KTH ROYAL INSTITUTE
OF TECHNOLOGY

Swedish Resonant-Earthed Systems and Earth-Fault Location Methods

Third Nordic Workshop on Power System Protection and Control

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Outline

- Background
- Resonant-earthed systems in Sweden
- Overview of earth-fault location methods
- Conclusions

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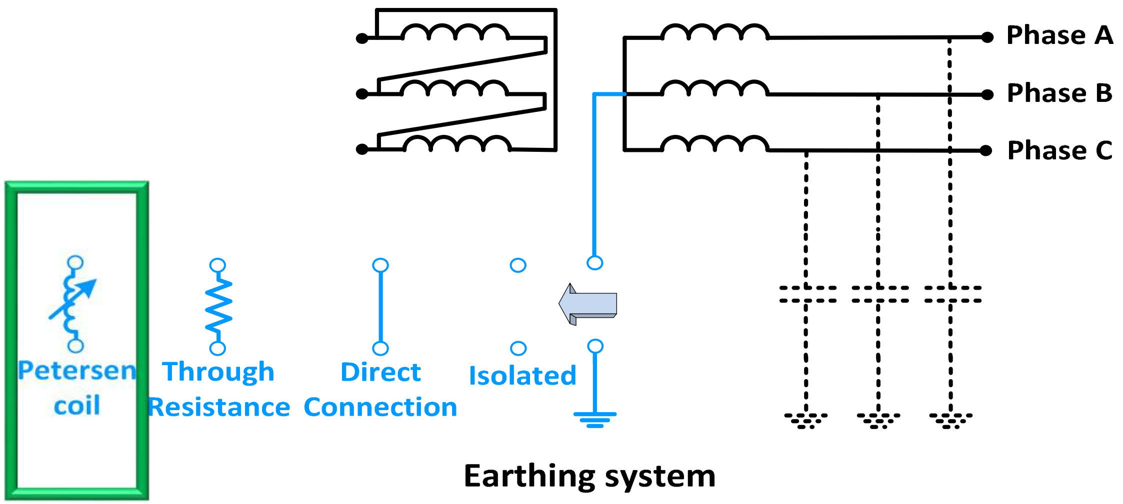
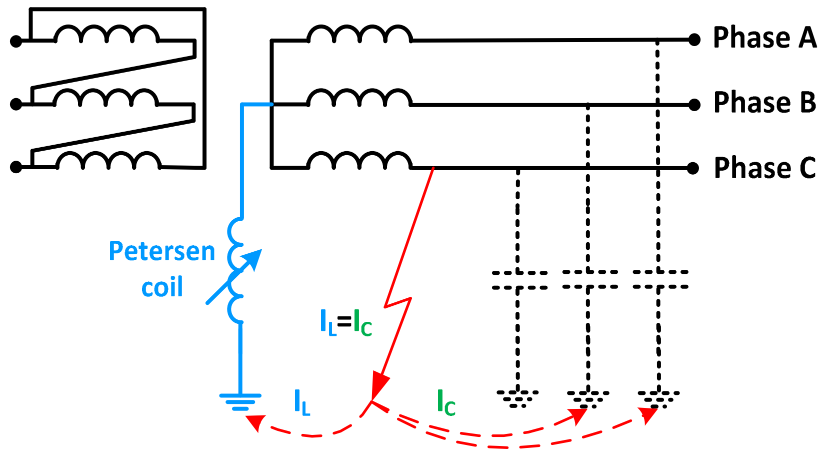
- ➢ Background
- ❑ Few features of MV distribution network in Sweden
- ❑ Overview of earth-fault location methods
- ❑ Conclusions

System Earthing



- System earthing is defined by the connection method between the transformer neutral and the earth
- It is very important for the fault detection, control of the fault current and the operational philosophy of the system

Resonant-Earthed Systems



Resonant-earthed / Compensated network

- ❑ Petersen coil is tuned in such a way that the inductive current compensates the capacitive current during the fault in order to make the fault current close to zero (ideally)

- ❑ Numerous faults are self-extinguishing, e.g. air gap flashovers
  - ➢ Less number of interruptions *(Positive impact on service quality)*

- ❑ Fault localization is very complicated
  - ➢ Long downtime to locate faults *(Negative impact on service quality)*

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Resonant-Earthed Systems in Sweden

- Resonant-earthing is used in the MV distribution networks (10 kV and 20 kV)
- Typically, Petersen coil is used for central compensation. However, distributed compensation is recommended for long feeders with underground cables
- A resistor is kept connected parallel to the Petersen coil during normal operation and automatically disconnected if there is a fault.
- The resistive current through the neutral is kept within the limit of 5 A

Resonant-Earthed Systems in Sweden

- Earth-faults up to 20 kΩ need to be detected and the mandatory limit for line disconnection is 5 kΩ.
- The detection and disconnection should be done within 5 s
- The usual protection for the primary substation is wattmetric-type relays on each outgoing line and the backup is from zero sequence measurement

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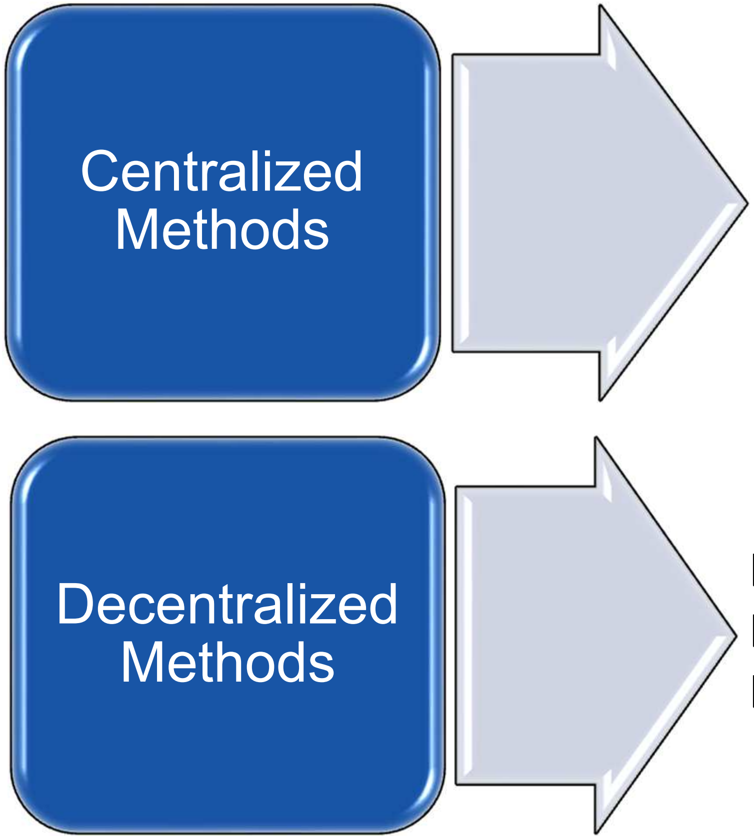
Earth-Fault Location Methods



Centralized Methods:
- ❑ Impedance based
- ❑ Travelling wave
- ❑ Artificial intelligence

Decentralized Methods:
- ❑ Fault Passage Indicators (FPI)
- ❑ Signal injection based
- ❑ Negative sequence component

Earth-Fault Location Methods (Cont.)

- **Impedance based**

  The changes in the zero sequence current and the faulty phase voltage caused by the shunt resistor are utilized the reactance. The fault location is determined through the reactance from the substation to the fault location

  - \+ Simple implementation and cost-effective
  - \- Limited by the accuracy of measurement and network parameters

- **Travelling wave based**

  Travelling waves are generated at the fault location that propagate away from that point in both directions towards the terminals of the line. Fault location can be determined by measuring the travel time and comparing it with the speed of light

  - \+ Theoretical accuracy is very high
  - \- Requires very high sampling rate and costly detection devices
  - \- Branches of distribution network makes it more complicated

Earth-Fault Location Methods (Cont.)

❑ Artificial Intelligence based

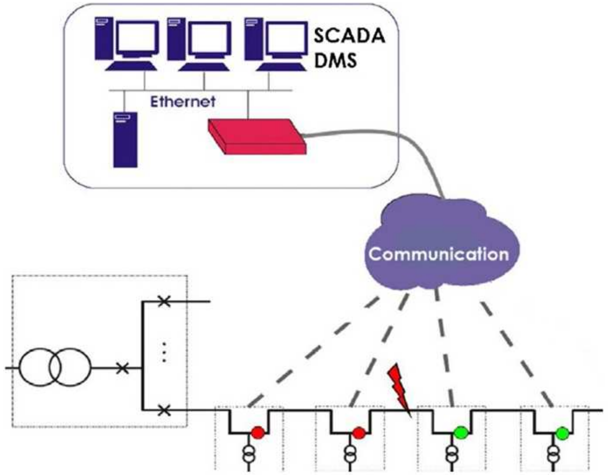
The idea is to train an artificial intelligent system to detect the faulted area utilizing voltage and current information from different substations.

- \+ Might be useful for a highly meshed and complicated network
- \- Almost no evidence on real-life implementations

❑ Fault passage indicator (FPI) based

Some FPI's are capable of detecting the fault and sending this information to the substation. The information can be utilized to identify the faulty section.

- \+ High sensitivity and verified functionally
- \- Requires FPI's along the feeder which might become challenging (economically) for some network structures

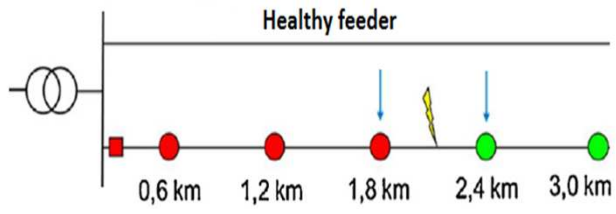


FPI based decentralized earth-fault location method

Earth-Fault Location Methods (Cont.)

- **Negative sequence component based**

  The negative sequence current is significant from the feeding substation up to the fault point, but not afterwards. If Condition 1 is satisfied then the fault section is between the last secondary substation with $\Delta I_{negseq} > I_{negseq\_set}$ and the first secondary substation with $\Delta I_{negseq} < I_{negseq\_set}$



Negative sequence component based earth-fault location method

Condition 1: $\Delta I_0 > I_{0\_set}$; ***Condition 2:*** $\Delta I_{negseq} > I_{negseq\_set}$

  - Evaluation is done through simulation only

- **Signal injection method**

  The method is based on the injection of non-grid-frequency to the neutral of the system. Signal detection and communication are also required in order to identify the faulty section.

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Conclusions

- Different solutions are available for identifying the earth-fault location but only few are tested in the real system
- Most of the centralized methods are subjected to the network features, measurement errors and uncertainty of the fault resistance and the load current
- Installation of FPI's is becoming a promising solution to locate the fault section between two FPI's. Recent focus is to centrally collect the information from different FPI's
- The identified section can be of several kilometers long as it is typically defined by the length between two measurement points
- More studies need to be done to improve the fault location accuracy especially if the section contains both overhead lines and underground cables

Thank you

for your attention