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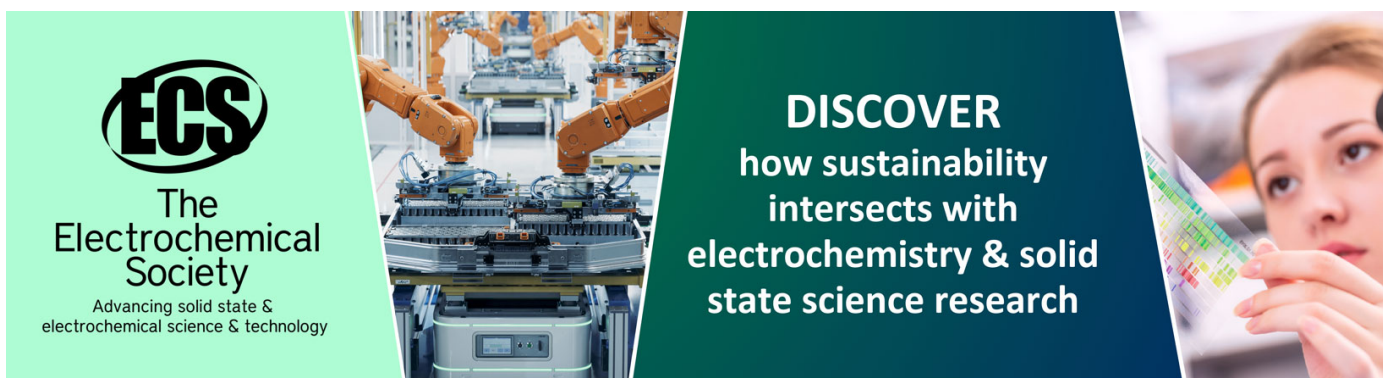
## Design of flow control system based on PLC armfield pressure control module in chemical engineering laboratory

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# Design of flow control system based on PLC armfield pressure control module in chemical engineering laboratory

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**Abstract.** A control system in industry has an important role to increase the effectiveness and efficiency in manufacture process. Laboratory of Chemical Engineering Department in State Polytechnic of Malang has several tools to develop competence in automation process control system, one of them is the pressure control module. This module aims to control the rate of compressed air flow coming out from the compressor. Nonetheless, the control system used is still analog. In order to improve the performance of module, rejuvenation has created by PLC that is optimized by PID controller method. This rejuvenation process is carried out in several stages, such as designing PLC hardware and software then testing and analyzing the system. There are four stages in testing and analyzing the system, both testing and analyzing the open loop system without tank and with tank, PID close loop with tank and without tank. Based on the results, this study indicated that the close loop system with PID has a better response than open loop system, which is able to improve the errors and transient responses so that the system is more stable and fit with set point value. The PID parameter that produces a good response when used in the pressure control module is  $K_p = 100$   $K_i = 1$  and  $K_d = 0$ . This parameter is able to produce a system measurement value of 80% with error of 0%.

## 1. Introduction

Chemical Engineering Laboratory of State Polytechnic of Malang has several teaching modules, one of those modules is the pressure control module. The module is used as learning for Chemical Engineering students to figure out the flow rate of compressed air that comes out from the tank or without tank by applying the open loop and close loop systems (with feedback). Furthermore, analyse some parts of air pressure when conducting experiments using tanks. The problem of the system is the controller itself as the main control in the module. The controller is broke which cannot accept input from the sensor results or providing a set point signal, so the module cannot be used properly and data retrieval still uses a recorder. PLC (Program Logic Controller) is one of the technological developments in controller field. The use of PLC in the pressure control module plays an important role as the main control in the module, therefore when using PLC, users can use the module manually and automatically. To improve the working principal of PLC, the writer put PID as an extra controller [1]. PID control consists of P (Proportional), I (Integral) and D (Derevative) which aims to accelerate and produce the best system response. The pressure control module uses PID to calculate the error value as the desired set point difference [2]. From these problems and descriptions, a PLC-based controller was made and evaluated the comparison of Open Loop experiments using tank and Close Loop trials using tank or without tank



on the compressed air control module that was upgraded by the Proportional, Integral, and Derivative algorithm (PID).

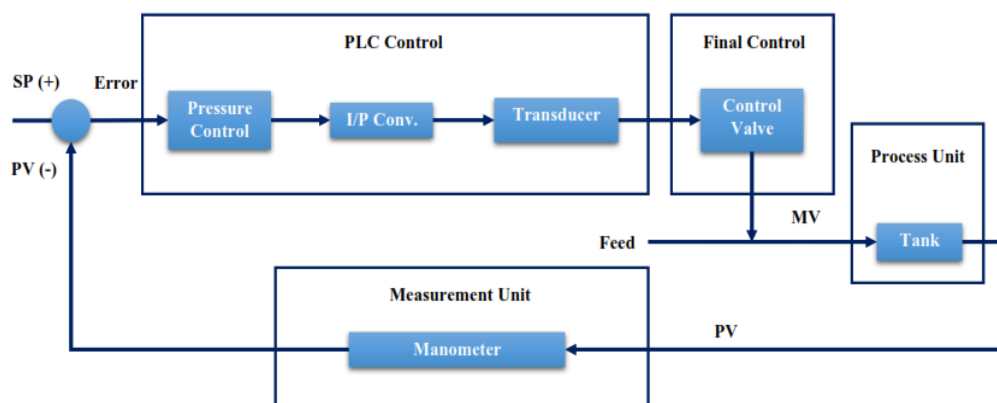
## 2. Methods

### 2.1. Schematic of process control system

Both models that contained in PCT 10 are manual and automatic mode. In relatively slow process, the controller is able to analyse the process which connected with controller, calculate the appropriate PID amount and set it automatically [3]. Such operations are referred to auto-tune or self-optimize and can be activated as follows. Set Point pressure is determined via HMI. From pressure value that has been read, the pressure data will be processed by controller then be used as a comparison with set point, which given the control results to the system [4]. The error value obtained by the controller is processed by the PID control output from the system and adjusted to the pressure set point value determined from the reading.



**Figure 1.** Pressure control module armfield PCT 14.

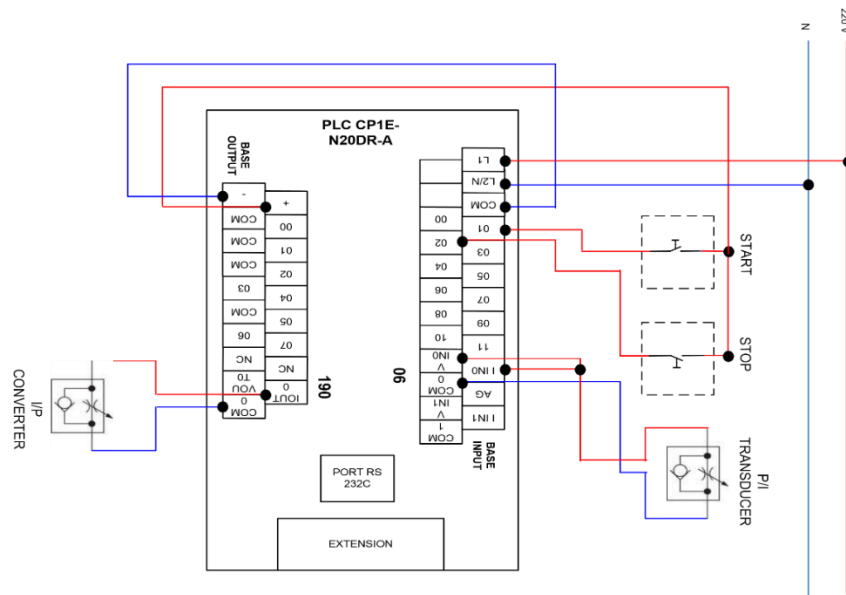


**Figure 2.** Process block diagram.

### 2.2. OMRON CP1E-NA20DR-A PLC wiring design

PLC is used as the main controller to control the holistic system. The Omron CP1E-NA20DR-A PLC type used is a power voltage configuration of 100 to 240 V AC, 12 inputs and 8 outputs. The I / O configuration of the Omron CP1E-NA20DR-A used is shown as in Figure 3 below. The flow of electricity from 220 voltage source flows to L1 PLC which functions as power from the PLC, then the neutral source is connected to the L2 PLC terminal as a neutral source.

The analog input from PLC is connected to transducer sensor, I IN0 is coupled with V IN0 and connected to sensor phase. Furthermore, COM 0 is connected to sensor neutral. The analog output and I Out 0 are connected to IP Converter phase and COM 0 is connected to the IP Converter. The START button enters the PLC input 01 address and the STOP button enters the PLC address 02 which connected to the PLC source.



**Figure 3.** Wiring I/O PLC Omron CP1E-NS20DR-A.

### 2.3. Omron CP1E-NA20DR-A PLC program design

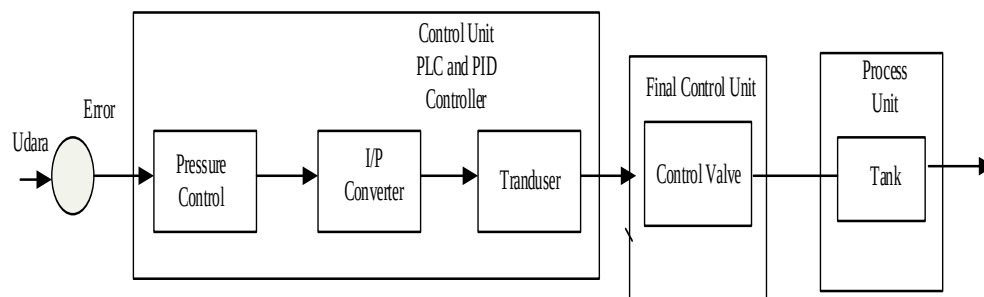
Program design on PLC Omron CP1E-NA20DR-A uses special software that user friendly program, CX Programmer. This software has been used to program the PLC Omron CP1E-NA20DR-A using ladder diagram programming language [5].

## 3. Analysis and testing

The analysis is carried out in order to determine whether the pressure module control system has been able to function as expected by testing the circuit tool. Testing tools in form of testing pressure module control system components, Open Loop testing and Close Loop testing with PID to prove the results of the design made.

### 3.1. Testing of open control with tanks (Open Loop)

The Open Loop test is carried out without providing feedback to the system. When the set value is entered, the response from the output will be analyzed.



**Figure 4.** Block diagram of Open Loop system with tank.

### 3.1.1. Test results and Open Loop testing graphs using tank

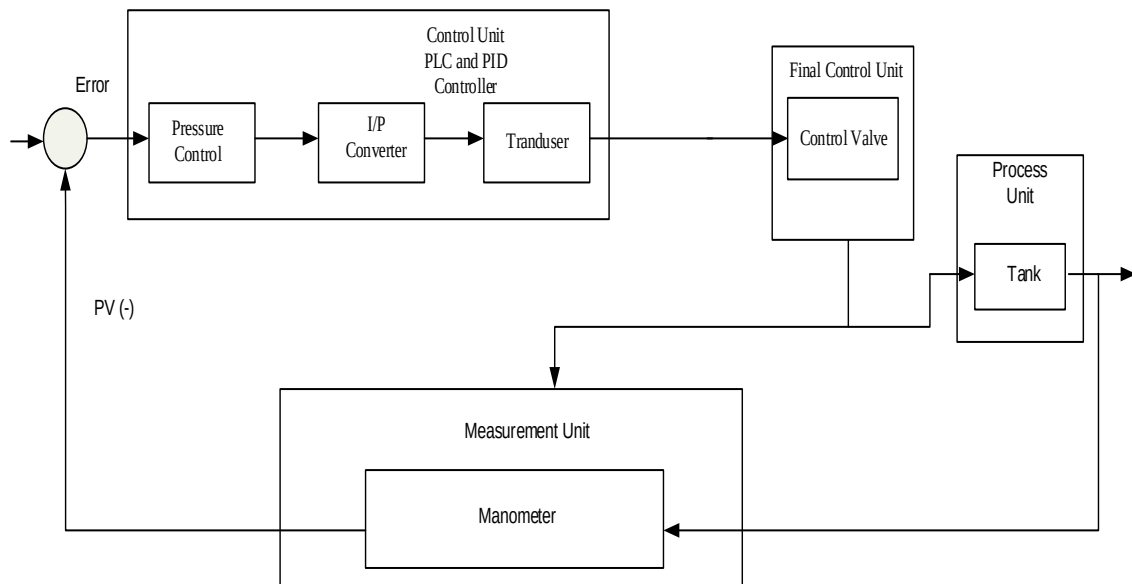
**Table 1.** Test results with 0-100% PO tank.

| %PO | %PV | P4(Psi) | P2(Psi) | % PVideal | $\Delta\%P_{ideal}$ |
|-----|-----|---------|---------|-----------|---------------------|
| 0   | 100 | 8.5     | 3       | 100       | 0                   |
| 10  | 97  | 8       | 4       | 90        | 7                   |
| 20  | 86  | 7.7     | 5       | 80        | 6                   |
| 30  | 80  | 7.1     | 6.2     | 70        | 10                  |
| 40  | 67  | 6.6     | 7.5     | 60        | 7                   |
| 50  | 52  | 6       | 8.7     | 50        | 2                   |
| 60  | 37  | 5.1     | 10      | 40        | 3                   |
| 70  | 22  | 4.2     | 11      | 30        | 8                   |
| 80  | 6   | 3       | 12,3    | 20        | 8                   |
| 90  | 2   | 1.5     | 13.5    | 10        | 8                   |
| 100 | 0   | 0       | 15      | 0         | 0                   |

**3.1.2. Open Loop experiment analysis using tank.** When conducting an open loop experiment on pressure control through the tank, a significant change according to response of graph will show briefly. The graph shows decrease gradually when the initial set point settings change to steady state until subsequent set point. This phenomena can be happen because the air pressure that flowing through the tank is compressed and slows down the output of air pressure that is released, so the pressure will flow out slowly [6].

### 3.2. Automatic Close Loop testing mode using PID with tank

This system is applied in automatic mode because this experiment observes the amount of response time, error on a given setpoint. The test is carried out as follows:



**Figure 5.** Close Loop circuit diagram with PID using a tank.

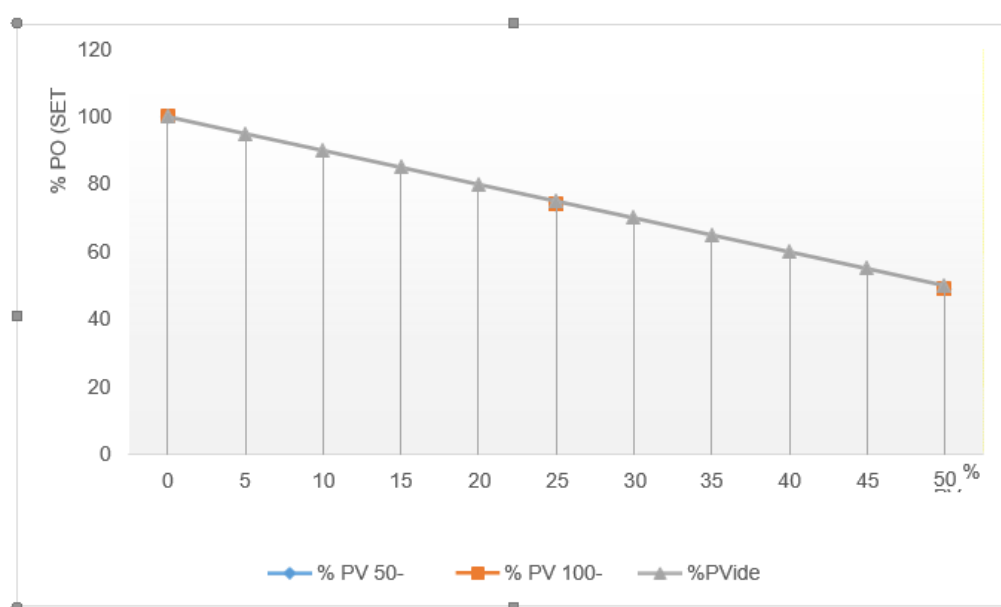
### 3.2.1. Test results and Close Loop testing graphs using a tank

**Table 2.** Close Loop testing using a tank with variable Kp.

| Parameter         | Kp = 80<br>Ki = 0 | Kp = 90<br>Ki = 0 | Kp = 100<br>Ki = 0 | Kp = 110<br>Ki = 0 |
|-------------------|-------------------|-------------------|--------------------|--------------------|
| Risetime (ms)     | 50                | 48                | 40                 | 40                 |
| Settling Time     | 0.02              | 0.02              | 0.02               | 0.02               |
| Error Average (%) | 2,5               | 2,5               | 2,5                | 2,5                |

**Table 3.** Close Loop testing using a tank with variable Ki.

| Parameter         | Kp = 10<br>Ki = 1 | Kp = 100<br>Ki = 2 | Kp = 100<br>Ki = 3 | Kp = 100<br>Ki = 5 |
|-------------------|-------------------|--------------------|--------------------|--------------------|
| Risetime (ms)     | 50                | 52                 | 50                 | 50                 |
| Settling Time     | 0.02              | 0.02               | 0.02               | 0.02               |
| Error Average (%) | 0                 | 0                  | 0                  | 1,25               |



**Figure 6.** Comparison change of % PO to % PV in a Close Loop system using a tank.

**3.2.2. Closed Loop experiment analysis using a tank.** This system can be obtained that the work tool system is in accordance with the target value of % PV Testing is close to % PVideal or % PV Testing = % PO = % PVideal, because the comparison of changes in the % PV value between 50-100 and 100-50 obtained data with a difference of 1 to 0 points. This happens because there are errors in the equipment which are quite small and these errors have been processed by feedback in the form of measurements and the PID system [7].

## 4. Conclusion

In operating this tool, there are 2 experimental practicums, open loop for manual mode and close loop for automatic mode, in each practicum there are two methods, without and using tank respectively.

- Open loop: The main target of testing is the value of  $\%PV = \%PV_{\text{testing}} - \%PV_{\text{ideal}}$  because in open loop system there is no feedback and corrections toward output error value in order to fix the system. So this system is suitable for manual mode and the value from  $\%PO$  to  $\%PV_{\text{ideal}}$  becomes the reference. When the system using a tank has the advantage of being able to easily provide a  $\%PO$  (set point) value for valve openings and has the disadvantage of not maximizing the  $\%PV$  test results against  $\%PV_{\text{ideal}}$  as to produce a difference of  $\%PV_{\text{max}} = 16$  points.
- Close loop: The main target for testing is a value of  $\%PO = \%PV$  because in close loop system there is feedback and corrections to output error value on the system using PID controller. This system is suitable for automatic mode so the reference of the target is the value of  $\%PO = \%PV$  and  $\%PV_{\text{max}} = 0$ .

Furthermore, when system using a tank has the advantage of being able to easily provide a  $\%PO$  (set point) value for the valve opening, by changing the values of  $K_p$ ,  $K_i$  and  $K_d$  will greatly affect the results of the process output. The drawback of this method is  $\%PV$  test results against  $\%PV_{\text{ideal}}$  are not maximal, resulting in a difference in value of  $\%PV_{\text{max}} = 0$  points. For further research, an automatic system with SCADA will be built, then HMI can be displayed according to the real conditions.

## References

- [1] Gozali R M 2005 Desain Kontrol Pid Dengan Metoda Tuning Direct Synthesis Untuk Pengaturan Kecepatan Motor Dc *Teknoin* **10**(4) 283-293
- [2] Wicaksono H and Pramudijanto J 2004 Kontrol PID Untuk Pengaturan Kecepatan Motor DC Dengan Metode Tuning Direct Synthesis *Jurnal Teknik Elektro* **4**(1) 10-17
- [3] Hardiansyah R 2018 Kendali Posisi Linear Actuator Berbasis PID Menggunakan PLC *Journal of Applied Electrical Engineering* **2**(1) 12-17
- [4] Suyanto S and Yulistyawan D 2007 Otomatisasi Sistem Pengendali Berbasis PLC Pada Mesin Vacuum Metalizer Untuk Proses Coating (Studi Kasus Di Pt. Astra Otoparts, Tbk-Divisi Adiwira Plastik, Bogor) *GEMATEK (Jurnal Teknik Komputer)* **9**(2)
- [5] Lukito E S 2018 *Pengembangan Media Pembelajaran PLC (Programmable Logic Controller) Studi Kasus Aplikasi Sorting Machine Pada Mata Kuliah PLC Di Prodi Pendidikan Teknik Elektronika Fakultas Teknik Universitas Negeri Yogyakarta* (Skripsi, Yogyakarta: Universitas Negeri Yogyakarta)
- [6] Amaroh H M 2017 *Kontrol Kecepatan Putar Motor Pada Proses Pembuatan Arum Manis Dengan Metode PID* (Skripsi, Malang: Politeknik Negeri Malang)
- [7] Hermawan W n.d. Simulasi Kontrol PID Berbasis PLC (Programmable Logic Controller) dan HMI (Human Machine Interface) Pada Sistem Automatic Well Test *Jurnal Universitas Jayabaya*