Program Name : **Diploma in Industrial Electronics**

Program Code : **IE**

Semester : **Fourth**

Course Title : **Electrical Machines and Transformers**

Course Code : **22431**

1. RATIONALE

Industrial Electronics Diploma graduates (also called as technologist) have to use various types of electric machines in the industry. This course has been designed considering emerging technologies in electric machines and transformers keeping in view the requirement of industries for the students of diploma in industrial electronics. Besides these, this course develops basic skills to operate and use electric machines, which will help them to discharge role as a supervisor in industrial electronics technology areas and assist in carrying out desired work in the industry.

2. COMPETENCY

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

- **Use different types of electrical machines and transformers.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented companies associated with the above mentioned competency:

a. Use DC motor in industrial electronics applications.
b. Use three phase induction motor in industrial electronics applications.
c. Use Alternators and synchronous motors in industrial electronics applications.
d. Select relevant special motors for in industrial electronics applications.
e. Use transformer for industrial electronics applications.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	-	2	6	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment 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,* **ESE** -*End Semester Examination;* **PA** - *Progressive Assessment*

COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

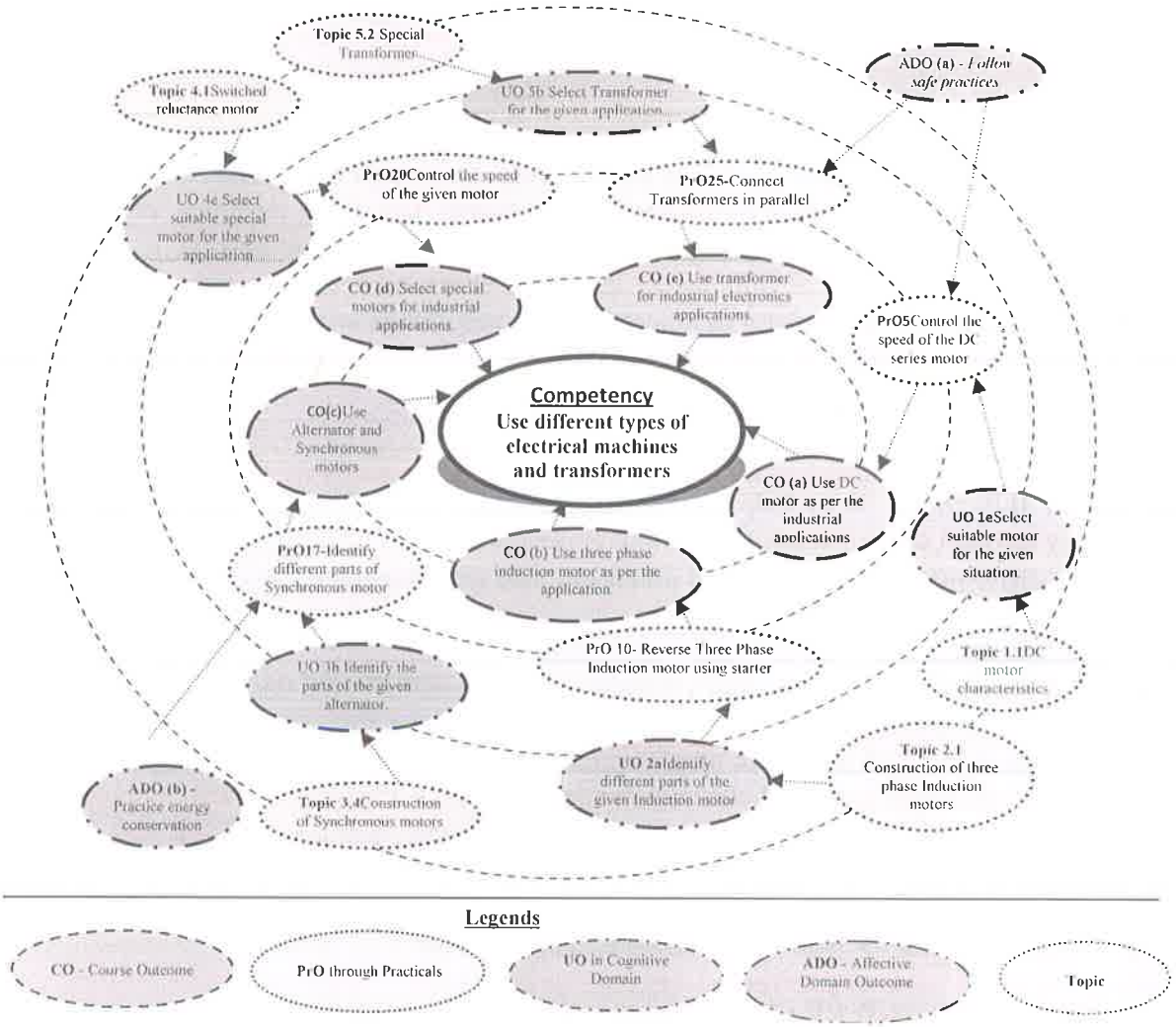

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Identify the parts of given DC motor.	I	02*
2	Start and reverse the given DC motor	I	02
3	Test the performance of given DC motor and draw characteristics.	I	02*
4	Control the speed of the DCshunt motor by Armature voltage control and field flux control method.	I	02*
5	Control the speed of the DC series motor.	I	02
6	Prepare trouble shooting chart of DC shunt motor.	I	02*
7	Prepare trouble shooting chart of DC series motor	I	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
8	Reverse the given three-phase induction motor using relevant starter.	II	02
9	Find out the maximum torque of the Induction motor by plotting torque-slip characteristics	II	02
10	Control the speed of the given three-phase induction motor.	II	02*
11	Find the regulation of alternator by direct loading method	III	02
12	Connect two alternators in parallel using any method of synchronization	III	02
13	Start synchronous motor and measure the speed.	III	02
14	Find out effect of change in excitation at constant load on Synchronous motor	III	02
15	Control the speed of given special motor.	IV	02*
16	Perform load test on single-phase Transformer	V	02
17	Perform OC and SC test on single-phase transformer to find efficiency and regulation	V	02
18	Perform polarity test on single-phase transformer	V	02*
	Total		**36**

Note:

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S.No.	Performance Indicators	Weightage in %
a.	Correctness of circuit connection	30
b.	Ability to select relevant measuring equipments	20
c.	Ability to take observations and interpret result	20
d.	Quality of input and output displayed	10
e.	Answers to sample questions	10
f.	Submit report in time	10
Total		**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safe practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment in healthy condition.
e. Follow ethical practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organizing Level' in 2nd year
- 'Characterizing Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTSREQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO.No.
1	DC motor(cut section)	1,2,3
2	DC shunt motor and series motor with loading arrangement:3kW, 230V DC, 1500RPM,	4,5,6,7
3	Cut section of Three-phase Induction motor	8
4	Autotransformer: 3kVA, 415V, 3-phase	9
5	Three-phase squirrel cage and /or slip ring Induction motor: 3HP, 415V, 1440RPM	10
6	DOL starter: suitable for 3HP, 415V, 1440RPM squirrel cage and /or slip ring Induction motor	10
7	Star-Delta starter: Automatic or semiautomatic for 3HP, 415V, 1440RPM squirrel cage and /or slip ring Induction motor	10
8	Rotor resistance starter: suitable for 3HP, 415V, 1440RPM slip ring Induction motor	10
9	Three phase induction motor with loading arrangement: 3HP, 415V, 1440RPM squirrel cage type (with coupled DC generator-230V, 3kW)	11,12
10	Cut section of Synchronous machine	14
11	5HP, 230V DC shunt motor coupled to 3kW ,415VThree phase Alternator with synchronizing panel:2 sets	11,12
12	Synchronous motor: 5HP, 1500RPM, 415V	13,14
13	AC servomotor (Typical specification) : 0.5 kW,220V,2 A,3000 rpm,1.27 N-m with 1000 ppr encoder	15
14	DC servomotor (Typical specification) : 200 W,75 V,3.3 A, 3000 rpm,6.5 Kg-cm with 1000 ppr encoder.	15
15	Stepper motor: DC , 4 winding, torque- 1.0 Kg-cm, step angle - 1.8°, power - 12V , 0.2 Amp/ phase	15
16	Transformer: 1kVA, single-phase, 230/115 V, open type : Two nos.	16,17,18
17	Rectifier: solid state, Input- 415 V, 3-Phase, AC, Output – 230 V DC regulated, 20 Amp	2,3,4,5

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Major Learning Outcomes (in cognitive domain)	Topics and Sub-topics
Unit – I DC Motors	1a. Interpret the Torque-Armature current, speed-Torque, Speed-Armature current characteristics of the given DC Motor. 1b. Explain with sketches the procedure to control the speed of the given DC Motor. 1c. Describe with sketches the procedure to test the performance of the given DC Motor. 1d. Select suitable braking method as per the requirement with justification. 1e. Select suitable DC Motor for the given situation with justification. 1f. Describe the trouble shooting procedure of the given DC Motor.	1.1 DC shunt motor, series motor, compound motor: characteristics. 1.2 Effect of armature voltage on speed of DC motor. 1.3 Effect of flux on speed of DC motor. 1.4 Application of DC motors 1.5 Losses and Efficiency of DC motor 1.6 Braking: Plugging, Rheostatic, Regenerative 1.7 Specification and Rating of DC motor 1.8 Troubleshooting of DC motor.
Unit– II Three phase induction motors	2a. Identify different parts in the given sketch of the Induction motor. 2b. Explain with sketches the working principle of the given three phase Induction motor. 2c. Find the maximum torque and corresponding slip from the given Torque-slip characteristics. 2d. Explain with sketches the procedure to control the speed of the given Induction motor. 2e. Select relevant starter for the given Induction motor with justification.	2.1 Three phase squirrel cage and slip ring induction motor: Construction 2.2 Generation of rotating magnetic field and working of induction motor 2.3 Concept of synchronous speed and slip, Torque equation, Torque speed characteristics 2.4 Speed control of three phase induction motor 2.5 Starters for three phase induction motors, Braking, Losses and Efficiency, Specification, Troubleshooting
Unit-III Synchronous Machines	3a. Identify the parts in the given sketch of the Alternator. 3b. Calculate voltage regulation of the given alternator for the given loads. 3c. Identify the different parts in the given sketch of the synchronous motor. 3d. Explain with sketches the working principle of the given type of synchronous motor. 3e. Select relevant excitation system for the given type of synchronous motor with justification.	3.1 Alternators: Construction, working and types, EMF equation, Voltage regulation, Rating, Specification, Applications. 3.2 Parallel operation of alternator: Necessity, conditions and advantages. 3.3 Methods of synchronization, 3.4 Synchronous Motors: Construction, working principle, Damper winding, Effect of changing field excitation of motor at constant load, 'V' curves, inverted 'V' curves, effect of

Unit	Major Learning Outcomes (in cognitive domain)	Topics and Sub-topics
	3f. Describe with sketches the braking methods of the given type of synchronous motor.	increased load at constant excitation. 3.6 Braking methods of synchronous motor, Specification ,Applications
Unit-IV Special Motors	4a. Identify different parts in the given sketch of the special motor. 4b. Describe with sketches the construction of the given special motors 4c. Explain with sketches the working principle of the given special motor 4d. Interpret the specifications of the given type of special motor. 4e. Recommend the relevant type of special motor for the given application with justification.	4.1 Switched reluctance motor 4.2 Permanent magnet DC motor 4.3 Brushless DC motor(BLDC) 4.4 Stepper motor: Variable reluctance, permanent magnet, Hybrid. 4.5 Low inertia DC motors. 4.6 Permanent magnet synchronous motor. 4.7 DC servomotors. 4.8 AC servo motors.
Unit –V Transformers	5a. Identify the different parts in the given sketch of the transformer. 5b. Choose the type of transformer for the given application with justification. 5c. Describe with sketches the procedure of OC and SC test of the given type of transformer. 5d. Calculate efficiency and regulation of the given type of transformer for the given load condition. 5e. State Electrical Insulation Classes.	5.1 Transformer: Shell, core, step up, step down, Specifications. 5.2 Special transformer: Isolation, audio frequency, radio frequency, ferrite core transformer and pulse transformer, Specifications. 5.3 Single phase transformer: Load test, Open circuit and short circuit tests, Efficiency and Regulation, Polarity test. 5.4 Electrical Insulation Classes: class: Y, A, E, B, F, H, C Maximum temperature.

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'ApplicationLevel' and above of Bloom's 'Cognitive Domain Taxonomy'*

9. SUGGESTED SPECIFICATION TABLE FORQUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	DC Motors	08	02	02	04	08
II	Three phase induction motors	20	04	06	08	18
III	Synchronous machines	20	04	06	10	20
IV	Special Motors	08	04	04	06	14
V	Transformers	08	02	04	04	10
Total		**64**	**16**	**22**	**32**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may 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 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. Visit to a small motor manufacturing industry and submit the report on the basis of different parameters.
b. Prepare a PowerPoint presentation on the working of DC motor, Induction motor, Synchronous motor, Special motors.
c. Make a market survey of different electrical machines and submit the report on the basis of following.
   - Type of machine
   - Manufacturer
   - Name plate details
   - Applications
d. Visit a nearby Transformer manufacturing company; check how different routine tests are carried out and submit report on it.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the LOs/COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Guide student(s) in undertaking micro-projects.

f. Demonstrate safety practice thoroughly before students start working in laboratory
g. Encourage students to refer different websites to have deeper understanding of the subject.
h. Encourage students to observe various animated videos concerning the construction and working of different electrical machines.
i. Observe continuously and monitor the performance of students in Lab.

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 are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, 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 total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs. Micro project report may be of four to five pages.

Suggestive lists of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. **DC motor:** Dissemble and assemble any Permanent Magnet DC motor and write a report on its construction.
b. **Three phase Induction motor:**
   - Visit nearby industry to observe the operational problems, causes and their remedies.
   - Visit nearby small scale industry to collect the specifications and tabulate types of induction motors along with the application.
c. **Synchronous machines**:
   - Prepare a PowerPoint presentation elaborating the application of synchronous machines.
   - Prepare a PowerPoint presentation detailing the constructional features of Alternator.
d. **Special Motors** :
   - Dissemble and assemble stepper motor and write a report on its construction.
   - Build a small toy robot using servomotor.
e. **Transformers**:
   - Visit nearby distribution substations and prepare a report of the specifications of transformers used.
   - Any other micro-projects suggested by subject faculty on similar line.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Principles of Electrical Machines	Mehta,V.K.and Mehta,Rohit	S.Chand and Co.Pvt. Ltd.,New Delhi,2016, ISBN:978-8121921916.
2	Electrical Technology Vol. II	Theraja, B.L. and Theraja ,A.K.	BPB Publications, New Delhi 2016, ISBN:978-8183331630 .
3	Electric Machinery and Transformers	Bhag, Guru Huseyin, Hiziroglu	Oxford University Press, New Delhi ISBN: 978-0198089827.
4	Electrical Machines	Ghosh,Samarajit	Pearson Education India ,New Delhi 2005, ISBN : 978-8131705094.
5	Electrical Machines	Deshpande, M.V.	PHI Learning Pvt. Ltd., New Delhi 2011,ISBN: 978-8120340268.
6	Electrical Machinery	Bimbhara, P.S.	Khanna Publishers, New Delhi 2011, ISBN: 978-8174091734.

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a. www.nptel.ac.in/courses/106105085/4
b. www.electricaleasy.com/2014/01
c. www.electrical-engineering-portal.com/