Program Name : **Diploma in Industrial Electronics**

Program Code : **IE**

Semester : **Fourth**

Course Title : **Applied Power Electronics**

Course Code : **22430**

1. RATIONALE

Day by day the enhanced development in the industry is dynamic. The role of Diploma pass outs (also called as technologists) in the industry has changed over the years. Selection and applications of Power electronic circuits play a major role in nearly all industries by virtue of their performance, for which study of these circuits is very essential for the industrial electronic technician to handle and maintain them. Hence they must be well conversant with the power electronic circuits and their applications. This course aims to impart the knowledge and skills related to handling in terms of the use and maintenance of these circuits.

2. COMPETENCY

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

- **Maintain power electronic circuits used in Industries.**

3. COURSE OUTCOMES (COs)

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

a. Use SCR as Phase Controlled Rectifiers.
b. Maintain triggering circuits for Phase-Controlled Rectifiers.
c. Maintain the functioning of the different types of chopper circuits.
d. Maintain the functioning of the different types of Inverters.
e. Maintain the functioning of the different types of Dual Converters and Cycloconverters.
f. Simulate power electronic circuits.

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*

5. 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.

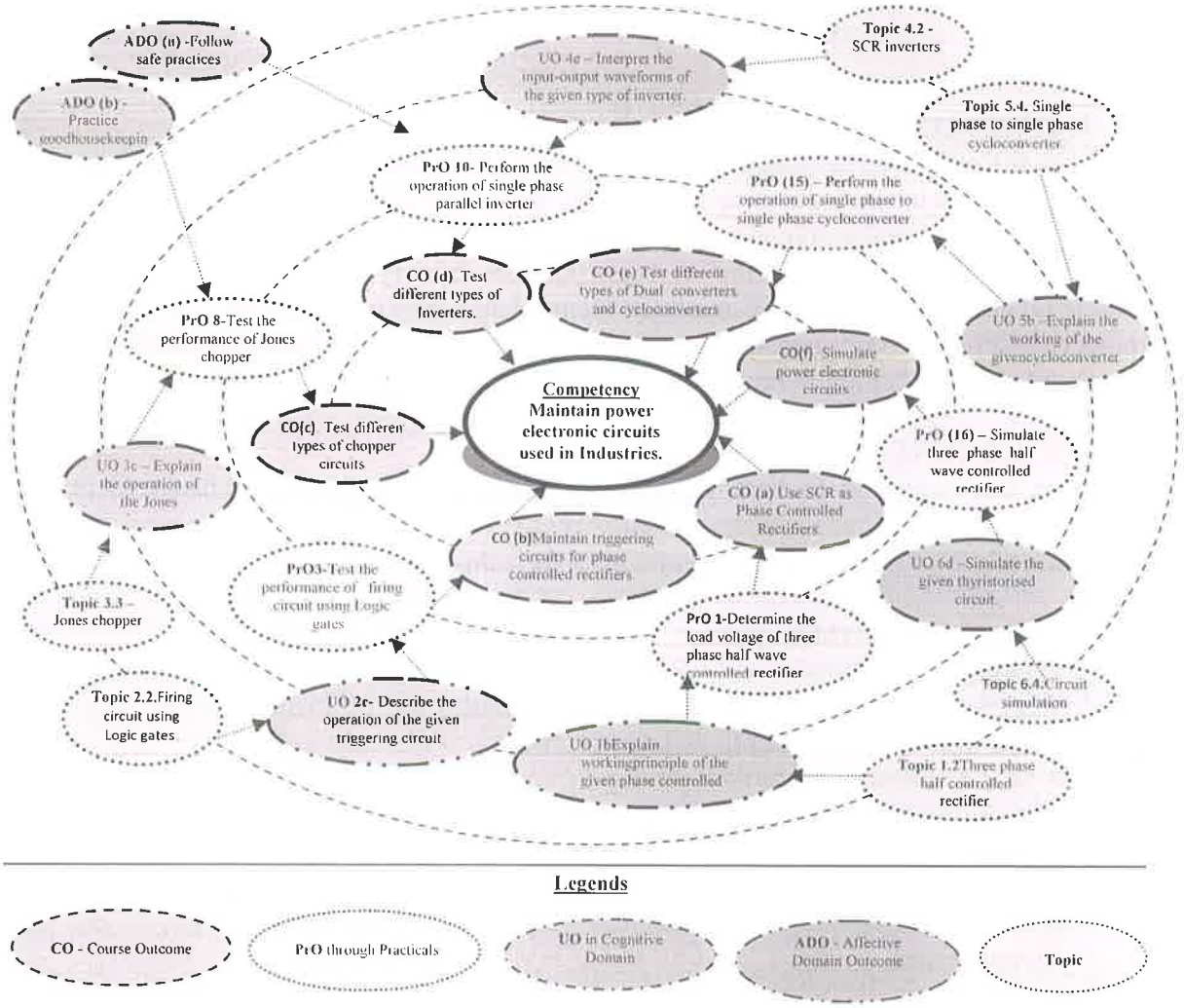

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practical 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	Determine the load voltage of three phase half wave controlled rectifier for R and R-L load with output waveform.	I	02*
2	Determine the load voltage of three phase full wave controlled rectifier for R and R-L load with output waveform.	I	02
3	Troubleshoot Transistorized firing circuit.	II	02*
4	Troubleshoot firing circuit using logic gates.	II	02*
5	Troubleshoot PLL oscillator pulse timing control firing circuit and	II	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	calculate the frequency of output pulses.		
6	Test the performance of step-up chopper.	III	02
7	Test the performance of step-down chopper.	III	02*
8	Test the performance of Morgan or Jones chopper.	III	02
9	Check the performance of the single phase series inverter.	III	02*
10	Perform the operation of single phase parallel inverter, observe the output voltage waveform and measure the load voltage.	IV	02
11	Check the performance of the single phase bridge inverter.	IV	02
12	Check the performance of the McMurray half bridge inverter.	IV	02
13	Check the performance of the circulatory current free modeOR circulatory current mode dual converter.	V	02
14	Check the performance of the single-phase to single-phase cycloconverter.	V	02*
15	Check the performance of the single-phase to three-phase cycloconverter.	V	02
16	Simulate three-phase half-wave controlled rectifier using open source software.	V	02
17	Simulate the given chopper circuit in an open source software	VI	02*
18	Simulate the given Thyristorised circuit in an open source software.	VI	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 diagrams	40
b.	Troubleshooting ability	20
c.	Quality of input and output displayed (observing , measuring, plotting and analysis of graph/characteristics/parameters)	20
d.	Answer to sample questions	10
e.	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.

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	Digital Multimeter: 3½ digit, 0-800Volts,0-10A Micro-ammeters:0-100μA	All
2	Dual channel CRO: 25 MHz with isolation transformer OR Power scope , Attenuator probe for CRO	
3	DC Regulated Power Supply: 0-30 V,0-2 A,0-300 V,0- 10 A,	1 to 8
4	Three phase/single phase AC supply with 440 V/230 V , 10 A.	9 to 12
5	Experimental Thyristorised kits related to phase controlled rectifier, Choppers, Inverter, Dual converters, Cycloconverter and connecting cords.	All
6	Resistive load:(Lamp-100W,Heater coil- 500W), Resistive-Inductive load: (single phase fractional ¼ HP, 60W/75W Motor), as per requirement of the load.	1,2
7	Digital Tachometer with Opto-Coupler (Photo tachometer): 4000 RPM	1,2
8	Open Source Software free/License version	3,4

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	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Phase Controlled Rectifier	1a. Describe with sketches the function of the power electronic devices. 1b. Explain with sketches the working principle of the given types of phase controlled rectifier. 1c. Describe with sketches the functions of the given type of phase controlled circuits. 1d. Interpret the output voltage and current waveforms for the	1.1 Single-phase, three phase and higher phase Controlled Rectifiers: Comparison 1.2 Three phase half wave controlled rectifier with resistive and inductive load. 1.3 Three phase half and full controlled bridge rectifier with resistive and inductive load. 1.4 Six pulse half wave or double star controlled rectifier with resistive and inductive load, Twelve and higher

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	given type of bridge rectifier with given load. 1e. Select relevant SCRs for the given phase controlled rectifiers with justification.	pulse circuits. 1.5 Simple numerical to calculate load voltage and current for all above circuits.
Unit– II Triggering circuits for Phase-Controlled Rectifiers	2a. Select the relevant triggering circuits for the given application with justification. 2b. Describe with sketches the given thyristor triggering device. 2c. Describe with sketches the operation of the given triggering circuit. 2d. Interpret waveforms of the given type of pulse timing controlled firing circuit. 2e. Select relevant triggering methods for the given application with justification. 2f. Describe with sketches the procedure to troubleshoot given Phase-Controlled Rectifiers	Circuit and description of following triggering circuits : 2.1 Inverse cosine method, magnetic firing circuit, solid state firing circuit 2.2 UJT firing circuit, Transistorized firing circuit, Firing circuits using logic gates 2.3 Three phase firing circuits, Three phase pulse forming circuit, Transistorized three phase firing circuit. 2.4 Integral control, PLL oscillator pulse timing controlled firing circuit, End-stop control
Unit– III Choppers	3a. Classify the type of choppers in the given charts. 3b. Compare with sketches the working of the given type of choppers. 3c. Interpret the output wave forms of the given choppers. 3d. Explain the effects of saturable core reactor in the given type of chopper. 3e. Describe with sketches the procedure to troubleshoot the given chopper circuits.	3.1 AC and DC choppers using MOSFET: Concept 3.2 Classification-step-up, step-down, single quadrant, double quadrant, four quadrants with circuits and related waveforms. 3.3 Morgan chopper, Jones chopper with circuits and related waveforms. 3.4 Morgan and Jones choppers: Merits, limitations and Applications.
Unit-IV Inverters	4a. Explain with sketches the function of the given types of Transistor inverter. 4b. Calculate the output voltage and current for the given parameters of the inverter. 4c. Interpret the input-output waveforms of the given type of	4.1 Classification: Voltage-driven and current-driven inverter. 4.2 Transistor/IGBT inverter, SCR inverters: Single-phase, parallel capacitor inverter, single-phase series inverter, single phase bridge inverter, description with circuits and waveforms.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	inverter. 4d. Describe with sketches the effects of the magnetically coupled inductor in the given McMurray-Bedford inverter with sketches. 4e. Describe with sketches the procedure to troubleshoot the given inverters.	4.3 Three-phase bridge inverter description with circuits and waveforms. 4.4 McMurray half bridge and full bridge inverters description with circuits and waveforms. 4.5 McMurray-Bedford inverter description with circuits and waveforms and applications. 4.6 Simple numerical to calculate load voltage and current for all circuits.
Unit –V Dual converters and Cycloconverters	5a. Explain with sketches the working of the given type of dual converters. 5b. Explain with sketches the working of the given type of Cycloconverter. 5c. Select Dual converter and Cycloconverter on the basis of applications with justification. 5d. Interpret the waveforms of the given type of Cycloconverter. 5e. Describe with sketches the procedure to troubleshoot the given Dual Converters/ Cycloconverters.	5.1 Dual converters: Principle and types. 5.2 Circulatory current free mode, circulatory current mode dual converters. 5.3 Cycloconverter: Principle and types. 5.4 Single phase to single phase and three phase Cycloconverter: operation with circuit and waveforms. 5.5 Circuits using MOSFET/IGBT
Unit –VI Thyristor mounting techniques, Heat sinks and Simulation	6a. Select the relevant mounting technique for the given rating of Thyristor with justification 6b. Describe with sketches the working of the given type of thyristor protection circuit. 6c. Select the relevant heat sink for the given rating of Thyristor with justification. 6d. Describe with sketches the procedure to troubleshoot the given heat sinks/associated circuits.	6.1 Thyristors: Ratings. 6.2 Overall protections of Thyristor and mounting techniques: Lead mounting, Stud mounting, Bolt-down mounting, Press fit mounting, Press-pack mounting. 6.3 Heat sink: Air cooled, liquid cooled, Hockey puck. 6.4 Circuit simulation using open source software: Controlled rectifiers, Choppers, Inverters, Dual converters, Cycloconverters (Any two circuits)

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' 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	Phase Controlled Rectifier	12	02	06	08	16
II	Triggering circuits for Phase-Controlled Rectifiers	10	02	04	04	10
III	Choppers	10	02	04	06	12
IV	Inverters	14	02	06	08	16
V	Dual converters and Cycloconverters	12	02	04	04	10
VI	Thyristor mounting techniques , Heat sinks and simulation	06	02	02	02	06
Total		**64**	**12**	**26**	**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 the nearby power electronics based industry and observe the processes.
b. Take the market survey of various specifications of available Thyristors and submit the report of their uses.
c. Survey the market and submit the report of available phase controlled rectifiers, choppers, inverters, dual and Cycloconverters and Heat sinks.
d. Survey the local market and identify the different triggering circuits for phase controlled rectifiers, inverters and Thyristors, available in the market.

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 students thoroughly before they start doing the practice.

g. Encourage students to refer different websites to have deeper understanding of the subject.
h. Observe continuously and monitor the performance of students in Lab work and micro project related activities.
i. Use simulation software's for demonstrating the performance of different Thyristors.

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. **Phase Controlled Rectifier:** Build and test the circuit of three phase half wave controlled rectifier.
b. **Triggering circuits for Phase-Controlled Rectifiers:** Build and test the triggering circuit using PLL for any type of inverter.
c. **Choppers:** Build and test the Jones chopper circuit.ofi) PUT and ii) UJT relaxation oscillator.
d. **Inverters: Construct** and test a circuit of transistorized inverter and simulate using MATLAB.
e. **Dual converters and Cycloconverters:** Build and test circuit of single phase to single phase Cycloconverter.
f. **Thyristor mounting techniques and Heat sinks** : Select and use air cooled type heat sink for Thyristors used in any above Micro Project or the micro project suggested by subject teacher.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Modern Power Electronics	Sen,P.C.	S.Chand& Company, New Delhi; 2013, ISBN: 978-8121924252.
2	Thyristors: Theory and Applications	Sugandhi, R. K. and Sugandhi, K. K.	New Age International Publishers, New Delhi, 2009, ISBN:978-0852268520.
3	Power Electronics and its Applications	Jain, Alok	Penram International Publishing Mumbai, 2006; ISBN: 978-8187972228.

S. No.	Title of Book	Author	Publication
4	Power Electronics Circuits Devices and Applications	Rashid , Muhammad H.	Pearson Education India, Noida, 2014; ISBN: 978-0133125900.
5	Power Electronics	Singh, M. D. and Khanchandani, K.B.	McGraw Hill Publishing Co. Ltd, New Delhi, 2008 ISBN: 978-0070583894.

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a. www.nptel.ac.in/courses/108101038
b. www.ee.iitb.ac.in/~apel/
c. www.tutorialspoint.com/power_electronics/
d. MATLAB: Software for Power Electronics Simulation
e. www.nptelvideos.in/2012/11/power-electronics.html
f. www.electrical4u.com/thyristor-triggering/
g. www.powerguru.org/power-electronics-videos/
h. www.youtube.com/watch?v=1Auay7ja2oY


MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION MUMBAI