THE UNIVERSITY OF MELBOURNE

The Impact of Electric Vehicles on the Grid

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Presentation to Economy and Infrastructure Committee,
State Parliament of Victoria, Australia

9 November 2017

Feb 2012 – Feb 2015 University of Melbourne Electric Vehicle Research Project: Goals

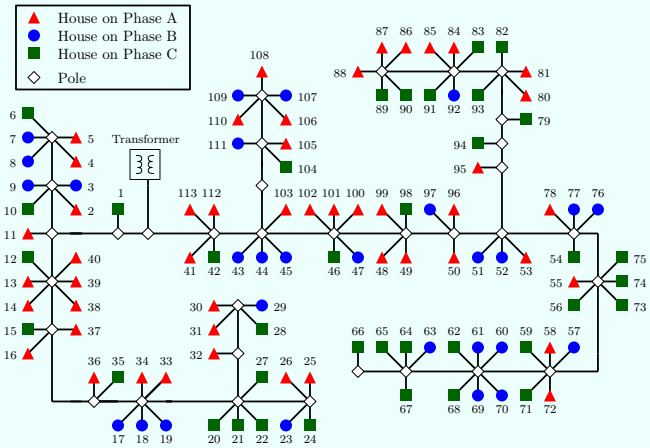
- Study impact of electric vehicles on the grid – at distribution level

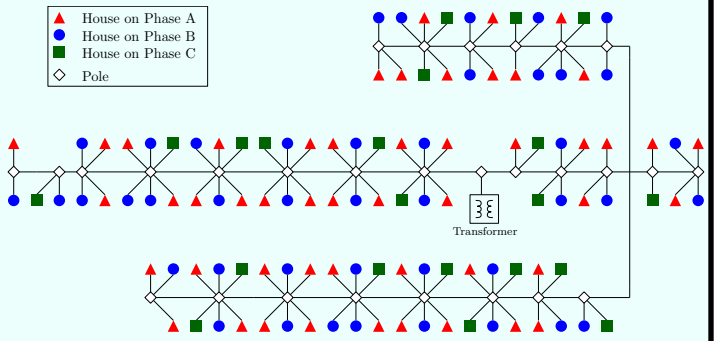
- Design an optimal charging policy, informed by:
  - Electricity market spot price
  - State of charge in every battery
  - Present and anticipated constraints of the distribution network

➢ Maximal uptake of electric vehicles with minimal capacity upgrade requirements

Simulation Approach

Networks



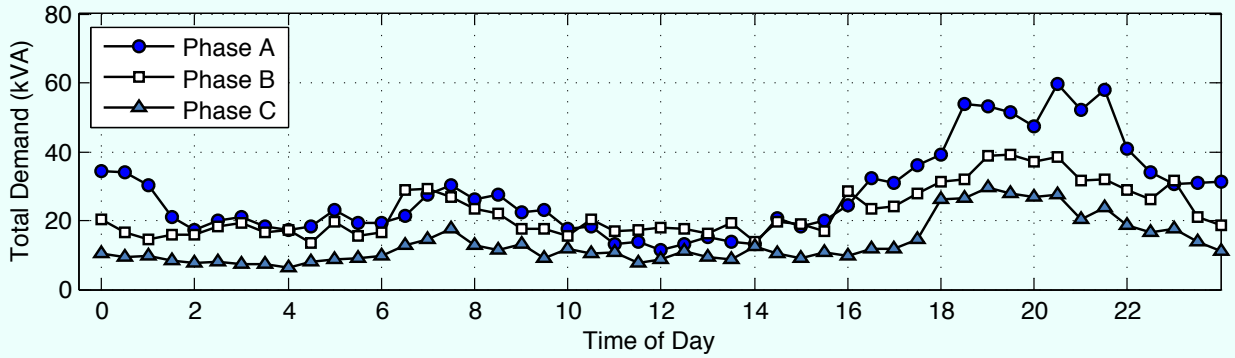


- Models of several neighbourhoods (Melbourne, Townsville)
- Real line and transformer specs
- Accurate phase allocation (although not for all)

Simulation Approach

Networks

Household Demand



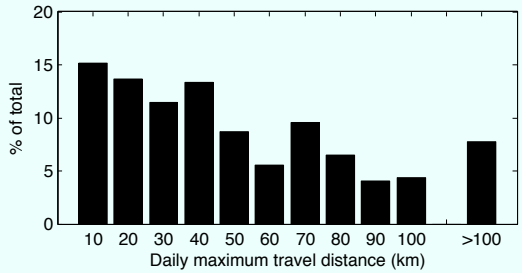
- Household demand as measured at distribution transformer / or at individual houses
- Range of months

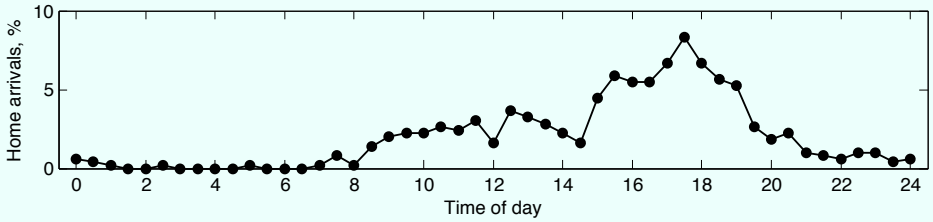
Simulation Approach

Networks

Household Demand

Travel Patterns and Charging Needs





- 2009 VISTA Travel Survey (Victoria Department of Transport)
- 13,000 records of 24-hour vehicle travel profiles
- Know *when* vehicles home, and *how far* they have travelled

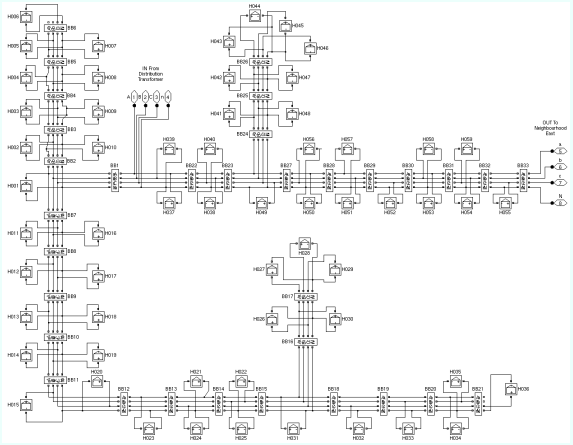
Simulation Approach

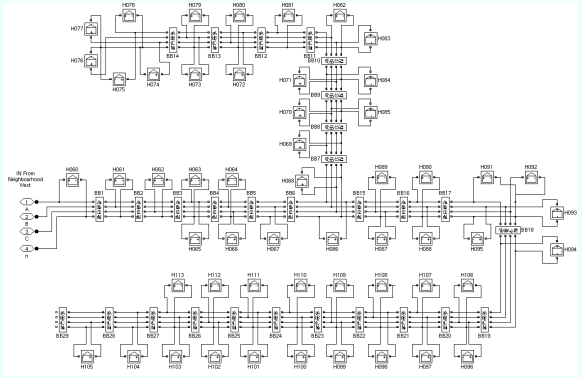
Networks

Household Demand

Travel Patterns and Charging Needs

Load Flow and Simulation





- Load flow using MATLAB SimPowerSystems
- Optimisation using MATLAB Optimisation Toolbox
- All else using POSSIM (POwer Systems SIMulator)

Simulation Approach

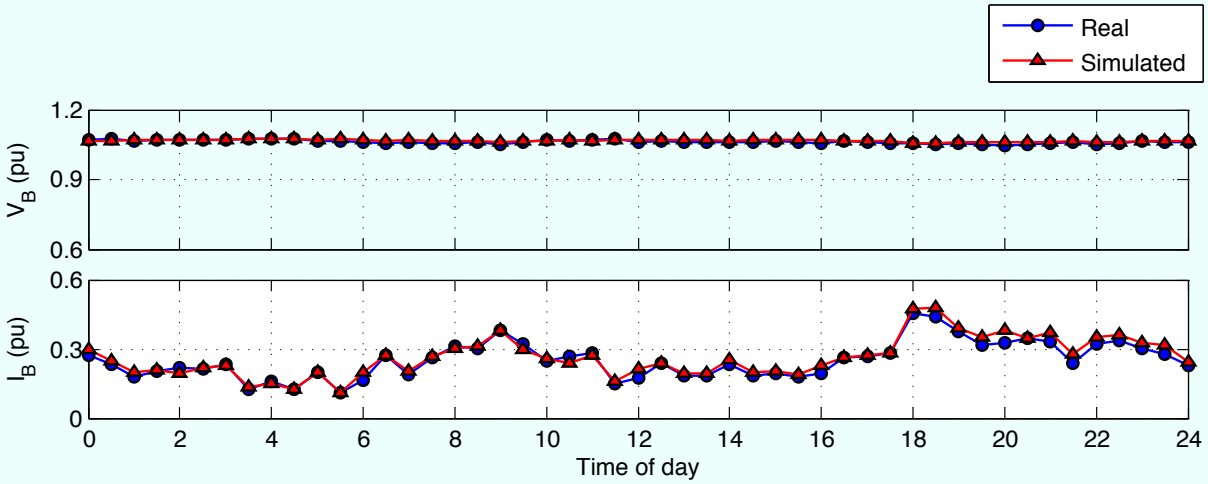
Networks

Household Demand

Travel Patterns and Charging Needs

Load Flow and Simulation

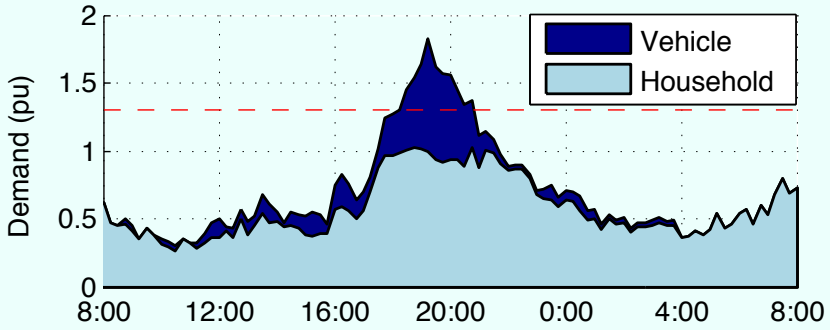
Validation

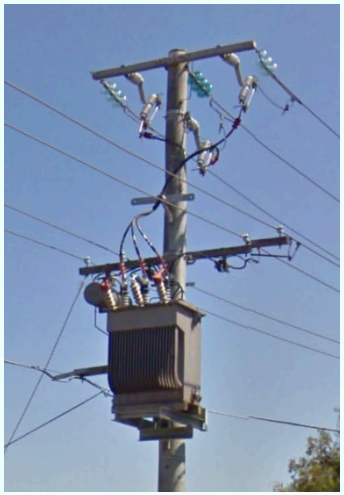


- Extensive comparison of simulator outputs to real measurements
- Voltages within 1.5 V on average (0.6%)
- Currents within 6 A on average (7%)

Early Observations 1: Network Impacts

Peak Demand



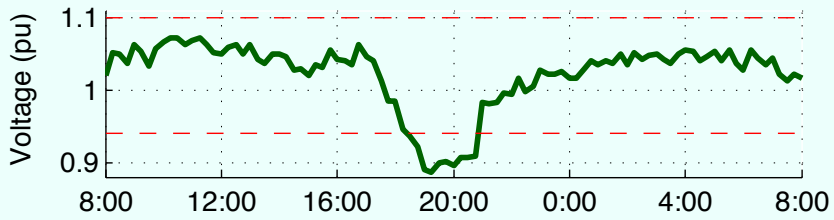


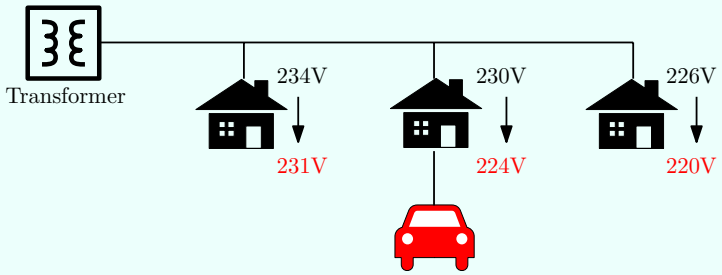
- Thermal overload
- Increased ageing / failure of network assets

Early Observations 1: Network Impacts

Peak Demand

Voltage Drop





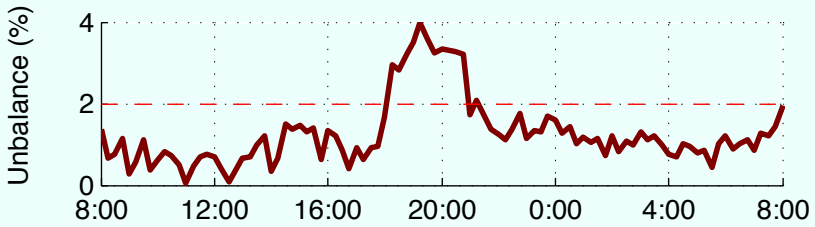
- Voltage below minimum required levels at certain houses in the network
- Appliances may run inefficiently / reduced lifetimes

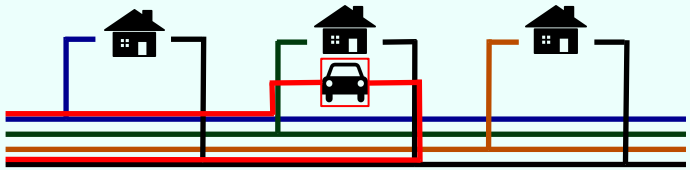
Early Observations 1: Network Impacts

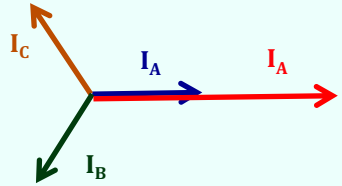
Peak Demand

Voltage Drop

Phase Unbalance

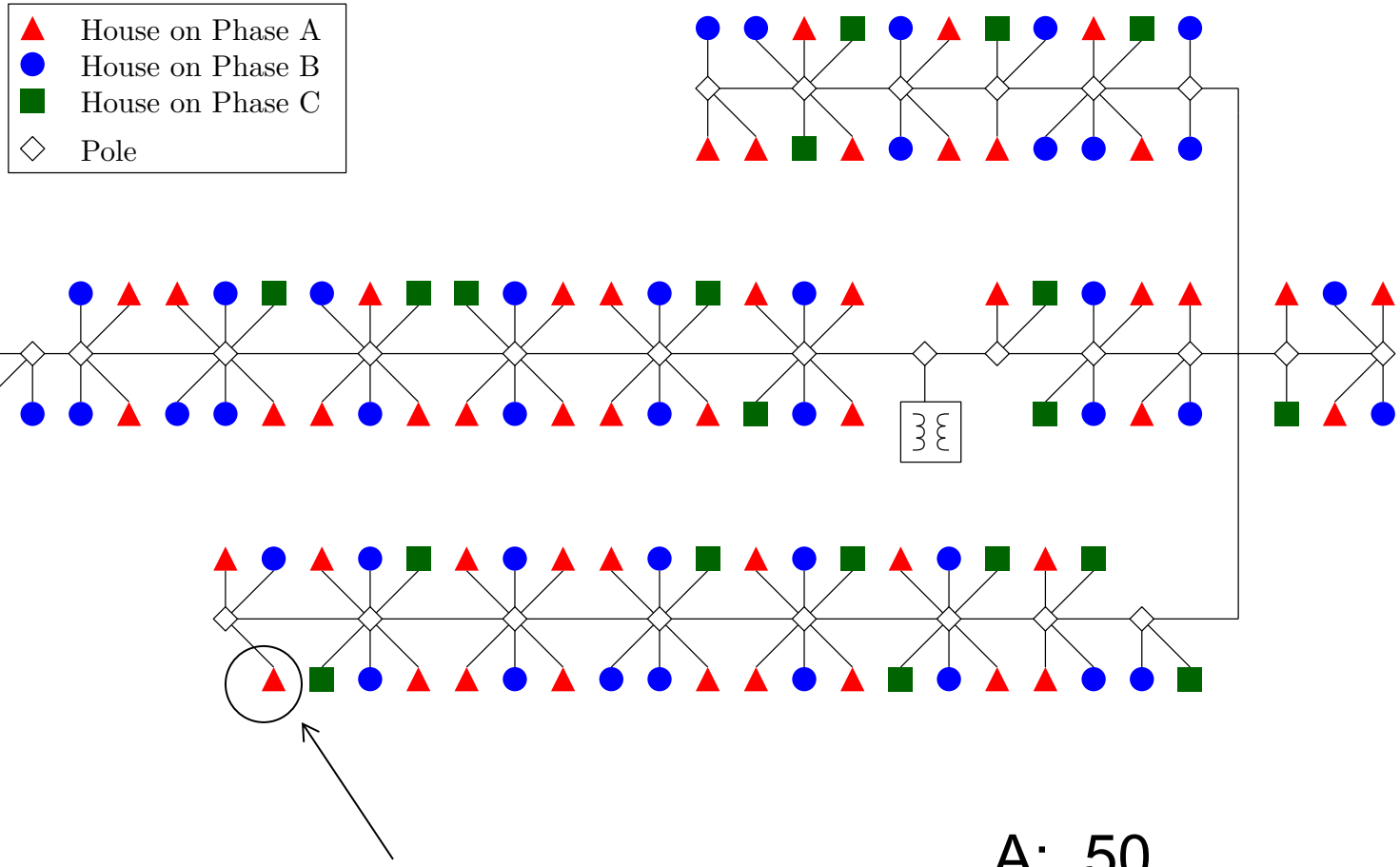






- Neutral current
- More losses
- Increased voltage drop

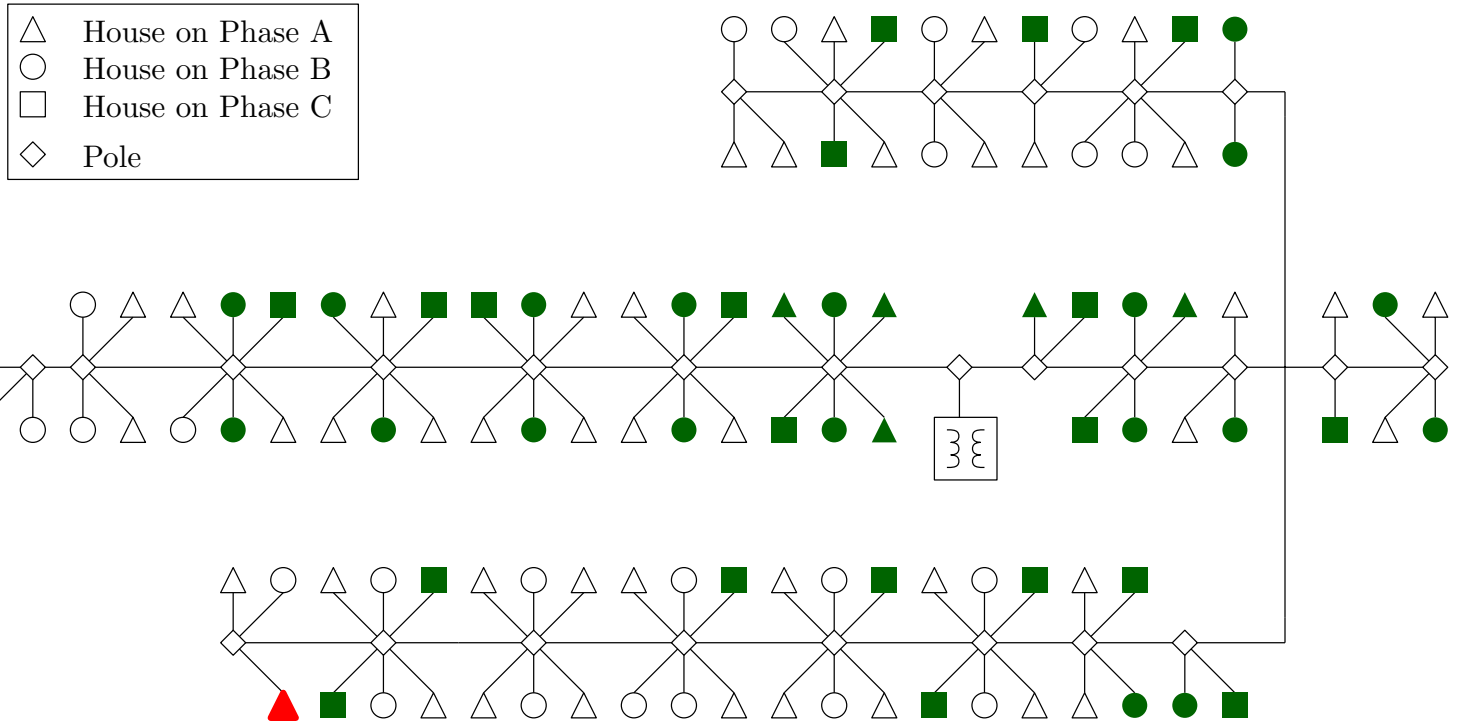
Early Observation 2: Importance of Location



Most sensitive!

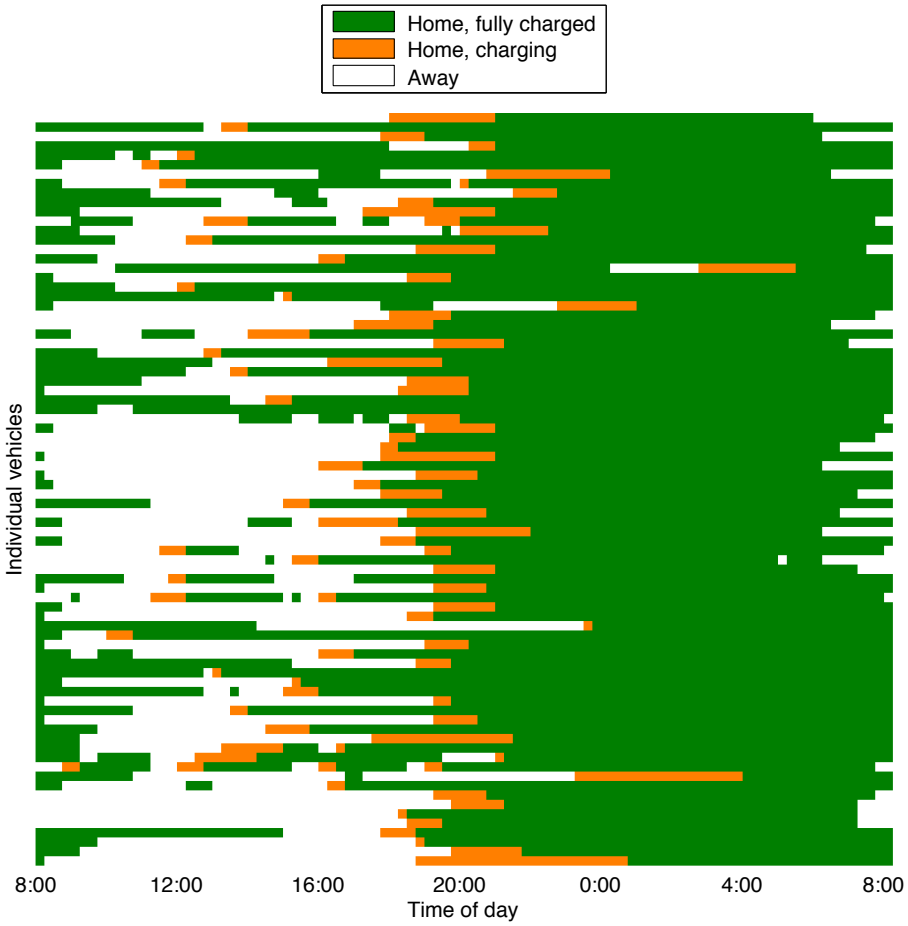
A: 50
B: 43
C: 21

Early Observation 2: Importance of Location



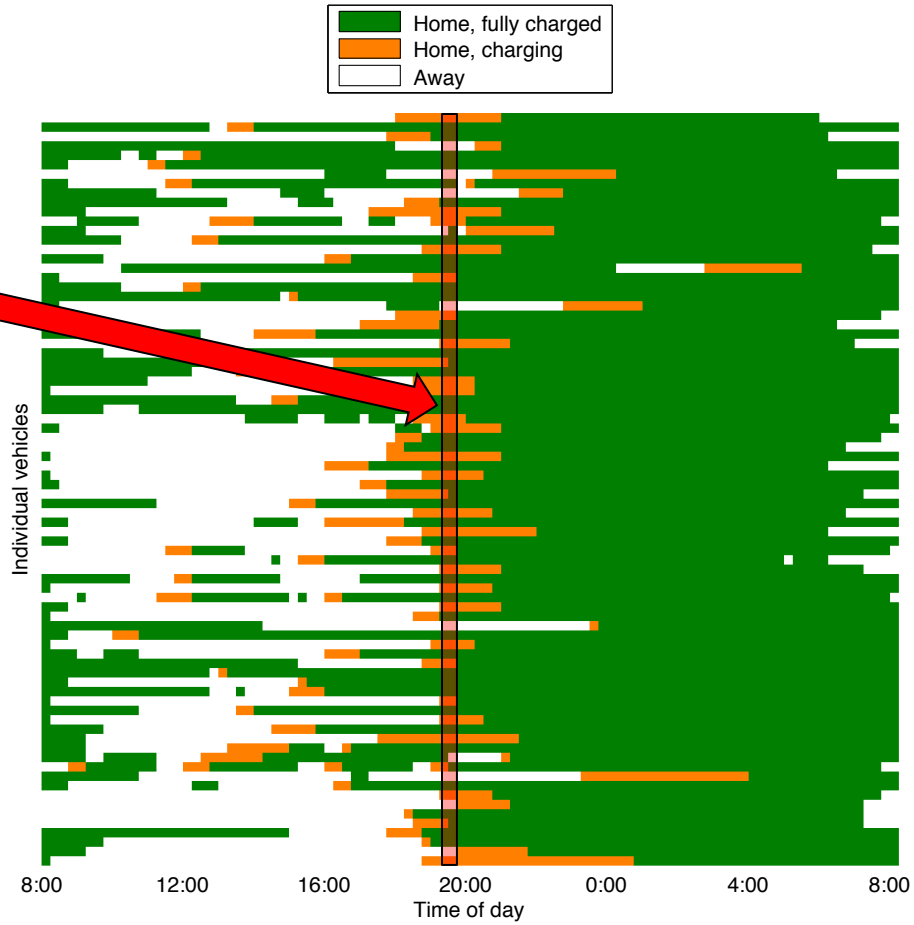
- Adding a single vehicle at the red house has the same impact on minimum voltage as adding vehicles at all (45) green houses!
- Reason: voltage drop and unbalance in the network
- Vulnerable: houses distant from the transformer on highly loaded phases
- Significant implications for *fairness* of charging. Should all customers have equal rights?

Early Observation 3: Flexibility



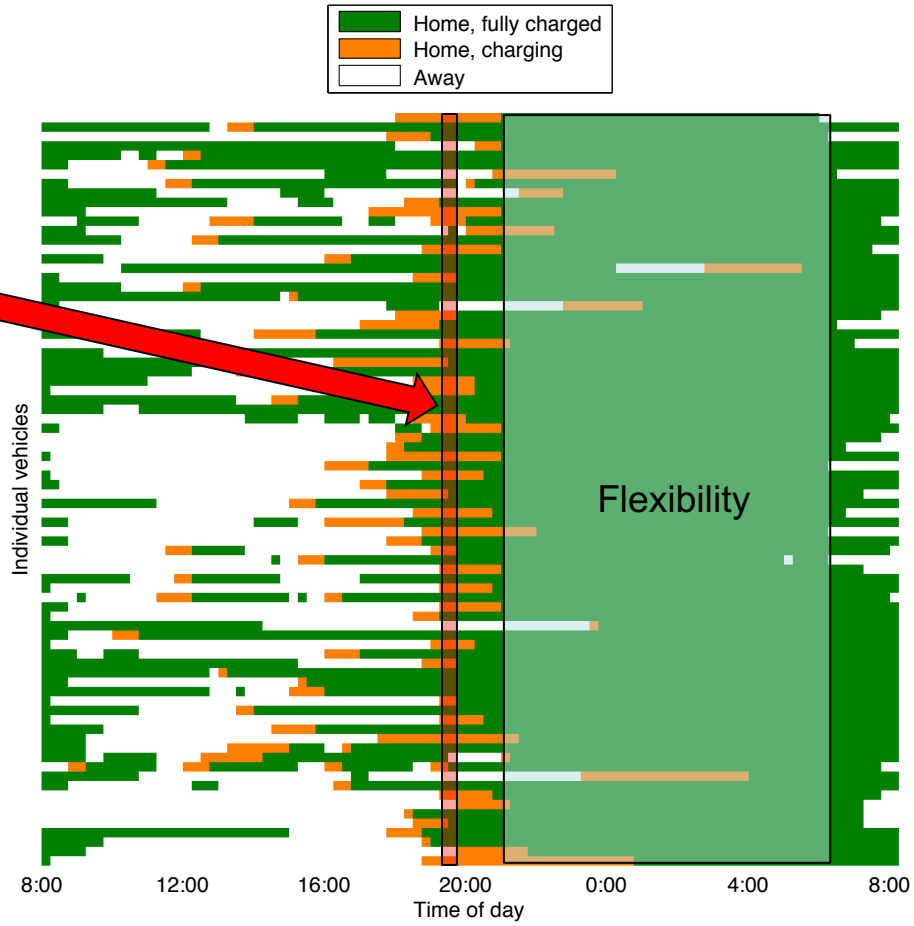
Early Observation 3: Flexibility

Coincident charging



Early Observation 3: Flexibility

Coincident charging



Load Shifting for Electric Vehicles

Utility Operator | Smart Meter | Charge Point | Electric Vehicle

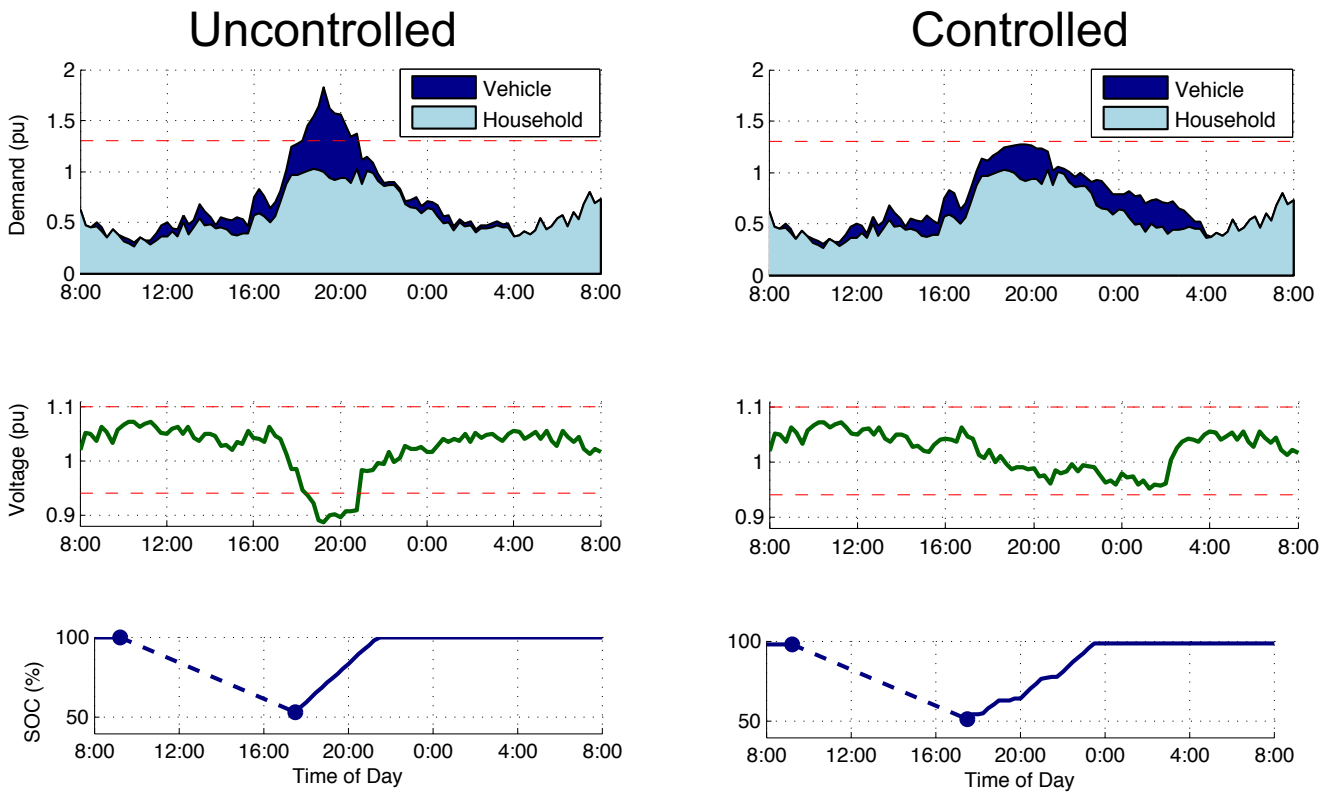
Z.Angelovski and K.Handberg (DiUS Computing), together with Raman Jegatheesan (United Energy)
Demand management of electric vehicle charging using Victoria's Smart Grid.
Technical report, DiUS Computing (May 2013).

By controlling timing of charging, negative impacts can be avoided

$x_{k,t}$: current supplied to vehicle *k* at time *t*

$$\max_{x_{k,t}} \sum_{k=1}^{K} \sum_{t=0}^{T} x_{k,t}$$

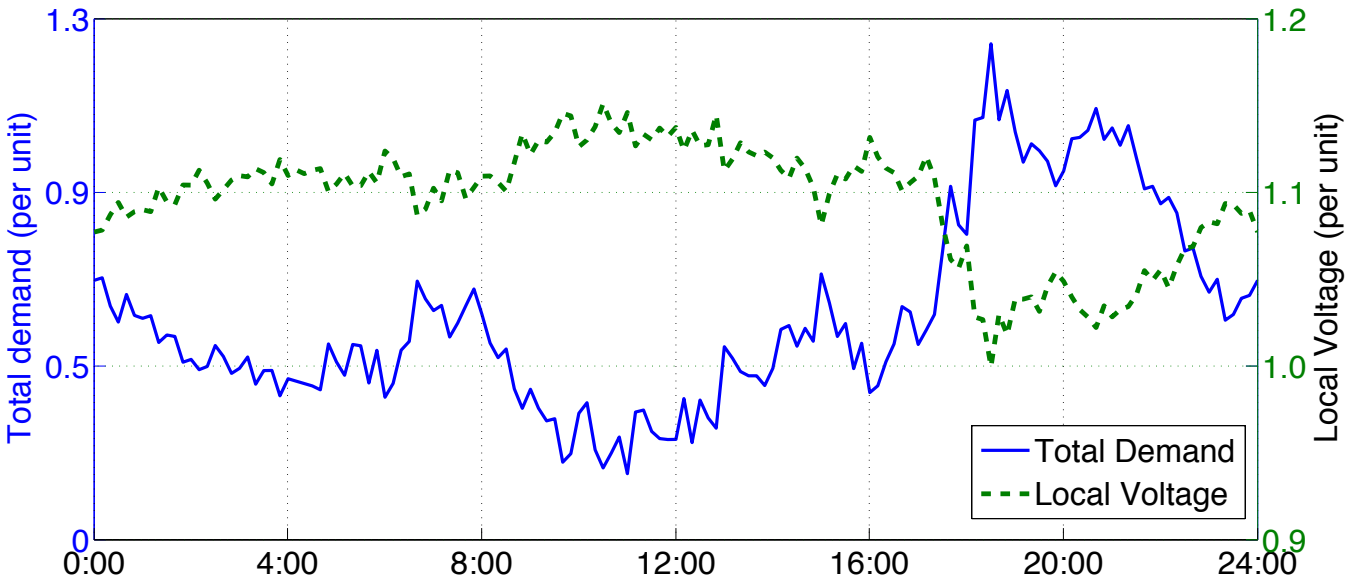
Provide as much current to vehicle charging as the network will allow



Conclusions

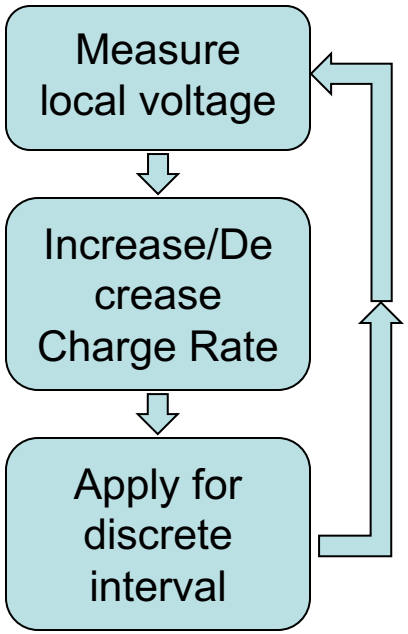
- **Uncontrolled** charging allows EV penetration of only **10-15%;** typically the first "point of failure" is voltage drop
- **Optimal** charging allows EV penetration of **80% or more** in the networks we studied, *using only existing infrastructure*
- Installing a new transformer costs ~$100,000 - $150,000… **Savings (or at least delayed upgrades) of $1000 - $2000 per household**.
- Price-based optimisation leads to **savings of 10-20%** (and considerably more on days with greater fluctuations in price)

Distributed Charge Control (Lu Xia)



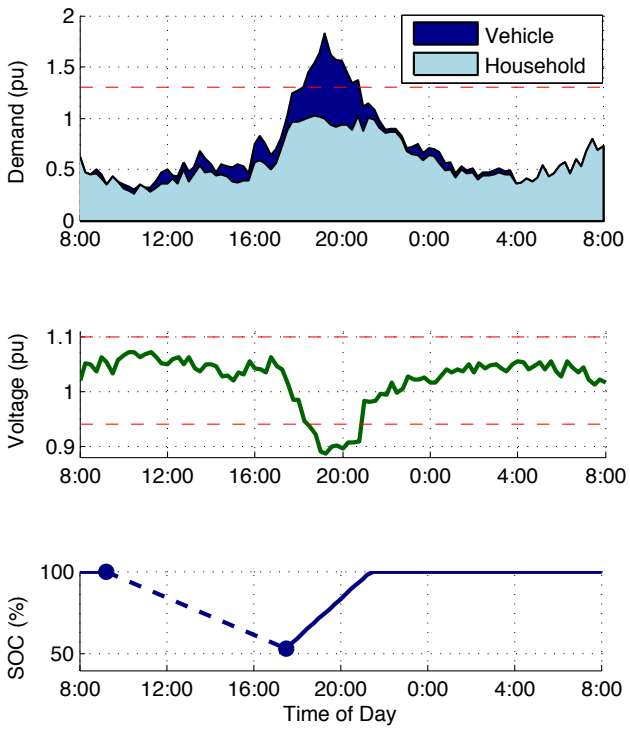
Local voltage is a good indicator of total network demand

Use local voltage as a demand response signal

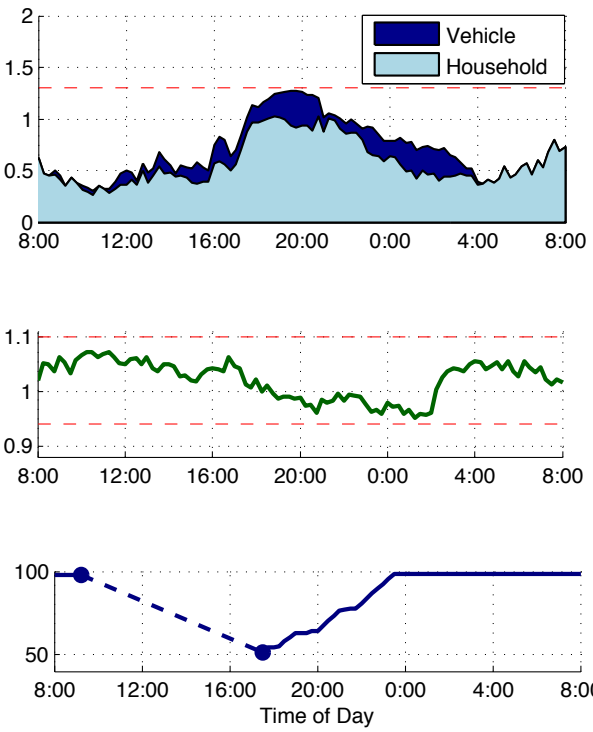


Distributed DSM solutions

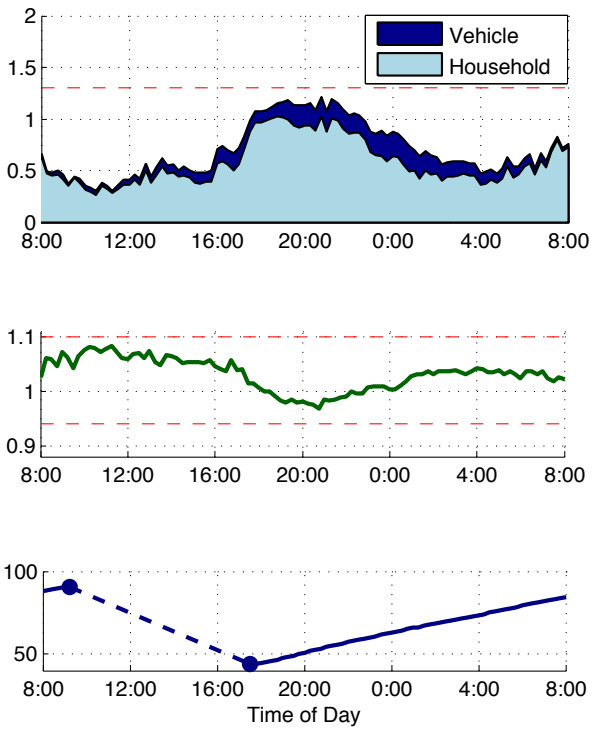
Uncontrolled



Centralised



Distributed



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Thank you!

Questions?