CONFERENCE PROGRAMME

Energy challenge and environmental sustainability

12th IAEE European Energy Conference

September 9-12, 2012
Ca' Foscari University of Venice, Italy

in cooperation with

Università Ca'Foscari Venezia

Fondazione Eni Enrico Mattei

www.iaeeu2012.it

PV-BASED CHARGING STRATEGIES OF ELECTRIC VEHICLES IN AUSTRIAN LOW VOLTAGE GRIDS

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Overview

Using renewable energy for charging of electric vehicles (EVs) significantly improves the environmental impacts of the transport sector due to the substitution of conventional passenger vehicles. [1] shows that EVs and HPs (Heat pumps) are helpful for integration of more PV power in Kansai Area (Japan) by absorbing excess electricity in different scenarios which also leads to more reduction of overall CO_2 emissions. On the contrary, a high penetration of PV and EVs within the low voltage grids (LV- Grids) could results in grid reinforcement needs due to grid bottlenecks in times of high levels of PV generation in combination with low demand and overlapping of the demand (e.g. household demand) with EV charging times in periods without or with low PV generation .

Therefore, the aim of this paper is the introduction of a PV based charging strategy which will result in a balanced load curve (household including EV and PV) within a LV-Grid. The charging and discharging strategy leads to a reduction of PV peak production and a corresponding reduction of the household demand during the night peaks, respectively. This may lead to a sustainable reduction of maximum values of each node's load curve within the LV-Grid compared to the system without PV and EV (only household demand). The estimation of the economic potential (future grid investment costs) due to the load reduction of the nodes within a LV-Grid case study closes the analysis.

Methodology

Figure 1 shows the system configuration and the used charging/ discharging strategies of EVs regarding priorities of EV charging and utilisation of the PV production. Two charging mechanisms for EVs are defined. The first one, as so called "PV charging strategy" as the primary charging strategy defines (based on daily energy consumption of EV, vehicle availability at node (home) and PV production), direct charging of the EV by energy from the PV plant. Here, a linear optimization program (Matlab) is used to identify the charging times with the highest level of PV generation.

If the energy from PV charging cannot fill the battery before the first daily drive, a secondary charging strategy is then triggered. It is set up to the times with the lowest energy price during a day, again by utilising a linear optimization tool. Partly covering household demand during evening and night peaks, if the EV is available, is defined as the discharging strategy.

The analysis refers to EVs which have a battery capacity of 16, 24 and 48 kWh. The driving patterns and the purpose of each usage (availability at home) are an outcome of an Austrian travel survey for the federal state of Salzburg in 2004 [2]. The different battery characteristics like its degradation due to discharging [3], efficiency from grid (PV) to the battery and vice versa [4] and battery charging properties [5] were considered in the analysis. The analysis will be conducted for Austrian load characteristic of one week in summer and one week in winter with a one minute resolution of the data set.

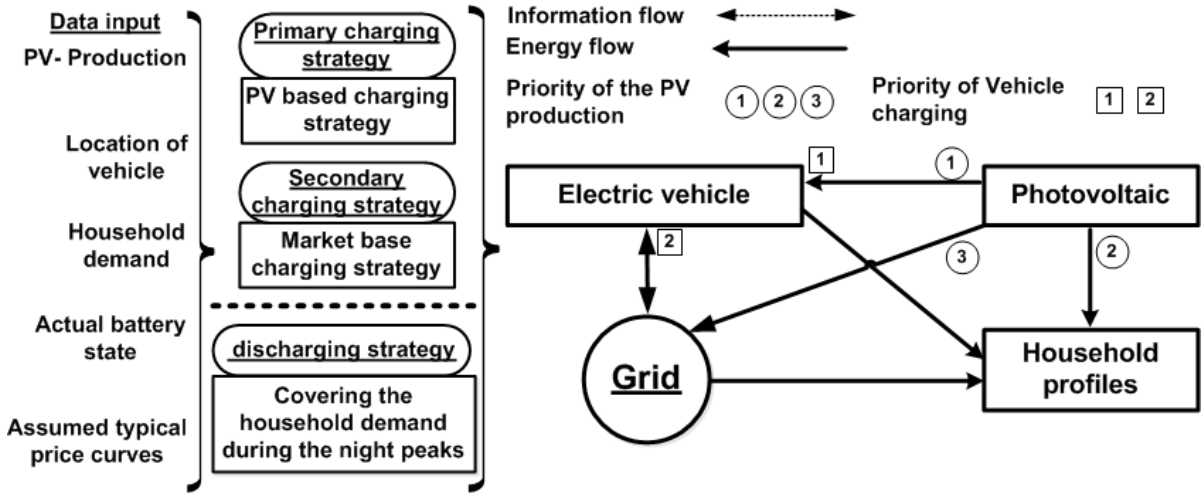

Figure 1: System configuration for the used/ possible charging and discharging strategies

Results

Figure 2 shows exemplarily for an EV the charging and discharging times derived by the model. The secondary charging times will take place in the early morning with low energy prices. The primary charging strategy uses the PV production if the vehicle is available at home. The discharging happens in the evening, as shown in the example between 19 and 21 o'clock and covers (if possible) the household demand.

The impact of the PV generation, and corresponding charging and discharging strategies on the node's power curve is given in Figure 3. The dotted line is the power curve in an exemplary node representing solely a household's demand, with a maximum power of 3.28 kW for a particular day. The other line depicts the sum of demand (household and EV charging) and generation (PV and EV discharging). This power curve has a maximum of 1.78 kW. In this case an introduction of PV and EV reduces the maximum load at the node for about 45 % compared to the case with only household demand.

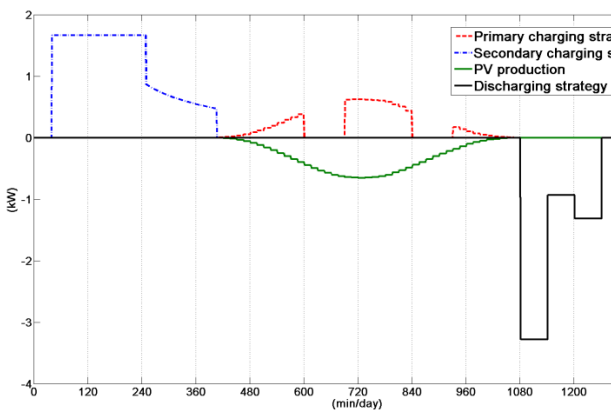

Figure 2: Modelling results of Charging/ discharging times for an EV during a day

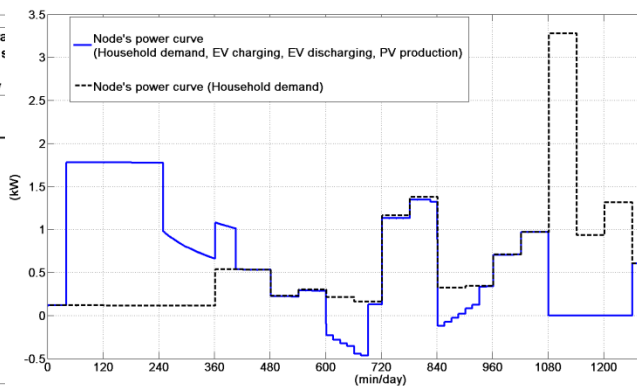

Figure 3: Modelling results of node's power curve with different number of connected producers and consumers

Outlook

To derive robust results the simulation tool will analyse more than 150 EVs (with different daily driving patterns, different household demand characteristic and typical winter/ summer PV

generation) on a weekly basis. The economic potential of the mentioned charging/ discharging strategies in conjunction with possible lower grid investment costs for a selected rural LV Grid case in Austria closes the analysis.

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