SNOOPI
Smart Network Control with Coordinated PV Infeed

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Outline

- Project Background
- Voltage Regulation Tool
- Testing Environments
- Simulation Results
- Conclusion and Outlook
Project Background

Integration of PV plants into the distribution grid

- Increasing amount of PV plants in the distribution grid
  - Voltage rise along the feeder at times with high PV infeed
  - Amount of PV plants is limited because of the permitted voltage deviation of \( \pm 10\% \)
- By providing reactive power, PV and battery inverter can reduce the voltage

Our Solution

- Development of a **SNOOPI-Box** to control PV and battery inverter in the distribution grid

**SNOOPI**

- **Smart Control**: Contains a voltage regulation tool to control reactive power
- **Autonomous**: Works independently without communicating with other boxes or devices
- **Transferable**: Uses the SunSpec protocol to communicate with the inverter → Applicable to almost any PV or battery inverter
Project Partner

Energynautics GmbH, Germany
- Development of the simulation model and the regulation algorithm
- Project management

KTH Royal Institute of Technology, Sweden
- Development of the voltage regulation

EWR Netz GmbH, Germany
- Supply of grid and measurement data
- Field Test Area

Associated Partner

Fronius International GmbH, Austria
- Assists with the communication
Project Phases

10/2015

Phase 1 • Identification of possible field test areas
• Development of simulation models

Phase 2 • Development of the voltage regulation tool

Phase 3 • Successful tests of the regulation tool in the simulation model

Phase 4 • Successful tests of the regulation tool in the lab tests

Phase 5 • Selection of field test areas
• Installation of battery systems

Phase 6 • Successful tests of the regulation tool in the field test

09/2018
Voltage Depended Reactive Power Control

- Reactive power setpoints are determined using an autonomously parameterized \( Q(U) \) characteristic curve

Parameter:

- \( Q_{max}, Q_{min} \): Max./ min. reactive power of the inverter
- \( U_N \): Nominal Voltage
- \( U_{max}, U_{min} \): Max./ min. measured voltage

Parameterization:

- \( U_4 = U_{max} \)
- \( U_3 = U_N + 0.5 \cdot (U_{max} - U_N) \)
- \( U_1 = U_{min} \)
- \( U_2 = U_{min} + 0.5 \cdot (U_{max} - U_N) \)
Coordinated Behaviour of all inverters

- The voltage at the beginning of the feeder is smaller than the voltage at the end of the feeder:
  Dependency of the starting point $U_3$ on $U_{max}$ → all inverters will start to provide reactive power at the same time

- Reactive Power provided at the beginning of the feeder has a smaller influence on the voltage:
  The $Q(U)$ curve is steeper if the maximum voltage is smaller → inverters at the beginning of the feeder will have a steeper $Q(U)$ curve

Parameterization:

$U_4 = U_{max}$ ; $U_3 = U_N + 0.5 \cdot (U_{max} - U_N)$

$U_1 = U_{min}$ ; $U_2 = U_{min} + 0.5 \cdot (U_{max} - U_N)$
Voltage Regulation Tool

Change in the Grid Topology

- Grid Topology changed:
  - Inverter from the beginning of the feeder is now located at the end of the feeder
    \[ U_{max} \] is adjusted automatically by measuring the higher voltages
  - Inverter from the end of the feeder is now located at the beginning of the feeder
    \[ U_{max} \] will remain at its high value

- **Solution**: Determining the influence of the reactive power on the voltage
  - Periodical calibration to determine the influence:
    - different reactive power setpoints are passed to the inverter
    - The influence is determined by dividing the change of the voltage \( dU \) by the change of the reactive power \( dQ \)
  - Influence will change if the grid topology is changed \( U_{max} \) will be determined newly
Simulations in DlgsILENT PowerFactory

DlgsILENT PowerFactory

Active Power in kW
Reactive Power in kVar
Voltage in V

Active [kW] and Reactive Power Setpoints [kVar]

Python Interface for PowerFactory

Active Power in W
Reactive Power in Var
Voltage in V

Active [%] and Reactive Power Setpoints [%]

Control Algorithm (Python)
Lab Test

Battery Inverter

Active Power in W
Reactive Power in Var
Voltage in V

Active [%] and Reactive Power Setpoints [%]

Python Interface for Inverter (SunSpec)

Active Power in W
Reactive Power in Var
Voltage in V

Active [%] and Reactive Power Setpoints [%]

Control Algorithm (Python)
Installation of 7 battery systems equipped with the SNOOPI-Box in the field test area

SOURCE: Fronius, Adjustment: Energynautics
Field Test Area

- **PQA**: Power Quality Analyzer
- **PMU**: Phasor Measurement Unit
- Feeder with Voltages between 0.93 and 1.06 p.u.
- Battery locations
Field Test
Simulation Results

Learning Behaviour

Graphs showing the learning behaviour with data points for different variables and categories.
Simulation Results

**Q(U) Characteristic Curve**

![Graph showing Q(U) Characteristic Curve with Voltage and Reactive Power on the axes. The graph includes lines for B, D, and E, representing different conditions or scenarios. A map of a city is also included, showing various locations marked with letters A to F.]
Simulation Results

Example Day

![Graph showing voltage and reactive power over time on 24-06-2015]
Simulation Results

Correlation
Simulation Results - Switching

Learning Behaviour

New $\frac{dU}{dQ}$ after calibration

New $U_{\text{max}}$
Simulation Results - Switching

Voltage and Reactive Power

Voltage decreased → No reactive power infeed

New $U_{max}, U_{min}$

Calibration

Switching
Conclusion

- By an autonomous parameterization of the Q(U) curve, the inverters in a distribution grid are coordinated and help to reduce the voltage to the same extend.

- Advantage of a coordinate behaviour: Inverters placed at the beginning of a feeder also help to reduce the voltage although they don’t measure high voltages.

Outlook

- Field test has been started recently → evaluate field test results.

- Include active power control: Cut the midday peak of the PV generation by charging the battery without having a major impact on the self consumption rate.

- **Final outcome**: Device which reduces the voltage considerably by controlling reactive and active power without impairing the system operator and without the need of any presets or reconfigurations.