CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET458	SOLAR PV SYSTEMS	PEC	2	1	0	3

Preamble: This course introduces solar PV system and its grid integration aspects. It also give insight to basic knowhow for the implementation of Solar PV system utilizing modern simulation software.

Prerequisite : Nil

Course Outcomes : After the completion of the course the student will be able to:

CO 1	Explain the basics of solar energy conversion systems.(K1)
CO 2	Design a standalone PV system. (K3)
CO 3	Demonstrate the operation of a grid interactive PV system and its protection against islanding.(K2)
CO 4	Utilize life cycle cost analysis in the planning of Solar PV System (K3)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	1										1
CO 2	3	3	3									2
CO 3	3	3	2									2
CO 4	3	3	2	1	2						1	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	20
Understand (K2)	25	25	50
Apply (K3)	15	15	30
Analyse (K4)	-	-	-
Evaluate (K5)	-	-	-
Create (K6)	-	-	-

End Semester Examination Pattern : There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain what do you mean by solar constant (K1, PO1)
2. Discuss about the different instruments used for measuring solar radiation and sun shine (K2,PO2)

Course Outcome 2 (CO2):

1. Design a stand alone PV system. (K3, PO1, PO2, PO3)
3. Design an off grid PV system to backup 10kW system for 3 hours and draw the block level representation of the final system. (K3, PO1, PO2, PO3)

Course Outcome 3 (CO3):

1. Demonstrate the operation of a grid connected PV system. (K2, PO1, PO2,PO3).
2. Summarize the protection of PV system against islanding and reverse power flow. (K2, PO1, PO2,PO3).

Course Outcome 4 (CO4):

1. The life cycle cost of a system is Rs. 10000/- for a life period of 20 years. The rate of interest is 8% and the inflation rate is 5%. What is the annual life cycle cost for the system? (K3, PO1, PO2,PO3)
2. Design a grid connected PV system utilizing a suitable simulation software. (K3, PO1, PO2,PO3,PO4,PO5)

Model Question Paper

QP CODE:

PAGES:2

Reg. No:_____
Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
EIGHTH SEMESTER B.TECH DEGREE
EXAMINATION, MONTH & YEAR

Course Code: EET458

Course Name: SOLAR PV SYSTEMS

Max. Marks: 100 Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. Explain briefly what do you mean by solar azimuth angle and zenith angle.
2. Differentiate between extraterrestrial and terrestrial solar radiation.

3. Write notes on the working of a solar cooker.
4. Discuss what do you mean by a solar green house.
5. Write notes on the different materials used for making solar cells.
6. Discuss the characteristics of a solar cell.
7. Give a description on of Power Quality related IEEE standards for distributed resource grid integration
8. Differentiate SoC and DoD of storage battery .
9. Write notes on the planned and unplanned islanding .
10. Explain life-cycle cost of renewable energy system.

PART B (14 x 5 = 70 Marks)

Answer any one full question from each module. Each question carries 14 Marks

Module 1

11. a. With the help of a neat diagram, explain the working of a pyrheliometer. (7)
    b. Explain how monthly average solar radiation on inclined surfaces can be calculated. (7)
12. a. State the reasons for variation in the amount of solar energy reaching earth surface. (4)
    b. With the help of a neat diagram, explain the working of a sunshine recorder. (6)
    c. Explain the difference in the working of pyrheliometer and pyranometer. (4)

Module 2

13. a. Explain the different types of solar collectors based on the way they collect solar radiation. (7)
    b. Explain in detail, the working of a solar air conditioning system (7)
14. a. With the help of a diagram, explain the function of different components of a flat plate solar collector. (7)
    b. Design a solar water heater for domestic application. (7)

Module 3

15. a. Write notes on the efficiency of a solar cell. (3)
    b. Discuss the effect of shadowing on the performance of solar cells. (3)
    c. Explain how maximum power point tracking can be done using buck-boost converter. (8)
16. a. Compare the performance of single junction and multijunction PV modules. (4)
    b. Write notes on packing factor of a PV module. (3)
    c. Explain the Perturb and Observe MPPT method. Compare with incremental conductance method. (7)

Module 4

17.

a. Design an off grid PV system to backup 10kW system for 3 hours and draw the block level representation of the final system. (7)

b. Explain with a neat sketch, the working principle of a grid connected solar system. (7)

18.

a. In a water pumping system, the water is being pumped from a sump to an overhead tank situated 25m above ground. The sump bottom is 2m below ground. The motor-pump system is located at ground level. The water is being pumped at the rate of 24.6 litres/sec. The pipe inner diameter is 10 cm. The pipe is placed completely vertical with no horizontal part. The friction factor is 0.037. The efficiencies of the pump, motor and dc-dc converter are 70%, 80% and 90% respectively. If the system is being powered by a PV source, what is the output power requirement for the PV panels? (7)

b. Explain the voltage and frequency matching method in grid connected PV system. (7)

Module 5

19.

a. Detail the anti-islanding protection with suitable block diagram. (7)

b. The life cycle cost of a system is Rs. 10000/- for a life period of 20 years. The rate of interest is 8% and the inflation rate is 5%. What is the annual life cycle cost for the system? (7)

20.

a. Draw and explain the line of protection equipment in PV array installation. (6)

b. Suppose the energy-efficiency retrofit of a large building reduces the annual electricity demand for heating and cooling from 2.3 × 106 kWh to 0.8 × 106 kWh and the peak demand for power from by 150 kW. Electricity costs Rs. 5/kWh and demand charges are Rs. 500/kW per month, both of which are projected to rise at an annual rate of 5%. If the project costs Rs. 3,50,00,000, what is the internal rate of return over a project lifetime of 15 years? (8)

Syllabus

Module 1

Introduction - Basic Concept of Energy -Source of Solar Energy -Formation of the Atmosphere - Solar Spectrum. Solar Constant -Air Mass -Solar Time-Sun–Earth Angles-Solar Radiation-Instruments to Measure Solar Radiation-Pyrheliometer –Pyranometer - Sunshine Recorder -Solar Radiation on a Horizontal Surface - Extra-terrestrial Region.-Terrestrial Region -Solar Radiation on an Inclined Surface -Conversion Factors -Total Solar Radiation on an Inclined/Tilted Surface -Monthly Average Daily Solar Radiation on Inclined Surfaces .

Module 2

Solar Thermal system-Principle of Conversion of Solar Radiation into Heat, –Solar thermal collectors –General description and characteristics –Flat plate collectors –Heat transfer processes –Solar concentrators (parabolic trough, parabolic dish, Central Tower Collector) –performance evaluation. Applications -Solar heating system, Air conditioning and Refrigeration system, Pumping system, solar cooker, Solar Furnace, Solar Greenhouse -Design of solar water heater

Module 3

Solar PV Systems-Introduction -Fundamentals of Semiconductor and Solar Cells -Photovoltaic Effect -Solar Cell (Photovoltaic) Materials - Basic Parameters of the Solar Cell -Generation of Solar Cell (Photovoltaic) Materials-.Photovoltaic (PV) Module and PV Array -Single-Crystal Solar Cell Module, Thin-Film PV Modules, III–V Single Junction and Multifunction PV Modules-Emerging and New PV Systems -Packing Factor of the PV Module - Efficiency of the PV Module -Energy Balance Equations for PV Modules -Series and Parallel Combination of PV Modules.- Effect of shadowing-MPPT Techniques-P&O , incremental conductance method-Maximum Power Point Tracker (MPPT) using buck-boost converter.

Module 4

Solar PV Systems –stand-alone and grid connected -Design steps for a Stand-Alone system –Storage batteries and Ultra capacitors. Design PV powered DC fan and pump without battery-Design of Standalone System with Battery and AC or DC Load. A Grid Interactive PV System - Phase , Frequency Matching and Voltage Consideration – Operation of a Grid Interactive Inverter –Overview of IEEE -2018 Standard for Interconnecting Distributed Resources with Electric Power Systems

Module 5

Protection Against Islanding and Reverse Power Flow – AC Modules Design of EMI Filters. Overcurrent protection of solar PV power system, Selective fuse links for PV String protection, PV fuse selection flow chart, Fuse rating for PV Applications.

Life cycle costing, Growth models, Annual payment and present worth factor, payback period, LCC with examples. Introduction to simulation software for solar PV system design.*(An assignment can be given corresponding to CO2,CO3 and CO4 utilizing the simulation tools)*

Text book:

1. D.P. Kothari, M Jamil. Grid Integration of Solar Photovoltaic Systems, CRC Press 2018

2. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies And Applications 3rd Edition, PHI
3. G.N. Tiwari: Solar Energy-Fundamentals, Design, Modelling and Applications, Narosa Publishers,2002
4. A.A.M. Saigh(Ed): Solar Energy Engineering, Academic Press, 1977

References:

1. Masters, Gilbert M., Renewable and efficient electric power systems, John Wiley & Sons, Inc., Hoboken, New Jersey, 2004.
2. A. Duffie and W.A. Beckman: Solar Energy Thermal Processes, J. Wiley, 1994.
3. Thomas E. Kissell, David M. Buchla, Thomas L. Floyd Renewable energy systems, Pearson 2017
4. G. N. Tiwari,ArvindTiwari,Shyam, Handbook of Solar Energy: Theory, Analysis and Applications, springer,2016.
5. F. Kreith and J.F. Kreider: Principles of Solar Engineering, McGraw Hill, 1978
6. Khan B. H., Non-Conventional Energy Resources, Tata McGraw Hill, 2009.
7. D.P.Kothari, K.C.Singal, RakeshRanjan, *Renewable Energy Sources and Emerging Technologies*, Prentice Hall of India, New Delhi, 2009.
8. Rao S. and B. B. Parulekar, Energy Technology, Khanna Publishers, 1999.
9. Sab S. L., Renewable and Novel Energy Sources, MI. Publications, 1995.
10. Sawhney G. S., Non-Conventional Energy Resources, PHI Learning, 2012.
11. Abbasi S. A. and N. Abbasi, Renewable Energy Sources and Their Environmental Impact, Prentice Hall of India, 2001.
12. Boyle G. (ed.), Renewable Energy -Power for Sustainable Future, Oxford University Press, 1996.
13. Johansson T. B., H. Kelly, A. K. N. Reddy and R. H. Williams, Renewable Energy – Sources for Fuel and Electricity, Earth scan Publications, London, 1993.
14. Tara Chandra Kandpal, Hari Prakash Garg, Financial evaluation of renewable energy technologies, Mac Millam India Limited.,2003.
15. "IEEE Application Guide for IEEE Std 1547(TM), IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems," in IEEE Std 1547.2-2008 , vol., no., pp.1-217, 15 April 2009, doi: 10.1109/IEEESTD.2008.4816078

Course Contents and Lecture Schedule:

No	Topic	No. of Lectures
1	**Solar energy (7 hours)**	
1.1	Introduction - Basic Concept of Energy -Source of Solar Energy - Formation of the Atmosphere - Solar Spectrum.	1
1.2	Solar Constant -Air Mass -Solar Time-Sun–Earth Angles-Solar Radiation-Instruments to Measure Solar Radiation-Pyrheliometer – Pyranometer -Sunshine Recorder	2
1.3	Solar Radiation on a Horizontal Surface –Extra-terrestrial Region.- Terrestrial Region -Solar Radiation on an Inclined Surface -Conversion Factors	2
1.4	Total Solar Radiation on an Inclined/Tilted Surface -Monthly Average Daily Solar Radiation on Inclined Surfaces.	2
2	**Solar Thermal Systems (6 hours)**	
2.1	Principle of Conversion of Solar Radiation into Heat, –Solar thermal collectors –General description and characteristics	1
2.2	Flat plate collectors –Heat transfer processes –Solar concentrators (parabolic trough, parabolic dish, Central Tower Collector) – performance evaluation.	2
2.3	Applications -Solar heating system, Air conditioning and Refrigeration system	1
2.4	Pumping system, solar cooker, Solar Furnace, Solar Greenhouse	1
2.5	Design of solar water heater	1
3	**Solar PV systems (7 Hours)**	
3.1	Introduction -Fundamentals of Semiconductor and Solar Cells - Photovoltaic Effect -Solar Cell (Photovoltaic) Materials - Basic Parameters of the Solar Cell -Generation of Solar Cell (Photovoltaic) Materials	2
3.2	Photovoltaic (PV) Module and PV Array - Single-Crystal Solar Cell Module, Thin-Film PV Modules, III–V Single Junction and Multijunction PV Modules -Emerging and New PV Systems	1
3.3	Packing Factor of the PV Module - Efficiency of the PV Module - Energy Balance Equations for PV Modules	1
3.4	Series and Parallel Combination of PV Modules.- Effect of shadowing-	1
3.5	MPPT Techniques-P&O , incremental conductance methd-Maximum Power Point Tracker (MPPT) using buck-boost converter.	2

4	**Stand Alone and Grid integrated PV System (9 Hours)**	
4.1	Solar PV Systems –stand-alone and grid connected -Design steps for a Stand-Alone system –Storage batteries and Ultra capacitors.	2
4.2	Design PV powered DC fan and pump without battery	2
4.3	Design of Standalone System with Battery and AC or DC Load.	2
4.4	A Grid Interactive PV System - Phase , Frequency Matching and Voltage Consideration – Operation of a Grid Interactive Inverter	2
4.5	IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems	1
5	**GIPV System Protection and LCC (7)**	
5.1	Protection Against Islanding and Reverse Power Flow	1
5.2	AC Modules Design of EMI Filters. .	1
5.3	Overcurrent protection of solar PV power system, Selective fuse links for PV String protection, PV fuse selection flow chart, Fuse rating for PV Applications	2
5.4	Life cycle costing, Growth models, Annual payment and present worth factor, payback period of solar PV system, LCC with examples.	2
5.5	Introduction to simulation software for solar PV system design like PV syst, PV SOL etc.	1