Construction design system of constant pressure control in water distribution system with PID method using PLC based on IoT

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Construction design system of constant pressure control in water distribution system with PID method using PLC based on IoT

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Abstract. The objective of this research is to make a constant pressure control in water supply with the method of PID using PLC Siemens S7-1200 as a controller and also to monitor the process of its work system from a distance through the internet of things (IoT). The water distribution system is created utilizing 3 phase pump which will supply water from the tank. The pressure sensor will be used as an analog input signal of PLC to detect the pressure of water in the pipe. Using inverter, water pressure will be kept constantly matched with the desired set point through the setting of pump speed using the digital PID method that is available on PLC. The score of the set point is done through HMI of touch panel KTP700basic. By using Wi-Fi communication that has been connected to the internet, PLC data can be sent to a cloud server through raspberry pi3 using the MQTT protocol. Raspberry pi3 program is designed using the java script coding language. Research result showing that this system can keep the water pressure at a constant level of 1.2 bar in the water supply. It is also able to monitor the water pressure through HMI and handphone via IoT Technology in the GoIoT server.

1. Introduction
The water distribution system is a very important medium for industry or buildings to stream clean water from its source to the output. Water pressure is one of the key parameters that are always a concern for its users. The lack of water pressure in one industry can create the work of one machine that needs water supply less optimal [1]. On the contrary, for high rise buildings, because there is a gap different of the height in every floor, the output of water pressure from the plumbing tool will not be the same for every floor [2]. This will affect customer satisfaction in using water. To create an optimum of pressure water, a good design of installation or having a machine that is capable to produce water pressure constantly is needed. With the technology advancement in electronic, an inverter can become a solution in solving the constant water pressure issue [3].

Inverter or commonly called a variable speed drive can be used to adjust pump motor speed by the pressure needed [4]. This inverter can be controlled using the PID method available on PLC (Programmable Logic Controller) [5]. PLC is a controller which that can be programmed and works digitally based on logic operation according to an algorithm programmed on it so it can control a process. A control process will make sure the steps of the control process will be done correctly based on the step process that has been set. PID (Proportional Integral Derivative) controller is a controller to
determine the precision of the instrumentation system with the characteristic of the feedback to that system [6].

Along with the times, an industry currently has experienced with industry revolution 4.0. Likewise, vice versa in industrial automation using PLC controllers [7]. The government has grouping five main industries that will be prepared for this industry revolution 4.0. There are food and beverage industries, textiles, automotive, electronics, and chemicals. Industry revolution 4.0 or the fourth generation of the industry is a change in the industry world which influenced by the widespread of technology and internet development. Internet of Things (IoT) is a technology that capable to change one device into a valuable device, some of them are used for monitoring home automation, automotive, factory/assembly line automation, medical/preventive healthcare, retail [8]. Based on the facts above, therefore in this research, a control system for constant pressure in water distribution will be created with the method of PID using PLC based on HMI and IoT.

2. Research method
The method used in this research is an experimental method, which is designing a system, making a program, do a program trying to be implemented in a system to be able to get the desired output. This testing is used to measure how much voltage is generated when the sensor is detecting the water pressure and the number read by PLC. PLC Siemens S7-1200 CPU 1214C is used as a control system with the input signals are a push button, pressure sensor, and signal from HMI which are control auto/manual and the desired setpoint value. The block diagram system can be seen in figure 1. Meanwhile, a schematic diagram system can be seen in figure 2.

![Figure 1. Block diagram system.](image-url)
As seen in figures 1 and 2, the push button is used for turning the system on and off, while the pressure sensor is used to detect the height of the water level in the tank and water pressure in the pipe [9]. The output signal controlled by PLC is an inverter. The inverter is used to control the speed of 3 phase pump rotation through the frequency setting given to the motor using the digital PID method that is avail on PLC.

The PID algorithm has operates under three basic modes, the Proportional mode, Integral mode, and the Derivative mode. The PID algorithm is used to control an analog process having a single control point and a single feedback signal. The difference between measured value by the sensor and the setpoint is the error that is continuously calculated by a PID controller. The PID algorithm controls the output to the control point so that the water pressure can be constantly aligned with the desired setpoint regardless of how many valves are opened. An inverter will increase the speed of the motor pump when the water pressure is decreased and inverter will decrease the speed of the motor pump when the water pressure is increased. The work process of the system can also be monitored through HMI and IoT. PLC data will then be read by raspberry pi through Wi-Fi communication in the router. Henceforward, those data will be sent to the internet server so that the user can monitor the control of constant water pressure system.

2.1. Hardware design
Tools used in this system of the constant pressure of water distribution are 3 phase pump, 3 phase inverter, pressure sensor, PLC, HMI of touch panel KTP700 Basic, hub switch and raspberry pi. Design results can be seen in figures 3 and 4.

Figure 2. schematic diagram system.
As seen in figures 3 and 4, the pressure sensor is connected to an analog input module SM12131 4AI. The type of sensor used to detect water pressure in the pipe is PSAN_LT with the voltage output is 1-5 volt. This pressure sensor is connected to the A13 terminal in the analog input module of PLC. While the pressure sensor with the current signal of 4-20mA which is used to detect the height of the tank is connected to the A10 terminal in the analog input module of PLC. The installation of analog input is shown in figure 5. Meanwhile, the inverter installation is shown in figure 6.
As seen in figure 6, the type of inverter used is SV-IG5. The centrifugal pump is connected to the output of the inverter in U, V, W terminal. The voltage source used by this inverter is 380 VAC with an output power of 0.75 kW. The inverter converts power in DC form to AC at the required frequency and voltage output. The step that must be done in operating the inverter is setting the inverter parameters by pressing the FUNC key found on the inverter keypad. Set DRV-03 (drv) to 1 (Fx/Rx-1) and DRV-04 (frq) to 2 (V1) for input signals in the form of a voltage between 0-10 V.
In the IoT system, we use TCP/IP protocol to communicate between raspberry pi and PLC. Raspberry Pi will send PLC data block to a cloud server through Wi-Fi communication that has been connected to the internet. The Raspberry Pi is a low cost, credit card sized single-board developed at the United Kingdom by the Raspberry Pi Foundation with the purpose to advance the educating of fundamental software engineering in schools and creating nations. The Raspberry Pi has a built-in video, audio, and USB input that can be connected to the keyboard and mouse as well as network connection capabilities via Ethernet, wireless and USB [10].

2.2. Software design
The design of the PLC logic program is using software Tia Portal V14 using the ladder diagram as its programming language. PLC programming is created using OB (organization block), FC (Function Call), FB (Function Block) and DB (Data Block). The PID algorithm that lies in PLC is made on OB30. PID Compact is using FB with DB2 (PID_Compact_1) as its DB Instance. PID parameters which are kp, ti and td are set to get the respond of the desired result.

PID program on PLC can be seen in Figure 7 while the PLC program which is used to read the pressure sensor can be seen in Figure 8. %IW102 and %IW96 are the addresses of word analog input PLC on channel3 and channel 0. A scaling program is needed in processing analog signal data from the sensor. PLC scaling program with the instruction of norm_x is used to represent the output data of pressure sensor which is a voltage of 1-5V or current of 4-20mA into decimal number 0-27648. Furthermore, the output data of norm_x function will be inputted to scale_x function to read the pressure of 0-10 bar. While the program to adjust output analog is used for instruction of norm_x and scale_x.

![Figure 7. PID program on PLC.](image-url)
As seen in Figure 8, PLC data for pressure sensor stored in %DB1.DBD4. Raspberry Pi is used to send PLC to IoT data using javascript programming. Here the following program is used to read PLC data blocks from pressure sensors, setpoint, actual frequency from the result of output PID and manual frequency can be seen in figure 9.

```javascript
    { "no_db": 1,
        "no_register": 4,
        "type_register": "REAL",
        "nama_tag_mqtt": "ACT_BAR" },
    { "no_db": 1,
        "no_register": 40,
        "type_register": "REAL",
        "nama_tag_mqtt": "ACT_FREQ" },
    { "no_db": 1,
        "no_register": 28,
        "type_register": "REAL",
        "nama_tag_mqtt": "MAN_FREQ" },
    { "no_db": 1,
        "no_register": 20,
        "type_register": "REAL",
        "nama_tag_mqtt": "SP_BAR" }
```

**Figure 9.** Javascript program for reading analog input and output.

The algorithm used so that PLC data can be sent to IoT Cloud through the MQTT platform is as follows:

- Prepare library snaps 7 Siemens, library MQTT client, library read a file, prepare connection MQTT. Then try connecting to the MQTT server
- Have you connected to the MQTT server? If yes, read the JSON file configuration for No DB, No Register and Name Tag_MQTT. If not, then try connecting to the MQTT server again
- Is the register.json file configuration valid? If yes, try connecting to the PLC server. If not, then exit the program and correct the configuration of the register.json file.
- Have you connected to the PLC server? If yes, read register PLC and take the value. If not, then try connecting to the server PLC until connected;
- Read the PLC register and take the value
- Publish to the MQTT name_tag server with the values from the PLC register taken;

Message Queuing Telemetry Transport (MQTT) is a lightweight transport protocol that efficiently uses the network bandwidth with a 2byte fixed header. MQTT works on TCP and assures the delivery of messages from node to the server. Being a message-oriented information exchange protocol, MQTT is ideally suited for the IoT nodes which have limited capabilities and resources [11]. Javascript programs are used for reading PLC data in the raspberry pi.

3. Results and discussion

3.1. Inverter testing

This test is done in manual mode and its objective is to find out whether giving frequency value to HMI aligns with the frequency given from inverter to pump. The inverter result test can be seen in Table 1.

| HMI | Analog output PLC | Inverter | Sensor |
|-----|------------------|----------|--------|
| Set Freq | AQ data (integer) | Voltage (volt) | Frequency (Hz) | RPM | Pressure (bar) |
| 0 | 0 | 0 | 0 | 0 | 0.02 |
| 5 | 2765 | 1.03 | 5.48 | 159 | 0.08 |
| 10 | 5530 | 2.01 | 10.54 | 310 | 0.15 |
| 15 | 8294 | 3.00 | 15.68 | 465 | 0.21 |
| 20 | 11059 | 4.00 | 20.76 | 617 | 0.29 |
| 25 | 13824 | 5.02 | 25.86 | 771 | 0.40 |
| 30 | 16589 | 6.04 | 30.98 | 924 | 0.63 |
| 35 | 19354 | 7.07 | 36.04 | 1077 | 0.68 |
| 40 | 22118 | 8.09 | 41.15 | 1230 | 0.85 |
| 45 | 24883 | 9.15 | 46.23 | 1382 | 1.04 |
| 50 | 27648 | 9.95 | 50.00 | 1500 | 1.20 |

As seen in table 1, The bigger the frequency produced, the greater the pump speed. Pump speed when the maximum frequency (50 Hz) is 1500 rpm. The minimum frequency given to the pump so that it can discharge water is 15 Hz with a speed of 465 rpm. Under the 15 Hz frequency, the pump cannot remove water even if the pump is rotating.

3.2. PID testing

This test is created in auto mode and give the set point through HMI. The objective of this test is to measure the response of the control system in constant pressure.

3.3. IoT testing

Internet of Things (IoT) program is used to monitor water pressure in the pipe, pressure setpoint, and motor frequency remotely in handphone or computer via the internet network. Data from the PLC can be sent to the cloud in the GoIoT server through raspberry pi using the MQTT protocol. There are several steps to use that server which are creating your account, fill the channel, add device and tags. Furthermore, copy ID Channel in the GoIoT Server to the raspberry pi program. The result of the IoT monitoring system can be seen in Figure10. This result shows the pressure setpoint given to controller by 1.2 bar. When the actual water pressure is far below the setpoint value, the frequency given to the motor reaches a maximum of 50 Hz.
4. Conclusion

In this research, the design of a constant pressure control system has been successfully created and implemented in the water distribution system. PLC S7-1200 can be used as a control system of constant water pressure by using the PID algorithm. An inverter will adjust pump motor speed by sending the frequency of 0-50Hz to pump. The maximum pressure that can be set is 1.2 bar. If it is more than that then the pump is unable to increase its speed to produce the desired pressure. The work process of the system can be controlled and monitored through HMI and IoT (Internet of Things). Raspberry Pi can be used to read PLC data through wifi communication and can be sent to the GoIoT server using the MQTT protocol that has been connected to the internet.

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References

[1] Mo X L 2014 Based on PLC the Automatic Constant Pressure Control Water Supply System Design Appl Mech Mater 716–717 1587–90
[2] Zhang P and Li T Z 2014 Design of Water Supply System with no Tower under Constant Pressure Based on PLC Appl Mech Mater. 644–650:3701–4
[3] Peng X, Xiao L, Mo Z and Liu G 2009 The Variable Frequency and Speed Regulation Constant Pressure Water Supply System Based on PLC and Fuzzy Control International Conference on Measuring Technology and Mechatronics Automation IEEE 910–3
[4] Vodovozov V, Raud Z and Gevorkov L 2015 PLC-Based Pressure Control in Multi-Pump Applications Electr. Control Commun Eng. 9(1) 23–9
[5] Xing M R, Zhang J and Zhang X D 2013 The Design of Constant Pressure Water Supply Control System Based on S7-200 PLC Adv Mater Res.
[6] Rooholahi B and Lokender Reddy P 2015 Concept and Application of PID Control and Implementation of Continuous PID Controller in Siemens PLCs Indian J Sci Technol. 8(35)
[7] Langmann R and Rojas-Peña L 2016 PLCs as Industry 4.0 Components in Laboratory Applications Int J. Online Eng. 12(07) 37
[8] Kishor K R, Kajijidoni M B and Pradeep Kumar M S 2017 Smart Agriculture System Using IoT In: Third International Conference on Current Trends in Engineering Science and Technology ICCTEST-2017. Grenze Scientific Society 1229–33
[9] Zhang M 2014 Design of Water Level Intelligent Control System Based on SCM Appl Mech Mater. 602–605;1395–8
[10] Maksimović M, Vujović V, Davidović N, Milošević V and Perišić B 2014 Raspberry Pi as Internet of Things hardware: Performances and Constraints Proc 1st Int Conf Electr Electron Comput Eng IcETRAN 2014, Vrnjačka Banja, Serbia 3 8
[11] Atmoko R A, Riantini R and Hasin M K 2017 IoT real time data acquisition using MQTT protocol J. Phys. Conf. Ser. 853:012003