MCEDD

DEEPWATER DEVELOPMENT

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GULF QUEST

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Role of Electrical Protection in ETH-PiP system

Michal Lazarczyk

Radoslaw Jez

TechnipFMC

Agenda

1. Flow assurance problems for subsea pipelines
2. Electrically Trace Heated Pipe in Pipe (ETH-PiP)
3. General role of Electrical Protection
4. ETH-PiP protection challenges
5. Key requirements in the protection of ETH-PiP
6. Conclusions

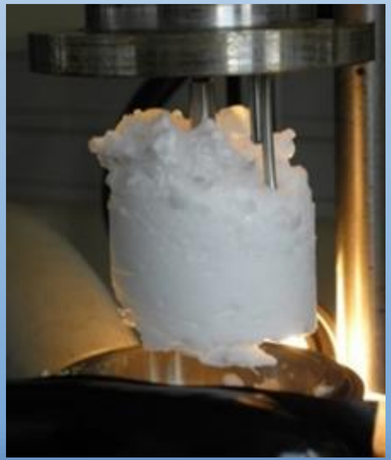
Flow Assurance Problems for Subsea Pipelines

Typical **length** of subsea oil pipeline: 20km - 80km

Typical ambient temperature at seabed: -1°C to 10°C

Typical hydrate/wax appearance temp.: 25°C - 35°C

Result:
Risk of plugging during turndown phases.


Hydrate plug

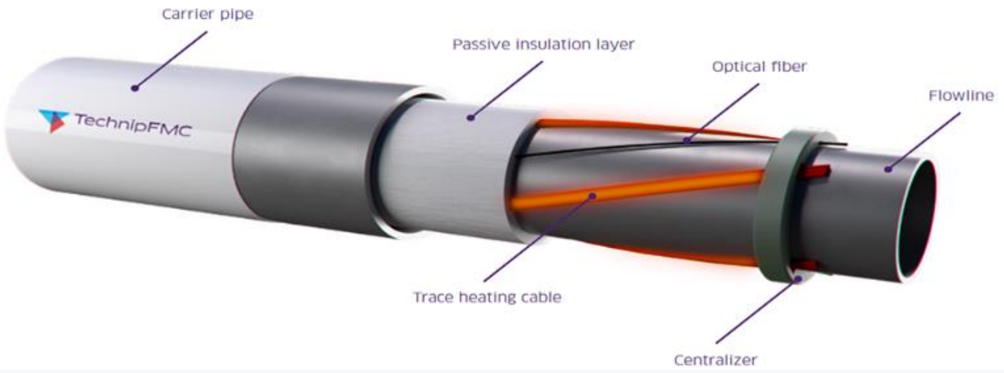

Wax plug

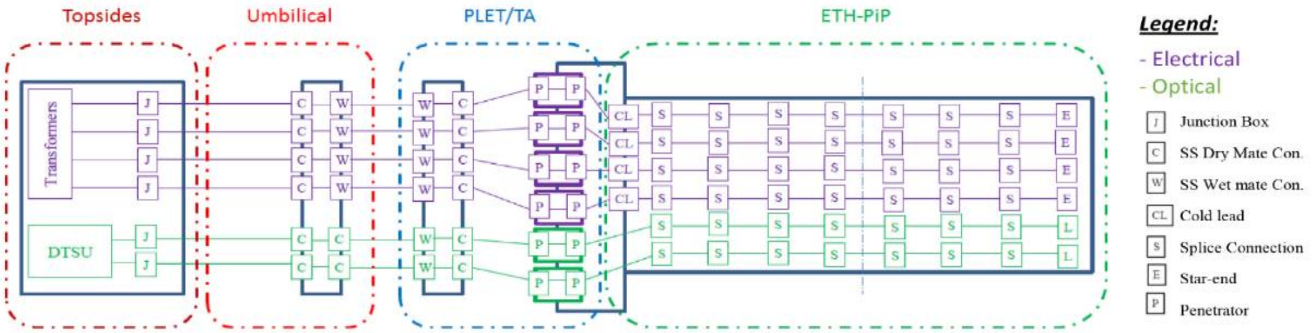
Produced fluids enter pipeline at temp. 50-150°C and cools down along the pipeline

Production fluid is multiphasic by nature and prone to hydrate and wax formation

Electrically Trace Heated Pipe in Pipe (ETH-PiP)

- Active heating technology for flow assurance
- Heat produced by Joule effect in heating cables
- System based on pipe-in-pipe technology equipped with heating cables
- System can be seen as a long heating/transmission line with load distributed along a pipeline
- Challenge of electrical modelling (a long load with distributed parameters and permanent short circuit at the end)
- Influence on modelling accuracy (distributed model of ETH cable required for computation)





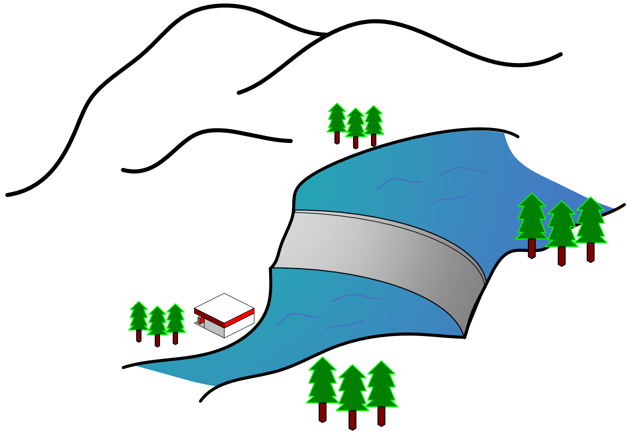
Faults in Power Systems

Why do we need electrical protection?

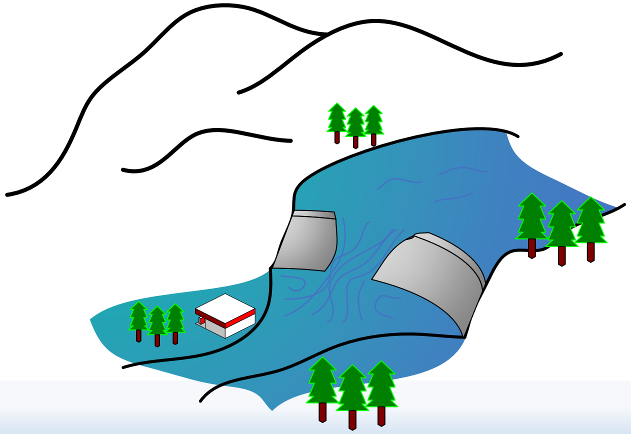
- In **normal operation** (healthy system condition) all parameters are within safety limits

- In **a fault case** (e.g., short circuit or insulation deterioration) some physical parameters are out of safety limits:
  - the current can be higher than nominal value,
  - the voltage can be below/over the nominal value,
  - the temperature over the nominal value,
  - the load impedance out of the range
    - impedance lower than nominal → insulation deterioration or short-circuit
    - impedance higher than nominal → break of electric path continuity

Nominal operation

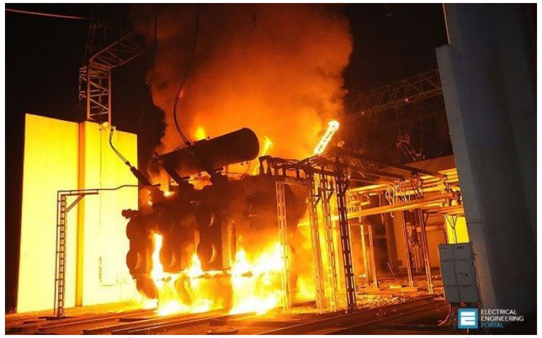


Fault case (overcurrent)



General Role of Protection in Power Systems

Why do we need electrical protection?



source: Electrical Engineering Portal

- Consequences of system operation in a fault condition:
  - Risk of explosion/destruction of system components
  - Risk of a fault propagation to other system components
  - Risk for health and life
- **Solution** → Electrical Protection system
  - Permanent monitoring of entire system conditions
  - In the case of fault detection:
    - Faulty part of a system is turned-off
    - Healthy part of system can be still in a power-on condition

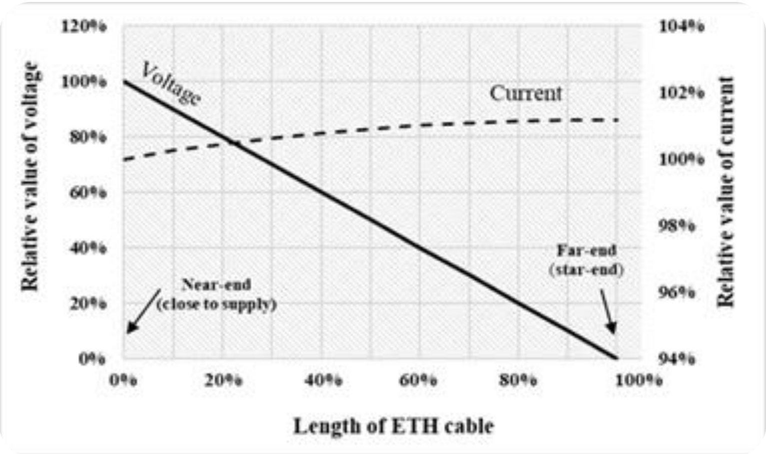
- A fault can occur due to number of reasons, not all are predictable.
- Electrical protection does not protect power system against fault appearance.
- Electrical protection protects the power system against long-term consequences of fault and separates faulty part from healthy part of a system.

ETH-PiP Protection Challenges

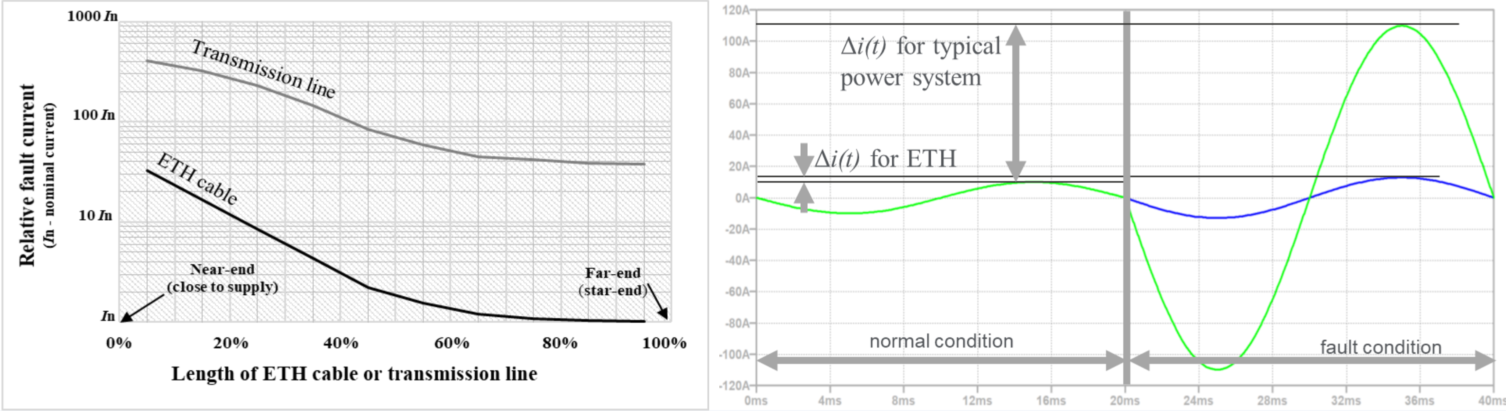
- Typically, in power system fault amplitudes are much higher than a nominal current level
- Fault current amplitudes are much lower for ETH system than usually expected in a power system
- For ETH system fault current amplitude decreases close to the level of nominal current if the fault is located beyond approx. 60% of the pipeline length

Consequence:
challenges for protection of ETH-PiP system

Voltage current profile



Fault currents for ETH-PiP power system

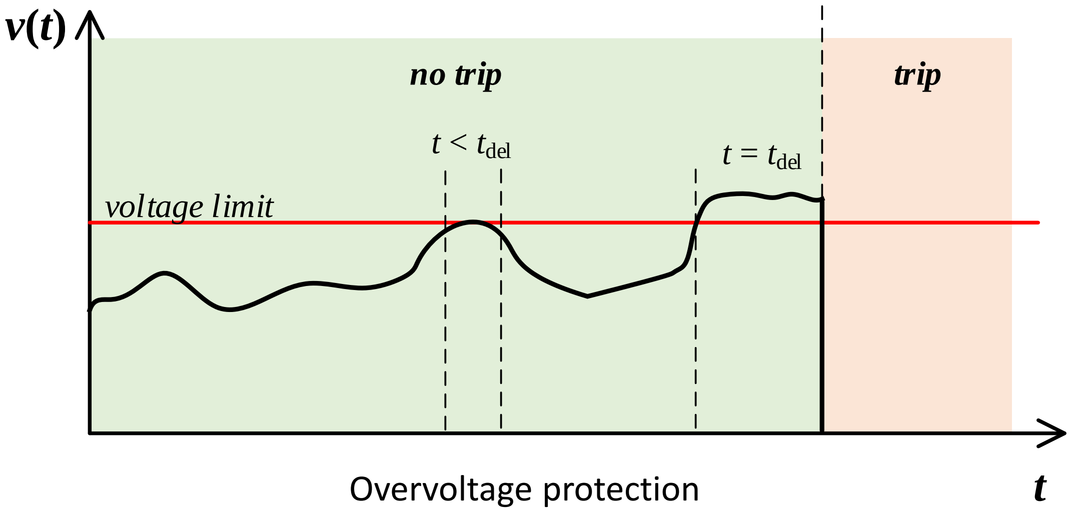


Examples of Protection Functions Applicable to the ETH-PiP System

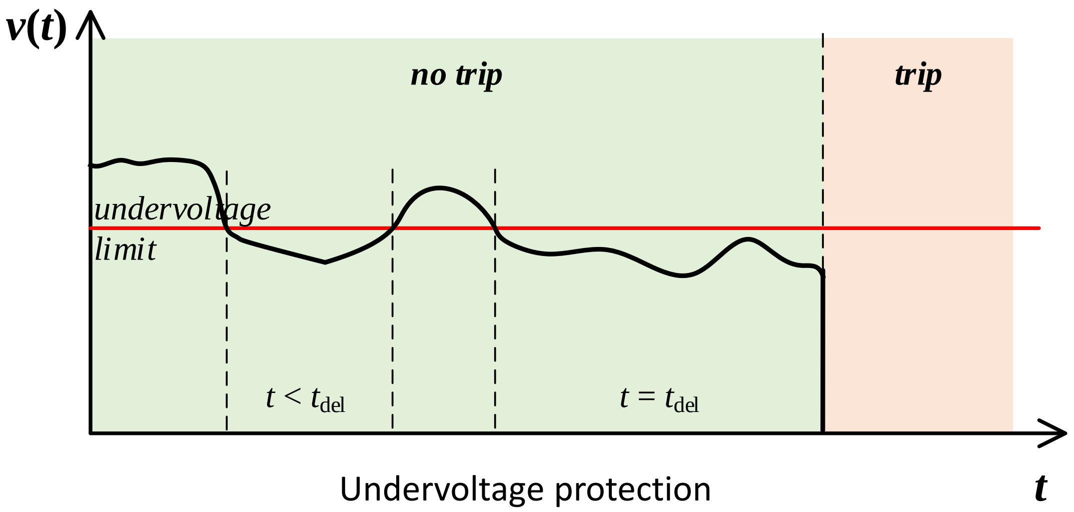
- Overvoltage / Undervoltage protection
- Overcurrent protection
- Phase unbalance protection
- Impedance (distance) protection
- Neutral overvoltage protection
- Neutral overcurrent protection
- Directional overcurrent protection
- Thermal protection
- Insulation Monitoring

Overvoltage/Undervoltage Protection

- The voltage level (phase-phase and phase-ground) is continuously monitored
- Normal operation: the voltage is at nominal level (it may vary within assumed margin)
- Overvoltage fault: If the voltage exceeds acceptable limits the appropriate action is initiated
- Undervoltage fault: If the voltage is below acceptable limits the appropriate action is initiated



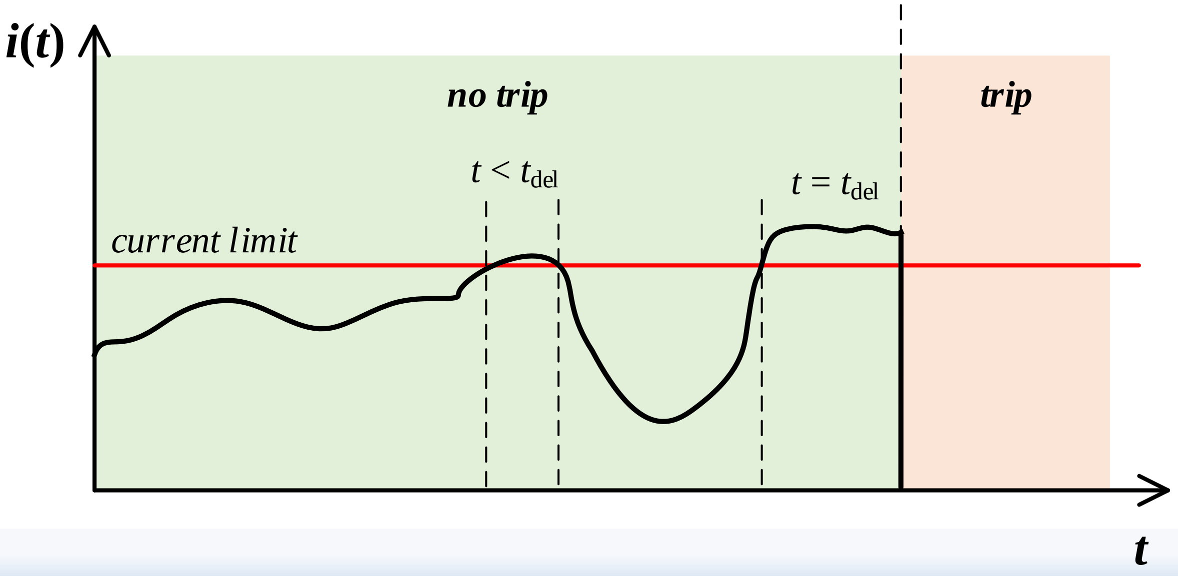
Overvoltage protection



Undervoltage protection

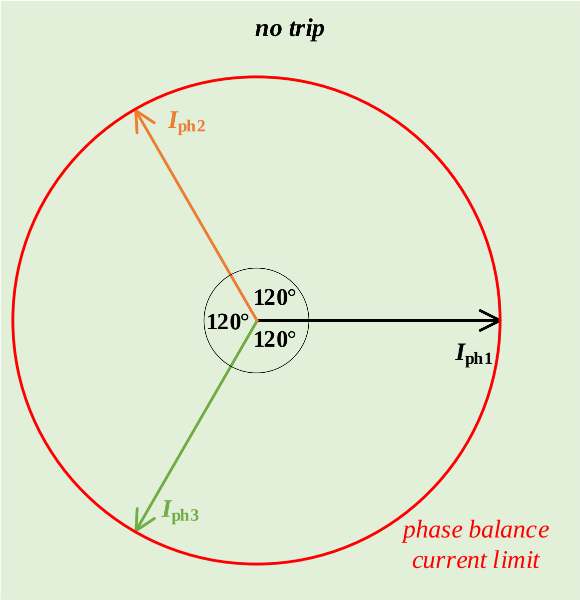
Overcurrent Protection

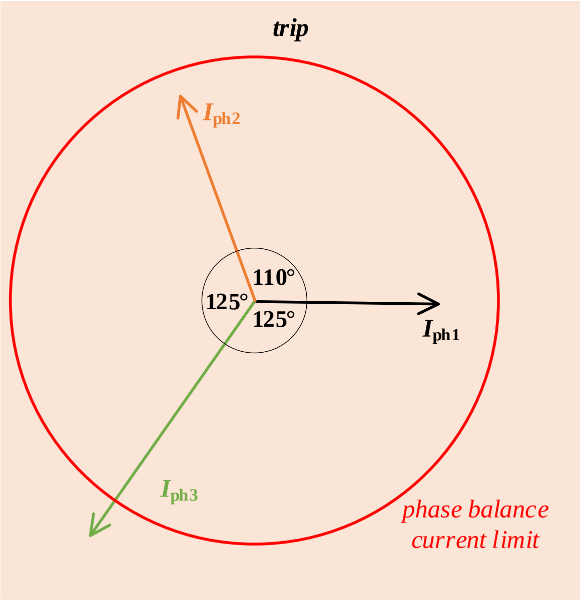
- The current level (in each phase) is continuously monitored
- Normal operation: the current is no higher than nominal level (it may vary depending on the load conditions)
- Overcurrent fault: If the current exceeds acceptable limits the appropriate action is initiated



Phase Unbalance Protection

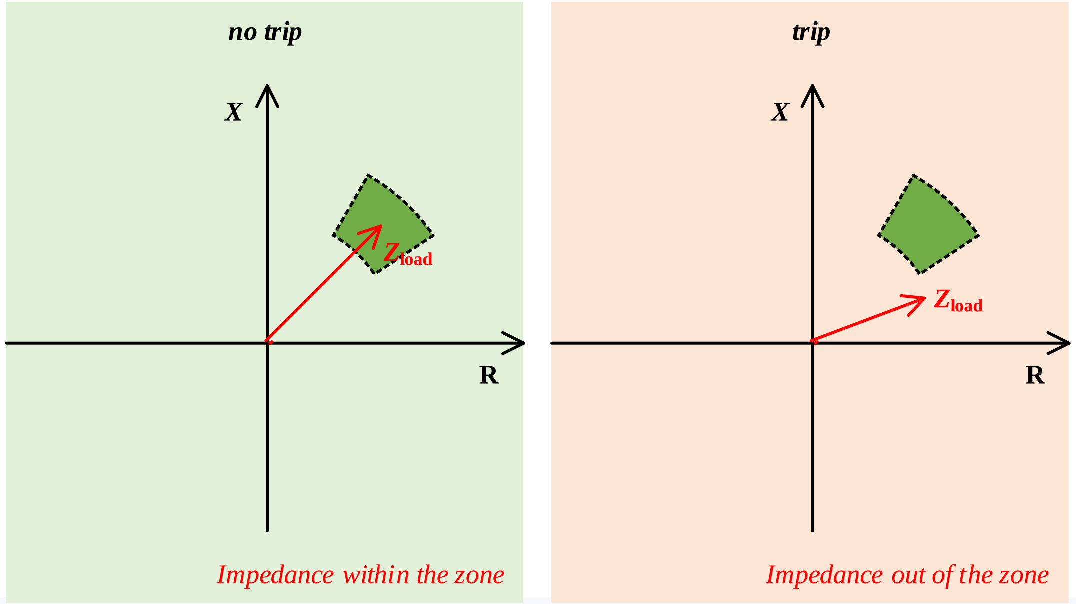
- The current amplitudes and phase shifting (in each phase) is continuously monitored
- Normal operation: current amplitudes similar for each phase & phase shifting is ~120°
- Unbalance fault: If unbalance of current amplitudes or phase shifting exceed acceptable limits the appropriate action is initiated





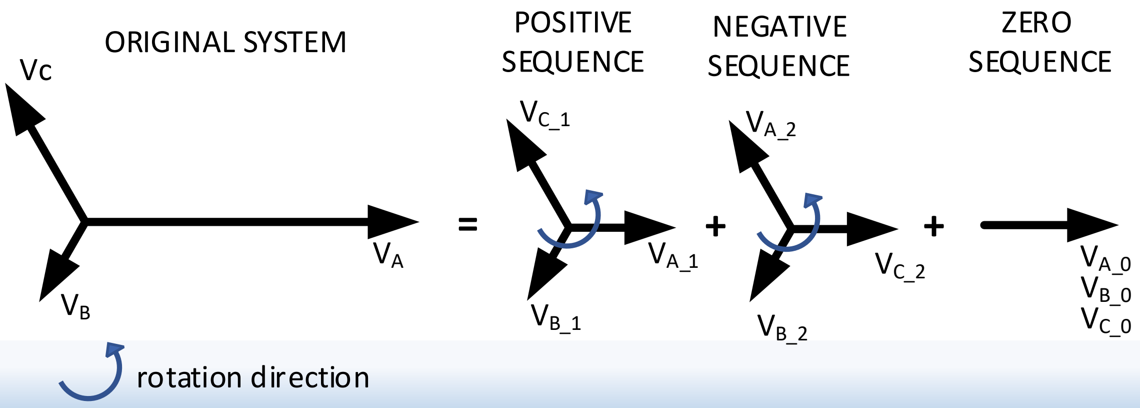
Impedance (distance) Protection

- Impedance vector is continuously monitored (based on voltages and current waveforms)
- Normal operation: impedance vector resides within the nominal zone
- Impedance fault: If impedance vector leaves the nominal zone the appropriate action is initiated



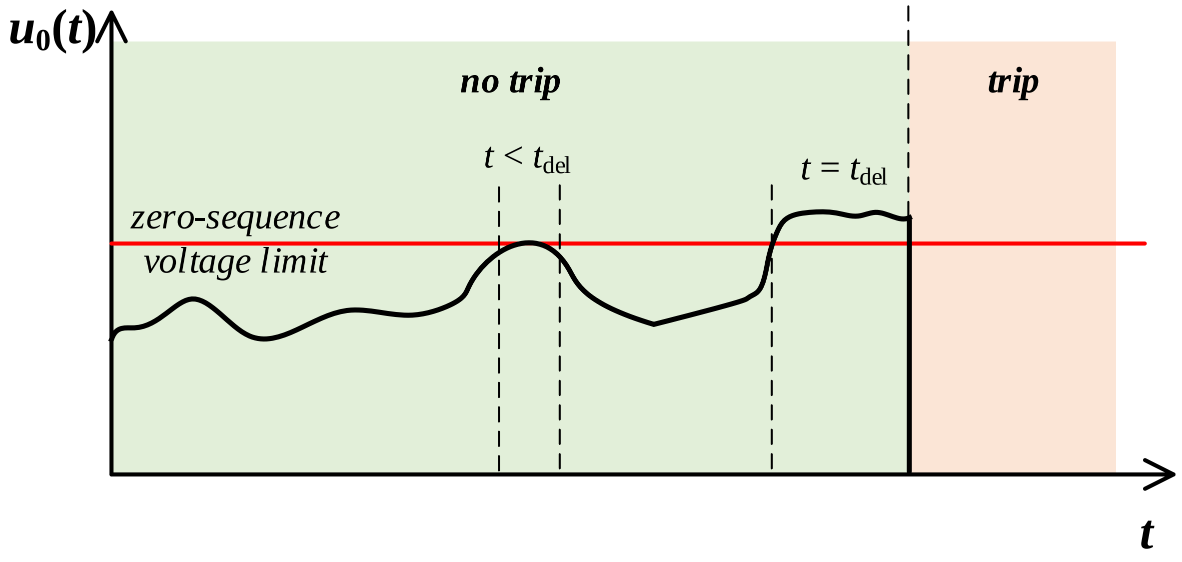
Voltage and Current Symmetrical Components

- **Symmetrical components**: three-phase system in normal and abnormal condition can be described by three phasors' sequences: direct component (or positive sequence), inverse components (or negative sequence) and zero component (or homopolar sequence)
- **Positive sequence** – the natural set of phasors that can be expected in an ideal system.
- **Negative sequence** – the balanced three phasors with reversed order
- **Zero sequence** – balanced three phasors having the same phase angles



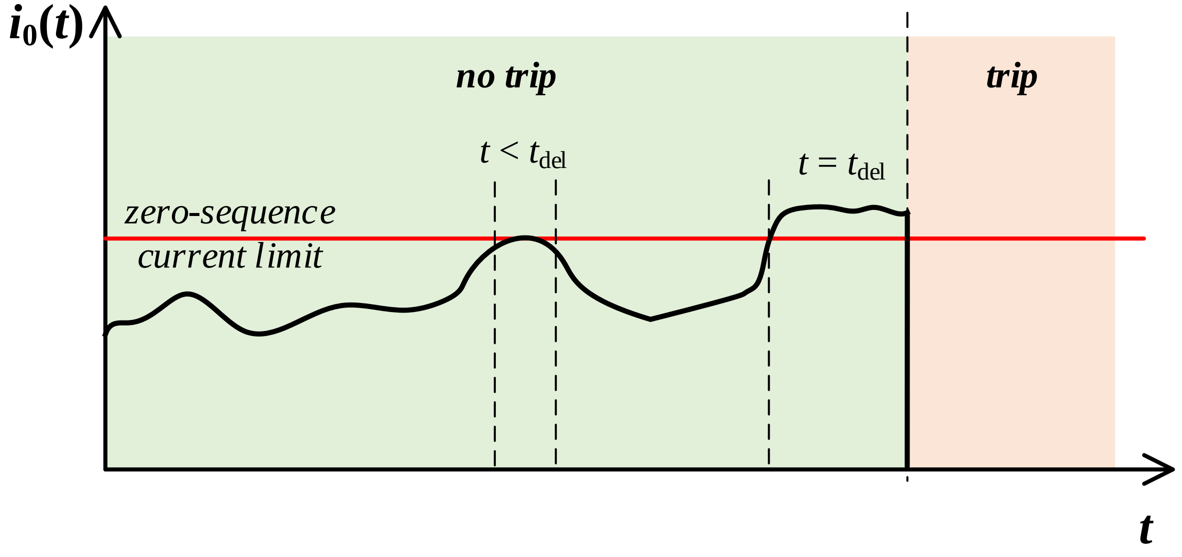
Neutral Overvoltage Protection

- Zero sequence of voltage is continuously monitored (based of phase voltages)
- Normal operation: zero seq. value is very close to „0" (for perfectly symmetrical system is exactly „0")
- Neutral overvoltage fault: fault causes voltage imbalance – zero seq. is much higher than „0"- this fact is detected, and the appropriate action is initiated



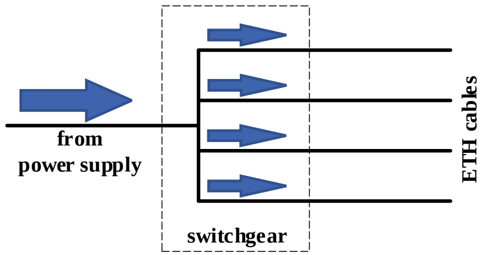
Neutral Overcurrent Protection

- Zero sequence current is continuously monitored (based of phase currents)
- Normal operation: zero seq. value is very close to „0" (for perfectly symmetrical system is exactly „0")
- Neutral overcurrent fault: fault causes imbalance of phase currents – zero seq. is much higher than „0"- this fact is detected, and the appropriate action is initiated

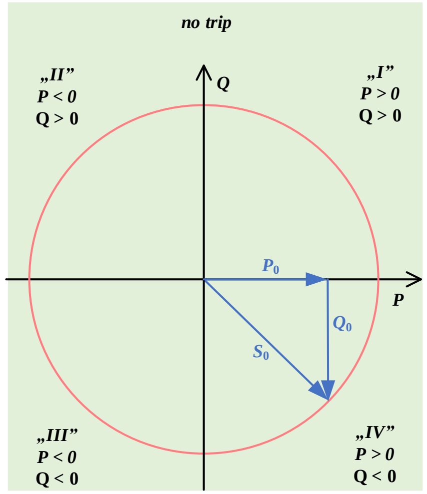


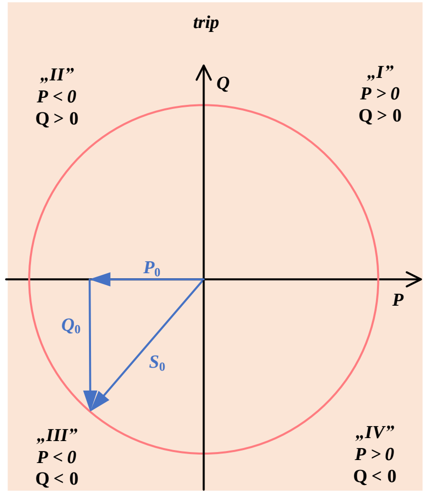
Directional Overcurrent Protection

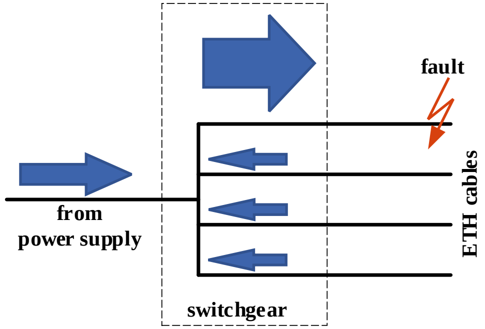
- Phase voltages and currents are continuously monitored
- Normal operation: the phase shift between voltage and current phasors resides within nominal zone
- Directional overcurrent fault: the phase shift between voltage and current phasors changes the angle (the energy flow direction is reversed – it flows from the entire system to the faulty place) – in the case of detection the appropriate action is initiated



Normal operation
(energy flows from a source to loads)



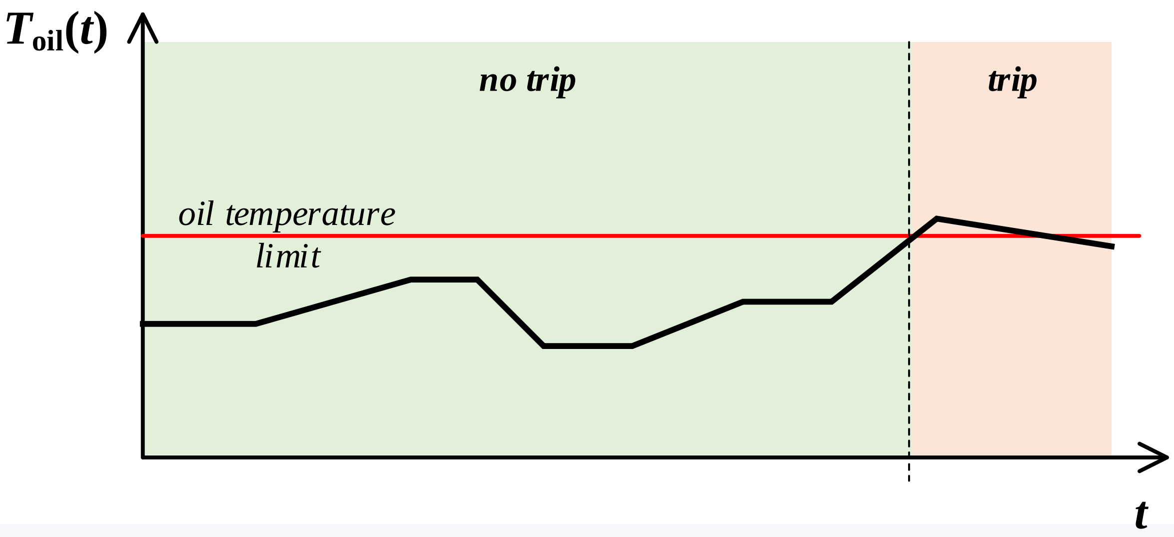




Fault operation
(energy flows from entire system to the faulty place)

Thermal Protection

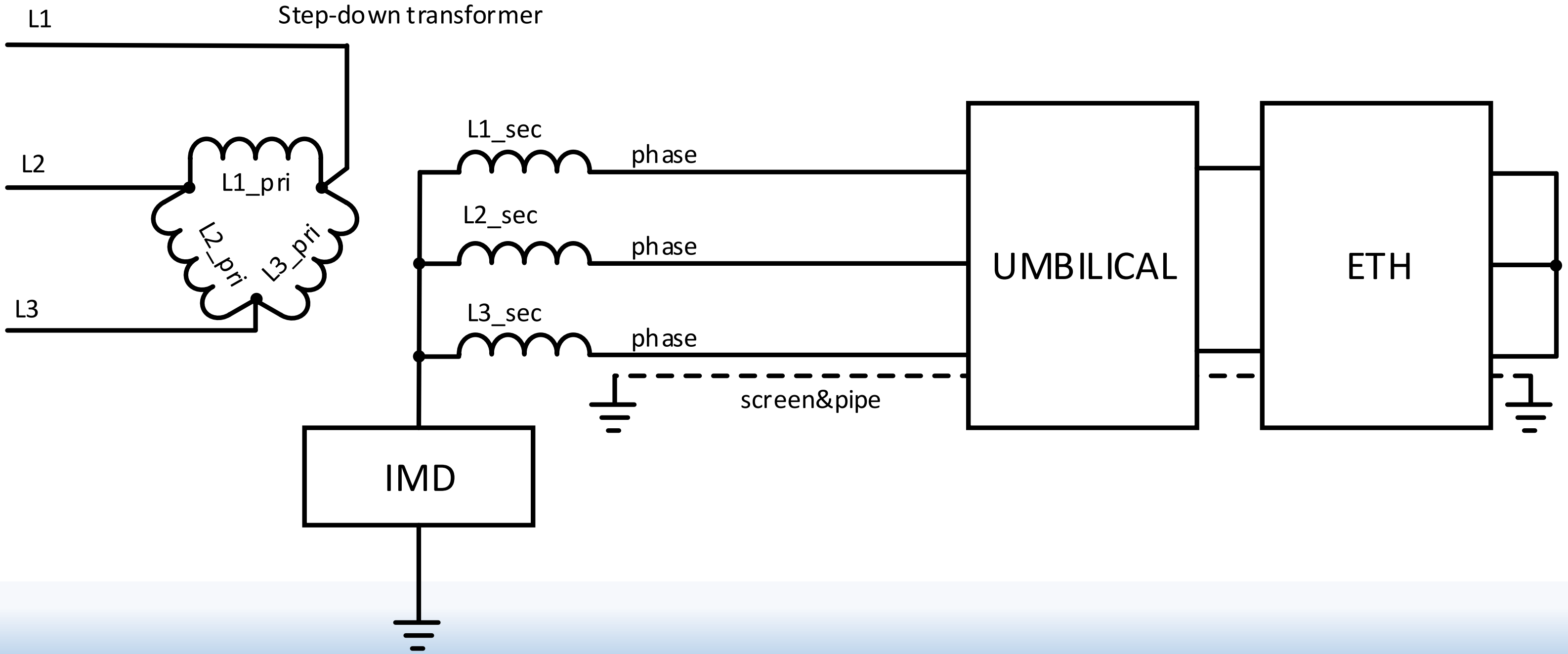
- Temperature of sensitive system components (e.g., transformer) is continuously monitored
- Normal operation: temperature is below the limit
- Thermal fault: if temperature across the limit the appropriate action is initiated



Insulation Monitoring

Implemented in form of an Insulation Monitoring Device (IMD)

- IMD is dedicated for use in ungrounded (isolated) systems – it injects the voltage signal to the neutral point of a transformer and monitors the grounding current
- Normal operation: the grounding current is below detection level (~nanoamperes)
- Insulation fault: the current is significantly higher (hundreds of milliamperes)



Key Requirements in the Protection of ETH-PiP

- **Selectivity:** the reaction to faults shall occur only in the monitored and protected part of electrical system (in ETH-PiP selectivity highly depends on **system topology**)

- **Speed of reaction**: as short as possible, but with time reservation on the fault confirmation (in ETH-PiP speed of reaction highly depends on **implemented protection functions**)

- **Reliability**: the protection system shall consistently detect over a wide range of operating conditions, while minimizing false calls, (in ETH-PiP reliability highly depends on protection functions **settings**)

- **Sensitivity**: the absolute amount of change that can be detected by the protection system shall be as small as possible (in ETH-PiP sensitivity highly depends on a **fault type and fault location**)

Key Engineering Steps in ETH-PiP Protection Design

- **Early-stage Evaluation:** identify and analyze relevant fault scenarios through power system analyses.
- **Definition of Electrical Protection Strategy:** address identified scenarios and comply with relevant regulations.
- **Selection of Protection Functions:** select set of protection functions to cover all potential fault scenarios and define associated settings.
- **Verify:** through dedicated power system analyses as well as in field during commissioning.

Conclusions

- The electrical protection system is a **key component** of any ETH-PiP application.
- **Is protection system preventing occurrence of faults?**
  - **NO -** the role of protection system is to detect faults, isolate affected part and allow rest of the system to continue operating
- **Can we use one super protection function to cover all faults?**
  - **NO** - due to the specific ETH-PIP topology, the protection strategy cannot be based on a single monitored parameter but shall rely on the monitoring of various ones.
- **Should we implement all possible protection functions in each ETH-PiP project?**
  - **NO** - the protection system should cover real condition of the ETH – PiP system operation
- **How to approach electrical protection system dedicated for the ETH-PiP?**
  - For each ETH-PIP application a **project specific protection strategy** shall be defined.
  - The protection strategy should cover selection of protection functions, selection of relays and the auxiliary equipment, settings of protection devices etc.
- **TechnipFMC ensures that power system protection requirements for our heating solutions are met to the highest standard**

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