

Introduction/Background

Problem Statement :

The current greenhouse management practices suffer from inadequate automation, leading to inconsistent environmental conditions and reduced crop productivity, so a smart greenhouse can be developed to optimize environmental parameters, ensure efficient resource management, and enhance overall crop yield and quality.

Constraints :

Time Constrains: the project duration is 15 weeks, one semester, the limited duration necessitates efficient time management and prioritization of tasks to ensure the successful setup and operation of the system

Budget Constrains: With a limited budget of 6000 Riyals, the design approach will be limited, as such during the concept generation and evaluation a deep understanding of the potential costs is mandatory.

Water Scarcity Constrains: Water is a critical resource for hydroponic systems. However, Saudi Arabia faces significant water scarcity issues, which could impact the reachability of the hydroponic system reaching far places where we are limited to 200 GPD

Power Source Constrains: As per the industrial form, there are farms that are located on remote places where we are limited to a maximum energy consumption of 650 watts-hours due to the use of solar power.

Network Access Constrains: Given the design's care of remote farms that do not have basic infrastructures, it is advised to use fiber optic cable to support long distances, but we are limited to use Ethernet cables due to the Raspberry Pi's lack of support for fiber optic port.

Target Specifications:

- Carbon Dioxide Range (100 – 1500 ppm)
- Temperature Sensors (15 - 55 Celsius)
- Humidity Level Range (50% - 70%)
- Sensors' Response Time (3-5 seconds)
- Water Treatment Range (5-25 GPH)
- pH Level (6-8)
- Power consumption (200 Wh-600 Wh)
- Setup time (10-30 minutes)
- Flow rate (5 to 30 GPM)
- Boot-up time (5-10 seconds)
- Footprint (100 - 1000 square feet)

Project Objective

The primary objective of this system is to create an optimized and self-regulating environment for plant growth within a greenhouse. By integrating intelligent control algorithms, sensors, actuators, and water treatment capabilities, the project aims to ensure optimal conditions for plant growth while maximizing resource efficiency.

Prototype Design

The system utilizes sensors, such as the DHT22, MQ2 and PH, to continuously monitor temperature, humidity CO2 and PH levels within the greenhouse. Based on predefined thresholds, the control system adjusts ventilation, heating, and cooling mechanisms to maintain an ideal growing environment for the plants. In addition, the system uses a water desalination module that removes excess salts and impurities from the water, ensuring optimal nutrient uptake by the plants and preventing soil salinization. Finally, the project includes a user-friendly dashboard that serves as the control center for the greenhouse by providing inputs to the system and monitor the environment conditions of the greenhouse.

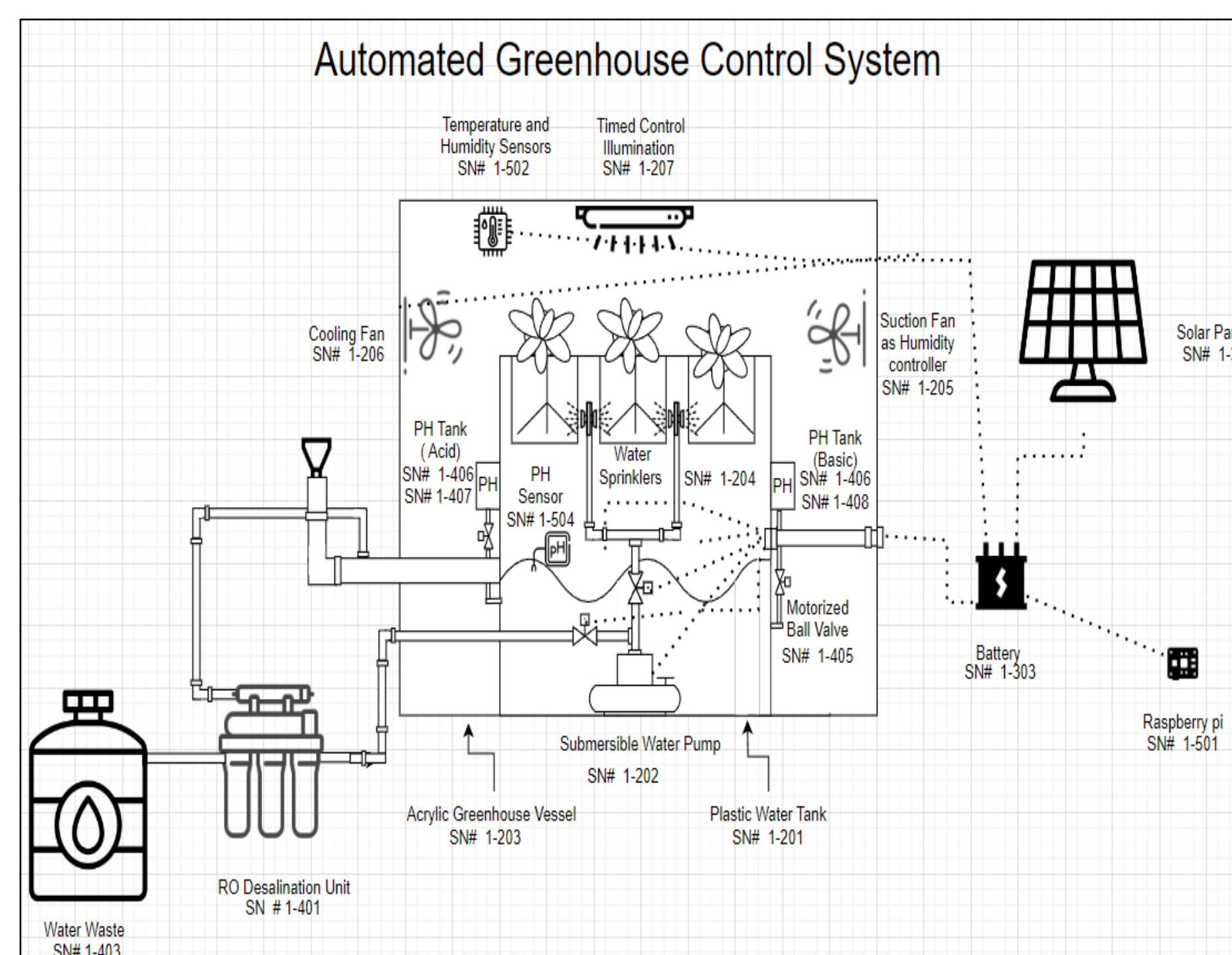


Figure 1. The Full Project Design

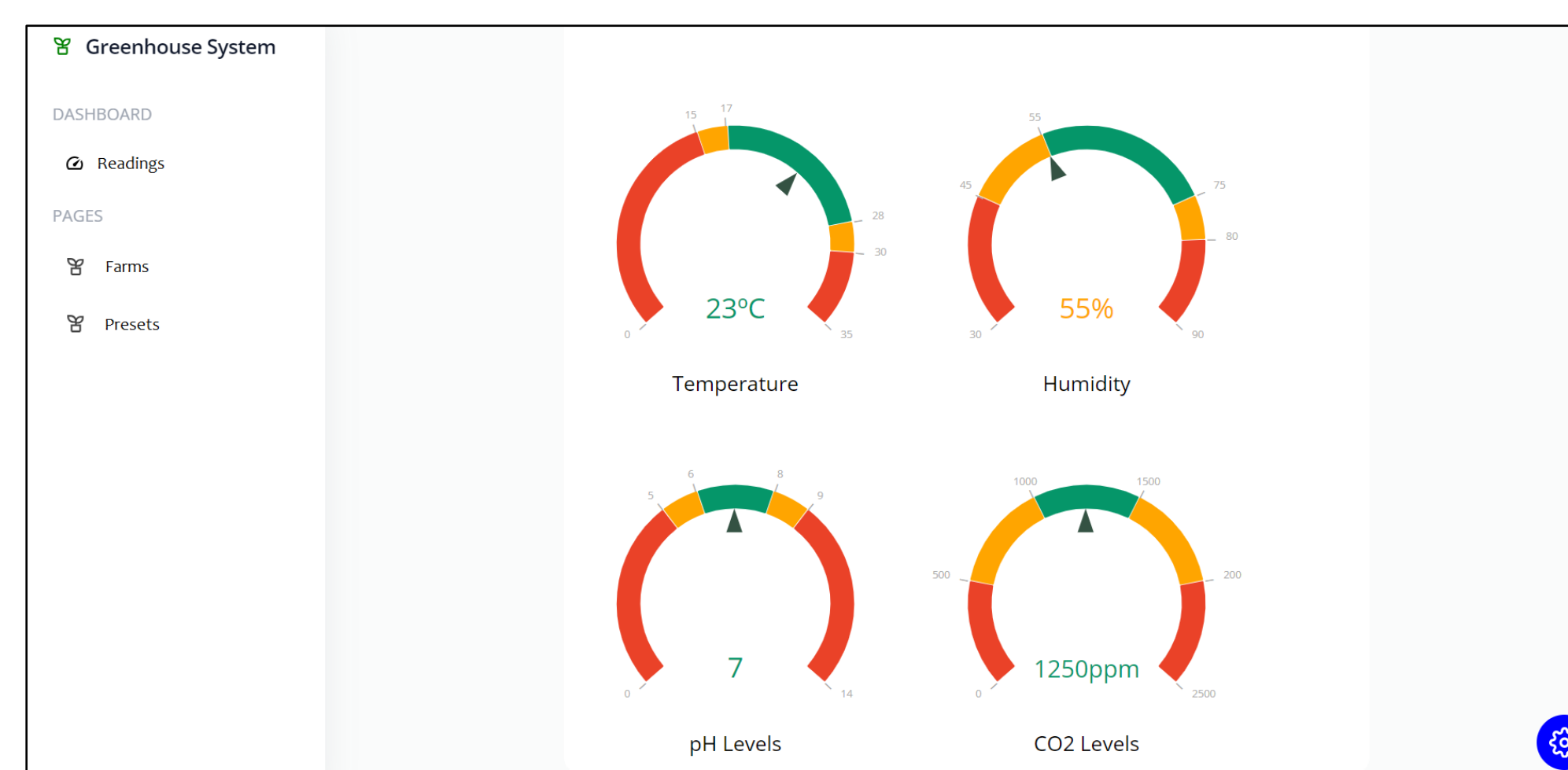


Figure 2. Greenhouse System Dashboard

Testing / Validation

The final greenhouse control system design successfully meets the engineering specifications outlined for the project:

Environmental Control: Control algorithms and PID tuning maintain temperature, humidity, CO2 levels, and other parameters within specified ranges for optimal plant growth.

Fast Sensor Response: The control system architecture provides sensor response times under 5 seconds, enabling prompt system adjustments.

Water Treatment: The designed reverse osmosis system treats water within the specified 5-30 GPH range while meeting targeted salt removal and recovery levels.

Power Consumption: Through energy optimizations, power draw stays within the 200-600Wh daily range to minimize environmental impact.

User-Friendly Interface: The dashboard and screens were refined through usability studies for an optimized user experience.

Reliable Communications: The WebSocket-based architecture provides reliable real-time communications between system components.

Security: Encrypted protocols and access controls prevent unauthorized access per cybersecurity standards.

Structural Integrity: FEA results validate the structural design for stability under environmental loading.

Conclusions

In conclusion, the development of the automated greenhouse control system for our senior project has been a significant achievement. This project aimed to optimize plant growth by providing precise control over crucial environmental factors such as temperature, humidity, lighting, and irrigation.

we successfully designed, implemented, and tested a comprehensive system that effectively monitors and regulates the greenhouse conditions.

The system's success in maintaining optimal environmental conditions has promising implications for agriculture, enabling improved crop yields, resource efficiency, and sustainability. By automating the control processes, we have provided a viable solution to enhance plant growth and productivity in controlled environments.

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