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December, 2016

Context

Smart-market

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Smart-World trend

Fig. source Romande Energie

Smart-World trend

Smart-Metering

Smart-City

Smart-Energy

Smart-Home

Smart-grid

Smart-Control

Smart-Market

Smart-Building

Europe

>3,000 DSOs have been involved in approx. 400 smart-grid projects since 2006

€ 5bn have been invested and another 400bn forecasted by 2020

45% of projects are concerned with R&D

50% with demonstration

5% with deployment

Other countries

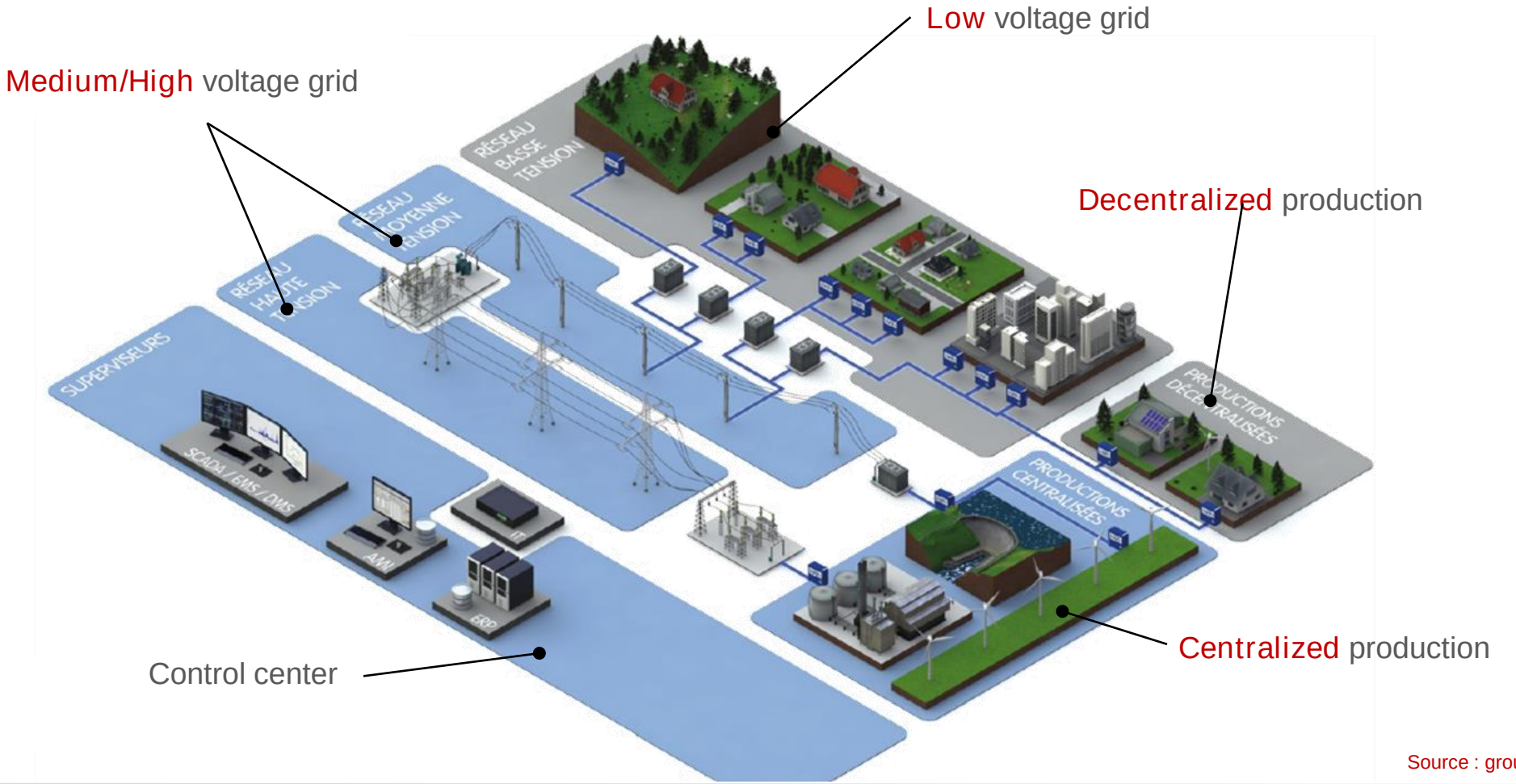
U.S : $ 476 bn forecasted for 2030

China : > $ 100bn by 2020

South Korea : $ 24bn by 2030

Fig. source Romande Energie

Power Grid : global overview

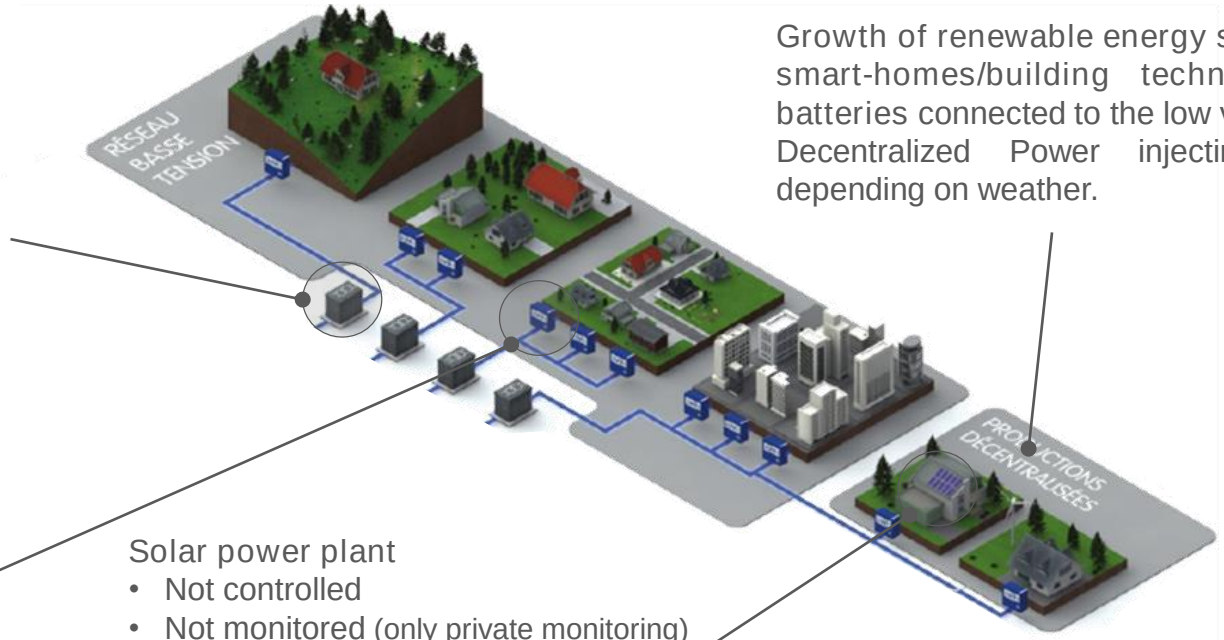


Source : groupe e

Low Voltage Grid

MV/LV transformer
- Not controlled
- Not monitored

Low voltage cabinets
- Not controlled
- Not monitored



Growth of renewable energy sources, EVs, smart-homes/building technologies and batteries connected to the low voltage side. Decentralized Power injecting electricity depending on weather.

Solar power plant
- Not controlled
- Not monitored (only private monitoring)

Source : groupe e

Power grid : paradigm change

Today's configuration

- Power generation is mainly **centralized**
- Power flow is **unidirectional** (from HV/MV to LV grid)
- **No technologies** installed into the LV-grid

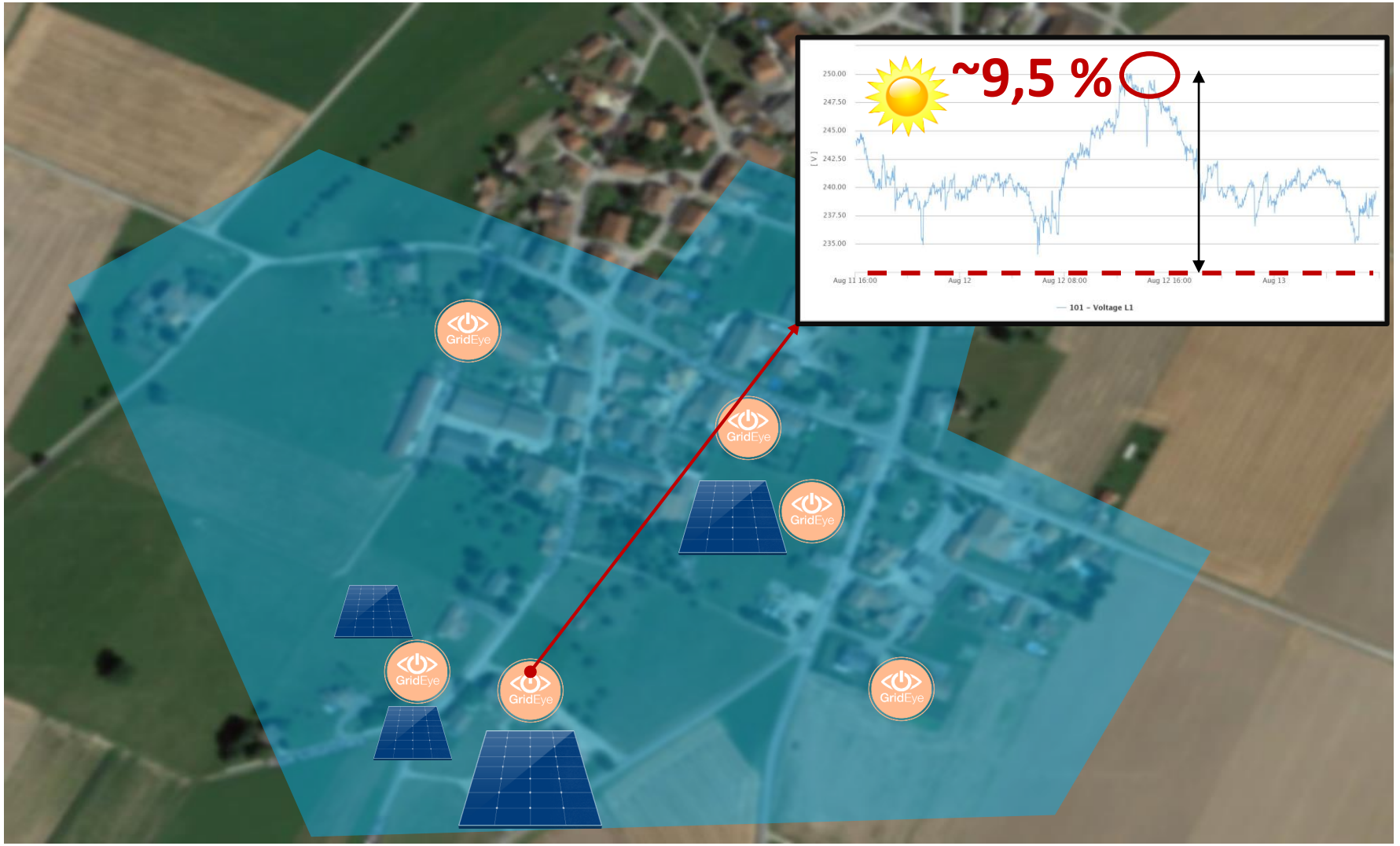
- Low to **none visibility and control** into the low voltage grid

Tomorrow's Evolution

- Expansion of **decentralized** power generation
- **Bi-directional** power flow
- **Smart-technologies** (homes, buildings, vehicles) consuming and injecting on demand energy into the LV-grid

- Communication between **monitoring, production and consumption** systems

PV impact : voltage profile during a sunny day



Area

- 200 people
- 4 PV power plants
- 6 meas. points

190 kW

80 kW

7 kW

Measure
U,I,P,Q

PV impact : voltage profile during a cloudly day

Area

- 200 people
- 4 PV power plants
- 6 meas. points

190 kW

80 kW

7 kW

Measure
U,I,P,Q

PV impact : Energy management

Area

- 200 people
- 4 PV
- 1 boiler : 60 kW
- Vaud (Switzerland)

190 kW

80 kW

7 kW

Measure U,I,P,Q

GridEye

Vision - USP

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DEPsys Vision

Bring Visibility

Ensure the Voltage Stability

Guarantee the Grid Safety

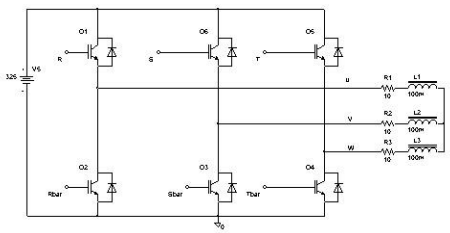
Increase Energy efficiency

Optimize the Grid Infrastructure

Minimize Losses

GridEye : 4 years – 4 generations

- > 150 DSOs meeting
- 4 years of market discussions
- University ➔ Lab test ➔ field test
- OFEN project support
- CTI project support



Smart Controller

2012

2013

2014

2015

2016

GridEye : a modular and scalable solution

- Obervability (real-time – PQ)
- Control : Stability / Energy optimization
- Updated remotely at any time
- Installed in 15 minutes
- Plug & Play

- Measurements are processed according to **IEC 61000-4-30** (EN 50160 reports).
- Optimal control approach **without knowledge of the grid parameters and topology**
  - Possibility to control production sources, storage and loads
  - Ensure technically secure and economically optimal operation
- **Decentralized intelligence**
- **Useful data** are communicated for monitoring and control functions
- **Resilient** to the loss of a module or communication.

GridEye : installation

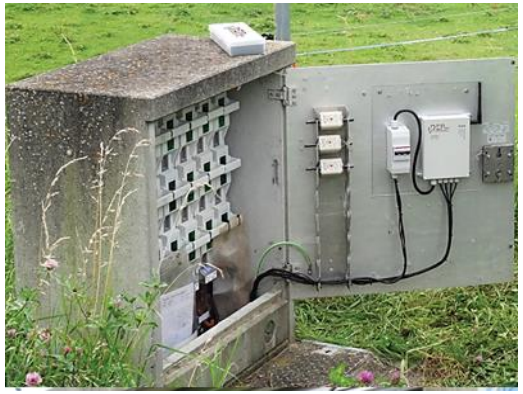
MV/LV transformer

MV/LV transformer

Measurements at transformer LV side

PV power plant

Distribution cabinet (urban area)

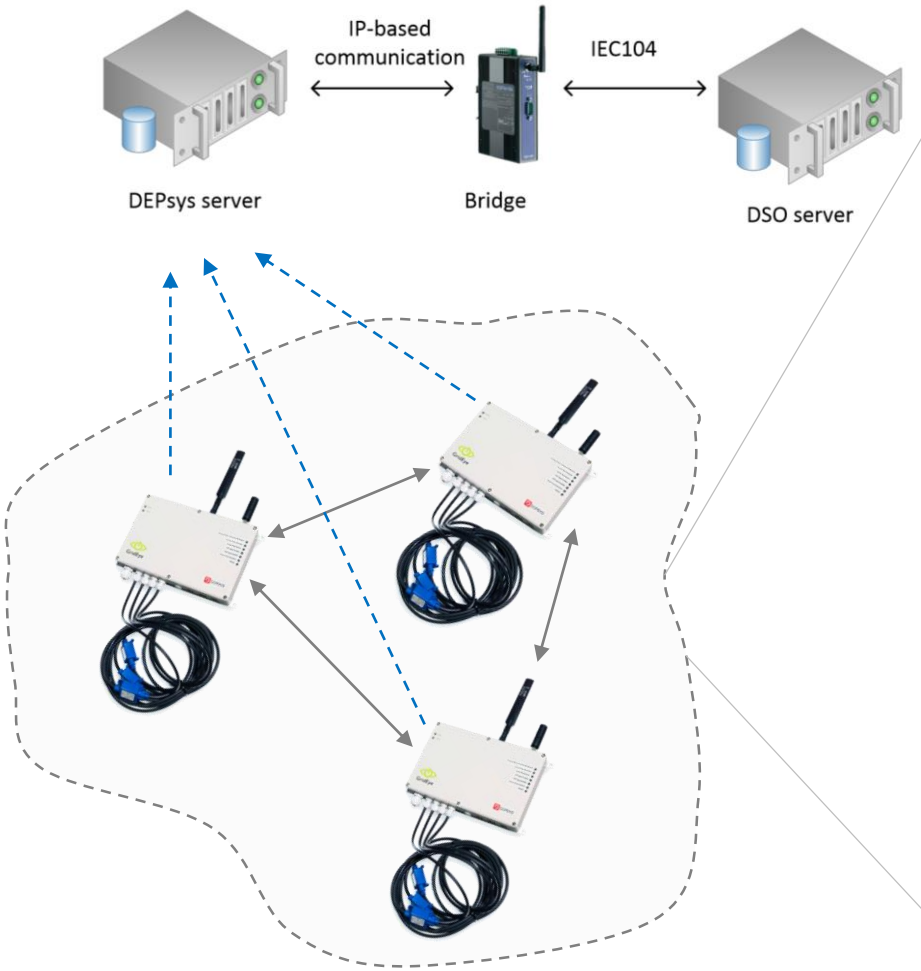


Distribution cabinet (rural area)

Inverters (production / storage)

Loads

Communication and Data



Measures :

- Voltages : U1, U2, U3
- Currents : I1, I2, I3, IN
- Energies (act.react.)
- Frequency
- Flicker, harmonics,
- Alarm

→
- Measures with Rogowski
- IEC 61000-4-30
- Power Quality

Calculated

- Losses
- Power : P/Q/S
- Distribution loads
- MV estimation

→
- Statistics/Graphs added on demand

Additional data

- Trafo temperature
- Door contact
- Smoke
- etc.

→
- Various data (on demand)
- Need additional I/O and gateway
- Communication with GridEye by MODbus UDP and/or MODbus RTU

Monitoring

Grid Analytics – Concrete example

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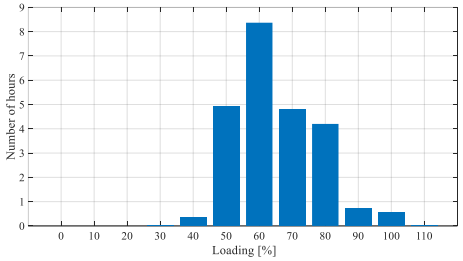
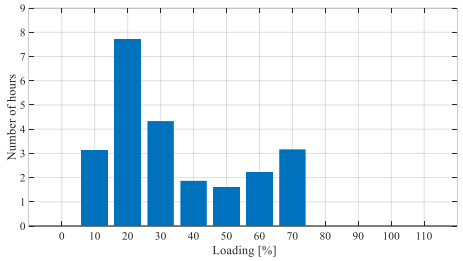
Grid analytics

Winter day



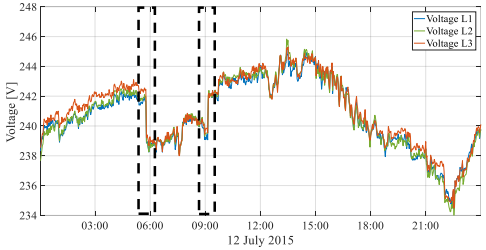
distribution of transformer loading

Summer day



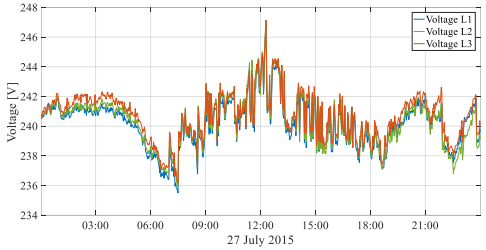
distribution of transformer loading

Sunny day

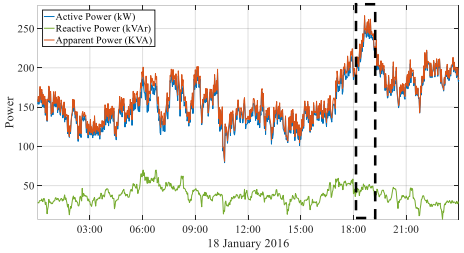


temporal profile of voltage

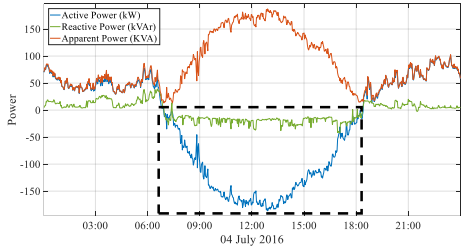
Cloudy day



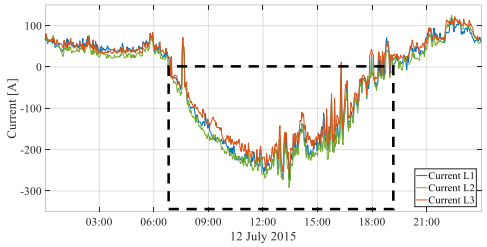
temporal profile of voltage



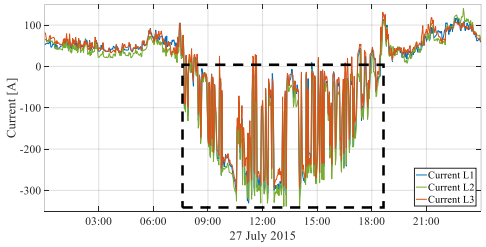
temporal profile of transformer loading



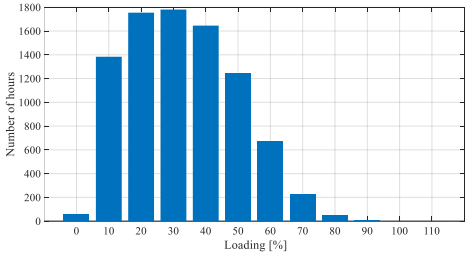
temporal profile of transformer loading



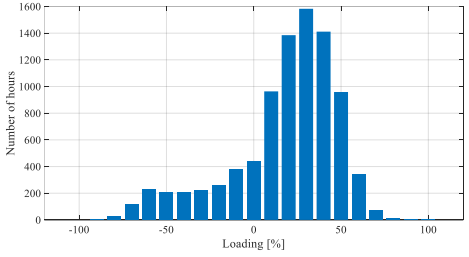
temporal profile of current



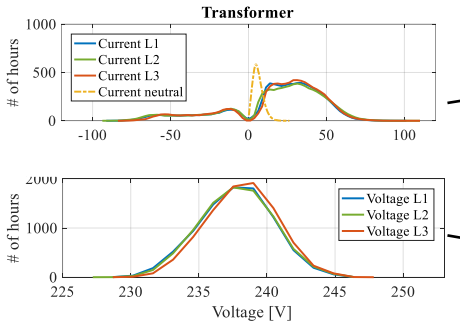
temporal profile of current

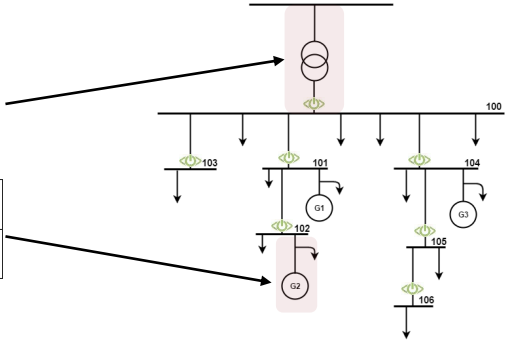


apparent power



active power with power flow direction



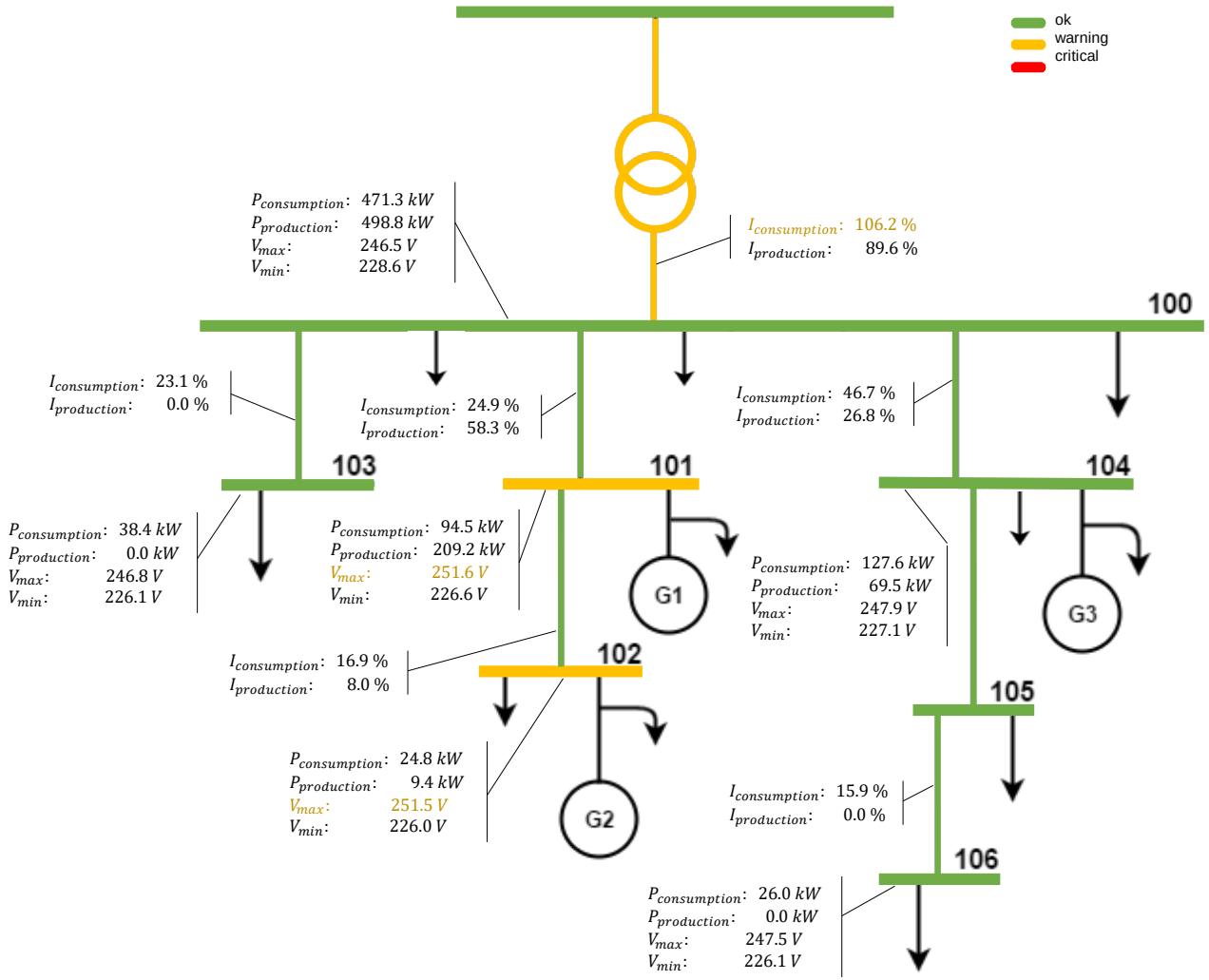


Statistics for network planning

The developed network planning approach allows the DSOs evaluating the value of several solutions, including :

- upgrade of transformer/cable,
- taking a certain level of overloading risk for of transformer/cable,
- deploying GridEye optimal control

This approach **enable the DSO to determine the additional consumption / production that can be added at every node** such that the technically secure operation of the grid is guaranteed.



Optimal control

Voltage stability / Energy optimization

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Optimal control approach

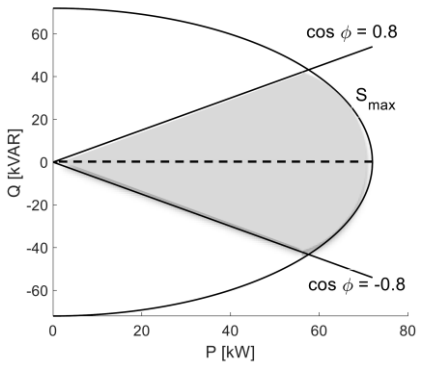
objectives and constraints for system operator and end-customer

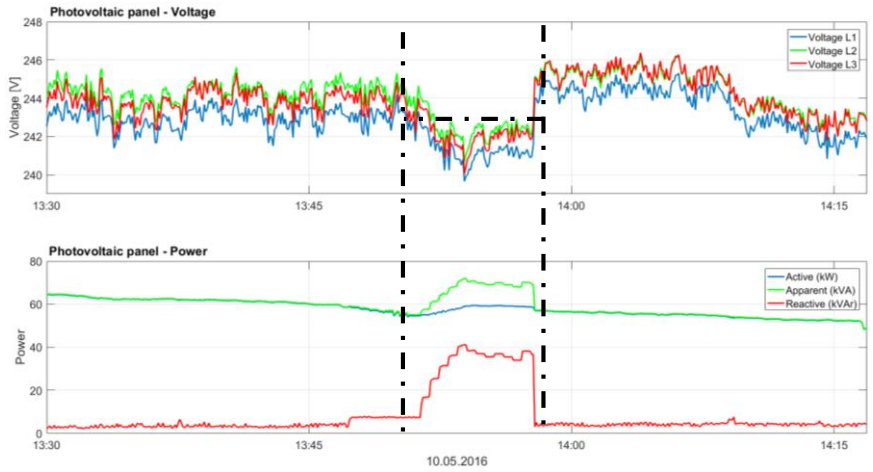
	objectives	constraints
system operator	• **technically secure** operation of grid • minimization of grid operation costs • satisfaction of customers	• voltage limits of nodes • **thermal limits** of transformers and cables • operational limits of **controllable devices**
end-customer	• access to reliable and economic power supply • **decrease its electricity bill** • increase its benefit from its installations	• guarantee secure operation of its installations

The optimal grid control approach is based on the sensitivity coefficients.

The solution of the optimal control algorithm is the active and reactive power set-points of controllable devices (e.g. PV inverters, energy storage systems, etc.) as well as the on/off switching status of heating devices (e.g. electric boilers, etc.).

Voltage control using reactive power

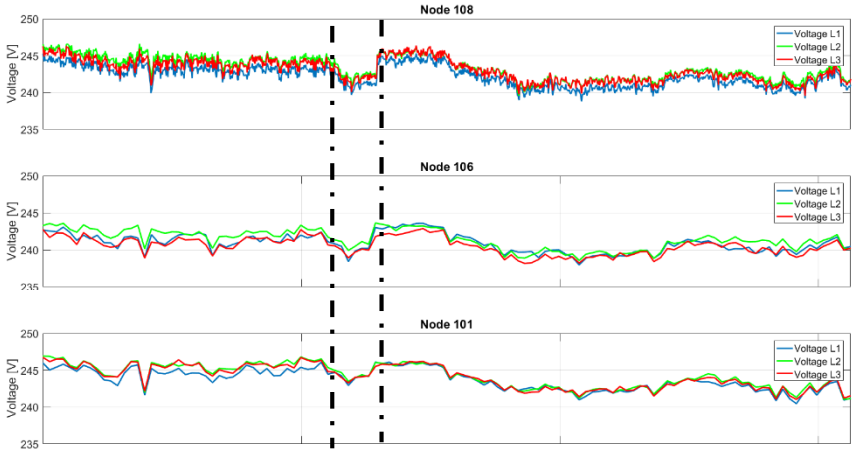




Temporal voltage and power profiles

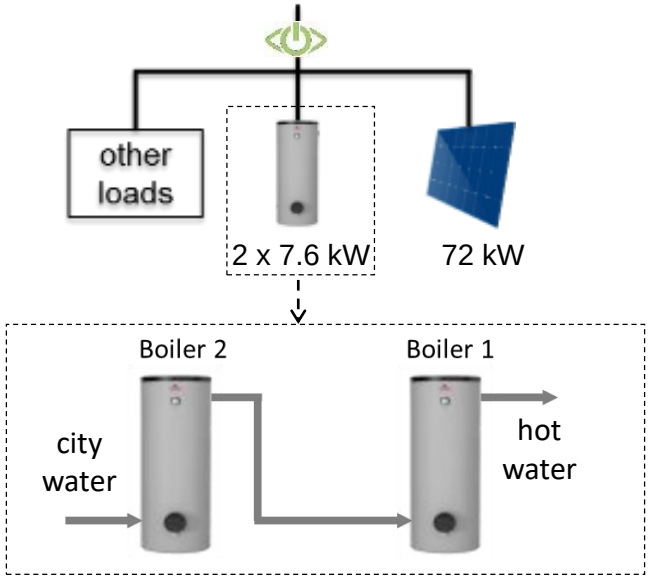
In the indicated period, the maximum voltage limit for node 104 is set at 243 V. The control algorithm adjusts the reactive power of the PV inverter such that the voltage of the node 104 remains within the selected limits.

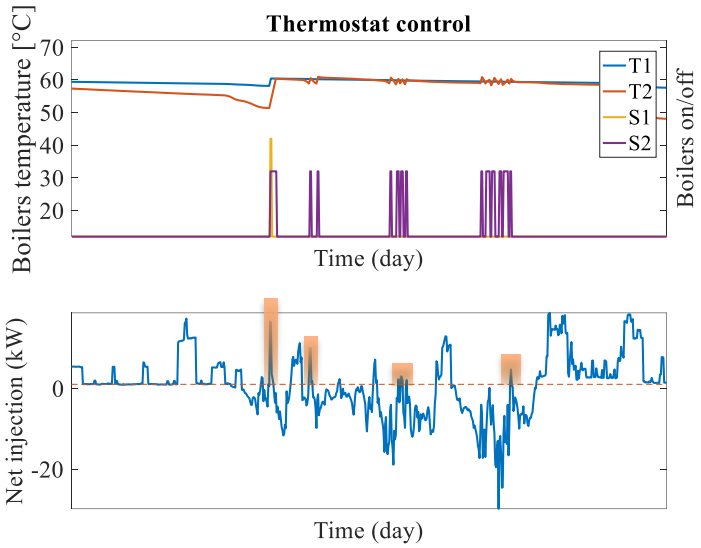
- The active power production is not changed during the voltage control.
- The influence of the control action is observed on the voltages of all the nodes of the grid.

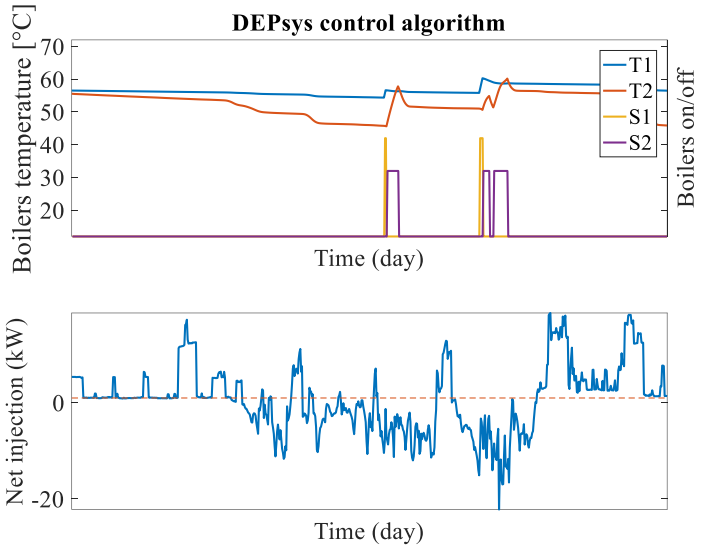


Temporal voltage profiles of nodes 106 and 101

Optimal control of electric boilers







Based on 3-months of data, the benefits of using «DEPsys control algorithm» are:

- Guarantee the comfort of client.
- Increase of auto-consumption by 365.6 kWh.
- Decrease of the number of boilers' switching by 48% and consequently **increase of boilers' life**-time.
- Reduction of the electricity bill by 68%

Conclusion

The smart-grid is being formed

- Initial observations of potential **critical state**
- Key step for smart grid technologies **rollout**
- **Initial DSO investments** in the smart grid roadmap

DEPsys point of view

- DSO and prosumers ➔ possible win-win business model :
  - Prosumers: financial gain
  - DSO : voltage under control and limited impact at the MV level
- Distributed Energy Resources impact is already affecting the LV-grid. Need to initiate installation of LV-technologies today
- DSOs should work/invest together within
  - Alliance creation
  - National grid projects

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Rethink energy

Thanks