Challenge Project: Design and Simulation of a Temperature-Controlled Water Tank System

Objective:

To apply key MATLAB and Simulink concepts in designing, modeling, and simulating a **temperature-controlled water tank** system. The project will require learners to work with data types, plotting, MATLAB enhancement features, anonymous functions, and integrate Simulink modeling using commonly used blocks.

Problem Overview:

You are tasked with modeling a **water tank heating system**. The goal is to control the temperature of water inside a tank based on external input and simulate this system using MATLAB and Simulink. The system should heat the water using a heater element until it reaches a desired temperature. A feedback mechanism will ensure that the temperature stays within a safe range using a control system.

Project Requirements:

The project consists of two main sections: MATLAB coding and Simulink modeling.

Part 1: MATLAB - Pre-Processing and Data Analysis

1. Anonymous Functions & Data Types

- Create an anonymous function to simulate the heating effect based on time and power input.
- Ensure that the function considers power as an input and returns the temperature change. The function should work for both scalar and vector inputs (utilize MATLAB data types effectively).

2. Data Analysis & Plotting

- Define time (in minutes) and power (in watts) vectors, representing different power inputs over time.
- Use MATLAB to calculate and plot the temperature increase in the water tank over time using your anonymous function.
- Ensure to display the temperature plot using proper labels, legends, and titles.

Steps:

- Create a time vector (e.g., 0 to 30 minutes).
- Define the power vector (representing the heating element's power input).
- Use `plot` to visualize the heating process (temperature vs. time).

Expected Output: A line graph showing temperature change over time for different power levels.

3. MATLAB Enhancement: Script Optimization

- Enhance your MATLAB script by creating a user-friendly interface. Prompt the user to enter the desired power levels and time duration using `input` commands.
- Use data validation techniques to ensure that the inputs are numeric and within a valid range.

Part 2: Simulink - Modeling the System

4. Simulink Environment: Modeling the Tank System

- Open Simulink and create a model of the **water tank heating system** using commonly used blocks. The system should include the following components:
  - A **heat source** (heater) that adds energy to the system.
  - A **temperature sensor** to monitor the water temperature.
  - A **control system** that regulates the heater based on feedback from the temperature sensor.
  - A **thermostat control logic** that turns off the heater once the target temperature is reached and turns it on when it drops below a threshold.

Blocks to Use:

- Constant, Gain, Sum, Transfer Function, Saturation, and Scope blocks.
- Implement the thermostat logic using a **Switch block** that simulates turning the heater on/off based on a set-point temperature.

5. Control Logic: Temperature Regulation

- Create a feedback system in Simulink where the current temperature is fed back into the system to regulate the heater's power.
- The heater should turn off when the temperature reaches a user-defined set point (e.g., 80°C), and turn back on when it drops below a certain threshold (e.g., 70°C).

6. Simulink Data Type Management

- Ensure that you manage different data types in Simulink properly. For instance, the input from the sensor should be handled as a double precision value, while control signals can be Boolean.
- Configure blocks to handle appropriate data types and scale your inputs or outputs as needed.

7. Simulink Simulation: System Response

- Run the simulation for a fixed duration (e.g., 30 minutes) and observe the response of the system using a **Scope block**.
- The output should show how the water temperature increases over time and stabilizes when it reaches the desired temperature.

Bonus Section: Advanced Feature - Heat Loss

For an extra challenge, model **heat loss** in the system. Assume that heat is lost to the environment in proportion to the temperature difference between the water and the

surroundings. Add a **transfer function** that simulates this behavior and affects the overall temperature calculation in Simulink.

8. MATLAB-Simulink Integration

- Import the power levels from your MATLAB code into Simulink using the **MATLAB Function block** or **From Workspace block**.
- Use the power data to control the heater element in the Simulink model.

Deliverables:

1. **MATLAB Script**:
    - Well-commented script that calculates temperature over time and allows user input.
    - Graphical plot showing temperature change for varying power levels.
2. **Simulink Model**:
    - A functional model of the water tank heating system with feedback control.
    - Proper usage of data types and blocks in Simulink.
3. **Simulation Output**:
    - Scope plot showing how the temperature is regulated over time.
    - Annotations in the model explaining key blocks and logic.

Key Learning Outcomes:

- **MATLAB Proficiency**: Use of anonymous functions, vectorized operations, plotting, and user input handling.
- **Simulink**: Model creation, block usage, feedback loops, and control systems.
- **System Integration**: Combining MATLAB analysis with Simulink simulation.
- **Control Theory**: Implementing basic control logic (on/off control).

This project gives a comprehensive learning experience, allowing learners to practice and apply all the core concepts they've learned while working toward a functional temperature-controlled system.