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Experimental based Comparative Analysis and Characteristics of DC Series Motor by using Different Techniques

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Abstract:

In this paper, distinct techniques of speed controlling of a Direct Current (DC) motor and its characteristics are discussed. The Direct Current (DC) motor has a wide range of speed control, which can be used in robots, drilling, cutting, and household applications due to affordable cost and low complexity of control configuration for speed and torque control. As DC Motors are considered as the best type of motors, in view of the speed control and speed regulation, numerous approaches are available to control the motor rotational speed. DC series motor control by using a resistive controller with and without a Programmable Logic Controller (PLC) is proposed. The motor voltage can be changed by inserting a resistor in series with DC motor. In this paper, through an experimental work armature resistive drive control technology and motor control PLC technology is used to control motor speed. PLC is used to control the resistance of the motor, thereby reducing driving voltage to change the speed. The results confirm the authentic efficiency of the proposed method of controlling motor speed.

Keywords: *DC Series Motor, PLC, Torque, Resistive controller.*

1. Introduction

The DC drives are used in rolling, wine winders, cranes, paper mills, machine tools, printing press, and textile mills, etc. DC motors have irregular essentials and used largely in uncertain speed. DC motor can produce immense origin torque and it is still achievable to gain speed control by the immense range [1]. DC Motors have variable characteristics and are used extensively in variable speed drives. DC motor can provide a high starting torque and it is also possible to obtain speed control over a wide range [2].

Generally, DC motor is used in several applications like robotics and domestic appliances due to affordable cost and low complexity of control configuration for speed and torque control [3]. DC Motors are considered as the best type of motors, in view of the speed control and speed regulation. Numerous approaches are available to control the motor rotational speed and armature voltage control is one method among these methods [4, 6].

The DC machine by a DC power source for determining the inductance in a DC machine disables some difficulties related to traditional methods using AC source [7, 8].

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DC machines are versatile energy conversion devices. These can be used for loads of high starting torques and to meet loads of high accelerating and decelerating torques [9]. For DC motors, the armature and field current are the same because the connection between them is standard [10, 11]. Armature voltage/armature control methods can be used to control the speed of dc motor [12, 13].

2. Conventional Controllers

Speed control of a motor escape intended to replace speed render to the demand of the workload connected with the motor. This preserve if done by mechanical expedients, such as by using stepped simple machines.

Nevertheless, speed control by the electrical way has greater advantages over mechanical. In many applications, DC motor is preferred over other types of motors because DC Motors offer easy speed control.

DC Motor Speed control methods depend upon,

a. Armature Control Method and
b. Armature Voltage Control Method [14].

2.1 Armature Control Method

It can apply during speeds where loading speed is not required. Supply voltage usually invariable, by place a flexible rheostat in series with armature circuit, the voltage across armature may change shown in figure1.

To decrease the armature speed potential difference beyond armature is dropped by increasing the value of resistance in the controller. For load-torque, speed is closely comparative to potential difference over the armature [15].

Armature resistance control is simple for small motors while it wastes energy and unusable with large motors [16].

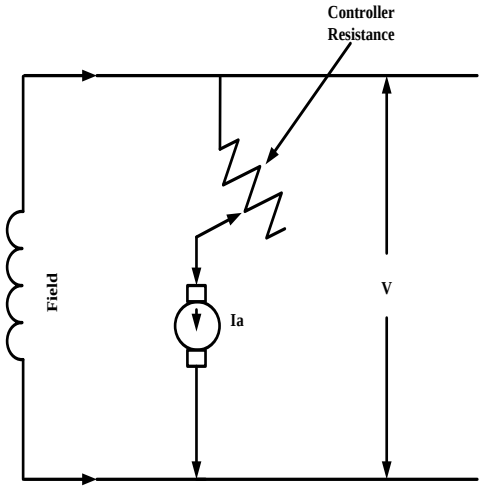

Fig 1: Armature Control Method

2.2 Armature Voltage Control Method

The speed of armature-controlled DC motor is controlled by armature voltage V_a and utilizes a constant field current shown in figure 2.

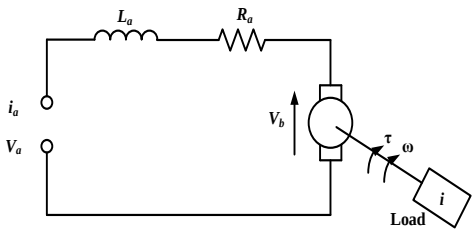

Fig 2: Armature Voltage Control Method

The armature controlled can be expressed by equations as:

$$I\omega = -b.\omega + K_t\, i_a T_L \quad (1)$$

$$V_a - V_b = La\ \frac{dia}{dt} + R_a.i_a \quad (2)$$

Where

$$V_b = K_b \cdot \omega$$

In the state-space form, the equation of DC Motor is:

$$\frac{d}{dt}\begin{bmatrix}\omega \\ i_a\end{bmatrix}=\begin{bmatrix}-\frac{b}{I} & \frac{K_t}{I} \\ -\frac{R_a}{L_a} & -\frac{K_b}{L_a}\end{bmatrix}\begin{Bmatrix}\omega \\ i_a\end{Bmatrix}+\begin{bmatrix}0 \\ \frac{1}{L_a}\end{bmatrix}\cdot V_a+\begin{bmatrix}\frac{-1}{I} \\ 0\end{bmatrix}\cdot T_L \quad (3)$$

3. Programmable Logic Controller

DC motors are one of the devices that can be connected and controlled by PLC [17]. The PLC-based control system is a microprocessor-based controller. In this, a memory specifically programmable memory is used to store the instructions and various functions. Presently Programmable Logic Controller is vastly used in industry [6]. The PLC is a functional computer employed in the machines where the control and operation of completion manner [18, 19]. It is the function of the programmable retention, accumulation guidance, and finishing including ON and OFF shown in figure 4.

Figure 3 shows the basic arrangement of PLC incorporated within the trainer. There are 20 I/O connectors, from which 10 for input and 10 for output, and a voltage stabilizer is used to maintain the required voltage.

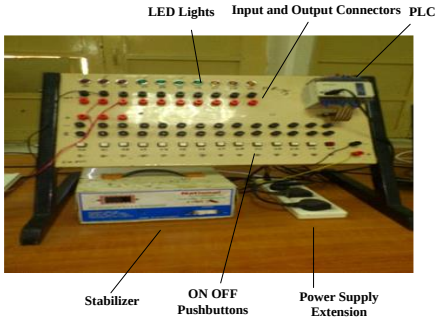

Fig 3: PLC

4. PLC Ladder Diagram

For ease of programming, the programmable controller is advanced by adopting existing relay ladder design and expressions to take as program logics, necessary to control the machine or process. A relay ladder diagram is shown in figure 6.

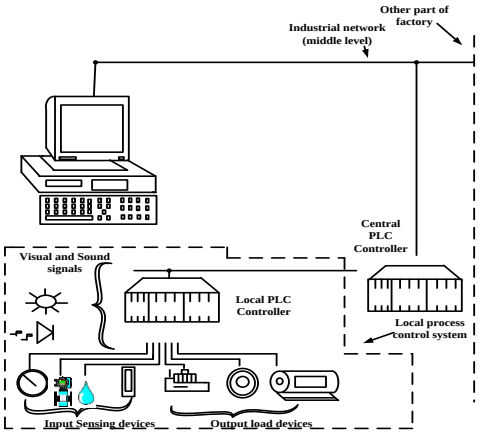

Fig 4: PLC Layout

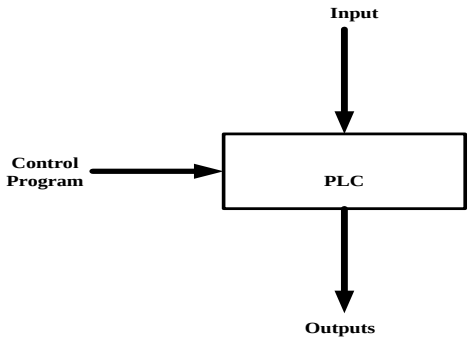

Fig 5: PLC as a Control Action

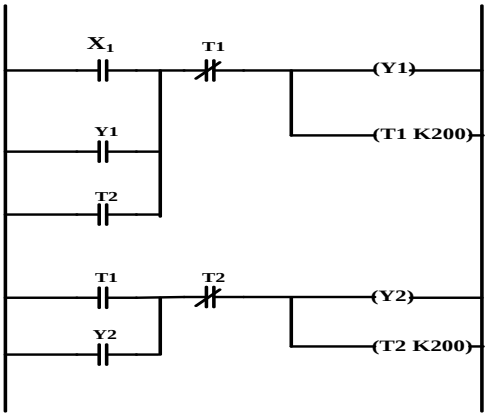

Fig 6: Ladder Diagram of a PLC

4.1 DC Motor Characteristics with Armature Controller

The characteristic of the motor means the determination relationship between speed, power, and current without load. Figure 7 shows the experimental setup of the dc series motor with the Armature controller.

Fig 7: Experimental setup of DC Series Motor with Armature Controller

4.1.1 Torque vs. speed characteristics of DC Motor with Armature Controller

The characteristic result of torque vs. speed of dc series motor is presented in Table 1 and graphically present shown in figure 8. In this table there are different levels of supply voltages are supplied and different torque are applied as a load from 0 Nm to 1 Nm in equal of 1 step respectively in order to observe the effectiveness of torque on the speed of DC Motor. It is clearly mentioned in the table that if the value of torque increased from 0.1 Nm to 1 Nm than the speed of DC Motor decreased

Figure 8 illustrates that as supply voltages raises from 30 to 50 voltages the speed of DC series motor is increased but as torque increases simultaneously the speed of dc series motor decreases.

Table 1: Toque Speed Characteristics with Armature Controller

Torque (N-M)	V=30 v	V=35 v	V=40 v	V=45 v	V=50 v
	Armature Controller				
	Speed (RPM)	Speed (RPM)	Speed (RPM)	Speed (RPM)	Speed (RPM)
0	1125	1440	1750	1980	2280
0.1	1065	1380	1690	1930	2265
0.2	1034	1336	1620	1890	2110
0.3	1000	1278	1555	1850	2080
0.4	968	1240	1510	1740	1960
0.5	924	1210	1470	1680	1910
0.6	886	1170	1400	1580	1703
0.7	868	1135	1340	1500	1680
0.8	852	1090	1290	1430	1660
0.9	809	1030	1280	1370	1600
1	770	1008	1222	1340	1530

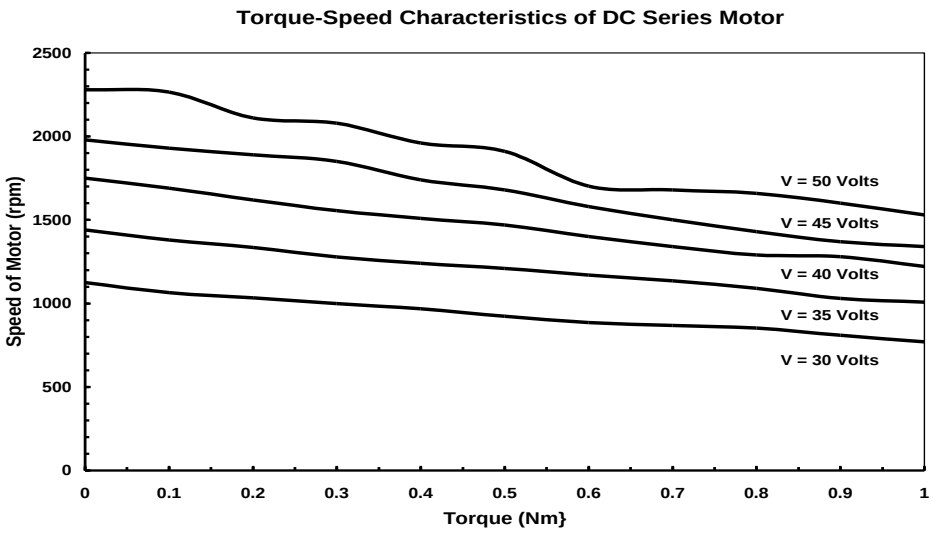

Fig 8: Torque vs. Speed characteristics of DC Series Motor

4.1.2 Torque vs. Current characteristics of DC Series Motor with Armature Controller

Result of torque and current characteristic of DC series motor presented in table 2 and graphically present in figure 9. In this table there are different levels of supply voltages are supplied and different torque are applied as a load from 0 Nm to 1 Nm in equal of 1 step respectively in order to observe the effectiveness torque on the speed of DC Motor. Clearly mention in the table that if the value of torque varies from 0.1 N-m to 1 N-m than the speed of DC Motor decreased.

Table 2: Torque Current characteristics DC Series Motor

Torque (N-M)	V=30V	V=35V	V=40V	V=45 V	V=50V
	Armature Controller				
	Current (A)	Current (A)	Current (A)	Current (A)	Current (A)
0	0.8	0.7	0.7	0.7	0.7
0.1	0.8	0.8	0.8	0.8	0.8
0.2	0.8	0.8	0.8	0.8	0.8
0.3	0.8	0.9	0.9	0.9	0.8
0.4	0.9	0.9	0.9	0.9	0.9
0.5	0.9	0.9	0.9	0.9	0.9
0.6	0.9	0.9	0.9	0.9	0.9
0.7	1	1	1	1	1
0.8	1	1	1	1	1
0.9	1	1	1	1	1
1	1	1	1	1	1

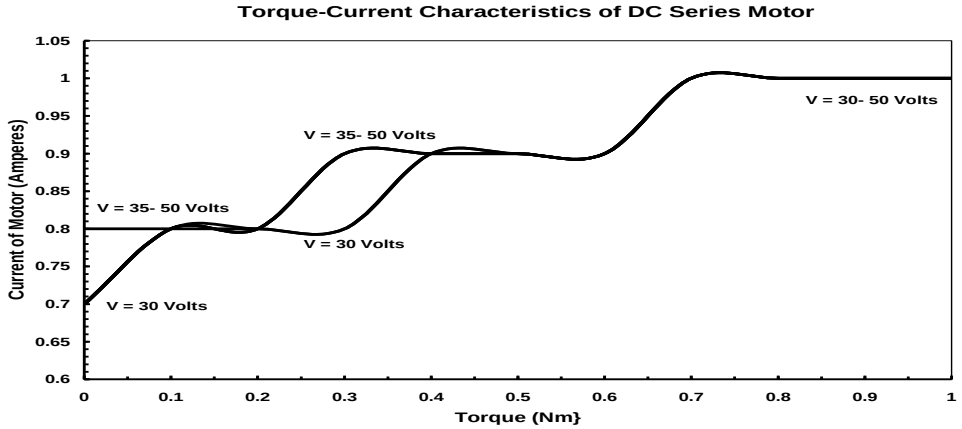

Fig 9: Torque vs. Current characteristics of DC Series Motor

4.1.3 Torque vs. Power characteristics of DC Series Motor with Armature Controller

The characteristic result of the torque and power of DC Series Motor is presented in table 3 and graphically present shown in figure 10. In this table there are different levels of supply voltages are supplied and different torque are applied as a load from 0 Nm to 1 Nm in equal of 1 step respectively to observe the effectiveness of torque on the speed of DC Motor. Here clearly mention in the table that if the value of torque increased from 0.1 Nm to 1 Nm than the speed of DC Motor decreased.

Table 3 Torque Power characteristics DC Series Motor

	V=30 V	V=35 V	V=40 V	V=45 V	V=50 V
	Armature Controller				
Torque (N-M)	Power (Watt)	Power (Watt)	Power (Watt)	Power (Watt)	Power (Watt)
0	24	24.5	28	31.5	35
0.1	24	28	32	36	40
0.2	24	28	32	36	40
0.3	24	31.5	36	40.5	40
0.4	27	31.5	36	40.5	45
0.5	27	31.5	36	40.5	45
0.6	27	31.5	36	40.5	45
0.7	30	35	40	45	50
0.8	30	35	40	45	50
0.9	30	35	40	45	50
1	30	35	40	45	50

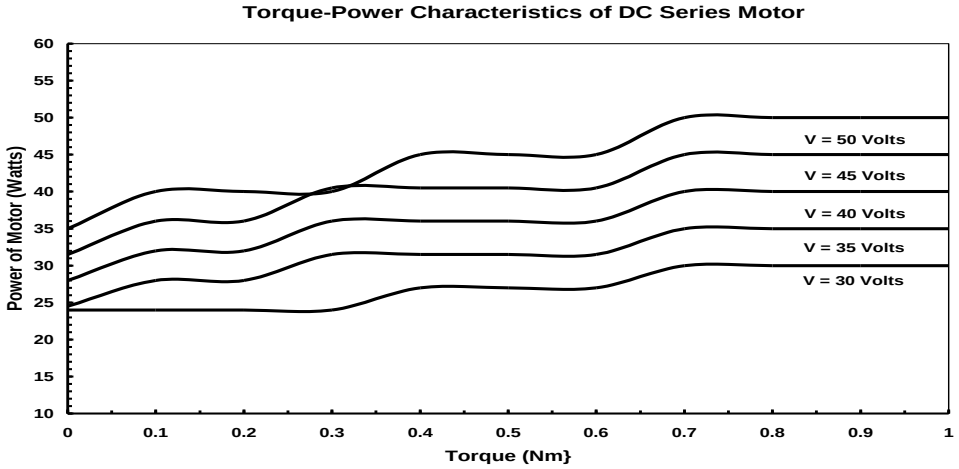

Fig 10: Torque Power characteristics of DC Series Motor

4.2 Experimental structure of DC Series Motor with PLC

`Experimental setup is illustrated in figure 11.

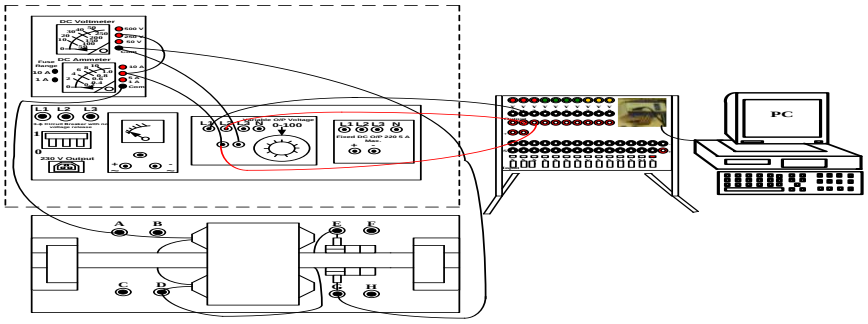

Fig 11: Experimental structure of DC Series Motor with PLC

4.2.1 DC Motor Torque vs. speed characteristics with PLC

The characteristic result of torque vs. speed of DC series motor is presented in Table 4 and graphically present shown in figure 12. In this table there are different levels of supply voltages are supplied and different torque are applied as a load from 0 Nm to 1 Nm in equal of 1 step respectively to observe the effectiveness of torque on the speed of DC Motor. It's clearly mentioned in the table that if the value of torque increased from 0.1 Nm to 1 Nm than the speed of dc motor decreased.

Table 4: DC Series Motor Torque vs. Speed characteristics with PLC

Torque (N-M)	V=30 v	V=35 v	V=40 v	V=45 v	V=50 v
	With PLC				
	Speed (RPM)	Speed (RPM)	Speed (RPM)	Speed (RPM)	Speed (RPM)
0	1000	1200	1530	1736	1940
0.1	982	1150	1520	1690	1700
0.2	950	1130	1480	1650	1680
0.3	880	1070	1320	1470	1590
0.4	870	1060	1300	1460	1580
0.5	850	978	1150	1290	1400
0.6	800	950	1140	1230	1380
0.7	670	900	1040	1200	1250
0.8	650	833	1000	1100	1230
0.9	630	820	935	1060	1220
1	594	800	900	980	1150

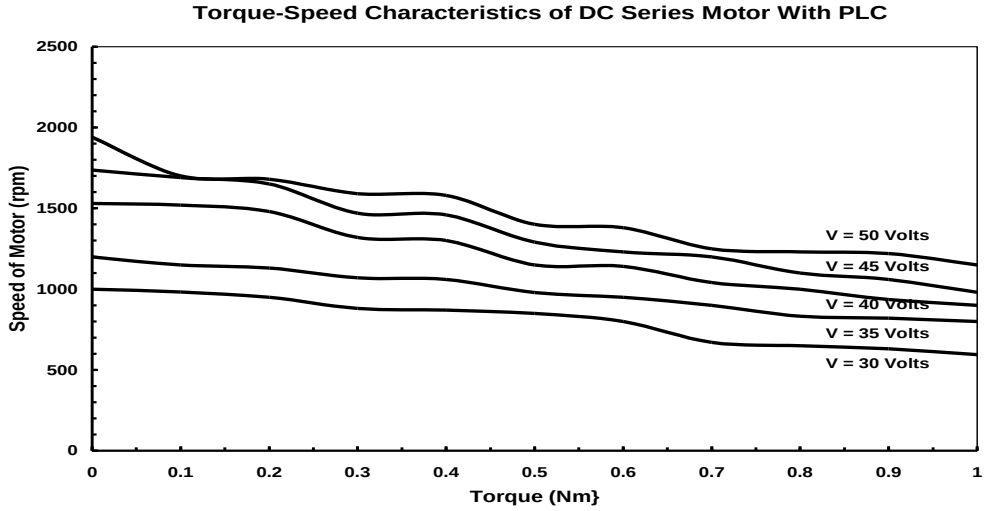

Fig 12: DC Series Motor Torque vs. Speed characteristics with PLC [5]

Torque vs. current characteristics of DC Series Motor with PLC

The characteristic result of torque and current of DC series motor is presented in table 5 and graphically present shown in figure 13. In this table there are different levels of supply voltages are supplied and different torque are applied as a load from 0 Nm to 1 Nm in equal of 1 step respectively to observe the effectiveness of torque on the speed of DC Motor. It is clearly mentioned in the table that if the value of torque varies from 0.1 Nm to 1 Nm than the speed of DC motor decreased.

Table 5: DC Series Motor Torque Current characteristics with PLC

Torque (N -M)	V =30 v	V =35 v	V =40 v	V =45 v	V =50 v
	With PLC				
	Current (A)	Current (A)	Current (A)	Current (A)	Current (A)
0	0.8	0.8	0.8	0.9	0.9
0.1	0.9	0.9	0.9	0.9	0.9
0.2	0.9	0.9	0.9	0.9	0.9
0.3	0.9	0.9	0.9	0.9	0.9
0.4	0.9	0.9	0.9	0.9	0.9
0.5	1	1	1.1	1.1	1.1
0.6	1.2	1	1.1	1.1	1.1
0.7	1.2	1.2	1.2	1.2	1.2
0.8	1.2	1.2	1.2	1.2	1.3
0.9	1.2	1.2	1.2	1.2	1.3
1	1.3	1.3	1.3	1.3	1.3

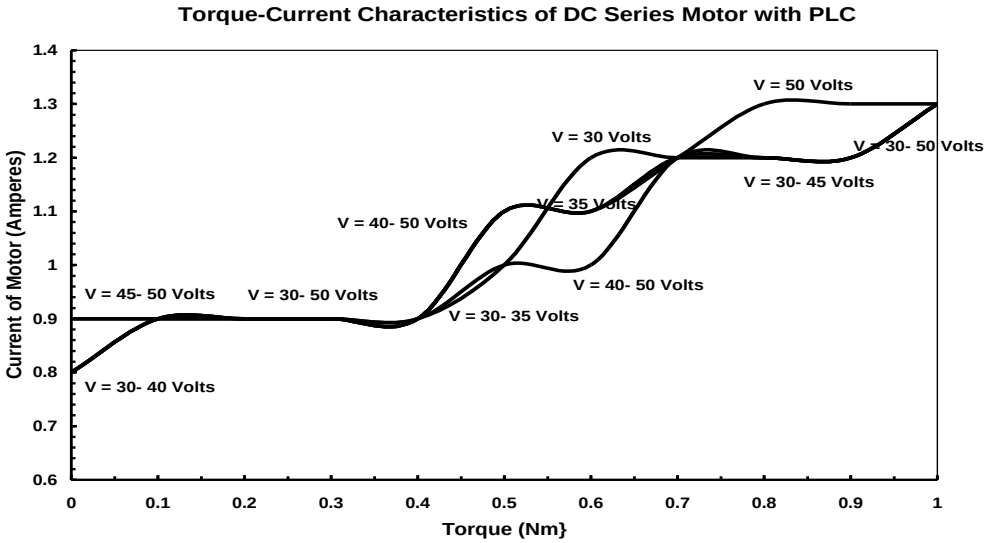

Fig 13: DC series Motor Torque vs. Current characteristics of with PLC

4.2.2 DC Series Motor Torque power characteristics with PLC

Characteristic result of torque power of DC series motor presented in table 6 and graphically present in figure 14. In this table respectively to observe the effectiveness of torque on the speed of DC Motor. It is clearly mentioned in the table that if the value of torque increased from 0.1 Nm to 1 Nm than the speed of DC motor decreased

Table 6 Torque Power characteristics DC Series Motor with PLC

	V=30V	V=35V	V=40 V	V=45 V	V=50 V
	With PLC				
Torque (N-M)	Power (Watt)	Power (Watt)	Power (Watt)	Power (Watt)	Power (Watt)
0	24	28	32	40.5	45
0.1	27	31.5	36	40.5	45
0.2	27	31.5	36	40.5	45
0.3	27	31.5	36	40.5	45
0.4	27	31.5	36	40.5	45
0.5	30	35	44	49.5	55
0.6	36	35	44	49.5	55
0.7	36	42	48	54	60
0.8	36	42	48	54	65
0.9	36	42	48	54	65
1	39	45.5	52	58.5	65

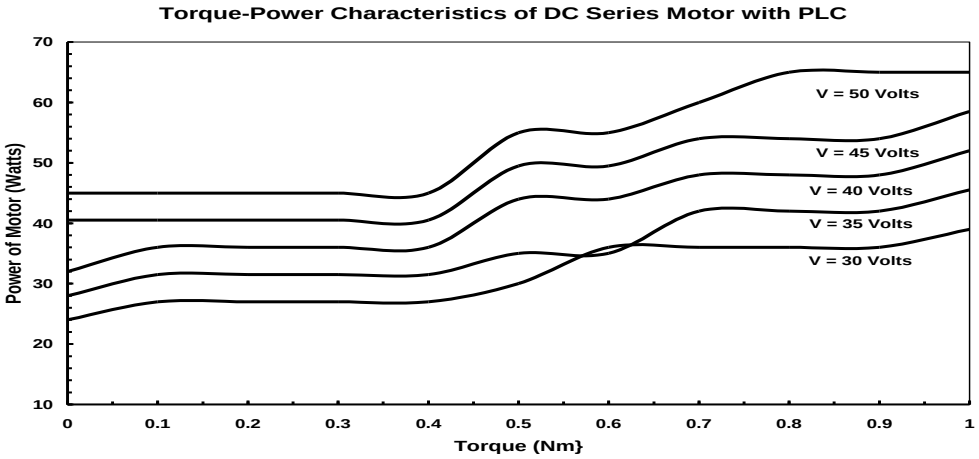

Fig14: DC Series Motor Torque vs. Power characteristics with PLC

Table 7 Comparison of Torque Speed characteristics DC Series Motor PLC with Armature Controller

Torque (N.m)	Speed (rpm)									
	V = 30v		V = 35v		V = 40v		V = 45v		V = 50v	
	Without PLC	With PLC	Without PLC	With PLC	Without PLC	With PLC	Without PLC	With PLC	Without PLC	With PLC
0	1125	1000	1440	1200	1750	1530	1980	1736	2280	1940
0.1	1065	982	1380	1150	1690	1520	1930	1690	2265	1700
0.2	1034	950	1336	1130	1620	1480	1890	1650	2110	1680
0.3	1000	880	1278	1070	1555	1320	1850	1470	2080	1590
0.4	968	870	1240	1060	1510	1300	1740	1460	1960	1580
0.5	924	850	1210	978	1470	1150	1680	1290	1910	1400
0.6	886	800	1170	950	1400	1140	1580	1230	1703	1380
0.7	868	670	1135	900	1340	1040	1500	1200	1680	1250
0.8	852	650	1090	833	1290	1000	1430	1100	1660	1230
0.9	809	630	1030	820	1280	935	1370	1060	1600	1220
1	770	594	1008	800	1222	900	1340	980	1530	1150

4.3 Characteristics comparison of DC Series Motor with PLC and Armature Controller

A comparison between PLC and armature controller here is presented.

4.3.1 Comparison Torque vs. speed characteristics of DC Series Motor with PLC and Armature Controller

A comparison between torque and speed are shown in table 7 and graphically represented in figure 15.

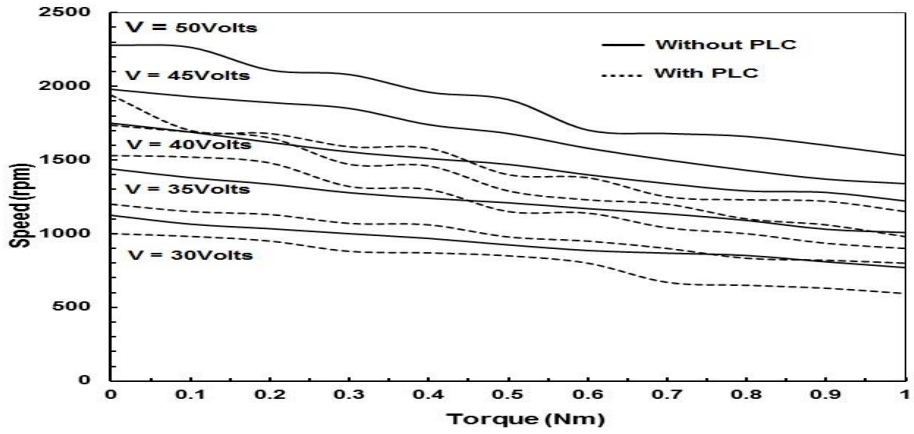

Fig 15: Graphically representation of Torque and Speed of DC Series motor with PLC and Armature controller [5].

4.3.2 Characteristics Comparison of Torque vs. current of DC Series Motor with PLC and Armature Controller

Comparison between torque and current are shown in table 8 and graphically represented in figure 16.

Table 8 Comparison of Torque Current characteristics DC Series Motor PLC with Armature Controller

Torque (NM)	Current (Ampere)									
	V =30v		V =35v		V =40v		V =45v		V =50v	
	Without PLC	With PLC	Without PLC	With PLC	Without PLC	With PLC	Without PLC	With PLC	Without PLC	With PLC
0	0.8	0.8	0.7	0.8	0.7	0.8	0.7	0.9	0.7	0.9
0.1	0.8	0.9	0.8	0.9	0.8	0.9	0.8	0.9	0.8	0.9
0.2	0.8	0.9	0.8	0.9	0.8	0.9	0.8	0.9	0.8	0.9
0.3	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.9
0.4	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
0.5	0.9	1	0.9	1	0.9	1.1	0.9	1.1	0.9	1.1
0.6	0.9	1.2	0.9	1	0.9	1.1	0.9	1.1	0.9	1.1
0.7	1	1.2	1	1.2	1	1.2	1	1.2	1	1.2
0.8	1	1.2	1	1.2	1	1.2	1	1.2	1	1.3
0.9	1	1.2	1	1.2	1	1.2	1	1.2	1	1.3
1	1	1.3	1	1.3	1	1.3	1	1.3	1	1.3

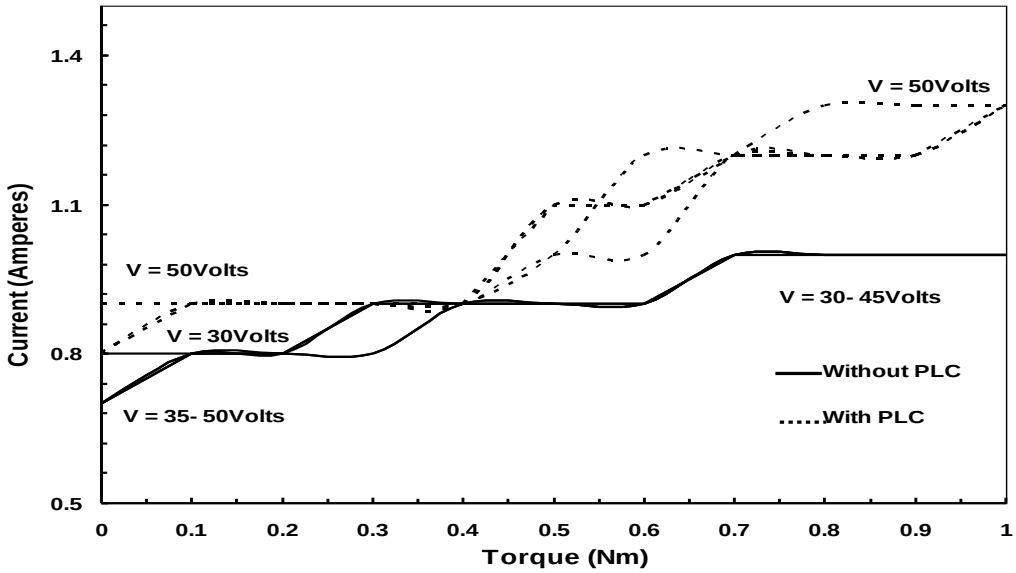

Fig 16: Graphically representation of Torque and Current of DC Series motor with PLC and Armature controller

4.3.3 Comparison Torque power characteristics of DC Series Motor with PLC and Armature Controller

Comparison between torque and current are shown in table 9 and graphically represented in figure 17.

Table 9 Comparison of Torque Power characteristics DC Series Motor PLC with Armature Controller

	Power									
	V =30v		V =35v		V =40v		V =45v		V =50v	
Torque (N- M)	Without PLC	With PLC	Without PLC	With PLC	Without PLC	With PLC	Without PLC	With PLC	Without PLC	With PLC
0	24	24	24.5	28	28	32	31.5	40.5	35	45
0.1	24	27	28	31.5	32	36	36	40.5	40	45
0.2	24	27	28	31.5	32	36	36	40.5	40	45
0.3	24	27	31.5	31.5	36	36	40.5	40.5	40	45
0.4	27	27	31.5	31.5	36	36	40.5	40.5	45	45
0.5	27	30	31.5	35	36	44	40.5	49.5	45	55
0.6	27	36	31.5	35	36	44	40.5	49.5	45	55
0.7	30	36	35	42	40	48	45	54	50	60
0.8	30	36	35	42	40	48	45	54	50	65
0.9	30	36	35	42	40	48	45	54	50	65
1	30	39	35	45.5	40	52	45	58.5	50	65

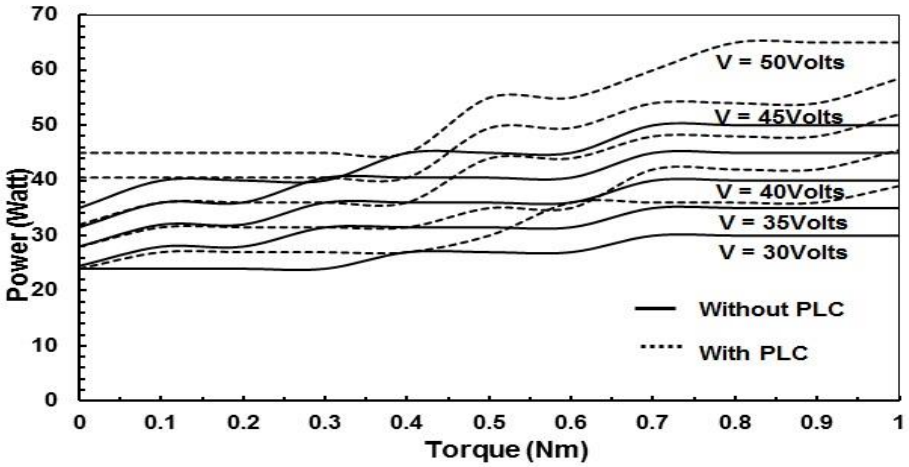

Fig 17: Graphically representation of Torque and Power of DC Series motor with PLC and Armature controller.

Figure 17 represents the relationship between power with respect to torque with and without PLC. At different voltages from 30 to 50 V as torque gradually increases from 0 NM to 1 NM power is increased.

5 Conclusion and Future Work

In this paper, the characteristics results of DC Series Motor have been obtained by using different controller techniques such as PLC and Armature controllers. In the above results and discussion, it can be easily understood that the best results are obtained by using PLC as compare to the armature controller.

By this research work, speed and torque of DC Motor can be controlled for laboratories and industrial applications.

This work can be further enhanced in the future in the following ways.

- It can be applied in industry.
- It is also used in an educational institute.
- An adaptive controller can be used for Motor control.
- Combined controlling techniques with PLC can be used to observe torque vs. speed characteristics.
- Matlab based Motor can be simulated for power drives and medical appliances.

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