Using Smart Breakers for Demand Side Management in Smart Grids

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iniGrid – Integration of Innovative Distributed Sensors and Actuators in Smart Grids

- **Flagship project**
  - RTI initiative, bmvit, FFG, Klima+Energie Fonds
  - e!MISSION.at – 4th call for proposals

- **Funding & Duration**
  - 4.1 Mio € costs (2.3 Mio funded)
  - 2014-2018, 42 months

- **Diverse consortium**
  - Institute of Computertechology, TU Wien
  - Austrian Institute of Technology GmbH
  - Eaton Industries (Austria) GmbH
  - Infineon Technologies Austria AG
  - Zelisko GmbH
  - Sprecher Automation GmbH
  - Fachhochschule Oberösterreich
  - Linz Strom Netz GmbH
  - MOOSMOAR Energies OG
iniGrid - Goals

- **A) Energy Management on Prosumer Level** (focus of this work)
- B) Low Voltage Network Optimisation
- C) Medium Voltage Network Optimisation on Substation Level
- D) Medium Voltage Network Optimisation on Management System Level
- E) Distribution Optimisation across Voltage Levels
Hybrid Switching Smart Breakers
Active components and sensors with existing devices

Integrate into Smart Device → Smart Breaker

First technical proof of concept validation prototype
Final Demonstrator-1 samples
(4 phases and 2 phases)
Functionality Requirement – Customer Energy Management System (CEMS)

- main customer benefit on different levels
  - installations in residential/commercial/industrial segment
  - installations of 10-100s Smart Breaker switchable loads

- four smart grid functionalities for Smart Breakers (SB)
  - **fail safe**: providing limits to SB ahead of communication loss
  - **priority list**: configuring importance of switched devices for soft start after shutdown or blackout
  - **self consumption**: algorithms optimizing reliable self consumption using local switchable battery storages and generation
  - **switch patterns**: SB-network operator (e.g., SCADA) learn / build knowledgebase of successful patterns of switch-states & communicate them as emergency plans (in different granularization hour/day/week)

SCADA: Supervisory Control and Data Acquisition
PoC – Process

simulate distribution system, provider or automated sensor

interface to wireless equipment

Raspberry Pi

housing communication, actors, and intelligence

demonstration board for testing and presentations

development stages

draft

proof of concept

SCADA: Supervisory Control and Data Acquisition

PoC: Proof of Concept
Experimental PoC: Customer Energy Management System (CEMS)

- deployable on affordable off-the-shelf hardware (Raspberry Pi 3)
  - switches+meters, display, input, CEMS, GUI
  - open communication framework OpenMUC for accessing the hardware, testbed board
  - secure communication by VHPready, SSH tunnels, IEC 62351 and IEC 61850

- communication failure testbed
  - hardware setup
  - Charles proxy

- emulation of low voltage grid
  - tapchanger transformer
  - continuous testing of communication mocks
  - STT800 controller, IEC 61850 & Modbus drivers
  - Wireshark communication records for security analysis
PoC – RaspberryPi

- **fail safe functionality**
  limits for smart breakers ahead of communication loss

- **priority list functionality**
  configuring importance of switched loads for soft start after shutdown or pre-blackout critical emergency states

- **self consumption functionality** (FHOE partner cooperation)
  optimizing usage of local renewable generation and battery storage systems (3rd party algorithms)

PoC: Proof of Concept  OT: Operational Technology  IT: Information Technology
PoC - SCADA

- the right tool for the job

switch patterns functionality
allows distribution optimization across voltage levels, increases predictability, and allows configurable emergency behaviors

- emergency shedding for crisis simulation
- adjustable shedding percentage *(switch patterns)*
- uni-directional communication (SCADA → CEMS)
Function proof with PoC at AIT SmartEST Laboratory

- use case (A-E) based usage scenarios
- grid simulator
- switching of (more) realistic loads
- successful validation of various concepts
Field Test Location

- deployment at active museum in Lower Austria
- approx. 30000 visitors / year
- approx. 45000 – 48000 kWh yearly total consumption (we only control a small part of that)
- local PV system with 82 kWp
- centralized ventilation system
- flexible exhibition setup
Field Test Use Cases

- use case 1: multimedia (MM)
  - control various MM equipment with varying bootup times
  - based on movement sensors in adjacent rooms

- use case 2: ventilation
  - multicriteria decision: air quality, regular intervals, manual triggers
  - marked as “optional equipment” for use case 4

- use case 3: lights
  - triggered by movement sensors
  - multiple entries and exits

- use case 4: demand response communication
  - simulated grid stress
  - attempt remote active grid stabilization
Field Test Setup

- **local deployment**
  - two stage deployment using laptop and Pi
  - CEMS measurements
- **local optimization**
- **remote interaction via secure tunnel**
- **total deployed hardware**
  - 1x Raspberry Pi 3 incl. touch LCD
  - 1x ethernet switch
  - 1x ethernet communication interface
  - 4x smart breakers
  - 2x switch cabinets
  - 4x binary input, xComfort
  - 1x analog input, xComfort
  - 1x air quality sensor, xComfort
  - 4x movement sensors, xComfort
Field Test Data Results

- validated concepts
  - commanding limits of power/voltage successfully
  - emergency shedding possible
  - according to security standard VHPready
  - centralized installation and by-power-line control feasible

- consumption impact
  - 1 month baseline, 8 operational
  - significant improvements for ventilation and multimedia equipment
  - meeting commercial baseline for lighting

Comparison of Annual Projection in kWh

- UC1: Ventilation - 33%
- UC2: Multimedia - 25%
- UC3: Lighting - 6%
Results – Multimedia Details (UC2 example)

Before iniGrid

With iniGrid
Results Ventilation Details  (UC1 example)

massive changes (challenges):

- increased volatility on device level
- frequent switching events
- changing operation levels
- not deterministic
Distributed Control Test Results (UC 4 example)

- on-Site at Linz Strom Netz
- secure communication in accordance to VHPready IEC 62351, IEC 61850
- succesfull state communication
- succesfull load shedding
Field Test Summary

‣ using smart breakers for DSM validated -> new challenges

‣ traditional building automation & hybrid breakers (goal A)
  • local centralized setup w/ less switches & central access
  • modular framework for control algorithms
    – closed loop eg.: for movement and air-quality
    – open loop eg.: for regular venting and exhibition hours
    – allows integration of sophisticated 3rd party algorithms

‣ validating dynamic reaction to grid (goal E)
  • disabling non-essential components on demand (ventilation)
  • encrypted communication in secure tunnel (security)
  • uni-directional communication (privacy … and security)
Thank you!  
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