Program Name : **Electrical Engineering Program Group & Diploma in Industrial Electronics**

Program Code : **EE/EP/EU/IE**

Semester : **Third**

Course Title : **Fundamentals of Power Electronics**

Course Code : **22326**

1. RATIONALE

Day by day the enhanced development in the industry is dynamic. The role of technicians (Diploma engineers) has changed over the years. Power electronic devices and circuits play a major role in nearly all industries. By virtue of their operating characteristics; for which study of these devices is very essential for the electrical and electronic technician to handle them. Hence they must be well conversant with the power electronic devices and their applications. This course aims to impart the knowledge and skills related to handling in terms of the applications and maintenance of these devices.

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 the proper functioning of power electronic devices.**

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. Select power electronic devices for specific applications.
b. Maintain the performance of Thyristors.
c. Troubleshoot turn-on and turn-off circuits of Thyristors.
d. Maintain phase controlled rectifiers.
e. Maintain industrial control 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.

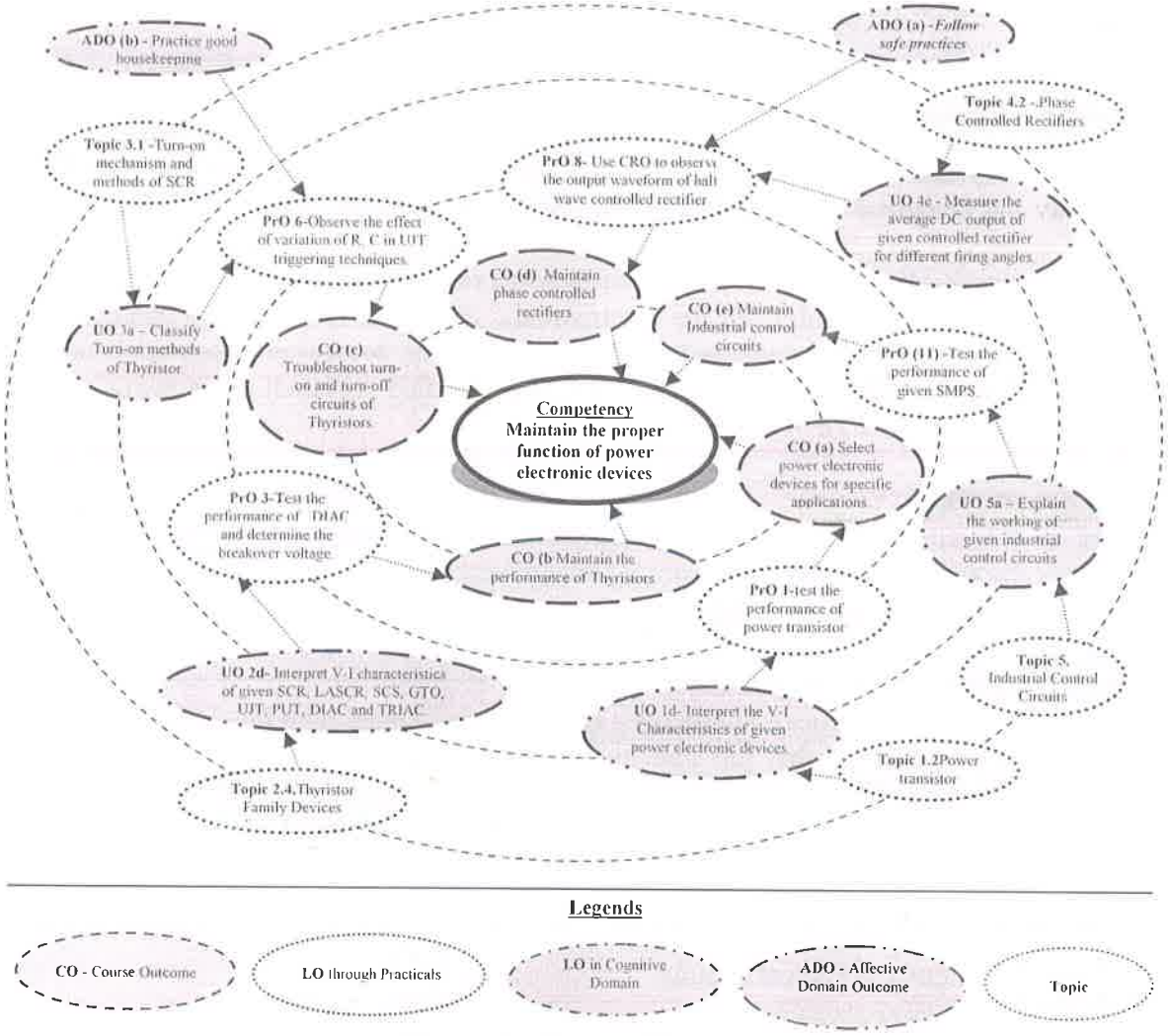

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The 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	Test the proper functioning of power transistor.	I	02*
2	Test the proper functioning of IGBT.	I	02
3	Test the proper functioning of DIAC to determine the break over voltage.	II	02*
4	Determine the latching current and holding current using V-I characteristics of SCR.	II	02
5	Test the variation of R,C in R and RC triggering circuits on firing angle of SCR.	III	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
6	Test the effect of variation of R, C in UJT triggering technique.	III	02
7	Perform the operation of Class – A, B, C, turn off circuits.	III	02
8	Perform the operation of Class –D, E, F turn off circuits.	III	02
9	Use CRO to observe the output waveform of half wave controlled rectifier with resistive load and determine the load voltage.	IV	02*
10	Draw the output waveform of Full wave controlled rectifier with R load, RL load, freewheeling diode and determine the load voltage.	IV	02
11	Determine the firing angle using DIAC and TRIAC phase controlled circuit on output power under different loads such as lamp , motor or heater	V	02*
12	Simulate above firing angle control on SCILAB software	V	02*
13	Test the performance of given SMPS.	V	02
14	Test the performance of given UPS	V	02
15	Troubleshoot the Burglar's alarm.	V	02
16	Troubleshoot the Emergency light system.	V	02
17	Troubleshoot the Speed control system.	V	02
18	Troubleshoot the Temperature control system.	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 diagrams	40
b.	Troubleshooting ability	20
c.	Quality of input and output displayed (observing , measuring, plotting and analysis of graph/characteristics/parameters)	10
d.	Answer to sample questions	20
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 safety 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
- 'Organising Level' in 2nd year
- 'Characterising 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. S. No.
1	Digital Multimeter: 3and1/2 digit 0-800Volts,0-10A , Micro-ammeters:0-100uA	All
2	Dual channel CRO: 25 MHz with isolation transformer OR Power scope , Attenuator probe for CRO	All
3	SCR, LASCR, SCS, GTO, UJT, PUT, DIAC and TRIAC – 5 each	All
4	DC Regulated Power Supply: 0-300 V,0- 10 A	1 to 7
5	Experimental kits related to Thyristors, connecting cords	All
6	Resistive load: (Lamp100W, heater coil 500W), Resistive-Inductive load: (single phase fractional ¼ HP, 60W,75W Motor)	8,9,10
7	Digital Tachometer with opto-coupler (phototechometer) 4000 RPM	15
8	SCILAB Software	10

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 Power Electronic Devices	1a. Explain with sketches the working of the given power electronic device(s). 1b. Describe with sketches the construction of the given power transistor. 1c. Interpret the V-I characteristics of the given power electronic device. 1d. Select suitable power electronic device for given situation with justification. 1e. Suggest suitable IGBT for given application. 1f. Describe the procedure to troubleshoot the given power	1.1 Power electronic devices 1.2 Power transistor: construction, working principle, V-I characteristics and uses. 1.3 IGBT: Construction, working principle, V-I characteristics and uses. 1.4 Concept of single electron transistor (SET) - aspects of Nano-technology.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	electronic device (s)	
Unit– II Thyristor Family Devices	2a. Classify given power semiconductor devices 2b. Identify given thyristors and triggering devices with justification 2c. Explain with sketches the working of the given type of thyristor 2d. Describe the procedure to troubleshoot the given type of thyristor.	2.1 SCR: construction, two transistor analogy, types, working and V-I characteristics. 2.2 SCR mounting and cooling. 2.3 Types of Thyristors: SCR, LASCR, SCS, GTO, UJT, PUT, DIAC and TRIAC 2.4 Thyristor family devices: symbol, construction, operating principle and V-I characteristics. 2.5 Protection circuits: over-voltage, over-current, Snubber, Crowbar.
Unit– III Turn-on and Turn-off Methods of Thyristors	3a. Explain with sketches the working of the given type of triggering circuit. 3b. Explain the role of pulse transformer in given triggering circuits. 3c. Explain with sketches the working of the given type of turn-on method. 3d. Describe the procedure to troubleshoot the given type of turn-on method. 3e. Explain with sketches the working of the given type of turn-off method. 3f. Describe the procedure to troubleshoot the given type of turn-off method.	3.1 SCR Turn-ON methods: High Voltage thermal triggering, Illumination triggering, dv/dt triggering, Gate triggering. 3.2 Gate trigger circuits – Resistance and Resistance-Capacitance circuits. 3.3 SCR triggering using UJT, PUT: Relaxation Oscillator and Synchronized UJT circuit. 3.4 Pulse transformer and opto-coupler based triggering. 3.5 SCR Turn-OFF methods: Class A- Series resonant commutation circuit, Class B-Shunt resonant commutation circuit, Class C-Complimentary Symmetry commutation circuit, Class D –Auxiliary commutation, Class E- External pulse commutation , Class F- Line or natural commutation.
Unit-IV Phase Controlled Rectifiers	4a. Explain with sketches the operation of the phase control. 4b. Calculate the average voltage of the given controlled rectifier. 4c. Interpret / draw the input-output waveforms of the power electronic circuit. 4d. Explain with sketches the operation of the given bridge configuration. 4e. Describe the procedure to troubleshoot the given phase controlled rectifier(s) circuit.	4.1 Phase control: firing angle, conduction angle. 4.2 Single phase half controlled, full controlled and midpoint controlled rectifier with R, RL load: Circuit diagram, working, input- output waveforms, equations for DC output and effect of freewheeling diode. 4.3 Different configurations of bridge controlled rectifiers: Full bridge, half bridge with common anode, common cathode, SCRs in one arm and diodes in another arm.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit –V Industrial Control Circuits	5a. Explain with sketches the working of given industrial control circuits. 5b. Describe the troubleshooting procedure of the given type of SMPS. 5c. Describe the troubleshooting procedure of the given type of online and offline UPS. 5d. Explain with sketches the working of the given type of SCR-based circuit breaker. 5e. Describe the procedure to troubleshoot phase controlled rectifier(s).	5.1 Applications: Burglar's alarm system, Battery charger using SCR, Emergency light system, Temperature controller using SCR and; Illumination control / fan speed control using TRIAC. 5.2 SMPS. 5.3 UPS: Offline and Online 5.4 SCR based AC and DC circuit breakers.

***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	Power Electronic Devices	08	01	02	03	06
II	Thyristor Family Devices	16	03	06	08	17
III	Turn-on and Turn-off Methods of Thyristors	14	03	04	07	14
IV	Phase Controlled Rectifiers	18	02	06	10	18
V	Industrial Control Circuits.	08	02	05	08	15
Total		**64**	**11**	**23**	**36**	**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 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 circuit breakers, SMPS and different types of UPSs.

d. Survey the local market and identify the different types of fan regulator 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 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 COs through classroom presentations (see implementation guideline for details).
a. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
b. Guide student(s) in undertaking micro-projects
c. 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.

A suggestive list of micro-projects is given here. Similar micro-projects could be added by the concerned faculty:

a. **Power Electronic Devices:** Build and test the circuit of electronic switch using power transistor and control the operation with wireless devices.
b. **Thyristor family devices:** Build and test the circuit of digital logic gates : AND , OR , NOT , NAND , NOR , Ex-OR , Ex-NOR using SCRs (any four).
c. **Turn-on and Turn-off methods:** Build and test the circuit of
   i) PUT and
   ii) UJT relaxation oscillator.
d. **Phase controlled rectifier:** Construct and test a circuit of fractional HP DC motor speed control (Open Loop) .
e. **Industrial control circuits:** Build and test circuit of
   i) fan regulator using TRIAC – DIAC or
   ii) SCR lamp flasher.
f. Any Other Micro Project: based on the curriculum suggested by the Teacher.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	An Introduction to Thyristors and their applications	Ramamoorty M.	East-West Press Pvt. Ltd., New Delhi, 1980, ISBN: 8185336679.
2	Thyristors: Theory and Applications	Sugandhi, Rajendra Kumar and Sugandhi, Krishna Kumar.	New Age International (P) ltd. Publishers, New Delhi, 2009, ISBN: 978-0-85226-852-0.
3	Fundamentals of Power Electronics	Bhattacharya, S.K.	Vikas Publishing House Pvt. Ltd. Noida. 2009,ISBN: 978-8125918530.
4	Power Electronics and its Applications	Jain, Alok	Penram International Publishing (India) Pvt. Ltd, Mumbai, 2006 ISBN: 978-8187972228.
5	Power Electronics Circuits Devices and Applications	Rashid , Muhammad, H.	Pearson Education India, Noida, 2014 ISBN: 978-0133125900.
6	Power Electronics	Singh, M. D. and Khanchandani, K.B.	Tata McGraw Hill Publishing Co. Ltd, New Delhi, 2008 ISBN: 9780070583894.
7	Industrial Electronics: A Text –Lab Manual	Zbar, Paul B.	McGraw Hill Publishing Co. Ltd. , New Delhi, 1990 ISBN: 978-0070728226.
8	SCR Manual	Grafham D.R.	General Electric Co., 1982 ISBN: 978-0137967711.
9	Understanding the Nanotechnology Revolution	Edward L Wolf and Manasa Mediconda	Wiley- VCH verlag GmbH and Co. kGaA, ISBN: 978-3527411092

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a. www.nptel.ac.in/courses/108101038
b. www.ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-334-power-electronics-spring-2007
c. SCILab
d. www.nptelvideos.in/2012/11/power-electronics.html
e. www.coursera.org/learn/power-electronics
f. www.powerguru.org/power-electronics-videos/
g. www.youtube.com/watch?v=1Auay7ja2oY