Date: March 21, 2023

Electric Vehicle Fleet Management Progress Report

1 Project Summary

The goal of our project is to create a tool that assists in managing large electric vehicle fleets. Our tool will utilize data from various sources such as past driving patterns, energy usage, building energy profiles, weather and traffic predictions, and use them to make charging and discharging decisions for both individual vehicles and the fleet as a whole.

Our primary deployment product will be a software tool that facilitates multi-objective decision-making for managing electric vehicle fleets alongside building energy management systems. The tool will output charging decisions for each vehicle based on the constraints of the EV fleet and the building. We plan to thoroughly analyze the tool's performance, including total energy usage and fleet size.

2 Project Optimization Problem

As electric vehicles (EVs) become increasingly popular, efficient and effective charging infrastructure management is essential to ensure the smooth operation of EV fleets. The optimization of EV charging is crucial to reduce energy consumption, minimize operating costs, and improve charging infrastructure utilization. The lack of proper charging management often leads to inefficient charging practices, overloading of the power grid, and increased operating costs. There is a need to develop a decision-making tool that can optimize the charging process for EVs, taking into account the EV fleet's needs, the charging infrastructure capacity, and energy consumption. Such a tool could help reduce operating costs, minimize energy usage, and increase the lifespan of EV batteries, contributing to the sustainable development of the transportation industry. Therefore, there is a pressing need for a comprehensive approach to EV charging optimization, which can efficiently manage charging infrastructure while meeting the EV fleet's energy requirements.

3 Literature Review

Pei Huang (2020) and his team have developed an automated coordination mechanism that enables the grid operator to plan a charging strategy for electric vehicles while maintaining grid capacity constraints. The mechanism includes three main components: a central grid agent, an EV agent, and a request queue. The central grid agent manages energy utilization and sends requests to the grid agent to get feedback on available power and price of energy at each time period. The grid agent then sends this information back to the EV agent, which optimizes the charging strategy for the vehicle for the next planning period.

The optimization process considers factors such as trip details, battery capacity, available energy, electricity price, and charger availability to suggest a charging pattern that ensures the vehicle is charged enough to complete its scheduled trips, while also fulfilling battery state-of-charge constraints and minimizing charging costs. Each charging event is recorded with information about the start time, duration, amount of energy charged, location of charging, and power at which the energy was charged. The research focuses on optimizing the charging strategy to balance energy demand during peak hours and reduce the load on the grid.

In 2022, Saleh Aghajan-Eshkevari published a paper that aims to provide a comprehensive review of control structures of electric vehicles (EVs) in charging stations, objectives of EV management in power systems, and optimization methodologies for charge and discharge management of EVs in energy systems. The paper analyzes the goals that can be achieved with efficient charge and discharge management of EVs, which are divided into three groups: network activity, economic, and environmental goals.

The paper highlights that with optimal EV management, the system operator can reduce the number of power purchases from the upstream network during peak periods, integrate a larger number of renewable resources into the grid, and minimize the cost of starting, shutting down, and fueling generators, ultimately reducing costs. The paper emphasizes the importance of EV management in achieving these goals and highlights the various optimization methodologies that can be used for charge and discharge management of EVs in energy systems. Overall, the paper provides a valuable resource for researchers and practitioners interested in optimizing EV management in power systems.

In 2015, Junjie Hu published a paper that provides a review and classification of methods for smart charging, including power to vehicle and vehicle-to-grid charging of electric vehicles for fleet operators. The paper presents three control strategies: centralized control, transactive control, and price control.

Centralized control refers to the fleet operators directly scheduling and controlling the charging of electric vehicles. Transactive control is a market-based control method that aims to reach equilibriums by exchanging information concerning generation, loads, constraints, and responsive assets over dynamic, real-time forecasting periods using economic incentive signals. Transactive control typically requires two-way communication, where information regarding the price and power schedule is exchanged.

Price control, on the other hand, uses one-way communication and broadcasts price signals with a regularly updated frequency to the demand-side resources. The paper emphasizes that each control strategy has its advantages and limitations and that the choice of strategy depends on the specific requirements of the fleet operator.

4 Problem Formulation

4.1 Notations

t: current time slot

N_v: number of the vehicles

$x_v(t)$: power that vehicle v receives during time slot t

c(t): price of electricity in every time slot

L: total power for the entire day and all vehicles

L(t): total power our vehicle charge are charged at time slot t

4.2 Formulation

$$L(t) = \sum_{v=1}^{N_v} x_v(t)$$

$$L = \sum_{t=0}^{T} L(t)$$

$$C = \sum_{t=0}^{T} c(t)L(t)$$

$$Min\ aC^2 + bC$$

5 Project Progress Stages

5.1 Stage 1:

- Divided 24 hours of the day into the 96 time slot which mean every time slot contain 15 minutes
- Infrastructure charging rate is from zero to 2 Kwh
- This optimization done for 5 cars
- We consider the spot price of electricity which from 12 a.m. to 6 a.m. and 12 p.m. to 6 p.m. are the cheap time and the other times are expensive

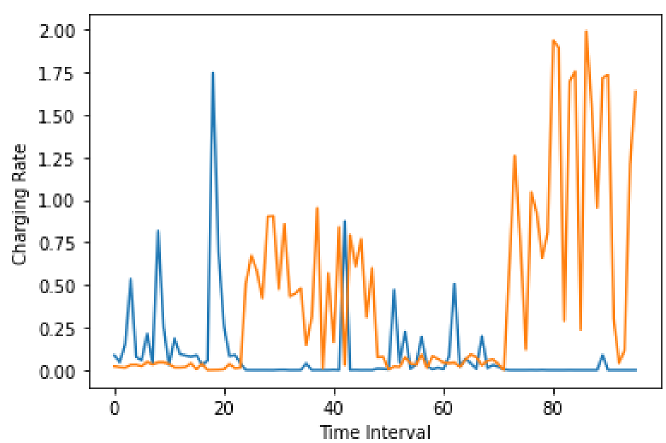


Figure 1

5.2 Stage 2:

- Adjusted constant cost for different times and the prices pick times like the past stage
- Applied optimization for different number of the EVs

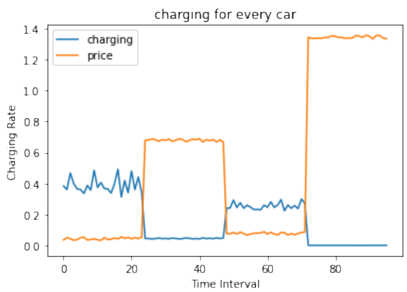


Figure 2: 10 EVs

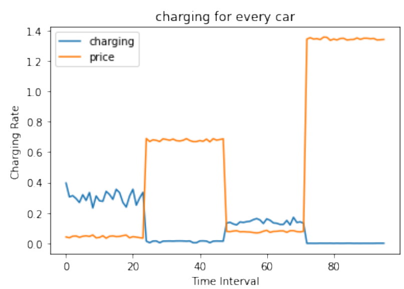


Figure 4: 20 EVs

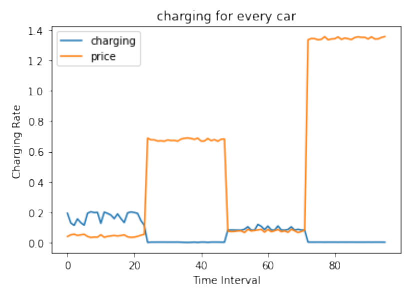


Figure 3: 30 EVs

5.3 Stage 3:

- Limit the charging time duration to 2.5 hours
- Limit the charging need of the cars
- Charging Rate rang is: [0,2]

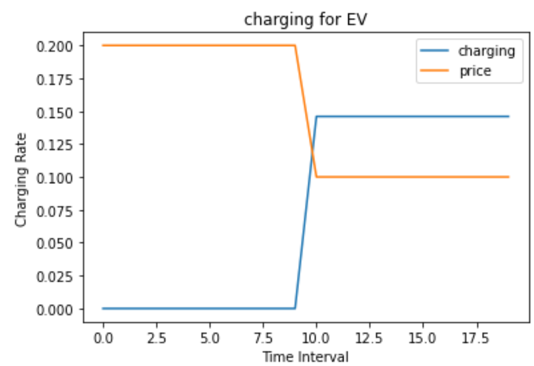


Figure 5

5.4 Stage 4

- Charging during the expensive times because the Electric Vehicle charging need can't cover during the cheap times.

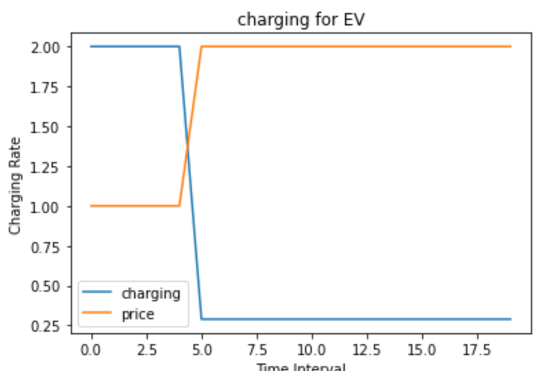
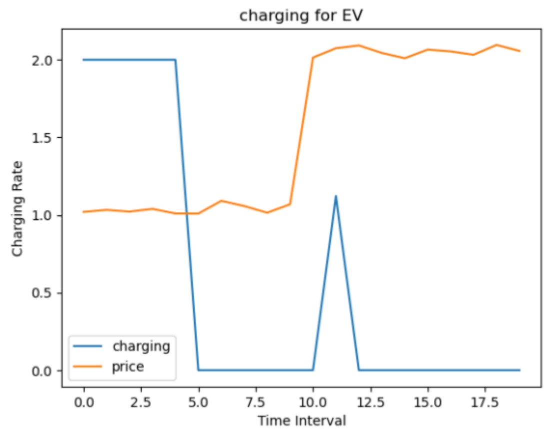


Figure 6

Total Charging = 14.33
Cheap time charging = 1.99
Expensive time charging = 0.28
Cheap time slot = [0,5]
Expensive time slot = [6,20]

5.5 Stage 5

- Consider specific available times to charge the EV during the day



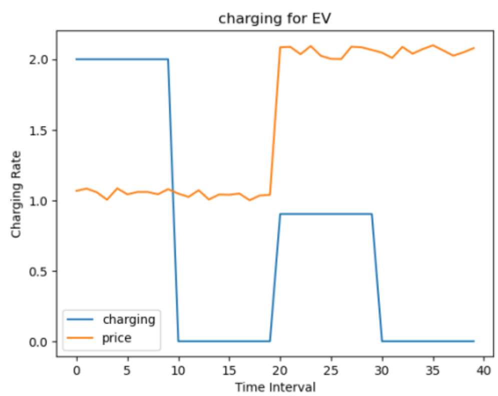
Available to charge: [0 – 5], Price: $1
Unavailable to charge: [5– 10], Price: $1
Available to charge: [10-15], Price: $2
Unavailable to charge: [15-20], Price: $2

EV Power need: 11.12 Kwh
The prices will fluctuate over $1 and $2

Figure 7

5.6 Stage 6

- Change the model and add the future demand as a constraint which means we know the amount of charging in the future
- *2 EVs with Different needs and Unavailable times to charge*



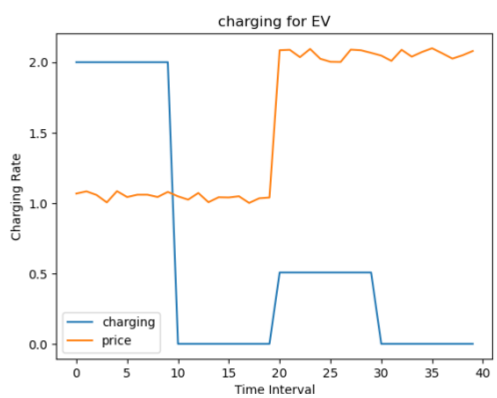
EV 1
Charging Need: 29.02 Kwh
Charing Times

- *Time Slot "0 -10": 1.99 Kwh*
- *Time Slot "20 -30": 0.90 Kwh*

Unavailable time

- *Time slot "10-20" to "20-30"*

Figure 8



EV 2
Charging Need: 25.06 Kwh
Charing Times

- Time Slot "0 -10": 1.99 Kwh
- Time Slot "20 -30": 0.50 Kwh

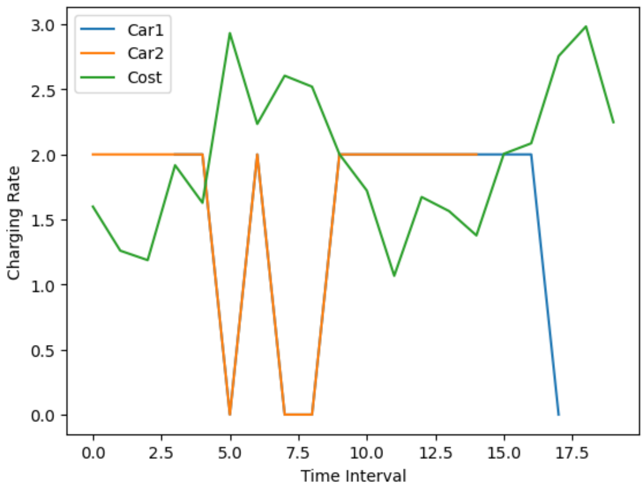
Unavailable time

- Time slot "10-20" to "20-30"

Figure 9

5.7 Stage 7

- Two Cars with random time intervals availability to charge



- Every Car have 15 intervals to charge
- The cost function is constant over time
- The start points are random

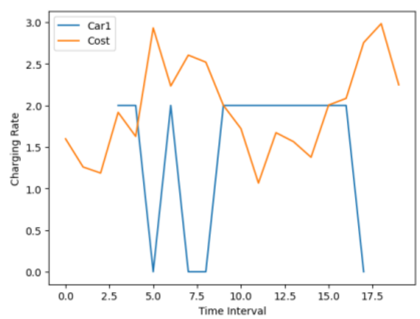
  Car 1 intervals: [3:17]

  Car 2 intervals: [0:14]
- Cost Intervals:

  [0:4], [10:14] = Cheap

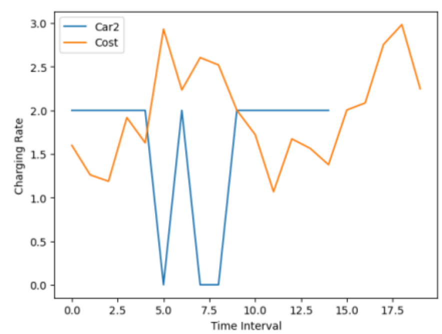
  [5:9], [15:19] = Expensive

Figure 10



2.000000e+00	0	3
2.000000e+00	0	4
3.677068e-11	0	5
2.000000e+00	0	6
6.805341e-11	0	7
9.031899e-11	0	8
2.000000e+00	0	9
2.000000e+00	0	10
2.000000e+00	0	11
2.000000e+00	0	12
2.000000e+00	0	13
2.000000e+00	0	14
2.000000e+00	0	15
2.000000e+00	0	16
4.768341e-11	0	17

Figure 12



charge	car	time
2.000000e+00	1	0
2.000000e+00	1	1
2.000000e+00	1	2
2.000000e+00	1	3
2.000000e+00	1	4
3.916941e-11	1	5
2.000000e+00	1	6
7.254670e-11	1	7
1.017656e-10	1	8
2.000000e+00	1	9
2.000000e+00	1	10
2.000000e+00	1	11
2.000000e+00	1	12
2.000000e+00	1	13
2.000000e+00	1	14

Figure 11

5.8 Stage 8

- Add unavailability cost by noticing to the uniform distribution for the unavailability times

$$\sum_{j=1}^{T} C_j X_j + U_c * 1[\sum_{j=1}^{T} X_j < P]$$

U_c: Unavailability Cost

C: Cost of Charging

X: Decision Variable

P: Energy Needed when the EV is requested

T: Charging Intervals

1: Indicator Function

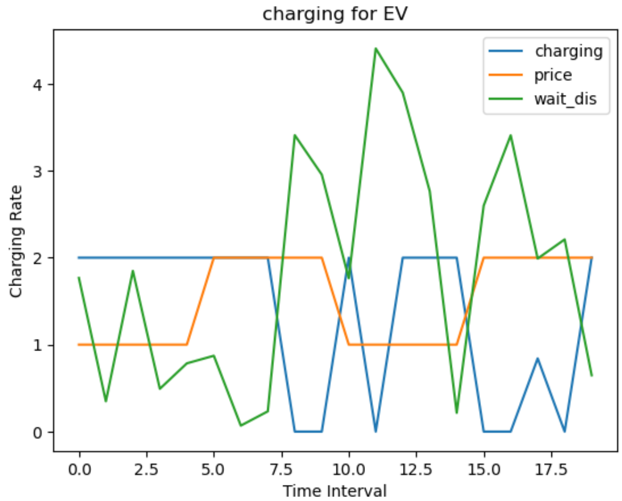


Figure 14: Charge Needs= 26.84

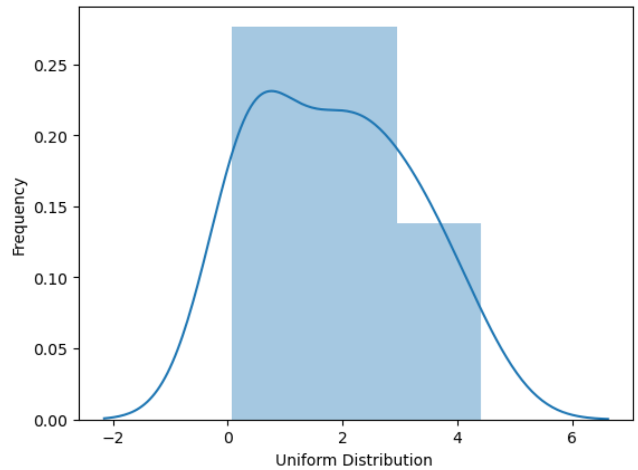


Figure 13