EARTH FAULT DETECTING METHODS ON COMPENSATED NETWORKS
SUMMARY

- Events during normal network condition
  - Asymmetry on compensated networks
  - Usage of Petersen coil controller
- Events during single earth-fault condition
  - Prevention of evolving permanent earth faults
  - Main types of permanent earth faults
- Different methods for detecting earth faults
  - Residual definite time overcurrent protection
  - Directional residual delayed overcurrent protection
  - Transient earth fault protection
  - New method: admittance earth fault protection
ASYMMETRY ON COMPENSATED NETWORKS
Sources of Asymmetry on Compensated Networks

- Asymmetrical arrangement of phase conductors
- Iron core structure of power transformers
- Isolator’s leakage resistance
- Asymmetrical elements connected to the network
CONSEQUENCES OF ASYMMETRY

☑ Increased phase voltages
  ☑ Increased risk of earth-faults

☑ It can block the tuning of the Petersen coil (because of high \( U_0 \))
  ☑ Petersen coil is not tuned
  ☑ Earth-fault current is increased
  ☑ Earth-fault is continuous
  ☑ Risk of dangerous step voltage is high
  ☑ Protection trip is needed
**Symmetrization Methods**

- Cyclic transposition of the phase conductors
  - Needs reconstruction of the network
  - Mounting on several locations
  - Long time without power supply
- Continuous grounding resistor
  - Several disadvantages
- Added symmetrizing capacitors (provided by Protecta)
  - Mounting at the substation only
  - Lower costs
  - Short time without power supply
USAGE OF PETERSEN COIL CONTROLLER
PRINCIPLE OF COMPENSATION
(PETERSEN COIL)
PRINCIPLE OF COMPENSATION (PETERSEN COIL)

\[
Z = \frac{j3\omega L \frac{1}{j\omega C_0}}{j3\omega L - j\frac{1}{\omega C_0}}
\]
ADVANTAGES OF USING PETERSEN COIL CONTROLLER

Why is it important to use an automatical controller for the Petersen coil?

- To check the level of compensation whenever it is needed
- The network always changes: feeders can be connected or disconnected to the busbar any time
- Because the capacity of the zero sequence network can change any time, the Petersen coil must follow the change of the capacity
- It always keeps the Petersen coil in a well-tuned position
RESULT OF THE MEASUREMENT: THE RESONANT CURVE

Resonance Point: 24.3A, 47.2V

- Actual Petersen position: 30A
- Actual Uo: 26V
- OverCompensation: 23.6%
PREVENTION OF EVOLVING PERMANENT EARTH FAULTS
WHAT CAN INCREASE THE RISK OF EVOLVING PERMANENT EARTH FAULTS?

☑️ Use of grounding (shunt) resistor → it increases the fault current, so the fault becomes stable

☑️ The Petersen coil is not well tuned → High under- or overcompensation

☑️ Short time for using the Petersen coil alone
AN EFFECTIVE WAY OF PREVENTION

☑ Well-tuned Petersen coil

Example 1:

Example 2:

Example 3:
WHY "EXACT" COMPENSATION CAN CAUSE PROBLEMS?

- The $U_0$ is relatively high:

- Increased phase voltages

- Problems of Petersen tuning procedure
WHAT CAN BE THE BEST SOLUTION? (IDEA OF PROTECTA)

☑ Use of shunt inductance, which is connected parallel to the Petersen coil → in case of possible earth fault the "exact" compensation can be approached:

ADAPTIVE COMPENSATION
MAIN TYPES OF PERMANENT EARTH FAULTS
**STABLE EARTH FAULTS WITH LOW FAULT RESISTANCE**

- The fault current flows continuously

- If the grounding resistance is switched on, the increased fault current is high enough for overcurrent protections to detect the earth fault
Stable earth faults with high fault resistance

- The fault current flows continuously.
- If the grounding resistance is switched on, the increased fault current is NOT enough for overcurrent protections to detect the earth fault.

The primary $3I_0$ is 18A!
**INTERMITTENT EARTH FAULTS**

- The fault current does not flow continuously.
- The exact fault time is around 5-10msec, then the fault is cleared for many periods.
- The time between faults can be 100msec – 500msec.
RESIDUAL DEFINITE TIME OVERCURRENT PROTECTION
The symmetrical component network:
Earth fault current-booster method

The zero sequence voltage and currents during the earth fault:

Healthy feeder:

Faulty feeder:
Residual definite time overcurrent protection

- The setting parameters are:
  - Starting current \( (I_{\text{start}}) \)
  - Definite time delay \( (T_{\text{delay}}) \)
**Residual Definite Time Overcurrent Protection**

**Advantages**
- Very simple solution
- The list of parameters is short
- It does not require $U_0$ voltage

**Disadvantages**
- Maintenance of the resistance is expensive
- It cannot detect earth faults with high fault resistance
- If the resistance is switched on, then the chance of clearing the earth fault by the Petersen coil is zero
- Dangerous step and touching voltage: the IEC-50522 standard does not allow to keep the increased fault current for a long time (the fault time can be maximum 100-200ms)
DIRECTIONAL RESIDUAL DELAYED OVERCURRENT PROTECTION
Wattmetric method

☐ The symmetrical component network:
WATTMETRIC METHOD

The zero sequence voltage and currents during the earth fault:

Healthy feeder:  
Faulty feeder:

![Diagram showing zero sequence voltage and currents for healthy and faulty feeders.](image)
**Directional Residual Delayed Overcurrent Protection**

- The setting parameters are:
  - Starting current ($I_{\text{start}}$)
  - Characteristic angle (RCA)
  - Operating angle (ROA)
  - Operating characteristic
Directional Residual Delayed Overcurrent Protection

☑ Advantages

☑ It does not require any added primary or secondary element
☑ The earth fault current is not increased

☑ Disadvantages

☑ It cannot detect intermittent earth faults
☑ If the resistance of the Petersen coil is low, then the wattmetric component of the fault current is too low → it is hard to set the characteristic well
☑ It requires $U_0$ voltage (and of course $I_0$ current)
TRANSIENT EARTH
FAULT PROTECTION
The symmetrical component network at the transient:

- Healthy
- Faulty
- Petersen

- $I_{\text{healthy}}$
- $I_{\text{faulty}}$
- $I_{\text{meas}}$
- $U_0$
The zero sequence voltage and currents at the faulty moment:

Healthy feeder:

Faulty feeder:
The setting parameters are:

- Minimal residual voltage ($U_{0,\text{min}}$) and current ($I_{0,\text{min}}$)
- Number of the counted peaks
- Reset time after the last detected peak ($T_{\text{reset}}$)
TRANSIENT EARTH FAULT PROTECTION

☑ Advantages
☐ It does not require any added primary or secondary element
☐ The earth fault current is not increased
☐ Very simple solution
☐ The list of parameters is short

☑ Disadvantages
☐ It cannot detect the stable earth faults with high fault resistance
☐ It requires $U_0$ voltage (and of course $I_0$ current)
NEW METHOD: ADMITTANCE EARTH FAULT PROTECTION
The symmetrical component network:
ADMITTANCE CHANGE METHOD

- The zero sequence voltage and currents

Healthy feeder:

Faulty feeder:
The measured zero sequence admittances ($3I_0/3U_0$):

<table>
<thead>
<tr>
<th></th>
<th>$\Delta Y$ switched OFF</th>
<th>$\Delta Y$ switched ON</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy feeder</td>
<td>$YC$</td>
<td>$YC$</td>
<td>0</td>
</tr>
<tr>
<td>Faulty feeder</td>
<td>$-(YC+YP)$</td>
<td>$-(YC+YP+\Delta Y)$</td>
<td>$\Delta Y$</td>
</tr>
</tbody>
</table>
Admittance Change Method

- The application:
The setting parameters are:

- Minimal residual voltage \((U_{0,min})\) and current \((I_{0,min})\)
- Voltage and current transformer ratios
- Admittance value of the added coil
- Line parameters (for calculating the fault location only)
Advantages

- It can detect stable faults with high fault resistance
- The earth fault current is not increased
- It can calculate the exact fault resistance
- It can separate the earth faults (all the three types)
- It can be used for adaptive compensation (mentioned earlier)

Disadvantages

- It cannot detect the intermittent fault: it requires a different method. This different method is built to the admittance protection
- It requires $U_0$ voltage (and of course $I_0$ current)
THANK YOU FOR YOUR ATTENTION!

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