B. Tech Project Report on

Cost Estimation for Electric Vehicles Charging Stations

Capstone Project - 2 (CP303)

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Declaration

We hereby declare that the report entitled ***"Cost Estimation for Electric Vehicles Charging"*** is submitted by us in fulfilment for the B. Tech Final Year Capstone Project - 2 (CP303) in the final year of the B. Tech program at IIT Ropar. The course was coordinated by ***Dr. Devarshi Das***, *Assistant Professor*, Department of Electrical Engineering, IIT Ropar.

The work was carried out by us under the supervision of ***Dr. K. Ramachandra Sekhar***, *Assistant Professor*, Department of Electrical Engineering, IIT Ropar and ***Nikhil****, PhD Scholar,* Department of Electrical Engineering, IIT Ropar.

We further declare that this written submission represents our ideas, and others' ideas or words have been included. We also have adequately cited and referenced the original sources in the case of others' ideas or words. We have not misrepresented any idea/data/fact/source to the best of our knowledge. Therefore, we affirm that our group has adhered to all academic honesty and integrity principles.

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Place: Ropar

Date: 11th May 2023

Contents

1. Problem Definition and Motivation of the Work

1.1. Introduction

Electric Vehicles are a promising technology in the coming times due to their pollution-free nature. Every electric vehicle needs to be charged, and the charging cost is calculated at the time of charging. Currently, there is yet to be a method which can determine/estimate the cost of charging an electric vehicle beforehand. Our team has decided to work on that part.

1.2. Project's Impact / Motivation for Work

- To develop an advanced algorithm that correctly predicts the charging cost in a charging station while considering various factors like the weather, grid power availability and traffic rush.
- To develop a futuristic vehicle charging station that uses ML to predict the charging time, cost and best available option to the user, which helps in minimising the rush at the charging station and maximising the charging efficiency.

The first thing we need to estimate is the power of the solar panels. This further depends on the irradiance and temperature of the area. There is currently no API which gives the current irradiance data. Our first step now was to estimate the irradiance using the weather data. For that, we need to use Machine Learning. The data was taken from openweathermap.com and some private institutes.

After that, we need to use that predicted power output to predict the cost of charging.

2. Technical View of the Project

Most of the technical work of the project deals with the analysis of data, making API calls for getting the weather data and using machine learning to predict the irradiance and output power. For making the **API** calls, we have used the Python library **requests**. For the **ML** models, we have used the **scikit-learn** and **TensorFlow**. For analysing the data and making the **graphs,** we have used the **matplotlib** and the **pandas** library.

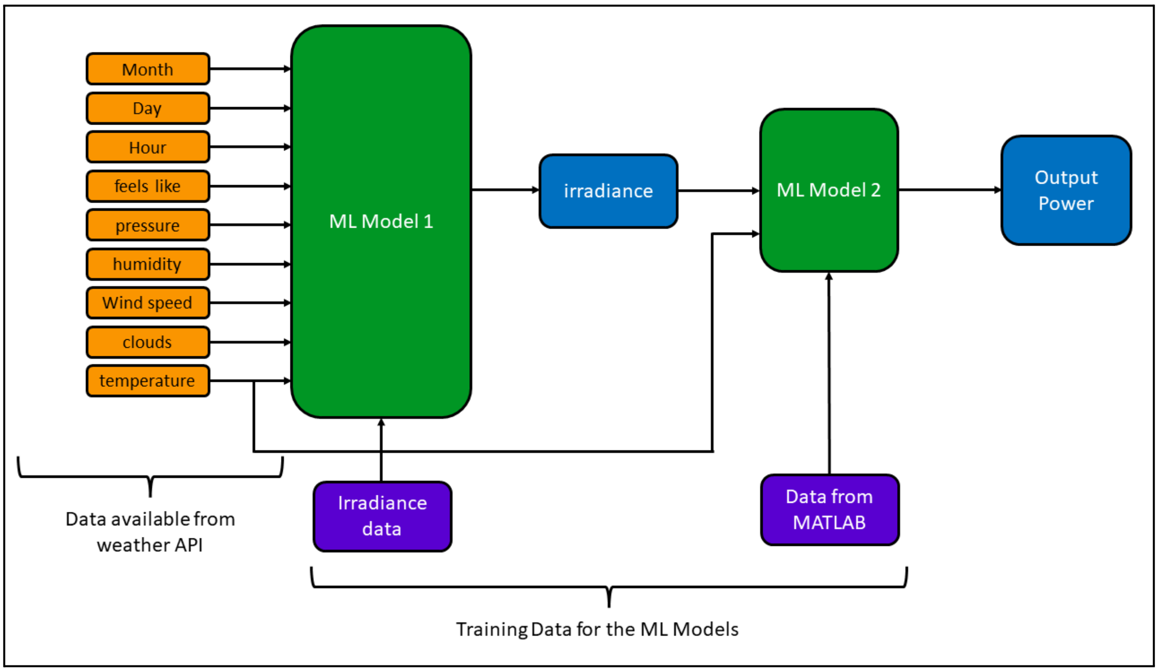


Figure 1: Low-level design of the ML model

- The ML Model1, which is an ExtraTrees Regressor, takes the input from the API call, the weather attributes such as month, hour, pressure, temperature, wind speed, clouds etc., and predicts the irradiance, which is used as an input for ML Model2.
- The ML Model2 uses irradiance and temperature for predicting the output power point which is further used for predicting the final Cost. This is also an ExtraTrees Regressor.

After both of these models, we implemented a cost model to predict the cost.

2.1. Code Flow

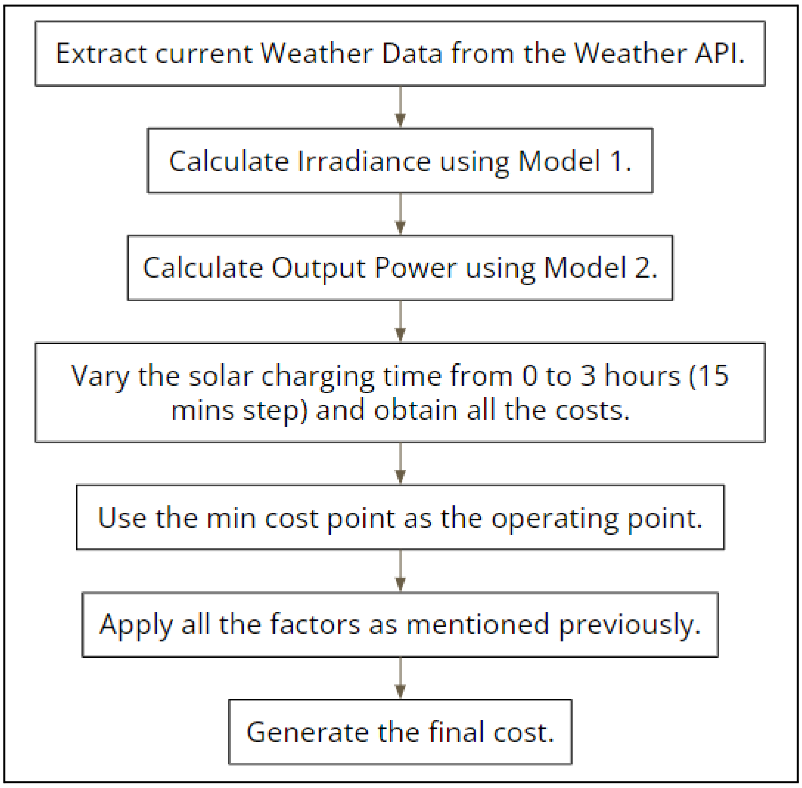


Figure 2: Flow chart of the overall cost estimation model

2.2. Tech Stack

Programming languages used	Python, Matlab
Framework, Libraries used	Tensorflow.js, NLTK, Scikit-Learn, Simulink, Keras, Pandas, Matplotlib, Django, Joblib (for saving model)
Tools Used	Google Colab, Google Sheets

Table 1: Tech Stack Used

3. Background work

The project aims to provide the estimated charging cost for an electrical vehicle. For this, we can divide the project into the following major tasks.

I. Estimating the irradiance from the current weather data.
II. Finding the maximum power point for the solar cell using irradiance and voltage.
III. Estimating the final cost of charging.
IV. Hosting the model as Webpage.

3.1. Prerequisites

- For estimating the irradiance from the weather data, first, we needed the current weather data. For this, we need to make an API request to the weather data app (openweathermap.org).
- Also, for calculating the max power point of the solar panel, we needed the MATLAB data from which we can use the voltage to predict the maximum power it can generate.
- Next, we need to have initial cost information according to current tariff charges for predicting the final cost of solar charging.
- Additionally, we were required to have some basic understanding of EV charging cost variation with respect to various factors like - rush during traffic, profit margin, priority basis and fixed cost etc.

3.2. Research Work

- We researched the working of solar cells, like the different factors that determine the power output of solar cells and the relation of the different parameters, i.e. directly dependent or indirectly dependent. The correlation of different factors with the power output was studied.
- We researched the different ML models applicable to the project. When we made the ML model for estimating the irradiance, we began with the artificial neural networks, and with that, we achieved an accuracy of about 64%. We also tried with a random forest regressor. We finally worked with an extra trees regressor, with which we achieved an accuracy of more than 95%.
- We had also done mathematical analysis and referenced some research articles for the same, to include various factors affecting the EV charging cost. Then, we came up with the relations for overall cost estimation.

4. Completed Work Timeline

<table>
<tr><th>Week Number</th><th>Task</th></tr>
<tr><td>Week 1</td><td>1. Worked and tested the bugs of previous machine learning models.</td></tr>
<tr><td>Week 2</td><td rowspan="2">1. Implemented the cost calculation for the charging station.
2. Integrated the previous ml model with the current cost calculation function.</td></tr>
<tr><td>Week 3</td></tr>
<tr><td>Week 4</td><td rowspan="3">1. After discussing the shortcoming of the current model, We updated the process to calculate the charging cost of an Electric Vehicle.
2. We plotted various graphs associated with the model and analysed the optimal charging time and cost for charging the vehicle.
3. We updated the code to work automatically with the help of API calls.</td></tr>
<tr><td>Week 5</td></tr>
<tr><td>Week 6</td></tr>
<tr><td>Week 7</td><td rowspan="2">1. We analysed the different factors associated with charging our vehicle.
2. We formulated the different factors associated such as rush factors, and pre-booking factors.
3. We tested the effects of these factors on charging time and cost.</td></tr>
<tr><td>Week 8</td></tr>
<tr><td>Week 9</td><td rowspan="2">1. We made a webpage for hosting our website on the internet with the help of Django. (Backend part)
2. Designed the frontend part of our Website.</td></tr>
<tr><td>Week 10</td></tr>
<tr><td>Week 11</td><td rowspan="3">1. We hosted the website on the local server and tested it against various user inputs.
2. We wrote a scientific journal along with IEEE standards to explain the work of our project.
3. We made the final presentation to explain the working of our project and also made a formal report of our project.</td></tr>
<tr><td>Week 12</td></tr>
<tr><td>Week 13</td></tr>
</table>

Table 2: Week-wise details for the work completed

5. Mathematical Interpretation

5.1. Solar Charging Time vs Grid Charging Time

It's important to pick the right time frame for solar energy. We plotted different cost values that were acquired for varied t_solar (time frame for solar energy) in order to observe the variation. This graph is time-dependent.

It is planned and advisable to charge using solar energy for a lengthy period of time in the morning because we anticipate good irradiance for a number of hours. However, we should only use solar energy briefly in the evening.

This leads to a crucial finding about the power output rate to the panel's cost rate. The longer we use it, the more this ratio should be used. We should use the grid when it has a greater power-to-cost ratio (typically, solar power output is lower at night).

The plots for various values of solar charging time are shown in section 6.3 (blue curve), which provides the cost estimation for various battery percentages (the time for which solar panel is used is varied). The x-axis has time in hours, and the y-axis has cost. Date and time: 16:00 11/05/2023. Location: Rupnagar, Punjab, India.

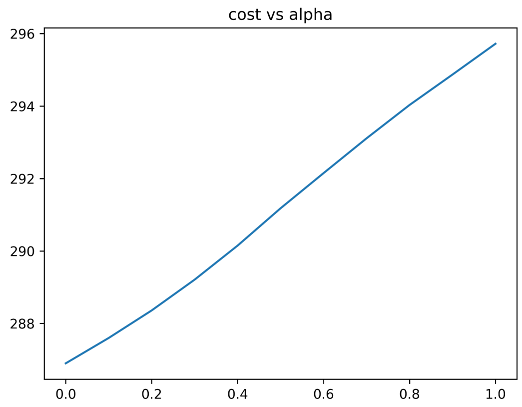
For the optimal cost, we selected the minimum cost point and then used that solar charging time to calculate the solar panel's power output. After that, the remaining energy is charged by the grid.

5.2. Rush Factor

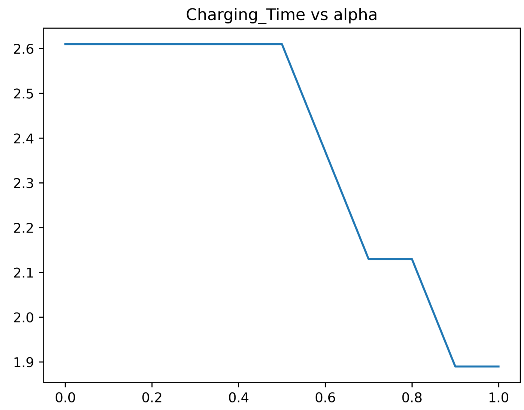
Whenever there is a rush at the charging station, we should charge more for solar energy, as solar charging is slow. To account for this, we have considered a factor α. α varies between 0 and 1 depending on the rush. The solar charging cost is hence increased, and the overall cost and time are recalculated.

$$rate\_solar_{new} = rate\_solar_{old} \times (e^{\alpha})$$

The plot of cost vs alpha is almost linearly increasing. And the plot of charging time vs alpha is decreasing as shown in figure 4.



(a)



(b)

Figure 4: Variation of cost and charging time with respect to α

5.3. Fixed Cost Factor

A charging station must have some fixed cost (like installation fee, etc.). This cost must be divided among all the customers and they should be charged appropriately. Our mathematical model has the below formula:

$$cost_{new} = cost_{old} + \frac{fixed\ \ cost}{number\ \ of\ \ transactions}$$

The number of transactions is the number of customers among which the fixed cost is to be distributed.

5.4. Pre-booking Factor

The charging station may be booked beforehand. If someone books a day before and comes on time, they should be charged less. Depending on the time at which the booking is done, there could be many categories. The mathematical equation is given below:

$$cost_{new} = cost_{old} - \frac{prebooking\ \ category \times prebooking\ \ cost}{max\ \ prebooking\ \ category}$$

5.5. Priority Factor

If someone wants to charge first based on priority, they should be charged more. Similar to the previous factor, there may be categories:

$$cost_{new} = cost_{old} + \frac{priority\ \ rating \times priority\ \ cost}{max\ \ priority\ \ rating}$$

5.6. Profit Factor

The station owner may charge some extra money for profit. This factor is included as follows:

$$cost_{new} = cost_{old} \times (1 + profit\ \ margin)$$

6. Results

6.1. Correlation and Predictions for Irradiance and Power

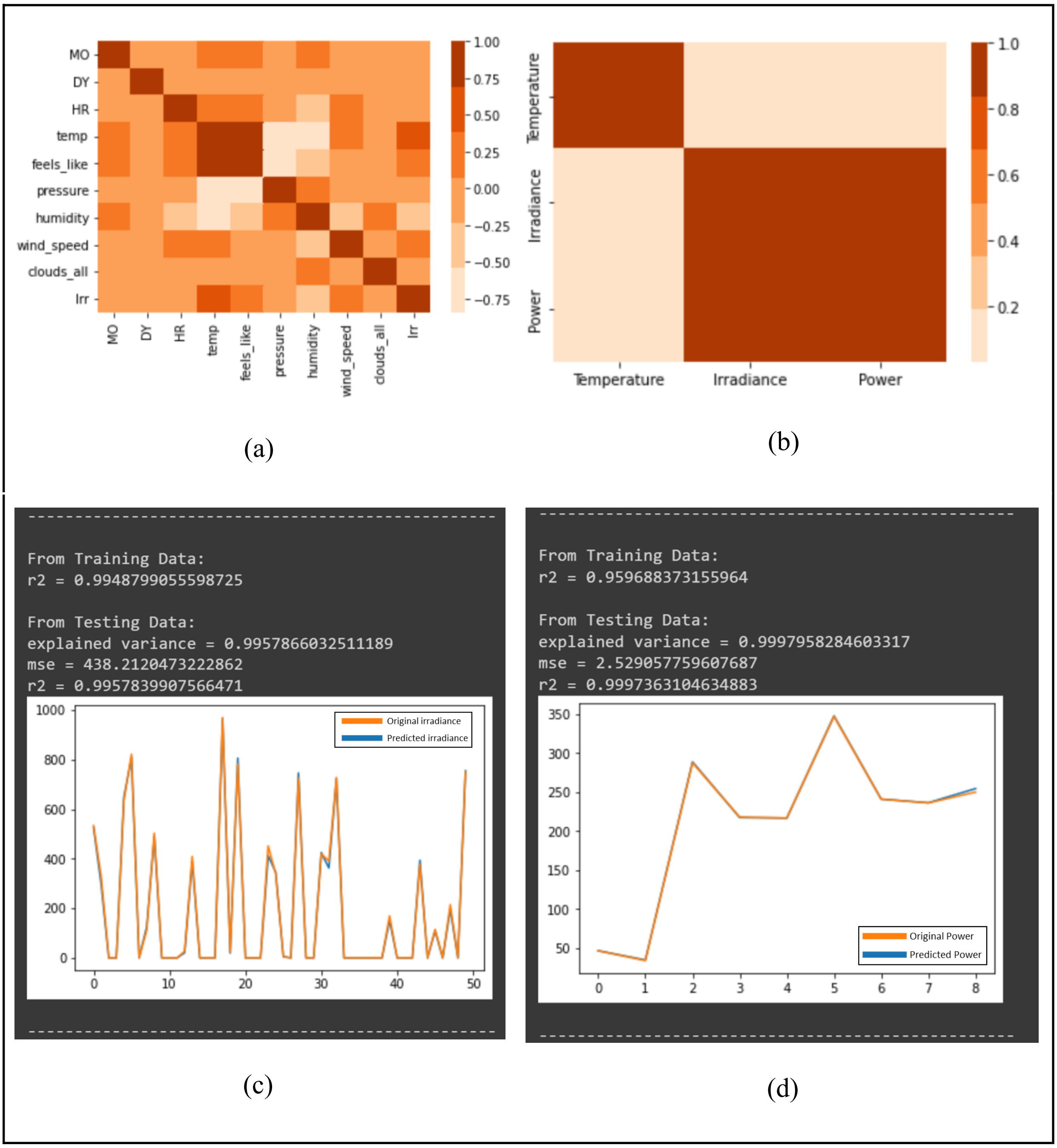


Figure 3: Results from the ML model

The results are shown above. The inferences are as follows:

a) It shows the correlation between the various weather attributes and irradiance. From this, we can observe that irradiance highly depends on temperature and wind speed.
b) It shows the correlation between power, irradiance and temperature.
c) It shows the results obtained by the machine learning model on the test data. From it we can observe that there is very high accuracy in the irradiance prediction.

d) It shows the results obtained by the machine learning model on MATLAB data. From it, we can observe that there is high accuracy in predicting output power.

6.2. EV Charging Predictions Including Various Factors

The cost of electric vehicle charging was predicted considering the factors mentioned above. The results shown below are for 11/05/2023, at time 16:00, at the location Rupnagar, Punjab.

```
latitude = 30.9688367
longitude = 76.526088
Successfully fetched the data from the API.
Month: 5.0
Day: 11.0
hour: 2.0
Temperature: 298.02
Feels_Like: 297.08
Pressure: 1005.0
Humidity: 20.0
Wind Speed: 2.31
Clouds: 0.0
alpha = 0.4
prebooking_category = 2
priority_rating = 2
base cost = 234.11
solar charging time = 1.25
total_charging_time = 2.4
cost after rush factor = 236.2
solar charging time = 1.0
total charging time = 2.15
cost after fixed cost factor = 256.2
cost after prebooking factor = 236.2
cost after priority factor = 268.2
cost after profit factor = 295.02
FINAL COST = 295.02
SOLAR CHARGING TIME = 1.0
TOTAL CHARGING TIME = 2.15
```

6.3. Plots of Solar Charging Cost vs Solar Charging Time

The plots for various values of solar charging time are shown below, which provide the cost estimation for various battery percentages (the time for which solar panel is used is varied). The x-axis has time in hours, and the y-axis has cost. Date and time: 16:00 11/05/2023. Location: Rupnagar, Punjab, India.

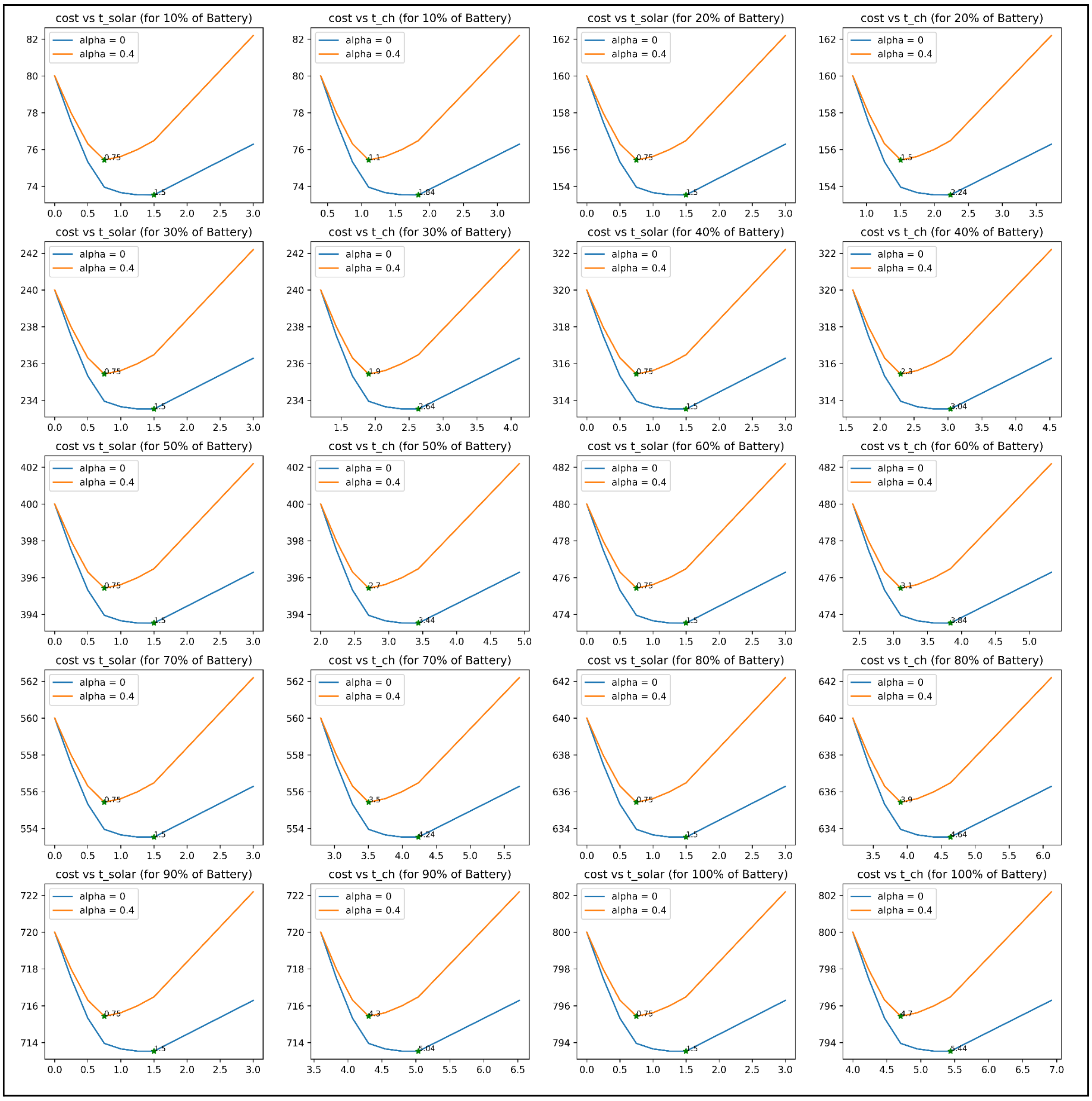


Figure 5: The variation of charging cost with respect to charging time

6.4. Results obtained on Webpage after user input

Figure 6: The final webpage which calculates the optimal charging cost according to the user specifications

7. Future Scope

- Our current machine learning model for predicting the irradiance is trained on the data for a single region. Thus it may have errors in predicting the irradiance for some other regions.
- This error can be diminished by training the model with two new features (longitude and latitude of the region)
- The urban areas can be classified into - residential, commercial and public. The cost of EV charging is different for rural and urban areas. These factors can be considered in future research and implementation.
- Also, if we have the traffic data for a charging station, we can automate the alpha (rush factor) prediction according to the traffic.
- We can also show the user different charging prices according to the time specified by the user in the application environment.
- Adding features to the app, e.g., showing vehicle category according to the parking area, total expense till date, nearest charging station, etc.

8. References

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