FlyGrid – Integration of Flywheel Energy Storage Systems into EV Fast Charging Infrastructure

Integrierte Netze der Zukunft

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Motivation and Research Question(s)

On both the European [1] and the national level [2], climate-neutrality shall be realized, inter alia, by a transition towards clean electric mobility. However, future electric vehicle (EV) numbers will also challenge existing distribution systems [3]. On this account, new innovative solutions must be found to avoid costly grid expansions yet fulfilling the EV user's mobility needs. The integration of energy storage systems (ESS) into EV charging infrastructure represents one of them. Nevertheless, integrating decentralized ESS into future grid planning processes certainly requires detailed knowledge about their required specifications depending on the supplied EV use case.

Methodology

Within the project "FlyGrid," high-performance flywheel energy storage systems (FESSs) are integrated into EV fast-charging infrastructure to mitigate peak loads (Fig.1). As the first step, we identify e-mobility use cases, most relevant in terms of environmental and economic aspects: Private- (at home or work) and public charging (fast-charging at highways or shopping centers) of individual passenger vehicles, electric car-sharing vehicles, electric taxies, electric busses, and electric last-mile delivery vehicles. In the second step, each use case's impacts on the local power grid are analyzed in terms of thermal congestions and voltage violations. Therefore, time-resolved grid simulations are performed using real-life low- and medium-voltage grids, operated by Energienetze Steiermark GmbH. For each use case, time-resolved EV charging load profiles are modeled based on real-life mobility data [4–7] and state-of-the-art charging characteristics.



Figure 1: Scheme of the project "FlyGrid": Grid integration of future e-mobility use cases and local renewable energy sources by implementing FESSs [8]

Based on the evaluation of critical grid lines and grid nodes, potential grid locations in need of FESS units as grid-stabilizing elements are detected spatially for each use case. Furthermore, the energy capacity and discharging power of FESSs, required for providing sufficient grid support, are determined temporarily depending on the grid location and the EV-penetration.

Results and Conclusions

As part of the project "FlyGrid", this work presents initial results and conclusions acquired so far. The modeling of timely-resolved charging profiles based on accurate mobility data demonstrates crucial differences in the charging behavior of varying EV use cases. When applying these realistic charging profiles, even numerous charging points (CPs) can be integrated into existing low- and medium-voltage grids considering EV charging with moderate charging power (up to 44 kVA). Furthermore, the project's initial results confirm that FESSs can severely mitigate potential grid congestions in many cases. However, the required FESS specifications depend significantly on the individual EV use case, EV charging power, and the grid location. For example, a FESS integrated into an electric taxi charging station with six CPs and charging power of 22 kVA each requires at least a capacity of 2.2 kWh and a discharging power of 24.6 kVA (Fig. 2).

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Figure 2: Required FESS energy capacity (a) and FESS discharging power (b) per charging point (CP) considering the supply of e-taxies depending on the number of CPs and the charging power

In conclusion, most EV cases can entirely be supplied by the FESS specifications of 100 kVA discharging power and 5 kWh capacity per FESS module. Thereby, even high-power charging EV applications, e.g., opportunity charging of electric busses, can be supplied in a grid-friendly way considering a moderate number of charging points and moderate charging power.

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