

Distribution automation and functionalities for active network management

IDEAL

ideal grid for all

*Smart Energy Workshop 2015
Konstanz, Germany*

*Dr. Tech. Anna Kulmala
Tampere University of Technology, Finland*





Content

- IDE4L project overview
- Decentralized automation architecture
- Congestion management



Introduction

• Motivation

- RES and energy efficiency actions increase the complexity of network planning and operation
- Existing and new networks and resources should be utilized more efficiently
- Continuity of the electricity supply is important for the modern society and must be guaranteed

• Scope

- Planning of active network
- Distribution automation in MV and LV networks
- Active network management utilizing DERs
- Interactions of DSO/TSO and DSO/market actors



From concept to demonstrations

1. Defining the concepts

- Active network (D2.1)
- Automation for active network management (D3.1)
- Aggregator system (D6.1)

2. Developing planning methods and automation functionality

3. Building and running the demonstrations in:

- Denmark (Østkraft Holding A/S)
- Italy (A2A Reti Electriche SpA)
- Spain (Unión Fenosa Distribución, S.A.)



Main objectives

- **Develop an advanced distribution network automation system** enabling utilization of flexibility services of DERs and their aggregators
- **Develop advanced functions** for monitoring and control of the whole network
- **Demonstrate** the automation system and selected use cases for active distribution network
- **Develop planning tools** to design active distribution network and to evaluate costs and benefits of developed concept and technical solutions



Breakthroughs of IDE4L project

WP7 Demonstrations

WP2

Planning tools for distribution network management

ANM concept

Target and expansion planning including ANM

Operational planning including DER uncertainty

WP3

Distribution network automation architecture

Automation concept

Smart meter as a sensor

Testing Platform for monitoring & control systems

Hierarchical and decentralized automation

WP4

Fault location, isolation and supply restoration

Decentralized FLISR

IEC 61850 Distribution Protection System Reconfiguration

Microgrid interconnection switch

WP5

Congestion management

Decentralized state estimation and state forecast

Tertiary control – Network reconfiguration

Secondary control – Coordination of voltage controllers

Dynamic tariff

WP6

Distribution networks dynamics

Aggregator concept

Optimal scheduling of flexibility

Transmitting synchro-phasors & real-time model syntheses

Improved microgrid operation



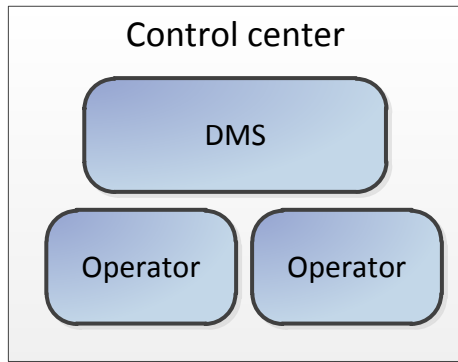


Content

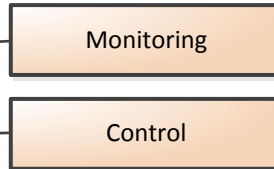
- IDE4L project overview
- Decentralized automation architecture
- Congestion management



Decentralized automation

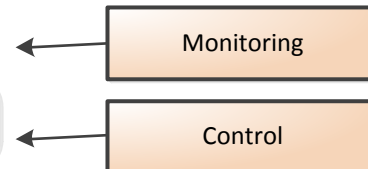


Grid Level



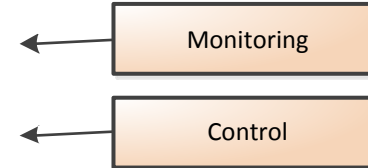
1. Cooperation with commercial aggregator and Electrical market
2. Decision of Grid tariff
3. Collection and harmonization of measurements at grid level
4. Coordination of PSAUs
5. Coordination of secondary controllers

MV level

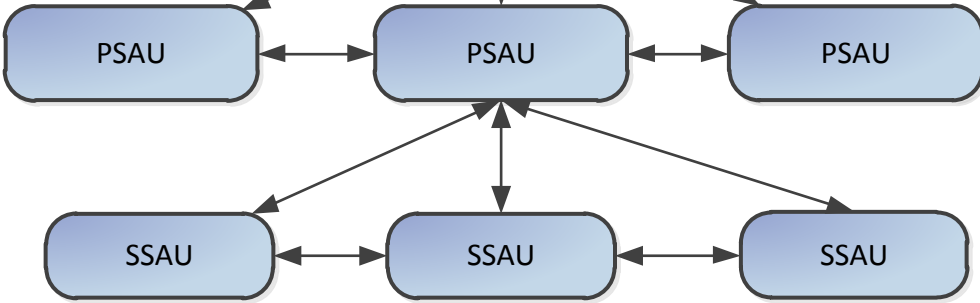


1. Coordination of FLISR
2. Control of PS IEDs (OLTC, capacitors)
3. Collection and harmonization of measurements at MV level
4. Coordination of SSAUs
5. Secondary power control

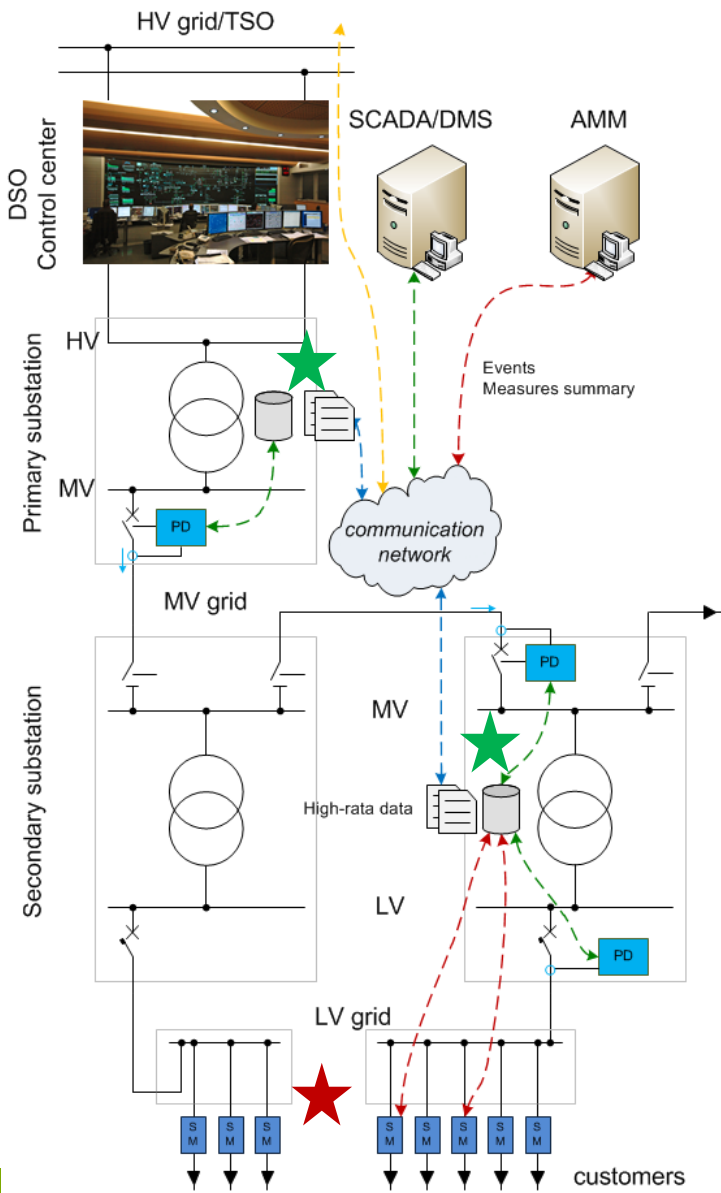
LV level



1. Control of SS IEDs (OLTC, capacitors, DGs)
2. Collection and harmonization of measurements at LV level (smart meters)
3. Secondary power control



Real-time monitoring and state estimation



- LV grid ★
 - EV, PV, HP and demand-response schemes mainly affect the LV grid
 - **Monitor the LV grid**
 - Data management ★
 - Data coming from heterogeneous system
 - Incomplete: Some nodes are not monitored; Broken/unreachable device
 - Uncertain: Low synchronization accuracy; Measure corrupted
- **MV & LV State Estimation**
- **Network Description Update**



Outcomes of IDE4L architecture

1. Integration and participation of DERs in the automation system
2. Extension of monitoring and control functions to the distribution network
 - Distribution of such functions on several levels
 - Hierarchy, modularity, scalability
3. Wide applicability in European context



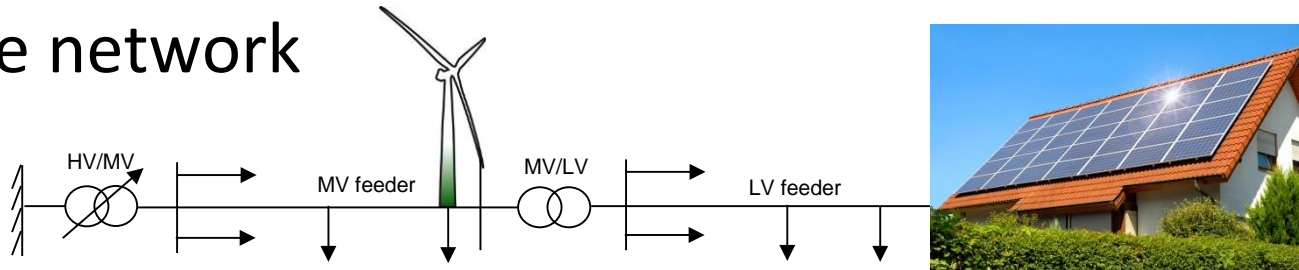
Content

- IDE4L project overview
- Decentralized automation architecture
- Congestion management

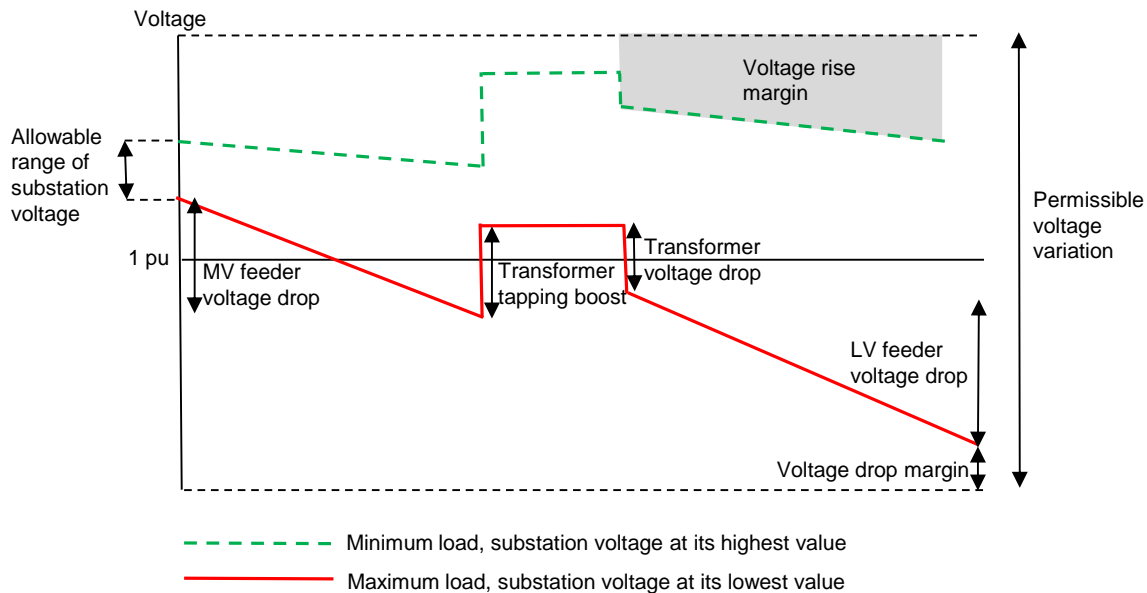


Congestion management

- Mitigate voltage rise and prevent overloading of feeders and transformers
- Optimize network state



+ HP
+ EV





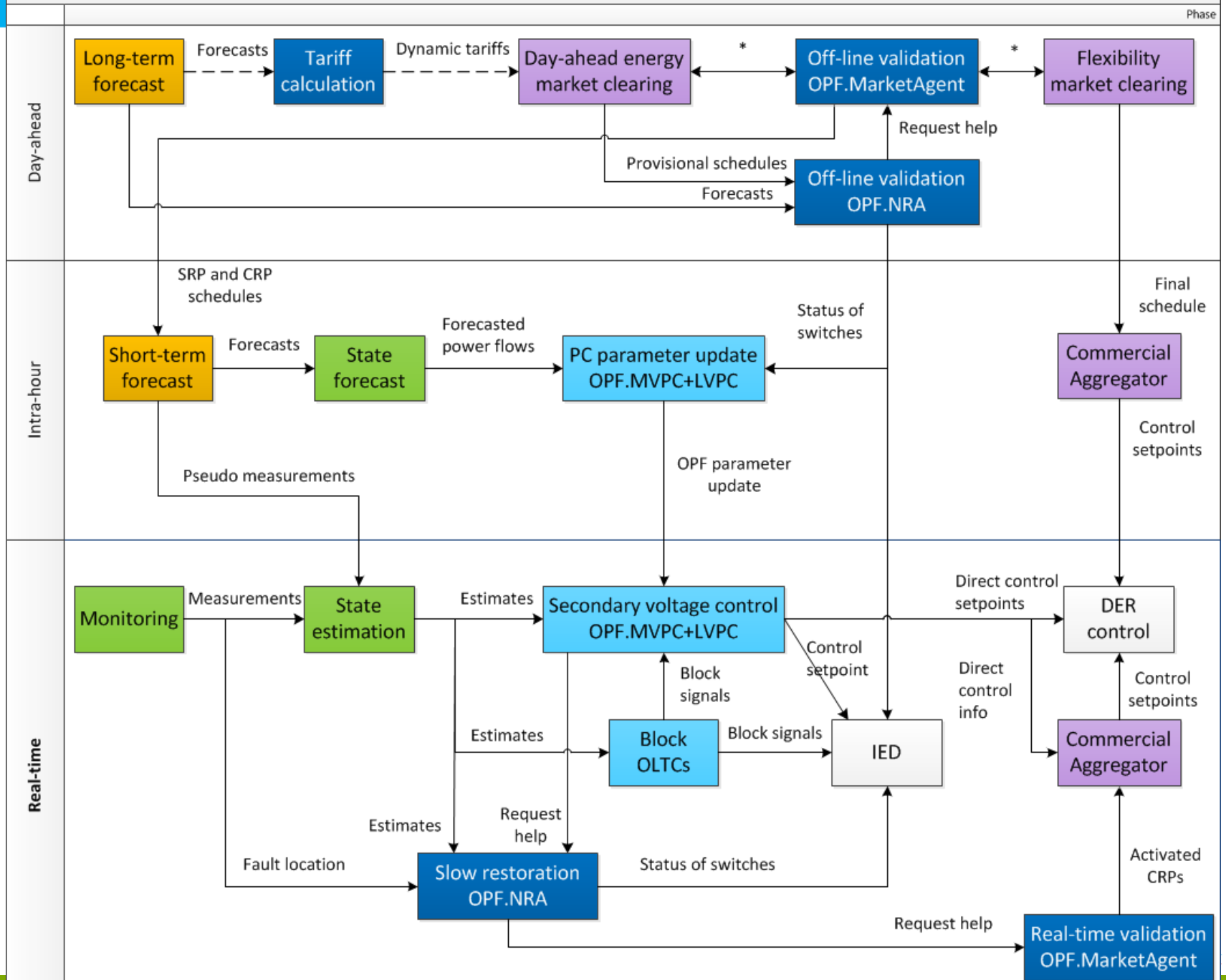
Control hierarchy of congestion management

• Secondary control

- Mitigates congestions and optimizes the network state
- Operates through changing the set points of primary controllers
- No connection to the market place. Only direct control - predefined contracts, grid code requirements and DSO's resources
- Real time control based on present state estimation results
- Located at primary and secondary substations

• Tertiary control

- Network reconfiguration based on forecasts
- Flexibility services from Commercial Aggregator
- No direct control of DER. DER activated through the market place
- Control decisions based on state forecasts for a longer time interval
- Located at the control center





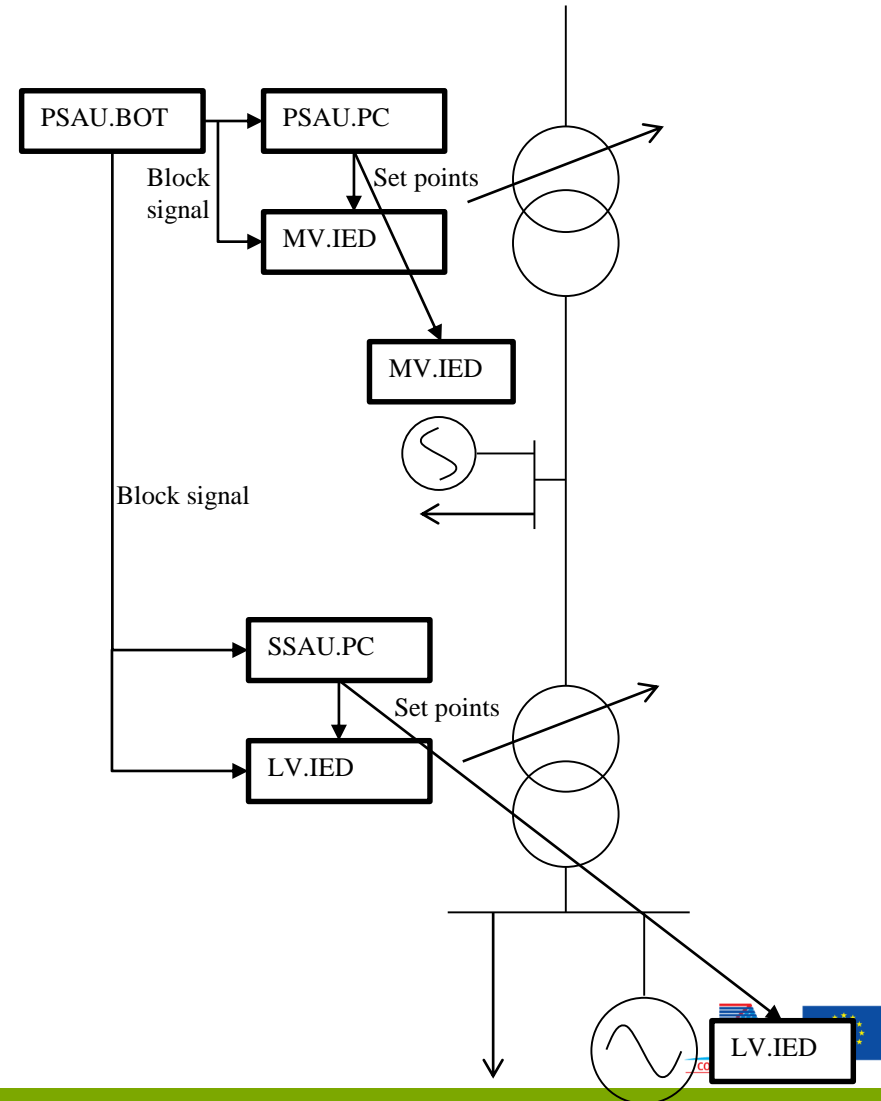
Structure of secondary control

Real time control

- Medium voltage power control algorithm (PSAU.PC) optimizes the MV network operation and low voltage power control algorithm (SSAU.PC) the LV network operation
- Block OLTC's of Transformers (PSAU.BOT) generates block signals for PCs and transformer OLTCs to prevent hunting phenomena

Offline control

- Cost parameters of the real time functions are determined by an offline control algorithm





Real time secondary control

- Objective function

$$f(\mathbf{x}, \mathbf{u}_d, \mathbf{u}_c) = C_{\text{losses}} \cdot P_{\text{losses}} + \Sigma(C_{\text{cur}} \cdot P_{\text{cur}}) + \Sigma(C_{\text{DR}} \cdot P_{\text{DR}}) + C_{\text{tap}} \cdot n_{\text{tap}} + \Sigma(C_{\text{Vdiff}} \cdot |V_{i,r} - V_i|)$$

- Inequality constraints

$$V_{\text{lower}} \leq V_i \leq V_{\text{upper}}$$

Feeder voltage limits

$$I_{ij} \leq I_{ij\text{max}}$$

Branch current limits

$$P_{\text{activeimin}} \leq P_{\text{activei}} \leq P_{\text{activeimax}}$$

Limits for active power of controllable resources

$$Q_{\text{activeimin}} \leq Q_{\text{activei}} \leq Q_{\text{activeimax}}$$

Limits for reactive power of controllable resources

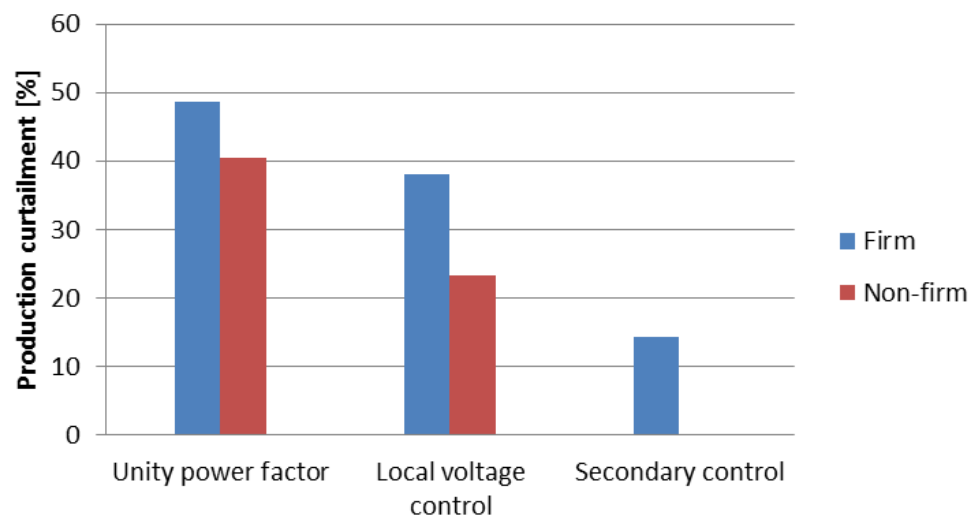
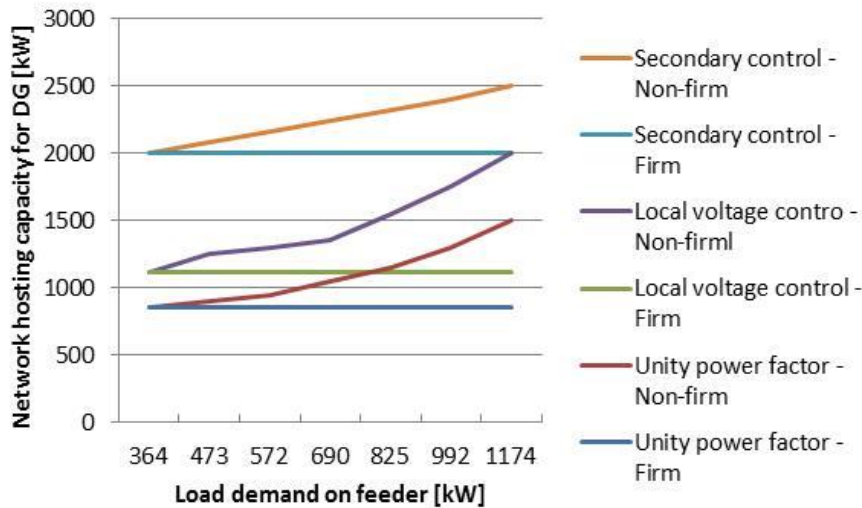
$$m_{\text{min}} \leq m \leq m_{\text{max}}$$

Limits for transformer tap ratio

- Load flow equations are nonlinear equality constraints
- Sequential quadratic programming (SQP) algorithm is used



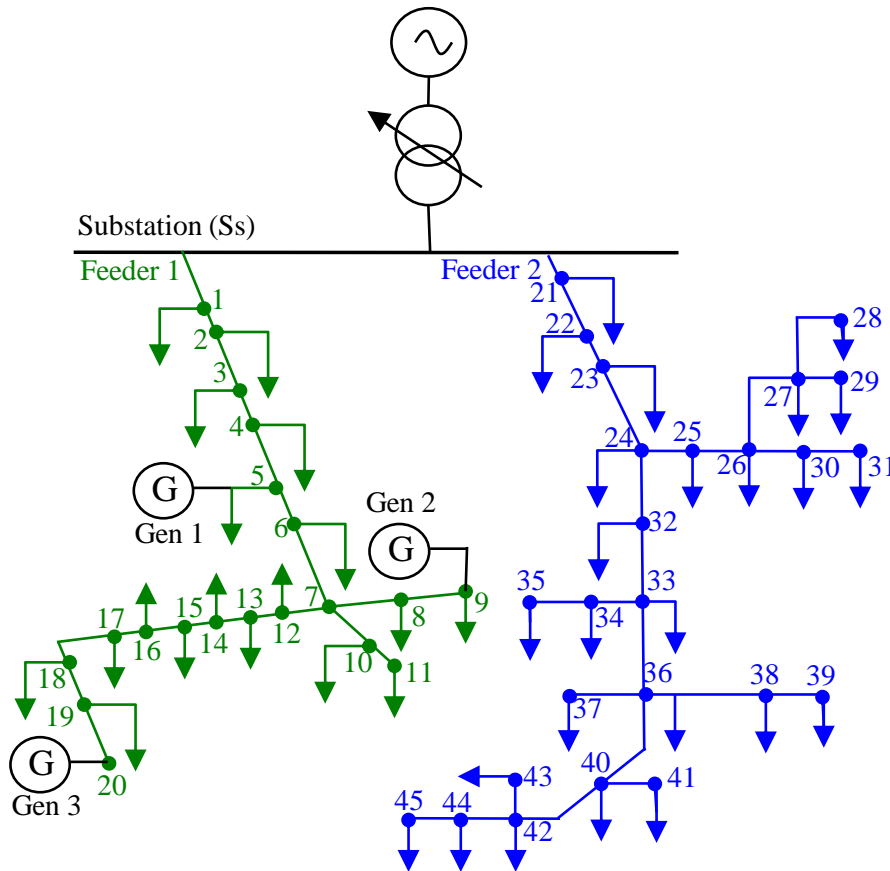
Secondary control increases hosting capacity remarkably



3 MW wind turbine in weak 20 kV network
 Distance to primary substation 22 km
 Results based on stochastic MV network analysis



Example simulation

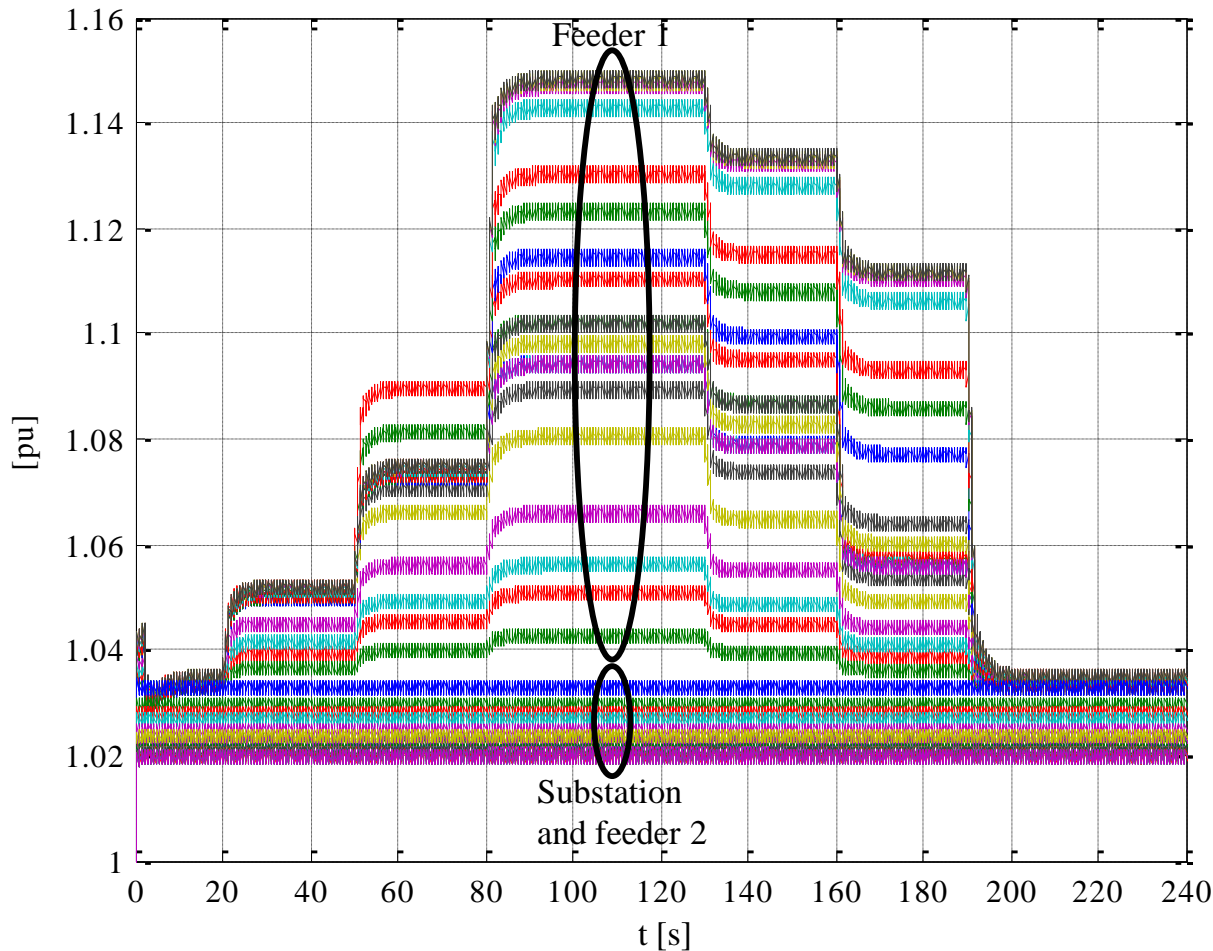


Simulation sequence

Time [s]	P_{set1} [pu]	P_{set2} [pu]	P_{set3} [pu]
0	0.1	0.1	0.1
20	1.0	0.1	0.1
50	1.0	1.0	0.1
80	1.0	1.0	1.0
130	0.1	1.0	1.0
160	0.1	0.1	1.0
190	0.1	0.1	0.1



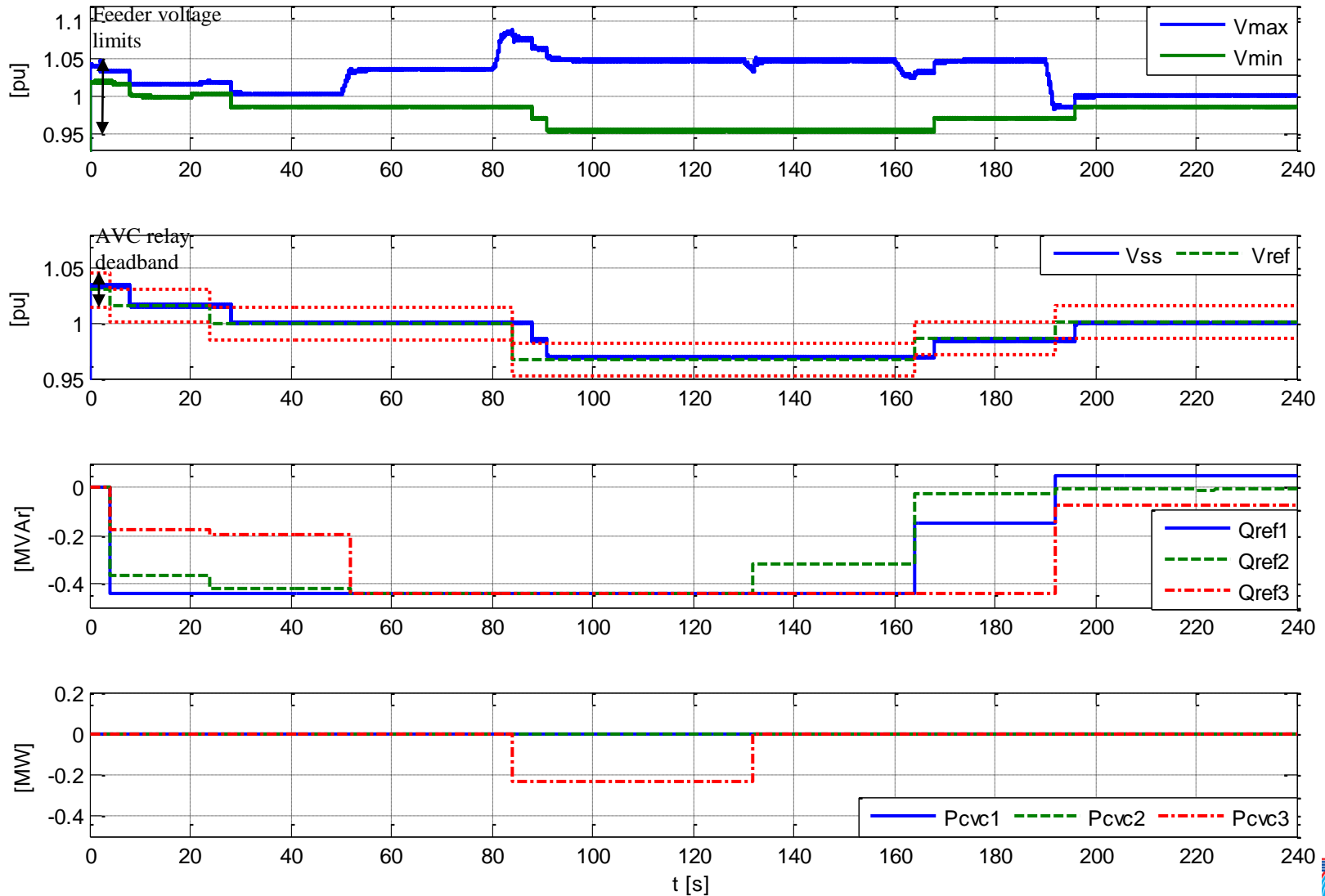
Node voltages without secondary control



Unacceptable!



Secondary control in operation





THANK YOU

FURTHER INFORMATION: WWW.IDE4L.EU



Universidad Carlos III de Madrid

