

Comparison of DC Motor Speed Calculation Efficiency between Inductive Proximity Sensor and Rotary Encoder

Dino Dwi Aryanto¹, Sukir²

^{1,2}Master of Electrical Engineering Education Faculty of Engineering Universitas Negeri Yogyakarta

Email: Dinodwi.2020@student.uny.ac.id

ABSTRACT

This study examines the level of effectiveness and efficiency of a sensor on the calculation of the rotational speed (RPM) of a DC motor, considering that the calculation of the rotational speed of an electric motor, both AC motors and DC motors, greatly influences the output of the system. The speed of motor rotation is very influential in several fields, such as power generation, which will affect the output voltage that will be generated. There are many methods for measuring the rotational speed of a motor, including using an inductive proximity sensor and a rotary encoder combined with a PLC as a control center and data processor so that the rotational speed can be read. The output of the proximity sensor and rotary encoder will be connected to the PLC input pin so that data will appear in the form of a pulse value which can be seen in the program that has been made. The data obtained will be processed in a program that uses special instructions, namely PRV. In comparison, the speed of a DC motor will be changed using a PWM module or pulse width modulation to adjust the rotational speed of the motor. From the results of experiments that have been carried out using the proximity sensor, it gives an average motor speed reading of 6420 Rpm with an error of -10.3, and experiments carried out using a rotary encoder give an average motor speed reading of 6409.3 Rpm with an error of 0.4 so that it can be concluded that the use of a rotary encoder is more accurate than the use of a proximity sensor to calculate motor speed.

Keywords: RPM, PLC, inductive proximity sensor, rotary encoder, PRV

INTRODUCTION

The rotational speed is very important in production systems in the industry. In power plants, speed greatly affects the output voltage, so speed is very important in a system to achieve maximum results. Rotational speed measurement is usually measured on an electric motor. Electric motors are often found in ranging from industrial equipment to equipment in household appliances. The need for variable-speed AC induction motors arises in certain industrial applications, and this is often difficult to achieve because induction motors have a fixed speed, so it is very influential in production systems [1]. The use of an electric motor that is very easy is one of the advantages. There are many ways to measure speed, one of which is using a proximity sensor and an encoder sensor with a PLC controller. In both sensors, researchers will conduct experiments on sensors related to the efficiency of readings by comparison using a tachometer with a standard as a reference. The following components are used in this study. For the turning process for the production of objects,

the production results must produce maximum products. These products must be precise or match the desired size, and roughness must also be maximized with economic work [2]. At this time, many modules can calculate the speed of the motor that has been equipped with the RS485 communication module.

PLC is a microcomputer-based controller that stores instructions in the form of logic, sequence, time, calculation, machine, and process [3]. The advantages of a PLC compared to other controllers include programming. It is easier than installing a control panel wiring a relay, and it can be reprogrammed, compared to smaller relays, so it doesn't take up space. It is easier to maintain and has higher maintenance, can be connected to a computer more easily than a relay, and can perform a wider variety of controls than a relay [4].

METHODS

The research method used is the quantitative method. According to Prof. Dr.

Sugiono in his book stating that the quantitative method is a traditional method because it has been used quite often, so it has become a tradition as method for research. This method is also called the scientific method because it meets scientific principles, namely concrete, empirical, objective, measurable, rational, and systematic. This method is also called the discovery method because, with this method, various new science and technology can be found and developed. Quantitative research methods can also be interpreted as research methods based on the philosophy of positivism, used to examine a particular population or sample, data collection using research instruments, and quantitative/ statistical data analysis to test predetermined hypotheses [5]. Figure 1 shows the flow of quantitative research that researchers use.

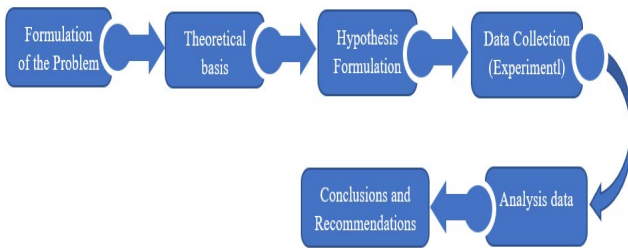


Figure 1 Quantitative Research Process

A. Wiring of Rotary Encoder

The rotary encoder used has an NPN type, so the blue cable is connected to 0VDC from the power supply, the brown cable is connected to 24VDC from the power supply, and the black cable is connected to Channel 0.00, the COM input PLC is connected to 24VDC. pictures of wiring measurements using a rotary encoder can be seen in Figure 2.

B. Wiring of Proximity Induktif

The Inductive Proximity Sensor used has the NPN type so that the blue cable is connected to 0VDC from the power supply, the brown cable is connected to 24VDC from the power supply, and the black cable is connected to Channel 0.00, the COM input PLC is connected to 24VDC. pictures of wiring measurements using a rotary encoder can be seen in Figure 3.

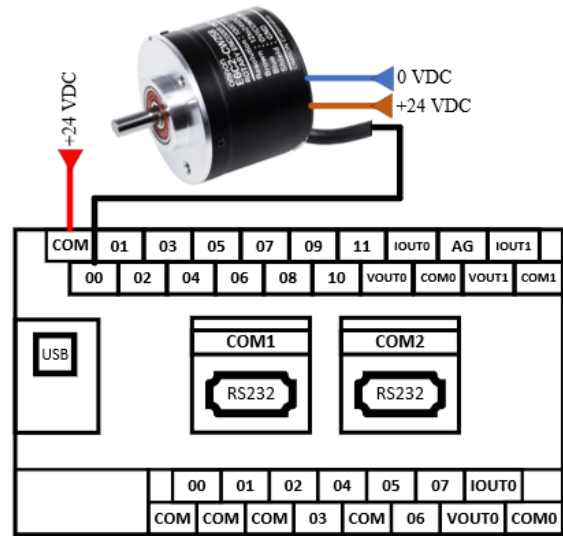


Figure 2. Wiring Rotary Encoder

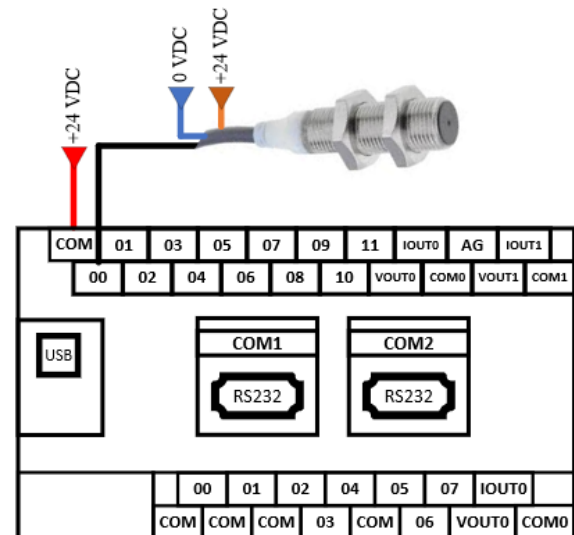


Figure 3. Wiring Proximity Inductive

C. PLC Programs

The program uses can be seen in Figure 4. The PRV(881) instruction functions to read the PV High-Speed Counter and output PV pulses, and interrupt input PV in counter mode.

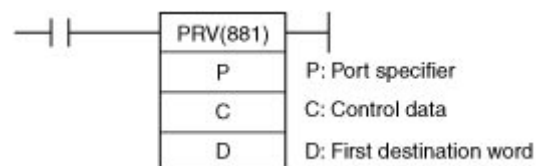


Figure 4. PRV instructions

In the PRV instruction, there are 3 parts, namely: (1) Port Specifier: in this section, the selection of usage on what part will be used,

with the following Table 1; (2) Control Data: in this section, the selection of PV readings, status readings, and others can be seen in the following Table 2; (3) First Destination Word: function to store data that has been managed.

Table 1. Port Specifier

No	P	Information
1	0000 hex	Pulse output 0
2	0001 hex	Pulse output 1
3	0010 hex	High-speed counter 0
4	0011 hex	High-speed counter 1
5	0012 hex	High-speed counter 2
8	0013 hex	High-speed counter 3
9	0014 hex	High-speed counter 4
10	0015 hex	High-speed counter 5 (Cannot be used in CP1E-E10D-)
11	1000 hex	PWM(891) output 0

Table 2. Control Data Table

No	P	Information
1	0000 hex	Reads the PV
2	0001 hex	Reads status
3	0002 hex	Reads range comparison results P = 0000 or 0001: Reads the output frequency of pulse output 0 or pulse output 1. C = 0003 hex
4	00 3 hex	P = 0010: Reads the frequency of high-speed counter input 0. C = 0013 hex: 10-ms sampling method C = 0023 hex: 100-ms sampling method C = 0033 hex: 1-s sampling method

In order to use the program effectively, it is essential first to complete the initial configuration, as shown in Figure 5.

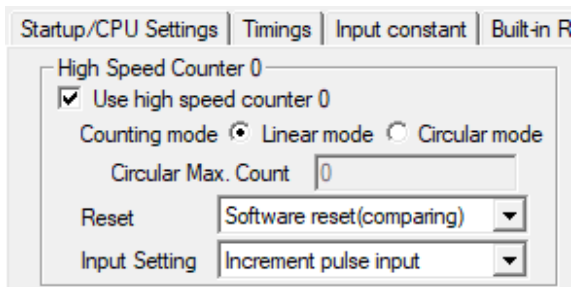


Figure 5. Setting High-Speed Counter

The equation formula can be determined as follows [15]:

$$RPM = \frac{\text{pulse per second}}{\text{pulse per rotation}} \times 60 \quad (1)$$

D. Program Proximity Inductive

Before utilizing the PLC, it is essential to carry out programming using the primary instruction known as PRV. For a thorough understanding of the entire set of instructions can be seen in Figure 6.

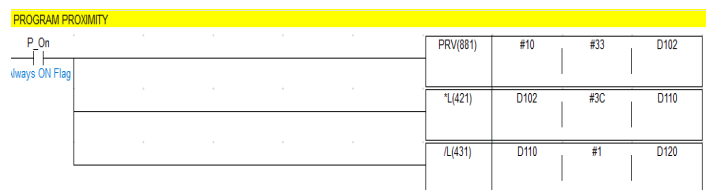


Figure 6. Program Proximity Inductive

An explanation of program instructions from Figure 5 can be seen in Table 3.

Table 3. Explanation of the Inductive Proximity Program

Function	Instruction	Information
PRV	#10	High-speed counter 0
	#33	1-s sampling method
	D102	Destination Word
*L	D102	First multiplicand word
	#3C	First multiplier word (Hex Value of 60)
	D110	First result word
/L	D110	First dividend word
	#1	First divisor word (Hex Value 1 of Pulse Per Rotation)
	D120	First result word

E. Rotary Encoder Program

To ensure proper usage, programming on the PLC should be conducted beforehand using the primary instruction known as PRV. Complete details can be seen in Figure 7.

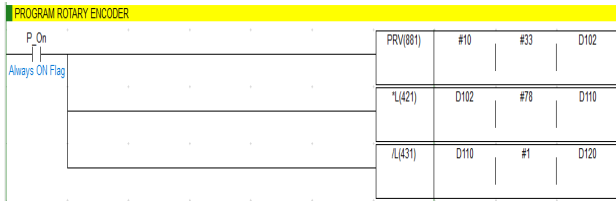


Figure 7. Rotary Encoder Program

An explanation of program instructions from Figure 7 can be seen in Table 4.

Table 4. Explanation of the Inductive Proximity Program

Function	Instruction	Information
PRV	#10	High-speed counter 0
	#33	1-s sampling method
	D102	Destination Word
*L	D102	First multiplicand word
	#3C	First multiplier word (The hex value of 120 serves for calibration because the rotary encoder loses 1 phase)
	D110	First result word
/L	D110	First dividend word
	#1	First divisor word (Hex Value 1 of Pulse Per Rotation)
	D120	First result word

RESULT AND DISCUSSION

In this study, the researcher conducted a literature study on several components and working system recognition of the control and conducted a literature study on the hypothesis found that in measuring rotational speed, the rotary encoder sensor reading has a high level of precision compared to readings using the proximity sensor due to the sensitivity level possessed by the proximity sensor lower so it has the potential to be lost on the reading. This study also uses the same program and only needs to be made a little adjustment because the type of sensor is slightly different so that the sensor can be read correctly. This study uses one brand that is the same as one another, namely OMRON, to minimize imbalances.

Figure 8 shows a graph of the difference between the readings from the inductive proximity and the tachometer, which shows that the difference in the readings is not too significant, but the difference can be seen.

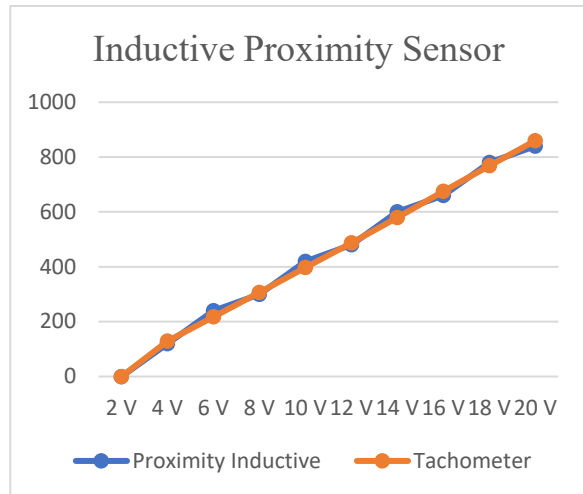


Figure 8. Comparison of proximity sensors and tachometers

Figure 9 shows a graph of the difference between the readings from the rotary encoder and the tachometer which shows that the difference in the readings is not too significant, even approaching the tachometer reading as a reference reading.

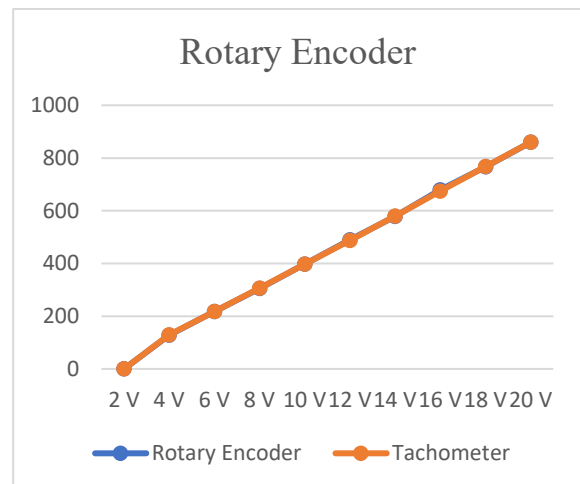


Figure 9. Comparison of rotary encoder and tachometers

The experimental results of the proximity sensor, rotary encoder, and tachometer that have been carried out can be seen in Table 5.

Table 5. Experiment Results Table

Voltage	Proximity Inductive	Rotary Encoder	Tachometer
2 Volt	0 Rpm	0 Rpm	0 Rpm
4 Volt	120 Rpm	128.1 Rpm	129.2 Rpm
6 Volt	240 Rpm	217.5 Rpm	217.3 Rpm
8 Volt	300 Rpm	305.6 Rpm	305.9 Rpm
10 Volt	420 Rpm	397.3 Rpm	397 Rpm
12 Volt	480 Rpm	489.6 Rpm	487.5 Rpm
14 Volt	600 Rpm	578.7 Rpm	579.4 Rpm
16 Volt	660 Rpm	678.8 Rpm	674.7 Rpm
18 Volt	780 Rpm	767.1 Rpm	768.4 Rpm
20 Volt	840 Rpm	859.8 Rpm	860 Rpm
Total	6420 Rpm	6409.3 Rpm	6409.7 Rpm

From the experimental data in Table 5, it can be determined the error value in the reading of the inductive proximity sensor and rotary encoder to the tachometer with the following equation [15]. Error calculation on the rotary encoder:

$$e = |Total\ RPM\ Tachometer - Total\ RPM\ Rotary\ Encoder|$$

$$e = |6409.7 - 6409.3|$$

$$e = 0.4$$

$$X = \frac{e}{Total\ RPM\ Tachometer} \times 100\ %$$

$$X = \frac{0.4}{6409.7} \times 100\ %$$

$$X = 0.062\ %$$

From the calculation above, it can be seen that the error calculation from the rotary encoder has a value of 0.4 with a percentage of 0.062%, which means that the average speed calculation has a smaller calculation than the taco meter. Calculate the error in inductive proximity:

$$e = |Total\ RPM\ Tachometer - Total\ RPM\ Proximity\ Inductive|$$

$$e = |6409.7 - 6420|$$

$$e = -10.3$$

$$X = \frac{e}{Total\ RPM\ Tachometer} \times 100\ %$$

$$X = \frac{-10.3}{6409.7} \times 100\ %$$

$$X = -0.16\ %$$

From the calculation above, it can be seen that the error calculation from the proximity sensor has a value of -10.3 with a percentage of -0.16%, which means that the average speed calculation has a calculation greater than the taco meter.

CONCLUSION

Based on the experimental results and device implementation, and data collection, it can be concluded that the system can work properly. This tool is able to calculate the speed of a DC motor. Based on the experiments that have been carried out using the proximity sensor give motor speed readings with an average of 6420 Rpm with an error of -10.3 which means that calculations using the proximity sensor have more calculations than the tachometer as a reference for calculations. Experiments carried out using a rotary encoder gave an average motor speed reading of 6409.3 Rpm with an error of 0.4, which means that calculations using a rotary encoder have smaller and closer calculations than the tachometer as a reference for calculations. so it can be concluded that the use of a rotary encoder has more efficiency than the use of a proximity sensor for calculating motor speed.

REFERENCES

- [1] Atmam, E. Zondra dan H. Yuvendius, "Konsumsi energi listrik terhadap perubahan kecepatan motor induksi," *Jurnal Sain, Energi, Teknologi & Industri*, vol. 4, no. 1, p. 9, 2019.
- [2] M. Farokhi, W. Sumbodo dan Rusiyanto, "Pengaruh kecepatan putar spindle (RPM) dan jenis sudut pahat pada proses pembuatan terhadap tingkat kekasaran benda kerja baja EMS 45," *SAINTEKNOL*, vol. 15, no. 1, p. 86, 2017.

- [3] D. Yuhendri, "Penggunaan PLC Sebagai Pengontrol Peralatan Building Automatis," *Journal of Electrical Technology*, vol. 3, no. 3, pp. 121-123, 2018.
- [4] T. Mulyana, R. Ibrahim dan E. A. Rahim, "Development and Analysis of Programmable Logic Controller Program for Defect Detection Prototype by CX Programmer," *International Conference on Mechanical and Manufacturing Engineering*, vol. 1, no. 1, pp. 1-8, 2019.
- [5] P. D. Sugiyono, Metode penelitian kuantitatif, kualitatif dan R&D, Bandung: CV Alfabeta, 2013.
- [6] F. A. Aziz dan R. D. Puriyanto, "Rancang Bangun Mesin Pengecat Dinding Otomatis Berbasis PLC CP1E-NA20DR-A," *Buletin Ilmiah Sarjana Teknik Elektro*, vol. 1, no. 3, pp. 118-130, 2019.
- [7] C. A. J. Malik dan S. Hadi, "The Design of Mini CNC Assembly Simulator Based on Virtual Reality Toolkit (VRTK)," *Journal of Physics: Conference Series*, vol. 2111, no. 1, pp. 1-7, 2021.
- [8] H. Mandala, S. M. Haris Rachmat dan S. Denny Sukma Eka Atmaja, "Perancangan Sistem Otomatisasi Penggilingan Teh Hitam Orthodox Menggunakan Pengendali PLC Siemens S7 1200 dan Supervisory Control and Data Acquisition (SCADA) di PT. Perkebunan Nusantara VIII Rancabali," *e-Proceeding of Engineering*, vol. 2, no. 1, pp. 990-997, 2015.
- [9] G. P. Aji dan B. A. Sumbodo, "Implementasi Komunikasi Master – Slave pada PLC OMRON CP1H," *Indonesian Journal of Electronics and Instrumentation Systems (IJEIS)*, vol. 11, no. 2, pp. 143-153, 2021.
- [10] P. G. Chamdareno, F. Azharuddin dan Budiyanto, "Sistem Monitoring Energi Listrik Sel Surya Secara Realtime dengan Sistem Scada," *eLEKTUM*, vol. 14, no. 2, pp. 35-42, 2017.
- [11] Ta'ali, Eliza dan Fivia, "Sistem Monitoring dan Kontrol Motor AC Berbasis SCADA," *JTEIN: Jurnal Teknik Elektro Indonesia*, vol. 1, no. 1, pp. 15-20, 2020.
- [12] D. Onen, "Appropriate Conceptualisation: The Foundation of Any Solid Quantitative Research," *The Electronic Journal of Business Research Methods*, vol. 14, no. 1, pp. 20-37, 2016.
- [13] A. Braun, R. Wichert, A. Kuijper dan D. W. Fellner, "Capacitive proximity sensing in smart environments," *Journal of Ambient Intelligence and Smart Environments*, vol. 1, no. 1, 2015.
- [14] H. Huang, "A method for tachometer-free and resampling-free bearing fault diagnostics under time-varying speed conditions," *Measurement*, vol. 134, pp. 101-104, 2019.
- [15] R. D. Klarawati dan G. A. P. a. A. Surtono, "Desain Water Quality Control pada Otomatisasi Kincir Air dan Penggantian Air Tambak Udang Menggunakan Software Cx-Programmer yang Terintegrasi dengan Programmable Logic Controller (PLC) CPM1A," *Jurnal Fisika Indonesia*, pp. 60-65, 2020.
- [16] A. S. MN, "Penerapan Trainer Human Machine Interface (HMI) Berbasis CX-Designer Sebagai Media Pembelajaran Programmable Logic Controller (PLC)," *Jurnal Informatika Universitas Pamulang*, vol. 3, no. 4, pp. 27-22, 2018.
- [17] E. Susilawati, Yulkifli dan Z. Kamus, "Pembuatan alat ukur kecepatan putar gear menggunakan sensor proximity induktif dan mikrokontroler arduino uno," *Pillar of Physics*, vol. 10, no. 1, pp. 9-13, 2017.
- [18] D. Aribowo, Desmira, R. Ekawati dan N. Rahmah, "Sistem perancangan conveyor menggunakan sensor proximity PR18-8DN wood sanding machine," *Edusaintek: Jurnal Pendidikan, Sains dan Teknologi*, vol. 8, no. 1, pp. 67-81, 2021.
- [19] M. Hendy Pradika, "Thermal overload relay sebagai pengaman overload pada miniatur gardu induk berbasis programmable logic controller CP1E-

- E40DR-A,” *Gema Teknologi*, vol. 17, no. 2, p. 81, 2012.
- [20] R. Muhandian dan Krismadinata, “Kendali Kecepatan Motor DC Dengan Kontroller PID dan Antarmuka Visual Basic,” *JTEV (Jurnal Teknik Elektro dan Vokasional)*, vol. 6, no. 1, pp. 328-338, 2020.
- [21] T. Darmana dan W. Sya’ban, “Rancang bangun alat ukur kecepatan motor dan pendeteksi kestabilan putaran pada porosnya,” *Jurnal Energi & Kelistrikan*, vol. 7, no. 1, pp. 71-76, 2015.
- [22] I. Indrawan dan E. H. a. D. L. Hakim, “Pembuatan antarmuka mesin manusia pada modul latih PLC berbasis perangkat lunak CX-Designer,” *ELECTRANS*, vol. 12, no. 3, pp. 97-106, 2013.
- [23] Atmam, E. Zondra dan H. Yuwendius, “Konsumsi energi listrik terhadap perubahan kecepatan motor induksi,” *Jurnal Sain, Energi, Teknologi & Industri*, p. 9, 2019.
- [24] W. Widiyanto, W. Sumbodo dan D. H. A. Janan, “analisis perancangan dan pembuatan program PLC pembacaan encoder pada sistem robot record and replay,” *Journal of Mechanical Engineering Learning*, vol. 1, no. 1, pp. 1-9, 2012.
- [25] K. Khalid, H. Hilman dan D. Kumar, “Get along with quantitative research process,” *International Journal of Research in Management*, vol. 2, no. 2, pp. 15-25, 2012.