Marwadi University Marwadi Chandarana Group NAAC A+	Marwadi University Faculty of Technology Department of Information and Communication Technology	
Subject: Human Centered Design (01CT0617)	**Aim**: Project Requirement Documentation (CO1, CO2 - PO1, PO2, PO6, PO10, PO11)	
Task - 3	**Date:** 09-03-25	**Enrollment No:** 92200133028 92310133011

Requirements Specification and System Architecture of IOT based Water Tank Device

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1. Introduction

The IoT Water Tank Level Controller project addresses the common challenges of residential water management through an innovative automated monitoring and control system. Using ultrasonic sensors, LoRa wireless communication, and microcontroller-based units, this system provides real-time monitoring of both terrace and underground water tanks while automatically controlling pump operation. Developed through a human-centered design approach, the solution directly responds to user needs identified through extensive research: reducing manual monitoring, preventing tank overflow, eliminating pump damage, and decreasing electricity consumption. The system's modular architecture, featuring solar-powered options and simple user interfaces, creates a sustainable solution that improves quality of life while promoting water and energy conservation.

2. Functional Requirements

2.1 Terrace Tank Level Monitoring Subsystem

ID	Description	Priority	Acceptance Criteria
FR1	The system must measure water level in the terrace tank using an ultrasonic sensor and transmit the data wirelessly.	High	Water level measurements should be accurate within ±1cm and transmitted successfully to the display and pump control units.
FR2	The terrace tank sensor must be powered by solar energy with battery backup.	Medium	The unit should operate continuously for at least 72 hours without direct sunlight when battery is fully charged.
FR3	The terrace tank sensor must transmit water level data at least once every 30 seconds.	High	Data transmission frequency should be verifiable through receiver logs, with timestamps showing updates at 5-minute intervals or less.
FR4	The terrace tank sensor must include a waterproof enclosure for outdoor installation.	High	The unit should maintain functionality after exposure to direct rainfall or water splashes (IP65 rating or higher).

2.2 Underground Tank Level Monitoring Subsystem

ID	Description	Priority	Acceptance Criteria
FR5	The system must measure water level in the underground tank using an ultrasonic sensor and transmit the data wirelessly.	High	Water level measurements should be accurate within ±1cm and transmitted successfully to the display and pump control units.
FR6	The underground tank sensor must be powered by AC supply with DC conversion.	High	The unit should operate continuously when connected to household power supply (220V AC).
FR7	The underground tank sensor must transmit water level data at least once every 5 minutes.	High	Data transmission frequency should be verifiable through receiver logs, with timestamps showing updates at 5-minute intervals or less.
FR8	The underground tank sensor must include an appropriate enclosure for damp environment installation.	High	The unit should maintain functionality in high-humidity environments (IP44 rating or higher).

2.3 User Display Subsystem

ID	Description	Priority	Acceptance Criteria
FR9	The system must receive and display water level data from both terrace and underground tanks simultaneously.	High	Display unit should show data from both tanks, updating within 1 minute of new transmissions.
FR10	The display unit must allow users to set high and low water level thresholds for pump control.	High	Users should be able to adjust thresholds using SET/RESET buttons, with visual confirmation of the new settings.
FR11	The display must show water levels as both numeric values and visual indicators.	Medium	Display should show percentage or height values and include visual elements like bar graphs for quick understanding.
FR12	The display unit must maintain the latest readings during temporary communication failures.	Medium	Display should show the most recent valid reading along with a timestamp or indicator showing data age.
FR13	The display unit must run on household AC power with protection against power surges.	High	The unit should operate continuously when connected to household power and include appropriate surge protection.

2.4 Water Pump Control Subsystem

ID	Description	Priority	Acceptance Criteria
FR14	The system must automatically turn ON the water pump when terrace tank level falls below the user-set threshold AND underground tank has sufficient water.	High	Pump activation should occur within 30 seconds of conditions being met, verified through status indicators and actual pump operation.
FR15	The system must automatically turn OFF the water pump when terrace tank level reaches the user-set high threshold OR underground tank level falls below minimum safe level.	High	Pump deactivation should occur within 30 seconds of conditions being met, preventing overflow or dry running.
FR16	The pump control unit must include a high-capacity relay (40A) suitable for water pump control.	High	Relay should switch standard residential water pumps (up to 2HP) without failure for at least 10,000 cycles.
FR17	The pump control unit must include manual override capabilities for direct pump control.	Medium	Manual override should function regardless of automatic settings, allowing users to force pump ON/OFF when needed.
FR18	The pump control unit must include status indicators showing current pump state (ON/OFF).	Medium	Status indicators should be clearly visible from 2 meters distance in normal indoor lighting conditions.
FR19	The pump control unit must run on household AC power with appropriate protection.	High	The unit should operate continuously when connected to household power and include appropriate circuit protection.

2.5 Communication Subsystem

ID	Description	Priority	Acceptance Criteria
FR20	The system must use LoRa wireless technology to transmit data between all units.	High	Communication should be reliable up to 1km line-of-sight or through typical residential construction (2-3 walls).
FR21	The system must implement message acknowledgment to ensure critical commands are received.	High	Pump control commands must be acknowledged and retried if acknowledgment is not received within 10 seconds.
FR22	The system must use unique identifiers to prevent interference from other nearby systems.	Medium	Each system should have a unique network ID configurable during installation to prevent cross-talk between neighboring systems.

3. Non-Functional Requirements

3.1 Performance Requirements

ID	Description
NFR1	The system must respond to water level changes within 30 seconds of actual change occurring.
NFR2	The pump control system must activate/deactivate the pump within 30 seconds of threshold conditions being met.
NFR3	The ultrasonic sensors must provide distance measurements with an accuracy of ±1cm or better.
NFR4	The display must update within 10 seconds of receiving new data from the sensor units.
NFR5	The maximum end-to-end latency from sensor measurement to display update should not exceed 1 minute under normal operating conditions.

3.2 Reliability Requirements

ID	Description
NFR6	The system must maintain 99% uptime under normal operating conditions (excluding power outages beyond the system's control).
NFR7	The solar-powered terrace unit must operate for at least 72 hours without direct sunlight when the battery is fully charged.
NFR8	The system should detect and alert users to communication failures between components within 15 minutes of failure.
NFR9	The pump control decision logic must prevent rapid cycling of the pump (minimum 3-minute delay between state changes) to protect pump hardware.

ID	Description
NFR10	The system must recover automatically from power outages, resuming normal operation without user intervention.
NFR11	Critical components should have a Mean Time Between Failures (MTBF) of at least 5 years under normal operating conditions.

3.3 Power Consumption Requirements

ID	Description
NFR12	The terrace tank sensor unit's solar panel and battery system must be sufficient to power the unit continuously with average daily sunlight conditions in the target region.
NFR13	The underground tank sensor unit should consume no more than 3W of power during normal operation.
NFR14	The display unit should consume no more than 5W of power during normal operation.
NFR15	The pump control unit should consume no more than 3W of power during normal operation (excluding power used by the pump itself).
NFR16	All AC-powered units must include power-saving modes for components not actively in use.

4. System Architecture

4.1 High-Level Architecture Overview

The IoT Water Tank Level Controller system employs a distributed architecture with four main subsystems communicating via LoRa wireless technology. Each subsystem serves a specific purpose while contributing to the overall system functionality.

4.2 Component Description

4.2.1 Terrace Tank Level Sensor Unit

Microcontroller: ESP32/STM32 or equivalent with integrated LoRa capability

- Processes ultrasonic sensor readings
- Controls LoRa transmission
- Manages power consumption and battery charging

Sensors:

- HC-SR04 or JSN-SR04T ultrasonic distance sensor for water level detection
- Optional temperature compensation sensor for improved accuracy

Power System:

- 5W solar panel
- 3.7V 2000mAh Lithium-ion battery
- TP4056 battery charging and protection circuit
- Low-power management circuitry

Communication:

- RFM95W 868/915MHz LoRa module
- Antenna appropriate for residential installation

Enclosure:

- IP65 rated waterproof case
- Mounting hardware for tank installation

4.2.2 Underground Tank Level Sensor Unit

Microcontroller: ESP32/STM32 or equivalent with integrated LoRa capability

- Processes ultrasonic sensor readings
- Controls LoRa transmission
- Manages power and operation modes

Sensors:

- HC-SR04 or JSN-SR04T ultrasonic distance sensor for water level detection
- Optional temperature compensation sensor for improved accuracy

Power System:

- AC to DC power supply (220V AC to 5V DC)
- Power filtering and protection circuitry

Communication:

- RFM95W 868/915MHz LoRa module
- Antenna appropriate for underground/indoor installation

Enclosure:

- IP44 or higher rated moisture-resistant case
- Mounting hardware for tank installation

4.2.3 User Display Unit

Microcontroller: ESP32/STM32 or equivalent with integrated LoRa capability

- Processes and displays tank level data
- Manages user interface and controls
- Stores user preferences and system settings

Display:

- OLED 1.3" or 0.96" 128x64 pixel display
- Status LEDs for system state indication

User Interface:

- SET/RESET buttons for threshold configuration
- Optional additional control buttons for system management

Power System:

- AC to DC power supply (220V AC to 5V DC)
- Power filtering and protection circuitry

Communication:

- RFM95W 868/915MHz LoRa module
- Antenna appropriate for indoor installation

Enclosure:

- Indoor-rated plastic case
- Wall-mounting options

4.2.4 Pump Control Unit

Microcontroller: ESP32/STM32 or equivalent with integrated LoRa capability

- Processes tank level data and makes pump control decisions
- Manages relay operation and safety features
- Implements pump protection algorithms

Relay System:

- 40A power relay suitable for water pump control
- Relay driver circuitry with optical isolation
- Snubber circuit for inductive load protection

User Interface:

- Status LEDs for pump state indication
- Manual override switch for direct pump control

Power System:

- AC to DC power supply (220V AC to 5V DC)
- Power filtering and protection circuitry
- Surge protection for pump switching

Communication:

- RFM95W 868/915MHz LoRa module
- Antenna appropriate for installation location

Enclosure:

- IP44 or higher rated enclosure
- Wall-mounting options near pump installation

4.3 Communication Architecture

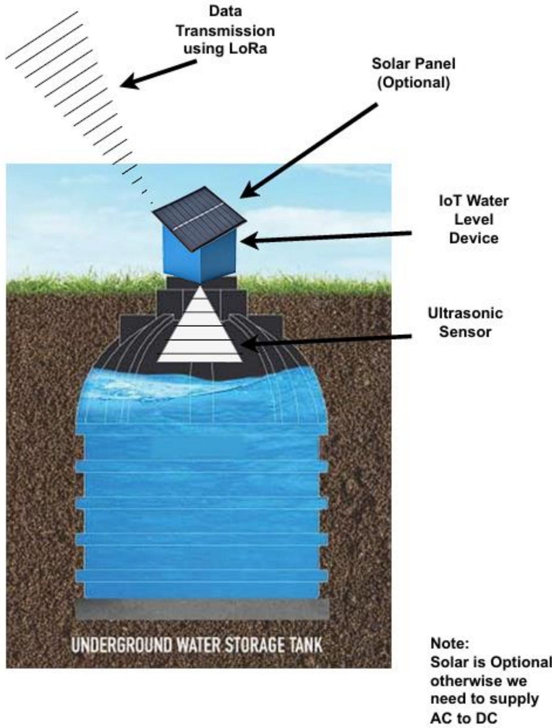
The system uses a star network topology with bidirectional communication:

1. **Sensor Units (Transmitters):**
   - Terrace Tank Level Sensor
   - Underground Tank Level Sensor
2. **Control Units (Receivers):**
   - User Display Unit
   - Pump Control Unit

Communication Protocol:

- LoRa wireless technology (868/915MHz frequency band)
- Simple message structure with:
  - Sender ID
  - Message type (data, command, acknowledgment)
  - Payload (measurements, status, or commands)
  - Error detection/correction
- Acknowledgment system for critical commands
- Periodic heartbeat messages to verify system operation

4.4 Data Flow



1. Sensor Data Collection:

- Ultrasonic sensors measure distance to water surface
- Microcontrollers convert distance to water level percentage
- Data is formatted for transmission

2. Data Transmission:

- Sensor units transmit data via LoRa
- Transmission occurs periodically (every 30 seconds) or upon significant changes

3. Data Reception and Processing:

- Display and pump control units receive data
- Data is validated and processed
- Water levels are calculated and compared to thresholds

4. User Interface:

- Display unit shows water levels
- Status indicators show system state
- User input is processed for threshold settings

5. Pump Control Logic:

- Decision algorithm evaluates tank levels against thresholds
- Safety checks are performed (prevent dry running, etc.)
- Pump relay is activated/deactivated based on decision

6. Feedback Loop:

- Pump action affects water levels
- Changed levels are detected by sensors
- Updated data flows through the system

4.5 Control Logic

The pump control logic follows this decision tree:

1. **Pump Activation Conditions (ALL must be true):**
   - Terrace tank level is below user-set minimum threshold
   - Underground tank level is above minimum safe level
   - Pump has not cycled within minimum protection time period
   - No system errors or safety conditions are present
2. **Pump Deactivation Conditions (ANY can trigger):**
   - Terrace tank level reaches user-set maximum threshold
   - Underground tank level falls below minimum safe level
   - Manual override is activated (OFF position)
   - Safety condition is detected (power issue, communication failure)
3. **Safety Features:**
   - Minimum cycle time enforcement to prevent pump damage
   - Dry-run protection based on underground tank level
   - Overflow prevention based on terrace tank level
   - Communication failure detection and safe state default

4.6 Power Management Architecture

Terrace Tank Unit (Solar Powered):

- Solar panel charges battery during daylight
- Battery management system prevents overcharging/deep discharge
- Low-power sleep modes during inactivity periods
- Wake-up scheduling for sensor readings and transmission

AC-Powered Units:

- Regulated power supplies with appropriate filtering
- Surge protection on AC input
- Power-efficient component selection
- Sleep modes for microcontroller during inactive periods

4.7 Physical Architecture

Terrace Unit Installation:

- Mounted securely at top of water tank
- Ultrasonic sensor positioned for direct line to water surface
- Solar panel oriented for maximum sunlight exposure
- Weather-protected enclosure

Underground Unit Installation:

- Mounted securely at top of underground tank
- Ultrasonic sensor positioned for direct line to water surface
- Wired power connection with appropriate protection
- Moisture-resistant enclosure

Display Unit Installation:

- Wall-mounted in convenient indoor location
- Positioned at eye level for easy reading
- Accessible for user interaction
- Connected to household power supply

Pump Control Unit Installation:

- Located near water pump and electrical supply
- Secured in weather-appropriate enclosure

- Accessible for maintenance
- Connected to both power supply and pump circuit

4.8 Technology Stack

Hardware:

- STM32 or equivalent microcontrollers
- RFM95W LoRa modules for wireless communication
- HC-SR04/JSN-SR04T ultrasonic sensors
- OLED displays and status LEDs
- 40A relay module for pump control
- Solar charging and battery management systems

Software/Firmware:

- STM32Cube and Microvision keil for development
- FreeRTOS for task management
- LoRa library for communication
- Power management libraries
- LCD/OLED libraries for display control

Development Tools:

- STM32Cube, Keil
- Circuit design tools (KiCad, Proteus)
- 3D design tools for enclosures

5. Conclusion

The IoT Water Tank Level Controller system architecture and requirements presented in this document provide a comprehensive foundation for developing a reliable, user-friendly solution for automated water management in residential settings. The system's modular design, wireless communication capabilities, and thoughtful integration of power management strategies ensure it will meet the identified user needs while providing a sustainable, long-term solution.

The detailed functional and non-functional requirements establish clear development targets and evaluation criteria, while the system architecture provides a blueprint for implementation. Together, these elements form a complete specification that balances technical feasibility with user-centered design principles, resulting in a solution that will significantly improve residential water management while promoting conservation and efficiency.