UNIVERSITY OF TWENTE.

SMART CHARGING OF ELECTRIC VEHICLES IN RESIDENTIAL DISTRIBUTION GRIDS

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ABOUT ME

- BSc, MSc Applied Mathematics at University of Twente
- 2016: MSc thesis on robust charging of electric vehicles (EVs)
- Now: PhD student in “Energy group” (collaboration between CAES and DMMP)
- Area: optimization algorithms for (devices within) smart grids

RESEARCH OF THE “ENERGY GROUP”

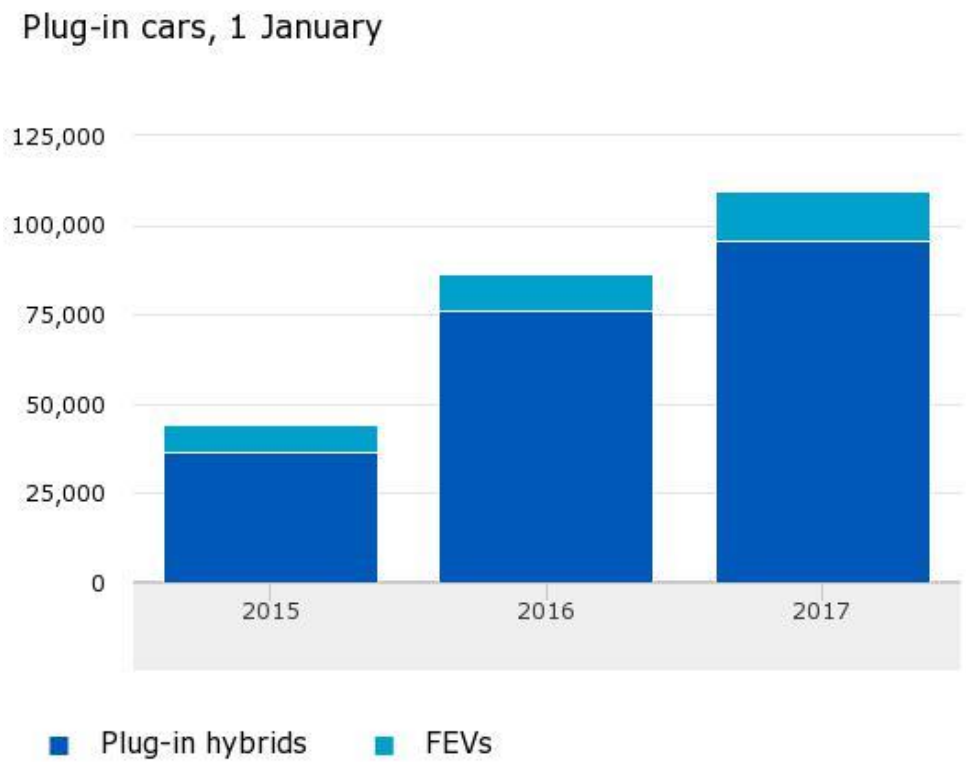
- Development of management and control strategies for smart grids
- Multidisciplinary: people with background in
  - Embedded Systems
  - Electrical Engineering
  - Computer Science
  - Mathematics
  - …

OUTLINE

- Residential EV charging - a field test
- Strategy for EV charging
- Coordination of multiple EVs

ELECTRIC VEHICLES IN THE NETHERLANDS

RAPID INCREASE



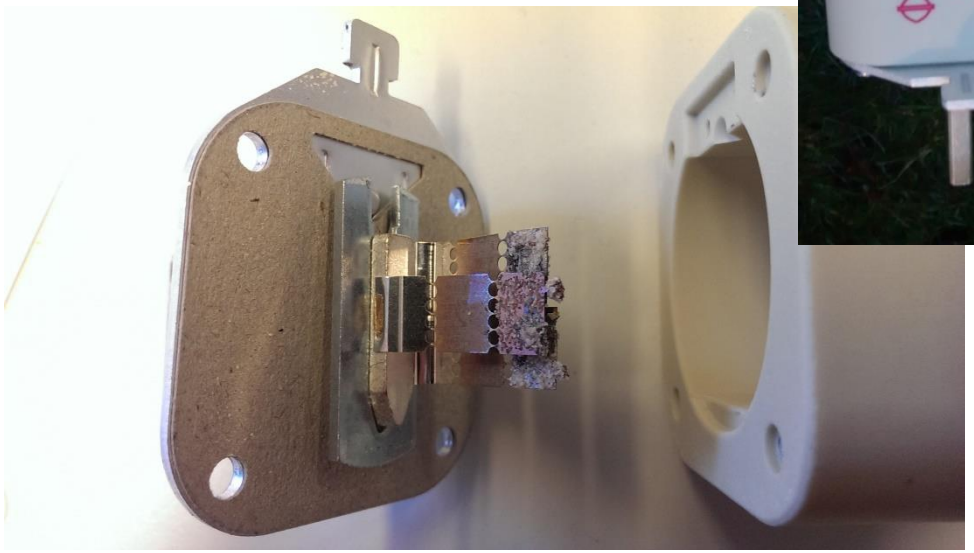
- % of cars that were EVs:
  - 2010: 0.05%
  - 2015: 2.0%
  - 2016: 2.6%
- Political ambition: to sell only emission-free cars from 2030 onward

A FIELD TEST
SETTING

- Lochem: test site (“proeftuin”) for smart grid management approaches
- Field test in 2015
- Charge 20 EVs during the evening
- Measure stability of network

A FIELD TEST
WHAT HAPPENED?

- After ±30 min.: melted fuse on phase 3 due to overloading!
- Outage for 5 minutes



A FIELD TEST
LOAD UNBALANCE

Figure 1 in “G. Hoogsteen et al.: 'Charging electric vehicles, baking pizzas, and melting a fuse in Lochem', CIRED - Open Access Proceedings Journal, 2017(1), p. 1629-1633”
http://cired.net/publications/cired2017/pdfs/CIRED2017_0340_final.pdf

A FIELD TEST
MAJOR PROBLEMS

- Peak consumption
- Consumption synchronization
- Load unbalance

Conclusion: the current grid cannot accommodate large-scale EV charging without any control

So what to do?

STRATEGY FOR EV CHARGING

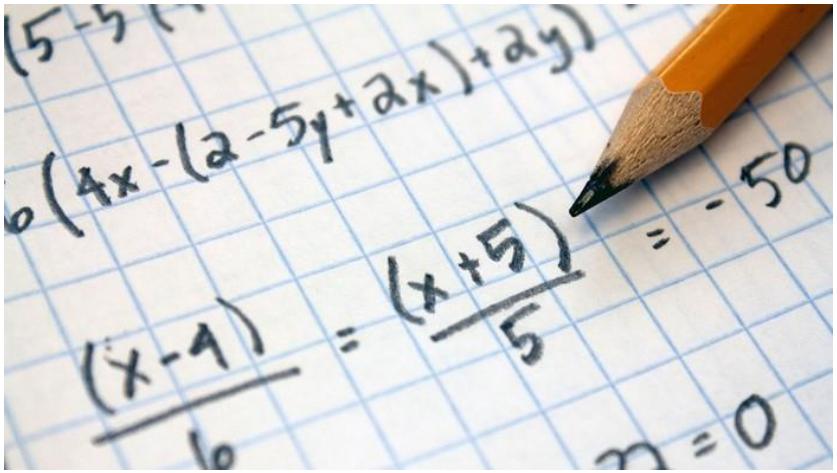
ENERGY MANAGEMENT SYSTEM

STRATEGY FOR EV CHARGING
PREDICTION

- When is an EV available for charging?
- How much must be charged?
- What is the consumption of other devices?

STRATEGY FOR EV CHARGING
PLANNING

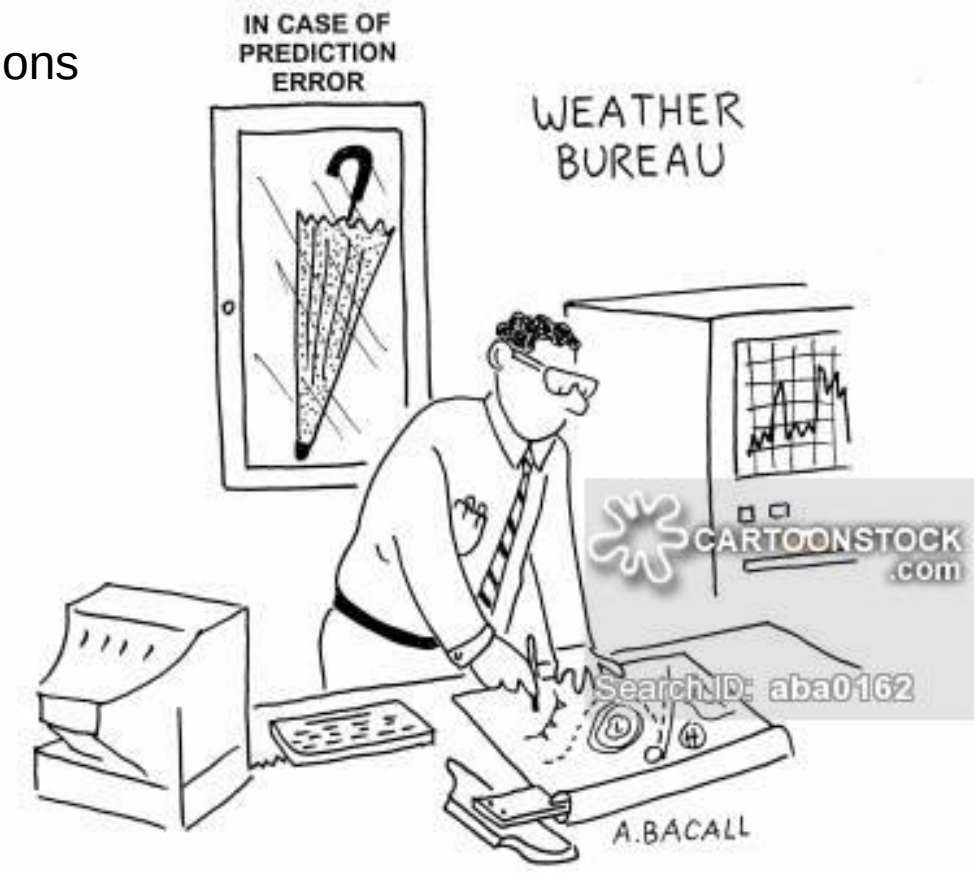
- Using predictions: determine optimal charging schedule for EVs
- Here, optimal means “as flat as possible”
- Apply mathematical optimization algorithms



STRATEGY FOR EV CHARGING

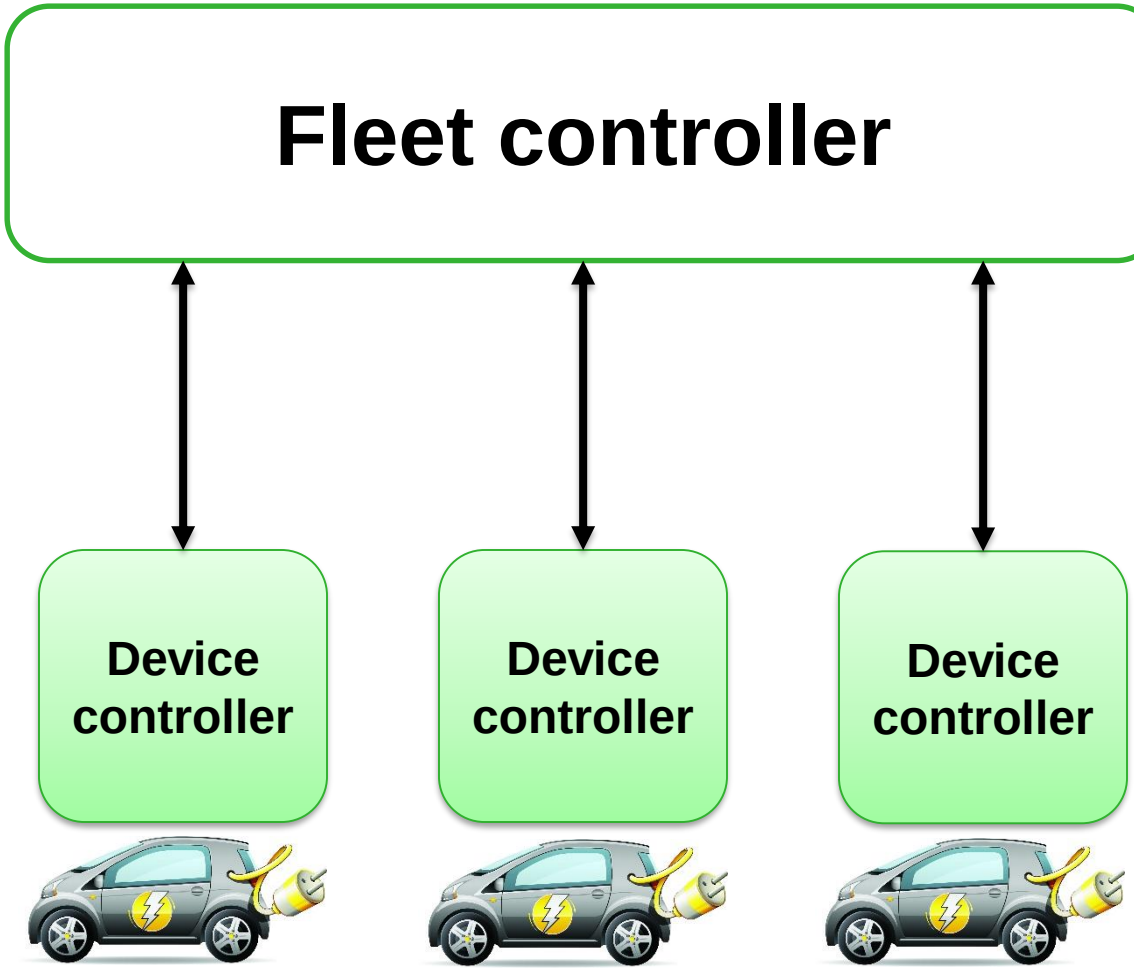
REAL-TIME CONTROL

- What to do when predictions turn out to be wrong / inaccurate?
- Dealing with unexpected behavior



COORDINATION OF MULTIPLE EVS

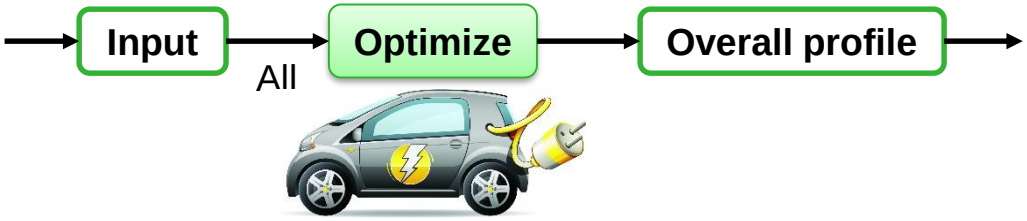
DEVICE CONTROL STRUCTURE



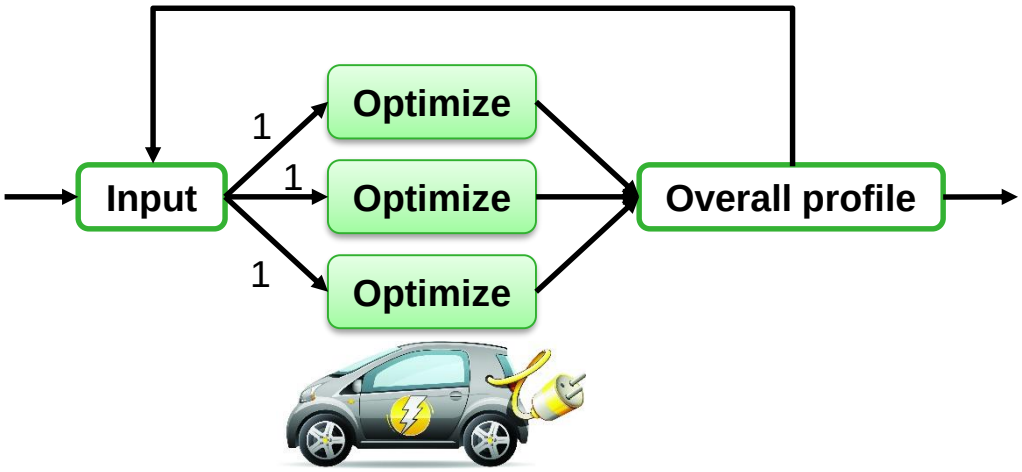
COORDINATION OF MULTIPLE EVS

CENTRALIZED VS. DECENTRALIZED

- Centralized: all EVs together

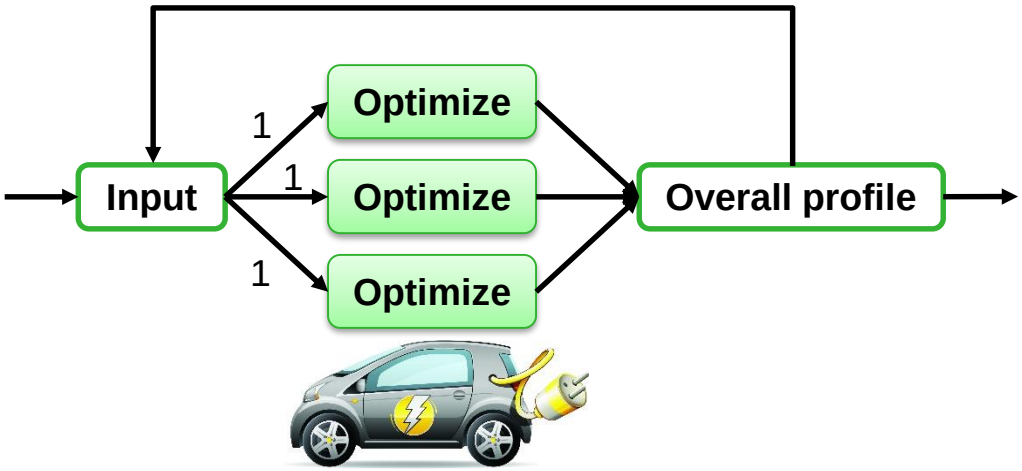


- Decentralized: separately per EV and use feedback loop



COORDINATION OF MULTIPLE EVS

PROFILE STEERING



- Fleet controller sends “target profiles” to device controllers
- Devices: match consumption with target as well as possible
- Repeat to cancel out over / undershoot

OUTLOOK
ONGOING SMART GRID RESEARCH AT THE UNIVERSITY OF TWENTE

- Multi-commodity smart grids (electricity + heat)
- Implementations in the “real” world
- Cost allocation
- ... and more …

MORE INFORMATION
(OR: SHAMELESS PROMOTION…)

- Our research: https://www.utwente.nl/ctit/energy/
- A recent (and accessible!) paper on the Lochem field test:

  G. Hoogsteen et al.: 'Charging electric vehicles, baking pizzas, and melting a fuse in Lochem', CIRED - Open Access Proceedings Journal, 2017(1), p. 1629-1633

- Many possibilities for BSc and MSc assignments, also in cooperation with companies

THANK YOU!

QUESTIONS?