

EVALUATING THE INFLUENCE OF HOUSEHOLD LOAD TRANSFERS ON ENERGY COMMUNITIES GRID FRIENDLINESS

Gebäudesektor, Energiegemeinschaften, Endkunden
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Motivation

During the previous years, several drastic and disruptive changes occurred within the European energy system. First, following the need for carbon emission reduction, the energy system is gradually shifting towards implementing distributed, renewable energy sources. Namely, the installation of wind and solar power plants and flexible components. As a result of Russia's invasion of Ukraine in 2022, natural gas as an energy carrier has been subject to not only drastic price changes but also supply interruptions. Subsequently, this has led to ambitious plans to fade out gas powered systems even more and to a certain level of energy awareness among Europeans. Moreover, following the COVID pandemic, significant changes occurred around the load profile of businesses and households. To be exact, closing office spaces and businesses due to infection mitigation has resulted in a load increase in residential households due to people continuing their work from home. Finally, the number of energy communities has drastically increased in the past years and these actors, still considered as novel, can alter the loading of power systems with, for example, their inherent energy sharing possibilities.

Following these extraordinary changes in the power systems, it has yet to be analyzed how they affect the grid's state. This contribution aims at evaluating the influence of "low threshold" load transfers, i.e., load transfers without explicitly installing new equipment, on the low voltage grid dominated by residential dwellings. The evaluation of increased energy awareness is out of the scope of this paper. A special focus is put on energy communities as well as energy sharing initiatives and what role they play with regards to grid effects. We present a simulative study of multiple low voltage grid scenarios, combining real-world grids, representing different region types, with realistic future technology distribution scenarios.

Methodology

In a first step, several representative scenarios shall be defined. These scenarios include the settlement type, grid model, the energy communities' structure, that being the number of members, households and businesses, and the integration of renewables and flexibilities. The scenario development methodology is presented in [1]. In detail, a rural, suburban and urban settlements, and two different flexibility penetration types, one current and one future case, are inspected. Each of these scenarios consists of community members, non-members, prosumers and consumers with constant and dynamic electricity supply tariffs.

In a second step, the load profiles are defined. As mentioned above, residential households face a load increase during the day which results in a general load increase. Therefore, two scenarios are defined:

1. **Baseline:** State-of-the-art load profiles from [2] for residential households (mostly unoccupied during the day) and [3] for businesses transformed to their known yearly consumption
2. **"Stay at home":** Residential household load profiles for households which are occupied during the day. The subsequent total increase in electricity demand constitutes roughly 15%.

In total, a pool of 60 yearly load profiles is generated for each of the scenarios offering a wide range of installed devices, household types and usage patterns. Based on the known community metadata, the fitting profiles are selected for a given scenario.

To evaluate the communities' behavior, the flexible components, that being EV charging systems, heat pumps, boilers and batteries as well as nonflexible components, namely PV generation and load profiles, are simulated in the optimization framework FEMTO.JL [4] with a daily rolling horizon optimization, a timestep of 15 minutes and a yearly simulation. The objective is to minimize the total cost within the community. Nonmembers perform a household-individual cost minimization.

To assess the impact on the grid, iterative static load flow calculations are performed based on representative real-worlds grid models from [5] for each of the settlements. Output parameters are terminal voltages, line and transformer loadings. Finally, a thorough data analysis is performed where the load scenarios as denoted above are consistently compared.

Preliminary Results

Figure 1 presents two exemplary residential load profiles for a given year one for the Baseline scenario and one for the “Stay at home” scenario. As clearly visible, the Baseline profile shows the typical bi-daily load pattern while the load in the “Stay at home” schedule is more evenly distributed.

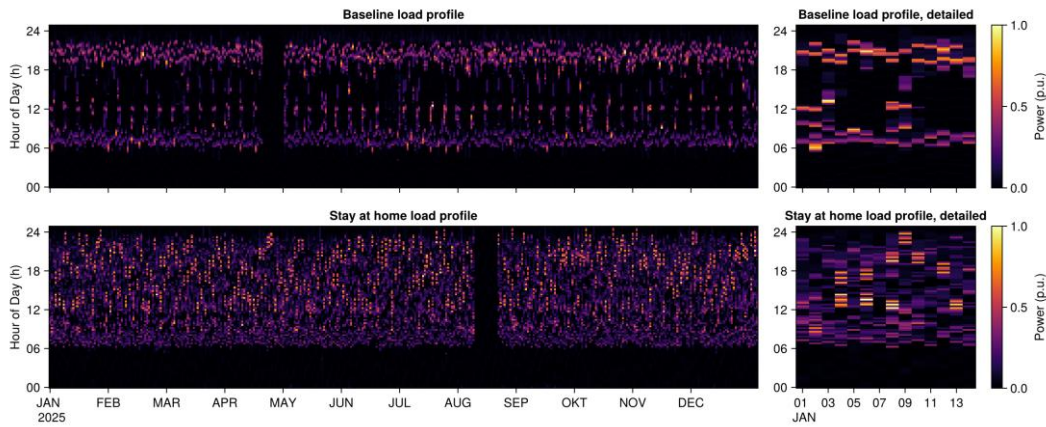


Figure 1: Comparison between two normalized exemplary residential load profiles for the Baseline and the “Stay at home” scenario, respectively.

To reduce the vast amount of simulation data, several assumptions need to be made. First, the community’s performance shall be described by both the Self-consumption ratio (SCR) and the Self-sufficiency ratio (SSR) where the first denotes the amount of self-produced energy that gets used within the community while the latter describes the amount of energy that is covered by self-production. Further, the grid impact should ideally be described with a reduced-order description. Here, analogue to [1], the grid impact is denoted by the Mean Absolute Percentual Deviation (MAPD, also MAPE) between the upper envelope of the KPIs for the Baseline and the “Stay at home” scenario, respectively. To link the change in load structure to the communities’ performance and the grid impact, Figure 2 displays the SSR, SCR, MAPD values for each of the scenarios.

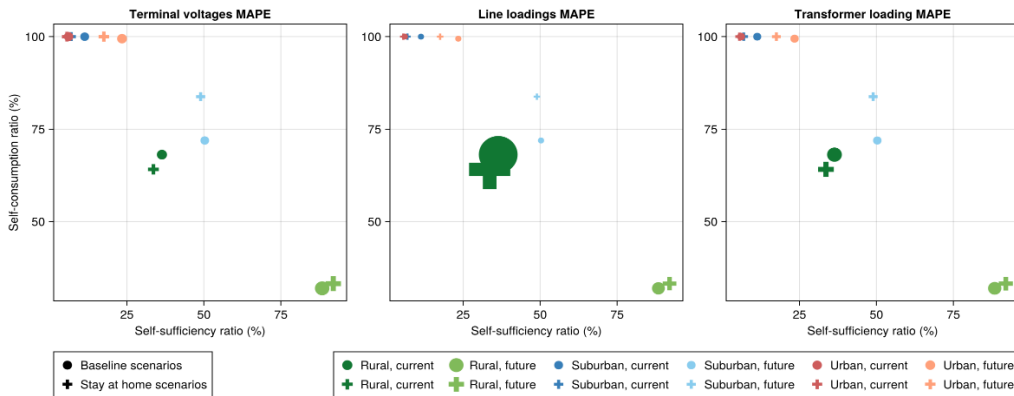


Figure 2: SCR vs. SSR for each scenario. The markers are sized by the MAPD of the corresponding KPI and indicate the grid impact.

The results show that, the change in load profiles can result in a significantly higher SCR. However, these results appear to be very scenario dependent. Furthermore, the observed grid impact denoted by the MAPD values, is most notable for rural scenarios. While these preliminary results look promising, further scenarios need to be developed and the analysis needs to be extended to allow for a better understanding and evaluation of energy communities’ grid impact under low-threshold load transfers.

Literature

[1]: F. Strebl et. al.: ON THE LARGE-SCALE INTEGRATION OF RENEWABLE ENERGY COMMUNITIES INTO THE DISTRIBUTION NETWORK, 23rd Wind and Solar Integration Workshop, October 2024 (In press)
 [2]: Load profiles: Pflugradt et al, 2022, “LoadProfileGenerator: An Agent-Based Behavior Simulation for Generating Residential Load Profiles.”
 [3]: APCS Power Clearing & Settlement. Synthetische Lastprofile APCS. 2023.
 [4]: Daniel Schwabeneder, 2023, „Femto.jl“
 [5]: Frontier Economics & AIT, 2022, “Der volkswirtschaftliche Wert der Stromverteilungsnetze auf dem Weg zur Klimaneutralität in Österreich