Thesis Description

"Digital Twins and Reinforcement Learning for Energy Distribution Optimization"

Abstracts

Efficient distribution of compressed natural gas (CNG) to customers is a complex challenge faced by gas companies, involving factors such as varying customer demands, transportation constraints, and uncertainties. This research proposes a novel framework that integrates digital twin technology, optimization models, and reinforcement learning techniques to enhance decision-making processes in CNG distribution networks. The key objectives are to develop a digital twin system for the CNG distribution network in the Southeast region, formulate an optimization model for vehicle scheduling and dispatching, and apply reinforcement learning algorithms to continuously improve distribution decisions. The digital twin system will enable simulations and scenario analyses, while the optimization model will identify optimal scheduling strategies under various constraints, such as plant capacity, vehicle availability, and time windows. Reinforcement learning techniques will be employed to learn from real-world data or dispatcher feedback, leading to adaptable and improved decision-making. This integrated framework has the potential to maximize profitability, ensure customer satisfaction, and efficiently manage resources in the natural gas industry, contributing to enhanced operational efficiency and sustainable energy distribution.

1. Introdution

The natural gas industry is essential for meeting the energy needs of various sectors. However, the distribution of Compressed Natural Gas (CNG) to customers poses complex logistical challenges due to factors such as fluctuating demands, transportation constraints, and uncertainties that can impact delivery schedules and costs. Addressing these challenges is crucial for ensuring reliable and cost-effective CNG supply.

Traditionally, gas distribution companies have relied on manual processes and heuristic approaches for decision-making, which often struggle to account for the dynamic nature of the problem and may lead to suboptimal solutions. Advances in digital technologies, optimization techniques, and machine learning offer new opportunities to transform the CNG distribution process.

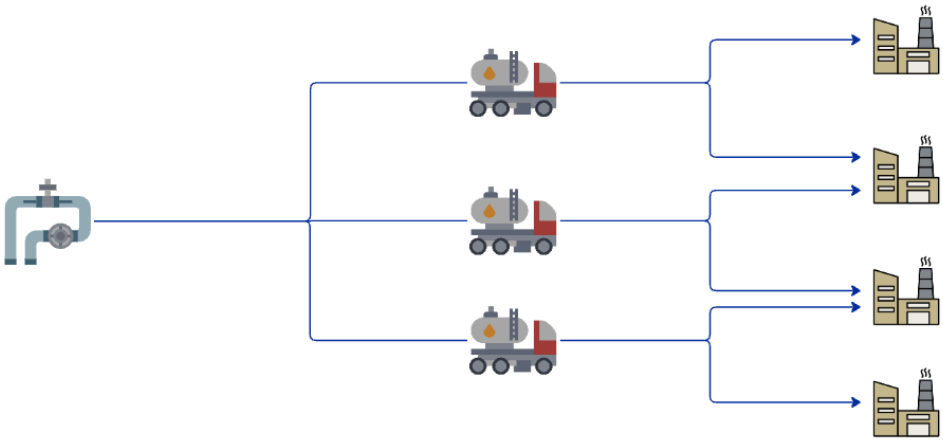
This research proposes an innovative framework that synergizes digital twin technology, optimization models, and reinforcement learning techniques to enhance decision-making processes in CNG distribution networks. The integration of these components aims to provide a comprehensive decision support tool for gas distribution companies.

The digital twin system, a virtual representation of the physical CNG distribution network, will enable detailed simulations and scenario analyses, allowing for the exploration of various optimization strategies and reinforcement learning algorithms. The optimization model, formulated specifically for vehicle scheduling and dispatching, will identify optimal strategies considering constraints such as plant capacity, vehicle availability, and time windows for meeting customer demands.

Furthermore, reinforcement learning techniques will be employed to continuously improve the decision-making process. By learning from real-world data or feedback from dispatchers, the system will adapt and refine its strategies, leading to more efficient and responsive distribution decisions.

The proposed framework addresses key challenges faced by CNG distribution companies, such as maximizing profitability, ensuring customer satisfaction, and efficiently managing resources under various constraints, including varying customer demands, uncertainties during transportation, and differences in tank sizes and ownership types.

By leveraging the synergy of digital twin technology, optimization models, and reinforcement learning techniques, this research aims to contribute to the broader field of logistics and supply chain management, with potential applications in other domains where efficient distribution of resources is crucial.



Gas plants

Optimize objective function:
- Maximize his profit
- Satisfaction of customer

Decisions need to be made:
- Which customers should be served?
- How many customers should I serve in one ride?
- Which size of tank should be chosen?
- Should I choose owned tanks/cars or rental tanks/cars?

Constraints:
- Capacity of gas plant
- Availability of owned/rental tanks/cars
- Time to meet customer demand

Tanks and vehicles
- Time to serve customers
- Uncertainty on the way
- Vary in tanks size and ownership of tanks
- Vary in cost for types of tank

End-customers
- Uncertainty in customer demand
- Distance from gas plant to customer
- Vary in allowable time window for gas supply for each group of customer

Figure 1. The overview of energy distribution optimization problem

2. Objectives

- Build a digital twin system linked to the CNG gas distribution system to customers in the Southeast region to serve simulation for optimization and reinforcement learning problems in later stages;
- Develop an optimization model for selecting parameters for vehicle scheduling and dispatching, supplying to customers in the Southeast region;
- Combine the distribution optimization model and the digital twin system, apply reinforcement learning (from reality or feedback from dispatchers) to upgrade the model for vehicle scheduling and dispatching decisions.