Voltage control in MV and LV grid
Distributed automation solution

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- Aggregator concept
- Optimal scheduling of flexibility
- Transmitting synchro-phasors & real-time model syntheses
- Improved microgrid operation

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Problem of voltage control

[Diagram showing voltage control in an electrical grid with HV, MV, and LV networks, OLTC's operating values, and voltage margins for minimum and maximum load.]
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

- SAU
- SAU - Secondary subst.
- RTU
- IED
- Switch
- Smart meter
- Smart meter
- Switch
- Smart meter
- HEMS
- IED

MV/LV
Secondary controller

• Objective function

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

• Inequality constraints

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

• 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**
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
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