MV Network Switchgear, Protection and Control

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Agenda

- An Overview
- MV Network
- Basic Definitions
  - Circuit breaker
  - Switchgear
  - Control gear
  - Fault
- Basic functions
  - Disconnection
  - Control
  - Protection
- Protection Index
- Faults
- Arc breaking techniques
- Discrimination
- Current limitation
- Cascading
- IEC 60 947
- LV Control
Overview

- Production units
  - Generator
  - Overhead lines
- HV/MV substations
- MV/MV distribution substations
- Motors
- Industries
- Transformers
- Underground cables
- MV/LV distribution substations
Overview

- LV power control
Different types of MV networks

- Two types of configuration
  - Radial
  - Loop

- It can be either Overhead or underground
Radial network

33kV
20MVA

11kV

Primary 1

Load Centre 1
Load Centre 2
Load Centre 3
Load Centre 11

IEEMA- Schneider Electric
Radial network

- Suited to applications where load is quite widely distributed throughout site
  - Used mainly for LV distribution

**ADVANTAGES**

- Simplest system configuration
- Easily protect with time graded overcurrent

**DISADVANTAGES**

- Occurrence of a single fault will result in complete loss of supply to the load centre
- Supply cannot be restored until fault is repaired - long disconnection times

How can we improve?
Open ring network

33kV

Primary 1

20MVA

11kV

Load Centre 11

Load Centre 3
Normal Configuration

MAIN SUBSTATION

OPEN POINT

IEEMA- Schneider Electric
Earth Fault On System
System Re-configured
Overview

- LV Electrical Network

Main power distribution board

Sub-distribution board

Final distribution board

DC 400 Hz
Basic definitions

- Circuit breaker:
  Switching and current interrupting device

- Switchgear:
  All equipments associated with the fault clearing process

- Control gear:
  Used for switching and controlling power consuming devices

- Fault:
  A defect in its electrical circuit due to which current is diverted from its intended path
Switch

A mechanical switching device capable of making, carrying and breaking currents under normal conditions which may include specified operating overload conditions and also carrying for a specified time currents under specified abnormal circuit conditions such as those of short circuit
Contactor

- A mechanical switching device having only one position of rest, operated otherwise by hand, capable of making, carrying & breaking current under normal circuit conditions including operation overload conditions
Fuse

- A device that by fusing of one or more of its specifically designed & proportioned components opens the circuit in which its inserted by breaking the current when this exceeds a given value for a sufficient time.
Circuit breaker

- A mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short circuit
Isolator / Disconnector

- A mechanical switching device which, in the open position, complies with the requirements specified for the isolating function:
  - Leakage current
  - Contact bond strength
  - Impulse withstand voltage

- The isolating function can be added to others.
Basic Functions

- Isolation
- Control
- Protection

- disconnecter
- contactor
- circuit breaker
Basic Functions

- **Isolation**
  - Positive break indication
  - Visible break

- **Control**
  - Functional
  - Emergency
  - Breaking for maintenance

- **Protection**
  - Overload
  - Short circuit
  - Insulation faults
Isolation

- Disconnector according to IEC 60 364 & 462 – 1

- Disconnector: Mechanical switching device which, in open position complies with the requirements specified for isolating function

- Purpose: Isolate and separate a circuit or device from the rest of the installation

- Disconnector

- Switch disconnector

- Circuit breaker
Isolation

Power on ...
... BUT no loads
The “functional” control

Purpose: Energizing or de-energizing all parts of the installation in normal operation

- Switch
- Contactor
- Impulse relay
- Circuit breaker
Protection

Protection of people

Protection of property
Electrical Protection as per IEC 60364 & 43

- Protection of property

- Purpose: to protect cables and equipments against:
  
  - Overloads, over currents occurring due to faulty use
  
  - Short circuit currents occurring due to fault between the conductors
Protection index

- Protection of people against direct contact and protection of equipment against certain external influences is required by international standards.

- The protection index is the level of protection provided to by an enclosure against access to hazardous parts, the penetration of solid foreign bodies and of water.

- The IP code is a coding system to indicate protection index.

- It applies to enclosure of electrical equipments with a rated voltage of less than or equal to 72.5kV.
<table>
<thead>
<tr>
<th>Item</th>
<th>Figures or letters</th>
<th>Meaning for protection of equipment</th>
<th>Meaning for protection of people</th>
<th>Representation</th>
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<tbody>
<tr>
<td>Code letter first characteristic figure</td>
<td>IP</td>
<td>against penetration of solid foreign bodies</td>
<td>against access to hazardous parts with</td>
<td></td>
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<tr>
<td>0</td>
<td>0</td>
<td>(not protected)</td>
<td>(not protected)</td>
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<tr>
<td>1</td>
<td>diameter ≥ 50 mm</td>
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<td>tool</td>
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<td>5</td>
<td>protected against dust</td>
<td>wire</td>
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<td>second characteristic figure</td>
<td>against penetration of water with detrimental effects</td>
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<tr>
<td>0</td>
<td>0</td>
<td>vertical water drops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>water drops (15° inclination)</td>
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<td>2</td>
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<td>rain</td>
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<td>4</td>
<td>spray projection</td>
<td></td>
<td><img src="image10" alt="Diagram" /></td>
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<tr>
<td>5</td>
<td>5</td>
<td>high power spray projection</td>
<td></td>
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<tr>
<td>6</td>
<td>6</td>
<td>temporary immersion</td>
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<td>7</td>
<td>7</td>
<td>prolonged immersion</td>
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Fault

- A fault in an electrical equipment is defined as a defect in its electrical circuit due to which the current is diverted to the un-intended path.

- Generally caused by breaking of conductors or failure of insulation.

- Other causes:
  - Mechanical failure
  - Accidents
  - Excessive stresses
Fault

- Classification
  - Open circuit - most common fault
  - Single line to ground fault - most common fault
  - Line to line fault
  - Double line to ground fault
  - Three phase fault – Dead short circuit
  - Three phase to ground fault – Rare fault

Faults cannot be eliminated but can be minimized
Fault

ערב שunts

**Phase-to-phase Isc**

- Phase 1
- Phase 2
- Phase 3

- Isolated two-phase short-circuit
- Rare but destructive

**Phase-to-earth Isc**

- Phase 1
- Phase 2
- Phase 3

- Earth single-phase short-circuit
- The Most Common

**Energy loss**

- Phase 1
- Phase 2
- Phase 3

- Three-phase short-circuit (5% of cases)

**Two-phase short-circuit**

- Phase 1
- Phase 2
- Phase 3

- Two-phase short-circuit (80% of cases)
Other disturbances

- Surges
- Under voltage and voltage sags
- Frequency fluctuations
- Harmonics
- Overload
- Transients
Basic Operation of Circuit Breaker

Operating Principle:

- It essentially consists of fixed and moving contacts, called electrodes.
- When a fault occurs on any part of the system the trip coils of the circuit breaker get energised through relays and the moving contacts are pulled apart by some mechanism, thus opening the circuit.
Fault clearing process

- Circuit Breaker
- Trip Coil
- Battery
- Tripping circuit
- C.T.
- Relay operating circuit
- Sensing circuit
- Relay Coil
Fault clearing process

Circuit Breaker

Trip Coil

Battery

C.T.

Relay Coil

Healthy system
Fault clearing process

- Circuit Breaker
- Trip Coil
- Battery
- C.T.
- Relay Coil
- Fault occurs
Fault clearing process

Circuit Breaker

Trip Coil

Battery

C.T. senses the fault

Relay Coil operates

Fault
Fault clearing process

Circuit Breaker

Trip Coil

Battery

C.T. senses the fault

Fault

NO Gets Closed

Relay Coil Operates
Fault clearing process

Battery sends current to the Trip Coil

Circuit Breaker

Trip Coil

C.T.

Relay Coil

Fault
Fault clearing process

Circuit Breaker

C.T.

Fault

Trip Coil attracts the plunger

Battery

Relay Coil
Fault clearing process

- Circuit Breaker breaks the circuit
- C.T. Relay Coil
- Trip Coil attracts the plunger
- Faulty circuit is isolated
- Arc breaking techniques

- An arc is created when the voltage between two conductors is greater than the maximum dielectric withstand of the medium between the conductors
- Irreversible deterioration in solid insulating materials
- Ionization of the medium between the contacts
  - air
  - SF6 gas
  - oil
  - vacuum: vaporization of metal on the contacts
- The ionized insulating medium becomes temporarily conductive
- Presence of an arc voltage according to the ionized medium and the type of electrodes

MV breaking techniques...
-the "puffer" technique

Moving contact

Fixed contact

Flow of current

Separation of contacts & arcing

Lengthening of the arc & blow-out

Extinction of the arc when the current reaches zero

IEEMA- Schneider Electric
- the vacuum technique

Moving contact

Fixed contact

Flow of current

Initial

RMF

Constricted

AMF

Diffuse

Control of the arc

Interruption

U net
Discrimination

- **Total discrimination**
  - CB1 and CB2 trip
  - Only CB2 trips
  - The power supply to the other feeders is still ensured

- **No discrimination**
  - CB1 and CB2 trip
  - The power supply to the other feeders is no longer ensured
Current limitation

- Technique that allows harmful effects of short circuit currents to be diminished
- Limitation reduces effects of following types
  - Electromagnetic: reduction in EMC disturbances
  - Mechanical: reduction in deformation and / or breaks
  - Thermal: rise in the span of trunkings
Cascading

- The limiting upstream breaker helps the downstream circuit breakers to open
- Technique that allows for the cost of LV electrical distribution to be optimized
Standard IEC 60947-2

- Came into force in 1989
- Takes into account the circuit-breaker main technological upgrades
- Is internationally recognized and approved

and is applied in the majority of countries (> 100)
IEC 60 947 - 2

- IEC 60 947 – 2 is a part of a set of 7 standards characterizing LV switchgear

Diagram:

IEC 60947

IEC 60947-1

IEC 60947-3

IEC 60947-6-2

IEC 60947-7-1

IEC 60947-2

Circuit-breakers

or

IEC 60947-4-1

or

IEC 60947-4-2

or

Switches

or

Contactors and starters

or

Dimmers and starters

or

Control and connection devices

or

Terminal block

or

……
The Scope

Standard IEC 60947-2 applies to circuit-breakers, the main contacts of which are intended to be connected to circuits, the rated voltage of which does not in exceed 1000 V AC or 1500 DC; … »

The standard applies to circuit breakers intended for use by experienced operators
Definition – Circuit breaker

Mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short circuit [441-14-20]
IEC 60 947 - 2

- Standard IEC 60 947 – 2 defines
- The circuit breaker classification
  - According to utilization category A or B
  - According to design type - air circuit breaker, moulded case circuit breaker

- The circuit breaker mechanical and electrical data: size, trip unit, etc
## Circuit breaker classification

<table>
<thead>
<tr>
<th>Utilization category A</th>
<th>Utilization category B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit breaker not specifically intended for discrimination</td>
<td>Circuit breaker specifically intended for discrimination</td>
</tr>
<tr>
<td>■ Without an intentional short time delay</td>
<td>■ With intentional short time delay (adjustable)</td>
</tr>
<tr>
<td>■ Without short time withstand current</td>
<td>■ With short time withstand current</td>
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</table>
## Extract form appendix K of standard IEC 60947 - 2

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Ue</th>
<th>Rated operational voltage</th>
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<tbody>
<tr>
<td></td>
<td>Ui</td>
<td>Rated insulation voltage</td>
</tr>
<tr>
<td></td>
<td>Uimp</td>
<td>Rated impulse withstand voltage</td>
</tr>
<tr>
<td>Current</td>
<td>In</td>
<td>Rated current</td>
</tr>
<tr>
<td></td>
<td>Ith</td>
<td>Conventional free – air thermal current</td>
</tr>
<tr>
<td></td>
<td>Ithe</td>
<td>Conventional enclosed thermal current</td>
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<tr>
<td>Short - Circuit</td>
<td>Icm</td>
<td>Rated short circuit making capacity</td>
</tr>
<tr>
<td></td>
<td>Icu</td>
<td>Rated ultimate short circuit breaking capacity</td>
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<td></td>
<td>Ics</td>
<td>Rated service short circuit breaking capacity</td>
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<tr>
<td></td>
<td>Icw</td>
<td>Rated short time withstand current</td>
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<tr>
<td>Trip unit</td>
<td>Ir</td>
<td>Adjustable overload setting current</td>
</tr>
<tr>
<td></td>
<td>1.05xIr</td>
<td>Conventional non – tripping current</td>
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<tr>
<td></td>
<td>1.30xIr</td>
<td>Conventional tripping current</td>
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<td></td>
<td>Isd</td>
<td>Short time delay tripping setting current</td>
</tr>
<tr>
<td></td>
<td>Ii</td>
<td>Instantaneous tripping setting current</td>
</tr>
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</table>
Starters and contactors as per IEC 60 947 - 4

- Scope:
  - Applies to the types of equipments listed whose main contacts are intended to be connected to the circuits the rated voltage of which does not exceed 1000 V A.C or 1500 V D.C
  - Starters and / or contactors dealt with in this standard are not normally designed to interrupt short circuit currents.
  - Therefore suitable additional short circuit protection is recommended
  - AC / DC Contactors, AC motor starters, DOL, reduced voltage AC, Star delta, rheostat rotor starters…..

-------- Source IEC 60 947 - 4
Starters and contactors as per IEC 60 947 - 4

- Electromagnetic Contactor

  A contactor is a mechanical switching device having only one position of rest, operated otherwise by an electromagnet, capable of making carrying and breaking currents under normal circuit conditions including operating overloads.

- Starter

  A starter is a combination of all switching means necessary to start and stop a motor in combination with suitable overload protection.

-----Source IEC 60 947 - 4
Characteristics of Contactor and starters

- Characteristics of contactor and starter are stated in following terms, wherever applicable

- Type of equipment (Contactor, DOL, Star – Delta…..)
- Rated and limiting values for main circuit
- Utilization category
- Control circuits
- Auxiliary circuits
- Relays and releases
- Coordination with SCPD
- Over voltages……..

------Source IEC 60 947 - 4
Low voltage Industrial Control

- Contactors & overload relays
- MPCB’s for motor protection
- Variable speed drives & Soft starters
- Motor starters
- Control Stations
- MMI equipments
  - Push buttons
  - Pilot & indicator lamps
  - MMI
  - Intelligent relays
- Detection
  - Limit switches,
  - Proximity & optical sensors
  - Encoders, etc
Thank you for your attention

And don't hesitate to mail or ask at any time

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