GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-IV

Course Title: AC Rotating Machines
(Course Code: 4342402)

Diploma programmer in which this course is offered	Semester in which offered
Power Electronics	4th semester

1. RATIONALE

Different types of AC machines with power electronic applications are widely used in the industry. It is because of power electronics that renewable energy could make major inroads in the electrical power sector especially the use of induction and synchronous machines. Therefore, this course is intended to enable the student understand the concepts, principles and operate various AC machines used in the industry, which will enable him/her to get employment and work effectively in the industry.

2. COMPETENCY

The purpose of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Operate different types of AC machines efficiently.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

CO 1) Operate single phase induction motor efficiently
CO 2) Operate three phase induction machines efficiently
CO 3) Operate synchronous machines efficiently
CO 4) Operate special electrical machines efficiently
CO 5) Test and troubleshoot AC motor effectively.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
4	-	2	5	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) that are the sub-components of the Course Outcomes (Cos). Some of the **PrOs** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1	Identify the parts of the various single-phase induction motors.	I	2*
2	Identify the parts of the 3-phase squirrel cage and wound rotor induction motor	II	2*
3	Perform voltage ratio test on three phase induction motor.	V	2
4	Test the performance of Stepper motor.	IV	2*
5	Test the performance of universal motor.	IV	2
6	Test the performance of brushless DC motor.	IV	2
7	Study of (Manual and Semi automatic) Auto transformer starter and rotor resistance starter connection and running a 3-phase induction motor and measurement of starting current.	II	2*
8	Study and Practice of connection & Reverse the direction of rotation of Three Phase Induction motor.	II	2
9	Study and Practice of connection & Reverse the direction of rotation of Single Phase Induction motor	I	2*
10	Perform No load and blocked rotor test on a 3- ϕ induction motor	V	4*
11	To Perform load test on 3-phase ac slip ring induction motor	V	2*
12	Conduct load test on the given 1 phase induction motor and to determine and plot its performance characteristics.	I	2*
13	Determine the eq. circuit parameters of a 1 phase induction motor by performing the no- load and blocked rotor tests.	I	2*
14	plot the 'v' and 'inverted v' curves of Synchronous motor.	III	2*
15	To determine Xd and Xq by conducting a slip test on a salient pole synchronous machine.	III	2*
16	Perform beak test on three phase induction motor.	II	2*
17	Perform Speed Control of 3 Phase Slip-Ring Induction Motor By Rotor Resistance Control	II	2*
	Minimum 14 Practical Exercises		**28* Hrs.**

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 suggestive list.*

*ii. 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.*

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Prepare of experimental setup	20
2	Operate the equipment setup or circuit	20
3	Follow safe practices measures	10
4	Record observations correctly	20
5	Interpret the result and conclude	30

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

These major equipments with broad specifications for the PrOs is a guide to procure them by the administrators to user in uniformity of practical's in all institutions across the state.

S. No.	Equipment Name with Broad Specifications	PrO.No.
1	AC Motors with Mechanical Load Arrangement Type : 1 Phase induction motor. Power Rating : 1HP, 2HP, 3HP and 5HP Voltage Rating : 415V AC ± 5% Rated Speed : 1440RPM ± 7.5% Insulation : Class 'B' Loading arrangement : Mechanical Spring Balance : 2Nos.(Tubular Type) Brake Drum/Pulley : Aluminum casted with heat suppression facility Machine Base : "C" Channel	1,9,12,13
2	Three Phase AC Motors with Mechanical Load Type : Three Phase Slip-Ring / Synchronous / Squirrel Cage Type Power Rating : 1HP, 2HP, 3HP and 5HP Voltage Rating : 415V AC ± 5% Rated Speed : 1440RPM ± 7.5% Insulation : Class 'B' Loading arrangement : Mechanical Spring Balance : 2Nos.(Tubular Type) Brake Drum/Pulley : Aluminum casted with heat suppression facility Machine Base : "C" Channel	2,7,8,16,17
3	Variac(Variable Auto Transformer) 230 V, 20A	7 to 17
4	Starter(DOL) Rheostat 250/1.5A SPST switch	7
5	Stepper motor (FHP)	4
6	Work Bench For Synchronous Motor 3HP Work Bench For Synchronous Motor 3HP Supplied with 3 Phase Synchronous Motor 3HP ,DC source for excitation with Control Panel fitted with Necessary Meters & DOL Starter	14,15
7	Speed Control of 3 Phase Slip-Ring Induction Motor By Rotor Resistance Control test kit	17
8	**To Connect Start & Reverse the Direction of a 3 Phase Induction Motor kit :** Control Panel To Find Xd And Xq Of A Salient Pole, One No. of AC Voltmeter Range 0-300V of size 9696mm provided on the front panel, One No. of AC Current Meter Range 0-3A of size 9696mm provided on the front panel, One No. of DC Current Meter Range 0-10A of size 9696mm provided on the front panel, One no. of DC Voltmeter 0-300V of size 9696mm provided on the front panel, One No. of Variac for Speed Variation, One no. of Line connector provided on the left side of the control panel, One no. of MCB/DP provided on the left side of the front panel.	15

7. AFFECTIVE DOMAIN OUTCOMES

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

a) Work as a leader/a team member.
b) Follow error free measurement rules during measurement.
c) Practice environmentally friendly methods and processes.(Environment related)

The ADOs are best developed through the 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' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

Only the major Underpinning Theory is formulated as higher level UOs of *Revised Bloom's taxonomy* in order development of the COs and competency is not missed out by the students and teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
Unit – I Single Phase Induction Motor	1.a Describe working principle of single phase induction motor.	1.1 Single phase induction motor: Construction, The Double-Revolving-Field Theory of Single-Phase Induction Motor, The Cross-Field Theory of Single-Phase Induction Motor, Rotor Slip With Respect to Two Rotating Field.
	1.b Explain equivalent circuit of single-phase, single winding induction motor. 1.c Calculate performance of a single-phase, single-winding induction motor.	1.2 Equivalent circuit: based on: Two-Revolving-Field Theory. 1.3 Performance calculations of a single-phase, Single-winding induction motor, power flow diagram.
	1.d Describe no load and blocked rotor test with sketches and its significance.	1.4 Blocked rotor test, No load test, Losses and efficiency in the induction motor
	1.e Describe the starting methods of different types of induction motors	1.5 Starting of Induction Motor: split phase winding, capacitor start motor, capacitor start capacitor run motor, comparison.
Unit– II Three Phase Induction Machines	2.a Explain construction of induction motor. 2.b Explain basic induction motor concepts.	2.1 Induction motor: construction, cage rotor, wound rotor, comparison. 2.2 Basic concept: The Development of Induced Torque in an Induction Motor, concept of rotor slip, slip and speed, The Electrical Frequency on the Rotor.
	2.c Derive per phase equivalent circuit of induction motor.	2.3 Final per phase equivalent circuit of induction motor.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
	2.d Explain power and torque in induction motor.	2.4 Power flow in induction motor: Losses and power flow diagram, power and torque relation, separation of losses. 2.5 Torque in induction motor: Developed torque, starting torque, torque at synchronous speed, condition for maximum torque, maximum torque at starting.
	2.e Explain torque speed and torque slip characteristics of an induction motor.	2.6 The torque-slip characteristic: low-slip region, medium-slip region and high-slip region. 2.7 Torque-speed characteristic: torque speed curve, variations in induction motor torque-speed characteristics.
	2.f Describe starting methods of three phase induction motors.	2.8 Starting: starting methods of squirrel-cage and wound rotor motor
	2.g Explain speed control methods of three phase induction motors.	2.9 Speed control methods: by changing pole, by changing line frequency, by changing line voltage, by changing rotor resistance.
	2.h Explain cogging and crawling.	2.10 Cogging and crawling phenomenon in induction motors.
	2.i Differentiate between squirrel cage and wound rotor induction generator.	2.11 Induction generator: Squirrel cage, Wound rotor.
	2.j Explain power factor control of squirrel cage and wound rotor. induction generator	2.12 Power factor control in squirrel cage and wound rotor induction generator.
Unit – III Poly Phase Synchronous Machine	3.a Explain the working of synchronous machine	3.1 Synchronous machine: construction, working principle, main features, equivalent circuit of synchronous motor.
	3.b Explain different torque in synchronous motor.	3.2 Different torque in synchronous motor: Locked-rotor torque, Running torque, Pull-in torque, Pull-out torque.
	3.c Explain phasor diagram of synchronous motor.	3.3 Phasor diagram: for lagging, leading and unity power factor effect of varying field current.
	3.d Calculate efficiency of synchronous machine	3.4 Synchronous machine efficiency: Losses, efficiency.
	3.e Explain starting methods of synchronous motor.	3.5 Starting methods: by external prime mover, by damper windings.
	3.f Explain V-curve and inverted V curve of an synchronous motor	3.6 V-curve and inverted V-curve for synchronous motor.
	3.g Explain hunting in synchronous machine.	3.7 Hunting in synchronous machine.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
	3.h Explain slip test of synchronous machine	3.8 Slip test: determination of Xd and Xq
	3.i Explain 3-phase permanent magnet synchronous motor.	3.9 3-phase permanent magnet synchronous motor: construction, working principle, characteristics and its applications
Unit – IV Special Electrical Machines	4.a Explain the working of switched Reluctance motor with its characteristics.	4.1 Switched Reluctance Motor: working principle, characteristics and its applications.
	4.b Explain the working of Stepper motor with its characteristics. 4.c Differentiate the working principles of various types of stepper motors.	4.2 Stepper Motor: construction, working principle, characteristics. 4.3 Various types: variable reluctance, permanent magnet, hybrid stepper motor and applications.
	4.d Explain the working of Brushless 4.e DC motor.	4.4 Brushless DC motor: working principle, construction and applications.
	4.f Explain the working of Universal motor	4.5 Universal Motor: construction, working principle, applications.
Unit – V Testing and Troubleshooting of AC Motors.	5.a State and explain procedure for various tests on the induction machine.	5.1 Various test on induction machine: voltage ratio test, measurement of DC resistance, no load test, locked rotor test, load test, measurement of slip.
	5.b State and explain procedure for various tests on the synchronous machine.	5.2 Various test on synchronous machine: DC resistance, Dielectric test, OC test, SC test, slip test, voltage recovery test, line to line short ckt test, negative phase sequence test.
	5.c Troubleshooting the Capacitor-Run Motor 5.d Troubleshooting the split phase induction motor. 5.e Troubleshooting the Capacitor-start Motor. 5.f Troubleshooting the Capacitor-start capacitor run Motor.	5.3 Capacitor run motor: Troubleshooting. 5.4 Split phase induction motor: troubleshooting. 5.5 Capacitor start motor: Troubleshooting. 5.6 Troubleshooting the oil field capacitor in capacitor start capacitor run motor.
	5.g Troubleshoot three phase motors.	5.7 Typical winding problems: shorted turns, ground problem, Ph-to Ph short, open winding, burned winding, submerged motor and assorted rotor problems. 5.8 When motor overheating: Line caused, Operator caused, control caused, motor fault caused, location caused and maintenance caused.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
	5.h Troubleshoot synchronous motor.	5.9 Breakdown of DC exciter field and discharge register, squirrel cage winding, the stator winding and barring.

***Note**: The UOs need to be formulated at an 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I.	Single Phase Induction Motor	08	04	04	04	12
II.	Three Phase Induction Machines	18	04	12	04	20
III.	Poly Phase Synchronous Machine	14	04	08	06	18
IV.	Special Electrical Machines	06	04	04	00	8
V.	Testing and Troubleshooting of AC Motors.	10	00	06	06	12
Total		56	16	34	20	70

***Legends:** R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary slightly from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Make a chart of Special electric machine along with its applications.
b) Interpret the various parameters by reading Name plate of AC motor.
c) Make a chart of classes of insulating materials used in Electric motor.
d) Make a chart of comparisons of Induction and Synchronous motor.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4***means different types of teaching methods that are to be employed by teachers to develop the outcomes.

d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessedusing different assessment methods.
e) With respect to ***section No.11***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students for reading name plate for AC machines.
g) Guide students for selecting a AC machine for various industrial applications.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project is group-based (group 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 will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before 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 micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive 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:

a) Make a Presentation for characteristics of various AC motors.
b) Design at least one testing circuit/procedure for induction machine.
c) Design at least one testing circuit/procedure for synchronous machine.

13. SUGGESTED LEARNING RESOURCES:

S. No.	Title of Book	Author	Publication with place, year and ISBN
1	Electric Machines	Husain Ashfaq, Harroon Ashfaq	Dhanpat Rai & Co. 2016 ISBN: 978-8177001662
2	Electric Machinery fundamentals	Stephen J. Chapman	McGraw Hill Education,2012 ISBN 9780073529547
3	Electrical Machines	Nagrath I. J. & Kothari D. P	McGraw Hill Education,2010 ISBN 978-0070699670
4	Electric motor Maintenance and Troubleshooting.	Augie Hand	McGraw Hill Education, 2011 ISBN: 978-0071763950
5	Testing Commissioning Operation & Maintenance of Electrical Equipments	Rao S.	Khanna Publishers,2021 ISBN: 9788174091857

14. SOFTWARE/LEARNING WEBSITES

a) https://www.vlab.co.in
b) https://nptel.ac.in
c) https://www.classcentral.com
d) https://swayam.gov.in/
e) https://shodhganga.inflibnet.ac.in/
f) https://onlinecourses.nptel.ac.in/

15. PO-COMPETENCY-CO MAPPING

Semester IV	AC Rotating Machines (4342402)						
	POs and PSOs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimentation &Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency	**Operate different types of AC machines efficiently.**						
CO 1) Operate single phase induction motor efficiently	1	1	--	1	2	2	2
CO 2) Operate three phase induction machines efficiently	1	1	1	2	2	2	3
CO 3) Operate synchronous machines efficiently	1	1	1	2	2	2	3
CO 4) Operate special electrical machines efficiently	--	1	1	2	1	2	3
CO 5) Maintain AC motor effectively.	--	3	1	1	1	2	2

Legend: '**3**' for high, '**2**' for medium, '**1**' for low or '**-**' for the relevant correlation of each competency, CO, with PO/ PSO

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

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1.	Mr. Vinod N. Makwana Lecturer – Power Electronics Department.	Dr. S. & S. S. Ghandhy college of engineering & Technology, Surat	9427386784	vinodmakwana1@rediffmail.com
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