Hamdard University

Department of Computing

Final Year Project

INTELLIGENT HOME ENERGY MANAGEMENT SYSTEM FOR POWER CONSUMPTION

FYP-021/FL24

Software Design Specifications

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Document Sign off Sheet

1.1.1 Document Information

Project Title	Intelligent Home Energy Management System For Power Consumption
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Name	Role	Signature	Date
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Revision History

Date	Version	Description	Author
26-12-24	1.0	Data entered	Khizer, Shoaib
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Definition of Terms, Acronyms, and Abbreviations

Term	Description

2 Table of Contents

3 Introduction

3.1 Purpose of Document

This document outlines the design and specifications for developing an Intelligent Home Energy Management System (IHEMS) aimed at monitoring and optimizing energy consumption. It details the architectural framework, design considerations, and implementation strategies to ensure the system meets functional and non-functional requirements.

3.2 Intended Audience

The primary audience includes:

- **Project Team Members**: Developers, testers, and designers working on the project.
- **Supervisors**: Dr. Umer Farooq and Dr. Rashid Hussain for project oversight.
- **Stakeholders**: Homeowners, researchers, and industry professionals interested in smart energy solutions.
- **Evaluators**: Faculty and committee members at Hamdard University.

3.3 Document Convention

The document uses the following conventions:

- **Font**: Times New Roman
- **Font Size**: 12pt for text, 14pt for headings.
- **Spacing**: Single-spaced.

3.4 Project Overview

The IHEMS project aims to develop a smart home energy management system that leverages sensors, AI algorithms, and user-friendly interfaces. The system monitors real-time energy consumption, provides predictive analytics, and recommends optimization strategies. It also switches to alternate energy sources when consumption exceeds predefined thresholds

3.5 Scope

The project involves the design and development of:

- Real-time energy consumption monitoring.
- AI-driven predictive analytics for consumption trends.
- Smart notifications for energy-saving measures.
- Integration of alternative energy sources (solar, generator).
- A user-friendly web/mobile application for Android

4 Design Considerations

4.1 Assumptions and Dependencies

- Dependence on accurate and real-time sensor data for effective monitoring.
- Availability of reliable network connectivity for real-time updates.
- Dependence on the user's willingness to adopt energy-saving recommendations.

4.2 Risks and Volatile Areas

- **Technological Risks**: Sensor inaccuracies, network failures.
- **Regulatory Risks**: Compliance with local energy usage regulations.
- **Change Risks**: Evolving user requirements or updates in mobile OS standards.

5 System Architecture

The system is decomposed into the following major subsystems:

5.1 System Level Architecture

1. **User Interaction Layer**: Handles user input and output. This includes pages like login, signup, form filling, and dashboard visualization.
2. **Tariff Management Subsystem**: Processes energy-related pricing, including base tariffs, fuel adjustment prices, and taxes.
3. **Room and Appliance Configuration Subsystem**: Captures details about the user's home, including the number of rooms and appliances per room.
4. **Solar Generation Subsystem**: Manages live sensor readings and future solar energy predictions.
5. **Dashboard Subsystem**: Displays real-time usage and future consumption predictions based on user data and system calculations.

Relationships Between Components

- The User Interaction Layer communicates directly with the Room Configuration, Tariff Management, and Solar Generation Subsystems to capture input and display output.
- The Tariff Management Subsystem uses external data (e.g., general sales tax and fuel adjustment prices) to calculate energy costs.
- The Solar Generation Subsystem interacts with hardware sensors for live readings and prediction algorithms.
- The Dashboard Subsystem aggregates information from all other components and presents it visually to the user.

Interfaces to External Systems

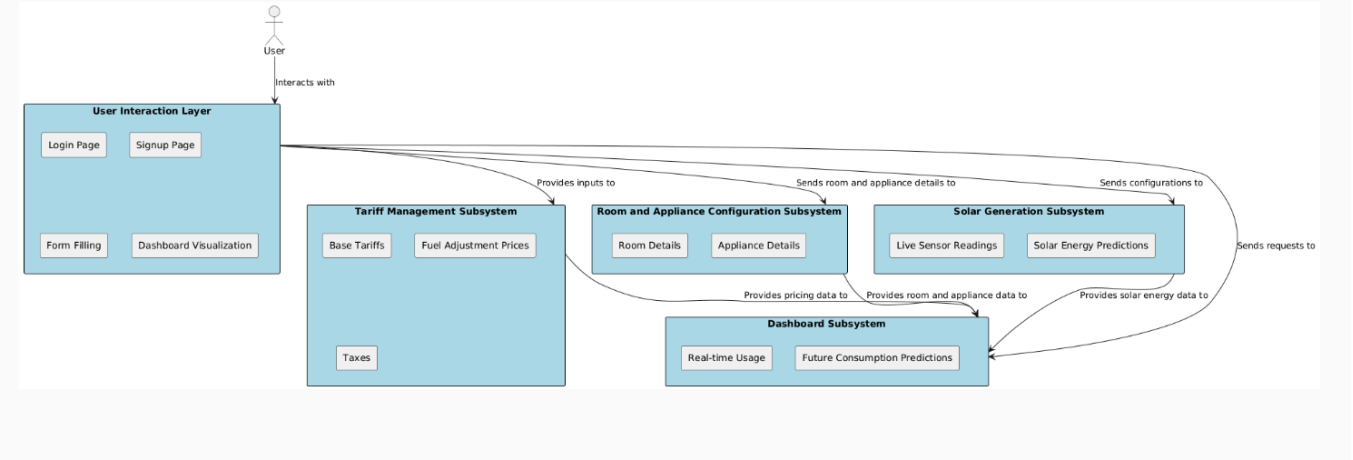
- **Tariff Management** connects to external databases for tariff data and tax regulations.
- **Solar Generation** interfaces with IoT devices and sensors.

Major Physical Design Issues

- The **User Interface Layer** will execute on client devices (web or mobile).
- The **Middle Layer** (business logic) and **Data Layer** will execute on a central server.

Global Design Strategies

- **Error Handling**: Centralized error logging with real-time notifications for critical failures.
- **Security**: Authentication for login/signup and data encryption for sensitive information.



5.2 Software Architecture

The software architecture is layered as follows:

User Interface Layer

- **Description**: This layer includes the login, signup, form filling, and dashboard pages. It collects user input and displays results.
- **Technology**: Web frameworks (e.g., React, Angular) or mobile frameworks (e.g., Flutter).

Middle Tier (Business Logic Layer)

- **Description**: Processes inputs from the user interface and manages the interactions between subsystems.
- **Modules**:
  - Tariff calculations
  - Room configuration logic
  - Solar energy predictions
- **Technology**: Server-side frameworks (e.g., Node.js, Django, or Spring Boot).

Data Access Layer

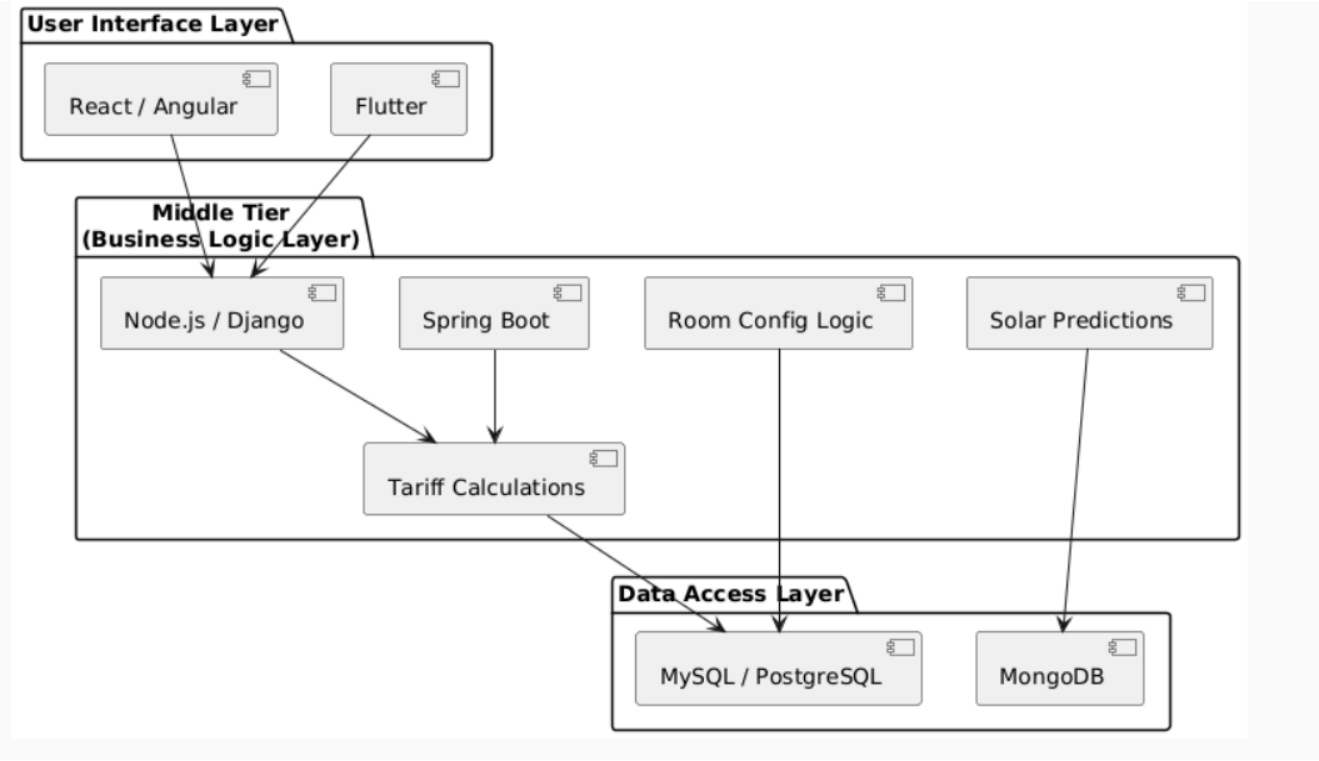
- **Description**: Interfaces with the database to store and retrieve user details, tariff data, room configurations, and solar readings.

- **Technology**: Relational databases (e.g., MySQL, PostgreSQL) or NoSQL databases (e.g., MongoDB).

Layer Interaction Diagram

- The interaction between layers can be visualized as:

1. User requests (e.g., tariff settings) sent from the User Interface Layer.
2. Requests processed by the Middle Tier.
3. Data retrieved or stored via the Data Access Layer.



6 Design Strategy

Future System Extension or Enhancement

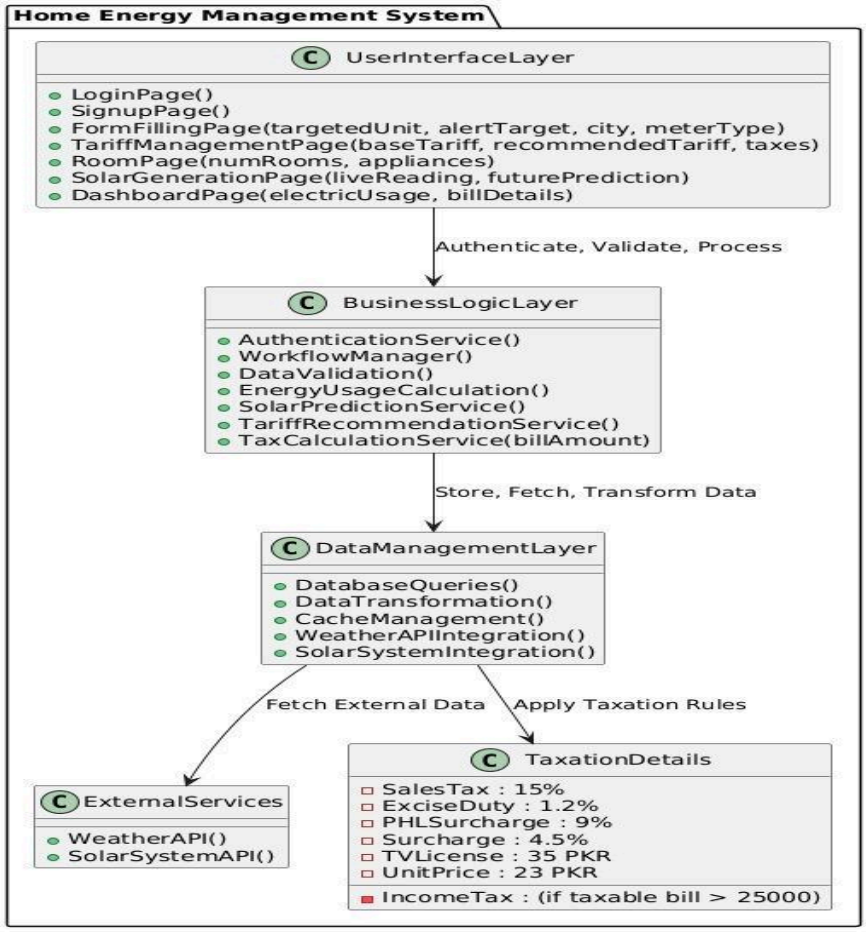
- **Modularity**: **Future System Extension/Enhancement**
  - **Modularity**: Independent subsystems enable seamless feature addition (e.g., smart appliances).
  - **Scalability**: Architecture supports high user loads effectively.

- **System Reuse**
  - Components like Solar Generation and Tariff Management can be reused in other systems.

- **User Interface Paradigms**
  - **Intuitive Design**: Simple interface for all users.
  - **Real-Time Feedback**: Dashboard shows live energy updates.

- **Data Management**
- **Storage**: Relational DB for structured data, NoSQL for unstructured sensor data.
  - **Distribution**: Real-time sync between UI and server.
  - **Persistence**: Historical data maintained for analysis.

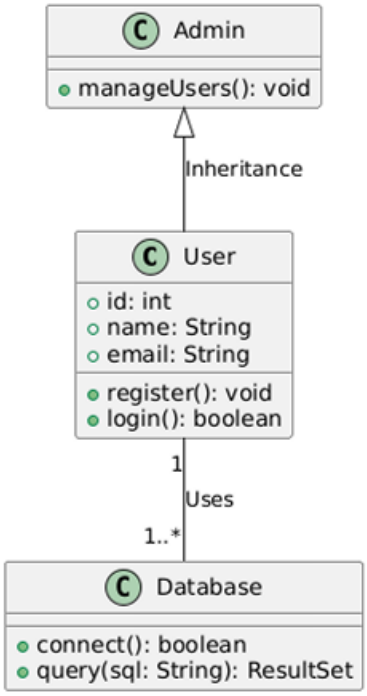
- **Concurrency and Synchronization**
  - **Concurrency**: Supports multiple simultaneous users.
  - **Synchronization**: Locking ensures data integrity during updates



7 Detailed System Design

1.1 Design Class Diagram

- Provides a detailed class diagram.
- Attributes, methods, and interactions between classes are described.
- Logical data models (e.g., E/R models) are included.



1.2 Database Design

User Singup

id	username	password	email	created_at
1	testuser	hashed_password	testuser@example.com	2025-01-12 12:00:00

Form filling

id	targeted_unit_use	city	meter_type	created_at
1	200.	Karachi	Residential	2025-01-12 12:00:00
2	350	Karachi	Industrial	2025-01-12 12:00:00
3	250.	Karachi	commercial	2025-01-12 12:00:00

Terrif calculation

Selected City	Sales. tax	Exercise duty.	PHL Surcharge	Surcharge	TV License	Price of per unit
Karachi	15%.	1.2%	9%	4.5%	35 pkr.	23

Room. No of Appliance

Room 1 3
Room 2 3

Room Appliances

Room1

Appliance 1	Estimated Usage (hours/day)	Appliance 2	Estimated Usage (hours/day)	Appliance 3	Estimated Usage (hours/day)	Daily Usage (kWh)
Bulb	5	Fan	6	AC	1	8

Room2

Appliance 1	Estimated Usage (hours/day)	Appliance 2	Estimated Usage (hours/day)	Appliance 3	Estimated Usage (hours/day)	Daily Usage (kWh)
Bulb	5	Fan	6	Refrigerator	14	15

Solar

Date	Live (kWh) Generation. (kWh).	Predicted Generation. (kWh)	Weather Condition
2025-01-12	150	180	Sunny
2025-01-12	150	180	Sunny
2025-01-13	130	155.	Partly Cloudy

Average Daily Usage and Weekly Cost

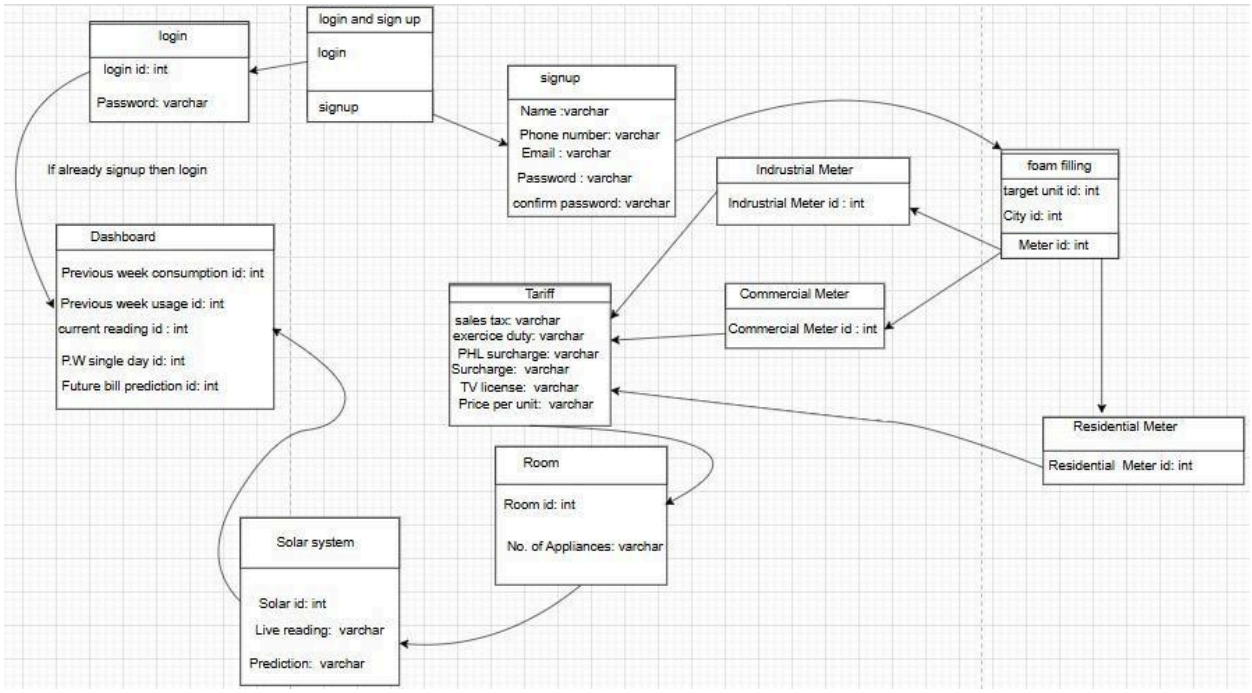
Metric	Value
Average Daily Usage (units).	6.5
Weekly Consumption (units)	45
Cost per Unit (Rupees)	24

Weekly Cost (Rupees) 1080

Weekly Consumption Breakdown

Day	Units. Consumed	Cost (Rupees)
Sunday	7.5.	156
Monday	6.0	156
Tuesday	6.0	156
Wednesday	6.5	156
Thursday	5.5.	156
Friday	6.5	156
Saturday	7.0	156

7.1.1 ER Diagram



7.1.2 ER Data Model

Entities:

User: Attributes: login_id, Password, Name, Phone_number, Email

Tariff: Attributes: Tariff_id, sales_tax, exercise_duty, PHL_surcharge, Surcharge, TV_license, Price_per_unit

Meter: Attributes: Meter_id, Industrial Meter_id, Commercial Meter_id, Residential Meter_id, target_unit, City_id

Room: Attributes: Room_id, No_of_Appliances

SolarSystem: Attributes: Solar_id, Live_reading, Prediction

Dashboard: Attributes: Previous_week_consumption_id, Previous_week_usage, Current_reading_id, Future_bill_prediction_id

Relationships:

User ↔ Tariff: One-to-many (One user can have multiple tariffs based on usage)

Meter ↔ User: Many-to-one (Multiple meters are linked to a single user)

Room ↔ Meter: Many-to-one (Rooms are linked to a specific meter)

SolarSystem ↔ Dashboard: One-to-one (Live readings are linked directly to dashboard details)

7.1.3 Data Dictionary

7.1.3.1 Data 1: User Information

Attributes:

login_id: Primary Key, INT

Password: VARCHAR

Name: VARCHAR

Phone_number: VARCHAR

Email: VARCHAR

Description: Stores user credentials and personal details for login and signup purposes.

7.1.3.2 Data 2: Tariff Information

Attributes:

Tariff_id: Primary Key, INT

sales_tax: VARCHAR

exercise_duty: VARCHAR

PHL_surcharge: VARCHAR

Surcharge: VARCHAR

TV_license: VARCHAR

Price_per_unit: VARCHAR

Description: Stores tariff details for different user categories

7.1.3.3 Data: Meter Information

Attributes:

Meter_id: Primary Key, INT

Industrial Meter_id: INT

Commercial Meter_id: INT

Residential Meter_id: INT

target_unit: INT

City_id: INT

Description: Stores meter-specific information related to industrial, commercial, and residential users.

7.1.3.4 Data: Room and Appliance Details

Attributes:

Room_id: Primary Key, INT

No_of_Appliances: VARCHAR

Description: Captures the number of rooms and appliances per room

7.1.3.5 Data: Solar System

Attributes:

Solar_id: Primary Key, INT

Live_reading: VARCHAR

Prediction: VARCHAR

Description: Manages live readings and predictions related to solar energy.

7.1.3.6 Data: Dashboard

Attributes:

Previous_week_consumption_id: INT

Previous_week_usage: INT

Current_reading_id: INT

Future_bill_prediction_id: INT

Description: Displays real-time consumption and historical data.

7.1.3.7

< Data 1: User Information >

Name	User
Alias	User Table
Where-used/how-used	Used for login, signup, and managing user credentials and personal details.
Content description	Stores information about user accounts, including login ID, password, and contact details.

Column Name	Description	Type	Length	Nullable	Default Value	Key Type
login_id	Unique identifier for user login	INT	10	NO	AUTO_INCREMENT	PK
password	User's account password	VARCHAR	50	NO	NULL	
name	Full name of the user	VARCHAR	100	NO	NULL	
phone_number	User's contact number	VARCHAR	15	YES	NULL	
email	User's email address	VARCHAR	50	NO	NULL	

< Data 2: Tariff Information >

Name	Tariff
Alias	Tariff Table
Where-used/how-used	Used for calculating energy costs, including taxes, surcharges, and base tariff rates.
Content description	Stores pricing details and additional charges for energy consumption.

Column Name	Description	Type	Length	Nullable	Default Value	Key Type
tariff_id	Unique identifier for tariff	INT	10	NO	AUTO_INCREMENT	PK
sales_tax	Percentage of sales tax	FLOAT	5,2	YES	NULL	
fuel_adjustment	Adjustment charges for fuel costs	FLOAT	5,2	YES	NULL	
surcharge	Additional surcharge amount	FLOAT	5,2	YES	NULL	
base_price	Base price per unit of energy	FLOAT	5,2	NO	NULL	

< Data 3: Meter Information >

Name	Meter
Alias	Meter Table
Where-used/how-used	Used for tracking energy usage across residential, industrial, and commercial meters.
Content description	Stores data related to meter types and their energy consumption details.

Column Name	Description	Type	Length	Nullable	Default Value	Key Type
meter_id	Unique identifier for each meter	INT	10	NO	AUTO_INCREMENT	PK
meter_type	Type of meter (residential/commercial)	VARCHAR	20	NO	NULL	
target_unit	Energy unit consumption target	INT	10	YES	NULL	
city_id	City to which the meter belongs	INT	10	YES	NULL	FK

< Data 4: Solar System >

Name	Solar System
Alias	Solar Table
Where-used/how-used	Used for tracking live solar energy readings and predictions.
Content description	Stores data about solar energy generation and predictions for future energy savings.

Column Name	Description	Type	Length	Nullable	Default Value	Key Type
solar_id	Unique identifier for solar system	INT	10	NO	AUTO_INCREMENT	PK
live_reading	Current energy generation reading	FLOAT	10,2	NO	NULL	
prediction	Predicted energy generation	FLOAT	10,2	YES	NULL	

< Data 5: Dashboard >

Name	Dashboard
Alias	Energy Monitoring Dashboard
Where-used/how-used	Displays user-specific energy consumption, billing, and predictions in real time.
Content description	Stores data related to user energy usage and bill predictions for dashboard display.

Column Name	Description	Type	Length	Nullable	Default Value	Key Type
dashboard_id	Unique identifier for dashboard entry	INT	10	NO	AUTO_INCREMENT	PK
user_id	ID of the user accessing the dashboard	INT	10	NO	NULL	FK
prev_week_usage	Energy usage in the previous week (units)	INT	10	YES	NULL	
current_usage	Current energy usage (units)	INT	10	YES	NULL	
bill_prediction	Predicted bill based on current usage	FLOAT	10,2	YES	NULL	

< Data 6: Room Information >

Name	Room
Alias	Room Details Table
Where-used/how-used	Tracks energy consumption at the room level and lists associated appliances.
Content description	Stores data about rooms and the number of connected appliances for monitoring purposes.

Column Name	Description	Type	Length	Nullable	Default Value	Key Type
room_id	Unique identifier for each room	INT	10	NO	AUTO_INCREMENT	PK
user_id	ID of the user to whom the room belongs	INT	10	NO	NULL	FK
room_name	Name of the room (e.g., Living Room)	VARCHAR	50	NO	NULL	
appliance_count	Number of appliances in the room	INT	5	YES	NULL	

< Data 7: Login and Signup >

Name	Login and Signup
Alias	User Authentication Table
Where-used/how-used	Used for user authentication and managing account creation and access credentials.
Content description	Stores data about user login credentials and profile information.

Column Name	Description	Type	Length	Nullable	Default Value	Key Type
user_id	Unique identifier for each user	INT	10	NO	AUTO_INCREMENT	PK
username	Username for account login	VARCHAR	50	NO	NULL	
email	User email address	VARCHAR	100	NO	NULL	
password	Password for authentication	VARCHAR	255	NO	NULL	
phone_number	User's phone number	VARCHAR	15	YES	NULL	

The notation to develop content description is given below:

Data Construct	Notation	Meaning
Is Composed Of	=	Indicates that a data construct is composed of other constructs.
Sequence	+	Represents the sequencing of data items (used to link them together).
Selection	[	]
Repetition	{ }n	Specifies that the enclosed data items can repeat `n` times.
Optional Data	( )	Represents that the data enclosed is optional and may or may not appear.
Comments	* ... *	Used to include comments or explanatory notes within the data construct.

Application Design

This section focuses on system workflows and interaction.

7.1.4 Sequence Diagram

· Illustrates object interactions over time.

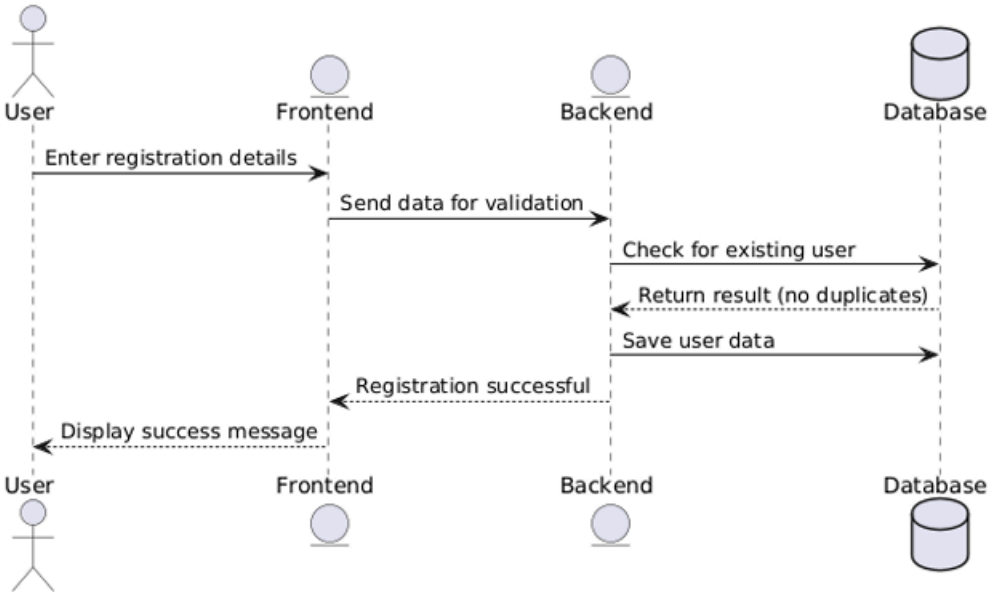
· Each diagram includes explanations.

7.1.4.1 <Sequence Diagram 1>

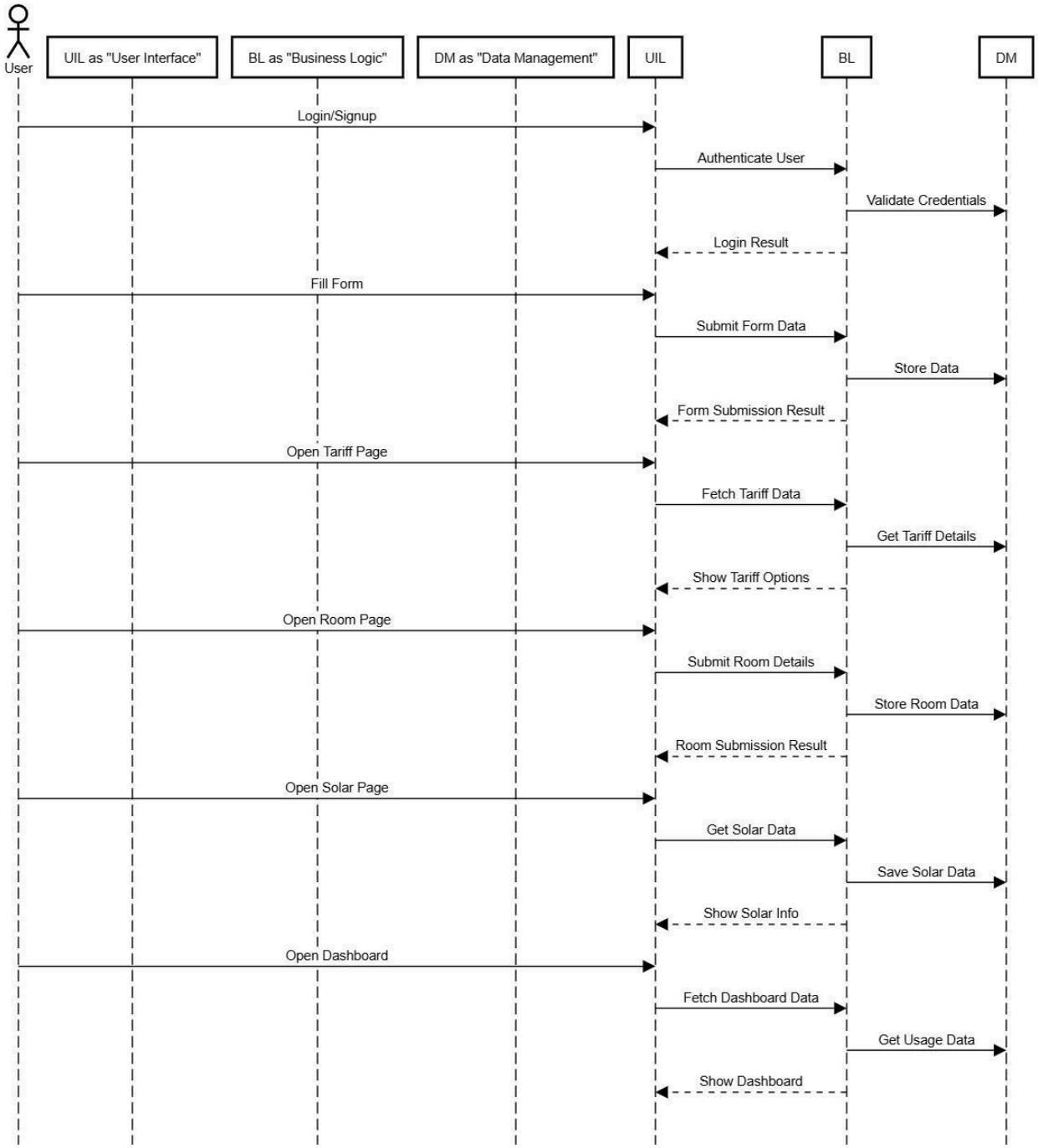
Diagram Explanation:

This diagram represents the flow of interactions during a user registration process in an application. The main components include the User, Frontend, Backend, and Database. The steps include:

1. **User Input:** The User provides registration details via the frontend.
2. **Validation:** The Frontend sends data to the Backend for validation.
3. **Database Check:** The Backend checks the Database for duplicate entries.
4. **Save User Data:** If no duplicates are found, the Backend saves the user's data in the Database.
5. **Response to User:** Confirmation is sent back to the Frontend and displayed to the User.



7.1.4.2 <Sequence Diagram 2>



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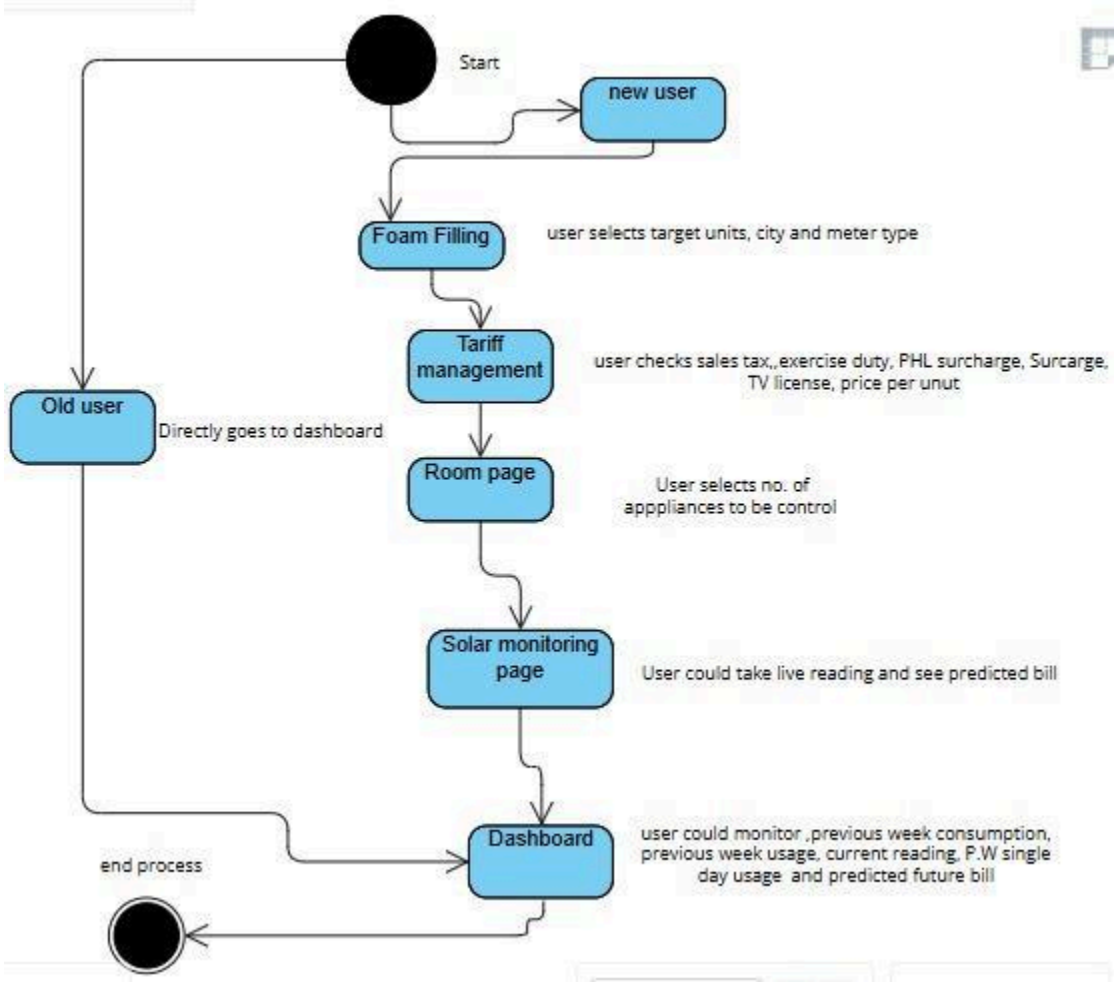
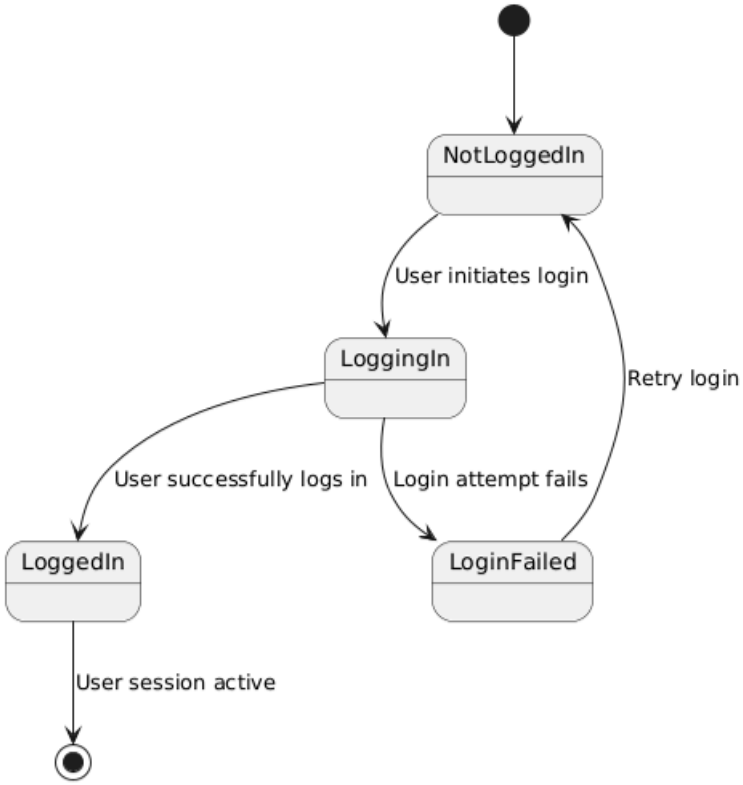
7.1.5 State Diagram

7.1.5.1 <State Diagram 1>



7.1.5.2 <State Diagram 2>

[Diagram & Explanation of diagram]



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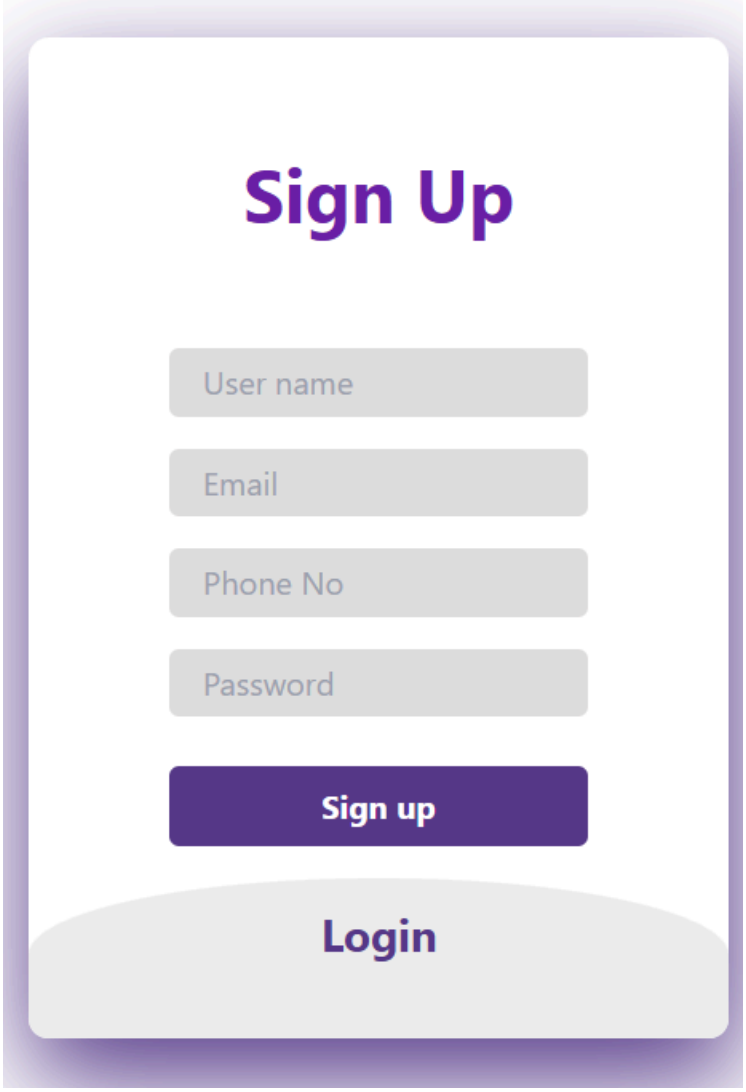
1.3 GUI Design

7.1.6 <Sign Up - Mock Screen 1>



7.1.7 <Login - Mock Screen 2>

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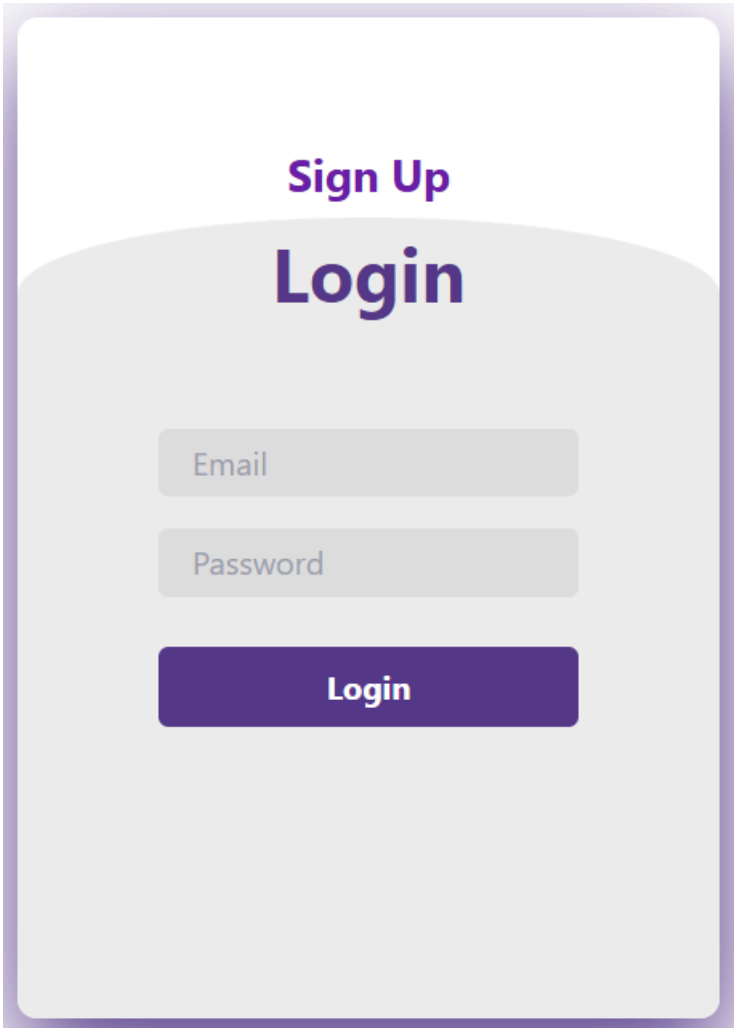
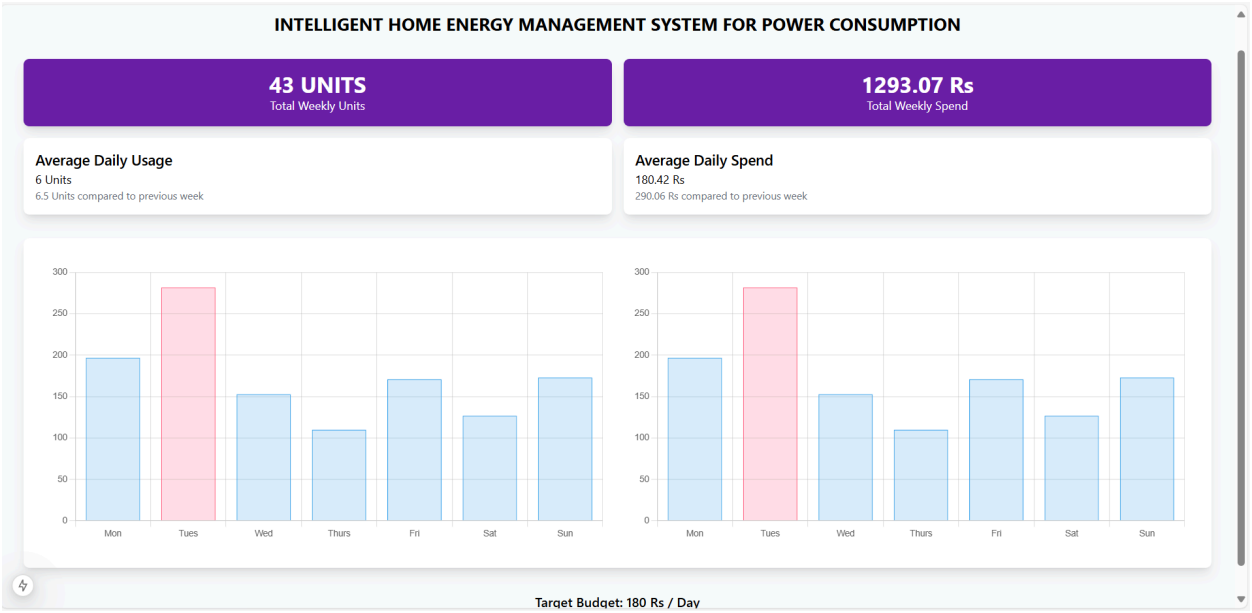
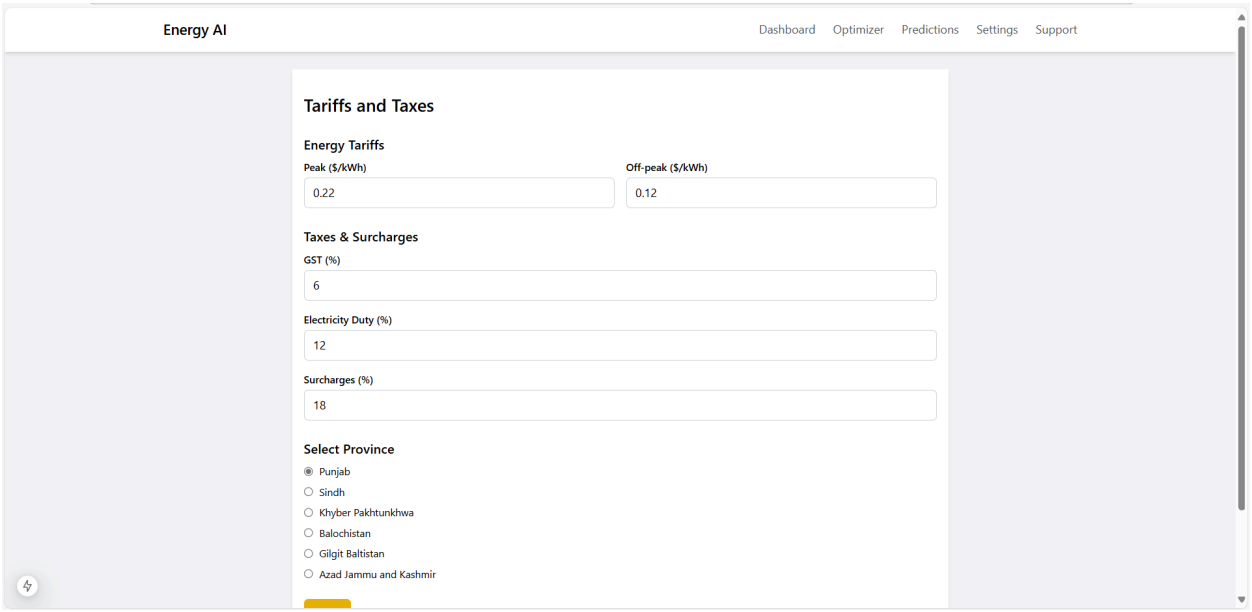


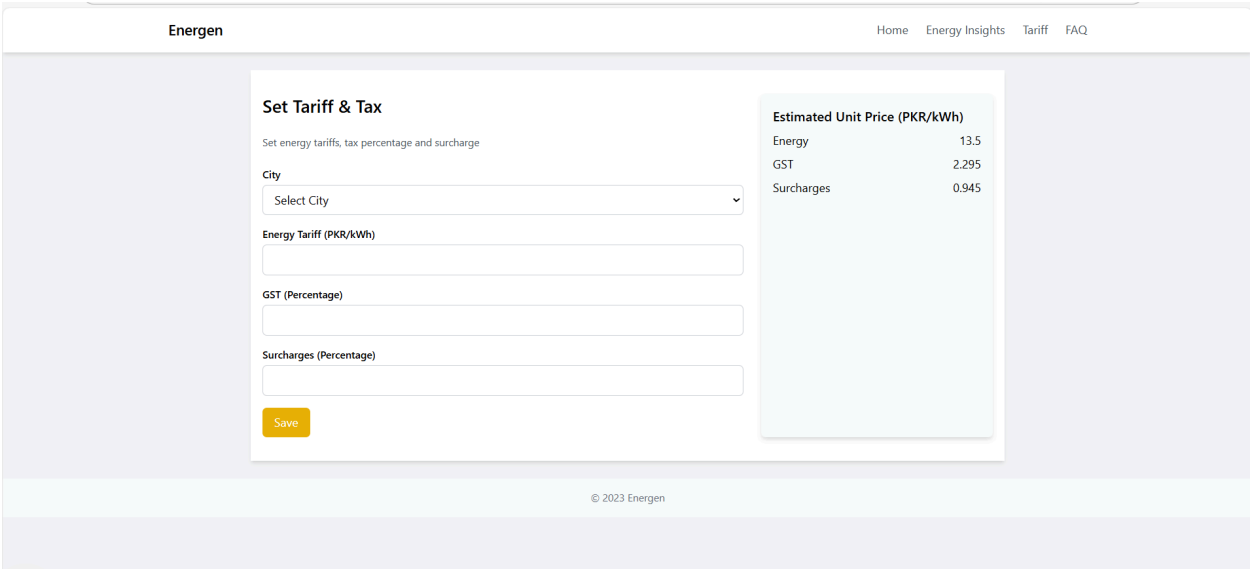
7.1.8 <Dashboard - Mock Screen 3>



7.1.9 <Tarrifs- Mock Screen 3>



7.1.10 <Set Tarrifs and Taxes- Mock Screen 3>



8 References

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9 Appendices

9.1 Glossary of Terms

- **User Interface (UI):** The visual component of the system through which users interact with the software.
- **Solar Prediction Algorithm:** A mechanism that forecasts solar energy generation based on historical and real-time data.
- **Tariff Management System:** A subsystem that calculates energy pricing based on different tariffs, taxes, and adjustments.

9.2 Code Snippets

Include important code snippets used in the project. For example:

- Example API integration.
- Database connection logic.
- A key algorithm (e.g., solar prediction calculation).

9.3 Data Dictionary

- Include detailed tables outlining all data attributes, their types, relationships, and constraints (refer to the tables created earlier).

9.4 Tools and Technologies

List the tools and technologies used in the project:

- Programming Languages: Python, JavaScript.
- Frameworks: Django, React.
- Databases: MySQL, MongoDB.
- Others: Docker, Postman, Git.

9.5 Diagrams and Models

Include high-level architecture diagrams, UML diagrams, ER diagrams, and any additional visual representations relevant to the project.

9.6 Testing Documentation

- Testing Plan: Include details of test cases executed.
- Results: Provide a summary of the testing phase, such as performance and bug fixes.

9.7 Project Timeline

Provide a Gantt chart or a detailed timeline showing the project's phases and milestones.

9.8 References

List all sources of information used in your project:

- Research papers.
- Online articles.
- Technical documentation.

9.9 Future Work

Highlight potential future enhancements to the system, such as:

- Integration with IoT-based appliances.
- Advanced AI algorithms for better prediction accuracy.
- Multi-lingual support for the user interface.

9.10 User Manual

Provide a step-by-step guide for end-users to navigate and use the system, including screenshots where applicable.