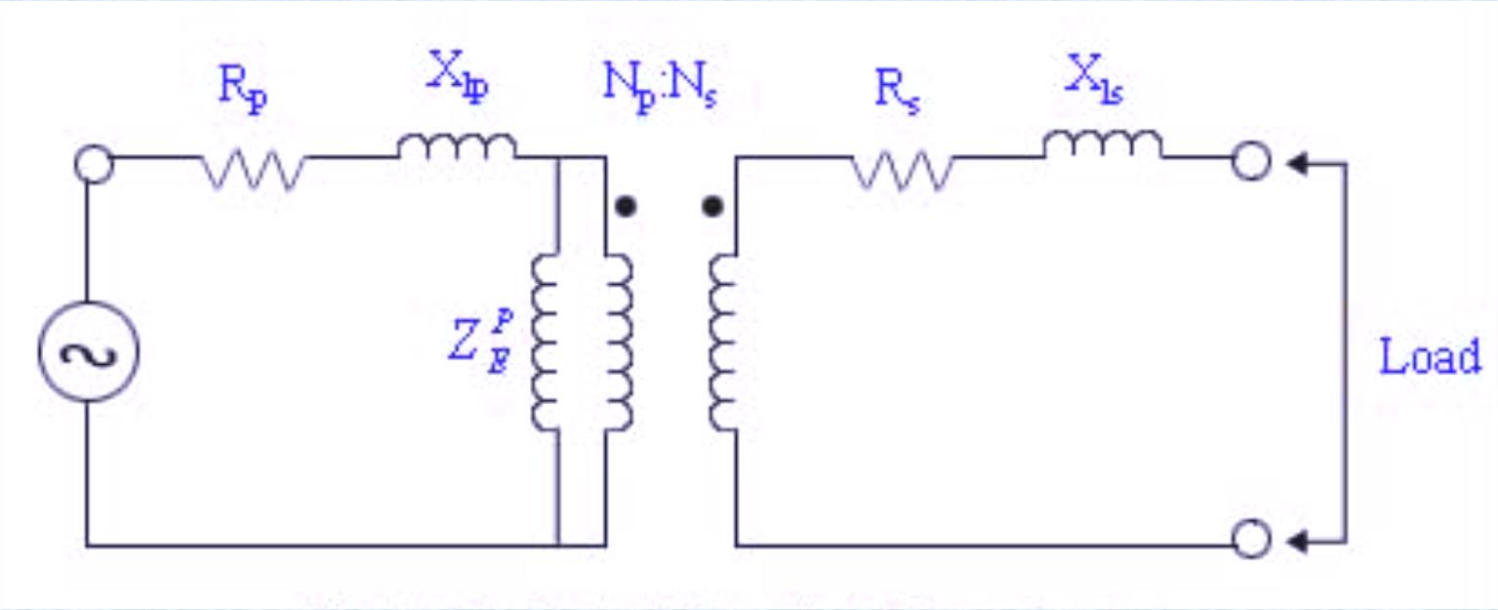
Introduction

- All electrical measurements and relaying decisions are derived from current and voltage signals. CTs and VTs are necessary because
- They scale down line currents and bus voltages to fed into the relays.
- They are sensors for the relay.
- They electrically isolate the relaying system from the apparatus.
- Electrical isolation from the primary voltage provides safety for both human personnel and equipment.
- It is similar to that of a regular transformer.

Current Transformer

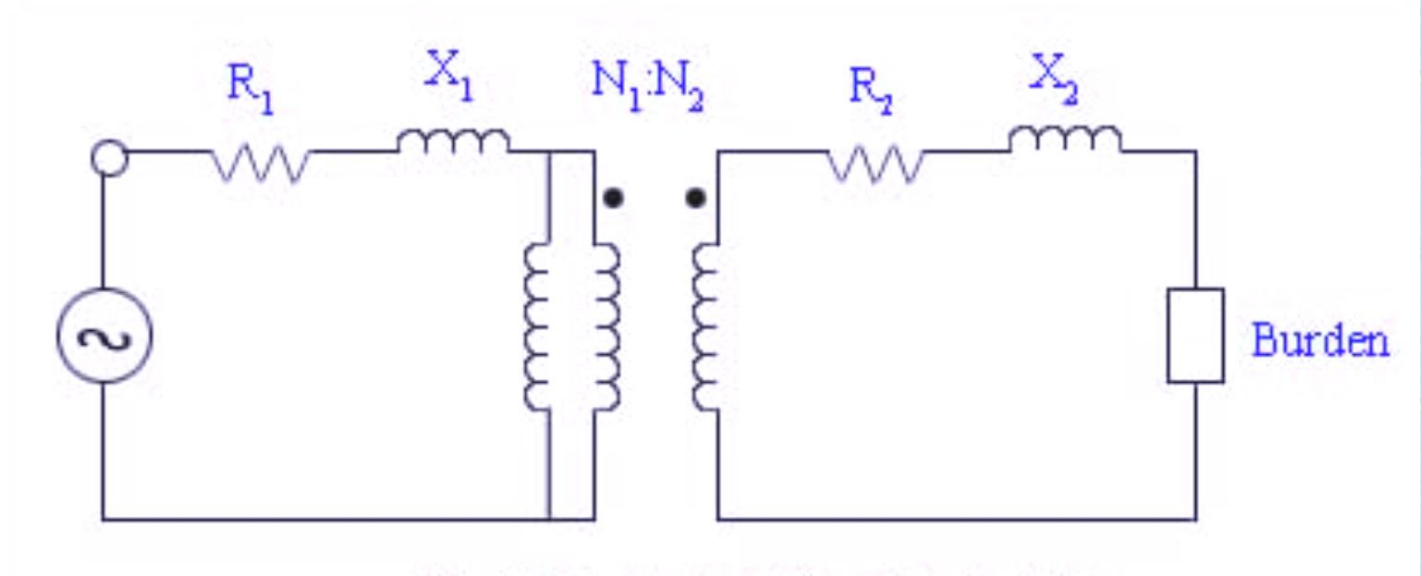
Equivalent diagram

- According to IEEE standards CT's are classified in two categories
  - Class T CT's
  - Class C CT's



Voltage Transformer

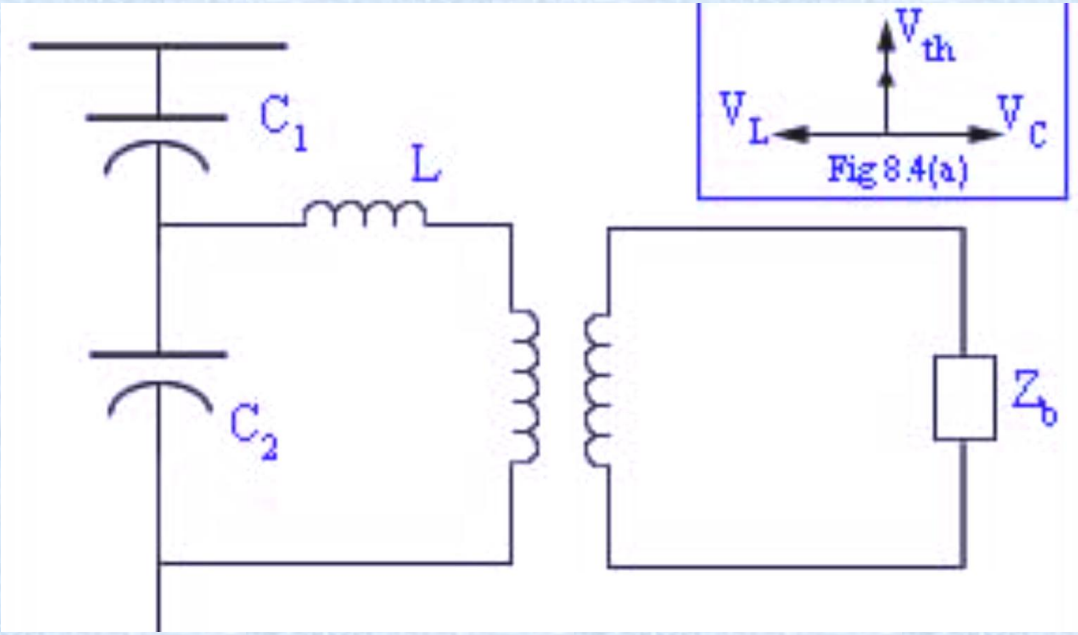
- The measurement of voltage for various relaying schemes is done by a VT.
- The equivalent circuit of a VT is similar to that of a conventional transformer.



Voltage Transformer

Coupling Capacitor Voltage Transformer

- A capacitor potential divider is used to cut down VT size and cost.
- A reduced voltage is fed to primary of the VT.
- A tuning inductor is connected to compensate for capacitance effect.

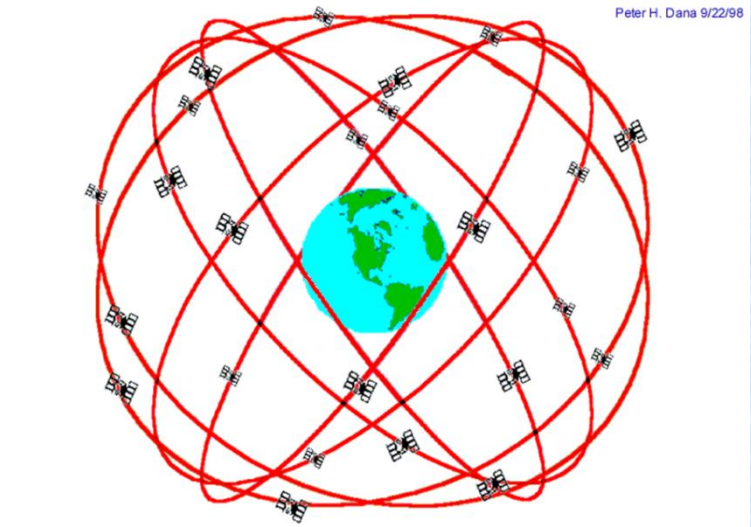


Technological Development

Global Positioning System (GPS)

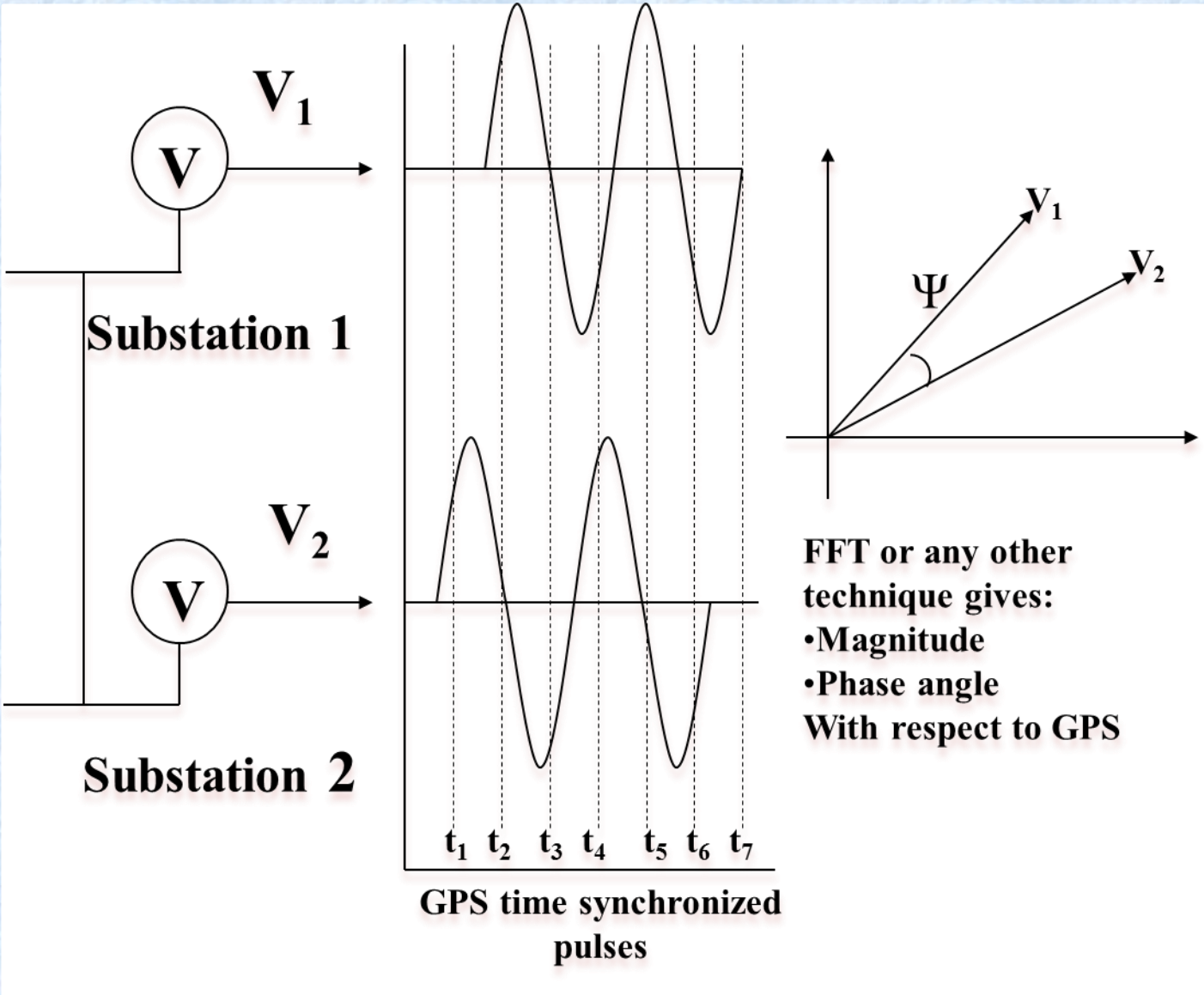
- GPS or Global Positioning Systems is a highly sophisticated navigation system developed by the United States Department of Défense. This system utilizes satellite technology with receivers and high accuracy clocks to determine the position of an object.

1. **Navigation - Where do I want to go?**
2. **Location - Where am I?**
3. **Tracking - Monitoring something as it moves**
4. **Mapping - Where is everything else?**
5. **Timing - When will it happen?**



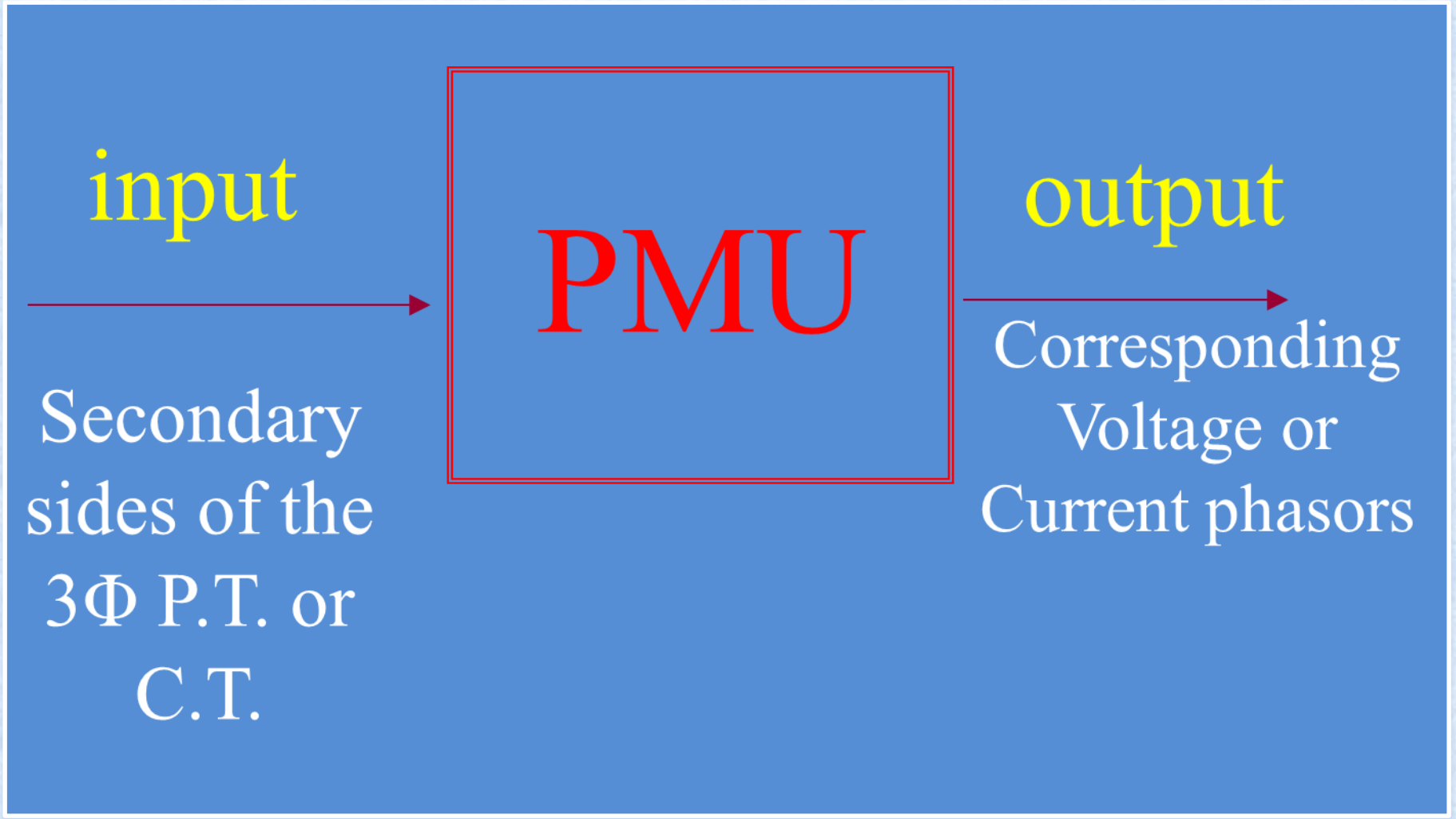
Technological Development

GPS Time Synchronization



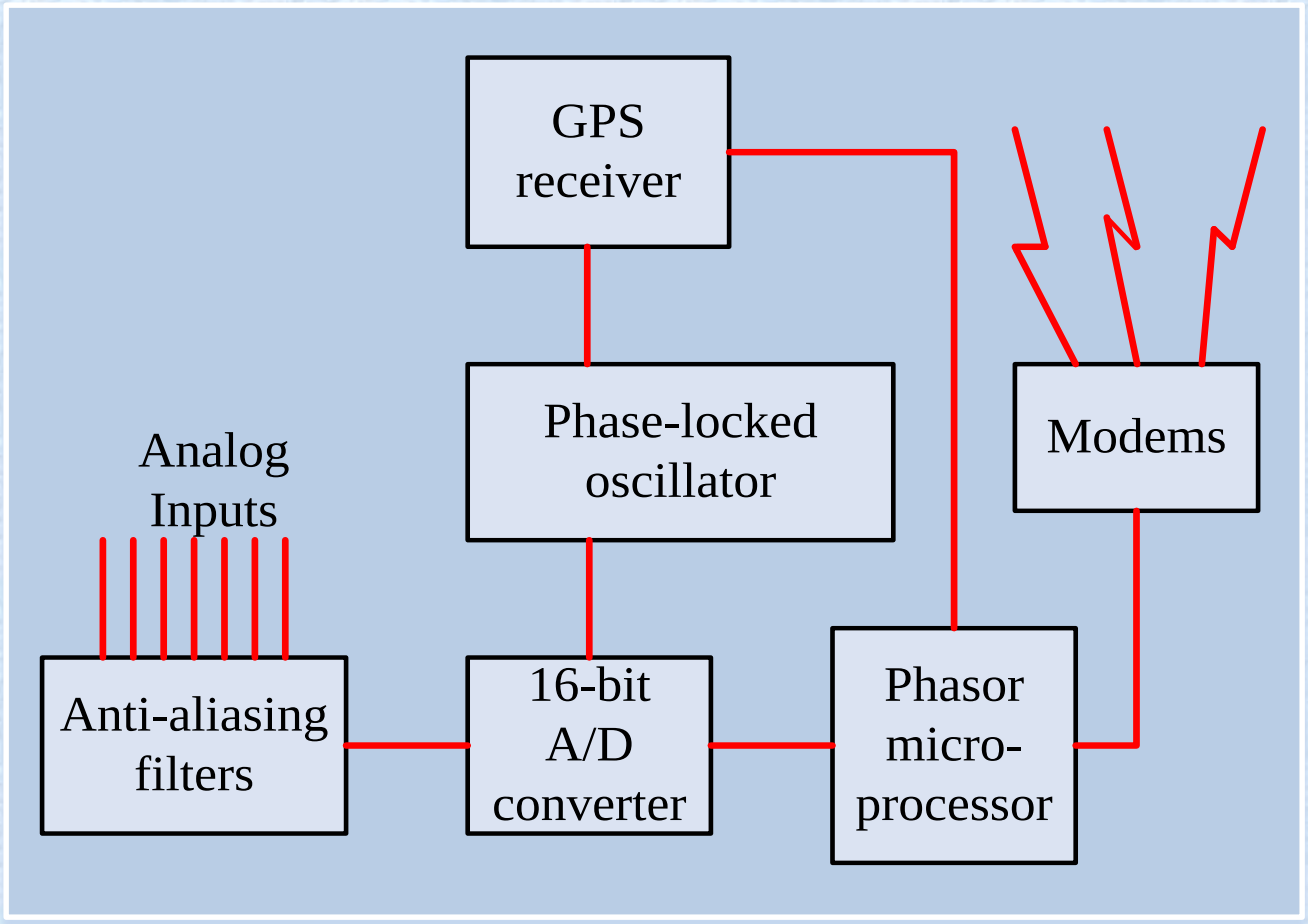
Technological Development

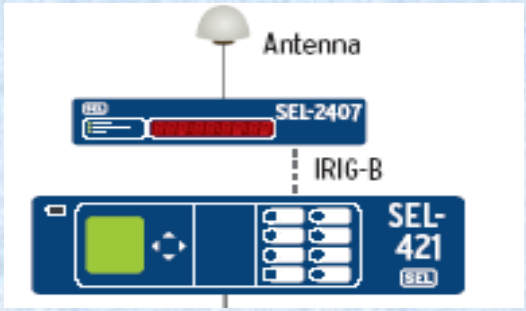
Phasor Measurement Unit (PMU)



Technological Development

PMU Hardware block daigram





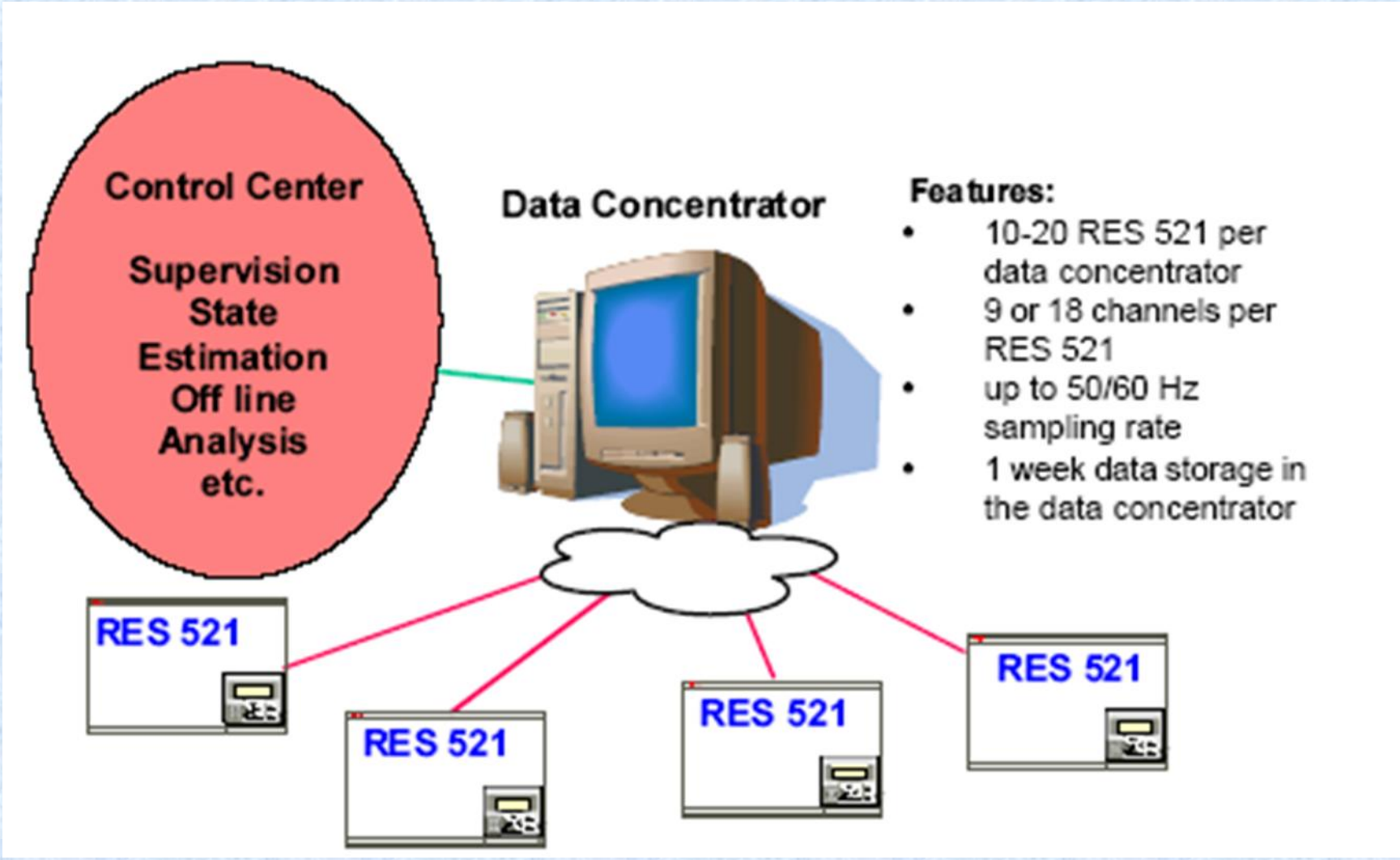
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RES 521

Technological Development

Data Concentrator



Technological Development

Applications of PMU in power System

- Adaptive relaying
- Instability prediction
- State estimation
- Improved control
- Fault recording
- Disturbance recording
- Transmission and generation modeling verification
- Wide area Protection
- Fault location etc.

Thank you