



Faculty of Engineering and Technology  
Electrical and Computer Engineering Department  
Simulation Lab (ENEE4104)  
**Linear System Analysis in MATLAB**

---

Prepared By:

Name: Anas Tomaizeh

Number: 1152325

Instructor: Dr. Jamal seyam

TA: Eng. Ahmed Hamed

Date: 7/3/2019

Sec#: 1

## **Abstract**

In these experiments, some concepts were studied using MATLAB program. The aims of these experiments are to become familiar with some commands help in time and frequency domain analysis of linear system, to become familiar with some principle of MATLAB SIMULINK by analysis the DC motor as an example, study the effect of variation some parameter of DC motor such as (Torque, resister, input voltage and moment of inertia) and analysis the different filter using SPTOOL which shows the time and frequency representation of the signals before apply the signals at the filters, and show the frequency representations of the signals after apply in the filter.

# Table of Contents

<b>2. Introduction:</b> .....	<b>6</b>
<b>3. Theoretical Background:</b> .....	<b>6</b>
<b>3.1: MATLAB commands:</b> .....	<b>6</b>
<b>3.2: MATLAB Simulink:</b> .....	<b>6</b>
<b>3.3: SPTOOL:</b> .....	<b>6</b>
<b>4. Methods and Materials:</b> .....	<b>7</b>
<b>5. Procedure:</b> .....	<b>11</b>
<b>5.1: Linear System Simulation:</b> .....	<b>11</b>
<b>5.2: Simulate a DC motor in MATLAB Simulink:</b> .....	<b>12</b>
• <b>Part A: Building of DC motor:</b> .....	<b>12</b>
• <b>Part B: Added Working load</b> .....	<b>12</b>
• <b>Step 1 Effect of Load Torque:</b> .....	<b>12</b>
• <b>Step 2 Effect of Armature resistance</b> .....	<b>12</b>
• <b>Step 3: Effect of Input Voltage:</b> .....	<b>13</b>
• <b>Step 4: Effect of the moment of inertia (J):</b> .....	<b>13</b>
• <b>Step 5: Extracting a model of DC motor:</b> .....	<b>14</b>
<b>5.3: Filter Design used SPTOOL:</b> .....	<b>14</b>
<b>Part 1: Generated discrete time signal:</b> .....	<b>14</b>
<b>Part 2: SPTOOL:</b> .....	<b>14</b>
<b>Part 3: Filter Design:</b> .....	<b>14</b>
<b>6. Results:</b> .....	<b>15</b>
<b>6.1: Linear system Simulation:</b> .....	<b>15</b>
<b>6.2: Simulate a DC motor in MATLAB Simulink:</b> .....	<b>19</b>
<b>6.3: Filter Design used SPTOOL:</b> .....	<b>30</b>
<b>7. Discussion of the Results:</b> .....	<b>34</b>
<b>7.1: Linear system:</b> .....	<b>34</b>
<b>7.2: Model of DC motor in MATLAB Simulink:</b> .....	<b>35</b>
<b>7.3: Filter Design used SPTOOL:</b> .....	<b>35</b>
<b>8. Conclusion:</b> .....	<b>37</b>
<b>8. Appendix:</b> .....	<b>38</b>
<b>Appendix A.1:</b> .....	<b>38</b>
<b>Appendix A.2:</b> .....	<b>40</b>
<b>Appendix A.3:</b> .....	<b>41</b>
<b>9. References:</b> .....	<b>42</b>

## List of Figures:

Figure 1: The Circuit of Part 1.....	7
Figure 2: The Control system.....	7
Figure 3: The Circuit 1.....	8
Figure 4: The Circuit 2.....	8
Figure 5: The Circuit 3.....	<i>Error! Bookmark not defined.</i>
Figure 6: The Model of DC motor .....	9
Figure 7: The DC motor With Working load .....	9
Figure 8: Signal Builder Setting.....	<i>Error! Bookmark not defined.</i>
Figure 9: DC motor system with input, output blocks.....	10
Figure 10: The Values of the Currents of Circuit shown in the Figure 1 .....	<i>Error! Bookmark not defined.</i>
Figure 11: The Step Response of control System shown in the Figure 2 .....	15
Figure 12: The Magnitude plot of the transfer function $f(s)$ shown in part 3 in procedure part .....	16
Figure 13: The Phase of transfer function shown in part 3 in procedure part .....	<i>Error! Bookmark not defined.</i>
Figure 14: The Bode Plot of transfer function $F(s)$ shown in the part 3 in procedure part .....	16
Figure 15: The plot of function $y(t)$ shown in step 4 in procedure part.....	16
Figure 16: The Bode plot of the transfer function of the Circuit 1 in Figure 3....	17
Figure 17: The Current Response of Circuit 2 in Figure 4 .....	18
Figure 18: The Voltage response of Circuit shown in the Figure 4 .....	18
Figure 19: The Bode Diagram of Circuit 3 shown in the Figure 5 .....	19
Figure 20: The Speed of DC motor shown in the Figure 6.....	19
Figure 21: The Speed of DC motor shown in the Figure 7 at Different Value of Torque.....	19
Figure 22: The Current in DC motor shown in the Figure 7 at Different Value of Torque.....	20
Figure 23: Torque-Load Curve of DC motor shown in Figure 7 at different value of Torque .....	20
Figure 24: The Plot of Speed of DC motor shown in the figure 7 when armature resistance = $2 \Omega$ , and Different Value of Torque. ....	21
Figure 25: The plot of Current in DC motor shown in the Figure 7 when the Value of resistance = $2 \Omega$ , and Different Value of Torque.....	21
Figure 26: The Plot of Speed of DC motor shown in the figure 7 when armature resistance = $4 \Omega$ , and Different Value of Torque. ....	22
Figure 27: The plot of Current in DC motor shown in the Figure 7 when the Value of resistance = $4 \Omega$ , and Different Value of Torque.....	22

<b>Figure 28: The Plot of Speed of DC motor shown in the figure 7 when armature resistance =6 <math>\Omega</math>, and Different Value of Torque. ....</b>	<b>23</b>
<b>Figure 29: The plot of Current in DC motor shown in the Figure 7 when the Value of resistance =4 <math>\Omega</math>, and Different Value of Torque.....</b>	<b>23</b>
<b>Figure 30: The Plot of Speed of DC motor shown in the figure 7 when armature resistance =8 <math>\Omega</math>, and Different Value of Torque. ....</b>	<b>24</b>
<b>Figure 31: The plot of Current in DC motor shown in the Figure 7 when the Value of resistance =8 <math>\Omega</math>, and Different Value of Torque.....</b>	<b>24</b>
<b>Figure 32: The plot of Torque-Speed load of DC motor shown in the Figure 7 at Different Value of Armature Resistance.....</b>	<b>25</b>
<b>Figure 33: The plot of speed of DC motor shown in the Figure 7 when the value of Armature resistance set to 0.5 <math>\Omega</math> and the input voltage set to 50 V .....</b>	<b>25</b>
<b>Figure 34: The plot of speed of DC motor shown in the Figure 7 when the value of Armature resistance set to 0.5 <math>\Omega</math> and the input voltage set to 100 V .....</b>	<b>26</b>
<b>Figure 35: The plot of speed of DC motor shown in the Figure 7 when the value of Armature resistance set to 0.5 <math>\Omega</math> and the input voltage set to 150 V .....</b>	<b>26</b>
<b>Figure 36: The plot of speed of DC motor shown in the Figure 7 when the value of Armature resistance set to 0.5 <math>\Omega</math> and the input voltage set to 180 V:.....</b>	<b>27</b>
<b>Figure 37: The plot of speed of DC motor shown in the Figure 7 when the value of Armature resistance set to 0.5 <math>\Omega</math> and the input voltage set to 220 V .....</b>	<b>27</b>
<b>Figure 38: The plot of Torque load Curve of DC motor shown in the Figure 7 under changing the Voltage.....</b>	<b>28</b>
<b>Figure 39: The Speed of DC motor shown in the Figure 7 when <math>J=0.05e-3</math>. ....</b>	<b>28</b>
<b>Figure 40: The Speed of DC motor shown in the Figure 7 when <math>J=1e-3</math>. ....</b>	<b>29</b>
<b>Figure 41: The Speed of DC motor shown in the Figure 7 when <math>J=5e-3</math>. ....</b>	<b>29</b>
<b>Figure 42: The Speed of DC motor shown in the Figure 7 when <math>J=10e-3</math>. ....</b>	<b>29</b>
<b>Figure 43: The Discrete Time Signals.....</b>	<b><i>Error! Bookmark not defined.</i></b>
<b>Figure 44: Some of discrete time signal in Figure 43 without noise .....</b>	<b>30</b>
<b>Figure 45: Sum of discrete time signal shown in Figure 43 with noise.....</b>	<b>30</b>
<b>Figure 46: The Time Domain Representation of Signal shown in the Figure 45 .</b>	<b>31</b>
<b>Figure 47: The Frequency Domain representation of The Signal shown in the Figure 45.....</b>	<b>31</b>
<b>Figure 48: Response of Low Pass Filter .....</b>	<b>32</b>
<b>Figure 49: Response of High Pass Filter.....</b>	<b>32</b>
<b>Figure 50: Response of Band Pass Filter.....</b>	<b>33</b>
<b>Figure 51: The Response of The Signal shown in the Figure 45 after Apply to low pass Filter .....</b>	<b>33</b>
<b>Figure 52: The Response of The Signal shown in the Figure 45 after Apply to high pass Filter.....</b>	<b>34</b>
<b>Figure 53: The Response of The Signal shown in the Figure 45 after Apply to Band pass Filter .....</b>	<b><i>Error! Bookmark not defined.</i></b>

## List of Tables

<b>Table 1: The Values of Speed and Current of Armature Controller DC motor shown in the Figure 6 at Different value of Torque. ....</b>	<b>20</b>
<b>Table 2: The Value of Speed and Current of DC motor shown in the Figure 6 when the Value of resistance =2 ohm and Different Value of Torque. ....</b>	<b>21</b>
<b>Table 3: The Value of Speed and Current of DC motor shown in the Figure 6 when the Value of resistance =4 <math>\Omega</math> and Different Value of Torque. ....</b>	<b>22</b>
<b>Table 4: The Value of Speed and Current of DC motor shown in the Figure 6 when the Value of resistance =6 <math>\Omega</math> and Different Value of Torque. ....</b>	<b>23</b>
<b>Table 5: The Value of Speed and Current of DC motor shown in the Figure 6 when the Value of resistance =8 <math>\Omega</math> and Different Value of Torque. ....</b>	<b>24</b>
<b>Table 6: The Values of Speed of DC motor shown in Figure 6 when the input Voltage =50 and Armature resistance =0.5 ohm.....</b>	<b>25</b>
<b>Table 7: The Values of Speed of DC motor shown in Figure 6 when the input Voltage =100 and Armature resistance =0.5 ohm.....</b>	<b>26</b>
<b>Table 8: The Values of Speed of DC motor shown in Figure 6 when the input Voltage =150 and Armature resistance =0.5 ohm.....</b>	<b>26</b>
<b>Table 9: The Values of Speed of DC motor shown in Figure 6 when the input Voltage =180 and Armature resistance =0.5 ohm.....</b>	<b>27</b>
<b>Table 10: The Values of Speed of DC motor shown in Figure 6 when the input Voltage =220 and Armature resistance =0.5 ohm.....</b>	<b>27</b>

## **2. Introduction:**

The objectives of these experiments, firstly, linear system analysis using MATLAB commands such as, matrix operations, complex arithmetic, time and frequency analysis the electric circuit and deal with close loop transfer function. Second, to become familiar with MATLAB Simulink by built the DC motor as an example and studied the variations of torque, resistor, input voltage and inertia at output speed and current of motor. Third, to deal with SPTOOL and show the time and frequency representations of each signals, design low pass, high pass and band pass filters and apply the signals at each filter to show the new frequency representations of each signals and show the response of each type of filters.

## **3. Theatrical Background:**

### **3.1: MATLAB commands:**

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and proprietary programming language developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, Fortran and Python. [1]

### **3.2: MATLAB Simulink:**

Simulink, developed by MathWorks, is a graphical programming environment for modeling, simulating and analyzing multidomain dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. [2]

### **3.3: SPTOOL:**

SPTOOL, is a tool in MATLAB used to design and analysis the filter, in this window the representation of the signal in time domain, spectrum of the signal after and before Applying the filter and the spectrum of the filter can be shown easily.

## 4. Methods and Materials:

In these experiments the MATLAB commands, MATLAB Simulink and SPTOOL were used to achieve the objective of experiments.

For the Circuit shown in Figures (1-4) the MATLAB script was used to solve the problem, from the Figures (5-7) the Simulink used to simulate the system and get the results and from Figures ( 8 and 9) the SPTOOL was used to solve the problem.

- The Resistance matrix and the voltage vector of the Circuit shown in the Figure 1 were found, and a MATLAB program was written to solve the Meshes Current:

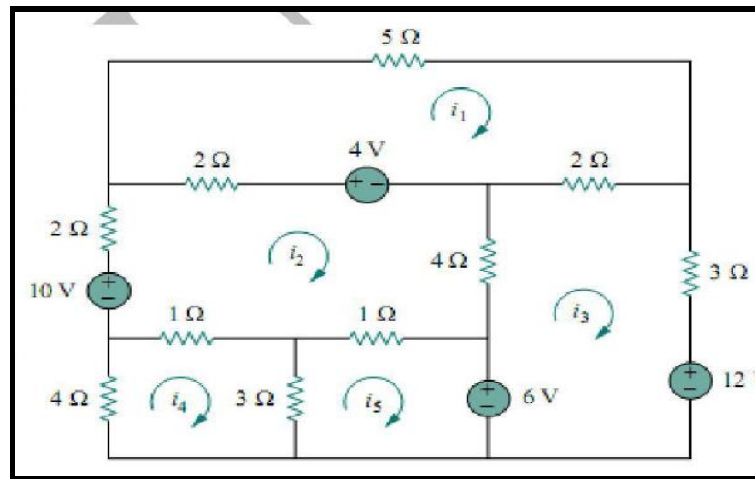


Figure 1: The Circuit need to solve used mesh analysis

- The MATLAB commands were used to describe the control system shown in the Figure 2, and the value of K set to 10, R is reference value and C is output from the Control system, and the step response of it was found.

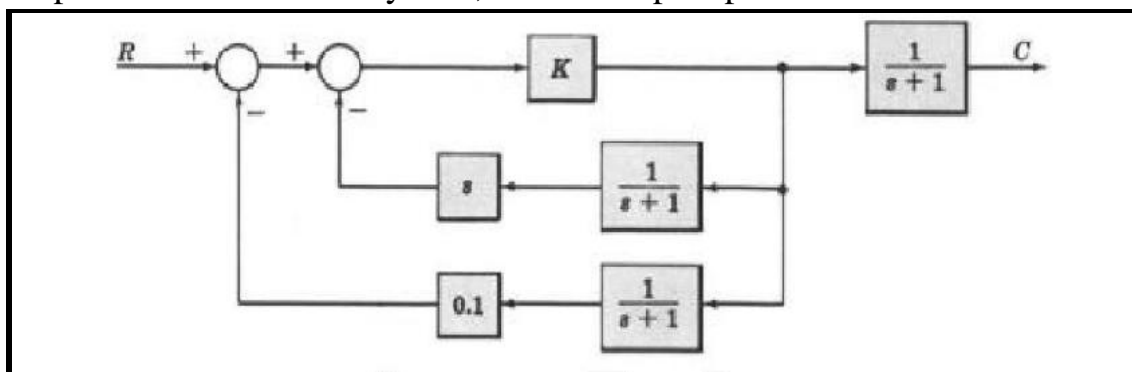


Figure 2: The Control system need to describe used command and find step response.



- The transfer function of the inverting amplifier shown in the Figure 3 was derived and the poles, zeros and plot of magnitude and phase of it were found:

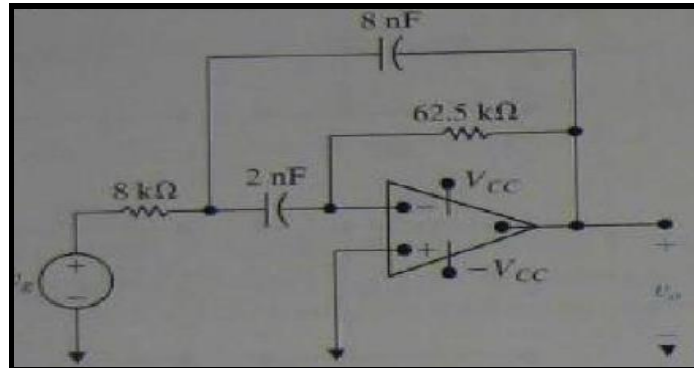


Figure 3: The inverting Amplifier

The transfer function of the 2<sup>nd</sup> order circuit shown in the Figure 4 was derived the pole, voltage  $V_C$ , response of Voltage and response of current damping coefficient, corner frequency and plot the Bode diagram were found.

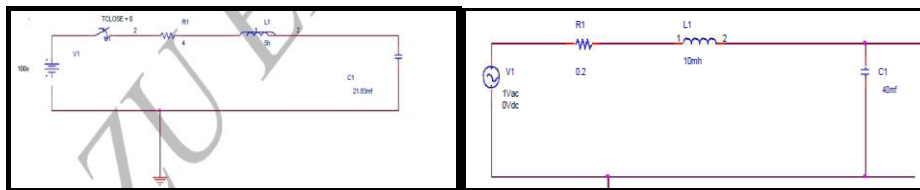


Figure 4: The 2<sup>nd</sup> Order Circuit

- The Model of DC motor shown in Figure 5 was built in Simulink used some liberals and the parameter of it were set in “model parameter” and the system was run to study different concepts about DC motor, which is the speed and Current of the DC motor at different value of Armature resistor, different torque, and different input voltage.

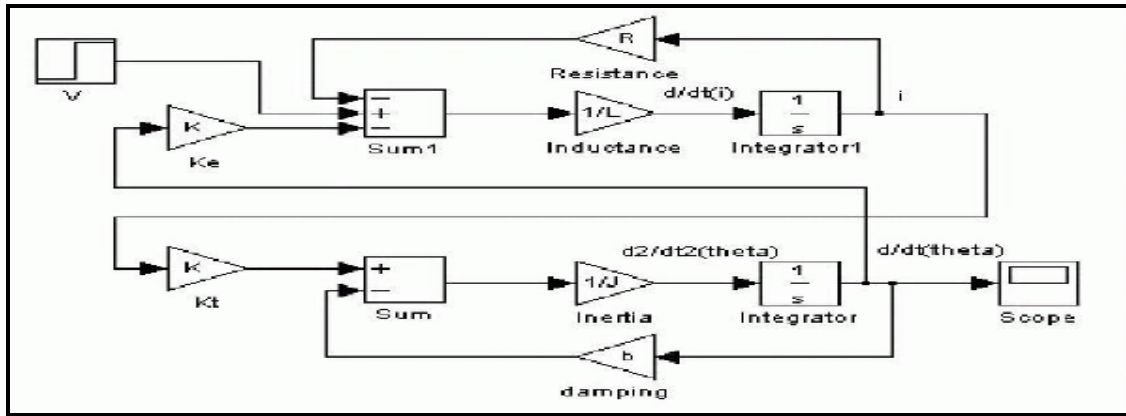


Figure 5: The Model of Armature controller DC motor

- The Working load was added to the System, which is represent the torque at DC motor, the new plot of it shown in the Figure 6.

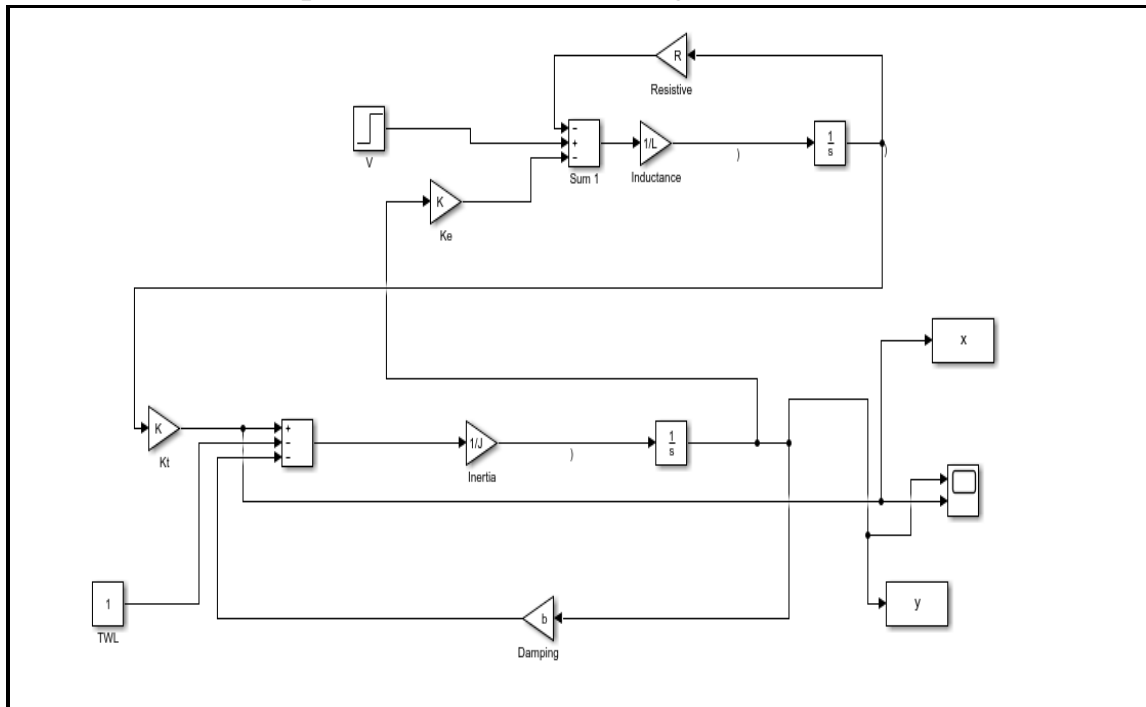


Figure 6: The Armature controller DC motor when working load component added to represent the torque at the DC motor .

- The input, output blocks were inserted to a DC motor system as show in the Figure 7 to extract it transfer function.

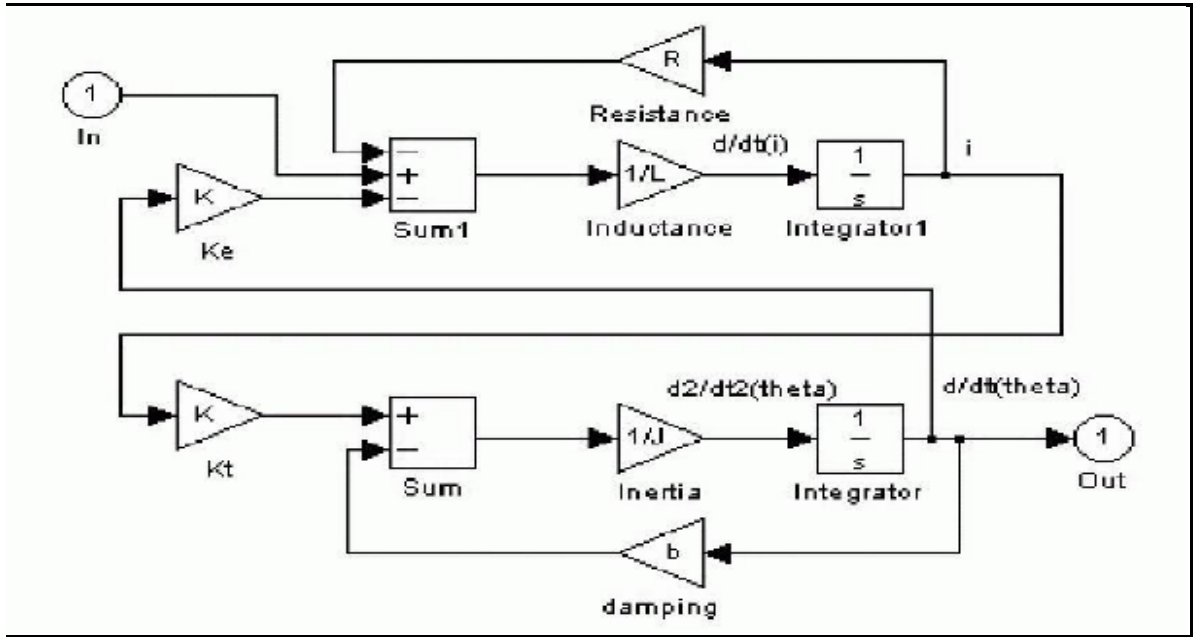


Figure 7: Armature Controller DC motor system with input, output blocks to extract the transfer function.

- The Discrete time Signal show in the Figure 8 generated, the sum of it were found and added AWGN to it sum, the result show in the Figure 10 and it import to SPTool to show the frequency and time representation and designed some Filters.

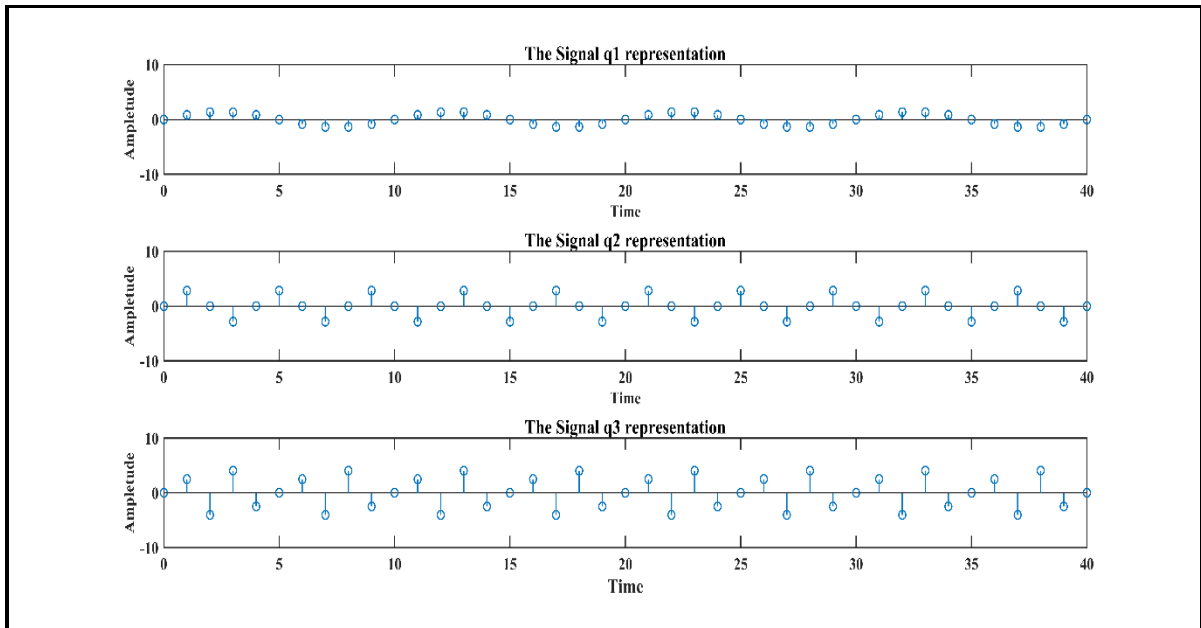


Figure 8: The Discrete Time Signal generated and imported to SPTool

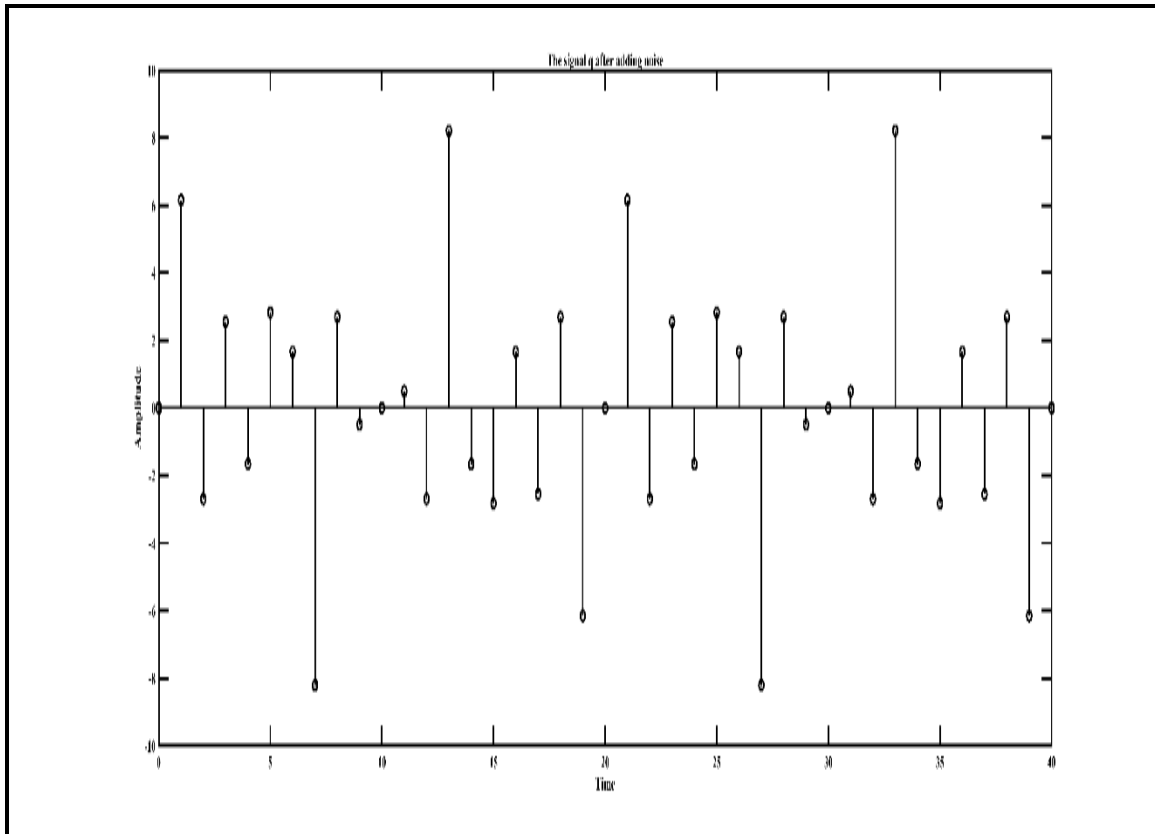


Figure 9: The Sum of discrete time signal show in figure 8 with AWGN

## 5. Procedure:

### 5.1: Linear System Simulation:

- **Part 1:** For the circuit shown in the Figure 1, the matrix shown in step 1 in results part describe it and the Code 1 in Appendix A.1 was used to solve the meshes current, the results are shown in the step 1 in result part .
- **Part 2:** For the system shown in the Figure 2 the Code 2 in Appendix A.1 was used to programed it and found the step response, the results is shown in the Figure 11 and the transfer function  $j(S)$  is shown in part 2 in results part.
- **Part 3:** The MALAB program was used to plot the frequency response of the following transfer function:

$$f(s) = \frac{10^5(s+7)(s+13)}{s(s+25)(s+55)(s^2+7s+75)(s^2+7s+45)} \dots (2)$$

used: 1) Standard plotting and complex number capabilities, Code 3 in Appendix A.1 was used to this part, the results shown in the Figure 12 in results part.

2) Standard plotting and complex number capabilities for generating Bode plots, Code 4 in Appendix A.1 was used to this part, the result shown in the Figure 13 in results part.

- **Part 4:** The MATLAB program Code 6 in Appendix A.1 was used to plot the following Compounded Signal:

$$y(t) = t^2[u(t + 1) - u(t)] + (t - 1)[u(t) - u(t - 1)] + (-1)[u(t - 1) - u(t - 2)], -3 < t < 5 \dots (3)$$

The result shown in the Figure 14 in results part.

- **Part 5:** The MATLAB program Code 7 and 8 in Appendix A.1 was used to found the voltage VC, response of Voltage and response of current, poles, zeros, and plot of magnitude and phase of the 2<sup>nd</sup> order Circuit shown in the Figure 4, and the results shown in the Part 5 and 6 in results part.
- **Part 6:** The MATLAB program Code 9 in Appendix A.1 was used to found the damping coefficient, corner frequency and plot the Bode diagram of the 2<sup>nd</sup> order circuit shown in the Figure 4, the results are shown in part 7 in results part, the Bode diagram shown in the Figure 18.

## 5.2: Simulate a DC motor in MATLAB Simulink:

- **Part A: Building of DC motor:**

The system of Armature Controller DC motor built as show in the Figure 5, and the system run to show the speed, the result shown in Figure 19 in results part.

- **Part B: Added Working load**

The Working load was added to the Armature Controller DC motor as shown in the Figure 6.

- **Step 1 Effect of Load Torque:**

The Torque apply to the Armature Controller DC motor shown in Figure 6 were changes as the follow [0.2 0.4 0.6 0.8 1.0 1.2], the Speed and Current of DC motor were found, the results are shown in the Figure 20,21 respectively, the value of Speed and Current were found and it recorded in Table 1 and the Torque load Curve plotted, all these results recorded in results part.

- **Step 2 Effect of Armature resistance:**

The Armature resistance of DC motor shown in Figure 6 were changes as the follow [2 4 6 8], for each value of resistance the Step 1 above were repeated.

- ✓ The plot of Speed and Current when the Armature resistance of DC motor shown in Figure 6 set to 2  $\Omega$ , shown in the Figure 23, 24 respectively, and the value of speed and current recorded in Table 2 in results part.

- ✓ The plot of Speed and Current when the Armature resistance of DC motor shown in Figure 6 set to  $4\ \Omega$ , shown in the Figure 25, 26 respectively, and the value of speed and current recorded in Table 3 in results part.
- ✓ The plot of Speed and Current when the Armature resistance of DC motor shown in Figure 6 set to  $6\ \Omega$ , shown in the Figure 27, 28 respectively, and the value of speed and current recorded in Table 4 in results part.
- ✓ The plot of Speed and Current when the Armature resistance of DC motor shown in Figure 6 set to  $8\ \Omega$ , shown in the Figure 29, 30 respectively, and the value of speed and current recorded in Table 5 in results part.
- **Step 3: Effect of Input Voltage:** The Value of Armature resistance of DC motor shown in the Figure 6 was set to  $0.5\ \Omega$  and the input voltage were changed as the follow [50 100 150 180 220], for each value of voltage the speed of DC motor were take and the results tabulated.
  - ✓ The plot of speed of DC motor shown in the Figure 6 when the input Voltage set to 50Volt shown in the Figure 32, and the value of the speed recorded in Table 6 in Results part.
  - ✓ The plot of speed of DC motor shown in the Figure 6 when the input Voltage set to 100Volt shown in the Figure 33, and the value of the speed recorded in Table 7 in Results part.
  - ✓ The plot of speed of DC motor shown in the Figure 6 when the input Voltage set to 150Volt shown in the Figure 34, and the value of the speed recorded in Table 8 in Results part.
  - ✓ The plot of speed of DC motor shown in the Figure 6 when the input Voltage set to 180Volt shown in the Figure 35, and the value of the speed recorded in Table 9 in Results part.
  - ✓ The plot of speed of DC motor shown in the Figure 6 when the input Voltage set to 220Volt shown in the Figure 36, and the value of the speed recorded in Table 10 in Results part.
- **Step 4: Effect of the moment of inertia (J):**  
The Torque at DC motor was set as shown in Figure 10, and the Value of J were changed as follow  $[0.05\ 1\ 5\ 10]*10^{-3}$ , the results show in the Figures 38,39,40 and 41 in results Part.

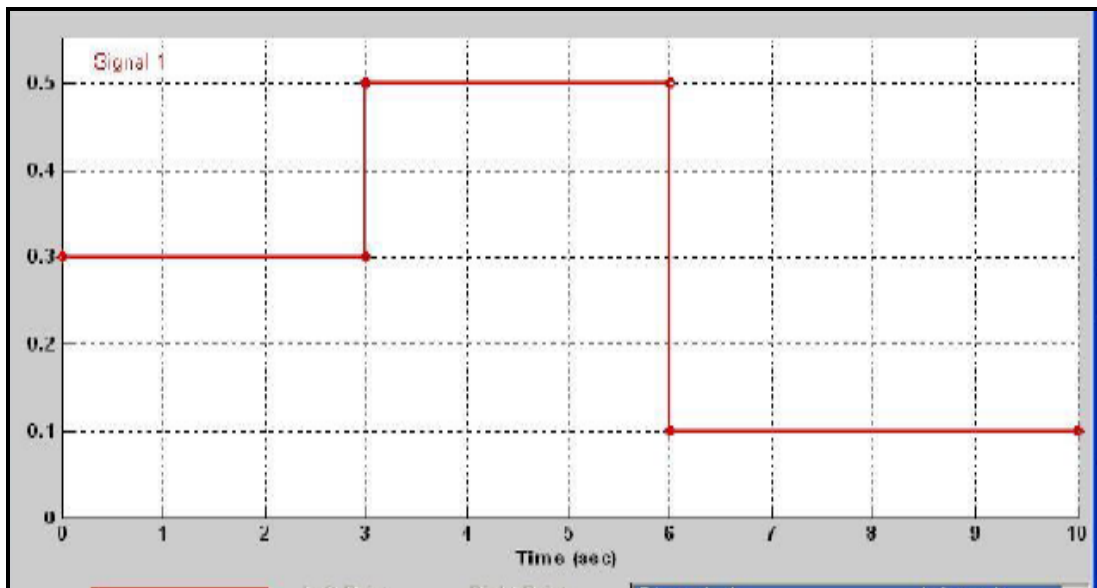


Figure 10: Different Torque at Armature Controller DC motor

- **Step 5: Extracting a model of DC motor:**

The Code 1 in Appendix A.2 used to Extracted the DC motor shown in the Figure 6 to MATLAB, the results show in the in results part.

### 5.3: Filter Design used SPTOOL:

#### Part 1: Generated discrete time signal:

The MATLAB scripts were used to generated discrete time signal (X) which is sum of three sine signals with frequency 100,250 and 400 and RMS voltage 1,2 and 3 respectively, the Code 1 in Appendix A.3 used to create the signals, the result shown in the Figure 8, 9 and 43 in results part .

#### Part 2: SPTOOL:

The Sptool window opened and the signal with noise which is sum of three sine signals shown in Figure 43 inserted to it, the time domain and Frequency domain representation of the signal shown in Figure 43 are found, the results show in Figure 44,45 respectively in results Part.

#### Part 3: Filter Design:

The low, high, and band Pass Filter were designed used SPTOOL, and the Signal shown in Figure 43 applied to each other of it, the response of Filters are shown in the Figure 48, 49 and 50 respectively and the spectrum representation of the signal after applied to the Filters shown in the Figure 46, 47 and 48 respectively in results part.

## 6. Results:

### 6.1: Linear system Simulation:

- **Part 1:** the Matrixes describe the Circuit shown in the Figure 1:

$$\begin{bmatrix} 4 \\ 6 \\ 6 \\ 0 \\ 6 \end{bmatrix} = \begin{bmatrix} 9 & -2 & -2 & 0 & 0 \\ -2 & 10 & -4 & -1 & -1 \\ -2 & -4 & 9 & 0 & 0 \\ 0 & -1 & 0 & 8 & -3 \\ 0 & -1 & 0 & -3 & 4 \end{bmatrix} \begin{bmatrix} I1 \\ I2 \\ I3 \\ I4 \\ I5 \end{bmatrix} \dots 1$$

➤ The Values of the Currents:

$$I1= 1.32, I2=2.06, I3=1.87, I4=1.41, I5= 3.07.$$

- **Part 2:** The transfer function  $j(s)$  of the control system shown in the Figure 2:

➤  $j =$

$$\frac{10 s^2 + 20 s + 10}{11 s^3 + 24 s^2 + 15 s + 2} \dots (4)$$

➤ The Step Response of the control system shown in the Figure 2:

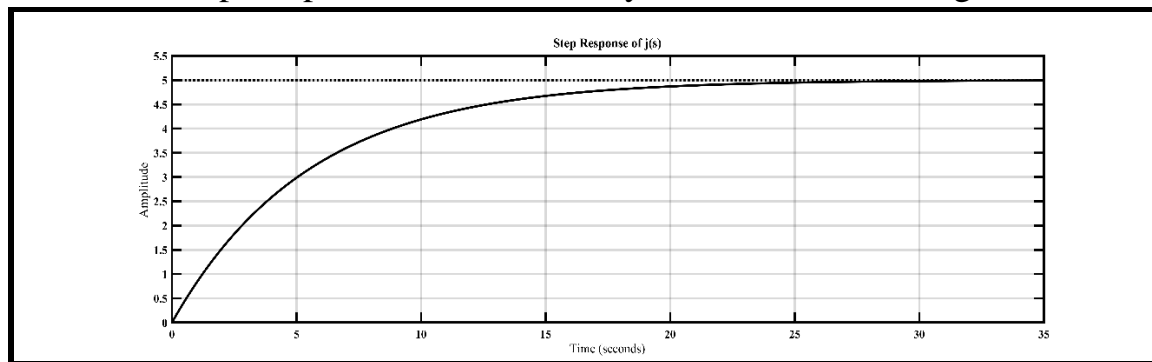


Figure 11: The Step Response of control System shown in the Figure 2

➤ **Part 3:** The following transfer function:

➤  $F =$

$$\frac{100000 s^2 + 2e06 s + 9.1e06}{s^7 + 94 s^6 + 2664 s^5 + 33610 s^4 + 302950 s^3 + 1.425e06 s^2 + 4.641e06 s} \dots (5)$$



➤ For Standard plotting and complex number capabilities:

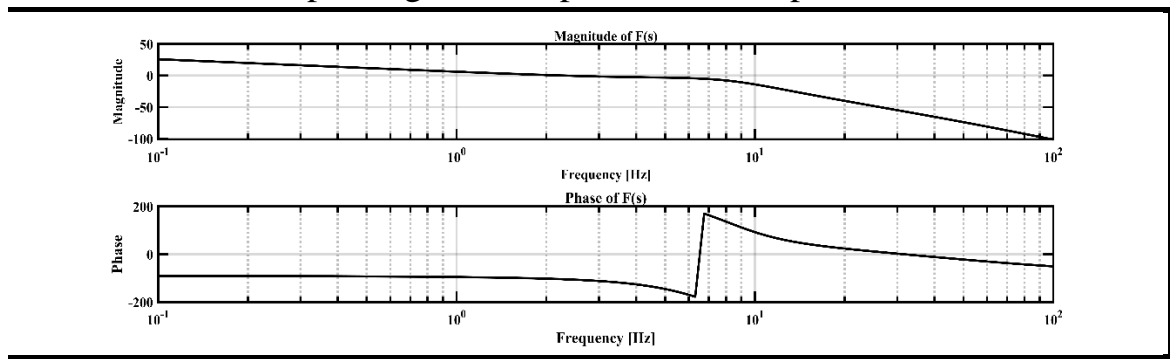


Figure 12: The Bode Diagram of Transfer Function  $F(s)$  2 shown in part 3 in procedure part.

Figure 5: The Magnitude and phase plot of the transfer function  $f(s)$  shown in part 3 in procedure part

➤ For generating Bode Plots of the transfer function shown in the part 3

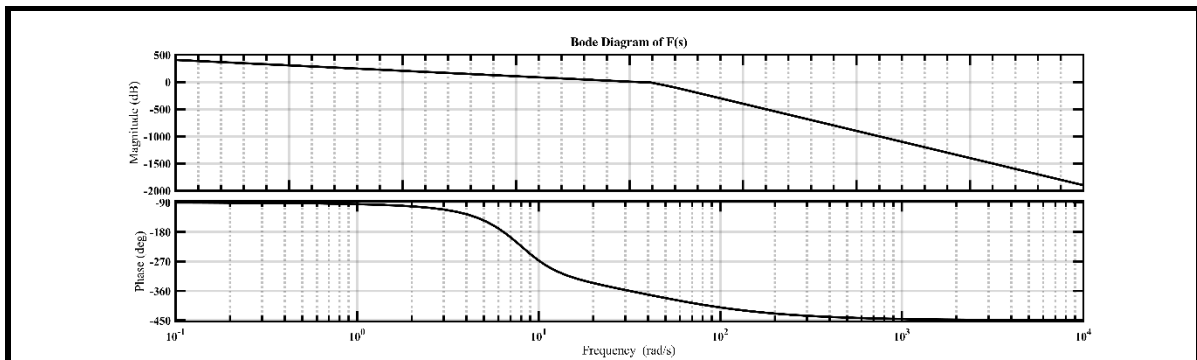


Figure 13: The Bode Plot of transfer function  $F(s)$  2 shown in the part 3 in procedure part

● **Part 4:** the plot of the function  $y(t)$  shown in step 4 in procedure part:

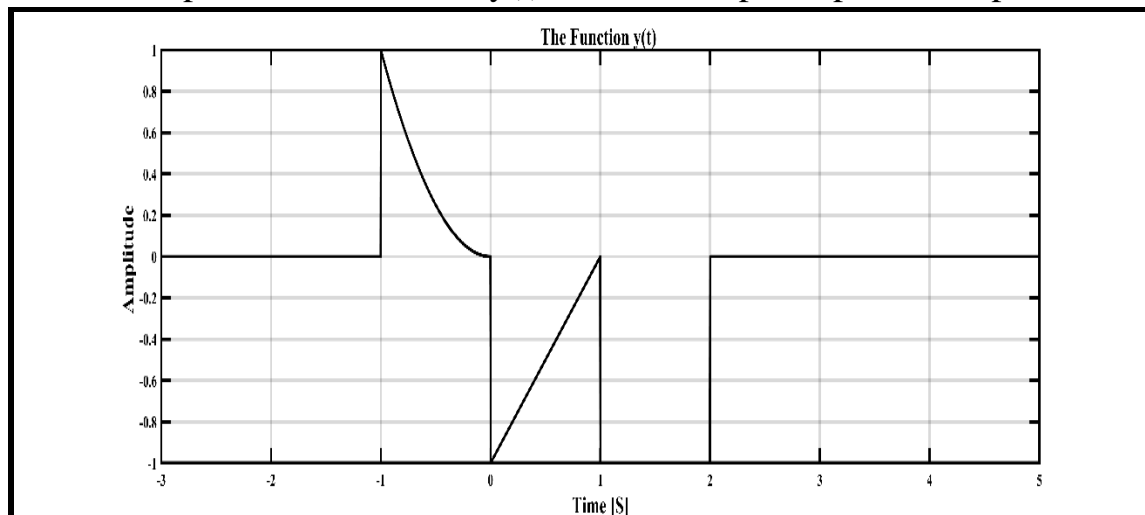


Figure 14: The plot of compounded signal -equation 3- shown in step 4 in procedure part

- **Part 5:** the transfer function  $a(s)$  of the 2<sup>nd</sup> order circuit shown in the Figure 4:  
 $a =$

$$\frac{-15625 s}{s^2 + 10000 s + 1.25e08} \dots(6)$$

- The pole and zero of  $a(s)$ :
- $b = 1.0e+04 * -0.5000 + 1.0000i \quad -0.5000 - 1.0000i$
- $c = 0$
- The Bode plot of the transfer function  $a(s)$  of the 2<sup>nd</sup> order circuit shown in the Figure 4:

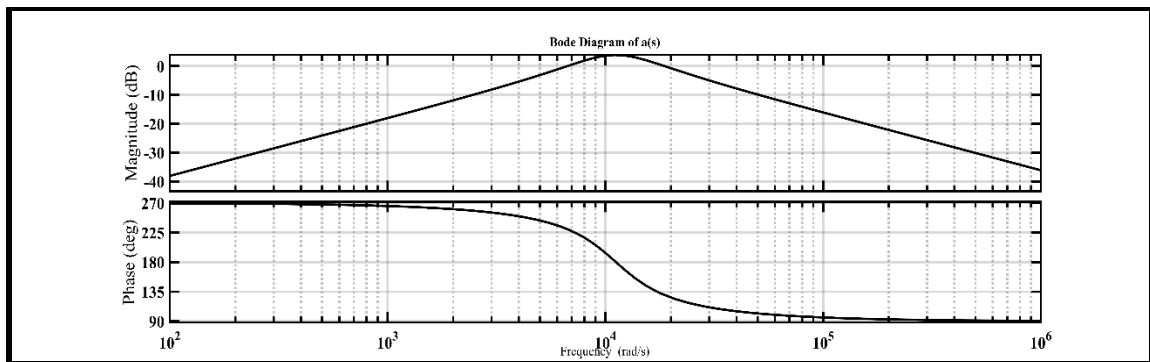


Figure 15: The Bode plot of the transfer function of the 2<sup>nd</sup> order circuit in Figure 4

- **Part 6:** the transfer function  $n(s)$  of the 2<sup>nd</sup> order circuit shown in the Figure 4:  
 $n =$

$$\frac{9.162}{s^2 + 0.8 s + 9.162} \dots(7)$$

- The Pole of  $n(s)$ :  
 $b =$   
 $-0.4000 + 3.0003i$   
 $-0.4000 - 3.0003i$
- The Voltage  $V$ :  
 $v =$   
 $916.2$   
 $\dots(8)$   
 $s^2 + 0.8 s + 9.162$

- The Current Response of the 2<sup>nd</sup> order circuit shown in the Figure 4

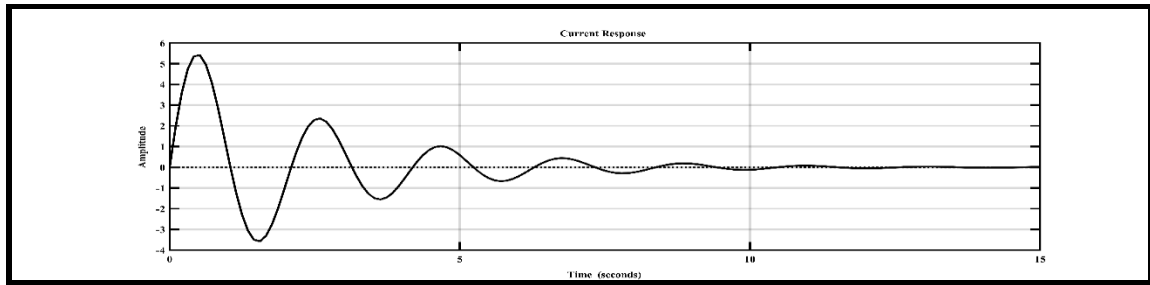


Figure 16: The Current Response of 2<sup>nd</sup> order Circuit in Figure 4

- The Voltage response of 2<sup>nd</sup> order circuit shown in the Figure 4

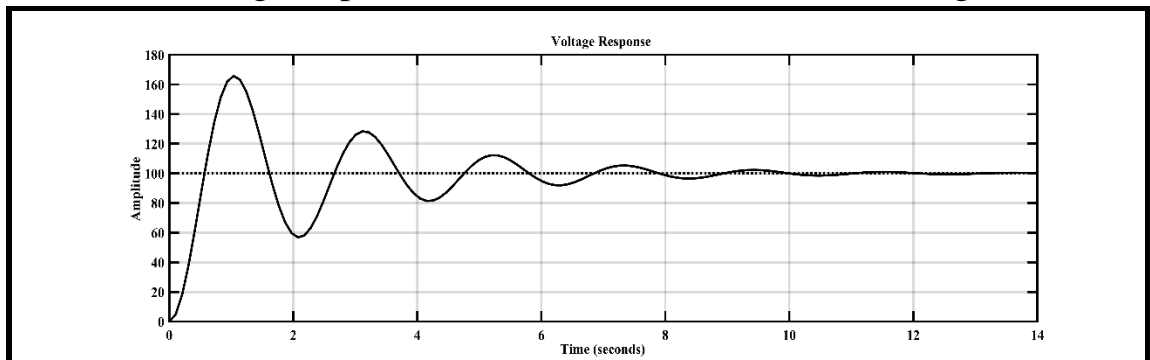


Figure 16: The Voltage response of Circuit shown in the Figure 4

- **Part 7:**

- The transfer function:

$h =$

$$\frac{2500}{s^2 + 20s + 2500} \dots(9)$$

- The Corner frequency  $W_n$  of the 2<sup>nd</sup> order circuit shown in the Figure 4 equal to 50.
- The Damping Coefficients of the 2<sup>nd</sup> order circuit shown in the Figure 4 = 0.2.
- Bode Diagram of the Circuit 3 shown in the Figure 4.

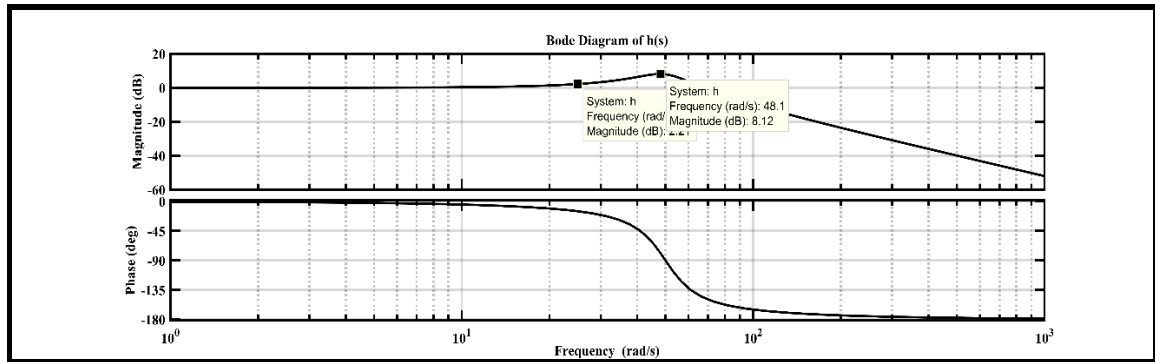


Figure 17: The Bode Diagram of 2<sup>nd</sup> order circuit shown in the Figure 4.

## 6.2: Simulate a DC motor in MATLAB Simulink:

Part A: The Speed of DC motor shown in the Figure 5.

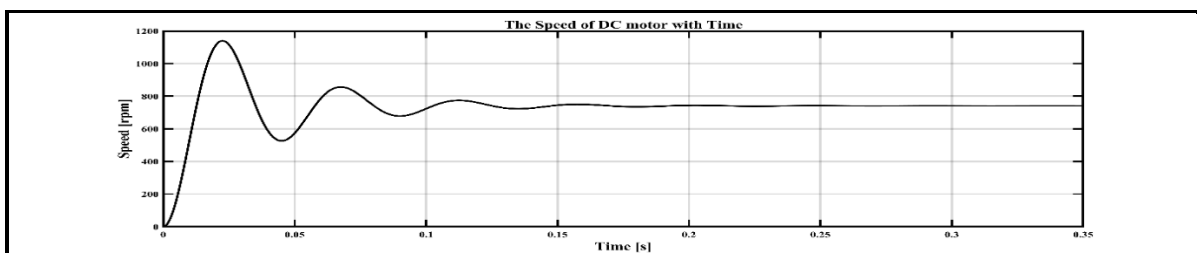


Figure 18: The Speed of DC motor shown in the Figure 5

- **Step 1:** The Plot Speed and Current of DC shown in the Figure 6 motor at Different Value of Torque:

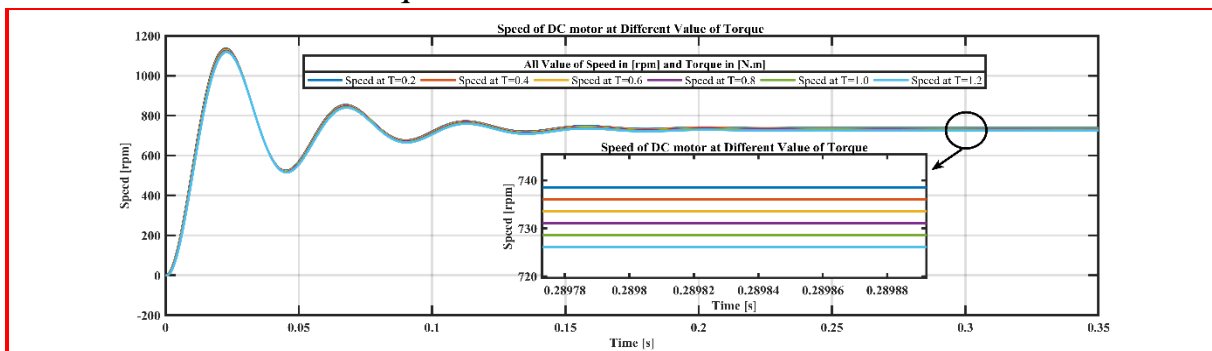
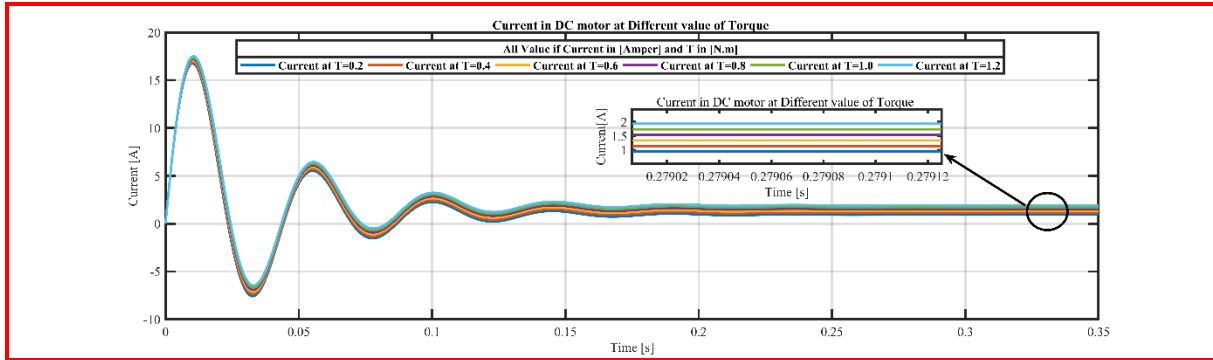


Figure 20: The Speed of DC motor shown in the Figure 6 at Different Value of Torque

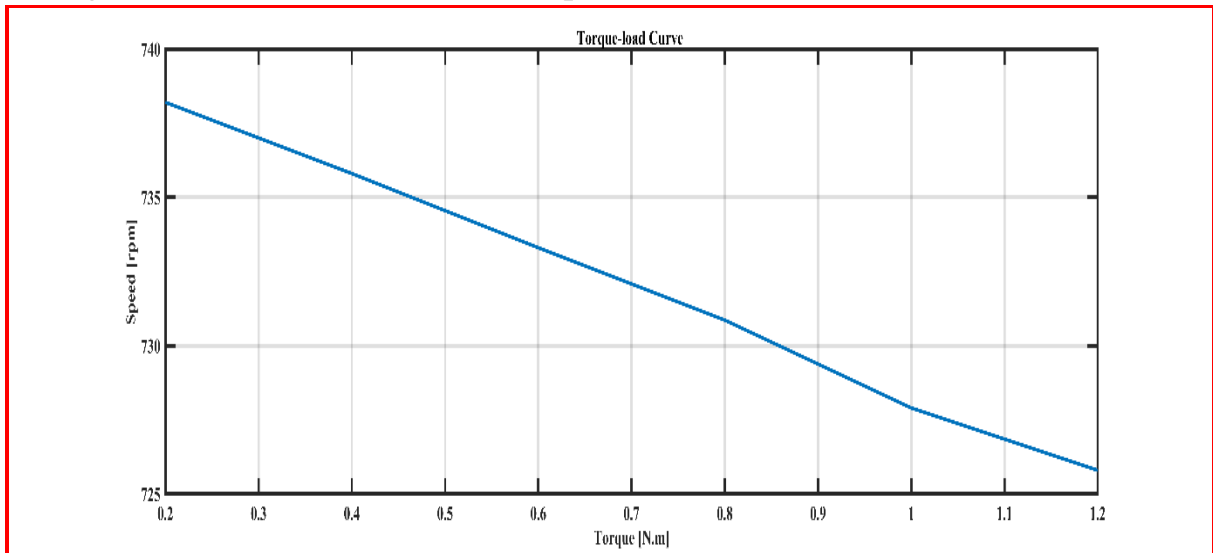


**Figure 21: The Current in Armature Controller DC motor shown in the Figure 6 at Different Value of Torque**

**Table 1: The Values of Speed and Current of Armature Controller DC motor shown in the Figure 6 at Different value of Torque.**

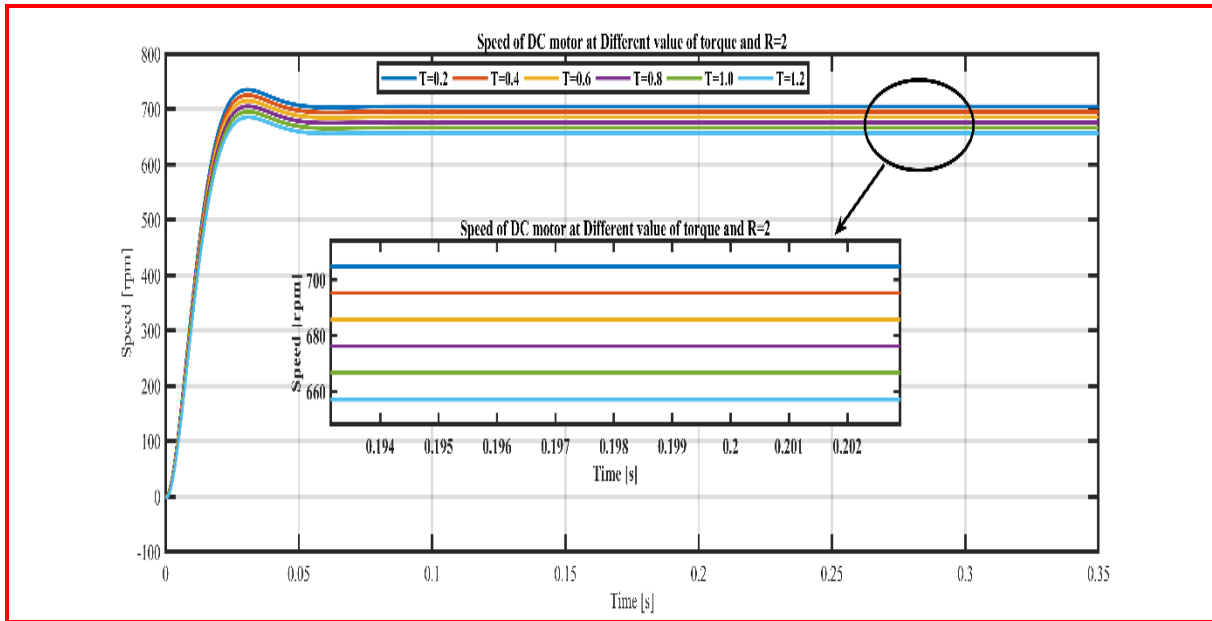
Torque [N.m]	Speed [rpm]	Current [A]
0.2	738.2	0.85
0.4	735.8	1.06
0.6	733.3	1.27
0.8	730.86	1.54
1.0	727.9	1.68
1.2	725.8	1.85

The Torque Speed Curve of the Armature Controller DC motor shown in the Figure 6 at Different value of Torque:

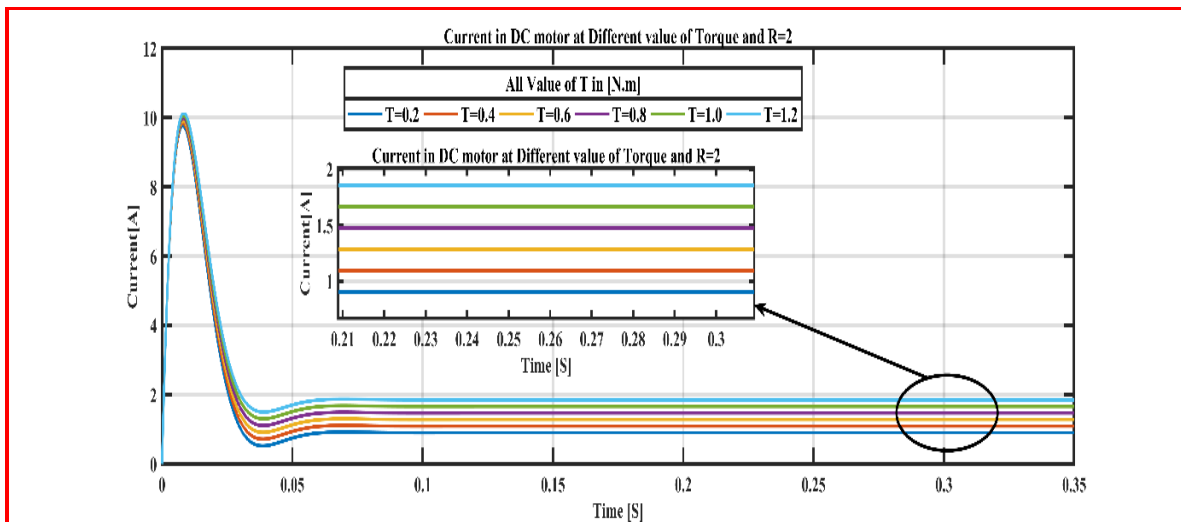


**Figure 22: Torque-Load Curve of DC motor shown in Figure 6 at different value of Torque**

- **Step 2:** The plot of Speed and Current of DC motor shown in the Figure 6 when the value of Armature resistance set  $2 \Omega$ :



**Figure 23: The Plot of Speed of DC motor shown in the figure 6 when armature resistance =2  $\Omega$ , and Different Value of Torque.**



**Figure 24: The plot of Current in DC motor shown in the Figure 6 when the Value of resistance =2  $\Omega$ , and Different Value of Torque.**

**Table 2: The Value of Speed and Current of DC motor shown in the Figure 6 when the Value of resistance =2 ohm and Different Value of Torque.**

Torque [N.m]	Speed [rpm]	Current [A]
0.2	704.55	0.94
0.4	695.2	1.09
0.6	685.71	1.28
0.8	676.1	1.47
1.0	666.6	1.66
1.2	657.1	1.85

The plot of Speed and Current of DC motor shown in the Figure 6 when the value of Armature resistance set  $4 \Omega$ :

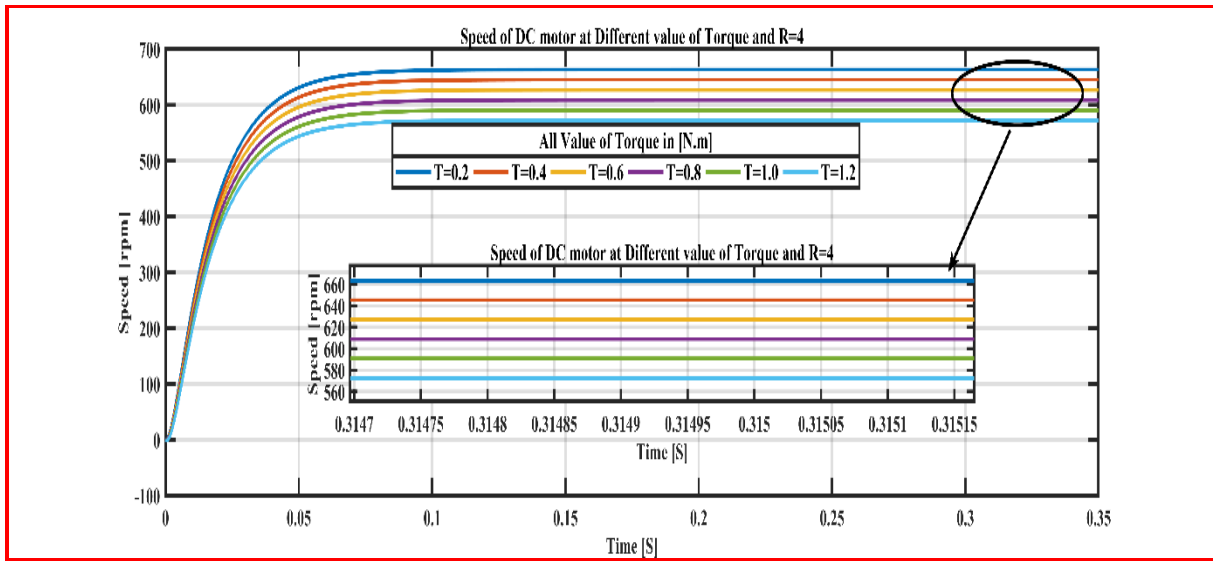


Figure 25: The Plot of Speed of DC motor shown in the figure 6 when armature resistance =  $4 \Omega$ , and Different Value of Torque.

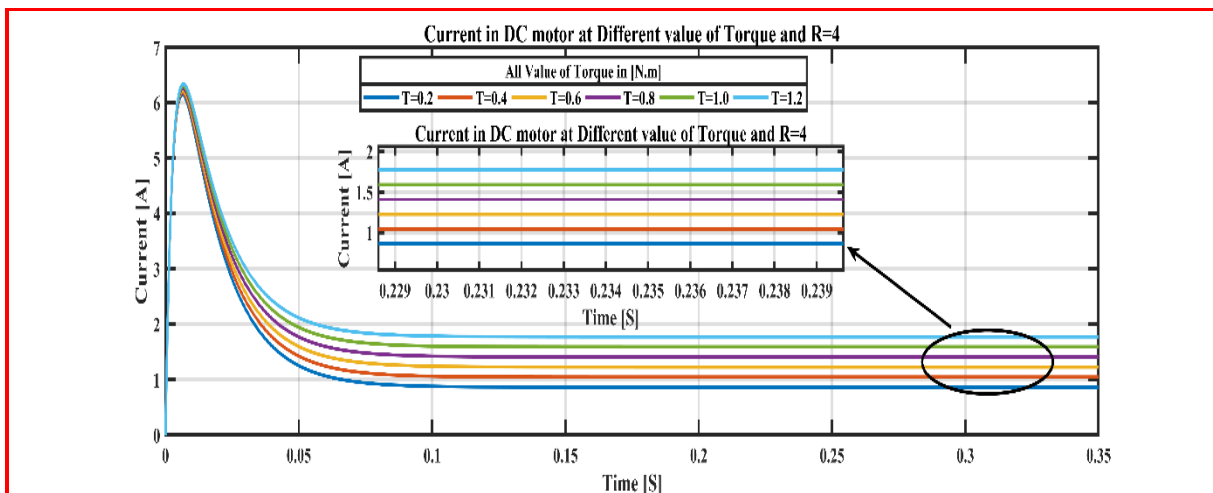


Figure 26: The plot of Current in DC motor shown in the Figure 6 when the Value of resistance =  $4 \Omega$ , and Different Value of Torque.

Table 3: The Value of Speed and Current of DC motor shown in the Figure 6 when the Value of resistance =  $4 \Omega$  and Different Value of Torque.

Torque [N.m]	Speed [rpm]	Current [A]
0.2	663.6	0.86
0.4	645.5	1.04
0.6	627.2	1.22
0.8	609.1	1.41
1.0	590.9	1.59
1.2	572.7	1.77

The plot of Speed and Current of DC motor shown in the Figure 6 when the value of Armature resistance set 6  $\Omega$ :

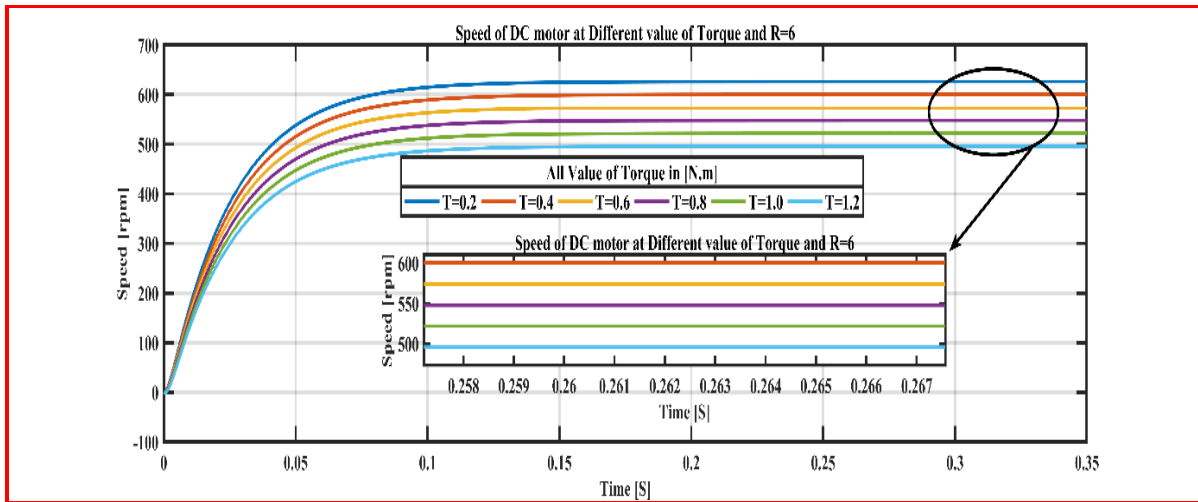


Figure 27: The Plot of Speed of DC motor shown in the figure 6 when armature resistance =6  $\Omega$ , and Different Value of Torque.

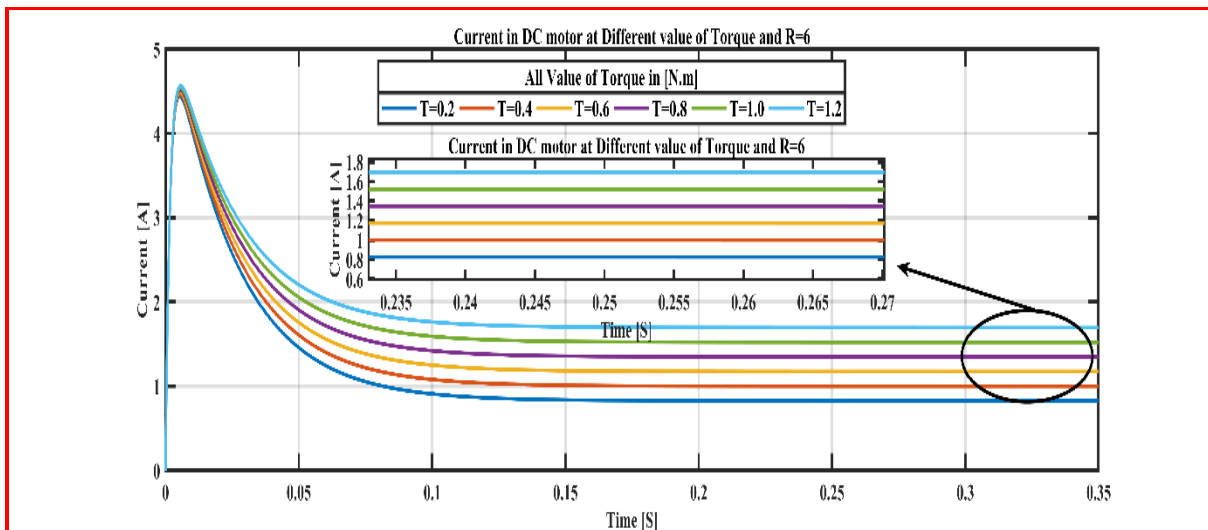


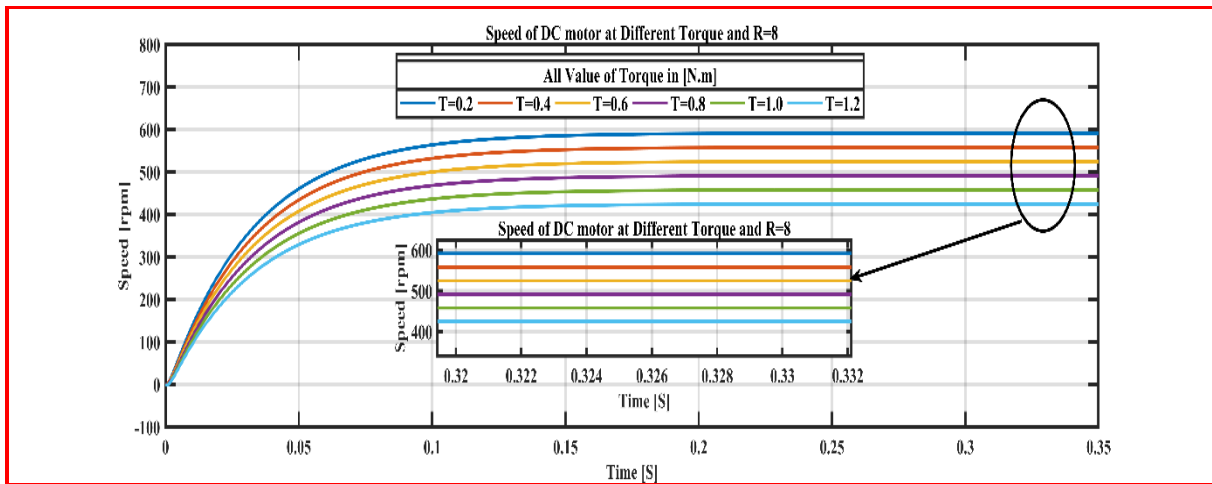
Figure 28: The plot of Current in DC motor shown in the Figure 6 when the Value of resistance =4  $\Omega$ , and Different Value of Torque.

Table 4: The Value of Speed and Current of DC motor shown in the Figure 6 when the Value of resistance =6  $\Omega$  and Different Value of Torque.

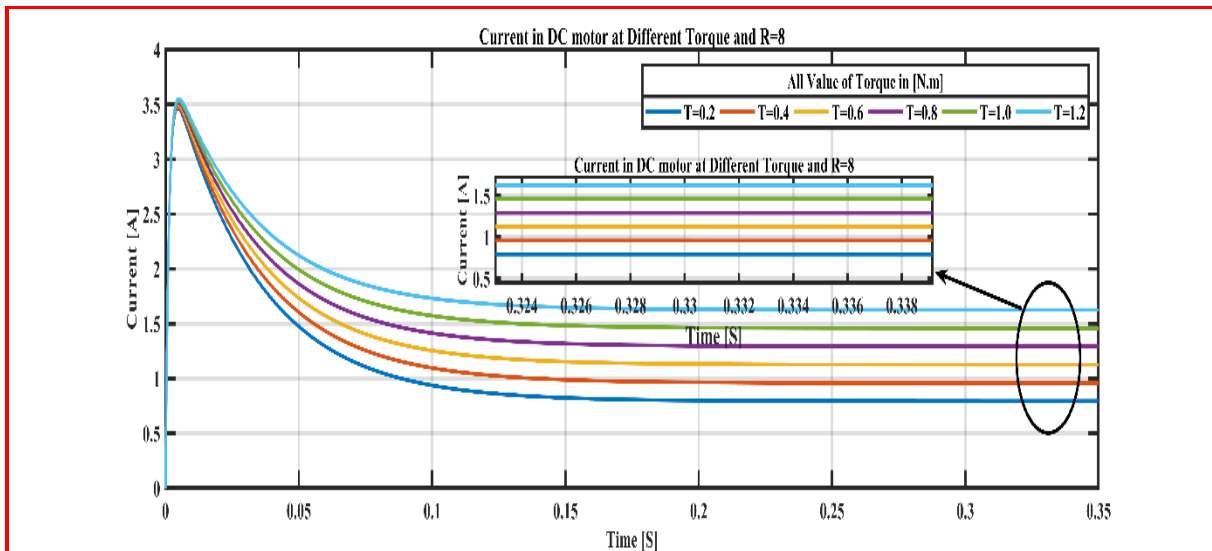
Torque [N.m]	Speed [rpm]	Current [A]
0.2	626	0.84
0.4	600	1.0
0.6	574	1.17
0.8	548.1	1.34
1.0	521.8	1.52
1.2	495.5	1.69



- The plot of Speed and Current of DC motor shown in the Figure 6 when the value of Armature resistance set  $8\Omega$ :



**Figure 29: The Plot of Speed of DC motor shown in the figure 6 when armature resistance =  $8\Omega$ , and Different Value of Torque.**



**Figure 30: The plot of Current in DC motor shown in the Figure 6 when the Value of resistance =  $8\Omega$ , and Different Value of Torque.**

**Table 5: The Value of Speed and Current of DC motor shown in the Figure 6 when the Value of resistance =  $8\Omega$  and Different Value of Torque.**

Torque [N.m]	Speed [rpm]	Current [A]
0.2	592	0.80
0.4	558	0.96
0.6	525	1.10
0.8	491.6	1.29
1.0	458.2	1.46
1.2	425	1.62

- The plot of Torque-Speed load of DC motor shown in the Figure 6 at Different Value of Armature Resistance:

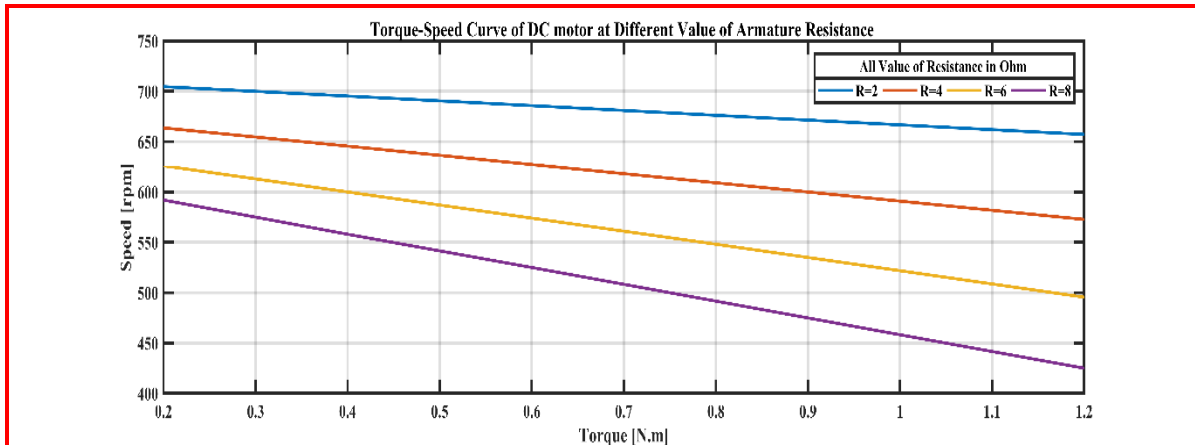


Figure 31: The plot of Torque-Speed load of DC motor shown in the Figure 6 at Different Value of Armature Resistance.

- **Step 3:** The plot of speed of DC motor shown in the Figure 6 when the value of Armature resistance set to  $0.5 \Omega$  and the input voltage set to 50 V:

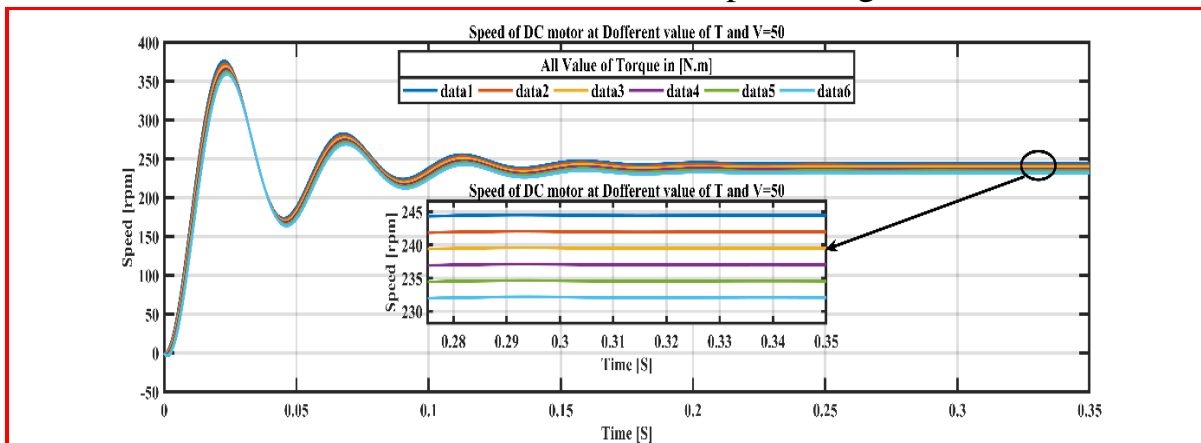


Figure 32: The plot of speed of DC motor shown in the Figure 6 when the value of Armature resistance set to  $0.5 \Omega$  and the input voltage set to 50 V

Table 6: The Values of Speed of DC motor shown in Figure 6 when the input Voltage =50 and Armature resistance =0.5 ohm

Torque [N.m]	Speed [rpm]
0.2	244.5
0.4	242
0.6	239.5
0.8	237.1
1.0	234.5
1.2	232

- The plot of speed of DC motor shown in the Figure 6 when the value of Armature resistance set to  $0.5 \Omega$  and the input voltage set to 100 V:

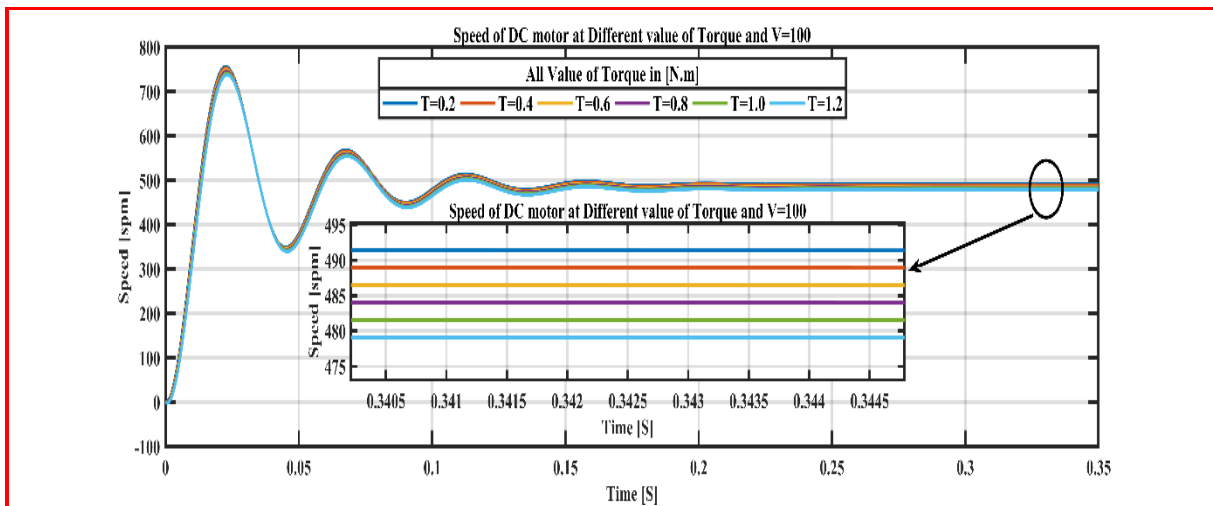


Figure 33: The plot of speed of DC motor shown in the Figure 6 when the value of Armature resistance set to  $0.5 \Omega$  and the input voltage set to 100 V

Table 7: The Values of Speed of DC motor shown in Figure 6 when the input Voltage =100 and Armature resistance =0.5 ohm

Torque [N.m]	Speed [rpm]
0.2	491.5
0.4	488.9
0.6	486.5
0.8	483.9
1.0	481.5
1.2	479

- The plot of speed of DC motor shown in the Figure 6 when the value of Armature resistance set to  $0.5 \Omega$  and the input voltage set to 150 V:

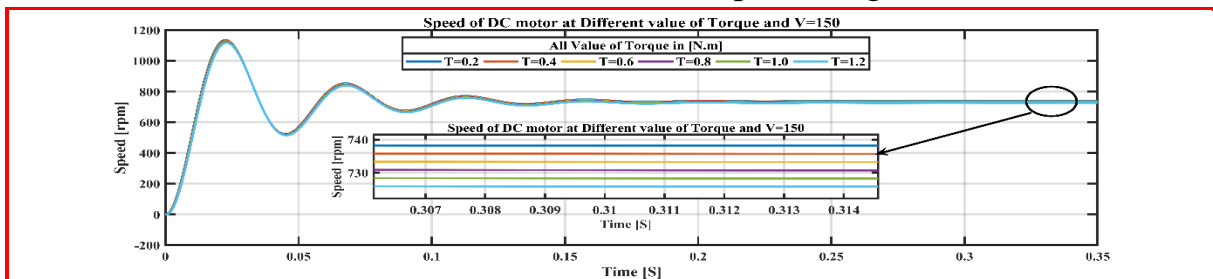


Figure 34: The plot of speed of DC motor shown in the Figure 6 when the value of Armature resistance set to  $0.5 \Omega$  and the input voltage set to 150 V

Table 8: The Values of Speed of DC motor shown in Figure 6 when the input Voltage =150 and Armature resistance =0.5 ohm

Torque [N.m]	Speed [rpm]
0.2	738.1
0.4	735.7

<b>0.6</b>	<b>733.2</b>
<b>0.8</b>	<b>730.5</b>
<b>1.0</b>	<b>728.4</b>
<b>1.2</b>	<b>726</b>

- The plot of speed of DC motor shown in the Figure 6 when the value of Armature resistance set to  $0.5 \Omega$  and the input voltage set to 180 V

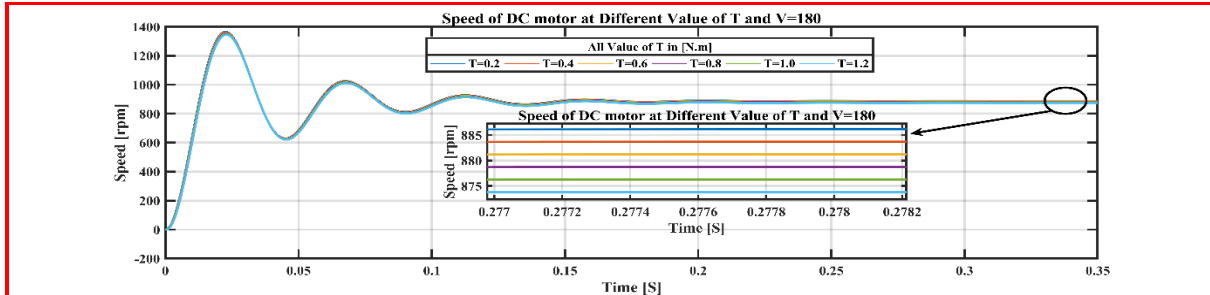


Figure 35: The plot of speed of DC motor shown in the Figure 7 when the value of Armature resistance set to  $0.5 \Omega$  and the input voltage set to 180 V:

Table 9: The Values of Speed of DC motor shown in Figure 6 when the input Voltage =180 and Armature resistance = $0.5 \text{ ohm}$

<b>Torque [N.m]</b>	<b>Speed [rpm]</b>
<b>0.2</b>	<b>886.4</b>
<b>0.4</b>	<b>883.8</b>
<b>0.6</b>	<b>881.4</b>
<b>0.8</b>	<b>878.9</b>
<b>1.0</b>	<b>876.4</b>
<b>1.2</b>	<b>874</b>

- The plot of speed of DC motor shown in the Figure 6 when the value of Armature resistance set to  $0.5 \Omega$  and the input voltage set to 220 V

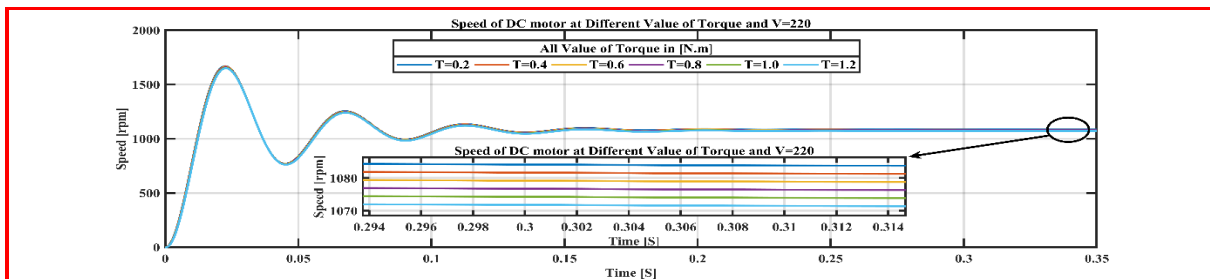


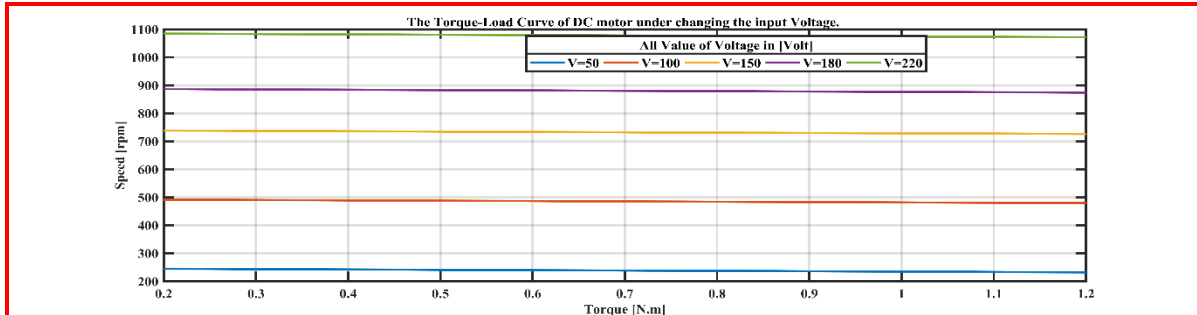
Figure 36: The plot of speed of DC motor shown in the Figure 6 when the value of Armature resistance set to  $0.5 \Omega$  and the input voltage set to 220 V

Table 10: The Values of Speed of DC motor shown in Figure 6 when the input Voltage =220 and Armature resistance = $0.5 \text{ ohm}$

<b>Torque [N.m]</b>	<b>Speed [rpm]</b>
<b>0.2</b>	<b>1084.1</b>
<b>0.4</b>	<b>1081.6</b>

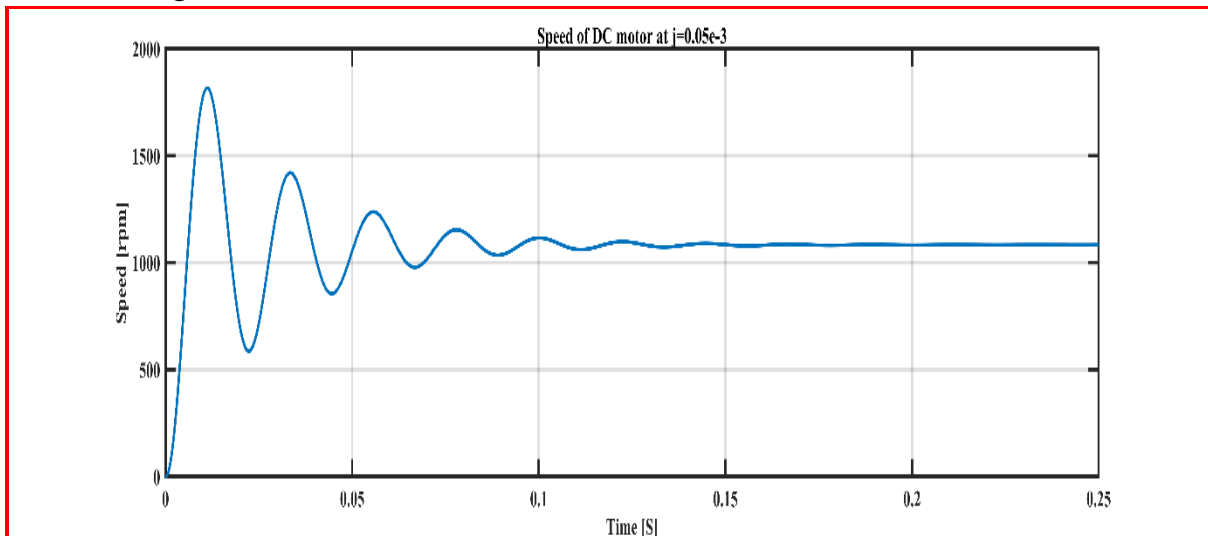
<b>0.6</b>	<b>1079</b>
<b>0.8</b>	<b>1076.5</b>
<b>1.0</b>	<b>1074.1</b>
<b>1.2</b>	<b>1071.5</b>

- The plot of Torque load Curve of DC motor shown in Figure 6 under changing the Voltage:

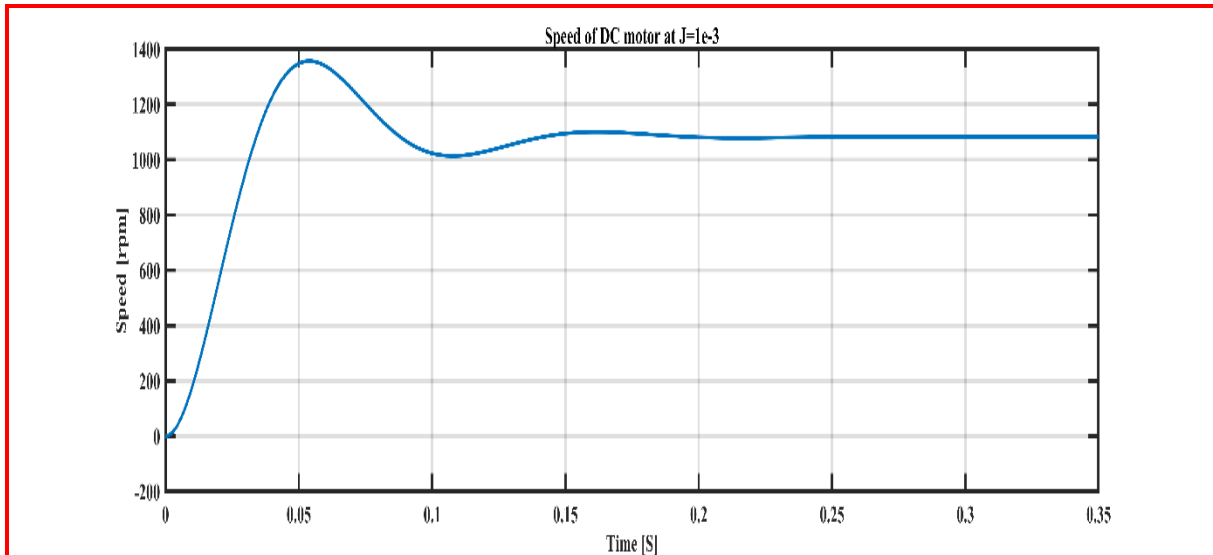


**Figure 37: The plot of Torque load Curve of DC motor shown in the Figure 6 under changing the Voltage**

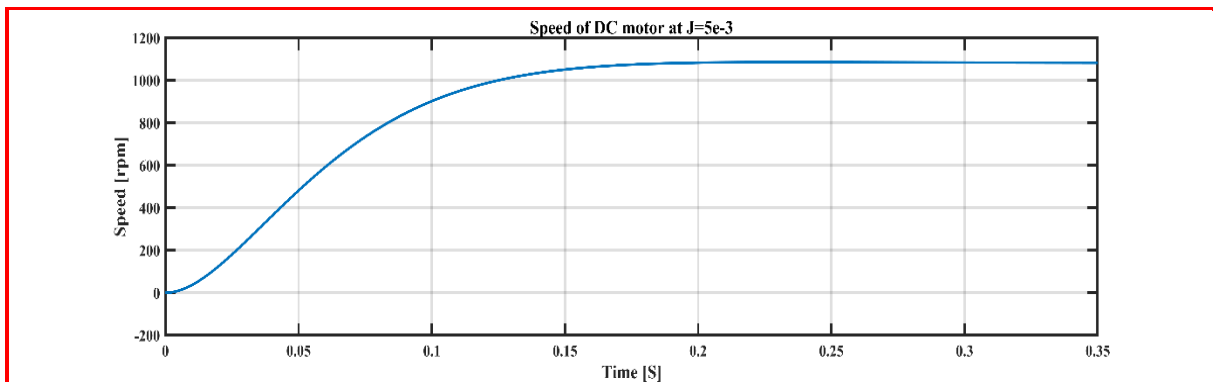
- **Step 4:** The plot of Speed of DC motor shown in the Figure 6 when the J changed.



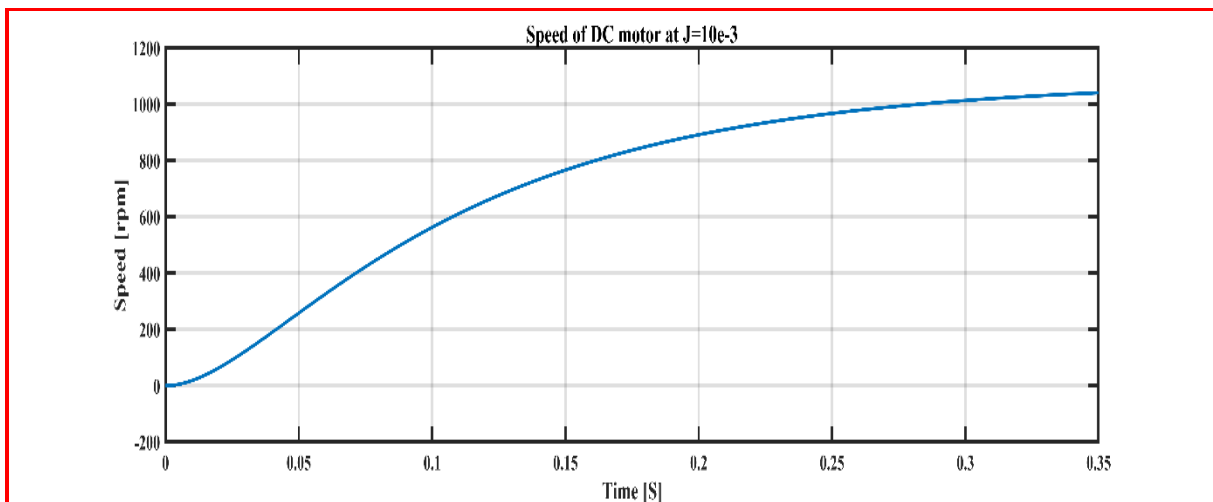
**Figure 38: The Speed of DC motor shown in the Figure 6 when  $J=0.05e-3$ .**



**Figure 39: The Speed of DC motor shown in the Figure 6 when  $J=1e-3$ .**



**Figure 40: The Speed of DC motor shown in the Figure 6 when  $J=5e-3$ .**



**Figure 41: The Speed of DC motor shown in the Figure 6 when  $J=10e-3$ .**

- Extracting of DC motor shown in the Figure 6:

$$G(s) = \frac{100000}{s^2 + 55s + 2025} \dots (10)$$

### 6.3: Filter Design used SPTOOL:

- **Part 1:** The Discrete time Signal show in the Figure in generated to Sptool:

Sum of discrete time signal shown in the Figure 43 without noise:

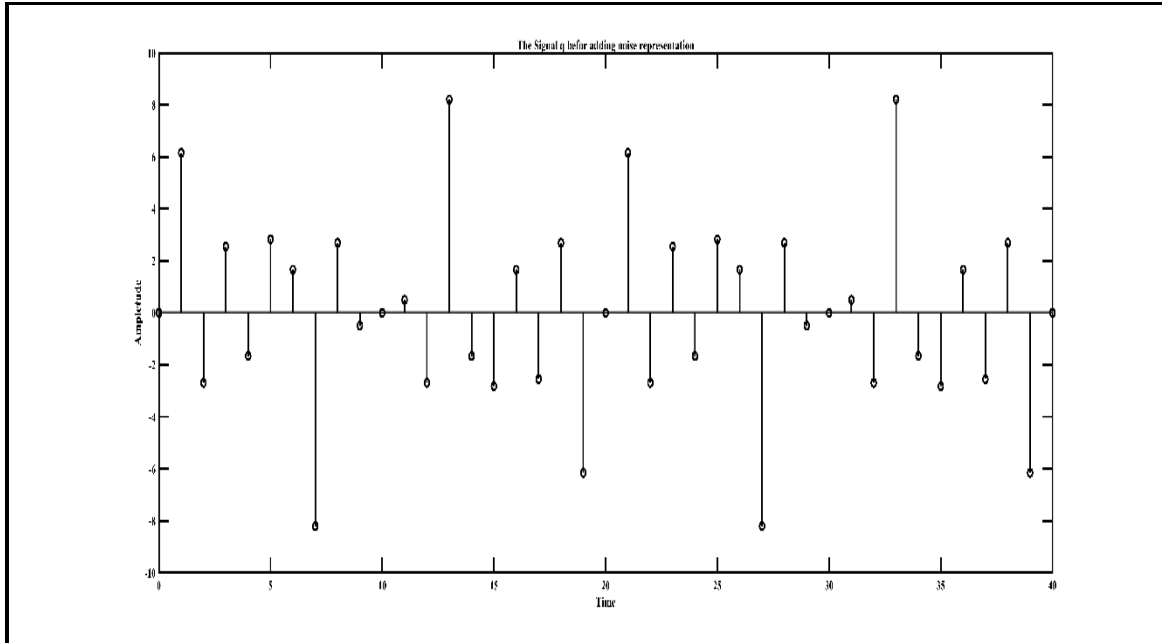


Figure 42: sum of discrete time signal of Sptool in Figure 43 without noise

Sum of discrete time signal shown in Figure 43 with noise:

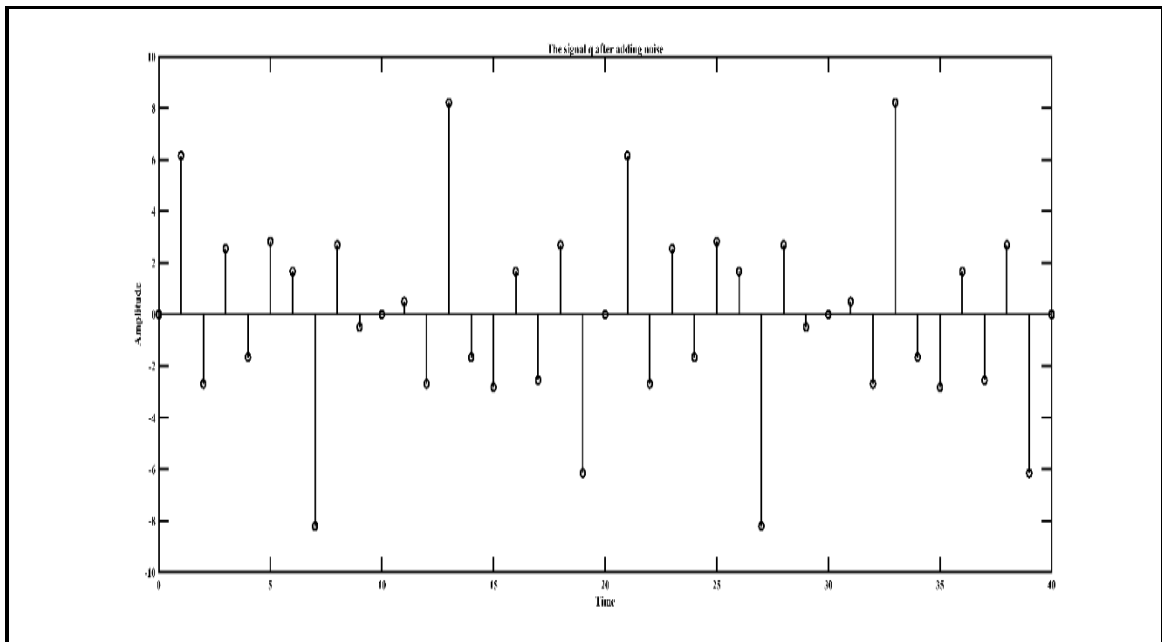
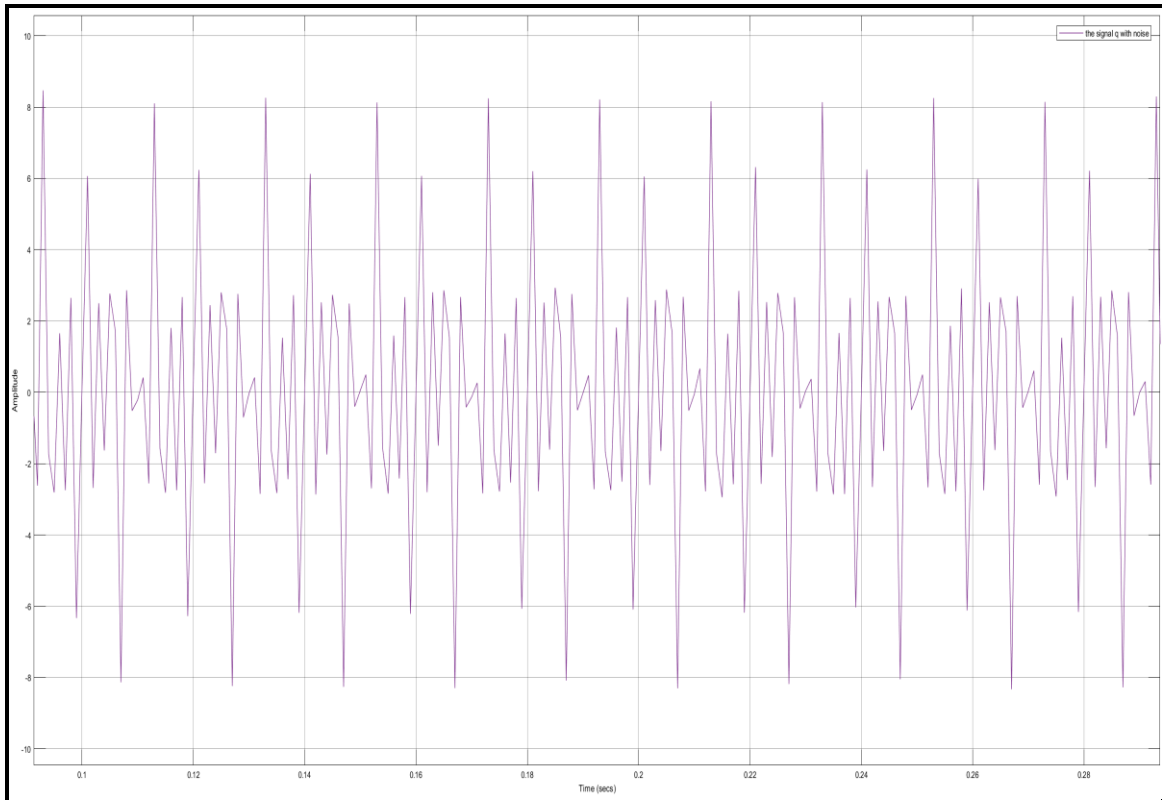
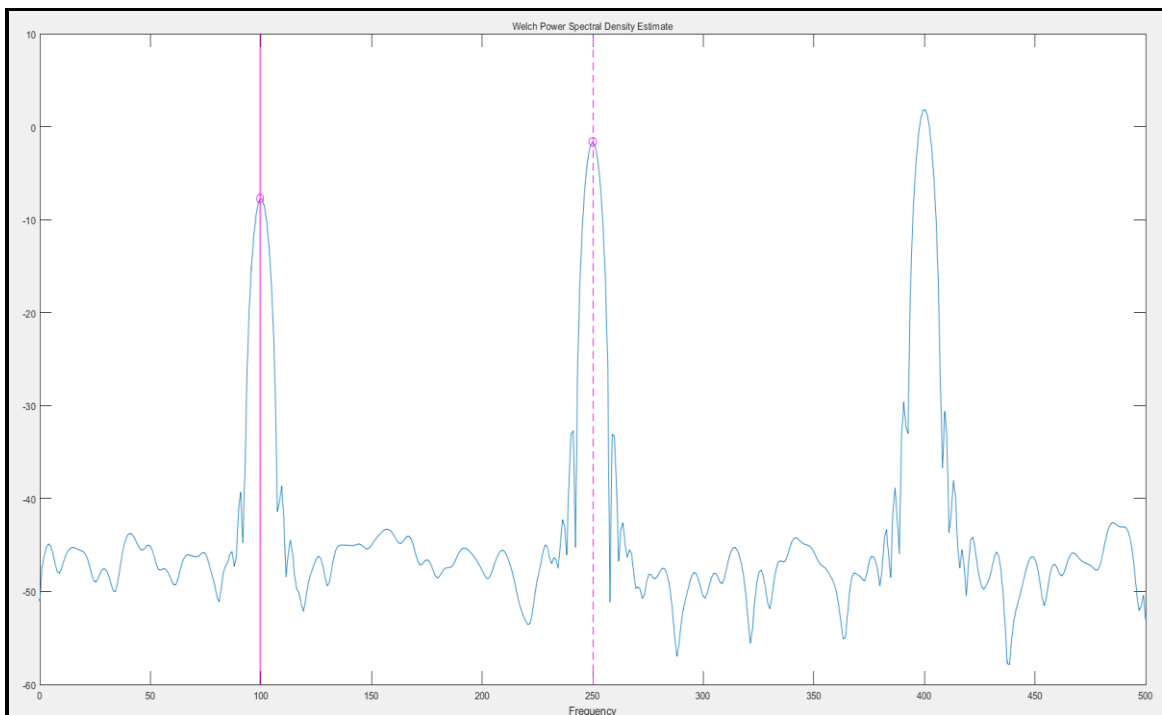


Figure 43: Sum of discrete time signal of Sptool shown in Figure 43 with noise

**Part 2:** The time domain and frequency domain representation of the signal shown in the Figure 45, shown in Figure 46 and 47 respectively:



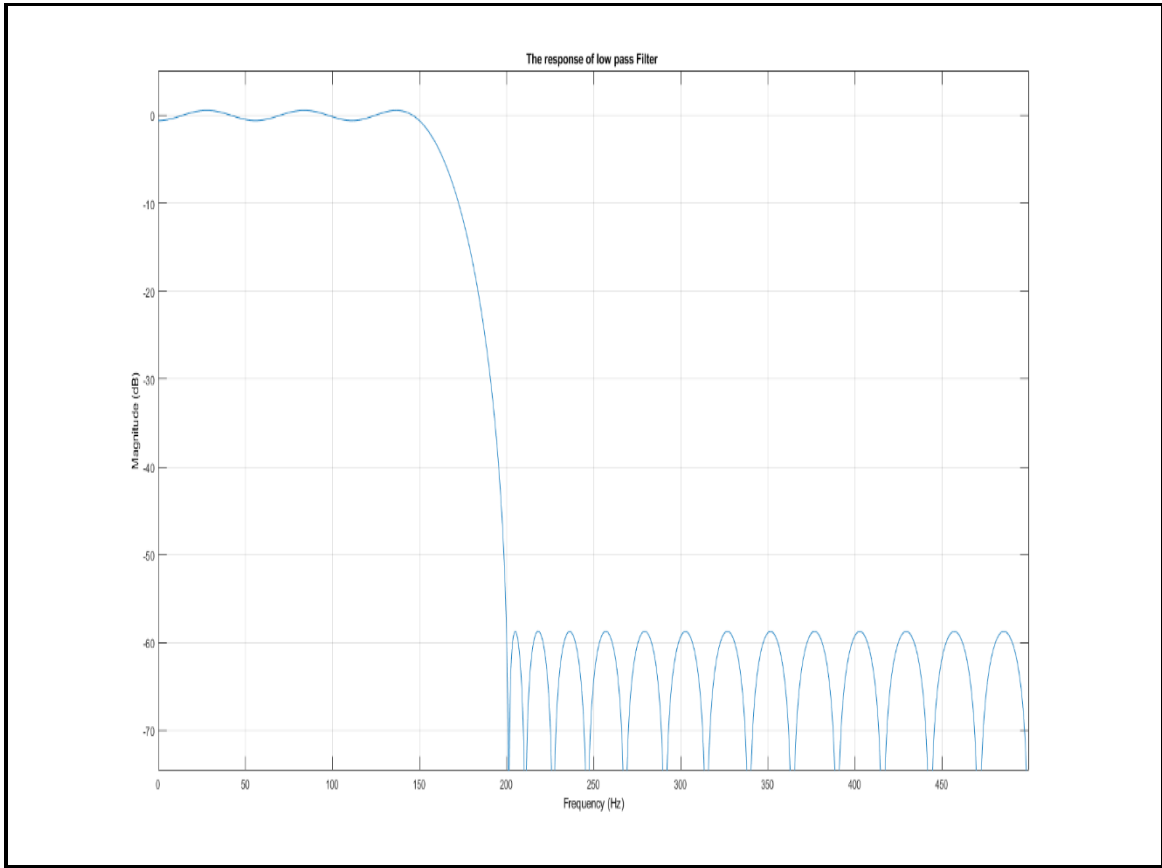
**Figure 44:** The Time Domain Representation of discrete Signal shown in the Figure



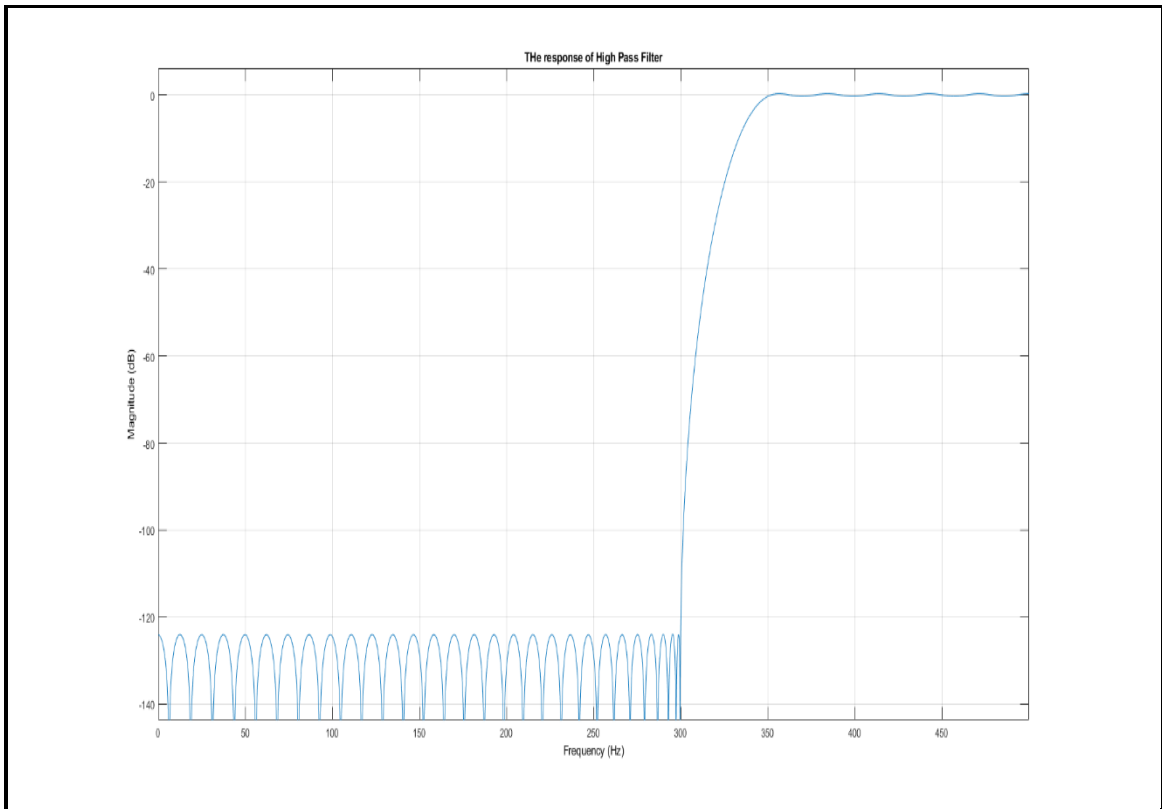
**Figure 45:** The Frequency Domain representation of The discrete time Signal shown in the Figure 45

**Part 3:** The response of the Filters low, high and Band Pass respectively:

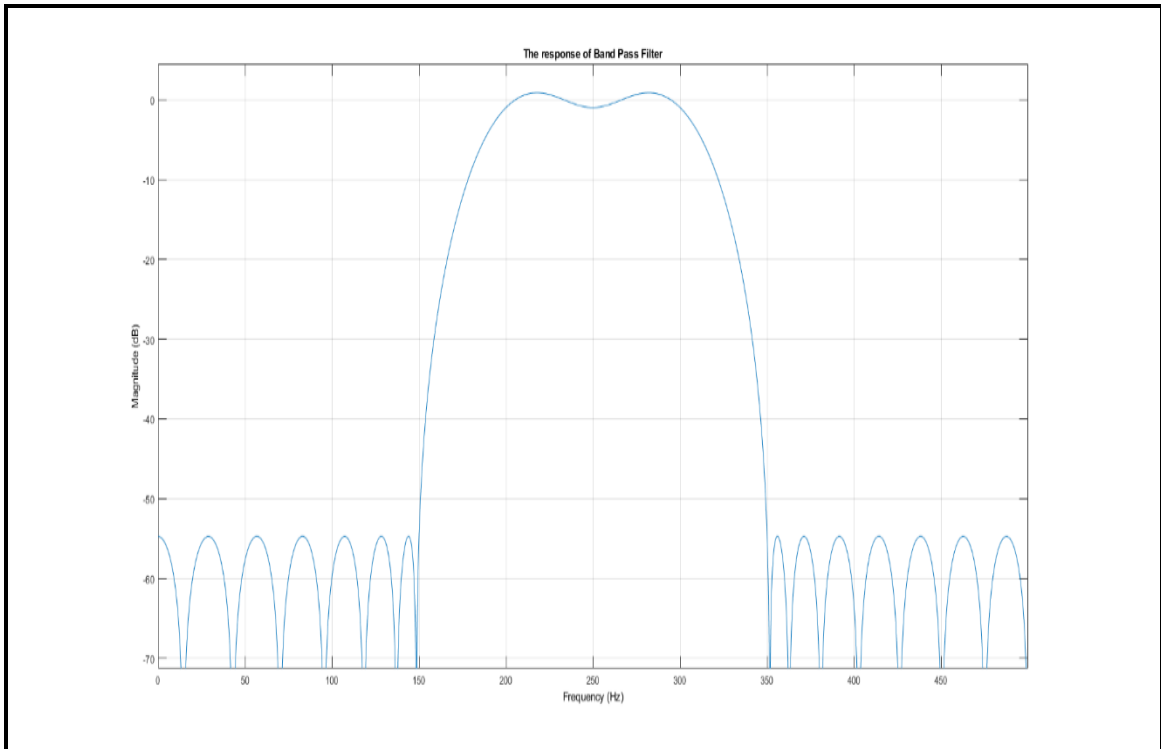




**Figure 46: Response of Low Pass Filter**

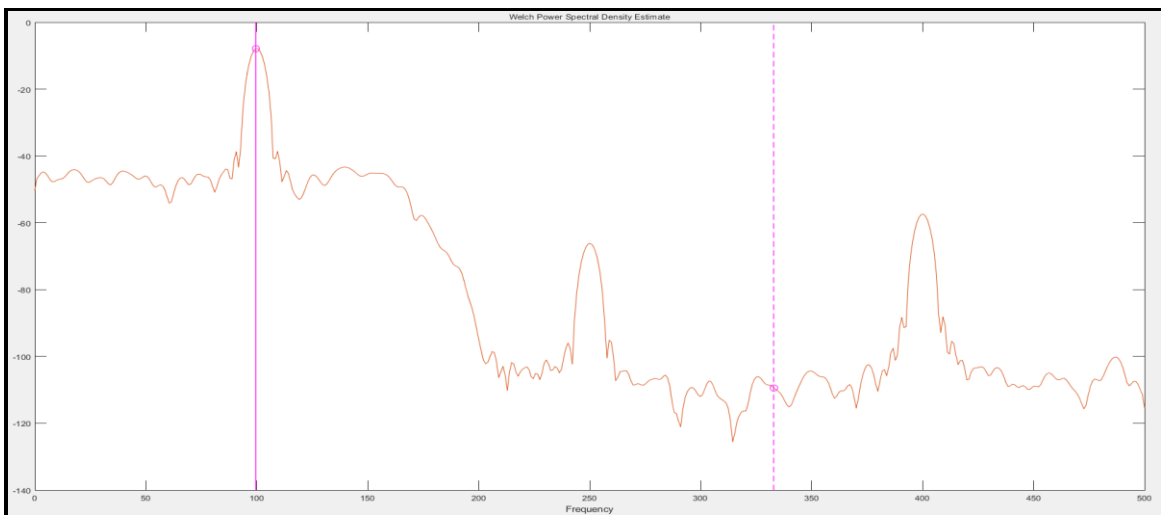


**Figure 47: Response of High Pass Filter**

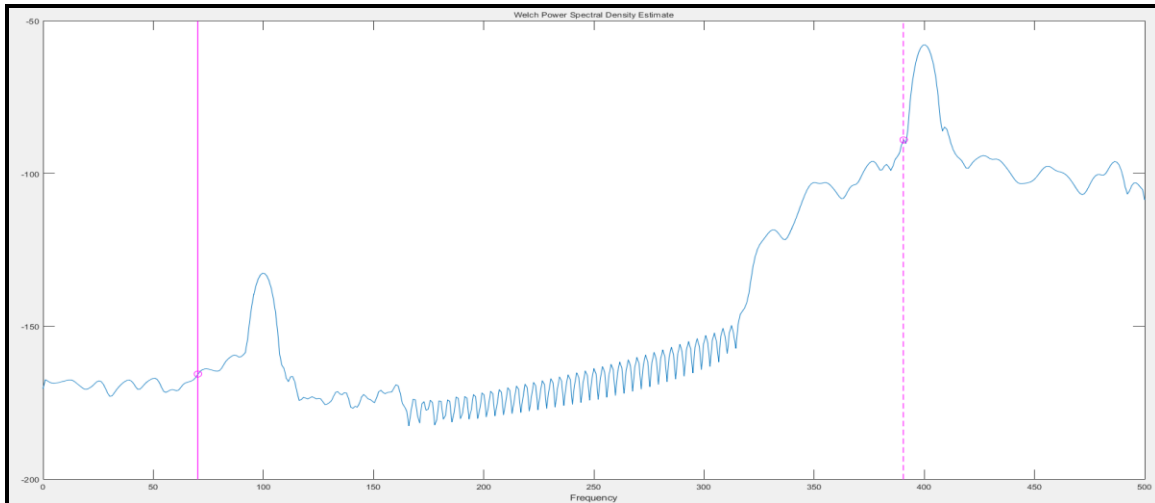


**Figure 48: Response of Band Pass Filter**

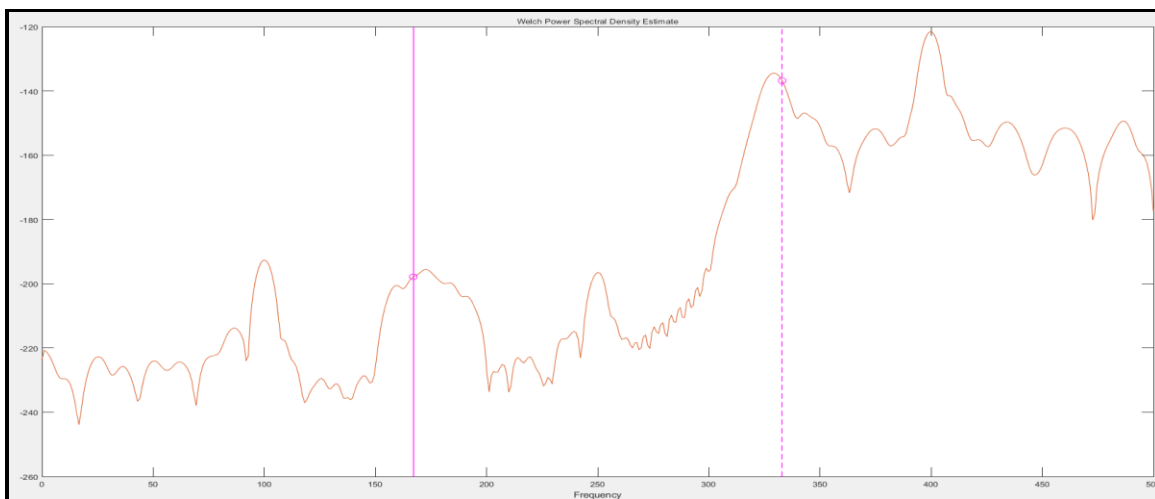
The Spectrum representation of the Signal shown in the Figure 45 after apply to the Filters:



**Figure 49: The Response of The Signal shown in the Figure 45 after Apply to low pass Filter**



**Figure 50: The Response of The Signal shown in the Figure 45 after Apply to high pass Filter**



**Figure 51: The Response of The Signal shown in the Figure 45 after Apply to Band pass Filter**

## 7. Discussion of the Results:

### 7.1: Linear system:

Firstly, the ohms  $V=I \cdot R$  applied to the Circuit shown in the Figure 1, since the circuit contain five meshes the number of equations need to solve the current also five, after that the transfer function and the step response of the system shown in the Figure 2 found, from the Figure 11 which is the step response of the system shown in the Figure 2 notice that the system is stable without over shoot, another things in this part the frequency response of the 2<sup>nd</sup> order Circuit shown in the Figure 4 and the transfer function  $G(s)$  in part 3 in procedure part found, from the Bode diagram of these system notice that the systems are stable, for the 2<sup>nd</sup> order Circuit shown in the Figure 4 the Current response of inductor shown in the figure 16 and Voltage response of capacitor shown in Figure 17 found, from these results notice that the current and voltage initially high, after

short time the response reach to steady state so, in this region the inductor can be modelled as short Circuit and the capacitor can modelled as open circuit.

### **7.2: Model of DC motor in MATLAB Simulink:**

In this section, the model of Armature Controller DC motor implemented at Simulink, Firstly, the Speed of DC motor found from the Figure 19 notice that the DC motor is stable with small over shoot, after that the speed of DC motor at different value of torque found, from the Figure 20 notice that when the maximum speed achieve when the Torque is little as possible another note about it when the Torque is increase the Current in DC motor increase it is shown in Figure 21.

Secondly, the Armature resistance of the DC motor Varied with torque and the Speed of DC motor found at each value of resistance, the torque speed Curve of these cases shown in the Figure 31, from it notice that the when the Armature resistance of DC motor increases the speed is Decreases.

Thirdly, the input voltage in DC motor varied with torque and the Speed of DC motor found at each value of input voltage, the torque Speed Curve of these cases shown in Figure 37, from it notice that the speed of DC motor increases when the input voltage increases.

Finally, the inertia of rotor of DC motor varied and the Speed of DC motor found from the Figure 38 when the inertia is little the percentage over shoot in the response is high, and from the Figure 41 when the inertia is high the percentage over shoot is small.

### **7.3: Filter Design used SPTOOL:**

In this section, the three discrete time sin signal generated there are shown in the Figure 8 and the summation of these signal shown in the Figure 9, the equivalent signal take in two cases with noise shown in the Figure 9 and without noise shown in the Figure 42, after that, firstly, the time and frequency domain representation of the signal shown in Figure 44 found by SPTOOL, from the Figure 45, which is the frequency domain representation of the signal with noise notice that there are three signal which it the component of signal shown in Figure 9.

Secondly, the low, high and band pass filters designed and the response of each shown in the Figures 46, 47 and 48, from the Figure 46 which is the response of low pass Filter notice that the gain of the filter at low frequency is high and at high frequency is low so the small frequencies can pass from this filter however,

from the Figure 47 which is the response of high pass filter notice that the gain of the Filter at low frequencies is low and at high frequency is high so the high frequencies can pass from this type of filters, and from the Figure 48 which is the response of band pass Filter the gain is low at low and very high frequency but at mid frequencies the gain is high so, the mid frequency can pass from this type of Filter.

Finally, the signal shown in the Figure 43 applied at each type of filters the response of the signal shown in the Figures 49 and 50 from the Figure 49 which is the response of the signal after applied to low pass filter the component at low frequency just pass and another component rejected, from the Figure 50 which is the response of signal after applied to high pass filter notice that the component at high frequency pass just and another frequencies rejected and from the Figure 51 which is the response of signal after applied to band pass filter notice that the mid frequency component pass and another component rejected.

## **8. Conclusion:**

At the first time of these experiments, the MATLAB commands used to solve and analysis the linear system these commands are benefits in Electrical Engineering since there are saved the time and the effort of the students and researchers.

Another part of these experiments, the Simulink used to simulate and run the model of DC motor at different mode, the Simulink allow to the researcher to development the system at short time without cost, it the aim is archive so the system can be implemented at ground.

Finally, the SPTOOL used to design the filters; this tool is easily for used so the filter designer save the cost, time and effort.

In general, the MATLAB program is very useful for Electrical engineering specially and another sciences generally.

## 8. Appendix:

### Appendix A.1:

#### **CODE 1: The Code used to solve the meshes currents:**

---

```
a=[4;6;6;0;6];
b=[9 -2 -2 0 0;-2 10 -4 -1 -1;-2 -4 9 0 0;0 -1 0 8 -3;0 -1 0 -3 4];
c=inv(b);
i=c*a;
```

---

#### **CODE 2: the Code used to describe the control system and plot the step response**

```
K=10;
a=tf([1 0],[1]);
b=tf([0 1],[1 1]);
c=a*b
x=feedback(10,c)
d=tf([0 1],[1 1])
e=0.1;
f=e*d;
v=feedback(x,f)
r=tf([0 1],[1 1])
j=r*v
step(j)
```

---

#### **CODE 3: The Code used to plot the frequency response of F(s) by Standard plotting and complex number capabilities**

```
num= conv([100000 700000],[1 13]);
d1= conv([1 7 45],[1 7 75]);
d2= conv([1 25 0],[0 1 55]);
den= conv(d1,d2);
F=tf(num,den)
w=logspace(-1,2,101)
Gain=freqs(num,den,w);
mag=abs(Gain)
db=20*log10(mag)
ph=angle(Gain)*180/pi
semilogx(w,db),grid
figure;
semilogx(w,ph),grid
```

---

#### **CODE 4: The Code used to plot the Bode Plot of F(s):**

```
num= conv([100000 700000],[1 13]);
d1= conv([1 7 45],[1 7 75]);
d2= conv([1 25 0],[0 1 55]);
den= conv(d1,d2);
F=tf(num,den)
bode(F);
```

---

#### **CODE 4: The Code used to define the transfer function in MATLAB:**

```
num= conv([100000 700000],[1 13]);
d1= conv([1 7 45],[1 7 75]);
d2= conv([1 25 0],[0 1 55]);
den= conv(d1,d2);
```

---

```
F=tf(num,den)
```

---

**CODE 6: The Code used to plot the function y(t)**

```
t= -3:0.001:5;
a=(t.^2).* (heaviside(t+1)-heaviside(t));
b=(t-1).* (heaviside(t)-heaviside(t-1));
c=(-1).* (heaviside(t-1)-heaviside(t-2))
d=a+b+c;
plot(t,d);
```

---

**CODE 7: The Code used to found the pole, zero and Bode plot of a(s) “Figure 3”:**

```
a=tf([-15625 0],[1 10000 125e6])
b=pole(a)
c=zero(a)
bode(a)
```

---

**CODE 8: The Code used to solve the Circuit shown in the Figure 4**

```
l=5;c=21.83e-3
r=4; s=tf('s');
n=tf([1/(l*c)], [1 r/l 1/(l*c)])
b=pole(n)
v=100*n;
i=c*s*v;
step(i)
figure;
step(v)
```

---

**CODE 9: The Code used to solve the circuit shown in the Figure 4:**

```
h=tf([2500],[1 20 2500]);
bode(h)
wn=sqrt(2500)
zeta=10/wn
```

---



## Appendix A.2:

---

**CODE 10: The Code used to extracted DC motor shown in the Figure 7 to MATLAB:**

```
[A,B,C,D]=linmod('motormodel')  
[num,den]=ss2tf(A,B,C,D)
```

## Appendix A.3:

---

### CODE 11: The Code used to generate the discrete time signal.

```
clear all
clc
n=0:1:1023;
fs=1000;
q1=sqrt(2)*sin(2*pi*100*n/fs);
q2=2*sqrt(2)*sin(2*pi*250*n/fs);
q3=3*sqrt(2)*sin(2*pi*400*n/fs);
figure;
subplot(3,1,1)
stem(n,q1);
axis([0 40 -10 10]);
xlabel('Time')
ylabel('Amplitude');
title('The Signal q1 representation')
subplot(3,1,2)
stem(n,q2)
axis([0 40 -10 10]);
xlabel('Time')
ylabel('Amplitude');
title('The Signal q2 representation')
subplot(3,1,3)
stem(n,q3)
axis([0 40 -10 10]);
xlabel('Time')
ylabel('Amplitude');
title('The Signal q3 representation')
figure;
q=q1+q2+q3;
stem(n,q)
axis([0 40 -10 10]);
xlabel('Time')
ylabel('Amplitude');
title('The Signal q befor adding noise representation')
y=awgn(q,20);
figure;
stem(n,q)
axis([0 40 -10 10]);
xlabel('Time')
ylabel('Amplitude')
title('The signal q after adding noise')
```

---

## 9. References:

[1]: Gilat, Amos (2004). *MATLAB: An Introduction with Applications 2nd Edition*. John Wiley & Sons March 25, 2019 12.47 AM

[2]: [https://www.mathworks.com/products/simulink/requirements.html?s\\_cid=wiki\\_simulink\\_1](https://www.mathworks.com/products/simulink/requirements.html?s_cid=wiki_simulink_1)  
March 25, 2019 12.47 AM.

[3]: Simulation LAB manual March 6, 2019 11.29 PM. 2019 2<sup>nd</sup> Semester Version .