GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Polyphase Transformers and Rotating AC Machines
(Course Code: 4340901)

Diploma programmer in which this course is offered	Semester in which offered
Electrical Engineering	4th Semester

1. RATIONALE

The electrical engineering applications in industries use small and large electric motors in some crucial application systems. This course will enable the students to develop skills to select, operate, and maintain various types of A.C. Motors and transformers. Practical features of the course will make the students capable of performing various tests on these machines. This course will also make the students familiar with the working and applications of Three-phase transformer and A.C. Motors.

2. COMPETENCY

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

- **Maintain various types of A.C. Motors and Three-phase transformers safely.**

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:

- ***a)*** Maintain the working of a three phase transformer.
- ***b)*** Maintain the working of three phase induction motor.
- ***c)*** Use the relevant single phase induction motor for various applications.
- ***d)*** Maintain the working of Synchronous machines.

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	
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

The following practical outcomes (PrOs) are the subcomponents 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	Identify various parts of the three phase transformer.	I	2
2	Perform parallel operation of two three phase transformers.	I	4
3	Make connections of different vector groups in two three phase transformers.	I	4
4	Identify various parts of the three phase induction motor.	II	2
5	Perform direct loading test of three phase induction motor to find out efficiency.	II	2*
6	Perform no load and blocked rotor test on a three phase induction motor to obtain various parameters using a circle diagram.	II	4*
7	Make connections of DOL and Star delta starter with appropriate three phase induction motors.	II	2
8	Perform speed control of three phase squirrel cage induction motor.	II	2
9	Perform speed control of three phase slip ring induction motor.	II	2
10	Test the circuit of capacitor start capacitor run single phase induction motor used in a ceiling fan	III	2
11	Perform No load test on single phase induction motor to determine the friction and windage loss.	III	2
12	Perform direct loading test on alternator to find out voltage regulation.	IV	2*
13	Find out voltage regulation of alternator by synchronous impedance method.	IV	4*
14	Find out voltage regulation of alternator by ampere turns method.	IV	4
15	Perform parallel operation of two alternators.	IV	4
16	Synchronize given Alternator with infinite bus bar.	IV	4

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
17	Construct V-curve of synchronous motor at different load conditions to see the effect of variation of excitation.	V	4*
18	Use a synchronous motor to improve the power factor.	V	2
			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.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Experimental setup, Procedure and conduction by following safety practices.	40
2	Conceptual clarity	30
3	Interpretation of Results and Ethical values.	30
Total		**100**

5. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr.No.	Equipment Name with Broad Specifications	PrO. No.
1	D.C. supply, 250 Volt, 25 Amp.	12 to 18
2	Three phase transformer, 1100/415 volt, 3 to 5 KVA	1,2,3
3	Three phase induction motor-DC shunt generator set. 5 HP, 415 volt.	5,6
4	Three Phase Squirrel cage Induction motor. 3 HP, 415 volt.	6
5	Three-phase auto transformer- 0 to 500 V, 25 Amp.	5,6,8,9
6	DC motor- Alternator Set (5 KVA, 415 volt, 3 phase 4 wire	12 to 16

Sr.No.	Equipment Name with Broad Specifications	PrO. No.
	Alternator)	
7	Synchronous Induction motor 415 volt 3 to 5 HP	17,18
8	Cut section of three phase induction motor.	4
9	Lamp load (10-20 A)	5,12

6. 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 safety practices while using D.C. and AC supply and electrical equipment.
c. Work as a group member (while performing experiments and taking readings)
d. 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

The major underpinning theory is given below based on the higher level 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) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit 1 Three Phase Transformer	**1a**. Justify the advantage of using 3- phase transformer over a bank of 3 single phase transformers **1b**. Sketch the different types of connections of 3-phase transformers including vector groups. **1c**. Explain the major parts of	**1.1** Comparison of three phase transformer with bank of three single phase transformer. **1.2** Construction of three phase transformer (Core and winding arrangement, Types of Winding.) **1.3** Winding Connections / Vector group of three phase transformers. (Star-Star, Delta-Delta, Delta-Star, Star-

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
	the 3-phase transformer. **1d.** Discuss the need and working of a tap changer. **1e**. Explain different cooling methods used in transformer,	Delta, Open Delta or V -V connection, Scott connection.) **1.4** Parallel Operation of three phase Transformers. **1.5** OFF load and ON load tap changer. **1.6** Accessories of three phase transformers, Buchholz relay, Name plate of three phase transformers. **1.7** Cooling of transformers, Natural and forced cooling.
Unit-II Three phase Induction Motors	**2a**. Explain how a rotating field is produced in a three phase induction motor **2b**. Differentiate between squirrel cage and wound rotor induction motor with their salient features. **2c**. Explain Torque slip characteristic of three phase induction motor. **2d**. Explain various methods of speed control of 3 phase induction motors. **2e**. Discuss Need of starters in three phase induction motors. **2f**. Solve numerical based on slip, Torque and power of three phase induction motors.	**2.1** Construction of a three phase induction motor and its types and applications. **2.2** Rotating magnetic field due to two phase supply and three phase supply. **2.3** Working Principle of three phase induction motor, Synchronous speed and Slip. **2.4** Effect of slip in rotor circuit parameters. **2.5** Derivation of Starting and Running torque, condition for maximum torque, Relation between torque and maximum torque. **2.6** Torque slip and torque speed curve of three phase induction motor. (Generating, breaking and motoring mode) **2.7** Power stages in an induction motor. **2.8** Equivalent circuit of 3 phase I.M. **2.9** Induction generator and its application **2.10** Starting of three phase I.M. Necessity and types of starters- DOL, Star delta. **2.11** Speed control of squirrel cage and slip-ring induction motor. **2.12** No Load, Block rotor test and Circle diagram.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit-III Single Phase Induction motor	**3a**.Discuss two field revolving theory in single phase induction motor. **3b**.Describe the working principle of different types of single phase motors. **3c**. Select various single phase induction motors for relevant applications.	**3.1** Double field Revolving Theory. **3.2** Making Single phase induction motor self-starting. **3.3** Types of Single phase induction motor. Split phase induction motor, Shaded pole motor, Resistance start motor, Capacitor start motor, Capacitor start capacitor run motor. **3.4** Equivalent circuit of Single Phase induction motor.
Unit-IV Synchronous machines	**4a**. Explain the working principle of an alternator. **4b**. Differentiate between turbo generator and hydro generators **4c**. Derive e.m.f equation of alternator. **4d**. Determine the voltage regulation of an alternator by various methods. **4e**. Synchronize an alternator with an infinite bus bar. **4f.** Explain different cooling methods used in alternators. **4g**. Connect and operate synchronous motor using proper starting method **4h**. Improve the power factor of the system using synchronous condenser. **4i.** Explain the effect of excitation in a synchronous motor.	**4.1** Construction of Alternator and its types. **4.2** Alternator Operation, Frequency **4.3** A.C. Armature windings, Winding Factors, Numerical **4.4** EMF Equation of Alternator. **4.5** Equivalent Circuit and Phasor Diagram of Alternator. **4.6** Armature Reaction and its effect. **4.7** Voltage Regulation of Alternator Determination of voltage regulation by direct loading method and Synchronous impedance method. **4.8** Parallel Operation of alternator **4.9** Synchronization of alternator with infinite bus bar/ alternator. **4.10** Cooling of an alternator, Applications of alternators. **4.11** Construction and working of synchronous motor and its starting. **4.12** Effect of change in Excitation, V curve of Synchronous motor. **4.13** Hunting and its prevention. **4.14** Synchronous condenser and power factor improvement. **4.15** Applications of Synchronous motors and its comparison with induction motor.

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	Three Phase Transformer	08	4	6	4	14
II	Three phase Induction Motor	14	8	8	7	23
III	Single phase Induction motor	06	4	4	2	10
IV	Synchronous machines	14	8	8	7	23
Total		**42**	**24**	**26**	**20**	**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 evidence for their (student's) portfolio which may be useful for their placement interviews:

a) Present seminar on various topics from course content
b) Prepare nameplate of three-phase transformer, three phase induction motor and alternator.

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/subtopics.
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) Co-relating the importance of content of this course with other courses/ practical applications. (e.g. importance of a content course or whole course related to A.C. Machines, Transmission and Distribution of Electrical Power, Energy Conservation Switchgear and Protection etc. and in practical industrial &/ domestic applications.
f) Introduce E-waste recycling technology among the students.
g) 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 a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about **12-14** ***(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 working model of control wiring of Direct on Line starter. .
b) Make a working model of control wiring of star delta starter with contactors.
c) Make a working model of control wiring of sequence operation of two motors.
d) Make a working model of control wiring of forward reverse of three phase I.M.
e) Make a working model of control wiring of the autotransformer starter.
f) Prepare a chart of different vector groups of three phase transformers.
g) Prepare a chart showing different materials used for various parts of the Polyphase transformer and Polyphase Induction motor.
h) Collect specifications from different manufacturers of Polyphase transformers and prepare a market survey report.
i) Collect specifications from different manufacturers of single-phase Induction motors and prepare a market survey report.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	A textbook of Electrical Technology Volume-II	B. L. Theraja & A.K. Theraja	S. Chand and Co., New Delhi, 23 edition or Latest edition (ISBN : 9788121924405)
2	Principle of Electrical Machines	V.K.Mehta, Rohit Mehta	S.Chand and Co. Ltd, New Delhi ISBN: 9788121930888
3	A textbook of electrical machines	K R Siddhapura D B Raval	Vikas Publishing house PVT LTD ISBN: 9789325975620
4	Electrical Machinery	Dr. P.S.Bimbhra	Khanna Publication. New Delhi ISBN: 9788174091734
5	Electrical Machine	P.K. Mukherjee and S. Chakravorti	Dhanpat Rai Publications (P) Ltd. [2nd revised edition] ISBN: 9788189928667

14. SOFTWARE/LEARNING WEBSITES

WEBSITE

- https://archive.nptel.ac.in/courses/108/105/108105155/
- https://archive.nptel.ac.in/courses/108/105/108105131/
- https://www.electrical4u.com/electrical-engineering-articles/transformer/
- https://electrical4u.in/A.C.-machines/
- https://lectures.gtu.ac.in/
- https://circuitglobe.com/
- https://www.electricaltechnology.org/
- www.vlab.co.in
- https://www.powertransformernews.com
- https://nptel.ac.in/courses/108105017

15. PO-COMPETENCY-CO MAPPING:

Semester I	D.C. Machines and Transformer (Course Code:4330901)						
	POs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design / development of solution	PO4 Engineering Tools, Experimen-tation & Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Manage-ment	PO 7 Life-long learning
Competency	**Maintain various types of A.C. machines and three -phase transformers safely.**						
Course Outcomes CO1 Maintain the working of three phase transformer.	3	2	2	1	2	-	2
CO2 Maintain the working of three phase induction motor.	3	2	2	2	2	-	2
CO3 Use the relevant single phase induction motor for various applications.	3	-	1	1	2	-	-
CO4 Maintain the working of Synchronous machines.	3	2	-	2	-	-	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

S. No.	Name and Designation	Institute	Contact No.	Email
1.	Mr. Ravi J. Dattani Lecturer Electrical Engg.	G.P. Jamnagar	9016593517	rjdele@gmail.com
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