Streszczenie w języku angielskim pracy doktorskiej pt.: „*Model of energetic cooperation between electrical vehicles and solar office building*” (*Model współpracy samochodu elektrycznego z solarnym biurowcem*)

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Abstract

With an increase in urbanization becoming a global trend, rise in energy demand is observed worldwide. Cities are usually characterized by a very high population density and simultaneously very low self-sufficiency in terms of food, water and energy. At the same time, the ever increasing climate changes heavily affect the characteristics and the structure of the energy demand. These changes are noticeable on both a country and an individual consumer's level. Actions are being undertaken to counteract the unavoidable consequences of rising air temperatures and see water levels. One of the key aspects which is envisioned as a solution enabling stopping the climate change is the transformation of the energy system to the one characterized by very low or almost zero CO_2 emissions. The transformation also refers to the transportation sector, which should in the future be based entirely on electrical energy or its environmentally friendly alternative, like hydrogen.

This dissertation is dedicated to the topic of the potential use of photovoltaic (PV) systems, operating as office buildings (OB) partial energy supply source, whilst the office building is also equipped with an electrical vehicle (EV) charging station. Such a station is a part of the OB infrastructure. The motivation to undertake such a topic is as follows:

- Office buildings have a particular load pattern, which is to a substantial extent driven by cooling demand. The number of office buildings across the globe is increasing and this trend can also be observed in Poland.
- The cooling demand tends to match very well with the photovoltaics energy generation profile, as usually the days with high temperatures (what leads to a high cooling demand) are characterized by high irradiation values (usually greater energy yield from photovoltaics).
- The office buildings due to a large glazed area of facades and substantial roof area have the potential to accommodate a certain capacity of photovoltaic installation that is worth considering and thereby contribute to covering the OB electrical load. Although an off-site PV station is a promising alternative.

- Electrical vehicles are becoming an economically interesting option in cities, which aim at improving their air quality by reducing the number of conventional fuels powered cars entering the city. It can be expected that companies' cars/fleets may become fully electric in the future.
- Companies residing in office buildings/office building owners may want to provide their employees/renters with additional benefits/services like EV charging stations.

Considering the above in this dissertation, a model of an energetic cooperation between EVs and OB with a PV system was developed. From the modelling point of view, five different models have been presented. Namely:

- A benchmark model, which aims at recreating the most commonly observed current situation, which is an office building, connected to the electricity grid without energy supply from PV system and EV charging load.
- A modified model where the office building is simultaneously supplied in energy from the national grid and own PV installation. The exact location of the PV system is however outside the scope of the analysis.
- A model where the office building has an EV charging station. However, it uses only the electricity from the national grid. Although, the energy flow is not enabled from the EV to the office building.
- Similar to the above model but with an option to supply part of the load (both the office building and electrical vehicles) from a PV installation.
- The final model, which is an improved version of the last model by allowing the energy flow from the electrical vehicles to the office building. Therefore, this model considers the opportunity of using EVs as mobile energy storage.

For the simulation and optimization purposes the models were implemented in MS Excel and Matlab software. To solve the linear optimization problem a freeware Open Solver software was used with an academic license for the Gurobi linear solver, and Matlab for linear programming (*optimproblem* – Matlab 2019a). The models were provided with historical data regarding electrical load, irradiation and temperature. The precise location of the office building cannot be disclosed due to the confidentiality policy although it can be mentioned that the building is located in Cracow (Poland).

Based on the simulations, the following results/conclusions were drawn:

- Electricity tariff C21 is the cheapest option for office buildings without PV installation.
- Adding PV system reduced the total electricity cost by roughly 0.06 PLN/kWh (0.015 Euro/kWh assuming 1 Euro = 4 PLN) and ensures higher resilience in case of expected energy prices increase in the future.
- PV system significantly modifies the office building energy demand pattern. There is a good daily match between generation and demand. On a weekly basis, an oversized PV system may produce more energy than consumed by the building.
- From the national power system perspective, the PV system has potential to shave the observed peak load – which is a huge benefit for the power system, where the peak load is observed during hot days when simultaneously the efficiency of conventional generators is lower.
- Charging a fleet of 50 EVs naturally increases the total cost of electricity in the office building (considering that the charging station is its internal part). However, this increase is different depending on the energy tariff: from 2.9% for C21 to 3.0% for C22b.
- The charging strategy can and should be optimized in such a manner that its negative impact on the residual (if PV system is present) load is minimized. A simplified charging strategy (charging immediately upon arrival) results in an increase in the observed peak demand.
- The optimization of the charging strategy focused on minimizing the total electricity cost undoubtedly increases the overall variability of the office building (with PV and EV) load profile.
- The potential future increase in electricity prices significantly rises the role of EVs as a mobile energy storage in the case of office buildings.
- The future implementation of the proposed concept will clearly require a powerful informatics system which will enable an information exchange between weather forecasts, PV yield forecasts, electricity prices forecasts (if tariffs are not present), building electrical load forecast, expected duration of EV trips and resulting electricity consumption along with expected time of arrival and later departure.

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