Multi Agent Control Based Energy Optimisation of a Prosumer Household and a Community with Bidirectional Electric Vehicles

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Introduction

Prosumer households with photovoltaic (PV) systems face the problem of occasionally generating electricity that cannot be used within the house but must be fed into the electricity grid [1]. This is not desired since with changing policies in Germany [2], the feed-in tariff has been reduced considerably [3] and the cost of power consumed from the grid has increased significantly [4].

Aim of Analysis:
In this study a controller based hierarchical model was developed to improve the self-consumption (SC) and self-sufficiency (SS) of a household and a community (Figure 1) using bidirectional electric vehicles (EV)

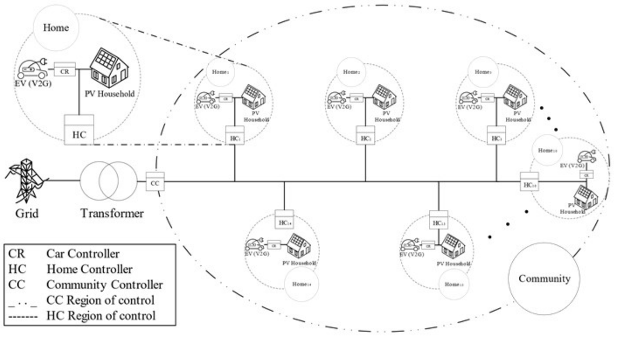

Figure 1: Grid structure of the community with controllers where each household has a load, PV system and EV.

Model Setup & Simulation

- Usage of DIgSILENT PowerFactory along with Python for simulation and developing the control framework
- Realization in a MONA-grid [5] with real load and PV-profiles

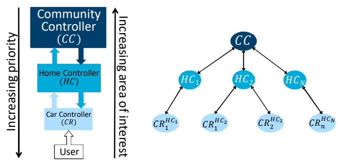

Figure 2: Controller hierarchy

Car Controller

- ▶ Similar to a bidirectional charging station at the household
- ▶ User input required: T_{leave}, SoC_{target} & $Control\ Mode$

Normal Charging (NC)
- Charging with nominal power when it's plugged in
- Setpoint of charging is given by the CR itself

Optimised Charging (OC)
- Setpoint of charging/discharging for the EV is given by its HC
- If the HC is not available the EV charges with NC mode

Home Controller

- ▶ Measure load and PV power of the household
- ▶ Calculates the charging/discharging power of the EV(s) connected to its household based on the EV's $Battery\ Capacity$, SoC, SoC_{target}, T_{leave}, and the household's PV in-feed and load consumption

Community Controller

- ▶ On-the-top optimisation of the community
- ▶ The CC performs its optimisation in the following situations:
  - When there is power outflow to the medium voltage grid, it instructs the HCs to absorb the excess generation, which leads to an increase in the SC of the community
  - When there is power inflow from the medium voltage grid, it instructs the HCs to deliver power to suffice the loads resulting an increase in the SS of the community

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Results: Single Household

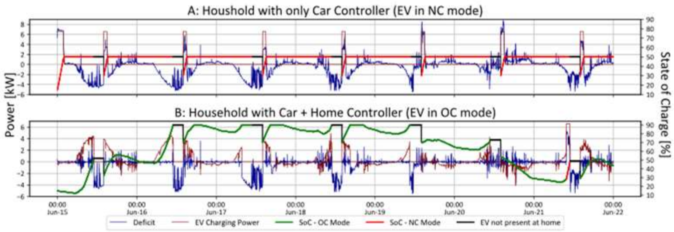

Figure 3: Deficit, EV charging power and its state of charge in a single household scenario with only car controller (A) and with car and home controller (B); System configuration is 1x & 1y as in Figure 4

System configuration of a single household (1x,1y):

PV system:	6 kW_p
Loads:	78 kWh/week
EV:	35.5 kWh battery
T_{leave}:	11:00
T_{return}:	14:00
SoC_{target}:	50%
$SoC_{reduction}$:	20%

Dependency on the Grid (DotG):

$$DotG\ [kWh] = E_{grid\ consumed} + E_{grid\ feed-in}$$

$$DotG\ [\%] = \frac{DotG\ [kWh] * 100}{DotG_{base\ case}\ [kWh]}$$

For Fig 3 and 1x,1y of Fig 4:

With only CR:
SC = 30% | SS = 44%
DotG = 221 kWh = 100%

With CR+HC:
SC = 61% | SS = 91%
DotG = 100 kWh = 45%

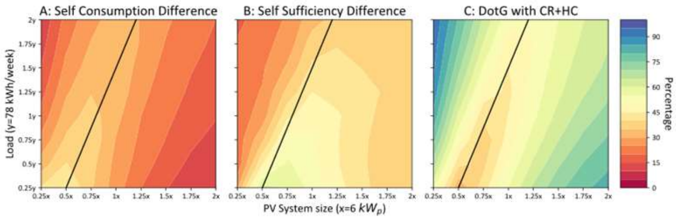

Figure 4: Sensitivity analysis of loads and PV system size by visualizing the difference of SC ($SC_{with\ HC+CR}$ - SC_{withCR}) and SS in A and B; the DotG with CR & HC is seen in C, where, DotG of a household with only CR is considered to be 100% i.e. base case

Results: Community

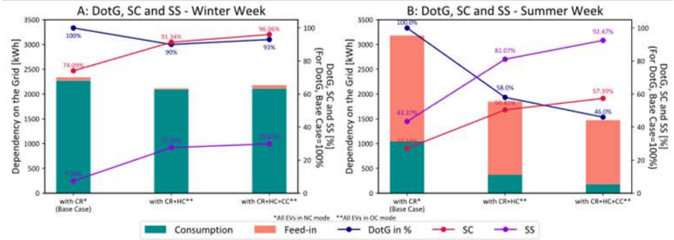

Figure 5: DotG, SC and SS of a community for a winter week (A) and for a summer week (B)

Configuration of the community:
The community has a total of 14 households each with loads, PV and an EV as seen in Figure 1.

PV system:	3.75 - 7.5 kW_p
Loads (Summer):	40 - 125 kWh/week
Loads (Winter):	52 - 190 kWh/week
EV:	35.5 kWh battery
T_{leave}:	Different for each EV
T_{return}:	Different for each EV
SoC_{target}:	50%
$SoC_{reduction}$:	20%

Key Findings:
- All the **results** obtained by the simulations are **system design specific**. Any change in the system size, EV parameters and their availability will change the outcome of the simulation results but the **trends** of decrease in the DotG and increase in the SC and SS are still **correlated**
- With **high PV** generation, the control algorithm gives **lower DotG** and **higher SS and SC** values
- For consumers, this model results in **financial savings**, whereas the grid operators can benefit from **reduced grid stresses** since balancing generation with consumption locally reduces power import/export requirements from/to the grid

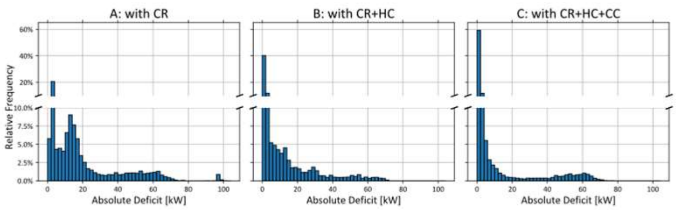

Figure 6: Probability distribution curve of the deficit (power exchanged between the community and the grid) for a summer week; on the y-axis 100% is 10080 simulation points (1 minute resolution)

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[3] BMWK, EEG 2021, § 48 (2)
[4] E. Thalman et al., Clean Energy Wire (access: 09.06.2022)
[5] F. Samweber et al., Forschungsstelle Für Energiewirtschaft (2017)