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Armature Control of a DC Motor Based on Programmable Logic Controller

Abstract. *A design and implementation of separately excited DC motor speed measurement using programmable logic controller (PLC) techniques is established alternatively of using imitative mechanical ways. The techniques available in PLC type (SIEMENS, LOGO! 230RC) are enough to achieve this connection and measure the speed with a simple way. separately excited DC motor speeds were taken according to speed meter (Autonics, MP5W). In this paper, the PLC armature resistive controlled and the traditional armature resistive control have been investigated for controlling the speed of DC separately excited motor. By comparison the obtained results for both methods, it appeared that the results are approximately similar but the suggested system is much simpler than the imitative system.*

Streszczenie. *Opracowano projekt i implementację pomiaru prędkości silnika obcowzbudnego prądu stałego przy użyciu technik programowalnego sterownika logicznego (PLC) alternatywnie z wykorzystaniem imitacyjnych metod mechanicznych. Techniki dostępne w typie PLC (SIEMENS, LOGO! 230RC) wystarczą, aby osiągnąć to połączenie i zmierzyć prędkość w prosty sposób. Prędkości silnika obcowzbudnego prądu stałego przyjęto zgodnie z prędkościomierzem (Autonics, MP5W). W tym artykule zbadanio sterowanie rezystancyjne twornika PLC i tradycyjne sterowanie rezystancyjne twornika do kontrolowania prędkości silnika oddzielnie wzbudzanego DC. Porównując otrzymane wyniki dla obu metod okazało się, że wyniki są w przybliżeniu podobne, ale proponowany system jest znacznie prostszy niż system imitacyjny.* (***Sterowanie twornikiem silnika prądu stałego w oparciu o programowalny sterownik logiczny***)

Keywords: Separately excited DC motor, armature control, PLC, timer setting, speed control.
Słowa kluczowe: silnik prądu stałego, sterowniki P{LC

Introduction

With the quick mutations in the information and during the industries technologies in the last year's control, calculations and monitoring of wholes information have been achieved thru the use of computers. PLC is broadly used in industrial fields because it is easy to install, inexpensive and very flexible in applications and easy to install. A PLC with the external world through its inputs and outputs [1,2]. In this work, a laboratory solutions were eked for divination the speed of a separately excited DC motor unresisted using the classical mechanical methods, but implementing the programmable control devices [3]. In such cases, a control unit covering a PLC must be superimposed to the system constitution in order to enable it a PLC-based monitoring and control system for, divination the speed of a DC motor. It parameterizes the design and the implementation of the configured hardware and software [4].

The test obtained results on separately excited DC motor performance appeared amended the accuracy and the efficiency is putting-up in speed measurements [5]. Therefore, the PLC controls the operational parameters and correlates required by the users and monitors the separately excited DC motor conditions during employment.

DC motors are commonly used in numerous applications due to disposable cost and low complexity of control configuration for speed control. The applications such as domestic and robotics appliances. DC Motors are considered as the optimum type of motors, in view of the speed control and speed organizing [6,7]. Numerous curriculums are available to control the motor rotational speed and the armature voltage control (traditional control method) is one method among these methods [8]. Speed control of separately excited DC motor can be easily acquired over a wide range, means below and above rated speed.

When there is a normal change in speed due to changing load the speed control has changed idea. Speed control can be achieved manual or automatic. Standard control has investigated to hold control trouble on system control never the less, usage confides on an accurate scientific model of the design the controller [9,10]. A modifiable DC voltage by a constant AC voltage controlled rectifiers can be acquired, while choppers sustain a changeable DC voltage from a static DC voltage. The revolution made for potence to provide a changeable voltage in modern control systems and changing the speed of motor according to the controlled rectifier [11].

Literature review

Mohsin and etal, (2012). They worked on speed control of DC motor with PLC device. The revolution made for ability to provide a changeable voltage in modern control systems as variable speed control. They measured DC motor at no load and the variation range in speed between approximately (50-100) R.P.M at ejection resistor one by one. They concluded that the discontinuous in armature current owing to each converter, also the limit of starting current can only be reduced by this way [12].

Akshoy and etal, (2015). They studied on speed control of DC motor accredited on PLC as monitor the input and activates the output control program. The output of PLC was fed to the transistors as ON and OFF process, the range of speed (295 up to 990) R.P.M was acquired below 100% duty cycle. The proposed controller was found to be capable of inditing speed without the use of an observer but the triggering process of the transistors was a big problem in this work [13].

Operation and algorithm

The hardware execution of speed control consists of separately excited DC motor and PLC software shown in Fig.1. [14].

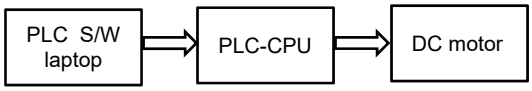


Fig.1. Block diagram for speed control.

System model

Model shown has electrical characteristics consisting of supply voltage (V), back e.m.f (Eb), armature resistance

(Ra) and control resistances (R). armature current (Ia) will flow through the resistances and rotate the DC motor in various speed [15,16]. Speed control of a separately excited DC motor means the intentional otherness of speed in accordance with the requirement of the work-load connected with the motor [17]. This can be achieved by mechanical means, such as by using, stepped pulleys, set of change gears and a friction clutch mechanism. However, control of speed by electrical means has better over mechanical speed control. separately excited DC motor offer easy speed control. Various speed control ways can be acquired from its ferrying which is [18,19]:

(1) $$N = V - I_a R_a / K$$

(2) $$E_b = V - I_a R_a$$

(3) $$E_b = \frac{PZ\emptyset N}{60A}$$

Put equation (2) in equation (1), we get

(4) $$\frac{PZ\emptyset N}{60A} = V - I_a R_a$$

Rearranging above equations, we get

(5) $$N = \frac{(V - I_a R_a)}{\emptyset} \frac{60A}{PZ}$$

where:

(6) $$K = \frac{60A}{PZ}$$

From substitute equation (5) in equation (4), produce:

(7) $$N = K \frac{(V - I_a R_a)}{\emptyset}$$

Substitute equation (1) in equation (6), produce:

(8) $$N = K \frac{E_b}{\emptyset}$$

Rearranging equation (7), we get

(9) $$N = \alpha \frac{E_b}{\emptyset}$$

where: N – motor speed, V – voltage supply, I_a – current of armature, R_a – resistance of armature, K – machine constant, R – external added resistances in series with R_a, E_b – back e.m.f., $\emptyset$ – flux of field, P – parallel paths in armature, Z – armature conductors.

Materials and method

Speed control of separately excited DC motor is doue by adjusting armature voltage. The speed has direct relation to armature voltage and has inverse effect of the magnetic flux produced by the poles [20].

Materials

The materials which used in this work are:

1. DC motor type (MOTCO IS:4722, MICROMOT).
2. Four resistances (100 ohm).
3. PLC type (SIEMENS, LOGO! 230RC).
4. Measurement devices (DC voltmeters, DC ameters, speed meter).

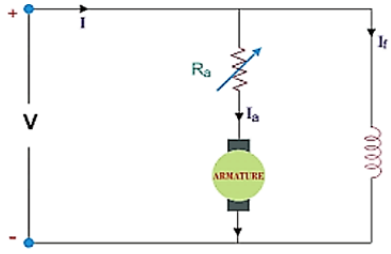


Fig.2. Armature control of DC motor

Armature voltage control method

Available voltage across the armature which lead to speed control. By varying the armature resistance then the controlled speed is acquired [21]. This method is usually used to control the speed of separately excited DC motor. Depending on a value of resistance the speed at full load should be reduced to desired value [22]. Fig. 2 represent the circuit diagram of separately excited DC motor with armature control and fixed field.

Implementation of PLC

A PLC is a solid state, industrial computer, digital and integrated circuits were built in it instead of the electromechanical apparatuses to implement control functions it is capable of storing instructions, like counting, arithmetic, sequencing and timing to control on the electrical motor and processes [23,24]. PLC is a function computer added in the electrical machines for controlling on the operation as shown in Fig.3.

Fig. 3. PLC controller.

The proposed structure that used with PLC consists of four resistances, DC motor/Gen set and HMI [25]. Unit as shown in Fig. 4.

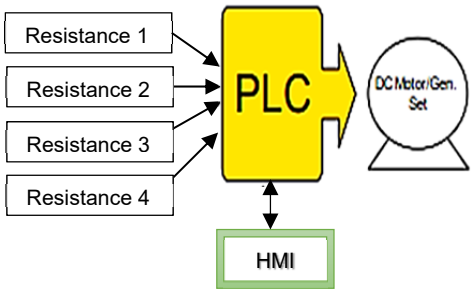


Fig. 4. Schematic diagram of proposed model with PLC.

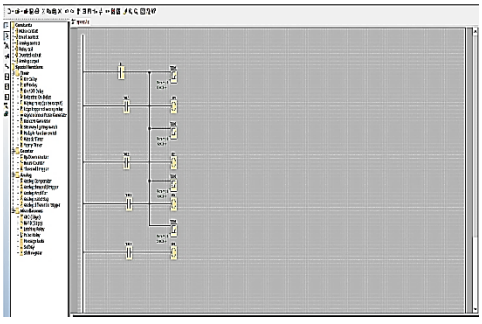


Fig. 5. Ladder logic program for armature resistance control

PLC ladder diagram

ladder logic symbols and expressions were used for PLC programming. The basic ladder symbols are used to develop the programming language for speed control of DC motor. PLC instructions set for ladder diagram are given

below. This program work for ejection the four resistances one by one according to the timer period, where the first time ejected the first resistance after 6 hours and similarity the other times ejected all resistances after every 6 hours as shown in Fig. 5.

Flowchart of DC armature control based PLC

The armature current that drawn by separately excited DC motor is variated by the relation V, Eb and Ra No Eb developed in the armature at rest the motor, a full V is applied a cross the armature, it will draw the current because all four resistances were in series with armature resistance when PLC ejection the resistance one by one the speed was increased gradually. Fig. 6, illustrates the procedure of DC armature control based PLC.

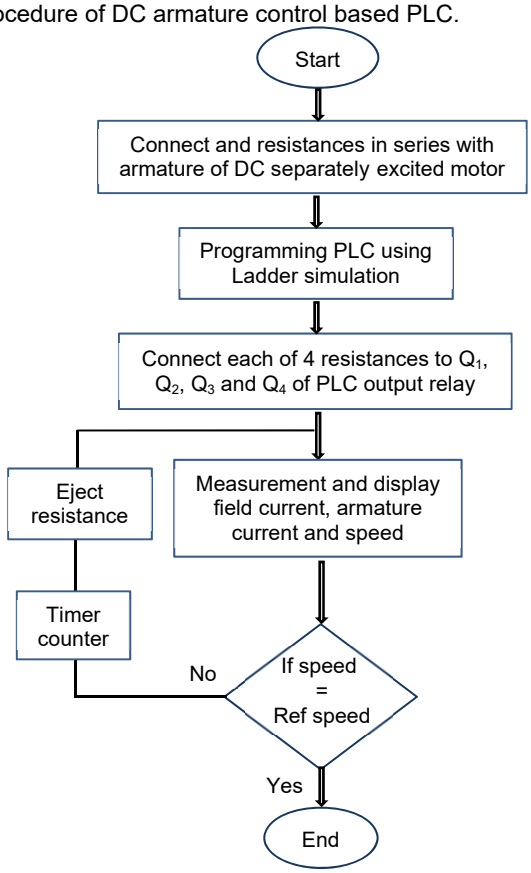


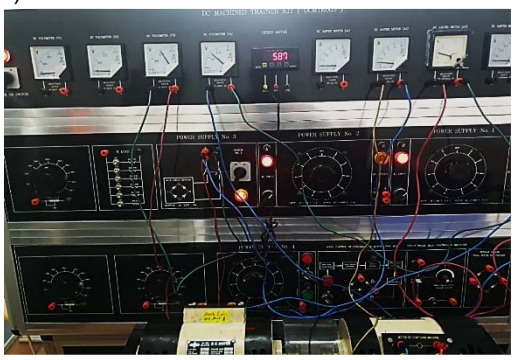
Fig. 6. Flowchart of armature resistance based PLC.

Results and discussion

The practical circuit for speed control of DC separately excited motor with PLC armature resistance control was connected as shown in Fig. 7, where four resistors were added in series with the internal armature resistor and each resistor has a value (100 ohm).

a)

b)



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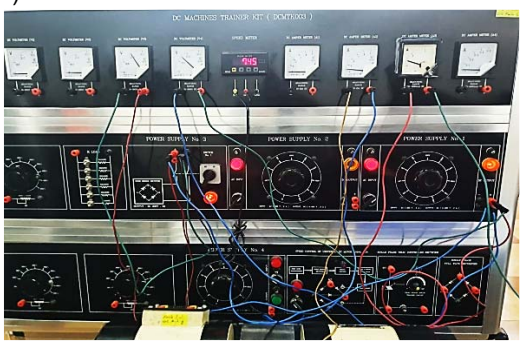

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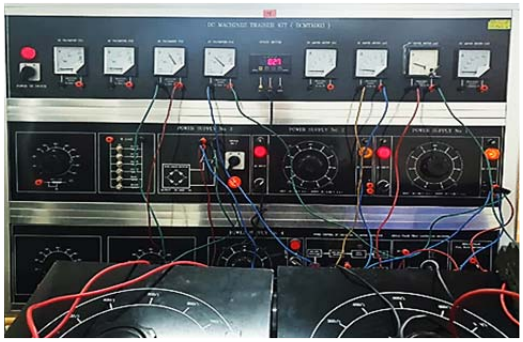


e)

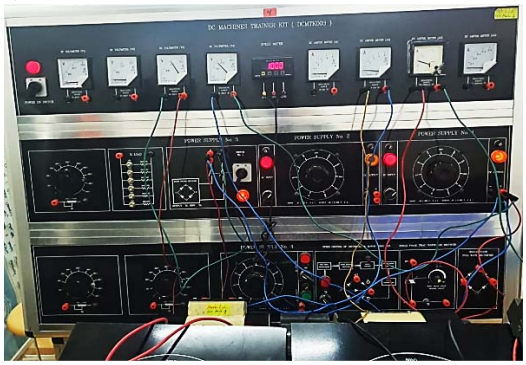


Fig. 7. Practical circuit for speed control of separately excited DC motor.

- ***(a)*** General experimental connection readings with all resistors.
- ***(b)*** Parameters readings after ejection one resistor.
- ***(c)*** Parameters readings after ejection two resistors.
- ***(d)*** Parameters readings after ejection three resistors.
- ***(e)*** Parameters readings after ejection four resistors.

Fig. (7-a to 7-e) gives the reading of field current, armature current and speed for all resistors in series with the internal armature resistor of separately excited DC motor, after ejection one resistor, after ejection two

resistors, after ejection three resistors, after ejection four resistors respectively. The specification of separately excited DC motor is shown in table 1. The parameters readings of all cases in Fig. 7, were taken laboratory and listed in table 1.

Table 1. Parameters readings.

Resistors connection	E_b (V)	I_f (A)	I_a (A)	N (RPM)
All resistors with internal armature resistor	140	0.2	0.19	425
After ejection one resistor	142	0.2	0.18	587
After ejection two resistor	144	0.2	0.17	745
After ejection three resistor	146	0.2	0.16	826
After ejection four resistor	150	0.2	0.15	1000

From table 1, the speed of separately excited DC motor was increased gradually after ejection the four resistors one by one respectively until ejection the four resistors and remain the effect of internal armature resistor only, this increased in the speed associated with the increases of the voltage after ejection the resistors.

Speed is inversely propotional to the armature current, therefore when the armature current will increase the speed of DC motor will decrease as shown in Fig.8. The speed is directly propotional to back e.m.f, when the back e.m.f will increase the speed of separately excited DC motor will increase as shown in Fig. 9.

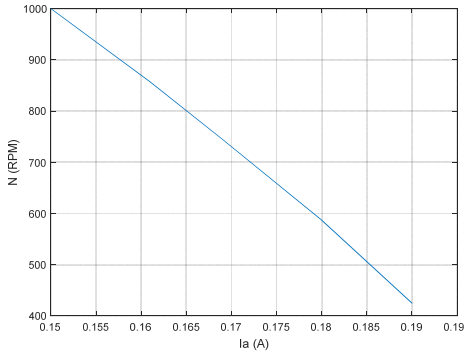
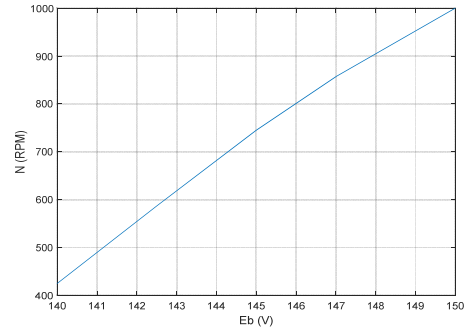


Fig. 8. Speed of DC motor vs armature current



The specification of separately excited DC motor is listed in table 2.

Table 2. Specification of DC motor.

Parameters	Value and units
Types	Motco 4722
H.P./KW	0.75 W
Field voltage	240V
Armature voltage	240V
Current	3 A
Speed	1750 RPM

The experiment is implementation practically on DC separately excited motor as shown in Fig. 10.

Fig. 10. Practical circuit for speed control of separately excited DC motor.

Conclusions

In this work, the experimental curves of DC separately motor with PLC were obtained and from speed characteristics with respect to the armature current (Ia) and the back e.m.f. (E_b) is achieved inside the laboratory of Northern Technical University (NTU).

From table 1, there is a small percentage (10.8%) of speed increasing between the period of ejection three and four resistances.

From Fig. 8, the speed of DC motor was slowed down to (425 RPM) as the armature current was increased.

From Fig. 9, the speed of DC motor was exceeded up to (1000 RPM) as the back e.m.f. was increased also.

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