DEVELOPMENT OF DCS SCADA TEACHING MODULE ON A PID-BASED WATER LEVEL CONTROL CASE USING LABVIEW AND FACTORY I/O

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ABSTRACT

The DCS SCADA course is one of the latest courses for the 2022 curriculum at Politeknik ATI Makassar. This course has case study-based learning from the industrial world and involves very expensive instrumentation devices for Real Plant, so a Teaching Module with factory i/o was created. This research aims to develop a DCS SCADA Teaching Module based on the Water Level Control case using Labview and Factory I/O. The virtual plant uses a water tank with instruments consisting of two control valves, namely the fill valve and the discharge valve, and two transducers, namely the level meter and the flow meter. To connect the factory I/O to NI Labview, the open protocol Modbus Ethernet is used. Based on the testing results, the calibration for the level measurement has an accuracy of 99.59% and a precision of 0.69% with the interpolation $y = 0.301x - 0.536$ for a 100% correlation. For the system response with SP = 150 without disturbance, the PID parameters should be set to Kp = 25, Ti = 0.1, and Td = 0 with a system response consisting of Rise Time = 396 seconds, no Overshoot, Settling Time = 430 seconds, and Steady state error = 0.566 cm. For the system response with SP = 150 with a DV = 50% disturbance, the PID parameters should be set to Kp = 25, Ti = 0.1, and Td = 0 with a system response consisting of Rise Time = 382 seconds, no Overshoot, Settling Time = 462 seconds, and Steady state error = 1.469 cm.

Keywords: DCS SCADA, Factory I/O, Labview, PID, Water Level Control.

1. INTRODUCTION

Operators working in the Central Control Room (CCR) in industry must have adequate knowledge and competencies about DCS and SCADA. They are responsible for monitoring and controlling instruments at the Field Devices level, such as sensors and actuators, through computers at the Remote Stations level (Ani et al., 2019); (Khanna et al., 2019). This competency is very important for operators to be able to perform their tasks well. DCS SCADA is one of the latest courses offered at Politeknik ATI Makassar in the Automation of Machining Systems program for the 2022 curriculum. The main focus of this course is students' understanding of the design of the Human Machine Interface (HMI), the connection of controllers such as PLC to the HMI using Open Protocol technologies such as Modbus and OPC, and the connection of the HMI to the database.

To understand DCS and SCADA, the best way is through case studies using expensive instrumentation devices, from the field devices level, Field Control Station or Remote Terminal

Unit, to the Human Interface Station or Master Terminal Unit. One way to save cost is by using a virtual plant application, such as the Factory I/O application, which can replace the expensive instrumentation devices (Martinez et al., 2018); (AMIR, 2020); (Naim, 2021). The water tank level control system or Water Level Controller (WLC) is a case study that is often raised in the control and automation laboratory of Politeknik ATI Makassar, such as in the practice of control systems (process control systems), PLC practice and microcontroller practice. This is because this case is simple enough but widely applied in industry.

Several innovations have been made from the WLC case study during the practical process. One of them is by collaborating between the NI Labview application and Factory I/O to control the water level in the tank using an ON OFF (two-position) controller and a PID controller. Based on the need for curriculum development and some innovation results during the practical process, this research aims to develop a teaching module for the DCS SCADA subject for the case study of the PID-based water tank level control system using the NI Labview and Factory I/O application.

2. THEORY

A water level controller is a system that controls the height of water in a container or tank using a sensor that measures the height of the water, a control system that receives signals from the sensor and adjusts the system output according to the predetermined setpoint, and an actuator that receives signals from the control system and changes the system condition according to the signal (Siregar et al., 2020); (Olejnik Pawełand Awrejcewicz, 2022). Water level controllers are usually used in applications that require accurate water level control, such as water heating systems, water cooling systems, water storage systems, and others (Desnanjaya et al., 2013).

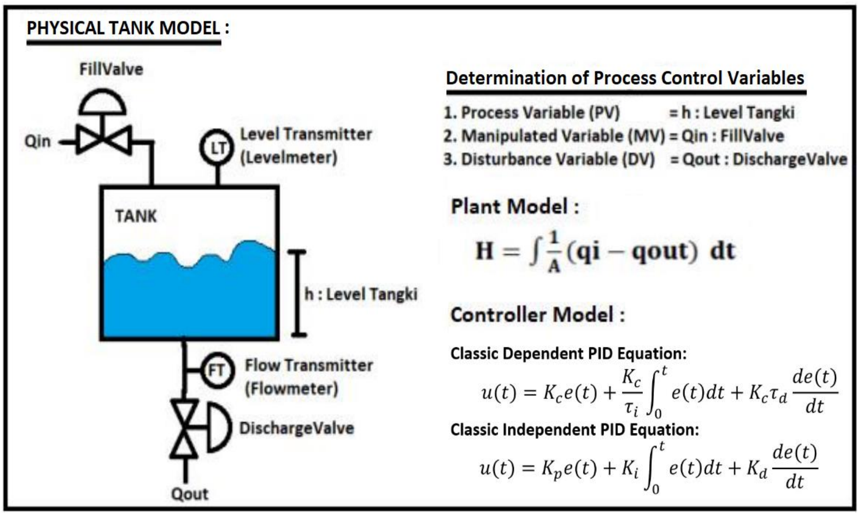
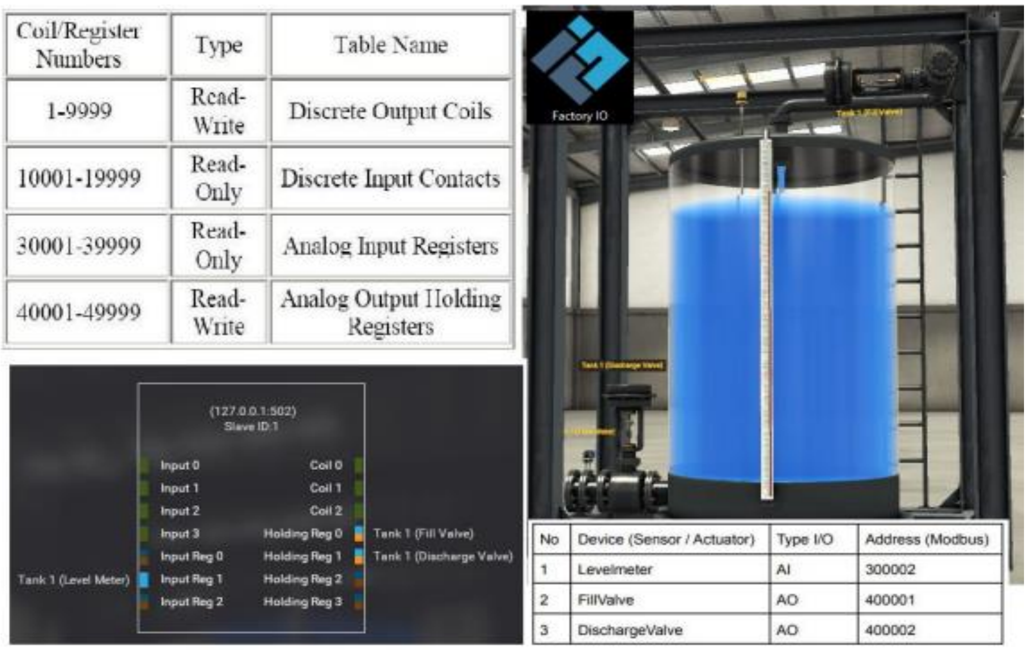


Figure 1. Physical model and mathematical model for water level controller case

The water tank being used is a simulation of a "factory I/O" panel station spare tank, in which the liquid tank includes two control valves and a capacitive level sensor that can be used to control the flow of liquid into and out of the tank (Omijeh et al., 2015). The control valves are controlled by a pneumatic actuator that can be positioned with a signal between 0 and 10 volts. The shape of the tank is similar to a cylinder with a height of 3 meters or 300 cm and a crosssection diameter of 2 meters. The maximum flow rate for water intake is 0.25 m3/s and the maximum flow rate for water outflow is 0.3543 m3/s. There are two analog input sensors, a capacitive level meter with a specification of 0-3 meters linear with 0-10 volts, and a flow meter with a specification of 0-0.3543 m3/s linear with 0-10 volts. There are two analog output actuators, a fill valve and a discharge valve, each with a specification of 0-100% linear with 0-10 volts.



Coil/Register Numbers	Type	Table Name
1-9999	Read-Write	Discrete Output Coils
10001-19999	Read-Only	Discrete Input Contacts
30001-39999	Read-Only	Analog Input Registers
40001-49999	Read-Write	Analog Output Holding Registers

No	Device (Sensor / Actuator)	Type I/O	Address (Modbus)
1	Levelmeter	AI	300002
2	FillValve	AO	400001
3	DischargeValve	AO	400002

Figure 2. Scene Factory I/O for Water Level Controller
Case Study with Modbus addressing

Mapping sensor or actuator tags to I/O points with drivers is necessary to allow communication between the virtual plant Factory I/O and the controller application (Mora-Salinas & Hernández, 2022); (De Melo & Godoy, 2019). PLCs from Allen Bradley and Siemens can be connected to the factory, but controllers from other vendors such as NI Labview require the use of the Modbus Ethernet (TCP/IP Server) protocol with IP 127.0.0.1. Modbus TCP/IP is a protocol that uses TCP/IP for communication and is commonly used in industrial automation for reliable communication between devices. A Modbus TCP/IP server is a device that responds to requests from a Modbus TCP/IP master and can be a PLC, computer, or other device with a TCP/IP connection and the ability to respond to Modbus messages. The Modbus TCP/IP protocol specifies the format and rules for messaging and communication.

3. METHOD

This research was conducted at the Control and Automation Laboratory located in Politeknik ATI Makassar. The research was carried out for four months during the process control systems (process control systems) practical. In this research, several tools and materials are used as follows:

1. PC with Windows 64 bit, Intel Core i7 CPU 3.20GHz, RAM 16GB.
2. 3D Virtual Plant **Factory I/O** software (Scene : Liquid Level Tank).
3. NI **Labview** software (Include Datalogging and Supervisory Control (DSC) Module).

4. A spreadsheet application like Microsoft Excel or Google Sheets.

This research is a deductive quantitative research that is experimental through simulation modeling and prototype creation referring to the theory and hypothesis related to the component parameters used. Research data can be divided into primary data in the form of level measurement (cm) against ADC value on PLC and voltage value on NI Labview as well as secondary data in the form of supporting literature review for water tank simulation and tank parameter data from factory i/o documentation help. The implementation of the research consists of several stages, namely the stage of literature review related to Factory I/O, NI Labview, Modbus Ethernet, Water Level Controller and PID Controller, the stage of creating a system simulation with factory I/O, the stage of developing research results through innovation during practicals in the laboratory, and the stage of documenting research results in the form of research journals. Innovative teaching materials can be implemented in practical sessions through project-based learning using the STEM (science, technology, engineering, and math) method, following the steps shown in the following image.

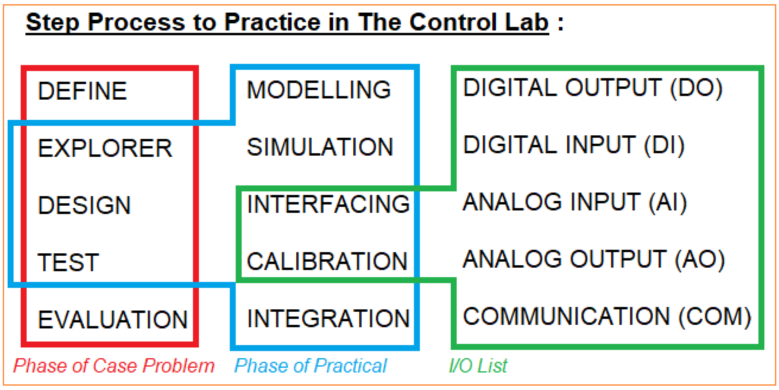
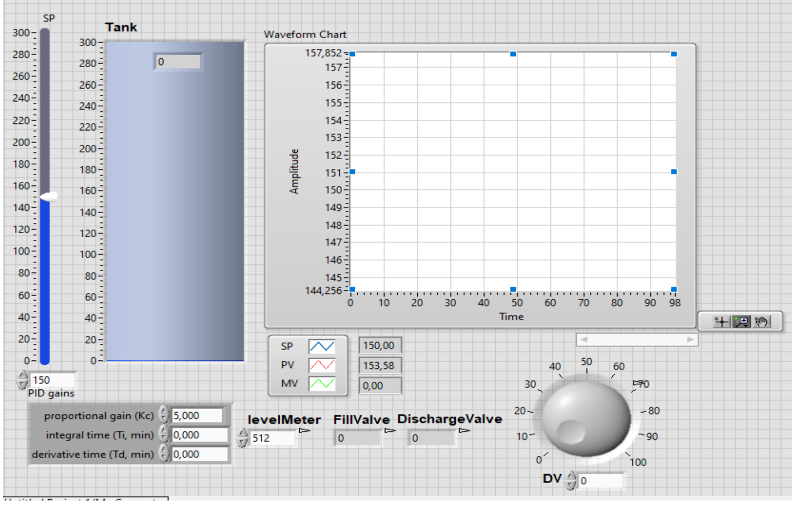


Figure 3. Engineering design process for innovative learning in the laboratory

4. RESULTS AND DISCUSSION

The below figure shows the schematic design for a system based on the LabView program, including a separate GUI for the water tank system with a PID controller made in LabView and a block diagram for the system in LabView. The set point, or input value for the control system, can be changed through the GUI.



SP 150
PID gains
proportional gain (Kc) 5,000
integral time (Ti, min) 0,000
derivative time (Td, min) 0,000
SP 150,00
PV 153,58
MV 0,00
levelMeter 512
FillValve 0
DischargeValve 0
DV 0

Figure 4. Labview Front Panel Display for PID-based Water Level Control

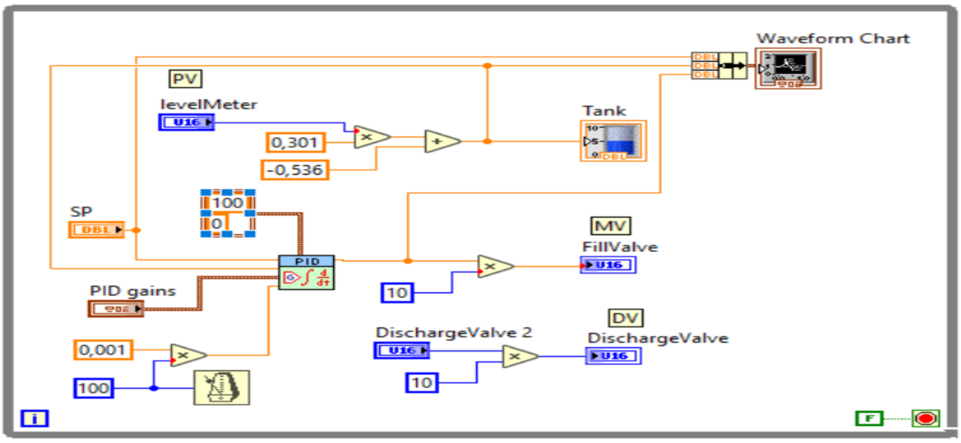


Figure 5. Labview Block Diagram Display for PID-based Water Level Control

Figure 5 shows the block diagram for a PID-based water level control system in a tank, which can be divided into three parts: the PID controller, the plant process (tank) using Tag I/O mapped by the Modbus protocol, and the calibrator obtained through the following data analysis.

Table 1. Data acquisition of tank level linearity in Factory I/O and NI Labview

Tank Level in Factory I/O (cm)	**Measured voltage in Labview (mV)**				**Level (cm)**	**Error (%)**	**Accuracy (%)**	**Standard Deviation (mV)**	**Precision (%)**
	1	**2**	**3**	**mean**					
10	37	35	35	35.67	10.20	2.00	98.00	1.15	3.24
20	69	68	68	68.33	20.03	0.16	99.84	0.58	0.84
30	102	99	101	100.67	29.76	0.78	99.22	1.53	1.52
40	134	140	134	136.00	40.40	1.00	99.00	3.46	2.55
50	169	168	167	168.00	50.03	0.06	99.94	1.00	0.60
60	200	199	199	199.33	59.46	0.89	99.11	0.58	0.29

70	233	234	234	233.67	69.80	0.29	99.71	0.58	0.25
80	268	267	267	267.33	79.93	0.09	99.91	0.58	0.22
90	302	301	300	301.00	90.07	0.07	99.93	1.00	0.33
100	335	334	334	334.33	100.10	0.10	99.90	0.58	0.17
110	368	368	368	368.00	110.23	0.21	99.79	0.00	0.00
120	399	399	399	399.00	119.56	0.36	99.64	0.00	0.00
130	435	434	433	434.00	130.10	0.08	99.92	1.00	0.23
140	468	467	467	467.33	140.13	0.09	99.91	0.58	0.12
150	500	500	500	500.00	149.96	0.02	99.98	0.00	0.00
					Rata-rata	0.41	99.59	0.84	0.69

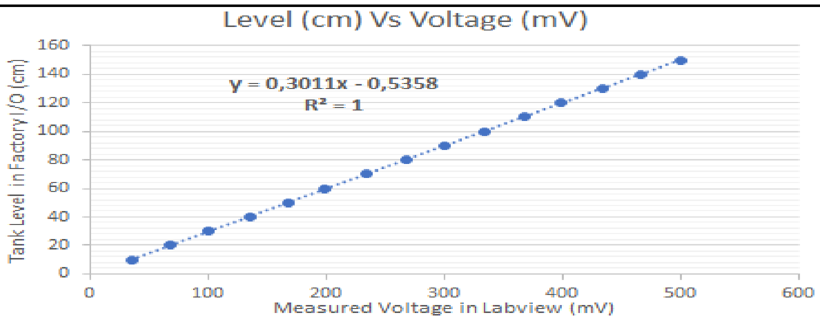


Figure 6. Linearity curve between tank level (cm) and measured voltage (mV)

To display the level in the NI Labview application, the measured voltage must be converted into a level using the linear interpolation formula y = 0.301 x - 0.536, so that the error can be measured at 0.41% or accuracy at 99.59% with precision at 0.69%. After calibrating using the LabVIEW block diagram, the PID parameter data was collected to determine the system response, including rise time, overshoot, settling time, and steady state error. The results of testing the system response to PID parameters tuned using the trial and error method can be seen in the following table.

Table 2. System Response Testing to PID Parameters

A. Testing without disturbance (PV_initial = 0, SetPoint = 150, Disturbance Value = 0)

No	**KP**	**TI**	**TD**	**Rise time (second)**	**Overshoot (cm)**	**Settling time (detik)**	**Steady state error (cm)**
1	20	0	0	223	13	285	12,606
2	30	0.5	0	1047	0	1047	0.036
3	25	0.1	0	396	0	430	0.566
4	15	0.2	0	35	1.469	163	1.469 (underdamped)
5	22	0.3	0	785	0	785	0.036

Testing with 50% disturbance (PV_initial = 0, SetPoint = 150, Disturbance Value = 50)

No	KP	TI	TD	Rise time (second)	Overshoot (cm)	Settling time (detik)	Steady state error (cm)
1	20	0	0	258	15	309	12.004
2	30	0.5	0	1060	0	1180	0.265
3	25	0.1	0	382	0	462	1.469
4	15	0.2	0	741	0	742	0.265
5	22	0.3	0	895	0	895	0.265

Using the PID parameters Kp=25, Ti=0,1, and Td=0, the system will give a Rise Time=396 seconds and Settling Time=430 seconds with a steady state error of 0.566 cm when there is no disturbance. However, when there is a DV=50% disturbance, the same PID parameters will give a Rise Time=382 seconds, Settling Time=462 seconds, and a steady state error of 1.469 cm.

5. CONCLUSIONS AND SUGGESTIONS

According to the research and discussion that has been outlined, it can be concluded that the DCS SCADA teaching module for a PID-based water level control system using NI Labview and Factory I/O has been successfully developed and tested with an accuracy of 99.59% and a precision of 0.69%. The test results show that the best PID parameters for SP = 150 are Kp = 25, Ti = 0.1, Td = 0 with a system response of Rise Time = 396 seconds, no Overshoot, Settling Time = 430 seconds, and Steady state error = 0.566 cm. When there is a disturbance of DV = 50%, the best PID parameters are Kp = 25, Ti = 0.1, Td = 0 with a system response of Rise Time = 382 seconds, no Overshoot, Settling Time = 462 seconds, and Steady state error = 1.469 cm.

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