iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** III **Month of publication:** March 2024

DOI: https://doi.org/10.22214/ijraset.2024.59678

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue III Mar 2024- Available at www.ijraset.com

Comparison of Different MATLAB Environments for Designing DC Motor Main Dimensions

Ms. Niharika Gupta, Mr. Sagar Manjrekar
Department of Electrical Engineering, Prestige Institute of Engineering Management & Research, Indore, India

Abstract: ***DC motor is an important device for various industries due to its variable speed control, efficiency, reliability and versatility. The Design calculations of DC Motor are long and tedious process if done manually. A program can be made in any programming language, but again the program length is large, and it is difficult to understand and summarize the design steps in short. In this paper an effort has been made to understand the Design Procedure of a DC Motor using different MATLAB environments. Design of main dimensions of DC Motor was done in three MATLAB environments. First by writing program in editor file, second using Simulink block sets and lastly by forming MATLAB GUI interface. Comparison between each method is discussed in short.***

Keywords: DC Motor, Electrical Machine Design, MATLAB GUI, MATLAB Simulink

I. INTRODUCTION

DC Motor is an important device used in Industries today. DC motors are very versatile, controllable, and reliable, making them useful in a wide range of industries. [1].

The design of DC Motor is a huge business in the electrical power industry. Basically, the aim of designing a DC Motor is to obtain the dimensions of all parts of the DC Motor in order to supply these data to the manufacturer. But, the complexity of designing DC Motor demands reliable and rigorous solution methods. DC Motor design is a complex task in which engineers have to ensure that the imposed specifications are met, at the same time keeping manufacturing cost at lower side [2][3]. It is difficult to meet accurately today's DC Motor electrical parameters via conventional design techniques .

Computer-aided design (CAD) of DC Motor is a method by which they are designed with the use of programming software packages among which are C++, Java, and MATLAB etc.[4]The other method of designing DC Motor is the manual method, which offers a more laborious process due to its long mathematical calculations which are error-prone, time-consuming and less effective when compared to the CAD method. MATLAB program for DC Motor design is also very long, and it becomes difficult to understand the flow of design processes by going through the longer coding. [5-7]

In this paper, DC Motor main dimensions design is realized in three different MATLAB environments. To overcome the difficulty in understanding the longer programs and for analyzing the step by step design DC Motor procedure, a MATLAB GUI model and MATLAB Simulink Model are formed [9-10].

II. DC MOTOR DESIGN STEPS

A DC Motor goes through a number of optimizations in the design process to guarantee that it will function as intended and run smoothly. Motor Torque-speed characteristics, efficiency, power rating, size constraints, and performance requirements etc., are to be considered first for starting the design process. Stator of DC motor provides the stationary magnetic field necessary for the motor's operation. Usually, laminated steel sheets are stacked to create a cylindrical or rectangular shape for the stator core. These laminations increase the motor's efficiency by lowering eddy current losses. In addition to offering mechanical support, the core directs magnetic flux. Often, the core is sliced with slots to make room for the field winding. The field winding is wound around the slots in the stator core. It consists of coils of insulated wire, usually made of copper. When a current flows through the field winding, it generates a magnetic field perpendicular to the rotor's rotation axis. The direction of this magnetic field determines the direction of rotation of the motor.[8]

The rotor of a DC motor is responsible for converting Electrical energy into Mechanical energy. The shaft offers mechanical support and acts as the rotor's main axis of rotation. Like the stator core, the rotor core is frequently composed of laminated steel sheets. These laminations increase efficiency and decrease eddy current losses. In order to fit the armature winding, the rotor core, which is mounted on the shaft, contains slots. Armature winding consists of coils of insulated copper wire. When a current is passed through the armature winding, it generates a magnetic field that interacts with the magnetic field produced by the stator, resulting in the rotation of the rotor.

©IJRASET: All Rights are Reserved

The Commutator, a cylinder-shaped arrangement of copper segments that are isolated from one another, is located at one end of the rotor. These segments are connected to the armature winding. The Commutator segments come into touch with brushes, and transmit power from the stationary terminals to the rotating armature winding.

DC motor design is divided in following points:

1) Main dimensions Design

First armature developed power is calculated from the given rated power and efficiency requirement.

$$P_a = \frac{1+2\eta}{3\eta} \quad (1)$$

Calculate value of output coefficient from the selected value of specific loadings.

$$C_o = \frac{\pi^2 B_{av} ac}{1000} \quad (2)$$

Calculate the product D^2L using the below relation

$$D^2L = \frac{P_a}{nC_O} \quad (3)$$

For a square pole face

$$L = \psi\tau = \psi\pi\frac{D}{p} \quad (4)$$

Putting the value of L in equation 3 and solving we can get value of Armature diameter D and Length L. From the Calculated values of D and L rotor peripheral speed, frequency of flux reversal and pole pitch values are checked for within the permissible values.

2) Armature winding Design

Line current is calculated by using the formula

$$I_l = \frac{P \times 1000}{\eta \times V_t} \quad (5)$$

Taking field current as a percentage of line current armature current is calculated as

$$I_a = I_l - I_f \quad (6)$$

No. of Armature conductors are given as

$$Z = \frac{E \times a}{p\phi n} \quad (7)$$

Suitable number of slots is then selected and no. of armature conductors per slot, slot dimensions is calculated.

3) Field Winding DESIGN

By assuming the leakage coefficient of main poles flux in the pole body its area, axial length and width of pole body is calculated.

Axial length of pole $L_p = L$

Width of pole

$$b_p = A_p / L_{pi} \quad (8)$$

Height of Field winding is calculated as

$$h_f = \frac{AT_{fl}}{10^4 \times \sqrt{q_f S_f d_f}} \quad (9)$$

Depth of Yoke

$$d_y = A_y / L_{pi} \quad (10)$$

Outer diameter of Yoke

$$D_y = D + 2\left(l_g + h_{pl} + d_y\right) \quad (11)$$

Area of Field conductor

$$a_f = \frac{AT_{fl}\rho L_{mt}}{V} \quad (12)$$

4) *Design of Commutator*

Area of each brush is determined as.

$$a_b = \frac{I_b}{\delta_b} \quad (13)$$

Width of each brush

$$W_b = a_b / t_b \quad (14)$$

Overall length of Commutator, brush losses and Temperature rise of Commutator are calculated.

5) *Design of Interpoles*

Width of commutation zone is given as

$$w_c = \left\{\left[\frac{u}{2} - \frac{\alpha}{p}\right]\beta_c + \left(t_b - t_i\right)\right\}\frac{D}{D_c} \quad (15)$$

Specific slot permeance

$$\lambda_s = \mu_o\left[\frac{h_1}{3W_s} + \frac{h_2}{W_s} + \frac{2h_3}{W_s + W_o} + \frac{h_4}{W_o}\right] \quad (16)$$

Maximum Flux Density under the interpole

$$B_{gim} = E_{rm} / LV_a \quad (17)$$

6) *Losses and Efficiency*

Total losses in DC Motor are divided in three parts.

a. Friction and Windage Loss
b. Iron Losses
c. Copper Losses

Friction and Windage losses include Brush Friction Losses, Bearing friction and windage losses. Friction losses in bearings and windage losses depend upon the peripheral speed of the machine. Iron loss depends upon specific iron loss in core and weight of armature core. For calculating copper loss first length of mean turn of armature is determined

$$L_{mta} = 2L + 2.5\tau + 5d_s \quad (18)$$

Armature copper loss

$$I_{cua} = I_a^2 R_a \quad (19)$$

Efficiency of DC Motor

$$\eta = \frac{Input}{Input + TotalLosses} \times 100$$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue III Mar 2024- Available at www.ijraset.com

III. MATLAB PROGRAM

To start the design process first of all code is formed to input required specifications of DC motor.

```
P=input('Enter the Power of the DC Motor (KW) :'); n=input('Enter the Speed of the DC Motor (rpm) :');
eta=input('Enter the Efficiency of the DC Motor :'); Bav=input('Enter the value of Magnetic Loading (Wb/m^2) :');
ac=input('Enter the value of Electric Loading :');
Ki=input('Enter the value of Stacking Factor :');
p=input('Enter the no. of Poles');
shi=input('Enter the ratio Pole Arc to Pole Pitch (0.64 to 0.72):');
```

Rotor dimension are than calculated by writing code using input variables.

```
Pa=((1+(2*eta))/(3*eta))*P;
Co=(pi*pi*Bav*ac)/1000;
product=(Pa*60)/(Co*n);
Val1=(product*p)/(shi*pi);
D=Val1^(1/3);
disp([' Calculated Diameter of Armature is : ', num2str(D),'m']);
D=input('Enter the Standardrized Diameter (m) :');
L=product/(D*D);
disp([' Calculated Length of Armature is : ', num2str(L),'m']);
```

Design calculations for other parts can be realized similarly by writing the MATLAB Program. But the program is very long and difficult to understand the design flow.

IV. MATLAB SIMULINK MODEL

Another method to design DC Motor is by forming the MATLAB Simulink Model using basic block sets available in Simulink Library. Simulink model are shown in Figure-1 and Figure-2.

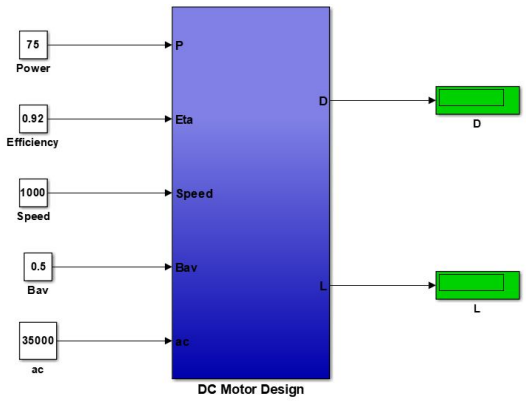


Figure – 1

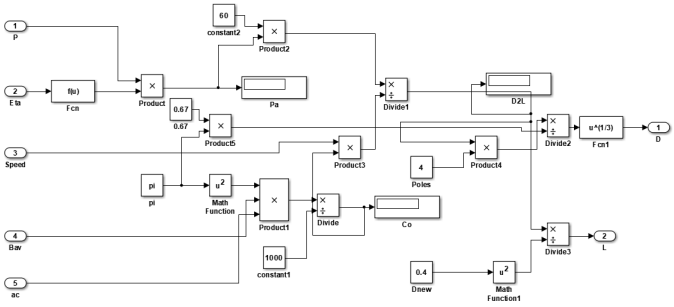


Figure – 2

From the basic relations between motor parameters motor diameter and length are calculated using block sets in MATLAB Simulink. Input variables are on the left hand side and the obtained output quantities are on the right hand side.

©IJRASET: All Rights are Reserved

From Figure-1 input and output variables are easily accessible in one window. The advantage of above method as compared to earlier one is that in one window we can change the input specifications an can obtain the results in same window. While in program for changing one variable also we have search the variable listing in longer program.
The disadvantage of this method is that for the complete design the Simulink model will become difficult to make, lot of subsystems are to be formed because lot of interconnections will be there between the various design parameters.

V. MATLAB GUI MODEL

Another method to design DC Motor parameters is forming a simple GUI Model in MATLAB. GUI model is realized by using static, edit text boxes and Push button. GUI model is shown in Figure-3.

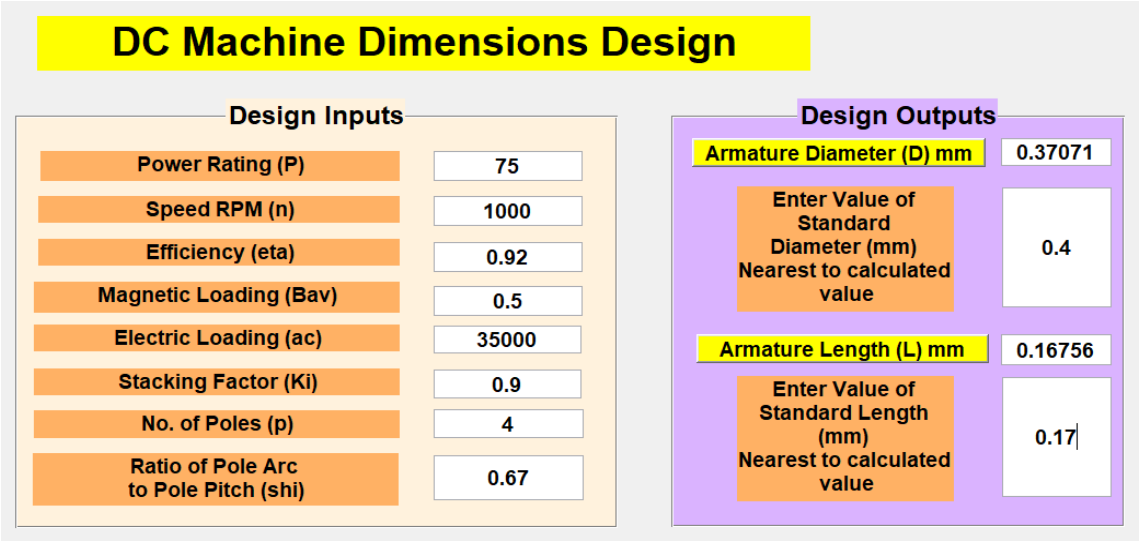


Figure – 3

For realizing the GUI Model each edit text box have given suitable tag name. When push button is pressed same tag name is used in the back end program to calculate the output variable and display the result in the edit text box.
One of the advantages of GUI Model is same as that of Simulink model that whole design is available to study in one window. Unlike the Simulink model there are no complex connections in between the block sets for the complete design. Disadvantage of GUI model is that the Program length is large in GUI model, but it is less than the first method of MATLAB Programming. Changing the program parameters are easier by just right clicking the respective edit text box.

VI. DESIGN DATA INPUTS

Design Data Inputs: Some of the initial design data inputs to be entered by designer is given in Table-1. [1]

Table-1

Motor Power Rating (KW)
Rated speed (rpm)
Motor efficency
Magnetic Loading (Wb/m^2)
Electric Loading
Stacking Factor
No. of Poles
Terminal Voltage (V)
Current density in Armature winding (A/m^2)
Gap contraction factor

VII. RESULTS

All the three methods works well for desining a DC Motor. The design calculation for one set of input data has been examined and presented here. However, the design has been very well verified for different DC Motor ratings and categories. Table-2 shows the input data for the one set of designed DC Motor.

Table-2

Motor Power Rating	75 KW
Rated speed	1000 rpm
Motor efficency	0.92
Average flux density in air Gap	0.5 Wb/m^2
Electric Loading	35000
No. of Poles	4
Terminal Voltage	240
Current density in Armature winding	6 A/m^2
Gap contraction factor	1.15

Table-3 shows the output of the designed core.

Table-3

Power developed by Armature	77.1739 W
Output Coefficent	172.7181
Calculated Diameter of Armature	0.37071 m
Calculated Length of Armature	0.16756 m

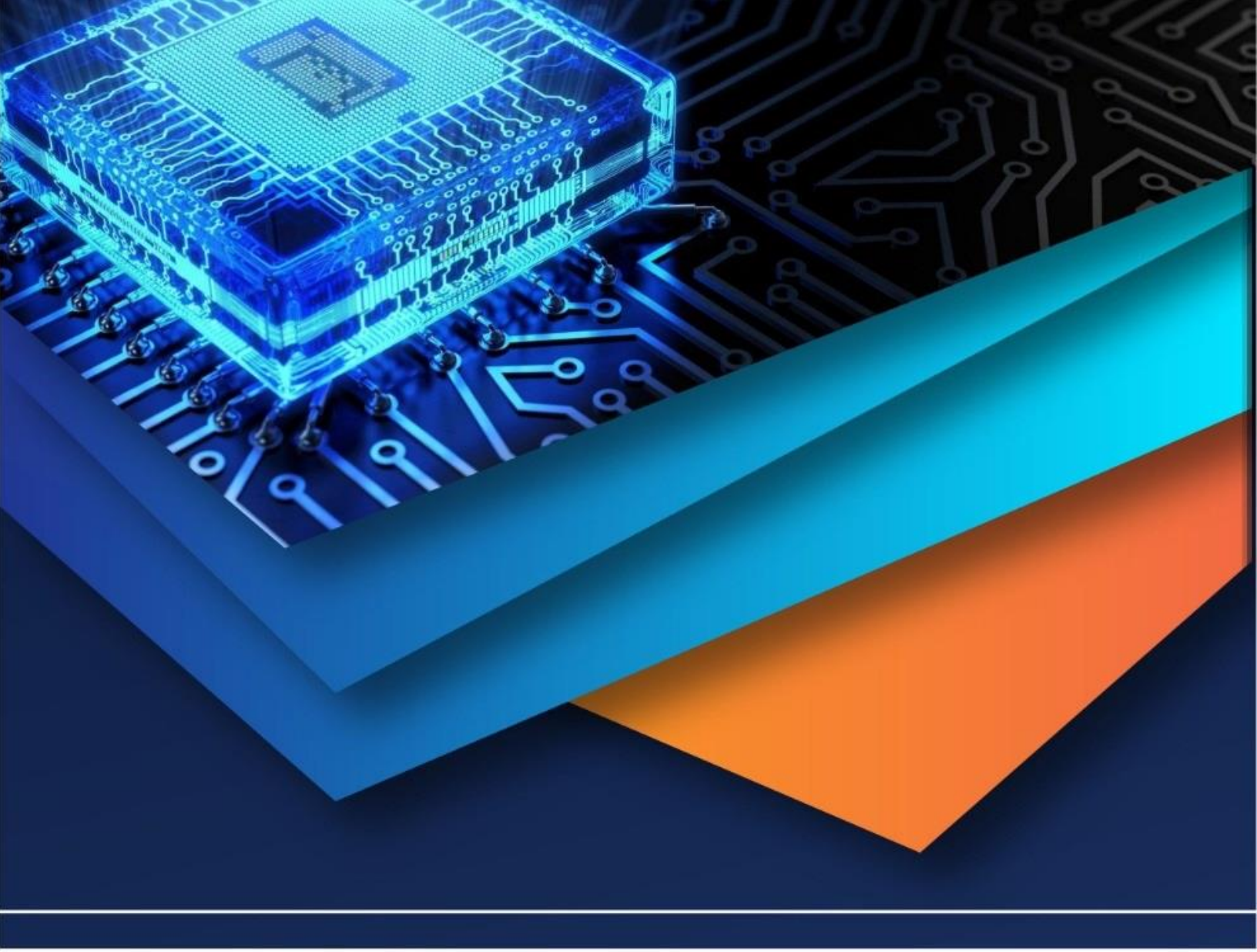
VIII.CONCLUSION

To analyze the DC Motor design three different environments are used in MATLAB software. Model was developed with the friendly GUI interface to take the input which is processed by the program coded giving the design parameters and efficiency as the output. As compared to computer program in any language such as C, C++ or MATLAB, understanding design flow is much easier in GUI interface.

This system can be used for preliminary design of DC Motor for manufacturing. The GUI model or program couldn't be used for the manufacturing process as the specification and parameters are within limited range up to certain rating of DC Motor. The program can be improvised to accommodate the need and the demand also. The major purpose of the paper is to make it as an educational tool for understanding the t DC Motor design process.

REFERENCES

[1] AK Sawhney and A Chakrabarti. Course in electrical machine design. Dhanpat Rai, 2010.
[2] Balogh Tibor, Viliam Fedák, František Ďurovský. Modeling and Simulation of the BLDC Motor in MATLAB GUI. IEEE, 2011.
[3] Jethwani, A., Aseri, D., Singh, T. S., & Jain, A. K. (2016). A simpler approach to the modelling of Permanent Magnet Brushless DC machine in MATLAB environment. 2016 IEEE 6th International Conference on Power Systems (ICPS).
[4] F. Liu, X. ming, D. Lei and X. He, "Design of DC motor operation monitoring system based on Matlab GUI," 2021 IEEE 5th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), Chongqing, China, 2021, pp. 1211-1215, doi: 10.1109/IAEAC50856.2021.9390686.
[5] Donabel Abuan, Konstantin Gaticales, Elmer P. Dadios, "Microprocessor Interfacing: Bidirectional Motor, Automata Vehicular Locomotion Programmed with MATLAB and Arduino IDE", 2022 International Conference on Electronics and Renewable Systems (ICEARS), pp.131-135, 2022.
[6] "DC Motor Design and Characteristics Using Matlab", *J. eng. sustain. dev.*, vol. 18, no. 3, pp. 197–207, May 2014, Accessed: Mar. 27, 2024.
[7] Assefa, Alemie. (2023). Design GUI App on MATLAB for Comparison Analysis of LQR and Pole Placement Controller for Speed Control of DC Motor. Automation Control and Intelligent Systems. 11. 45-56. 10.11648/j.acis.20231103.11.
[8] V. Sigarev, T. Kuzmina and A. Krasilnikov, "Real-time control system for a DC motor," 2016 IEEE NW Russia Young Researchers in Electrical and Electronic Engineering Conference (EIConRusNW), St. Petersburg, Russia, 2016, pp. 689-690, doi: 10.1109/EIConRusNW.2016.7448276.
[9] P. Verma, P. Gupta and B. Kumar, "Graphical user interface(GUI) to study DC motor dynamic characteristics," *2017 International conference of Electronics, Communication and Aerospace Technology (ICECA)*, Coimbatore, India, 2017, pp. 649-654, doi: 10.1109/ICECA.2017.8212746.
[10] Balogh Tibor, Viliam Fedák, František Ďurovský, "Modeling and Simulation of the BLDC Motor in MATLAB GUI", International Symposium on Industrial Electronics, pp. 1403-1407, 2011.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)