NEW YORK CITY BUS CHARGING STRATEGY

Columbia University
Erica Diaz
Spring 2021

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1 Overview

An electric bus charging simulation was created to gain insight into how New York City could potentially switch to a fleet of electric buses. The original overview of the simulation's functionality is outlined in the Electric Bus Simulator Project document written by Luiz do Valle. That simulation was expanded upon to improve the platform's capabilities with respect to its bus charging capabilities, charging logic, and user interface as outlined in in this document.

2 NYC Hosting Capacity

Originally, the simulation intended for all New York City buses to be charged at the Michael J Quill Bus depot in Midtown. To meaningfully interpret results for whether the simulation's bus charging output was actually possible within the constraints of New York City's electricity hosting capabilities, a graph of data ConEdison's website was created based on their stated hosting capacity and expected usage of electricity for each hour of the day as shown in Figure 1. Future data collected from the simulation was then compared to the hosting capacity demand curve for the Midtown West network to see whether the location of the current bus depot could successfully meet the load required to charge all of New York City's buses.

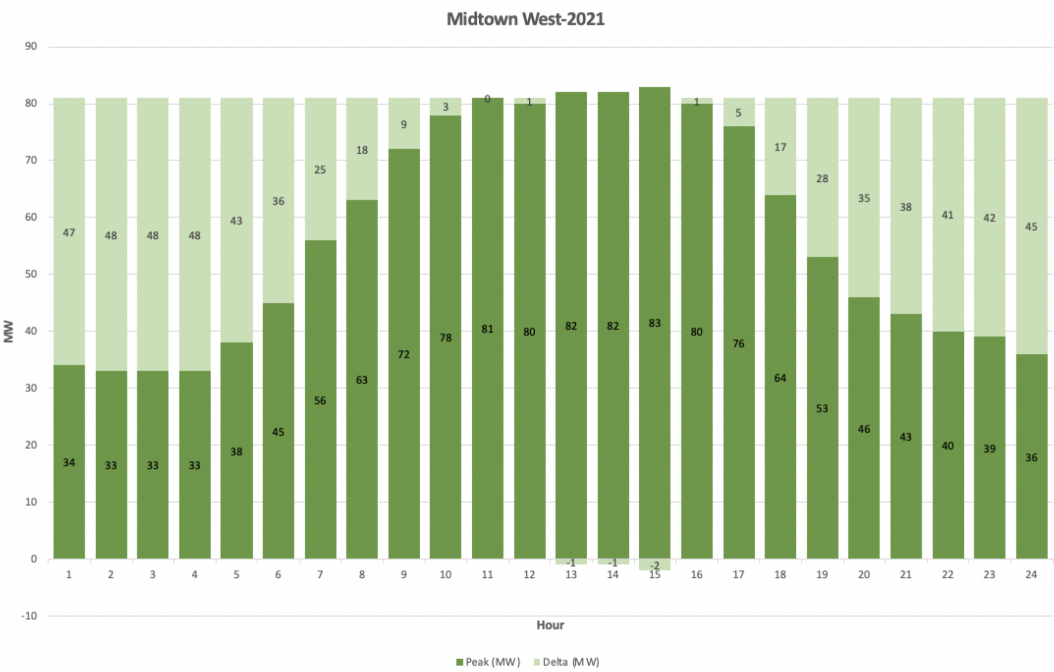

Figure 1: Hosting Capacity Midtown West Network

At the time of creating this demand profile, predictive demand data for 2021 already surpassed the hosting capacity for hours 13-15 as shown in Figure 1. For this reason, it is likely ConEdison has already increased the hosting capacity in this region and updated data could be used to create a more accurate load profile.

A Increasing Number of Chargers

When more buses are added to the simulation as discussed in the Electric Bus Simulator Project document, the number of chargers also needs to be increased. This can be done in the Initialize Stop Network section of the simulation. Here, any number of chargers can be set. However, to accurately collect the data in the CSV files, the Simulation class must also be updated to add columns for each new charging queue and charger number.

B Charging Rate Range

The charging logic for the simulation was built out to better represent how an actual bus route should be run. Originally, each bus would start at 100% charge and die until it could not make it to the next stop without charging. Then, the bus would move to the depot and charge only until it could reach the next stop. This caused buses to continuously move very little distance and return to the depot repeatedly. This charging logic was expanded upon to better represent how a route could be run. The logic now allows the buses to charge up to 90% and will not allow a bus return to the bus depot to charge unless it is below 50% charge or cannot make it to the next stop on at its current charge level. To update the top of this range, the charge_all_buses function in the Stop class must be updated from .9 to an alternative value. To update the lower end of the range, the can_reach_next_stop function in the Bus class must be changed.

C Charger Quantity Required

Once the charge range was updated, it was possible to load the simulation with 300 buses and find the quantity of chargers needed to match that load. As shown in Figures 2 through 4, Multiple charger quantities were experimented with. These figures show 3 buses to represent the full 300 buses. At approximately 12 chargers, buses no longer had to wait an extremely long time in the charging queue. As shown in Figure 4, there was still a long wait in the beginning of the charging simulation. This is likely due to the fact that all 300 of the buses started at exactly the same charge level and they also died at the same rate as well so they ended up needed to charge at the exact same time. However, after running the simulation over 10 days, it was clear that initial rush of charger use would become much more evenly spread over the course of the day due to differences in bus route length and location.

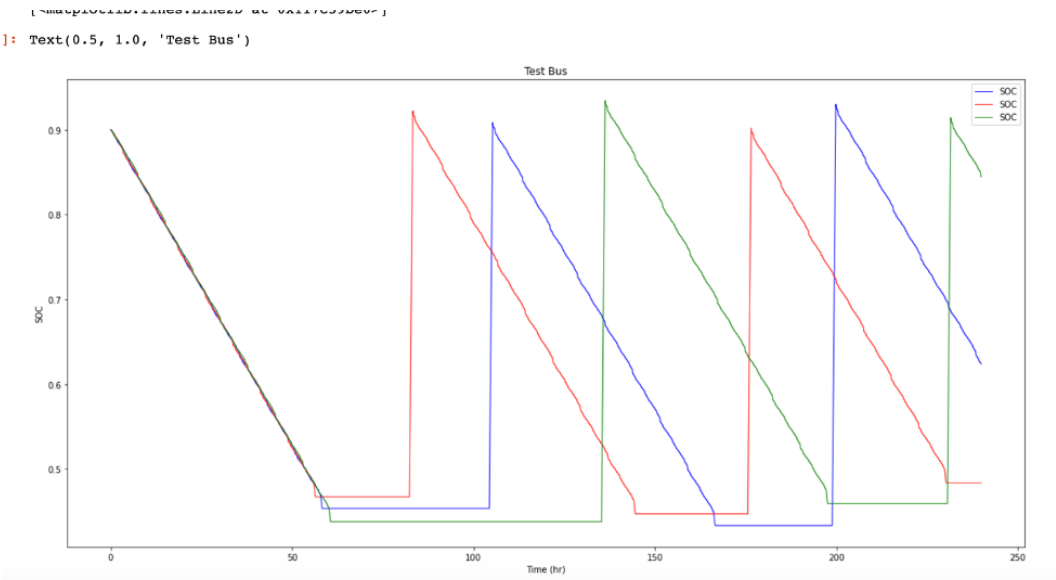

Figure 2: 3 Chargers: State of Charge over time for 3 sample buses

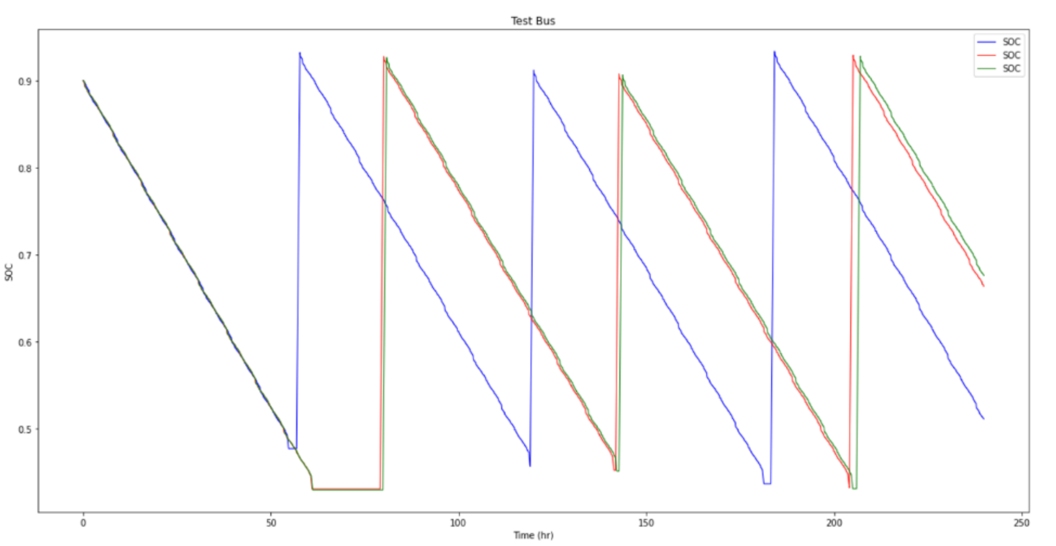

Figure 3: 10 Chargers: State of Charge over time for 3 sample buses

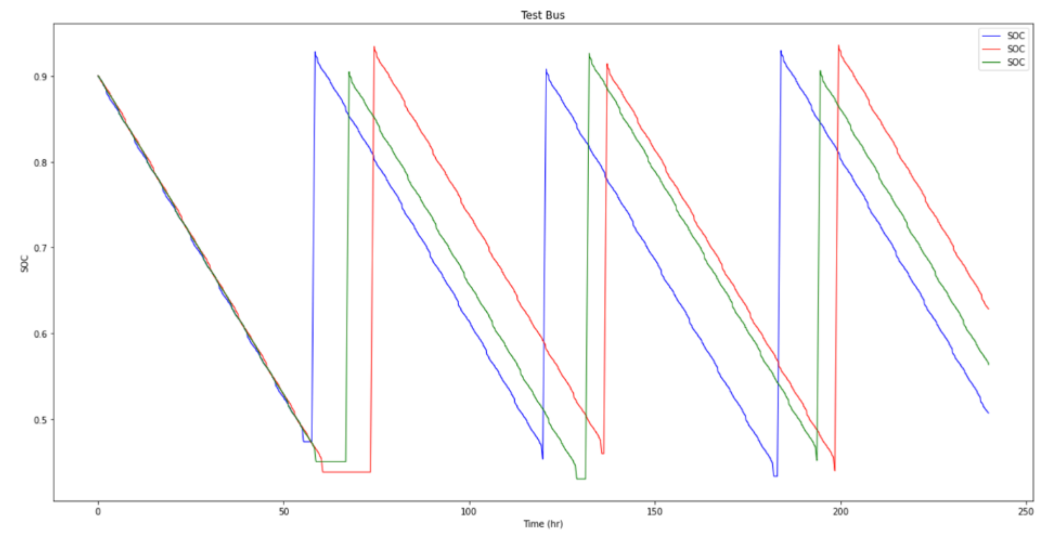

Figure 4: 12 Chargers: State of Charge over time for 3 sample buses

After 12 chargers was decided on as necessary to match a load of 300 buses, that charger quantity could then be compared with the New York City hosting capacity. Working under the assumption that all 12 chargers would always be in use, it was found that .84MW would be needed to keep all the chargers functioning at a charge rate of 70kWh. That .84MW per hour was then added to the current demand for the Midtown West hosting capacity as shown in Figure 5. It is clear from the graph that in hours 11 and 13-15, the Midtown West network cannot meet the demand necessary to operate the chargers. However, as stated earlier, the ConEdison data was predictive for 2021, so it is likely more transformers have been added to the area already. Additionally, more chargers could be added and charging logic could be altered so buses charge more frequently and to a higher capacity at night than during the day. This would spread the charging load into hours where there is much more hosting capacity available.

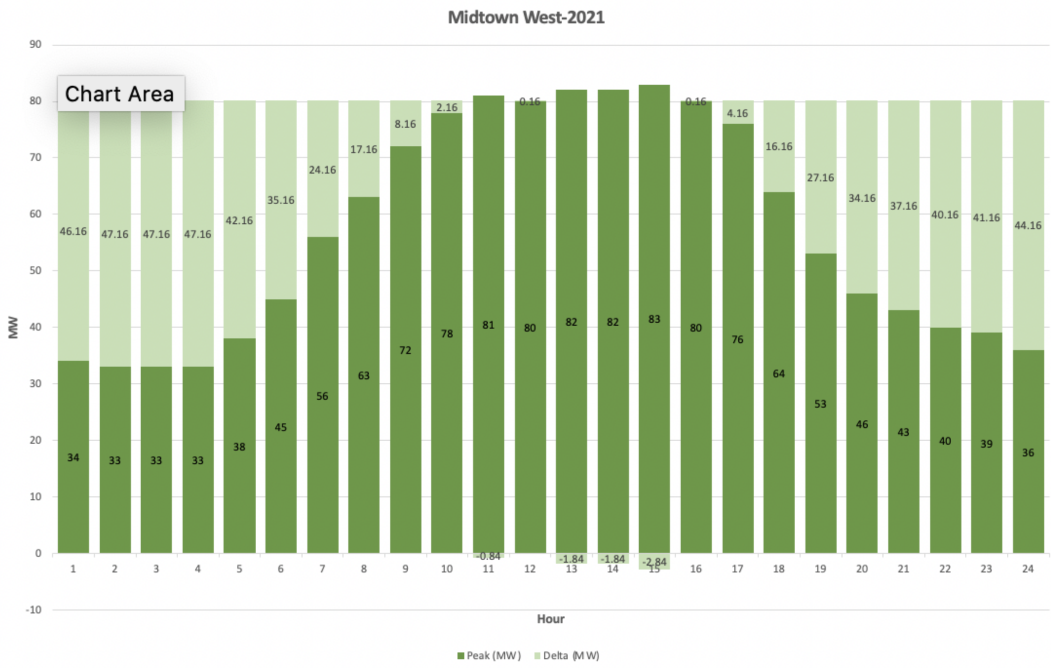

Figure 5: NYC Hosting Capacity with load of 12 Chargers

D Charging Rate Logic Expansion

The next addition to expand the charging logic was to change how the charge rate for each charger is assigned. The charging rate used to be a hardcoded value that was consistent no matter how many chargers were in use. This logic was altered so that there was a set maximum charge capacity that would then be divided by the quantity of chargers currently in use. At each timestep, the quantity of chargers in use is found and the charging rate for each charger is then set by dividing the maximum charging capacity by the number of chargers.

This goal was accomplished by initializing a new variable called charging_capacity. In the Initialize Stop Network section of the simulation, the charging_capacity variable can be updated so that in the Stop class, that charging capacity will be divided by the number of chargers in use. Then, that charging rate will be assigned to each charging station. This logic is shown in Figure 6 as throughout the hours of the day, each chargers is seen with difference charging rates.

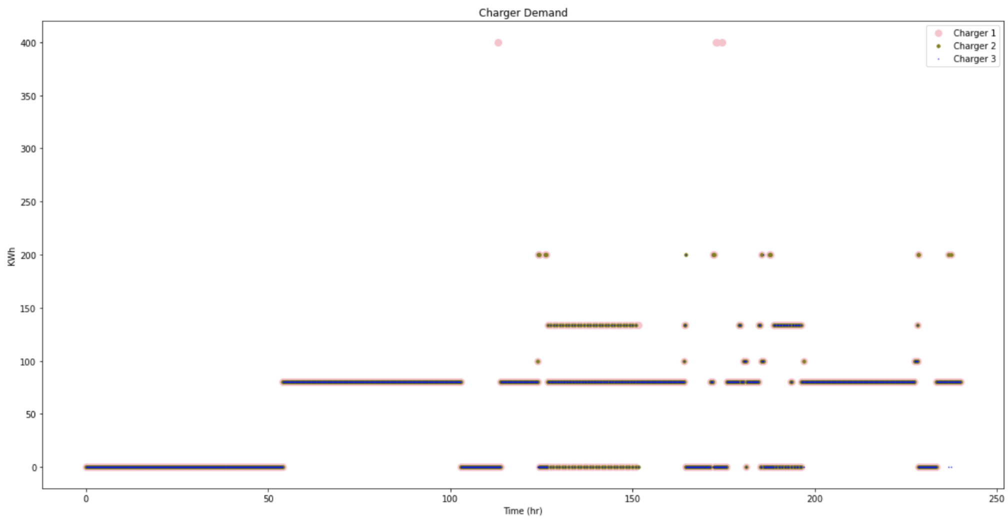

Figure 6: Charger rate for 3 chargers over 10 days

E Adding Chargers to New Stations

The charging logic does not allow for chargers to be added at any bus station along the route, so to add chargers, a new bus depot must be created. The CSV file for the route M14D-SBS_stop_graph was updated to add a new depot half a kilometer away from Chelsea Pier. New depots like this one can be used to simulate what New York City will need to do in the situation where enough buses are switched to electric vehicles that they overwhelm the Manhattan West hosting capacity. After updating the route CSV file, the Initialize Stop Network section needs to be updated to add a new depot stop, add chargers, and set a charging capacity. It is important to understand the edge method described in the Electric Bus Simulator Project document before updating the CSV file. The depot must be located off one stop on the route and then the bus must return to that stop after it finishes charging.

Additionally, if only one depot is being used, the second depot must be removed from both the CSV file and the Initialize Stop Network section of the code.

F Visualization

A new visualization system was also created for users. The Visualization simulation shows a map of New York City with the route's buses plotted at their current location. When a bus is hovered over, information about the bus stating its current latitude and longitude are shown. The bus ID and SOC are also displayed at the top of each point representing a bus. Additionally, there is a sliding bar at the bottom of the map that allows users to move through time and visualize the buses moving along their routes and losing charge as they go. The longitude and latitude coordinates of 9000 bus stops in greater New York area are also recorded in the CSV files.

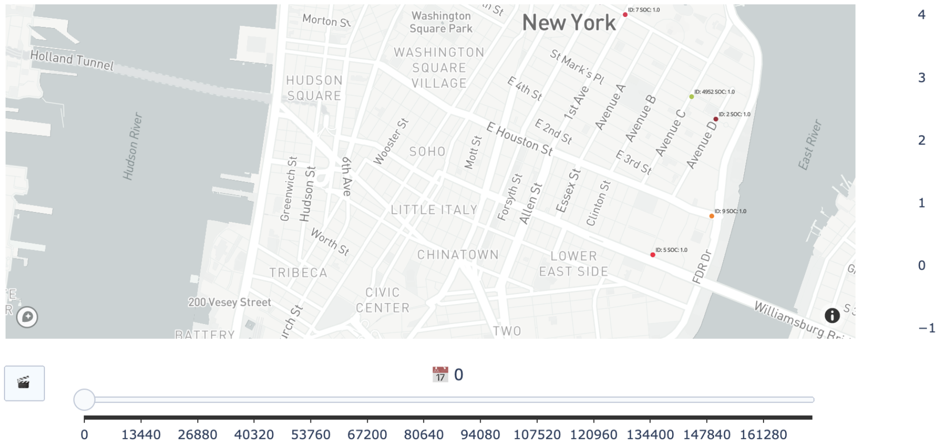

Figure 7: Visualization Simulation