INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE DESCRIPTOR

Course Title	**WIND AND SOLAR ENERGY SYSTEMS**				
Course Code	AEEB46				
Programme	B.Tech				
Semester	FIVE				
Course Type	Professional Elective				
Regulation	IARE - R18				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	-	3	-	-
Chief Coordinator	Mr. S. Srikanth, Assistant Professor				
Course Faculty	Mr. S. Srikanth, Assistant Professor Mr. A. Srikanth, Assistant Professor				

I. COURSE OVERVIEW:
Wind and Solar Energy Systems deals with design and operation of wind power system, design and operation of Photo voltaic system, power conditioning schemes for solar energy system, wind energy conversion systems and power quality issues in the integration of renewable energy resources.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
UG	AEEB14	IV	Electrical Power Generating Systems

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Wind and Solar Energy Systems	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✔	Chalk & Talk	✔	Quiz	✔	Assignments	✘	MOOCs
✔	LCD / PPT	✔	Seminars	✘	Mini Project	✘	Videos
✘	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into FIVE modules and each module carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each module. Each question carries 14 marks. **There could be a maximum of two sub divisions in a question.**

The expected percentage of cognitive level of the questions is broadly based on the criteria given in Table: 1.

Table 1: The expected percentage of cognitive level of questions in SEE

Percentage of Cognitive Level	Blooms Taxonomy Level
10 %	Remember
60 %	Understand
30 %	Apply
0 %	Analyze
0 %	Evaluate
0 %	Create

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 2), with 20 marks for Continuous Internal Examination (CIE), 05 marks for Quiz and 05 marks for Alternative Assessment Tool (Table 3).

Table 2: Assessment pattern for CIA

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Quiz	AAT	
CIA Marks	20	05	05	30

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 20 marks of 2 hours duration consisting of five descriptive type questions out of which four questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams

Quiz –Online Examination:

Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are to be answered by choosing the correct answer from a given set of choices (commonly four). Such a question paper shall be useful in testing of knowledge, skills, application, analysis, evaluation and understanding of the students. Marks shall be awarded considering the average of two quiz examinations for every course.

Alternative Assessment Tool (AAT):

This AAT enables faculty to design own assessment patterns during the CIA. The AAT converts the classroom into an effective learning center. The AAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video, MOOCs etc. The AAT chosen for this course is given in table 3**.**

Table 3: Assessment pattern for AAT

5 Minutes Video	Assignment	Tech-talk	Seminar	Open Ended Experiment
25%	25%	25%	25%	0%

VI. COURSE OBJECTIVES:

The students will try to learn:	
I	The fundamental concepts of power generation and gain enough knowledge about the wind and solar energy sources.
II	The construction, principle of operation of various equipments used in power generation using wind energy.
III	The key aspects in the design and operation of photovoltaic along with solar thermal power energy systems.
IV	The various factors affecting the power quality issues in integration of renewable energy resources.

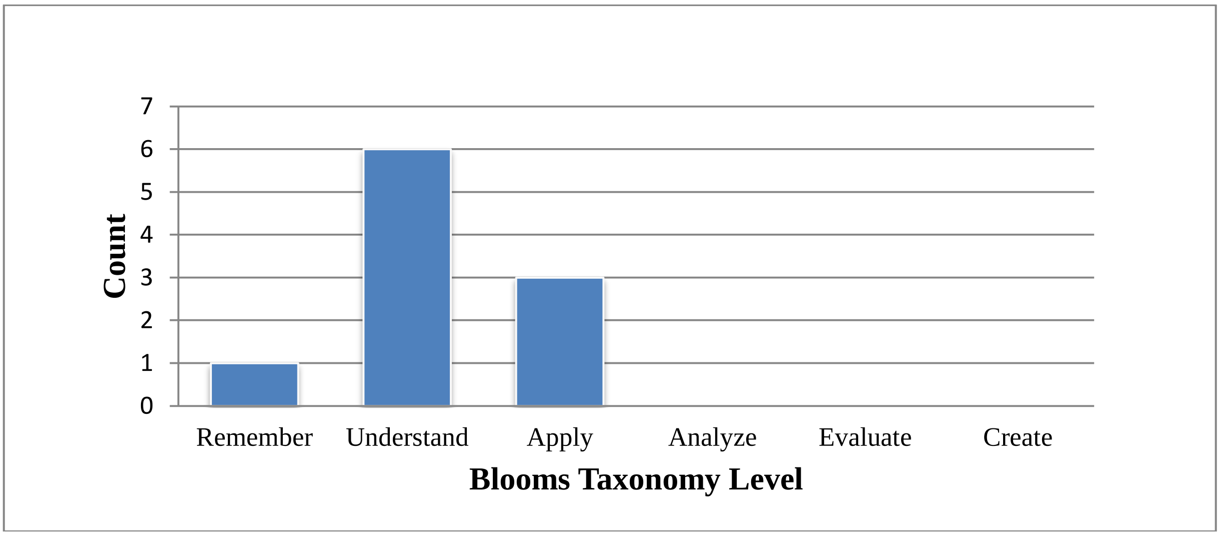
VII. COURSE OUTCOMES:

Upon the successful completion of the course students will be able to

CO No	Course outcomes	Knowledge Level (Bloom's Taxonomy)
CO 1	**Recall** the power conversions involved in windmills/ PV Systems for production of electricity.	Remember
CO 2	**Outline** various components involved and their functionality in production of electricity from wind and solar power plants.	Understand
CO 3	**Summarize** the control schemes, environmental aspects and classification of wind energy conversion systems for reliable operation.	Understand

CO 4	**Outline** the characteristics of solar PV modules for design of solar arrays.	Understand
CO 5	**Demonstrate** the functioning of various components involved in solar thermal systems for designing commercial solar power plants.	Understand
CO 6	**Develop** the suitable scheme for extracting maximum power from solar PV module using MPPT algorithms.	Apply
CO 7	**Utilize** the power conditioners and inverters for grid synchronization and harmonic reduction in solar PV systems.	Understand
CO 8	**Make use of** AC voltage controllers for power factor improvement and harmonic reduction in Isolated induction generators	Apply
CO 9	**Identify** the power quality issues and mitigation techniques used in standalone and grid connected systems for ensuring the quality of power.	Apply
CO 10	**Outline** the control and protection of renewable energy systems using custom power devices for stable operation of power systems.	Understand

COURSE KNOWLEDGE COMPETENCY LEVELS



VIII. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes		Proficiency assessed by
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	AAT/CIE/SEE
PO 2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	AAT/CIE/SEE
PO 3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	AAT/CIE/SEE

3 = High; 2 = Medium; 1 = Low

IX. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes		Proficiency assessed by
PSO2	Focus on the components of power system, its analysis, operation, control and protection; electrical drives with its converter topologies for energy conversion, management and auditing in specific applications of industry and academia.	AAT/CIE/SEE

3 = High; 2 = Medium; 1 = Low

X. MAPPING OF EACH CO WITH PO(s), PSO(s):

Course Outcomes	Program Outcomes												Program Specific Outcomes		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO 1	√														
CO 2	√	√	√											√	
CO 3	√	√												√	
CO 4	√	√	√											√	
CO 5	√	√												√	
CO 6	√	√												√	
CO 7	√	√	√											√	
CO 8	√		√											√	
CO 9	√	√												√	
CO 10	√	√												√	

XI. JUSTIFICATIONS FOR CO – (PO, PSO) MAPPING –DIRECT

Course Outcomes	POs / PSOs	Justification for mapping (Students will be able to)	No. of key competencies
CO 1	PO 1	Recall about the power conversions involved in wind mills for producing electricity **knowledge of mathematics, science and engineering fundamentals.**	2
CO 2	PO 1	Analyze various components involved and their functionality **using principles of mathematics, science and engineering fundamentals.**	3
	PO 2	Get knowledge on operations of modern energy sources with wind and solar plants using **principles of mathematics and engineering sciences.**	7
	PO 3	Design solutions for variable speed operation, system design featuresfor **complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration.**	5

	PSO 2	Utilizing wind energy system and solar power for modern energy demand and **commercializing the system.**	1
CO 3	**PO 1**	Provide knowledge about control schemes and classification of wind energy conversion systems with **basic fundamentals of science, and engineering fundamentals.**	3
	PO 2	Get knowledge on operations of modern energy sources to analyze wind energy conversion systems using **principles of mathematics and engineering sciences.**	6
	PSO2	Make use of wind energy conversion system as another source of aid to**power system.**	1
CO 4	**PO 1**	Equip with required skills to for the design PV cell and arrays with the **fundamentals of mathematics, science, and engineeringfundamentals.**	3
	PO 2	Derive the solutions forthe characteristics of PV cell **using basics of mathematics and engineering sciences.**	7
	PO 3	**Design the solution for problems of** PV cells, modules and arrays	5
	PSO2	Understand the importance of PV cell for generation of power in **power system.**	1
CO 5	**PO 1**	Summarize various operating modes of solar thermal systems with the **knowledge of mathematics, science and engineering fundamentals.**	3
	PO 2	Derive the solution for generating electrical power commercially **using basic mathematics and engineering principles.**	7
	PSO 2	Recogniz**e** the importance of various operating modes of solar thermal systems in **generation, transmission and distribution of power.**	1
CO 6	**PO 1**	**Use the basics of mathematics, science and engineering fundamentals** for obtaining maximum power tracking algorithms.	3
	PO 2	Develop maximum power point tracking algorithms and knowing the importance of maximum power tracking **in solving complex engineering problems.**	7
	PSO 2	Understand the maximum power point tracking algorithms used in**generation of electrical power with PV system**	1
CO 7	**PO 1**	Estimate the solar energy utilization, operation of power conditioner and inverters **using the principles of mathematics and engineering fundamentals.**	3
	PO 2	Develop the solutions for power conditioner and inverters **using which complex engineering problems can be solved with help of basic mathematics and engineering sciences.**	6
	PO 3	**Design the solution for problems** of harmonic reduction in solar energy production	4
	PSO 2	Summarize the grid synchronization using **electrical machines in power system.**	1
CO 8	**PO 1**	Distinguish different AC voltage controllers for power factor improvement by applying **basic knowledge of science and engineering fundamentals.**	2
	PO 3	Understanding the harmonic reduction in induction generators**according to the necessities.**	5
	PSO 2	Understand the solar energy collection and generation of **electrical power with PV system**	1

CO 9	**PO 1**	Summarize power quality issues, mitigation techniques used in standalone and grid connected systems with the help of **basic fundamentals of mathematics science and engineering fundamentals.**	3
	PO 2	Determine power quality issues of grid connected system for **analyzing the behavior of complex electrical components.**	6
	PSO 2	Summarize the power quality features of standalone and grid connected systems with the **required electrical machines in power system.**	1
CO 10	**PO 1**	Outline the control and protection and their impact on renewable energy systems with the help of **basic fundamentals of mathematics science and engineering fundamentals.**	3
	PO 2	Determine the protection equipment used in the renewable energy systems **using basics of mathematics and engineering sciences.**	6
	PSO 2	Focus on the custom power devices for operation and control of **different modes of power system.**	1

XII. TOTAL COUNT OF KEY COMPETENCIES FOR CO – (PO, PSO) MAPPING

Course Outcomes	**Program Outcomes / Number of Vital Features**												**PSOs / No. of Vital Features**		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
	3	**10**	**10**	**11**	**1**	**5**	**3**	**3**	**12**	**5**	**12**	**12**	**2**	**2**	**2**
CO 1	2														
CO 2	3	7	5											1	
CO 3	3	6												1	
CO 4	3	7	5											1	
CO 5	3	7												1	
CO 6	3	7												1	
CO 7	3	6	4											1	
CO 8	2		5											1	
CO 9	3	6												1	
CO 10	3	6												1	

XIII. PERCENTAGE OF KEY COMPETENCIES FOR CO – PO MAPPING:

Course Outcomes	**Program Outcomes / Number of Vital Features**												**PSOs / No. of Vital Features**		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
	3	**10**	**10**	**11**	**1**	**5**	**3**	**3**	**12**	**5**	**12**	**12**	**2**	**2**	**2**
CO 1	66.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

CO 2	100.0	70.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0
CO 3	100.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0
CO 4	100.0	70.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0
CO 5	100.0	70.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0
CO 6	100.0	70.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0
CO 7	100.0	60.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0
CO 8	100.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0
CO 9	100.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0
CO 10	100.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0

XIV. COURSE ARTICULATION MATRIX (PO – PSO MAPPING)

COs and POs and COs and PSOs on the scale of 0 to 3, **0** being **no correlation**, **1** being the **low correlation**, **2** being **medium correlation** and **3** being **high correlation**.

0 – **0**≤ C≤ 5%–No correlation;

1 – 5 <C≤ 40%– Low/ Slight;

2 – 40 % <C< 60% –Moderate

3 – 60% ≤ C< 100% – Substantial /High

Course Outcomes	**Program Outcomes**												**Program Specific Outcomes**		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
CO 1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO 2	3	3	2	-	-	-	-	-	-	-	-	-	-	2	-
CO 3	3	3	-	-	-	-	-	-	-	-	-	-	-	2	-
CO 4	3	3	2	-	-	-	-	-	-	-	-	-	-	2	-
CO 5	3	3	-	-	-	-	-	-	-	-	-	-	-	2	-
CO 6	3	3	-	-	-	-	-	-	-	-	-	-	-	2	-
CO 7	3	3	2	-	-	-	-	-	-	-	-	-	-	2	-
CO 8	3	-	2	-	-	-	-	-	-	-	-	-	-	2	-
CO 9	3	3	-	-	-	-	-	-	-	-	-	-	-	2	-
CO 10	3	3	-	-	-	-	-	-	-	-	-	-	-	2	-
TOTAL	30	24	8											18	
AVERAGE	**3.0**	**3.0**	**2.0**											**2.0**	

XV. ASSESSMENT METHODOLOGIES–DIRECT

CIE Exams	PO 1,PO 2, PO 3	SEE Exams	PO1,PO 2, PO 3	Assignments	PO 1,PO 2, PO 3	Seminars	PO 1,PO 2, PO 3
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	-	5 Minutes Video	PO 1,PO 2, PO 3	Tech talk	PO 1,PO 2, PO 3	Open Ended Experiments	-

XVI. ASSESSMENT METHODOLOGIES–INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✘	Assessment of Mini Projects by Experts		

XVII. SYLLABUS

MODULE-I	**DESIGN AND OPERATION OF WIND POWER SYSTEM**
Wind Power System: Components, turbine rating, electrical load matching, variable-speed operation, system design features, maximum power operation, system control requirements, speed control, rate control and environmental aspects, wind energy conversion systems and their classification.	
MODULE-II	**DESIGN AND OPERATION OF PV SYSTEM**
Solar Photovoltaic Power System: The PV Cell, module and array, equivalent electrical circuit, open circuit voltage and short circuit current, I-V and P-V curves, array design, peak power point operation, PV system components; Solar Thermal System: Energy collection, synchronous generator, equivalent electrical circuit, excitation methods, electrical power output, transient stability limit, commercial power plants.	
MODULE-III	**POWER CONDITIONING SCHEMES FOR SOLAR ENERGY SYSTEMS**
Switching devices for solar energy conversion: DC power conditioning converters, maximum power point tracking algorithms. AC Power conditioners, Line commutated inverters, synchronized operation with grid supply, Harmonic reduction.	
MODULE-IV	**WIND ENERGY CONVERSION SYSTEMS**
Wind energy Conversion system (WECS): Performance of Induction generators for WECS, Self-excited induction generator (SEIG) for isolated power generators. Controllable DC power from SEIGs, system performance, Grid related problems, generator control, AC voltage controllers, Harmonic reduction and Power factor improvement.	
MODULE-V	**POWER QUALITY ISSUES IN INTEGRATION OF RENEWABLE ENERGY RESOURCES**
Stand alone and Grid connected systems, Power Quality issues, Impact of power quality problems on DG, Mitigation of power quality problems, and Role of custom power devices in Distributed Generation.	
Text Books:	
1 Mukund R Patel, “Wind and Solar Power Systems”, CRC Press, 1st Edition, 1999. 2 G D Rai, “Non- Conventional Energy Resources”, Khanna Publishers, 1st Edition, 2002.	

Reference Books:
1 Daniel, Hunt. V Wind Power, A Hand Book of WECS, Van Nostrend Co., Newyork, 2nd Edition, 1998. 2 ArindamGhosh, Gerard Ledwich, "Power Quality Enhancement Using Custom Power Devices", Springer, 1st Edition, 2002. 3 Roger C Dugan, Mark E Mc. Granaghan, Surya Santosoh and H. Wayne Beaty, "Electrical Power Systems Quality", TATA McGraw Hill, 2nd Edition, 2010.
Web References:
1. https://www.NPTEL video lectures. 2. https://www.books.askvenkat.com/engineering-textbooks 3. https://www.electrical4u.com.
E-Text Books:
1. ArindamGhosh, Gerard Ledwich, Power Quality Enhancement Using Custom Power Devices, Springer, 2002. 2. https://www.freebookcentre.net

XVIII. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No.	Topics to be covered	CO	Reference
1	Wind Power System Components	CO 2	T1: 5.1 R4:1.1-1.8
2	Wind Turbine rating, electrical load matching	CO 2	T1: 5.2 R4:1.1-1.8
3	Wind turbine Variable-speed operation, system design features	CO 2	T1: 5.4 R4:1.1-1.8
4	Maximum power operation in wind turbines	CO 3	T1: 5.6 R2:2.3
5	Wind power system control requirements	CO 3	T1: 5.7 R2:2.3
6	Speed control, rate control of wind turbines	CO 3	T1: 5.7.1 R2:3.2
7	Environmental aspects of wind power stations	CO 3	T1:5.8 R2:3.2
8	Wind energy conversion systems and their classification.	CO 1	T2:6.6 R2:2.9
9	Review of wind energy systems	CO 1	T2:6.6 R2:2.9
10	PV Cell, module and array,equivalent electrical circuit	CO 4	T1: 8.1 R2:2.9-2.10
11	Open circuit voltage and short circuit current in solar system	CO 4	T1: 8.4 R2:2.11
12	Solar plate I-V and P-V curves, array design	CO 4	T1:8.5 R2:2.11
13	PV system components of solar power plant	CO 5	T1:8.8 R2:3.5
14	Solar Thermal System,energy collection of solar plates	CO 5	T1:9.1 R2:3.5
15	Synchronous generator used in solar power stations	CO 5	T1:6.1.2 R2:3.7
16	Equivalent electrical circuit of synchronous generator	CO 5	T1:6.1.2 R2:3.7
17	Excitation methods, electrical power output of synchronous generator	CO 5	T1:6.1.3 R2:3.7

18	Transient stability limit in synchronous generator	CO 5	T1:6.1.4 R2:3.7
19	Commercial solar power plants	CO 5	T1:8.6 R2:3.7
20	Overview of solar thermal power plants	CO 4	T1:8.5 R2:2.11
21	Switching devices for solar energy conversion	CO 7	T1:8.2 R2:4.1
22	DC power conditioning converters used in solar power plant	CO 7	T1:8.3 R2:5.1
23	Maximum power point tracking algorithms in solar power system	CO 6	T1:8.7 R2:5.2
24	AC Power conditioners used in solar power plants	CO 7	T1:8.8 R2:5.4
25	Line commutated inverters used in solar power generation	CO 7	T1:8.9 R2:4.3-4.4
26	Synchronized operation of solar plant with grid supply	CO 7	T1:8.6.2 R2:4.3-4.4
27	Harmonic reduction in solar power stations	CO 7	T1:8.6.3 R2:4.5
28	Overview of power switching devices used in solar thermal plant	CO 6	T1:8.7 R2:5.2
29	Introduction wind energy Conversion system	CO 1	T2:6.1 R2:6.1
30	Performance of Induction generators used for WECS	CO 8	T2:6.1 R2:6.2
31	Self-excited induction generator (SEIG) for isolated power generators	CO 8	T2:6.5 R2:7.1-7.2
32	Controllable DC power from SEIGs	CO 8	T2:6.11 R2:7.4
33	Wind energy conversion system performance	CO 1	T2:6.10 R2:7.4
34	Grid related problems with wind power plants	CO 8	T2:6.12 R2:7.4
35	Induction Generator control in wind power stations	CO 8	T2:6.11 R2:7.4
36	AC voltage controllers used in wind power stations	CO 8	T2:6.13 R2:7.3
37	Harmonic reduction in AC voltage controllers used in wind farms	CO 8	T2:6.14 R2:7.3
38	Overview AC power conditioners used in wind power plants	CO 8	T2:6.11 R2:7.4
39	Power factor improvement in wind power plants	CO 8	T2:6.16
40	Stand alone and Grid connected systems of wind power stations	CO 9	T2:6.3-6.4
41	Power Quality issues in integration of renewable energy systems	CO 9	T2:6.3-6.4 R2:7.4
42	Impact of power quality problems on Distributed Generation	CO 9	T2:6.2 R2:6.3
43	Mitigation of power quality problems	CO 9	T2:6.3-6.4 R2:7.8
44	Role of custom power devices in Distributed Generation	CO 10	T1:6.3-6.4 R2:7.8
45	Review of power quality issues in wind and solar power plants	CO 9	T2:6.2 R2:6.3

Prepared by:
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