Protection Relays

Best practice in implementing coordinated electrical protection scheme

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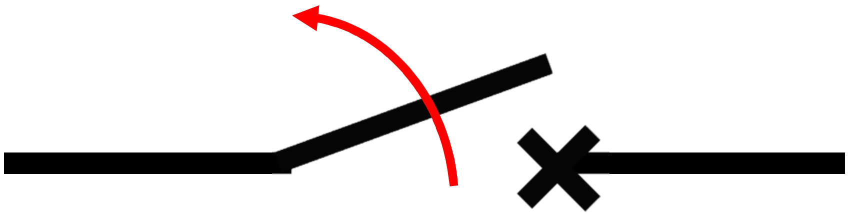
Importance of Coordinated Electrical Protection Scheme

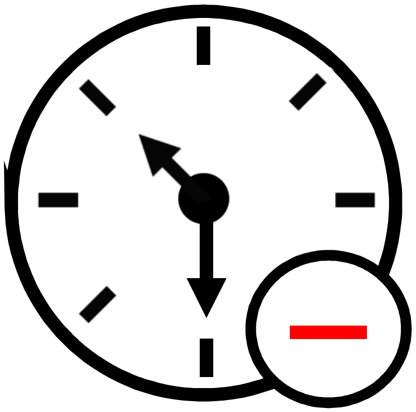
Safeguard of
electrical equipment

Protection against electric shock

System reliability
&
continuity of service



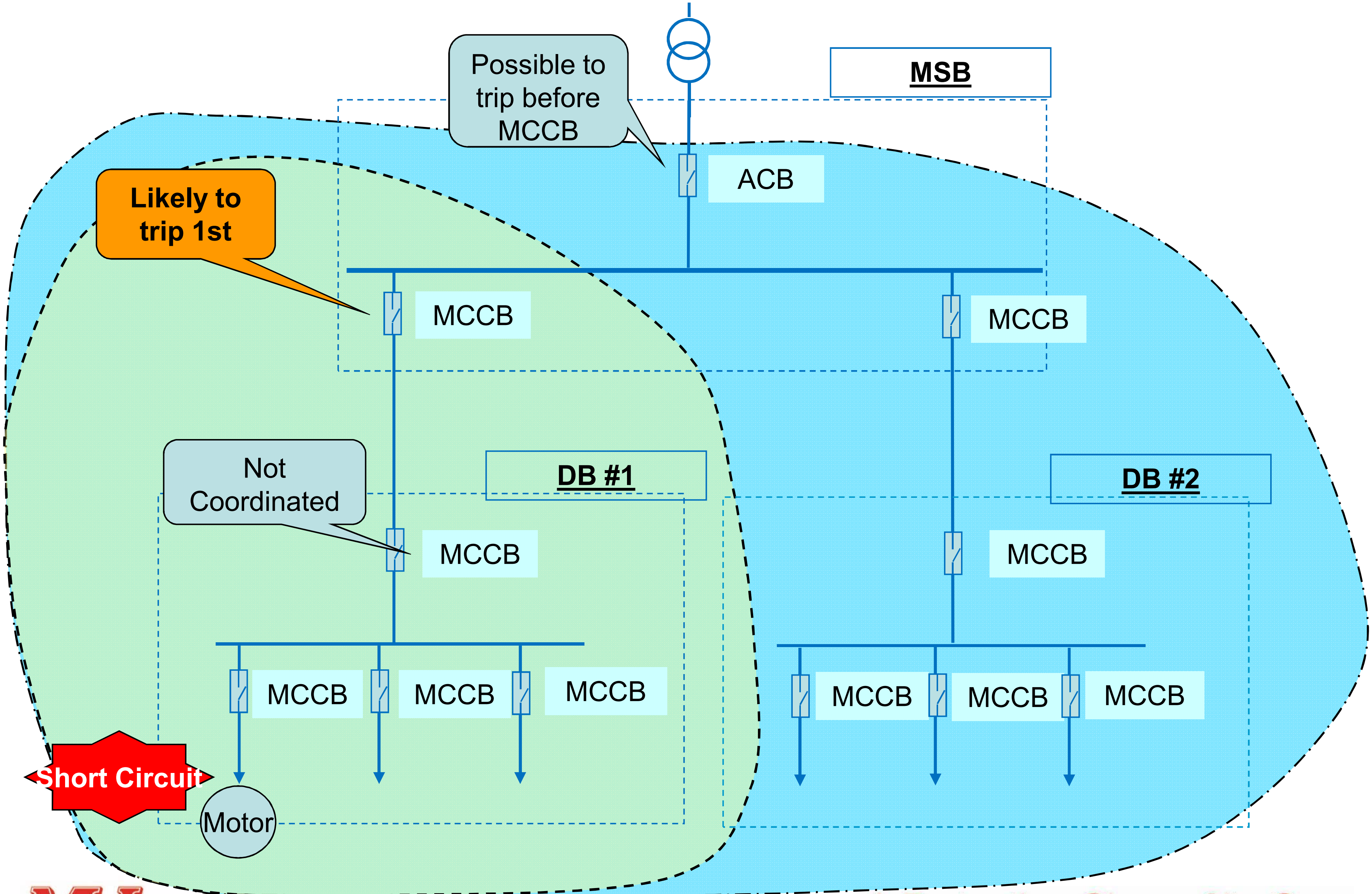
Minimize the affected zone



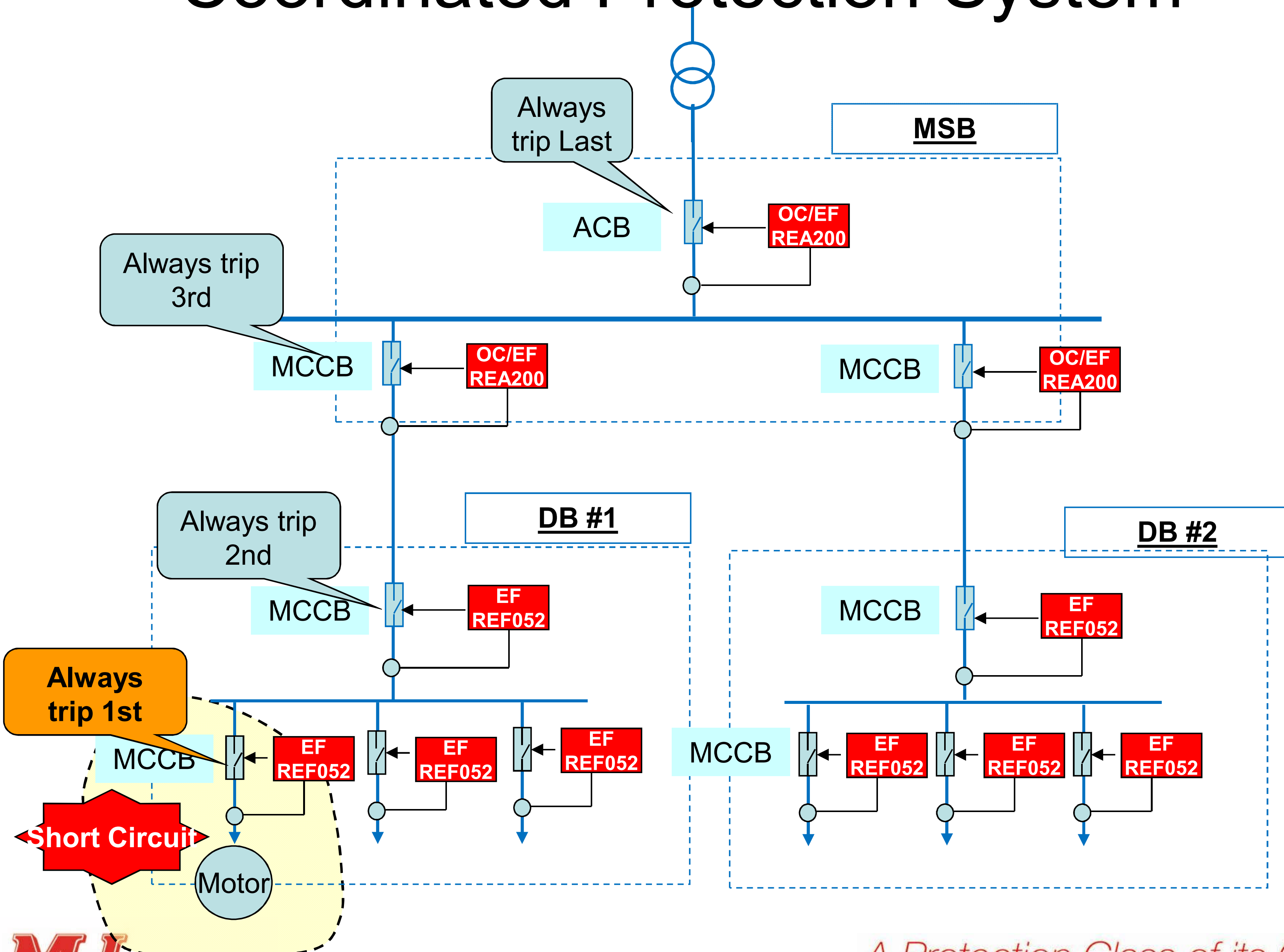
Reduce time spent in fault finding

Improper electrical protection system coordination may cause greater interruption

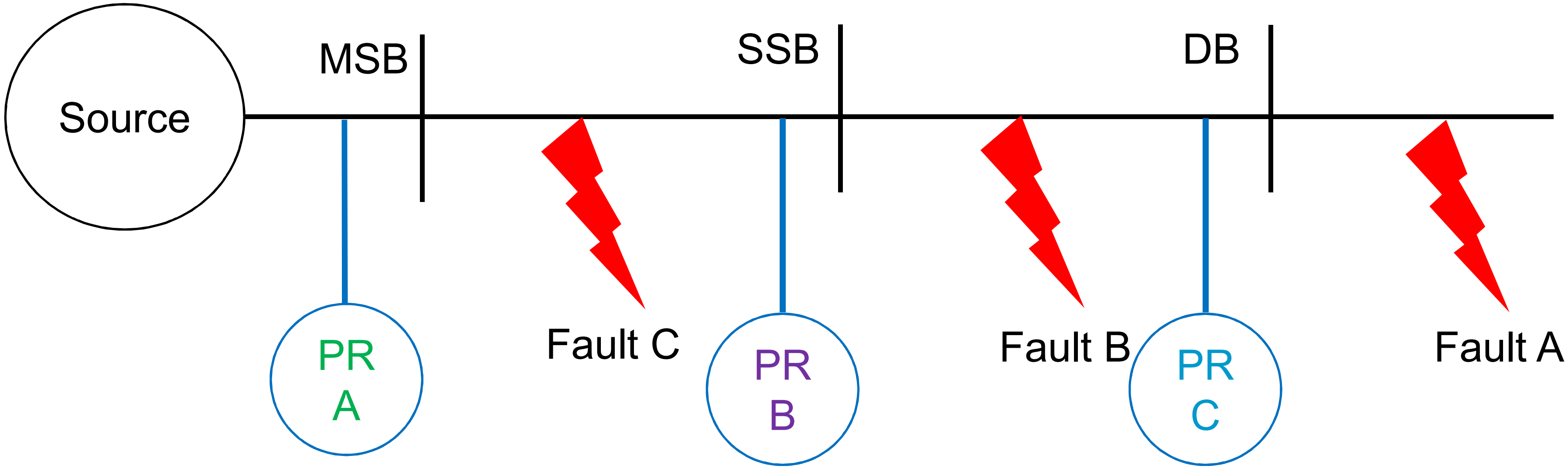
Uncoordinated Protection System



Coordinated Protection System



Purpose of Electrical Protection System Coordination



Fault Location	I_{SC}	PR A Trip Time	PR B Trip Time	PR C Trip Time
Fault A	20kA	0.5s	0.3s	0.1s
Fault B	30kA	0.3s	0.1s	NA
Fault C	50kA	0.1s	NA	NA

- PR C is the primary protection for DB. PR A and PR B are the backup protection.
- If PR C does not operate, then PR B (first backup) will operate.
- If both PR B & C do not operate, then PR A (second backup) will operate.

Coordination Procedures

Data Collection

Collect nameplate information of transformers, motors, protective relays, power cables, feeder circuits, etc.

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Short Circuit Study

Check for equipment short circuit withstand capacity, determine protective device setting, and prerequisite for arc flash study and protection coordination study.

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Protection Coordination Study

Determine the setting of protective devices, zone of protection, coordination between zone.

Short Circuit Study

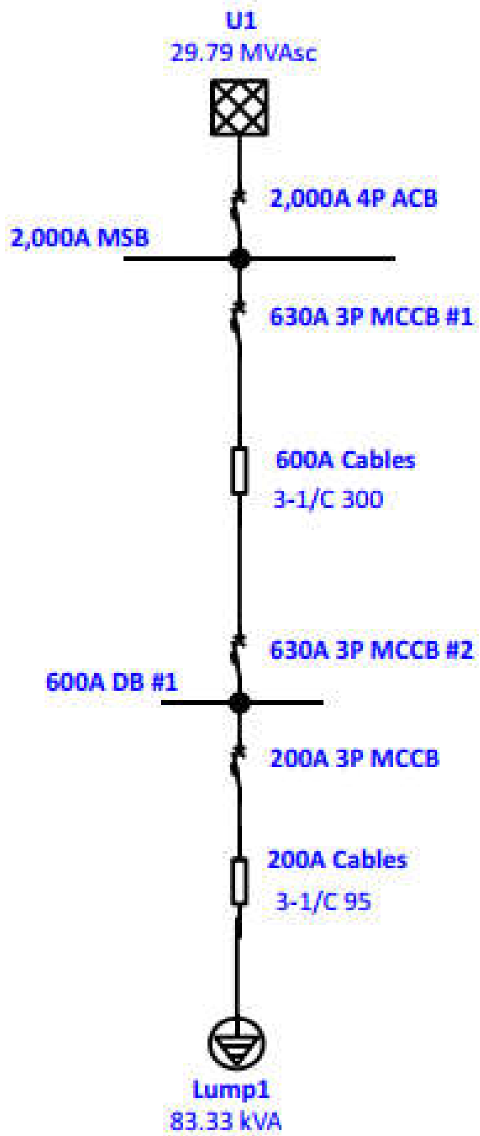
- Maximum short circuit current – determine time-garding for protective relays, capacity or rating of electrical equipment.
- Minimum short circuit current – selection of fuses, setting of protective devices.

Protection Coordination Study

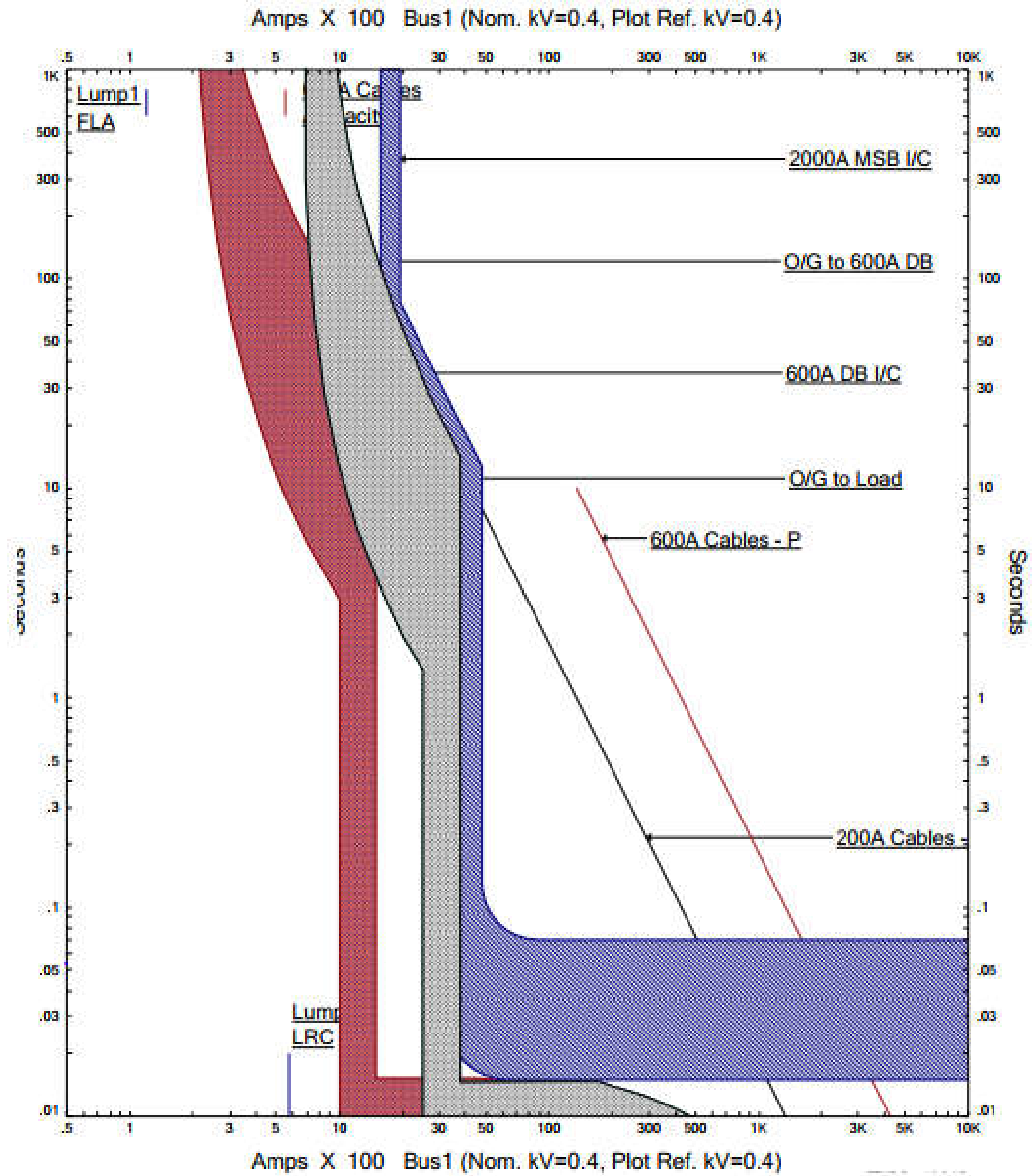
- Plot time current curves (phase fault) of protective relays and equipment.
- Determine time and current grading.
- Repeat the above for earth fault.

Why an external protective relay is better than in-built protection function of a circuit breaker?

Time Current Curve of In-built protection of Circuit Breaker

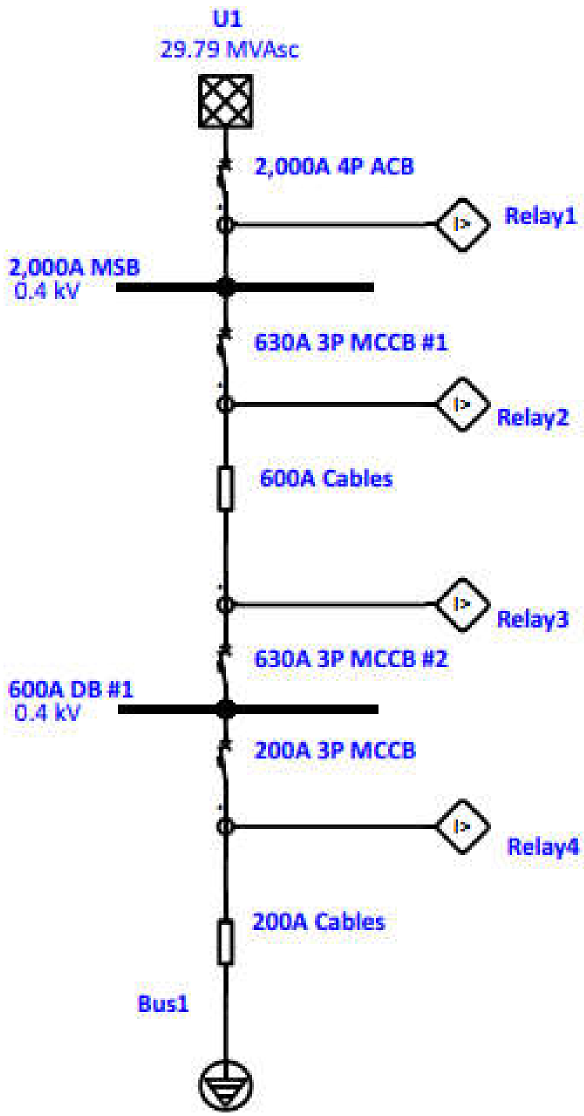


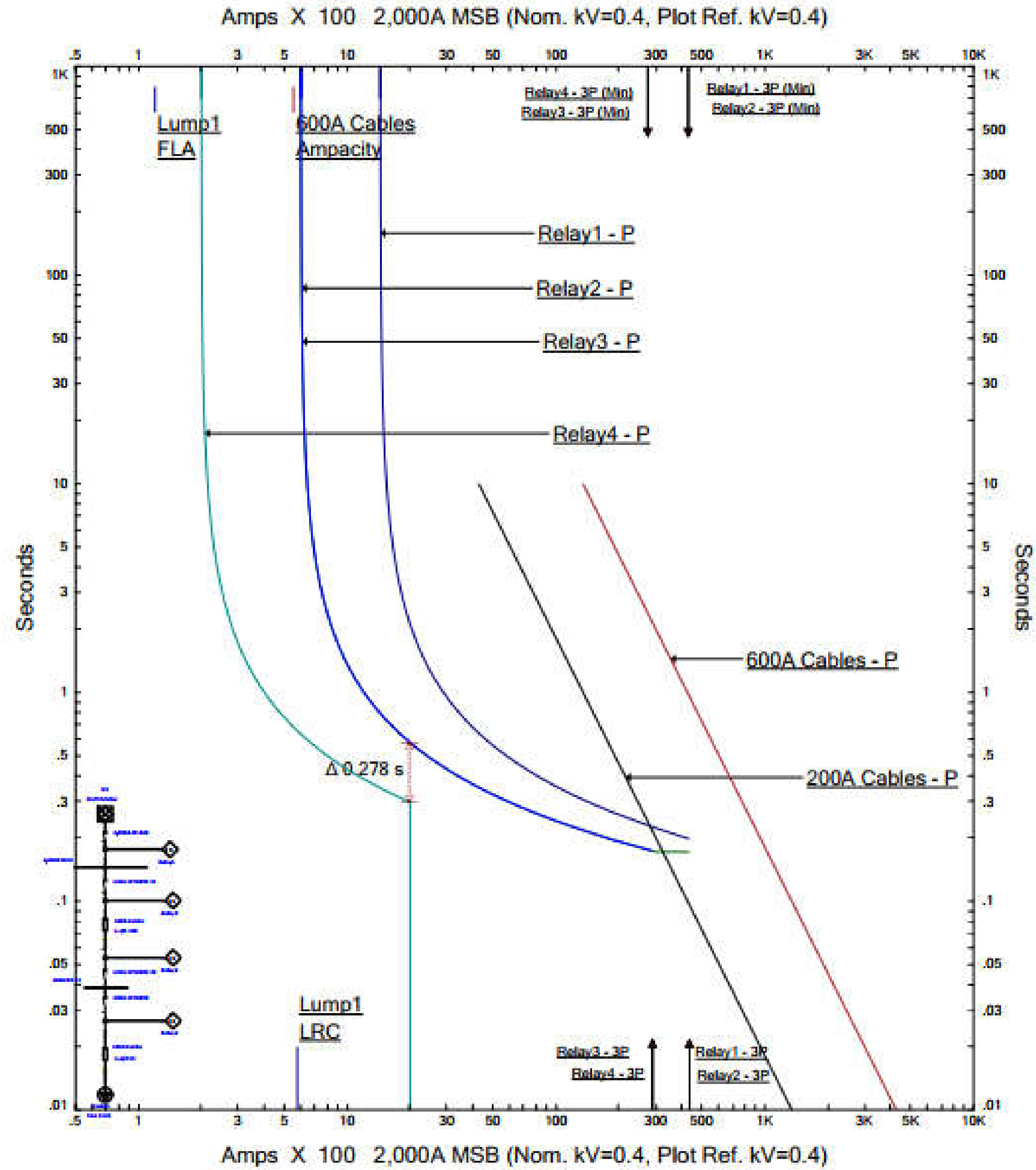
U1
29.79 MVAsc
2,000A 4P ACB
2,000A MSB
630A 3P MCCB #1
600A Cables
3-1/C 300
630A 3P MCCB #2
600A DB #1
200A 3P MCCB
200A Cables
3-1/C 95
Lump1
83.33 kVA



Amps X 100 Bus1 (Nom. kV=0.4, Plot Ref. kV=0.4)
Lump1
FLA
2000A MSB I/C
O/G to 600A DB
600A DB I/C
O/G to Load
600A Cables - P
200A Cables -
LRC
Seconds
Amps X 100 Bus1 (Nom. kV=0.4, Plot Ref. kV=0.4)

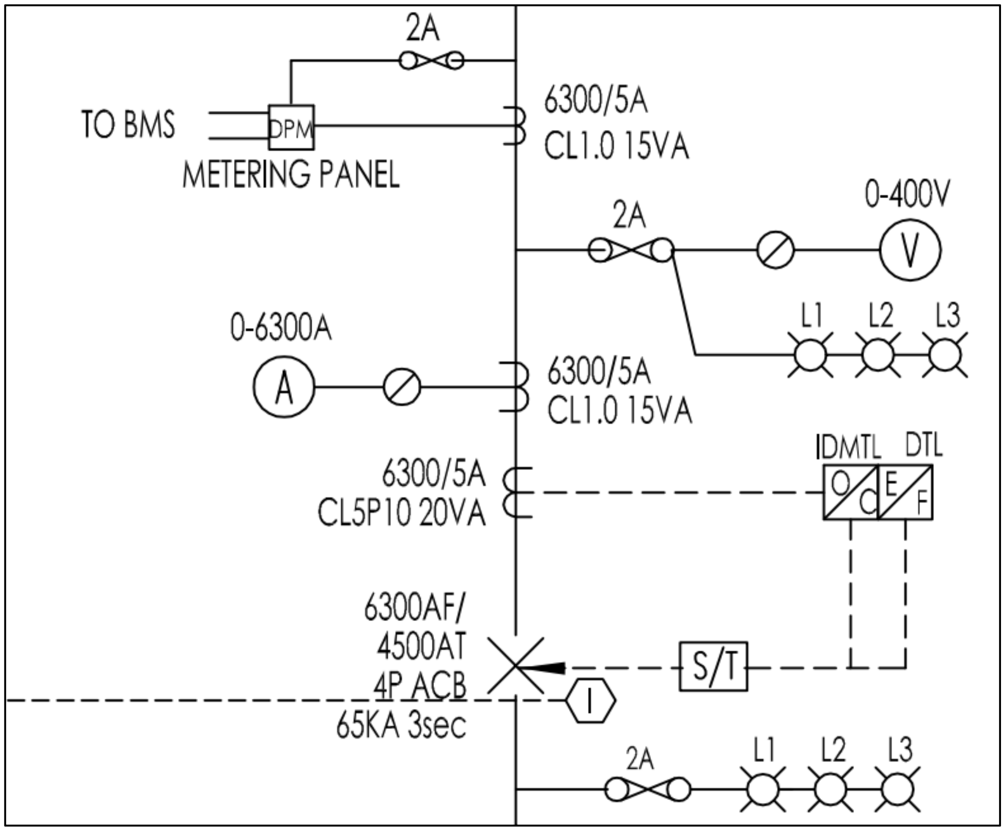
Time Current Curve of External Protective Relays


U1
29.79 MVAsc
2,000A 4P ACB
Relay1
2,000A MSB
0.4 kV
630A 3P MCCB #1
Relay2
600A Cables
Relay3
630A 3P MCCB #2
600A DB #1
0.4 kV
200A 3P MCCB
Relay4
200A Cables
Bus1


Amps X 100 2,000A MSB (Nom. kV=0.4, Plot Ref. kV=0.4)
Seconds
Lump1
FLA
600A Cables
Ampacity
Relay4 - 3P (Min)
Relay3 - 3P (Min)
Relay1 - 3P (Min)
Relay2 - 3P (Min)
Relay1 - P
Relay2 - P
Relay3 - P
Relay4 - P
600A Cables - P
200A Cables - P
Δ 0.278 s
Lump1
LRC
Relay3 - 3P
Relay4 - 3P
Relay1 - 3P
Relay2 - 3P

Examples of External Protective Relay in LV Installation

Overcurrent and Earth Fault

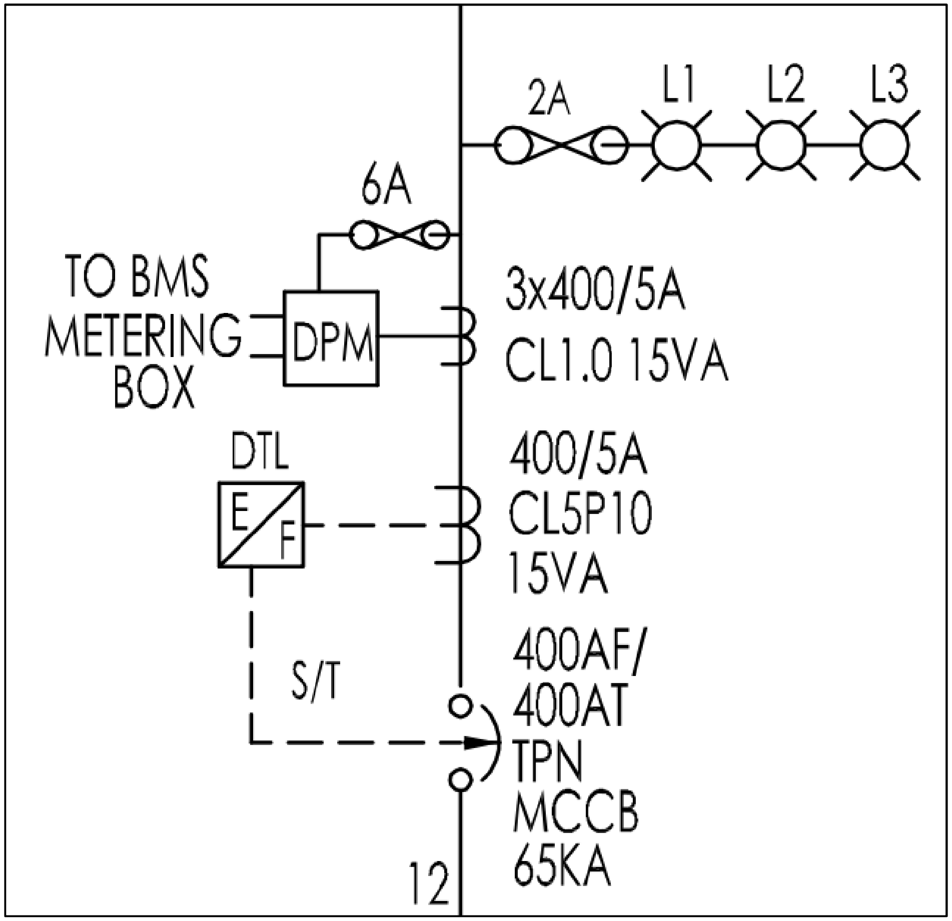


Legends:

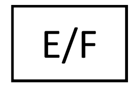
O/C	Overcurrent Relay
E/F	Earth Fault Relay
S/T	Shunt Trip

Application
≥ 630A circuits

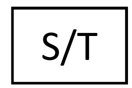
Earth Fault Protective Relay



Legends:



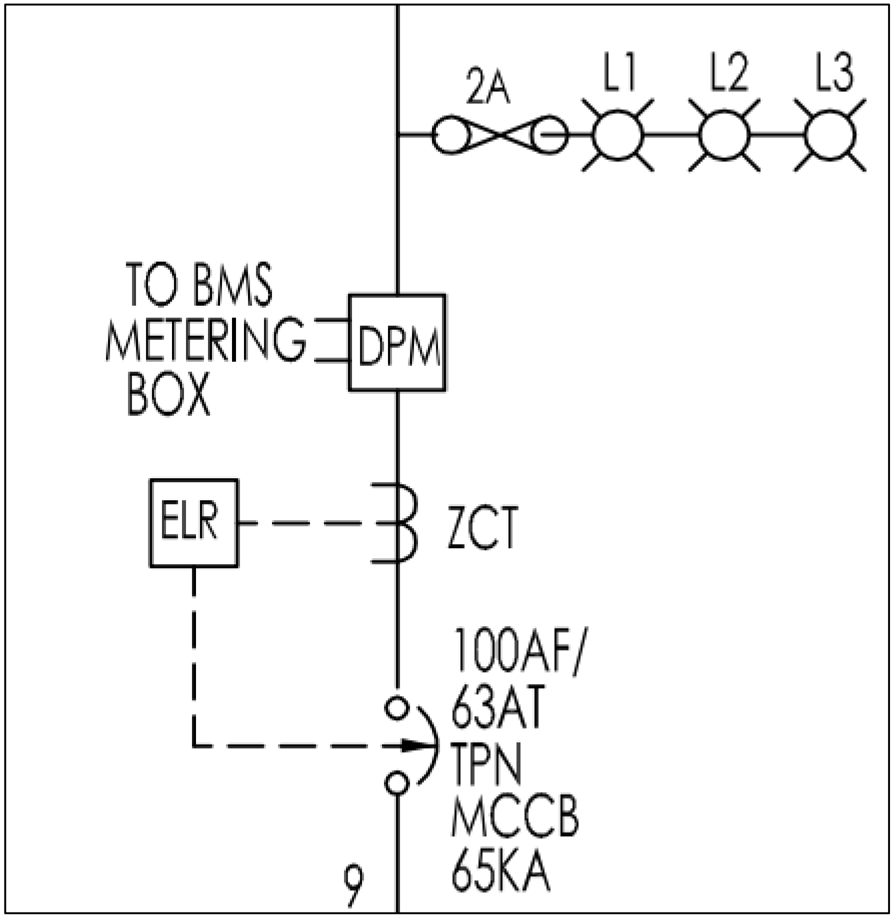
Earth Fault Relay



Shunt Trip

Application:
250~630A circuit

Earth Leakage Relay



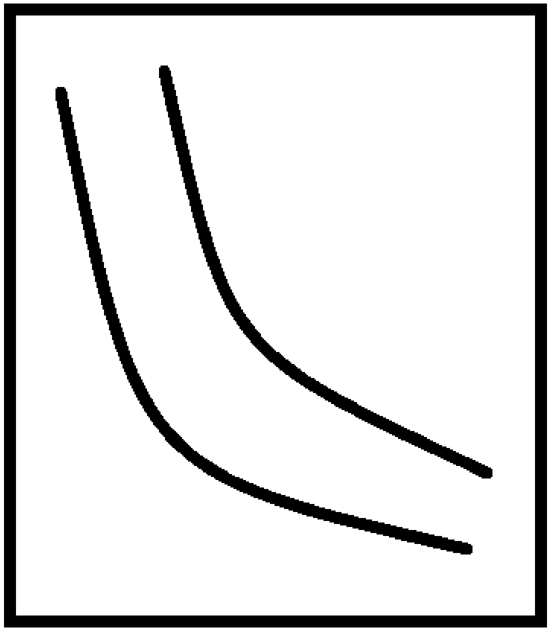
Legends:

ELR Earth leakage Protection relay

ZCT Zero sequence CT

Application:
<250A Circuits

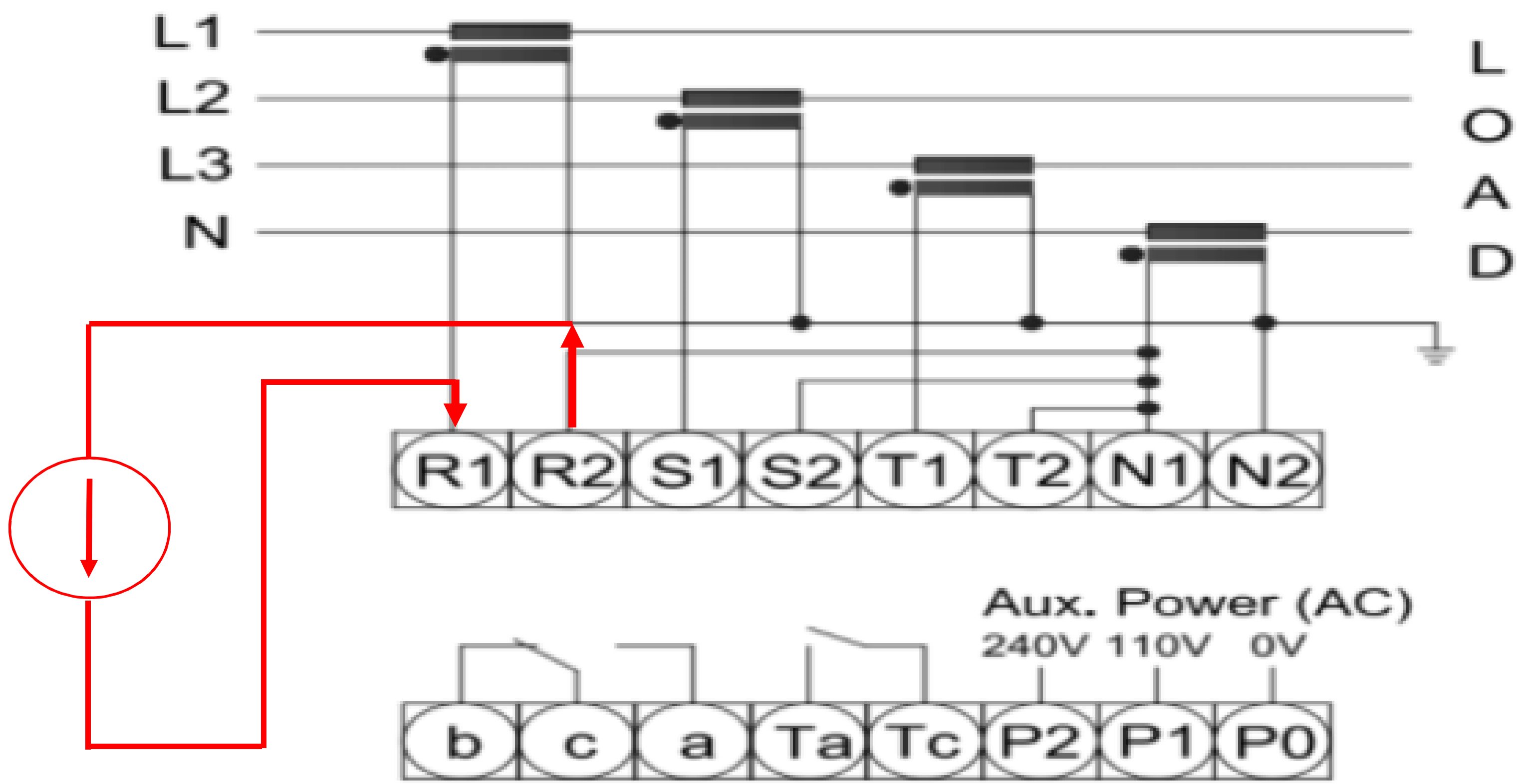
Advantages of using external protective relay



Easier for coordination

Accuracy remain

Can be TESTED and VERIFIED at Site


L1
L2
L3
N
LOAD
R1 R2 S1 S2 T1 T2 N1 N2
Aux. Power (AC)
240V 110V 0V
b c a Ta Tc P2 P1 P0

Improve Electrical Protection System

International Standard current/time tripping characteristics of external protective relay

Normal Inverse / Standard Inverse (NI / SI / 3/10)

- Most commonly used.

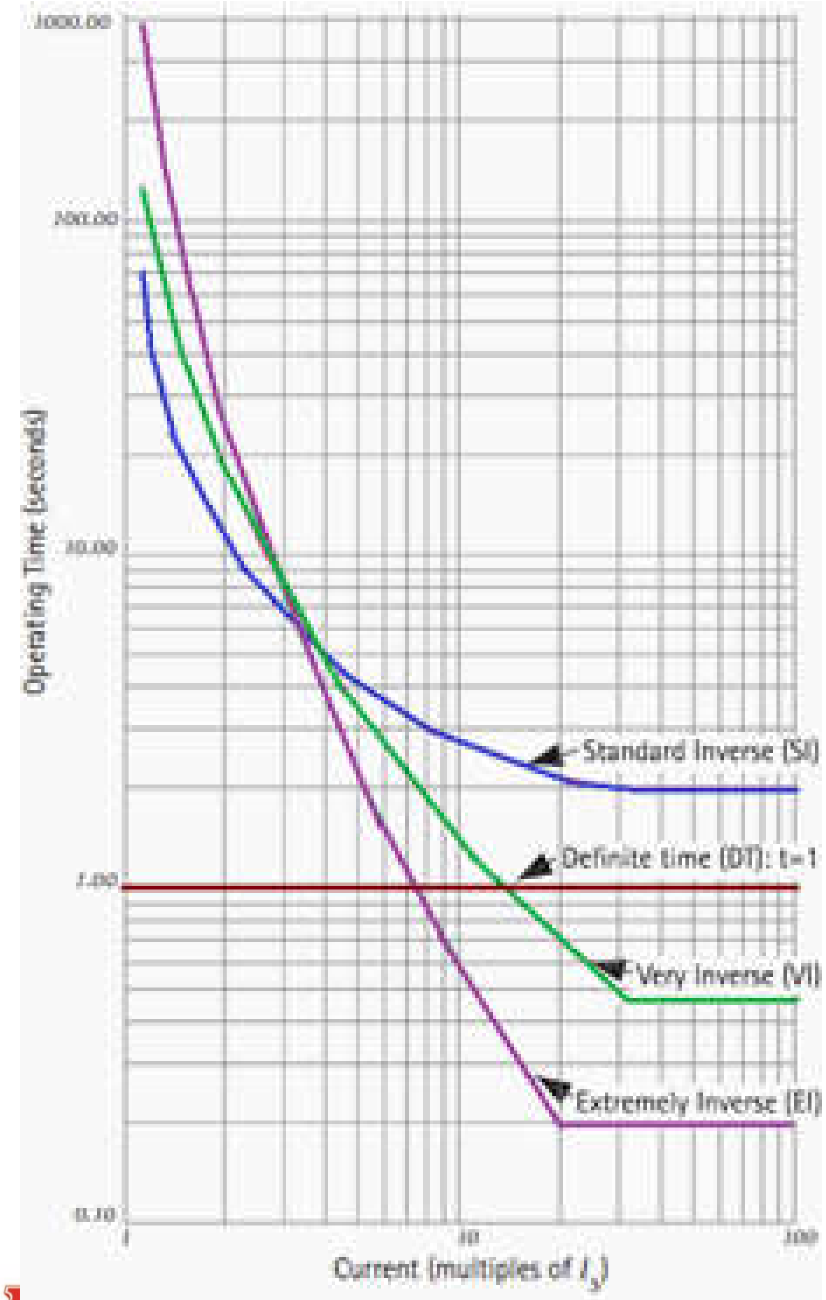
Very Inverse (VI)

- VI curve is much steeper and hence the operation increases much faster for the same decrease in current in comparison to the SI protection curve.
- Suitable for short-circuit current drops rapidly with the distance from the substation. i.e. circuit with smaller cables' diameter

Extreme Inverse (EI)

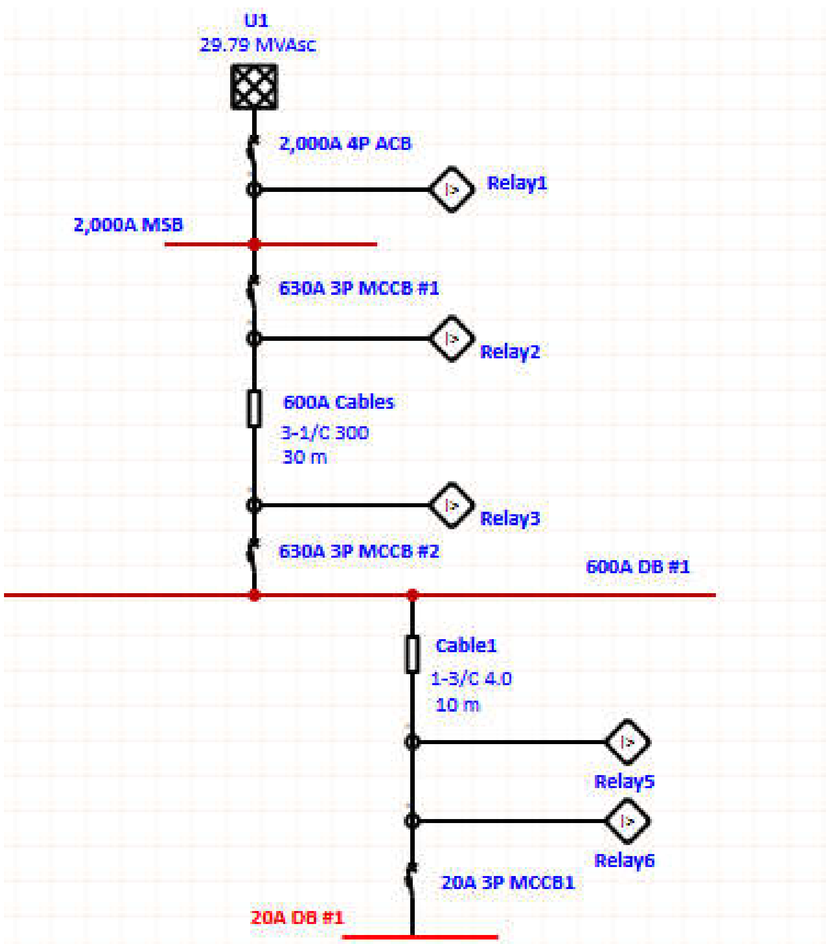
- More inverse characteristics than SI and VI
- Suitable for protection of motor load with peak currents on switching in.
- Suitable for grading with fuses.

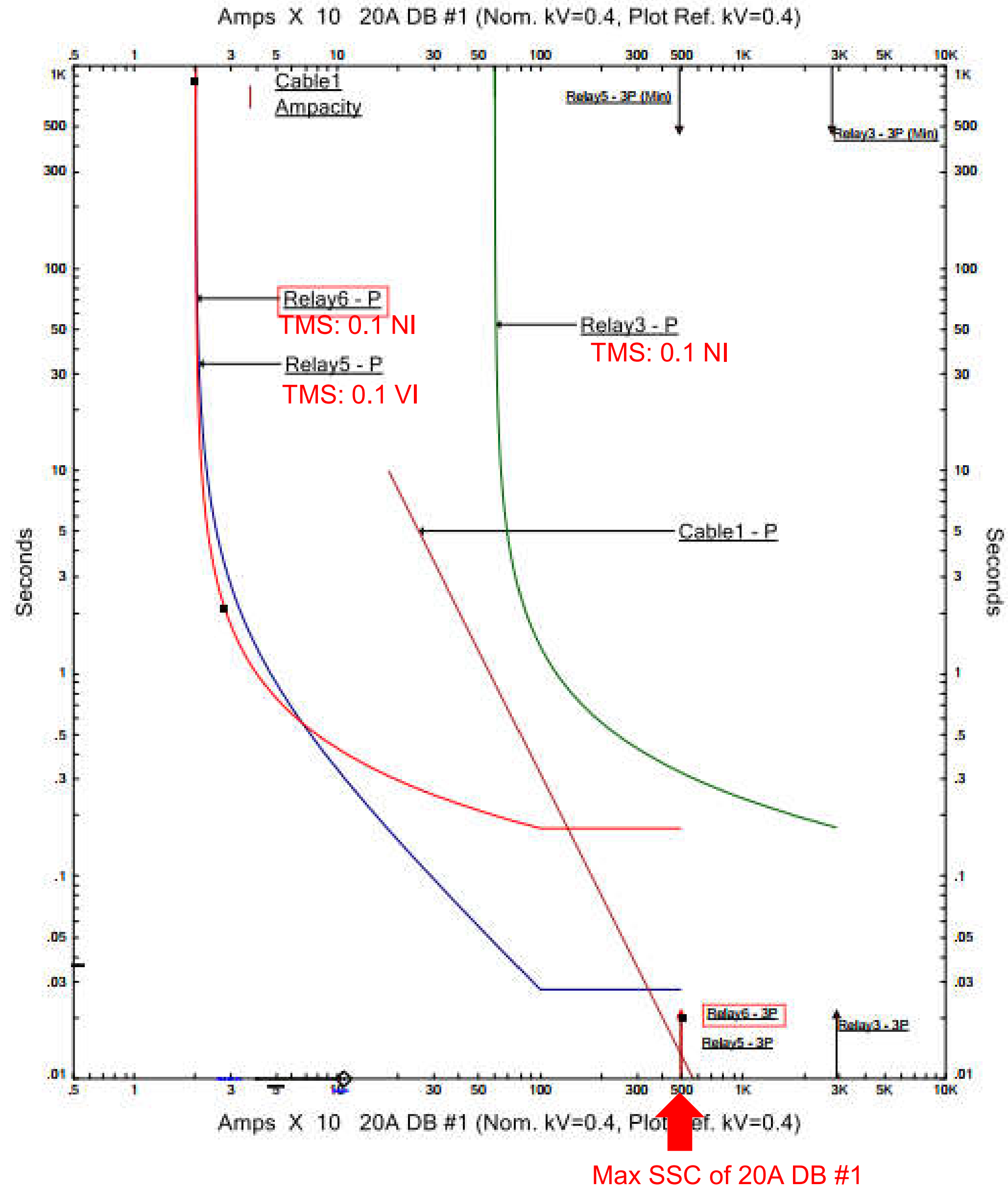
Definite Time (DT)



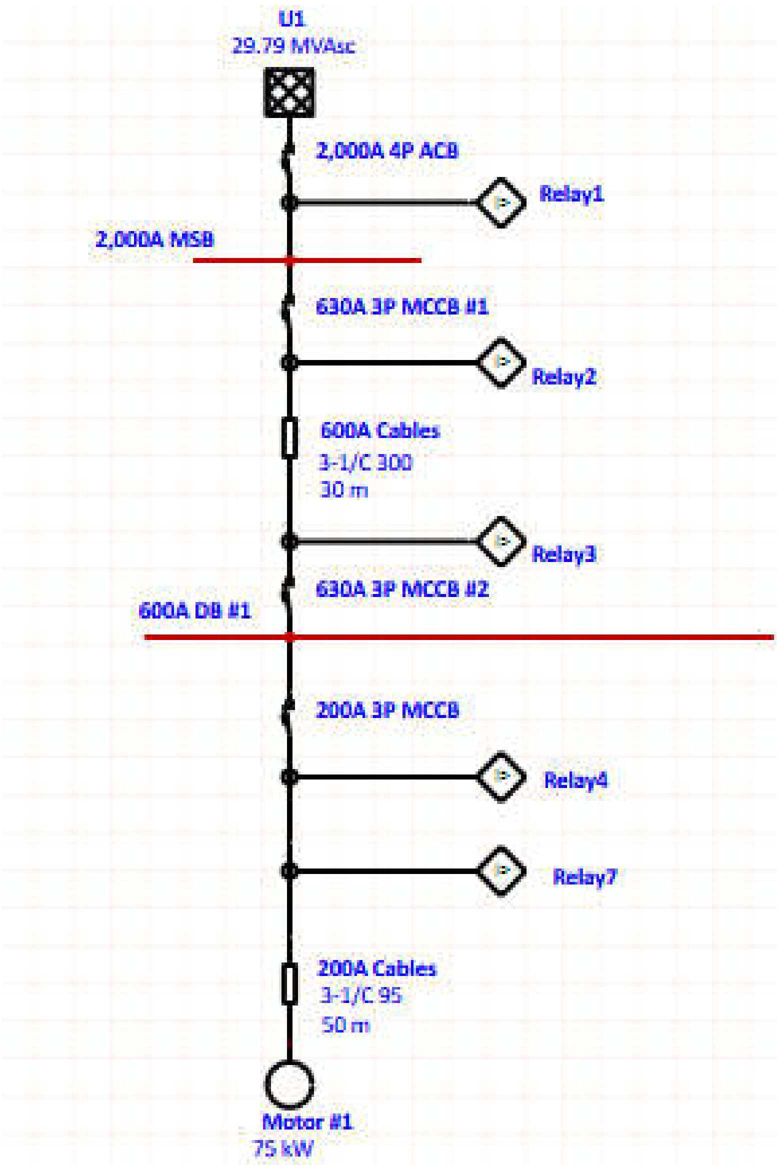
Comparison of Normal Inverse, Very Inverse, Extreme Inverse, and Definite time

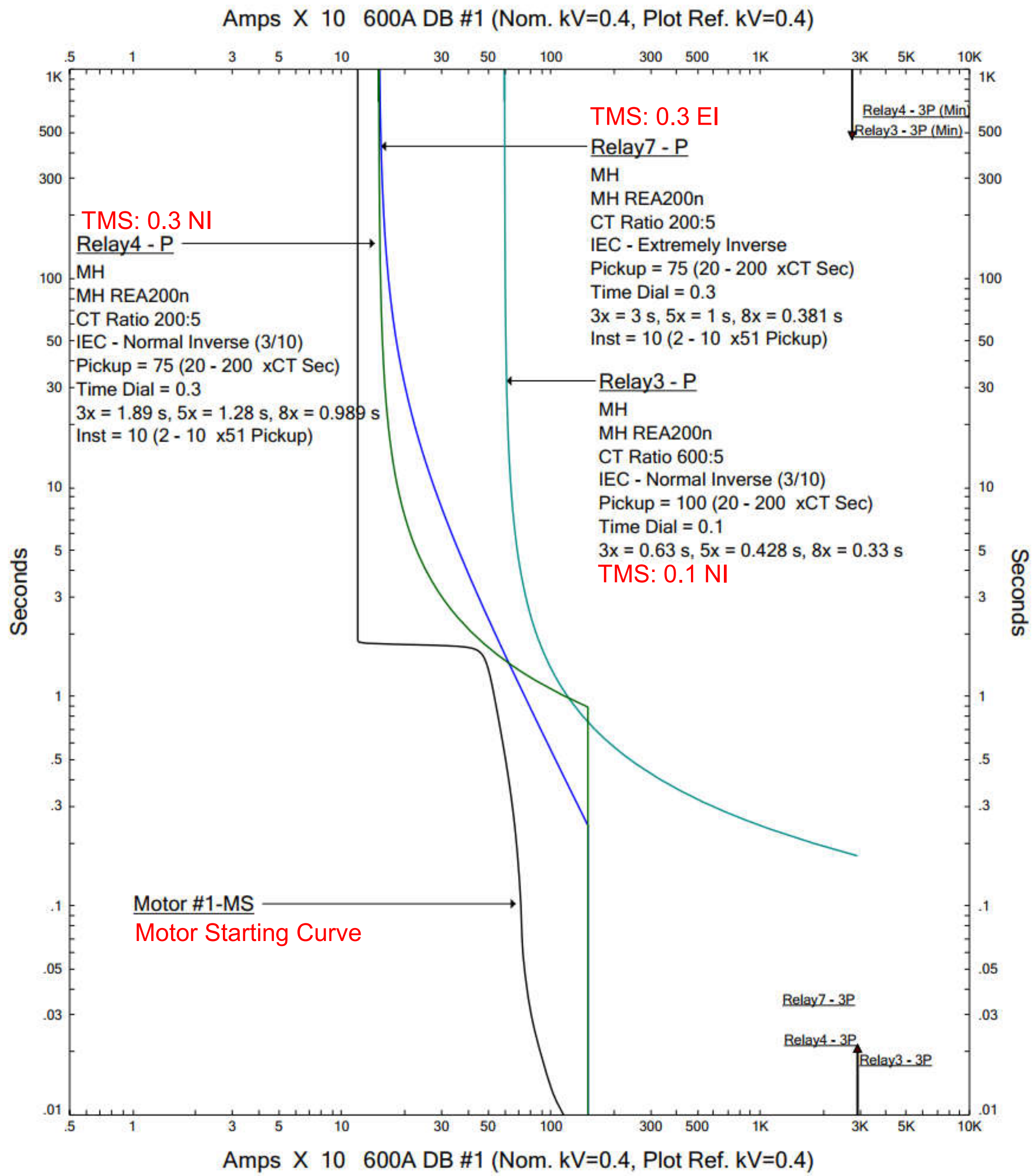
Case Study No. 1: NI and VI curves for circuit with short-circuit current drops rapidly


U1
29.79 MVAsc
2,000A 4P ACB
Relay1
2,000A MSB
630A 3P MCCB #1
Relay2
600A Cables
3-1/C 300
30 m
Relay3
630A 3P MCCB #2
600A DB #1
Cable1
1-3/C 4.0
10 m
Relay5
Relay6
20A 3P MCCB1
20A DB #1

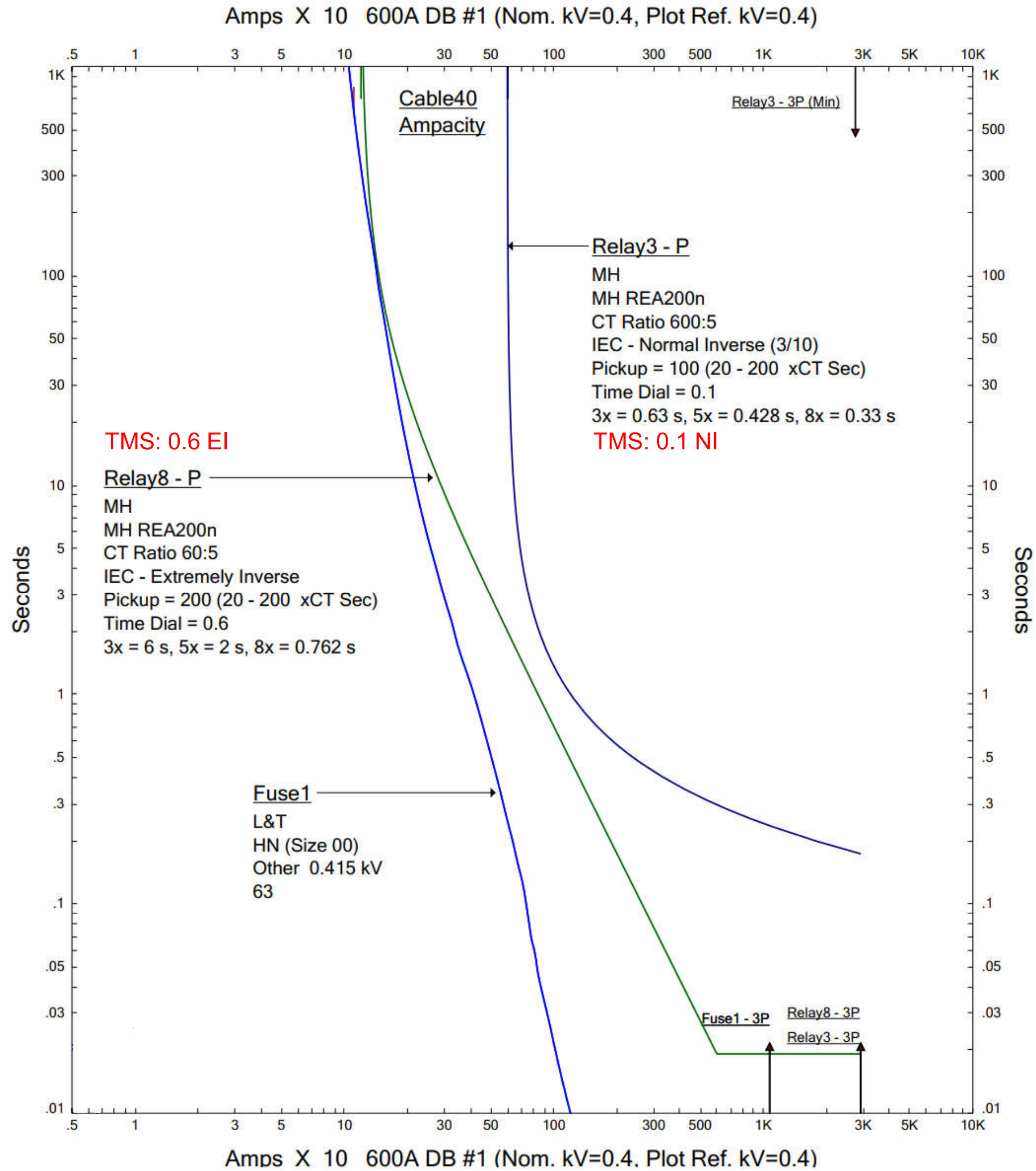

Amps X 10 20A DB #1 (Nom. kV=0.4, Plot Ref. kV=0.4)
Cable1
Ampacity
Relay5 - 3P (Min)
Relay3 - 3P (Min)
Relay6 - P
TMS: 0.1 NI
Relay5 - P
TMS: 0.1 VI
Relay3 - P
TMS: 0.1 NI
Cable1 - P
Seconds
Relay6 - 3P
Relay5 - 3P
Relay3 - 3P
Max SSC of 20A DB #1

Case Study No. 2: NI and EI curves vs Motor Starting


U1
29.79 MVAsc
2,000A 4P ACB
Relay1
2,000A MSB
630A 3P MCCB #1
Relay2
600A Cables
3-1/C 300
30 m
Relay3
630A 3P MCCB #2
600A DB #1
200A 3P MCCB
Relay4
Relay7
200A Cables
3-1/C 95
50 m
Motor #1
75 kW


Amps X 10 600A DB #1 (Nom. kV=0.4, Plot Ref. kV=0.4)
Seconds
TMS: 0.3 EI
Relay7 - P
MH
MH REA200n
CT Ratio 200:5
IEC - Extremely Inverse
Pickup = 75 (20 - 200 xCT Sec)
Time Dial = 0.3
3x = 3 s, 5x = 1 s, 8x = 0.381 s
Inst = 10 (2 - 10 x51 Pickup)
TMS: 0.3 NI
Relay4 - P
MH
MH REA200n
CT Ratio 200:5
IEC - Normal Inverse (3/10)
Pickup = 75 (20 - 200 xCT Sec)
Time Dial = 0.3
3x = 1.89 s, 5x = 1.28 s, 8x = 0.989 s
Inst = 10 (2 - 10 x51 Pickup)
Relay3 - P
MH
MH REA200n
CT Ratio 600:5
IEC - Normal Inverse (3/10)
Pickup = 100 (20 - 200 xCT Sec)
Time Dial = 0.1
3x = 0.63 s, 5x = 0.428 s, 8x = 0.33 s
TMS: 0.1 NI
Relay4 - 3P (Min)
Relay3 - 3P (Min)
Motor #1-MS
Motor Starting Curve
Relay7 - 3P
Relay4 - 3P
Relay3 - 3P

Case Study No. 3: EI curve vs Fuse



Amps X 10 600A DB #1 (Nom. kV=0.4, Plot Ref. kV=0.4)
Seconds
Cable40 Ampacity
Relay3 - 3P (Min)
Relay3 - P
MH
MH REA200n
CT Ratio 600:5
IEC - Normal Inverse (3/10)
Pickup = 100 (20 - 200 xCT Sec)
Time Dial = 0.1
3x = 0.63 s, 5x = 0.428 s, 8x = 0.33 s
TMS: 0.1 NI
TMS: 0.6 EI
Relay8 - P
MH
MH REA200n
CT Ratio 60:5
IEC - Extremely Inverse
Pickup = 200 (20 - 200 xCT Sec)
Time Dial = 0.6
3x = 6 s, 5x = 2 s, 8x = 0.762 s
Fuse1
L&T
HN (Size 00)
Other 0.415 kV
63
Fuse1 - 3P
Relay8 - 3P
Relay3 - 3P
Amps X 10 600A DB #1 (Nom. kV=0.4, Plot Ref. kV=0.4)

Relay Time Grading Margin

Dependent factors:

i. the fault current interrupting time of the circuit breaker, t_{CB}
ii. relay timing errors, t_E
iii. the overshoot time of the relay, t_R
iv. final margin on completion of operation, t_M

Grading: Relay to Relay

t_{CB} typically 50ms
t_E typically 50~250ms
t_R typically 30ms
t_M typically 20ms

Minimum Time Grading between IDMTL relays,
$\Delta t = t_{CB} + t_E + t_R + t_M$
$\Delta t = 150 \sim 350ms$

Grading: Relay to Fuse

- Typically relay backs up the fuse and not vice versa
- Relay uses extremely inverse (EI) curve
- Primary current setting of the relay should be approximately 3X the current rating of the fuse
- Minimum Time Grading between relay and fuse, $\Delta t > 0.4s$

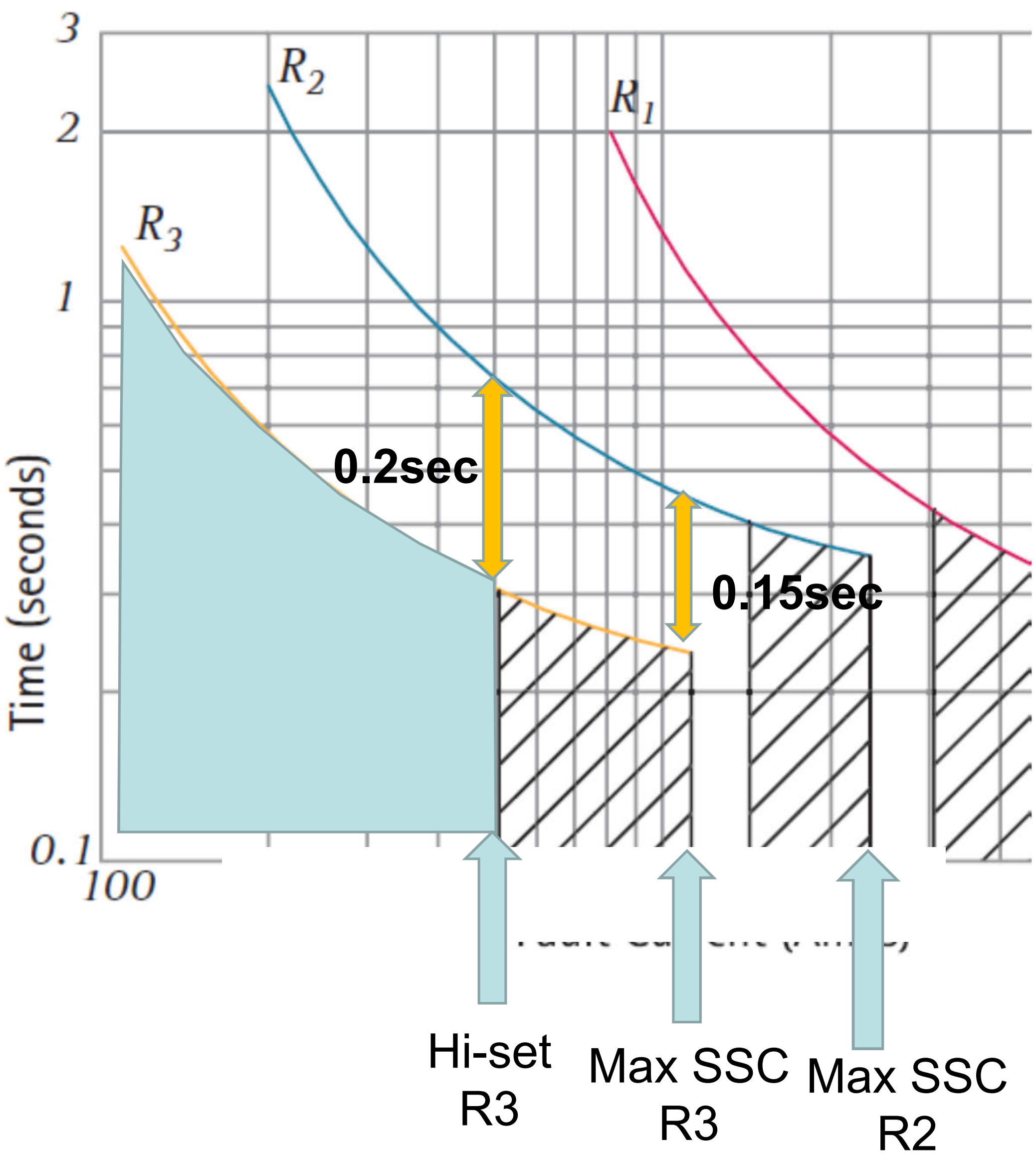
$$\Delta t = 0.4t+0.15 \text{ seconds}$$

where t is the nominal operating time of fuse

Use high-set instantaneous to achieve time grading

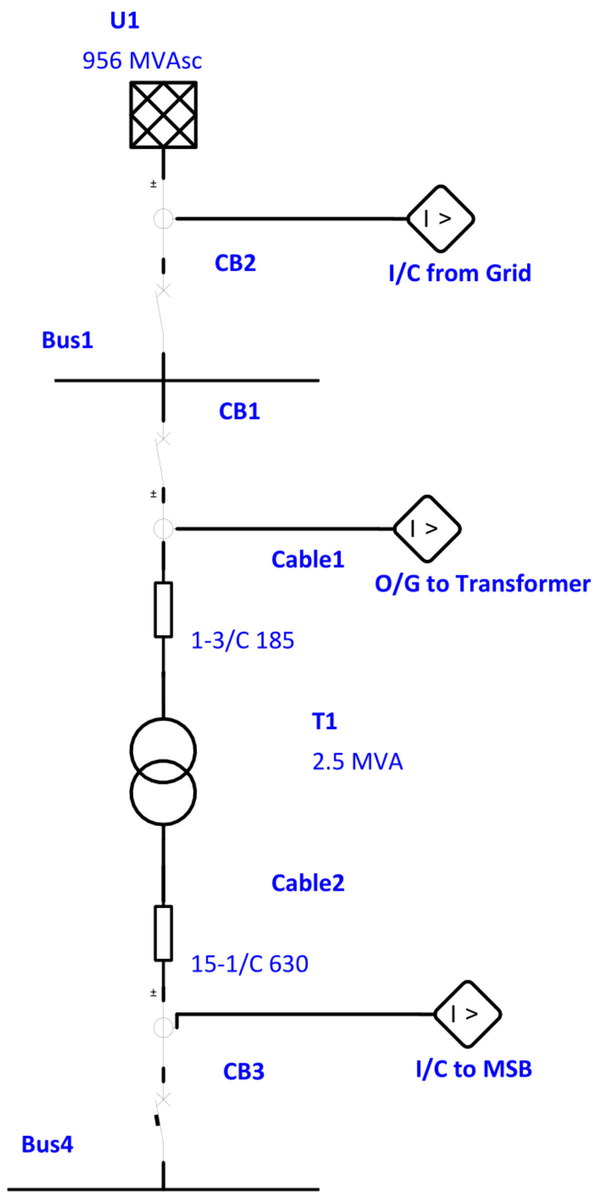
High-set Instantaneous

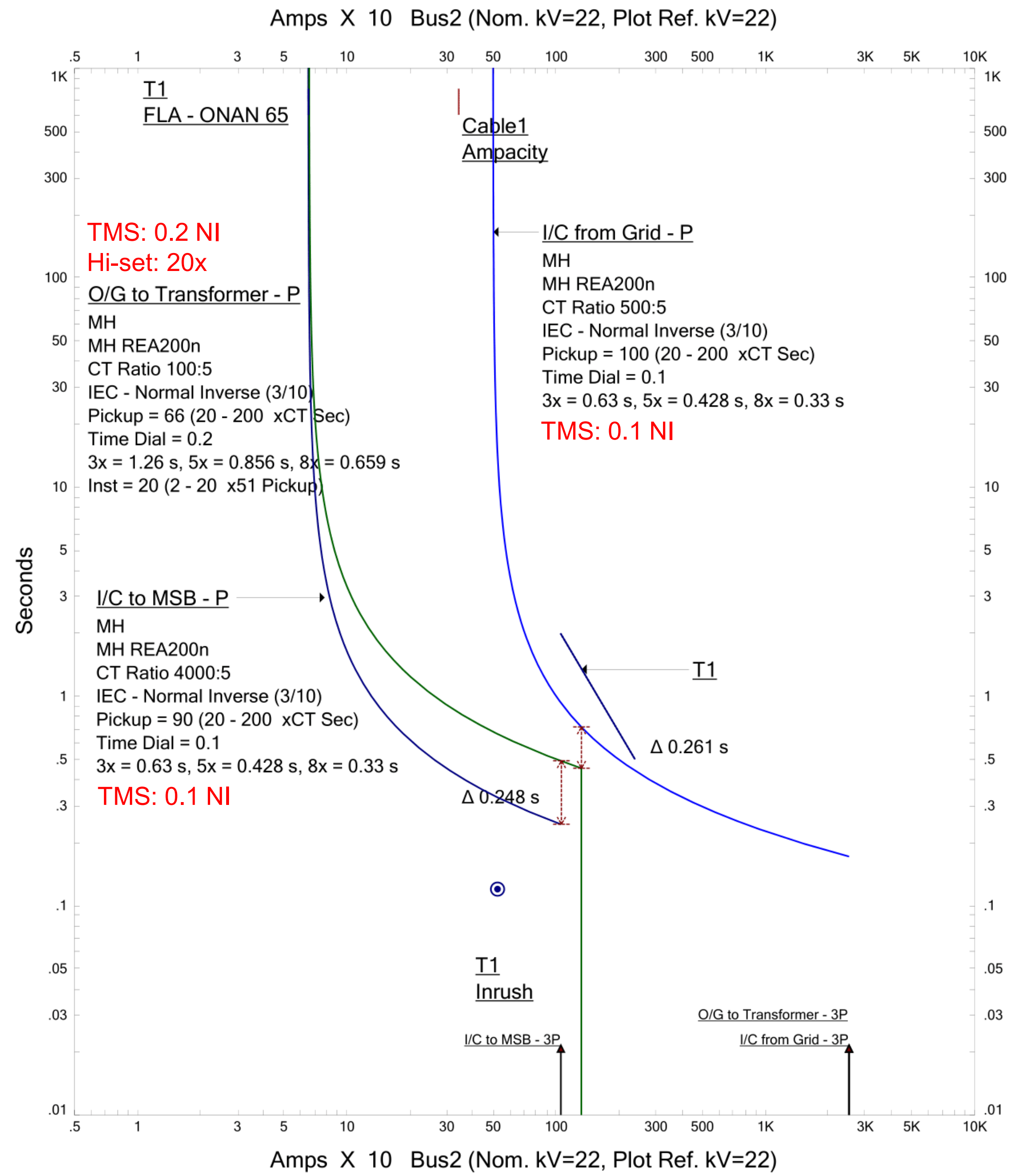
- Used where the source impedance is small in comparison with the protected circuit impedance.
- This makes a reduction in the tripping time at high fault levels possible.
- It also improves the overall system grading by allowing the 'discriminating curves' behind the high set instantaneous elements to be lowered.



Relay R3 is graded with R2 with 0.2 sec instead of 0.15 sec

Case Study No. 4: High-set Instantaneous for outgoing circuit to transformer


U1
956 MVAsc
CB2
I/C from Grid
I >
Bus1
CB1
Cable1
O/G to Transformer
I >
1-3/C 185
T1
2.5 MVA
Cable2
15-1/C 630
CB3
I/C to MSB
I >
Bus4

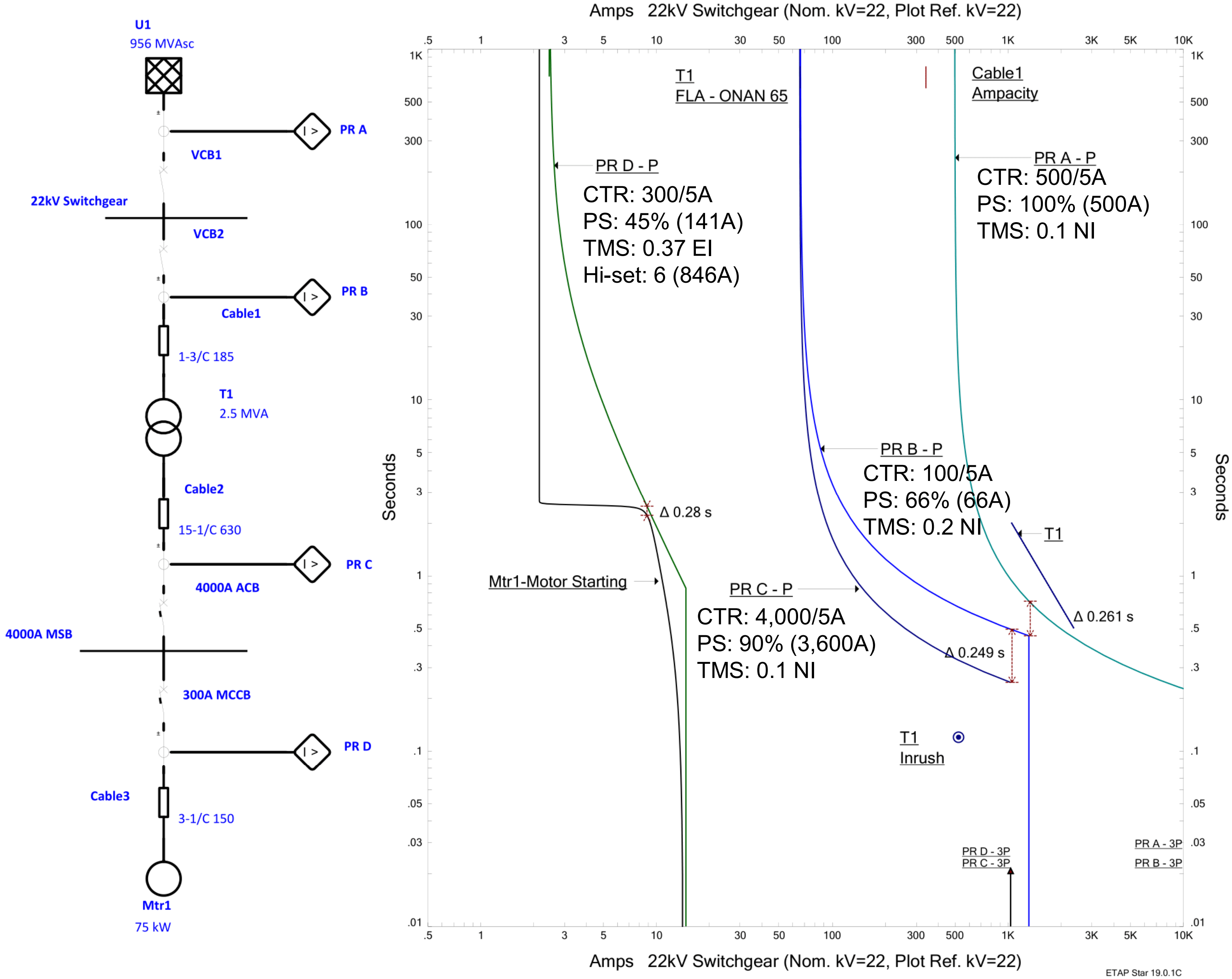

Amps X 10 Bus2 (Nom. kV=22, Plot Ref. kV=22)
Seconds
T1
FLA - ONAN 65
Cable1
Ampacity
TMS: 0.2 NI
Hi-set: 20x
O/G to Transformer - P
MH
MH REA200n
CT Ratio 100:5
IEC - Normal Inverse (3/10)
Pickup = 66 (20 - 200 xCT Sec)
Time Dial = 0.2
3x = 1.26 s, 5x = 0.856 s, 8x = 0.659 s
Inst = 20 (2 - 20 x51 Pickup)
I/C from Grid - P
MH
MH REA200n
CT Ratio 500:5
IEC - Normal Inverse (3/10)
Pickup = 100 (20 - 200 xCT Sec)
Time Dial = 0.1
3x = 0.63 s, 5x = 0.428 s, 8x = 0.33 s
TMS: 0.1 NI
I/C to MSB - P
MH
MH REA200n
CT Ratio 4000:5
IEC - Normal Inverse (3/10)
Pickup = 90 (20 - 200 xCT Sec)
Time Dial = 0.1
3x = 0.63 s, 5x = 0.428 s, 8x = 0.33 s
TMS: 0.1 NI
T1
Δ 0.261 s
Δ 0.248 s
T1
Inrush
O/G to Transformer - 3P
I/C to MSB - 3P
I/C from Grid - 3P

High-set Instantaneous

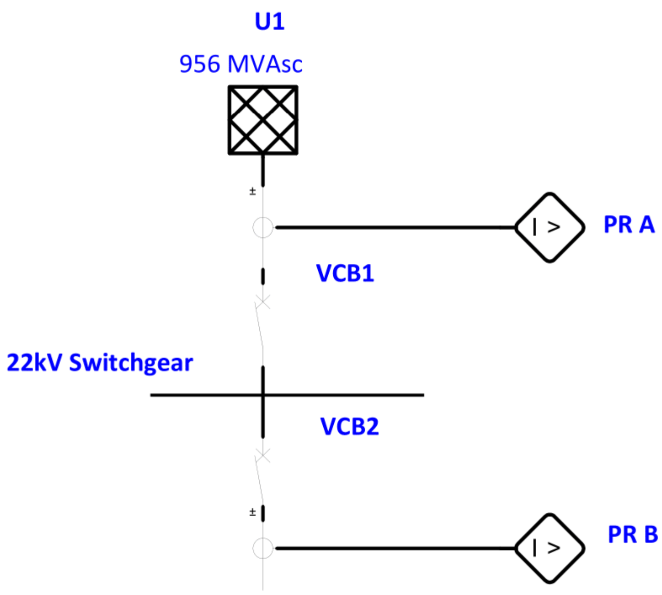
- High-set for should not be used at incoming feeder.
- High-set can be used at outgoing feeder but with care.
- High-set recommended at outgoing to transformer. But setting must be higher than max short circuit current of transformer secondary and transformer starting inrush current

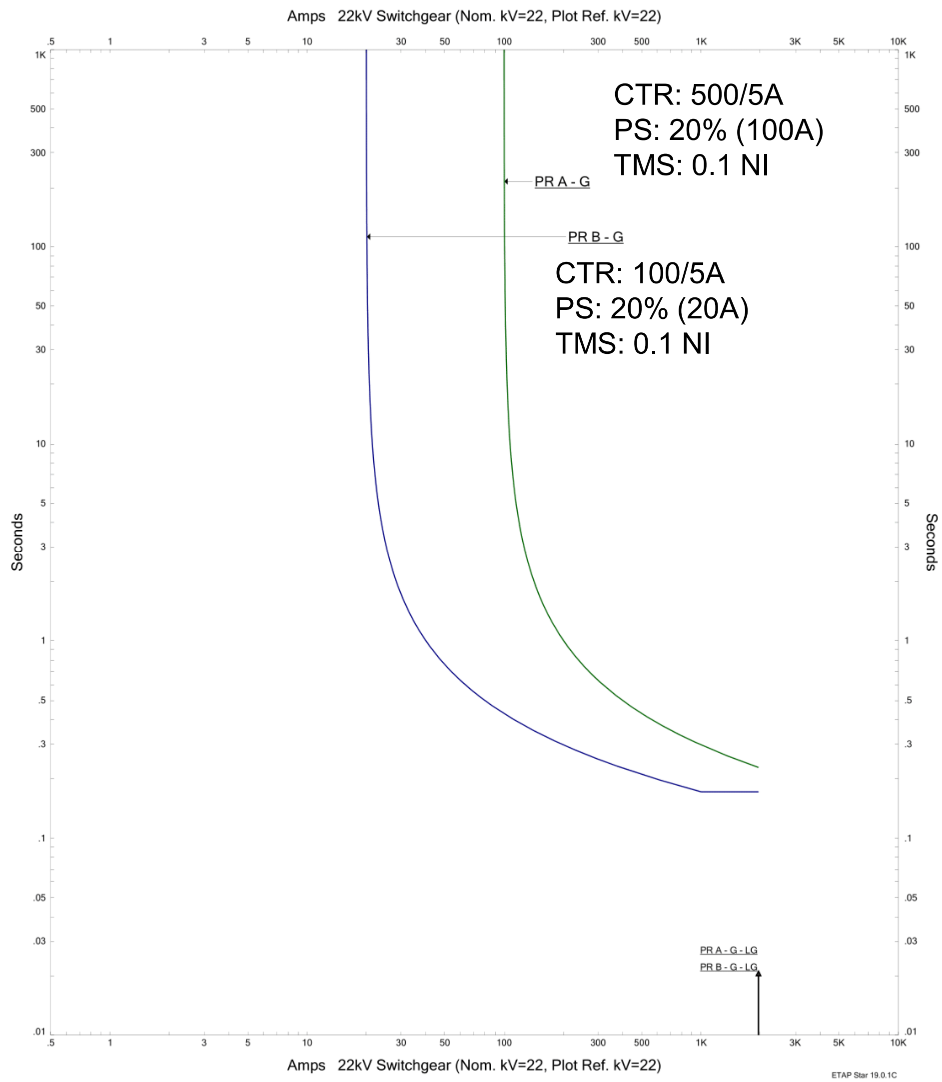
Example of time and current grading

TCC - Phase Fault

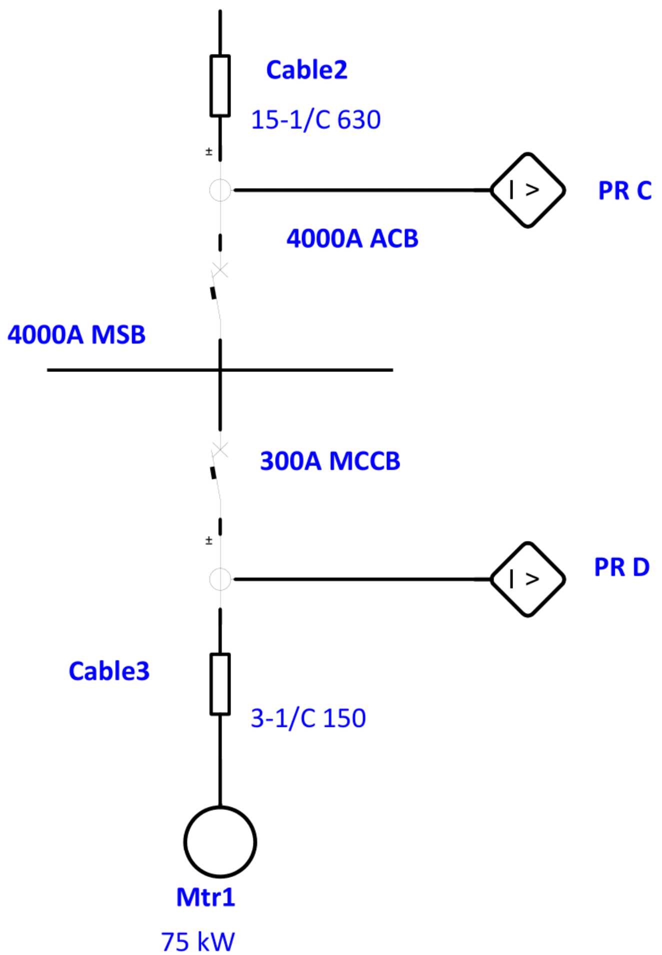


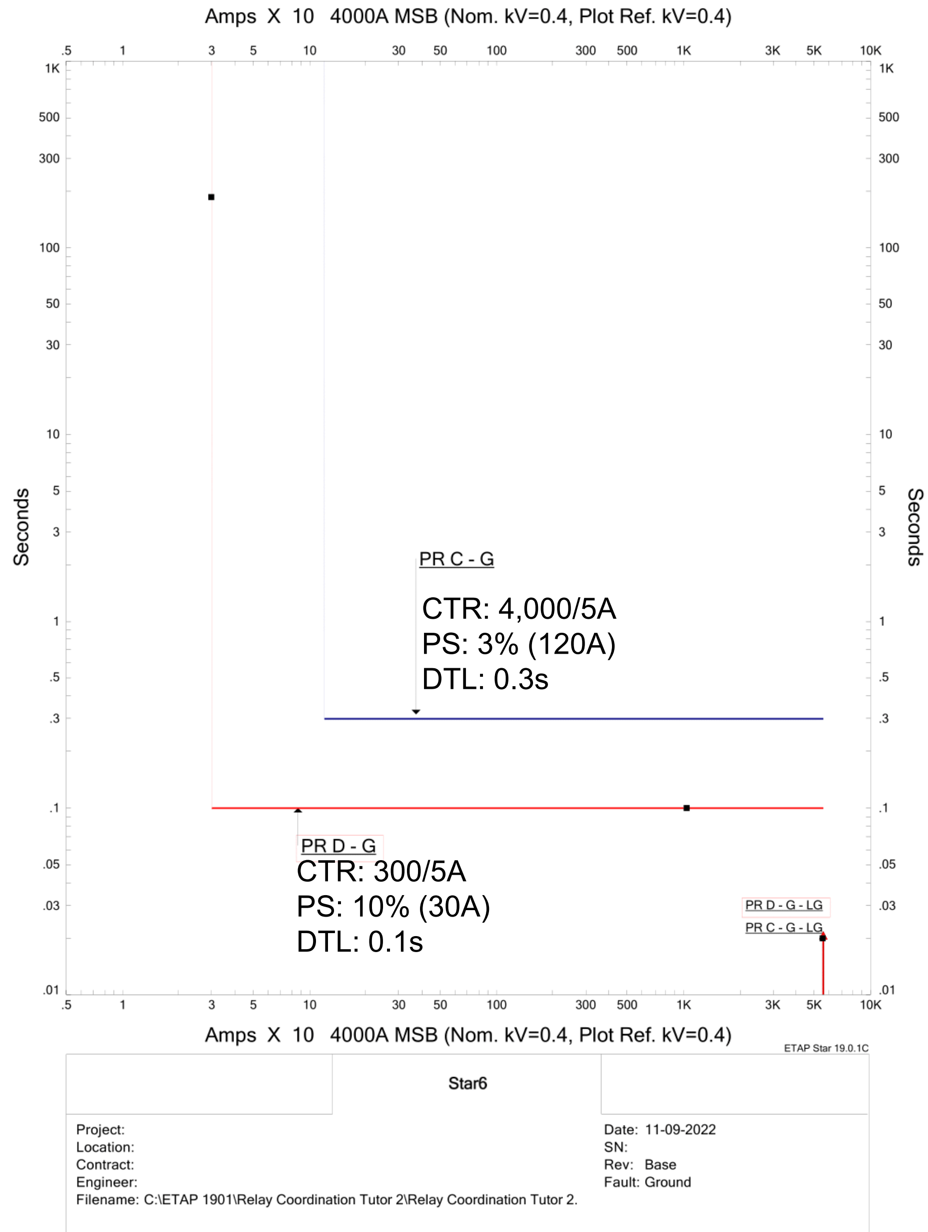
TCC - Earth Fault (HT)





TCC - Earth Fault (LV)





Summary

- External protective relays are easier to achieve protection system coordination
- Normal Inverse curve is the main selection
- Extreme Inverse curve is used to coordinate with fuse and motor
- High-set instantaneous should not be used in incoming feeder, and should be used with care
- Minimum Time Grading between protective relays shall be 150ms to 350ms

MH Protection Relays