| Name:<br>Enrolment No: | UPES |
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# UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

## End Semester Examination, December 2018

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| **Programme Name:** | **M.Tech REE** | **Semester** | **: I** |
| **Course Name :** | **Solar Photovoltaic Technologies** | **Time** | **: 03 hrs** |
| **Course Code :** | **EPEC-7024** | **Max. Marks** | **: 100** |
| **Nos. of page(s) :** | **4** | | |

### SECTION A

| S. No. | | Marks | COs |
|---|---|---|---|
| Q 1 | Find the day of the year on which the sun is directly overhead at 12:00h (AST) at Pune ($18.53^0$ N) | **4** | **CO1** |
| Q.2 | Discuss the advantages and disadvantages of thin film solar cells when compared with single crystalline solar cells. | **4** | **CO2** |
| Q.3 | Write the brief note on Staekler-Wronski effect. | **4** | **CO2** |
| Q.4 | On a sketch of an IV and power curve, indicate open circuit voltage, short circuit current and maximum power point for a typical c-Si solar cell including typical magnitude for open circuit voltage and short circuit current. | **4** | **CO3** |
| Q.5 | What is a grid-connected PV system? What are single-stage and multistage grid connected systems? | **4** | **CO4** |

### SECTION B

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| Q.6 | Name the instruments for measuring the solar radiations. With the help of neat diagram, detailed the construction and measuring principle of pyranometers. | **8** | **CO1** |
| Q.7 | (i) List and explain the different type of optical losses within a solar cell. Your answer should include how these losses can be minimized.<br>(ii) Discuss the roll of TCO layer in the thin film solar cells. List different type of materials used as a TCO. | **4**<br><br>**4** | **CO2** |
| Q.8 | Describe the process steps involved in the manufacturing of monocrystalline (CZ process) silicon wafers. | **8** | **CO2** |
| Q.9 | Starting with the solar cell equation, derives the expression for open circuit voltage ($V_{OC}$). What factors determine the order of magnitude of $V_{OC}$.?<br>**OR**<br>When the cell temperature is 300K, a certain silicon cell of area 100 $cm^2$ has an open circuit voltage of 600 mV and a short circuit current of 3.3A under 1kW/$m^2$ illumination. Assuming that the cell behaves ideally, what is its energy conversion efficiency at the | **8** | **CO2** |

| | | | |
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| | maximum power point.<br><br>What would be its corresponding efficiency if the cell had a series resistance of 0.1 Ω and a shunt resistance of 3 Ω? | | |
| Q.10 | (i) Explain how localized 'hot spots' can occur in a partially shaded cell connected into a large photovoltaic array.<br>(ii) Explain the steps that can be taken to prevent damage arising from such 'hot spots'. | **8** | **CO3** |

**SECTION-C**

| | | | |
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| Q.11 | **(i)** Define the following terms related to the lead acid batteries<br>(a) State of charge (b) Depth of discharge (c) Self-discharge (d) Stratification. | **8** | **CO3** |
| | **(ii)** A PV system is required to produce 96 W at 12 V. Design the PV panel, working at the maximum power point, if each cell is 80 $cm^2$ in area and having the following specification. Sketch the neat diagram of the designed array. | **12** | |

| Type of Cell | Cell Temperature In $^0K$ | $I_{SC}$ ($A/m^2$) | Dark Saturation Current Density $I_o$ ($A/m^2$) | Thermal Voltage $V_T$ |
|---|---|---|---|---|
| C-Si | 300 | 250 | 1.7e-08 | .026Volt |

| | | | |
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| Q.12 | (i) Give the basic flow chart for implementing the perturb and observe (P & O) approach. Discuss the basic schemes of MPPT controller for implementing the P & O algorithm.<br>**OR**<br>Using the simple design method, design a PV system using 60 W, 12 V panels and 145 Ah, 6 V batteries. The PV system is required to offer 3 days of autonomy, the battery efficiency is 75%, and the depth of discharge is 70%. The location where the system is located has 6 h of daylight during wintertime and the application is 24 V with a load of 1500 Wh. | **10** | **CO4** |
| | (ii) Define total harmonic distortion in relation with inverter. What should be the value of THD of an ideal sine wave inverter?<br>Draw the block diagram of shunt and series type controllers. How can a DC to DC converter be used in a charge controller?<br>**OR**<br>Design a PV water pumping system (DC), which is required to draw 25,000 lit of water every day from the depth of 10m. The Data required for calculations is as follows:<br>Total vertical lift = 12 m (5 m-elevation, 5m-standing water level, 2 m- drawdown)<br>Water density = 1000 $kg/m^3$, Solar PV module used = 75 $W_P$ (with operating factor 0.75)<br>Sun peak hours =6 /day, Pump efficiency= 30%, Mismatch factor = 0.85. The MPPT circuit is not used. | **10** | |

**Appendix-I**

Table: Recommended Average Days for Months and Values of n by Months

| Month | $n$ for $i$th Day of Month | For Average Day of Month | |
|---|---|---|---|
| | | Date | $n$ |
| January | $i$ | 17 | 17 |
| February | $31 + i$ | 16 | 47 |
| March | $59 + i$ | 16 | 75 |
| April | $90 + i$ | 15 | 105 |
| May | $120 + i$ | 15 | 135 |
| June | $151 + i$ | 11 | 162 |
| July | $181 + i$ | 17 | 198 |
| August | $212 + i$ | 16 | 228 |
| September | $243 + i$ | 15 | 258 |
| October | $273 + i$ | 15 | 288 |
| November | $304 + i$ | 14 | 318 |
| December | $334 + i$ | 10 | 344 |

**Useful Models and Equations**

1. Estimation models for diffuse component of hourly and monthly radiations.

For $\omega_s \leq 81.4^\circ$

$$\frac{H_d}{H} = \begin{cases} 1.0 - 0.2727K_T + 2.4495K_T^2 - 11.9514K_T^3 + 9.3879K_T^4 & \text{for } K_T < 0.715 \\ 0.143 & \text{for } K_T \geq 0.715 \end{cases}$$

and for $\omega_s > 81.4^\circ$

$$\frac{H_d}{H} = \begin{cases} 1.0 + 0.2832K_T - 2.5557K_T^2 + 0.8448K_T^3 & \text{for } K_T < 0.722 \\ 0.175 & \text{for } K_T \geq 0.722 \end{cases}$$

$$\frac{I_d}{I} = \begin{cases} 1.0 - 0.09k_T & \text{for } k_T \leq 0.22 \\ 0.9511 - 0.1604k_T + 4.388k_T^2 \\ \quad -16.638k_T^3 + 12.336k_T^4 & \text{for } 0.22 < k_T \leq 0.80 \\ 0.165 & \text{for } k_T > 0.8 \end{cases}$$

2. Monthly average Extraterrestrial Solar Radiation

$$H_0 = \frac{24\times3600\ G_{sc}}{\pi}\left(1+0.033\cos\frac{360n}{365}\right)\times\left[\cos\varnothing\ \cos\delta\sin\omega_s + \frac{\pi\ \omega_s}{180}\ \sin\varnothing\ \sin\delta\right]$$

$$I_0 = \frac{12\times3600\ G_{sc}}{\pi}\left(1+0.033\ \cos\frac{360n}{365}\right)\times\left[\cos\varnothing\ \ \cos\delta\ \ (\sin\omega_2 - \sin\omega_1) + \frac{\pi(\omega_2 - \omega_1)}{180}\ \sin\varnothing\ \ \sin\delta\right]$$

3. Declination $\delta = 23.45\sin\left[\frac{360}{365}(284+n)\right]$

4. Sun rise hour angle for tilted surfaces $\cos^{-1}[-\tan(\varnothing-\beta)\tan\delta]$ in Northern Sphere

5. Solar Constant $G_{sc}$ = 1367 W/m$^2$

6. Isotropic Model to estimate the total Insolation on tilted surface

$$I_T = I_b R_b + I_d\left(\frac{1+\cos\beta}{2}\right) + I\rho_g\left(\frac{1-\cos\beta}{2}\right)$$

7. Sun set/sun rise hour angle

$\omega_s = \cos^{-1}(-\tan\varnothing tan\delta)$

8. Angle of incidence on inclined surface

$$\cos\theta = \sin\delta\sin\phi\cos\beta - \sin\delta\cos\phi\sin\beta\cos\gamma \\ + \cos\delta\cos\phi\cos\beta\cos\omega + \cos\delta\sin\phi\sin\beta\cos\gamma\cos\omega \\ + \cos\delta\sin\beta\sin\gamma\sin\omega$$