Basic knowledge of protection relay

ABB Protection relay and solution
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Basic knowledge of protection relay

Objective

- Protection purpose and requirements
- Key terminology
  - Selectivity
  - Sensitivity
  - Stability
  - Back-up protection
  - Dependability and security
  - Protected zone
- Time coordination and grading
- Types of faults
- ABB protection and solution
Protection purpose and requirements
## Protection purpose and requirements

**The basics**

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<th>Protection purpose</th>
<th>Protection requirements</th>
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<td>• Detect electrical faults and disturbances</td>
<td>• Sensitive</td>
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<td>• Protect people and property</td>
<td>• Fast</td>
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<td></td>
<td>• Selective</td>
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<td></td>
<td>• Full coverage</td>
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<td>• Reliable</td>
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Key terminology

• Selectivity
• Sensitivity
• Stability
• Back-up protection
• Dependability and security
• Protected zone
Key terminology

Selectivity

Selectivity is a mandatory requirement for all protection, but the importance of it depends on the application.

For example, unselective protection operation during a medium voltage network fault will cause an outage for an unnecessarily large number of consumers. While this is bad, it’s not a complete disaster.

On the other hand, unselective protection operation in the extra high voltage network – i.e. at the national grid level – may endanger the stability of the whole power system, possibly leading to a country – wide blackout.
Here, several circuit breakers in the fault current paths from the generators to the fault location have been tripped. Note that all generators—the power sources—have been disconnected. Therefore, the whole system has gone down, even though many circuit breakers have remained closed. So, the outage affects all the customers unnecessarily.
Here, only the circuit breakers closest to the fault have tripped and that means that the fault has been isolated. Therefore, the outage has been minimized to just the part of the system where the fault occurred.
Key terminology

Sensitivity

Select a setting

150A | 500A | 700A | 1000A
The further down the line we go, the lower the fault current will be due to the fault resistance. So, in this case, to protect the whole line, the setting has to be able to detect fault current above 150 A.

At this setting, this is as far as we can reach down the line before the fault becomes undetectable.

We need to detect all the faults in the feeder.
Key terminology

Stability

STABILITY OF POWER SYSTEM

- Power system stability is mostly ability of all generators in the system to run in synchronism with each other
- Power system stability means also ability to maintain acceptable voltage.
- Stability may be lost due to too long clearing time of faults (too long operate times of protection)
- Problem with selectivity can also cause a loss of stability due to loss of too many transmission paths.
- The components used in the power system are usually dimensioned to withstand a short circuit current for one or three seconds but power system stability during short circuit current may be endangered already after 200ms.
- So, protection has to be able to clear the faults in less than 200ms, including CB opening time

STABILITY OF PROTECTION

- A protection scheme – for example, a differential protection scheme – is stable when it does not operate on the fault outside of its protected zone.
- So, stability of protection is closely related of security.
**Key terminology**

Back-up protection

Upstream relay provides backup for outgoing feeder relay

Incoming feeder relay

Outgoing feeder relay

MV switchgear
Key terminology

Dependability and security

Security
No trip when there isn’t a fault

Dependability
A reliable trip when there is a fault
Key terminology

Security

How to increase security

- It may be necessary to increase the security of protection in case of critical loads. Such cases arise when false operation of protection can cause severe damage or high economic loss.

- Security is increased by having two relays in series. The circuit breaker is tripped only if both 1 AND 2 operate.

- Security may also be increased for parts of the protection system. For example, the 2-out-of-3 logic for PT 100 sensors for the thermal protection of motors. The idea is that in a real over-temperature situation the fault is seen by more than just one sensor. If only a single sensor indicates high temperature, it is probably a false indication.

- Modern microprocessor based relays have a comprehensive self-supervision system. Self-supervision will give an alarm and disable tripping if it detects an internal fault in the relay. Then the operating personnel can replace the relay. Therefore, nowadays, increased security by two relays in series is actually a very rare solution.
Key terminology

Dependability

How to increase dependability

• DUPLICATION OF PROTECTION

• Dependability is increased by using two relays in parallel so that if either or both operate the circuit breaker is opened.

• In the diagram we see main1 — main 2 protection, which means that both will operate simultaneously.

An example of main 1 – main 2 protection working in parallel

Relay 1 and 2 trip contacts

Circuit breaker trip coils 1 & 2
Key terminology

Protected zone

Key point

A protected zone is the part of the network in which faults cause the protection function to operate.
Key terminology
Protected zone – differential protection

- Only differential protection has an precisely defined protected zone.
- It lies in between the current transformers.
- This brings one of the benefits of differential protection — the absolute selectivity.
Key terminology

Protected zone – distance protection

- For distance protection, the zone *reach* is limited by the fault loop impedance.
- The protected zone starts at the local current transformers, but the far end of the zone is not exact. It depends on the measurement accuracy and correctness of the data about the impedance values of the protected line.

Reach

- With overcurrent protection and distance protection, the term *reach* is also used.
- *Reach* defines how far the protection zone extends — i.e. the length of the protected zone.
- Reach can be defined in impedances (ohms), but also as physical distance (km, miles) when the protected object is a power line.
Key terminology
Protected zone – overcurrent protection

- For overcurrent protection the zone is **limited by the fault current magnitude**.
- For overcurrent protection, the zone reach is even more blurred. It depends on the magnitude of the fault current, which depends on the source short-circuit power. The reach is **not defined by the protected object itself**.
- Moreover, the fault current magnitude depends on **fault resistance and how many phases** are involved in the fault.
- In the diagram, the high-set overcurrent is set so that it operates only on faults on the high voltage side of the transformer. This is possible because the transformer is a significant current limiting impedance, and therefore the difference in the fault current magnitude is large between faults on the high and low voltage sides of the transformer.
Time coordination and grading
Time coordination and grading

- I > 200 A, t > 1.2 s
- I > 1750 A, t > 0.8 s
- I > 200 A, t > 0.5 s
- I > 3500 A, t > 0.2 s

Diagram:

- Node 1: I > 200 A, t > 1.2 s
- Node 2: I > 1750 A, t > 0.8 s
- Node 3: I > 200 A, t > 0.5 s
- Node 4: I > 3500 A, t > 0.2 s
Time coordination and grading

Time delays

Definite time

VS.

Inverse time
Time coordination and grading

Time delays

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Time coordination and grading

Coordination between upstream and downstream relays with overcurrent protection.
Take aways

- Protection is needed to detect electrical faults and abnormal operating conditions.
- Protection is also needed for protecting people and property around the power network.
- When taking about protection
  - Selectivity means that the minimum part of the network is de-energized
  - Sensitivity means that all the faults are detected
  - Dependability means that a real fault will trip the protection
  - Security means that a false fault will not trip the protection
- The protected zone is the part of the network in which faults cause the protection function to operate.
- The protected zone is defined and limited by different things depending on the protection function.
- Definite time delay means that the protection operate time does not change or depend on the fault type or the fault current magnitude.
- Inverse time delay, on the other hand, depends on the current magnitude so, the higher the current, the shorter the delay.
Types of faults
Protected objects

- Power lines
- Transformers
- Generators
- Motors
- Capacitor banks
- Busbars
- Power systems
Power lines (overhead lines and underground cables)

- Two-phase short circuit
- Two-phase-to-earth fault
- Three-phase short circuit
- Earth fault
- A double earth fault (Cross-country earth-fault)
- Broken conductor and an earth-fault
Transformers

Other faults that can occur are:
- Over-excitation
- Overload
**Typical fault types**

**Stator**
- Interturn faults (1)
- Short circuits (2)
- Earth faults (3)
- Hot-spots (4)

**Rotor & excitation**
- Earth faults and interturn faults (5)
- Over- and under-excitation (6)

**Prime mover**
- Reverse power (7)
- Jamming (7)

**External network**
- Short circuits (8)
- Earth faults (9)

**Other external network faults**
- Unbalanced load
- Overload
- Under- or over-voltage
- Under- or over-frequency
- Disconnection of load or generators
EXTERNAL FAULTS
• Jamming
• Overloading, insufficient cooling
• Start-up stress, reversed sequence starting
• Supply voltage unbalance or single phasing
• Over- and under-voltage
• Vibration

INTERNAL FAULTS
• Short circuits
• Interturn faults
• Earth faults
• Hot-spots
• Bearing damages
• Over- and under-excitation (Synchronous machines only)
Capacitor banks

INTERNAL FAULTS
- Short circuits
- Earth faults
- (Single) element failures $\Rightarrow$ unbalance

EXTERNAL FAULTS
- Overloading due to over-voltage
- Overloading due to harmonics
- Switching resonance
Busbars

A busbar in a single line diagram and protected zone of busbar differential protection (blue dotted line).

The typical faults are:

- Short circuits (phase-to-phase faults)
- Earth faults (phase-to-earth faults)
- Multiple fault loops (phase-to-phase-to-earth or three phase faults)
Power system
Power system

The typical faults are:

• Load/power generation unbalance => under-/over-frequency
• Reactive power consumption / production unbalance => under-/over-voltage
• Loss of stability of synchronous operation:
  • Fault clearance time
  • Exceeding of transmission capability (not same as overload)
  • Loss of critical transmission paths
ABB protection and solution
## ABB Distribution Automation

### Portfolio

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<th>Hi-end Range</th>
<th>Grid Automation</th>
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<td>615 series</td>
<td>630 series</td>
<td>RER/REC 615 series</td>
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<tr>
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<td>611 series</td>
<td>620 series</td>
<td>640 series</td>
<td>RER 620 series</td>
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</tbody>
</table>

### 600 family

#### Station products
- SSC600
- COM600
- RIO600
- Arctic
- PCM600, ZEE600 (ABB Zenon + Envisage)
- FT’s & cables
- DSC
- 500 series (REA, EM, SACO)

#### Other solutions and legacy
- REA, EM, SACO
Improve energy efficiency
Power Management System (PMS) for secured power supply to critical loads in the to reduce unplanned downtime for important production areas and to reduce power consumption by planned downtime.

Easy maintenance
Monitoring system for fast event recognizing allows operators, maintenance staff and production supervisors to prevent or fix effectively downtime issues as they happen, instead of weeks later.

Power Quality, Protection and Utility connection
Relion protection and control relays for several application reduce complexity. Long term cost reduction (TCO) for trainings and maintenance by reduce variety of relays.

Power Management
Monitoring and effective power and energy management environment from medium and low voltage – ensure service continuity and reliability of the network.

People/plant safety
A fast and selective arc fault mitigation for air-insulated LV & MV switchgear and Relion protection and control relays and sensor technology protect staff and plant facilities for many years.

Increase OEE
Various application for automatically transferring supply to a healthy incoming feeder to increase manufacturing time that is truly productive which includes three main factors: availability, performance, quality.
ABB Electrification Digital Solutions

Protection & control devices
- Relion 605 series
- Relion 615 series
- Relion 620/630
- Relion 640
- PMLS30 Load-shedding controller
- SSC600

Distribution automation solutions
- Arc Flash protection
- Relay retrofit
- Fiona w/RTU
- Smart Control
- Directional fault location + restoration
- Communication Public Wireless

High-voltage
- Transmission Sub-transmission
- Power transformer 2/3 cores with OLTC

Medium-voltage
- LV Main
- RMU MV sensors
- MNS Digital

LV MCC
- LV Sub
- EDCS

Renewables / Consumers
- Energy storage
- Loads

Motors

Cloud-Enabled
- Condition monitoring

Local HMI + Tools
- Engineering IEC61850
- SSC600 Centrized Protection
- P&C cabinets
- PCM600

Electrical Control System
- ABB Ability COM600
- ABB Zenon ZEE600
- ABB Envisage (US)

Applications
- compact PMS
- ATS – Fast transfer switch
- Loop Control

Renewables / Consumers
- Energy storage
- Loads

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# Digital Solution Centers

**Digital Solution Centers offering - Detailed**

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<th>Engineering Services and IEC61850 logics/templates</th>
<th>REA arc detector + UFES - extinguishing time of &lt; 4 ms</th>
<th>SUE3000 with fast breakers VM1-T &lt; 10 ms</th>
<th>Full PMS systems including 800xA/Zenon up to 6 generators</th>
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<tr>
<td>Trainings, Certifications and support</td>
<td>REA arc detector + breaker trip - extinguishing time of &lt; 60 ms</td>
<td>SUE3000 and conventional breakers &lt; 100 ms</td>
<td>+ Generator synchronisation, Transformer control, Load-sharing, Power control</td>
</tr>
<tr>
<td>Pre-configured matching units and RRP + customized solutions</td>
<td>Arc detection in Relion series + trip breaker - extinguishing time of &lt; 65 ms</td>
<td>Transfer switch with IEC61850, Goose &lt; 500 ms</td>
<td>COM600 with ABB Zenon Energy Edition</td>
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<td>Arctic GPRS/LTE devices with configuration</td>
<td>Grid automation boxes packages, FIONA</td>
<td>COM600 with COM600 software</td>
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<td>Pre-configured protection panels and cabinets</td>
<td>Pre-configured automation cabinets for HMI/Gateway applications</td>
<td>Supervision, control and Load shedding cPMS</td>
</tr>
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</table>

**Services**

- Arc fault protection
- Communication
- Transfer switch
- Grid Automation
- Control and Relay cabinet
- ECS Electrical Control System
- PMS Power Management System

*Note: majority of Distribution Automation Solutions and Success stories do combine different solutions, based on customer need’s and KPI’s*
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