Smart City: Managing Electric Vehicle Demand in Smart Grids

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Background

Efficient management of electrical power distribution is essential to support the increasing number of Electric Vehicles (EVs). Properly assigning customers to feeders can result in **significant cost savings** and **enhanced service reliability.** The significance of this project is highlighted by:

- The **growing number of EVs** necessitating **efficient power distribution**.
- EVs' contribution to **reducing carbon emissions**.
- The increasing demand for **reliable charging infrastructure**.

This project aimed to develop and test algorithms to provide optimal or near-optimal solutions for feeder assignments. The solution is crucial for multiple stakeholders by:

- Ensuring **cost-effective** power distribution.
- Enhancing **service reliability and customer satisfaction**.
- Improving **operational efficiency** for utility providers.

Various algorithms were explored to achieve an optimal assignment, considering constraints related to feeder capacity and customer demand.

Project Goal

The primary objective was to efficiently **match EV customers to electric feeders** in San Antonio, ensuring each feeder **meets the demand** of assigned customers while **minimizing the total distance** between customers and feeders. The constraints considered were:

- One feeder per customer.
- Multiple customers per feeder.
- Customer demand must be met by a single feeder.
- Feeders must have the capacity to serve the assigned customers.

Datasets

We worked on 3 datasets:

- **Customers**: containing customers and their **demand,** in kWh, for a given period.
- **Feeders**: containing feeders and the **capacity**, in mWh, they can supply in a given period.
- **Customer-Feeder distance**: the distance in mile between every possible customer-feeder pair.

Methods

We tested several algorithms for matching customers to feeders:

1. **Linear Programming:** Optimizes the assignment by solving a set of linear equations.
2. **Random Assignment:** Randomly assigns customers to feeders.
3. **Greedy Algorithms:**
   - Greedy by Demand: Prioritizes customers with higher demand.
   - Greedy by Capacity: Prioritizes feeders with higher capacity.
   - Greedy by Distance: Prioritizes customers and feeders based on proximity.
   - Randomizing Order of Customers and Feeders: Introduces randomness in the order of processing.

Each algorithm was evaluated based on its ability to meet the customer demand and minimize the total distance between customers and feeders.

Results

Method	Total distance (meters)
Linear programming	144.5465
Greedy by distance	144.5687
Greedy by demand and distance	144.5687
Greedy by capacity	144.5687
Greedy with randomness by customer	144.5465
Greedy with randomness by feeder	144.5465
Fully random (mean over 1000 iterations)	4565.0667

Table 1. Comparative table of the results for each method analyzed.

- **Linear Programming and Greedy Algorithms:** Achieved a total distance of 144.56 miles.
- **Random Assignment:** Had a mean value of 4,565.06 miles over 1,000 iterations..

The results showed that all tested algorithms, except for random assignment, performed similarly and effectively minimized the total distance to 144.56 miles.

Conclusions and future work

Conclusions:

- The results indicate that **linear programming and greedy algorithms show similar performance** in optimizing the assignment of EV customers to feeders.
- **Random assignment, proved to be significantly less efficient**, emphasizing the importance of strategic approaches.
- Since the problem can be stated as a Linear Programming one, then the solutions found are optimal within the feasible region and therefore it makes sense that the solution found by other matching algorithms coincided with Linear Programming.
- **Randomized greedy algorithms** have a very small **edge over the other** methods, however are **much more costly** in both time and computer resources.

Future Work

- Exploring machine learning techniques to predict demand patterns and improve assignment efficiency.
- Extending the model to include additional constraints, such as feeder maintenance schedules and customer priority levels.

References

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