GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Electrical Machines
(Course Code: 1336401)

Diploma program in which this course is offered	Semester in which offered
Renewable Energy	3rd semester

1. RATIONALE:

The course on Electrical Machines is designed to provide students with a comprehensive understanding of the fundamental principles, operation, and applications of various types of electrical machines. The course focuses on four key areas of electrical machines, namely: (1) Single-phase transformer, (2) Synchronous Generator, (3) Induction Motors, and (4) Induction Generator. By studying these topics, students will develop a solid foundation in electrical machine theory and gain practical knowledge necessary for their future careers in electrical engineering.

2. COMPETENCY

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

Students will be able to explain the physical and electrical characteristics of electrical machines, analyze their behavior under different operating conditions, and identify the key parameters affecting their performance.

3. COURSE OUT COMES (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:

a) **Comprehend the performance of low rated single phase transformer and operate them in parallel.**
b) **Determine the performance of low rated alternator by conducting required tests; synchronize it with grid or another alternator.**
c) **Determine the performance of low rated induction motor by conducting tests; appreciate significance of starters and control the speed of the given induction motor.**
d) **Comprehend the operation of different types of induction generator.**

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(M)	ESE(E)	CA(I)	ESE(V)	
3	0	4	5	30*	70	50	50	200

(*): 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 forth 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

The following practical outcomes (PrOs) 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'.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Familiarization of electrical machine laboratory apparatus.	-	2
2	Identify various parts of single phase transformer. Prepare report on nameplate details of core type and shell type single phase transformer.	I	4*
3	Perform polarity test on single phase transformer.	I	2*
4	Perform direct loading test of single phase transformer to determine efficiency and voltage regulation at various load.	I	4*
5	Perform open circuit test and short circuit test to obtain transformer parameters.	I	4*
6	Perform parallel operation of two single phase transformers.	I	2
7	Identify various parts of 3 phase synchronous generator. Prepare report on nameplate details of any 3 phase synchronous generator.	II	4*
8	Perform direct loading test on alternator to determine voltage regulation.	II	4*
9	Perform parallel operation of two alternators.	II	4

10	Synchronize given alternator with infinite busbar.	II	4
11	Identify various parts of 3 phase induction motor. Prepare report on nameplate details of 3 phase induction motor.	III	4*
12	Perform direct loading test of 3 phase induction motor to determine efficiency.	III	4*
13	Perform no load and blocked rotor test to determine induction motor parameters.	III	4*
14	Demonstrate wiring connection of Direct Online Starter.	III	2
15	Demonstrate wiring connection of Star-Delta Starter.	III	2*
16	Perform speed control of 3 phase squirrel cage induction motor.	III	2*
17	Perform speed control of 3 phase slip-ring induction motor.	III	2
18	Test performance of Doubly Fed Induction Generator.	IV	2*
19	Identify various parts of Doubly Fed Induction Generator.	IV	2*
			56 Hrs

Note:

a) *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.*

b) *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%
1	Ability to set up the experiment with required equipment, instruments of proper range.	30
2	Ability to read and record the observations with minimum errors.	10
3	Ability to interpret the calculated and graphical observations.	20
4	Ability to report the experiment with specific conclusion.	20
5	Ability to work in team and adhering to safety instructions.	20
Total		**100**

6. MAJOR EQUIPMENT/INSTRUMENTS REQUIRED

Major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to use in uniformity of practical experiments in all institutions across the state.

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Single phase AC Dimmer, 0-270 V, 5 A	2 to 6
2	Single phase transformers, 1 KVA, 115 V/ 230 V	2 to 6
3	Three phase AC Dimmer (VARIAC), 0-470 V, 15 A	12-13 & 16 to 18
4	Three phase synchronous generator coupled with DC Shunt Motor, Rating: Synchronous generator: 3 Phase, 415 V , 3 KVA, DC Field voltage = 230 V DC, Duty-S1 DC Shunt Motor: 5 KW, 230 V, Shunt, Duty-S1	7, 8
5	Three phase squirrel cage induction motor with brake pulley arrangement: Induction motor: 5 HP, 415 V, 1500 rpm	12, 16
6	Three phase slip-ring induction machine mechanically coupled with DC Shunt Generator Induction Motor specs: 5 HP, 415 Volt, 1500 RPM DC Shunt Generator specs: 3 KW, 230 V, 1500 RPM	12-13, 17
7	3 phase Double Fed Induction Generator: 3 KW to 5 KW, 415 V	18, 19
8	Cut section model of single phase transformer - shell type and core type	2
9	Cut section model of 3 phase induction motor - squirrel cage and slip-ring induction motor	11
10	Three phase load (20 A)	4, 8, 9, 18
11	Variable DC Supply, 250 Volt, 25 A	8, 9, 10
12	Direct on line starter, 415 V, 3 HP; Star delta starter, 415 V, 7 HP	14, 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 course competency.

a) Work as a leader/a team member (while doing a micro-project).
b) Follow ethical practices.
c) Work as a group member (while performing experiments and taking readings).
d) Practice environmental 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 increases planned below:

i. 'Valuing Level' in1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
Unit I Single Phase Transformer	**1a.** Explain construction of core type and shell type single phase transformer. **1b.** Explain working principle of single phase transformer. **1c.** Calculate various losses, efficiency and voltage regulation of given single phase transformer at specified load condition with necessary data. **1d.** Conduct tests to determine voltage regulation and performance of given low rated transformer. **1e.** Explain the parallel operation of single phase transformers.	**1.1** Construction of single phase transformer – core type and shell type **1.2** Working principle of single phase transformer **1.3** EMF equation, transformation ratio and equivalent circuit. **1.4** Losses, efficiency and voltage regulation **1.5** Numerical pertaining to single phase transformer **1.6** Direct loading and Open circuit-Short circuit test **1.7** Parallel operation of single phase transformer
Unit II Synchronous Generator	**2a.** Explain the construction of synchronous generator. **2b.** Explain various methods of excitation for synchronous generator. **2c.** Calculate the generated emf and voltage regulation of specified	**2.1** Construction of synchronous generator **2.2** Working principle of synchronous generator **2.3** Methods of excitation **2.4** EMF equation of alternator **2.5** Terminal voltage at different power

	alternator with given winding factor and necessary data. **2d.** Explain the procedure of synchronization of alternator with infinite bus or another alternator. **2e.** State need and essential conditions for parallel operation of alternators.	factor loads **2.6** Voltage regulation and load angle, direct loading test to determine voltage regulation **2.7** Numerical practice **2.8** Synchronization of alternator with infinite bus / another alternator, parallel operation
Unit III Three phase Induction Motor	**3a.** Differentiate between squirrel cage and slip-ring induction motor from construction and application point of view. **3b.** Explain the working of 3 phase induction motor. **3c.** Calculate induction motor parameters such as rotor speed, slip, slip speed, starting torque, running torque, losses and efficiency of given induction motor with necessary data. **3d.** Explain the need and various types of induction motor starters. **3e.** Explain various speed control methods of induction motor.	**3.1** Types, Construction and application of 3 phase induction motors **3.2** Working principle of 3 phase induction motor **3.3** Concept of synchronous speed, per unit slip, percentage slip, slip speed and numerical **3.4** Induction motor losses and efficiency, direct loading test, no load and blocked rotor test **3.5** Torque equations (Starting and Running torque) **3.6** Torque – Slip – Speed Characteristics **3.7** Need and types of starters **3.8** Speed control methods of induction motor
Unit IV Induction Generator	**4a.** Explain types and construction of induction generator. **4b.** State types of excitation methods of induction generator. **4c.** Explain torque-slip-speed characteristics of induction generator. **4d.** State applications and limitations	**4.1** Types and construction of induction generator **4.2** Working principle of induction generator **4.3** Types of excitation methods (active power off grid IG, capacitor, self etc.) **4.4** Torque-slip-speed characteristics of Induction Generator

	of induction generator.	**4.5** Voltage buildup in induction generator **4.6** Applications & limitations of induction generator

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	**Single Phase Transformer**	08	3	7	4	14
II	**Synchronous Generator**	12	6	11	3	20
III	**Three phase Induction Motor**	14	7	11	6	24
IV	**Induction Generator**	08	3	6	3	12
Total		**42**	**23**	**22**	**25**	**70**

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

Note*: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/ setters to formulate test items/questions to 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 slightly vary 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 perform following activities in group (or individual) and prepare reports of about 5 pages for each activity. They should also collect/record physical evidences for their (student's) portfolio which may be useful for their placement interviews:

a) Present seminar on various topics from course content.
b) Prepare specification of electrical machines.
c) Present models of parts of electrical machines.

d) Undertake market survey of various electrical machines.
e) Undertake micro-projects in teams.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES

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***) maybe 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) Show animation/video related to course content.
e) Some of the topics/sub-topics which are relatively simpler or descriptive are to be given to the students for self-learning but to be assessed using different assessment methods.
f) Correlating the importance of the content of this course with other courses/practical applications.
g) Guide students for using data manuals.
h) Guide students on how to address issues on environment and sustainability.

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-projects are 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) Prepare demo model of single phase transformer.

b) Demonstrate various parts of single phase transformer.
c) Carry out market survey of available single phase transformers along with their applications, cost, rating and other specifications.
d) Demonstrate various parts of 3 phase alternator.
e) Prepare demo model of 3 phase alternator.
f) Prepare working model of DOL starter.
g) Prepare working model of manual star-delta starter.
h) Demonstrate various parts of 3 phase induction motor.
i) Prepare working model of forward-reverse control of 3 phase induction motor.
j) Carry out market survey of various 3 phase induction motor.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Electric Machines: Principles, Applications, and Control Schemes	D. P. Kothari and I. J. Nagrath	ISBN: 978-0070682654 Publication: McGraw-Hill Education
2	Electrical Machines	P. S. Bimbhra	ISBN: 978-8170089703 Publication: Khanna Publishers
3	Electrical Machinery	Dr. A. S. Bhavikatti	ISBN: 978-9386710442 Publication: I. K. International Publishing House
4	Electrical Machines	U. A. Bakshi and M. V. Bakshi	ISBN: 978-8184317790 Publication: Technical Publications Pune
5	Electrical Machines, Theory and Practice	M. N. Bandyopadhyay	ISBN: 978-81-203-2997-3 Publication: Prentice-Hall, India, New Delhi
6	Electrical Machines	Dr. J. G. Jamnani	ISBN: 978-93-84955-55-7 Publication: Mahajan Publishing House
7	Theory and Performance of Electrical Machines	J. B. Gupta	ISBN: 978-93-5014-277-6 Publication: S. K. Kataria and Sons.

14. SOFTWARE/LEARNING WEBSITES

1. www.nptel.iitm.ac.in
2. https://ndl.iitkgp.ac.in
3. https://www.coursera.org/
4. https://ocw.mit.edu/index.html
5. https://lectures.gtu.ac.in/(related to course content)
6. https://www.electricaltechnology.org/
7. https://www.engineeringtoolbox.com/electrical-systems-t_33.html
8. https://vp-dei.vlabs.ac.in/Dreamweaver/list.html: virtual lab for synchronization of alternator with infinite bus
9. https://em-coep.vlabs.ac.in/List%20of%20experiments.html: virtual lab for induction motor and alternator experiments
10. https://ems-iitr.vlabs.ac.in/List%20of%20experiments.html: virtual lab for speed control of induction motor

15. PO-COMPETENCY-COMAPPING:

Semester III	Electrical Machine (Course Code:)						
	POs						
Competency & Course Outcomes	PO1 Basic & Discipline specific knowledge	PO2 Problem Analysis	PO3 Design/development of solution	PO4 Engineering Tools, Experimentation & Testing	PO5 Engineering practices for society, sustainability& environment	PO6 Project Management	PO7 Life-long learning
Competency							
CO1	3	1	-	2	-	1	2
CO2	3	1	-	2	-	1	2
CO3	3	1	-	2	-	1	2
CO4	3	-	-	1	3	1	2

*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.	A. R. Nijanandi Lecturer-Electrical Engineering	Government Polytechnic, Himatnagar	9099196191	anuraggp2016@gmail.com
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