DISTRIBUTION NETWORK RECONFIGURATION WITH DECENTRALIZED AUTONOMOUS ELECTRIC VEHICLES

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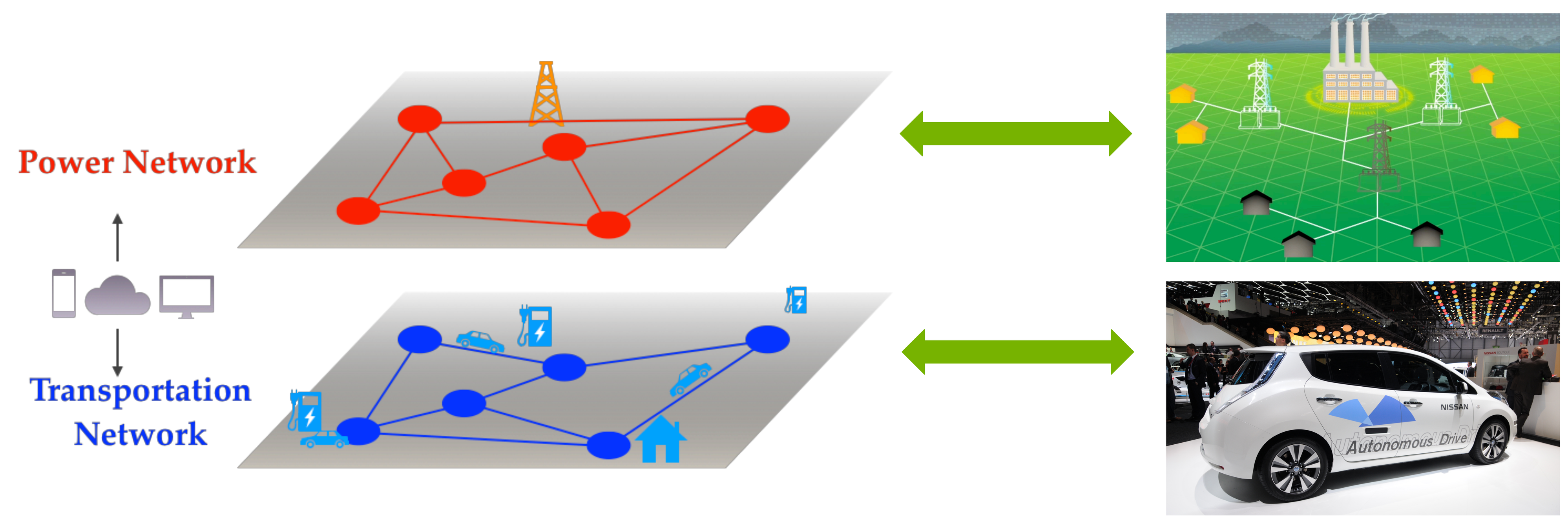
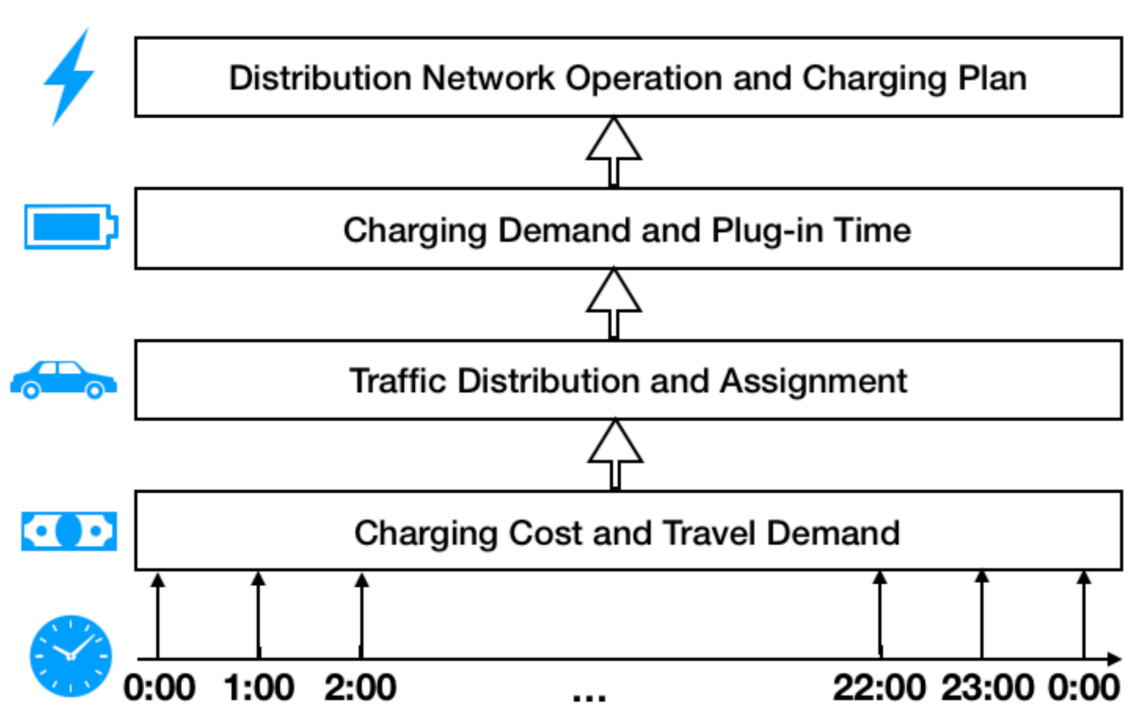
CHALLENGES

- **Motivations:** Autonomous electric vehicles (AEVs) provide unique opportunities to improve distribution network efficiency and reliability, because of their spatial and temporal charging flexibility, but the effects are limited by the inherent radial topology of distribution network.
- **Research Question:** What are the potential benefits of dynamic distribution network reconfiguration (DDNR) combined with AEVs?
- **Challenges:** (1) AEVs' decentralized travel and charging behaviors; (2) battery degradation.



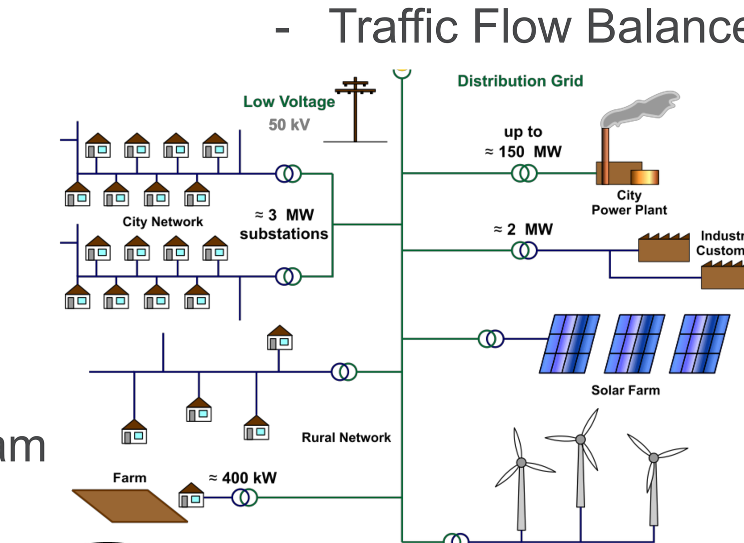
MODEL OVERVIEW

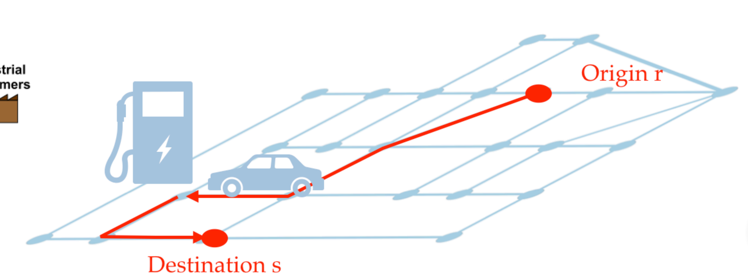


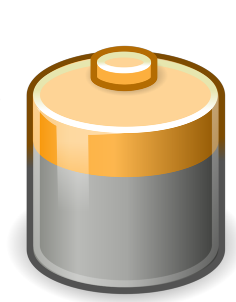
- The operation of distribution network will consider energy demand and duration of AEVs plug-in time.
- Energy demand and AEVs plug-in time are estimated from hourly Traffic Distribution and Assignment (TDA) Model, in which AEVs select their charging/parking destination and travel routes after drop off passengers.
- The AEVs destination choice are based on locational attractiveness, travel time, charging cost; the AEVs route choice are based on shortest-path.
- Hourly charging cost and travel demand are considered as given in this study.

MODEL DESCRIPTIONS

- **Distribution Network Reconfiguration Models**
  - Decision Variables: reconfigurations, power flow
  - Objective: minimize line losses, battery degradation and switching cost
  - Constraints:
    - Power Flow Capacity
    - Power Balancing
    - Power Quality Control
    - Radial Topology
    - Reconfiguration limit
  - Second-order Conic Program
- **Travel behaviors of AEVs in transportation network**
  - Decision Variables: facility location, travel routes
  - Objective: User equilibrium + Logit discrete choice utility
  - Constraints:
    - Traffic Flow Balance
- **Battery Degradation**
  - Cycle degradation occurs in the charging and discharging process, which is affected by many factors, such as temperature, charging / discharging rate, depth of discharge, etc.
  - Ah-throughput counting model

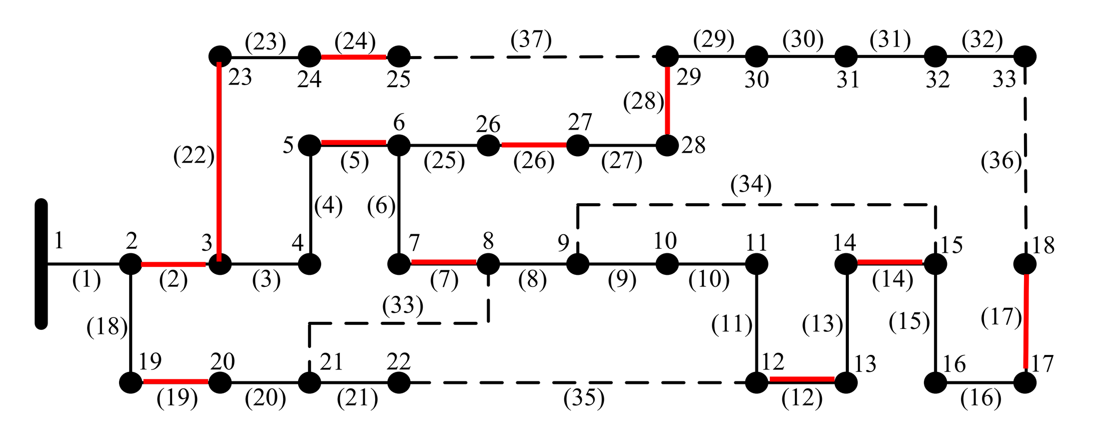






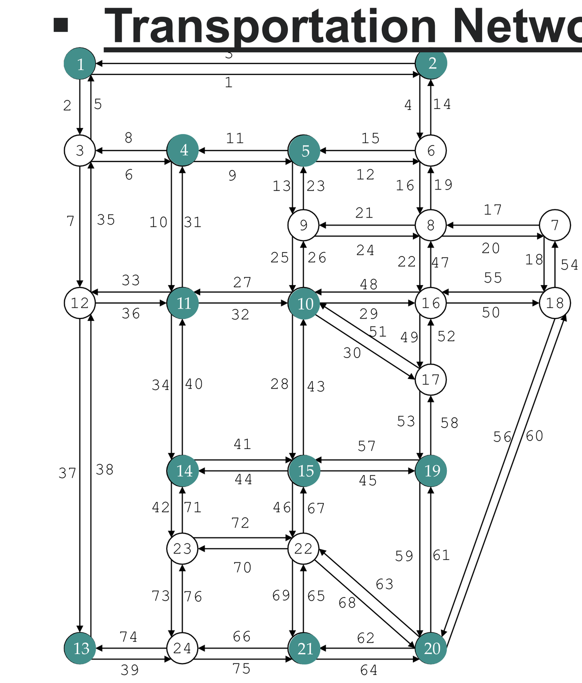
NUMERICAL EXAMPLES

- **Distribution Feeder: IEEE 33-node test feeder**



Load Profile: the Electric Reliability Council of Texas (ERCOT) demand data.

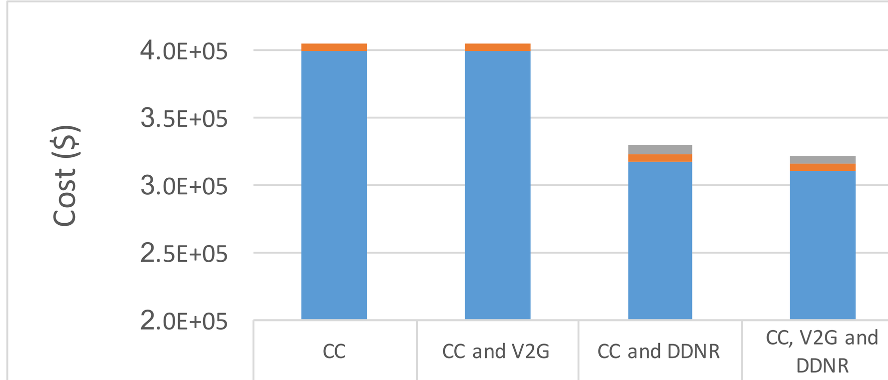
- **Transportation Network : 24-node Sioux Falls**



Travel Behavior: the 2011 Raw Data of Travel Behavior released by the Atlanta Regional Commission (ARC).

KEY RESULTS

- **System Cost for Different Technologies Availability**

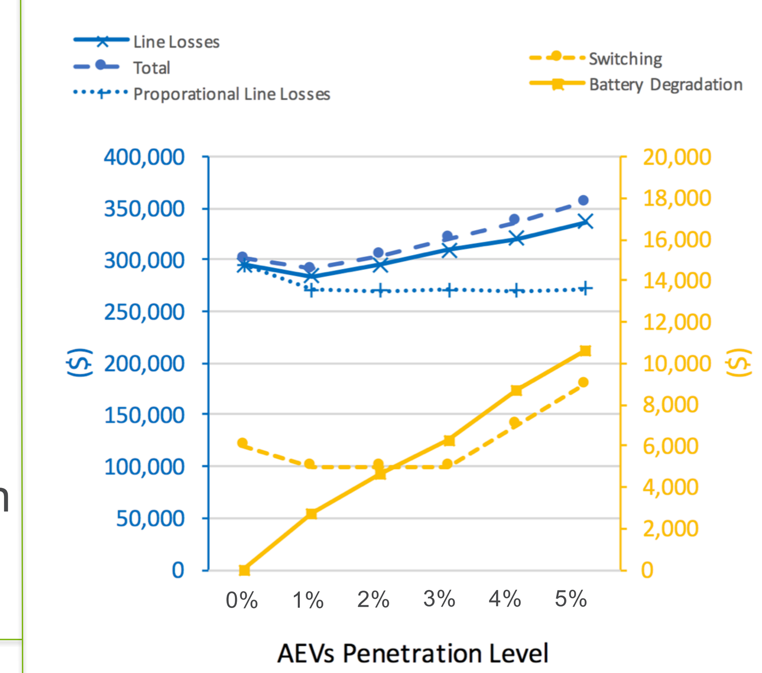


	CC	CC and V2G	CC and DDNR	CC, V2G and DDNR
Total	4.04E+05	4.04E+05	3.29E+05	3.21E+05
Switching	0	0	7000	5000
Battery Degradation	5690	5987	5690	6275
Line Losses	398734	398331	316568	309263

CC: controllable charging; V2G: Vehicle-to-Grid; DDNR: dynamic distribution network reconfiguration

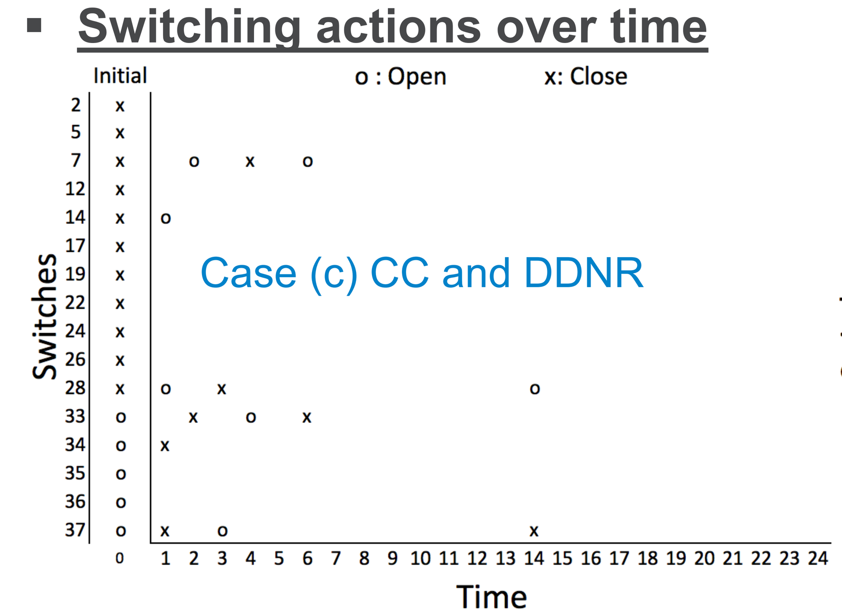
- Adding DDNR to the distribution network can reduce the total system cost by nearly 20% compared to the cases without DDNR.
- Adding V2G does not reduce the system cost unless DDNR is available.
- The additional battery degradation cost due to V2G is only 7.5% of the total system cost reduction.

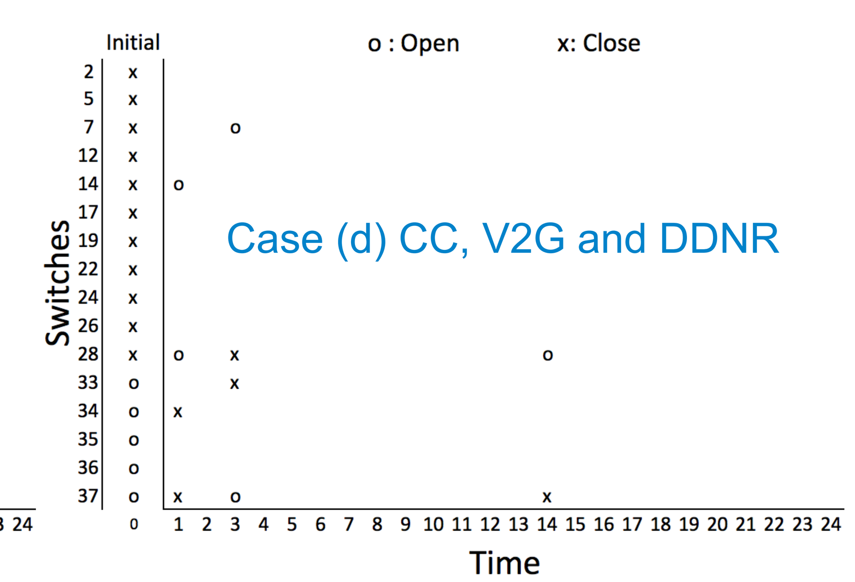
- **Sensitivity on AEV Penetration**



- Tradeoff of more AEVs: increasing system energy flexibility and increase system energy demand.
- Relatively low level (~1%) of AEV participation in V2G can be optimal in terms of total system cost.

- **Switching actions over time**





- Adding V2G decreases switching frequency from 14 times to 10 times.

SUMMARY AND FUTURE WORK

- We develop a modeling framework to capture the interaction between transportation and power network.
- DDNR technologies well complement V2G in terms of minimizing the total system cost, even considering the extra battery degradation cost associated with V2G services.
- As a side benefit, switching frequency decreases when coordinating AEVs charging/discharging with DDNR.
- There exists an optimal level (~1%) of AEVs that could minimize the total system cost.
- Additional battery degradation due to V2G services is only a small portion (~7.5%) of the total cost saving.
- Future work: incentive design of charging to achieve system optimality, in terms of efficiency, reliability, etc.

ACKNOWLEDGEMENT

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