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Asia Institute of Power Management

SCADA

April 2017

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SCADA

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SUPERVISORY CONTROL AND DATA ACQUSITION

SCADA is not a specific technology, but a type of application - "any application that gets data about a system in order to control that system is a SCADA application"

The process/system/machinery we want to monitor and control

this can be a Electric power Plant , a water & sewage system, a network, a system of traffic lights, mass transit etc.

A network of intelligent devices that interfaces with the first system through sensors and control outputs. This network, called SCADA system, gives us the ability to measure and control specific elements of the first system.

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SCADA

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- What is SCADA
- Components of SCADA
- Types of signal
- Related Protocols
- Application of SCADA
- Benefits of SCADA

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What is SCADA?

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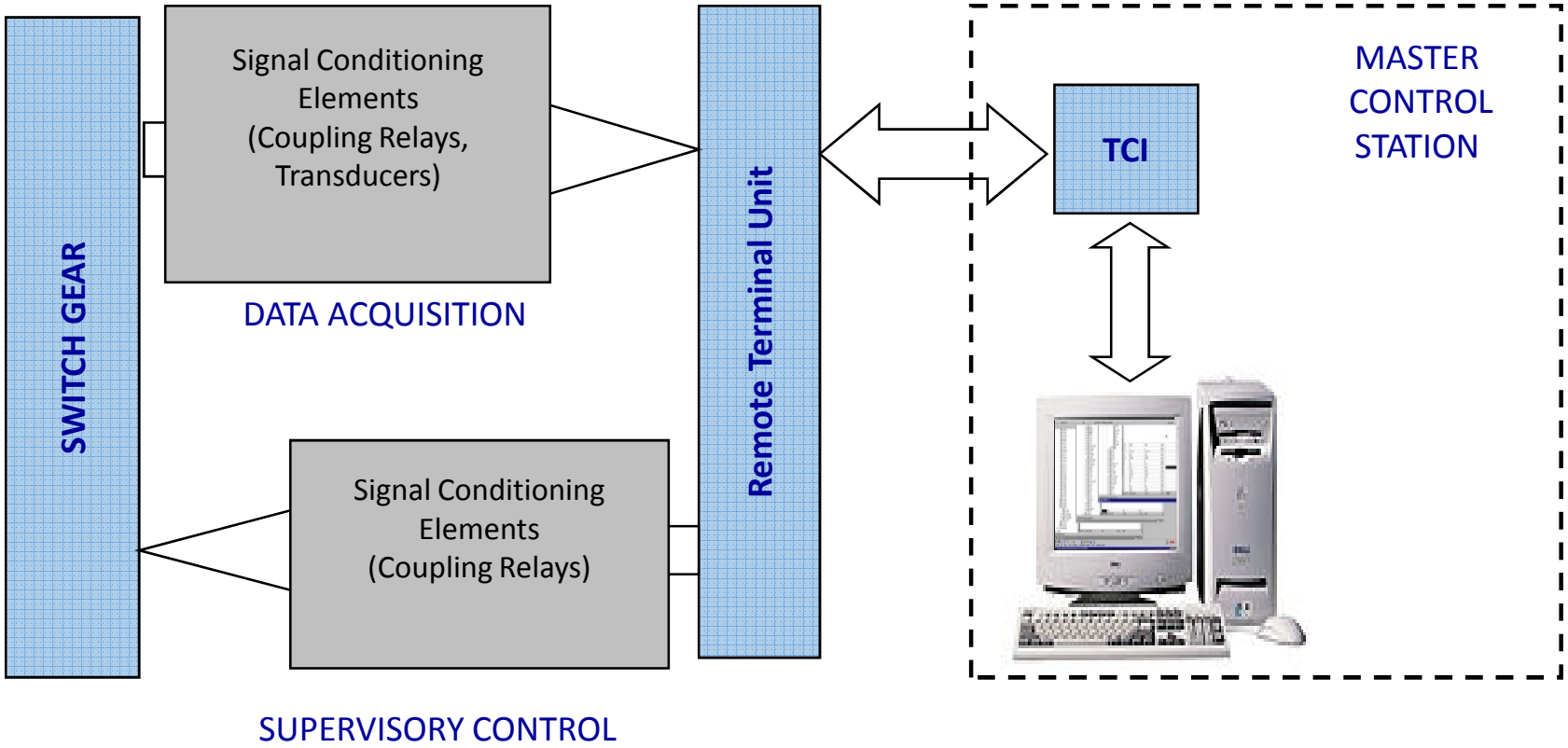
SUPERVISORY CONTROL AND DATA ACQUSITION



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Components of SCADA

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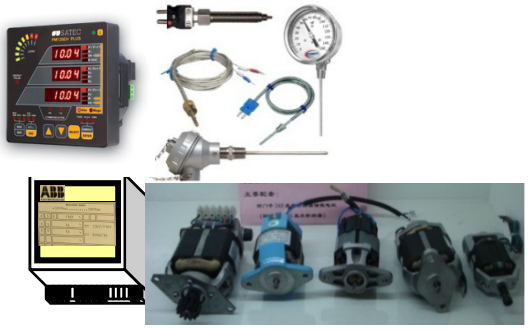
Field Instrumentation

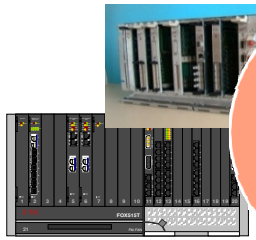


Master Control Station

Components of SCADA

RTU/ PLC /IEDs

Communication media



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Types of Signals and Protocol

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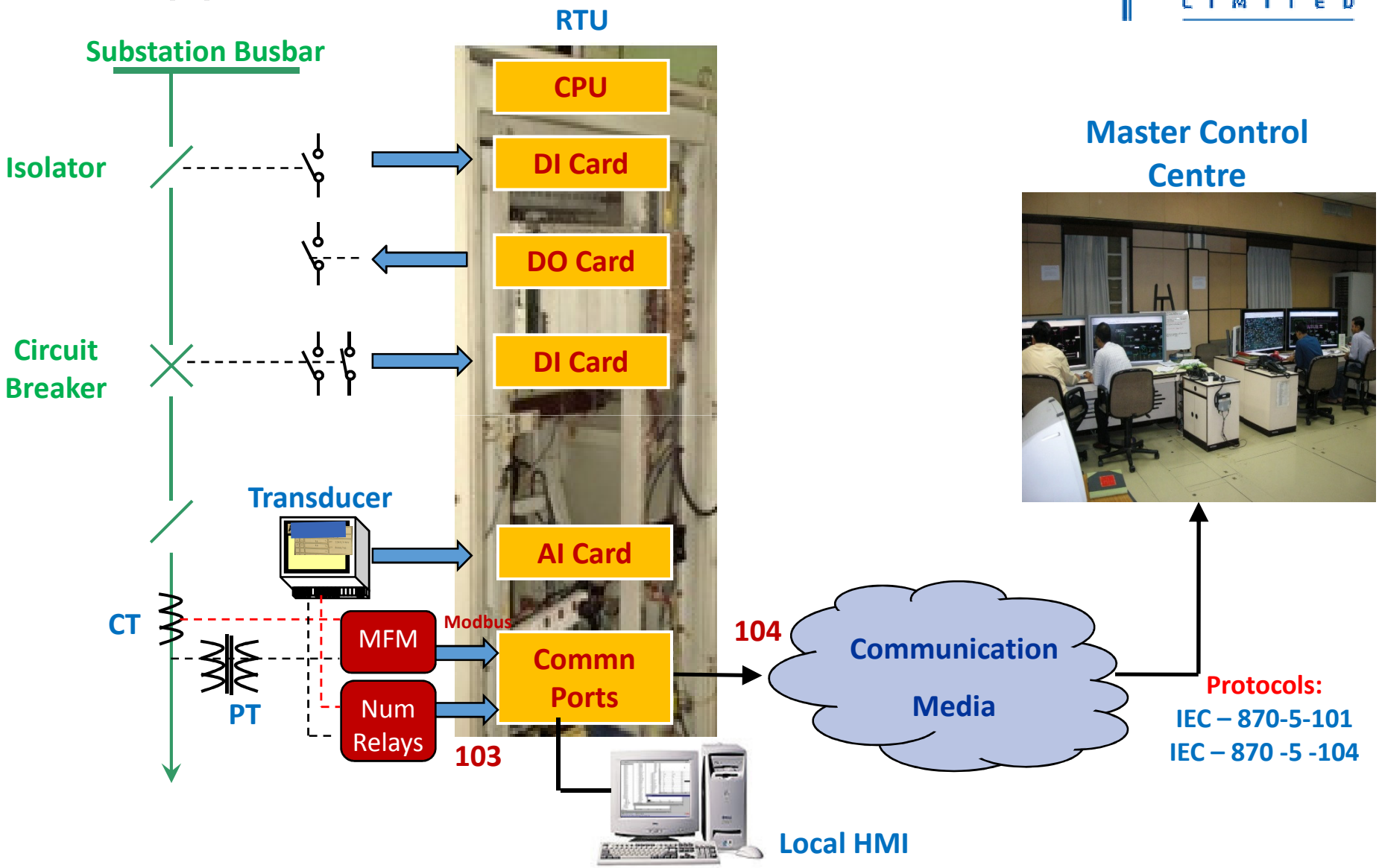

Communication Medium

For transferring of data on real time basis between, Master station & Remote station communication media is required

Types of comm media:

Wireless

- Microwave

Wired

- Optical fibre based telecommunication
- PLCC
- Leased line

Feature

- Reliable (24X7 availability)
- Channel level Redundancy
- Bandwidth
- Secure
- Min latency for real time data

Central SCADA – Control Room

1. It is the master unit of the SCADA system.
2. It is in charge of collecting information gathered by the remote stations and of generating necessary action for any event detected.
3. It can have a single computer configuration or it can be networked to workstations to allow sharing of information from the SCADA system.

Major SCADA Vendors:

1. Siemens – SINAUT Spectrum on SUN Solaris
2. Areva – e-Terra on Windows (Also supports Open Platform)
3. ABB – Spider on Unix, MicroSCADA on Windows

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Applications of SCADA

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The existing SCADA systems deployed in the automation of Power Distribution Network have the following monitoring and Control functions:

- Monitoring and control of Transmission Network
- Monitoring and control of Distribution Network
- Control and monitoring of HV consumers
- Study of load growth and its trend
- Demand monitoring
- Sequence of events (SOE) monitoring

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Benefits of SCADA

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Operational & Maintenance benefits

- Improved reliability by reducing outage duration using auto restoration scheme
- Reduced man hour and man power
- Accurate and useful planning and operational data information
- Better fault detection and diagnostic analysis
- Better management of system and component loading

Financial benefits

- Increased revenue due to quick restoration
- Improved utilization of system capacity
- Customer retention for improved quality of supply

Customer related benefits

- Better service reliability
- Reduce interruption cost for Industrial/Commercial customers
- Better quality of supply

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MFMs

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- MFMs in daisy chain RS 485 bus (SATEC PM130EH)
- Cable used 0.5mm^2 3 core screened cable (maxm length 110m/ chain)
- Connected to RS 485-RS 232 converter (CM 0829)
- RS 232 signal finally connected to the serial port of RTU
- Upto 8 MFMs in daisy chain for proper response time
- Used in import/ export points for parameters like

  Total MW, MVAR, PF, Freq, KWH, KVARH, L2L voltage, current

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Input and Output Interfacing

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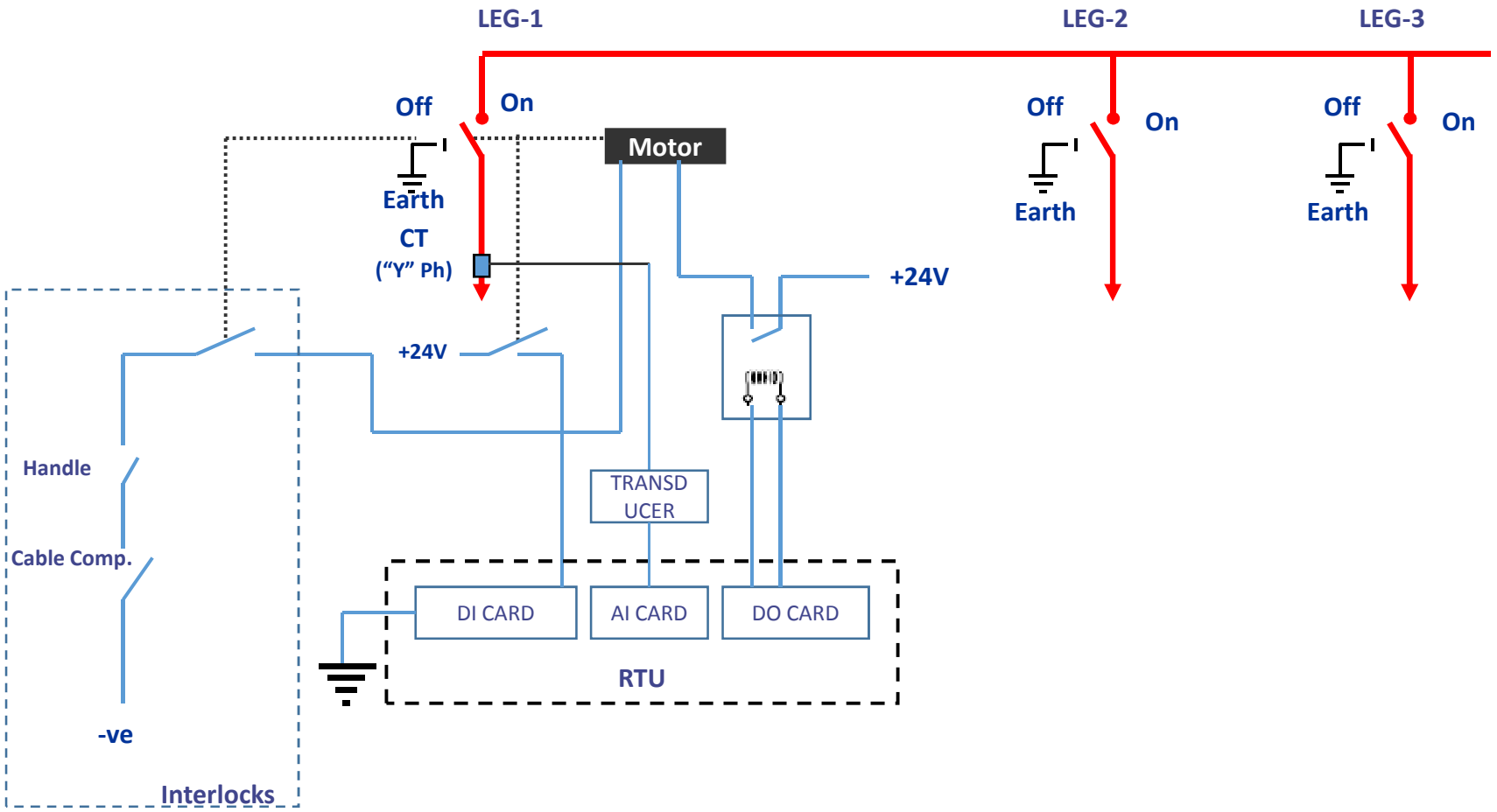

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POWER SYSTEM PROTECTION

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CESC Overview

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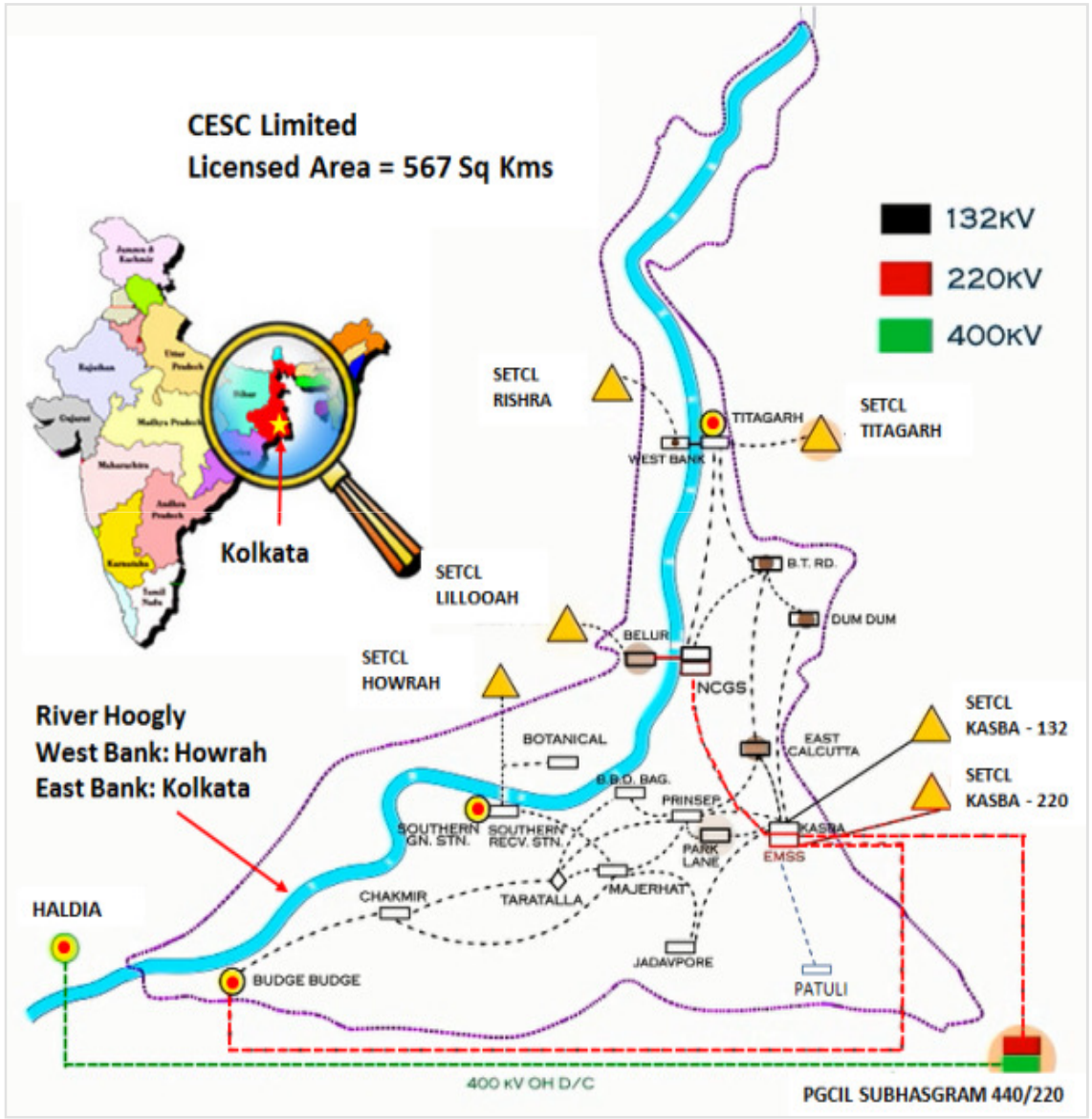

- **About 120 year old fully Integrated Energy Utility**
  - Oldest private electricity utility in India
  - Brought thermal power in India
- **Generation, Transmission, Distribution**
- **567 sq.km working Area**
- **3 million consumers**
- **Maximum Demand: 2000 MW +**
- **Own Generation: 1125MW**
- **Network: Majority UG**

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T&D Network and Protection System

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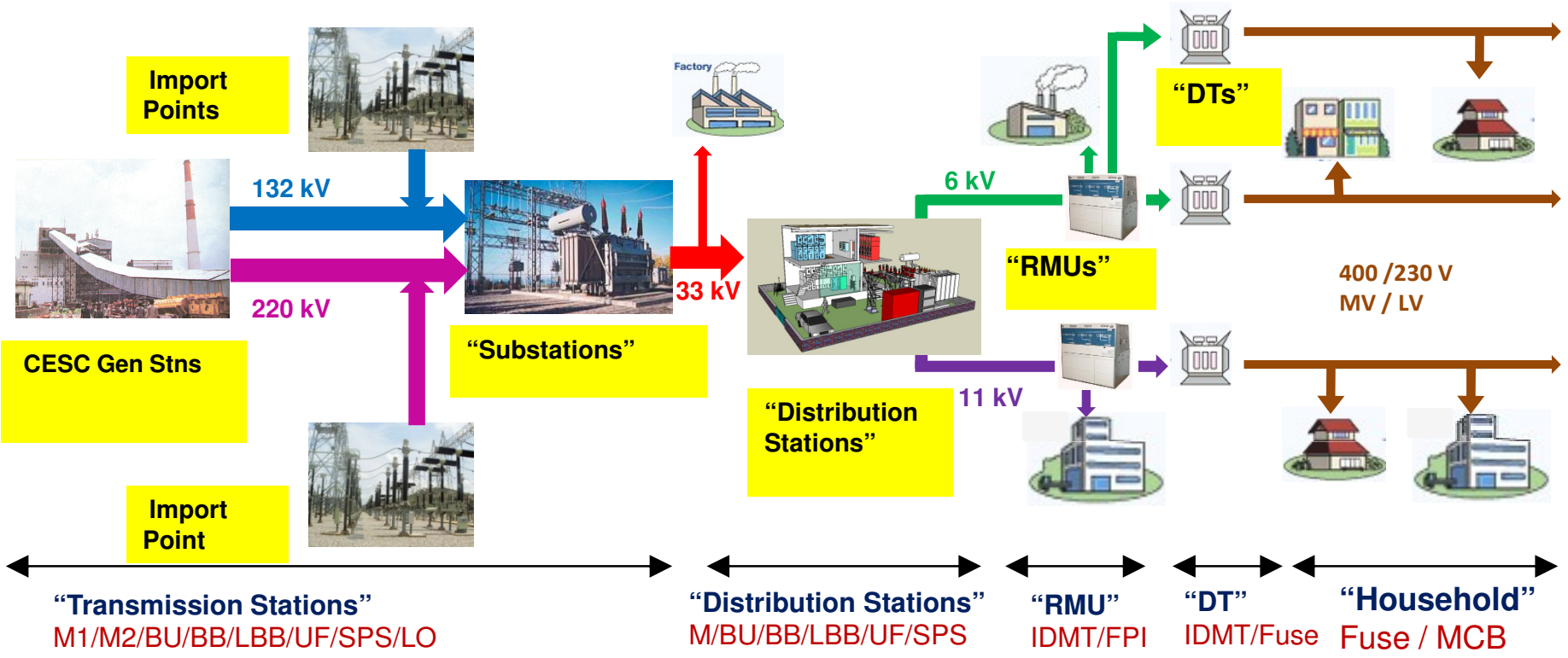
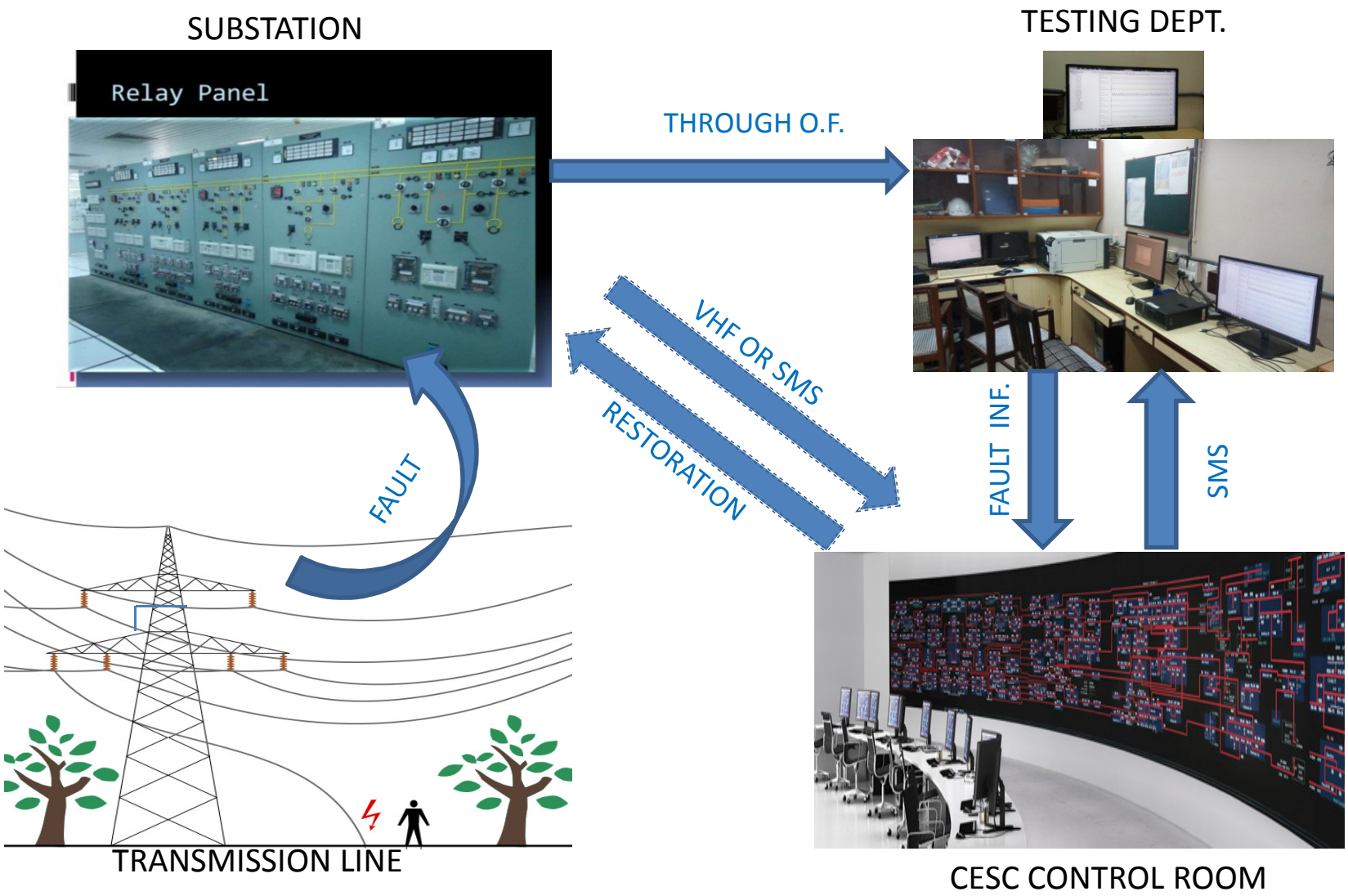


Disturbance Recorders are located at few strategic locations

HV consumers are provided with OFLD / HS protection

Extensive use of Fibre Optic / Pilot cable in Protection System

Centrallised Protection & Disturbance Record



Benefits

- Faster analysis & decision making process resulting faster restoration
- Flexibility of remote modification of protection settings

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Challenges of Protection Engineer

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- Learning – Studying – Understanding
- Eradication of mal-operation / undesired operation of protection system
- Information flow in case of tripping – Integration with SCADA
- Automatic download of NR & DR – Common platform of different relays
- Adaptation with Network changes & Synchronising points – SPS
- People orientation – some Automation in Link Changeover for SPS (selection from SCADA)
- Maintaining the Protection Availability & Adequacy
- Relay communication system fibre .
- Regular checking of CB / Battery / Battery EF
- Time Synchronisation of different devices
- Any abnormality in the system to be investigated, analysed and action required for prevention.
- Requirement of Protection Management System

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Protection Management System

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- Data base for keeping Relay Records
- Software based Fault level calculation
- Software based Relay Setting calculation & protection co-ordination
- Interface point co-ordination - all stake holders
- Access of Relays DRs from a central location
- Up-keepment of Control & Protection Schematic

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New Protection Initiatives

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- 2 OFLD protection in Transmission system in redundant optical path
- Separate DC circuits for 2 protection systems
- DC E/F detection – mandatory
- SMS generation in case of Protection outages
- Integration of protection signals in SCADA system
- HS protection in 6/11kV selective feeders

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Steps Ahead

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- All stakeholders to work together (Utility Interface points for protection co-ordination)
- Sharing of knowledge between Protection Engineers of Utilities
- Information to Manufacturers on new requirements / problem areas
- Automation Communication Protection Group to work in close association
- Prediction of Faults – CM of assets – online
- Smart Grid
  - Use of IT in protection system
  - Use of Communication Multiplexer in Protection Schemes
  - PMUs at strategic location

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PRESENTATION AGENDA

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- NEED OF PROTECTION
- FAULT CHARACTERISTICS
- PROTECTION PHILOSOPY & SPS
- RELAY &DISTURBANCE RECORDER
- GUIDELINE
- CASE STUDY

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Need of Protection

- The objective of a protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation.

- protection schemes must apply with very pragmatic and pessimistic approach to clearing system faults.

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Need of Protection

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WHY PROTECTION?

- Purpose
  - Senses abnormality in the network.
  - Detects that part of the network which is the cause of abnormality.
  - To maintain stability, isolates only the faulty part from rest of the healthy system.

ASPECTS

- Relays.
- Sensing devices.
- Measuring, comparing & logic devices.
- Location, circuitry & logics for selectivity.
- Operating devices.
- Control supply & communication.
- Power system fault level determination at protection application point in network.

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WHY PROTECTION IS SO IMPORTANT

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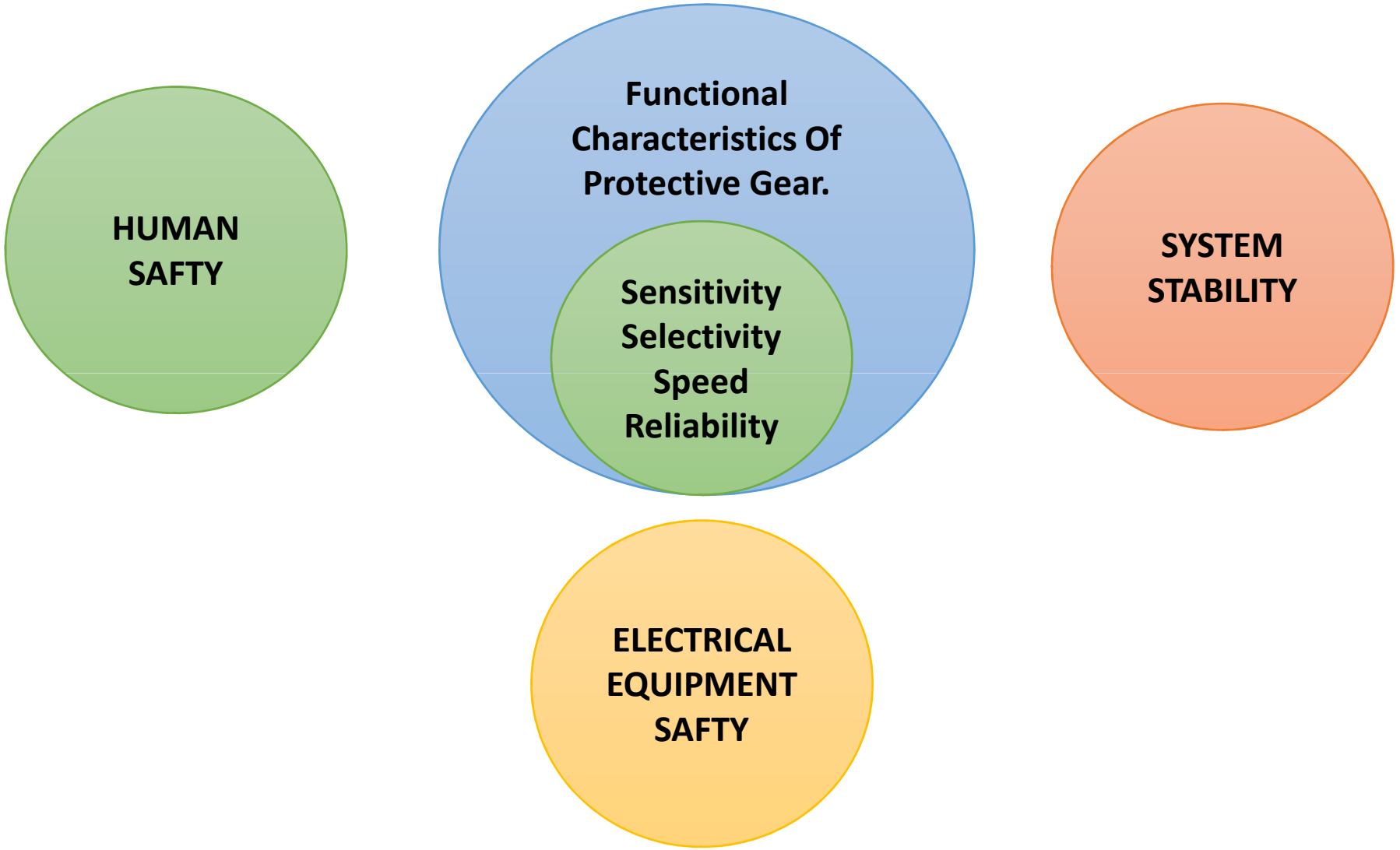

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FAULT CHARACTERISTICS

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Why calculation & analysis of fault current is required?

The **design** of machines, bus bars, isolators, circuit breakers etc. is based on the knowledge of normal current and fault currents in the system.

The **selection of protective relays and discrimination (with the relaying scheme)** is dependent on the knowledge of distribution of current & voltage in different parts of the system due to the fault.

Faults cause drop in voltage, unbalance and loss of stability. Hence another purpose of fault calculations is to **determine the change in voltages and the transient performance of the networks** under various fault conditions.

Depending upon type of fault we can divided in to two types

1. Symmetrical Fault(3 Ph short-circuit fault)

2. Asymmetrical Fault(Phase to Ground, Phase to Phase & Phase to Phase involving ground)

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FAULT CHARACTERISTICS

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Symmetrical components of 3-phase systems:

According to the theorem, unbalanced system of three vectors *(I_a, I_b, I_c or V_a, V_b, V_c)* can be resolved into three balanced systems of vectors, which are:

Positive Sequence Components consisting of three phasors *(V_{a1}, V_{b1}, V_{c1} or I_{a1}, I_{b1}, I_{c1})*, equal in magnitude, displaced from each other by 120^0 in phase, and having the same phase sequence as the original phasors.

Negative Sequence Components consisting of three phasors *(V_{a2}, V_{b2}, V_{c2} or I_{a2}, I_{b2}, I_{c2})* equal in magnitude, displaced from each other by 120^0 in phase and having the phase sequence opposite to that of the original phasors.

Zero Sequence Components consisting of three phasors *(V_{a0}, V_{b0}, V_{c0} or I_{a0}, I_{b0}, I_{c0})*, equal in magnitude and having zero relative phase displacements i.e. having same phase.

$$I_a = I_{a0} + I_{a1} + I_{a2}$$

$$I_b = I_{b0} + I_{b1} + I_{b2} \quad \text{- Eqn.1}$$

$$I_c = I_{c0} + I_{c1} + I_{c2}$$

$$\left.\begin{aligned} V_a &= V_{a0} + V_{a1} + V_{a2} \\ V_b &= V_{b0} + V_{b1} + V_{b2} \\ V_c &= V_{c0} + V_{c1} + V_{c1} \end{aligned}\right\} \quad \text{- Eqn.2}$$

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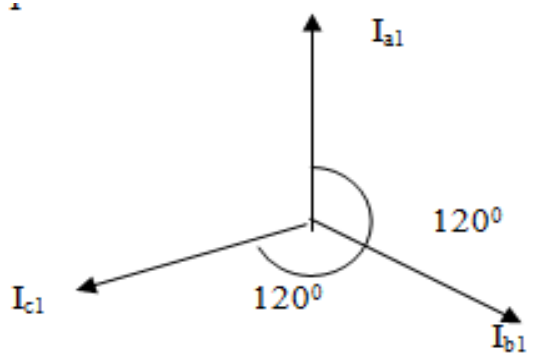
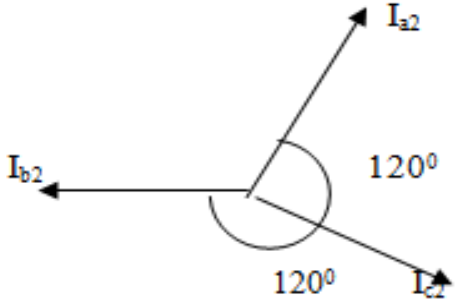
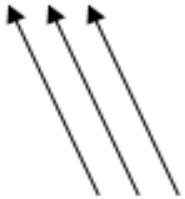
FAULT CHARACTERISTICS



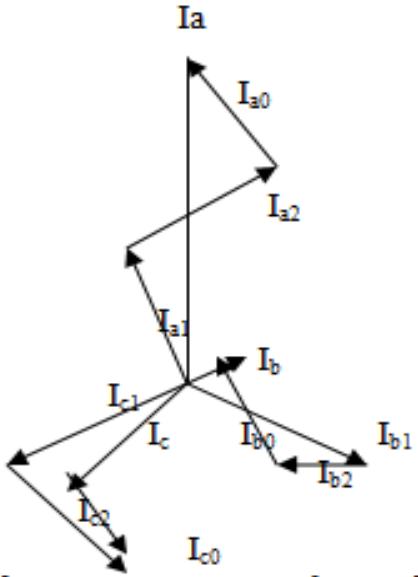
Positive Sequence components



Negative Sequence components



Zero Sequence Components



Addition of the components to obtain three unbalanced phases

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PROTECTION PHILOSOPY IN CESC

- The CESC transmission system, comprising of 220, 132 & 33kV cable & overhead network, have Unit Protection Scheme. At 220 & 132kV voltage level 2Nos main protection and 1No back-up protection are provided.

- At 33kV voltage level 1No main protection and 1No back-up protection are provided. The 11 & 6kV network are protected by IDMT overcurrent & earth fault relays.

- The Transformers (160/75/55/20/16 MVA) are protected by instantaneous transformer differential & restricted earth fault relays along with IDMT overcurrent & earth fault protection system.

- The Generator & GTs have standard protection schemes.

- All the system busbars (220/132/33/11/6kV) have phase segregated busbar protection schemes and all CBs (220/132/33/11/6kV) have local breaker back-up protection schemes barring few old switch boards.

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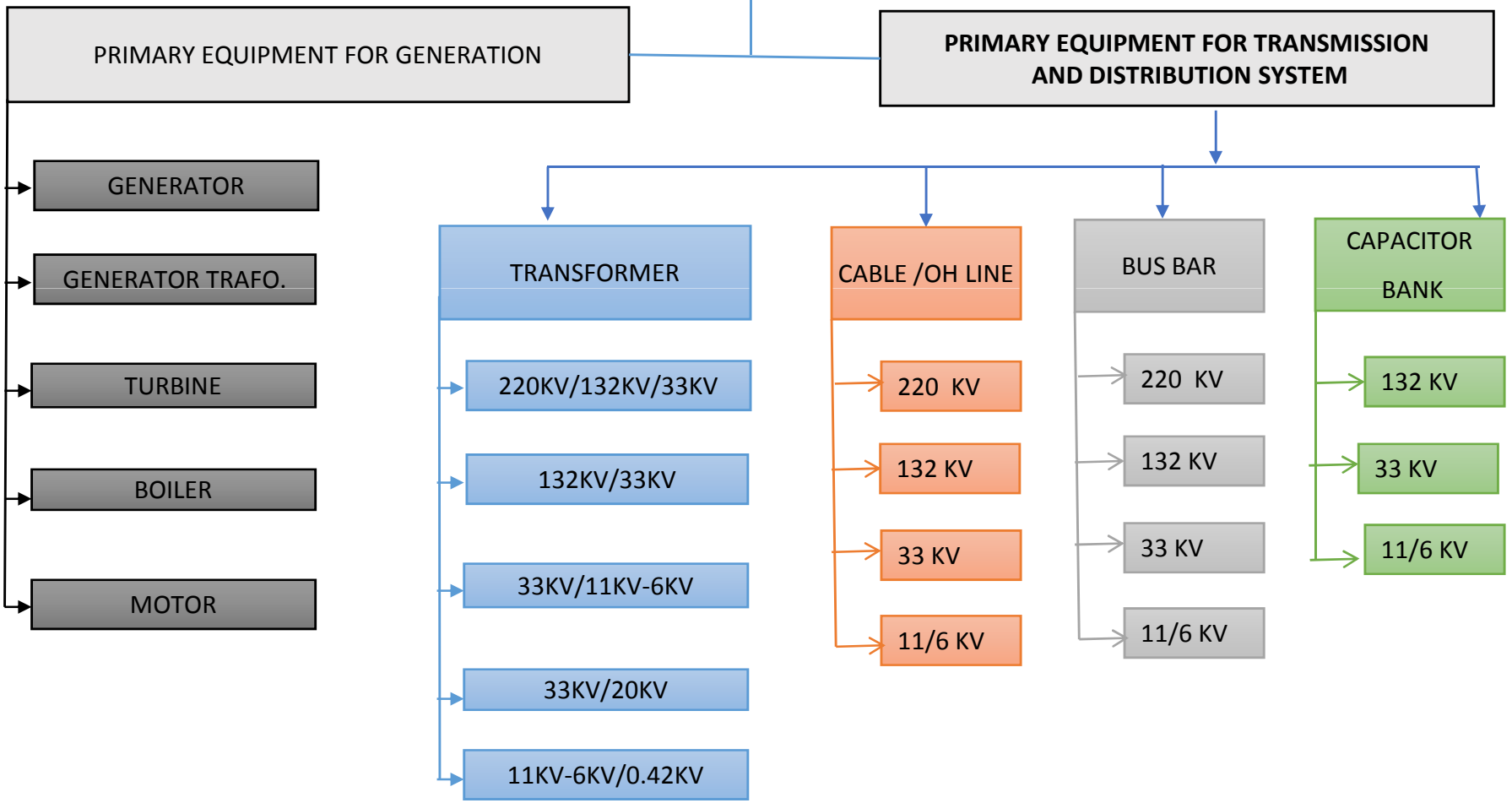
POWER SYSTEM COMPONENTS IN CESC



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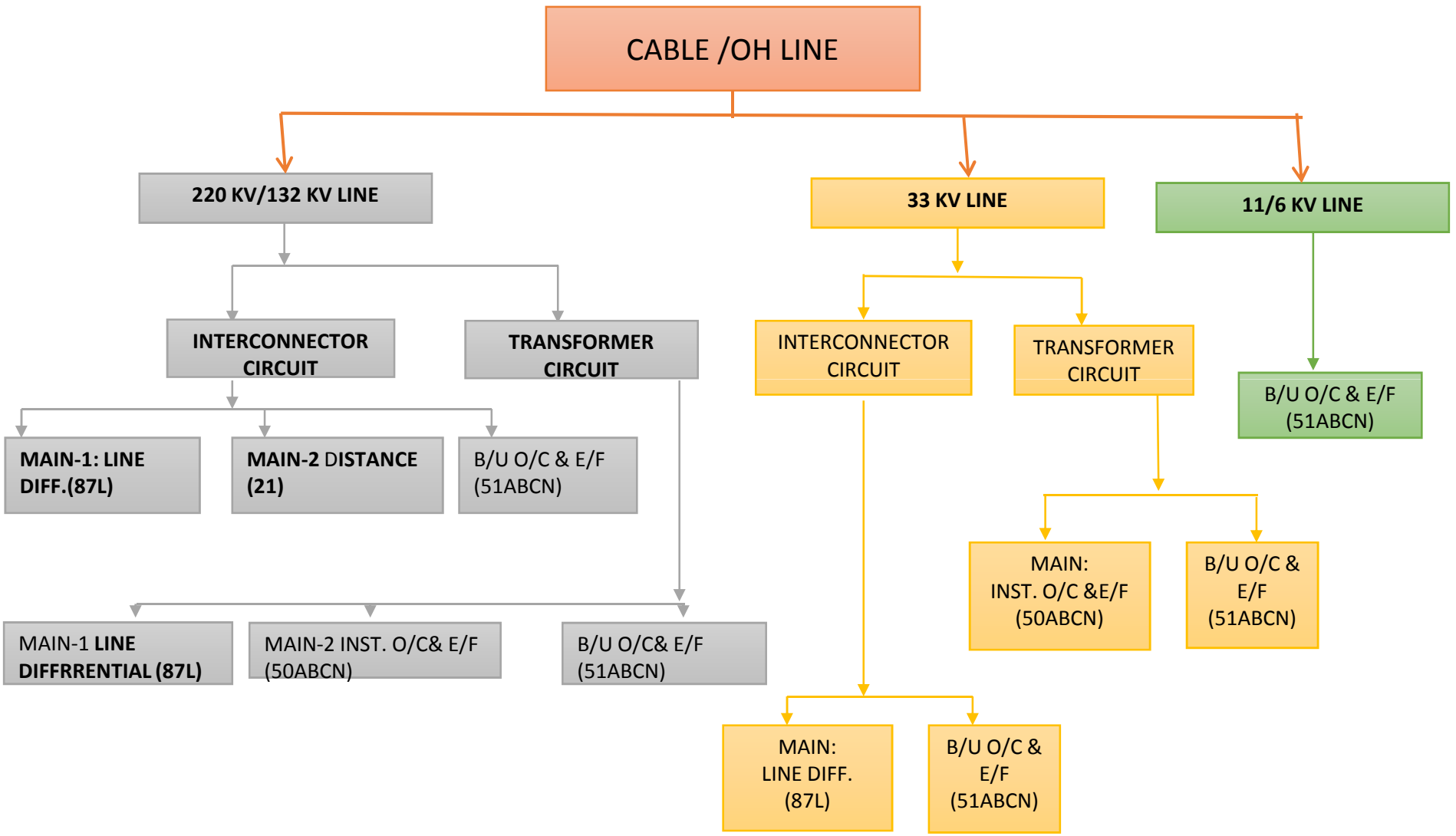
LINE/OH PROTECTION



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TRANSFORMER PROTECTION

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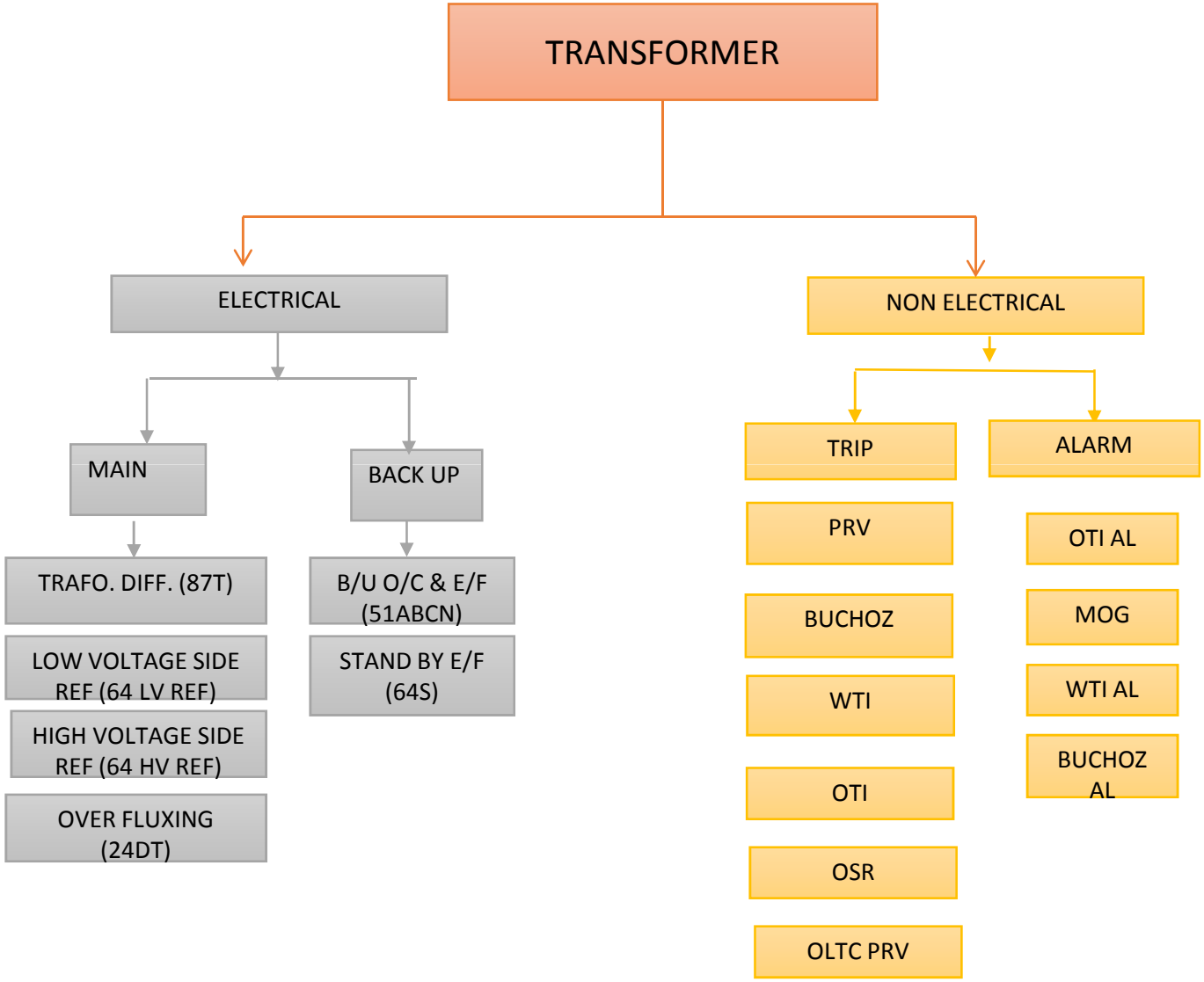

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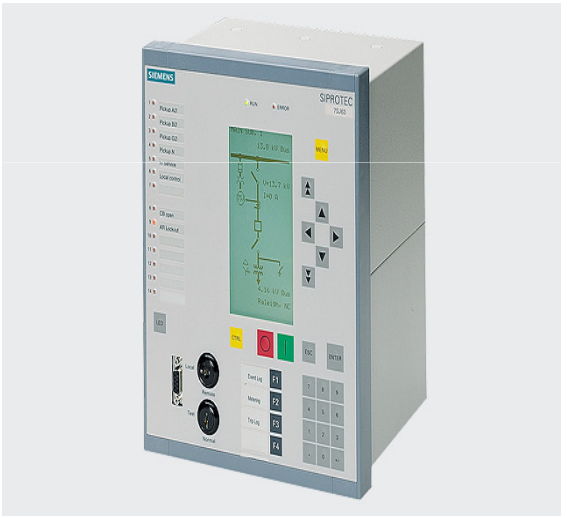
TRANSFORMER DIFFERENTIAL RELAY

DTH:
ELECTRO MECHANICAL

MBCH:
STATIC



7UT:
NUMERICAL

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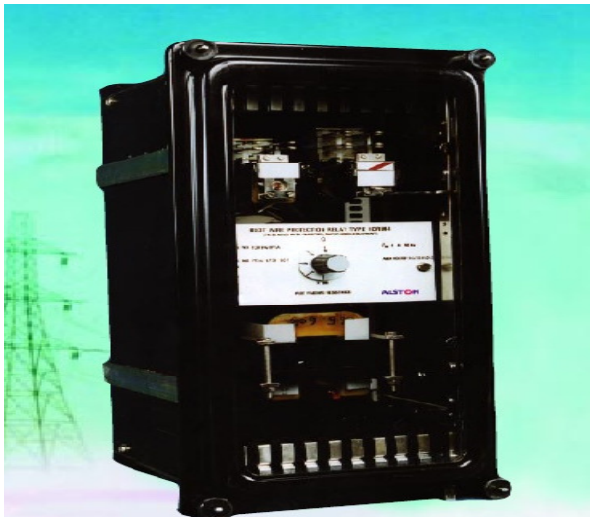
LINE DIFFERENTIAL RELAY



HORM4:
ELECTRO MECHANICAL

MBCI:
STATIC

7SD:
NUMERICAL

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B/U O/C & E/F RELAY

CDG:
ELECTRO MECHANICAL

RACID:
STATIC

7SJ:
NUMERICAL

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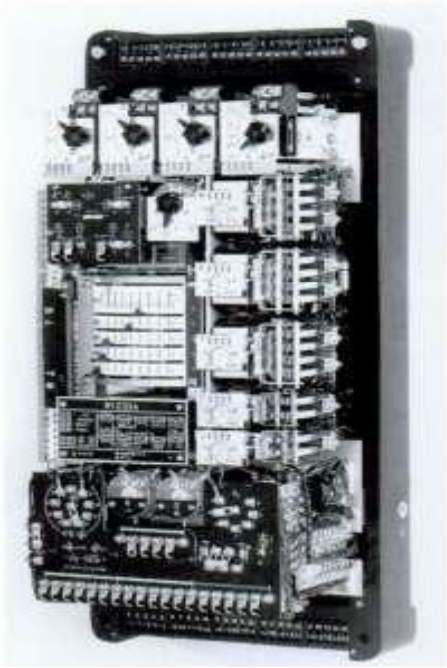
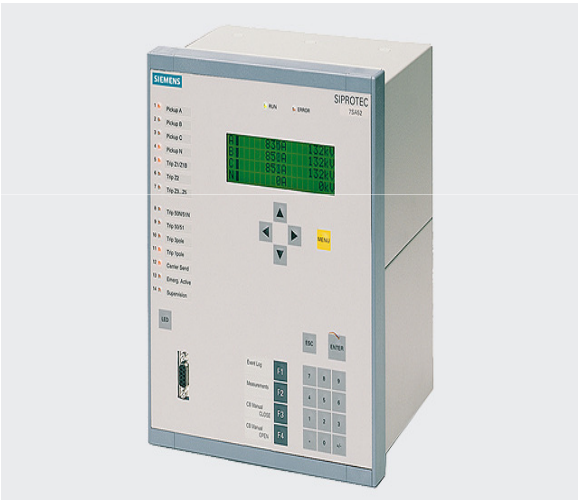
DISTANCE RELAY



7SL93:
ELECTRO MECHANICAL

PYTC :
STATIC



7SA:
NUMERICAL

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EVOLUTION OF RELAY

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FUNCTIONS	ELECTRO MENICAL	STATIC	NUMERICAL
Basic Protection	Only one	One or Two	Multiple
Metering/Display	Nil	Limited	Possible
Control	Nil	Nil	Available
Time Synchronisation	Nil	Nil	Possible
Self Monitoring	Nil	Only Power supply	Available
Remote Communication	Nil	Nil	Possible over different Protocols and media.
Event Recording	Nil	Nil	Available
Disturbance Recording	Nil	Only Current value	Available
Fault Location	Nil	Nil	Available with option

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ADVANTAGES OF NUMERICAL RELAYS

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Control

- ✓ Local and remote control
- ✓ Bay level interlocking of the controlled devices
- ✓ Status information
- ✓ Information of alarm channels
- ✓ HMI panel on device.

Metering

- ✓ Three-phase currents
- ✓ Neutral current
- ✓ Three-phase voltages
- ✓ Residual voltage
- ✓ Frequency
- ✓ Active power
- ✓ Reactive power
- ✓ Power factor
- ✓ Energy
- ✓ Harmonics
- ✓ Transient disturbance recorder

Communications

- ✓ Communication capability of an IED is one of the most important aspects of modern electrical and protection systems.
- ✓ IED has the capability of extensive communications directly to a SCADA system.

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Features of N. Relays used IN CESC

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- ✓ **Self Supervision :-**
- To ensure availability of Protection.
- ✓ **Protection :-**
- Use of multiple protections in a single unit.
- Reduction of panel size.
- Reduction of Total cost account for Protection.
- ✓ **Time synchronisation:-**
- Easy analysis of system disturbance.
- ✓ **Disturbance Recording :-**
- Quick Restoration/Isolation.
- Reduction of Outage Time.
- ✓ **Remote Communication:-**
- Reduction of Outage Time.
- ✓ **Fault Location:-**
- Faster identification of faulty zone.
- Quick Restoration/Isolation.

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SPECIAL PRORECTION SCHEME

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SYSTEM ISLANDING SPS

- CESC transmission system is connected to the outside network via WBSETCL and PGCIL network. CESC system can be synchronized at 6 nos. locations (depending on system requirement).
- At 5 locations the synchronizing voltage is 132kV and at 1 location the same is 220kV. However for ease of operation and maintenance, CESC keeps the synchronizing point at 1 location.
- Normally the system remains synchronized at 132kV level at EM Substation OR at Southern Receiving Station with 3 parallel WBSETCL circuits in either location.
- Any fault/disturbances occurring outside CESC network at 132/220kV level, the splitting scheme gets activated immediately and depending on the fault criticality/system condition, the CESC system gets isolated from the grid by tripping selected circuit breakers through operation of split relay.

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SPECIAL PRORECTION SCHEME

SYSTEM ISLANDING SPS

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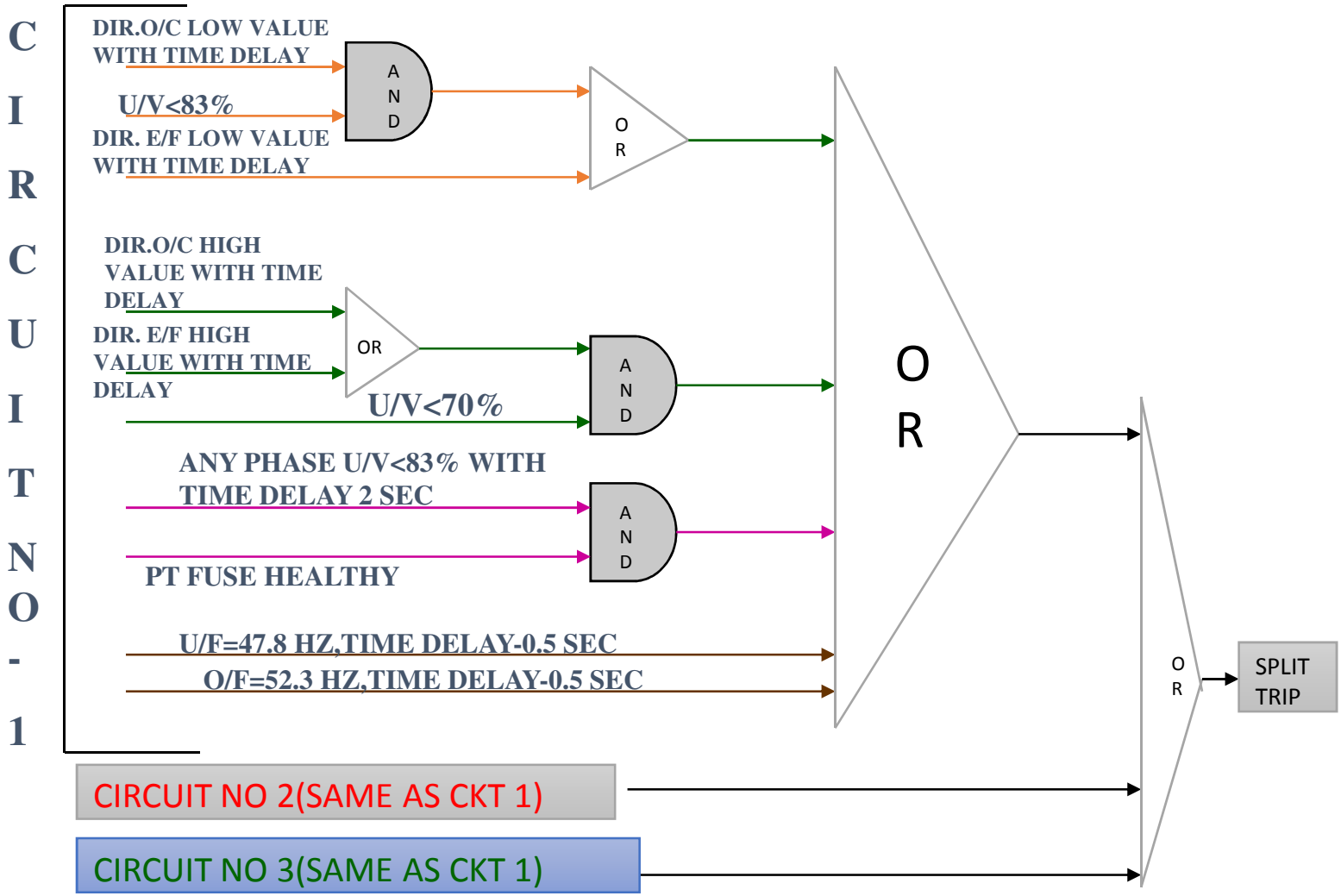

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SPECIAL PRORECTION SCHEME

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UNIT LOCK OUT SPS

- CESC has Generating Stations at 3 locations. In case of tripping of Generator Units OR all evacuation lines, SPS gets activated and send trip signal to strategic circuit breakers for proportionate load shed.

- This prevents excess withdrawal from grid and thereby protecting the grid from under frequency & cascade tripping.

- We have used optical fibre based Numerical relays and CESC owned high speed optical based redundant communication system (SDH/PDH) for transferring trip signals from Generating Stating to evacuating stations.

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SPECIAL PRORECTION SCHEME

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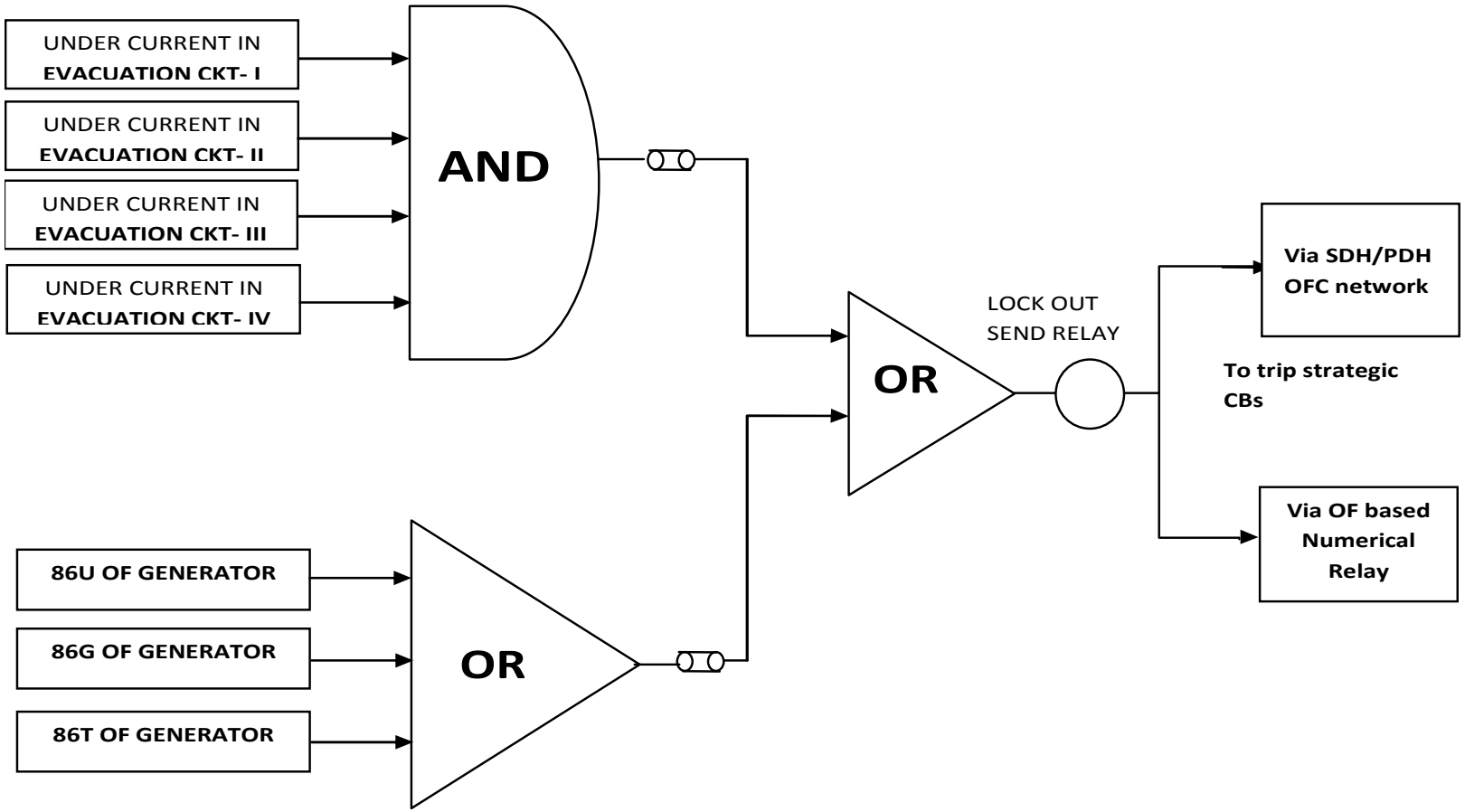
LOGICS DIAGRAM UNIT LOCK OUT SPS



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SPS IN DISTRIBUTION NETWORK

- CESC Distribution Station typically comprises of 33kV GIS, 20MVA - 33/11.5-6.25kV Transformers and 11kV & 6kV air insulated switch boards.

- The SPS is implemented to prevent the tripping of transformer 33kV side, in case of operation of busbar protection at 6 or 11kV switch board and if the fault is not involved in the circuit side of the 6 or 11kV incomer switch panel.

- This scheme has resulted increased availability of transformers. We have utilized features of Numerical relays to achieve the SPS logic.

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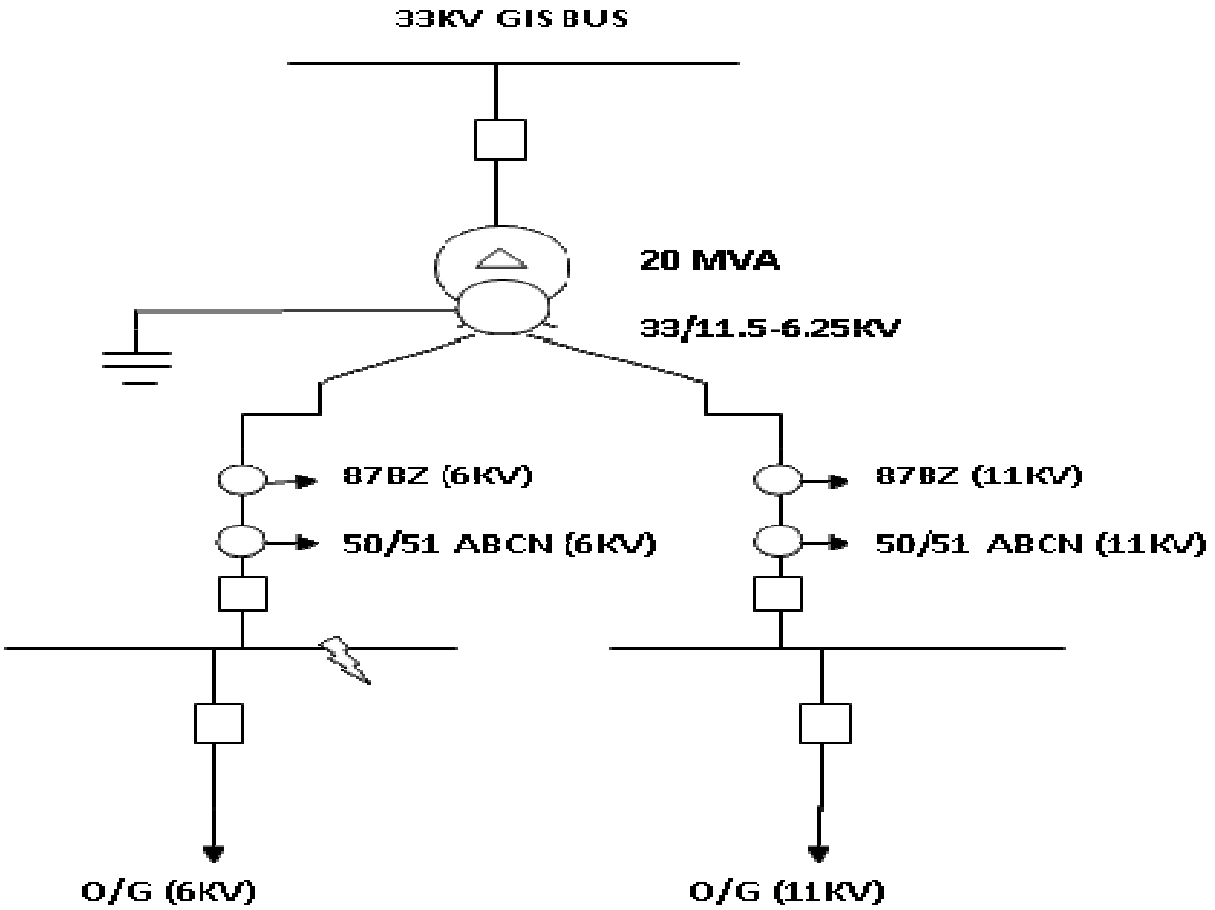
SPS IN DISTRIBUTION NETWORK

TIPICAL DIAGRAM IN DISTRIBUTION NETWORK



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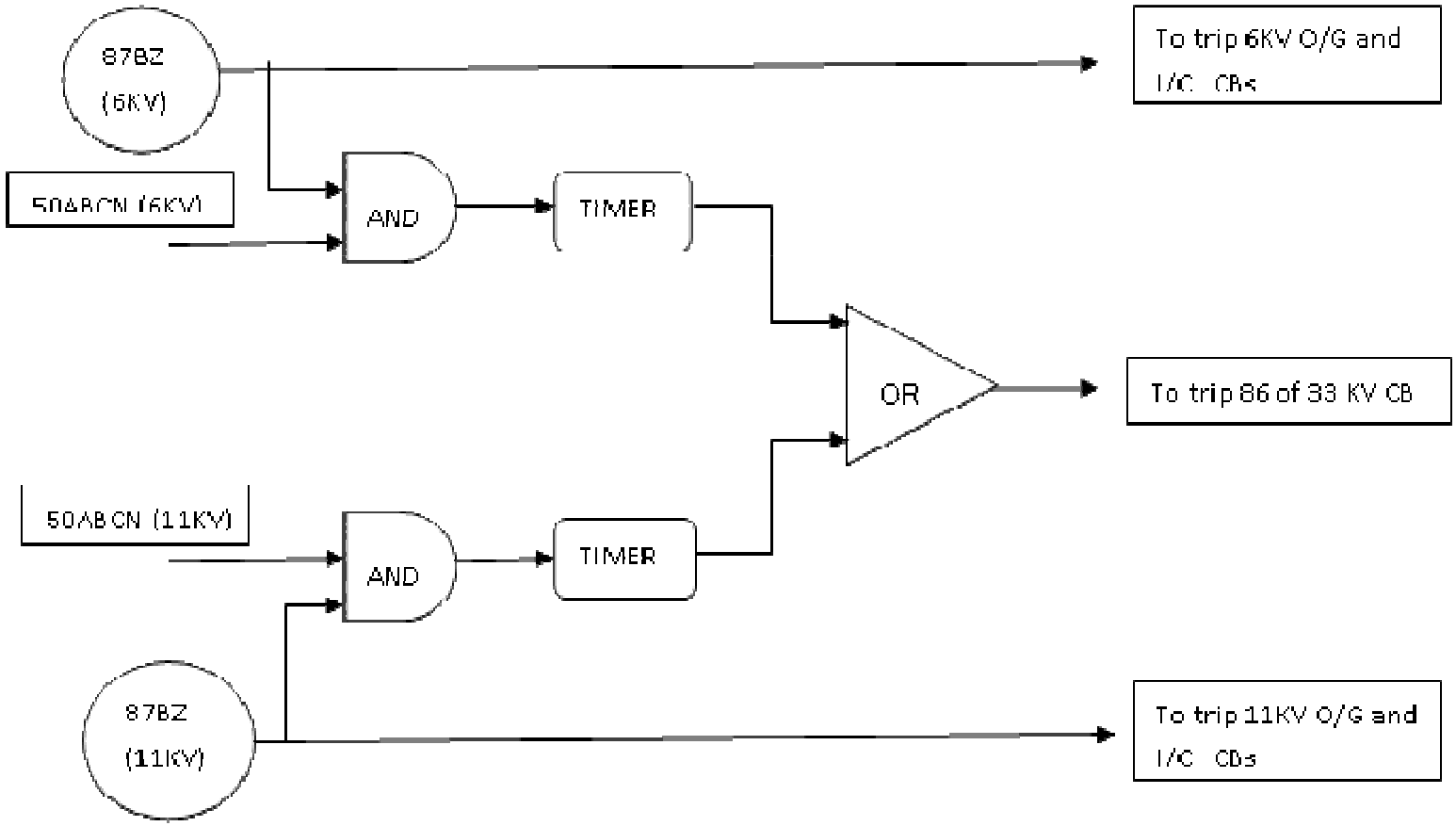
SPS IN DISTRIBUTION NETWORK

LOGICS DIAGRAM SPS IN DISTRIBUTION NETWORK



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DISTURBANCE RECORDER

- ✓ Disturbance Analysis.
- ✓ Quick Isolation.
- ✓ Quick Restoration.
- ✓ Power profile study.
- ✓ Fault Location.

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Guidelines related to Protection system

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CEA GUIDELINE

As per CEA Regulations, 2006, all Transco, DISCOM, & Utilities should provide standard protection systems having the reliability, selectivity, speed and sensitivity to isolate the faulty equipment and protect all components from any type of faults, within the specified fault clearance time and shall provide protection coordination as specified by the Regional Power Committee.

Explanation.- For the purpose of this regulation "fault clearance time" means the maximum fault clearance times are as specified in the Table below

Sl.no	Nominal System Voltage (kV rms)	Maximum Time(in msec.)
1	765 and 400	100
2	220 and 132	160

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DRAFT WBERC GUIDELINE

CESC LIMITED

Fault Clearance Times:

- The primary protection system shall be such that the fault clearance time of all equipments/lines connected to the InSTS whether of Users or of STU / Transmission Licensee, shall not be more than:

1. 100 milli seconds (ms) for 800 kV & 400 kV
2. 160 milli seconds (ms) for 220 kV & 132 kV
3. 400 milli seconds (/2nd Zone) for 132kV and above.
4. 200 milli seconds for 33 kV.

- Back-up protection shall be provided for system at 132 kV and above required isolation/protection in the event of failure of the primary protection systems to isolate the faulty element within the above fault clearance time requirements. The protection system shall comply with the provisions mentioned under CEA (technical Standards for connectivity to the Grid) Regulations, 2007.

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CASE STUDY-I

CESC LIMITED

EVENT

At 132 kV Jadavpur S/S during ON LOAD CHANGEOVER when EMSS ckt was made ON and Majerhat ckt was made OFF, the said Majerhat 132kV ckt tripped through Back-Up E/F relay.

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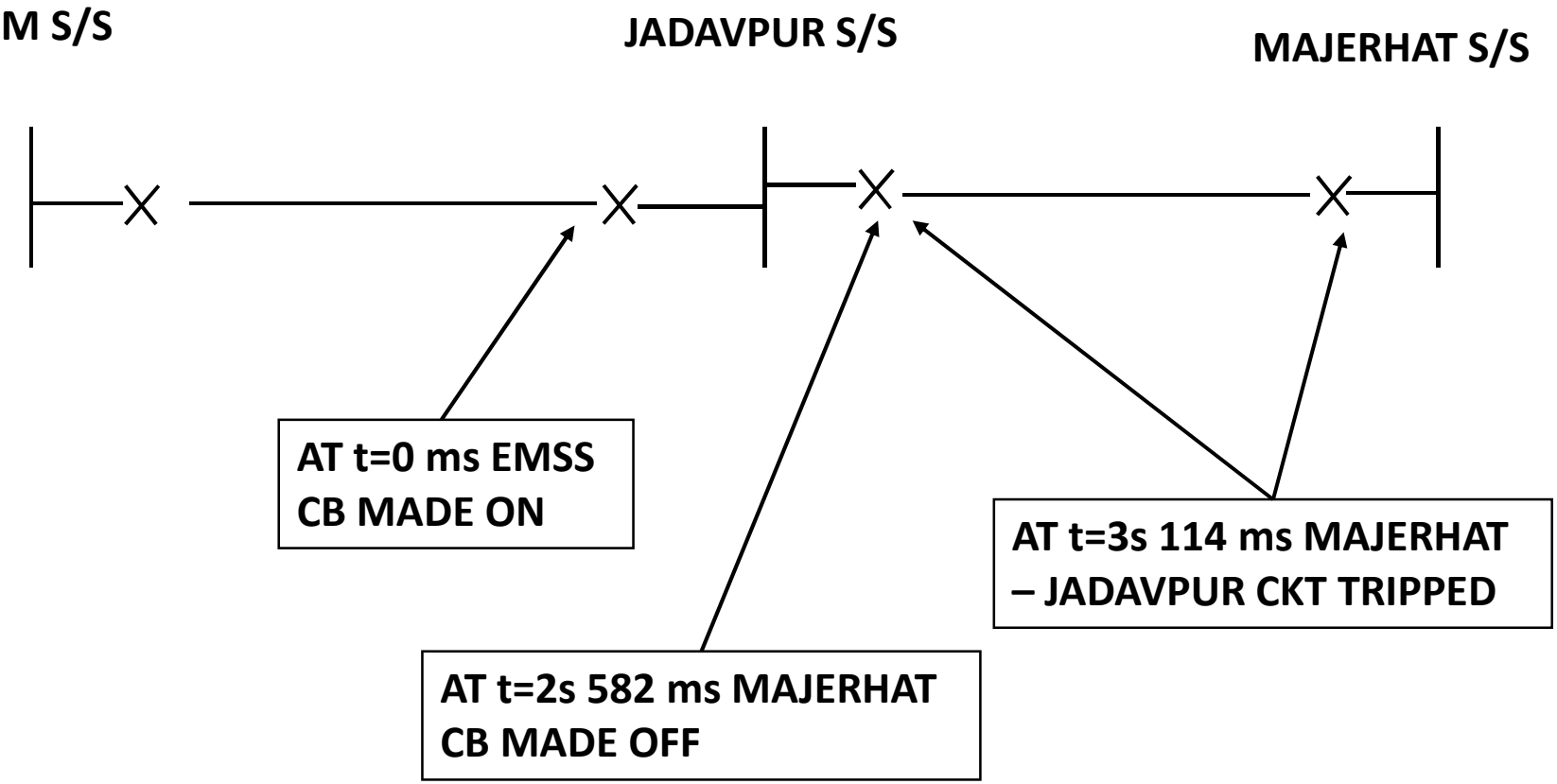
CASE STUDY-I

NETWORK



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CASE STUDY-I

FINDINGS

Y-ph CB pole of Majerhat ckt was not opened when it was made OFF at Jadavpur S/S. As a result E/F current came into the picture and the said ckt tripped though Back-Up E/F relay operation.

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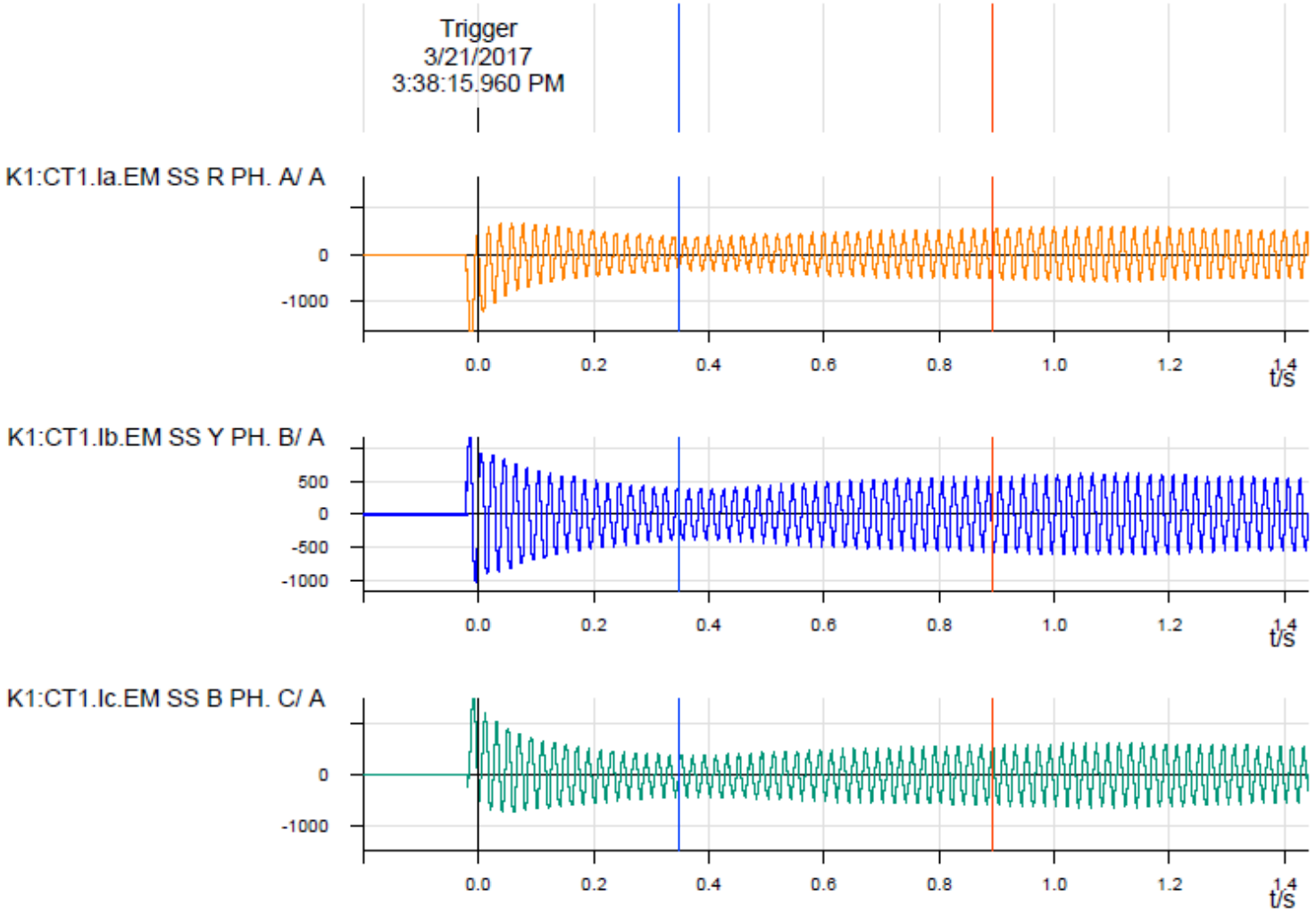
CASE STUDY-I



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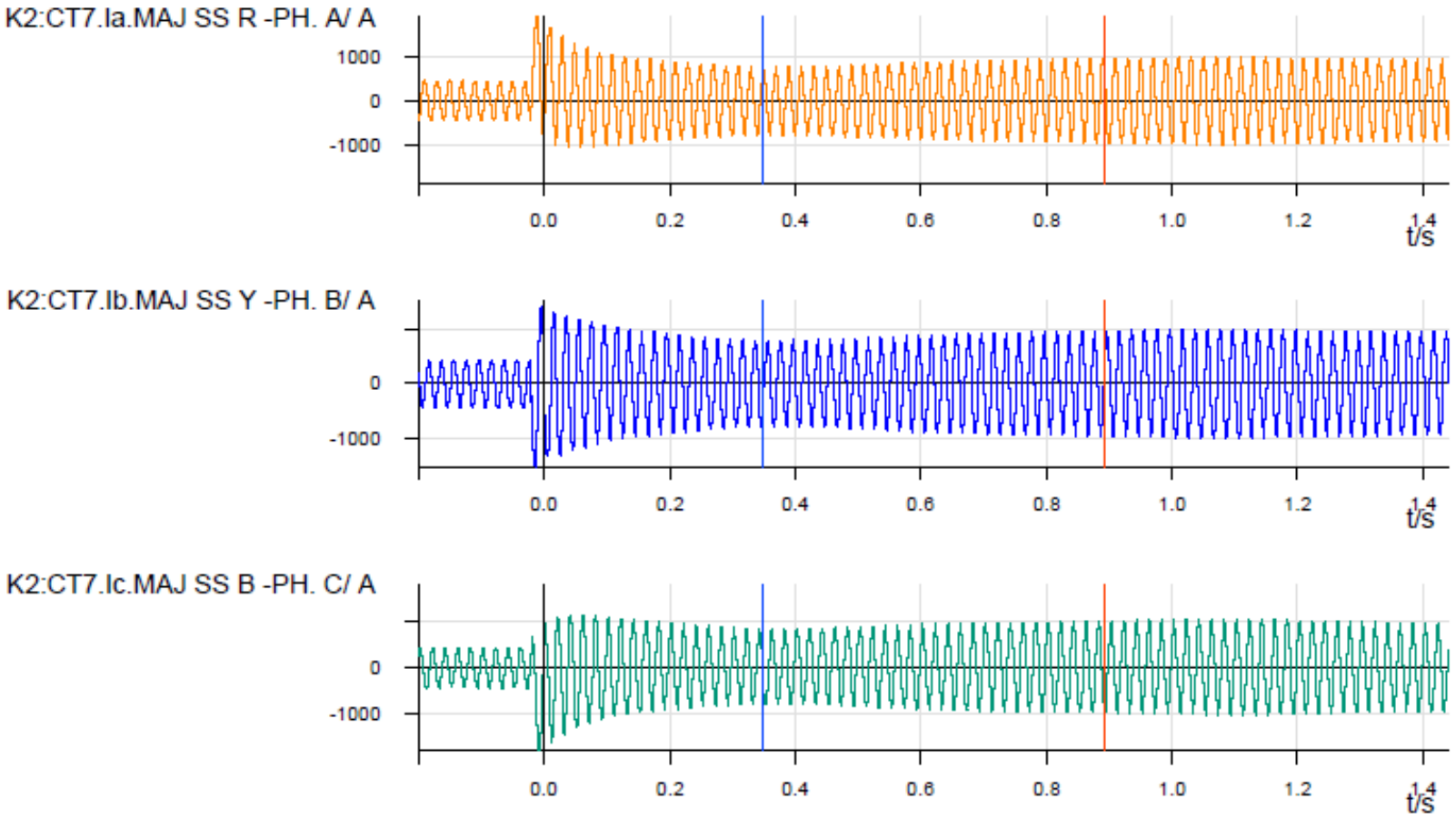
CASE STUDY-I



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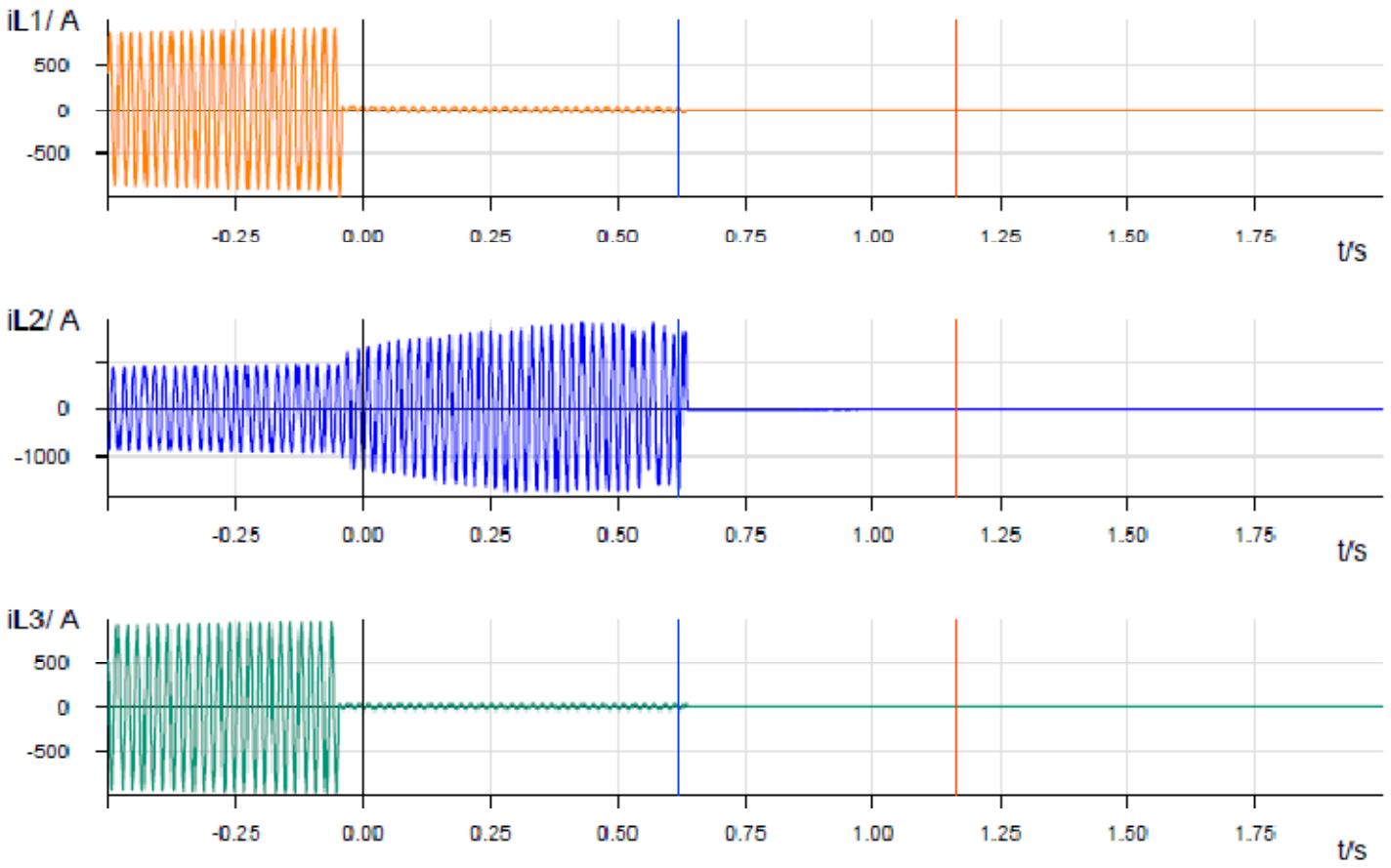
CASE STUDY-I



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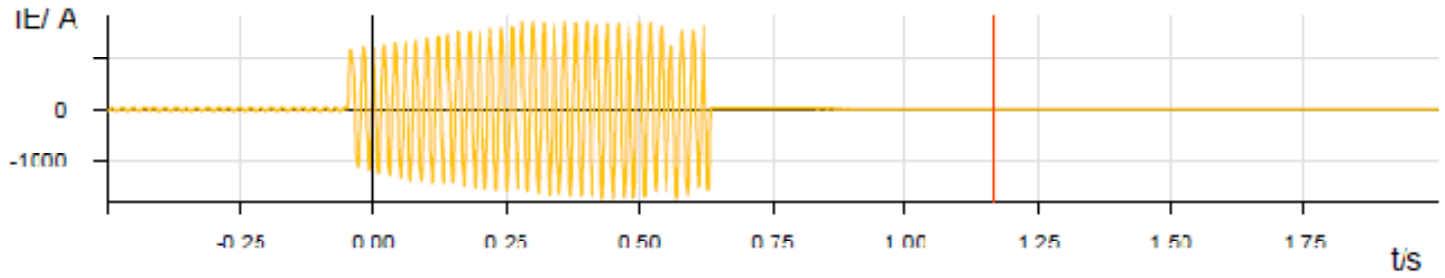
CASE STUDY-I



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CASE STUDY-II

EVENT

Y-B ph short ckt fault occurred in 220 kV BBGS-EMSS ckt-1. Line differential relay at EMSS end operated immediately but I/T was not received at BBGS end. Moreover slight delayed tripping occurred at BBGS end through its line differential relay.

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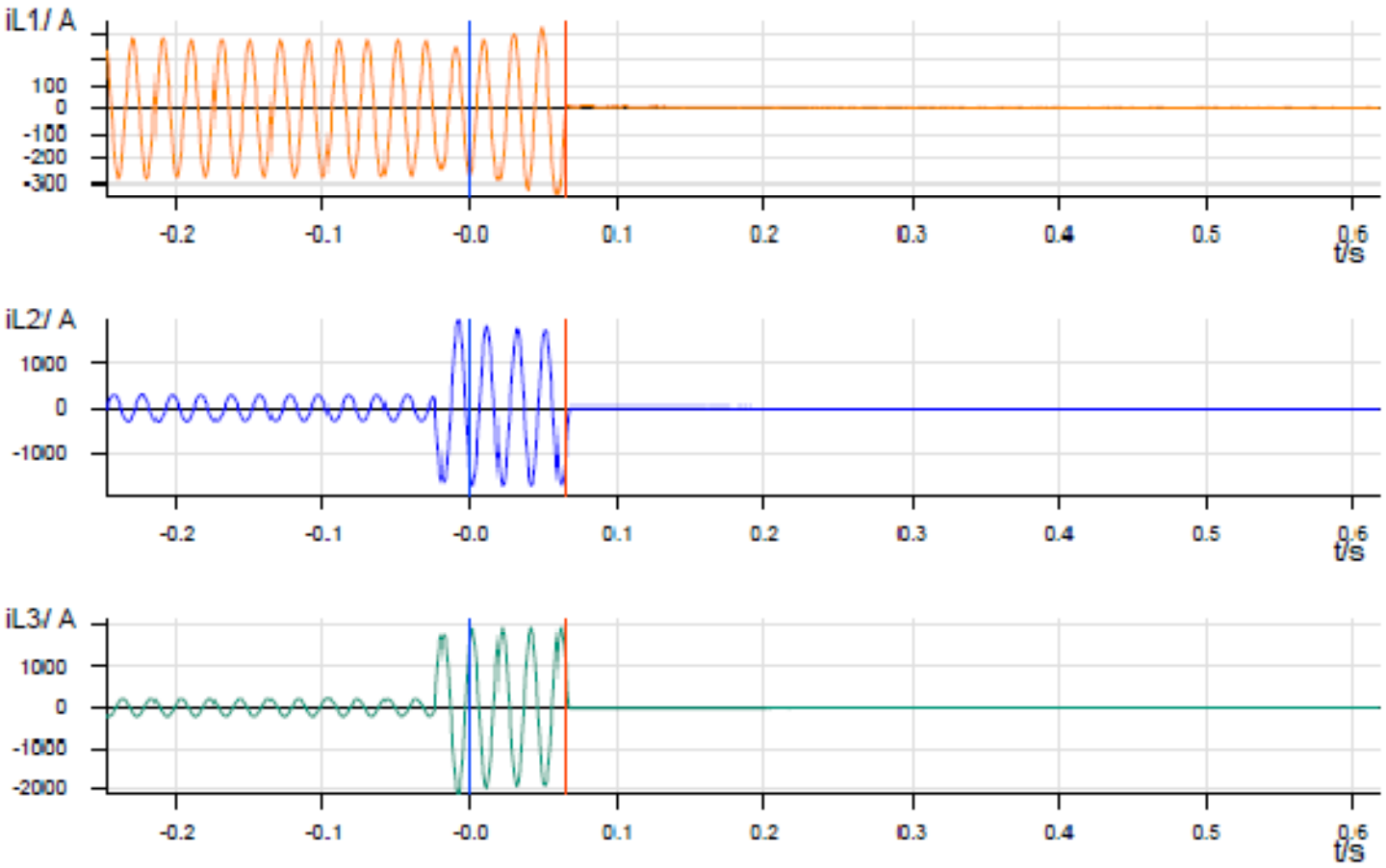
CASE STUDY-II



AT EMSS

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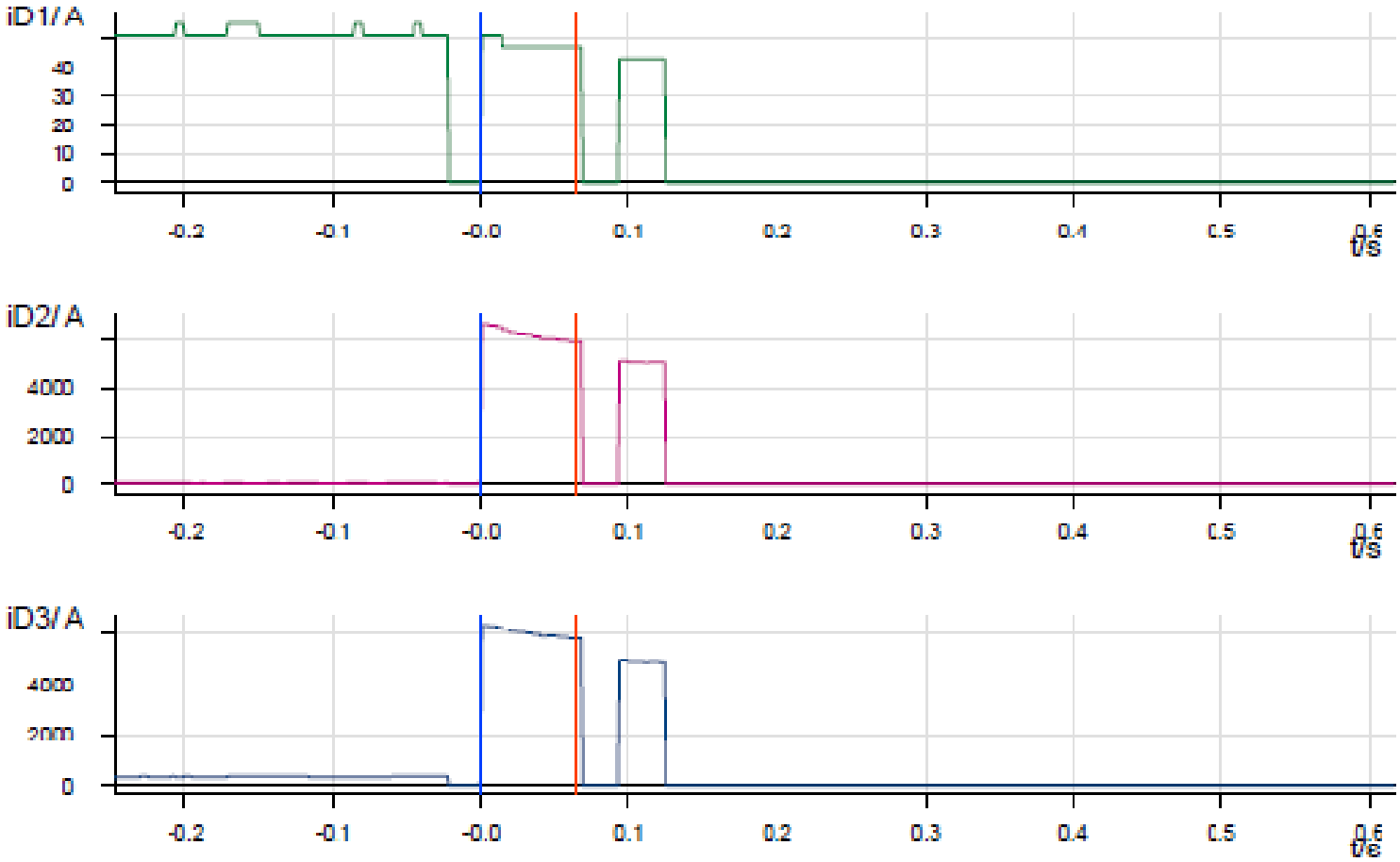
CASE STUDY-II



AT EMSS

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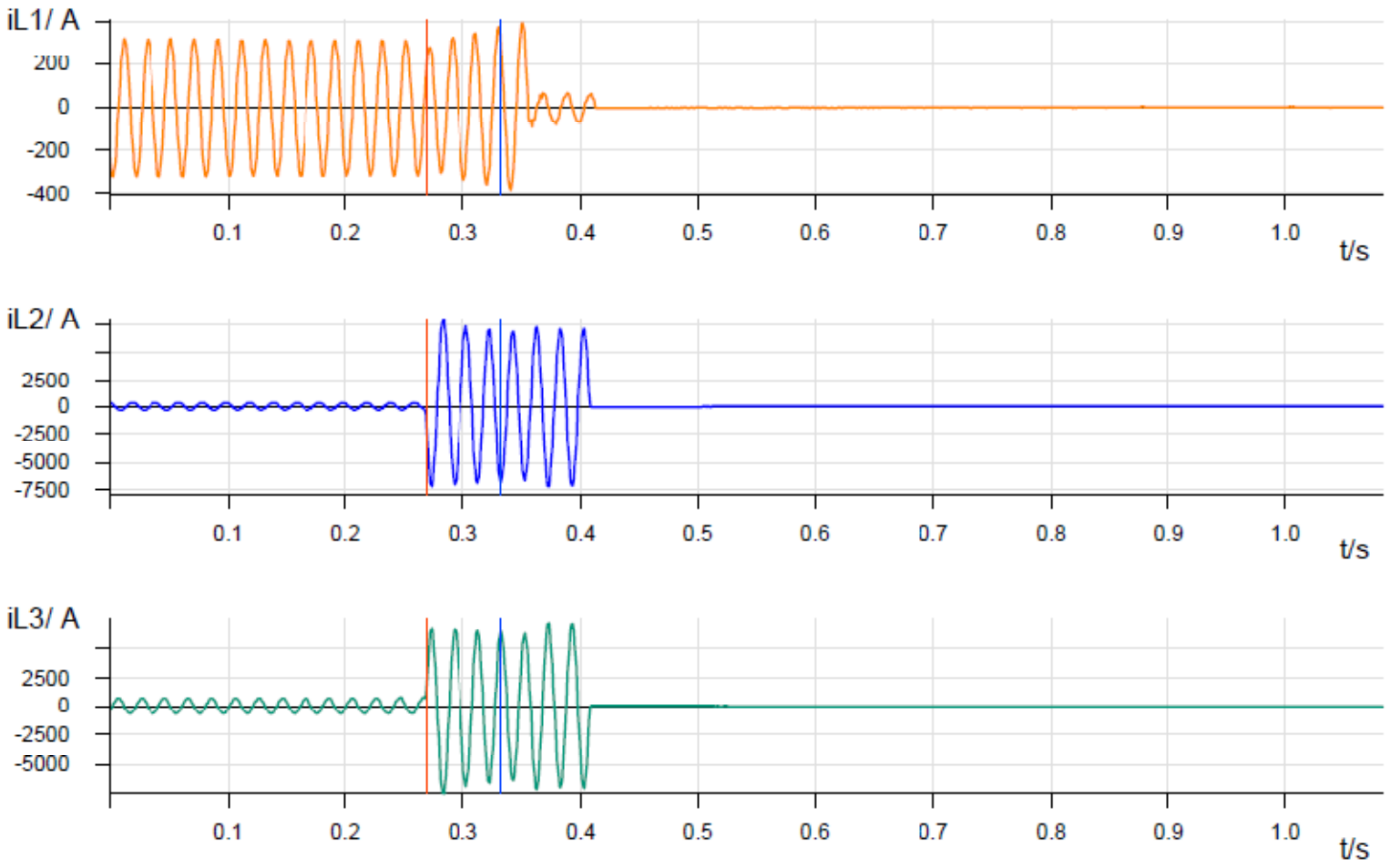
CASE STUDY-II



AT BBGS

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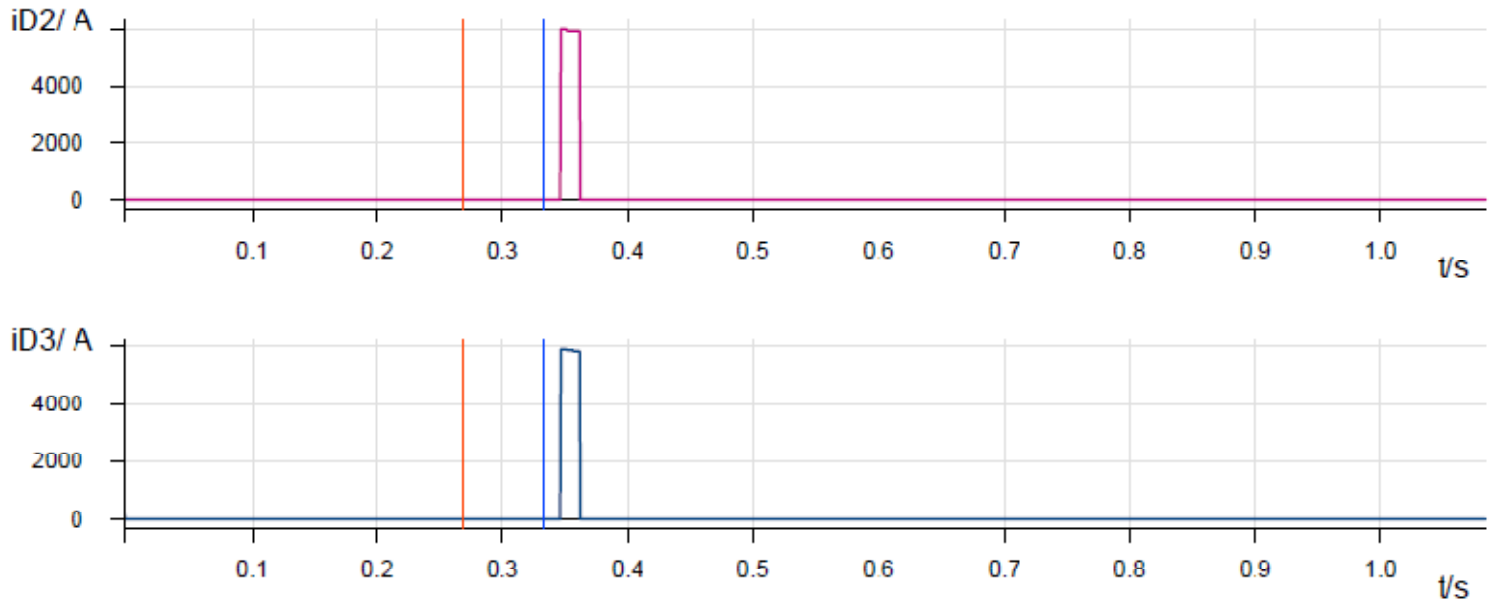
CASE STUDY-II



AT BBGS

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Growing Legacies

CESC LIMITED

CASE STUDY-II

FINDINGS

Receiving optical fiber had high loss for the line differential relay at BBGS end. Thus it was not continuously receiving the signal from other end relay. Hence delayed tripping occurred.

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Growing Legacies

CESC LIMITED

THANK YOU

CONCEPT OF DISTANCE PROTECTION

BY JAYANTA DUTTA
DEPUTY CHIEF ENGINEER
OS & U (SYSTEM) DVC KOLKATA

List of Topics

- Objective of Distance Protection
- Distance Relay Characteristics
- Zone Protection Philosophy.
- Impedance Computation for different types of Faults.
- Effect of Fault Resistance.
- Main 1 and Main II Concept.

OBJECTIVE OF RELAY PROTECTION

- **Protect persons and equipment in the surrounding of the power system.**
- **Protect apparatus in the power system.**
- **Separate faulty parts from the rest of the power system to facilitate the operation of the healthy part of the system**

CLASSIFICATION

Classification of line length depends on:

- Source-to-line Impedance Ratio (SIR),

  i.e Ratio of Source Impedance (Z_s) and Line Impedance (Z_L)
- Nominal voltage

Length considerations: (under Normal and N-1 contingent situations)

- Short Lines: SIR > 4
- Medium Lines: 0.5 < SIR < 4
- Long Lines: SIR < 0.5

TYPICAL PROTECTION SCHEMES

- Short Lines
  - Current differential
  - Phase comparison
  - Permissive Overreach Transfer Trip (POTT)
  - Directional Comparison Blocking (DCB)

TYPICAL PROTECTION SCHEMES

- Medium Lines
  - Phase Comparison
  - Directional comparison Blocking
  - Permissive Under reach transfer scheme.
  - Permissive overreach transfer scheme.
  - Unblocking
  - Step Distance
  - Co-ordinated Over current.
  - Inverse Time Overcurrent.
  - Current Differential

TYPICAL PROTECTION SCHEMES

- Long Lines
  - Phase Comparison
  - Directional comparison Blocking
  - Permissive Under reach transfer scheme.
  - Permissive overreach transfer scheme.
  - Unblocking
  - Step Distance
  - Step or Co-ordinated Over current.
  - Current Differential.

FAULT TYPES

TRANSIENT FAULTS

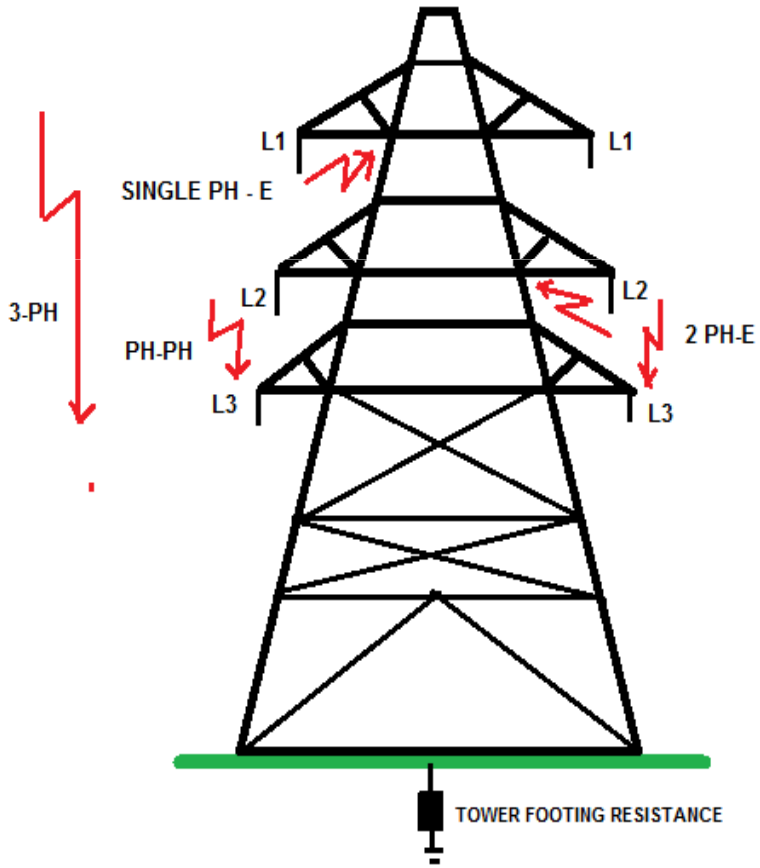
- are common on transmission lines, approximately 80-85%
- lightning's are the most common reason.
- can also be caused by birds, falling trees, Forest growth, swinging lines, High velocity winds etc.
- will disappear after a short dead interval

PERSISTENT FAULTS

- can be caused by a broken conductor fallen down
- can be a tree falling on a line.
- must be located and repaired before normal service

TRANSMISSION LINE

FAULTS



TYPE OF FAULTS IN TRANSMISSION LINE

FAULT STATISTICS

- **Single phase to earth :- 80%**
- **Two phases to earth:- 10%**
- **Phase to phase faults :- 5%**
- **Three phase faults :- 5%**

MAIN REQUIREMENTS ON LINE PROTECTION ARE:

- **SPEED**
- **SENSITIVITY**
- **SELECTIVITY**
- **DEPENDABILITY**
- **SECURITY**
- **RELIABILITY**

MEASURING PRINCIPLES OF DIFFERENT RELAYS OF TRANSMISSION LINES

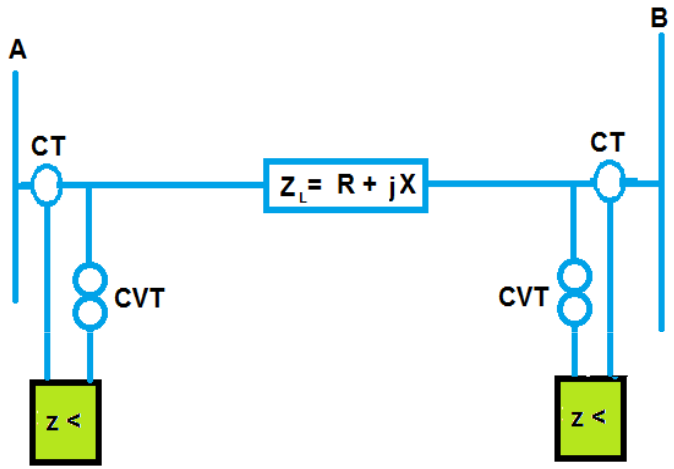
- **Over current protection**
- **Over current & under voltage combination.**
- **Differential protection.**
- **Distance protection**

MEASURING PRINCIPLES OF DISTANCE PROTECTION

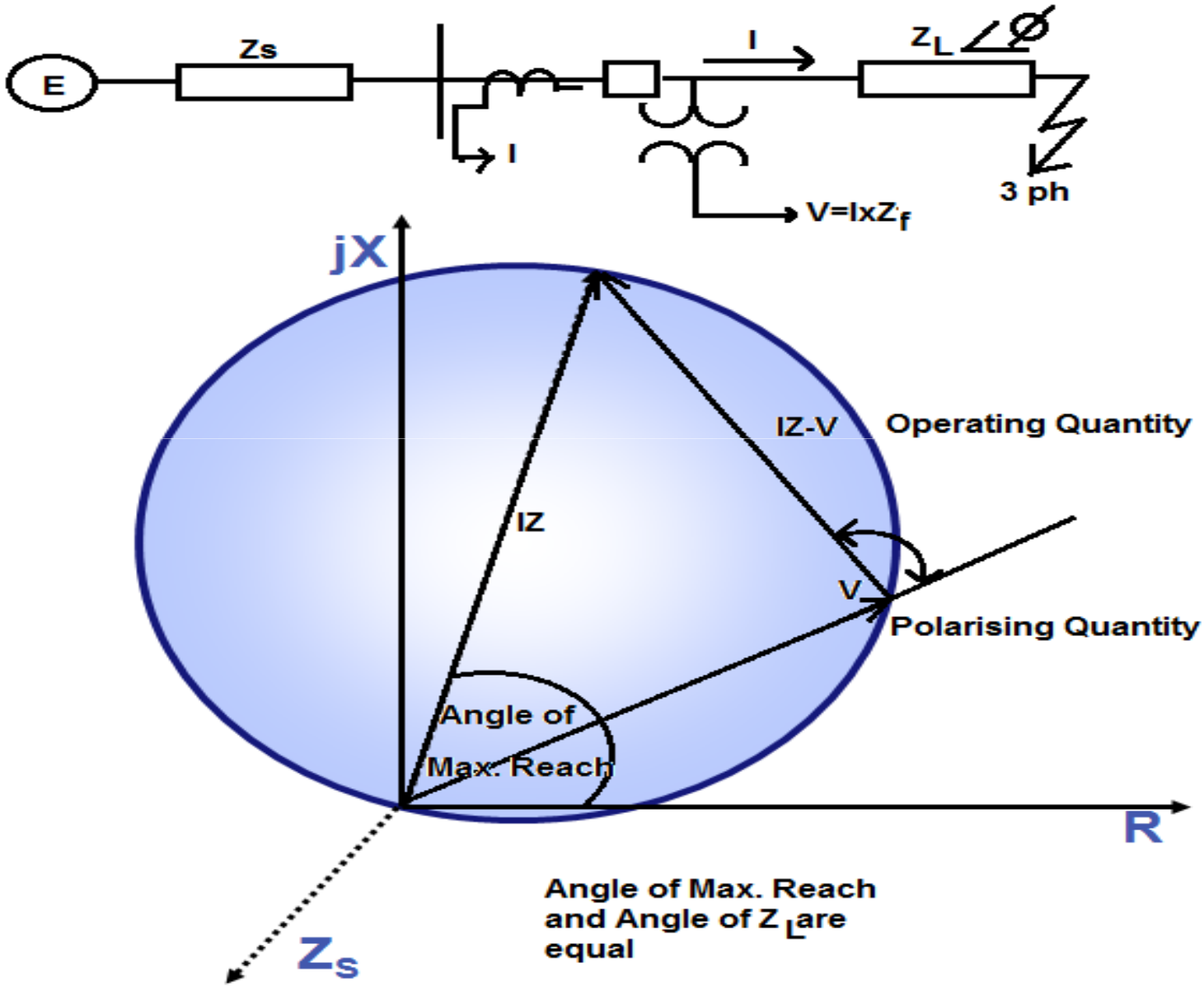
- **Power lines have impedances of size 0,3- 0,4 ohm/ km and normal angles of 80 - 85 degrees in a 50Hz systems.**

- **The Line Impedance has to be converted to secondary values with the formulae:-**

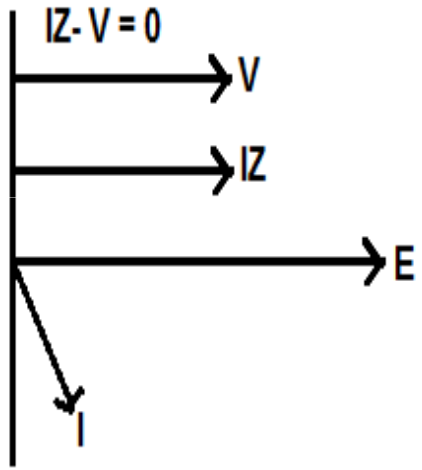
- **Zsec=$\frac{VTsec}{VTprim}$ X $\frac{CTprim}{CTsec}$ x Zprim**



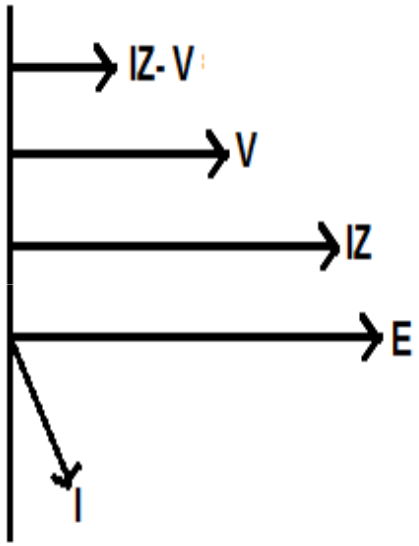
SIMPLE MHO FUNCTION



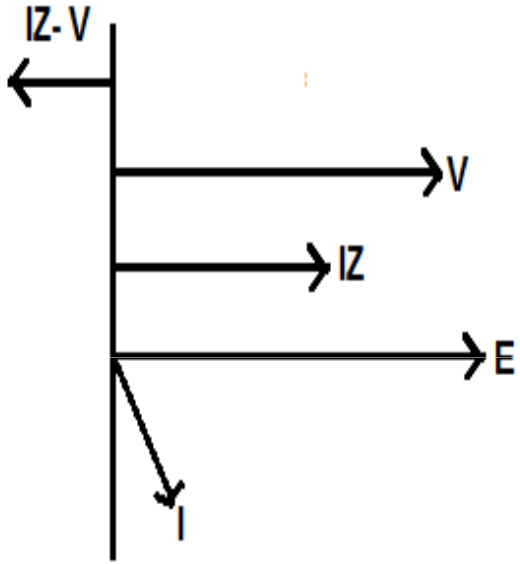
Phasor Analysis of operation of simple mho function



Balance Fault Point V = IZ



Internal Fault V< IZ



External Fault V > IZ

OPERATING CHARACTERISTICS

FIRST ZONE CHARACTERISTICS

- Should cover as much as possible of the Protected circuit and of additional resistance.
- In case of Phase to Ground Fault, Followed by Reclosure to tripping in the Un-faulted Phases.
- Fast Operation.
- Directional Discrimination.
- Reach in Resistive Direction should be large enough to cover large resistance and to get good dynamic performance but limited to avoid unwanted tripping in case of Power Swings, Over reach in additional resistance is seen with large capacitive reactance, short time overloading.

OPERATING CHARACTERISTICS

- SECOND ZONE CHARACTERISTICS

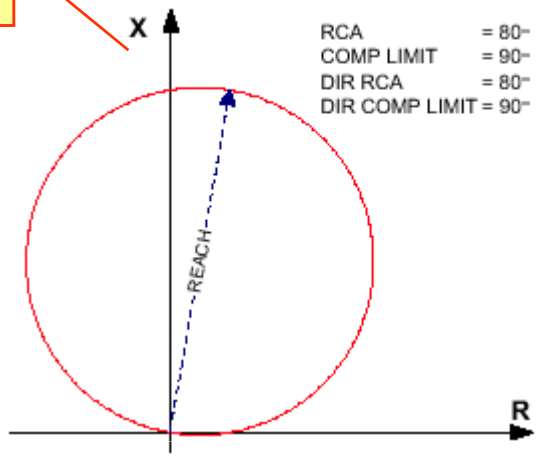
- Extension upwards is decided by impedance of protected line and setting of zone - I of adjacent lines.
- In most cases R-axis reach of zone - II same as zone –I is satisfactory. If additional resistances are expected which zone - I is not able to cover then different setting for zone – II is advantageous.

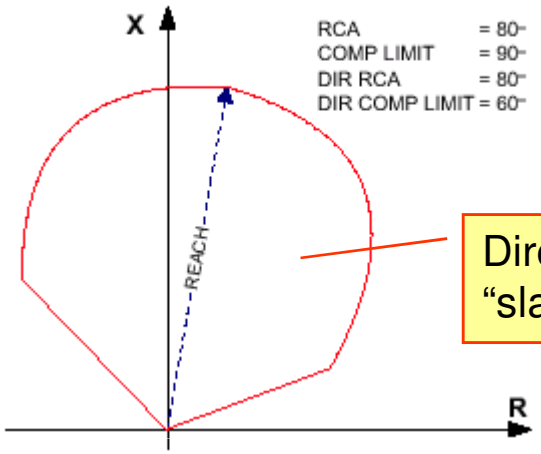
- THIRD ZONE CHARACTERISTICS

- This is the widest of zones in which tripping can occur after longest time delay.
- Is required to give remote backup though in many cases it is impossible to get comprehensive remote back up.

MHO CHARACTERISTICS

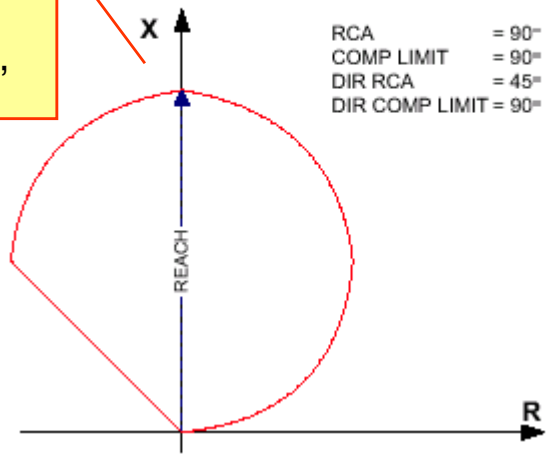
Traditional

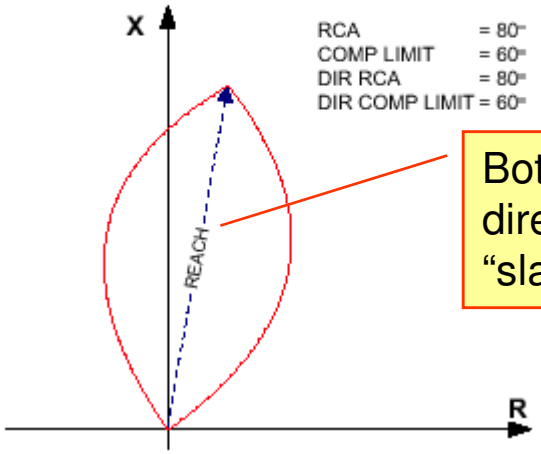




Directional angle "slammed"

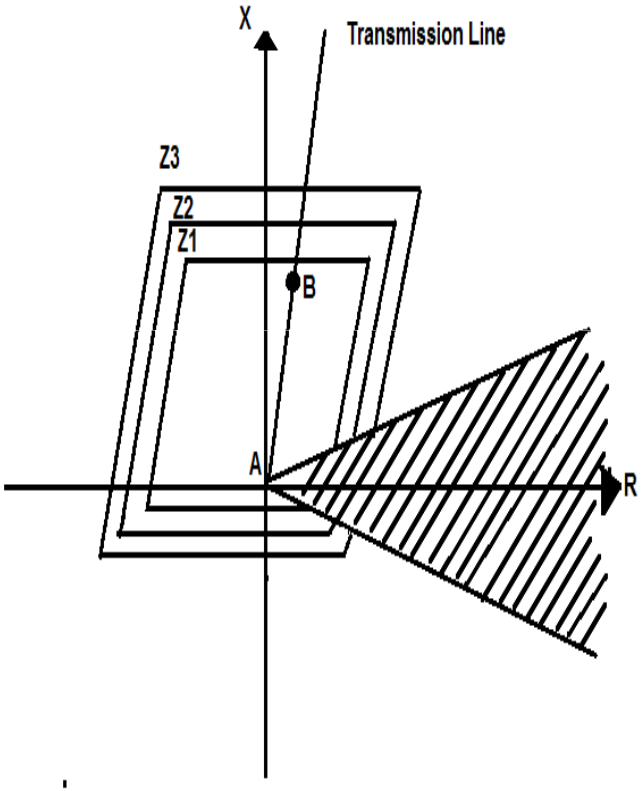
Directional angle lowered and "slammed"





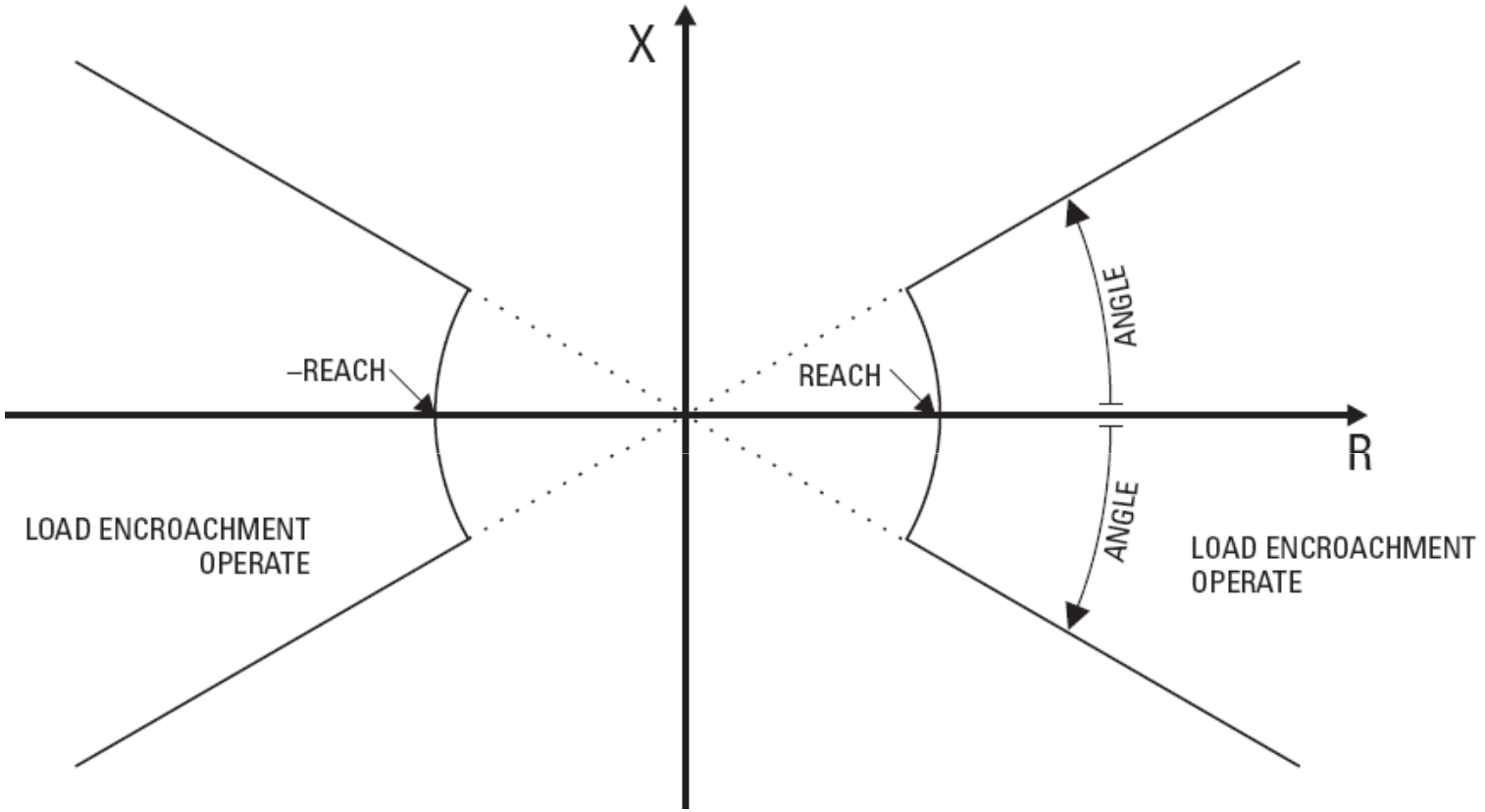
Both MHO and directional angles "slammed" (lens)

LOAD ENCROACHMENT



- $P_{ij} - jQ_{ij} = V_i x I = V_i x V_i / Z$
- So, $Z = V_i^2 / (P_{ij} - jQ_{ij})$
- $= V_i^2 (P_{ij} + jQ_{ij}) / (P_{ij}^2 + Q_{ij}^2$
- The apparent impedance seen by the Relay is proportional to square of the magnitude of bus voltage. If the bus voltage drops say to 0.9 pu from 1 pu, then Z reduces to 81% of its value at 1 pu. Again, if the bus voltage drops to say 0.8 pu, then the apparent impedance seen by the Relay will drop to 64% of its value at 1 pu.
- The apparent impedance seen by the Relay is inversely proportional to the apparent power flowing on the line. If the apparent power doubles up, the impedance seen by relay will reduce by 50%.

Load Encroachment Characteristic

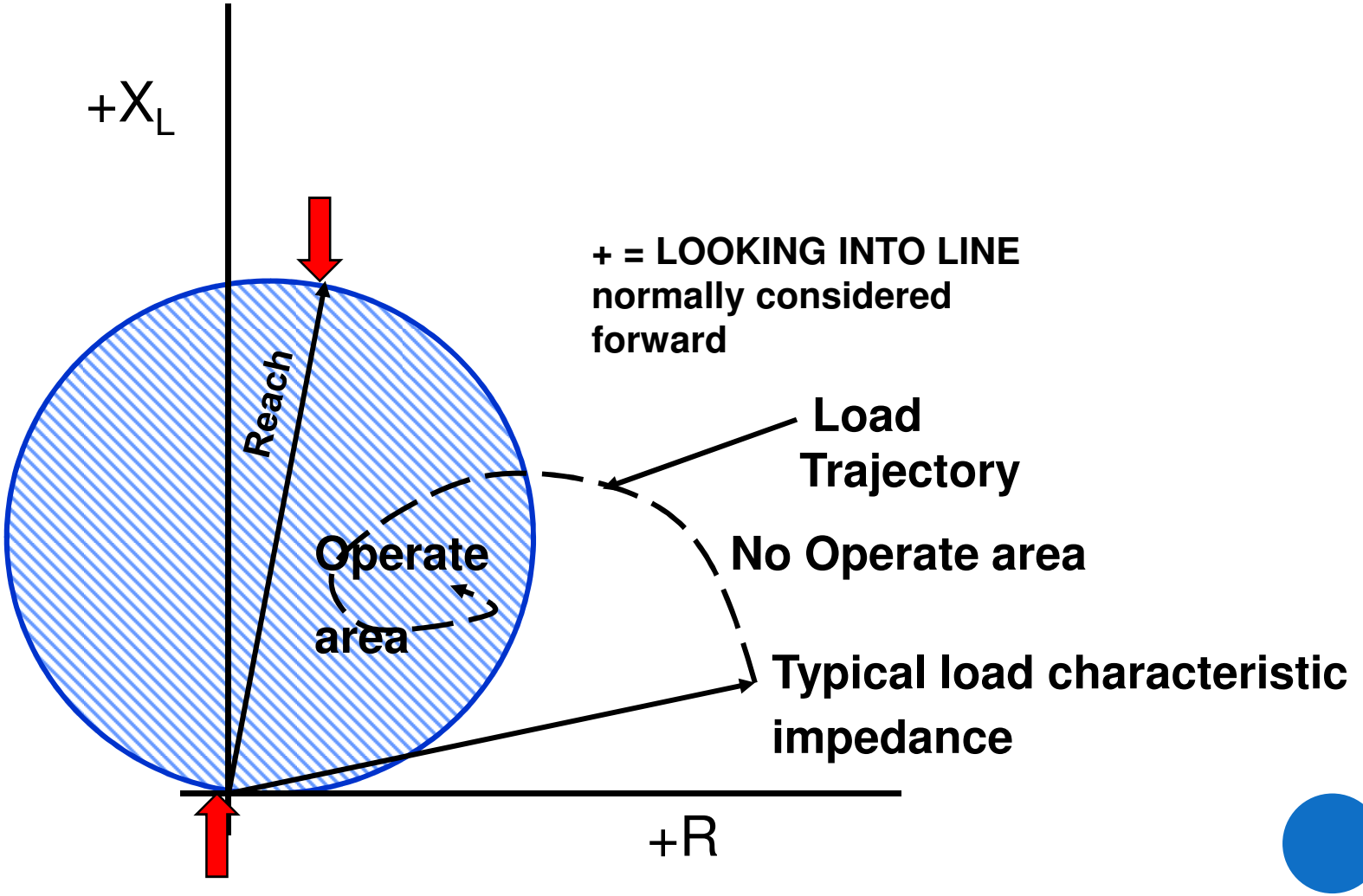


The load encroachment element responds to positive sequence voltage and current and can be used to block phase distance and phase overcurrent elements.

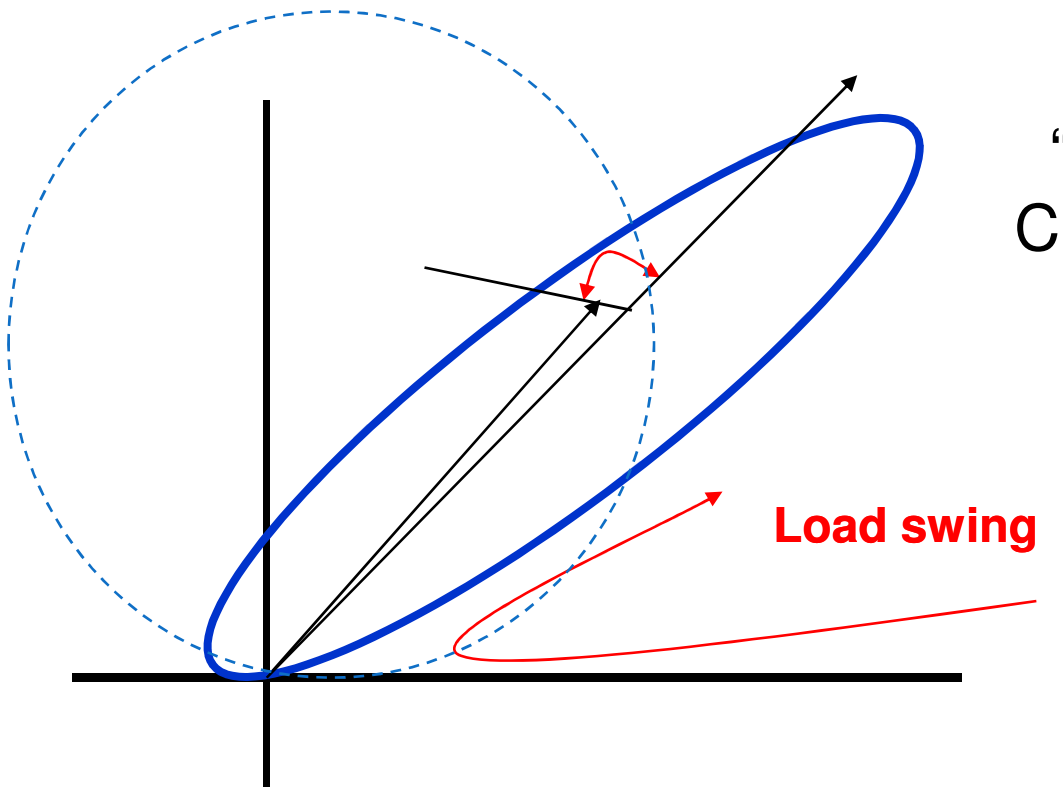
Blinders

- Blinders limit the operation of distance relays (quad or mho) to a narrow region that parallels and encompasses the protected line
- Applied to long transmission lines, where mho settings are large enough to pick up on maximum load or minor system swings

LOAD SWINGS

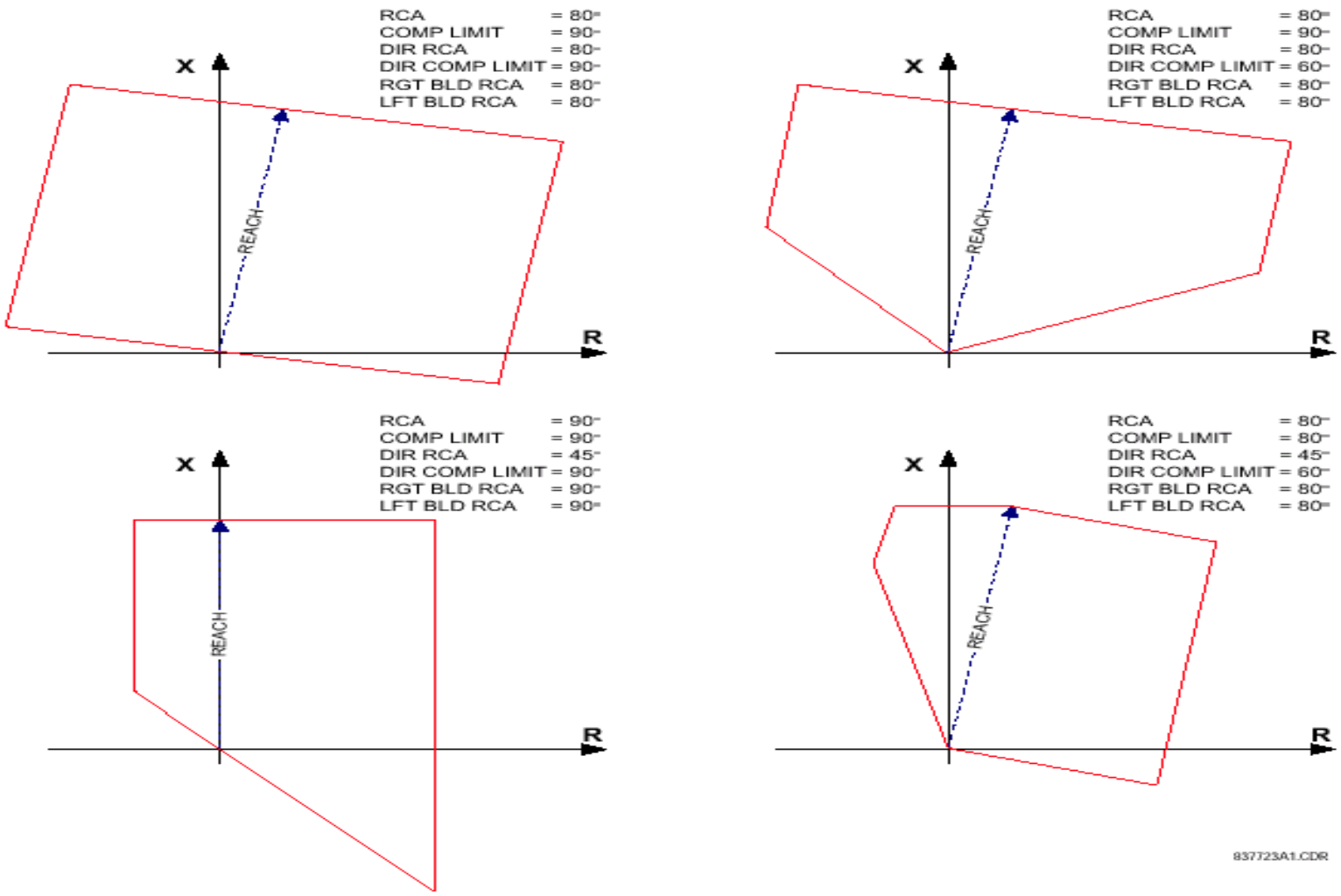

+X_L
Reach
+ = LOOKING INTO LINE
normally considered
forward
Load
Trajectory
No Operate area
Operate
area
Typical load characteristic
impedance
+R

Load Swings



"Lenticular"
Characteristic

QUADRILATERAL CHARACTERISTICS

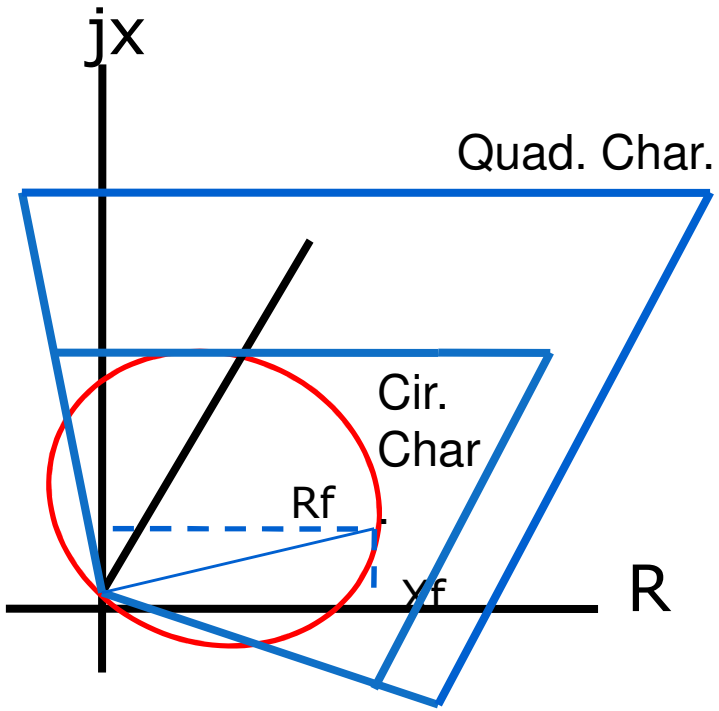


DISTANCE CHARACTERISTICS - SUMMARY

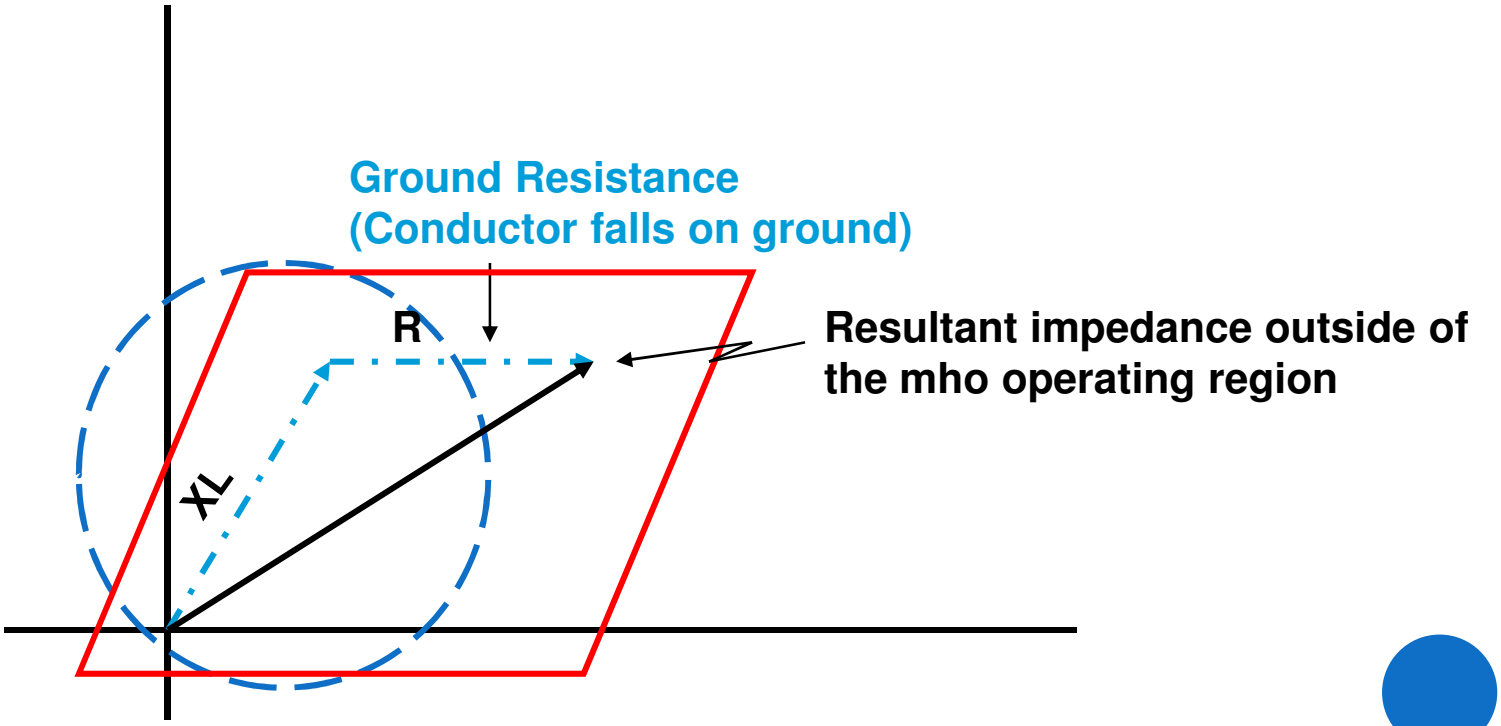
- **Circular Characteristics**
- Low measured reactance
- Ratio between fault resistance and reactance is high.
- Distance protection with mho characteristic can not see average fault resistance.

Quadrilateral characteristic

- Quadrilateral characteristic improves sensitivity for higher RF/XF ratio. Improves sensitivity for Higher Resistive Faults
- Tele metering schemes improve the total system behaviour.

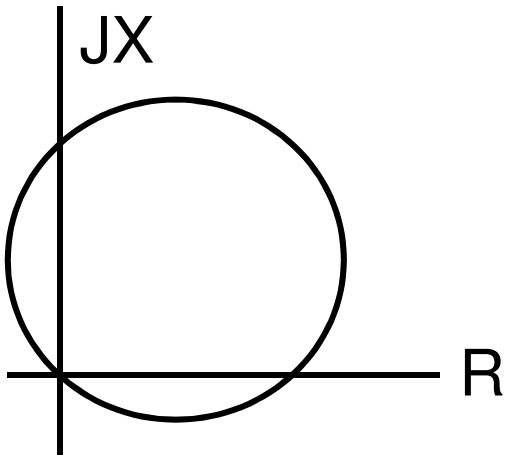


Quadrilateral Characteristics



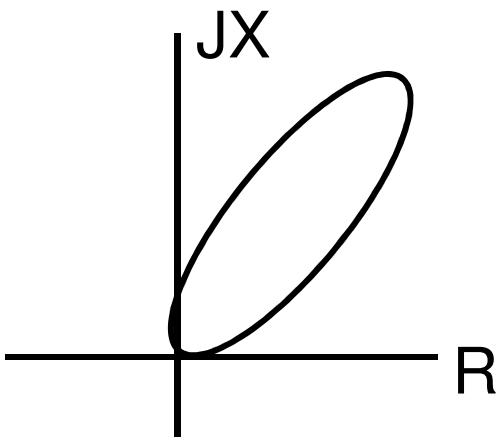
Distance Characteristics - Summary

Mho



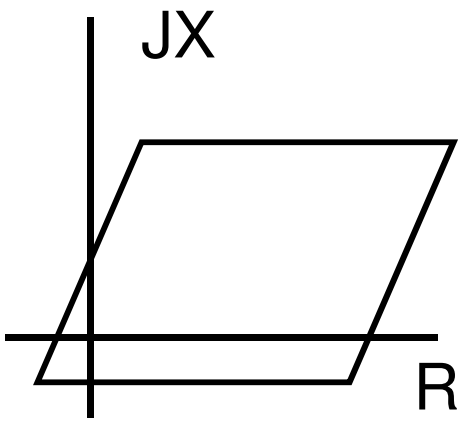
Standard for phase elements

Lenticular



Used for phase elements with long heavily loaded lines heavily loaded

Quadrilateral



Better coverage for ground faults due to resistance added to return path

Distance Element Polarization

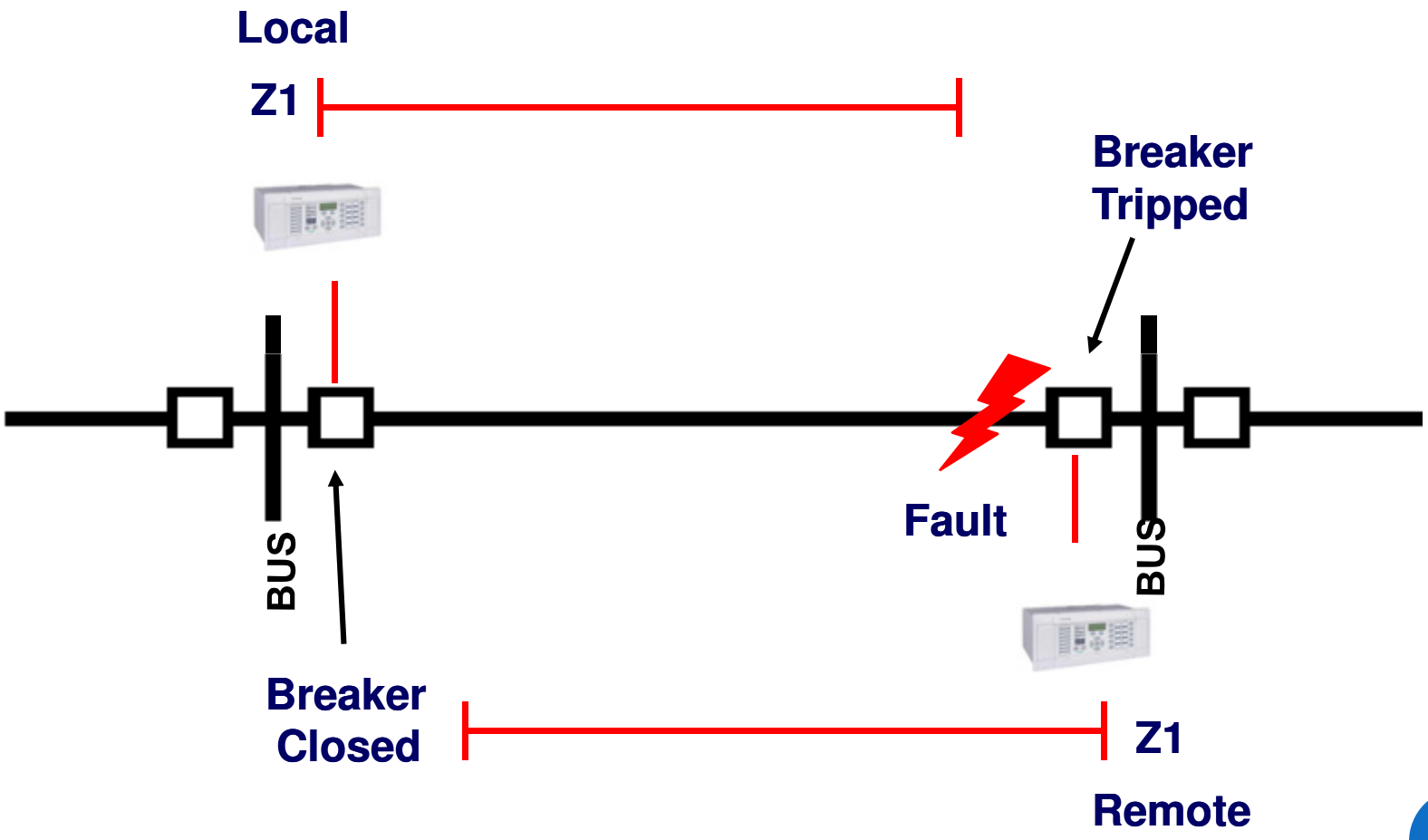
The following polarization quantities are commonly used in distance relays for determining directionality:

- Self-polarized
- Memory voltage
- Positive sequence voltage
- Quadrature voltage
- Leading phase voltage

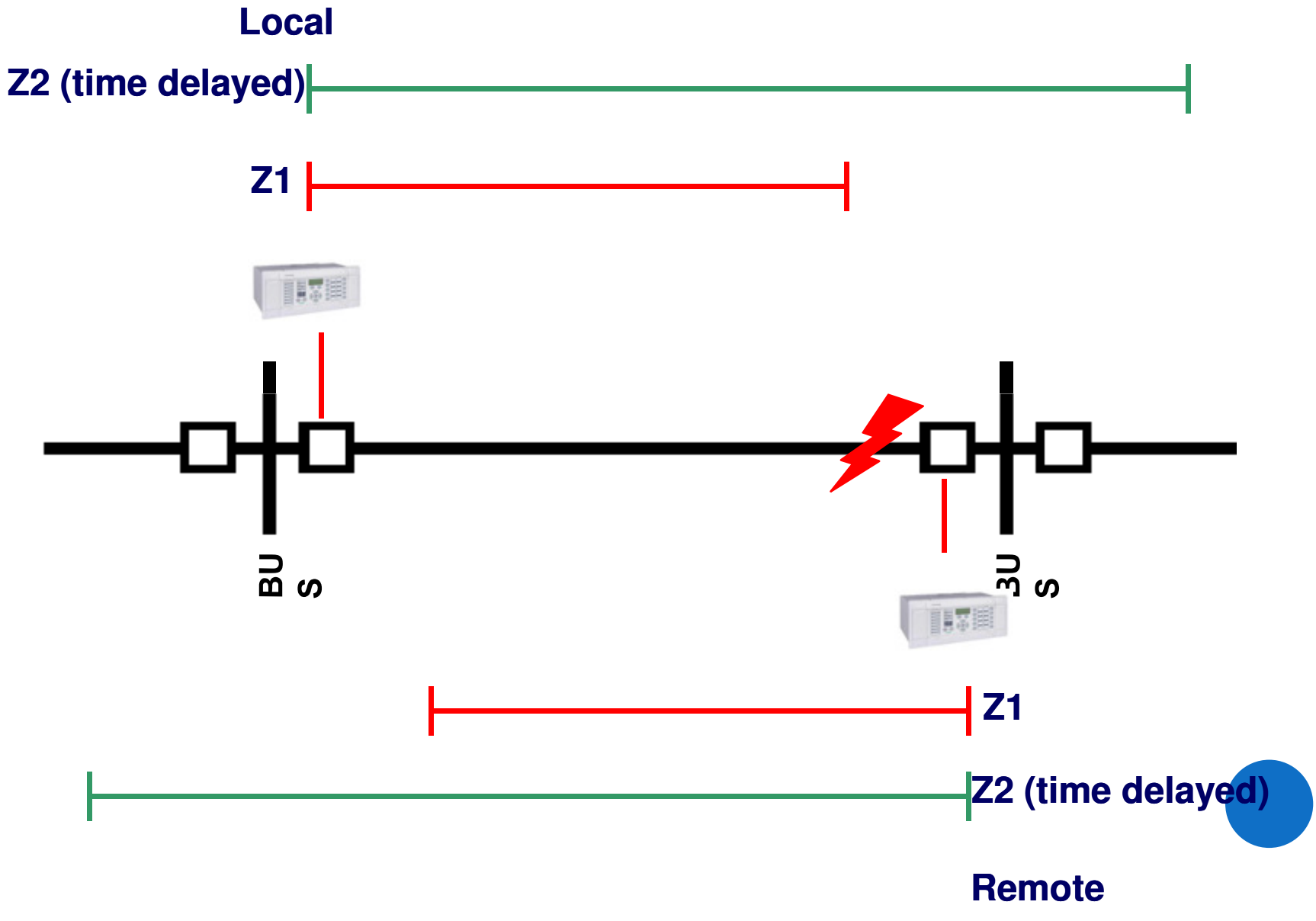
Memory Polarization

- Positive-sequence memorized voltage is used for polarizing:
  - Mho comparator (dynamic, expanding Mho)
  - Negative-sequence directional comparator (Ground Distance Mho and Quad)
  - Zero-sequence directional comparator (Ground Distance MHO and QUAD)
  - Directional comparator (Phase Distance MHO and QUAD)
- Memory duration is a common distance settings (all zones, phase and ground, MHO and QUAD)

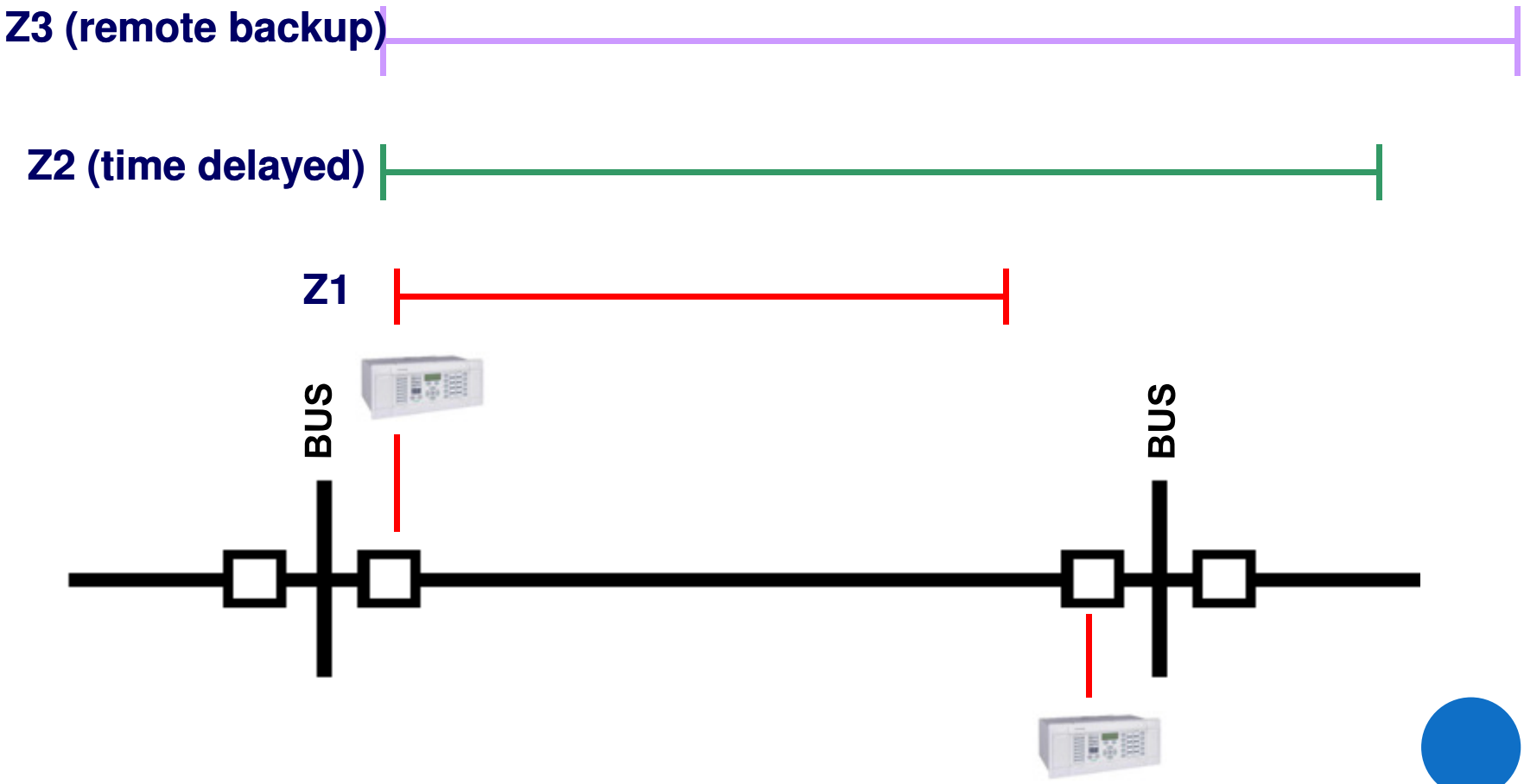
STEP DISTANCE SCHEME



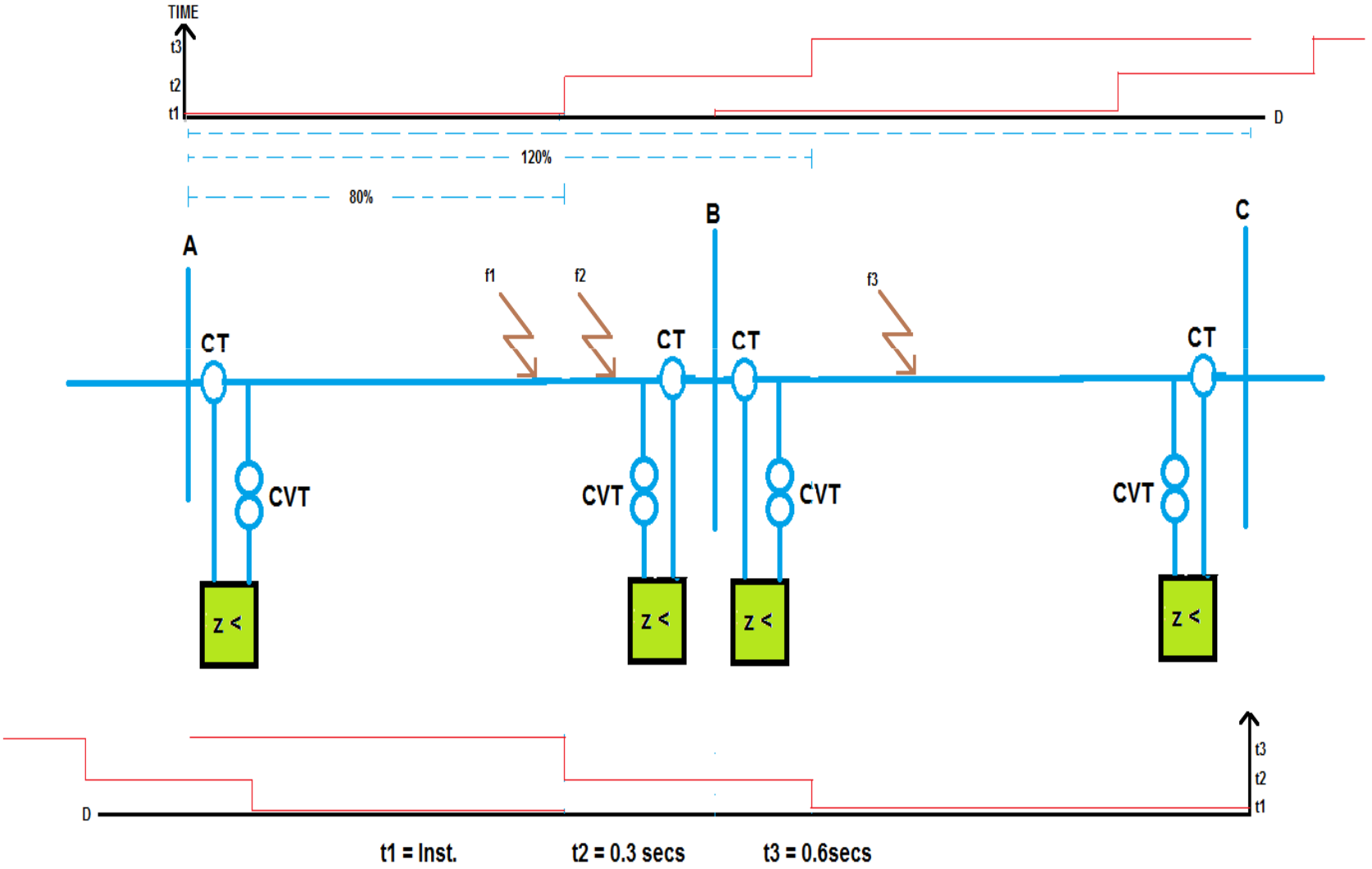
STEP DISTANCE SCHEME



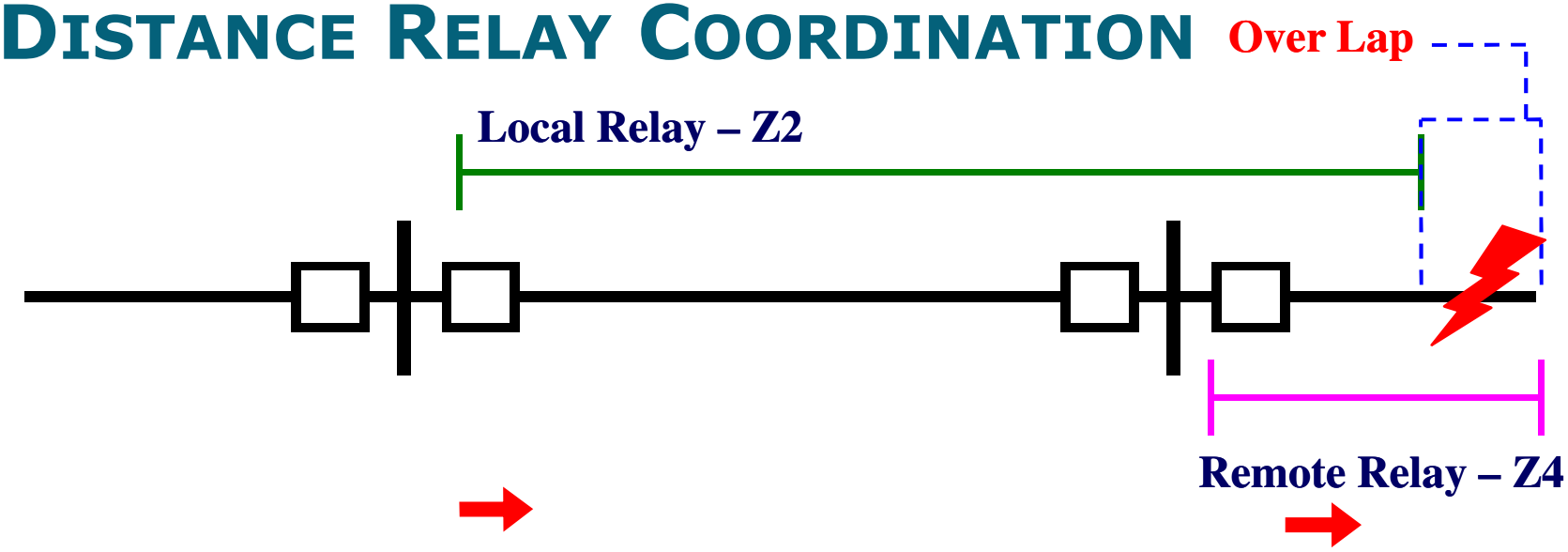
STEP DISTANCE SCHEME



PRINCIPLE OF DISTANCE PROTECTION



DISTANCE RELAY COORDINATION



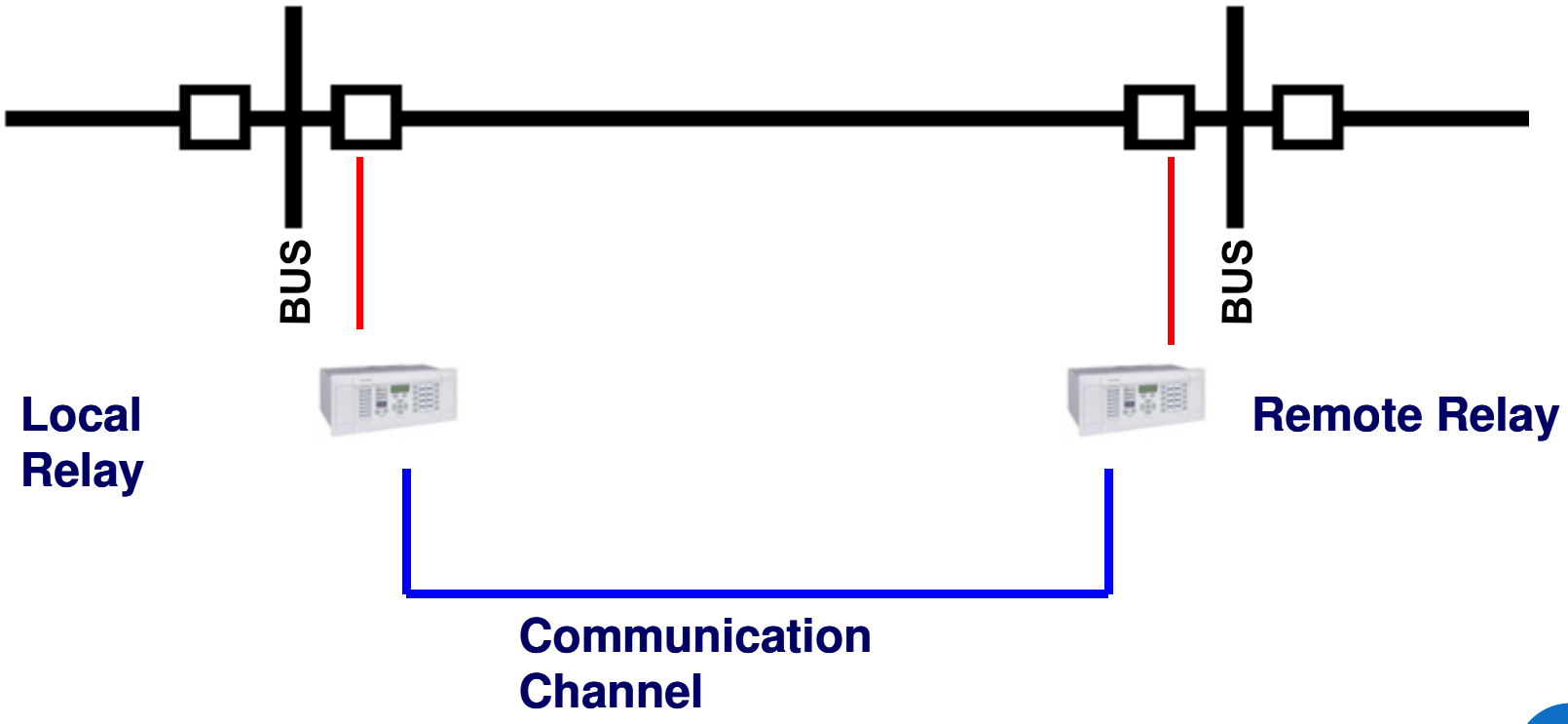
Local Relay

Zone 2 PKP

Remote Relay

Zone 4 PKP

Need For Pilot Aided Schemes



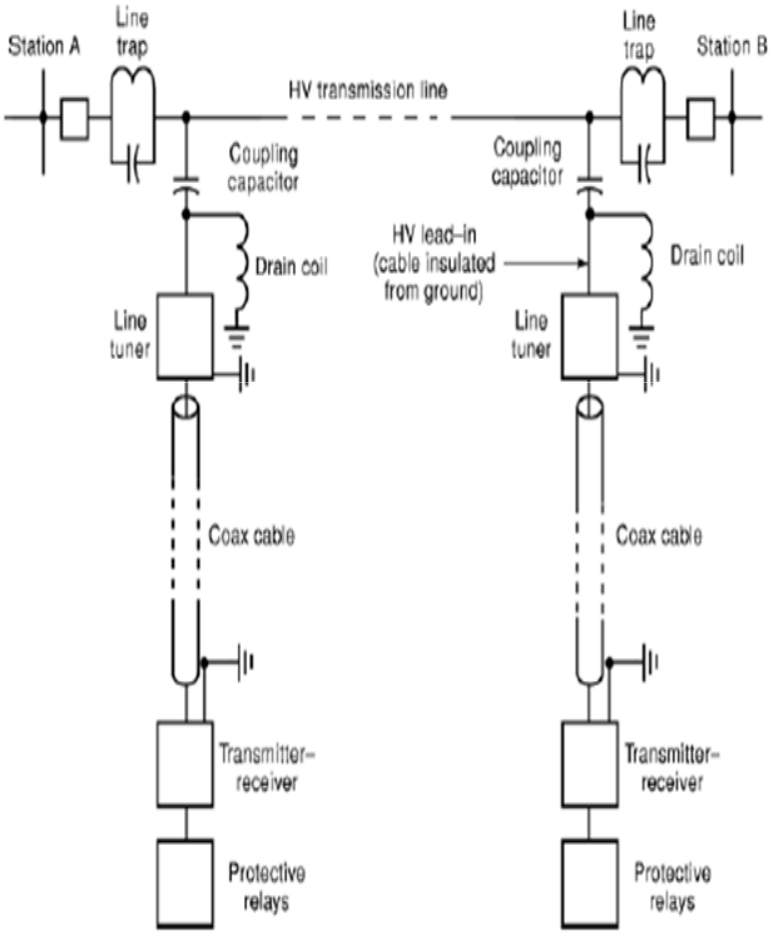
Pilot Communications Channels

- Distance-based pilot schemes traditionally utilize simple on/off communications between relays.
- Typical communications media include:
  - Pilot-wire
  - Power line carrier
  - Microwave
  - Radio
  - Optic fiber (directly connected or multiplexed channels)

Pilot-Aided Distance-Based Schemes

- ✓ DUTT – Direct Under-reaching Transfer Trip
- ✓ PUTT – Permissive Under-reaching Transfer Trip
- ✓ POTT – Permissive Over-reaching Transfer Trip
- ✓ DCB – Directional Comparison Blocking Scheme

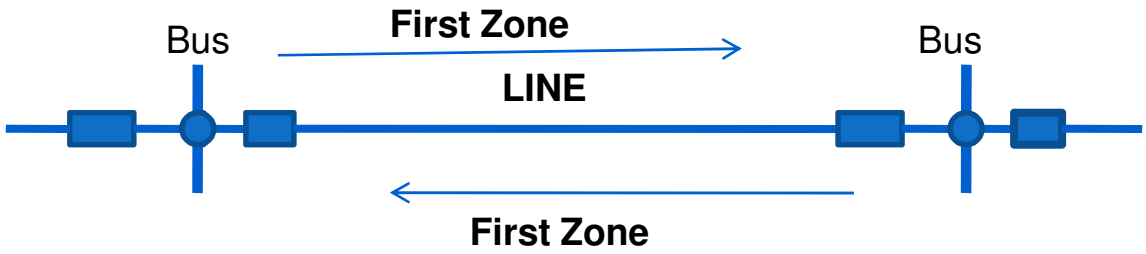
POWER LINE CARRIER COMMUNICATION



- **Used for speech Tele metering and Protection Tripping.**
- **COMPONENTS**
  - PLCC Terminal :- Translates voice and data into High Frequency Carrier. Fr. Range 50 – 500kHz.
  - Line Matching Unit :- For Impedance matching of Line and Coaxial Cable. It has impedance matching Transformer with High Voltage Protection.
  - Coupling Capacitor :- Couples High Frequency Carrier with Power Line. (4000 – 10000pF)
  - Line Trap :- Do not allow High Frequency Carrier to enter into sub-station.(L = 0.5 to 2mH)

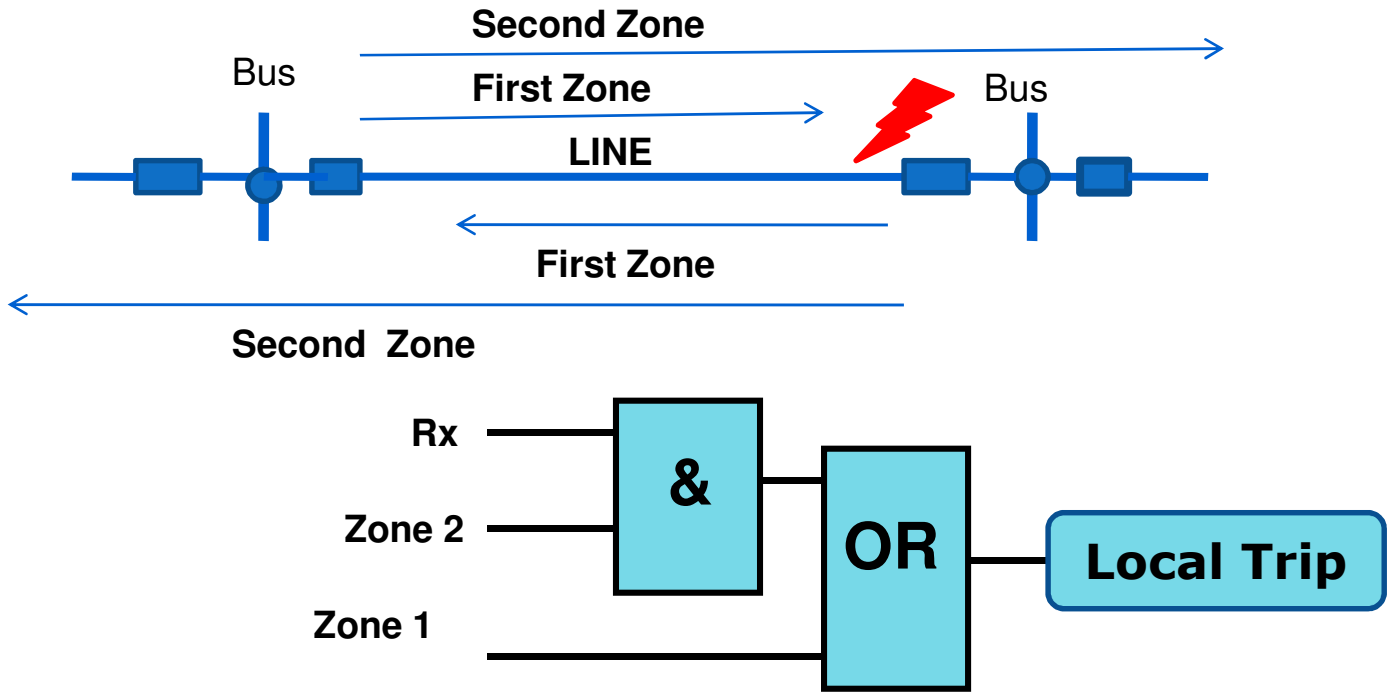
Direct Underreaching Transfer Trip (DUTT)

- Requires only under reaching (RU) functions which overlap in reach (Zone 1).
  - GUARD frequency transmitted during normal conditions
  - TRIP frequency when one RU function operates
- Scheme does not provide tripping for faults beyond RU reach if remote breaker is open or channel is inoperative.
- Dual pilot channels improve security



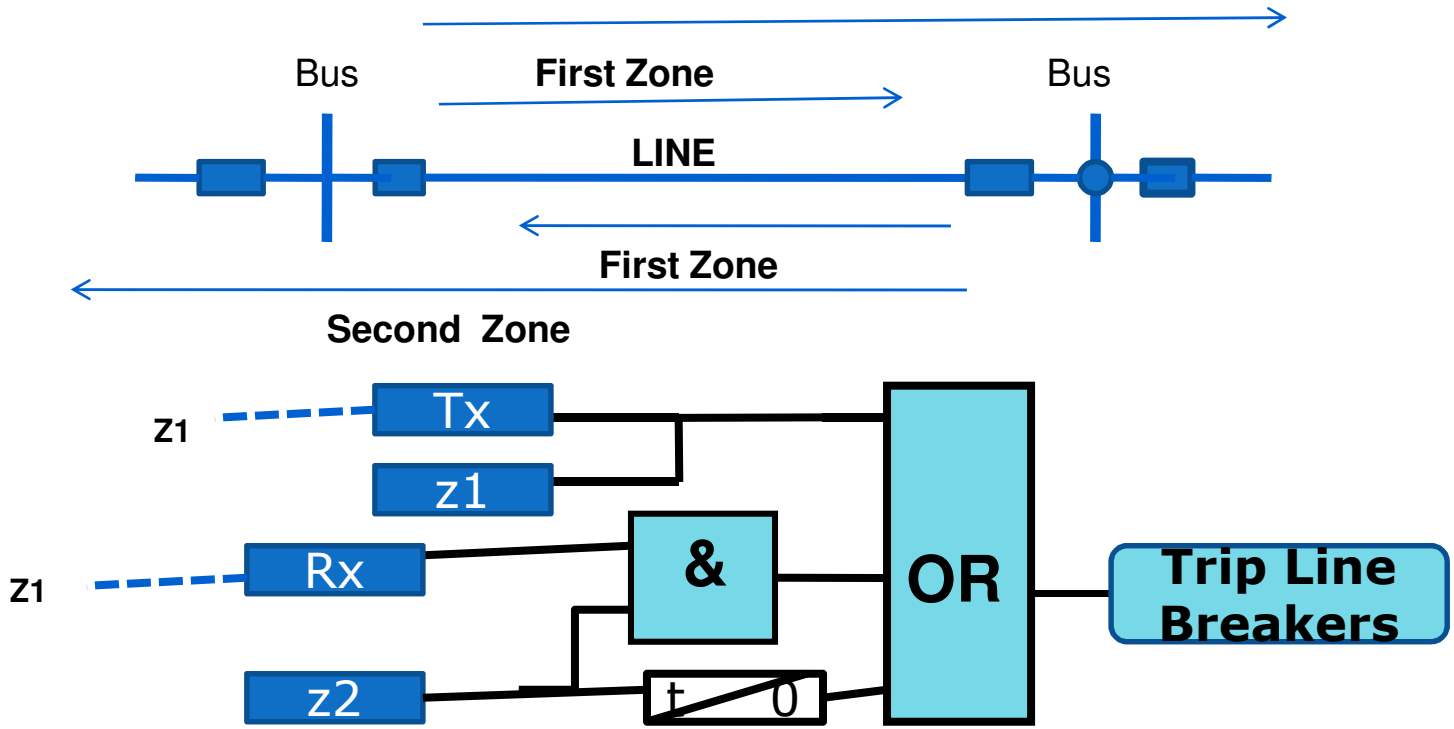
Permissive Underreaching Transfer Trip (PUTT)

- Requires both under (RU) and overreaching (RO) functions
- Identical to DUTT, with pilot tripping signal supervised by RO (Zone 2)



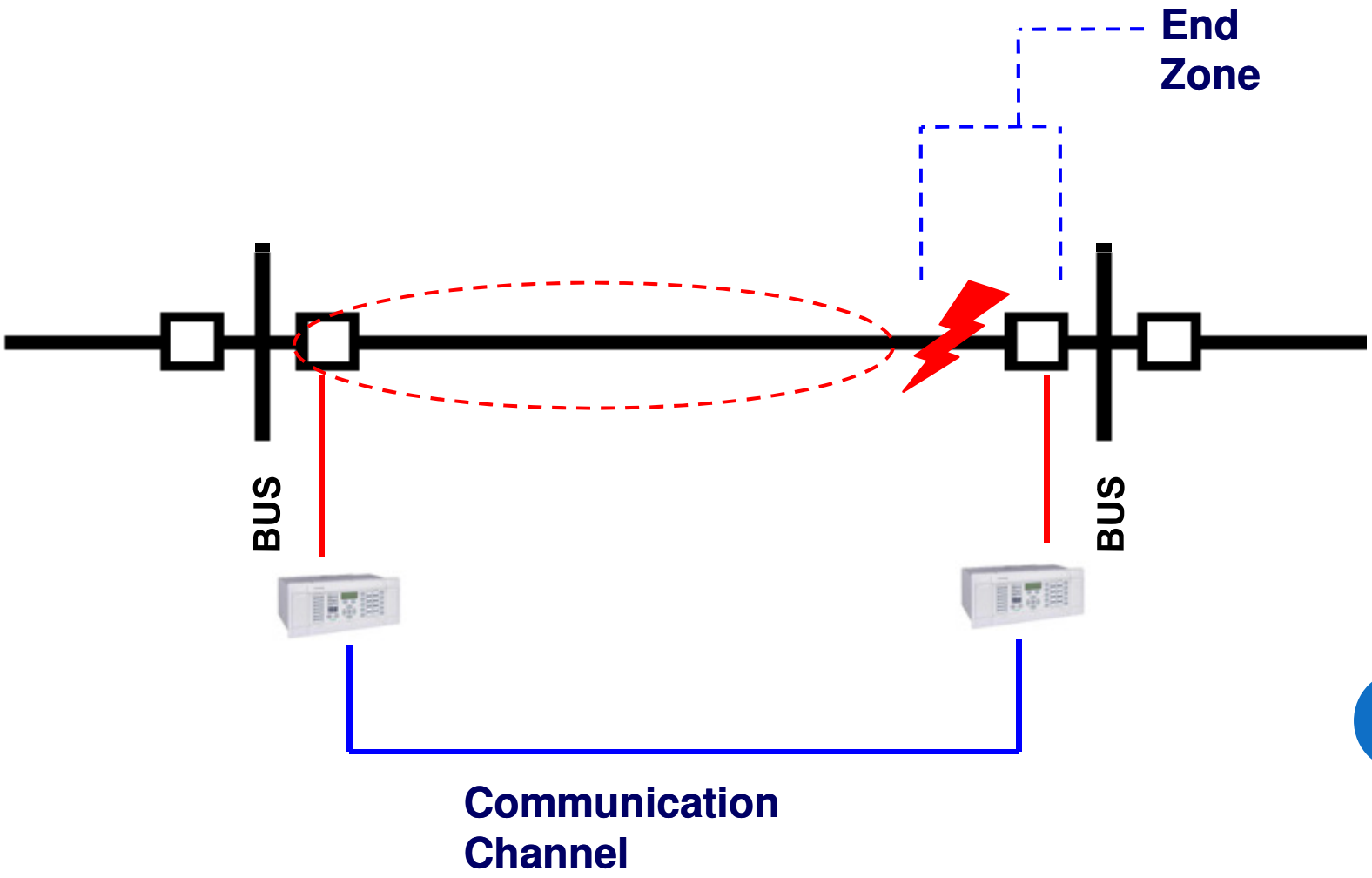
Permissive Overreaching Transfer Trip (POTT)

- Requires overreaching (RO) functions (Zone 2).
- GUARD frequency sent in stand-by
- TRIP frequency when one RO function operates
- No trip for external faults if pilot channel is inoperative
- Time-delayed tripping can be provided

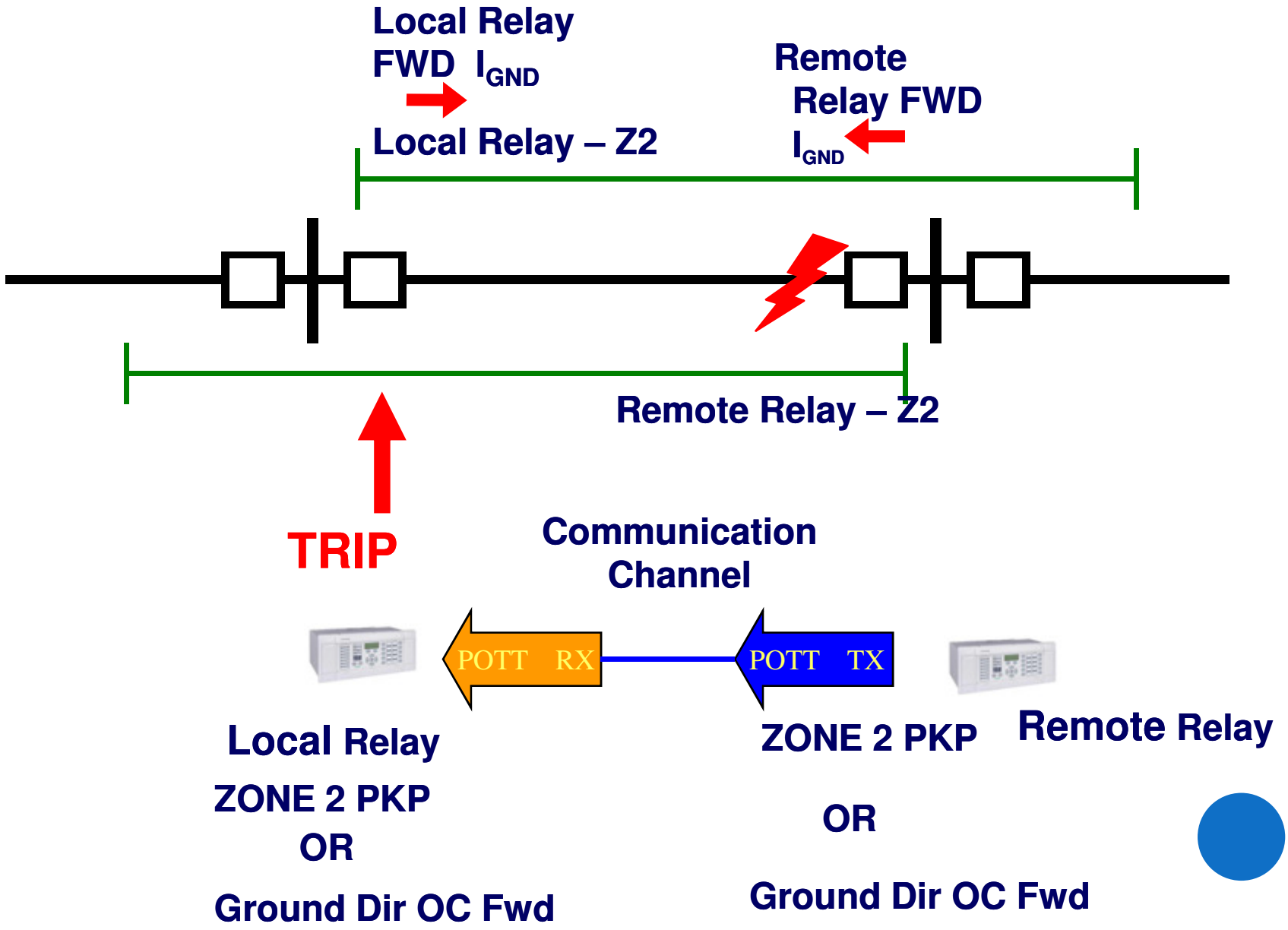


POTT Scheme

POTT – Permissive Over-reaching Transfer Trip

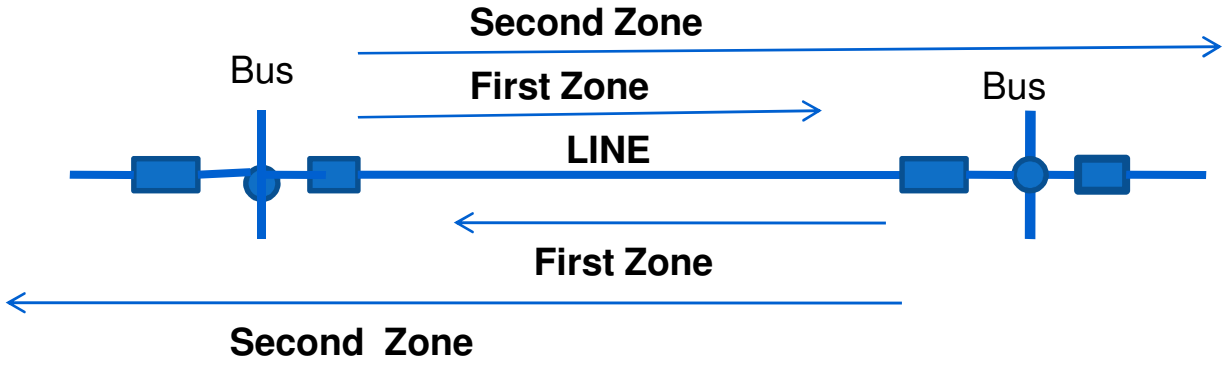


POTT Scheme

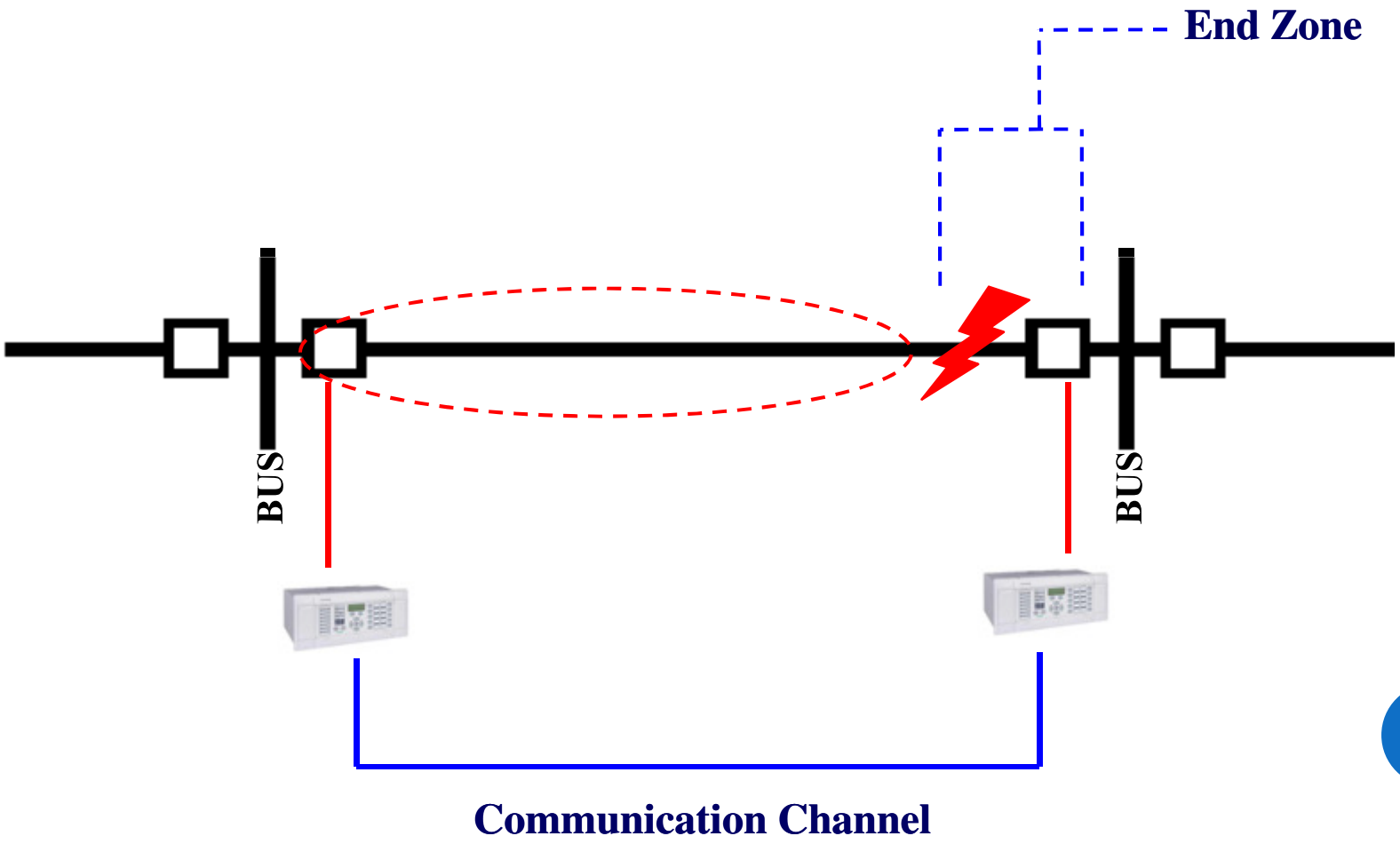

Local Relay
FWD I_{GND}
Local Relay – Z2
Remote
Relay FWD
I_{GND}
Remote Relay – Z2
TRIP
Communication
Channel
POTT RX
POTT TX
Local Relay
ZONE 2 PKP
OR
Ground Dir OC Fwd
ZONE 2 PKP
OR
Ground Dir OC Fwd
Remote Relay

Directional Comparison Blocking (DCB)

- Requires overreaching (RO) tripping and blocking (B) functions
- ON/OFF pilot channel typically used (i.e., PLC)
  - Transmitter is keyed to ON state when blocking function(s) operate
  - Receipt of signal from remote end blocks tripping relays
- Tripping function set with Zone 2 reach or greater
- Blocking functions include Zone 3 reverse and low-set ground overcurrent elements

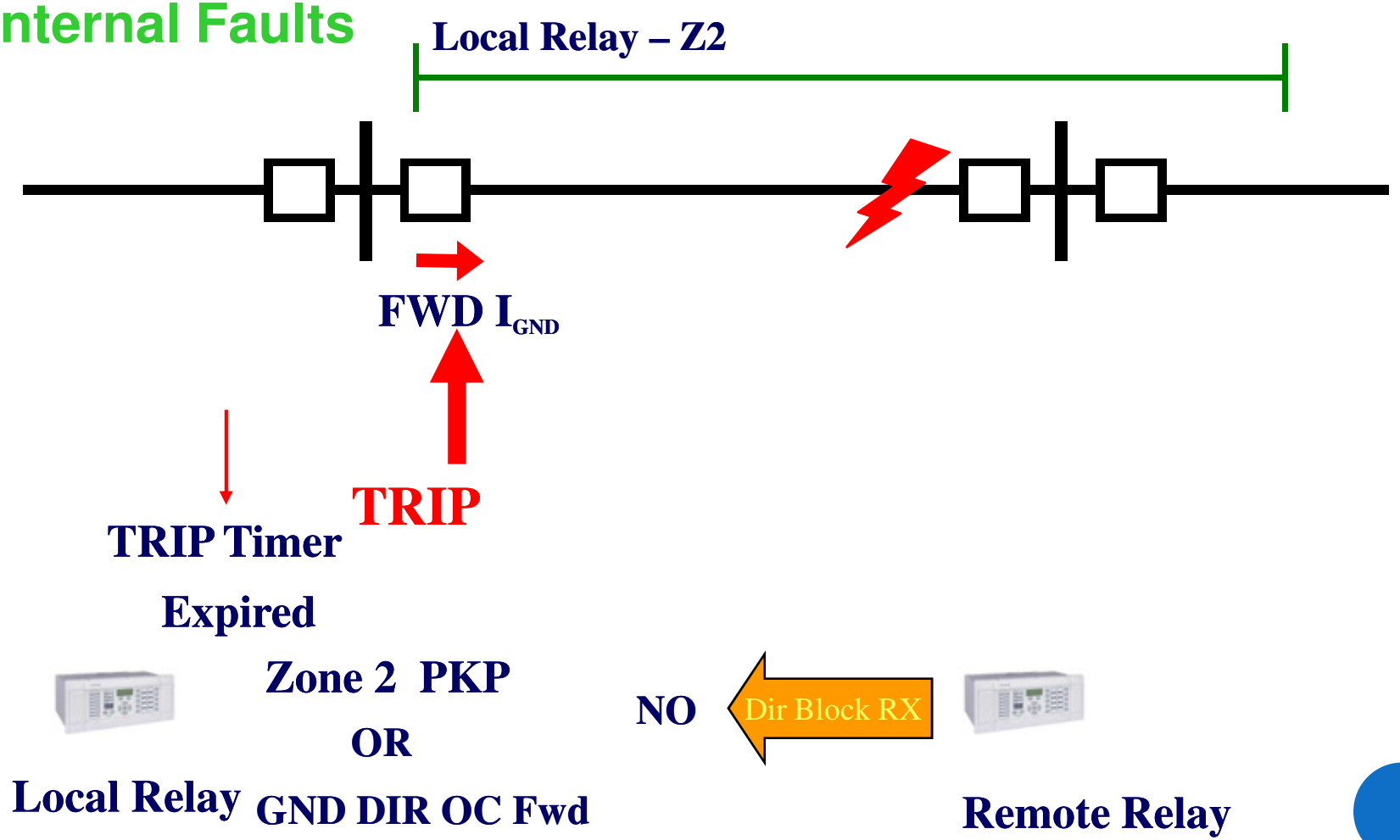


Directional Comparison Blocking (DCB)



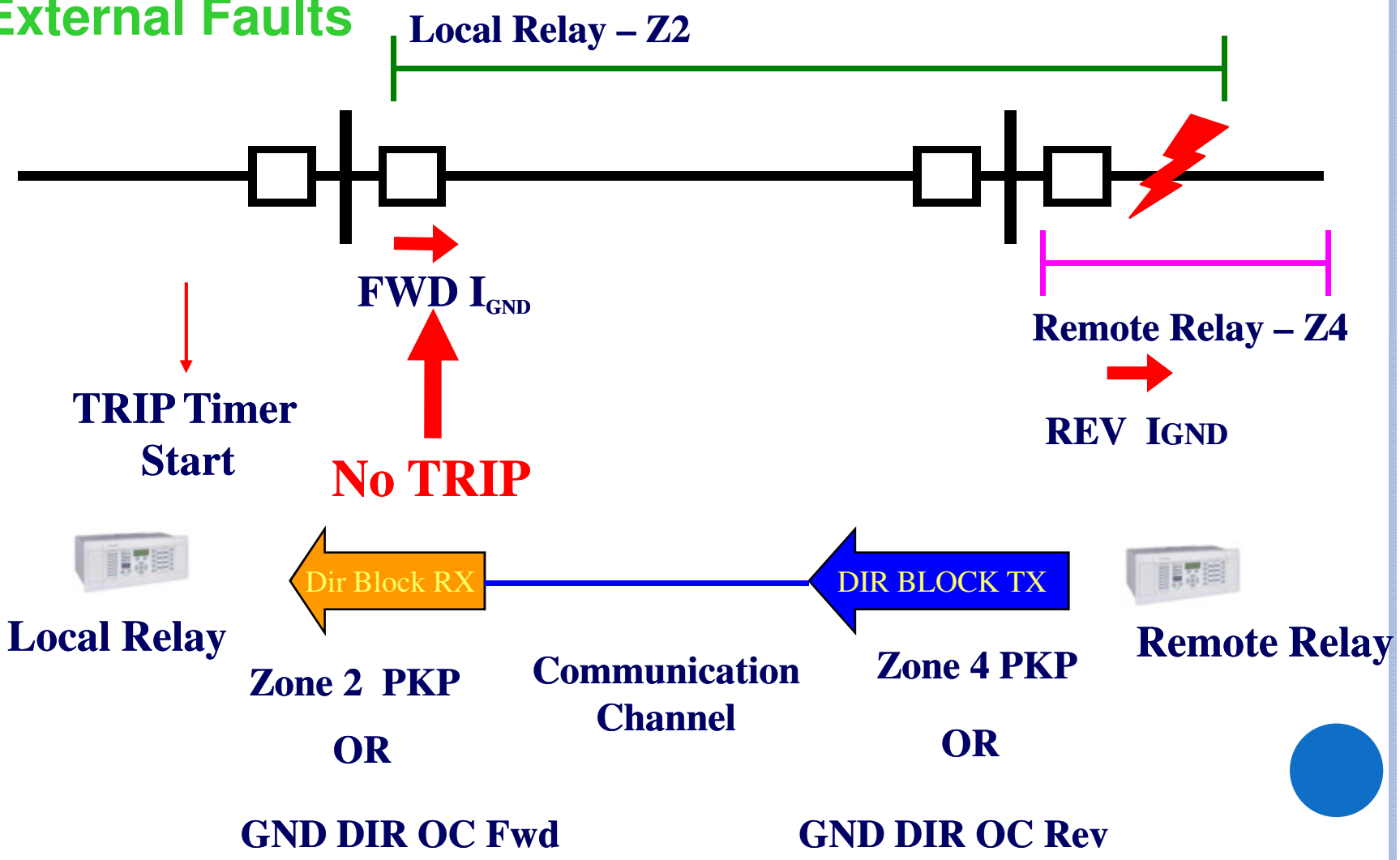
Directional Comparison Blocking (DCB)

Internal Faults



Directional Comparison Blocking (DCB)

External Faults



Different zones for transmission Line

Sl. No.	Zone	Direction	Protected Line Reach Settings	Time Settings (in Seconds)	Remarks
1	Zone-1	Forward	80%	Instantaneous	As per CEA
2a	Zone-2	Forward	For single ckt- 120 % of the protected line	0.5 to 0.6 - if Z2 reach overreaches the 50% of the shortest line ; 0.35- otherwise	As per CEA
			For double ckt- 150 % of the protected line		As per CEA
2b	Zone-2 (for 220 kV and below voltage Transmission lines of utilities)	Forward	120 % of the protected line, or 100% of the protected line + 50% of the adjacent shortest line	0.35	As per CEA with minor changes
3	Zone-3	Forward	120 % of the (Protected line + Next longest line)	0.8 - 1.0	As per CEA
4	Zone-4	Reverse	10%- for long lines (for line length of 100 km and above) 20%- for shot lines (for line length of less than 100 km)	0.5	As per CEA

DIRECT TRIP SCHEME AT 400KV

- It is required to trip other end breakers without any checking of the status at other end during the following conditions.
  - Operation of Over Voltage Protection.
  - Operation of Bus Bar Protection with Tie Breaker OFF.
  - Manual Tripping of both the breakers (Main and Tie) for one and Half Breaker Scheme.
  - Operation of LBB.
- On receipt of command through PLCC at other end, the breaker will trip directly.

OVER VOLTAGE PROTECTION FOR 400KV

- It will have 2 stages

  - **FIRST STAGE**
  - Setting :- 110% voltage.
    Time delay of 5 Secs

  - **SECOND STAGE**
  - Setting:- 140% voltage
    Time Delay:- Instantaneous

DIRECTIONAL E/F PROTECTION

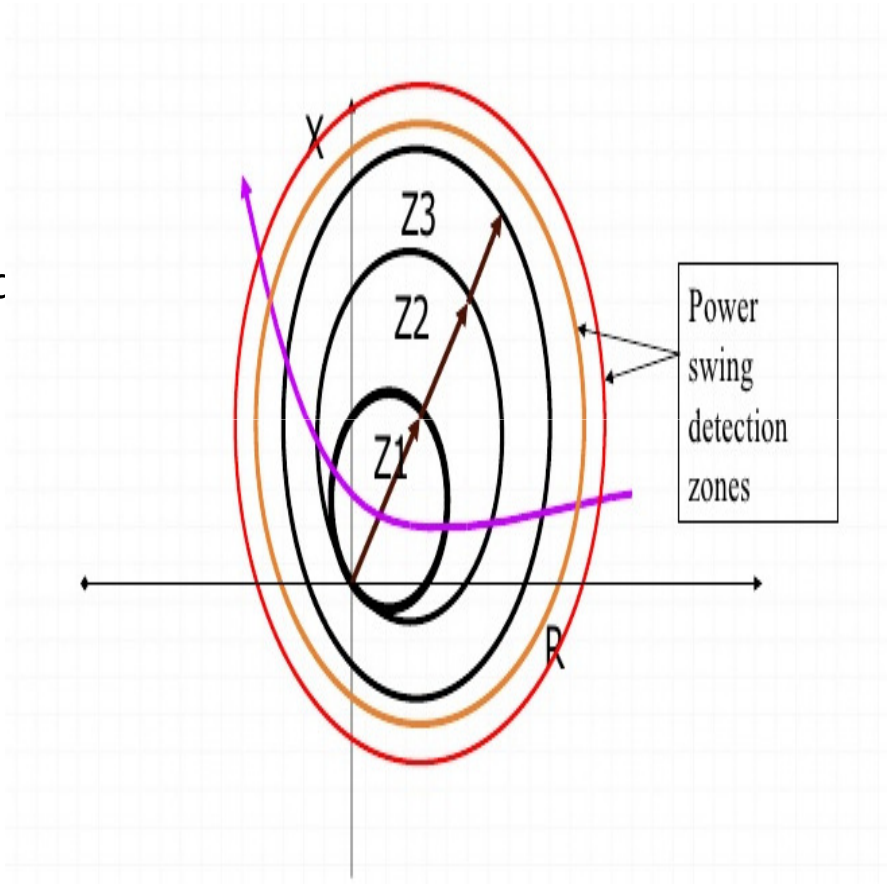
- It provides Back-Up protection to the transmission Lines.
- It provides reliable protection for High Resistance Earth Faults.
- It uses the calculated 3V0 voltage for necessary calculations.

SWITCH ON TO FAULT PROTECTION.

- This Feature provides protection against energisation of Transmission Line with Fault or Dead Short.
- Distance protection will not be able to provide reliable protection as voltage has just been impressed in the relay.
- It can be activated through TNC switch or CB auxiliary contact as Binary Input and internal detection of Current Rise.
- It provides Instantaneous 3-Phase Trip and Blocks Auto Reclosure.

POWER SWING BLOCKING

- Power Swings are disturbances in the system due to various reasons like sudden load through, Bad synchronization etc.
- Power Swings are characterized by slow power flow oscillations resulting in swinging of voltage and currents, resulting in operating point movement in distance relay characteristics, in turn causing tripping through distance relay.
- Tripping during power swings are undesirable since no actual fault is present and moreover line outage during power swing may cause further deterioration to system stability.
- Power Swing detection will block Zone2,3,4 operation. Normally zone 1 tripping is not blocked during power swing.



Time taken by fault locus to cross the power swing detection zones is more than 40-50ms, then it is called power swing.

FUSE FAILURE PROTECTION

- This function is based on condition

  3uo > 20 % of un / √3 and 3io < 20 % of in

- It is be selected to block protection and give alarm or just to give alarm. Non-Directional Protection automatically comes to service

- Fuse fail supervision is blocked for 200ms following line energisation in order not to operate for unequal pole closing and also during auto reclosing.

- MCB can also be used.

AUTO RECLOSURE

- **GENERAL**
- The auto-reclosing of power lines has become a generally accepted practice.
- Reports from different parts of the world show that in certain networks in region subject to a high lightening intensity only about 5% of the faults are permanent.
- Auto reclosing therefore provides significant advantages.
- Outage times will be short compared to where station personnel have to re-energize the lines after a fault.
- In interconnected networks auto-reclosing helps in maintaining system stability.

RECOMMENDATIONS AND SETTING CRITERION FOR PROVISION OF AUTO RECLOSURE

- **RECOMMENDATIONS**

  Presently 1 phase high speed auto-reclosure (HSAR) at 400kV and 220kV level is widely practiced including on lines emanating from Generating Stations and the same is recommended for adoption.

- If 3-phase auto-reclosure is adopted in 132KV system excluding the lines emanating from Generating Stations.

- **Setting Criterion**
  - **DEAD TIME**
  - Auto- reclosing requires a dead time which exceeds the de-ionising time.
  - Time required for the de-ionising of the fault path depends on:- arcing time, fault duration, wind conditions, circuit voltage, capacitive coupling to adjacent conductors, etc.
  - Single phase dead time of 1.0 sec is recommended for both 400kV and 220kV system.

SETTING CRITERION FOR PROVISION OF AUTO RECLOSURE

- **Setting Criterion**
  - **RECLAIM TIME**
  - The time during which a new start of the auto-reclosing equipment is blocked.
  - If reclosing shot has been carried out and the line is energized and a new fault occurs before the reclaim time has elapsed, the auto-reclosing equipment is blocked and a signal for definite tripping of the breaker is obtained.
  - After the reclaim time has elapsed, the auto-reclosing equipment returns to the starting position and a new reclosing sequence can occur.
  - The reclaim time must not be set to such a low value that the intended operating cycle of the breaker is exceeded, when two faults incidents occur close together.
  - If the breaker is closed manually, the auto reclosing equipment is blocked and cannot start again until the reclaim time has elapsed
  - For the breaker to be used for auto-reclosing, it is essential that it has the operating mechanism and breaking capacity necessary for it to be able to perform the auto-reclosing sequences required

CIRCUIT BREAKER REQUIREMENT

- According to IEC Publication 56.2, a breaker must be capable of withstanding the following operating cycle with full rated breaking current:-

  O + 0.3 s + CO + 3 min + CO

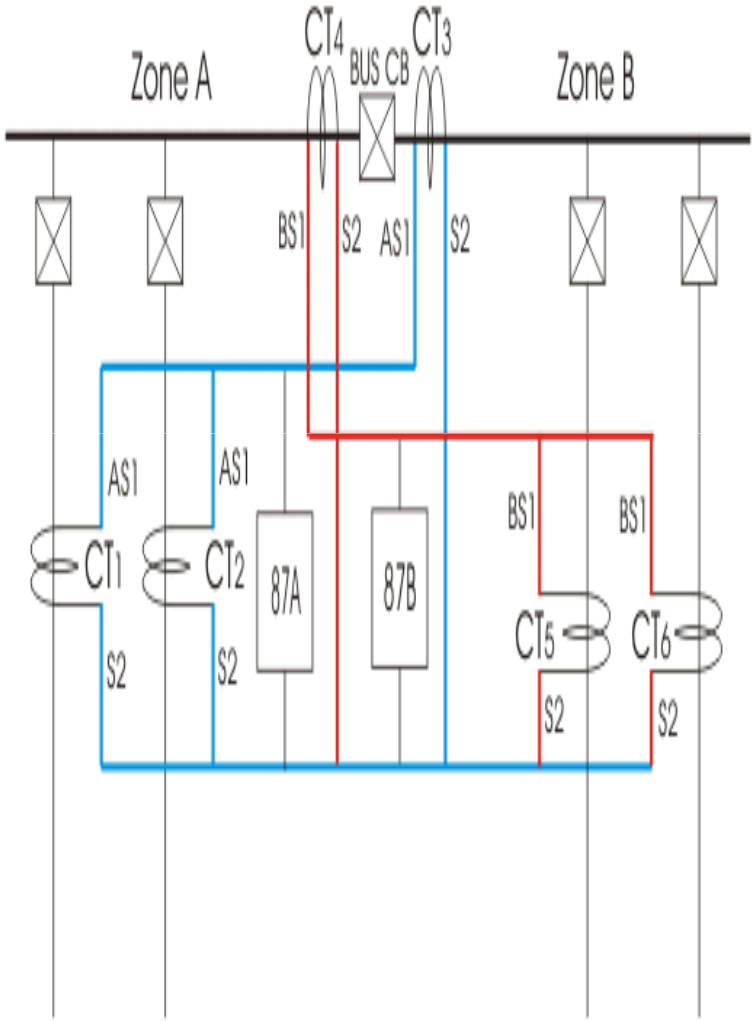
- Reclaim time of 25 sec is recommended for both 400KV and 220KV system.

LOCAL BREAKER BACKUP PROTECTION

- It is basically a secondary protection.
- It provides backup isolation during Failure of Breaker.
- It opens source to that breaker (i.e other end breakers, Bus Bars etc.)
- It will be triggered by operation of any primary protection (like distance, DEF, Bus – Bar etc.) and completion of its operation time. Operation of Lockout and presence of Current in the LBB relay initiates this protection and generates a trip signal after 200mSecs.
- It sends direct trip command to other end.

BUS BAR PROTECTION

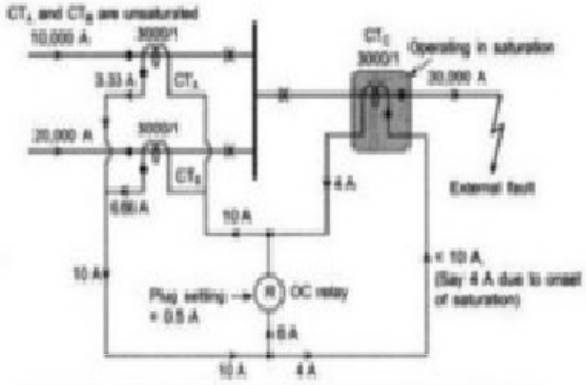
- Bus bar Differential protection scheme operates in simple Current differential Manner in Bus Bar.
- Here, bus section A or zone A is bounded by CT_1, CT_2 and CT_3 where CT_1 and CT_2 are feeder CTs and CT_3 is Bus Tie CT.
- Similarly bus section B or zone B is bounded by CT_4, CT_5 and CT_6 where CT_4 is Bus Tie CT, CT_5 and CT_6 are feeder CT.
- Therefore, zone A and B are overlapped to ensure that, there is no zone left behind this bus bar protection scheme.



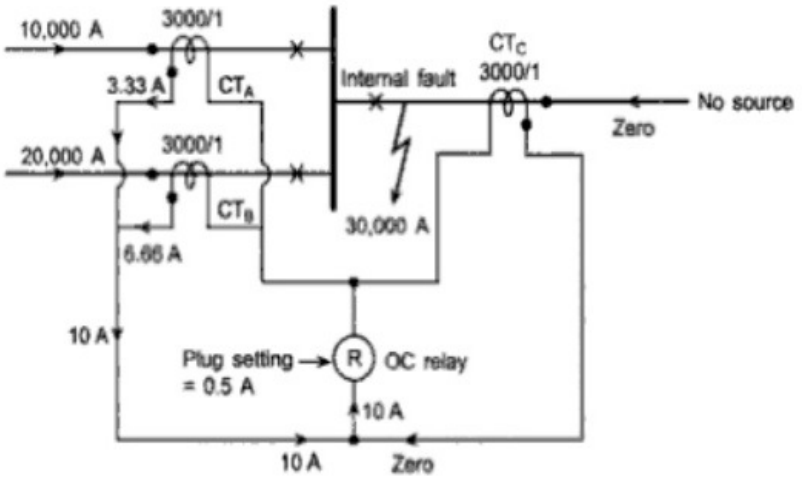
REQUIRMENTS OF BUS BAR PROTECTION

- Must have short tripping time as possible.
- Must be able to detect Internal Faults (sensitivity).
- Must be able to detect and trip only faulty part of the Bus Bar System.(selectivity).
- Must be secure against mal operation due to auxiliary Contact Failure.

External Fault



Internal Fault



THANK YOU