Control of Water Flow Rate in a Tank Using the Integral State Feedback Based on Arduino Uno

Raeyvaldo Dwi Hendriyanto [1], Riky Dwi Puriyanto [2,*], Alfian Ma'arif [3], Marco Antonio Márquez Vera [4], Oskar Ika Adi Nugroho [5], Choeung Chivon [6]
[1,2,3] Department of Electrical Engineering, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[4] Polytechnic University of Pachuca, Mexico
[5] Electrical Engineering Department, National Chung Cheng University, Taiwan
[6] National Polytechnic Institute of Cambodia, Cambodia
Email: [1] raeyvaldo2015022036@webmail.uad.ac.id, [2] rikydp@ee.uad.ac.id, [3] alfianmaarif@ee.uad.ac.id, [4] marquez@upp.edu.mx, [5] oskar@alum.ccu.edu.tw, [6] choeungchivon@npic.edu.kh
*Corresponding Author

***Abstract*—In the industrial world, many tools have been made to facilitate human work in carrying out control and measurement that is made automatically in a production process. Because in some parts of a production process in the industry that is done manually is no longer effective so that accurate and precise automatic control is needed. The control that will be used in this study is the Integral State Feedback (ISF) control with Arduino Uno as a microcontroller to design and run the system. The actuator used is a 12V water pump with the sensor used is the YF-S401. The system will run the ISF control as long as the data is less than 300 and if it reaches 300 data, the system will stop processing the ISF control and turn off the 12V water pump. The sensor reading error obtained is 27%. Parameters Ki = 0.3, K1 = 6, and K2 = 2 obtained from MATLAB Simulink can be applied to the research tool but have a slow system response Delay Time and Rise Time, so the researcher made a modification parameter with a value of Ki = 1, K1 = 6, and K2 = 2 and obtained a faster system response Delay Time and Rise Time. So it can be concluded that the best parameters for this study use modified parameters.**

Keywords*—*Integral State Feedback; Water Tank; Water Flow Sensor; Control Systems

I. INTRODUCTION

Currently, technology is advancing rapidly, providing various conveniences that significantly impact daily life [1], including human activities and tasks across multiple sectors [2]-[4]. In the industrial world, technological progress has led to the development of automated tools that simplify and accelerate various types of work, especially in control and measurement within the production process [5]-[7]. This automation technology allows tasks that previously required a significant amount of human labor and long processing times to be carried out more efficiently, quickly, and accurately [8].

Modern industries also face high demands to continuously optimize resource utilization, production efficiency, and intelligent management of every critical process [9]-[11]. Here, automatic control and monitoring systems play an essential role in maintaining both the quality and quantity of production, driven by the need for high product quality and increasingly fierce market competition. One particularly crucial aspect in this context is water flow control within production tanks. The flow rate in industrial production processes often becomes a variable that must be carefully managed, as it can serve as a key parameter influencing product quality or the final production outcome. Accurate control of water flow not only positively impacts production success but also directly influences the overall sustainability of industrial operations.

As the need for high production quality grows, an effective control system is required to perform optimal regulation of the water flow within production tanks [12], [13]. This control system must be able to adjust the incoming and outgoing water flow with precision, maintain balance, and minimize errors in the key parameters that affect the final production output. Important control system performance indicators include overshoot, settling time, rising time, and error in achieving the target output [14]-[16]. To achieve the best performance, an automatic control system is needed to manage these parameters with accuracy, stability, and consistency.

One automatic control approach that can be applied is the Integral State Feedback (ISF) method [17], [18]. In an ISF control system, the observed output variables include not only a single variable but also several interrelated output variables. This method enables more precise and adaptive control, as it allows the system to observe and adjust interconnected outputs if there is a change in one output variable. Consequently, ISF can provide better stability and respond swiftly to changes in water flow within the tank [19].

Although PID control mechanisms are still commonly used in industrial applications due to their ease of use and reliable results for many control tasks, research by Arrafiq et al. [20] has shown that in certain specific control cases, an Integral State Feedback (ISF) control system can deliver a better response compared to a PID system. This finding suggests that ISF can not only serve as an alternative to PID but also outperform it in certain control applications that require higher stability and accuracy, particularly in modern industrial environments where complexity and precision are critical.

Based on these reasons and the advantages of ISF, this study aims to design and implement an ISF control system for the process of filling a water tank to regulate the water flow entering or exiting the tank. This control implementation is carried out using Arduino software as the main controller in the system. Using Arduino offers several advantages, including affordability, ease of operation, and high flexibility for various applications. In this process, the ISF parameters used in the control system will be determined through system modeling followed by simulation. This simulation aims to obtain the most suitable parameters, allowing the designed control system to provide optimal results according to industrial requirements.

The parameters obtained from the simulation will then be applied to the developed control device, enabling this study to directly test the effectiveness and performance of the system in a laboratory-scale tank-filling scenario. This study is therefore expected to provide a tangible contribution to the industrial world by creating a reliable and high-performance automatic control solution that not only improves production quality but also supports operational efficiency and sustainability. The implementation of an ISF-based control system on the Arduino platform is also expected to pave the way for further advancements in the application of smarter, more economical, and flexible automatic control technology tailored to current industrial needs.

II. METHOD

The system design in this study is generally divided into two main stages to achieve optimal results that align with the research objectives. The first stage is the hardware design, which includes selecting and assembling the physical components that will be used in the system. This process involves analyzing hardware requirements based on desired functions, such as sensors, actuators, microcontrollers, and other supporting components. The hardware components are carefully chosen to ensure each one functions effectively within the designed system.

The second stage is the software design, which encompasses programming and configuring the control algorithms that will be used in the system. In this stage, control algorithms like ISF are implemented and adjusted according to system requirements to achieve the desired performance. The software design is carried out using Arduino software to program the system control, ensuring it operates according to specifications and can adjust control parameters under various conditions.

A. Integral State Feedback (ISF) Control

Integral State Feedback control is an approach in control system design that combines the integral (I) element with state feedback to enhance system performance. This control method aims to address steady-state errors that may arise within a control system by integrating state information and the integral control element [21]. Through this combination, ISF control ensures that the system can reach the setpoint without experiencing steady-state error and effectively respond to setpoint changes or disturbances. With integral control, the system continually adjusts to minimize discrepancies, providing precise and stable output performance even under sustained external disturbances.

Fig. 1 shows the ISF control diagram, illustrating a structure where integral and state feedback components work harmoniously to adjust control actions based on real-time system states. This configuration allows the control system to maintain stability and accuracy by monitoring key state variables and adjusting output to compensate for errors, enabling optimal tracking of the desired setpoint.

B. System Block Diagram

Fig. 2 illustrates the hardware diagram, where the Arduino UNO serves as the main component of the system, integrating and controlling all the circuit components. In this system, the Arduino UNO is paired with the YF-S401 water flow sensor [22], [23], which is responsible for measuring the flow rate of water passing through pipes or tanks. The YF-S401 sensor detects the flow rate in the form of pulses, which are then transmitted as input data to the Arduino UNO. This data is processed through a program written in the Arduino IDE [24], [25], generating the necessary information to control the output elements.

After the water flow data is processed by the Arduino, the system produces a PWM (Pulse Width Modulation) signal that is sent to the L298N Driver [26]-[28], which acts as the motor controller. The L298N Driver regulates the power to drive the DC pump, serving as the main output of the system, thus allowing it to adjust the water flow rate according to the desired setpoint. Additionally, the Arduino UNO sends the measured values and system status to a 16×2 I2C LCD display, which functions as the user interface. This LCD provides real-time information about the water flow rate, making it easier for users to monitor the system's performance directly.

C. Control System Block Diagram

This research designs a device aimed at accurately and efficiently measuring the water flow rate during the tank filling process. The device is equipped with a water flow sensor that functions to monitor the flow rate in real time. When the sensor detects that the water flow has reached a previously defined setpoint, the system will automatically maintain the stability of the water flow during the filling process. This is done to ensure that the water flow remains consistent with the desired setpoint, which is crucial for achieving optimal production results.

Subsequently, once the setpoint is reached, the device will turn off the water pump within a specified timeframe. This process is managed by a motor driver controlled by the Arduino UNO, which has been programmed using Arduino IDE software. Setting the timing for pump shutdown is vital to prevent overfilling, which could lead to issues within the system. Conversely, if the setpoint has not been met, the water pump will continue to operate, ensuring that water is pumped until the designated setpoint is achieved. Furthermore, the flow rate measured by the water flow sensor will be displayed in real time on a laptop and also on a 16x2 I2C LCD screen, providing users with an easy way to monitor system performance. The control system block diagram illustrating the entire process and interaction among components is shown in Fig. 3.

D. Flowchart of the Software

In Fig. 4, the system begins by reading the setpoint variable along with the control parameters Ki, K1, and K2 necessary for the control process. After that, if the received data is less than 300, the system will proceed to read the water flow rate detected by the sensor. This process is followed by calculating the error value, which is the difference between the setpoint and the measured flow rate. Using this error information, the system then calculates the Integral State Feedback (ISF) value, which will be output as a PWM (Pulse Width Modulation) signal to control the pump's performance. In addition to generating the PWM signal, the system also displays relevant information, including the measured flow rate and the resulting PWM value, on the I2C LCD screen. This provides users with direct access to important data regarding the system's performance. Once the processed data reaches a value of 300, the system will halt the entire program process, indicating that the measurement and control have been carried out effectively according to the specified requirements.

E. Diagram Wiring

The hardware design is followed by the creation of a wiring diagram that illustrates how the components used are interconnected. This wiring diagram is a crucial process that involves connecting one component to another via cables. All components must be connected to the Arduino Uno microcontroller and linked to a power supply or adapter with a voltage of 12V. A more detailed explanation of the wiring can be seen in Fig. 5, which presents a visual representation of the interactions among the components within the system. This diagram aims to ensure that all connections are made correctly and safely, allowing the system to function optimally.

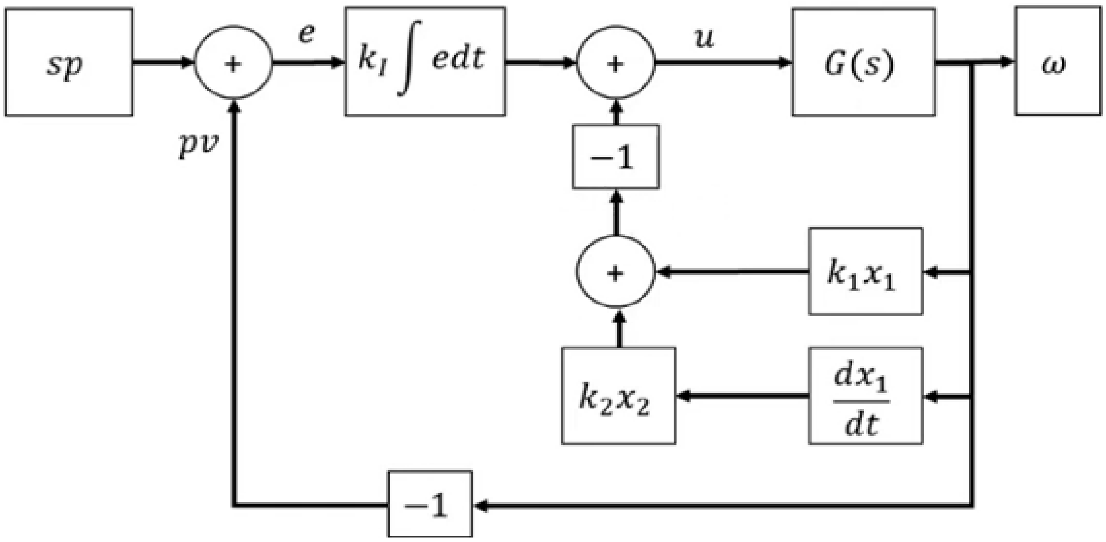

Fig. 1. Diagram of ISF Control

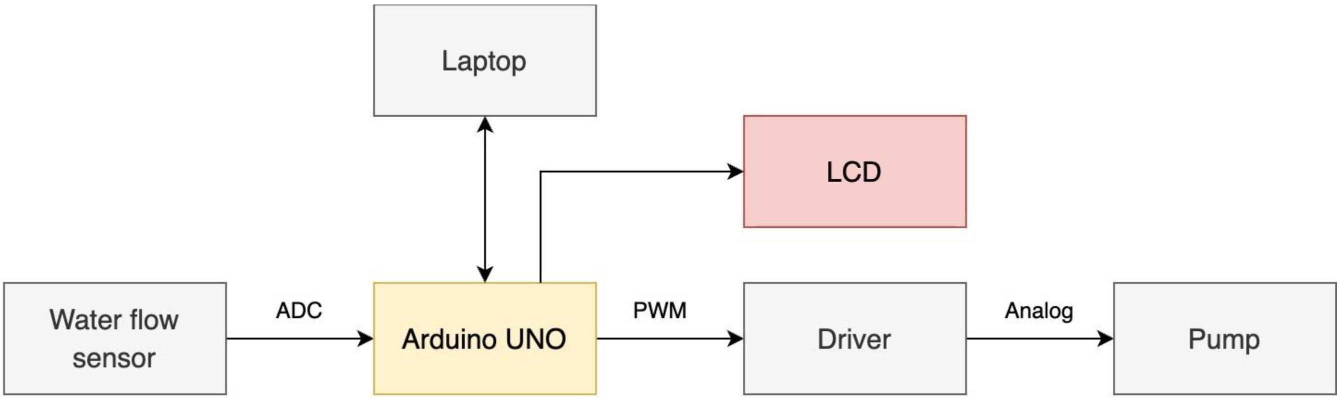

Fig. 2. System block diagram

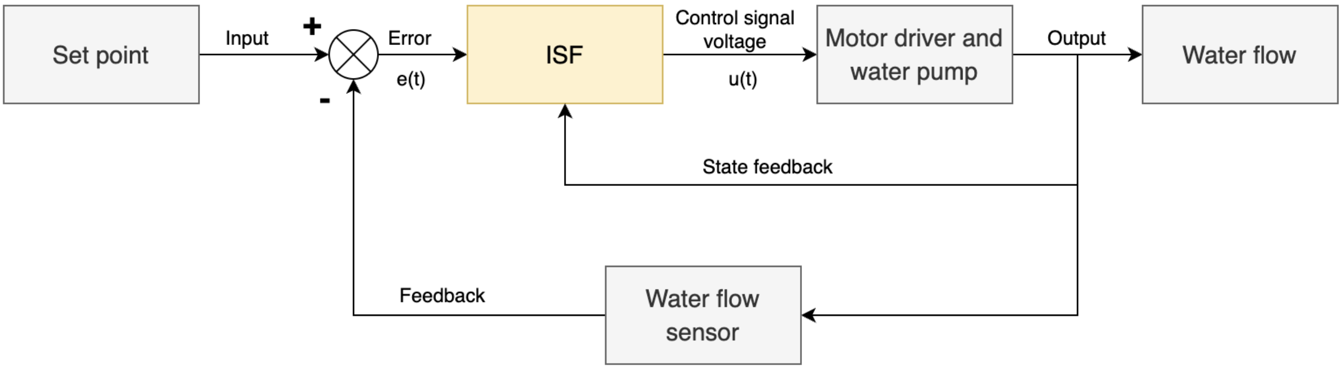

Fig. 3. Block diagram of the control system

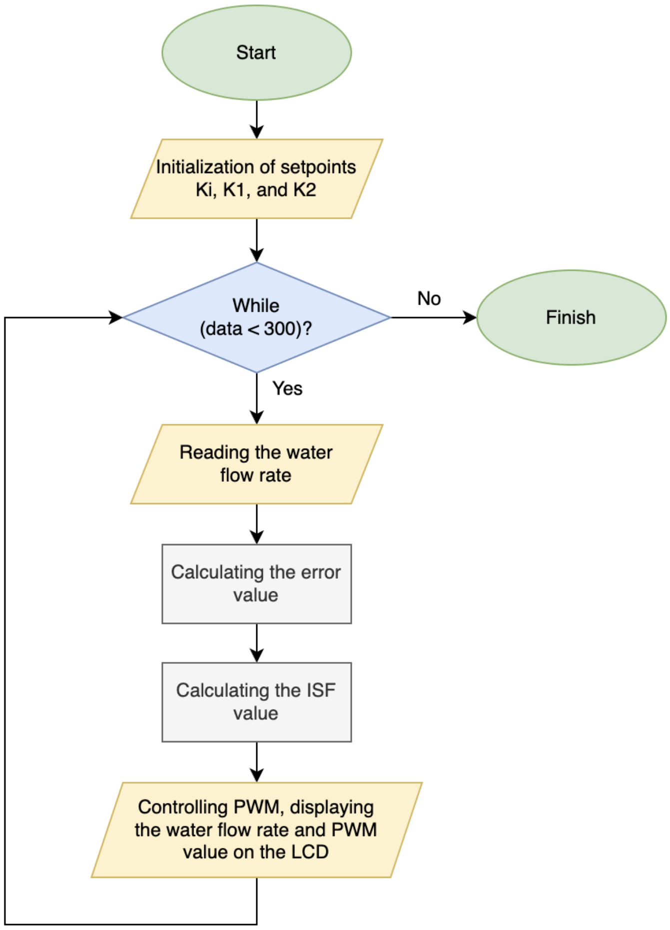

Fig. 4. Flowchart of the software

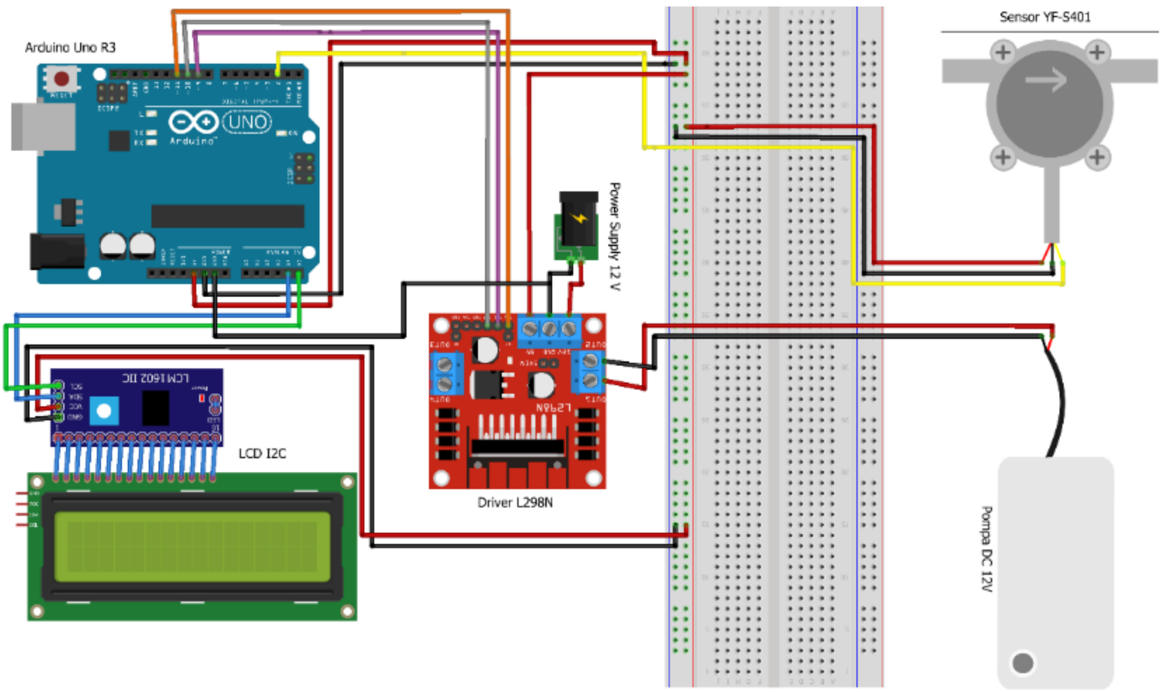

Fig. 5. Diagram wiring

III. Result and Discussion

In the results and discussion section of this research, several important processes will be outlined, including Equipment Testing, which aims to ensure that all components and systems are functioning properly before further testing is conducted.

Next, a System Model Development is carried out to facilitate the analysis and understanding of the system's behavior under different conditions. After the model is created, the System Model Simulation stage is conducted to virtually test the model, allowing researchers to evaluate the system's performance without the risk of damaging physical devices. The next process is No-Load Testing, which measures the system's performance in ideal conditions without any external load, followed by Load Testing to assess the system's ability to operate optimally in more realistic and complex situations.

A. Equipment Testing

In the first discussion, namely the equipment testing, tests will be conducted on the components of the device, specifically the 12V DC Pump actuator and the YF-S401 sensor. In this equipment testing, water will be filled into tanks (measuring cups with sizes of 1 liter and 2 liters) for a duration of 1 minute or 60 seconds, with a total of 12 trials performed, each with varying voltage levels. After the experiments are completed, the results of the testing will be recorded in Table 1.

Table 1 shows the calculated error values. The largest error in water volume reading by the YF-S401 sensor was 100%, while the smallest reading error was 5%. The average error in water volume readings by the YF-S401 water flow sensor was 27%.

B. System Model Development

The next step in the research process involved creating a system model by using the PWM value as the system model input and the water flow rate measured by the YF-S401 sensor as the system model output. Following this, system model processing was conducted by selecting a transfer function as the model type and setting the pole value to 2 and the zero value to 0. The resulting system model is shown in Fig. 6, with a similarity to the original data of 91.93%, as illustrated in Fig. 7.

C. System Model Simulation

The next step in the research process involves simulating the system model in MATLAB Simulink. The initial step is to create a block diagram of the ISF control system and input the system model values into the transfer function block diagram, as shown in Fig. 8. After that, a trial-and-error process was conducted by repeatedly changing the values of the parameters Ki, K1, and K2 to achieve the best system response. After several iterations of adjusting the parameters Ki, K1, and K2 in the ISF control block diagram, the researchers finally identified the optimal parameter values, with Ki = 0.3, K1 = 6, and K2 = 2, resulting in a system response as shown in Fig. 9.

D. No-Load Testing

In the discussion of the no-load testing, the control parameter values obtained from the Integral State Feedback control system simulation in Simulink—specifically, Ki = 0.3, K1 = 6, and K2 = 2—will be input into the program variables Ki, K1, and K2 within the research tool's program, which has been developed using the Arduino IDE software. Additionally, the graph showing the system response results from the Simulink simulation will be incorporated into the no-load test system response analysis graph to serve as a comparison with the response graph generated by the research tool. After the parameters have been successfully input, the next step involves conducting tests at a setpoint of 10 mL/s, with the testing duration set for 300 seconds on the research tool. The resulting graphs and system response data will then be presented in MATLAB, as shown in Fig. 10.

Table 1. Error value calculation

Water Volume Value (mL)		$\text{error}\ (\%) = \frac{\text{Measuring Cup} - \text{Sensor}}{\text{Measuring Cup}} \times 100$
Sensor	Measuring Cup	
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	1	100
0	10	100
10	60	83
2	150	99
0	280	100
0	290	100
3	350	99
60	380	84
119	420	72
275	450	39
300	480	38
358	510	30
374	550	32
418	580	28
436	600	27
479	630	24
503	660	24
529	680	22
555	710	22
582	740	21
671	760	12
660	780	15
707	800	12
751	830	10
766	850	10
764	880	13
809	900	10
837	930	10
842	940	10
40	960	13
871	990	12
912	1030	11
933	1060	12
902	1080	16
927	1100	16
973	1120	13
971	1140	15
977	1160	16
1015	1180	14
1034	1200	14
1046	1210	14
1076	1230	13
1100	1260	13
1100	1280	14
1103	1300	15
1138	1320	14
1154	1340	14
1206	1360	11
1311	1380	5
Average Error		27

Based on Fig. 10, the results of testing the water flow setpoint at 10 mL/s on the research device showed a different delay time between the response graph of the research device and the response graph from the Simulink simulation. The response graph from the research device indicated a longer delay time compared to the response graph from the Simulink simulation. Additionally, overshoot was observed at the 238-

second mark. The response graph in Fig. 10 has a peak time of 238 seconds, rise time of 64 seconds, overshoot of 10.0000, undershoot of 0, settling time of 293.8000 seconds, and a steady-state error of 0.

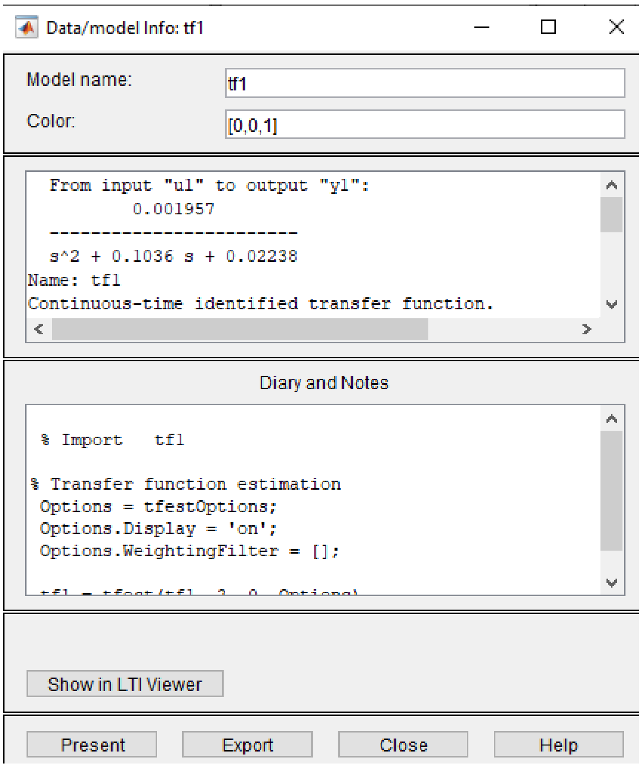

Fig. 6. System model transfer function

After conducting several tests at the specified setpoint, the response graph generated by the research device consistently showed a longer delay time than the delay time of the response system produced by Simulink MATLAB. As a result, the researcher modified the Ki parameter, changing it from Ki = 0.3 to Ki = 1, in hopes of achieving a faster system response. Following the modification of the parameter values, the new response graph and data are illustrated in Fig. 11.

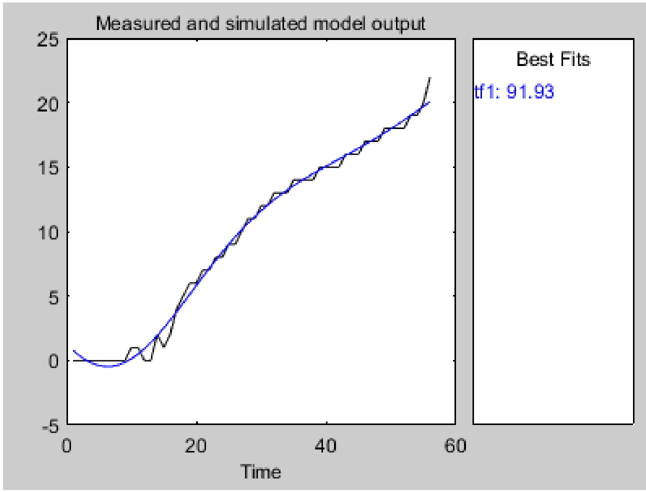

Fig. 7. System model data similarity

Based on Fig. 11, the results of testing the water flow setpoint at 10 mL/s on the research device showed a different delay time between the response graph using the modified parameters and the response graph using the Simulink parameters. The response graph with the modified parameters indicated a faster delay time compared to the response graph with the Simulink parameters. In Fig. 11, the response graph has a peak time of 87 seconds, rise time of 19.6667 seconds, overshoot of 10.0000, undershoot of 0, settling time of 128.8000 seconds, and a steady-state error of 0.

E. Testing with Load

Next, the setpoint testing was conducted by applying a load. In this research, the load was implemented by introducing a branching hose between the water pump and the sensor, which functions to reduce the amount of water entering through the water flow sensor, thereby decreasing the measured flow rate. Following this setup, the response of the integral state feedback control system in regulating the water flow during the tank filling process for 300 seconds will be observed.

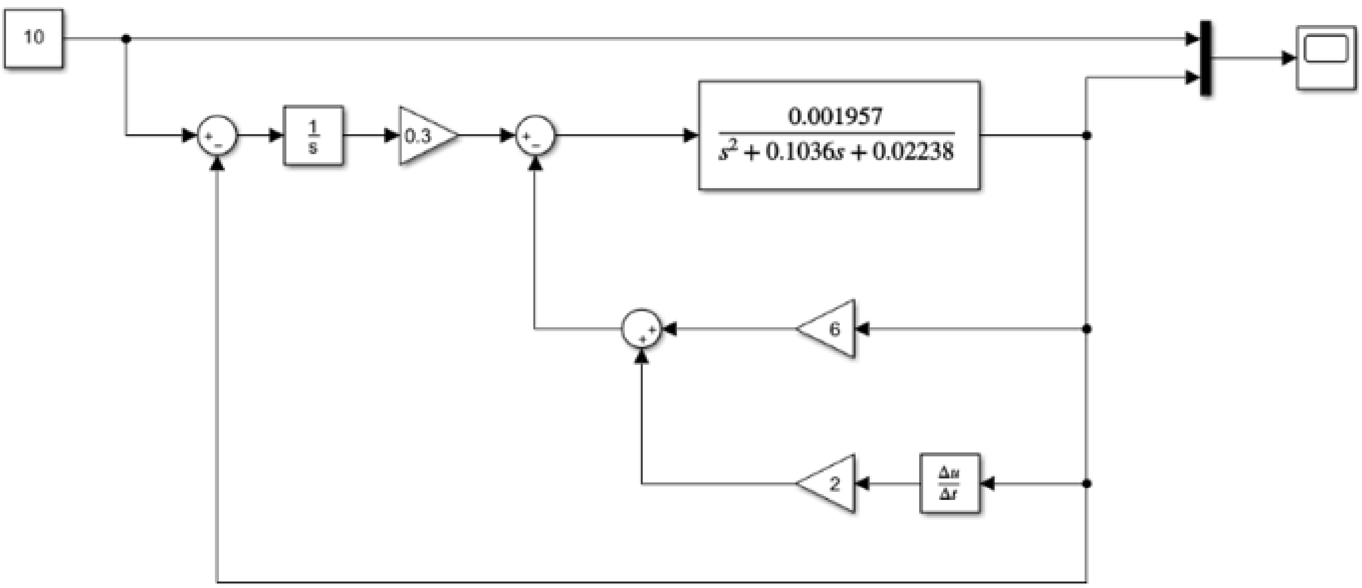

Fig. 8. Integral state feedback control system diagram

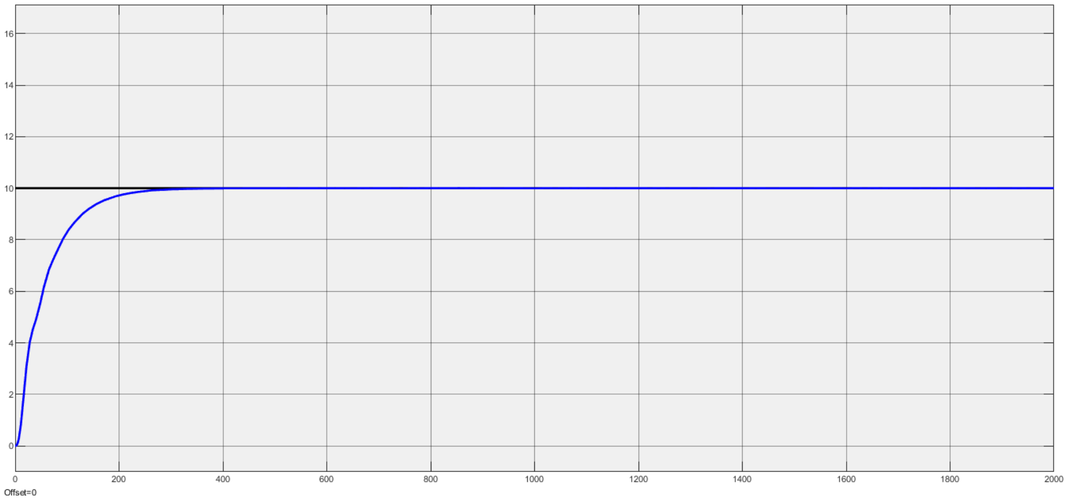

Fig. 9. Best system response results of ISF control

The load testing was carried out at a water flow setpoint of 10 mL/s using two sets of parameters, Ki, K1, and K2: the parameters from the Simulink simulation and the modified parameters. The first load test was conducted using the simulation parameters, resulting in the system response depicted in Fig. 12.

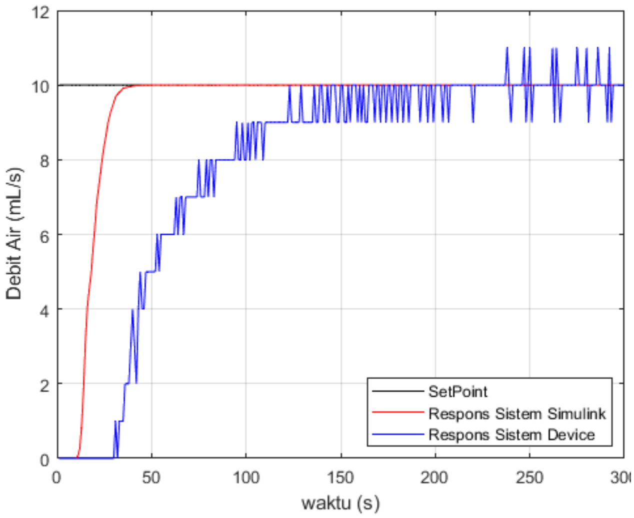

Fig. 10. System response at setpoint 10 mL/s

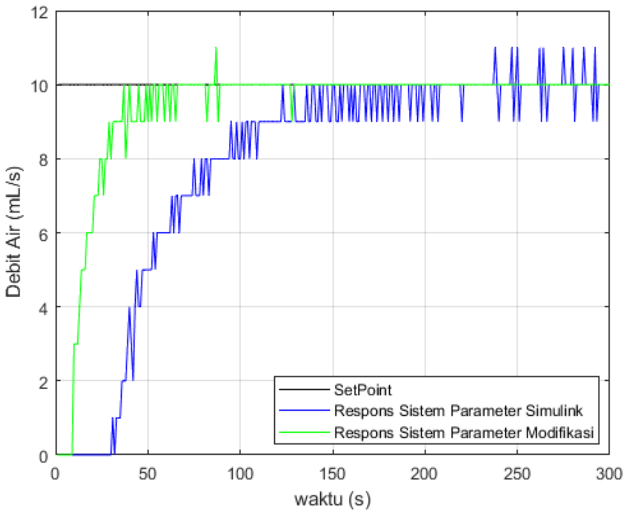

Fig. 11. System response at setpoint 10 mL/s with modified parameters

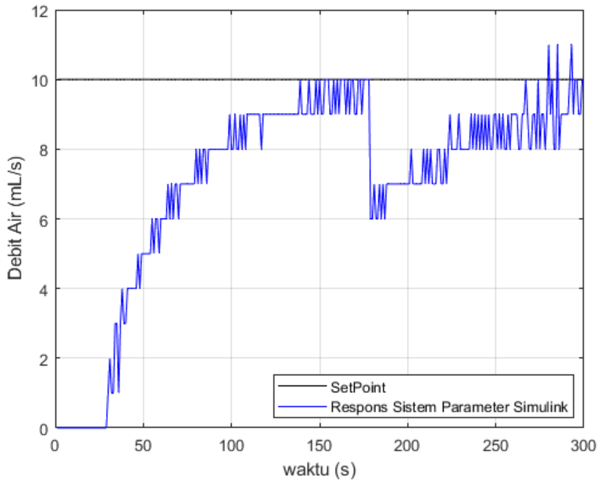

Fig. 12. Setpoint 10 mL/s with simulation parameter load

Based on Fig. 12, the results of the testing at a setpoint of 10 mL/s with a load using the simulation parameters show that at the 179-second mark, the reading of the water flow by the sensor decreases. This is due to the system being subjected to a load by opening the branching faucet between the water pump and the sensor, resulting in a reduction in the water flow reading. Additionally, as shown in Fig. 12, the rise time required for the system response to reach the setpoint for the first time after the load was applied is 88 seconds. Consequently, at the 267-second mark, the water flow reading by the sensor only reaches the setpoint, albeit still unstable and exhibiting overshoot.

The second test with a load was conducted using the modified parameters, resulting in the system response illustrated in Fig. 13. Based on Fig. 13, the results of the testing at a setpoint of 10 mL/s with a load using the modified parameters show that at the 228-second mark, the water flow reading by the sensor decreases. This occurs because the system is subjected to a load by opening the branching faucet between the water pump and the sensor, resulting in a reduction in the water flow reading. Additionally, as indicated in Fig. 13, the rise time required for the system response to reach the setpoint for the first time after the load is applied is 19 seconds. Therefore, at the 247-second mark, the water flow reading by the sensor only reaches the setpoint, although it is still unstable and exhibits overshoot.

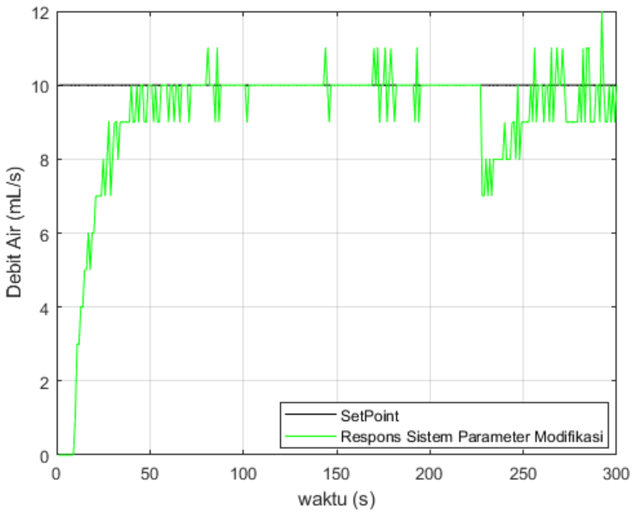

Fig. 13. Setpoint 10 mL/s with modified parameter load

From the two tests conducted at the setpoint of 10 mL/s, the system responses with a load generated using the simulation parameters and the modified parameters show different rise time values. The rise time produced by the system response with modified parameters is noticeably faster. This improvement is attributed to the increase in the integral control value in the Ki parameter, which was originally Ki = 0.3 and was changed to Ki = 1, allowing the system to respond more quickly to errors in the setpoint.

IV. Conclusion

The results of the four tests at the setpoint without a load indicate that the delay time of the system response using the modified parameters has a faster delay time compared to the delay time of the system response with Simulink MATLAB parameters. Additionally, in the results of the two tests at the setpoint with a load, the rise time of the system response using the modified parameters is also shorter when compared to the rise time of the system response with Simulink MATLAB parameters. Therefore, it can be concluded that the best parameters for Ki, K1, and K2 in this study are Ki = 1, K1 = 6, and K2 = 2. In future research, the water flow sensor used could be replaced with a more precise sensor for measuring water flow, with the hope of achieving even better system response results.

References

[1] F. Furizal, S. Sunardi, and A. Yudhana, "Temperature and Humidity Control System with Air Conditioner Based on Fuzzy Logic and Internet of Things," *Journal of Robotics and Control (JRC)*, vol. 4, no. 3, pp. 308–322, 2023, https://doi.org/10.18196/jrc.v4i3.18327.

[2] A. Haleem, M. Javaid, R. Pratap Singh, and R. Suman, "Medical 4.0 technologies for healthcare: Features, capabilities, and applications," *Internet of Things and Cyber-Physical Systems*, vol. 2, pp. 12–30, 2022, https://doi.org/10.1016/j.iotcps.2022.04.001.

[3] M. Javaid, A. Haleem, S. Rab, R. Pratap Singh, and R. Suman, "Sensors for daily life: A review," *Sensors International*, vol. 2, p. 100121, 2021, https://doi.org/10.1016/j.sintl.2021.100121.

[4] A. R. Javed *et al.*, "Future smart cities: requirements, emerging technologies, applications, challenges, and future aspects," *Cities*, vol. 129, p. 103794, 2022, https://doi.org/10.1016/j.cities.2022.103794.

[5] S. Sahoo and C. Lo, "Smart manufacturing powered by recent technological advancements: A review," *Journal of Manufacturing Systems*, vol. 64, pp. 236–250, 2022, https://doi.org/10.1016/j.jmsy.2022.06.008.

[6] M. Javaid, A. Haleem, R. P. Singh, S. Rab, and R. Suman, "Exploring impact and features of machine vision for progressive industry 4.0 culture," *Sensors International*, vol. 3, p. 100132, 2022, https://doi.org/10.1016/j.sintl.2021.100132.

[7] M. Javaid, A. Haleem, R. Pratap Singh, and R. Suman, "Significance of Quality 4.0 towards comprehensive enhancement in manufacturing sector," *Sensors International*, vol. 2, p. 100109, 2021, https://doi.org/10.1016/j.sintl.2021.100109.

[8] Sunardi, A. Yudhana and Furizal, "Tsukamoto Fuzzy Inference System on Internet of Things-Based for Room Temperature and Humidity Control," *IEEE Access*, vol. 11, pp. 6209-6227, 2023, https://doi.org/10.1109/ACCESS.2023.3236183.

[9] Z. Jiang, S. Yuan, J. Ma, and Q. Wang, "The evolution of production scheduling from Industry 3.0 through Industry 4.0," *International Journal of Production Research*, vol. 60, no. 11, pp. 3534–3554, 2022, https://doi.org/10.1080/00207543.2021.1925772.

[10] D. Y. Pimenov *et al.*, "Resource saving by optimization and machining environments for sustainable manufacturing: A review and future prospects," *Renewable and Sustainable Energy Reviews*, vol. 166, p. 112660, 2022, https://doi.org/10.1016/j.rser.2022.112660.

[11] L. Tang and Y. Meng, "Data analytics and optimization for smart industry," *Frontiers of Engineering Management*, vol. 8, no. 2, pp. 157–171, 2021, https://doi.org/10.1007/s42524-020-0126-0.

[12] M. E. A. El-Hack *et al.*, "Effect of environmental factors on growth performance of Nile tilapia (Oreochromis niloticus)," *International Journal of Biometeorology*, vol. 66, no. 11, pp. 2183–2194, 2022, https://doi.org/10.1007/s00484-022-02347-6.

[13] A. L. Reis, M. A. R. Lopes, A. Andrade-Campos, and C. Henggeler Antunes, "A review of operational control strategies in water supply systems for energy and cost efficiency," *Renewable and Sustainable Energy Reviews*, vol. 175, p. 113140, 2023, https://doi.org/10.1016/j.rser.2022.113140.

[14] M. Jabari, S. Ekinci, D. Izci, M. Bajaj, and I. Zaitsev, "Efficient DC motor speed control using a novel multi-stage FOPD(1 + PI) controller optimized by the Pelican optimization algorithm," *Scientific Reports*, vol. 14, no. 1, p. 22442, 2024, https://doi.org/10.1038/s41598-024-73409-5.

[15] Q. Wang, J. Sun, J. Zhang, J. Huang, J. Yu, and H. Dong, "Survey of transient performance control," *Control Engineering Practice*, vol. 138, p. 105559, 2023, https://doi.org/10.1016/j.conengprac.2023.105559.

[16] B. S. Solanki, R. Kumawat, and S. Srinivasan, "An Impact of Different Uncertainties and Attacks on the Performance Metrics and Stability of Industrial Control System," *Communication and Intelligent Systems*, pp. 557-574, 2021, https://doi.org/10.1007/978-981-16-1089-9_44.

[17] A. Ma'arif, I. Suwarno, H. Maghfiroh, W. Rahmaniar, A. A. Nuryono and N. M. Raharja, "Sliding Mode Control of Angular Speed DC Motor System with Parameter Uncertainty," *2022 IEEE International Conference on Communication, Networks and Satellite (COMNETSAT)*, pp. 380-387, 2022, https://doi.org/10.1109/COMNETSAT56033.2022.9994286.

[18] A. Ma'arif and N. R. Setiawan, "Control of DC Motor Using Integral State Feedback and Comparison with PID: Simulation and Arduino Implementation," *Journal of Robotics and Control (JRC)*, vol. 2, no. 5, pp. 456-461, 2021, https://doi.org/10.18196/jrc.25122.

[19] D. I. Saputra, I. Budiawan, and A. Jayanugraha, "Pemodelan dan Simulasi Sistem Kendali Volume Air Pada Process Plant Dengan Metode State Feedback," *Jurnal Otomasi Kontrol dan Instrumentasi*, vol. 14, no. 1, pp. 11–20, 2022, https://doi.org/10.5614/joki.2022.14.1.2.

[20] M. Arrofiq, L. S. Nugroho, F. Fahmizal, and E. Apriaskar, "Sistem Kendali Eddy Current Brakes Dinamometer menggunakan Linear Quadratic Regulator (LQR)," *ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika*, vol. 9, no. 4, p. 923, 2021, https://doi.org/10.26760/elkomika.v9i4.923.

[21] I. Iswanto and A. Ma'arif, "Robust Integral State Feedback Using Coefficient Diagram in Magnetic Levitation System," *IEEE Access*, vol. 8, pp. 57003-57011, 2020, https://doi.org/10.1109/ACCESS.2020.2981840.

[22] S. Aravind and S. S. Hiremath, "Design and Development of IEG Control and Characterization of Micro-holes Generated Using In-house Developed µ-ECM Setup," *Arabian Journal for Science and*

Engineering, vol. 47, no. 7, pp. 8877–8898, 2022, https://doi.org/10.1007/s13369-021-06392-y.

[23] C. Yu, S. Li, and Y. Liu, "A System for the Prediction of Fire Pump Failure Based on Internet of Things and Machine Learning Algorithms," *Proceedings of the 2024 4th International Conference on Internet of Things and Machine Learning*, pp. 216-221, 2024, https://doi.org/10.1145/3697467.3697644.

[24] E. A. Elkhidr, A. S. Elrashdi, S. E. Khiralla, N. A. Altawerghi and F. M. Hasan, "Using IoT for Patient Health Monitoring System (PHMS) to Measure Temperature, Blood Pressure and ECG Based on Arduino IDE 2.x," *2024 4th International Conference on Emerging Smart Technologies and Applications (eSmarTA)*, pp. 1-5, 2024, https://doi.org/10.1109/eSmarTA62850.2024.10638972.

[25] B. Perumal, J. Deny, K. Alekhya, V. Maneesha and M. Vaishnavi, "Air Pollution Monitoring System by using Arduino IDE," *2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC)*, pp. 797-802, 2021, https://doi.org/10.1109/ICESC51422.2021.9533007.

[26] V. S. M. Revanth Pasupuleti, B. M. Jollu, K. Chaithanya Janapati, A. Naseeha and P. Chandana, "Partial Automation of Automobiles using Embedded Systems," *2020 4th International Conference on Trends in Electronics and Informatics (ICOEI)(48184)*, pp. 191-195, 2020, https://doi.org/10.1109/ICOEI48184.2020.9142924.

[27] A. Buachoom, K. Wuttisela, and S. Wuttiprom, "Development of a simple line-follower robot with constant acceleration motion," *Journal of Physics: Conference Series*, vol. 1719, no. 1, p. 012091, 2021, https://doi.org/10.1088/1742-6596/1719/1/012091.

[28] Q. Ariyansyah and A. Ma'arif, "DC Motor Speed Control with Proportional Integral Derivative (PID) Control on the Prototype of a Mini-Submarine," *Journal of Fuzzy Systems and Control*, vol. 1, no. 1, pp. 18–24, 2023, https://doi.org/10.59247/jfsc.v1i1.26.