Program Name : **Diploma in Industrial Electronics**

Program Code : **IE**

Semester : **Fifth**

Course Title : **Power Electronics in Wind and Solar Systems**

Course Code : **22540**

1. RATIONALE

The rapid increase in global energy consumption and the impact of greenhouse gas emissions has accelerated the transition towards wind and solar energy sources. High power electronic systems, affordable high performance devices, and smart energy management principles are deemed to be an integral part of renewable, green and efficient energy systems. This course is intended to develop the competency of maintaining the power electronic circuits used in wind and solar power systems. The purpose of power electronic interface is to regulate the voltage, frequency, and power to make energy useable at low cost as per requirement.

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 power electronic circuits used in wind and solar power plants.**

3. COURSE OUTCOMES (COs)

The theory and 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. Maintain the functioning of the various components of wind power plants.
b. Interpret the power flow in wind power plants.
c. Maintain power electronic devices and circuits of wind power plants.
d. Maintain the functioning of the various components of solar PV power plants.
e. Maintain the power electronic devices and circuits of solar PV power plants.

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.

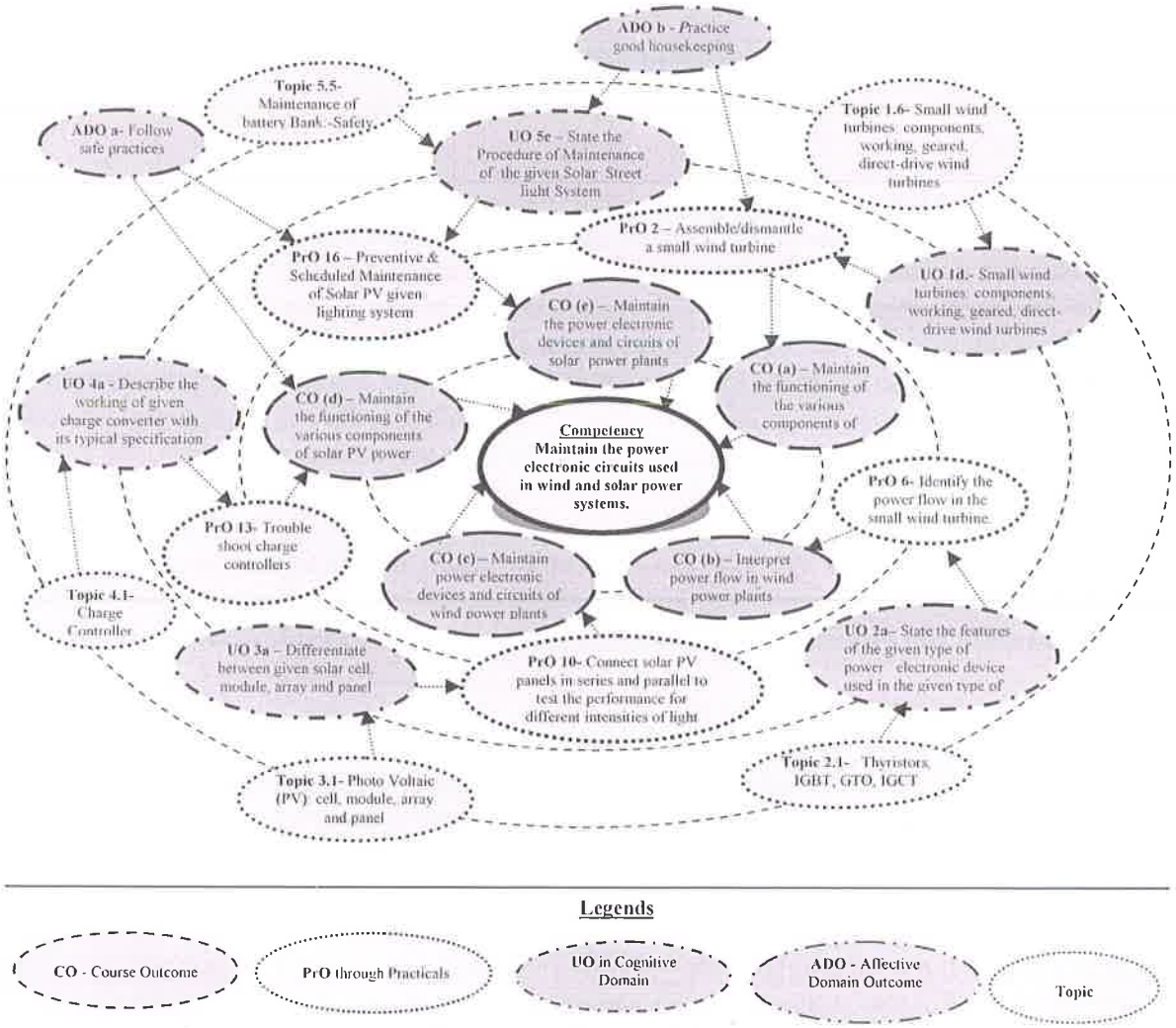

Figure 1 - Course Map

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	Identify Components and sub Components of Wind Power Plant	I	02*
2	Assemble/dismantle a small wind turbine	I	02
3	Lubricate the various parts of wind turbine	I	02*
4	Test the performance of the small wind turbine for different load.	I	02
5	Identify the parts of the large wind turbine after viewing the relevant video	I	02
6	Identify the power flow in the small wind turbine	II	02
7	Identify the power electronic devices and circuits in the small wind turbine.	II	02*
8	Test functioning of the power electronic circuits used in Given wind turbines	II	02*
9	Identify the power electronic components and circuits in the	II	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	Matrix converter used in Wind Power Plant		
10	Connect solar PV panels in series and parallel to test the performance for different intensities of light	III	02
11	Test the given Battery Charger used to charge the battery	III	02*
12	Test the performance of given inverter of Solar PV power system	IV	02*
13	Troubleshoot charge controllers	IV	02
14	Perform minor repairs of given wind power Plant	V	02
15	Build ¼ HP DC water pump Powered by Solar PV modules	V	02*
16	Perform preventive and scheduled Maintenance of given Solar PV lighting system	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 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.	Preparation of experimental set up	20
b.	Setting and operation	20
c.	Safety measures	10
d.	Observations and Recording	10
e.	Interpretation of result and Conclusion	20
f.	Answer to sample questions	10
g.	Submission of 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. Practice energy conservation.
d. Demonstrate working as a leader/a team member.
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/ INSTRUMENTS REQUIRED

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	Small wind power training system.	1,14
2	Small geared wind turbine	2,14
3	Permanent magnet generator	3,
4	Wind turbine gear box	2 - 8,14
5	Power oscilloscope	4 to 14
6	Wind Generator Meter	4 to 8
7	Matrix Converter	9
8	3 kW Solar PV system	10 to 13,16
9	Solar Array Meter	10 to 16
10	Solar PV training systems	10 to 13,16
11	DC-DC Converter module	10 to 13
12	DC-AC Converter module	10 to 13
13	Domestic Inverter	10 to12
14	Micro Inverter	10 to 12
15	Charge Controller	10 to 16
16	Training system for DC water Pump Powered by PV modules	10 to 16

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 Wind Power Plants	1a. Explain the working of the given type of wind power plant. 1b. Explain the aerodynamic braking of the given wind turbine. 1c. State the major features of the given types of wind power plants based on the electric generator used. 1d. Explain with sketches the construction features of the given type of wind power plants. 1e. Explain with sketches the construction features of the given type of small wind turbine 1f. Explain with sketches the working of the given type of small wind turbine	1.1 Wind energy basics: wind speed requirement and windy sites 1.2 Aerodynamics of Wind turbine: stall, active-stall and pitch control 1.3 Geared wind power plants and direct-drive wind power plants 1.4 Type-A, Type-B, Type-C, Type-D, wind power plants 1.5 Small wind turbines: horizontal axis and vertical axis wind turbine, drag type and lift principle, geared, direct-drive wind turbines, components, working principle,

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit– II Power Electronics in Small and large Wind Turbines	2a. State the features of the given type of power electronic devices used in the wind power plant 2b. Describe the working of the soft starter used in the given type of wind power plant 2c. Describe the working principle of the given type of converter used in wind power plant with sketches 2d. Select the relevant converter for the given situation.	2.1 Power electronics is small wind turbines 2.2 Power electronic circuits: Soft starters 2.3 Power Electronic Devices:- Thyristors, IGBT, GTO, IGCT 2.4 Converters: Back-to -back converters, Matrix Converter
Unit-III Solar PV System	3a. Illustrate with sketches the working of the given solar cell. 3b. Describe the components and function of the given solar power plant. 3c. Describe the features of the given component solar power plant 3d. Interpret the specifications of the given type of battery 3e. Describe the features of a hybrid wind solar system	3.1 Features of large Solar power plant 3.2 Features of roof top home solar system 3.3 Features hybrid wind solar system 3.4 Photo Voltaic(PV): Cell, module, array and panel 3.5 Electronics in Charge controllers and signal conditioning 3.6 Types of batteries used in solar PV system
Unit –IV Power Electronics in Solar PV Systems	4a. Illustrate the working of the given charge converter used for Solar PV System with its typical specification. 4b. Describe the working principle of the given signal conditioner in a solar system 4c. Select the appropriate inverter required for the given solar PV system. 4d. Draw the sketches of the given power electronics circuits used in solar PV systems. 4e. Prepare the specifications of the given power electronic devices used in solar PV systems. 4f. Justify the need for the given maximum power point tracking system in solar PV system	4.1 Charge Controller /System meter 4.2 Signal Conditioner 4.3 Inverter 4.4 Power Electronic Devices Used in solar PV system. 4.5 Power configuration for grid-connected PV systems: central, string and module inverters configuration. 4.6 Solar PV maximum power point tracking

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit-V Maintenance of Wind and Solar PV Power System	5a. Describe the procedure to Troubleshoot the Faults of the given type of Wind Power System 5b. Describe the Procedure to Troubleshoot the Faults of the given type of Solar PV System 5c. State the Procedure of Scheduled and Preventive Maintenance of the given type of Wind Power System 5d. State the Procedure of Maintenance of the given Solar PV System used in Water Pump System 5e. State the Procedure of testing charge control circuit of the given Solar Street light System.	5.1 Incorrectly fitted blades, Mechanical problems, Electrical issues, Control issues 5.2 Troubleshooting Problem:- 5.3 Cleaning Cell/Module/Array, Inverter, Load, blown fuse, Tripped breaker, Broken Wires 5.4 User Manual, Safety Measures, WPP logbook Record, Scheduled and Preventive Maintenance 5.5 User Manual, Safety Measures, SPS logbook Record, Maintenance of battery Bank:- Safety Measures Checking, Charging, Isolating, Cleaning Terminals.

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 FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Wind Power Plants	14	03	05	06	14
II	Power Electronics in Small and large wind turbines	12	03	05	06	14
III	Solar PV System	12	02	04	06	12
IV	Power Electronics in Solar PV Systems	12	03	05	06	14
V	Maintenance of Wind and Solar PV Power System	14	03	05	08	16
	Total	**64**	**14**	**24**	**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 any wind power plant nearby to your area and take the help of wind power plant in-charge to know the operation and maintenance of plant, and write the procedure of i) Maintenance ii) Calculation of cost per unit.
b. Visit any Solar PV power plant nearby to your area and take the help of Solar PV power plant in-charge to know operation and maintenance plant, and write the procedure of i) Maintenance ii) Calculation of Cost Per unit Area.
c. Read the safety manual on maintenance of i) wind power plant ii) Solar PV Plant and write important safety measures while troubleshooting Power Electronics circuits.
d. Do internet survey of various meters used in Wind Power Plant and Solar PV Power Plant and write the report on them with Specification.
e. Do internet survey of Hybrid power Plant (wind Power Plant and Solar PV Power Plant) and write the report with necessity and Capacity.
f. Library / Internet survey of wind power systems and Solar PV systems.
g. Prepare power point presentation or animation for understanding different Power electronics circuits behavior used in Wind Power systems and Solar PV Power Systems.
h. Analyse Power Electronics circuits behavior while troubleshooting the faults in wind and solar PV Power Systems.
i. Practice Pspice/Matlab to analyse power flow in the Solar PV system and Wind power system.

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).
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. Correlate subtopics with power system utility and electrical equipments.
g. Use proper equivalent analogy to explain different concepts.
h. Use Flash/Animations to explain various theorems in circuit analysis.
i. Use open source PSpice/Matlab models to explain different concepts of electric circuit.

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.

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

a. **Sun Tracking Solar Panel**: Build a sun tracking solar panel system so as to receive maximum radiation from the sun.
b. **Solar Powered LED Street light with auto intensity control**: Assemble LED based light system which should be powered from a solar power source and control it's intensity such that LED lights are switched on with maximum intensity only during the peak hours.
c. **Solar Energy Measurement System**: Assemble a system used to monitor any two parameters related to the solar panel like temperature, light intensity, voltage and current and display the parameters on a LCD display.
d. **Wind Turbine**: Build mini wind turbine to charge the given battery
e. **Mini Wind mill**: Build a mini wind mill using turbine blade and gearbox with suitable gear ratio to charge rechargeable batteries.
f. **Solar PV system:** Design Solar PV system to fulfill the load requirement; i)Two CFL 9W ii)One Fan 60W

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Power electronics for modern wind turbines	Frede Blaabjerg, Zhe Chen	Morgan and Claypool Publishers, latest edition ISBN:9781598290325
2	Wind Power Technology	Earnest, Joshua	PHI Learning, New Delhi, 2016, ISBN:978-81-203-5166-0
3	Power Electronics for Renewable and Distributed Energy Systems, A Sourcebook of Topologies, Control and Integration	Chakraborty Sudipta, Simões Marcelo G, William E. Kramer	Springer-Verlag London 2013 ISBN: 9781447159568
4	Power Electronics and Renewable Energy Systems	Kamalakannan, C., Suresh, L.P., Dash, S.S., Panigrahi, B.K.	Springer India ISBN:- 9788132235545
5	Wind and Solar Power Systems: Design, Analysis, and Operation,	Mukund R. Patel	CRC Press ISBN 9780849315701
6	Solar Electric Handbook: Photovoltaic Fundamentals and Applications	------	Media Bundle Publication ISBN -1256701661
7	Power Electronics for the Next Generation Wind Turbine System	Ma, Ke	Springer Open books ISBN 9783319212487
8	Power Solar Generation: Technology, New Concepts & Policy	P. Jayarama Reddy	CRC Press 2012 ISBN: 97804156211106
9	Technology Of Solar	Brahmpal Bhardwaj	Engineers India Research Institute, ISBN: 9789380772547

S. No.	Title of Book	Author	Publication
10	Solar Electricity Handbook	Michael Boxwel	Greenstream Publishing; 2015 ISBN:9781907670459

14. SOFTWARE/LEARNING WEBSITES

a. www.freesunpower.com
b. https://learn.adafruit.com/collins-lab-solar
c. www.tutorialspoint.com/power_electronics/
d. www.nptelvideos.in/2012/11/energy-resources-and-technology.htm
e. www.learnerstv.com/free-engineering
f. www.instructables.com
g. www.efxkits.com/blog/working-of-solar-wind-hybrid-system
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i. www.homepower.com
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