o/p power of array $P_a = P_{in} \times \eta_{cell} = 0.12 \times 562.5n = 67.5n$ — 1M

$P_a = (P_{in})_m$

$67.5n = 877.64$

$\therefore n = 13$ — 2M

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CMRIT

Internal Assesment Test – 2

Sub: Solar and Wind Energy (Professional Elective)				Code: 18EE731
Date: 04/12/2023	Duration: 90 mins	Max Marks: 50	Sem: 7	Section: A&B

Answer ANY FIVE full questions. Explain your notations explicitly and clearly. Sketch figures wherever necessary. Good luck!

		Marks	OBE	
			CO	RBT
Q1.	Derive an expression for the maximum power output (P_{max}) of a horizontal axis wind turbine.	[10]	CO4	L2
Q2a.	How you can construct solar Cell, Module and Array? Explain with neat diagram.	[6]	CO2	L2
Q2b.	What are the major advantages and disadvantages of solar PV system?	[4]	CO2	L1
Q3.	What is Balance of System (BOS) Components? Briefly explain about individual components.	[10]	CO2	L2
Q4.	Describe the working principle of a solar PV cell. With the help of a neat diagram explain the working of a grid tied solar PV system.	[10]	CO2	L2
Q5.	Explain the process of constructing (i) single and (ii) multi crystalline silicon solar cells.	[10]	CO2	L2
Q6.	A PV system feeds a dc motor to produce 1 HP power at the shaft. The motor efficiency is 85%. Each module has 36 multi crystalline silicon solar cells arranged in 9 × 4 matrix. The cell size of 125 mm × 125 mm and cell efficiency is 12%. Calculate the number of modules required in the PV array. Assume global radiation incident normally to the panel as 1 KW/m^2. Take 1 HP = 746 W.	[10]	CO4	L3

CI CCI HOD/EEE

$P_{out} = 1 \times 746 = 746\,W$

$(P_{in})_m = \frac{P_{out}}{\eta} = \frac{746}{0.85} = 877.64\,W$ → 2M

Area of 1 module $= 125\times10^{-3} \times 9 \times 125\times10^{-3} \times 4 = 0.5625\,m^2$ — 2M

Area of PV array having n modules $S = 0.5625n\ m^2$ — 1M

Solar radiation $E = 1\,kW/m^2 = 1000\,W/m^2$

$\therefore$ power i/p to PV array $P_{in} = E \times S = 1000 \times 0.5625n = 562.5n$ — 2M

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1) A PV cell feeds a DC motor to produce 1Hp power at the shaft. The motor Efficiency is 85%. Each module has 36 multicrystalline silicon solar cells arranged in 9×4 matrix. The cell size of 125mm × 125mm and cell efficiency is 12%. Calculate the number of modules required required in the PV array. Assume global radiation incident normally to the panel as 1KW/m². Take 1Hp = 746W.

1 hp = 746W

motor Efficiency = 85%

Motor Input = $\frac{746}{0.85}$ = 877.65W

Cell area in one solar module

$= 125 \times 125 \times 10^{-6} \times 9 \times 4$

$= 0.5625 \, m^2$

Let the number of modules be n

Solar radiation incident on panel = 1 Kw/m²

= 1000 W/m²

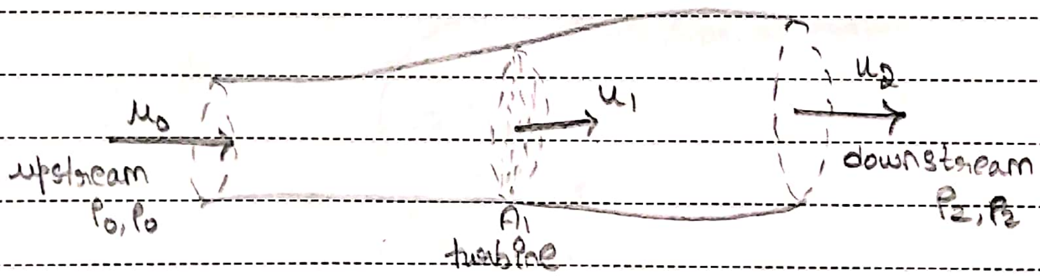
Cell Efficiency = 0.12

Output of solar array = $1000 \times 0.5625 \times x \times 0.12$

= 877.65

13 modules are required in the panel.

2) Derive an Expression for the maximum power output (Pmax) of a horizontal axis wind turbine.



Consider horizontal axis wind turbine

$$m = \frac{dm}{dt}$$

Air mass flow rate remains same throughout stream tube

$$m = \rho A_1 V_1 = \rho A_2 V_2 = \rho A V$$

where V_1 (or) V_2 velocity at upstream

$$F = ma = m\frac{dv}{dt}$$

$$= \rho A V (V_1 - V_2) \rightarrow ①$$

$$dE = F \times dx$$

Power Extracted by turbine is

$$P = \frac{dE}{dt} = F\frac{dx}{dt} = FV \rightarrow ②$$

① in ②

$$P = \rho A V^2 (V_1 - V_2) \rightarrow ③$$

$$P = \frac{\Delta E}{\Delta t} = \frac{1}{2} m V_1^2 - \frac{1}{2} m V_2^2 = \frac{1}{2} m (V_1^2 - V_2^2)$$

$$= \frac{1}{2} \rho A V (V_1^2 - V_2^2) \rightarrow ④$$

$$\rho A V^2 (V_1 - V_2) = \frac{1}{2} \rho A V (V_1^2 - V_2^2)$$

$$\rho A V^2 (V_1 - V_2) = \frac{1}{2} \rho A V (V_1 + V_2)(V_1 - V_2)$$

$$V = \frac{V_1 + V_2}{2} \rightarrow ⑤$$

$$P = \tfrac{1}{4} \rho A (V_1 + V_2)(V_1^2 - V_2^2) \rightarrow ⑥$$

$$P = \tfrac{1}{4} \rho A (V_1^3 - V_1 V_2^2 + V_2 V_1^2 - V_2^3)$$

$$\frac{dP}{dV_2} = 0$$

$$-V_1 2V_2 + V_1^2 - 3V_2^2 = 0$$

$$3V_2^2 + 2V_1 V_2 - V_1^2 = 0 \rightarrow ⑦$$

$$V_{2(opt)} = \tfrac{1}{3} V_1 \rightarrow ⑧$$

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$$P_{max} \text{ (or) } P_T = \frac{1}{4}\rho A \left(V_1 + \frac{1}{3}V_1\right)\left(V_1^2 - \frac{1}{9}V_1^2\right)$$

$$P_{max} = \frac{1}{4}\rho A \left(\frac{4V_1}{3}\right)\left(\frac{8V_1^2}{9}\right)$$

$$P_{max} = \frac{8}{27}\rho A V_1^3$$

$$\boxed{P_{max} = 0.593 \; P_a \text{ (or) } 0.593 P_{total}}$$

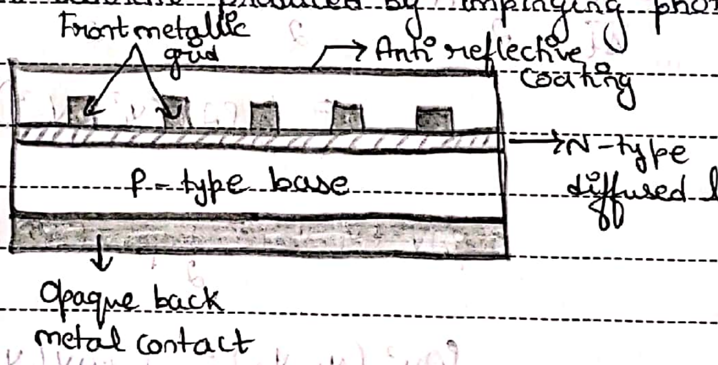
3)(a) How you can construct solar cell, module and array? Explain with neat diagram.

Solar cell :- Basic cell structure of typical N on P, and bulk silicon is used.

→ Bulk material used is P-type silicon with thickness of 100 to 350 micrometers.

→ A thin layer of N-type silicon is formed at top surface by diffusing an impurity from 5th group to get PN-junction.

→ Top active surface of N-layer has ohmic contact with metallic grid structure to collect current produced by impinging photons.



→ The bottom inactive surface has ohmic metallic contact cover over entire area.

Solar PV module :- A bare single cell cannot be used for outdoor energy generation by itself.

→ Workable voltage and reasonable power is obtained by interconnecting appropriate number of cells, cells from same batch are used to make PV modules.

→ The electrically connected cells are encapsulated by using 2 sheets of EVA, as EVA is good electrical insulation transparent material and has low water absorption.

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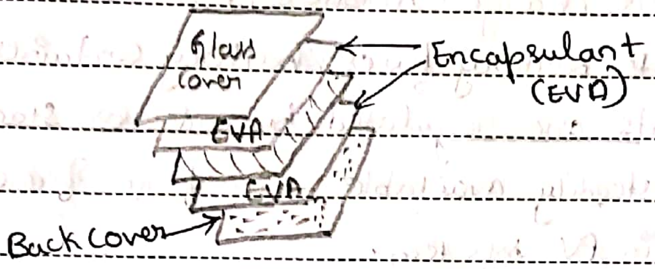
→ At rear side of module a hard polymer, polyvinyl flouride is used.
→ Most common commercial modules have series connection of 32 (or) 36 silicon cells to make it capable of charging a 12V storage battery.



Solar PV array:- A large number of interconnected solar panels knows as "solar PV array".
→ It is important to ensure that an installed panel does not cast its shadow on surface of its neighbouring panels during whole year.
→ The layout and mechanical design of array such as tilt angle of panels, height of panels, etc are carried out taking into consideration local climate, ease of maintenance, etc.

3) What are the major advantages and disadvantages of solar PV system?

Advantages:
→ Solar PV systems are reliable, modular, durable and generally maintenance free.
→ It converts solar energy into electrical energy without going through them of mechanical link.
→ These systems are quite, compatible.

Disadvantages:-
→ At present cost of solar cells are high, making them economically uncompetitive with other conventional power source.
→ The efficiency of solar cell is low.
→ Solar energy is intermittent, so electrical energy storage is required.

→ Grid acts as infinite source (or) sink of energy.
→ Employs two stages to appropriately condition solar power for feeding to grid.
→ First stage tracks maximum power while second stage inverts this dc to high quality ac.

6) Explain the process of constructing (i) single and (ii) multicrystalline silicon solar cells.

Single crystalline silicon solar cell

→ Silica is melted with measured amount of carbon.
→ Results in carbondioxide formation with silica reducing relatively pure silicon called metallurgical grade silicon.
→ It's then purified by treating MG-Si with HCL to get trichlorosilane gas which in turn is condensed and frictionally distilled to yield semiconductor grade SeG-Si.
→ SeG-Si is in multicrystalline form, it is converted to single crystalline by melting & solidification.
→ Crystal is obtained in form of 6 to 15 cm diameter long cylinder block, sliced into number of 250 μm thick wafers.
→ Metal contacts are fixed to both faces of water and antireflecting coating is laid.
→ Finally wafer is encapsulated in weather resistant transparent coating.

Multicrystalline silicon solar cells

→ It's same as process of single crystalline but conversion of single crystal is eliminated.
→ Wafers are prepared from large grain multicrystalline ingots.
→ It can be cut from octagonal tube of multicrystalline silicon with average wall thickness of 280 μm.
→ Wafers are square shape & higher packing density of cells in module.
→ Efficiency is about 20.3% and low cost.