GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2023 (COGC-2023)
Semester-V

Course Title: AC & DC Machines
(Course Code: 4352004)

Diploma program in which this course is offered	Semester in which offered
Mechatronics Engineering	5th Semester

1.RATIONALE

Mechatronics is a field of engineering which mainly encompasses uses and control of electric motors for the applications of CNC machines, robotics, drones, and quad-copter and electric vehicles having sensors for smart technology. Electric motors have been used since the inception of their invention. However, the requirement of smart sensor-based technology entails precise and smooth control of electric motors using advance and fast microcontrollers. This severely imposes strict requirements on control of electric motor. This course will enable the students to develop skills to select, operate and smartly control electric motors using advance microcontroller and electronic circuitry. Practical features of the course will make the students capable of operating various electric motors. Consequently, the students will become familiar with working, specifications and applications of DC motor, BLDC motor, induction motor, servo motor and stepper motor.

2.COMPETENCY

The course content should be taught and implemented to develop different skills so that students can acquire the following competency.

- **Operate and control AC as well as DC motors for different applications.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge, and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following Cos.

CO-1	Control speed of DC Motor by appropriate method.
CO-2	Control BLDC motor using appropriate driver circuit and microcontroller.
CO-3	Run three-phase induction motor using appropriate starter and control its speed.
CO-4	Control stepper motor using appropriate driver circuit and microcontroller.
CO-5	Control servo motor using appropriate driver circuit and microcontroller.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
Teaching Scheme			Total Credits	Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	4	30*	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

Legends: L-Lecture; T– Tutorial/Teacher Guided Theory Practice; P -Practical; C – Credit, CA - Continuous Assessment; ESE -End Semester Examination.

5. SUGGESTED PRACTICAL EXERCISES

Following practical outcomes (PrOs) are the sub-components of the Course Outcomes (COs).Some **POs** marked **'*'**are compulsory, as they are crucial for that particular CO at the' Precision Level' of Dave's Taxonomy related to the 'Psycho motor Domain.'

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
01	Demonstrate the construction and parts of DC motor.	1	02*
02	Perform the DC motor speed control using electronic devices.	1	02*
03	Control the speed of BLDC motor using appropriate driver circuit and Arduino microcontroller.	2	04*
04	Identify the various parts of the three-phase induction motor.	3	02*
05	Measure the slip of three-phase induction motor by using tachometer and by stroboscopic method.	3	02*
06	Make connections of DOL and star-delta starters for appropriate three-phase squirrel cage induction motor.	3	02*
07	Perform speed control of three-phase induction motor by 1. By changing the supply voltage 2. By changing the applied frequency	3	04*
08	Perform speed control of three-phase wound rotor/slip-ring induction motor by rotor rheostat control.	3	02
09	Test the circuit of capacitor start capacitor run single-phase induction motor used in a ceiling fan.	3	02*
10	Perform shaft position control of servo motor by interfacing it with Arduino microcontroller board.	4	04*

11	Perform control of stepper motor by interfacing it with driver circuit and Arduino microcontroller board.	5	04*
Total (Hours)		**-**	**28**

Note:

I. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry-relevant skills/outcomes to match the COs. The above table is only a representative list**.**

II. Care must be taken in assigning and assessing the study report as it is a Second-year study report. The study report, data collection, and analysis report must be assigned to a group. A teacher has to discuss the type of data(which and why)before the group starts their market survey.

The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above-listed **Practical Exercises** of this course required, which are embedded in the Cos and ,ultimately, the competency.

Sr. No.	**Sample Performance Indicators for the PrOs**	**Weightage in %**
Experimentation/performance type PrOs (PrOs Number: 2, 3, 4, 5, 6, 7, 8, 9, 10 &11)		
1	Knowledge	30
2	Quality of Report	30
3	Participation	20
4	Punctuality	20
	Total	**100**
For Demonstration type PrOs (PrOs Number: 1 & 12)		
1	Knowledge	20
2	Procedure follows	30
3	Observation Skill	20
4	Conclusion/ Summary	10
5	Quality of Report	10
6	Punctuality	10
	Total	**100**

Sample rubrics Performance Indicators for the PrOs

Demonstration type PrOs (PrOs Number 1 &12)					
Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	30%	Students give the correct answers 90% or more	Student give the correct answers between 70-89%	Student give the correct answers between 50-69%	Student give the correct answers less than 50%
Quality of Report	30%	Neat Handwriting, figure, and table.	Only formatting is not proper (Location of	A few required elements (labeling/ notations) are	Several require elements (content in paragraph,

		Complete labeling of figure and table.	figures/tables, use of pencil and scale)	missing	labels, figures, tables) are missing
Participation	25%	Excellent focused attention in the exercise	Moderately focused attention on exercise	Focused limited attention in the exercise	Participation is minimum
Punctuality	15%	Timely Submission	Submission late by one laboratory	Submission late by two laboratories	Submission late by more than two laboratories

Experimentation/performance type PrOs (PrOs number 2,3,4,5,6,7,8,9,10 & 11)					
Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	20%	Student give the correct answers 90% or more	Student give the correct answers between 70-89%	Student give the correct answers between 50-69%	Student give the correct answers less than 50%
Procedure follows	30%	Student follow all the procedure with precaution in a logical order	Student follow all the procedure with some precaution in a logical order	Student follow all the procedure without precaution in a logical order	Student follow all the procedure without precaution in an illogical order
Observation Skill	20%	Excellent focused attention in the exercise	Moderately focused attention on exercise	Focused limited attention in the exercise	Participation is minimum
Conclusion/ Summary	10%	Student concept is mostly clear	Student concept is partly clear	Student concept is somewhat clear	Student concept is not clear
Quality of Report	10%	Neat Handwriting, figure, and table. Complete labeling of figure and table.	Only formatting is not proper (Location of figures/tables, use of pencil and scale)	A few required elements (labeling/ notations) are missing	Several require elements (content in paragraph, labels, figures, tables) are missing
Punctuality	10%	Timely Submission	Submission late by one laboratory	Submission late by two laboratories	Submission late by more than two laboratories

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrO is a guide to procure them by the administrators to a user in uniformity of practice in all institutions across the state.

Sr. No.	Equipment Name	PrO. No.
1.	Cut section model of DC Motor.	1
2.	DC shunt motor – 230 V DC, 16 A, 1,000 RPM, 5 HP	2
3.	Three-phase out-runner type 1000 KV BLDC Motor driven by Li-Po 12 V Battery with 18 to 30 A Electronics Speed Controller (ESE) circuit and Arduino board.	3
4.	Cut section model of three-phase induction motor.	4
5.	Three-phase Squirrel Cage Induction Motor – 5 HP, 4 Pole, 415 V, 7.5 A, Class B Insulation, S1 Duty.	5, 6, 7
6.	Three-phase Wound Rotor / Slip-ring Induction Motor – 5 HP, 4 Pole, 415 V, 7.5 A, Class B Insulation, S1 Duty.	8
7.	5 Volt Servo motor having rotation of 0^o to 180^o and operating speed of 0.1s/60^o along with driver IC and Arduino board suitable for application like robotic arms, quad copter etc.	10
8.	5 Volt DC, Unipolar/Bipolar Stepper motor along with Driver Circuit (Darlington Array for Unipolar and H-bridge for Bipolar stepper motor) and Arduino Board.	11

7. AFFECTIVE DOMAIN OUT COMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the COs mentioned above and PrOs. More could be added to fulfill the development of this course competency.

a. Work as a leader/team member.

b. Follow safety practices.

c. Follow ethical practices

d. Maintain tools and equipment

e. Practice environment-friendly methods and processes.(Environment related)

The ADOs are best developed through laboratory/field-based exercises. Moreover, the level of achievement of the ADOs, according to Krathwohl's' Affective Domain Taxonomy, 'should gradually increase as planned below:

I. 'Valuing Level' in1st year

II. 'Organization Level' in 2ndyear.

III. 'Characterization Level' in 3rdyear.

8. UNDER PINNING THEORY

Based on the higher level UOs of Revised Bloom's taxonomy formulated for developing COs and competency, the primary underpinning theory is given below. If required, more such UOs could be included by the course teacher to focus on attaining COs and competency.

Unit	Unit Outcomes (UOs) (4 to6 UOs at different levels)	Topics and Sub-topics

Unit 1 **DC Motor**	1a. Explain working of DC motor. 1b. Describe the working of different parts of DC motor. 1c. State the material used for various parts of DC motor. 1d. Classify the different types of DC motors. 1e. Compare the speed-torque characteristics of different types of motors. 1f. Explain speed control of DC motor. 1g. List the applications of various types of DC motors. 1h. Explain the construction of PMDC mtoor. 1i. List the applications of PMDC motor.	1.1 Working principle of DC Motor. 1.2 Construction of DC Motor. 1.3 Types of DC Motors. 1.4 Torque-Armature current and Torque-Speed Characteristics of DC Motors. 1.5 Speed Control of DC Motor. - Armature and field control. 1.6 Specifications and Applications of DC Motors. 1.7 Construction of Permanent Magnet DC (PMDC) Motor. 1.8 Applications of PMDC Motor.
Unit 2 **Brushless DC Motor**	2a. Explain construction of BLDC motor. 2b. Explain working of BLDC motor. 2c. Give classification of BLDC motor. 2d. Explain in-runner and out-runner BLDC motor. 2e. Explain sensored and sensorless BLDC motor. 2f. Explain control of BLDC motor using driver circuit and microcontroller. 2g. List advantages of BLDC motor for electric vehicles. 2h. List the applications of BLDC motor.	2.1 Construction and working of Brushless DC (BLDC) motor. 2.2 Types of Brushless DC (BLDC) Motors • Based on Design – In-runner Brushless DC Motor, Out-runner Brushless DC Motor. • Based on Use of Sensor – Sensored BLDC Motor, Sensorless BLDC Motor. • Based on No of Poles – Single Pole BLDC Motor, Multi Pole BLDC Motor. 2.3 BLDC motor control using driver circuit and microcontroller. 2.3 Advantages of BLDC motor over brushed DC motor for electric vehicle applications. 2.4 Specifications and applications of BLDC motor.

Unit 3 **Induction Motor**	3a. Differentiate between squirrel cage and wound rotor induction motor with salient features. 3b. Explain how a rotational field is produced in a three-phase induction motor. 3c. State the relationship between synchronous speed and supply frequency. 3d. Draw and explain torque-slip characteristics of squirrel cage and wound rotor/slip-ring induction motor. 3e. State the necessity of starter in three-phase induction motor. 3f. Explain star-delta and rotor resistance starters. 3g. Explain various methods of speed control of three-phase induction motor. 3h. Explain working of different types of single-phase induction motor. 3i. State the applications of single-phase induction motor.	3.1 Construction of polyphase Induction Motor (IM), its types - Squirrel Cage Induction Motor (SCIM) and Wound Rotor Induction Motor (WRIM) / Slip Ring Induction Motor. 3.2 Rotating magnetic field and working principle of polyphase IM. 3.3 Relation between synchronous speed and supply frequency, slip, torque-slip curve, starting torque, running torque and condition for maximum torque. 3.4 Necessity of starter in polyphase IM. Types of starters – Direct Online (DOL), star-delta, autotransformer type and rotor resistance starter. 3.5 Methods of speed control of SCIM (Squirrel Cage IM) and WRIM (Wound Rotor IM). 3.6 Applications and Specifications of polyphase induction motors. 3.7 Types of Single-Phase Induction Motor (SPIM). 3.8 Principle and working of • Split Phase SPIM, • Resistance Start SPIM , • Capacitor Start SPIM, • Capacitor Start & Capacitor Run SPIM • Shaded Pole Induction Motor, • Fractional Horse Power (FHP) induction motor. 3.9 Applications and Specifications of single-phase induction motors.

Unit 4 **Servo Motor**	4a. Explain working principle of servo motor. 4b. Classify different types of servo motor. 4c. Explain different types of DC servo motors. 4d. Explain different types of AC servo motors. 4e. Explain speed control of servo motor. 4f. List the advantages and disadvantages of servo motor. 4g. State the applications of servo motor.	4.1 Working principle and mechanism of servo motor. 4.2 Types of servo motor. • DC Servo motor – Series motor, Split Series Motor, Shunt control motor, Permanent magnet servo motor. • AC Servo Motor – Positional Servo Motor, Continuous rotation servo motor, Linear servo motor. 4.3 Servo motor control using driver circuit and microcontroller. 4.4 Advantages and disadvantages of servo motor. 4.5 Specifications and applications of servo motor.
Unit 5 **Stepper Motor**	5a. Explain working and construction of stepper motor. 5b. Explain working of permanent magnet stepper motor. 5c. Explain working of hybrid synchronous stepper motor. 5d. Explain working of variable reluctance stepper motor. 5e. Explain characteristics of stepper motor. 5f. Explain stepper motor control using driver circuit and microcontroller. 5g. Compare stepper motor and servo motor. 5h. State the applications of stepper motor.	5.1 Construction and working of stepper motor. 5.2 Types of stepper motor – • Permanent magnet stepper motor. • Hybrid Synchronous stepper motor. • Variable reluctance stepper motor. 5.3 Torque equation and characteristics of stepper motor. 5.4 Stepper motor control using driver circuit and microcontroller. 5.5 Comparison of stepper motor and servo motor. 5.6 Specifications and application of stepper motors.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	DC Motor	08	05	05	04	14
II	Brushless DC Motor	05	03	03	02	08
III	Induction Motor	18	08	11	07	26
IV	Servo Motor	05	04	03	03	10
V	Stepper Motor	06	04	04	04	12
Total		**42**	**24**	**26**	**20**	**70**

Legends: R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)

10. SUGGESTED STUDENT ACTIVITIES

Sr. No.	Activity.
1.	Prepare chart of different parts of DC machine and label the material used for making each part.
2.	Prepare chart of different parts of three-phase induction motor and label the material used for making each part.
3.	Prepare Powerpoint presentation on different types of Brushless DC (BLDC) motors (with ratings) used in electric vehicles available in Indian market.
4.	Prepare chart showing construction of PMDC, Stepper and Servo Motor.
5.	Download and collect specifications of the BLDC motors used in drone applications
6.	Download and collect specifications of the servo motor used for robotic, quad copter applications.
7.	Prepare chart showing difference between brushed DC motor and brushless DC motor.
8.	Prepare nameplate of three-phase induction motor.
9.	Verify and compare the performances (rotation speed, airflow, and starting time) of ceiling fan having single-phase induction motor and a ceiling fan having BLDC motor.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

Unit	Unit Name	Strategies
1	DC Motor	Demonstration by cut-section model of the motor, videos, charts and animations.
2	Brushless DC Motor	Massive open online courses (MOOCs), Demonstration by videos, charts and animations. Industrial visit to Electric Vehicle (EV) manufacturing industry. Expert sessions on different

		types of motors used in EVs, their relative merits and demerits. Students' awareness workshop on using electric vehicles, government subsidy/incentives etc.
3	Induction Motor	Demonstration by cut-section model of the motor, animation, videos, Industrial visit to process industry where electronics speed control of three-phase induction motor is employed. Field visit to a small factory where rewinding of ceiling fans are carried out.
4	Servo Motor	Massive open online courses (MOOCs), demonstration by videos, animations, hands-on practices in laboratory.
5	Stepper Motor	Massive open online courses (MOOCs), demonstration by videos, animations, hands-on practices in laboratory.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her at the beginning of the semester. In the first four semesters, the micro-projects are group-based (groups of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based, or field-based. Each micro-project should encompass two or more COs which are, in fact, an integration of PrOs, UOs, and ADOs. Each student must maintain a dated workdiaryconsistingofindividualcontributionstotheprojectworkandgiveaseminarpresentationbefore submission. The duration of the micro project should be about**14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students ought to submit a micro-project by the end of these semester to develop the industry-oriented COs.

A representative list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher or using suggested student activity.

A representative list of micro-projects is given here. The concerned faculty could add similar micro-projects in any form (chart/presentation/report/model):

1. Prepare chart showing different parts of DC motor.
2. Prepare chart showing working principle and construction of three-phase induction motor.
3. Prepare a chart showing construction and working principle of BLDC motor.
4. Collect specifications from different manufacturers of BLDC motors for EV application and

make a survey report.

5. Use Arduino microcontroller board to develop control circuit for the BLDC motor and write a program with IDE (Integrated Development Environment) software.
6. Prepare a chart showing comparison between Brushed DC motor and Brushless DC Motor.
7. Prepare chart showing working of three-phase motor starters.
8. Make a working model of control wiring of star-delta starter with contactors.
9. Prepare chart showing construction of different types of single-phase induction motor.
10. Collect specifications from different manufacturers of single-phase Induction motors and prepare a market survey report.
11. Prepare chart showing working and construction of different types of servo motor.
12. Develop control circuit for the servo motor and write a program with IDE in Arduino microcontroller for its position control.
13. Collect specifications from different manufacturers of servo motor and prepare a market survey report.
14. Prepare chart showing working and construction of different types of stepper motor.
15. Develop control circuit for the stepper motor and write a program with IDE in Arduino microcontroller for controlling the speed of stepper motor.
16. Collect specifications from different manufacturers of stepper motor and prepare a market survey report.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication
1	A textbook of Electrical Technology Volume-II	B. L. Theraja & A.K. Theraja	S. Chand and Co., New Delhi, 23rd or Latest edition (ISBN : 9788121924405)
2	Electrical Machinery	Dr. P.S.Bimbhra	Khanna Publication. New Delhi ISBN: 9788174091734
3	Brushless DC (BLDC) Motor Fundamentals (AN885)	Padmaraja Yedamale, Microchip Technology Inc.	Available: https://www.microchip.com/en-us/application-notes/an885
4	Stepper Motors: Fundamentals Applications and Design	V. V. Athani	New Age International Pvt. Ltd.

14. SOFTWARE/LEARNING WEBSITES

- https://onlinecourses.nptel.ac.in/noc22_me59/preview
- https://nptel.ac.in/courses/108102156
- https://archive.nptel.ac.in/courses/108/105/108105155/

- https://archive.nptel.ac.in/courses/108/105/108105131/
- https://archive.nptel.ac.in/courses/108/105/108105062/
- https://www.digimat.in/nptel/courses/video/112105211/L07.html
- https://circuitdigest.com/microcontroller-projects/what-is-bldc-motor-and-arduino-bldc-motor-control
- https://www.embitel.com/blog/embedded-blog/motor-control-system-for-bldc-motors-in-automotive-application
- https://robu.in/brushed-dc-motor-working-principle-construction-applications/
- https://components101.com/motors/servo-motor-basics-pinout-datasheet
- https://www.allaboutcircuits.com/projects/servo-motor-control-with-an-arduino/
- https://docs.arduino.cc/learn/electronics/stepper-motors
- https://electricvehicles.in/types-of-motors-used-in-evs-and-why-bldc-motors-are-widely-used/

15. PO-COMPETENCY-COMAPPING

Semester-IV	Fluid Mechanics and Hydraulic Machinery (4341903)						
Semester-IV	**POs**						
	PO1	PO2	PO3	PO4	PO5	PO6	PO7
Competency &CourseOutcomes	Basic & Discipline-specific knowledge	Problem Analysis	Design/development of solutions	Engineering Tools, Experimentation & Testing	Engineering practices for society, sustainability & environment	Project Management	Life-long Learning
Competency	Operate and control AC as well as DC motors for different applications.						
CO-1	3	3	2	3	2	-	3
CO-2	3	3	2	3	2	1	3
CO-3	3	3	1	3	2	-	3
CO-4	3	3	1	3	-	1	3
CO-5	3	3	1	3	-	1	3

Legend:'3' for high, '2' for medium, '1' for low, and '-'for no correlation of each CO with PO.

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE (GTU Resource Persons)

Sr. No.	Name and Designation	Institute	Contact No.	Email
1.	Dr. Ankit P Shah (HOD Electrical Engg.)	B. & B. Institute of Technology, Vallabh Vidyanagar	9825026898	ankitbbit@gmail.com
2.	Prof. Rahul R. Chauhan	Mechatronics & Mechanical Dept. B. & B. Institute of Technology, Vallabh Vidyanagar	8780292946	crahul594@gmail.com

BOS Resource Persons

Sr. No.	Name and Designation	Department	ContactNo.	Email
1.	Dr. S. H. Sundarani, BOS (Chairman HOD Mechanical Engg.)	Government Polytechnic Ahmadabad	9227200147	gpasiraj@gmail.com
2.	Dr. Rakesh D. Patel (BOS Member, HOD Mechanical Engg.)	B. & B. Institute of Technology, Vallabh Vidyanagar	9825523982	rakeshgtu@gmail.com
3.	Dr. Atul S.Shah (BOS Member, Principal)	B. V. Patel Institute of Technology, Bardoli	7567421337	Asshah97@yahoo.in