ChaProEV: Generating Charging Profiles for Electric Vehicles

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Summary

ChaProEV is

Statement of need

- Profiles are good and useful, but optimisation modes might also need soem underlying parameters to do optimisation computations as well
- Provide optimisation models with the boundary conditions they need
- ChaProEV povides the necessary parameters (as explemplified in COMPETES, Mopo/Ines, etc.) in a clear and accessible way, with the also allowing a clear way to modify them without touching code (Sijm et al., 2022)

Conceptual innovations: Supporting optimisation models

Basic elements

A commonly used aggregated EV formulation is (Morales-España et al., 2022):

$$e_t = e_{t-1} + \eta^{\mathrm{G2V}} p_t^{\mathrm{G2V}} \Delta - \frac{p_t^{\mathrm{V2G}}}{\eta^{\mathrm{V2G}}} \Delta - E_t^{\mathrm{drive}} \Delta N \alpha \quad \forall t \qquad (1)$$

$$\underline{E} N_t^{\mathrm{plugged}} N \alpha \le e_t \le \bar{E} N_t^{\mathrm{plugged}} N \alpha \qquad \forall t \qquad (2)$$

$$0 \le p_t^{\mathrm{G2V}} \le \bar{P}_t^{\mathrm{G2V}} N_t^{\mathrm{plugged}} N \alpha \qquad \forall t \qquad (3)$$

$$0 \le p_t^{\mathrm{V2G}} \le \bar{P}_t^{\mathrm{V2G}} N_t^{\mathrm{plugged}} N \alpha \qquad \forall t \qquad (4)$$

where t is the time index and parameter Δ (h) is the duration of the time step. Variable e_t (kWh) tracks the total state of charge of the plugged EVs to the grid. Variables $p_t^{\mathrm{G2V}}/p_t^{V2G}$ (kW) are the power consumed/provided by the EVs from/to the grid. Parameters $\eta^{\mathrm{G2V}}/\eta^{\mathrm{V2G}}$ (p.u.) are the charging/discharging efficiencies; $\underline{E}/\bar{E}$ (kWh) are the minimum/maximum storage capacity per vehicle; N is the total number of EVs; and α (p.u.) is the share of controllable EVs providing demand response to the system.

Section **??** defines the remaining parameters (profiles).

Equation 1-Equation 4 model the demand response provided by controllable EVs through p_t^{G2V} and p_t^{V2G}. The total EV demand d_t^{Tot} (kW), including the non-controllable load, is defined as

$$d_t^{\mathrm{Tot}} = D_t^0 N (1 - \alpha) + p_t^{\mathrm{G2V}} - p_t^{\mathrm{V2G}} \qquad \forall t \qquad (5)$$

28 where D_t^0 is the reference (non-demand response) profile given by ChaProEV (see Section **??**),
29 and α is the proportion of vehicles that are optimally providing demand response.

Further modelling

31 The formulation Equation 1-Equation 4 has several shortcomings because there is no clear
32 distinction between plugged and unplugged EVs. For example, suppose that plugged EVs
33 were fully charged and the unplugged EVs were near to being empty, equation Equation 1
34 allows that unplugged EVs could be charging while they should be unavailable to the system.
35 (Momber et al., 2014) shows this and more detailed cases where the traditional EV aggregated
36 formulation fails.

37 To overcome the above shortcomings, (Momber et al., 2014) proposed a more rigorous
38 formulation, in which inventories for plugged/unplugged EVs are clearly distinguished from
39 each other. This formulation ensures that only EVs plugged to the grid are charged/discharged
40 from the electric system. It also guarantees that unplugged EVs cannot further charge while
41 driving.

42 The state of charge of EVs in Equation 1 is now replaced by the separated plugged Equation 6
43 and unplugged Equation 7 state of charges. Additionally, Equation 2 is replaced by Equation 8
44 and Equation 9.

$$
\begin{aligned}
e_t^{\text{plugged}} =& e_{t-1}^{\text{plugged}} + \eta^{\text{G2V}} p_t^{\text{G2V}} \Delta - \frac{p_t^{\text{V2G}}}{\eta^{\text{V2G}}} \Delta \\
& + N_{t-1}^{\text{plugging}} N \alpha e_{t-1}^{\text{unplugged}} - N_{t-1}^{\text{unplugging}} N \alpha e_{t-1}^{\text{plugged}} \quad \forall t
\end{aligned}
\tag{6}
$$

$$
\begin{aligned}
e_t^{\text{unplugged}} =& e_{t-1}^{\text{unplugged}} - E_{t-1}^{\text{drive}} \Delta N \alpha \\
& - N_{t-1}^{\text{plugging}} N \alpha e_{t-1}^{\text{unplugged}} + N_{t-1}^{\text{unplugging}} N \alpha e_{t-1}^{\text{plugged}} \quad \forall t
\end{aligned}
\tag{7}
$$

$$
\underline{E} N_t^{\text{plugged}} N \alpha \le e_t^{\text{plugged}} \le \bar{E} N_t^{\text{plugged}} N \alpha \quad \forall t
\tag{8}
$$

$$
\underline{E} N_t^{\text{unplugged}} N \alpha \le e_t^{\text{unplugged}} \le \bar{E} N_t^{\text{unplugged}} N \alpha \quad \forall t
\tag{9}
$$

Software innovations

46 No code parameters and profiles modification (explain what kind of modifications are possible)
47 Scenarios

48 1. Demand for next leg (kWh) (from network): The charge that the vehicles leaving in the
49   next time step need to pull from the network for the leg they are about to undertake,
50   corrected by the charger efficiency.
51 2. Demand for next leg (kWh) (to vehicles): The part of the above that vehicles get.
52   ($\{E_t^{\text{drive}}\}$ in Equation)
53 3. Connected vehicles: The share of vehicles that are connected to a charger ($\{N_t^{\text{plugged}}\}$ in
54   Equation)
55 4. *Charging Power from Network (kW):* Maximum power that connected vehicles can
56   potentially draw from the network. ($\{\bar{P}_t^{\text{G2V}}\}$ in Equation)
57 5. Charging Power to Vehicles (kW): Maximum power that can potentially go to vehicles
58   go to vehicles (i.e. the same as above with a charger efficiency correction).
59 6. *Vehicle Discharge Power (kW):* The amount of power connected vehicles can discharge
60   to the network.
61 7. Discharge Power to Network (kW): How much of that discharged power can go to the
62   network. ($\{\bar{P}_t^{\text{V2G}}\}$ in Equation)
63 8. Effective charging efficiency: Ratio between charging power going to the vehicle and
64   power coming from the network. This can vary in time, as the location of the charging
65   vehicles (and thus the efficiency of the involved chargers) changes as they move around.
66   (η^{G2V} in Equation)

9. Effective discharging efficiency: Same as above, but for discharging (it is the power going out of the vehicles divided by the power going into the network). (η^{V2G} in Equation)

Acknowledgements

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