NTNU – Trondheim
Norwegian University of
Science and Technology

Fault location in compensated networks using PMU measurements

The Nordic Workshop in Power System Protection and Control
Trondheim, 23.5.2017

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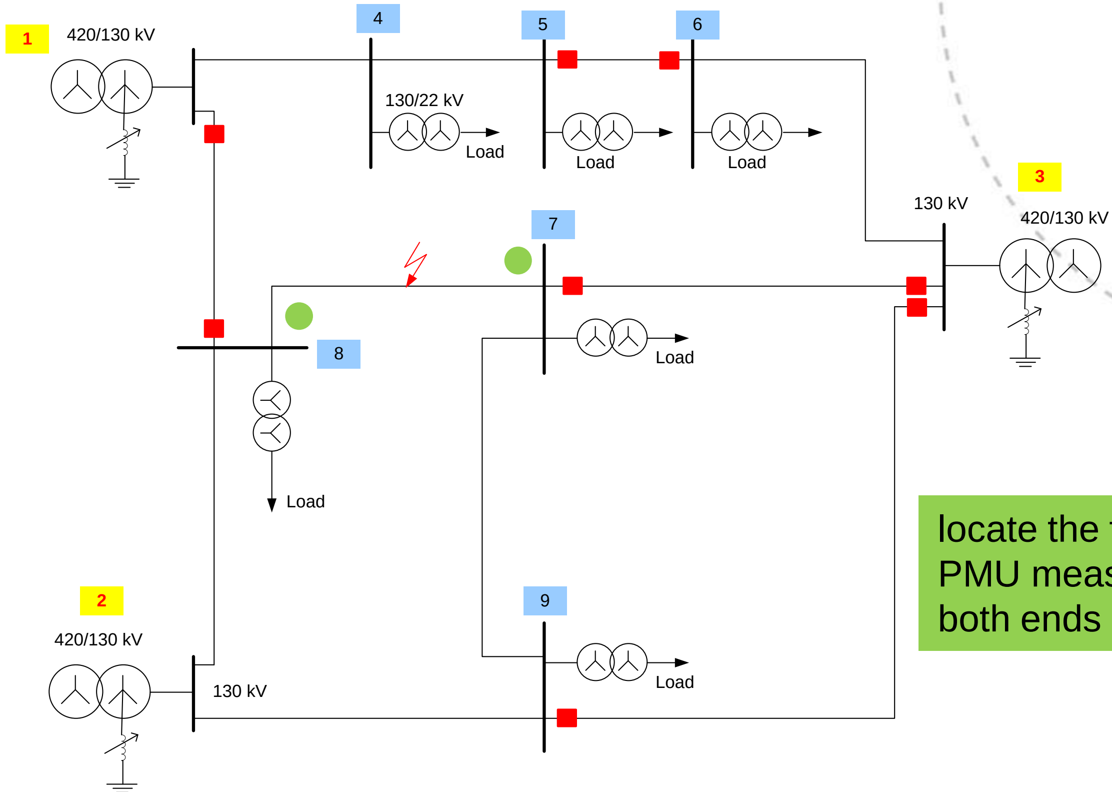
Outline:

1. Background
2. Fault location
3. Results

1. Background

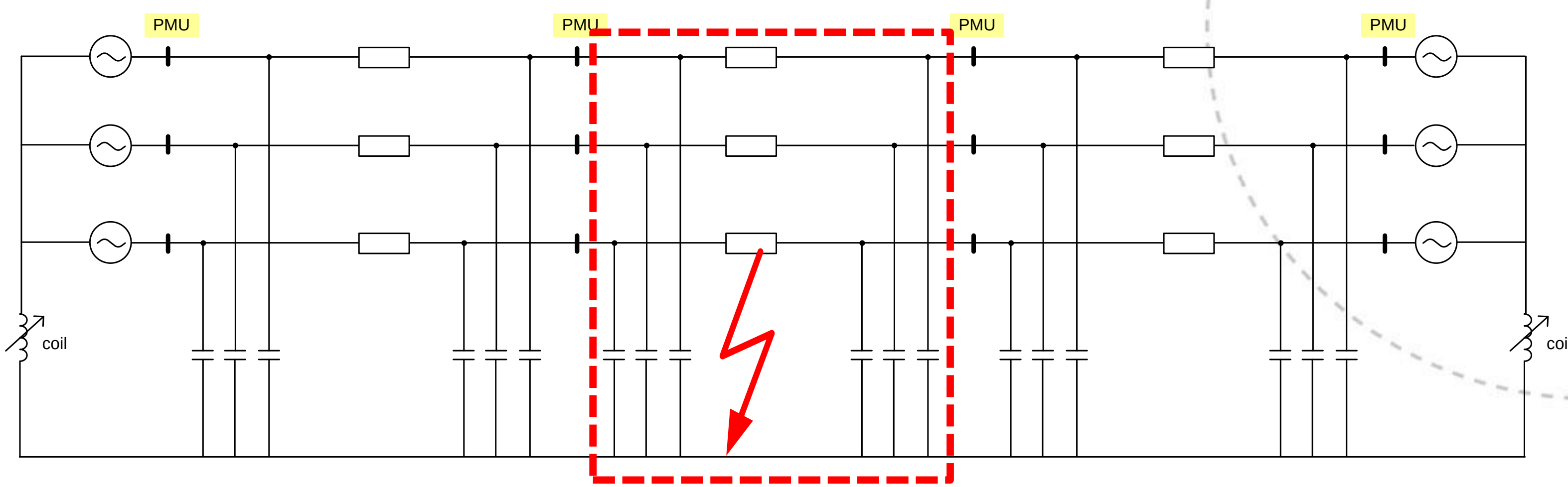
A 130 kV compensated network



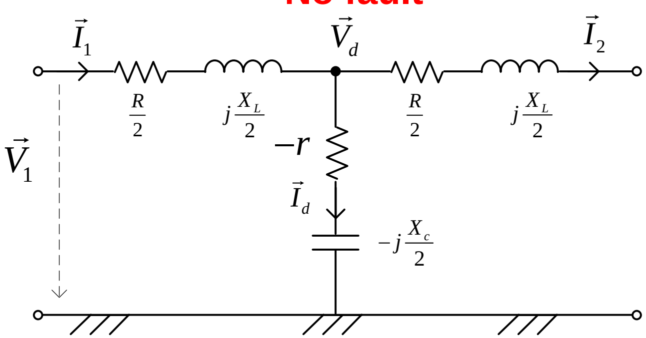
locate the fault based on PMU measurements at both ends of the line

1. Fault location takes time and weakens security of power supply
2. Wischer relay is mainly used in Norway for fault localization
3. PMU will be widely used in the near future, it is just a function in protective relays

2. Fault location in compensated network

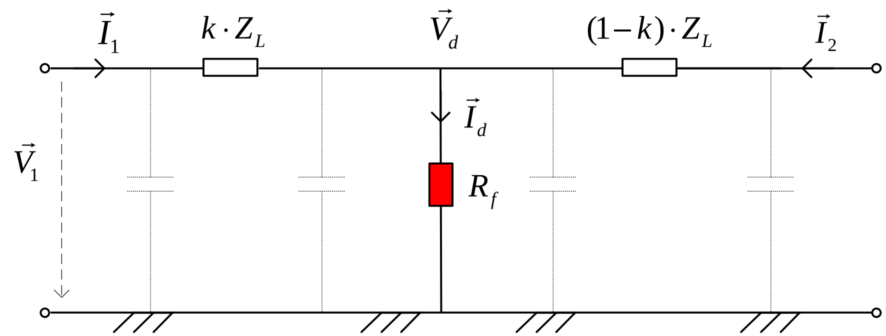


No fault



Around 90^0

fault

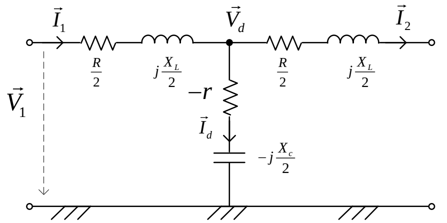


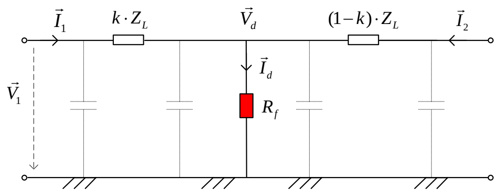
Around 0^0

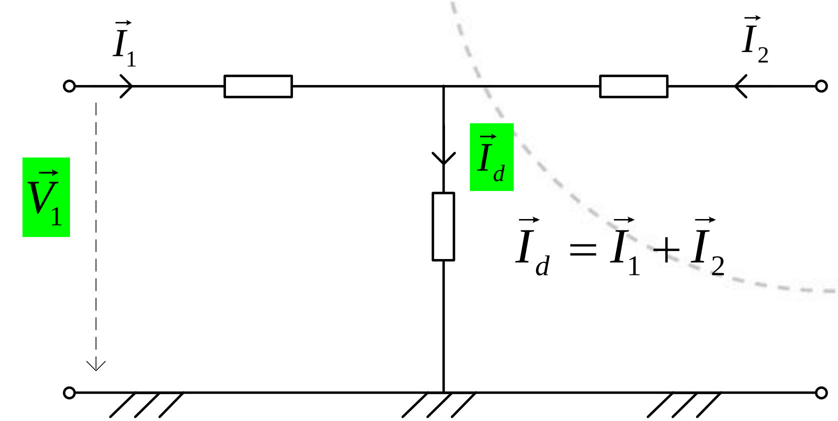
It is difficult to compute V_d since fault location is unknown

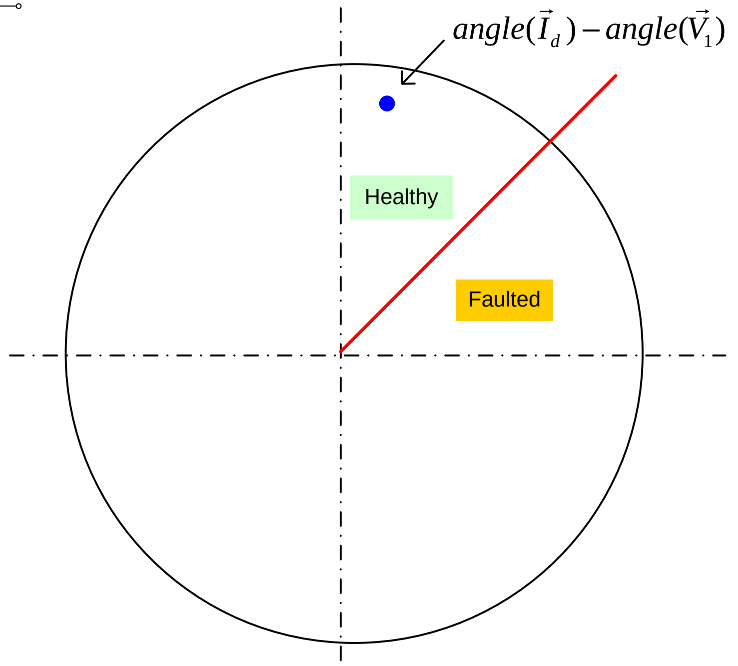
2. Fault location in compensated network

What about the terminal voltage and differential current?



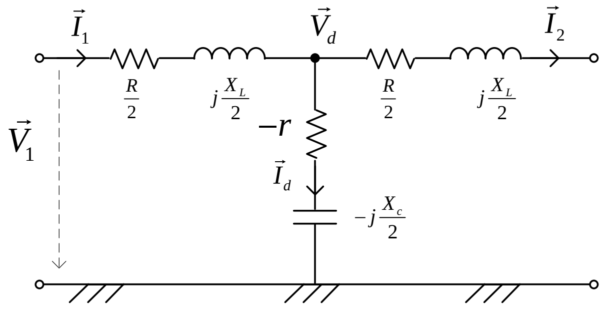




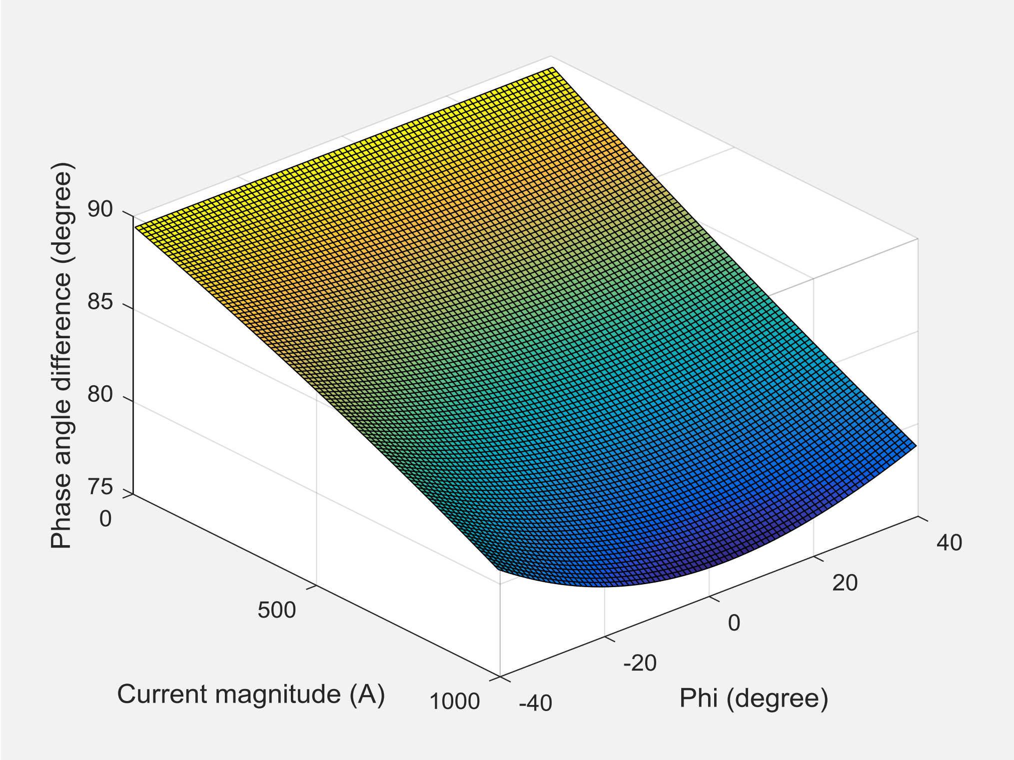


2. Fault location in compensated network

No fault condition

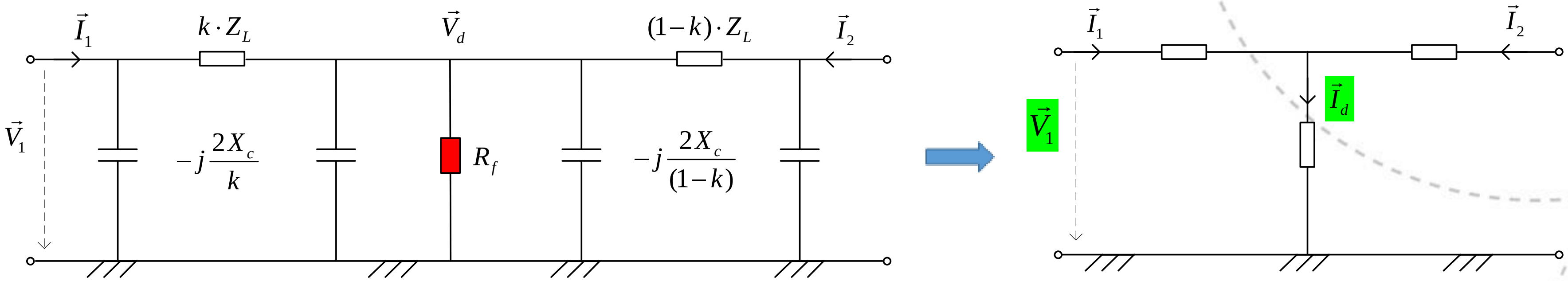


$$Z = 9.58 + j33$$
$$G = 0.5e-6$$
$$B = 1.11e-4$$



2. Fault location in compensated network

Fault condition

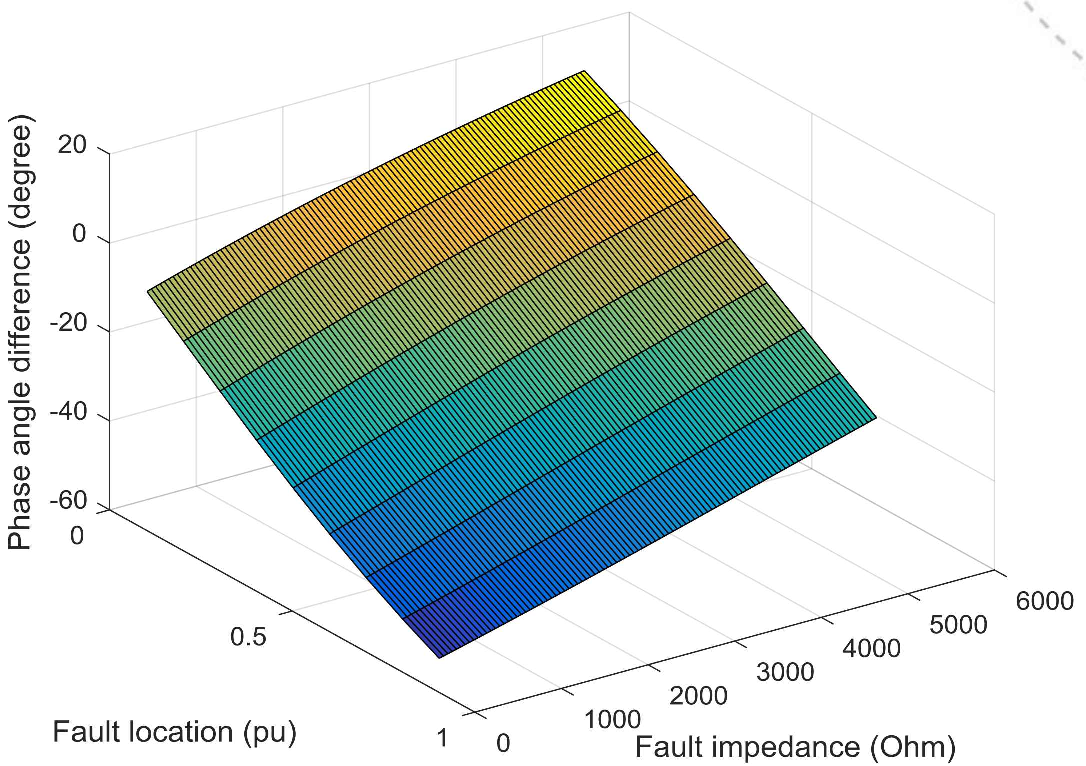


- Consider the angle between $\mathbf{V_1}$ and $\mathbf{I_d}$
- It is a function of:
  1. Fault location (k)
  2. Fault resistance (R_f)
  3. Voltage (V_1) of the faulted phase
  4. Current (I_1) of the faulted phase

2. Fault location in compensated network

Fault condition

Impact of fault location and fault impedance



$V_1 = 0.2*Un$
$I_1 = 500$ A
Phi = 3^0

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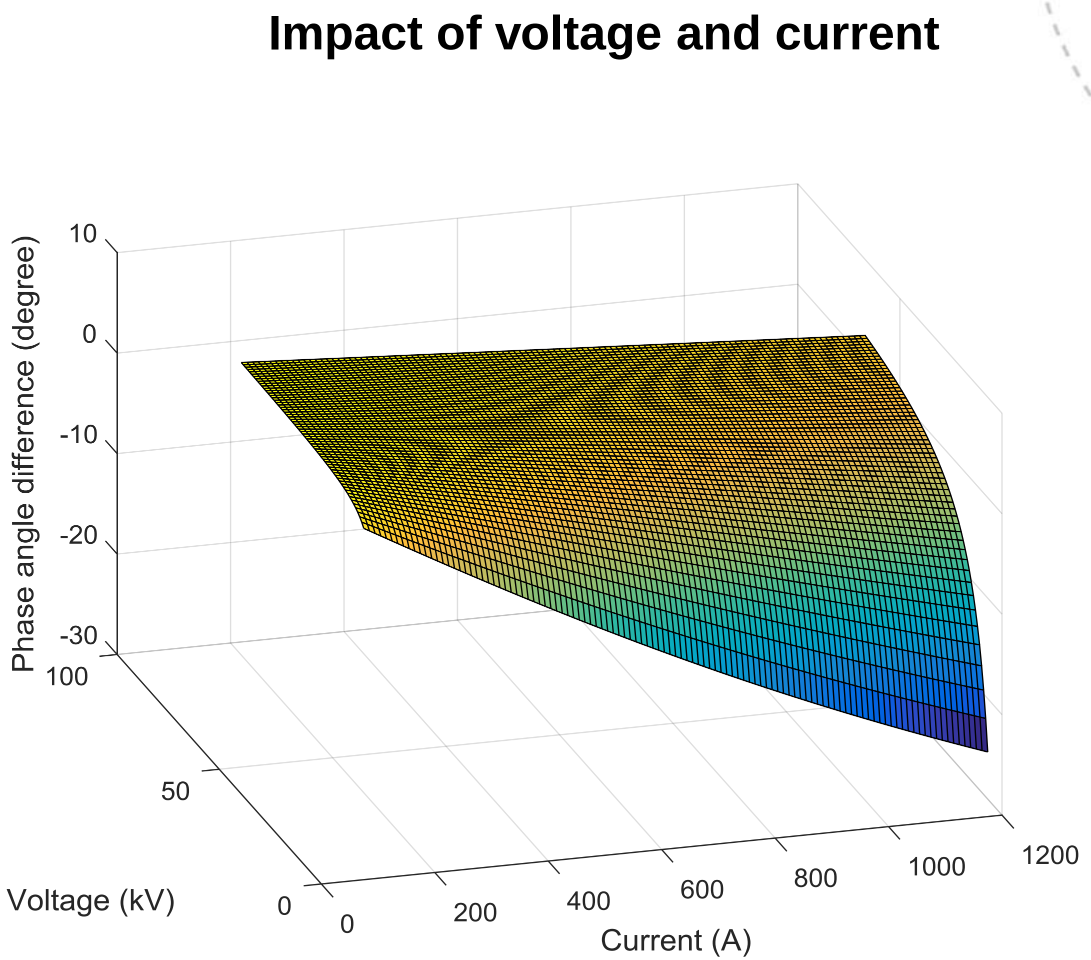
2. Fault location in compensated network

Fault condition

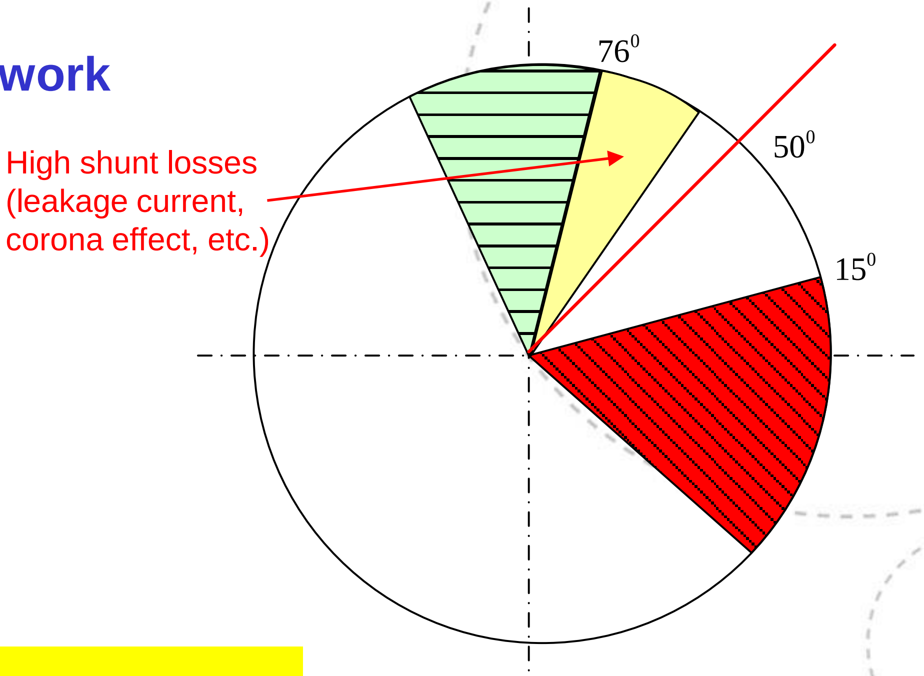


$R_f = 1000$
$k = 0.1$
$Phi = 4^0$

2. Fault location in compensated network

Detection of faulted line

- **Monitor each phase of the line.**
- **Compute phase angle difference between the differential current and terminal voltage where active power is active.**
- **Check the angle difference against predefined threshold (50^0)**



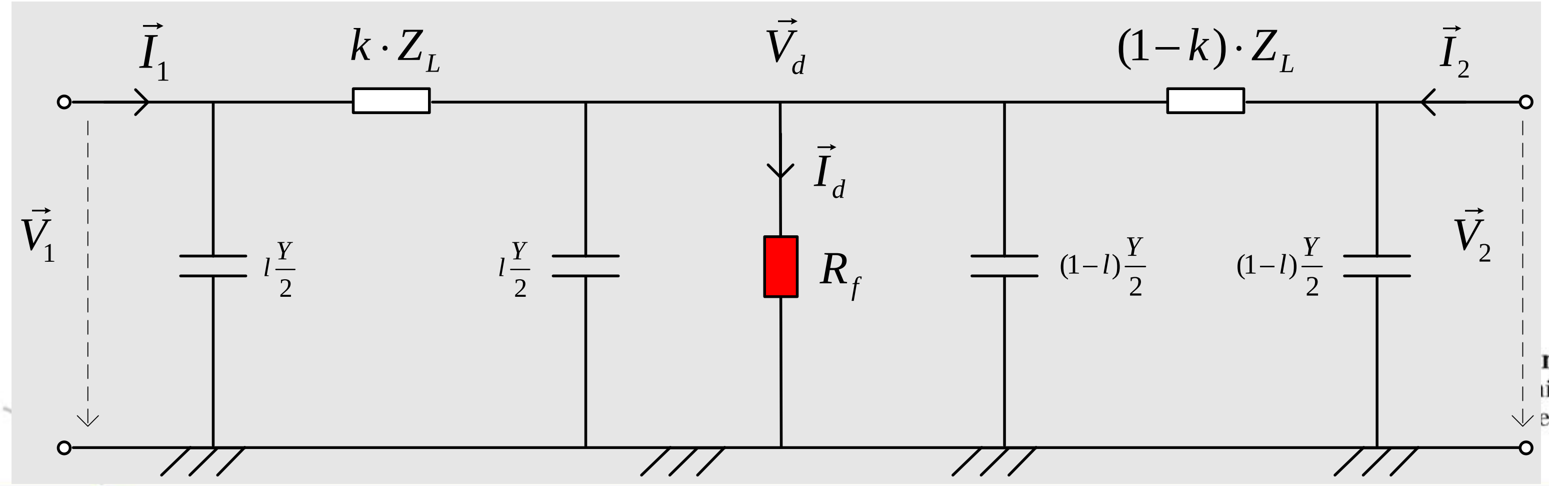
Fault location

$$a \cdot k^2 + b \cdot k + c \cdot k = 0$$

$a = Y \cdot Z \cdot (\vec{V}_1 - \vec{V}_2)/2$

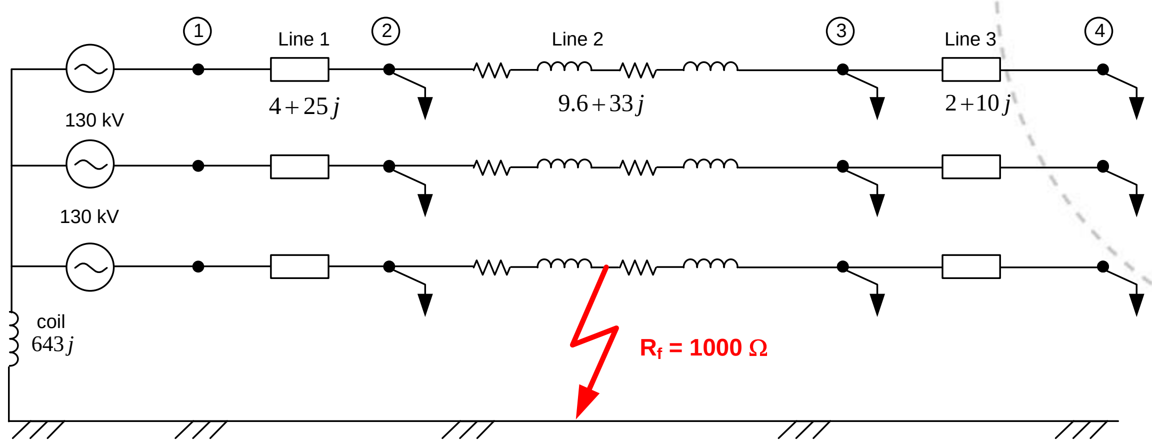
$b = Z \cdot (\vec{V}_2 \cdot Y - \vec{I}_1 - \vec{I}_2)$

$c = \vec{V}_1 + \vec{I}_2 \cdot Z - \vec{V}_2 (1 + Y \cdot Z / 2)$

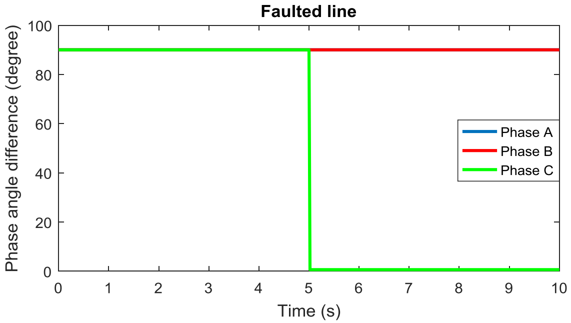


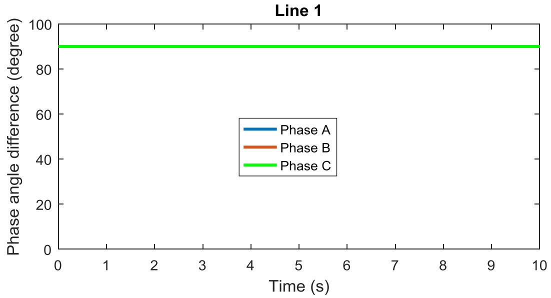
3. Results

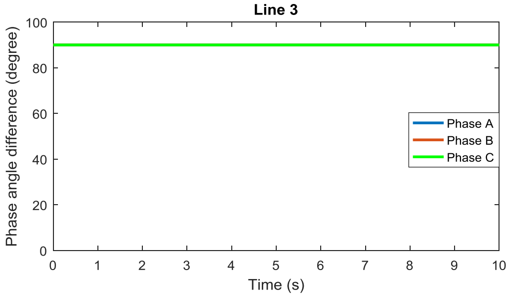
Simulation of a radial network



k = 0.5



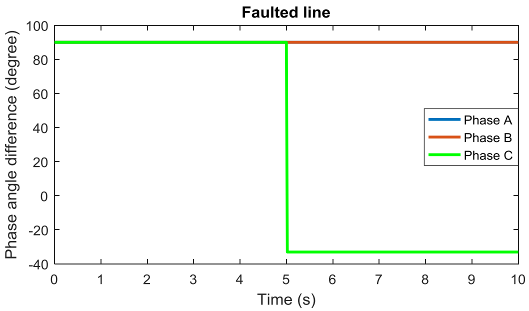


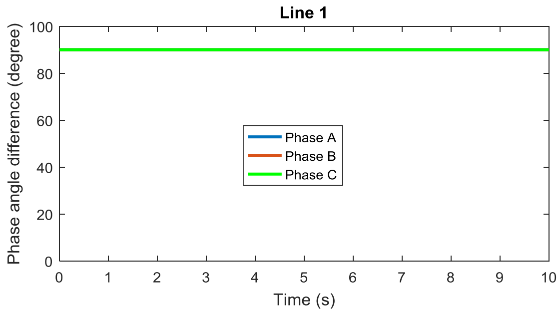


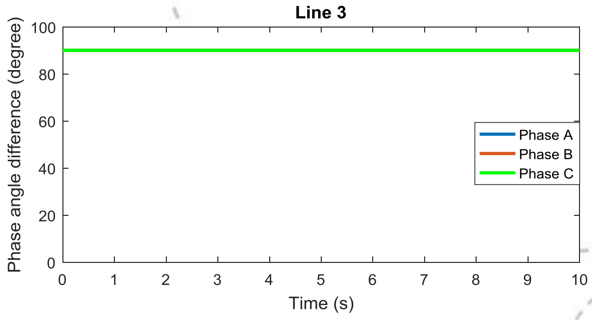
3. Results

Simulation of a radial network

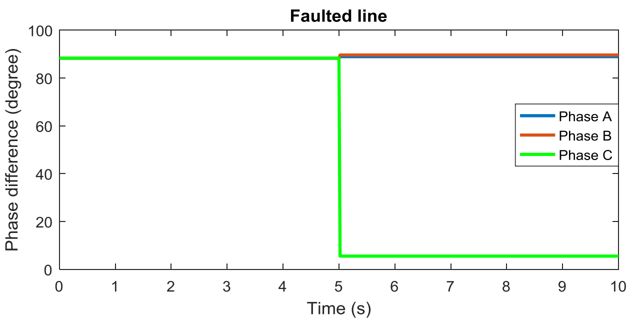
k = 0.9

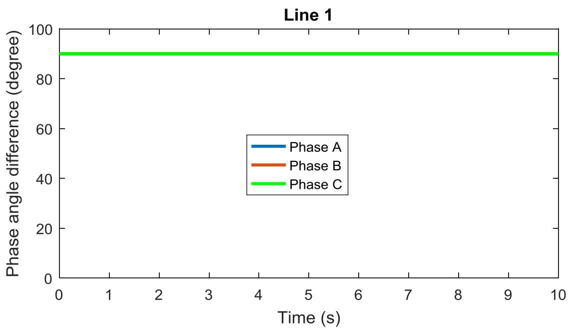


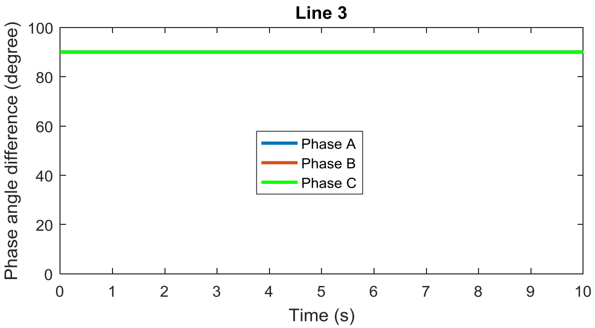




k = 0.1

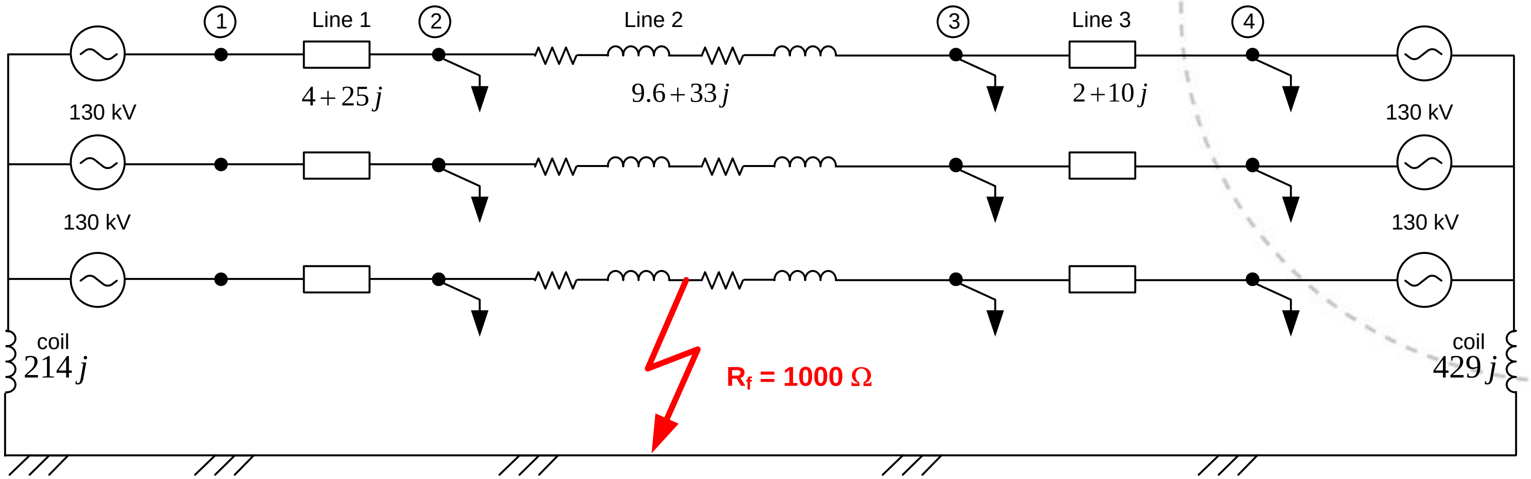




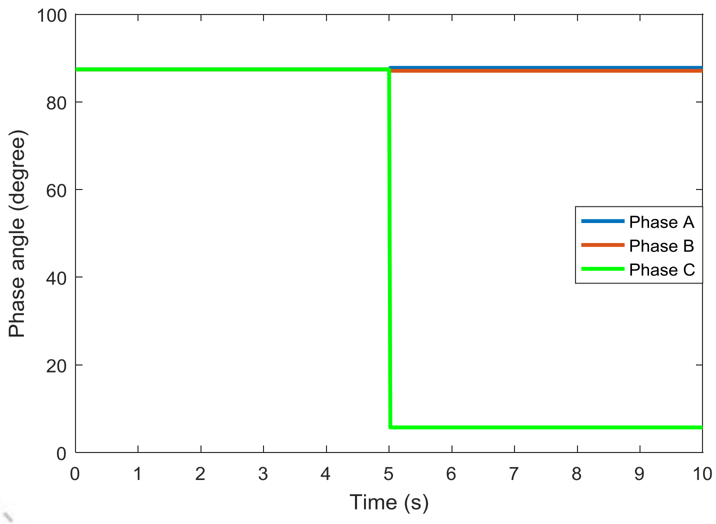


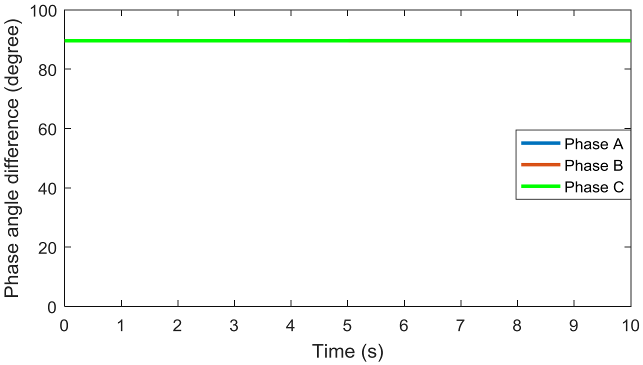
3. Results

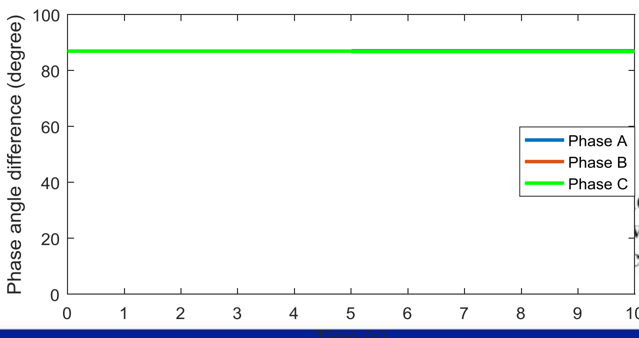
Simulation of a meshed network



- **k = 0.1**
- **R_f = 1000 Ohm**

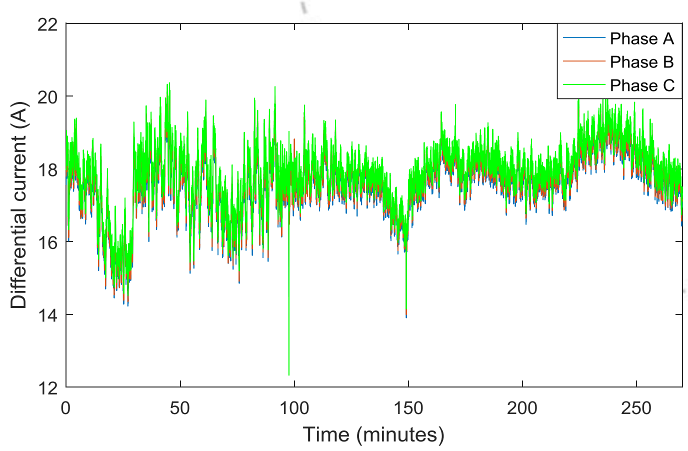


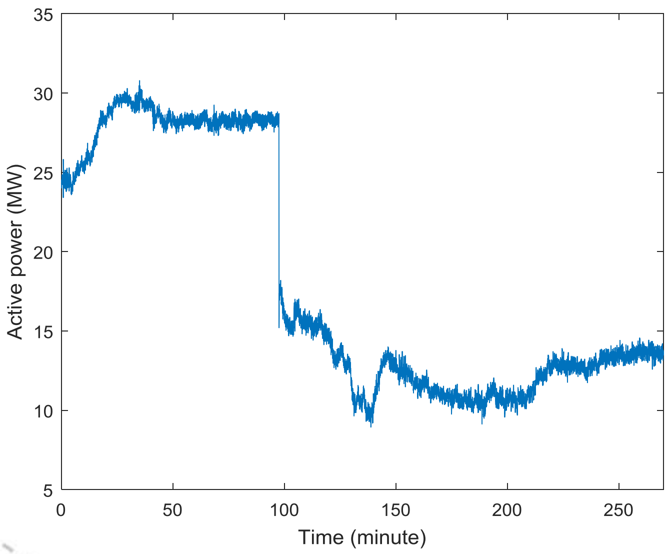


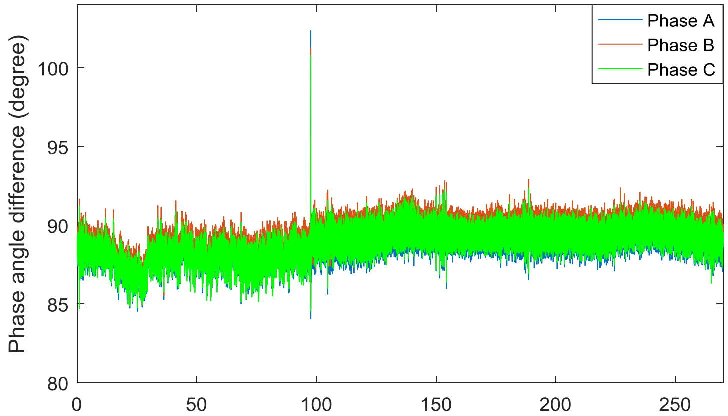


3. Results

PMU measurements of the 130 kV line Varangerbotn – Adamselv







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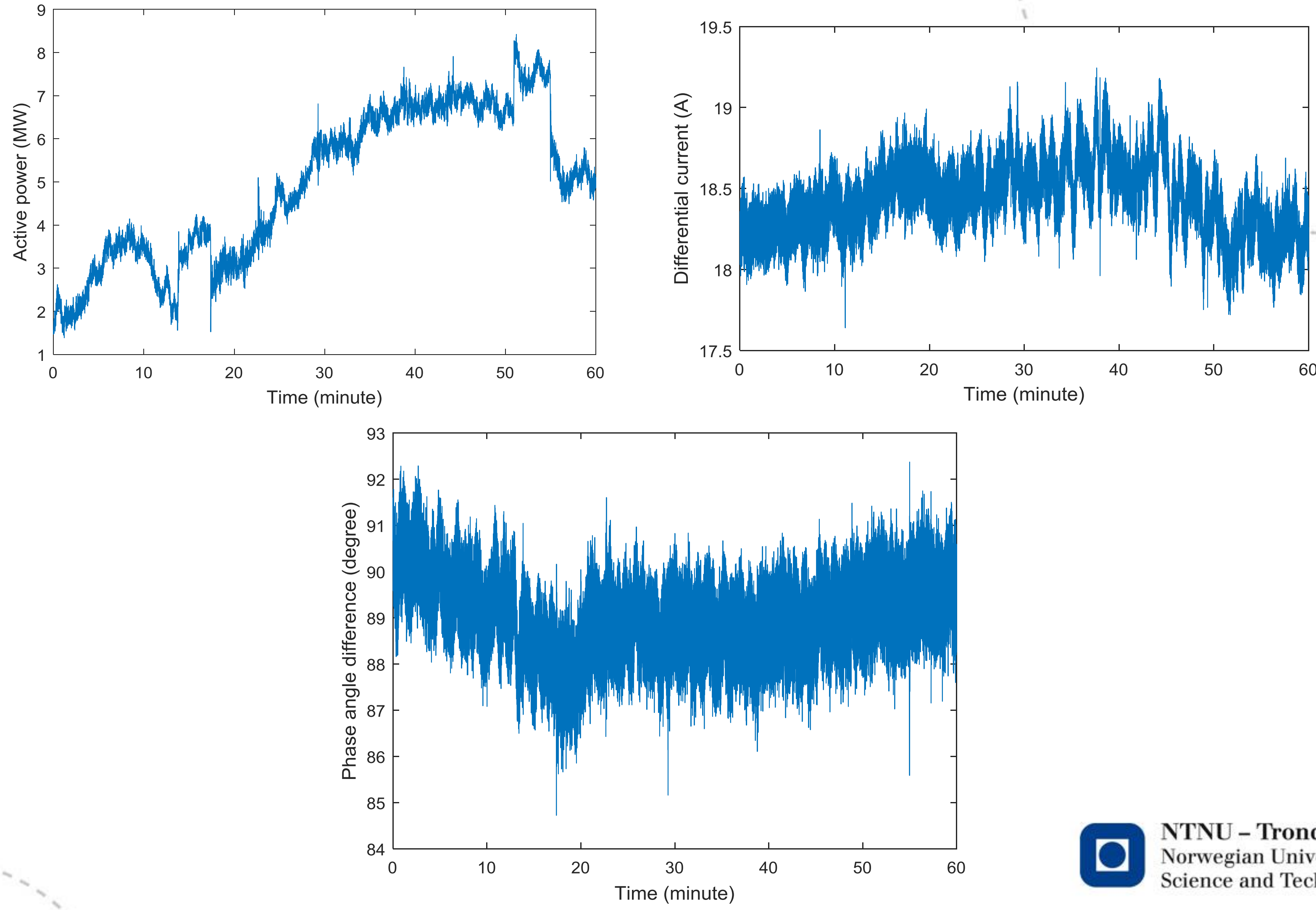
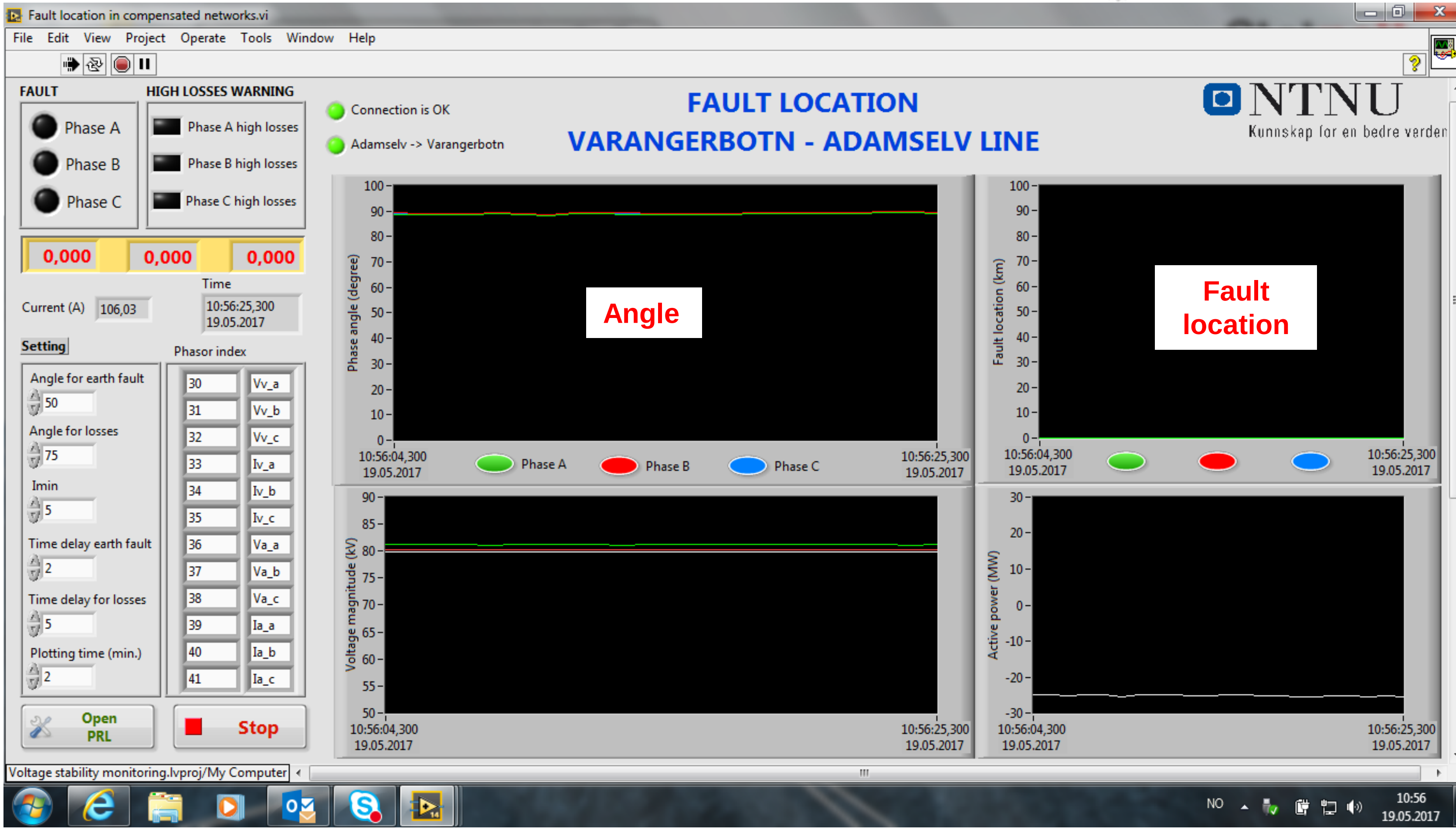
3. Results

PMU measurements of the 130 kV line Varangerbotn – Adamselv



A prototype application for the 130 kV line Varangerbotn – Adamselv



Thank you