Voltage control in MV and LV grid
Distributed automation solution

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Content

- IDE4L project
- Problem of voltage control in MV and LV grid
- Proposed voltage control scheme
- Discussion of field demonstrations

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

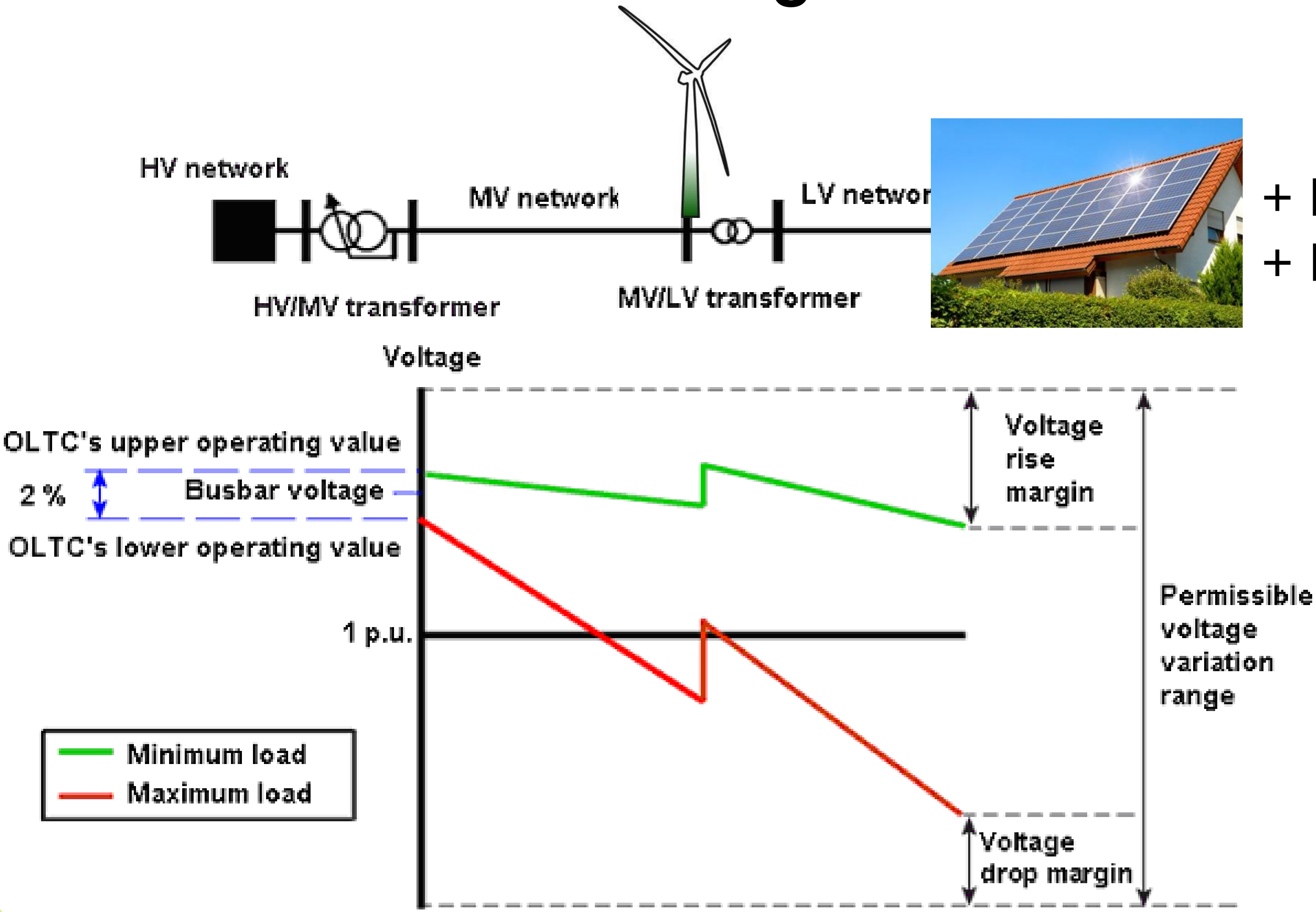
WP5
Congestion management

- 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

Problem of voltage control

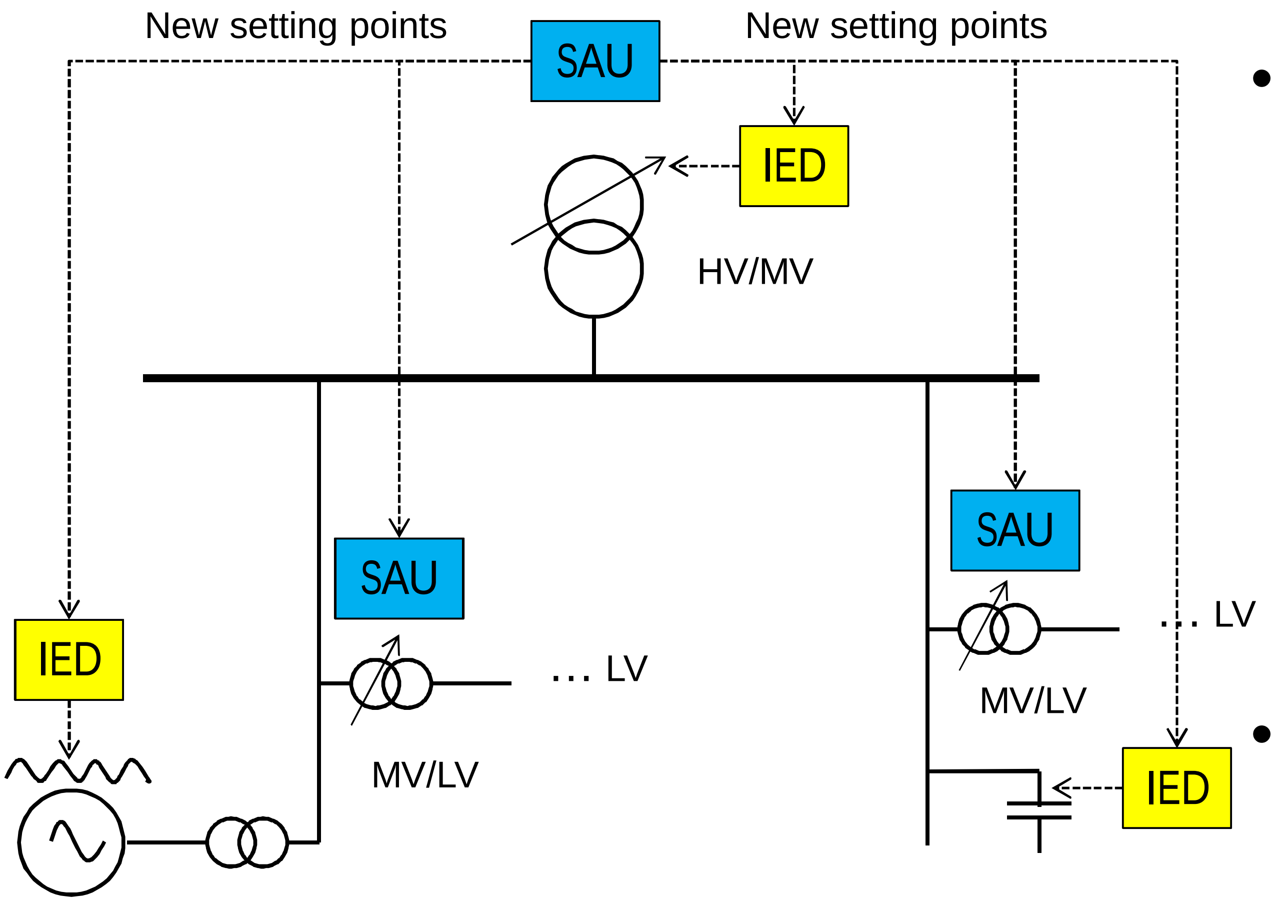


+ HP
+ EV

Control hierarchy of congestion management

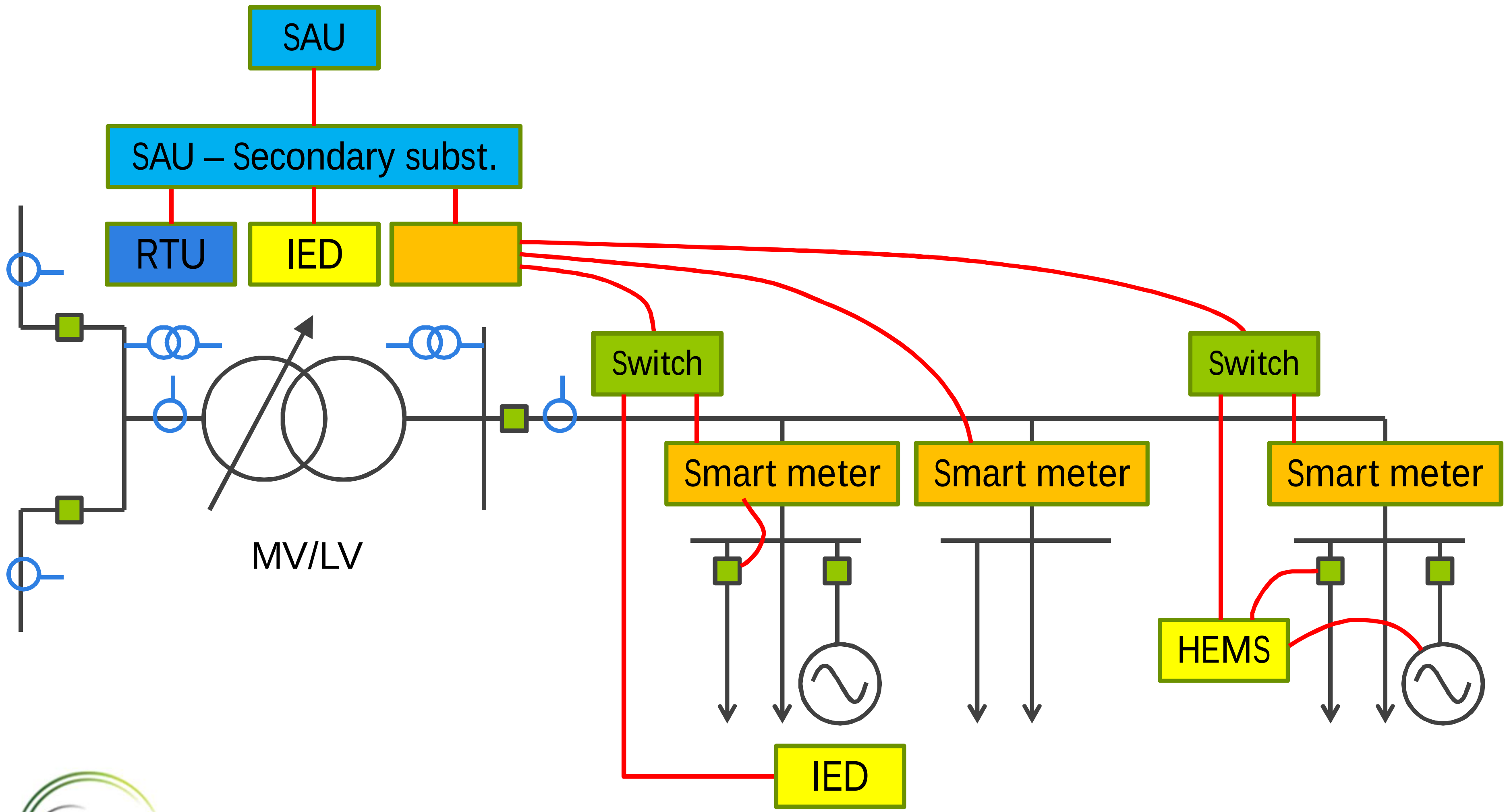
- Regulation
  - Connection requirements
  - Grid tariff
- Primary and secondary controllers
  - DSO's own resources (OLTC, Q-compensation)
  - Contracted control – Non-market based control actions
  - Emergency control
- Tertiary controller
  - Network reconfiguration based on forecasts
  - Flexibility services from Commercial Aggregator
  - No direct control of DER. DER activated through the market place

MV grid voltage control scheme



- SAU = Substation Automation Unit
  - SAU coordinates IEDs and SAUs below it
  - Coordination by secondary controller
  - Based on real-time monitoring and state estimation
- IEDs (primary controllers)
  - AVC of OLTC
  - AVR of DG

LV grid voltage control scheme



Secondary controller

- Objective function

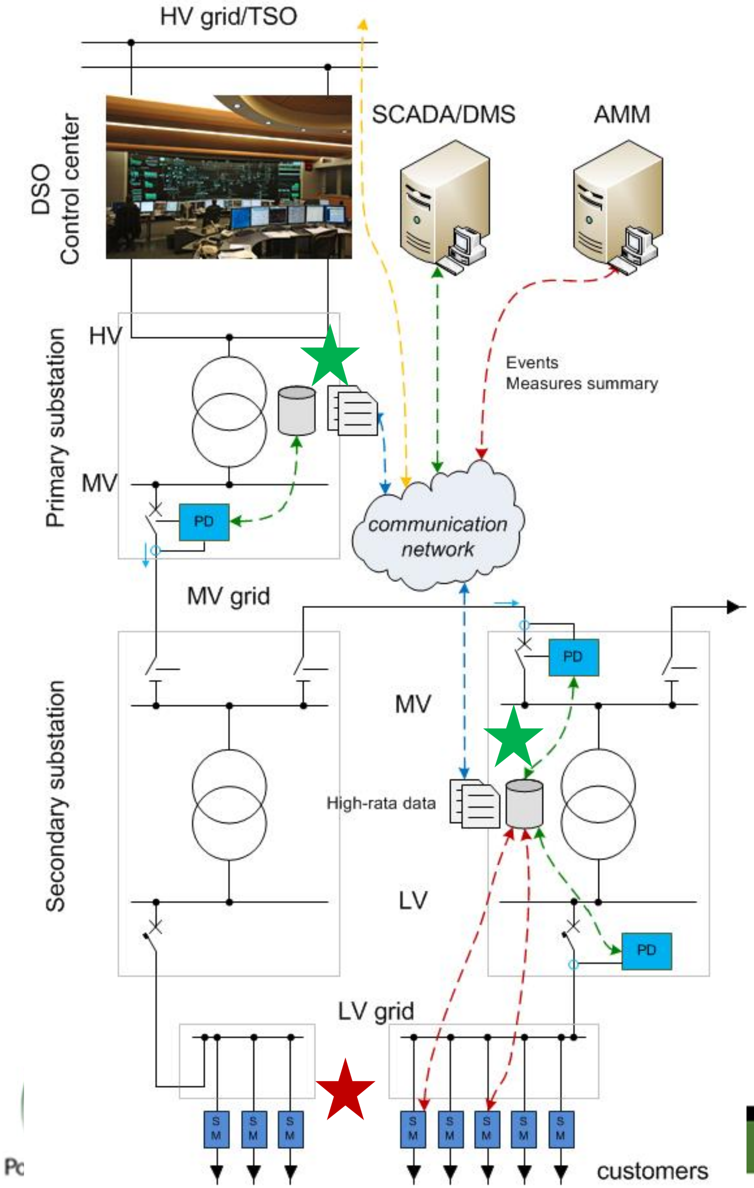
$$f(x,u_d,u_c) = C_{losses} \cdot P_{losses} + \Sigma(C_{cur} \cdot P_{cur}) + \Sigma(C_{DR} \cdot P_{DR}) + C_{tap} \cdot n_{tap} + \Sigma(C_{Vdiff} \cdot |V_{i,r} - V_i|)$$

- Inequality constraints

$V_{lower} \leq V_i \leq V_{upper}$	Feeder voltage limits
$P_{activeimin} \leq P_{activei} \leq P_{activeimax}$	Limits for active power of controllable resources
$Q_{activeimin} \leq Q_{activei} \leq Q_{activeimax}$	Limits for reactive power of controllable resources
$m_{min} \leq m \leq m_{max}$	Limits for transformer tap ratio
$I_{ij} \leq I_{ijmax}$	Branch current limits

- Load flow equations are nonlinear equality constraints
- Sequential quadratic programming (SQP) algorithm is used
  - In Matlab function fmincon is used
  - SQP algorithm available also in Octave

Real-time monitoring and state estimation

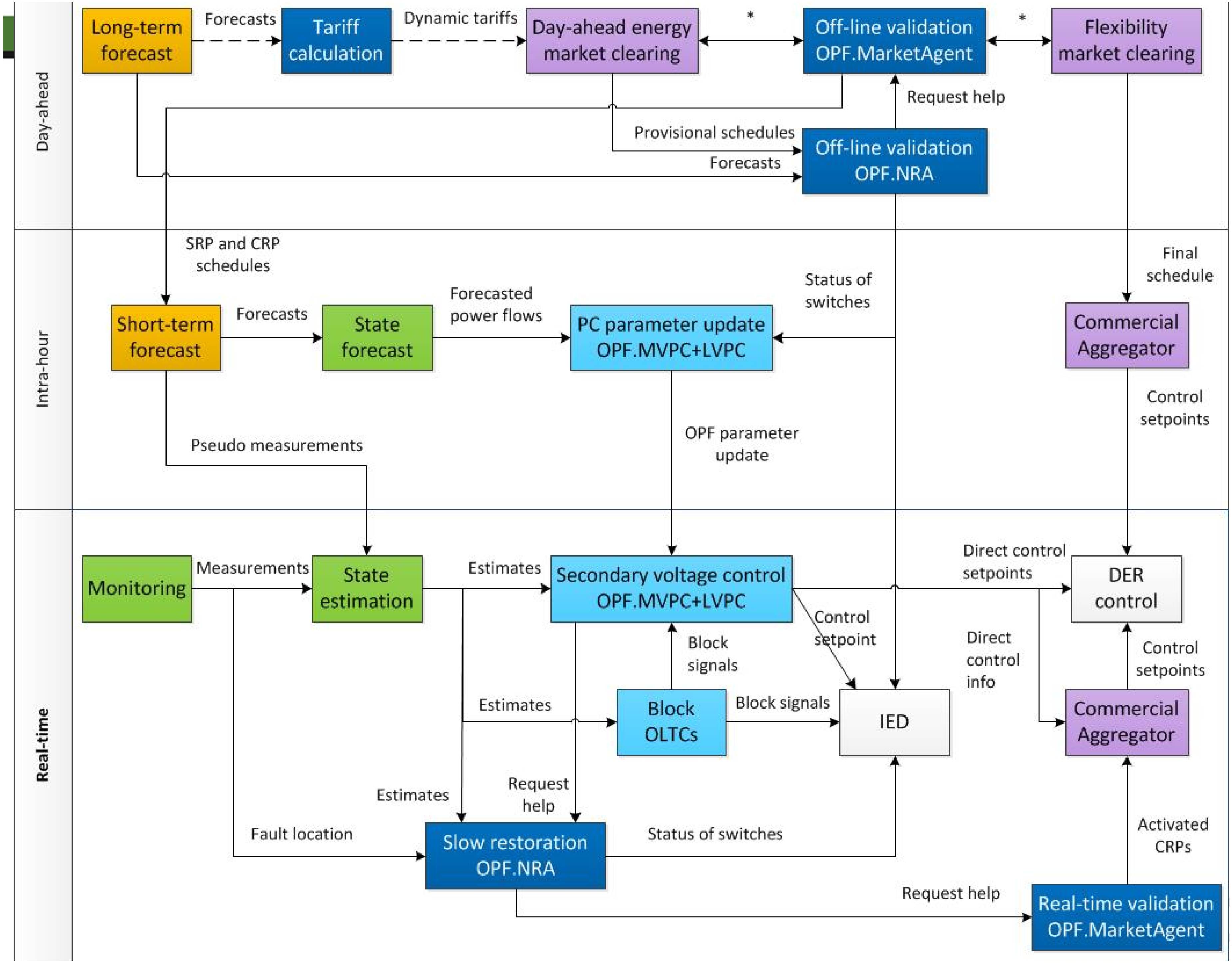


- LV grid ★
  - EV, PV, HP and demand-response schemes mainly affect the LV grid
  - *Monitor the LV grid*
- Data management ★
  - Data coming from heterogeneous system
  - Incomplete: Some nodes are not monitored; Broken/unreachable device
  - Uncertain: Low synchronization accuracy; Measure corrupted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

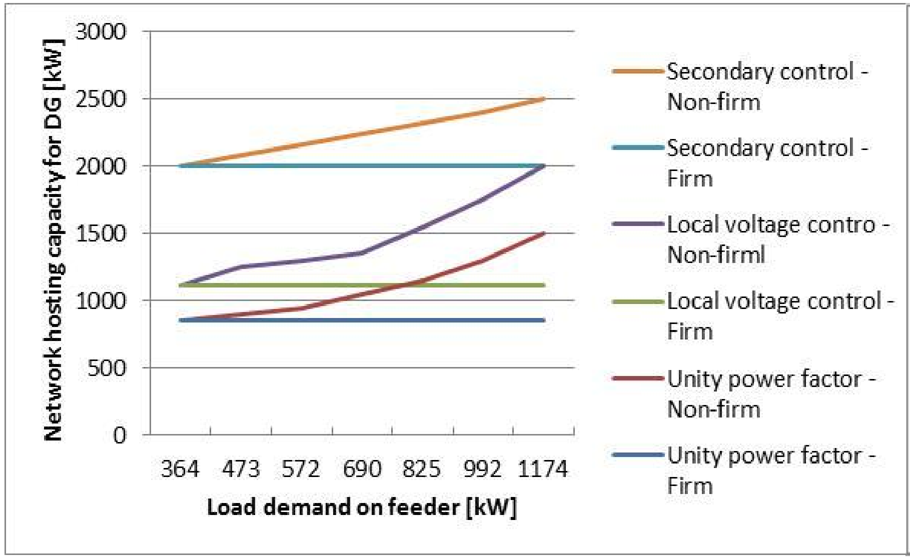
Pc

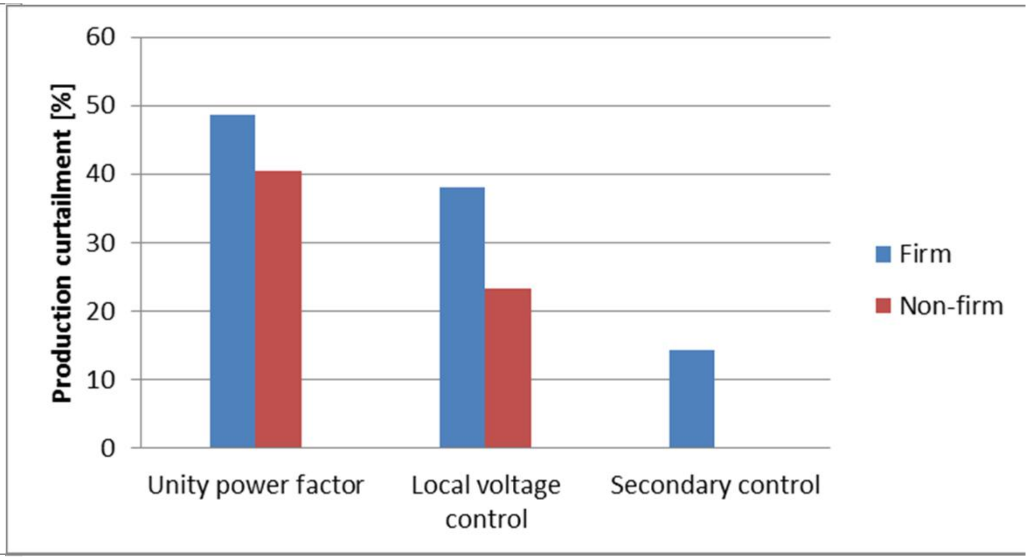
Discussion of field demonstrations

- Field is far from ideal environment
  - Lack of resources (finance, controllability, communication, …)
  - Mix of old and new technologies → Roadmap for automation
- Complexity of system is larger than expected
  - Regulation models → Compromises in general architecture
  - System should work in all conditions (normal, emergency, fault)
- There should be clear business benefits for investments
  - Study of single use case is not enough for an architecture
  - Full benefits of ANM is achieved when network planning principles are also changed → Automation functionality is enabler not a complete solution


Day-ahead
Intra-hour
Real-time
Long-term forecast
Forecasts
Tariff calculation
Dynamic tariffs
Day-ahead energy market clearing
*
Off-line validation OPF.MarketAgent
*
Flexibility market clearing
Request help
Provisional schedules
Forecasts
Off-line validation OPF.NRA
SRP and CRP schedules
Final schedule
Status of switches
Short-term forecast
Forecasts
State forecast
Forecasted power flows
PC parameter update OPF.MVPC+LVPC
Commercial Aggregator
Control setpoints
OPF parameter update
Pseudo measurements
Monitoring
Measurements
State estimation
Estimates
Secondary voltage control OPF.MVPC+LVPC
Direct control setpoints
DER control
Control setpoint
Block signals
Direct control info
Control setpoints
Estimates
Block OLTCs
Block signals
IED
Commercial Aggregator
Estimates
Request help
Fault location
Slow restoration OPF.NRA
Status of switches
Activated CRPs
Request help
Real-time validation OPF.MarketAgent

Secondary control increase hosting capacity remarkably





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

THANK YOU

FURTHER INFORMATION: WWW.IDE4L.EU