LABORATORY STUDIES OF SPEED CONTROL OF DC SHUNT MOTOR AND THE ANALYSIS OF PARAMETERS ESTIMATION

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Abstract **—In this research the speed of the motor with different controller will be examined in laboratory their results will be concluded, following the modern control techniques the drawbacks of these controllers will be rectified with modern technique of artificial intelligence using software based MATLAB /SIMULINK techniques. Following controlling techniques will be applied to get experimental results and then their software will be developed which will provide the basis for designing the artificial neural network speed controller for DC motor in order to achieve better performance**

- **Single Phase Half Wave Simple Motor Control**
- **Single Phase Full Wave Simple Motor Control**
- **Closed Loop Proportional Control**
- **Proportional Speed Control using Armature Voltage Feedback**
- **Proportional Speed Control with IR Compensation**
- **Proportional Speed Control with Integral Compensation**

I. INTRODUCTION

The shunt motor gets its name from the way it is wired. The field coil is connected in parallel or shunt with the armature. Because both sets of windings are connected in parallel, the same voltage is applied to both of them [1].

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It is clear that speed of a shunt motor is sufficiently constant and for the same current input its starting torque is not as high as that of series motor [2].

It is typically used for industrial, adjustable speed applications, such as machine tools winding/unwinding machines. The power supply of a DC motor connects directly to the field of the motor which allows for precise voltage control, speed and torque control applications [3].

A shunt DC motor has good speed regulation even as the load varies. This research will be focused to judge the performance of DC shunt motor by the implementation of different kinds of controllers such as: Proportional (P) Control which removes the delay and provides fast control [4]. Integral (I) Controller eliminates the residual steady-state error that occurs with a pure proportional controller [5]. The IR compensation method is used to provide the speed regulation in DC motor speed controls. IR compensation increases the voltage going to the motor. Current Limiter is one of the very nice features of electronic speed controls. This capability gives the motor/control combination the ability to prevent damage that might otherwise occur if higher values of torque were available [6]. Due to the vital role of DC machine this research focuses on hardware as well as software based studies and analysis of different types of controllers for the speed control and suggest the simple solution.

II. SINGLE PHASE HALF WAVE SIMPLE MOTOR CONTROL

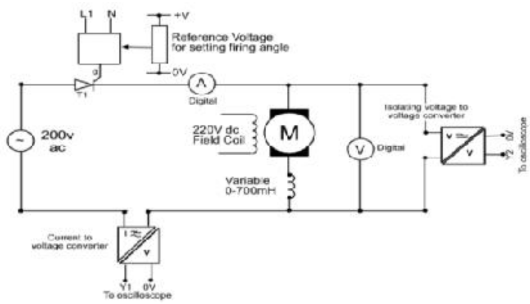


Fig. 1: Internal Circuit Diagram of Single Phase Half Wave Simple Motor Control

The internal circuit diagram and inter panel connections of single phase half wave simple motor control is shown in the fig. 1 & 2 respectively.

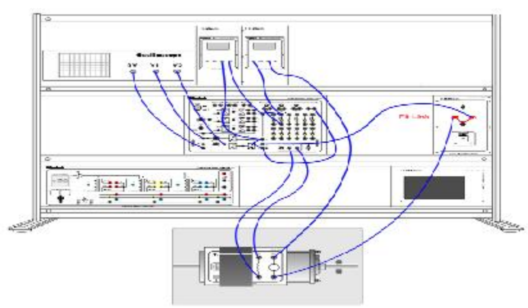


Fig. 2: Inter Panel Connections of Single Phase Half Wave Simple Motor Control

As the reference voltages applied to thyristor is increased then the speed of the motor is also increased it is clear from table I. Speed is inversely proportional to the applied torque this is clearly shown in table II.

Table I
Ref. Voltages vs Speed

Ref Voltage Scale Divisions	Speed rev/min	Armature Voltage (V)	Armature Current (A)
1	0	0	0.01
2	0	1.0	0.11
3	350	30.3	0.24
4	1645	122.6	0.26
5	2515	187.3	0.30
6	2870	222.4	0.32
7	2975	228.8	0.34
8	3100	240.0	0.34
9	3118	240.5	0.34
10	3110	240.8	0.34

Table II
Applied torque vs Speed

Torque (Nm)	Speed (rpm)	Armature Voltage (V)	Armature Current (A)
0	2900	230	0.25
0.2	2840	222	0.45
0.4	2550	200	0.67
0.6	2300	185	1.00
0.8	2110	170	1.15
1.0	2014	150	1.34
1.2	1700	145	1.55
1.4	-	-	-
1.6	-	-	-

III. SINGLE PHASE FULL WAVE SIMPLE MOTOR CONTROL

The internal circuit diagram and inter panel connections of single phase full wave simple motor control is shown in the fig. 3 & 4 respectively.

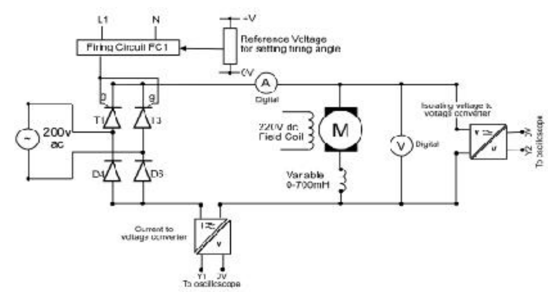


Fig. 3: Internal Circuit Diagram of Single Phase Full Wave Simple Motor Control

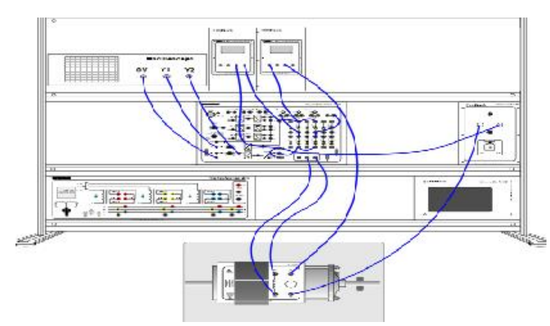


Fig. 4: Inter Panel Connections of Single Phase Full Wave Simple Motor Control

Now again by increasing the reference voltages applied to thyristor the speed of the motor could be increased it is clear from table III. In this case of full wave the speed can be controlled more efficiently than in the case of half wave. Speed is inversely proportional to the applied torque this is clearly shown in table IV.

Table III
Ref. Voltages vs Speed

Ref Voltage Scale Divisions	Speed rev/min	Armature Voltage (V)	Armature Current (A)
1	0	0.4	0.04
2	0	3.2	0.21
3	825	63	0.23
4	2428	184	0.26
5	3045	225	0.26
6	3440	255	0.27
7	3521	267	0.28
8	3520	267	0.28
9	3520	267	0.28
10	3520	267	0.28

Table IV
Applied torque vs Speed

Torque (Nm)	Speed (rpm)	Armature Voltage (V)	Armature Current (A)
0	3515	269	0.28
0.2	3289	251	0.51
0.4	3145	237	0.72
0.6	2930	230	0.92
0.8	2810	216	1.22
1.0	2600	208	1.47
1.2	2450	198	1.74
1.4	2376	192	1.99
1.6	2257	184	2.3

IV. CLOSED LOOP PROPORTIONAL CONTROL

The internal circuit diagram and inter panel connections of closed loop proportional control is shown in the fig. 5 & 6 respectively.

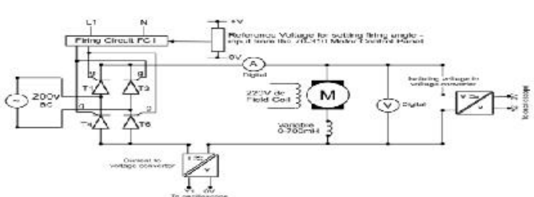


Fig. 5: Internal Circuit Diagram of Closed Loop Proportional Control

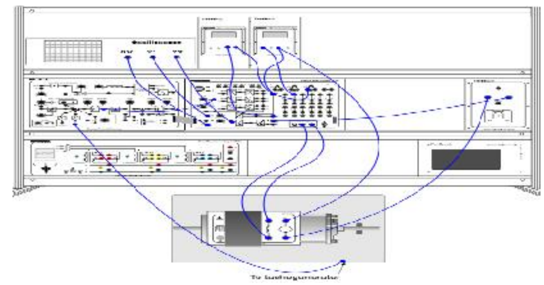


Fig. 6: Inter Panel Connections of Closed Loop Proportional Control

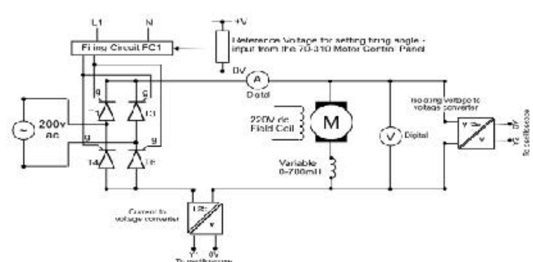
In this case of closed loop proportional control the speed is observed at various proportional gains (1, 4, 6 & 9). Table V shows speed response at various proportional gains under the application of torque.

Table V
Applied torque vs Speed

Torque (Nm)	P Gain 1	P Gain 4	P Gain 6	P Gain 9
	Speed (rpm)	Speed (rpm)	Speed (rpm)	Speed (rpm)
0	1500	1500	1500	1500
0.2	1320	1356	1455	1470
0.4	1210	1300	1400	1450
0.6	1120	1235	1345	1423
0.8	1035	1160	1280	1397
1.0	956	1090	1232	1371
1.2	910	1037	1190	1349
1.4	807	990	1150	1333
1.6	-	-	-	-

V. PROPORTIONAL CONTROL USING ARMATURE VOLTAGE FEEDBACK

The internal circuit diagram and inter panel connections of proportional control using armature voltage feedback is



shown in the fig. 7 & 8 respectively.

Fig. 7: Internal Circuit Diagram of Proportional Control using Armature voltage feedback

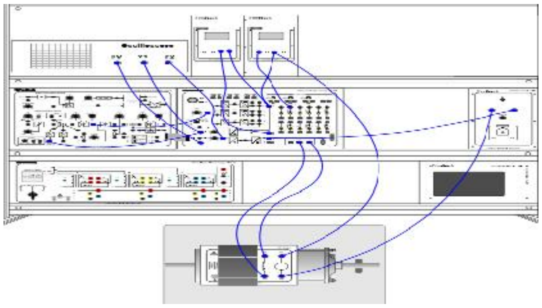


Fig. 8: Inter panel connections of Proportional Control using Armature voltage feedback

In this case of proportional control using armature voltage feedback the speed is observed at various armature voltages (1, 3, 5, 7 & 9) while proportional gain is set at 9 scale division. Table VI shows speed response at various Armature voltages and proportional gain at 9 scale division under the application of torque.

Table VI
Applied torque vs Speed

Proportional Gain = 9 Scale Division					
Torque	Armature Voltage 1	Armature Voltage 3	Armature Voltage 5	Armature Voltage 7	Armature Voltage 9
	Speed (r/m)	Speed (r/m)	Speed (r/m)	Speed (r/m)	Speed (r/m)
0	1500	1520	1527	1509	1502
0.2	1312	1466	1451	1465	1466
0.4	1115	1390	1379	1458	1446
0.6	930	1346	1363	1433	1403
0.8	756	1281	1340	1386	1379
1.0	630	1239	1280	1345	1365
1.2	510	1175	1256	1388	1325
1.4	350	1125	1190	1287	1315
1.6	-	-	-	-	-

VI. PROPORTIONAL SPEED CONTROL WITH ARMATURE VOLTAGE FEEDBACK AND IR COMPENSATION

The internal circuit diagram and inter panel connections of proportional speed control with armature voltage feedback and IR compensation is shown in the fig. 9 & 10 respectively.

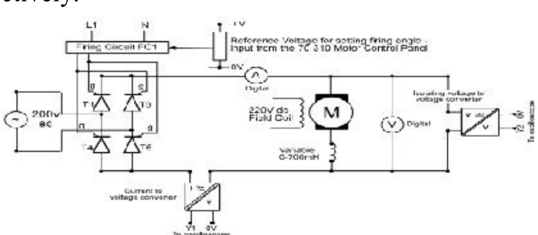


Fig. 9: Internal Circuit Diagram of Proportional Speed Control with Armature voltage feedback and IR Compensation

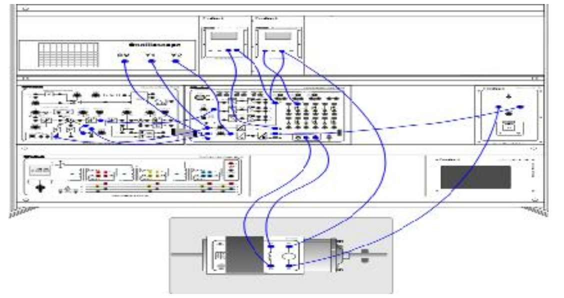


Fig. 10: Inter panel connections of Proportional Speed Control with Armature voltage feedback and IR Compensation

In this case of proportional speed control with armature voltage feedback and IR compensation the speed is observed at various IR compensation scale divisions (1, 2, 3, & 5) while proportional gain is set at 6 scale division. Table VII shows speed response at various IR compensation scale divisions and proportional gain at 6 scale division under the application of torque.

Table VII
Applied torque vs Speed

Proportional Gain= 6 scale division							
IR comp = 1 scale division		IR comp = 2 scale division		IR comp = 3 scale division		IR comp = 5 scale division	
Torque (Nm)	Speed (r/m)	Torque (Nm)	Speed (r/m)	Torque (Nm)	Speed (r/m)	Torque (Nm)	Speed (r/m)
0	1515	0	1508	0	1514	0	1513
0.2	1445	0.2	1438	0.2	1457	0.2	1455
0.4	1420	0.4	1393	0.4	1443	0.4	1450
0.6	1350	0.6	1374	0.6	1432	0.6	1448
0.8	1308	0.8	1345	0.8	1426	0.8	1447
1.0	1270	1.0	1325	1.0	1415	1.0	1450
1.2	1243	1.2	1306	1.2	1410	1.2	...
1.4	1214	1.4	1292	1.4	1408	1.4	...
1.6	-	1.6	-	1.6	-	1.6	-

VII. IMPLEMENTATION OF PROPORTIONAL AND INTEGRAL COMPENSATION TO OBSERVE TORQUE/SPEED CHARACTERISTICS

The internal circuit diagram and inter panel connections of proportional and integral control is shown in the fig. 11 & 12 respectively.

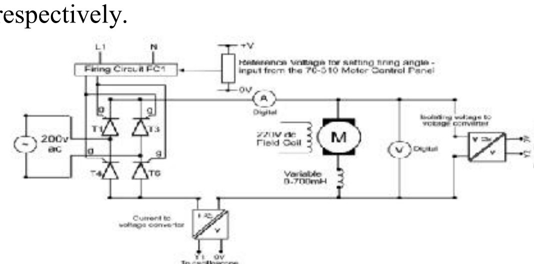


Fig. 11: Internal Circuit Diagram of Proportional and Integral Control of DC motor.

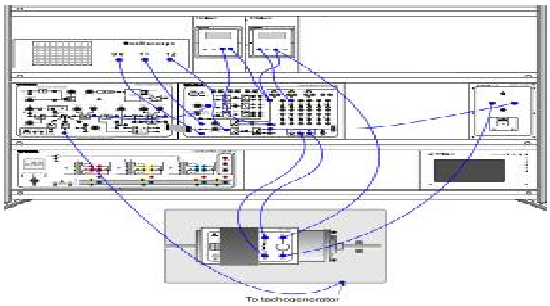


Fig. 12: Inter panel connections of Proportional and Integral Control of DC motor.

In this case of proportional and integral control for speed control of DC motor the speed is observed at integral time divisions 1 & 2 while proportional gain is set at 6 scale divisions. Table VIII shows speed response at integral time division 1 & 2 and proportional gain at 6 scale division under the application of torque.

Table VIII
Applied torque vs Speed

Proportional gain = 6 scale division			
Integral time = 1 division		Integral time = 2 division	
Torque (Nm)	Speed (rev/min)	Torque (Nm)	Speed (rev/min)
0	1519	0	1514
0.2	1514	0.2	1509
0.4	1519	0.4	1504
0.6	1519	0.6	1510
0.8	1514	0.8	1516
1.0	1520	1.0	1512
1.2	1512	1.2	1508
1.4	1511	1.4	1507
1.6	-	1.6	-

VIII. COMPARISON OF LABORATORY RESULTS

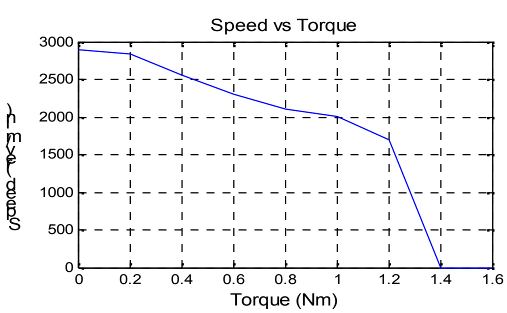


Fig. 13: Single phase half wave simple motor control

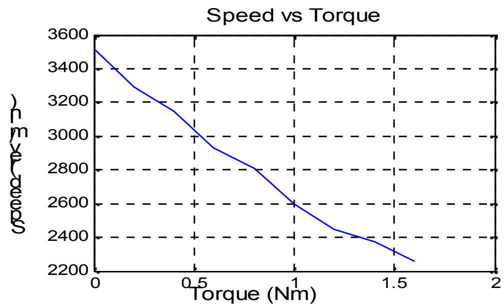


Fig. 14: Single phase full wave simple motor control

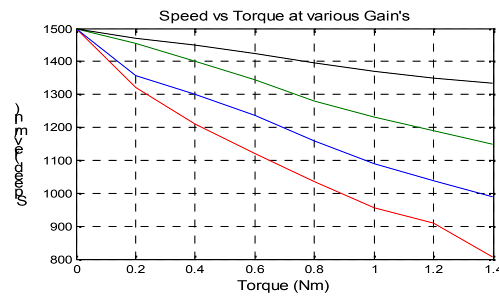


Fig. 15: Closed loop Proportional control

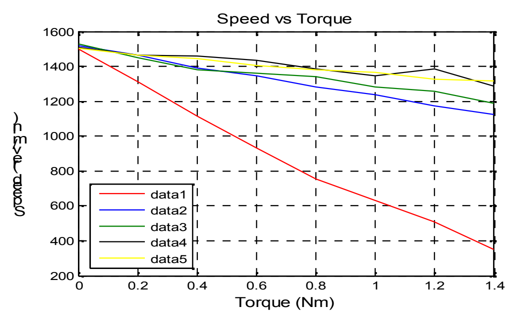


Fig. 16: Proportional control with armature voltage feedback

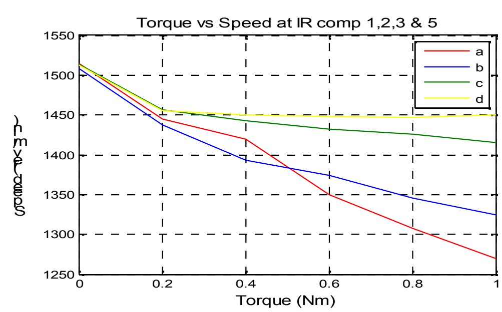


Fig. 17: P control with armature voltage feedback and IR compensation

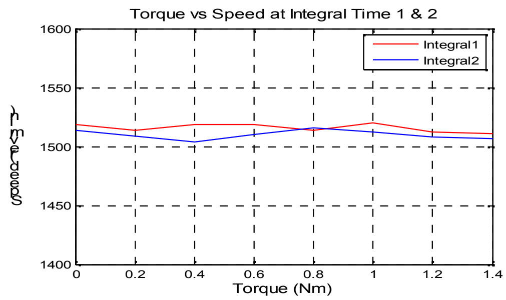


Fig. 18: PI control

IX. MATLAB/SIMULINK MODEL OF PI CONTROLLER FOR THE SPEED CONTROL OF DC MOTOR

From the laboratory studies it is proved that PI controller is best in all other controlling techniques. Therefore its MATLAB/SIMULINK model is developed. Simulink model is shown in fig. 19 and output at different P & I gains is shown in fig. 20 (A-C).

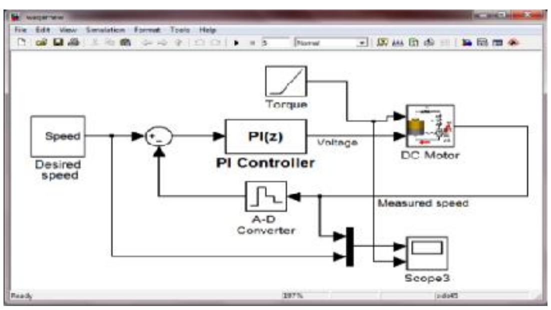


Fig. 19: Simulink model of PI controller for speed control of DC motor

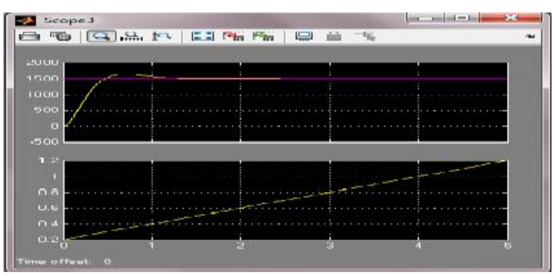


Fig. 20: (A) Output at P = 17, I = 39

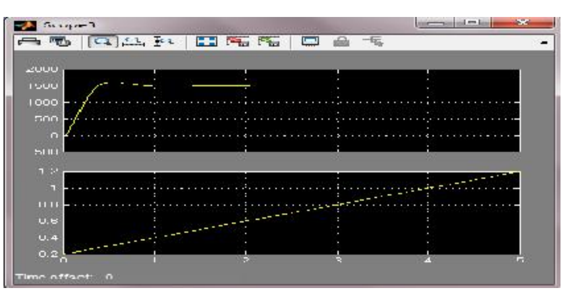


Fig. 20: (B) Output at P = 27, I = 62

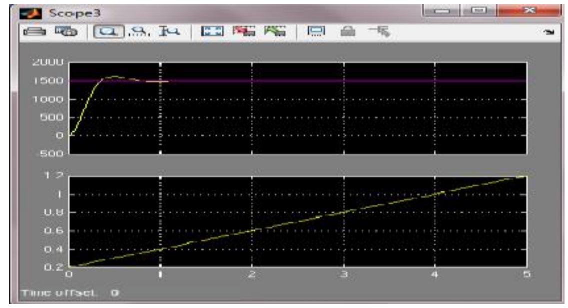


Fig. 20: (C) Output at P = 60, I = 136

X. MATLAB/SIMULINK MODEL OF PID CONTROLLER FOR THE SPEED CONTROL OF DC MOTOR

As in the industry PID controllers are the best suited controllers. Therefore its MATLAB/ SIMULINK model is developed. Simulink model is shown in the fig. 21 and output at different P, I and D gains is shown in fig, 22 (A-C).

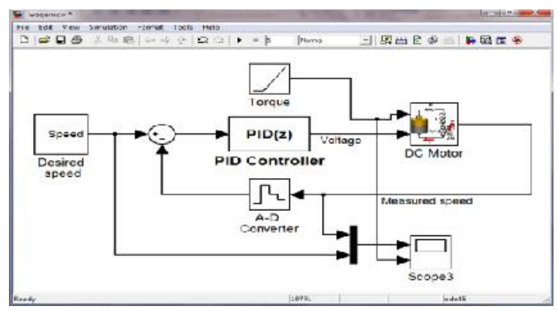


Fig. 21: Simulink model of PID controller for speed control of DC motor

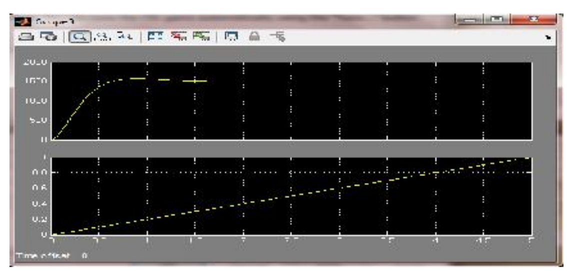


Fig. 22: (A) Output at P = 17, I = 39, D = 0.01

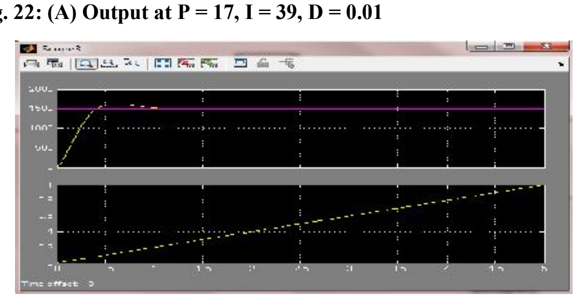


Fig. 22: (B) Output at P = 17, I = 39, D = 0.44

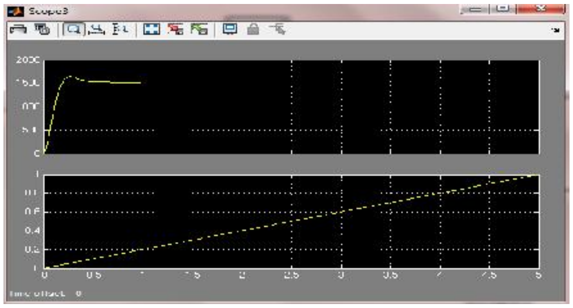


Fig. 22: (C) Output at P = 17, I = 39, D = 3.07

XI. CONCLUSION

Practical implementation of different types of controllers for speed control of DC motor is successfully demonstrated and suitable controller (PI) is selected. The model for this suitable controller is developed in MATLAB/Simulink and its accuracy is compared with its hardware data.

Due to some drawbacks of PI controller, PID control is suggested and demonstrated as the most suitable controller for this speed controller application which is modeled in Sim Power Systems in order to overcome the drawbacks of PI controller. These both (PI & PID) software model as speed controller of DC motor can provide more areas of research in drive systems very easily and economically.

XII. REFERENCES

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