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Real-Time Electric Vehicle Smart Charging at Workplaces: A Real-World Case Study

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Background

- Large-scale EV charging is increasing in popularity
- Companies are installing large numbers of EV chargers
  - Require charge scheduling algorithms to maximize benefit of resources
- Present a modifiable real-time smart-charging algorithm
  - Maximize energy delivered
  - Minimize energy costs
  - Uphold infrastructure constraints
- Data available via GISMO group at SLAC + Google

Real-Time Smart Charging Algorithm

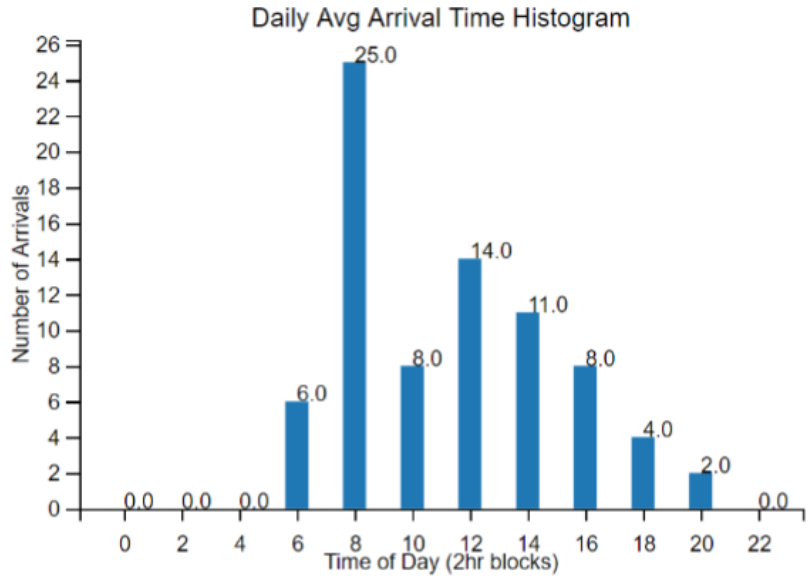
- Departure time scenario generation
- Certainty equivalent future model for EV arrivals
- Convex/concave objective functions
- Coupling constraints

Algorithm 1 REAL-TIME SMART CHARGING

for each day **do**
  Update current parking lot state
  for each 15 minute interval t **do**
    if new departure from parking lot **then**
      Update parking lot state
    end if
    if new arrival to parking lot **then**
      Generate N potential departure times for new arrival
      Update Parking lot state
    end if
    Formulate optimization for time t**:**
    for each EV i plugged in at time t **do**
      Add EV i to total objective function
      Add EV i to active constraints
    end for
    for each future EV j in daily model $t_{model} > t$ **do**
      Add EV j to total objective function
      Add EV j to active constraints
    end for
    Solve optimization for time t
    Store planned energy schedule for each EV i
    Set each EVSE's output power for the current 15 minute interval
    Update peak load $\hat{e}_{old}$ for demand charge calculation (if a new peak load is observed)
  end for
end for

Data

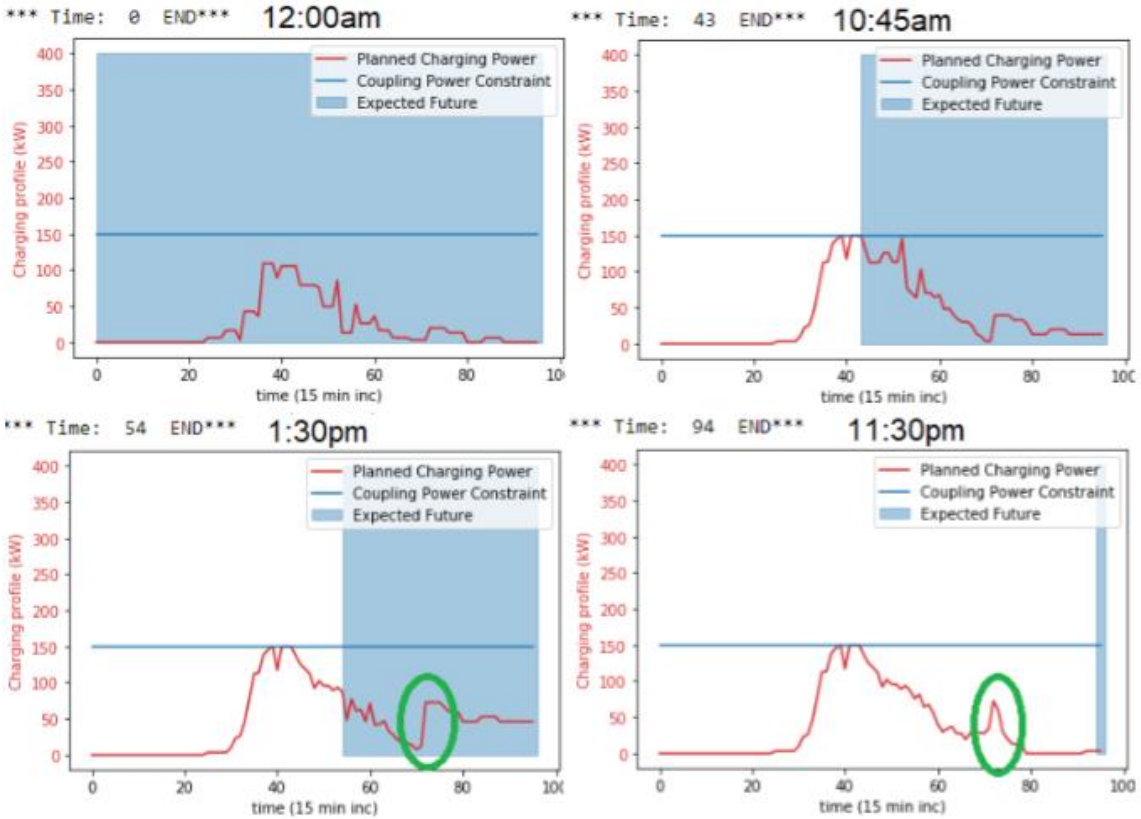
- Access to 5 years of historical ChargePoint charging data at several locations
- Examined 1 month period (June 2019)
- Google campus
  - 57 EV chargers
  - 50-100 EVs arriving per day
  - PG&E E-19 rate structure



Arrival Time Block	Avg Charge Amount (kWh)	Avg Stay Duration
12:00am-2:00am	5.56	4 hrs 38 mins
2:00am-4:00am	4.00	2 hrs 02 mins
4:00am-6:00am	12.91	3 hrs 52 mins
6:00am-8:00am	14.63	5 hrs 29 mins
8:00am-10:00am	15.79	6 hrs 02 mins
10:00am-12:00pm	9.27	6 hrs 02 mins
12:00pm-2:00pm	7.41	11 hrs 15 mins
2:00pm-4:00pm	6.80	16 hrs 06 mins
4:00pm-6:00pm	7.14	16 hrs 27 mins
6:00pm-8:00pm	6.61	23 hrs 19 mins
8:00pm-10:00pm	6.78	25 hrs 54 mins
10:00pm-12:00am	7.74	10 hrs 01 mins

TABLE I
AVERAGE CHARGE AMOUNT (KWH) AND AVERAGE STAY DURATION FOR DIFFERENT ARRIVAL TIME BLOCKS.

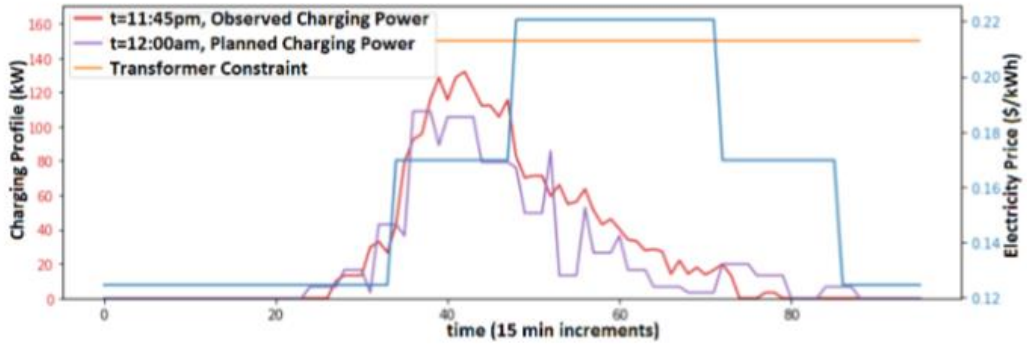
Results



Evolution of location's total charging profile throughout the day

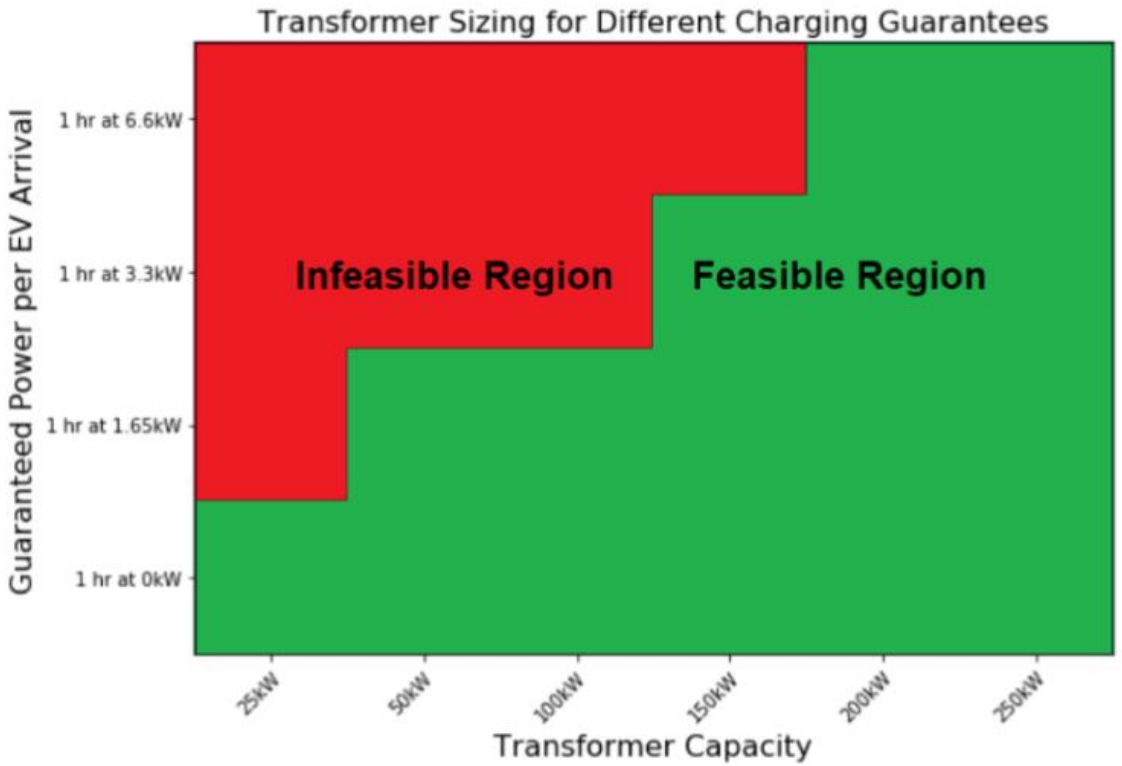
Test #	w_1	w_2	Coupling Constraint (kW)	Energy Delivered	Electricity Purchase Cost	Demand Charge Cost	Forced Initial Charge	Initial Charge Rate
Status Quo	n/a	n/a	n/a	100%	100%	100%	n/a	n/a
01	2	1	250	50.13%	45.78%	64.50%	Yes	$\frac{1}{3}p_{max}$
02	2	1	150	50.01%	45.83%	88.76%	Yes	$\frac{1}{2}p_{max}$
03	2	1	125	50.68%	46.33%	73.96%	Yes	$\frac{1}{3}p_{max}$
04	2	1	110	50.44%	45.94%	65.09%	Yes	$\frac{1}{2}p_{max}$
05	2	1	110	44.20%	36.40%	65.09%	No	n/a
06	2	1	100	45.05%	37.45%	59.17%	No	n/a
07	10	1	100	81.93%	81.36%	59.17%	No	n/a
08	10	1	150	83.85%	81.03%	88.76%	No	n/a
09	10	1	250	84.21%	80.98%	89.94%	No	n/a
10	10	1	100	Infeasible	Infeasible	Infeasible	Yes	$\frac{1}{3}p_{max}$
11	10	1	110	81.76%	81.09%	65.09%	Yes	$\frac{1}{2}p_{max}$
12	10	1	150	83.49%	81.80%	88.76%	Yes	$\frac{1}{2}p_{max}$
13	10	1	150	Infeasible	Infeasible	Infeasible	Yes	p_{max}
13	10	1	250	87.25%	84.81%	97.63%	Yes	p_{max}

TABLE II
RESULTS FOR 13 DIFFERENT TEST CASES.



Comparison of predicted vs actual total charging profile

Results



- Varied local transformer capacity
- Varied initial power delivery to each EV
  - Minimum energy guarantee
- Real-time smart charging algorithm allows for less infrastructure investment

Conclusions

- Companies are installing EV charging infrastructure
- However, benefits of this infrastructure are not maximized unless a smart-charging strategy is implemented
  - Presented a real-time smart charging algorithm
  - Extends the utility of constrained infrastructure
- Future work: Include more realistic utility functions and more revenue, profit, user-utility comparisons