Design Report:

Grand Valley Irrigation Company Automated Control Valve

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Contents

Executive Summary

The Grand Valley Irrigation Company (GVIC) Automated Control Valve Project is a senior capstone engineering initiative focused on modernizing irrigation infrastructure in Colorado's Grand Valley. GVIC currently operates a 100-mile canal system serving approximately 40,000 acres of agricultural land, relying on outdated, manually operated valves to manage water flow. These manual systems are labor-intensive, imprecise, and prone to inefficiencies that impact water conservation and distribution.

To address these challenges, the project team designed and prototyped a solar-powered, automated valve control system tailored for GVIC's open-ditch irrigation network. The system integrates a submersible level sensor, a 24V brushless DC motor for gate actuation, long-range radio communication, and a Siemens HMI for monitoring and control. Unlike commercially available SCADA-based systems, this solution is designed to be standalone, cost-effective, and suitable for remote rural applications.

Key features of the prototype include:

- Accurate water-level sensing within ±1% error using the Campbell Scientific CS451 sensor;
- Motorized valve operation capable of full actuation within 2 minutes;
- Radio communication over 0.5 miles for real-time gate control;
- User-friendly interface for manual and automated operation.

The prototype performed reliably in laboratory and limited field tests, validating most core system requirements. Challenges encountered included integration of the radio system with the PLC and limitations due to the lack of solar panel installation. Future improvements focus on full field deployment, weatherproofing, app and AI integration, and commercialization viability.

This project not only reduces manual labor and enhances water efficiency for GVIC but also lays the foundation for broader adoption of low-cost, smart irrigation solutions in similar agricultural communities.

Problem Definition

Introduction

Grand Valley Irrigation Company (GVIC) is a non-profit mutual irrigation company that plays a crucial role in water management for Colorado's Grand Valley. Established in 1882, GVIC privately owns and operates the Grand Valley Canal system, which extends nearly 100 miles. This extensive system is responsible for delivering irrigation water to approximately 40,000 acres of agricultural land, covering areas from Palisade to Mack.

GVIC's responsibilities include managing several key waterways, including the Mainline, Highline (not to be confused with the Government Highline Canal), Kiefer Extension, Mesa County Ditch, and the Independent Ranchmen's Ditch. It is important to note that GVIC is one of six major irrigation providers in the Grand Valley that collectively supply water to about 85,000 acres.

GVIC's primary function is to convey and deliver irrigation water to its shareholders. The infrastructure—consisting of ditches, roads, bridges, and headgates—is privately owned and maintained by GVIC. This infrastructure supports efficient and reliable water delivery, which is essential for sustaining the region's agricultural productivity.

Overall, GVIC is a vital organization in the region's agricultural economy, responsible for managing large volumes of water and delivering it to thousands of acres of farmland. Their role ensures that water resources are used effectively and that local farmers have consistent access to the water they need for crop irrigation.

GVIC seeks to modernize its water management infrastructure by implementing an automated control valve system for its open ditch canals. The project entails designing a system that efficiently regulates water flow to a concrete storage box, which supplies water to local farmers and residents. Currently, the manual operation of the control valve gate requires frequent travel between the water storage box and the control valve and is susceptible to errors. The manual control valve could cause issues like not optimizing water usage, and it is also susceptible to having too much water, causing an overflow, or not enough water, causing the residents to stop receiving water.

Background

Traditionally, control valves that regulate water flow through canals have been manually operated, requiring frequent on-site adjustments by farmers or other water users. This manual process is time-consuming, labor-intensive, and prone to human error, which can result in inefficient water usage. GVIC Superintendent Phil Bertrand and Assistant Superintendent Charles Guenther have identified an opportunity to modernize the system to reduce operational inefficiencies and labor demands, while also ensuring precise water management to meet the needs of stakeholders.

In the current market for automated control valves, several companies—such as Rubicon Water and Watch Technologies—offer solutions that typically rely on Supervisory Control and Data Acquisition (SCADA) systems for remote monitoring and control. SCADA is an industrial control system that enables centralized data collection and equipment management across geographically distributed infrastructure.

This project proposes a unique automated gate system that integrates solar power with existing valve infrastructure. The design is specifically tailored for rural and agricultural users who need a cost-effective, standalone solution for remote gate control without relying on SCADA infrastructure. The proposed system employs radio communication, enabling users to open and close irrigation gates from a distance with greater ease and flexibility. This makes it particularly suitable for rural applications where centralized infrastructure may be limited or unnecessary, offering a practical and accessible alternative to traditional and existing market solutions.

Literature Review

A notable example of innovation in this field is Watch Gate Technologies' line of smart gates [1][3]. These fully integrated, automated sluice gates are designed to handle both light and heavy lifting applications, demonstrating their versatility in diverse operational environments. The gates are equipped with programmable actuators that allow for both stand-alone functions, such as level or flow control, and integration within SCADA networks. This adaptability provides precise control over gate operations, making them suitable for modern automated systems requiring independent functionality and networked communication. The Watch Technologies gate can be seen in figure 1. Another example would be the Rubican Water linearly-actuated gates seen in figure 2. These would be hard to integrate with the project goals as the gate received has a turn handle to change the height of the gate as seen in figure 3.

Figure 1. Watch Technologies SMART SLUICE GATES.[3]

Figure 2. Rubicon Water linear-actuated gate at CSU research center.

Figure 3. GVIC modified Fresno Valve for extra extension and accessories.

Problem Scope

This project aims to design and implement an automated control valve system that will streamline the operation of existing manual irrigation gates—typically the Series 6600 Model 101C Slide Gate—along the Grand Valley Canal system. These gates currently require manual adjustment to regulate water flow into concrete collector boxes that supply irrigation water to local farms and residences. The proposed automation system will include a motorized actuator to control the gate, paired with a level sensor that monitors the water level within a concrete collector box located up to half a mile away. By continuously monitoring water levels, the system will adjust the gate position in real time to maintain optimal flow through the canals, benefiting both GVIC and the local agricultural community that depends on a consistent and reliable water supply.

Risk

One way to make sure a project goes as smoothly as possible is to make and analyze a risk matrix like the one seen in figure 4. The risk matrix wages the likelihood of the risk with the severity of the impact and makes a score based on the product of those two scores. Sourcing key components in time and integration errors are the biggest risks, so a mitigation strategy needs to be integrated. To decrease the likelihood of these risks the parts should be ordered far before hand if possible. Precise measurements and fabrication needs to be done to decrease the risk of integration.

Identify and Assess Risks				Risk Mitigation			
Description of risks and potential impact on individuals	Likelihood of Risk	Severity of Impact	Risk Rating	Describe mitigation measure(s) to reduce likelihood and/or severity of harm	Post-Mitigation		
					Likelihood of Risk	Severity of Impact	Residual Risk Rating
Delays in sourcing key components could push back the project timeline.	3	2	6	Identify multiple suppliers early and place orders with lead time buffers.	2	2	4
The motor may not provide sufficient torque for the gate operation.	1	2	2	Perform detailed torque calculations and test motor performance before finalizing the choice.	1	2	2
The power system might not meet the energy needs of the gate and sensors.	1	3	3	Conduct energy consumption analysis and consider backup power options early in the design process.	1	3	3
Components like sensors, motor, and power system may not integrate smoothly, causing delays.	2	3	6	Prototype component integration early to identify and resolve compatibility issues.	1	3	3
Solar panels may not generate sufficient power due to inconsistent sunlight or weather conditions.	2	1	2	Design the system with battery storage and assess the feasibility of hybrid power sources to ensure continuous operation.	1	1	1

Figure 4. Risk matrix

Stakeholder Analysis

The primary stakeholders in this project are the Grand Valley Irrigation Company (GVIC), local farmers and residents, and the student project team.

Although GVIC is directly involved in the project, Tom Benton, Director of the CMU Innovation Center and the project sponsor, initiated the request to improve water distribution infrastructure. GVIC, as the water delivery service provider, will benefit from improved system efficiency but assumes minimal risk, as it will not be responsible for purchasing or installing the proposed equipment.

The project team is responsible for designing and prototyping a long-lasting and reliable automated valve control system. The design must function in various weather conditions and demonstrate sufficient performance and ease of use to attract future buyers. Because similar systems are not readily available on the market in a standalone, solar-powered configuration without SCADA dependency, the development of a functional and demonstrable prototype could lead to potential commercialization. Therefore, the creation of a working system capable of being showcased is a critical step.

Farmers and residents represent the largest stakeholder group. The automated system is designed to reduce the manual labor required to regulate water levels, provide real-time monitoring capabilities, and enable more efficient water distribution, resulting in potential cost savings. However, this group assumes greater risk, as they will be responsible for system installation and maintenance. A system malfunction or improper installation could negatively impact their water supply. Additionally, since the end users are also expected to purchase the system, the cost-to-value ratio must be carefully considered.

Project Goals

The primary goal of this project is to design and implement an automated control valve system that reduces manual labor and increases irrigation efficiency for users of the Grand Valley Canal system. The system will use a level sensor to monitor water levels in a collector box and communicate with a motorized gate to automatically regulate water flow.

- **Specific:**
  Develop and install an automated control valve system equipped with a level sensor and a motor-driven gate for irrigation canals managed by the Grand Valley Irrigation Company. The system is intended to improve water level management and reduce the need for manual intervention.
- **Measurable:**
  Reduce manual labor time by 75% from the current average of 30 minutes per operation. The system will monitor and maintain water levels continuously over a 24-hour period to ensure consistent irrigation.
- **Achievable:**
  This goal will be achieved by utilizing existing valve technologies, including proven actuator systems and sensors, while following a structured process of design, testing, and implementation to meet functional and environmental constraints.
- **Relevant:**
  The system aligns with GVIC's broader mission to enhance water management and reduce operational costs for the agricultural community. Automating valve control will directly support more effective and resource-efficient irrigation practices.
- **Time-bound:**
  The project will be completed over the course of two academic semesters, with final delivery scheduled for May 2025, including all design documentation, system testing, and prototype demonstration.

Deliverables

- **Design:**
  A complete set of engineering schematics, component specifications, and control system documentation.

- **Prototype:**
  A functional, full-scale prototype of the automated control valve system.

- **Documentation:**
  User manuals, maintenance guides, and troubleshooting documentation tailored to non-technical users.

- **Training:**
  Hands-on training sessions for the sponsor (Tom Benton) and GVIC staff, covering installation, operation, and maintenance procedures.

Requirements

Level Sensor

- **Requirement:** Accurately measure water depth in inches with a margin of error no greater than ±1%.

- **Technical Specification:** The selected sensor is the *Campbell Scientific CS451*, a high-accuracy, submersible pressure transducer capable of real-time water level monitoring. It outputs both SDI-12 and RS-232 signals, compatible with the control system for seamless integration and data collection.

Motor-Driven Gate

- **Requirement:** Retrofit an existing Series 6600 Model 101C Slide Gate with a motorized actuator capable of full open/close actuation within two minutes, while operating reliably in subfreezing and snowy conditions.

- **Technical Specification:** The selected actuator is a *24V brushless DC motor* with sufficient torque to overcome the gate's breakaway force. The motor will include environmental protection features, integration with sensor feedback, and a manual override mechanism for power outages or emergencies.

Communication System

- **Requirement:** Maintain reliable data transmission between the level sensor and the gate actuator over a distance of up to 0.5 miles.

- **Technical Specification:** The communication system consists of a *Campbell Scientific RF401A radio module* paired with a *CR206X datalogger/controller*. Operating at 900 MHz, this system enables low-power, robust, long-distance wireless communication with minimal latency, and is well-suited for rural field environments.

Power Supply

- **Requirement:** Sustain system operation using solar power with 12V DC output and battery storage.
- **Technical Specification:** The system will incorporate high-wattage solar panels and 12V lithium-ion battery banks. This configuration supports energy efficiency, low maintenance, and off-grid operation, with enough capacity to handle cloudy conditions and nighttime operation.

Float Assembly

- **Requirement:** Mechanically detect water level changes and interact with the control system to adjust gate position as needed.
- **Technical Specification:** The float mechanism will be mechanically linked to the sensor housing and tuned to detect gradual changes in water level, providing consistent inputs to the control system for real-time adjustment. The float must withstand continuous exposure to water and debris.

System Learning and Adaptation

- **Requirement:** Implement adaptive logic to "learn" how water demand patterns change based on float rate and environmental factors.
- **Technical Specification:** Control algorithms embedded in the CR206X controller will analyze historical water level data and float rates to anticipate demand fluctuations. Adaptive controls will refine gate response times and improve long-term flow efficiency.

Overall Approach

- **Design Integration:** Ensure full compatibility among all components—level sensor, actuator, communication modules, and power supply—to support seamless system performance.
- **Testing and Validation:** Each system component will undergo individual and integrated system testing under simulated environmental conditions to confirm functionality and reliability.
- **Documentation and Training:** A detailed operations manual will be created, along with instructional materials for installation, maintenance, and troubleshooting. Training sessions will be conducted to prepare end users for independent operation of the system.

Budget and Timeline

The team was tasked with keeping the project budget to a minimum. The original estimated costs vs the actual costs can be seen in Table 1. The teams project timeline can be seen in figure 6.

Table 1-Estimated Project Budget

Spending Category	Estimated costs ($)	Actual Costs ($)	Difference ($)

Level sensor	$500.00	$0.00	$500.00
Motor	$100.00	$83.11	$16.89
PLC	$200.00	$85.41	$114.59
Raw Materials	$75.00	$56.00	$19.00
Eletrical Components	$120.00	$31.55	$88.45
Fabrication	$20.00	$0.00	$20.00
Communication Deivice	$100.00	$0.00	$100.00
Fasteners	$40.00	$36.25	$3.75
Miscellaneous	$100.00	$417.56	-$317.56
Solar panels	$300.00	n/a	n/a
Total	$1,555.00	$709.88	$845.12

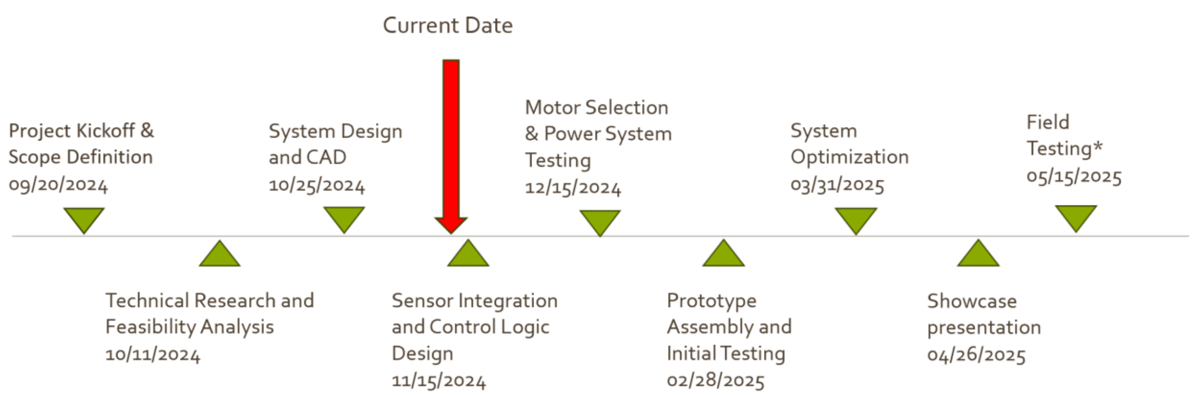

Figure 6. Timeline for project

Standards

For the design of the automated control valve system, several engineering standards must be considered to ensure safety, reliability, and effectiveness. One key standard that applies is ANSI/ISA-75.05.01-2000, developed by the International Society of Automation (ISA). This standard outlines the requirements for control valve sizing, which ensures that the selected valve can handle the expected water flow rate and pressure. Adhering to this standard guarantees that the valve is appropriately sized to regulate water efficiently, avoiding potential issues like overpressure or insufficient flow.

These standards will be addressed by carefully selecting components that comply with the sizing and communication requirements, conducting simulations and tests to verify that the system performs within the standard's parameters, and documenting the design process to ensure full compliance with these industry guidelines.

Impacts

Global Impacts

The automated control valve system for Grand Valley Irrigation Company primarily affects water management efficiency for the Grand Valley Area. While the immediate impact is localized, the project contributes to global sustainability efforts by promoting efficient water usage. By reducing water waste and optimizing distribution, the system can serve as a model for similar irrigation projects in other regions. The team will evaluate whether the system could be scaled to more communities.

The project is expected to yield significant economic benefits by reducing labor costs associated with manual valve operation and minimizing water wastage, thereby lowering operational expenses for local farmers and residents. Additionally, efficient water distribution can enhance agricultural productivity, leading to increased revenues for local farmers. The development and potential commercialization of the automated control valve system may also create business opportunities for the team. The team should make a cost-effective system so that local farmers and residents find it worth buying.

The automated value control system is expected to help optimize water usage, which will help with the issue of water waste. The use of energy-efficient components and solar panels is ideal as well because it contributes to an environmentally friendly design.

The project significantly impacts the local community by ensuring a reliable and efficient water supply for farmers and residents, which is essential for agriculture, household use, and overall quality of life. By automating water distribution, the system reduces the physical labor required to manage water flow, allowing community members to allocate their time to other productive activities. The team needs to consider making a detail-rich instruction and troubleshooting manual that the farmer and residents can use so they have fewer problems.

Economic Impacts

Automating irrigation systems can significantly reduce labor costs for farmers and water management companies. Additionally, improved water flow efficiency leads to savings in water usage, resulting in lower operational costs. The ethical responsibility of the team includes ensuring that the system provides cost benefits without imposing high upfront expenses or maintenance fees. Judgments about the economic impact must balance short-term costs with long-term savings and affordability for users of all economic levels.

Societal Impacts

From a societal perspective, the system alleviates the manual labor required by local farmers and residents, allowing them to focus on other productive activities. This improves quality of life and increases access to a reliable water supply. The ethical responsibility in this case lies in ensuring the system is user-friendly and accessible to all, particularly to those with limited technological experience. Judgments here must prioritize inclusivity and community benefit, ensuring that all segments of society can benefit from technology.

Environmental Impacts

The system directly impacts the environment by optimizing water usage, reducing waste and conserving a precious natural resource. This contributes to better irrigation practices and a reduced environmental footprint. The team is ethically obligated to design the system using environmentally sustainable materials and power sources, such as solar energy. Informed decisions must weigh the environmental benefits of reduced water consumption against any potential harm from the system's production or energy use.

Design Description

Overview

The proposed design for the automated gate control system features a streamlined direct-drive configuration, eliminating the need for intermediary components like nuts or additional linkages. This design choice ensures an efficient and durable connection between the actuator and the gate mechanism, enhancing overall performance and reducing potential points of failure. By removing the nut interface, the direct-drive system provides robust torque transfer from the actuator to the gate, allowing for precise gate position control with minimal mechanical loss.

In this system, a chain and handle mechanism are directly driven by the actuator, bypassing any intermediate components. The chain drive enables reliable force transmission, while the handle provides a manual override option for cases of power loss or system maintenance. This design choice allows for both automated and manual control, adding versatility and reliability to the system.

Opting for a direct-drive system that eliminates the original nut drive offers several key benefits. With fewer moving parts, the system requires less frequent maintenance, reducing overall maintenance needs. Additionally, the direct connection enables precise control over gate adjustments, which is essential for maintaining desired water levels in irrigation applications. This simplified design also streamlines assembly, making installation faster and more cost-effective. Overall, the direct-drive configuration provides a durable, efficient, and precise solution for automated gate control, aligning with the project's goals of improving operational efficiency and reducing manual labor.

The control box in the automated gate control system houses critical components that enable precise monitoring and control of water levels within the irrigation canal. A central feature of the control box is a 12-VDC level sensor with an analog output, specifically chosen to measure the water level in real time and relay this information to the control system. This level sensor is essential for achieving accurate control over gate positioning, as it continuously monitors water levels and provides feedback to the motor controller.

The analog output of the level sensor delivers a continuous signal proportional to the water level, which allows the system to make gradual adjustments to the gate position based on small fluctuations in water levels. This approach ensures a smooth and responsive control mechanism, reducing the chances of overshooting target levels and enhancing the system's ability to maintain optimal water flow.

A SOLIDWORKS assembly of the prototype that will be used for the student showcase is seen in figure 7. This prototype will serve as a proof-of-concept design that will need to be further improved upon to make it a working product for consumers. The front view of the rough internals of the box can be seen in figure 8.

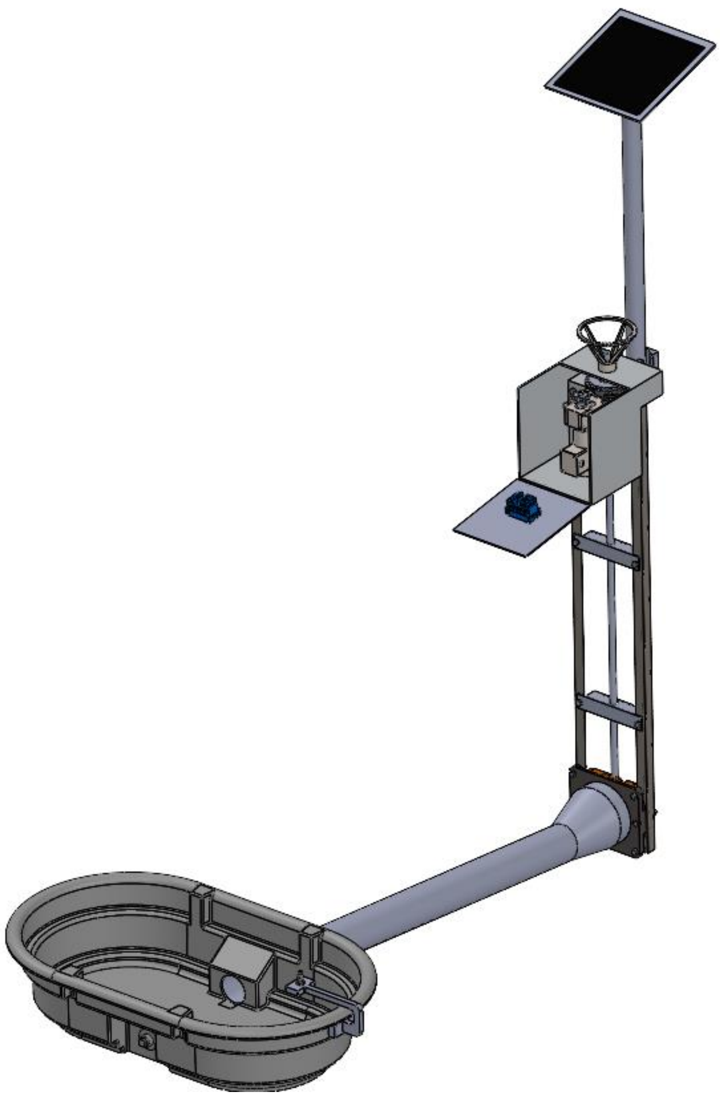

Figure 7. Automate gate and control box assembly for Student Showcase.

Detailed Descriptions

In the automated gate control system, a robust and reliable bidirectional motor is the primary actuator, providing the force required to open and close the gate. The motor, specified with a power range of 1/4 to 1/2 horsepower and operating at 12 volts DC (VDC), is optimized to deliver sufficient torque for the gate mechanism while ensuring compatibility with low-voltage, renewable power sources. This 12-VDC motor is powered by a 12-volt battery system which is charged by a solar panel array. The choice of a solar-powered battery setup is essential for field applications where access to grid electricity may be limited or nonexistent. By using solar energy to maintain battery charge levels, the system is designed to operate continuously and autonomously, reducing the need for frequent manual intervention or external power sources.

To ensure reliable and efficient torque transfer, the design incorporates American National Standards Institute standard chain gearing. The ANSI standard ensures compatibility, durability, and ease of replacement for the chain and sprockets used in the mechanism. This standardization is crucial for maintaining consistent performance, as the chain gearing directly translates the motor's rotational force to the gate control system. The ANSI chain's rugged design is well-suited for outdoor environments and can withstand the wear associated with repeated cycles, further enhancing the reliability of the gate control system.

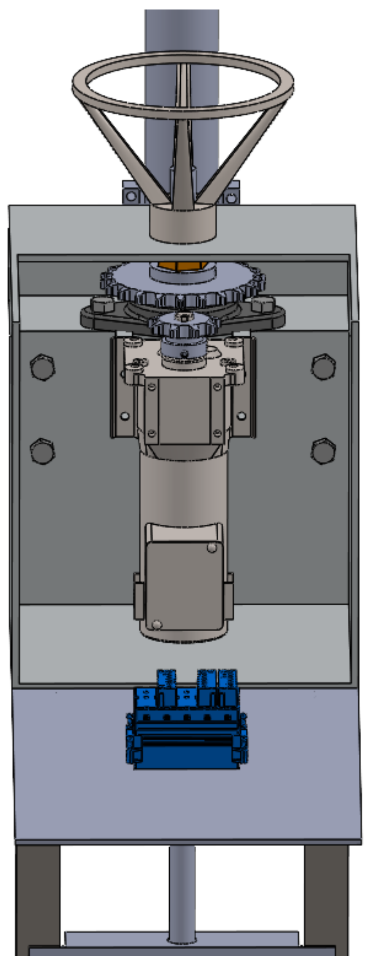

Figure 8. Gate actuator drive system

A key component of the control interface is the Siemens KTP600 HMI (Human Machine Interface) panel. The KTP600 provides a user-friendly interface for operators, allowing them to monitor system status, adjust settings, and manually control the gate if needed. The Siemens KTP600's compatibility with 12-VDC systems and its programmable interface makes it ideal for integration with our automated gate system. Through this HMI, users can set parameters, view real-time data, and perform diagnostic checks, all of which enhance the system's usability and ensure smooth operation. Additionally, the Siemens HMI allows for integration with Supervisory Control and Data Acquisition (SCADA) systems, providing remote monitoring and control capabilities that are valuable for larger, distributed irrigation networks.

Together, these components form a cohesive system designed for remote, solar-powered operation. The bidirectional 12-VDC motor provides reliable actuation, while the ANSI standard chain gearing ensures efficient force transmission. The Siemens KTP600 HMI enhances the system's accessibility and control, supporting local and remote management. This combination of components aligns with the project's goals of reducing manual labor, improving irrigation control, and creating a sustainable, low-maintenance solution.

Design Evaluation

Evaluation Overview

The evaluation of our autonomous, remote irrigation control valve focused on five core technical requirements: accurate water level sensing, reliable valve actuation via DC motor, robust wireless communication, adaptable power supply, and environmental durability. These requirements were tested through a combination of experimental trials using a physical prototype, sensor calibration validation, and remote communication tests in an outdoor setting.

Testing involved the use of the CS451 pressure transducer for level sensing, connected to a CR206X datalogger with RF401A radio modules for communication. Additional evaluation of actuation response, torque limitations, and environmental durability was carried out on the assembled prototype. Testing was conducted under realistic use-case conditions to simulate actual field deployment.

Table 1 summarizes the core requirements, target performance objectives, and methods used to evaluate each criterion.

Table 1. Summary of Design Requirements, Objectives, and Test Methods

Requirement	Target Objective	Test Method
Level Sensor Accuracy	Measure water depth with ±1% error margin	Bench testing in a calibrated water tank
Motorized Gate Actuation	Full open/close actuation within 2 minutes under normal conditions	Timed actuation tests in controlled indoor settings

Requirement	Target Objective	Test Method
Wireless Communication	Reliable data transmission up to 0.5 miles	Field testing in open and obstructed rural environments
Power Supply Operation	Ability to be powered by 12VDC solar-powered operation with battery backup	12 and 24 VDC outputs for all power needs measured with voltmeter.
Environmental Protection	Operate outdoors in varied weather for 1 year without major repair.	Weather exposure test (rain, dust, heat simulation)

Evaluation of Design Criteria

1 Level Sensor Evaluation

Purpose:
The evaluation focused on verifying that the Campbell Scientific CS451 level sensor accurately measured water levels within a ±1% error margin.

Test Methods and Materials:
A bench test was performed using a calibrated water tank. Water levels were adjusted manually, and sensor outputs were recorded. The measured values were compared with precise manual measurements taken with a calibrated ruler.

Results:

After doing the tests the results yielded positively, the level of the water collected by the CS451 transducer was very accurate.

Discussion:

It was hard to collect numbers within 1% but the numbers that the CS451 output were accurate up to 0.1 inches which is plenty for this specific application. In this application the level sensor only needs to be accurate by about ±0.5 inches, so if a cheaper level sensor could be implemented it would be a massive improvement.

2 Motorized Gate Evaluation

Purpose:
To confirm that the retrofitted Series 6600 Model 101C Slide Gate, actuated by a 24V brushless DC motor, could open and close reliably within two minutes under standard operating conditions.

Test Methods and Materials:
Timed actuation tests were conducted in a controlled indoor environment. The gate was cycled repeatedly while its open/close time was recorded using a high-resolution timer. Tests simulated normal operating conditions by varying the load and checking the repeatability of the motor response.

Results:

Based on the 2-minute threshold this test was a success. The motor with the gate integration raised and closed in just under 2 minutes at about 1 minute and 45 seconds. The exact time varied between tests, but every test was under the 2-minute threshold.

Discussion:

Being able to open and close under 2 minutes is a key thing to know for this project because when the gate is fully open water fills up the concrete box fast so having the capability to close fast is very important.

3 Wireless Communication Evaluation

Purpose:
To ensure robust, long-distance data transmission between the control box and the gate actuator over distances up to 0.5 miles.

Test Methods and Materials:
Field tests were conducted by establishing radio communication using the RF401A module and CR206X controller in both open line-of-sight and partially obstructed settings. Data packets were transmitted and monitored for loss and latency.

Results:
The RF401A and CR206X were able to communicate and transmit data across large distances, but the RF401A couldn't fully integrate with the PLC.

Discussion:

Future testing with radio communication needs to be done. The radio needs to be able to receive the output data from the CR206X and communicate to the PLC.

4 Power Supply Evaluation

Purpose:
To validate that the solar panel and 12V lithium-ion battery configuration could provide continuous, autonomous operation, including efficient recharge cycles.

Discussion:

Unfortunately, the solar system was not able to be implemented. The team was not able to purchase and integrate the solar panels. This is an improvement that could be implemented into future plans with the project.

5 Environmental protection

Purpose:
Be able to have continuous operation with no problems in a variety of different weather conditions for 1 year without any major repairs

Test Methods and Materials:
Conduct several different experiments to simulate different weather conditions such as rain, hot weather, dust, and others to confirm that the design is robust enough to withstand them.

Results:
The design worked with the small amount of testing done in this category. It worked without fail in rain, dust, and hot conditions

Discussion:
More time is needed to fully test this. Repeated exposure to the elements might affect the project's ability to work.

Conclusion

Overall, the system works perfectly as a proof-of-concept prototype. There were plenty of roadblocks throughout the project, but the team went through all of them. The biggest roadblock of the entire project was getting the output from the CS451 into the PLC so the numbers could be used. The project worked autonomously the entire student showcase. The design came together very well and all integrated together very well. The internals of the box fit almost perfectly as seen in figure 9. A lot of testing had to be done to get the program to work perfectly. The working prototype can be seen in figure 9.

4. Next Steps

Based on the evaluation results, the following next steps are recommended:

1. **Conduct Extended Field Testing:**
   Proceed with deploying the integrated prototype in an actual irrigation environment, Monitor the system to gather data on its long-term operational reliability, water management accuracy, and overall durability in the field.

2. **Environmental Condition Testing:**
   Establish controlled experiments to simulate a range of environmental conditions, including extreme temperatures and humidity levels. These tests will help validate how the system performs under conditions that mimic extended field use, with particular attention to assessing the potential impact of freezing conditions on system components.

3. **Battery and Power System Improvement:**

   Solar panels and batteries need to be integrated to make the project able to be used outdoors. Testing and some redesign will need to happen to ensure smooth integration into the system.

4. **Code Improvement**

   The code needs to be improved so it can work better autonomously, have alarms, and integrate with an app. The code needs to have the system work a little better autonomously as it still has the capability to make errors if certain conditions happen. There also needs to have an alarm system that can sense if something with the system has an error and stop the system and let the consumer know what happened.

5. **Radio integration**

   The radio is already working but it needs to be integrated with the PLC so the data can be sent from about 0.5 miles.

6. **Box Improvements**

   The box needs to be improved to fit the batteries and solar system that will need to be added. It also needs to be more weatherproof so it can protect the sensitive electrical components all year round.

7. **App Integration**

   Having an app that will be able to control the system from anywhere would be a massive improvement to the project. It should be able to see the current level and manually change the level based on the consumer's needs. It should also have the capability to alert the consumer to any problems that have arisen.

8. **AI Functionality**

   The system should have some sort of computer learning technology so it can learn how long it takes from when the gate opens for the water to get to the collection box. This will optimize the opening of the gate to save water.

9. **User Feedback and Operational Training:**
   As the system is deployed, arrange for initial trials with a small group of end-users. Collect feedback regarding ease of use, installation, and maintenance. Use this feedback to refine the operating manual and provide targeted training for GVIC personnel.

10. **Commercialization Feasibility Study:**
    In parallel with testing, perform a preliminary market analysis and cost assessment. This study will determine the potential for commercialization and guide adjustments in the design to meet economic as well as technical criteria.

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