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DESIGN OF AN AUTOMATIC BRACKISH WATER FILLING SYSTEM IN A COLLECTING TANK FOR AIRPORT WATER MANAGEMENT

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Abstract

This study develops an automated brackish-water filling prototype for airport clean-water management at Jenderal Ahmad Yani Airport in Semarang. The existing manual filling process required technicians to continuously monitor water levels and operate the pump switch, resulting in inefficiency and an overflow risk. A Research and Development (R&D) approach using the Waterfall model (Analysis, Design, Implementation, and System Testing) was applied. The prototype integrates two water level sensors connected to an Outseal PLC V5 microcontroller and a relay to automatically control a submersible pump. When the lower sensor detects minimum water level, the pump activates; when the upper sensor confirms the tank is full, the pump stops automatically. Expert validation by three validators yielded an overall feasibility score of 86%, categorized as "Suitable for Use." The system successfully eliminates manual standby monitoring and reduces the risks of overflow and human error in airport water management operations.

Keywords: *automation, collecting tank, programmable logic controller, water pond, water level sensor*

Introduction

The rapid growth of the global aviation industry has directly had a positive impact on Indonesia. The Indonesian government, through the Ministry of National Development Planning, has formulated and focused on several strategic efforts to support the development of the domestic aviation industry, such as improving the quality of aviation infrastructure, increasing investment and partnerships at both domestic and international levels, and enhancing the effectiveness of more standardized institutional governance regulations (Hendra et al., 2023). The rapid development of technology and changes in human lifestyles have led to an increasing number of activities people must perform to meet their increasingly complex needs. Human needs are not limited to goods but also include services, such as transportation, particularly air transportation (Farhan Ramadhan et al., 2025; Graham, 2023; Nang Fong & Law, 2014; Ngafifi, 2014).

With the increasing number of air transportation service users year over year, airports are required to continuously enhance services for passengers in line with the times and the era of digitalization (Maharani, 2023; Sallan & Lordan, 2023). One example is Jenderal Ahmad Yani Airport Semarang, which continuously improves its services, especially in providing clean water as a passenger facility to accommodate the increasing number of passengers and support public comfort.

In 2018, a new terminal was built at Ahmad Yani Airport in Semarang to increase passenger capacity, and the terminal area has expanded year over year. The initial terminal area was only 6,708 m², and with the construction of the new terminal, the total area reached 59,406.95 m². The construction of the new terminal was certainly in line with the increase in passenger numbers and the demand for clean water at Ahmad Yani Airport, Semarang.

The mechanical unit at the airport plays an important role in ensuring smooth operations by performing maintenance, repair, and operational tasks for mechanical equipment. They perform routine maintenance on air conditioning, escalators, elevators, and HVAC systems, and ensure that backup power generators function properly. In addition, their main responsibility is to ensure that the water supply system operates efficiently and reliably. This includes conducting routine inspections, maintenance, and repairs whenever problems arise. Furthermore, technicians are responsible for monitoring the quality of the water used at the airport and ensuring it meets established safety and quality standards. They must also ensure an adequate water supply for airport operations and maintain a proper emergency plan to handle water supply disruptions (Pambudi, 2019).

Based on initial field observations at Ahmad Yani Airport, Semarang, the author identified a potential problem: the filling of the collecting tank from the brackish water pond is still carried out manually. This manual operation is usually performed using a switch that turns the pump on and off at the electrical power source. This manual operation is time-consuming because the water level in the tank must be continuously monitored during filling, and when the tank is full, the pump must be turned off manually to prevent overflow.

To overcome this problem, many automatic water pumps have been developed to fill water tanks. In the Industry 4.0 era, implementing automation in production processes has become unavoidable. Using automation makes production processes faster and more efficient (Amalia, Oka, et al., 2023). Various devices have been utilized for water pump automation. The parameters focused on in this automatic brackish water filling system are within the collecting tank area of the brackish water pond.

Currently, many industries in Indonesia are transforming simple equipment into automated systems. For example, in the education sector at Pamulang University, researchers developed a system to fill a storage tank from a water source, using a water-detection system that serves as the start-and-stop control for the pump. This monitoring system uses an Omron CP1E PLC programmed with CX-Programmer software (Raharjo, 2015). Of course, automation must also be implemented in the aviation industry to facilitate operations. At Mutiara SIS Al-Jufri Airport Palu, the generator fuel tank filling was automated using a PLC to activate the pump upon receiving signals from a flow sensor, and the pump stopped operating when the ultrasonic sensor sent a full-tank signal to the generator tank (Putra & Hartono, 2018). Such a system can reduce delays in tank filling, minimize the risk of accidents, and reduce other human errors, as in a PLC-based water level control system in Rujban (Ali et al., 2021).

Automation helps ensure consistency in water quality (de Camargo et al., 2023; Tesfaye, 2024; Yang et al., 2022). Sensors and monitoring devices integrated into automated systems can quickly and accurately detect changes or contamination in the water (Ateia et al., 2024; Chen et al., 2024), enabling corrective action before problems become more serious. This is very important for protecting public health and ensuring a safe, clean water supply in accordance with the regulations stated in the Minister of Health Regulation Number 32 of 2017. Based on the explanation above, the author believes it is important to develop an innovation to address this issue. Therefore, the author is interested in conducting a final project entitled “Design and Development of an Automatic Brackish Water Filling System Prototype in the Collecting Tank” as a supporting facility for clean water management at the airport.

Methods

This study applied a Research and Development (R&D) approach using the Waterfall model, comprising four sequential stages: Analysis, Design, Implementation, and System Testing (John et al., 2023; Okpatrioka, 2023). The Waterfall model was selected for its systematic, structured nature, which is well suited to hardware prototype development. Research was conducted at the Ground Water Tank unit of Ahmad Yani Airport, Semarang, during On-the-Job Training (OJT) in October 2023, and prototype design and fabrication were carried out at Politeknik Penerbangan Palembang from February to July 2025. In the Analysis stage, field observations were conducted to document the existing manual filling procedure and identify operational deficiencies. In the Design stage, the system architecture, hardware components, electrical wiring schematic, control logic flowchart, and 3D structural design were planned. In the Implementation stage, hardware was assembled, and the control program was written in Ladder Diagram language using Outseal Studio software and uploaded to the Outseal PLC V5 (Fitriyanto et al., 2025; Riyanta et al., 2024). System Testing was conducted via expert validation, with three validators assessing the device's functionality and quality. Validation scores were calculated using the formula: Validation Value (%) = (Total scores obtained / Ideal maximum score) × 100%. Results were interpreted against five feasibility categories: Not Suitable (20.00–36.00%), Less Suitable (36.01–52.00%), Sufficiently Suitable (52.01–68.00%), Suitable (68.01–84.00%), and Very Suitable (84.01–100.00%).

Results and Discussions

Analysis

Field observations at the Ground Water Tank unit of Ahmad Yani Airport Semarang revealed that the brackish water filling process from Water pond 3 (capacity 3,422.25 m³) to the collecting tank (capacity 100.00 m³, reinforced concrete) was performed entirely manually.

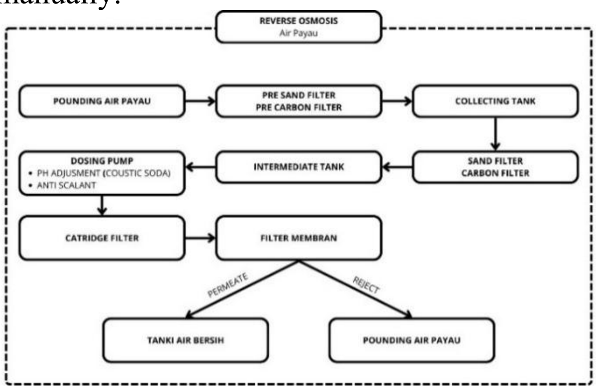

Figure 1. Existing Ground Water Tank System

A technician was required to climb a ladder to visually monitor the water level, switch the pump on when the level dropped to 20–30% capacity, and switch it off manually when the level reached 80–90% capacity. This procedure was repeated once daily and was identified as operationally inefficient, time-consuming, and prone to overflow risk and human error (Pambudi, 2019). Based on these findings, the requirement was established for an automated system capable of monitoring water level and controlling pump operation without manual intervention.

Design

Based on the analysis findings, the prototype was designed as a scaled physical model of the water pond-to-collecting tank filling system. The structural framework was fabricated to support all components. The collecting tank was built from 3 mm acrylic sheet and equipped with two water-level sensors at the lower and upper boundaries. The control panel houses the Outseal PLC V5 microcontroller and a relay module (Fitriyanto et al., 2025). The automatic control logic was designed as follows: when the lower sensor is OFF (water level below the minimum threshold), the PLC activates the relay, switching the pump ON. The pump fills the collecting tank until the upper sensor is triggered (ON), at which point the PLC deactivates the relay and switches the pump OFF. An interlock system in the Ladder Diagram ensures the pump remains ON after the lower sensor signal is lost and stops only when the upper sensor is triggered. This cycle repeats automatically without manual intervention.

Implementation

The prototype hardware was assembled based on the approved design. The collecting tank (acrylic, 3 mm thick) was fitted with two water-level sensors at the lower and upper boundaries. The Outseal PLC V5 and relay module were mounted in the control panel. The submersible mini pump was placed in the water pond section. All electrical connections were made according to the wiring schematic. The Ladder Diagram program was written in Outseal Studio and uploaded to the PLC. The program comprises three logic rungs: (1) ON/OFF system control via power supply switch (S.7 = ON, S.6 = OFF, output R.1); (2) pump activation when the lower sensor (S.1) detects low water level, activating output R.1 via interlock; (3) pump deactivation when the upper sensor (S.2) detects full level, breaking the interlock and deactivating R.1.

Simulation testing in Outseal Studio confirmed correct sequential operation of all three ladder rungs before physical deployment.

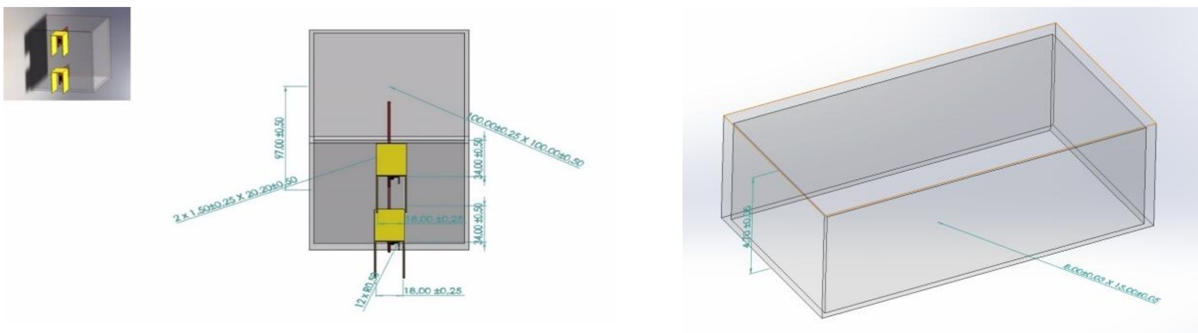

Figure 2. Collecting Tank and Waterpond Design

System Testing

System testing was conducted through expert validation in front of three validators. Each validator assessed the prototype on two dimensions: device function and device quality.

Table 1. Expert Validator Profiles

No	Name	Credentials	Role in Validation
1	Ir. Setiyo, M.M.	Lecturer, Poltekbang Palembang	Device Expert (Ahli Alat)
2	Eldy Kurniadi, S.T.	Practitioner Lecturer, Mechatronic; Engineer, Syneps Academy	Device Expert (Ahli Alat)
3	Rudito Purwo Nugroho, S.SiT.	Mechanical Supervisor, Ahmad Yani Airport Semarang	Device Expert & Operational User

The aggregate validation result across all three validators was 86%, placing the prototype in the “Suitable for Use” category. The variation in scores between validators is noteworthy. Validator 1’s lower quality score (68%) reflects feedback on hardware finish and component durability at the prototype scale, which is consistent with findings from similar PLC-based automation prototype studies, where build quality at small scale does not fully represent industrial-grade implementation (Afristanto et al., 2023; Andika et al., 2023). Validators 2 and 3, who assessed from both a mechatronic engineering and an operational perspective, respectively, awarded substantially higher scores, confirming that the system's functional logic and operational design meet practical airport water management requirements.

Table 2. Expert Validation Results by Dimension

Validator	Dev. Func (%)	Dev. Qty (%)	Overall (%)	Cat.
Validator-1 Ir. Setiyo, M.M.	80	68	74	Suitable
Validator-2 Eldy Kurniadi, S.T.	100	84	92	Very Suitable
Validator-3 **Rudito P. Nugroho, S.SiT.**	100	96	98	Very Suitable
Aggregate	**93.33**	**82.67**	**86.0**	**Suitable for Use**

Table 2 presents the detailed validation scores across the two assessed dimensions. The aggregate validation score of 86% places the prototype in the "Suitable for Use" category according to the feasibility criteria. Device function received a higher aggregate score (93.33%) than device quality (82.67%), indicating that the control logic and operational performance of the prototype were more consistently approved than its physical build quality at prototype scale.

The aggregate validation results show that both the device function and device quality dimensions exceeded the minimum "Suitable" threshold of 68%, confirming the prototype's overall feasibility.

Figure 3. Validator Assessment Results

The score variation between Validator 1 (74%) and Validators 2–3 (92% and 98%) warrants discussion. Validator 1's lower quality score (68%) reflects feedback focused on hardware finish and component durability at the prototype scale — specifically, the acrylic construction and miniature pump are not representative of the industrial-grade materials used in the actual 100 m^3 concrete-collecting tank system at Ahmad Yani Airport. This limitation is inherent to prototype-scale R&D studies and is consistent with findings from (Afristanto et al., 2023; Andika et al., 2023), in which prototype build-quality scores were lower than functional scores for similar PLC-based automation systems.

Validator 2, assessing from a mechatronic engineering perspective, awarded perfect marks for device function (100%), confirming that the Ladder Diagram logic, sensor integration, and relay control circuit performed correctly and without failure during the demonstration. Validator 3, as the operational end-user at Ahmad Yani Airport, awarded the highest overall score (98%), reflecting strong alignment between the prototype's design intent and the operational needs of the airport's Ground Water Tank unit. This score from the field practitioner is particularly significant, as it validates the system's real-world applicability beyond laboratory conditions.

The 86% feasibility score is consistent with validation outcomes reported in comparable PLC-based automation prototype studies. Hartanto et al. (2022) developed a PLC-based OMRON CP1E automatic filling system for a coffee machine and demonstrated successful time-based volume control, though without a sensor-triggered interlock — a key differentiating feature of the present prototype. (Febriandirza & Sahuri, 2024; Kurniasih et al., 2016; Okomba et al., 2024) developed a microcontroller-based automatic water filler using an Arduino Uno, reporting low measurement error in volume comparisons; however, their system targeted small-volume industrial applications, whereas the present study addresses large-capacity airport water infrastructure. Raharjo (2015) implemented a similar Omron CP1E PLC system for filling a storage tank with water-level-based pump start/stop control, the closest analogous study, confirming that sensor-triggered PLC automation is a proven and applicable approach for this category of problem. Also in a plumbing leakage detection system with a water-level detector controlled by a programmable logic controller using Omron (Hartanto et al., 2022).

What distinguishes the present prototype is its use of the domestically developed Outseal PLC V5, an Indonesian-made, open-source controller, which demonstrates that aviation infrastructure automation needs can be addressed using affordable, locally available technology (Amalia et al., 2021, 2024; Amalia, Nugraha, et al., 2023). This has practical implications for smaller regional airports in Indonesia where budget constraints may preclude the use of industrial-grade PLCs from international brands. Several limitations must be acknowledged.

First, validation was conducted by only three validators — a sample size that, while sufficient for assessing prototype feasibility, limits the statistical generalizability of the results. Second, the prototype uses miniature components (5V mini submersible pump, 3 mm acrylic tank) that do not reflect the actual scale of the collecting tank (100 m^3) and water pond pump system at Ahmad Yani Airport; performance under full industrial load conditions remains untested. Third, the current system does not incorporate remote monitoring or alert features; a technician must still be on-site to confirm system status, though no longer required for manual pump operation.

Future development should address: (1) scaling the prototype to full operational capacity; (2) integration of a remote notification system (SMS or network-based) as recommended by (Raharjo, 2015) for water filling monitoring; (3) addition of a water quality monitoring module consistent with Peraturan Menteri Kesehatan No. 32 Tahun 2017; and (4) a maintenance-phase evaluation at the actual site to validate long-term reliability.

Conclusion

This study successfully developed and validated an automated brackish-water filling prototype system using an Outseal PLC V5 microcontroller and two water-level sensors to control a submersible pump at Jenderal Ahmad Yani Airport, Semarang. The system operates via a Ladder Diagram interlock logic that activates the pump when the lower sensor detects the minimum water level and deactivates it when the upper sensor confirms the tank is full, eliminating the need for a manual technician standby. Expert validation by three validators yielded an overall feasibility score of 86%, categorized as "Suitable for Use," confirming that the system meets the functional and operational requirements for supporting airport clean water management. The prototype demonstrates that low-cost, domestically developed PLC technology (Outseal V5) can effectively address operational inefficiencies in airport mechanical systems. Future development should focus on scaling the prototype to full industrial capacity, adding remote monitoring and notification features, and conducting a maintenance-phase evaluation at the actual implementation site to ensure long-term operational reliability.

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