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AM18.1: Methods

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What is ‘Medium’ Voltage?

- BS 7671:2018, defines ‘High Voltage’ as anything exceeding 1,000 V AC
- But that is too broad a definition for the industries that deal with: Power Generation, Transmission, and Distribution

So, the following definitions are used for AM18....
- Low Voltage (LV): below 1 kV
- Medium Voltage (MV): 1 kV – 35 kV
- High Voltage (HV): 35 kV – 230 kV
- Extra High Voltage: (EHV) > 230 kV
Transmission System of Great Britain
Why MV?

- For any given load, the current requirement is lower
- Voltage losses are lower and a smaller fraction of the supply voltage

BUT

- Increased danger levels
- Higher cost of insulation
- Staff training mandatory for operation and maintenance
MV Protective Systems

Have three main functions:

• To safeguard the entire power system and maintain continuity of supply where it is safe to do so

• To minimise damage (and repair costs) if a fault occurs

• To ensure the safety of personnel
Protection Relays (and the Circuit Breakers they control)

Main functions:

• Selectivity (Discrimination) – to detect and isolate the faulty equipment and leave all remaining healthy circuits intact; thereby ensuring continuity of supply

• Sensitivity – to detect a fault before it can cause excessive damage or danger to life

• Speed – to operate dependably and rapidly when necessary – again to minimise damage and ensure safety to personnel.
Methods of Distribution

In practical terms, these resolve themselves into Radial and Ring-circuit, for example:

• Radial Distribution:
  • Cheapest method
  • **ALL** complex systems are broken down into a series of radial circuit calculations
  • Not very secure since a fault at any point will disconnect the remainder of the site
  • But may be appropriate where single overhead line is the source of power.
Radial Circuit Control

The type of switchgear often depends on the size of the load, e.g.:
- load < 1000 kVA and no standby generation: still common to use MV fuse-switches or circuit-breakers controlled by time-limit fuses (TLFs).
- Otherwise, circuit-breakers controlled by overcurrent relays are usually required.
Dual/Duplicate Feed

- More secure but expensive since it requires each feeder to be equipped with circuit breakers at each end and other controls for automatic changeover.
- The system is not common for building services.
• The method is more appropriate for transmission lines where the loss of service can disrupt major portions of the network.

Twin-circuit tower
Security of Supply

- For many users, a single incoming MV supply is all that can be justified, and in remote areas (where the 11 kV supply may be derived from a single overhead line) there is little point in trying to make any local distribution more secure. Money is better spent in providing standby generation.

- Urban supplies offer ring-main possibilities; the most secure being where the normal and the alternative supply are driven from separate sections of the DNO (Distribution Network Operator) network with automatic changeover.
Open Ring-main

- The most cost-effective and common method of MV distribution – it effectively ensures supply from two alternative directions to each part of the installation.

The ring-main is operated with an open point; usually set to evenly apportion the normal load across each leg of the ring.
Ring Main Unit (RMU)

- Usual configuration is:
  - 2 ring switches and a
  - ‘T-off’ fuse-switch or circuit breaker.

- Each **ring switch** will have three positions of operation: **ON, OFF** and **EARTH** (applies earth to the ring-main cable)

- The ‘T-off’ fuse switch will again have three operating positions: **ON, OFF** and **EARTH** (applies earth to the T-Section)

- Circuit-breakers can be Oil, Gas-insulated or Vacuum and can be operated by Time Limit Fuses or Protection Relays
Closed Ring-main

- More secure but expensive option. However, in the event of a fault only the faulty section isolated

- Because each substation is permanently fed from two directions it is necessary to provide directional protection or unit protection relays.
New Connections

Key
Customer assets
Connection works
Existing network assets
Removed
Contestable works
Non-contestable works

Following commissioning and handover, this will be the point of connection (POC), i.e. the ownership boundary between the customer and the DNO.

The contestable works include those works required to provide a connection between the customer's assets and the non-contestable works.

POCs between the contestable works and the non-contestable works.

The non-contestable works include any decommissioning works and the connection of the contestable works to the DNO network.
Electrical Safety

• The EAW Regulations – made under Section 15 of the Health and Safety at Work etc. Act 1974 – require precautions to be taken against the risk of death or personal injury from electricity in work and work-related activities.

• Injuries are those caused by electric shock, electric burns, electrical explosion or arcing, or from fire or explosion initiated by electrical energy.

• Their general effect is to require that all electrical systems, irrespective of operating voltage, are designed, installed, operated and maintained so as to prevent ‘danger’, which is defined as ‘risk of injury’.
Designated Personnel

- Authorising Engineer
- Senior Authorised Person
- Authorised Person
- Competent Person
- Responsible Person
Safety Documentation

- Safety Programme (Switching Schedule)
- Isolation and Earthing Diagram
- Permit to Work
- Sanction for Test
- Limitation of Access
Safety Documentation – Examples
AM18.2: Equipment

- Cable Types
- MV Switchgear
  - Isolation Methods
- Circuit Breakers
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  - Gas-Insulated
  - Alternatives to SF6
  - Vacuum
- Transformers
  - Types
  - Harmonics
  - Specification
- MV Maintenance
Cable Types

- Cable parameters
- Short-circuit ratings
- Selection Flowchart
- Cable Data for:
  - XLPE/SWA
  - XLPE/LSZH/SWA
  - XLPE/MDPE/SWA
  - XLPE/PVC
MV Switchgear
Isolation Methods

• Vertical Isolation

• Horizontal Isolation
Types of Circuit Breaker

- Circuit-breakers offer a very flexible form of protection and control for both the HV and the LV sides of the transformer. On the HV side common types include: ‘Oil’, ‘SF₆’ (Sulphur Hexafluoride) and ‘Vacuum’ circuit breakers.

- However, the need to install adequate fire precautions with oil-filled equipment meant that SF₆ or Vacuum circuit-breakers were usually the most suitable choice.
But ... !!!

- $\text{SF}_6$ (Sulphur Hexafluoride) is an extremely potent greenhouse gas ...
  - Global Warming Potential (GWP) = 23,900
  - $\text{CO}_2$ has a GWP = 1

- So although there are still a number of $\text{SF}_6$ breakers still in operation, the aim is to phase it out over time (Kyoto Protocol)
Gas-Insulated Switchgear

- Alternative to SF$_6$ include:

- ‘AirPlus’ (3M in collaboration with ABB) – a mixture of NOVEC (a fluoroketone) and dry air

- $g^3$ (‘g-cubed’ – 3M in collaboration with GE) – a fluoronitrile with nitrogen

- **Synthetic air** (Nuventura) – 80% nitrogen + 20% oxygen

- And of course, **vacuum** circuit breakers
Gas-Filled, Ring-Main Unit (RMU)

Ring-main feeder
- Busbars
- Three-position disconnecter
- Sealed gas-insulated switchgear chamber
- Cable to ring

Transformer feeder
- Switching operating mechanism
- VCB
- Control boards
- Cable to transformer

Ring feeders
- Tx feeder

MV switchgear panel
Vacuum Circuit-breaker
Current Chopping

• When CBs operate, the current does not always smoothly come to zero – whilst the current is still a few amperes, the arc becomes unstable and can be prematurely extinguished – current chopping.

• This can then produce large transient voltage peaks, but because of their mode of operation, with vacuum breakers this can occur at higher current levels – with the possibility of very high voltage peaks.

• Several mitigation methods are possible.
Transformers

- LV terminals
- Three-leg laminated core
- HV terminals
- LV winding
- HV winding
- Insulation (mixture of epoxy resin and quartz powder)
- Cross-flow fans (allowing a 50% increase in rated power)
Types

• Dry-type transformers
  – Air-cooled
  – Cast resin

• Liquid-filled transformers
  – Mineral oil
  – Midel or silicon fluid

A comparison: relevant to supplies to buildings
Transformer Specification

- Design/construction standards
- Type of transformer
- Insulation and cooling
- Transformer rating
- Vector group
- Primary/secondary supplies
- Transformer duty
- Location
- Location
- Impedance
- Neutral earthing
- Voltage tappings
- Cable boxes
- Tank fittings
- Enclosures
- Testing requirements
Harmonics

• Factor K (Europe) – De-rating factor

\[ K = \left[ 1 + \frac{e}{1 + e} \left( \frac{l_1}{l} \right)^2 \cdot \sum_{n=2}^{N} \left( n^q \cdot \left( \frac{l_n}{l_1} \right)^2 \right) \right]^{0.5} \]

• K-factor (USA) – Multiplier

\[ K = \sum_{n=1}^{N} (l_n^2 \cdot n^2) \]
Harmonics – Example

Table F1 Harmonic number and current (%)

| n  | 1   | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 15    | 16    | 17    | 18    | 19    | 20    |
|----|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1  | 100 | 3.47  | 20.32 | 3.22  | 9.45  | 2.21  | 8.12  | 1.15  | 6.19  | 0.77  | 4.55  | 0.90  | 3.84  | 0.75  | 3.30  | 0.83  | 4.86  | 0.56  | 2.47  | 0.49  |

Table F2 Factor K and K-factor calculations

<table>
<thead>
<tr>
<th>n</th>
<th>RMS current, $I_n$</th>
<th>$I_n/I_R$</th>
<th>$(I_n/I_R)^2$</th>
<th>$n^q$</th>
<th>$n^q \times (I_n/I_R)^2$</th>
<th>$I_n/I_{RMS}$</th>
<th>$(I_n/I_{RMS})^2$</th>
<th>$(I_n/I_{RMS})^2 \times n^2$</th>
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$\Sigma_1 = 1.0714 \quad \Sigma_2 = 1.5338$

K-factor $= 3.72$

Select TX with a K-factor of 4

Current @ 50 Hz = 100 A
Total RMS = 101.5A

Factor K = 1.06
i.e., derate to 94%

$(1 \div 1.06)$
Maintenance of MV Networks

Guidance on:

- Periodic inspections
- Planned intrusive maintenance
- 11kV, SF$_6$ and gas-filled CBs and RMUs
- 11kV transformer inspection and maintenance
AM18.3: Protection

- MV Fuses
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- I t Characteristics
  - Standard Inverse
  - Very Inverse
  - Extremely Inverse
- Logic Discrimination
High Voltage Fuses (IEC 282-1)

HV fuses
GEC
Type 'K'

Typical High-Voltage Fuse Ratings for 11 kV Distribution Transformers

<table>
<thead>
<tr>
<th>Transformer Rating (kVA)</th>
<th>Fuse Rating (A)</th>
<th>Transformer Rating (kVA)</th>
<th>Fuse Rating (A)</th>
</tr>
</thead>
<tbody>
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<td>25</td>
<td>5</td>
<td>315</td>
<td>36</td>
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<td>30</td>
<td>10</td>
<td>400</td>
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<tr>
<td>300</td>
<td>36</td>
<td>1500</td>
<td>125</td>
</tr>
</tbody>
</table>

90 A & 50 A, BS 2692
HV Fuses

Time (s)

Current (A)

1000

100

10

1

0.1
Fuse vs. Circuit Breakers?

• Fast with large fault currents, but slow with currents less than 3 times their rated values.

• So do very little to protect against overloads.

• Often a practical choice for smaller installations or those in remote areas.
Current Transformers

• Current transformers are used to provide a barrier between MV equipment and the protection relay.

• **PROTECTION CLASS** CTs are designated by the letter ‘P’ e.g. 5P, 10P etc, where the 5 or 10 are the % ratio error, as measured by the ‘Accuracy Limit Factor’.
CT Construction

<table>
<thead>
<tr>
<th>Class</th>
<th>Current Error (%) at Rated Primary Current</th>
<th>Error (%) at Rated Accuracy Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>5P</td>
<td>± 1</td>
<td>5</td>
</tr>
<tr>
<td>10P</td>
<td>± 3</td>
<td>10</td>
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</table>

Standard accuracy limit factors (ALFs) are: 5, 10, 15, 20 and 30.

e.g., a 50:1 CT used where the fault current is 1,000 A, then an ALF of 1000/50 = 20 would be required.
Specifying CTs

- Burden: 2.5, 5, 7.5, 10, 15, 30 VA
- Accuracy Class: 5P (5%), 10P (10%)
- Accuracy Limit Factor: 5, 10, 15, 20, 30
- e.g 15 VA, class 10P20 \(\equiv\) AC = 10P, ALF = 20

<table>
<thead>
<tr>
<th>Relay Type</th>
<th>Typical CT Requirement</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>VA</td>
<td>Class</td>
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<td>IDMT</td>
<td>15</td>
<td>10P</td>
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<tr>
<td>Earth-fault</td>
<td>15</td>
<td>10P</td>
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</tbody>
</table>

Modern protection relays have very low burdens (\(\sim 0.1 – 0.5\) VA) and this does **NOT CHANGE** with current setting.
Protection Relays

• Typically mounted in a separate compartment and connected to the circuit being protected by CTs and VTs.

• With a ring-circuit, current can flow in either of two directions. Hence the need for a directional relay – ONLY responds when current is flowing in one direction.
<table>
<thead>
<tr>
<th>ANSI Code</th>
<th>Name of function</th>
<th>Definition</th>
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<tbody>
<tr>
<td>49</td>
<td>Thermal overload</td>
<td>Protection against overloads</td>
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<tr>
<td>50</td>
<td>Instantaneous phase overcurrent</td>
<td>3-phase protection against short-circuits</td>
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<tr>
<td>50BF</td>
<td>Breaker failure</td>
<td>Checking and protection if the circuit breaker fails to trip</td>
</tr>
<tr>
<td>50N or 50G</td>
<td>Instantaneous earth fault</td>
<td>Protection against earth faults:</td>
</tr>
<tr>
<td>50V</td>
<td>Instantaneous voltage-restrained overcurrent</td>
<td>3-phase protection against short-circuits with voltage-dependent threshold</td>
</tr>
<tr>
<td>51</td>
<td>Delayed phase overcurrent</td>
<td>3-phase protection against overloads and short-circuits</td>
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<tr>
<td>51N or 51G</td>
<td>Delayed earth fault</td>
<td>Delayed protection against earth faults:</td>
</tr>
<tr>
<td>51V</td>
<td>Delayed voltage-restrained phase overcurrent</td>
<td>3-phase protection against short-circuits with voltage-dependent threshold</td>
</tr>
<tr>
<td>64REF</td>
<td>Restricted earth fault differential</td>
<td>Earth fault protection, star-connected 3-phase winding with earthed neutral</td>
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<tr>
<td>64G</td>
<td>100% generator stator earth fault</td>
<td>Detection of stator winding earth fault</td>
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<tr>
<td>67</td>
<td>Directional phase overcurrent</td>
<td>3-phase short-circuit protection dependent on direction of current flow</td>
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<td>67N or 67NC</td>
<td>Directional earth fault</td>
<td>Earth fault protection dependent on direction of current flow</td>
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<td>Busbar differential</td>
<td>3-phase protection against busbar internal faults</td>
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<td>87G</td>
<td>Generator differential</td>
<td>3-phase protection against internal faults for AC generators</td>
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<td>Line differential</td>
<td>3-phase protection against line internal faults</td>
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<td>Motor differential</td>
<td>3-phase protection against internal faults for motors</td>
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<tr>
<td>87T</td>
<td>Transformer differential</td>
<td>3-ohase protection against internal faults for transformers</td>
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Overcurrent Characteristics

Applications limited for relays using:
- Definite current – variations network fault currents during operation
- Definite time – produce long fault clearance times
Time Limit Fuses (TLFs)

**TLF - connection**
- Circuit-breaker
- Current transformer
- Time limit fuse
- Tripping coil of circuit-breaker

**50/5 CT, 10-A TLF**

<table>
<thead>
<tr>
<th>Operating time (s)</th>
<th>Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>400 - 480</td>
</tr>
<tr>
<td>0.5</td>
<td>200 - 240</td>
</tr>
<tr>
<td>1</td>
<td>166 - 198</td>
</tr>
<tr>
<td>2</td>
<td>150 - 176</td>
</tr>
<tr>
<td>3</td>
<td>145 - 170</td>
</tr>
<tr>
<td>10</td>
<td>136 - 162</td>
</tr>
<tr>
<td>20</td>
<td>135 - 160</td>
</tr>
</tbody>
</table>

**Discrimination**
Discrimination is progressively achieved by increasing the rating of the Time Limit Fuse.

**TLFs fitted to Merlin Gerin RMU**
Induction Relays

- Induction relays operate on the same basis as an induction motor – relay current causing the relay disc to rotate.
- The rotation is restrained by a simple spiral spring which must be overcome before disc rotation starts. – typically 110% of full-load current.
Relays Operation
Relay Adjustments

**Electro-Mechanical Relays:**
*Plus Settings (PS) (%):*
50, 75, 100, 125, 150, 175, 200

*Time Multiplier Settings (TMS):*
0.1 (10%) to 1 (100%)
in 0.05 (5%) steps

**Digital/Numeric Relays:**
*Current Multiplier (CM):*
5% to 240% in 5% steps

*Time Multiplier Settings (TMS):*
0.1 (10%) to 1 (100%)
in 0.05 (5%) steps
Unit Protection

- High speed operation [typically operating within 10 - 50 milliseconds (½ to 2½ cycles)] coupled with high sensitivity.

- Do not provide backup for each other, requires additional, time graded overcurrent relays or other breaker failure protection.
Grading Margin between Relays

The **minimum time difference** between relays:

- The operating time of the circuit-breaker
- Timing errors and overshoot of the relay
- A final ‘time-safety margin’ between relays.

Nominal values are:

- 0.1 s (relay and CT error) \([E_R, E_{CT}]\)
- 0.05 (overshoot) \([t_o]\)
- 0.15 (breaker operating time) \([t_{CB}]\)
- 0.1 (safety margin) \([t_s]\)
- **Sum 0.4 seconds**

Or we could use the equation:

\[
t' = \frac{\dot{e}2E_R + E_{CT}}{\dot{e}/100} \frac{\ddot{u}}{\dot{u}} t + t_{CB} + t_o + t_s
\]
Relay Characteristics

SI: \( t = \frac{0.14}{(M^{0.02} - 1)} \)

VI: \( t = \frac{13.5}{(M - 1)} \)

EI: \( t = \frac{80}{(M^2 - 1)} \)

t in seconds, 
M = Multiple of overload
Logic Discrimination

Time-based discrimination
\[ \Delta t = 0.3 \text{ s} \]

- Relay A: 1.0 s
- Relay B: 0.7 s
- Relay C: 0.4 s

Logic based discrimination
With immediate downstream fault
- 0.2 s
- 0.8 s

After downstream breaker failure
- 0.2 s
- 0.6 s
AM18.4 and AM18.5
AM 18.4: Fault Calculations

Three-phase Fault

Neutral point of supply

Phase 1

Phase 2

Phase 3

Neutral point of fault

Equivalent single-phase circuit of three-phase fault

Neutral point of supply

\( V_{\text{phase}} \)
Example Calculations

Fault level of incoming 33 kV supply = 1,000 MVA

2 x 33/11 kV, 10 MVA, Xpu = 6.25%

Distance = 15 km

33 kV

2 x 33/11 kV, 10 MVA, Xpu = 6.25%

11 kV

Distance = 5 km

Intake sub-station

Fault level of incoming 33 kV supply = 1,000 MVA

Xpu = 0.05%

2 x 33/11 kV, 10 MVA, Xpu = 6.25%

Reactance of incoming 33 kV supply:

Given from Xpu = \text{Base VA} / \text{Fault level}

= \frac{0.5 \text{ MVA}}{1,000 \text{ MVA}} = 0.0005 \text{ or } 0.05\%

Xpu = 0.313%

Reactance of 33/11 kV transformer:

= 6.25 \times \frac{\text{New base}}{\text{Old base}}

= 6.25 \times \frac{0.5 \text{ MVA}}{10 \text{ MVA}} = 0.313%

Rpu = 1.45%

Xpu = 0.9%

Impedance of total 20 km of cable:

Resistance = 3.5 Ohms

Reactance = 2.14 Ohms

Full-load current of base VA at 11 kV:

= \frac{500,000}{\sqrt{3} \times 11,000}

= 26.24 Ampere

Full-load impedance = \frac{V_{\text{phase}}}{I_{\text{full-load}}}

= \frac{11,000}{\sqrt{3} \times 26.24}

= 242 Ohms

Per unit impedance values for cable:

Resistance = \frac{3.5}{242} = 0.0145 \text{ or } 1.45%

Reactance = \frac{2.14}{242} = 0.009 \text{ or } 0.9%

Reactance of 11/0.415 kV transformer

= 5.2%

All per unit impedances quoted relative to a Base of 0.5 MVA
AM 18.5: Grading

- A graphical approach to design
Setting the Protection?

- Transformer magnetising current

- Co-ordination between MV breaker and largest Low Voltage fuse or circuit breaker

- Protection must allow ‘permissible overload current’
  - typically 1.5 x transformer rated load
11kV Radial System

33kV substation
Maximum fault level = 800MVA

33/11kV
15 MVA
Z_{pu} = 5.2\

CB3 controlled by protection relay:
800/5 CT, IDMT (5A)
Current Multiplier (CM) = 1.5,
Time Multiplier Setting (TMS) = 0.4

3 x Single-core, copper conductors
XLPE, 10 km
R = 0.036Ω/km; X = 0.086Ω/km

11kV site intake substation

1MVA
1.5MVA

2 MVA – Full-load (Short-term transient current = 170A)
## Fully Worked Solution

### Current/Time Characteristic

<table>
<thead>
<tr>
<th>CB#</th>
<th>CT ratio</th>
<th>Relay Characteristic</th>
<th>Current Multiplier (CM)</th>
<th>Relay Setting Current (A)</th>
<th>Time Multiplier Setting (TMS)</th>
<th>Maximum Short-circuit Current (kA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB3</td>
<td>800:5</td>
<td>IDMT</td>
<td>1.5</td>
<td>1200</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>CB2</td>
<td>250:1</td>
<td>IDMT</td>
<td>1.1</td>
<td>275</td>
<td>0.4</td>
<td>11.2</td>
</tr>
<tr>
<td>CB1</td>
<td>100:1</td>
<td>IDMT</td>
<td>1.2</td>
<td>120</td>
<td>0.3</td>
<td>4.3</td>
</tr>
</tbody>
</table>

![Graph of current/time characteristic for CB1, CB2, CB3]

- CB1: Current (Amp) vs. Time (Sec)
- CB2: Current (Amp) vs. Time (Sec)
- CB3: Current (Amp) vs. Time (Sec)

- CB3 max short-circuit current: 4.3 kA
- CB3 time multiplier setting: 0.4 s
Open Ring Main

- Incoming 11kV supply
- RMU
- 1000kVA
- VCB and relay
- 1000kVA
- ACB
- 800A, MCCB
- 400/230V
- 1000kVA
Fully Worked Solution
Closed Ring Main

11kV Intake substation (Fault Level = 200MVA)

80A, VI, TMS = 0.5
800kVA

DSS D

80A, VI, TMS = 0.5
800kVA

DSS A

1,000kVA
TMS = 0.4

DSS C

90A, VI, TMS = 0.4
1,000kVA

DSS B
Fully Worked Solution – Time Graded

<table>
<thead>
<tr>
<th>Relay Description</th>
<th>CT</th>
<th>CM</th>
<th>Type</th>
<th>TMS</th>
<th>Relay Operating Time at 10.5kA (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV feed to 800kVA Tx</td>
<td>100:1</td>
<td>0.8</td>
<td>VIDMT</td>
<td>0.5</td>
<td>0.23</td>
</tr>
<tr>
<td>MV feed to 1000kVA Tx</td>
<td>100:1</td>
<td>0.9</td>
<td>EIDMT</td>
<td>0.4</td>
<td>0.05</td>
</tr>
<tr>
<td>CW1 / ACW1</td>
<td>250:1</td>
<td>0.75</td>
<td>VIDMT</td>
<td>0.25</td>
<td>0.12</td>
</tr>
<tr>
<td>CW2 / ACW2</td>
<td>250:1</td>
<td>1.1</td>
<td>IDMT [SI]</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>CW3 / ACW3</td>
<td>250:1</td>
<td>1.1</td>
<td>IDMT [SI]</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>CW4 / ACW4</td>
<td>250:1</td>
<td>1.1</td>
<td>IDMT [SI]</td>
<td>0.7</td>
<td>1.4</td>
</tr>
<tr>
<td>CW5 / ACW5</td>
<td>250:1</td>
<td>1.1</td>
<td>IDMT [SI]</td>
<td>0.9</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Fully Worked Solution – Unit Protection
And More ...

• Transformer Balanced and Restricted Earth-Fault Protection (BEF and REF)
• Buchholz Relay
• Generator Protection
• Engineering Recommendation G99 (2019) (Generator connection in parallel with the grid)
• Typical Relay Configurations for Transformers and Generators.
• IEC Loading Guide for Transformers
Thank you

• Questions?