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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):

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

$$\underline{E} N_t^{\mathrm{plugged}} N\alpha \leq e_t \leq \bar{E} N_t^{\mathrm{plugged}} N\alpha \qquad \forall t \tag{2}$$

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

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

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

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

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

Further modelling

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

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

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

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

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

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

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

Software innovations

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

ChaProEV also provides charging sessions (in case they are not obtained from energy system models). This provides another description of the system that could be used for models and analyses that focus on charging sessions rather than profiles (which are aggregates of such sessions). Sessions include (in addition the elements that a profile gets):

1. *Location:* Where the session takes place
2. *Start time:* At which moment the vehicles in the session can start charging (i.e. when they arrive).
3. *End time:* At which moment the vehicles in the session must stop charging (i.e. when they leave).
4. *Demand for incoming leg (kWh) (to vehicle):* How much the incoming vehicles have spent on the leg arriving to the session.
5. *Maximal Possible Charge to Vehicles (kWh):* How much the vehicles could charge if they used the available power during their whole session.
6. *Charge to Vehicles (kWh):* How much of the vehicles actually charge during the session. This is based on the charging strategy of the vehicles and can be used to derive a charging profile.

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7. *Charge from Network (kWh):* The same as above, but corrected for charging efficiency (i.e. how much the network provides)

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Momber, I., Morales-Espana, G., Ramos, A., & Gomez, T. (2014). PEV Storage in Multi-Bus Scheduling Problems. *IEEE Transactions on Smart Grid*, *5*(2), 1079–1087. https://doi.org/10.1109/TSG.2013.2290594

Morales-España, G., Martínez-Gordón, R., & Sijm, J. (2022). Classifying and modelling demand response in power systems. *Energy*, *242*, 122544. https://doi.org/10.1016/j.energy.2021.122544

Sijm, J., Morales-España, G., & Hernández-Serna, R. (2022). *The role of demand response in the power system of the netherlands, 2030-2050* (Report No. P10131). TNO. https://publications.tno.nl/publication/34639481/emVYyq/TNO-2022-P10131.pdf

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