
Fundamentals of Teleprotection Systems

Three diagonal lines in green, red, and purple originate from a single point at the bottom center and extend towards the top right corner of the slide.

Teleprotection - Introduction

- **What is it ?**
-> **Tele**-Communication + **Protection** - Signalling
- **Where is it used ?**
-> Mainly at the higher and highest voltage levels
- **Why is it used ?**
-> Clearance of faults within the shortest possible time

TPS Standards and Publications

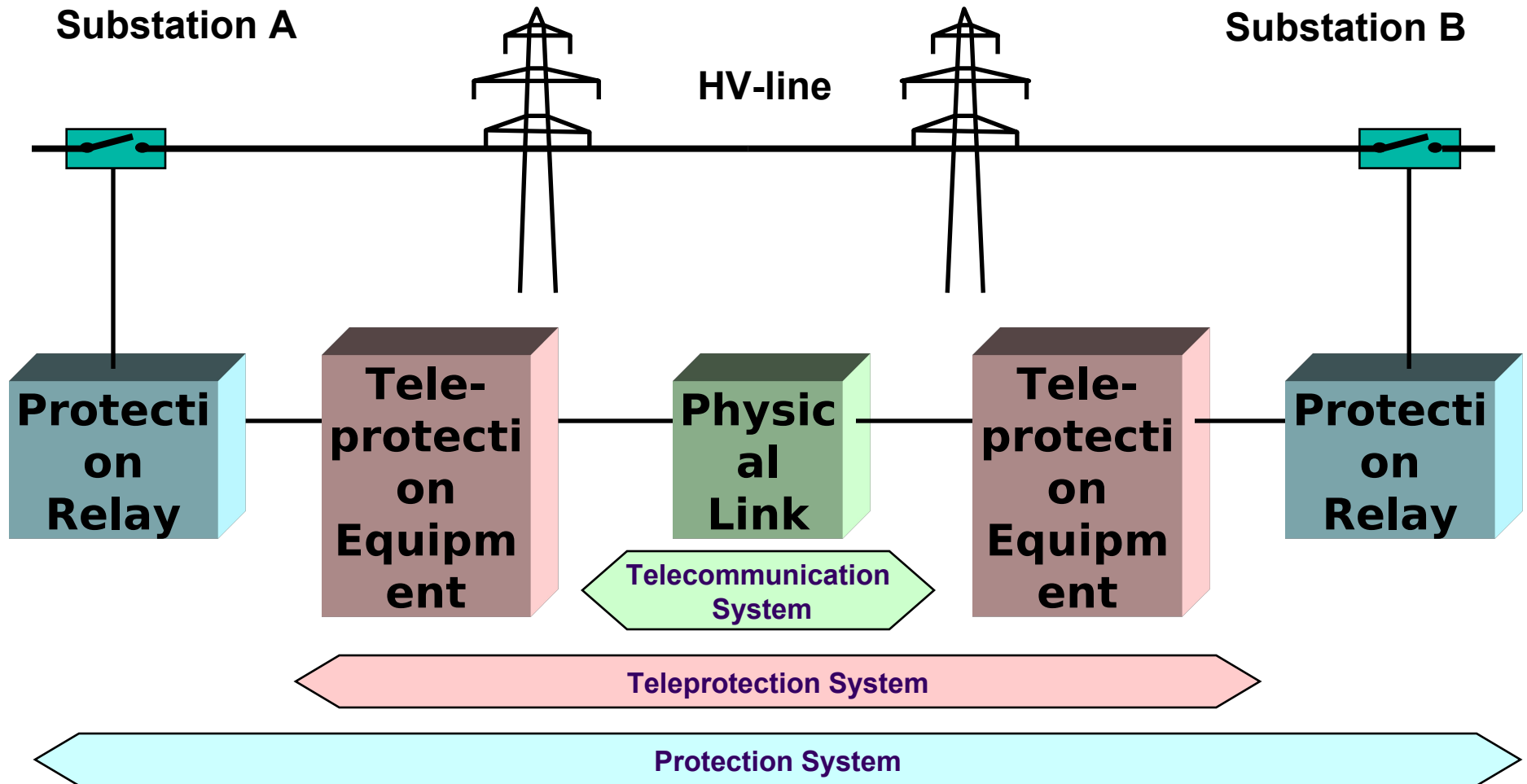
IEC standards:

- IEC 60834-1** **Teleprotection equipment of power systems - Performance and testing**
Part 1: Narrow-band systems (First edition, 1988)
Part 1: Command systems (Second edition, 1999)
- IEC 60834-2** **Performance and testing of teleprotection equipment of power systems**
Part 2: Analogue comparison systems (First Edition 1993)

CIGRE publications:

- "Teleprotection Guide", Study Committees 34 + 35, Joint Working Group on**
Teleprotection, 1969;
Revised Version "Protection Systems Using Telecommunication", 1985
Revised Version "Protection Using Telecommunications", 2000 (in preparation)

Protection System Architecture



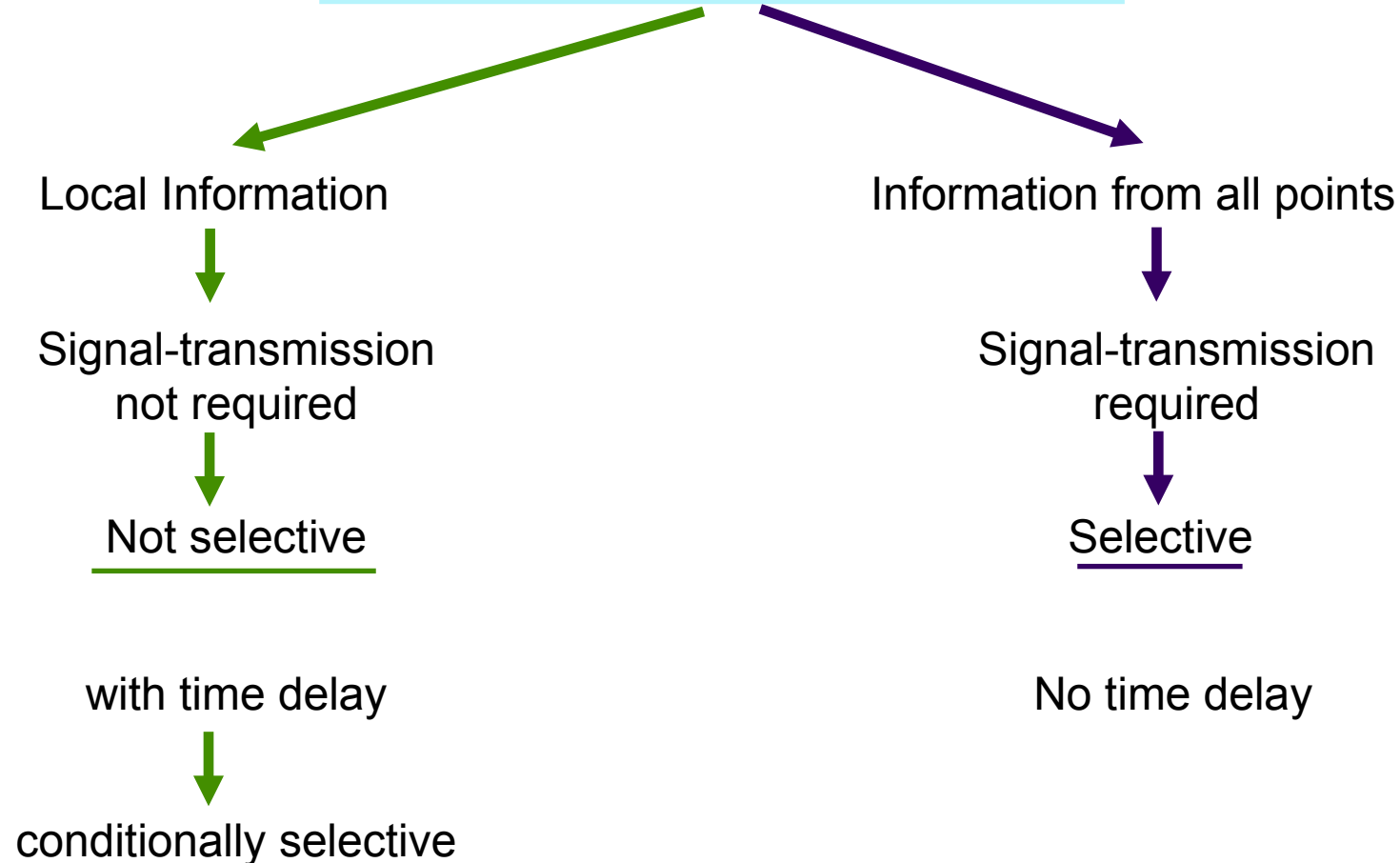
Protection Signal Transmission

Type of Information:

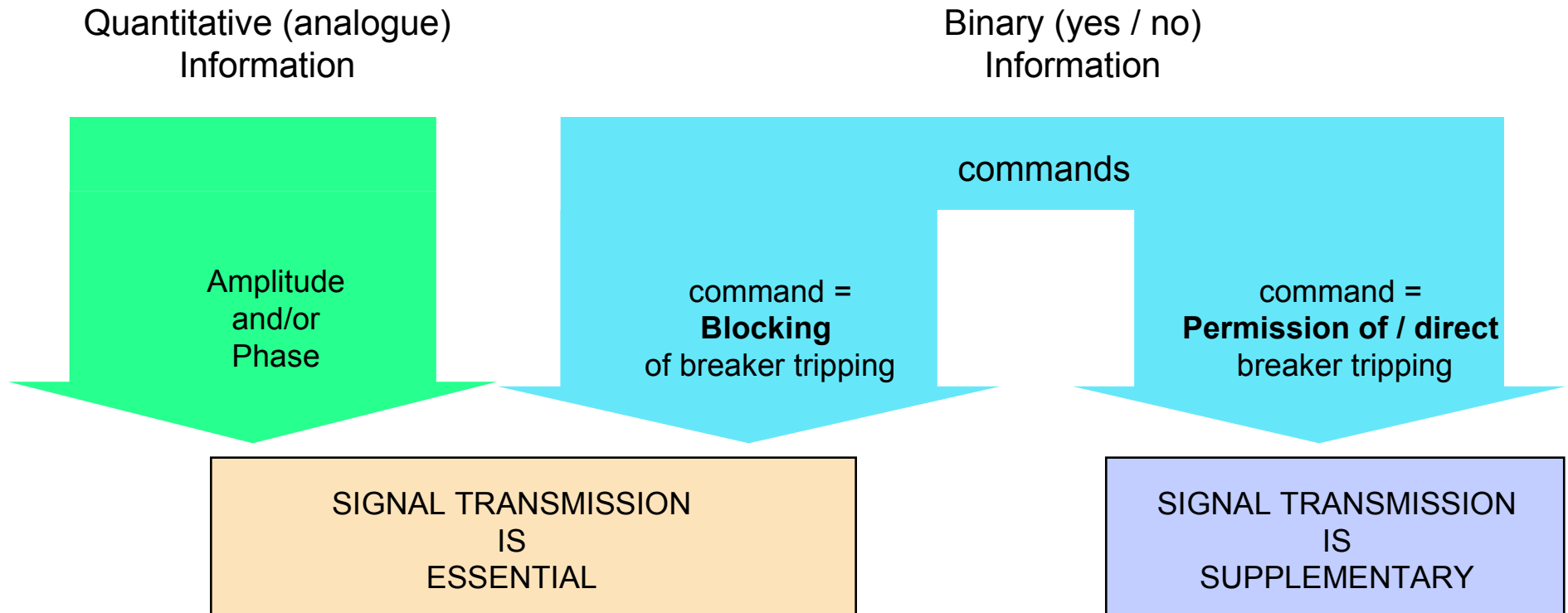
- Continuous signals
 - Magnitude and/or phase of power frequency currents
- Command type signals (on/off)
 - Trip / do not trip

Protection Systems

Protection system based on:

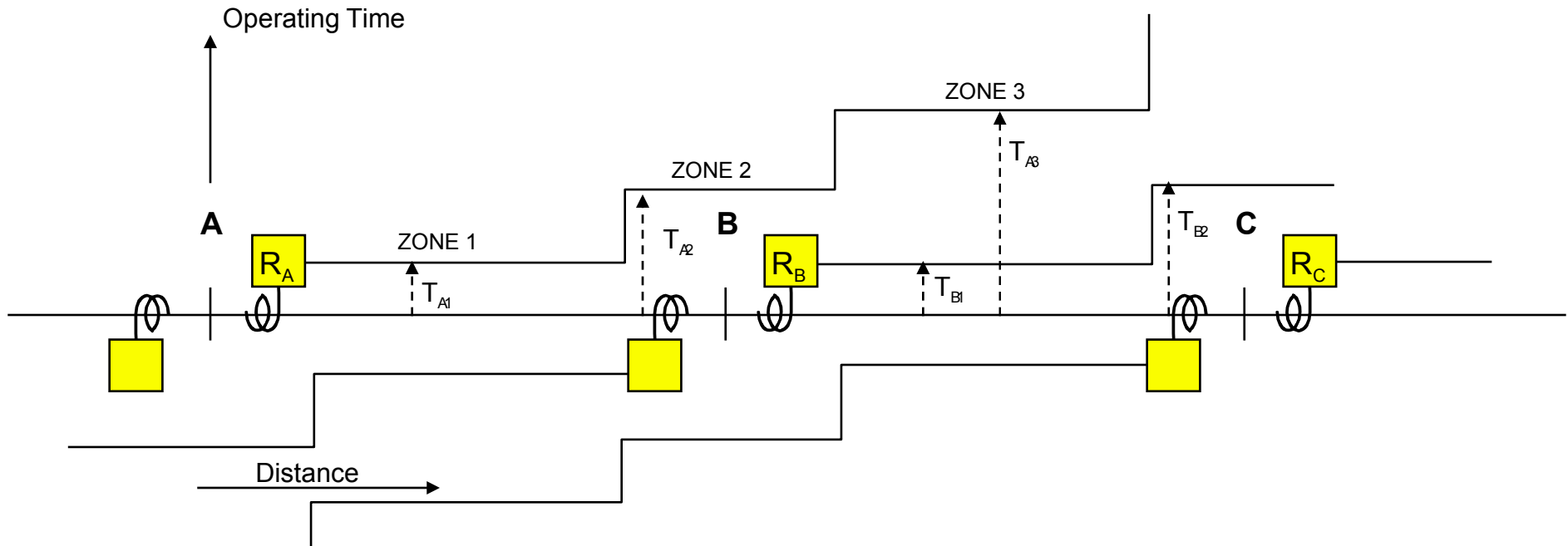


Signal Transmission for Line Protection



Distance Protection

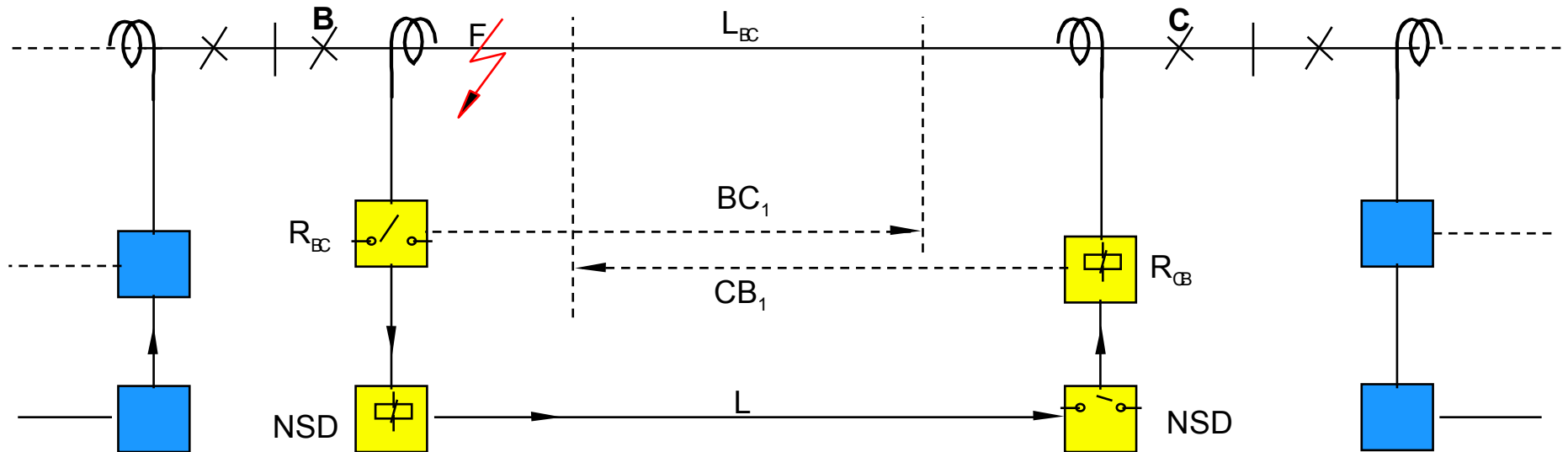
Typical stepped distance/time characteristics



A, B, C	Stations
R_A, R_B, R_C	Protection Relay
T_{A1}, T_{A2}, T_{A3}	Operating Times, Relay A
T_{B1}, T_{B2}, T_{B3}	Operating Times, Relay B

Distance Line Protection

Permissive Underreach Transferred Tripping (PUTT)

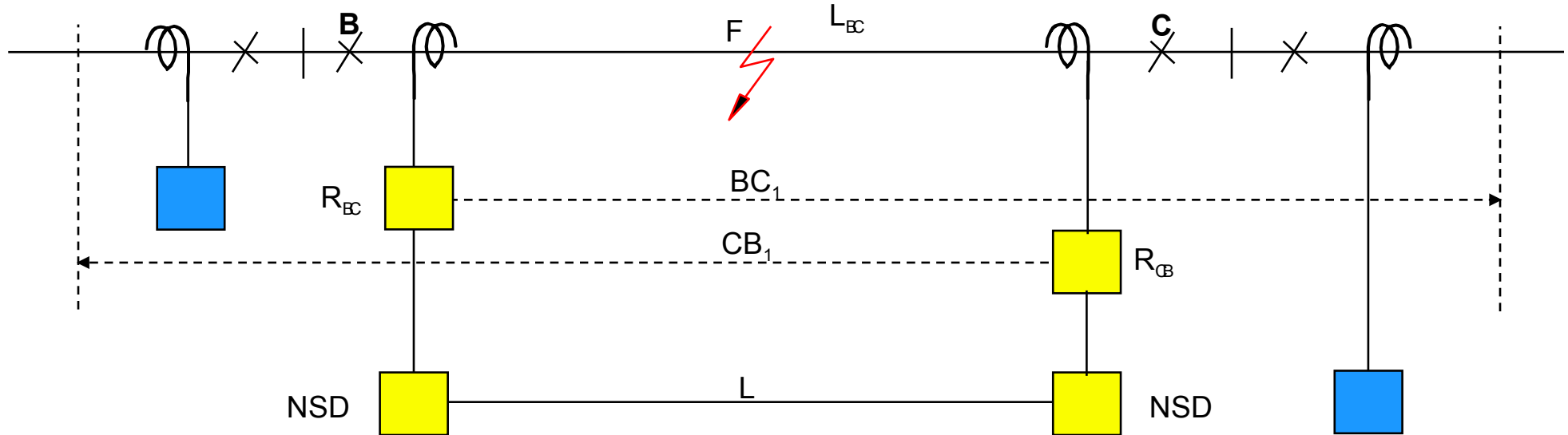


B, C	Substations
L_{BC}	Protected line section
R_{BC}, R_{CB}	Protection relay
BC_1, CB_1	Zone 1 reach, 85% of line section

F	Line fault
L	Communication channel (PLC, Microwave, Cable)

Distance Line Protection

Permissive Overreach Transferred Tripping (POTT)

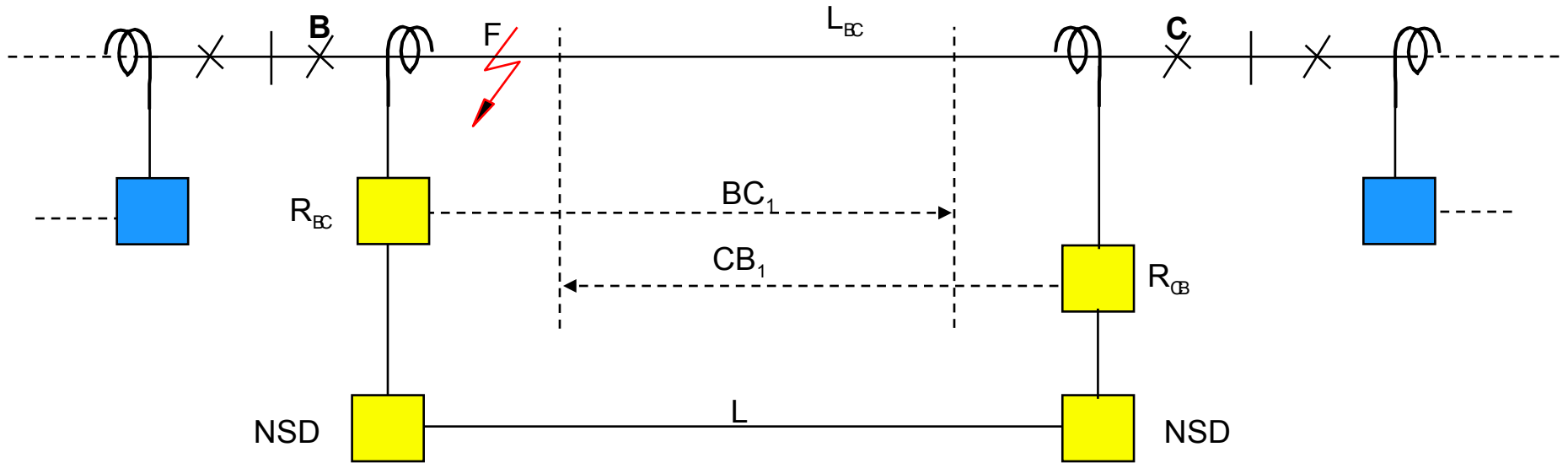


B, C	Substations
L_{BC}	Protected line section
R_{BC}, R_{CB}	Protection relay
BC_1, CB_1	Zone 1 reach, 130% of line section

F	Line fault
L	Communication channel (PLC, Microwave, Cable)

Distance Line Protection

Direct Transfer Tripping (DTT)

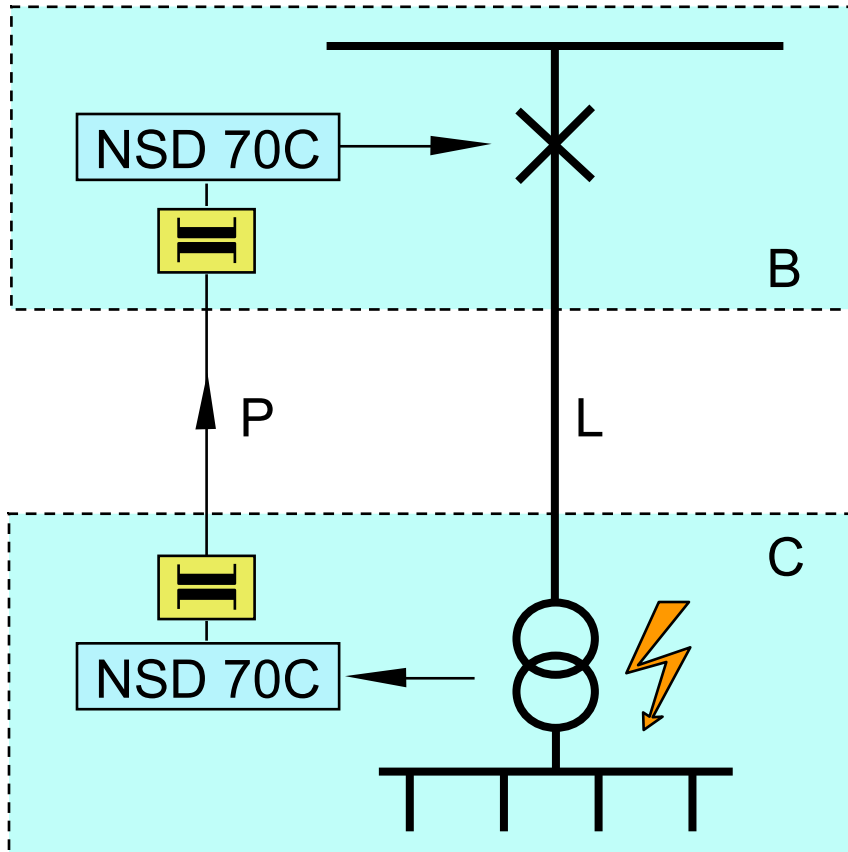


B, C	Substations
L_{EC}	Protected line section
R_{EC}, R_{CB}	Protection relay
BC_1, CB_1	Zone 1 reach, 85% of line section

F	Line fault
L	Communication channel (PLC, Microwave, Cable)

Transformer Protection

Example for direct tripping

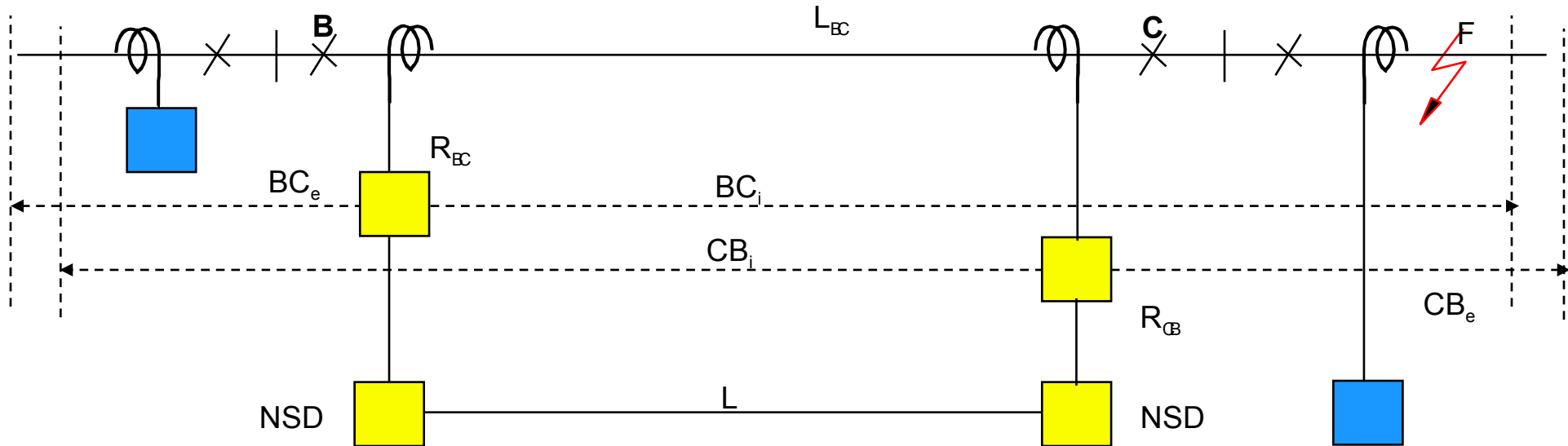


P Pilot cable

L HV Transmission Line
or -Cable

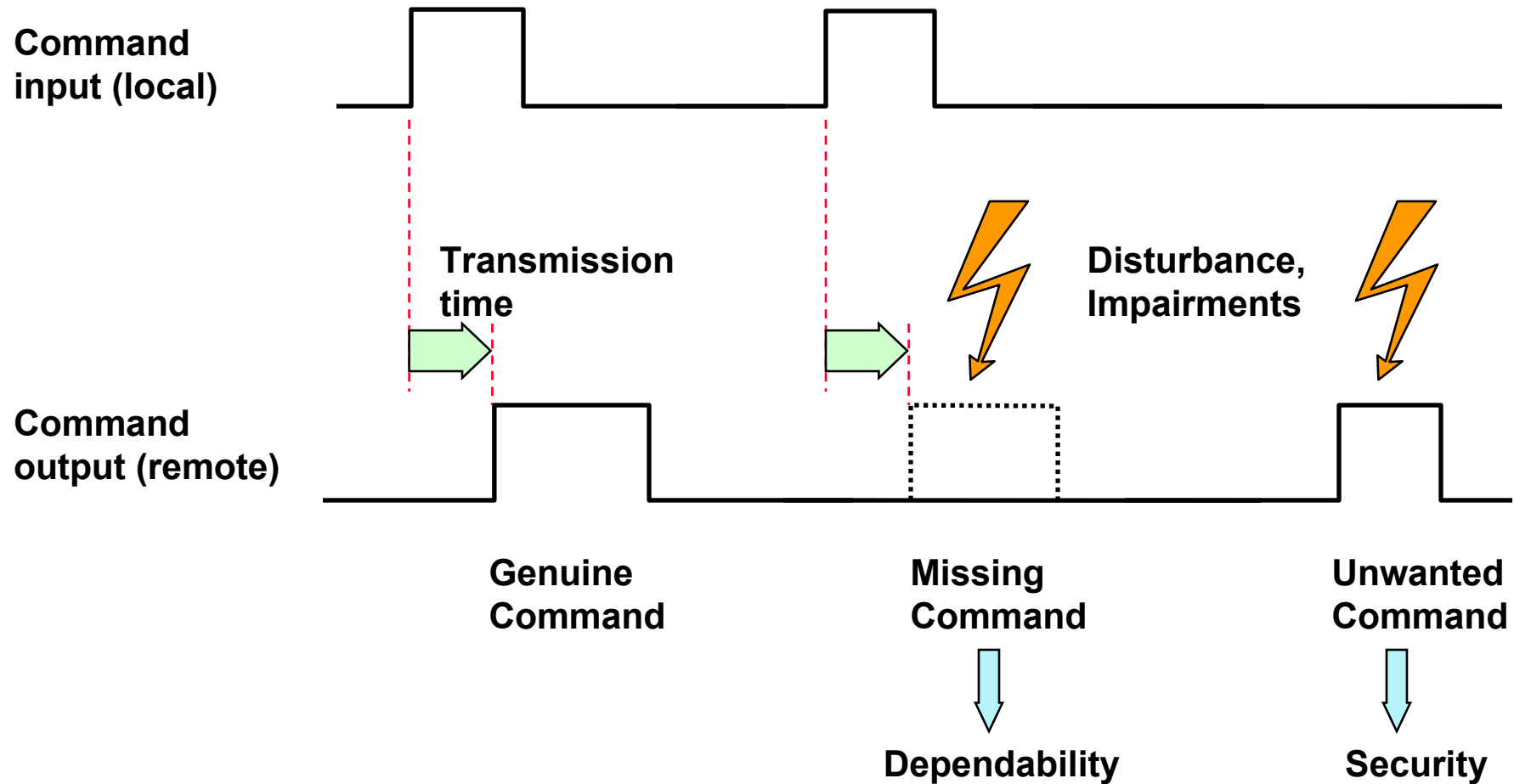
Distance Line Protection

Blocking



B, C	Substations	F	Line fault
L_{BC}	Protected line section	L	Communication channel (PLC, Microwave, Cable)
R_{BC}, R_{CB}	Protection relay		
BC_i, CB_i	Zone 1 reach, 130% in direction of the protected line section		
BC_e, CB_e	Range of protection relay in direction of busbars		

Teleprotection command transmission



Telecommunication Channel Impairments

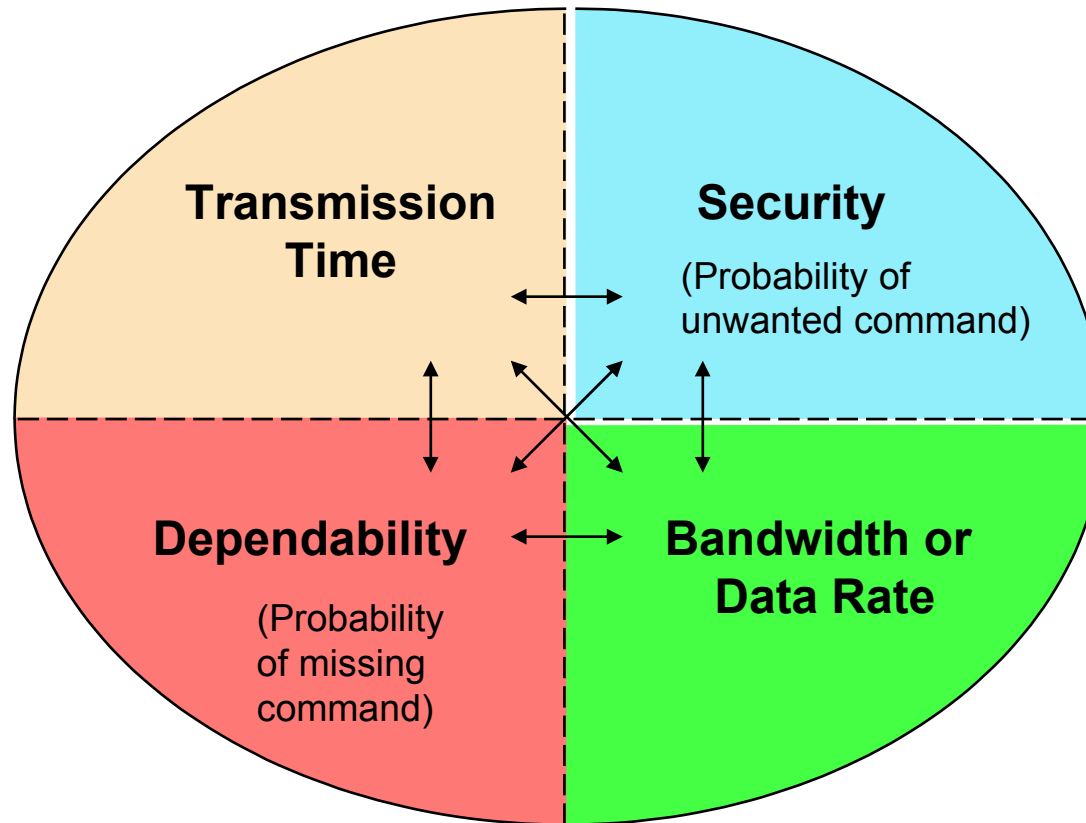
→ Impairments resulting from interference and noise

- Isolater / breaker operation
- 50/60 Hz harmonics (pilot cables)
- Corona noise (PLC channels)
- Fading (microwave channels)
- Jitter (digital networks)
- Temporary loss of synchronism (digital networks)
- Signal interruptions
- etc.



→ Disturbed signals may cause protection equipment to malfunction

Performance Criteria for Teleprotection



Optimization / Exchange according to application

Line Protection

Possible Signal Connections Between two Distance Relays

Designation relay setting (%) Step 1 Speed	Short description mission channel as regards	Typical distance	Requirements for trans-		
			Security	Dependability	
1 Permissive underreach transferred tripping	Starting of distance relay permits tripping	85	M-H	M-H	H
2 Permissive overreach transferred tripping	Directional comparison (signal permits tripping)	130	H	M	H
3 Permissive underreach transferred acceleration	Carrier acceleration by extension of step (*)	85 (130*)	H	L-M	H
4 Blocking (direct overreach, transferred blocking)	Blocking signals are transmitted over healthy lines	130	S	L	H
5 Blocking	Signal inhibits step extension (*)	85 (130*)	H-S	L	M
6 Unblocking tripping for limited time only	Loss of guard signal permits	130	H	M	M
7 Direct underreach transferred tripping	Status of relay at receiving end not taken into account	85	M-H	S	H

L = Low M = Medium H = High S = Very severe requirements

Total Fault-Clearance-Time

- Time delay between fault occurrence and line tripping
- The fault-clearance time results from:
 - Relay-time (fault detection) T_{REL}
 - Command transmission time T_{AC}
 - Switching delay of line breaker T_{BR}
- Typical values:
$$T_{Total} = T_{REL} + T_{AC} + T_{BR}$$
$$75 \text{ ms} = 20 \text{ ms} + 15 \text{ ms} + 40 \text{ ms}$$
- Target: T_{Total} = less than 100 ms, Worst Case
= 4.5 to 5 cycles max. (50 Hz)

Typical requirements for different applications

- Line protection with permissive transfer tripping:
 - Transmission time $T_0 = 10 \dots 20 \text{ ms}$
 - Dependability $P_{\text{lost command}} \leq 10^{-2} \dots 10^{-3}$
 - Security $P_{\text{false command}} \leq 10^{-3} \dots 10^{-4}$
- Line protection with blocking system:
 - Transmission time $T_0 = 6 \dots 15 \text{ ms}$
 - Dependability $P_{\text{lost command}} \leq 10^{-3}$
 - Security $P_{\text{false command}} \leq 10^{-2}$
- Direct transfer tripping (e.g. transformer protection):
 - Transmission time $T_0 = 20 \dots 50 \text{ ms}$
 - Dependability $P_{\text{lost command}} \leq 10^{-3} \dots 10^{-4}$
 - Security $P_{\text{false command}} \leq 10^{-5} \dots 10^{-6}$

Command Systems, Typical Figures

Blocking

- short transmission time
- moderate security
- high dependability

Analog systems

Tac	< 15 ms
Puc	< 1E-2
Pmc	< 1E-3

Digital systems

< 10 ms
< 1E-6
< 1E-3

Permissive tripping

- moderate transmission time
- moderate to high security
- moderate to high dependability

Tac	< 20 ms
Puc	< 1E-31E-4
Pmc	< 1E-21E-3

< 10 ms
< 1E-6
< 1E-3

Direct tripping

- moderate transmission time
- very high security
- very high dependability

Tac	< 40 ms
Puc	< 1E-5 1E-6
Pmc	< 1E-3

< 10 ms
< 1E-9
< 1E-3

Teleprotection Equipment Command Systems

NSD 50 / NSD550

- Plug in unit for multi-purpose Power Line Carrier type ETL

NSD 70, NSD 70C

- for analog bearers
 - cables
 - speech channels of analog and digital links
 - power line carrier channels

NSD 70D

- for digital bearers
 - digital multiplexers
 - digital radio, fibre optic links
- with plug-in fibre optic line unit for dedicated fibres

Digital Networks

High capacity = large number of channels

Basic channel capacity = 64 kbit/s

PDH (Plesiochronous digital hierarchy)

- Multiplexing into 2 Mbit/s (30 channels)
8 Mbit/s (120 channels)
etc. (..... channels)

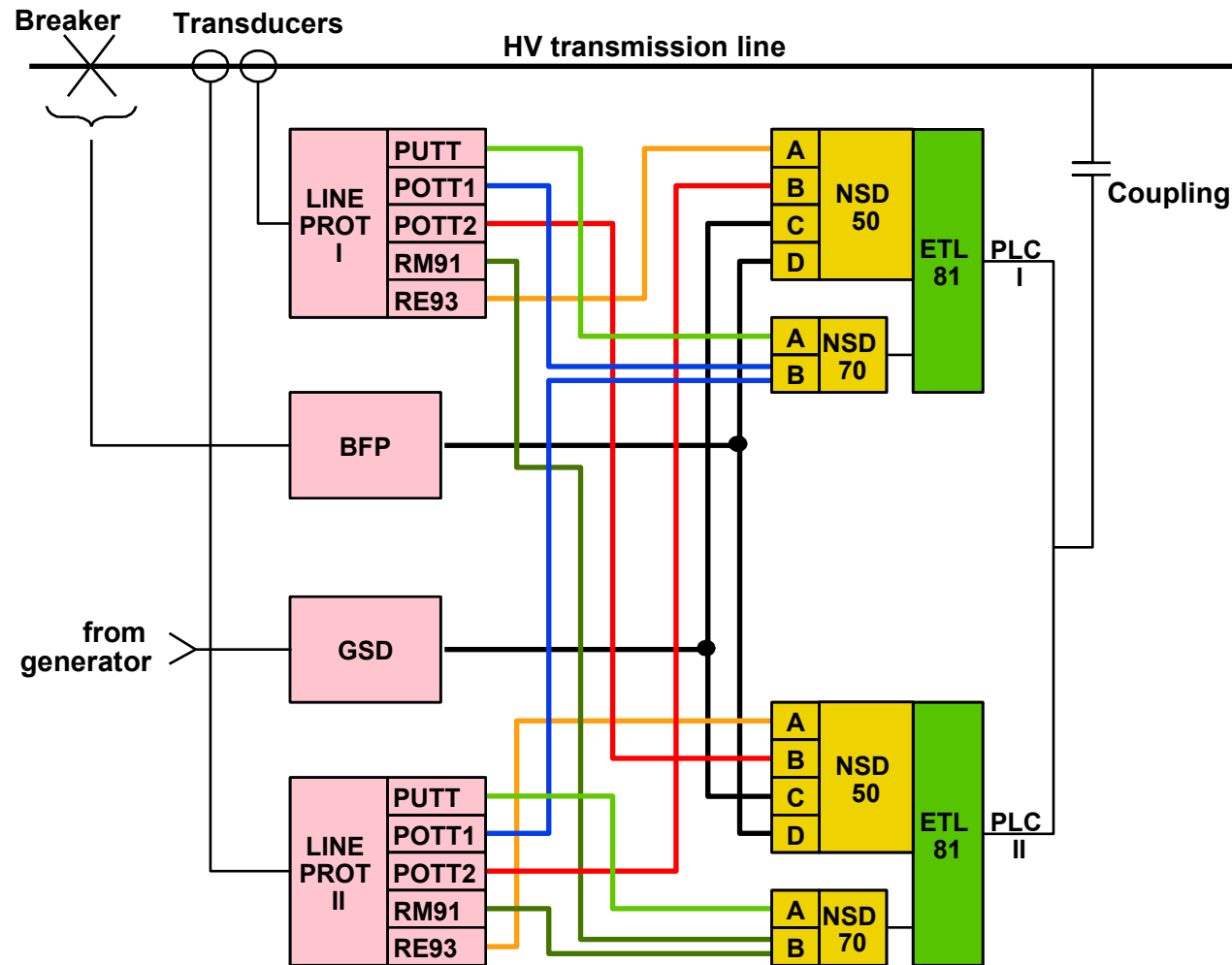
SDH (Synchronous Digital Hierarchy)

- Multiplexing of $n * 64 \text{ kbit/s}$ or $n * 2 \text{ Mbit/s}$ into 155 Mbit/s etc.

Cross-connect functionality

Radio or optical fibre links

800 kV redundant Line Protection (with NSD 50 and NSD 70)

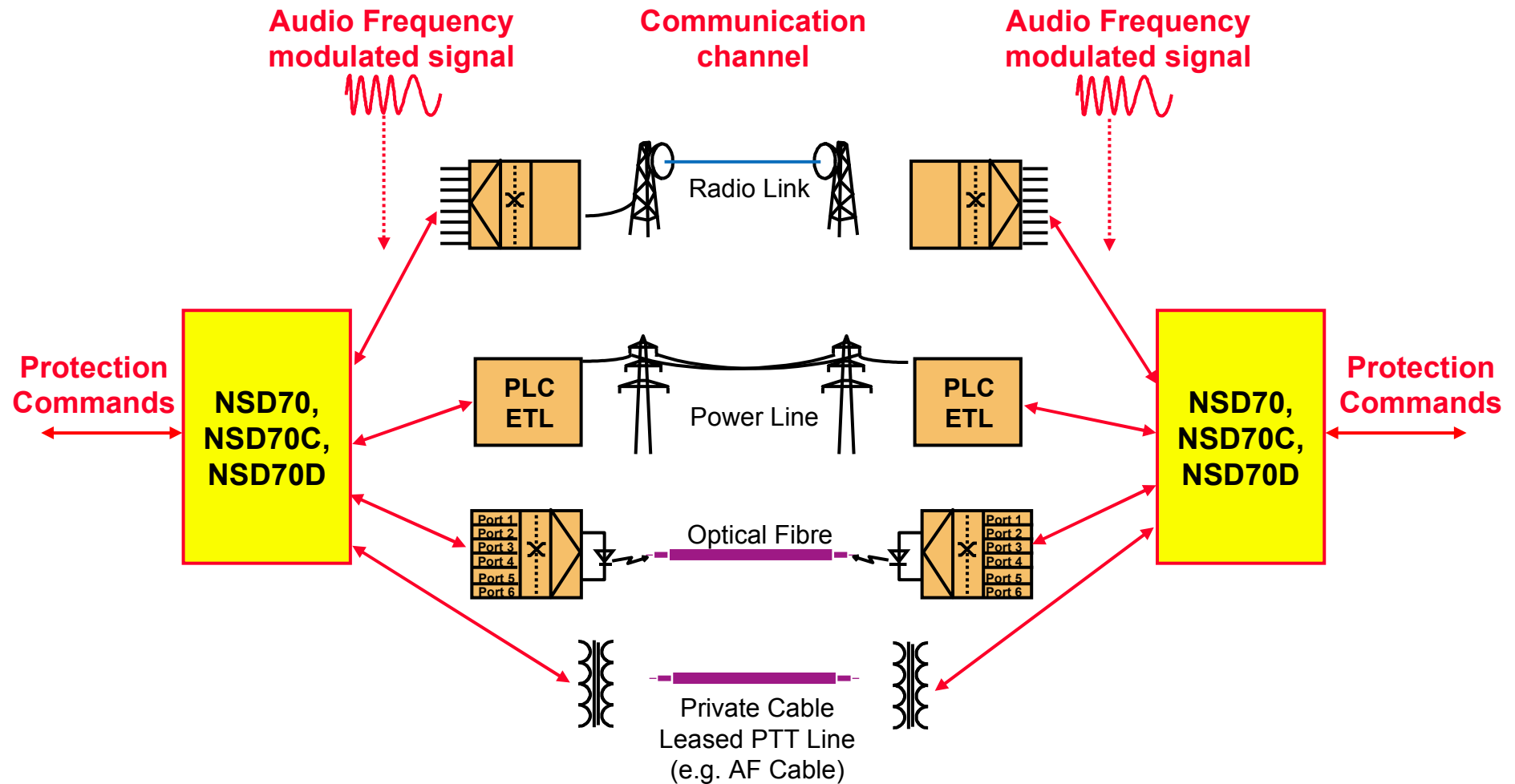


PUTT	Permissive underreach tripping NSD 70 indirect
POTT 1	Permissive overreach tripping NSD 70 indirect
POTT 2	Permissive overreach tripping NSD 50 indirect
RM 91	Directional comp. prot. NSD 70 indirect
RE 93	Earth fault protection NSD 50 indirect
BFP	Breaker fail protection NSD 50 direct
GSD	Generator protection NSD 50 direct

Teleprotection Equipment NSD70, NSD70C, NSD70D

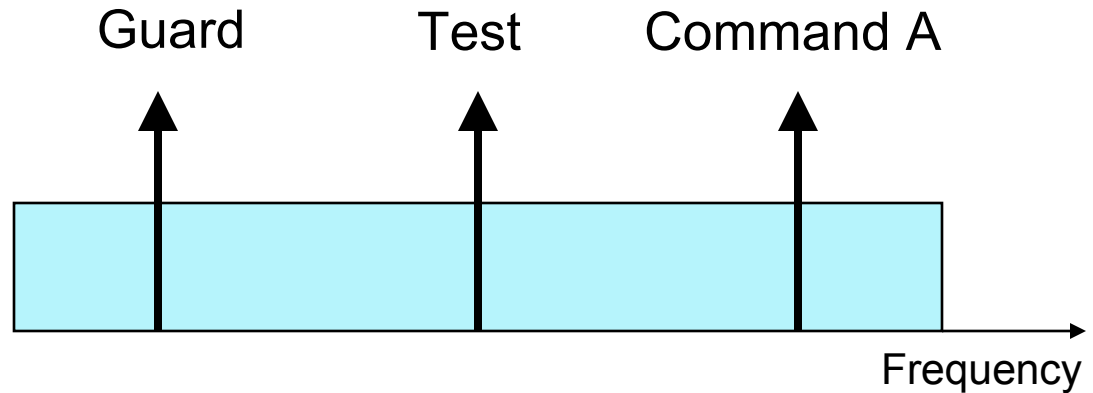
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Communication channels for teleprotection

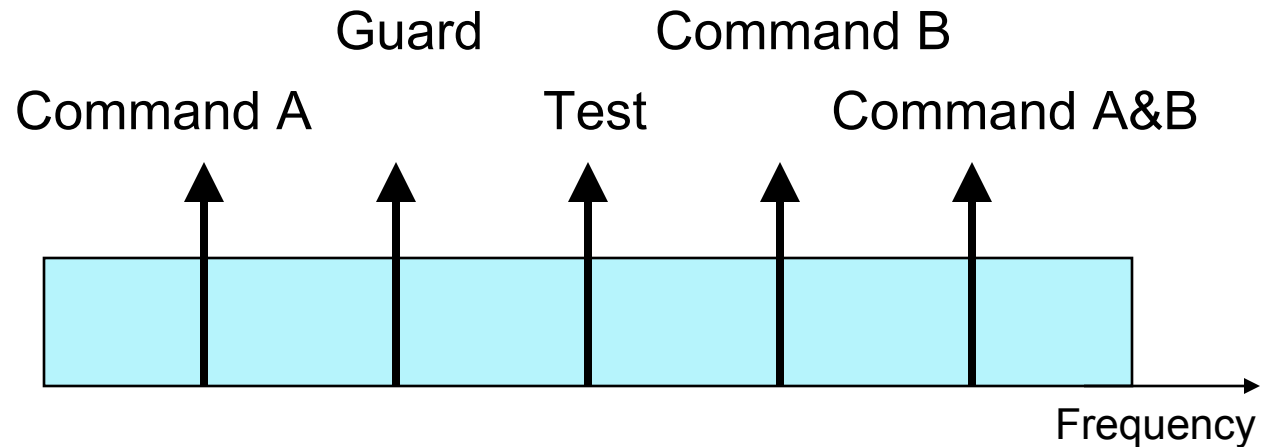


Operating Principle NSD 70 / 70C (mode 1)

One
uncoded
Command A



Two
uncoded
Commands
A, B



NSD 70 / 70C



Power Systems Communication



NSD70, NSD72, NSD70C

NSD 70

- single tone guard / single tone command(s)
- for 1 or 2 commands
- 1 or 2 NSD 70 in 1 subrack

NSD 72 (= 2 x NSD 70)

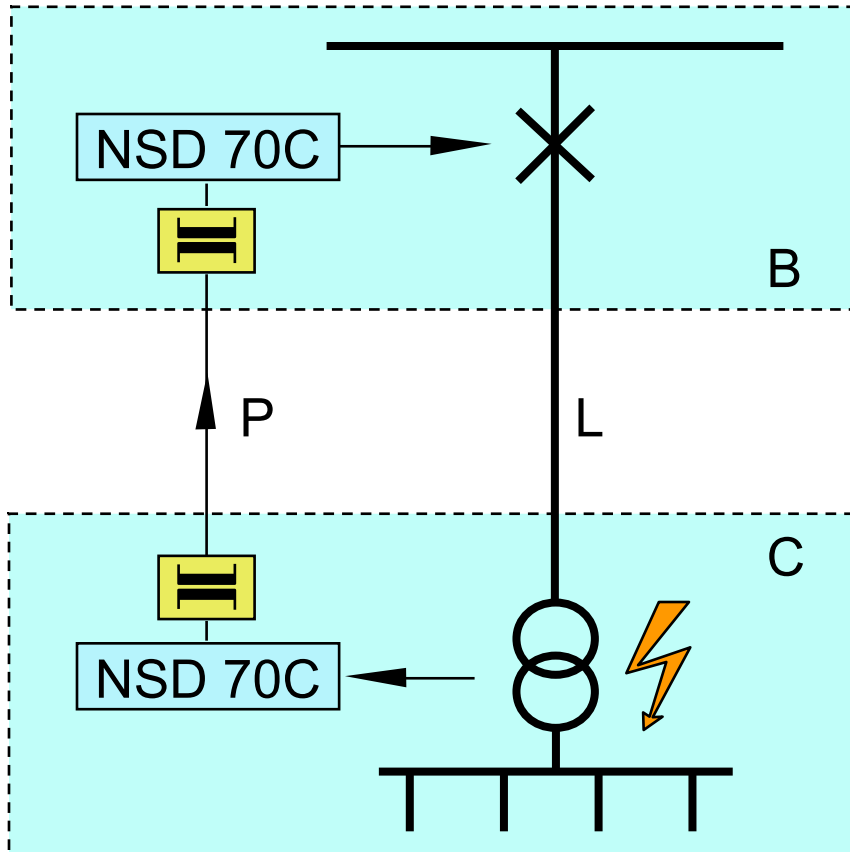
- dual tone guard / dual tone command(s)
- for 1 or 2 commands
- 1 NSD 72 in 1 subrack

NSD 70C

- single tone guard / dual tone command(s)
- 1 NSD 70C in 1 subrack with 1 to 4 commands
- 2 NSD 70C in 1 subrack with 1 to 3 commands each

Transformer Protection

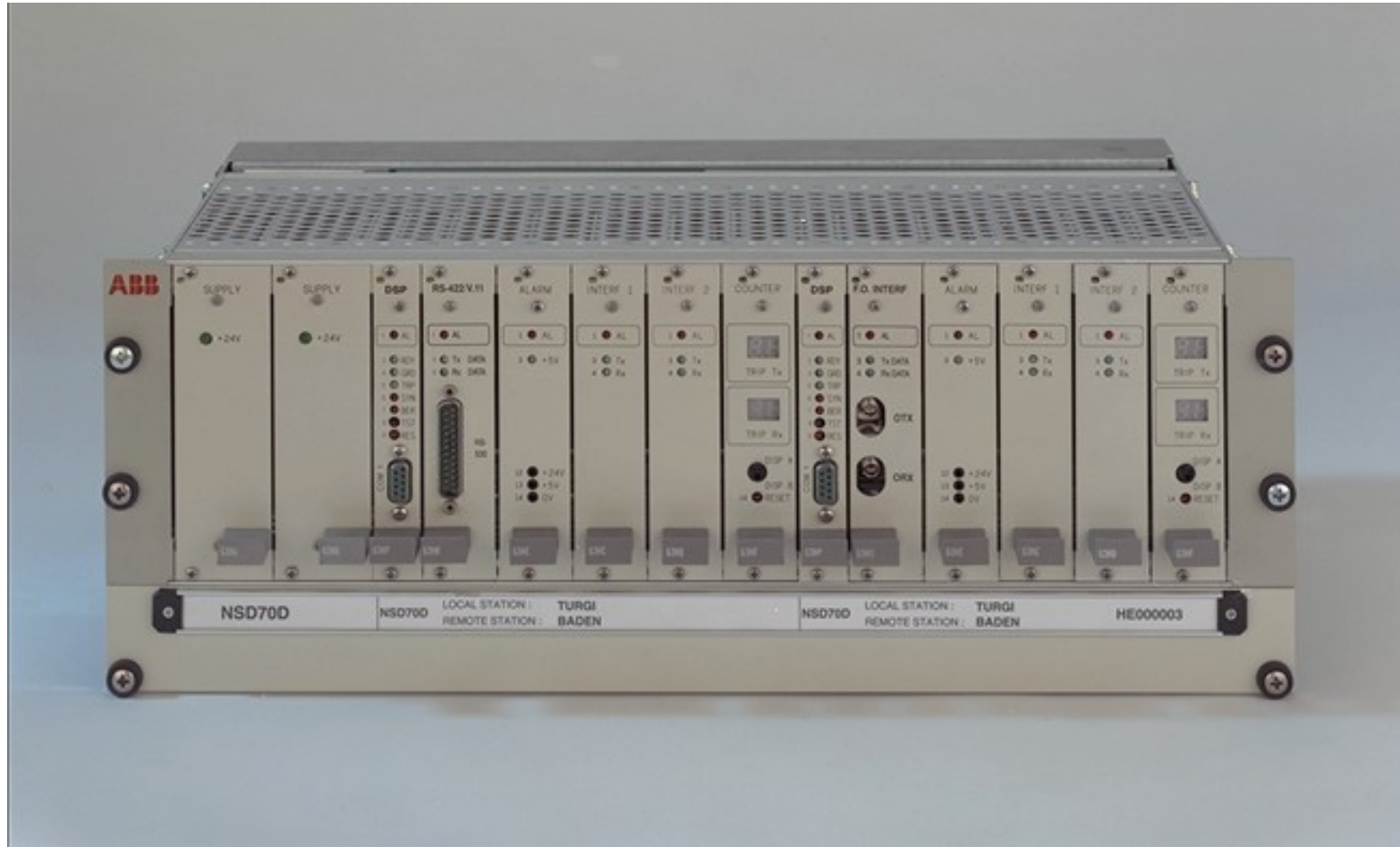
Example for direct tripping



P Pilot cable

L HV Transmission Line
or -Cable

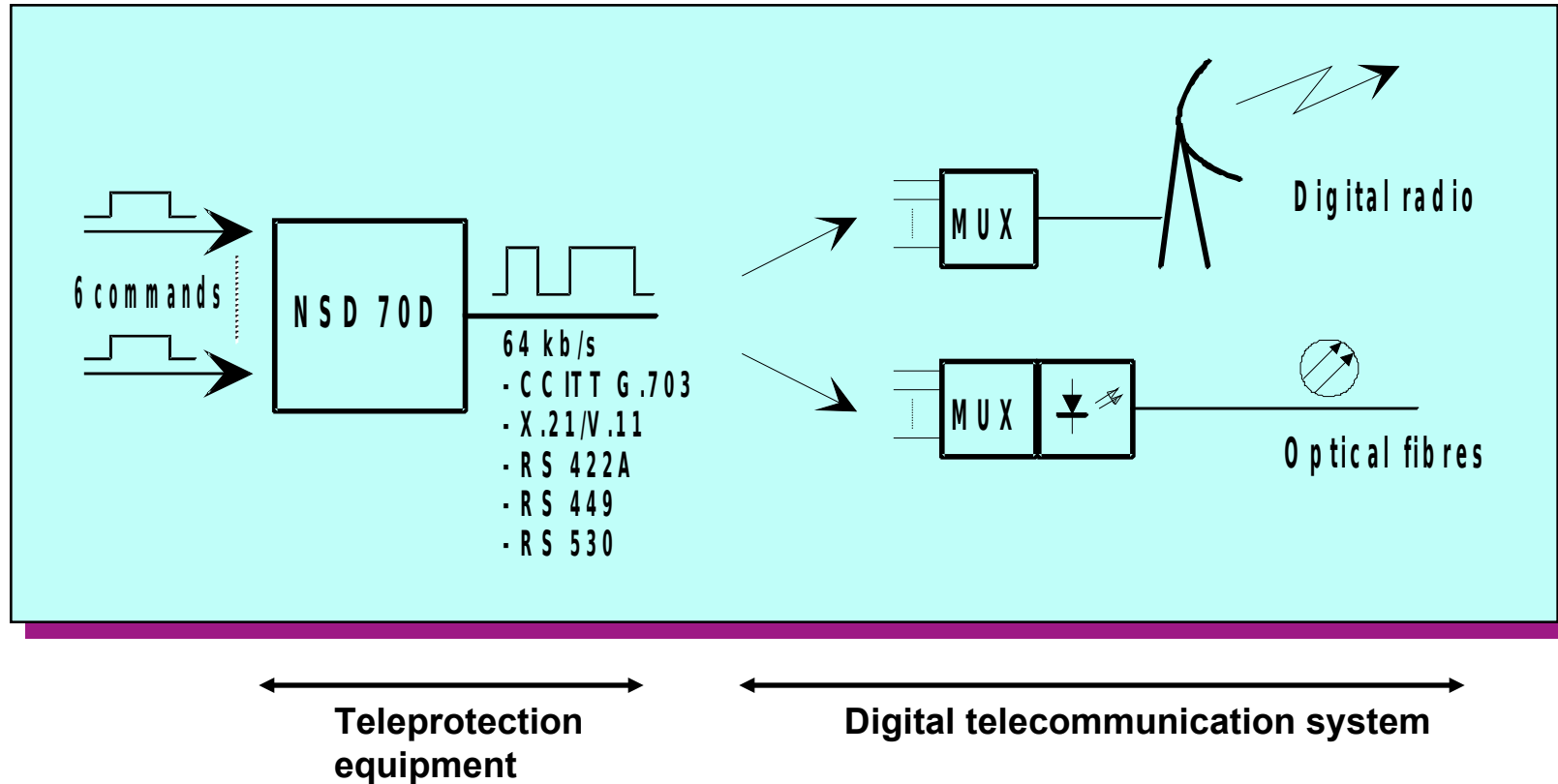
NSD 70D



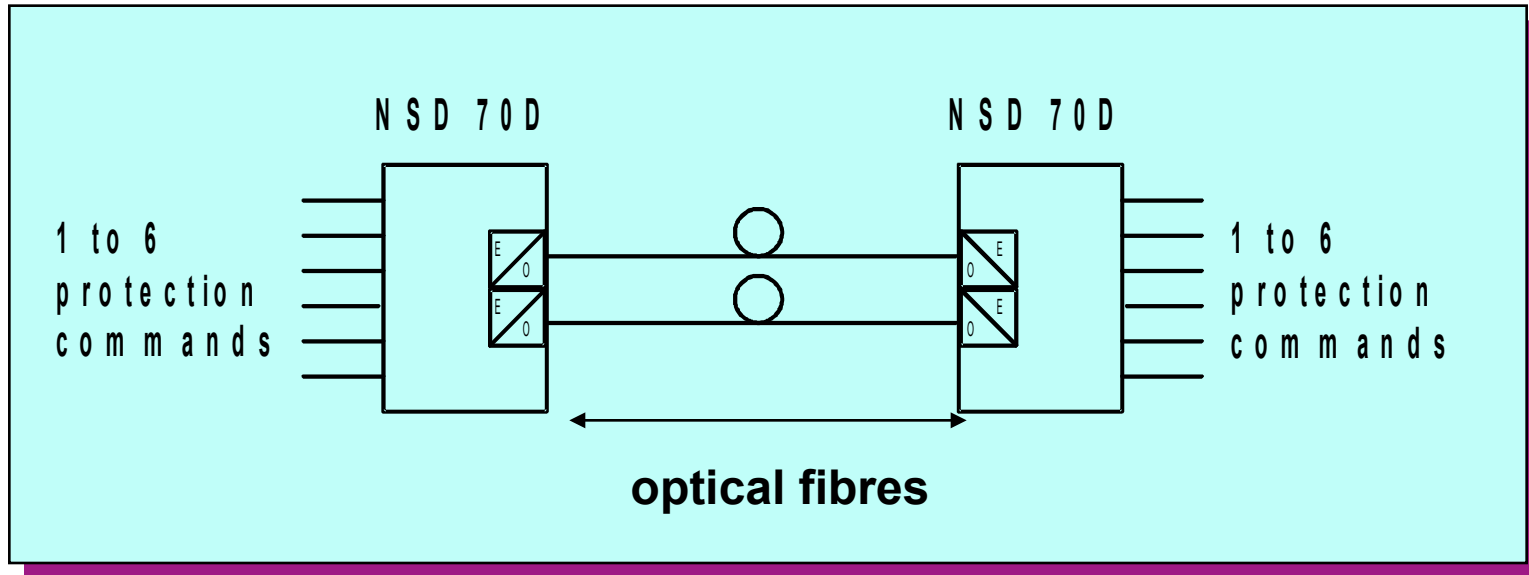
NSD 70D for Digital Channels

- ➔ **NSD 70 hardware platform**
- ➔ **Complete set of line interfaces**
 - electrical (conforming to CCITT and EIA standards)
 - fibreoptic transceiver
- ➔ **1 to 6 commands with common guard code**
- ➔ **Subrack accommodates 1 or 2 NSD 70D**
 - 1 NSD 70D with up to 6 commands
 - 2 NSD 70D with up to 3 commands each
- ➔ **Addressing facility**
- ➔ **Remote alarm message transfer**

Digital Channels for NSD70D



NSD70D over Dedicated Optical Fibres

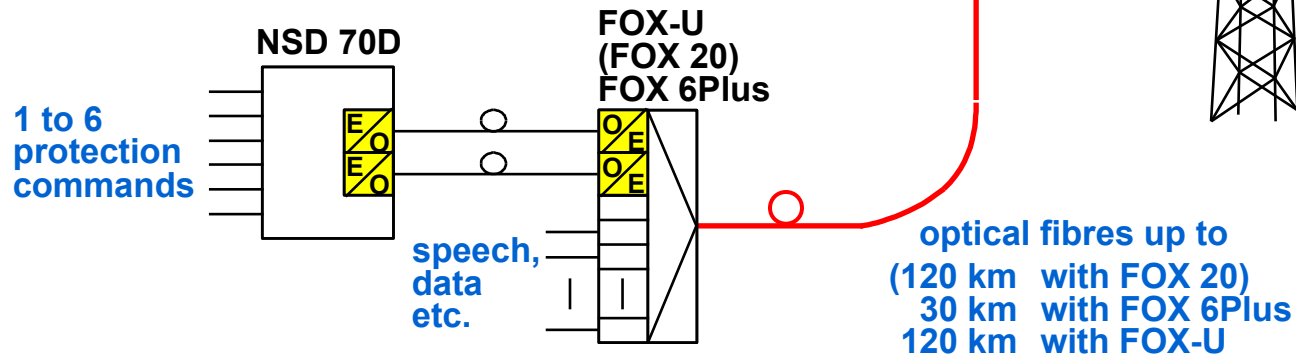


Notes:

- Operates on multi-mode fibres up to 18 km
- Operates on single-mode fibres up to 35 km

NSD 70D in FoxNet

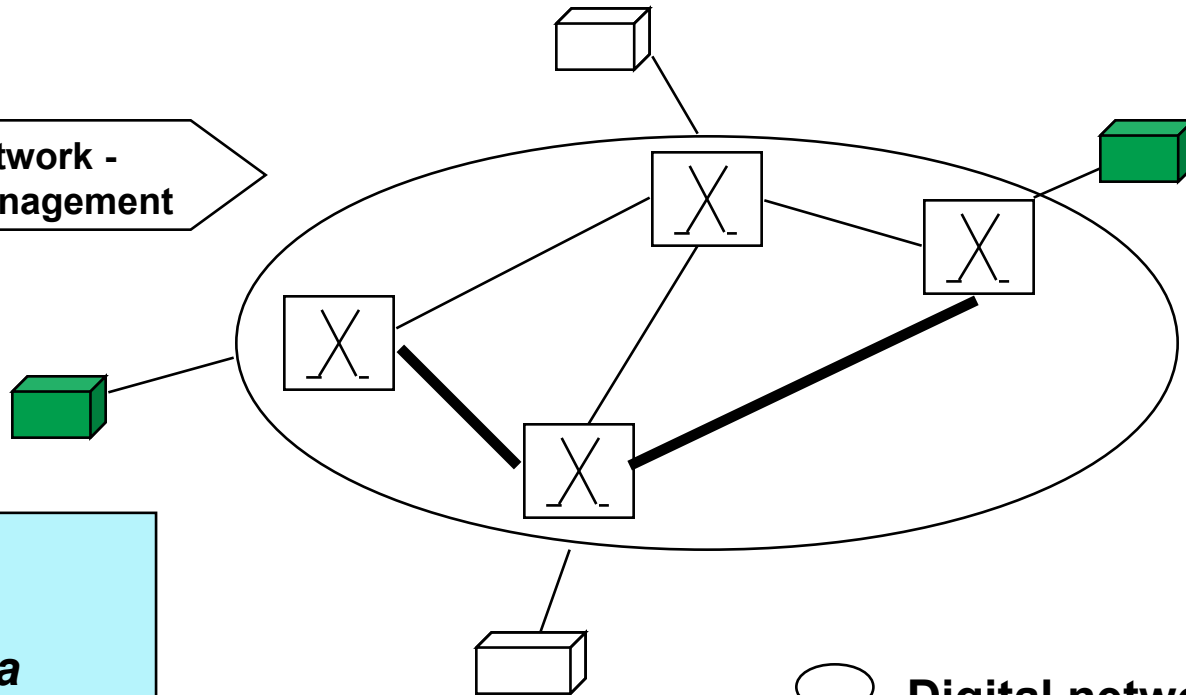
Note: The 6 commands of NSD 70D use only one 64 kbit channel in FOX



Digital Cross-Connect Networks



Network -
Management



Network management activities may have a detrimental impact on a protection system, unless adequate precautions are taken

-  **Digital network**
-  **Digital Cross-Connect**
-  **Protection terminal**

Digital Cross-Connect Precautions

Increasing Security

Restricted authorisation for re-routing

Inhibit auto-rerouting (possibility of excessive delay)

Use (tele)protection equipment with addressing facility

Use dedicated channels for protection signalling which are non-cross-connectable

Use dedicated links for protection signalling