Solving network constraints with DG and FACTS devices

A Case Study

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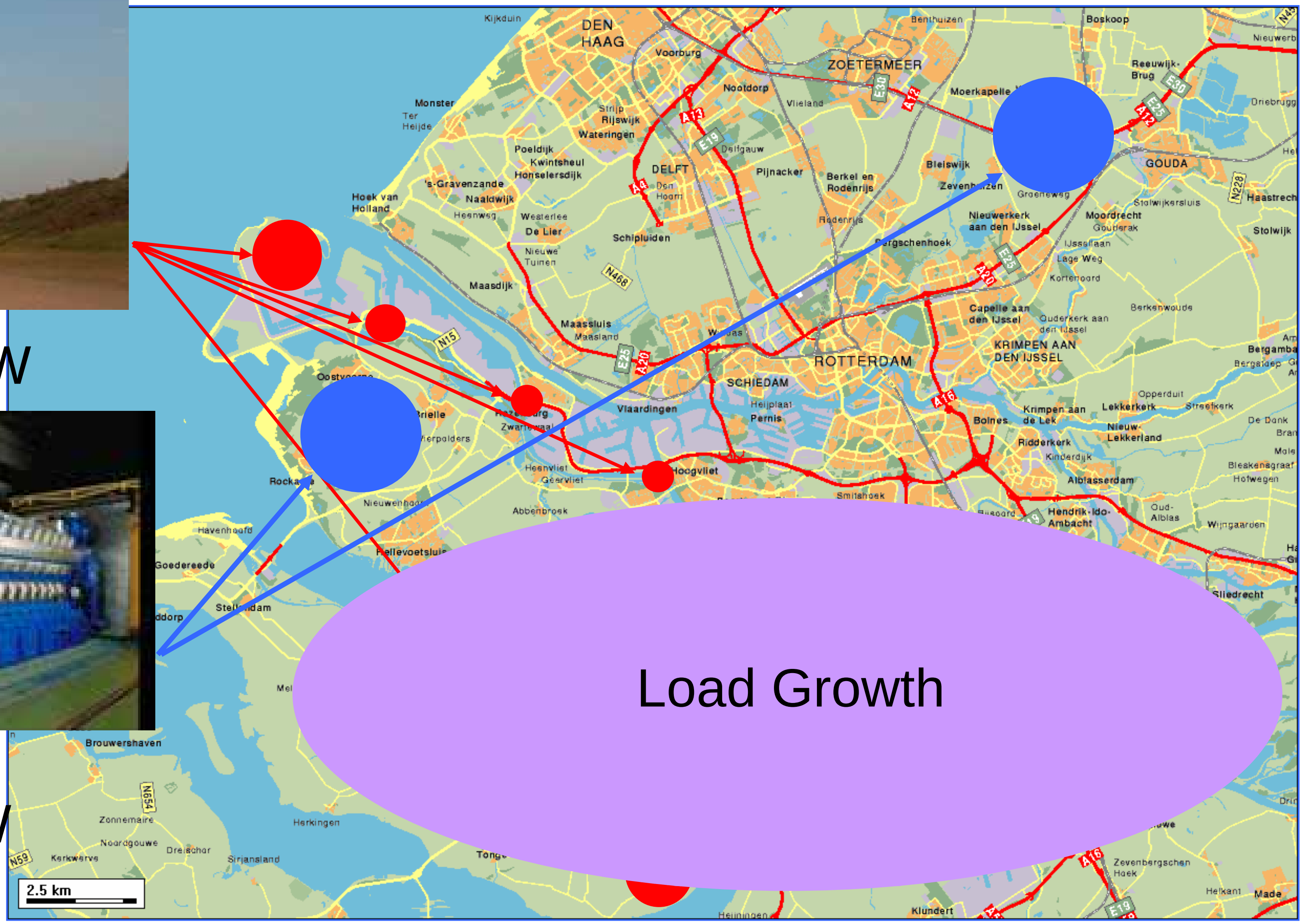
Grid developments

Total: 170 MW

Total: 300MW

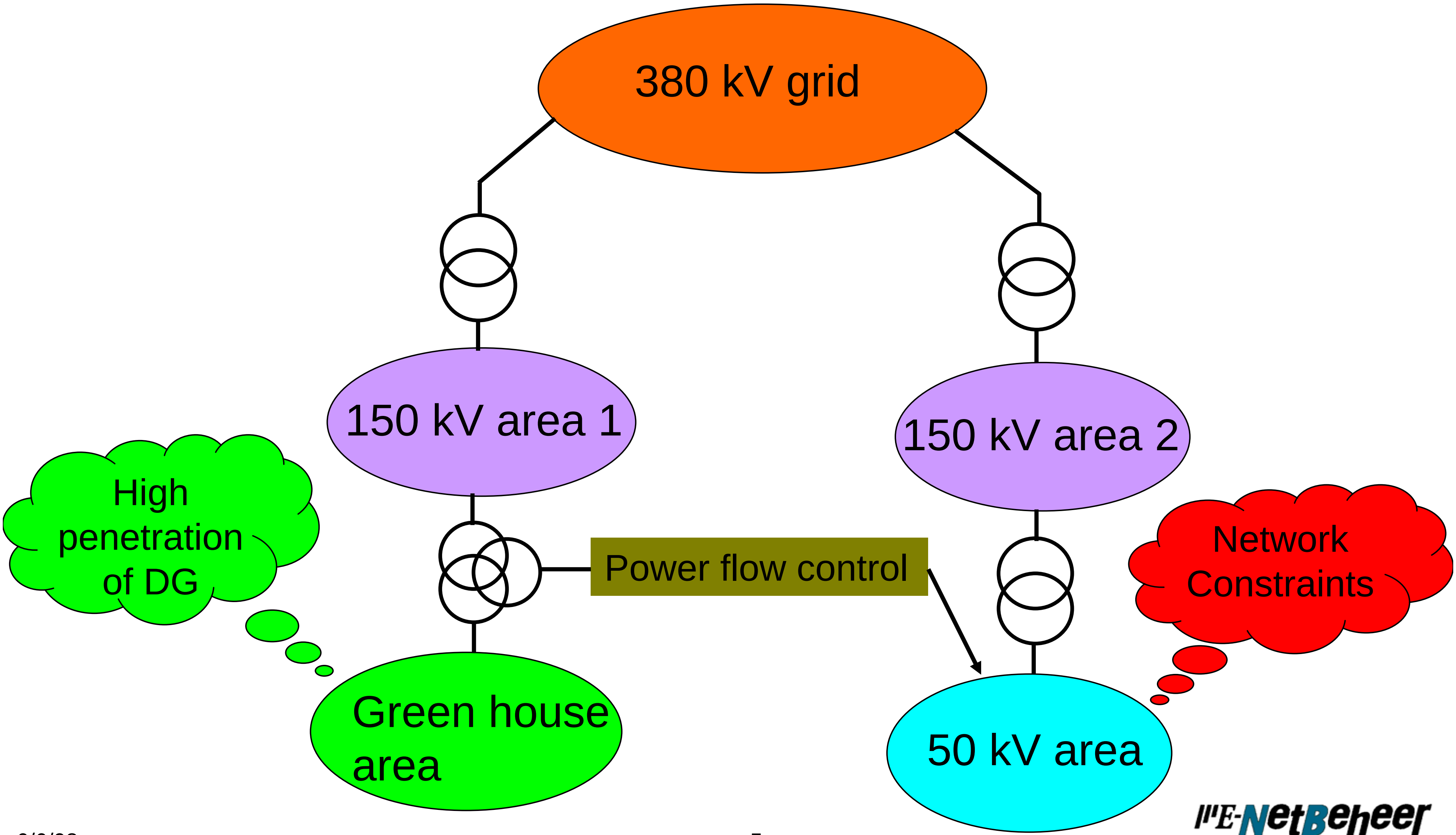


Problem Definition

How can the network constraints been solved by:

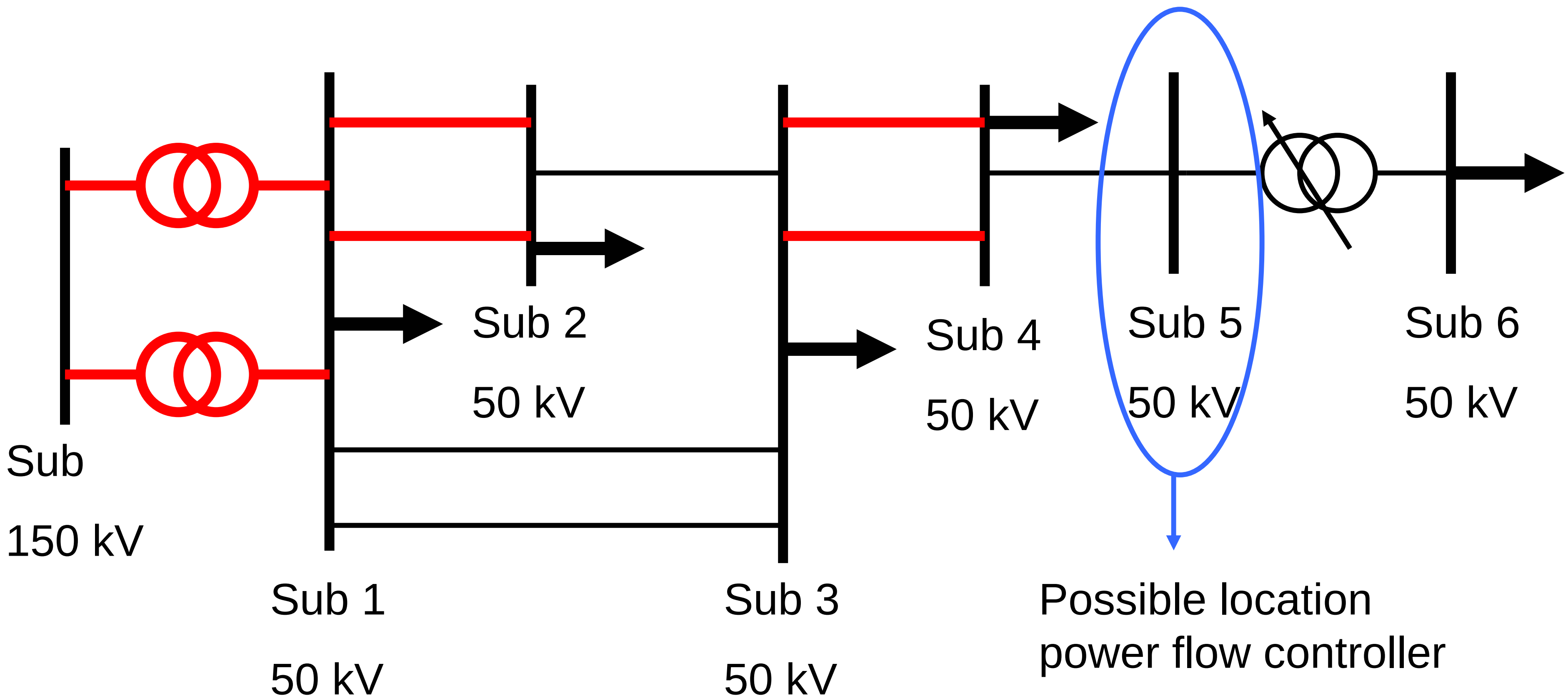
- Utilizing generated power of DG-units
- Incorporate power flow controllers

Overview of the transmission system



Grid developments

Network Constraints



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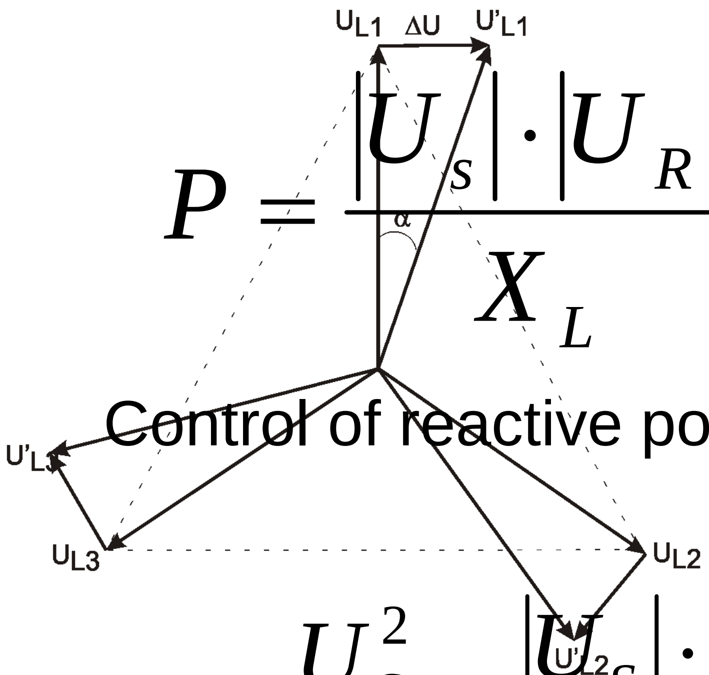
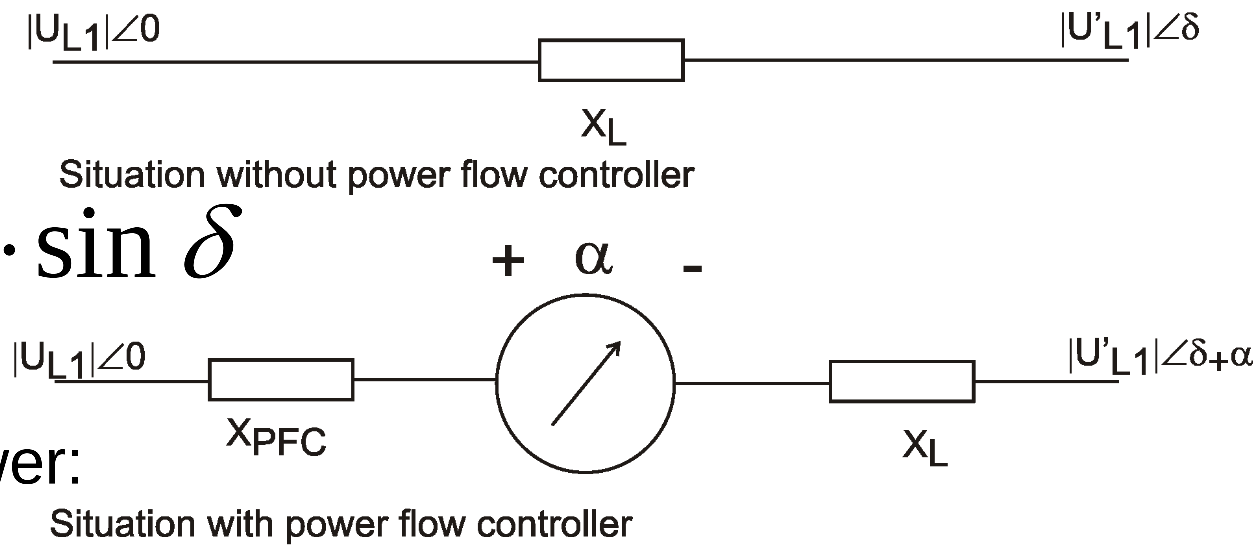
Power Flow Control

Control of active power:

$$P = \frac{|U_S| \cdot |U_R|}{X_L} \cdot \sin\delta$$





Control of reactive power:

$$Q = \frac{U_S^2}{X_L} - \frac{|U_S| \cdot |U_R|}{X_L} \cdot \cos\delta$$

X_{PFC} = reactance of power flow controller
X_L = reactance of transmission line

Power Flow Control Devices

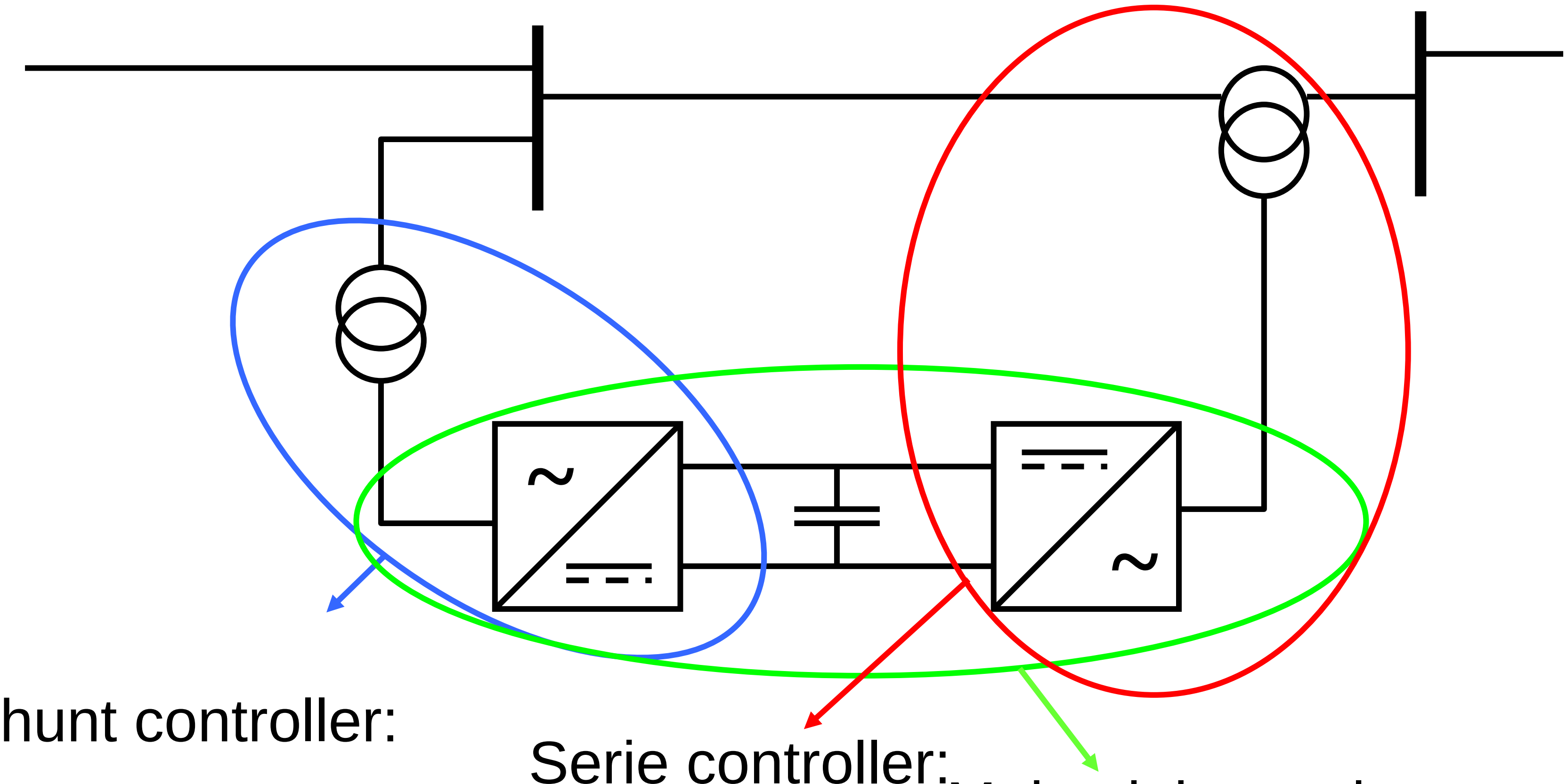
Classic control devices:

- Reactive power flow control
  - Capacitor Bank
  - Inductor Bank
- Active power flow control
  - Phase shift transformer

FACTS devices

- Shunt devices
  - Static Var Compensator/Static Compensator
- Series devices
  - Thyristor controlled capacitor/Static Synchronous Series Compensator
- Shunt and Series device
  - Unified Power Flow Controller (UPFC)

Principle of the Unified Power Flow Controller



Shunt controller:

Control of reactive power

Serie controller:

Control of Active power

Maintaining active power balance:

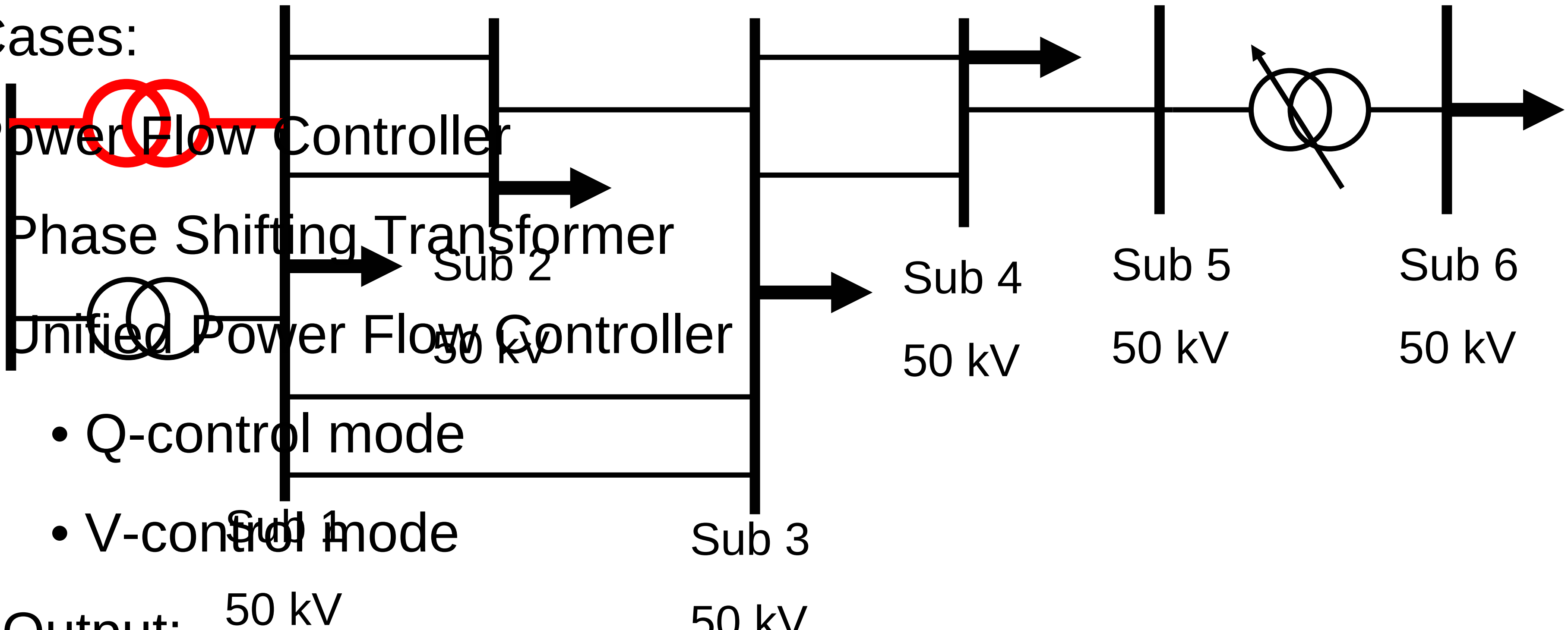
Case Study

Outage of a 150/50 kV transformer

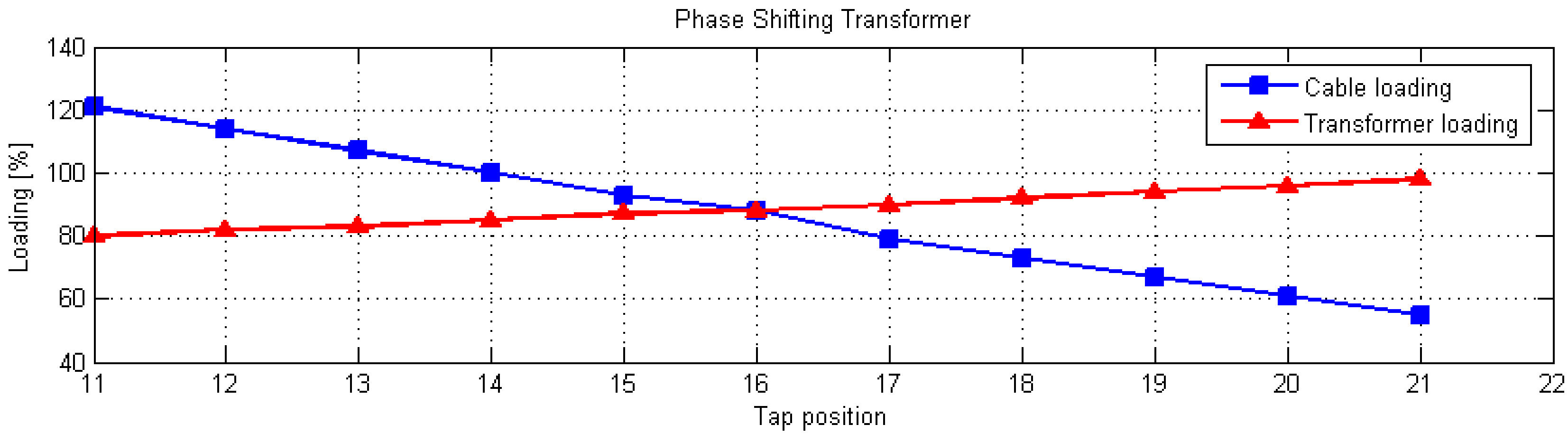
Cases:

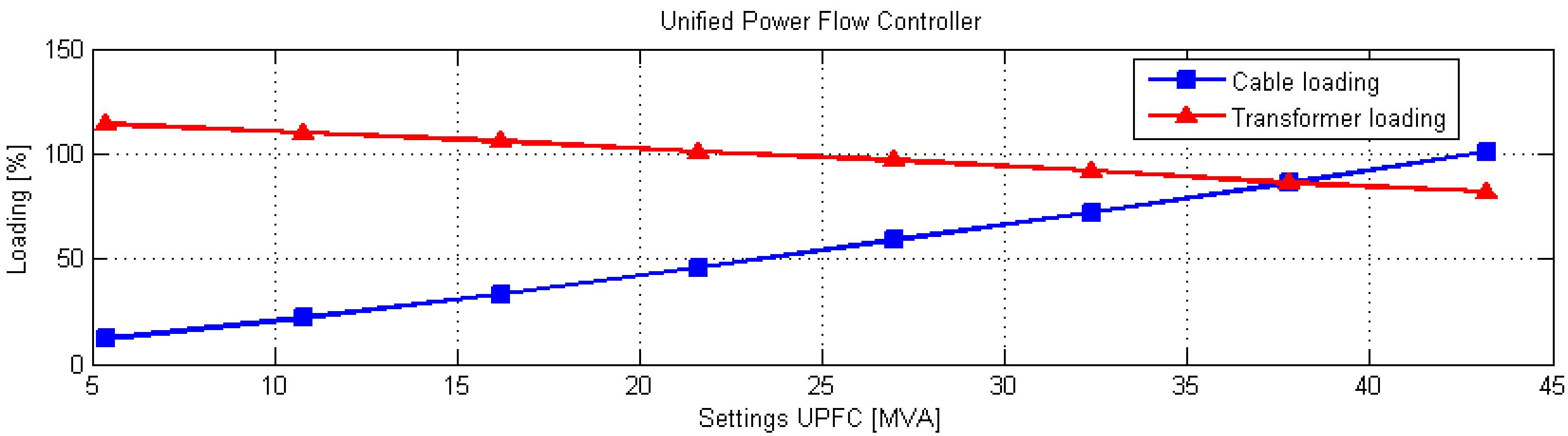
Power Flow Controller

- Phase Shifting Transformer
- Unified Power Flow Controller
    - Q-control mode
    - V-control mode
- Output:
    - Load Flow
    - Voltage profile of 50 kV grid



Case Study Results ‘*Loadflow*‘





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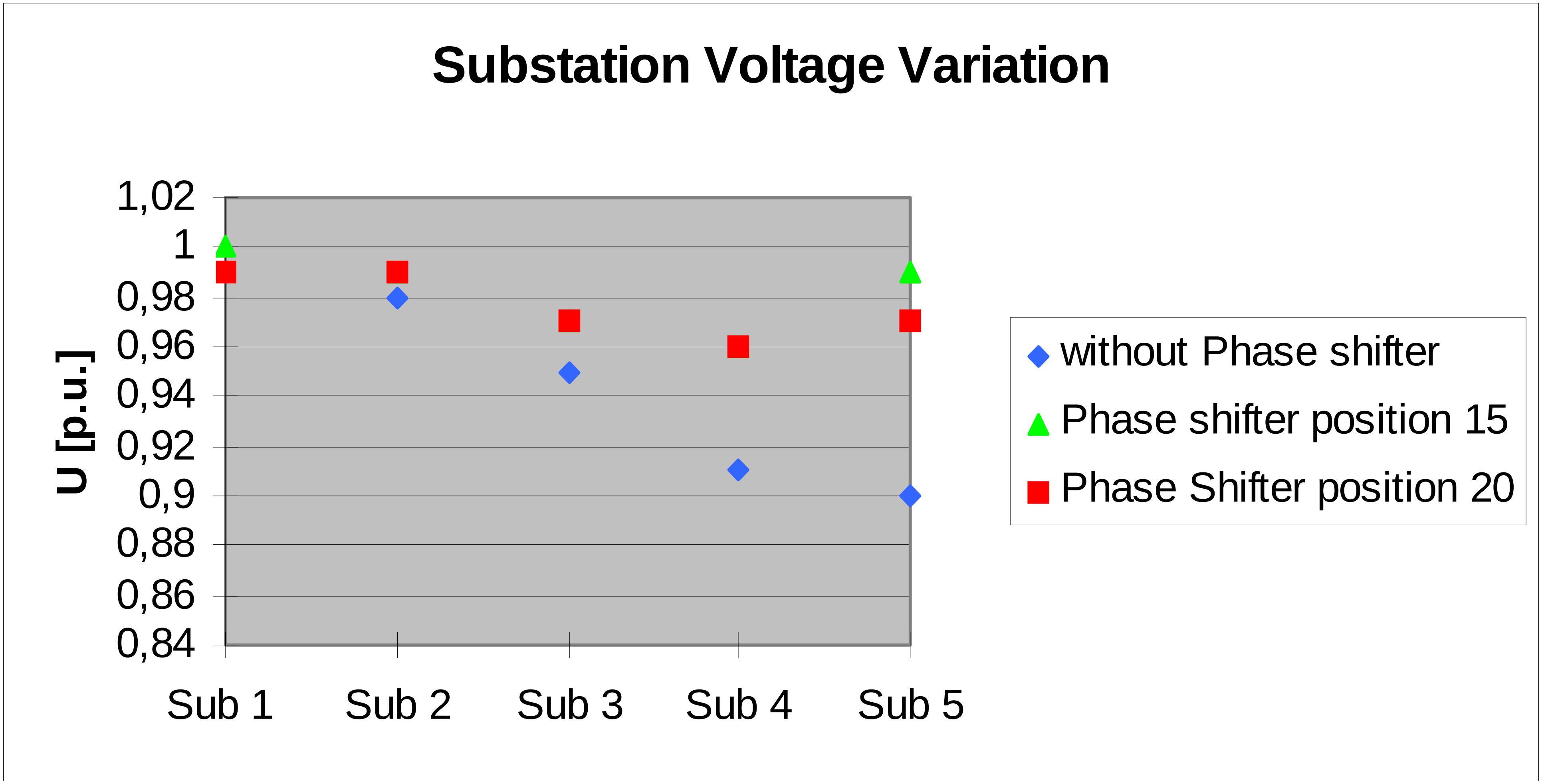
Case study Results 'Voltage profile Phase Shifter'



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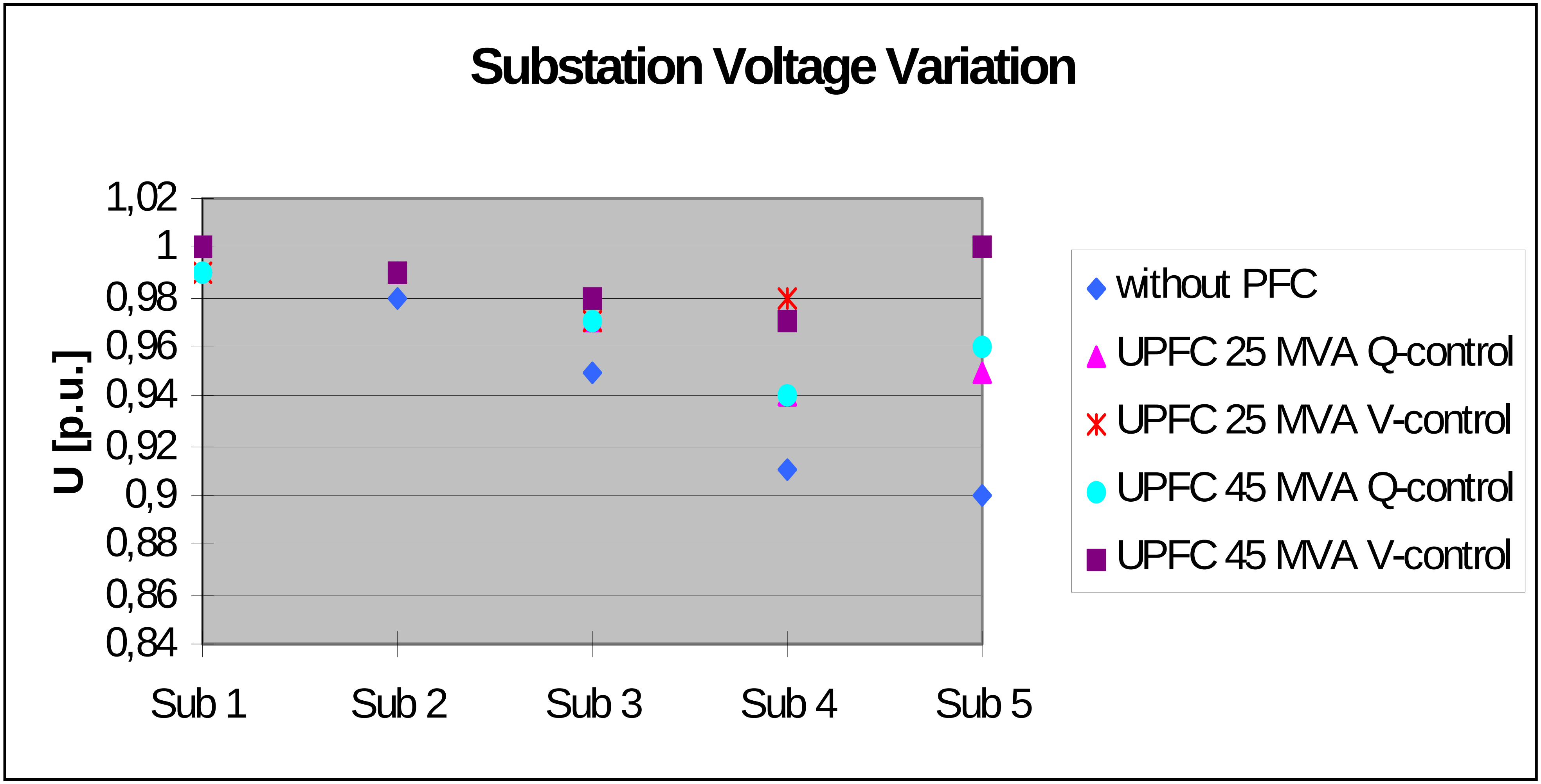
Case study Results 'Voltage profile UPFC'



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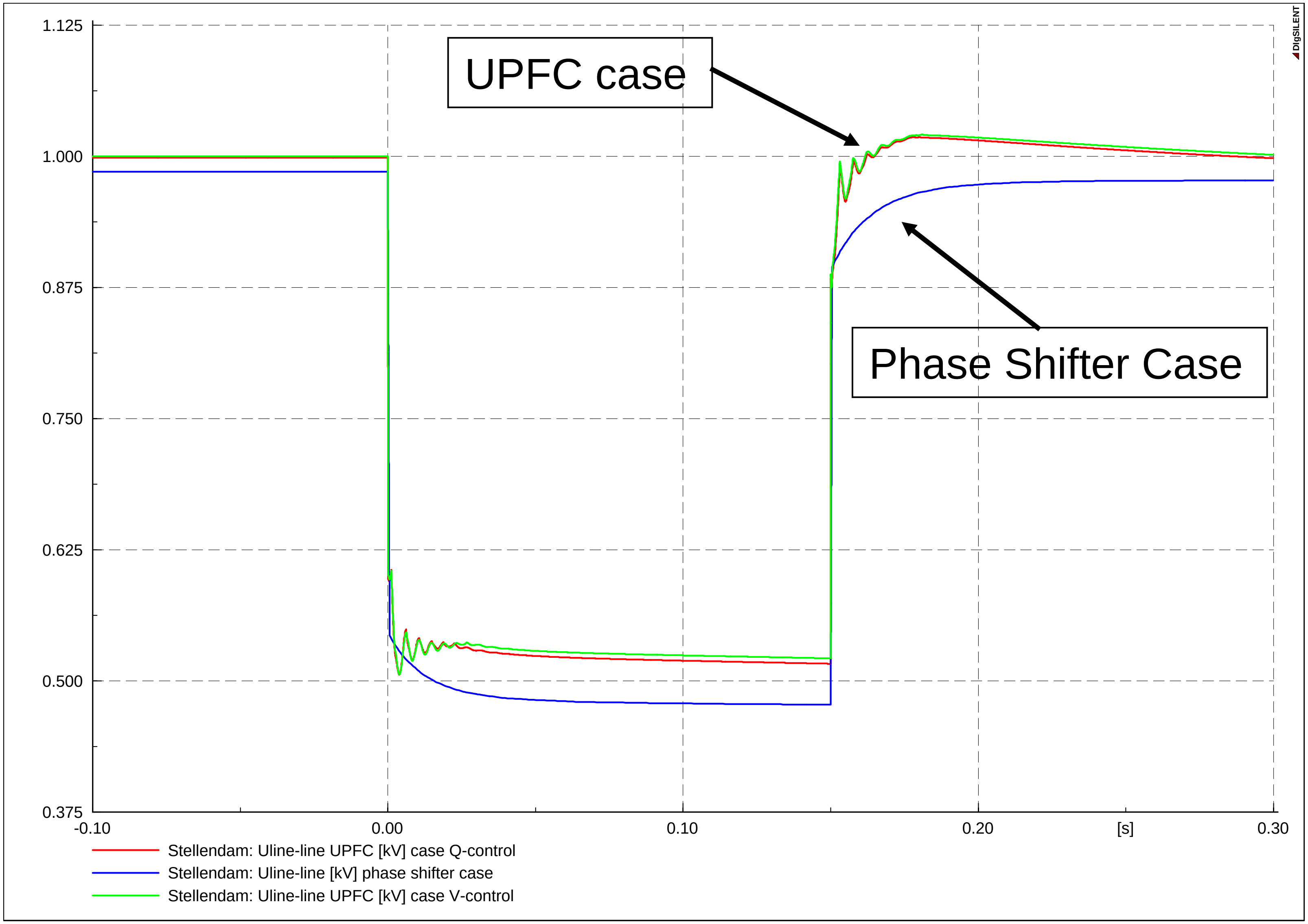
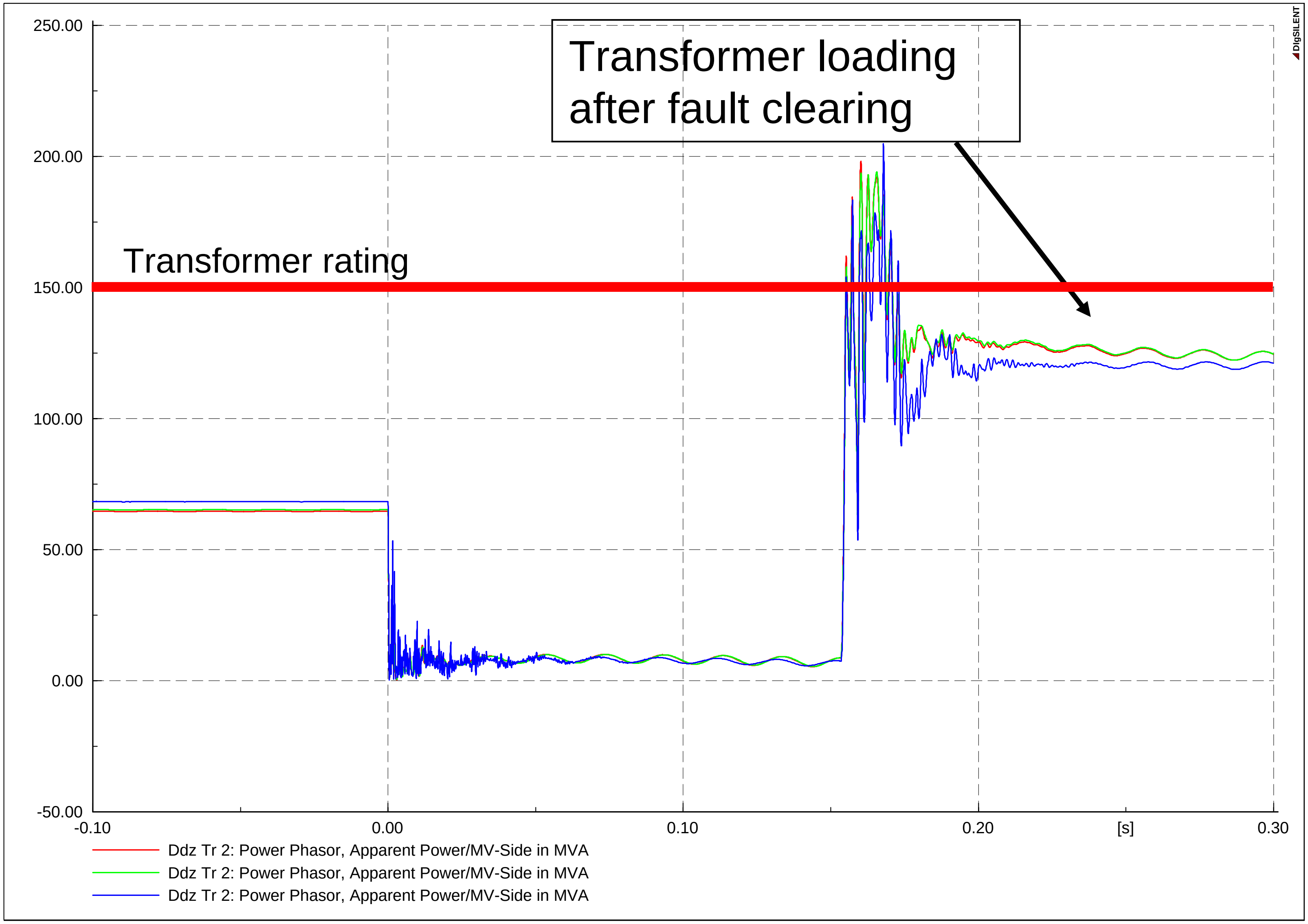
Dynamic Simulation ‘Transformer Outage’

- Dynamic simulation of the 150/50 kV transformer outage
- Three phase fault at 150/50 kV transformer
- Fault duration 150 ms
- Cases
  - Phase Shifting Transformer
  - UPFC Q-control
  - UPFC V-control

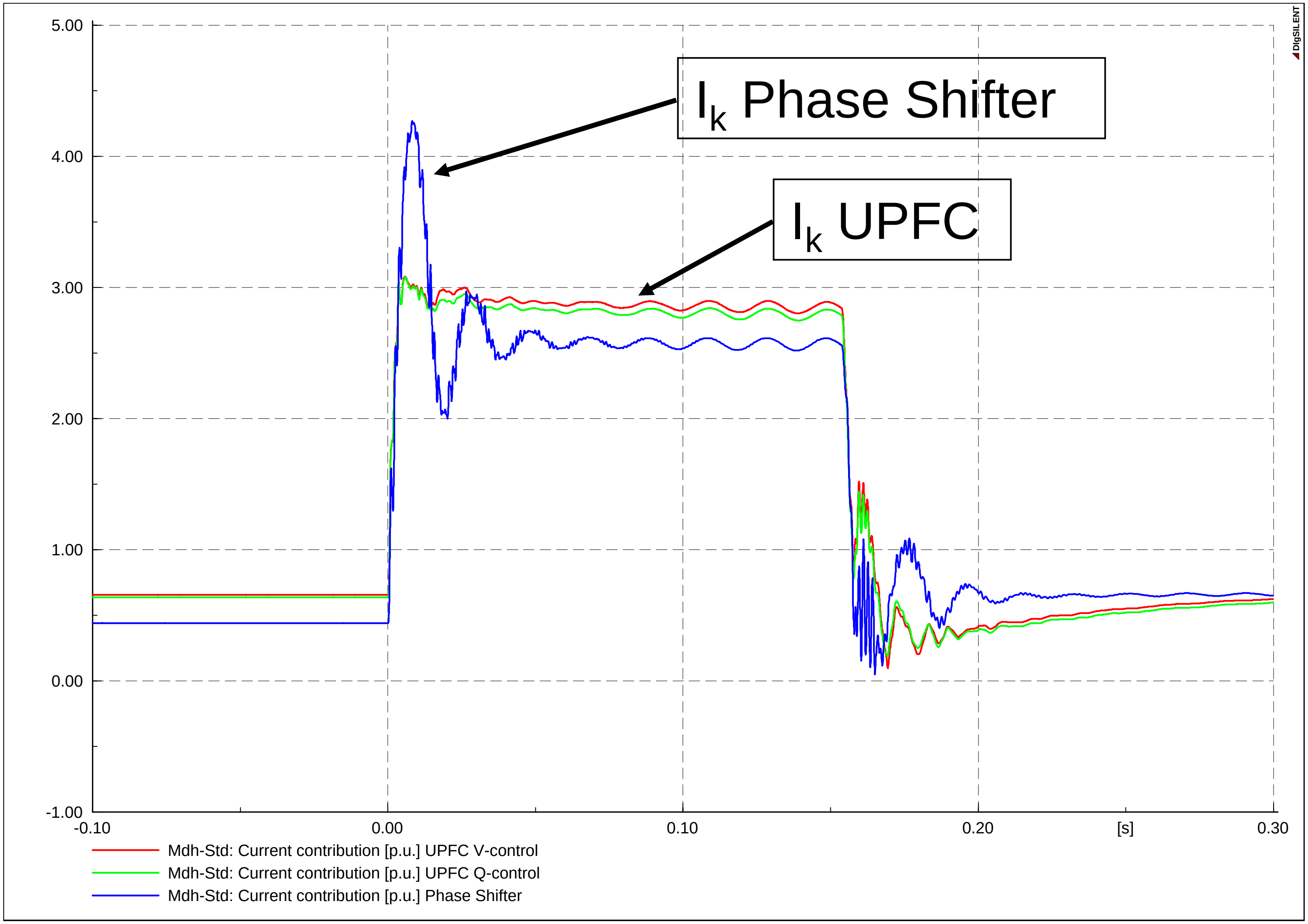
Dynamic Simulations 'Voltage Dip'



Dynamic Simulations ‘Transformer loading’



Dynamic Simulation 'Short Circuit Current Contribution'



Conclusions (1)

Comparison Power flow controllers

Phase Shifter

- Well known and accepted technique for power flow control
- Discrete and manual control which is a slight disadvantage
- Control of active power only
- Cost attractive in comparison with FACTS

Unified Power Flow Controller

- More control options, such as reactive power control, impedance compensation
- Continuous and automatic control possibilities
- Attractive when also reactive power flow or voltage control is applied
- Vulnerable due to power electronic components

Conclusions (2)

Network constraints

- Solved by directing DG power
- Both power flow controllers can do the job
- Cost saving due to reducing imported power of the transmission grid
- UPFC offers better voltage control options
- UPFC limits contribution of the short circuit current