

Implementation of communication system between Siemens PLC S7-1200 with Omron PLC CP1L-EL20DT1-D for induction motor speed controller

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Abstract. Nowadays, it has entered the era of the Industrial Revolution 4.0 where information and communication technology plays an important role almost in all fields such as transportation, industry, education and other fields. The Industrial Revolution 4.0 requires that all equipments or systems are connected to one another. At present, many equipments in the field of industrial automation have not integrated yet. The main device that must be connected in a control system is a PLC, because it is a data storage and control center. Some problems will arise if the PLCs are not connected to each other, such as asynchronous data which managed by each PLC, offline data recording and monitoring the performance of each PLC takes a relatively long time. This research discusses the multi PLC communication system for induction motor speed regulation. Induction motor is one type of motor that is widely used in industry because it is cheap and reliable. The communication media is used for communication between PLCs is modbus. The results showed that communication between PLCs could worked well with the master model (PLC Siemens) - slave (PLC Omron). The system had a steady state error of 17.07% with a maximum speed of 1267.6 rpm.

1. Introduction

Industrial revolution 4.0 requires that the field of industrial automation undergo a change from what was originally standalone, it must integrate between one system with another system. One of the most important parts in the field of industrial automation is the Programmable Logic Controller (PLC). PLC is one of device that is widely used in the manufacturing, pharmaceutical, garment and several other industrial fields. The PLC's function has evolved from being replaced only as a relay control, now PLC has additional functions as motion control, process control, distributive control system and complex networking [1]. Research on industrial automation has been carried out [2],[3],[4],[6] especially in the field of communication between PLC, such as research conducted by [1] about SMS communication between PLC masters and slaves using a GSM modem, in this research controlled plants are water treatment processes that are made in a simulation. Hence, the time delay in the process of transferring data from the slave to the plant is ignored, because the plant is in the form of simulation. Media for communication between PLCs uses GSM Modem. If the number of PLCs has increased, an additional GSM modem is needed. The system is not effective if it is used on many

PLCs. The next research carried out by [3] is about multi PLC communication with integrated SCADA-DCS system platforms.

The PLC system is made with a master slave system and it is displayed on an HMI with an Ethernet connection. The PLC is used as the master is Siemens S7-1200, while the slave PLC uses the Twido Schneider PLC and the Omron CP1H PLC. HMI is used for displaying data using Vijeo Architecture software. There is only a serial communication facility in the CP1H PLC to be able to communicate over long distances and it is necessary to add conversion equipment from serial data to Ethernet TCP / IP using WIZ110SR devices. The development of PLC technology has developed now both in terms of software and hardware, nowadays there has been a PLC that has facilitated communication via Ethernet TCP / IP for PLC e series.

In this research, a communication system design was made between two PLCs with the modbus communication protocol. PLCs that will be used in the system that will be built are Siemens S7-1200 and Omron CP1L-EL20DT1-D which have communication facilities with Profibus. Then, for testing the system, it will be applied to the induction motor speed regulation. The set point speed comes from the potentiometer and the motor speed value that is displayed on the LCD. The prototype of this tool will serve as a learning medium for the practice of PLCs in State Polytechnic of Cilacap in industrial automation laboratory. This paper will be divided into several sections. The first part is the background of the problem, the second part is the design of the system or method of research, the third part is the results and discussion, and the last part is the conclusion.

2. System design

The system design that used in this research consists of two parts ,i.e., the master and slave parts refer to [2]. The master part serves to provide control signals which originate from the motor speed set point. The slave part functions as the receiver of the control signal from the master, then it is processed to adjust the speed of the induction motor as we expected by the master section. System block diagram that has been made can be seen in Figure 1.

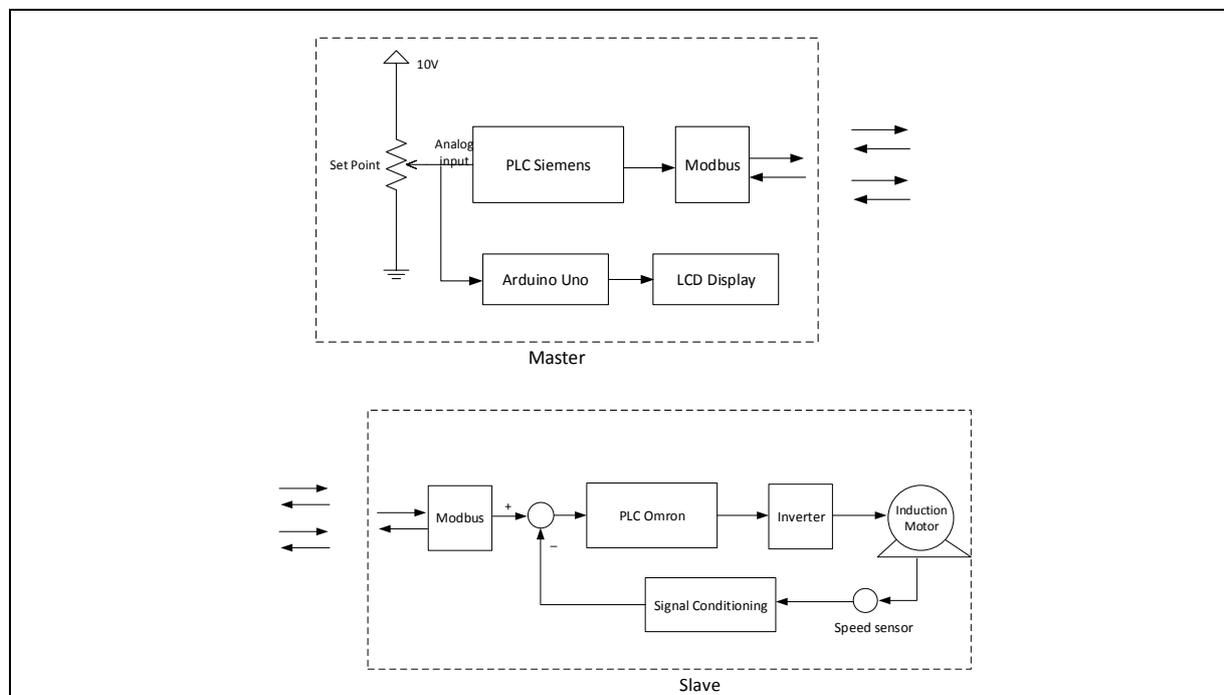


Figure 1. System block diagram.

Based on the block diagram that the PLC has made on the slave section has a vital role in this system because it serves to regulate the motor speed as well as sending actual motor speed data to the master section. So the motor speed can be adjusted linearly, an inverter with a variable voltage input that obtained from the PLC is used. The work principle of each part of the block diagram above are explained as follows.

2.1. PLC

PLC which used in this system is Siemens S7-1200 which has been supported by professional communication using standard TCP / IP connections and it can be used for communication with HMI or other devices which can be seen in Figure 2. The communication interface uses RJ45 connectors with autocross over functions that equipped with Ethernet network with data transmission up to 10/100 Mbps. Profinet protocol is possible to communicate with several third party devices using the open ethernet protocol and ISO on TCP. In addition, the software and library section also includes modbus over TCP instructions that have been used via the ethernet port.



Figure 2. PLC Siemens S7-1200.

The PLC that used as a slave in this system is the Omron PLC type CP1E, i.e., a series of CP1L-EL20DT1-D which shown in Figure 3. The omron PLC type is chosen because there is already a communication facility via an ethernet terminal. This PLC can be used for LCD Display and supporting expansion slots for analog input / output. Besides, the CP1L-EL20DT1-D series is equipped with a high speed counter for reading from speed sensors, such as a rotary encoder.



Figure 3. PLC Omron CP1L-EL20DT1-D.

2.2. Modbus Communication Protocol

The communication protocol that used in this research is Modbus. This protocol becomes the communication standard in industry. Some of the advantages of the Modbus communication protocol are as follows:

- Relatively easy to combine with industrial networks
- Are open protocol and royalty free
- Can transfer data "raw bits" or "word" without limiting the type of vendor

As an intermediary media of the modbus communication protocol can be via serial ports (RS 232, RS 485, FO), Ethernet (LAN) and networks that support internet protocols. The entire Modbus TCP / IP is packaged into standard TCP frame data and sent over TCP port 502, which is specific to the modbus application. The function code that used in Modbus can be seen in Table 1.

Table 1 Modbus function code.

Code	Function	Reference
01 (01H)	Read Coil (output) status	0xxx
03 (03H)	Read Holding Register	4xxx
04 (04H)	Read Input Registers	3xxx
05 (05H)	Force Single Coil (Output)	0xxx
06 (06H)	Preset Single Coils (Output)	4xxx
15 (0FH)	Force Multiple Coils (Output)	0xxx
16 (10H)	Preset Multiple Registers	4xxx
17 (11H)	Report Slave ID	Hidden

2.3. Induction motor

The load that is controlled in this system is the speed of the induction motor [5-6]. This single phase induction motor is a type of motor that is easy to regulate. The series of single phase induction motors for left and right turn can be seen in Figure 4. The part of a single phase induction motor consists of a stator containing the main winding, auxiliary winding and the coil on the rotor. The speed regulation of the motor is conducted by the inverter by regulating the frequency at the output voltage of the inverter. If the frequency is high, the motor rotation speed will be higher, vice versa if the output frequency is low, the motor rotation will also be lower. The direction of rotation of a single phase induction motor can be adjusted by changing the voltage polarity of the main coil as shown in Figure 4.

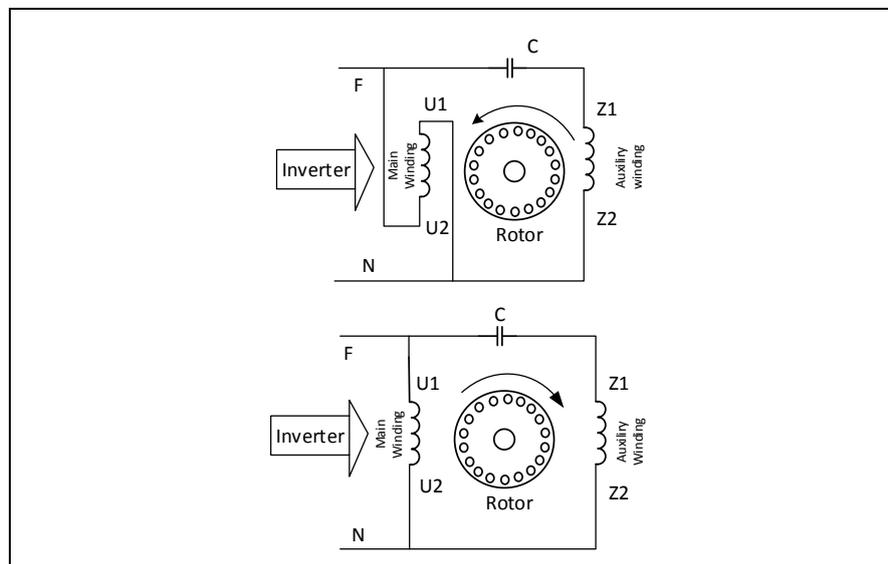


Figure 4. The series of single phase induction motor for left and right turn.

The symbol F is the phase for the supply voltage of the induction motor. This voltage is obtained from the inverter that has been controlled by the PLC. The amount of voltage applied is 220 V with a frequency that can change to adjust the speed.

2.4. Inverter

The inverter is used as an induction motor driver that functions as a soft starter and running. Inverter that used in the Sv008ic5-1f type system is from LS Industri System. This inverter operates with a 220V single phase input voltage with a maximum output power of 0.75kW [7]. The output of this inverter is three phase (U V W), because the induction motor that used is one phase, only the "U" phase is used. This inverter can be operated either internal mode or external mode which gets input from outside of the inverter. In this research, the inverter is operated in an external mode where the trigger from the inverter is obtained from the PLC output. There are two terminal parts in this inverter, i.e., the control terminal and power terminal, the structure of each terminal can be seen in Figure 5.

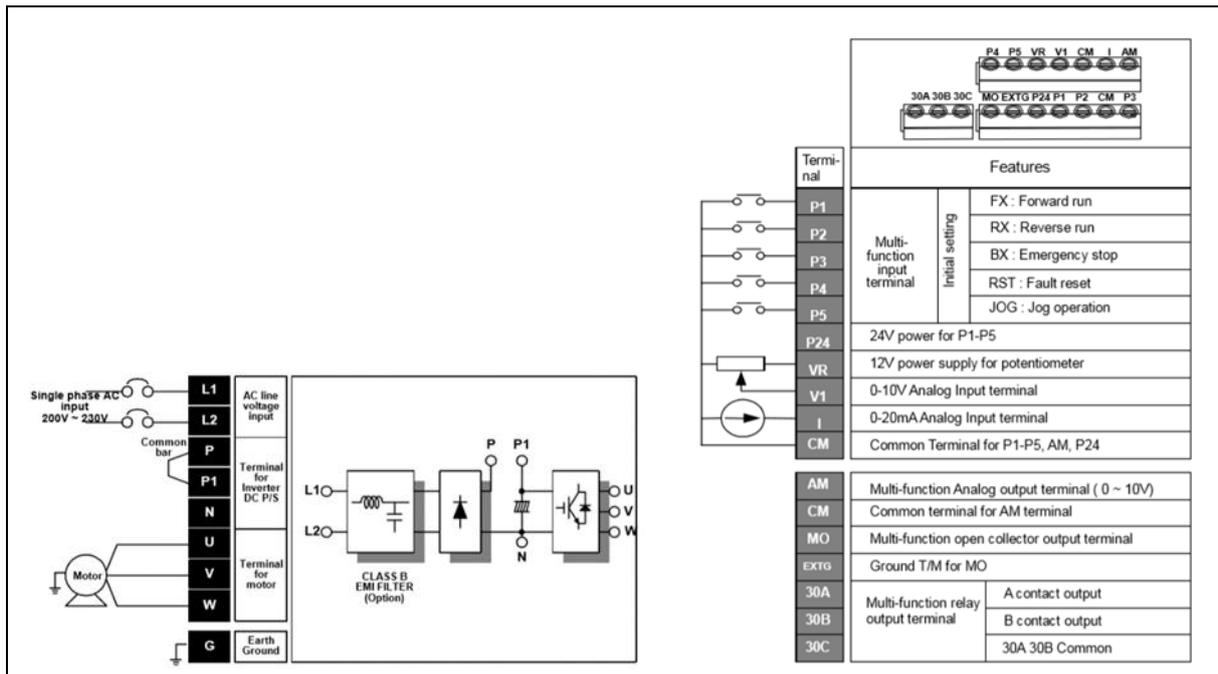


Figure 5. Control terminal and power inverter.

Operation with an external mode is conducted by giving a voltage of 0 to 10 V on terminal V1. In the operation of single-phase induction motors is only one phase is used from the three available phases, i.e., the "U" and Ground phases. This inverter has 4 menus that can be set, each menu has several parameters that can be set. The inverter menu can be seen in Figure 6 as follows.

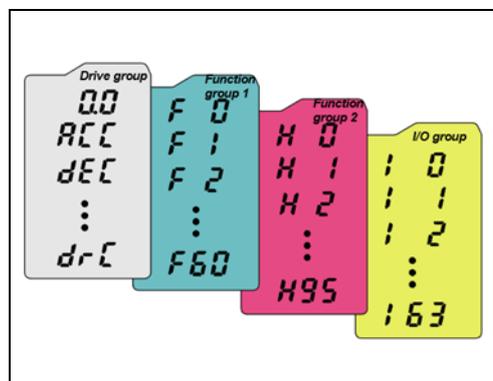


Figure 6. inverter setting menu.

Explanation of the setting of each menu group above can be seen in Table 2.

Table 2. inverter menu group.

Menu	Statement
Drive Group	Basic setting menu in order to run
Function Group 1	Basic parameter setting, such as voltage and output frequency
Function Group 2	Advanced setting for setting PID parameter
I/O Group	sequensial mode setting uses many inputs/outputs

In this research, the settings with external mode were selected. The settings menu is as follows:

- Drive group menu, select the parameter "00"
- Function Group 1 select F0 then set the parameter
 - The first parameter is filld in "00"
 - The second parameter is filled in "frq"
 - The third parameter is filled in "1"
 - The fourth parameter is filled in "3"

After all parameters are set, return to the initial menu then the inverter is ready to use. After an external voltage is applied to terminal V1, then give the trigger "0" to P1 in the control terminal section.

3. Results and discussion

The results of implementing the induction motor speed regulation system can be seen in Figure 7. The induction motor is placed above the control panel box, while the display in the form of an LCD display is placed beside the panel box. To adjust the speed using a potentiometer that is placed next to the LCD display. On the front panel there are the START, Rotate Right, Rotate Left and STOP buttons.



Figure 7. Designed system.

The direction of rotation of the motor is carried out by a combination of relay and contactor circuits, while the speed regulation of the induction motor is conducted by an inverter. Based on the test results that the communication system between Siemens PLC and PLC Omron can be conducted

by giving a High signal to the TCON.Req block. It aims to connect TCP / IP connections between Siemens PLC and PLC Omron. Then, it was conducted the IP Address equalization with each port. Connection results can be seen in the TCON value. Error Low, TCON. Busy Low, and TCON.Done by giving high pulses. If the connection is not connected, then TCON Error will be high.

Modbus testing between Siemens PLC as master and PLC Omron as slave can be conducted by looking at the "Connected" tag on each Client or Server data block. When the Siemens PLC is ON and each MD_Client and MD_server block is enabled, the connection will be automatically connected.

Test data that obtained from the system that has been made in the Laboratory of Industrial Automation of State Polytechnic of Cilacap can be seen in Table 3.

Table 3. Result of setting test of induction motor speed.

Vin (Volt)	Vout (Volt)	F(LCD) (Hz)	F(Invetr) (Hz)	Measure (rpm)	Calculation (rpm)
0.89	0.85	5	4.1	124.2	150
1.86	1.78	10	8.5	265	300
2.73	2.56	15	12.3	372.4	450
3.64	3.41	20	16.4	473	600
4.76	4.54	25	21.8	628	750
6.04	5.61	30	26.9	732.6	900
6.57	6.12	35	29.4	865.4	1050
7.45	6.75	40	32.4	975	1200
8.15	7.76	45	37.2	1124	1350
9.86	8.94	50	42.9	1267.6	1500

The data in table 3 is obtained when the motor speed has reached steady state. Where the voltage Vin is the voltage obtained from the speed sensor feedback. Then Vout is the voltage which released by the PLC analog output terminal. The output from the analog PLC output is used as an input inverter. Based on the data in table 3, it shows that the minimum frequency that can move an induction motor is 5 Hz and the maximum frequency is 50 Hz. There are 2 types of frequency data that shown in table 3: frequency data generated by the LCD Display that is connected indirectly to the potentiometer as a speed setpoint. Then the frequency data is displayed on the inverter display. There is a difference between the frequency data that was displayed by the LCD on the input panel and on the inverter, this is because the data that was displayed on the LCD input was controlled by Arduino Uno. Analog data that was obtained from the potentiometer were then it entered into the ADC and displayed to the LCD Display. It was conducted because of the incompatibility of the communication protocol between the LCD Display and the PLC that was used.

3.1. Comparison between V_{in} and V_{out}

In table 3, it appears that the magnitude of Vout and Vin is proportional. If Vin increases, then Vout also increases can be seen in Figure 8. Adding the value of Vin also affects the frequency generated by the inverter. If the frequency of the inverter increases, the motor speed also increases.

There is a difference in data between Vin and Vout, this is because Vout is obtained from the conversion of motor speed in units of rpm to voltage in units of volts. Vout is measured by the speed sensor has been burdened by an induction motor, so the value is relatively down from the input given. The average difference between Vin and Vout is 6.34%.

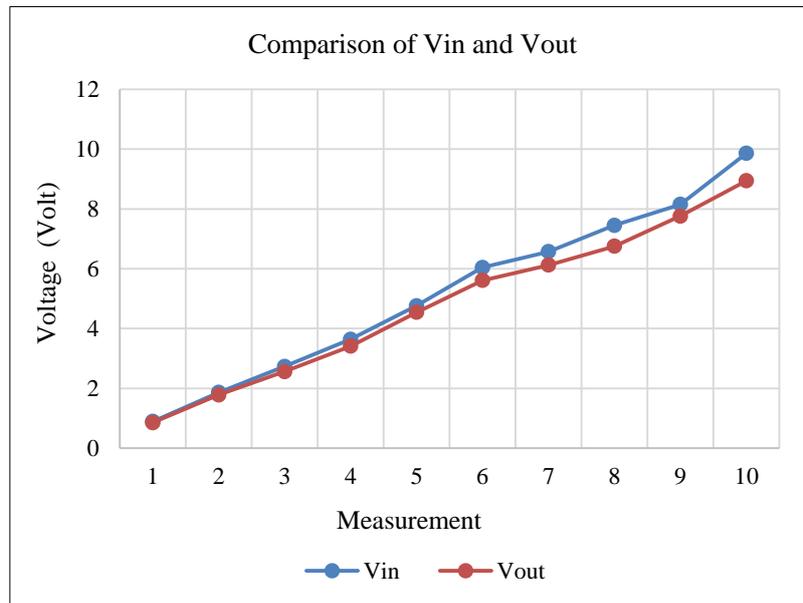


Figure 8. Comparison of Vin and Vout.

3.2. Comparison between turn and frequency

Based on measurement data that have been obtained, there are differences in the measurement data with the calculation. This is because the calculation results take data from the display frequency on the LCD on the input panel of the master, while the measurement results use the voltage data that goes into the inverter to be processed into frequency. The relationship between frequency and motor speed can be seen in Figure 9.

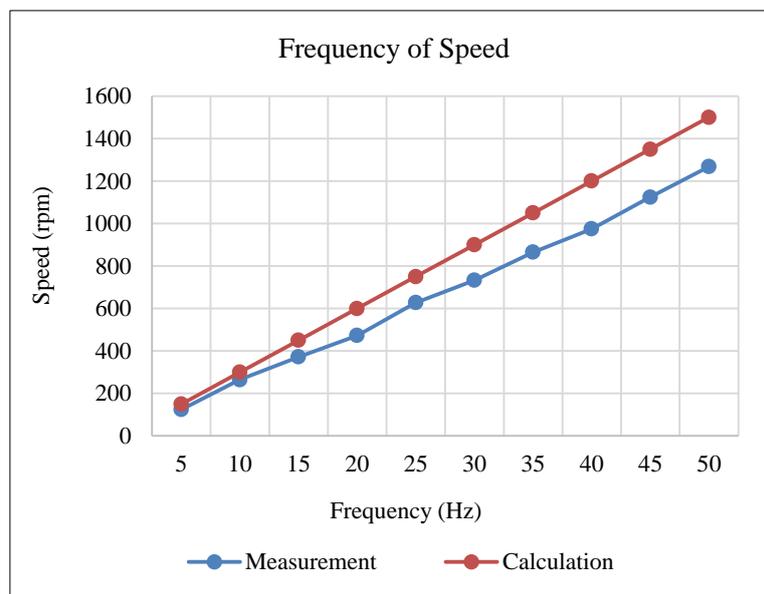


Figure 9. Frequency graph towards the turn speed of motor induction.

Based on Figure 9, it can be seen that the change of frequency is proportional to the change of motor rotation speed the higher the frequency, the greater the motor rotation speed will be. Based on table 3. The average difference between the measurement results and the calculation can be made at 17.07%.

This also corresponds to the Vout voltage that obtained from the speed sensor output which is lower than Vin. The controller that used in this system is only a proportional controller, so to determine the output equal to the set point has not been optimal. For further research, the controller can be improved by adding integral or derivative controls.

4. Conclusions

In the research that has been done, some conclusions can be described as follows:

- The communication system between Siemens PLC and PLC Omron can be conducted by providing a High signal to the TCON.Req block which functions to connect the TCP / IP connection between the Siemens PLC and the Omron PLC.
- Modbus testing between Siemens PLC as master and PLC Omron as slave can be conducted by looking at the "Connected" tag on each Client or Server data block.
- The average difference between Vin and Vout is 6.34%, because the Vout was measured by the speed sensor has been burdened by an induction motor
- The difference of motor rotation speed between the measurement results of the calculation or steady state error is 17.07% because the controller that used in this system is only a proportional controller.

5. References

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