Program Name : Electrical Engineering Program Group

Program Code : EE/EP/EU

Semester : Fifth

Course Title : Power Electronic Applications (Elective)

Course Code : 22527

1.RATIONALE With rapid development in modern technology, power electronic devices and circuits are integral part of control system. As an electrical engineer it is necessary to exercise control on power given to the machine to control its speed, voltage and current to suit the requirement of various loads. It includes application of power devices such as converters, inverters, induction heating, dielectric heating, electric welding etc. This course aims to impart the knowledge and skills related to handling in terms of the use and maintenance of power electronic devices and 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. Select power electronic devices for specific application(s).
b. Maintain functioning of the different types of chopper circuits.
c. Maintain functioning of the different types of inverters.
d. Maintain functioning of the different types of dual converters and cyclo-converters.
e. Use power electronic devices in various industrial 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
3	-	2	5	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.

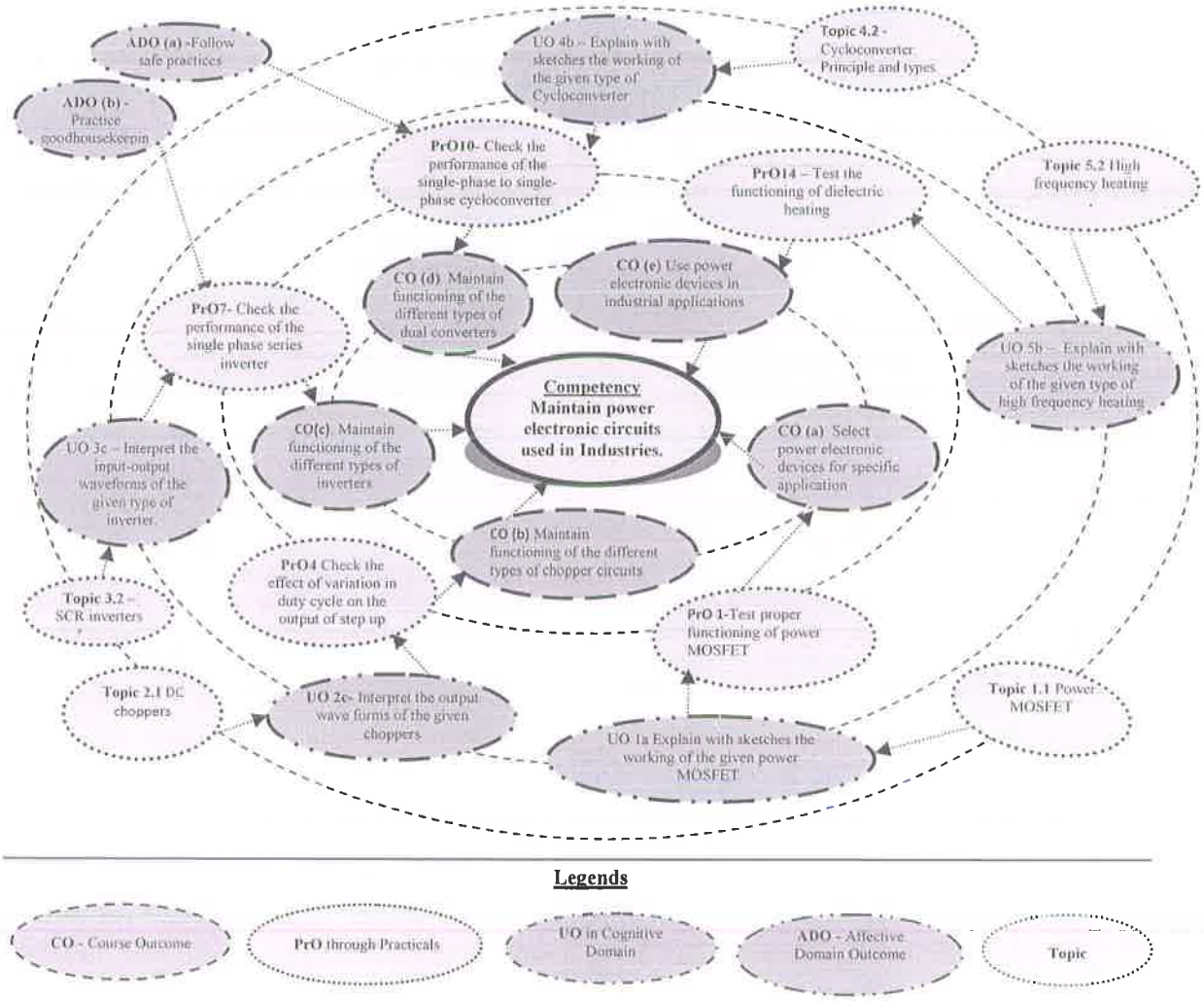

Figure 1 - Course Map

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 proper functioning of power MOSFET.	I	02*
2	Test proper functioning of MCT.	I	02*
3	Test proper functioning of SIT.	I	02
4	Check the effect of variation in duty cycle on the output of step up chopper.	II	02*
5	Check the effect of variation in duty cycle on the output of step down chopper.	II	02*
6	Simulate the given chopper circuit in an open source software.	II	02*
7	Check the performance of the single phase series inverter.	III	02*
8	Perform the operation of single phase parallel inverter, observe the output voltage waveform and measure the load voltage.	III	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
9	Check the performance of the McMurray half bridge inverter.	III	02
10	Check the performance of the single-phase to single-phase cycloconverter.	IV	02*
11	Check the performance of the blocking mode dual converter.	IV	02
12	Simulate the given cycloconverter circuit in an open source software.	IV	02
13	Test the functioning of induction heating.	V	02*
14	Test the functioning of dielectric heating.	V	02*
15	Test the functioning of resistance welding.	V	02*
16	Test the functioning of ac relay type voltage stabilizer.	V	02*
	Total		**32**

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 12or more practical need to be performed, out16 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
- '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. 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 10
4	Single phase AC supply with 230 V , 10 A.	All
5	Experimental Thyristorised kits related to Choppers, Inverter, Dual converters, Cycloconverter, induction heating, dielectric heating 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.	4 to 12
7	Open Source Software free/License version	6,12

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 Modern power devices	1a. Explain with sketches the working of the given power MOSFET&IGBT. 1b. Interpret the V-I characteristics of the given power electronic device. 1c. Describe the procedure to select suitable power electronic device for given situation with justification. 1d. Describe the procedure to trouble-shoot the given power electronic devices.	1.1 Power MOSFET& IGBT: construction, working, transfer characteristics, output characteristics, and application. 1.2 SCR construction, working, transfer characteristics, output characteristics, and application 1.3 SIT: construction, working, VI characteristics, and application. 1.4 MCT: construction, working, VI characteristics, and application. 1.5 FCT: construction, working, VI characteristics, and application.
Unit– II Chopper circuits	2a. Classify the type of choppers in the given chart. 2b. Compare with sketches the working of the given type of choppers. 2c. Interpret the output wave forms of the given choppers. 2d. Explain the effects of saturable core reactor in the given type of dual converter. 2e. Describe with sketches the	2.1 DC choppers: Types 2.2 Control strategies of chopper 2.3 Single quadrant, two quadrant, four quadrant chopper (circuit diagram, operation with waveforms) 2.4 Morgan chopper: circuit diagram, operation with waveforms. 2.5 Jones choppers: circuit diagram, operation with waveforms.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	procedure to troubleshoot the given chopper circuits.	
Unit– III Inverter circuits	3a. Explain with sketches the function of the given type of inverter. 3b. Calculate the output voltage and current for the given parameters of the inverter. 3c. Interpret the input-output waveforms of the given type of inverter. 3d. Describe with sketches the effects of the magnetically coupled inductor in the given McMurray-Bedford inverter with sketches. 3e. Describe with sketches the procedure to troubleshoot the given inverters.	3.1 Classification: Voltage-driven and current-driven inverter. 3.2 Transistor inverter, SCR inverters: Single-phase parallel inverter, single-phase series inverter, single phase bridge inverter description with circuits and waveforms. 3.3 Three-phase bridge inverter description with circuits and waveforms. 3.4 McMurray half bridge and full bridge inverters description with circuits and waveforms. 3.5 McMurray-Bedford inverter description with circuits and waveforms and applications.
Unit-IV Dual converters and Cycloconverters	4a. Explain with sketches the working of the given type of dual converters. 4b. Explain with sketches the working of the given type of Cyclo-converter. 4c. Select Dual converter and Cyclo-converter on the basis of applications with justification. 4d. Interpret the waveforms of the given type of Cyclo-converter.	4.1 Dual converters: Principle and types. 4.2 Circulatory current free mode, circulatory current mode dual converters. 4.3 Cyclo-converter: Principle and types. 4.4 Single phase to single phase and three phase Cyclo-converter: operation with circuit and waveforms.
Unit –V Industrial Applications of Power devices	5a. Explain with sketches the working of the given type of static circuit breaker. 5b. Explain with sketches the working of the given type of high frequency heating. 5c. Explain with sketches the working of the given type of AC voltage stabilizer. 5d. Describe speed control method for given servomotor. 5e. Simulation of chopper, Inverter and Cyclo-converter circuits.	5.1 Static circuit breaker(DC and AC). 5.2 High frequency heating: induction heating and dielectric heating control. 5.3 Electric welding control. 5.4 Battery charger control. 5.5 AC voltage stabilizer type: servo , solid state and relay. 5.6 Static VAR compensation system. 5.7 Closed loop speed control method for DC and AC servo motor. 5.8 Simulation: chopper, Inverter and Cyclo-converter 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	Modern power devices	06	02	02	04	08
II	Chopper circuits	10	02	06	08	16
III	Inverter circuits	10	02	06	08	16
IV	Dual converters and Cyclo converters	10	02	08	04	14
V	Industrial applications of power devices.	12	04	04	08	16
Total		**48**	**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 power devices and submit the report.
c. Survey the market and submit the report of availablechoppers,inverters,dual converters and Cycloconverters.
d. Use internet to submit the report of various industrial control circuits.

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 to the student 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 power devices.

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

a. **Automatic street light :** Build and test the circuit of automatic street light.
b. **Choppers:** Build and test the Jones chopper circuit.
c. **Inverters :** Construct and test a circuit of thyristorised inverter and simulate using Scilab.
d. **Dual converters and Cyclo-converters:** Build and test the circuit of three phase to single phase Cyclo-converter.
e. **Speed control of AC/DC motor**: Build and test the speed control of DC motor using power electronic devices.

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.
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.
6	Power Electronics	Bimbhra P.S.	Khanna Publication

S. No.	Title of Book	Author	Publication
			New Delhi,2008 ISBN-13:978-8174092793

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