Smart Grid Load Balancer Project Report

Name: Sarthak Gupta

Course: Distributed Systems

Roll No: G24AI2057

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Video Link: https://drive.google.com/file/d/1iX-GgijVmb0FxaOq4X_hr8AedClR-nyF/view?usp=sharing

GitHub link : https://github.com/gpt-sarthak/FDS_Assignment/tree/main/smart-grid-load-balancer

1. Objective

The objective of this project is to design and implement a scalable Smart Grid Load Balancer system that dynamically distributes electric vehicle (EV) charging requests across multiple substations based on real - time load. This system aims to optimize charging efficiency, prevent substation overload, and provide full observability into system performance using modern monitoring tools.

2. System Architecture

Components:

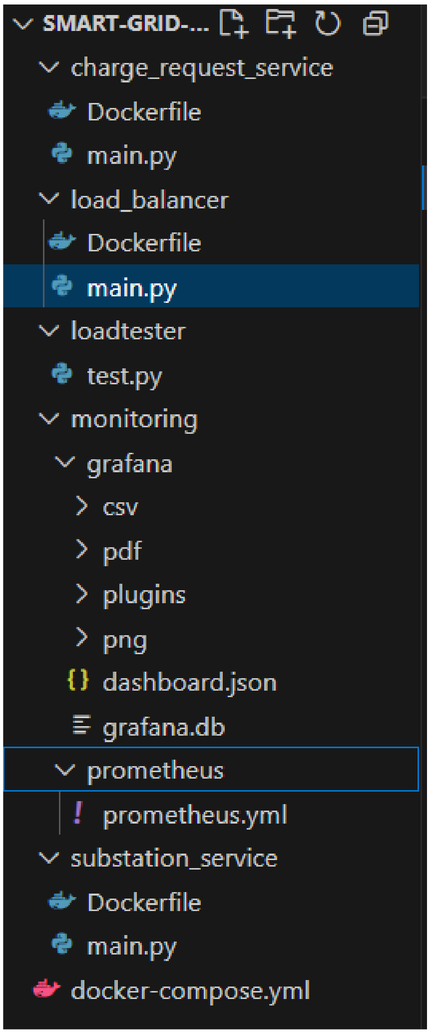
1. Charge Request Service
   a. Entry point for EVs to send charge requests via REST API.
2. Load Balancer
   a. Core logic that polls real - time substation load using Prometheus metrics and routes each request to the least - loaded substation.
3. Substation Services (2 replicas)
   a. Simulate EV charging and expose a Prometheus gauge metric substation_load .
4. Observability Stack
   a. Prometheus: Scrapes metrics from substations.
   b. Grafana: Visualizes substation load trends in a live dashboard.
5. Load Tester
   a. Python script simulating a high - traffic scenario with 50 EV charging requests.

3. Technologies Used

- Python 3.10 for all microservices
- Flask for REST APIs
- Prometheus Client for exposing metrics

- Docker & Docker Compose   for containerization
- Prometheus   for metric collection
- Grafana   for real - time visualization

4. File & Folder Structure



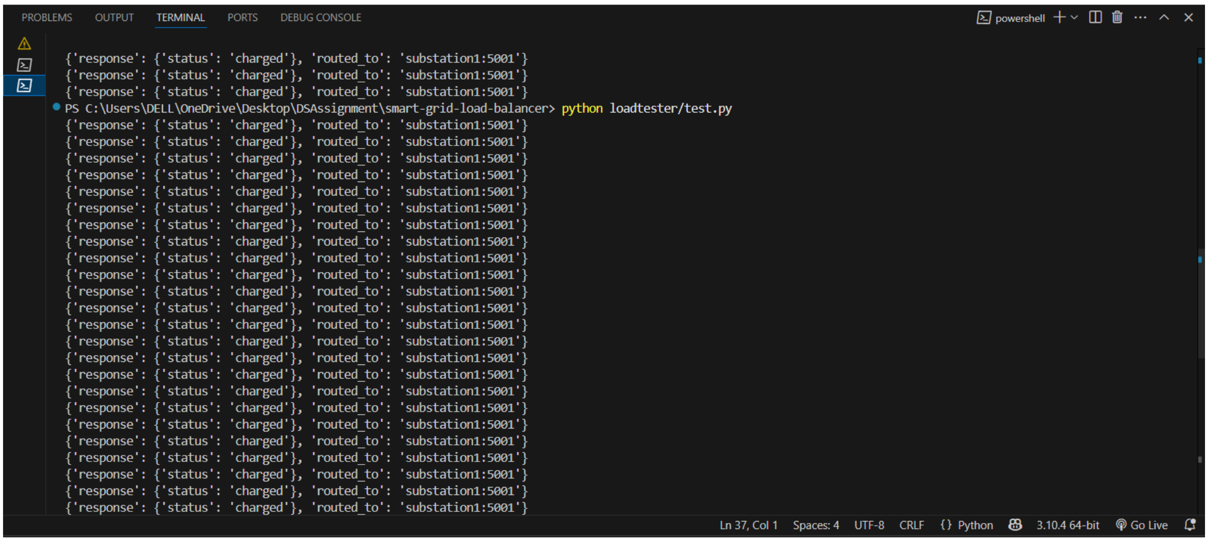
5. Load Balancing Logic

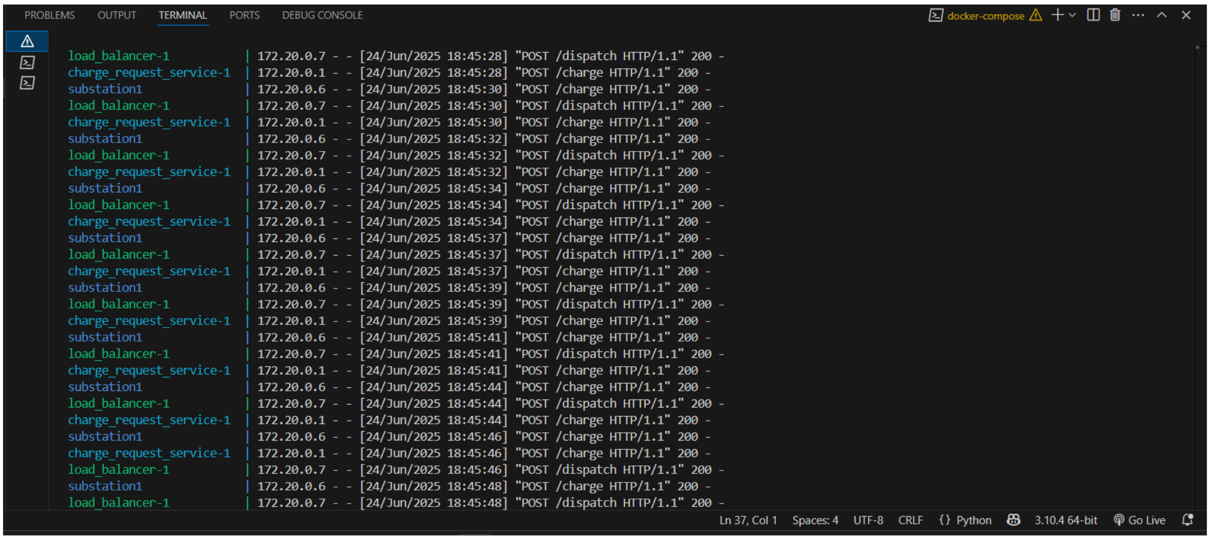
- The Load Balancer queries each substation's/metrics endpoint to fetch current load.
- It compares load values and routes the incoming charge request to the substation with the lowest load.
- This ensures optimal distribution of EV requests, minimizing overload risk.

6. Observability and Monitoring

- Each substation exposes a substation load metric.
- Prometheus scrapes these metrics at regular intervals.
- Grafana displays a time - series graph showing load on each substation.
- Dashboard showing live load distribution

•Terminal:





7. Load Test Results

- A Python script sends 50 EV requests in a simulated "rush hour."
- The load is observed to be dynamically balanced between both substations.
- Grafana charts confirm that requests were evenly distributed over time.

8. Conclusion

This project successfully demonstrates a cloud - native EV charging management system that balances load across substations using real - time metrics. It is scalable, observable, and designed following distributed systems best practices.