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Speed Control of DC Series Motor with Conventional and PLC Techniques

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ABSTRACT

In this paper various approaches of controlling the speed of DC motor have been discussed, resistive control of DC series motor with PLC (Programmable Logic Controller) is proposed. DC motor has wide range of speed control used in different places such as robotics, auto-mobiles, drilling, cutting and domestic's purposes etc. Armature voltage can be varied by inserting the resistance in series with armature of DC series motor. In this paper the conventional armature resistive control and PLC armature resistive controlled techniques have been exploited for controlling the speed the motor. PLC is used to control the armature resistance which decreases the armature voltage for changing the speed. The outcomes validate the efficiency of the projected method for the motor speed control.

Keywords: *DC series Motor, Resistive controller and PLC*

1. INTRODUCTION

DC motors are generally used in several applications due to affordable cost and low complexity of control configuration for speed and torque control. The applications such as robotics and domestic appliances [1]. DC Motors are considered as the best type of motors, in view of the speed control and speed regulation [2]. Numerous approaches are available to control the motor rotational speed and the armature voltage control (conventional control method) is one method among these methods [3]. High starting torque is provided for traction applications by these motors. In the motor control for speed can be easily obtained over a huge range, means below and above rated speed [4]. When there is a normal change in speed due to varying load the speed control is different idea. The motor speed control can be manual or automatic [5]. Standard control has analyzed to hold control trouble on control of the system; nevertheless usage confides on a precise scientific model of the design the controller [6]. An adjustable output dc voltage by a fixed ac voltage controlled rectifiers can be obtained, while choppers sustain a changeable dc voltage from a static d.c voltage. The revolution made for ability to provide a changeable voltage in modern control systems and variable speed motors the controlled rectifiers and dc choppers [7].

2. SYSTEM MODEL

The system models of DC motors are presented in Fig.1 and Fig.2 separately. In DC series motor, due to the field windings of DC series motor connected with armature in series the whole current flows through the field windings. For carrying full load current the series field is designed with thick wire and less number of turns. The series field resistance is kept very low [8].

$$\mathrm{Eb} = \mathrm{V} - \mathrm{IaRa} \tag{1}$$

But

$$Eb = \frac{\mathrm{P}\emptyset\mathrm{ZN}}{60A} \tag{2}$$

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

$$\frac{\mathrm{P}\emptyset\mathrm{ZN}}{60A} = \mathrm{V} - \mathrm{IaRa} \tag{3}$$

Rearranging above equations, we get

$$\mathrm{N} = \frac{(\mathrm{V}-\mathrm{IaRa})}{\emptyset}\frac{60\mathrm{A}}{\mathrm{PZ}} \tag{4}$$

Where

$$\mathrm{K} = \frac{60\mathrm{A}}{\mathrm{PZ}} \tag{5}$$

From substitute equation (5) in equation (4), we get

$$\mathrm{N} = \mathrm{K}\,\frac{(\mathrm{V}-\mathrm{IaRa})}{\emptyset} \tag{6}$$

Substitute equation (1) in equation (6), we get

$$\mathrm{N} = \mathrm{K}\,\frac{Eb}{\emptyset} \tag{7}$$

Rearranging equation (7), we get

$$\mathrm{N} \propto \frac{Eb}{\emptyset} \tag{8}$$

3. METHODS OF CONTROLLING SPEED OF DC MOTOR

There are two main types of motor speed control. It is accomplished by adjusting armature voltage or field current. The speed has direct relation to armature voltage and has inverse effect of the magnetic flux produced by the poles.

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3.1 Field Control Method

The variation in the resistance of DC motor field helps to control its speed. The reduction in field causes increase in the speed ($N \propto \frac{1}{\emptyset}$) of motor. The speed control method generally applied when the DC motor runs above the rated speed. The reduction of the voltage across field coil causes due to the decrease in field current and flux also will be reduced. Therefore reduction in back emf ($\boldsymbol{E_b}$), which will cause the armature current ($\boldsymbol{I_a}$) to increase resulting increase in motor speed. DC series motor speed can be controlled by varying the flux of the motor shown in Fig. 1.

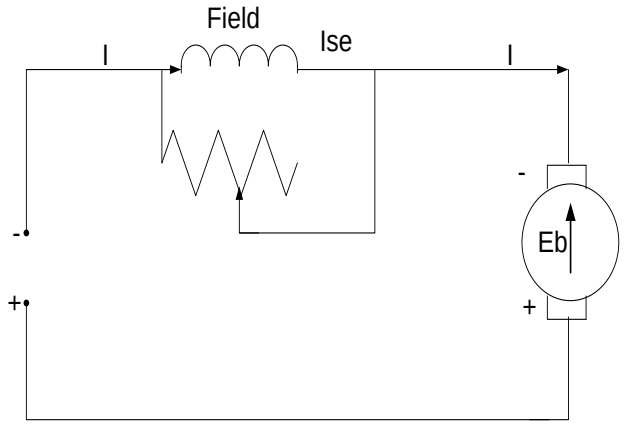

Figure.1. Field control of DC series motor

3.2 Armature Voltage Control of DC Motor

In Fig.2 it is shown that the resistance (Rse) is attached in series with source (Eb) in armature resistance control method.

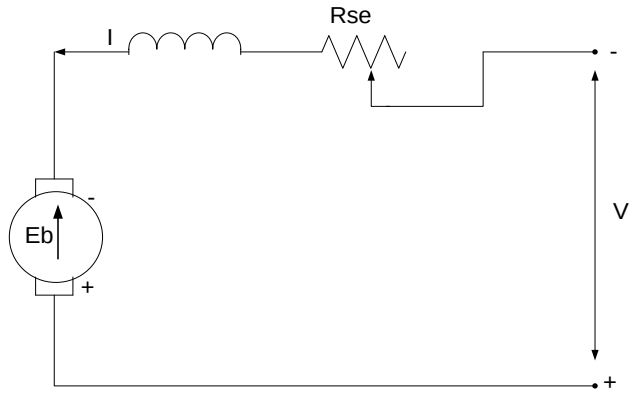

Figure.2. DC series motor's armature control

The method controls available voltage across the armature which results speed control. By significantly varying the armature resistance then the controlled speed is obtained. This method commonly used to speed control of DC motors. Depending on amount of resistance the speed at full load may be reduced to desired value. The speed of the motor can be reduced at the desired at the full load that depends on the amount of resistance.

3.3 PLC Controller

The PLC based control system is microprocessor based controller. In this a memory specifically programmable memory is used to store the instructions and various functions [10 & 11]. Presently Programmable Logic Controller is vastly in industry [10, 12][13].The PLC is a functional computer employed in the machines where the control and operation of completion manner [14 & 15]. It is the function of the programmable retention, accumulation guidance and finishing including ON and OFF [15 & 16].

3.4 PLC Ladder Diagram

The program for the existing ladder logic symbols and expressions in order to use and enable the programming of PLC to control the machine or process is needed to develop. The basic ladder symbols are used to develop programming language as depicted in Fig.3 at the last page. The PLC instruction set shows the steps of ladder diagram are given bellow.

```
  0   LDI     X000
  1   SET     Y000
  2   LD      Y000
  3   OUT     T0      K100
  6   LD      T0
  7   SET     Y001
  8   RST     Y000
  9   LD      Y001
 10   OUT     T1      K100
 13   LD      T1
 14   SET     Y002
 15   RST     Y001
 16   LD      Y002
 17   OUT     T2      K100
 20   LD      T2
 21   SET     Y003
 22   RST     Y002
 23   LD      Y003
 24   OUT     T3      K100
 27   LD      T3
 28   SET     Y004
 29   RST     Y003
 30   LD      Y004
 31   OUT     T4      K100
 34   LD      T4
 35   SET     Y005
 36   RST     Y004
 37   LD      Y005
 38   OUT     T5      K100
 41   LD      T5
 42   SET     Y006
```

4. RESULTS AND DISCUSSIONS

4.1 No-Load Speed Control of DC Motor at Different Resistances

When DC series motor runs on no-load at different resistor value connected series with armature circuit of motor. It is clearly pictured that when armature resistance increasing speed of motor has been decreasing as shown in Fig.4. All practical results of DC motor have been taken in Lab as in Table 1.

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Table 1. DC series motor at no load at individual resistor at constant supply voltage 30 V.

S.No	Resistance (KΩ)	Speed (rpm)	Armature Voltage
1	10	0	0
2	9	2000	5.05
3	8	2840	8
4	7	2890	8.5
5	6	2910	9.5
6	5	2960	10.05
7	4	3110	10.5
8	3	3160	11
9	2	3210	11.7
10	1	3260	12

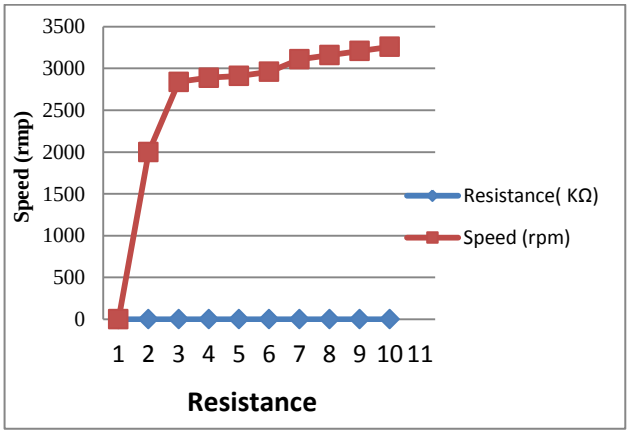

Figure.4. On load Speed-Torque of DC series Motor at Different Resistance Without PLC.

DC series motor runs on load condition with conventional method by inserting resistance to armature circuit of motor to reduce the starting high speed of motor this setup also carried in lab (QUEST Nawabshah). It is clearly showing in Fig. 5 on page number 24, that when armature resistance increasing the speed of DC series motor has been decreasing.

Different speed at constant torque has been observed by inserting the armature resistance to motor. It may be concluded that at different resistance, the starting speed may be controlled at desire value as shown in Table 2.

4.2 On Load Speed and Torque Control of DC Series Motor

DC series motor runs on load with PLC based inserting resistance to armature circuit to motor for reducing the starting speed of motor this experimental setup is carried in lab (QUEST Nawabshah). It is clearly showing in Fig.6 that when armature resistance inserting by using PLC the speed of DC series motor has been decreasing. In Table 3 different data of speed, torque and resistance has been taken by using PLC. It has different speed of DC series motor on different resistance value for controlling of starting speed of DC motor and specific torque value

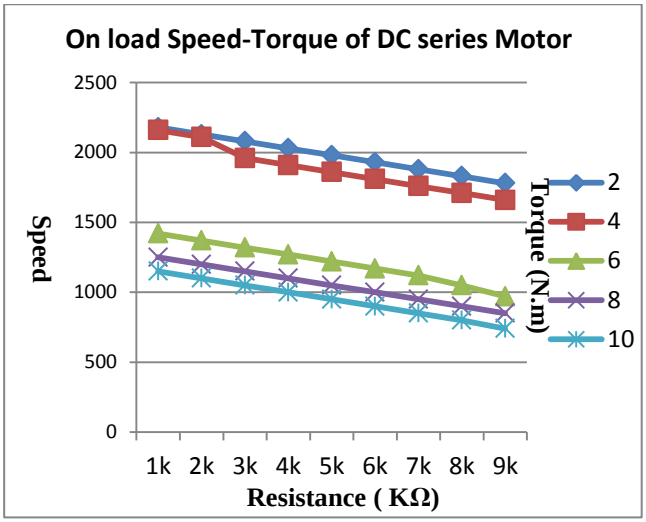

Figure.6. clearly show speed of DC motor can be carried by inserting the different resistance value as defined torque on DC motor.

4.3 Speed and Torque Control with and without PLC

Figure.7 shows the comparative analysis of DC series motor on conventional and PLC based speed-torque control. It is clearly view of speed and torque control of motor by inserting the resistances of different values from 1k to 9 k.

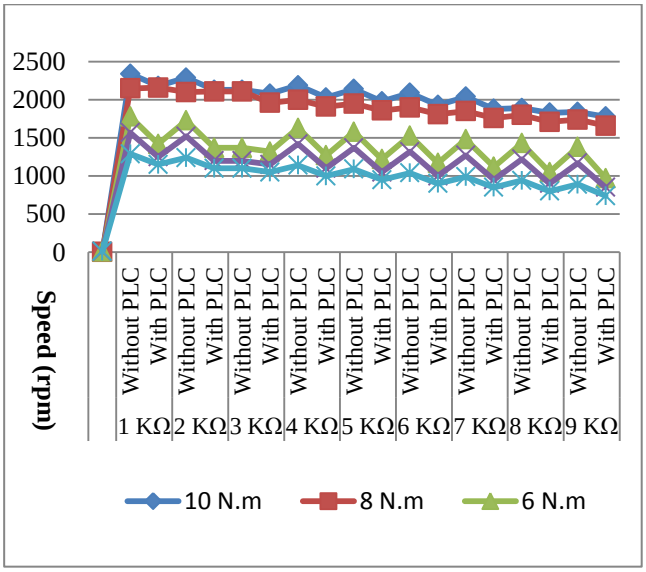

Figure.7. Speed of DC series motor by inserting the resistance on conventional and PLC based method

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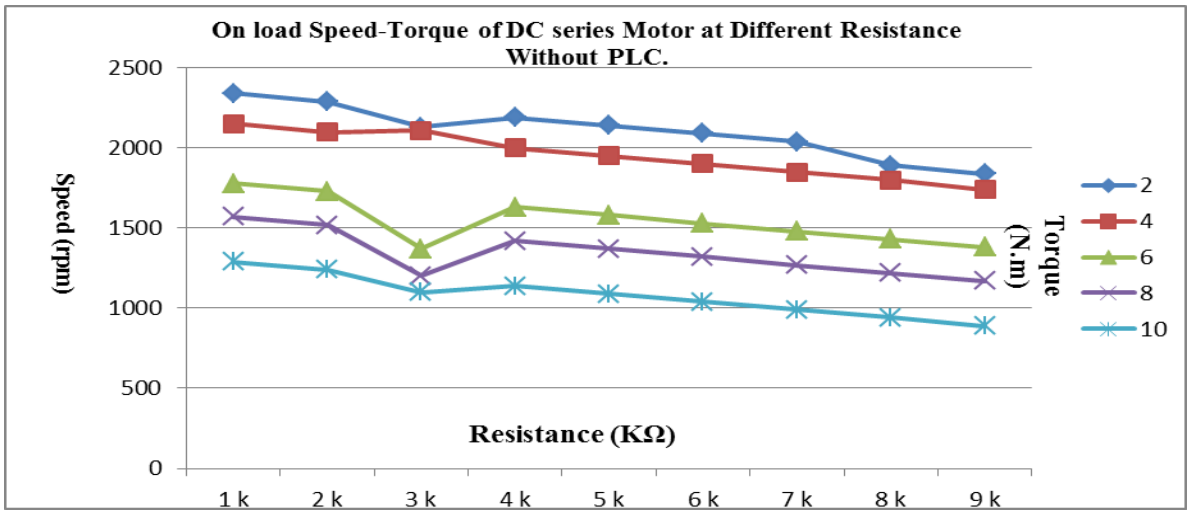

Figure. 5. Shows the comparative analysis of different starting torque of DC series motor at unequal resistance at fixed torque under conventional method of DC motor.

Table 2. DC series motor at on load condition with conventional method by inserting resistance

Torque N m	Speed								
2	2340	2340	2130	2190	2140	2090	2040	1890	1840
4	2150	2150	2110	2000	1950	1900	1850	1800	1740
6	1780	1780	1370	1630	1580	1530	1480	1430	1380
8	1570	1570	1200	1420	1370	1320	1270	1220	1170
10	1290	1290	1100	1140	1090	1040	990	940	890
Resistance kilo Ohm	**1K**	**2K**	**3K**	**4K**	**5K**	**6K**	**7K**	**8K**	**9K**

Table 3. DC series motor at on load with PLC based inserting resistance

Torque N m	Speed (rpm)								
2	2180	2130	2080	2030	1980	1930	1880	1830	1780
4	2160	2110	1960	1910	1860	1810	1760	1710	1660
6	1420	1370	1320	1270	1220	1170	1120	1050	970
8	1250	1200	1150	1100	1050	1000	950	900	850
10	1150	1100	1050	1000	950	900	850	800	740
Resistance kilo Ohm	**1 K**	**2 K**	**3 K**	**4 K**	**5 K**	**6 K**	**7 K**	**8 K**	**9 K**

5. CONCLUSION

In this work an experimental based comparative analysis of DC series motor with and without PLC and study of speed-torque characteristic of the DC motor for speed and torque mode is carried out. This study is accomplished in laboratory of the Quaid-e-Awam University of Engineering Sciences and Technology, Nawabshah, Sindh, Pakistan. The DC motor has been taken for experimental test on various torque (mechanical load) applied on DC motor ranging from 2 to 10 Nm. It has been observed that discontinuous in armature current due to each converter. DC series motor speed control is get done & the performance is exactly determined as adequately efficient. There is no any changing in hardware connection except changing the program in the PLC. The limit of starting current can only be reduced by this system. In the program, logic can be applied to drive motor and can be used for any industry.

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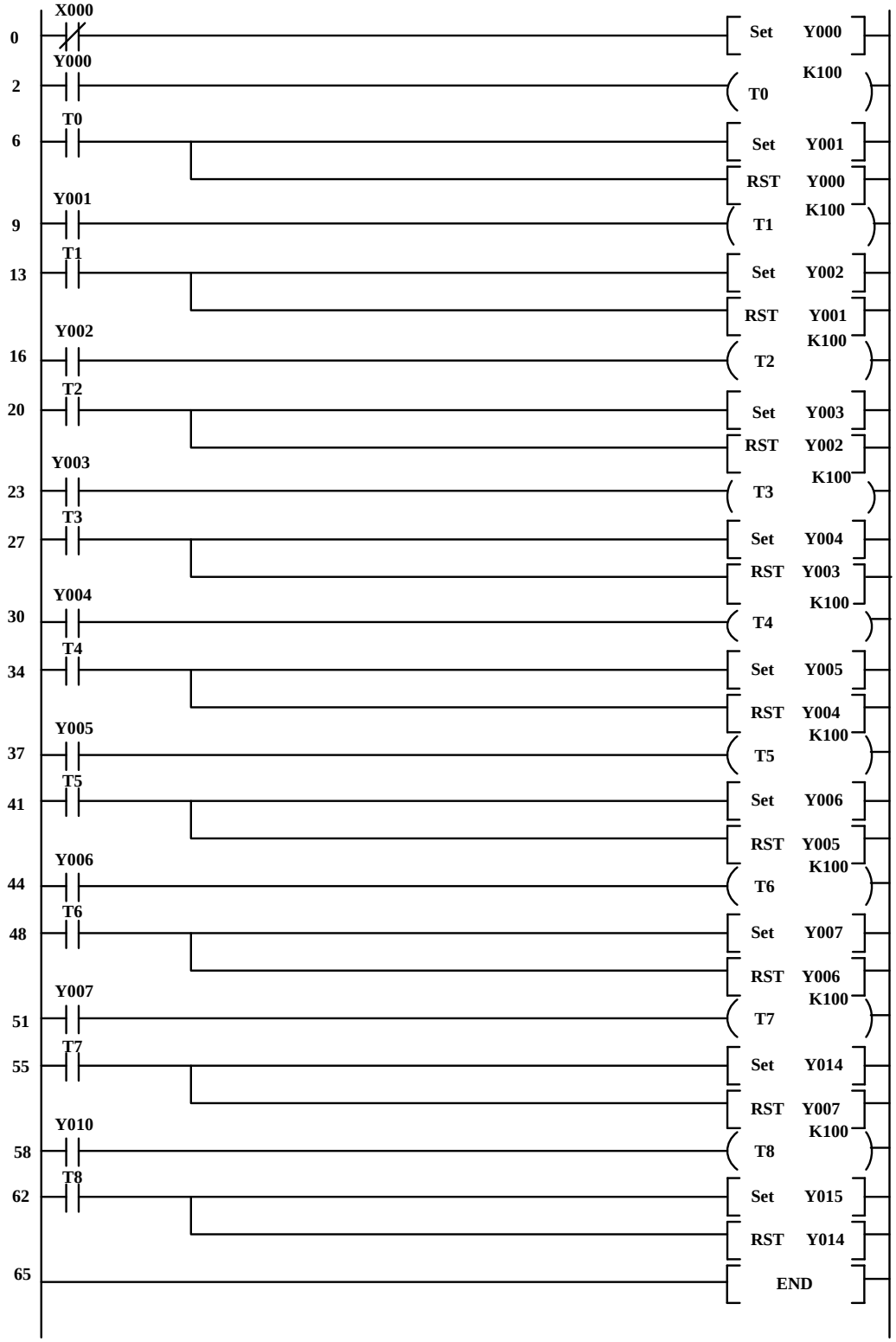

Figure.3 ladder diagram for the PLC program