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POTENTIAL IMPACT OF EV CHARGING STATIONS INTEGRATED WITH OFFICE BUILDINGS ON THEIR LOAD CURVE

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ABSTRACT

Electrification of the transport sector is a crucial goal, which has to be accomplished in order to ensure sustainable development of worldwide economy and human civilization. Currently electrical vehicles (EV) constitute to only a small fraction of the whole automobiles fleet. It is however anticipated that a significant cost reduction of EV, technological progress in energy storage and increasing conventional fuel prices will change this situation dramatically. As with each new product on the market the customers behavior can be modeled only to a certain extent. Bearing in mind the above this paper investigates the potential impact of EVs' charging station which is a part of an office building infrastructure. Various scenarios are analysed considering different charging strategies. Results indicate need for developing intelligent and forecasts based charging strategy.

Keywords: office building, load curve, charging station, transport electrification, peak load

NONMENCLATURE

Abbreviations	
EU	European Union
EV	Electrical Vehicle
OB	Office Building
RES	Renewable Energy Sources

1. INTRODUCTION

Transport and buildings sectors are together the biggest energy consumers in the modern economy (considering both electricity, heat and transport fuels) [1]. One of the fundamental goals, which has to be achieved if the humanity wants to base its development on sustainable economy, is to ensure that transport sector is environmentally friendly. The well-accepted solution is its electrification by large-scale adaptation of electrical vehicles (EV). Another question is however, that the energy used for charging EV batteries has to come from renewable energy sources (RES) or sources characterized by low environmental impact.

Each building and type of business has its specific load profile. As shown in [2] [3]photovoltaics are a good solution for office buildings (OB) when it comes to the reduction of peak demand. A question however, arises how will be the energy demand shaped if certain percentage of the OB will decide to commute to work in their own EV. I such case it can be considered as normal that on the parking spots belonging to the OB an EV charging station will be installed. Considering above in this paper we try to conduct initial simulations which aim at analyzing the potential change in OB load (by assuming that EV charging station is integrated with OB electrical infrastructure).

2. METHODS AND DATA

2.1 Office building – case study parameters

For the purpose of this study a historical hourly load, of a representative office building, covering year was used. The peak demand is observed during the summer months due to an intensive air-conditioning. The cumulative annual energy consumption amounts to slightly over 1.95 GWh with an average hourly consumption of 223.5 kWh. The working hours of the OB distinctively shape the weekly and daily energy demand profile (as shown of Fig. 1). The considered OB has a total available working space of 30 000 m^2. The total number of employees is unknown to the authors of this paper. Following [4] (average working space per employee in EU amounts to 25 m^2) we estimate the total number of employees as 1 200. Over the analysis we assume this number as constant.

2.2 Charging station assumption

For the purpose of simulating the charging process we have made following assumptions: accordingly to [5] 55% of employees in Poland use their own car for commuting therefore the maximal number of EV will not likely exceed 1 200 x 0.45 = 540; employees commute alone (no car sharing is considered); as shown in [6] the average distance from home to work is 13.57 kilometers (data as on 2010); the energy consumption in EV per 1 kilometer is 0.7 kWh (as assumed also in [7]) – here we neglect however the impact of air temperature impact on energy consumption); the charging can be performed only from 08:00 AM to 04:00 PM; it is also assumed that all employees arrive and leave work at the same time; cars needs to be charged before leaving work; the employees arrive at work with batteries state of charge indicating that car was fully charge before leaving to work; charging is performed only from Monday to Friday.

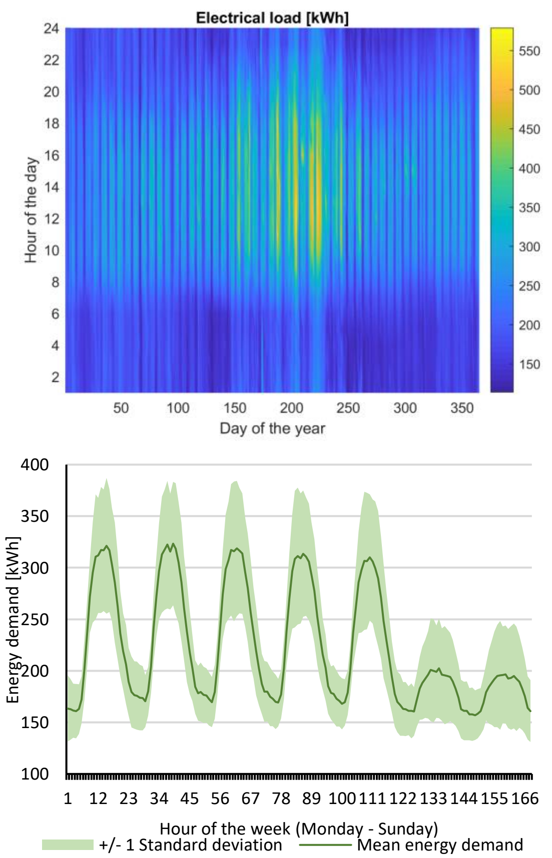

Fig 1 Spectrum of hourly load (left) and typical weekly load profile of considered building

3. RESULTS

When it comes to the charging strategy two approaches were proposed. A constant charging strategy where the EVs are charged with a constant power over the period of 8 hours. In this strategy the batteries state of charge is calculated and expected charging energy is estimated. Dividing energy needed to fully charge the batteries by 8 available charging hours the charging power is estimated. The second strategy is called an optimized charging. In this strategy a charging power is optimized for the whole year in advance by assuming the charging power should be distributed in such a way over that the peak demand of a typical week is minimal.

First of all our calculations show that if 100% of employees would decide to use EVs and charge them at work the OB total energy consumption would increase by almost 70%. This is an important result as companies which operate in given OB may often consider free charging of EVs as some sort of benefit for its employees. Summarizing this aspect of our analysis the energy consumption will most likely increase from almost 2 GWh to 2.28 GWh per annum.

The analysis of charging strategies indicates that having only 8 hours available for charging the power demand for charging itself may be as high as 641 kW. For a 100% saturation scenario, (all employees using EVs) the energy for charging needed per day would amount to 5.13 MWh (whereas the daily average demand based on whole year data is 5.26 MWh). For a typical week, if a constant charging is considered, the peak demand increases from 323 kW to 964 kW, also the average demand raises from 240 kW to 454 kW (Fig 2).

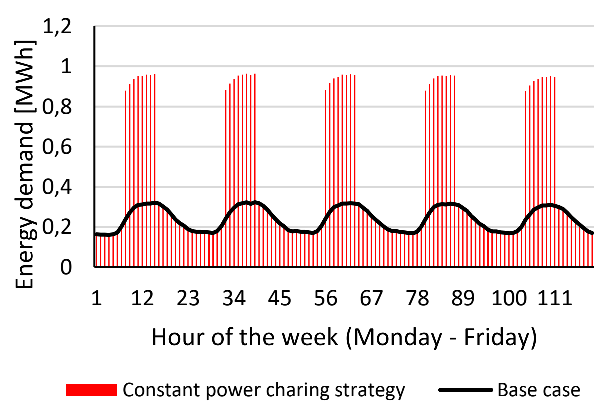

Fig 2 Old and modified OB typical weekly load profile

As indicated earlier part of the analysis focused on optimizing the charging strategy (within available 8 hour charging time). For that purpose, a simple optimization model was created and implemented in MS Excel Worksheet. To find the optimal solution for the analysed problem an inbuilt Solver was used and GRG method applied which is suitable for non-linear, non-smooth problems (this results from the model formulation in MS Excel).

First optimization was perfomered for a 100% EVs saturation scenario. On Fig. 3 we have visualized obtained charging pattern. What is clearly visible is the fact that the optimized charging strategy increases the required maximal installed capacity in charging station to 700 kW. Furthermore, the optimization tends to promote greater charging power during early morning hours and reducing the charging power during the midday. Our simple optimization shows that this approach can reduce the peak demand for a typical week from 964 kW (when constant charging is considered) to 942 kW (for optimized charging). These results are however for a typical year, when the whole year is considered both strategies results in peak demand respectively of 1.219 MW and 1.203 MW so over 2.1 times greater than the current peak demand.

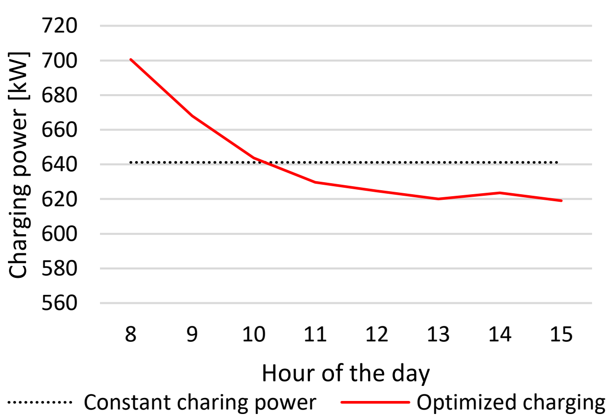

Fig 3 Two charging strategies during working hours

Clearly the EVs will have a significant impact on the load curve of traditional office buildings. If the owners of OBs will consider covering the employees' EV charging needs this will undoubtedly have a significant impact on the overall OB energy cost. This is especially important as such EV charging station will undoubtedly raise the building peak load. Peak load which plays a significant role in many countries energy tariffs [2].

As shown on Fig. 4 the modification of the office building load curve is significant. Full saturation and both charging strategies create a completely new load profile. In consequence higher energy costs must be expected.

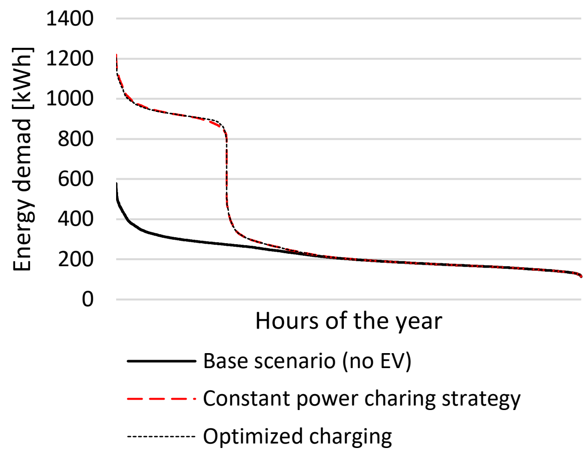

Fig 4 Ordered energy demand curves

What is more such modification in power demand will also significantly impact not only the local power grid but also the whole power system.

4. CONCLUSIONS

This study investigated the potential impact of EV charging station being part of the office building infrastructure on its energy demand. Two charging strategies were considered in a deterministic model. For made assumptions it was found the charging of EVs will significantly alter the building energy demand pattern and potential impact the cost of energy (which will be covered either by owners of the businesses or EV owners). This study investigated a deterministic model. Clearly a further research is needed where the energy demand uncertainty will be considered. Also a more detailed model for simulation of energy demand for charging is required. In further steps we will enhance the model by considering the actual energy tariffs and addition of PVs as additional energy source to minimize the energy cost of OB with EV charging infrastructure.

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