Planning stage system studies of a 106 km long, 400 kV cable line that might be installed in Denmark

Presented at WETS'07

on 28 June 2007

by Wojciech Wiechowski

Energinet.dk (TSO)

wwi@energinet.dk

Purpose of this presentation

- To discuss potential problems related to operation of the considered 106 km long HVAC cable line
- To discuss the required system studies that can be performed in the design phase, methodology, range, etc
- To address difficulties with modelling of the cable

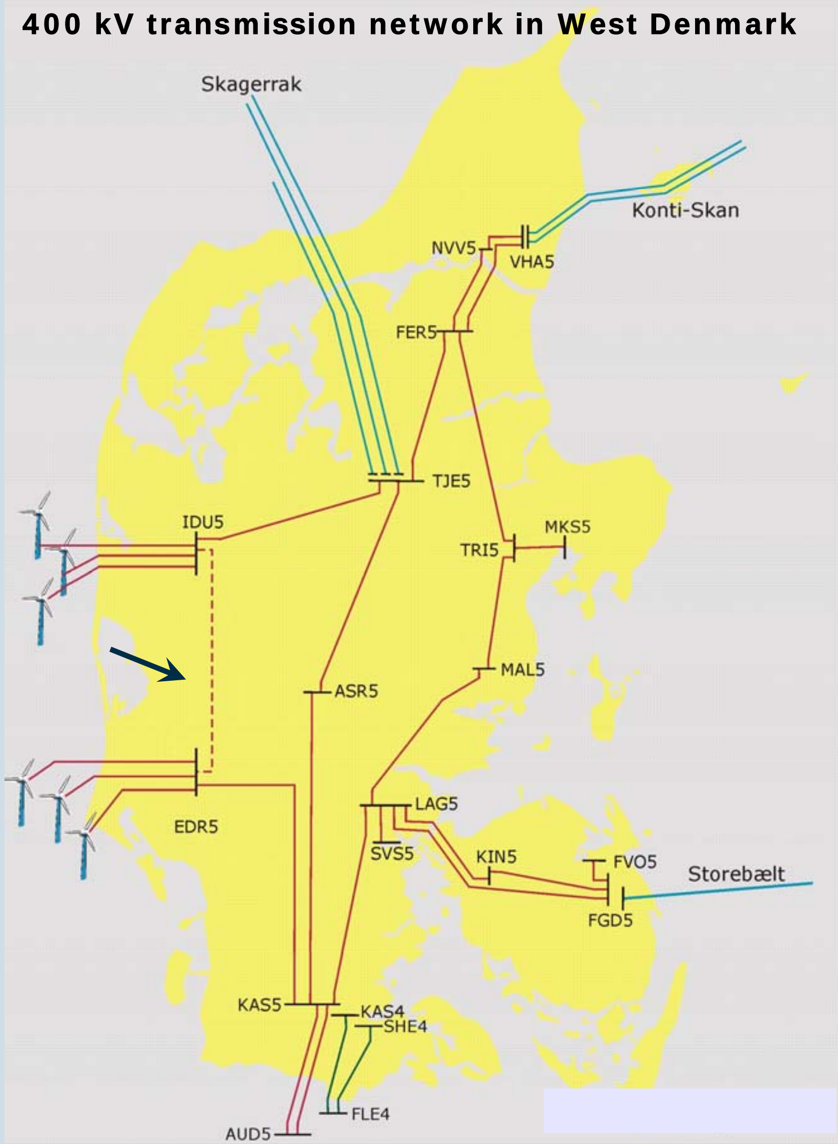
Contents

ENERGINET/DK

- Introduction and assumptions
- Power flow and reactive power compensation
- Problems with detailed cable modelling
- Example harmonic impedance
- Example transient overvoltages
- Simulations in the pre-design phase
- Conclusions

Introduction

- It become very difficult to build new overhead lines, even at the HV level
- Required new 106 km line IDU-EDR has to be built as HVAC underground cable line?
- Which technical issues must be considered?
  - What required active power transfer?
  - How much reactive power compensation along the line?
  - What about harmonic impedance?
  - Transient overvoltages and currents?
  - What are the remedy methods to the potential transient or harmonic problems?
- Is it possible to estimate any transient or harmonic problem and find a remedy method already in the design phase?



Assumptions

- Network stage 2025
- Off-shore wind power 3000 MW
- Reactive power of the cable compensated in 100%
- 3-phase reactors of up to 200 MVar
- At least 90% transfer capacity

Selected cable 1x3x2000mm2 Cu

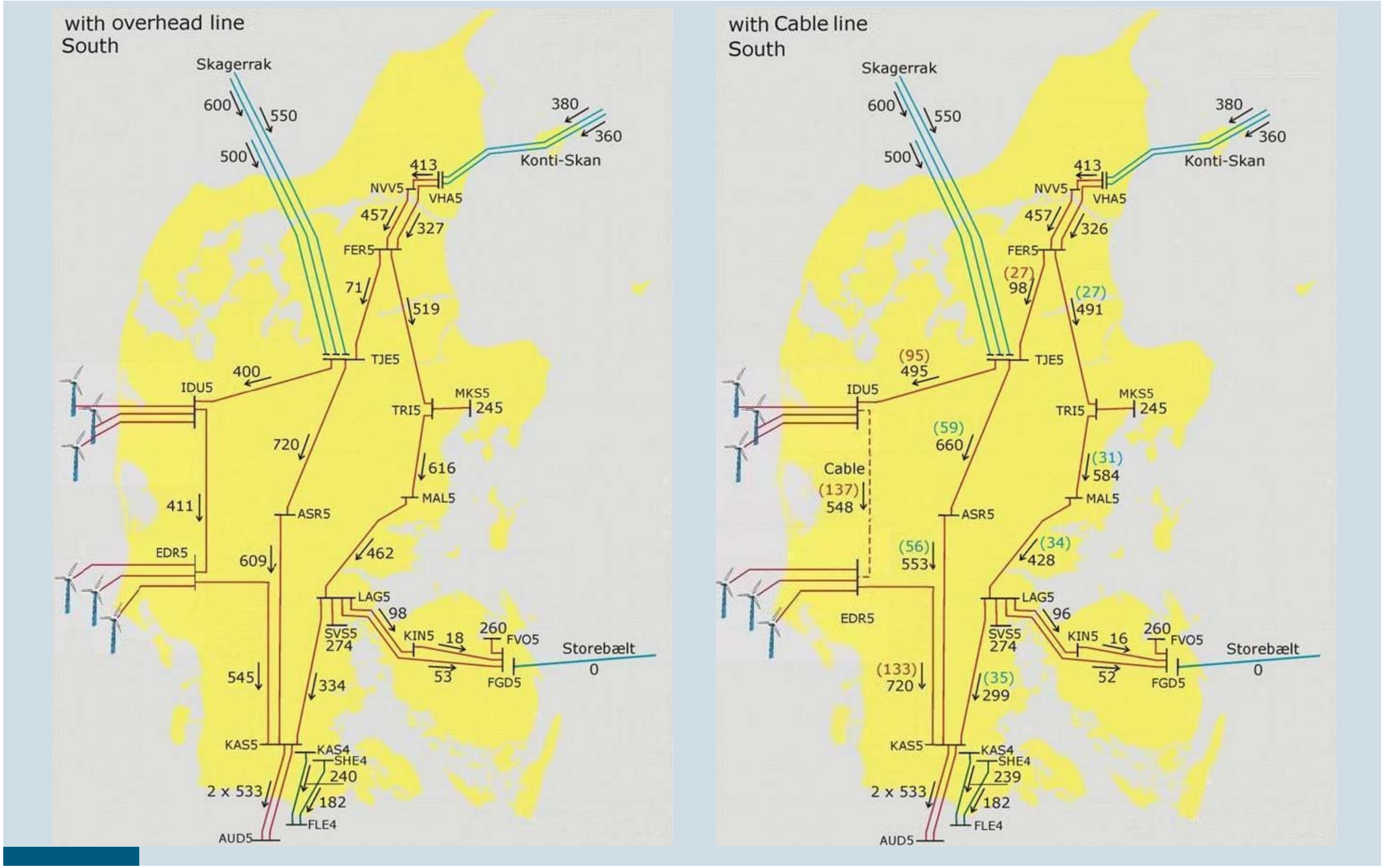
- Flat formation
- Burial depth 1,3 m
- Distance between cables 0,3 m
- Nominal current 1,75 kA
- Reactive power generation of the 106 km section ca. **1200 MVar** (400kV)
- R=**0,012** Ω/km; X=**0,18** Ω/km; C=**0,22**μF/km

For comparison an OHL parameters would be:

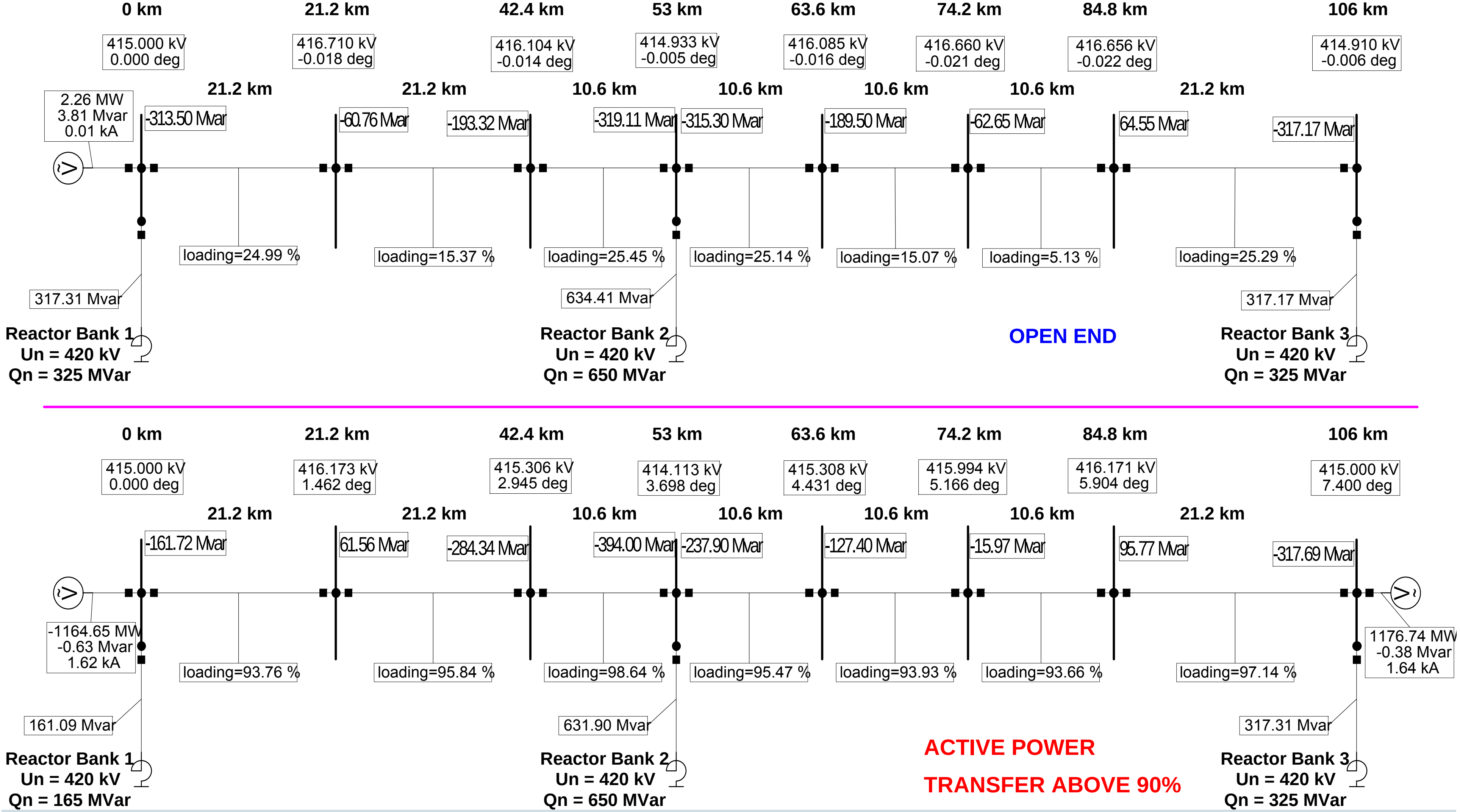
Reactive power generation of the 106 km section ca. **66 MVar**

R=**0,021** Ω/km; X=**0,3** Ω/km; C=**0,012**μF/km

Power flow in the 400 kV network

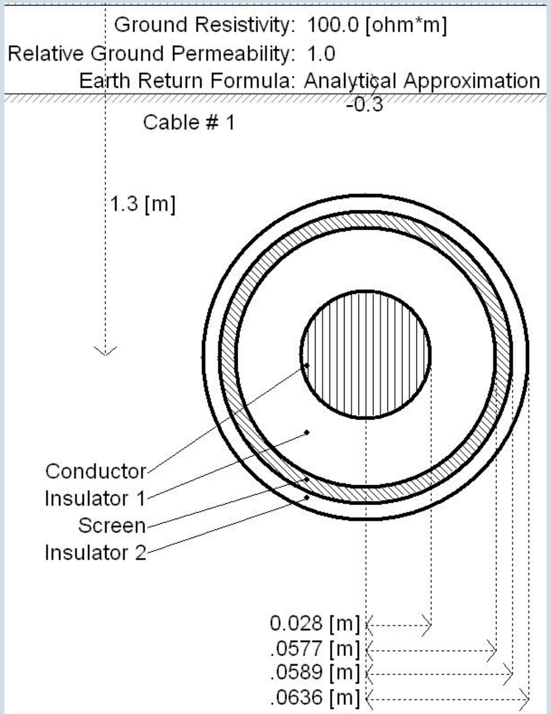


Reactive power compensation

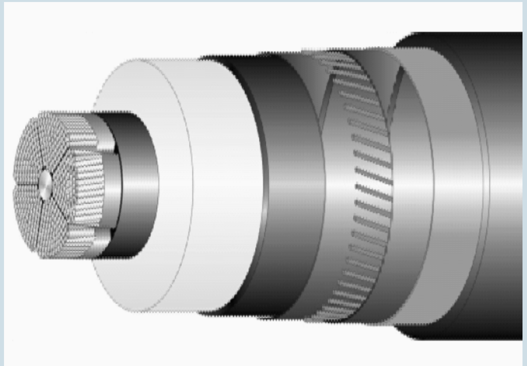


Harmonics and transients - cable modelling

Computer model of the cable



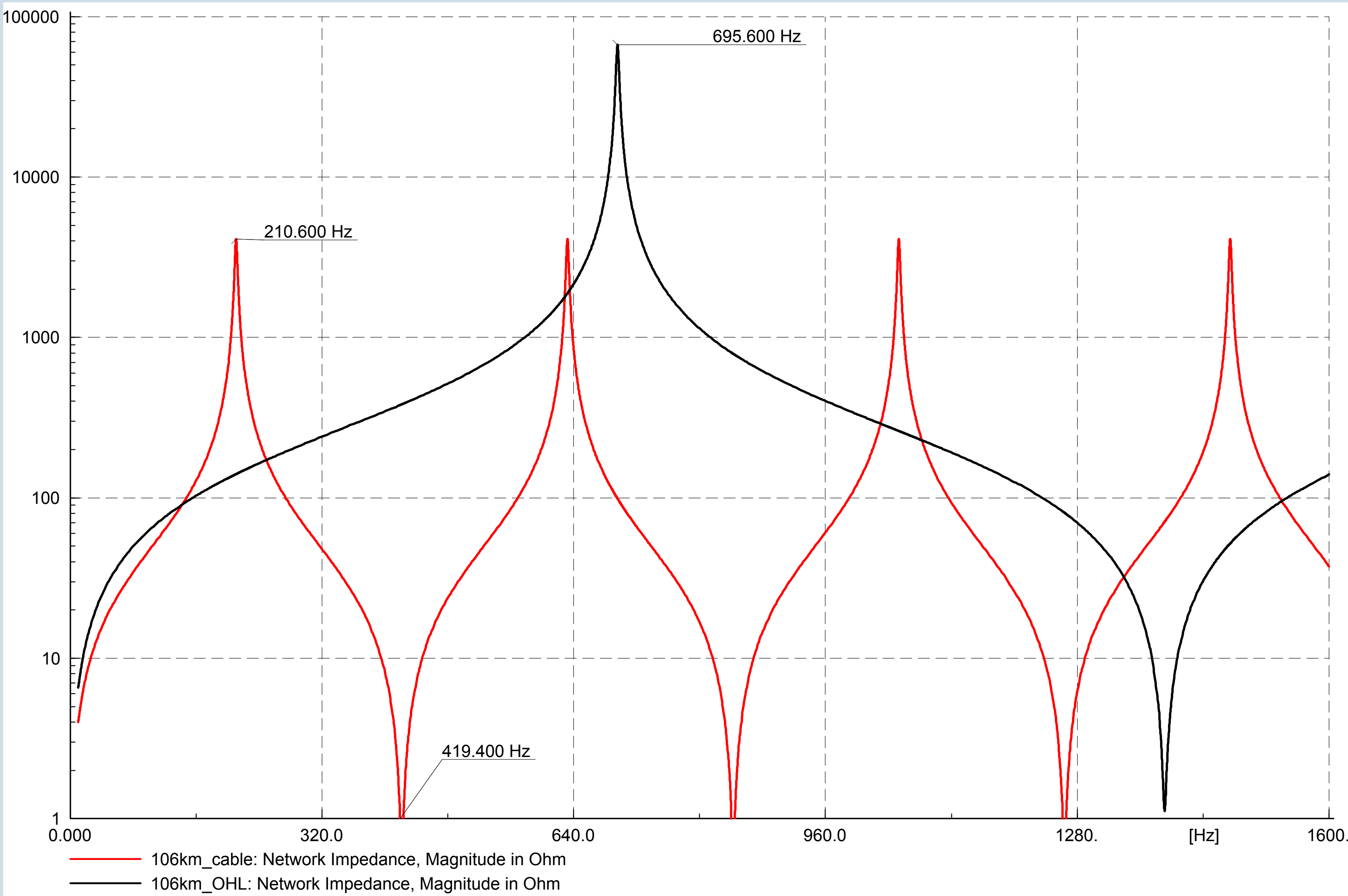
Actual cable



- Semiconductive layers
- Conductor segmentation
- Problems with computing constants of more complicated configurations
- Simplified, equivalent models maybe can be used but transient response or harmonic impedance of the cable is needed

Harmonics and transients - cable modelling

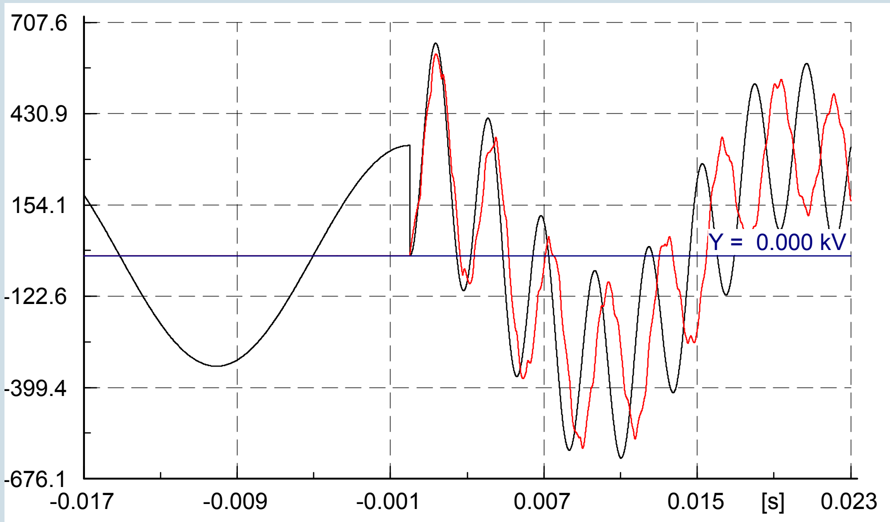
Harmonic impedance of cable vs OHL



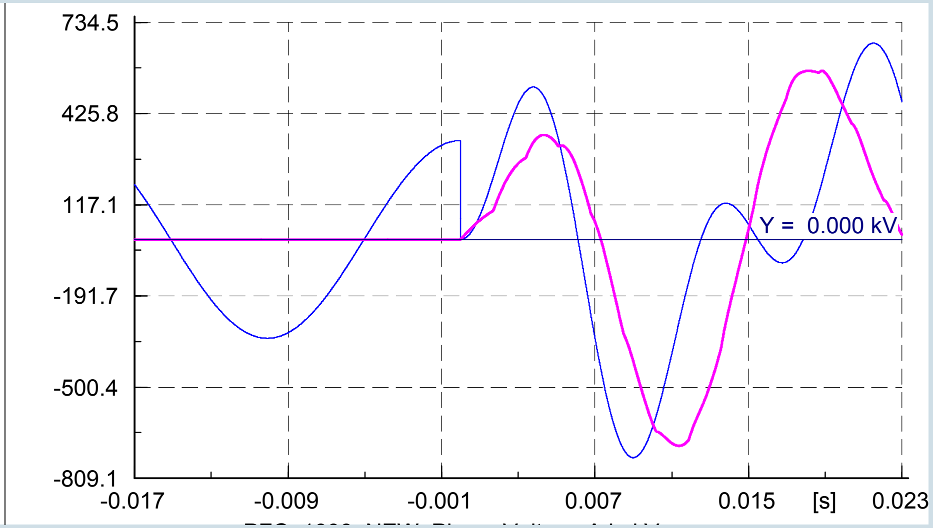
Example of line energization

initial voltage dip due to charging the cable capacitance through the system inductance

energization of an 106 km OHL
energization of a 70 MVar capacitor



energization of the 106 km cable line
energization of a 1200 MVar capacitor



Simulations in the pre-design phase

Example cases

- Line energization and line disconnection
- Various short-circuit faults in the vicinity and along the line, arcing faults?
- Autoreclosure in the neighbouring lines?
- Pole discrepancy in the circuit breaker?
- Saturation of transformers located in the vicinity during overvoltages
- Lightning
- Harmonic analysis
- ...?

Simulations in the pre-design phase

Lack of detailed information at this stage →

- Variation of selected parameters
- Sensitivity studies
- Different moments of the supplying voltage
- Various network topologies
- all combinations = thousands of cases!
- Pre-selection + "Multiple run" of PSCAD
- Assessment if the obtained phenomena are dangerous for any of the system components (the cable, insulation of other components, commutation failure of HVDC links, etc)
- If there is a probability → study remedy methods (pre-insertion resistance, etc)

Conclusions

- for this 106 km long cable, compensation at the ends + in the middle shall suffice
- Lower value of cable series impedance alters flows in the network
- Harmonic resonances will appear at lower frequencies – harmonic study may become a standard procedure like in case of harmonic filters
- test reports allow to verify cable model at 50 Hz. Transient response or harmonic impedance of the cable needed
- Exact determination of transients strongly depends on the precision of modelling of the cable and the components located in vicinity
- to determine worst case transient/harmonic phenomena, many cases have to be simulated and critical parameters must be varied.