Voltage management of low voltage network

Sami Repo
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Low voltage network scenarios
Low voltage network scenarios

• **Increasing loads**
  - Changes in heating / cooling type
    - Oil heating is replaced with heat pumps
    - Summer time loads are increasing
  - Electric vehicles
    - Annual energy: 0.2 kWh/km * 20000 km = 4000 kWh
    - Peak power: 3 kW – 10 kW at home
    - Uncontrolled / controlled charging
  - Elspot based energy management
    - Shiftable loads used at the same moments
Low voltage network scenarios

- Increasing production
  - Self-generation (PV) → decreasing load → DNO’s income decrease
  - High penetration of PV → network feed → voltage rise
Low voltage network scenarios

- Controllability of customers
  - Home/building automation → Energy cost minimization
  - Power based grid tariffs / Dynamic grid tariffs
  - Demand response contract or service
Low voltage network management

- Smart meter based LV network management
- Home Energy Management System
- INTEGRIS solution for LV network management
- New ideas for LV network management
Smart meter based LV network management

AMR alarms
AMR near real-time monitoring
AMR based demand response
AMR data in DSO’s processes

• Network planning and asset management
  • More accurate load profiles and customer classification → improved network analysis for long-term planning
  • Supervision of network status based on actual measurements → short-term reinforcement actions
  • Prioritization of network reinforcement actions based on supply quality
  • Estimations of assets’ expected life time based on actual power flows

• Normal operation
  • More accurate load profiles and customer classification → improved pseudo measurements for state estimation
  • Selected real-time voltage measurements to further improve the accuracy of state estimation
  • LV network monitoring and control becomes possible

• Emergency situations
  • Direct load control to reduce power flow
Aggregator services for network management

HEMS for customer needs
Market integration of HEMS
DSO interface for HEMS

NIS  DMS  CIS
SCADA  AMR gateway

MDC

Aggregator

Retailer 1  Retailer n

DSO interface for HEMS

Smart meter  HEMS
INTEGRIS solution for LV network management

- Secondary substation automation
  - MV network monitoring and control
  - LV feeder measurements
  - Monitoring of whole LV network based on real-time AMR data
- LV network management based on local decision making and DER control
- Single interface towards control centre
- Integris device operates as an IEC 61850 server → sends only requested or analyzed information like alarms or statistical data to the SCADA
Secondary substation automation

1. MV network and transformer
2. LV feeders
3. LV network real-time monitoring
4. LV network real-time management
Ideas for LV network management

- DSO provides services via automation system
  - AMR data $\rightarrow$ AMR HUB
  - AMR based Demand Response $\leftrightarrow$ Aggregator
  - SS-IDEV + AMR + HEMS $\leftrightarrow$ Aggregator

- Why DSO should provide infrastructure?
  - Neutral actor
  - DSO needs LV network management anyway
  - Separation of infrastructure and functionalities
  - Parallel systems create conflicts
  - Interoperability is easier to realize
  - Efficient utilization of capital investments for infrastructure
Decentralized and integrated automation systems
Ideal solution for LV network management

Integration of systems
Standard protocols
Open infrastructure
Autonomous

IDEAL
ideal grid for all

WWW.IDEAL.EU – Sami Repo

SCADA
DMS
NIS
CIS

Enterprise Service Bus

INTEGRIS device

RTU

AMR HUB
Aggregator

Switch

Smart meter

HEMS

Switch

Smart meter

HEMS
Simulations
Network impacts of PV and energy storage in LV network

- LV network from Orivesi
- Apartment houses
- House, direct electrical heating, hot water boiler (electric) < 300 l
  - PV: 3 kW, annual energy 3.2 MWh, measured radiation from Tampere
  - Energy storage: ideal, 5 kWh (hot water per person per day 40-50 litre → 2-4 kWh)

- Aim of simulations
  - Minimize energy supply from customer to network
  - Analyse impact of energy storage (demand response) on LV network currents and voltages
Results of single customer

Sum powers for simulation period

Sum power and battery SOC, Monday 14/05 to Sunday 20/05

Power (kW) / SOC (kWh)
Network impacts of PV and energy storage in LV network
Network impacts of PV and energy storage in LV network

Line current from Monday 14/05 to Sunday 20/05

Line far end voltage from Monday 14/05 to Sunday 20/05
Netotustavat

- Ei netotusta
- Summataan vaihekohtaiset tuntienergiat
- Netotetaan päiväenergiat, vaiheet erikseen.
- Netotetaan päiväenergiat ja vaiheet.
1-vaiheinen PV

Asiakkaille myyty energia

kWh
3-vaiheinen PV

Asiakkaille myyty energia

kWh
Voltage control methods

- Primary control (only local measurements)
  - Automatic Voltage Regulation (AVR) of DG unit
  - Automatic Voltage Controller (AVC) of MV/LV transformer on-line tap changer
- Secondary control (area control)
  - Coordinated control of all resources in LV network
LV network voltage control
LV network voltage control
10 kW PV per customer, middle load

<table>
<thead>
<tr>
<th></th>
<th>Base case</th>
<th>AVC</th>
<th>AVR</th>
<th>AVR DB</th>
<th>AVC + AVR</th>
<th>AVC + AVR DB</th>
<th>CVC</th>
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</thead>
<tbody>
<tr>
<td>Overvoltage volume (pu*s)</td>
<td>11.6601</td>
<td>1.0318</td>
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<td>Duration voltage is out of bounds (s)</td>
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<td>19.919</td>
<td>29.8780</td>
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<td>19.9187</td>
<td>9.9593</td>
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<tr>
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<td>0.0263</td>
<td>0.0274</td>
<td>0.0243</td>
<td>0.0232</td>
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<td>Real power losses (kWs)</td>
<td>65.255</td>
<td>71.873</td>
<td>83.243</td>
<td>72.39</td>
<td>85.1131</td>
<td>75.5502</td>
<td>74.645</td>
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</tbody>
</table>
### LV network voltage control

10 kW PV per customer, min load

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<th>AVC + AVR</th>
<th>AVC + AVR DB</th>
<th>CVC</th>
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<tbody>
<tr>
<td>Overvoltage volume (pu*s)</td>
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<td>Undervoltage volume (pu*s)</td>
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<td>19.919</td>
<td>29.8780</td>
<td>29.8780</td>
<td>19.919</td>
<td>19.9187</td>
<td>8.9634</td>
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<tr>
<td>Generalized mean of surface</td>
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<tr>
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<td>76.8551</td>
<td>89.965</td>
<td>82.1263</td>
<td>64.9320</td>
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</tbody>
</table>
a) Base case
b) AVC
c) AVR
d) AVR DB
e) AVR + AVC
f) AVR DB + AVC
g) CVC
ideal grid for all
a) AVR 

b) AVR DB 

c) AVR + AVC 

d) AVR DB + AVC 

e) CVC
Thank you