Smart Charging Station Operations in the Era of Vehicle-to-grid (V2G) Bidirectional Charging

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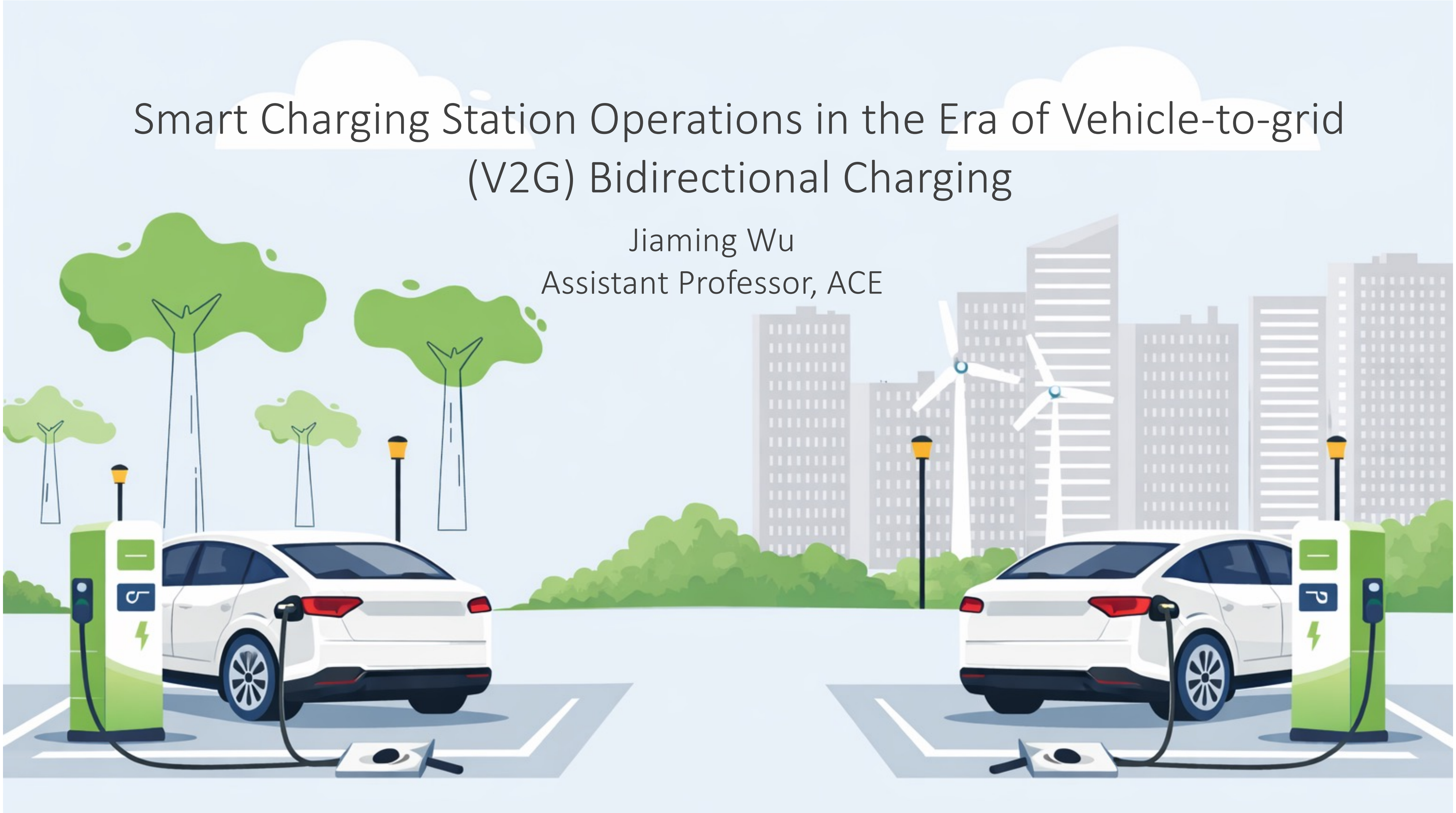


Motivation

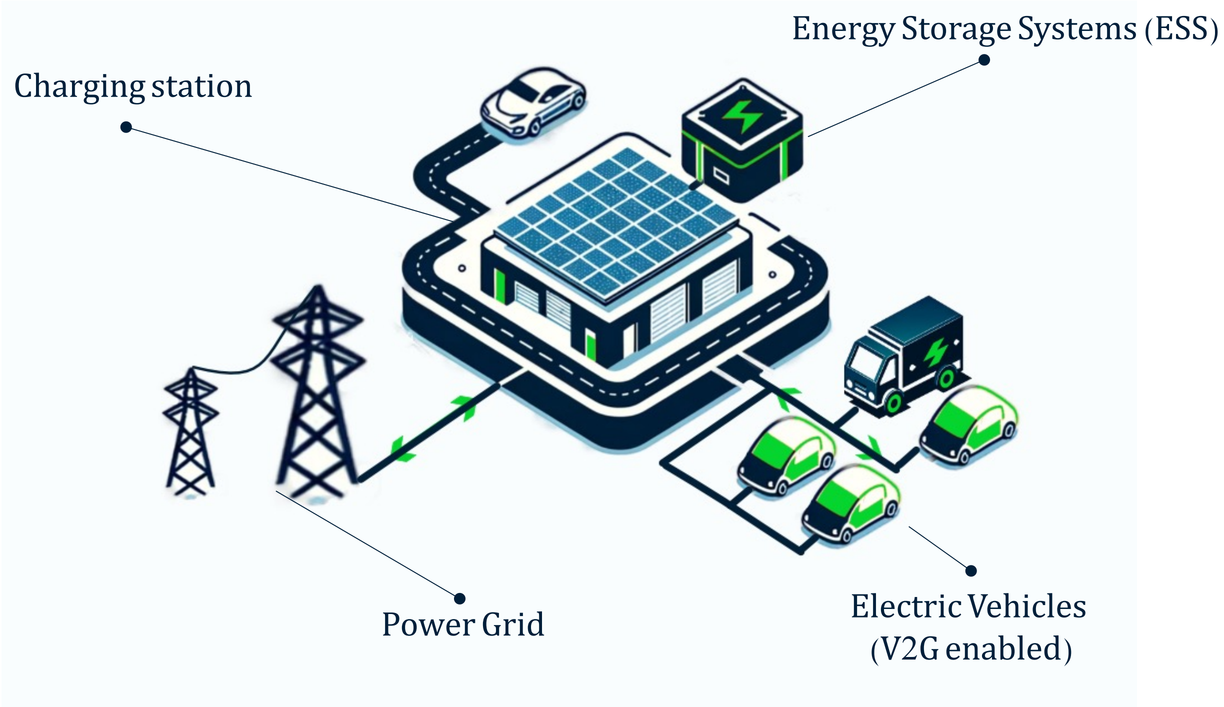
- In 2024, 17+ million EVs were sold worldwide, pushing the electrified share of new car sales above 20%.
- Between 2022 and 2024, the global stock of public chargers doubled to more than 5 million units.

- Key challenges remain, e.g., phasing out subsidies, rising charging prices, grid bottlenecks, etc.
- Bidirectional charging technology emerges as a promising solution for the above problems.

The general idea

In this project, we focus on public charging stations, which are a nontrivial part of the growing charging infrastructure.

- Easier to implement
- More profound incentives
- ESS further amplifies the benefits



We presume:

- Know electricity prices
- Centralized controller

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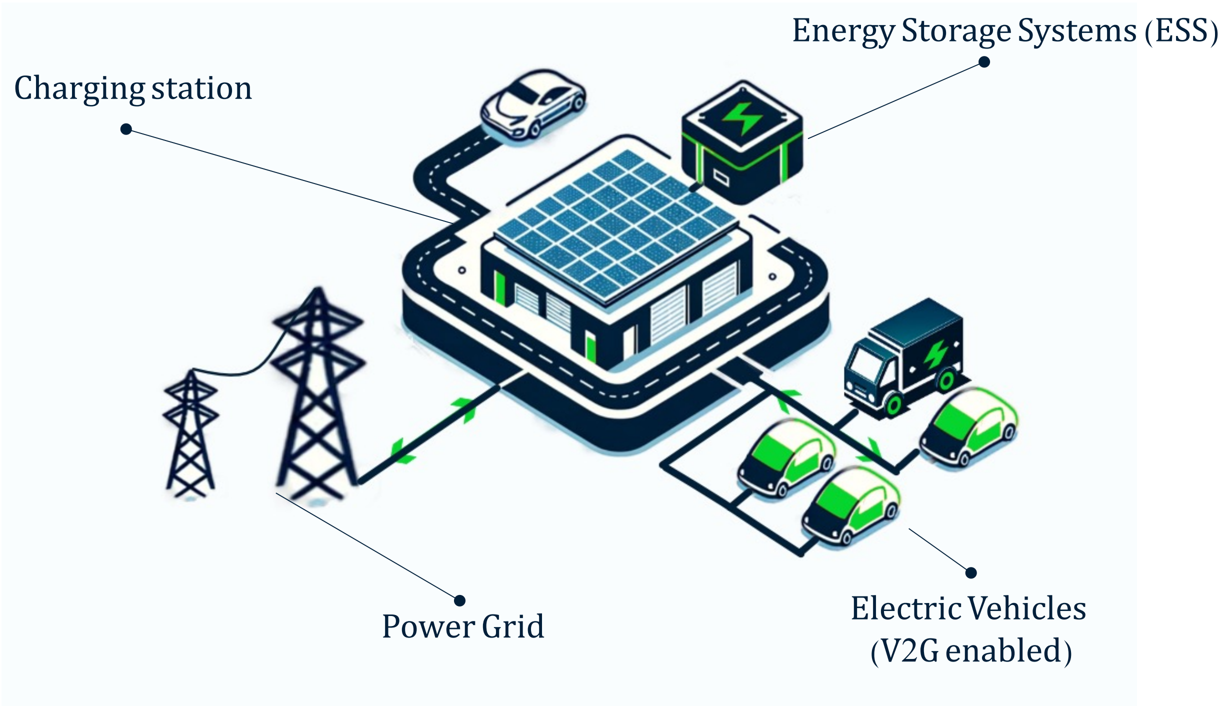


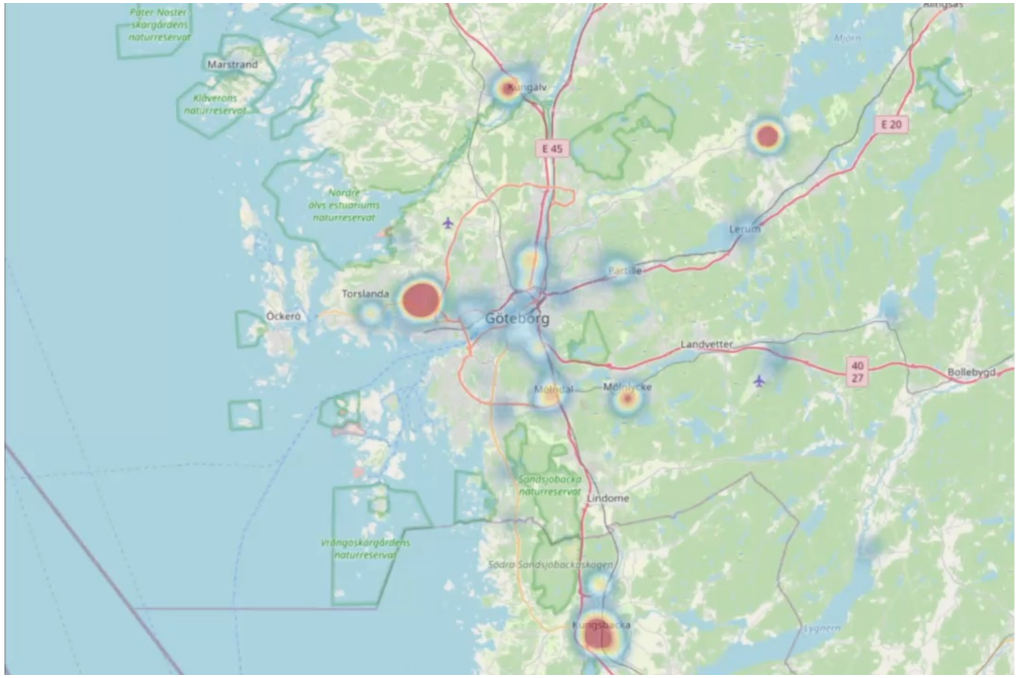
We completed two tasks:

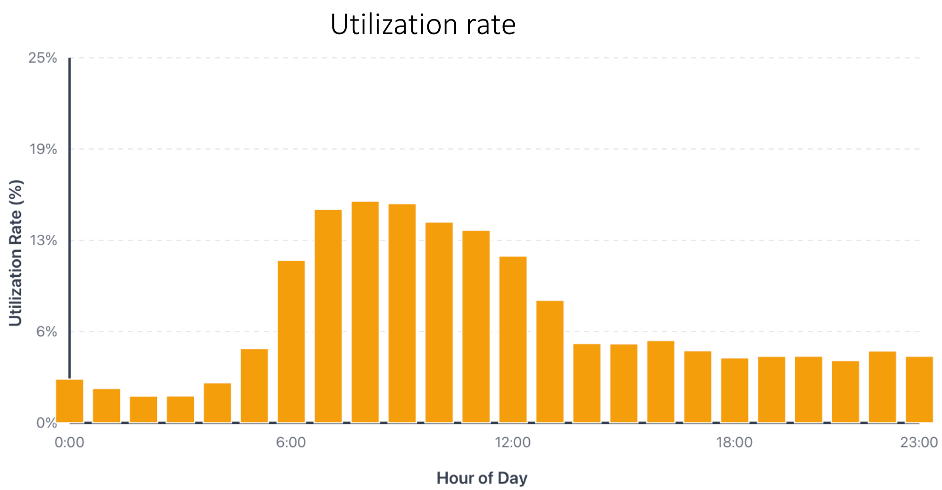
- Based the research on real data
- Developed optimization models

The charging station dataset

The dataset includes most public charging stations in major cities in Sweden, including

- The static distribution of charging stations;
- Where, when, and how much EVs are charged.





Summary for 2025-09-12

A deterministic charging scheduling model

In this model, we aim to maximize the profits of one charging station during a time period.

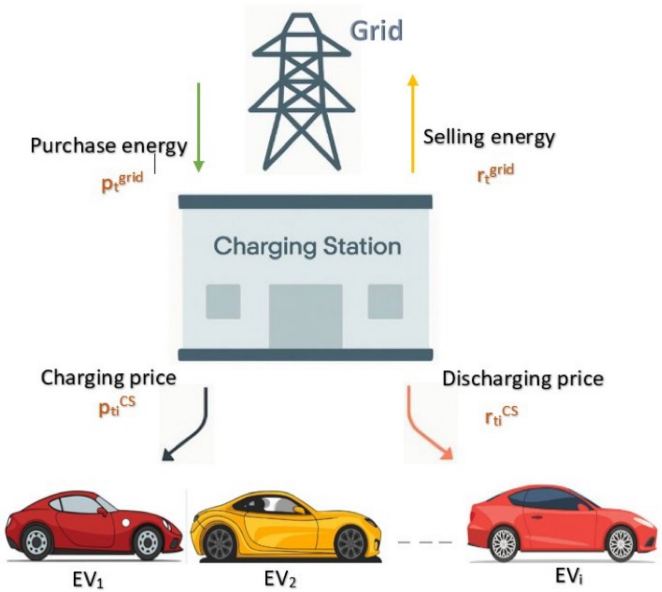
We further presume that the following information is known.

- The number of EVs that will charge at the studied charging station,
- The initial SOC and arrival time of each EV,
- The desired SOC.

The objective function:

$$\max \sum_{i \in I} \sum_{j \in J} \sum_{t=a_i}^{d_i} \left[(p_{t,i}^{\text{CS}} - p_t^{\text{grid}}) \cdot z_{t,i,j}^c \cdot \delta_i^c + (r_t^{\text{grid}} - r_{t,i}^{\text{CS}}) \cdot z_{t,i,j}^d \cdot \delta_i^d \right]$$

Charging profits   Discharging profits



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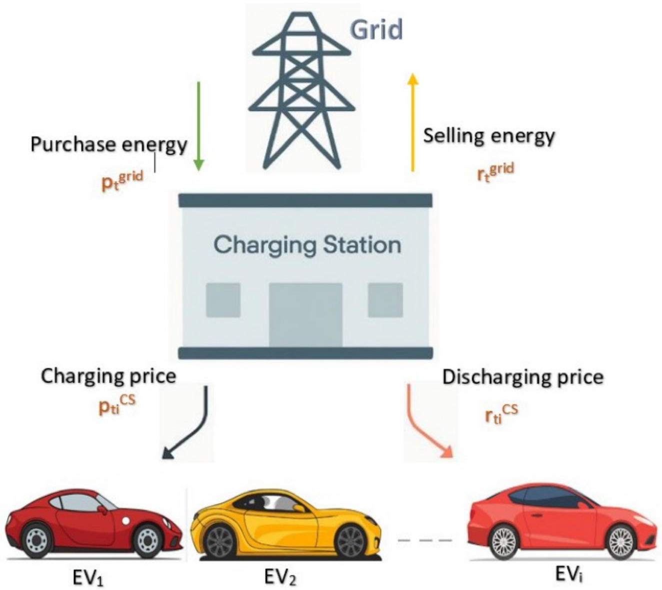
Charging profits — Discharging profits

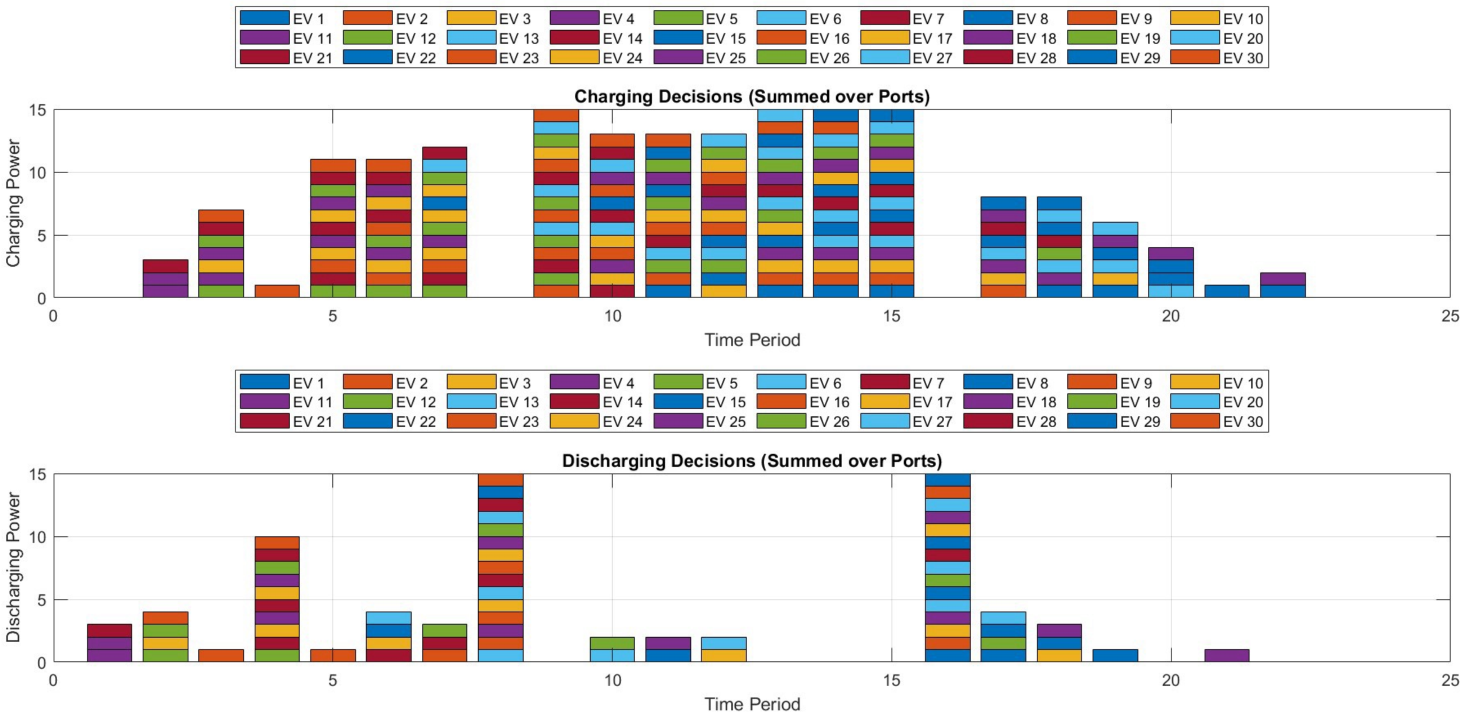


Constraints:

- SOC dynamics (e.g., min and max SOC)
- Charging port capacity
- Charging/discharging exclusiveness.

A deterministic charging scheduling model

A high demand scenario (more EVs than charging ports)



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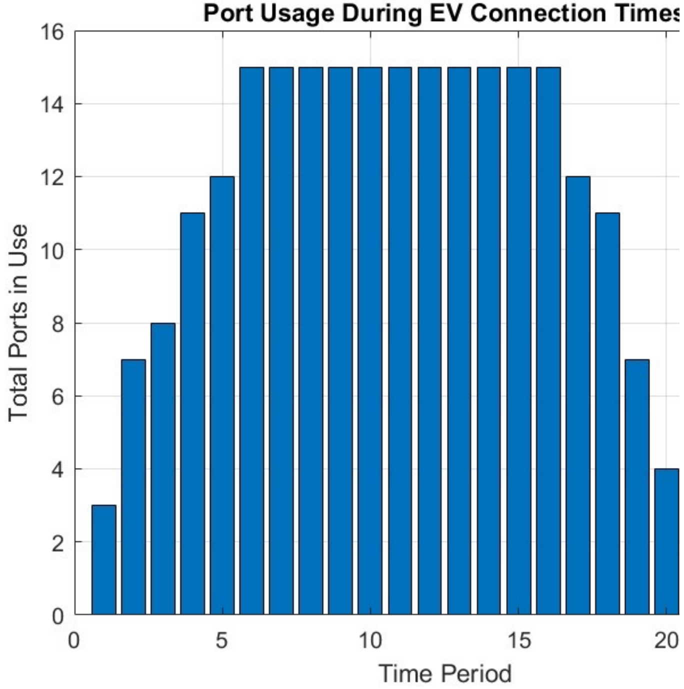
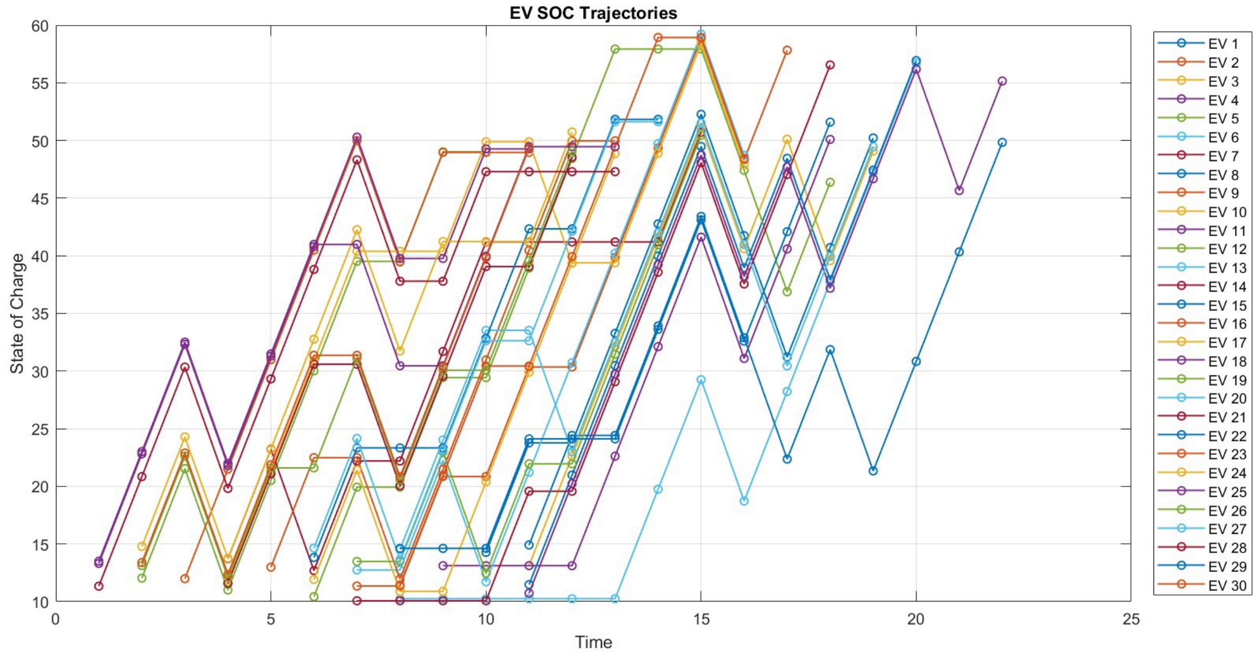
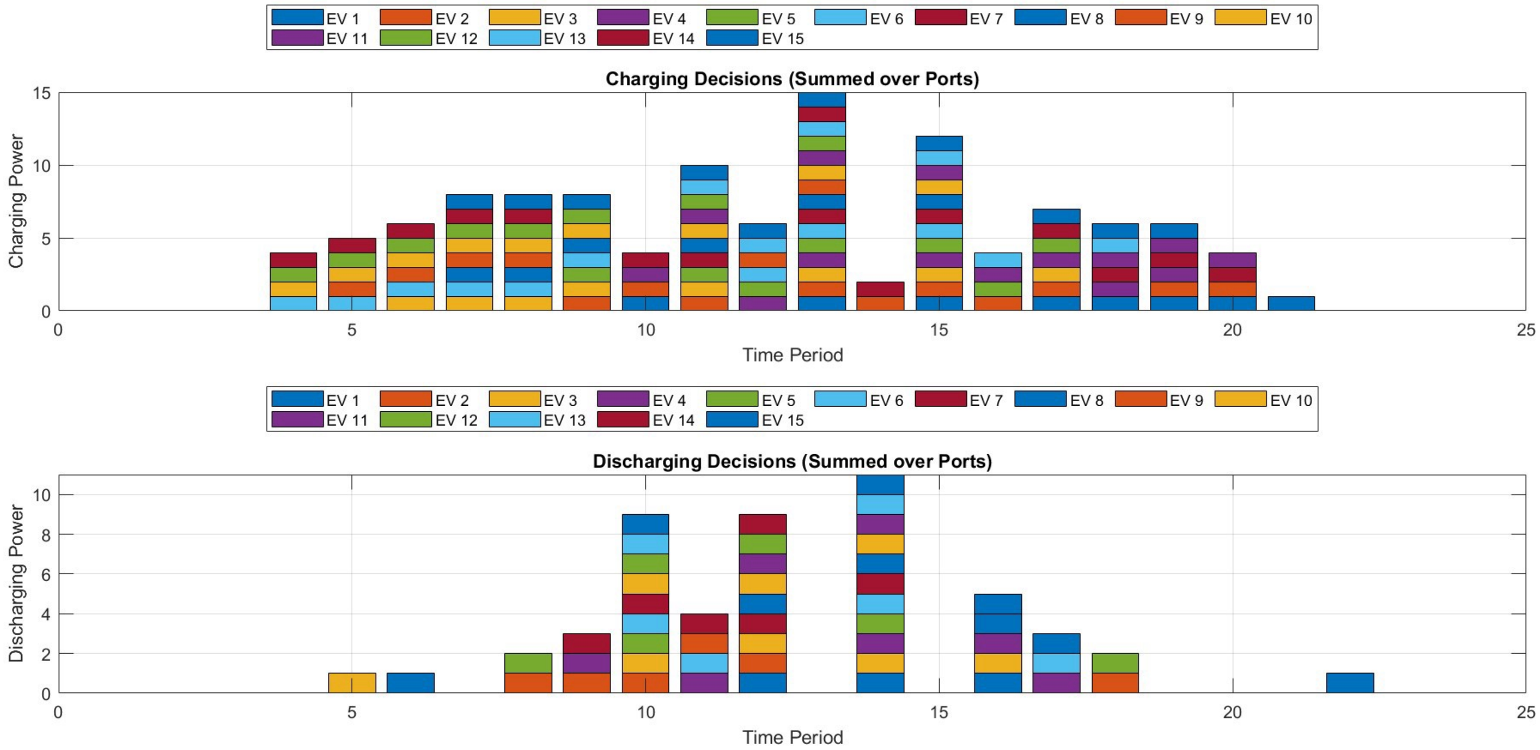




A deterministic charging scheduling model

A low demand scenario (more EVs than charging ports)



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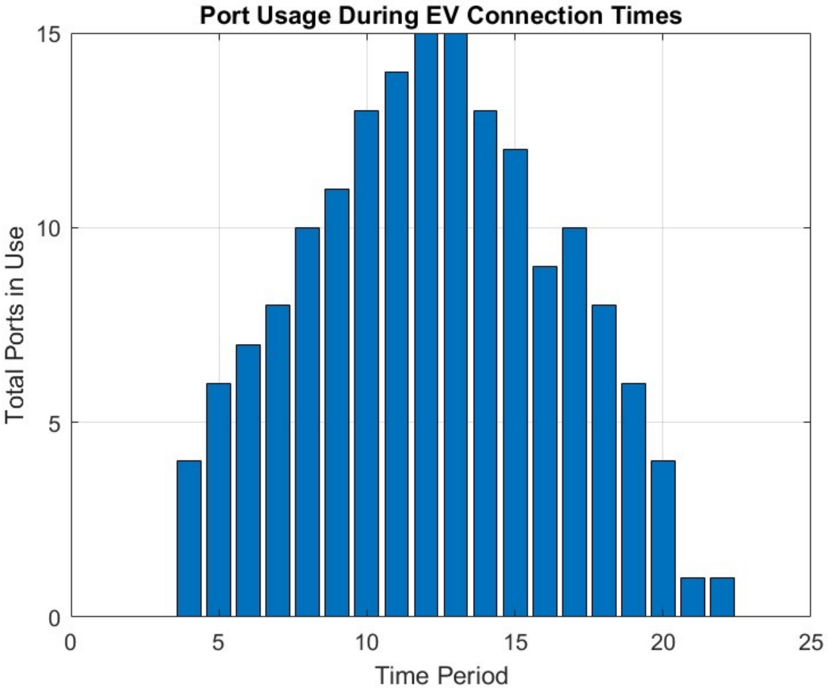

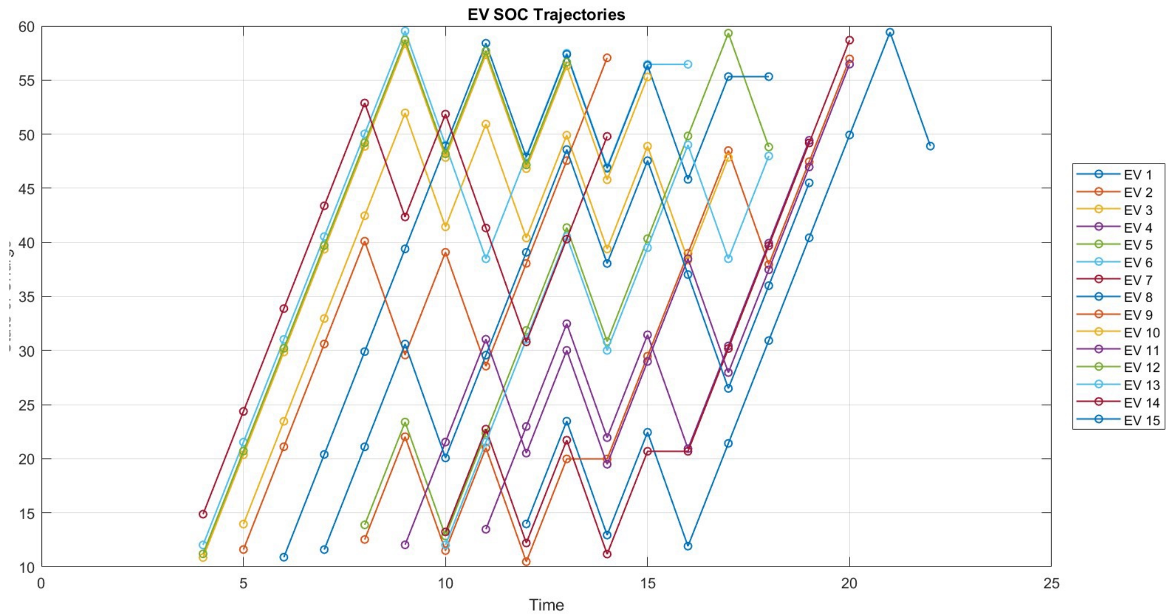

A stochastic charging scheduling model

In this model, we aim to maximize the profits of one charging station during a time period.

We presume that the following information is uncertain.

- The number of EVs that will charge at the studied charging station,
- The initial SOC and arrival time of each EV,
- The desired SOC.

They follow either a Normal distribution or a Poisson distribution.

The objective function:

$$\text{Max} \sum_{t\in T}\sum_{i\in I}\sum_{j\in J}\left(p_{t,i}^{\text{CS}}\,\delta_i\,z_{t,i,j}^{c} - r_{t,i}^{\text{CS}}\,\delta_i\,z_{t,i,j}^{d}\right) + \cdot \sum_{t\in T}\left(r_t^{\text{grid}}\,\delta_t^{\text{grid},d}\,z_t^{g,d} - p_t^{\text{grid}}\,\delta_t^{\text{grid},c}\,z_t^{g,c}\right) - p_0^{\text{grid}}\,E_0^{\text{ESS}}$$

EV-station profits | Grid-station profits | Day-ahead ESS costs

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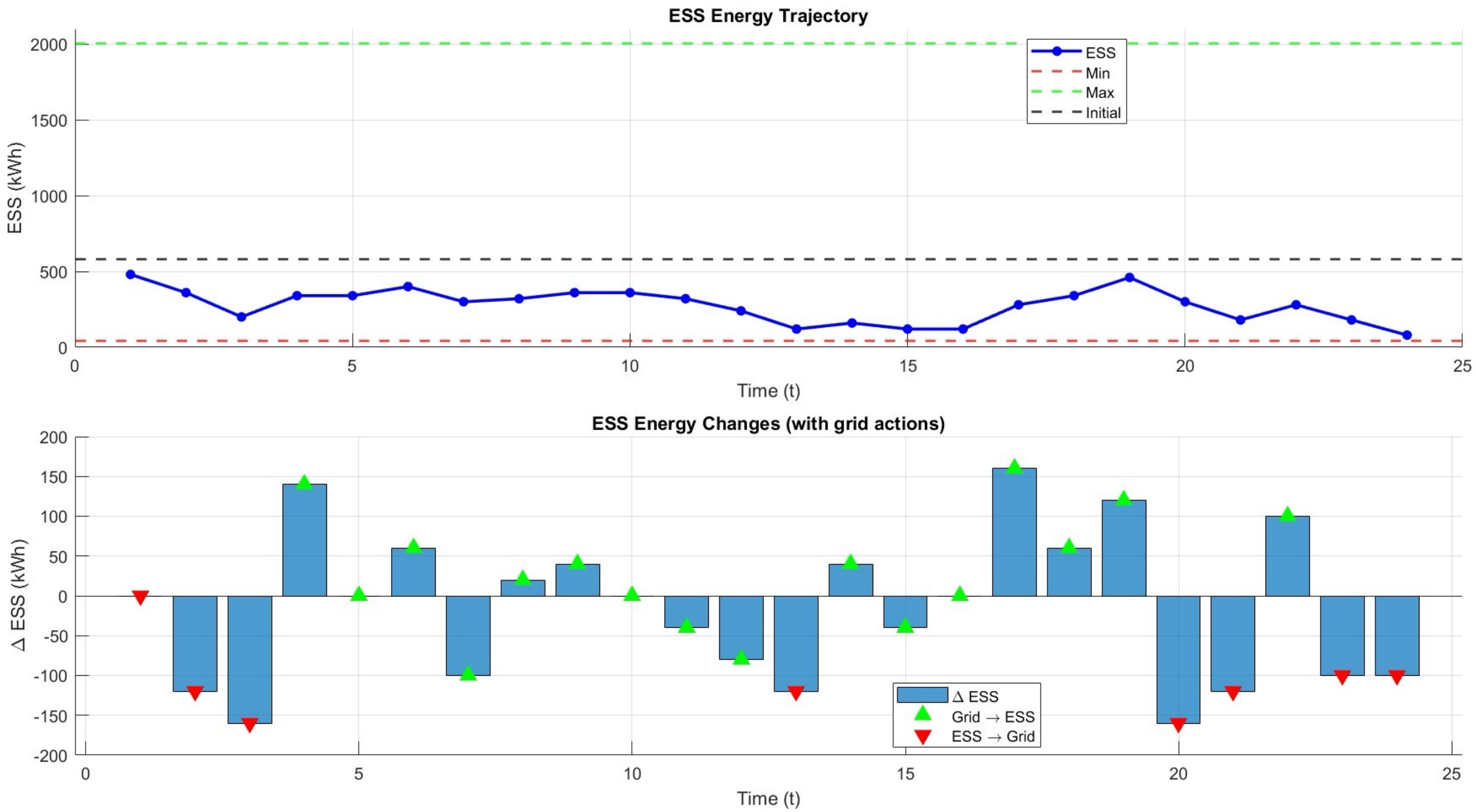

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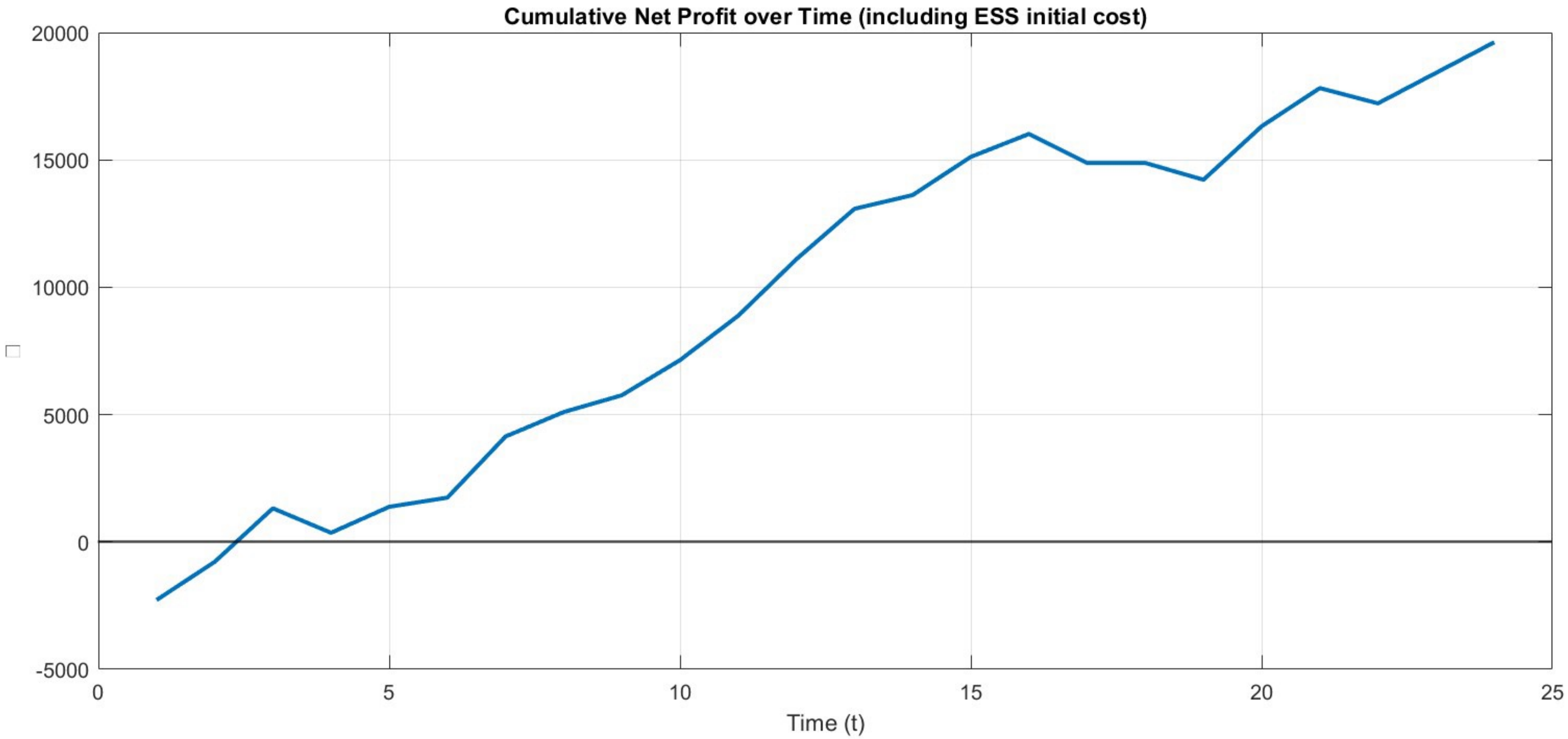

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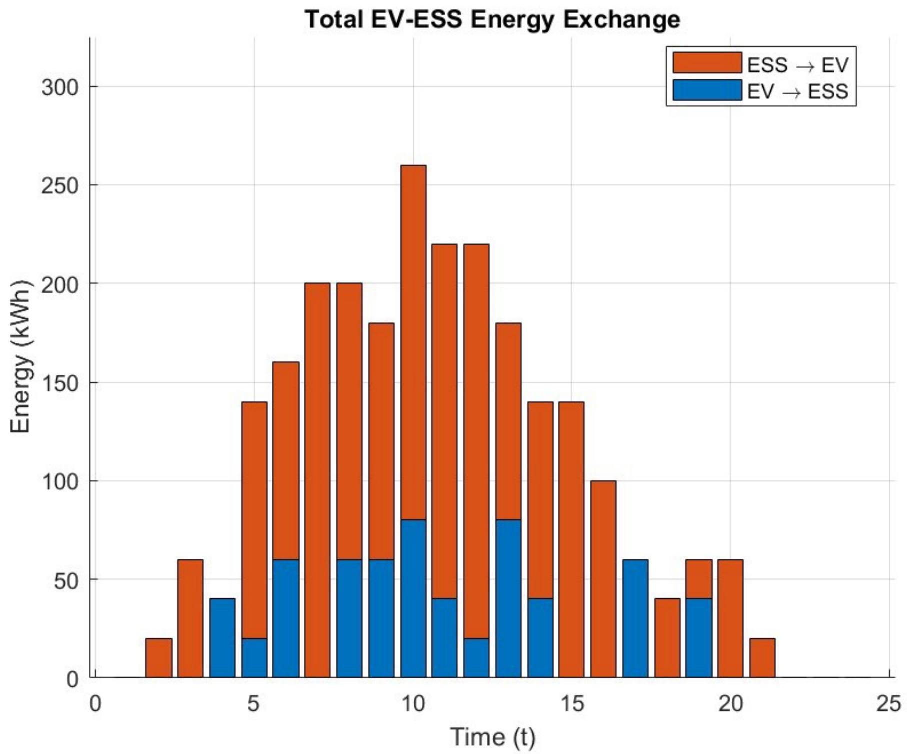

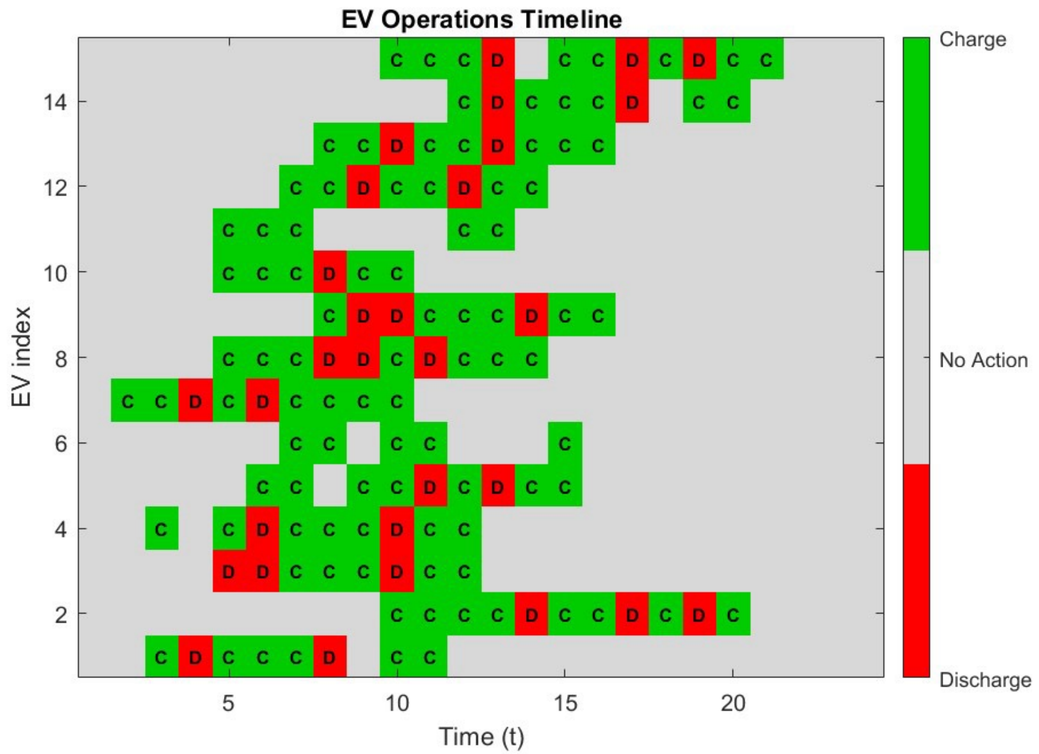

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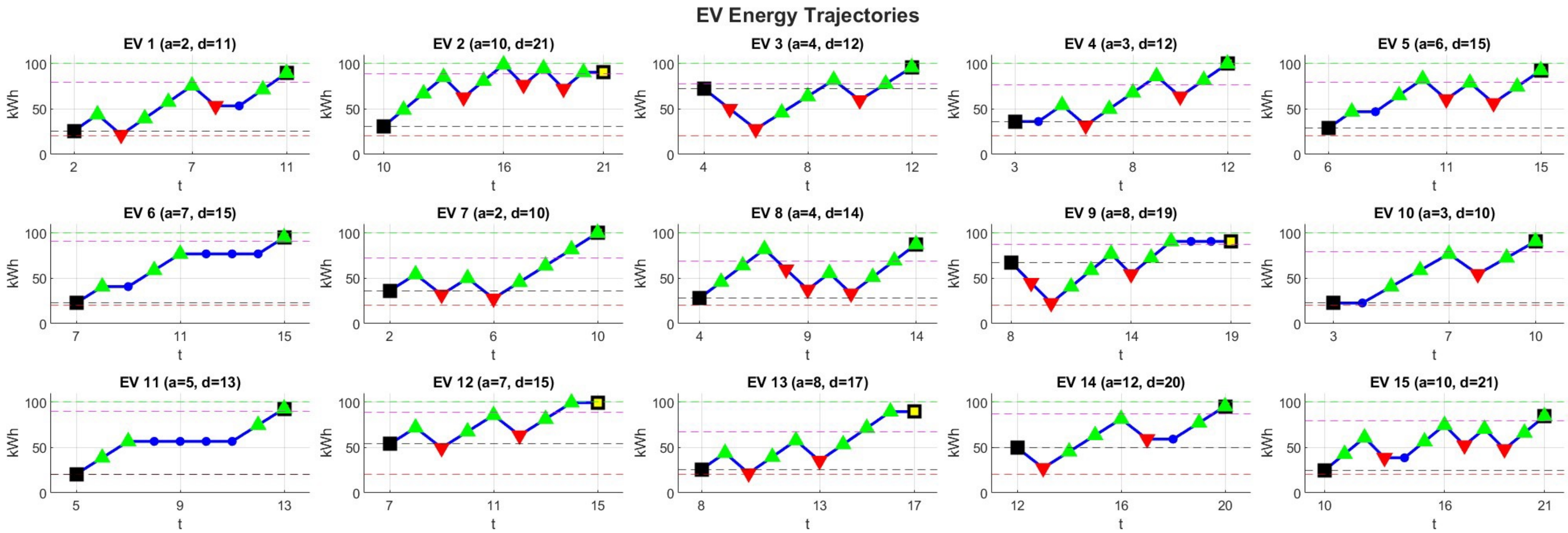

Thank you!

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