Faculty of Geosciences
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Increasing PV self-consumption with smart charging of EVs and V2G in a microgrid

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Smart grids are key in integrating large amounts of clean energy technologies into our current energy infrastructure. In a smart grid, electric vehicles (EVs) can be used as a flexible demand source and as a storage option with vehicle-to-grid technology (V2G) in order to increase self-consumption of photovoltaic (PV) solar power, thereby reducing the impact of both PV and EV on the electricity grid. LomboXnet is a company in Utrecht which provides internet services and rents EVs and has a large PV installation to power their activities. We show the benefits of smart charging of EVs and V2G for LomboXnet using computer simulations.

Methodology

Microgrid model

- We model the microgrid at LomboXnet, see figure 1.

EV control algorithms

- We develop several control algorithms for the smart charging of electric vehicles and V2G

Simulations

- We perform year simulations with 15 minute time-steps for each algorithm using data for PV, energy demand and EVs

Evaluation indicators

- **PV self-consumption**: Relative amount of PV power consumed within the microgrid
- **Relative peak reduction:** Reduction of peaks in energy demand due to smart charging compared to situation with no EV control scheme.

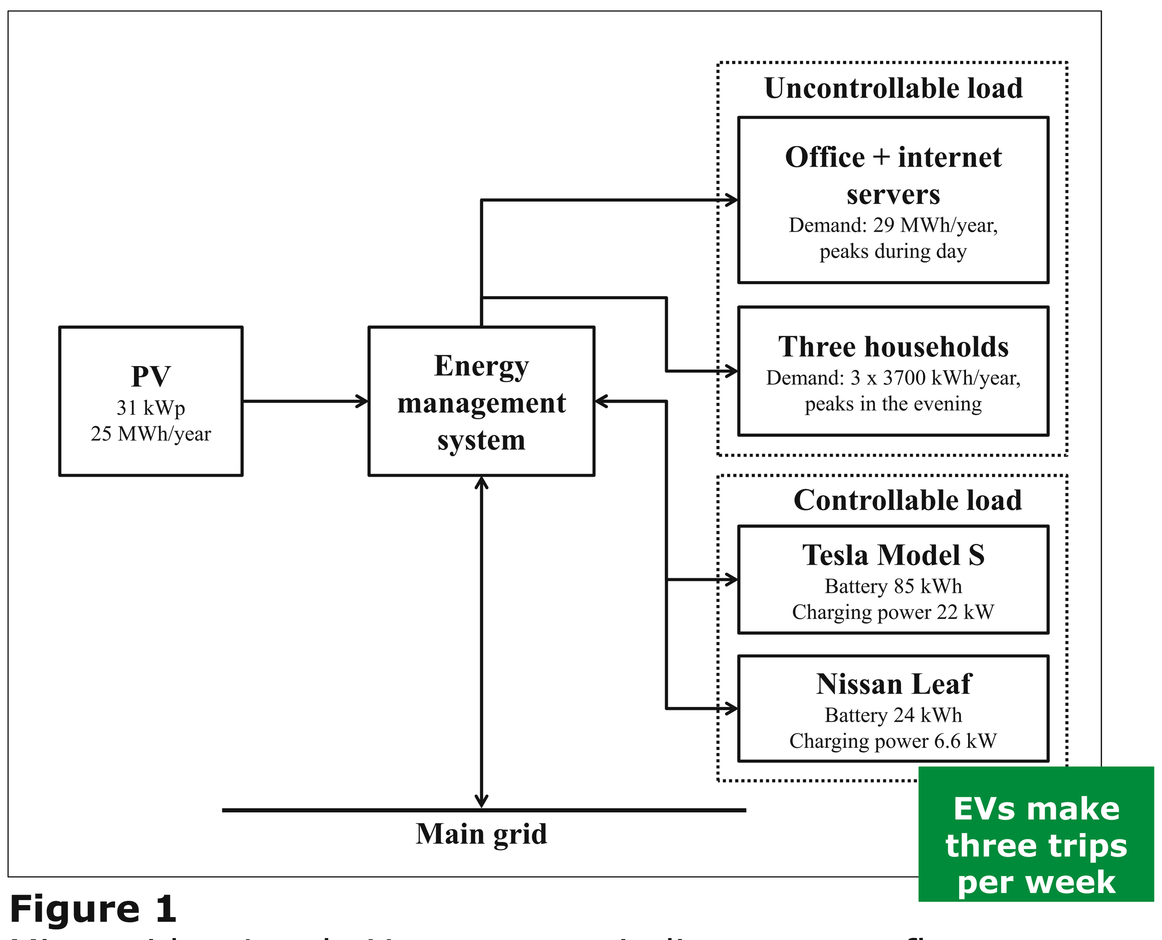


Figure 1
Microgrid at LomboXnet, arrows indicate power flows

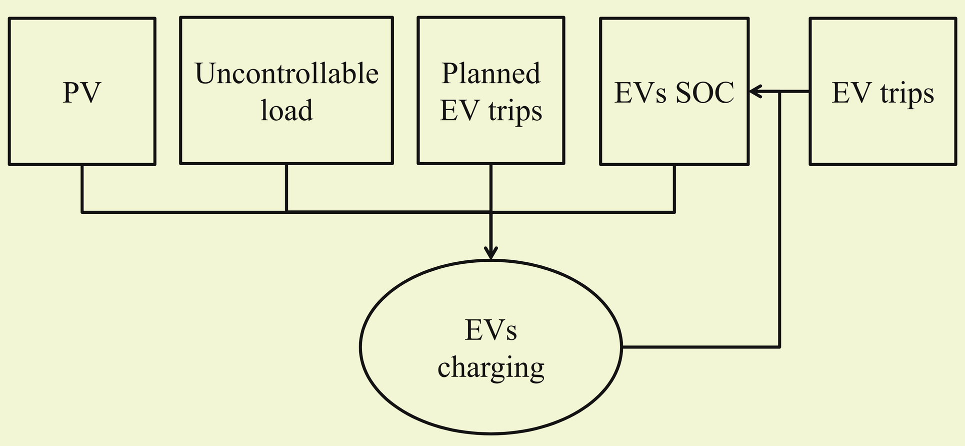
EV control algorithms

No control (reference)

- The EVs charge at maximum capacity until they are full

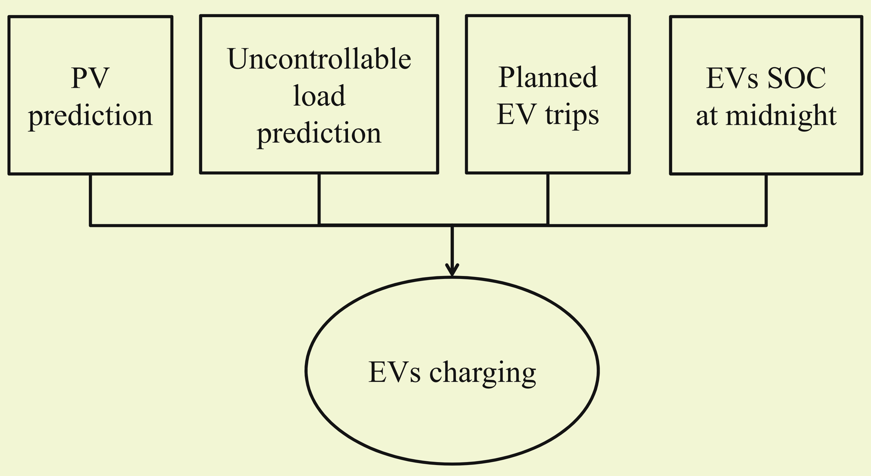
Real time control algorithms

- The EVs charge based on excess or shortage of PV power to cover uncontrollable load
- Trips must be planned in advance
- We model with and without the V2G option
- Flow of information:



Linear programming

- EVs charge based on mathematical optimisation method linear programming
- Optimisation for PV self-consumption
- Trips must be planned in advance
- Calculations are made at midnight and based on predictions for PV and uncontrollable load
- We model with and without uncertainties in predictions
- Flow of information:



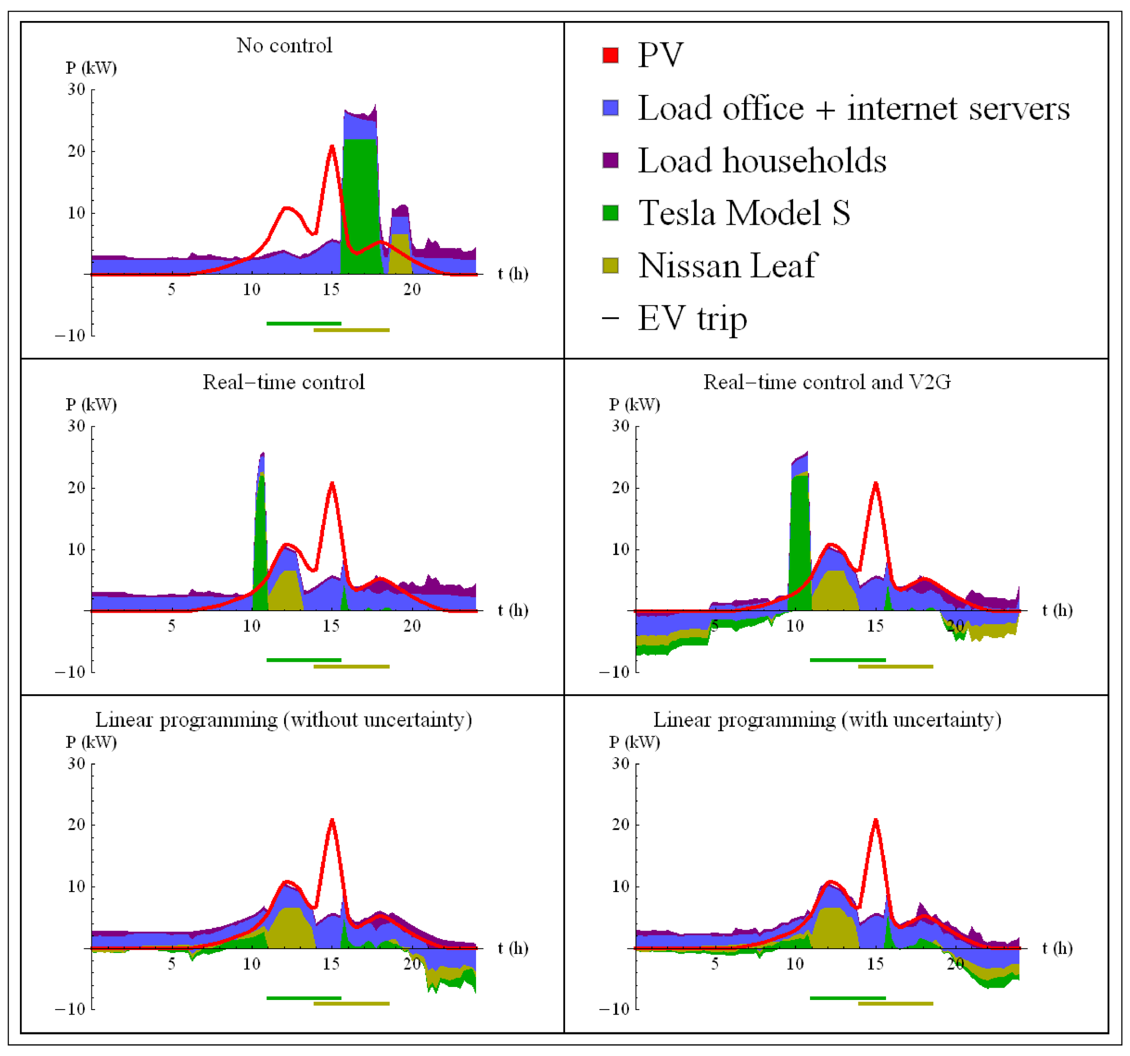


Figure 2
Example 24-hour simulations for all control algorithms. Lines indicate when the EV is away on a trip

Results

Load duration curve

Figure 3 presents the load duration curve resulting from the simulations. The load curves clearly illustrate the reduced energy demand and peak shaving due to the control algorithms both at the demand and supply side. Peak demand due to uncontrolled charging of EVs is easily recognizable and indicated in the figure.

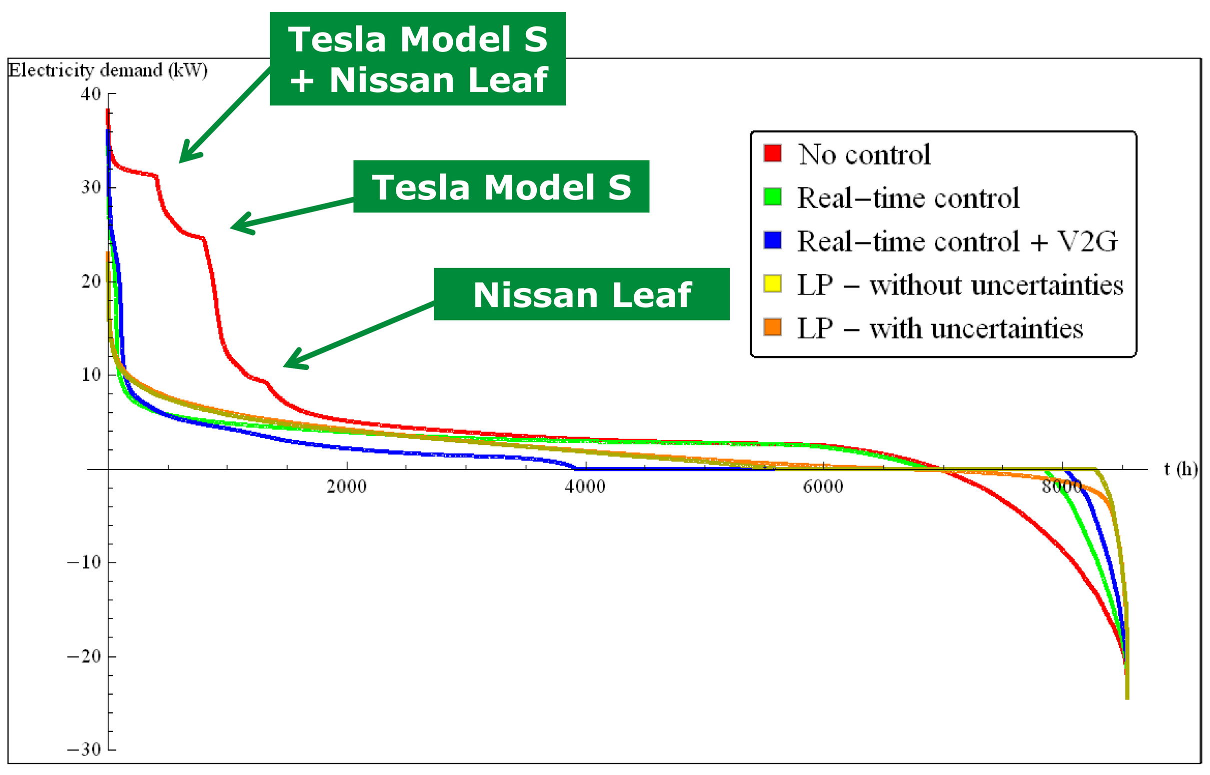


Figure 3
Load duration curve resulting from simulations.

Evaluation indicators

Table 1 presents the indicator scores for each algorithm. All proposed algorithms contribute significantly to PV self-consumption. The linear programming algorithm scores best, also when uncertainties are taken into account. The advantage of V2G is also clear from the results

Table 1
Simulation results

EV control algorithm	PV self-consumption	Relative peak reduction
No control	0.49	-
RT control	0.62	0.27
RT control + V2G	0.79	0.43
LP - without uncertainties	0.91	0.75
LP - with uncertainties	0.87	0.67

Conclusions

- **EVs can significantly increase PV self-consumption with smart charging and V2G**
- **With V2G much better results can be achieved than with using only smart charging**
- **LP scores best for both indicators and halves the largest peak in demand compared to the real-time algorithms**

This research project is part of

Rendement smartgrid voor iedereen!