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Internal Assesment Test – 2

Sub: Solar and Wind Energy (Professional Elective)				Code: 18EE731
Date: 01/12/2022	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.	Explain with neat sketches Trombe-Wall method of solar passive space heating system.	[10]	CO3	L2
Q2.	With neat diagrams, explain the working of solar water heater.	[10]	CO3	L2
Q3.	What is Balance of System (BOS) Components? Briefly explain about individual components.	[10]	CO2	L2
Q4a.	Briefly explain about Maximum Power Point Tracker (MPPT).	[6]	CO2	L2
Q4b.	Define: (i) Fill factor; and (ii) Conversion efficiency.	[4]	CO2	L1
Q5.	Describe the classifications of solar cells based on the type of active material used.	[10]	CO2	L2
Q6a.	Explain how the variation of insolation and temperature affects the I-V characteristics of a solar PV cell.	[4]	CO2	L2
Q6b.	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.	[6]	CO2	L3

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Assignment - 02 SWE

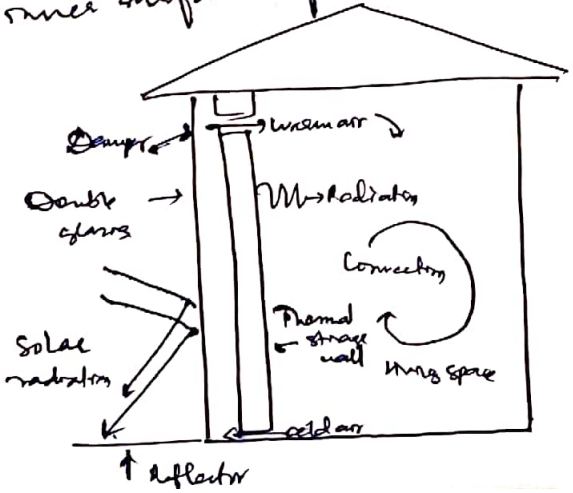
Keerthi. S. Arunglesi
ICR19EE042

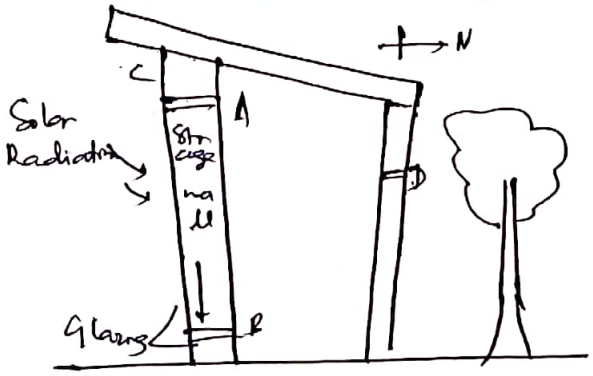
Q1) Explain with neat sketches Trombe - Wall Method of solar passive space heating system.

→

Passive heating / cooling architects building design to have natural heat flow possibility

* Such building is called solar house
* Active method need mechanical devices like pump
* Passive does not require mechanical devices
* South facing wall of the house provided with single / double glazing
* Blind glaze is a thick wall painted black for good absorption
* The wall is made of concrete, adobe, stone
* Wall absorbs radiation & serves as thermal storage.
* Air gap b/w inner glazing & wall is usually b/w 10cm to 15cm.
* Vents A & B are provided at top & bottom of the wall & can be kept open or closed
* Whole unit containing storage wall, vents & called Trombe Wall.
* During day vents A & B are kept open
* Air b/w inner glazing & wall get heated & enter in living room through vent A.
* Simultaneously cooler air from room is pulled out through vent B
* Thus natural circulation takes place.
* Energy transfer can happen due to radiation & convection from inner surface of storage wall.





* In summer vent B, C, D are kept open & A is closed
* Heated air b/w glazing & wall flows out through vent C drawing air from living room to replace it.
* This causes air to be pulled from vent D.
* Vent D should be located near cool & shaded area
* Overhang on roof prevents beam radiation from falling on glazing during summer to make ventilation effective.
* Sometimes a reflective horizontal surface is provided to get more radiation for thermal storage.
* Movable insulation is used to cover glazing to reduce heat loss from storage wall in night.

Q2) With neat diagrams, explain the working of solar water heater.

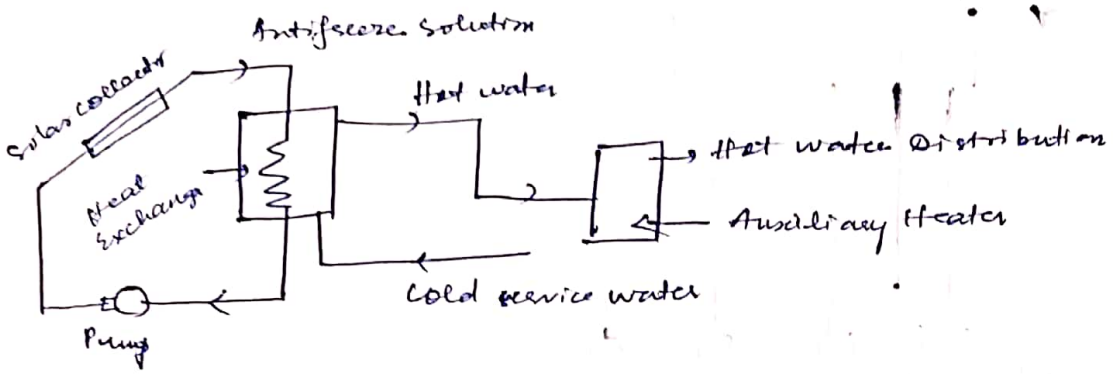
→ Two types of Solar water heaters.

1) Natural Circulation system
2) Forced Circulation system

1) Natural Circulation System (Passive)

* Cycle of hot water rising & cooler water falling is called Thermosyphon flow
* Combines roof mounted flat plate collector & storage tank.
* Convectional heat transfer method
* Tank is placed above the top of the collector.
* As water is heated in the collector it rises & is replaced by cold water from the bottom of the tank
* Cycle continues until temperature of water in the tank equals that of the panel
* One way valve prevents reverse occurring at night when temperature drops
* As water is drawn off for use fresh cold water is fed from the mains

Forced Circulation Systems (Closed Loop) :-



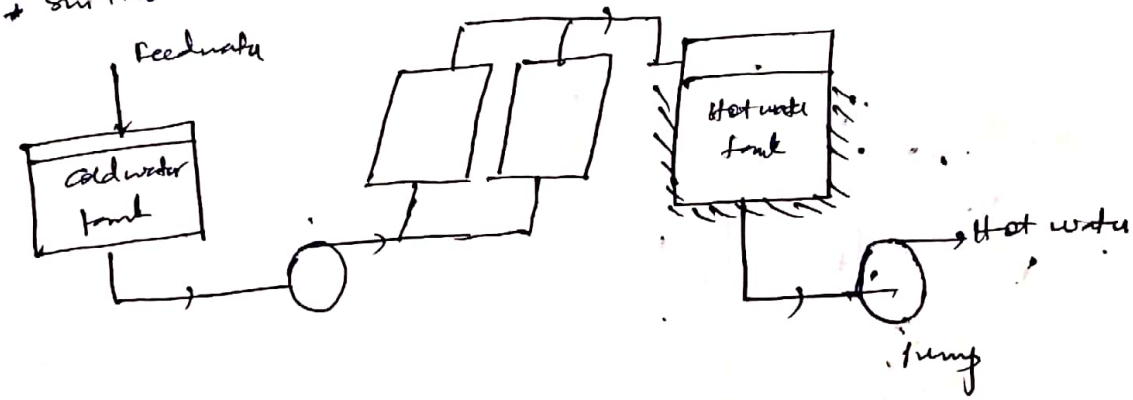
* Pumps circulate antifreeze mixture through the collector and then through a heat exchanger in the storage tank.
* Suitable in climates prone to freezing temperatures.
* Provision is made for auxiliary heater.
* Typically these systems cost ₹140/- per litre/day of hot water

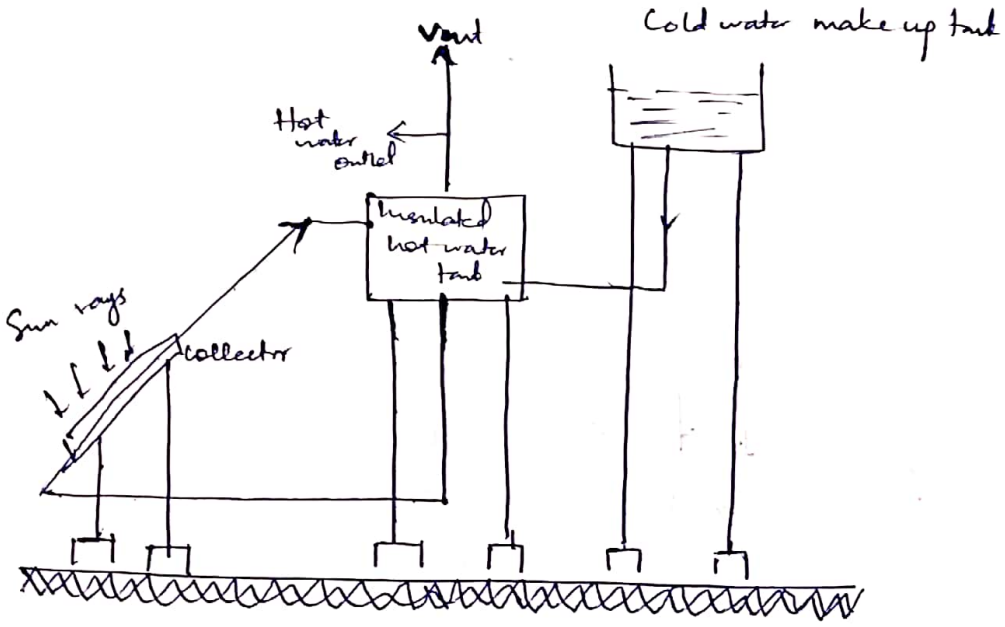
Parts of Active SWH :-

- Collector
- Circulation system
- Storage tank
- Backup heating system
- Control system

Open loop ↓

* Pumps circulates household water through the collector and to the storage tank.
* Suitable where temperature seldom falls below freezing.

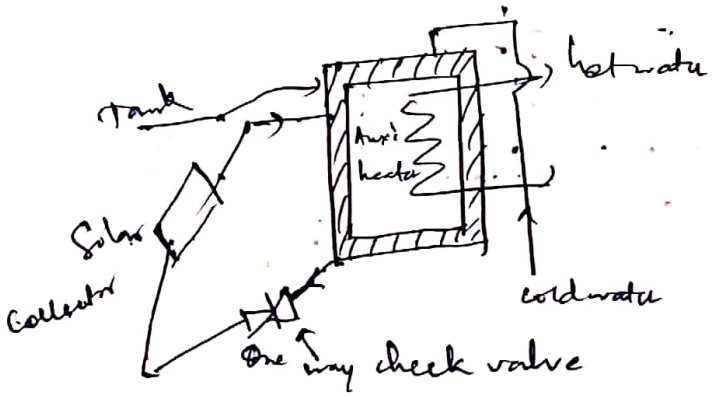




* Head height is b/w 1ft to 2ft
* Heating system requires careful designing hence it is expensive
* In average Indian climatic condition solar water heater can be used for about 300 days
* Heats water at 60 to 80°C
* Life span = 10 to 12 years

Natural circulation systems (Non-pressurized) :-

* Pressurized system can supply hot water at locations of the storage tank.
* Supplies hot water through gravity flow only to places lower than tank
* Simple construction
* Cheap
* One wave check valve to prevent reverse circulation & thus loss of heat at night



Q3) What is Balance of System Components ? Briefly explain about individual components.

→ It encompasses all components of a photovoltaic system other than the photovoltaic panels. This includes wiring, switches, a mounting system, one or many solar inverters, a battery bank & battery charger.

E Panel :-

A circuit breaker a product manufactured by Midnite solar that accomodates several models of inverters & controllers

Breakers :-

Automatically by Midnite solar that switch designed to protect an electrical ckt from damage caused by overload or short ckt.

Combiners :-

It is a simple electrical component for combining & housing the wirings coming from your solar panels.

Surge protecting :-

It is an appliance designed to protect electrical devices from voltage surges

Disconnects :

Used to ensure that an electrical ckt is completely de-energised for service

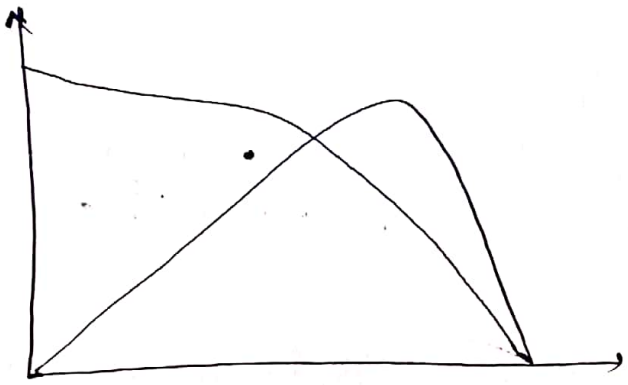
Wiring & Cable :-

Used to connect solar panels with controllers with inverters

Q4) Briefly explain about Maximum Power Point Tracker.

→ An algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called maximum power point.

Typical PV module produces power with maximum power voltage of around 17 V when measured at a cell temperature of 25°C, it can drop to around 15 V on a very hot day & it can also rise to 18 V on a very cold day.



I-V curves shows maximum power from PV modules when exposed to irradiance 1000 W/m².

Q5) Define

i) Fill factor :- Ratio of the actual maximum obtainable power, to the product of short-ckt current Is/c & open circuit voltage.

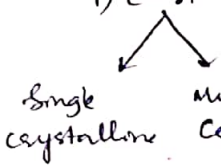
ii) Conversion Efficiency :-

Ratio b/n the useful o/p of an energy conversion m/c & the i/p in energy terms.

It can be chemical, electric power, mechanical work, light or heat.

Q6) Describe the classifications of solar cells based on the type of active material used.

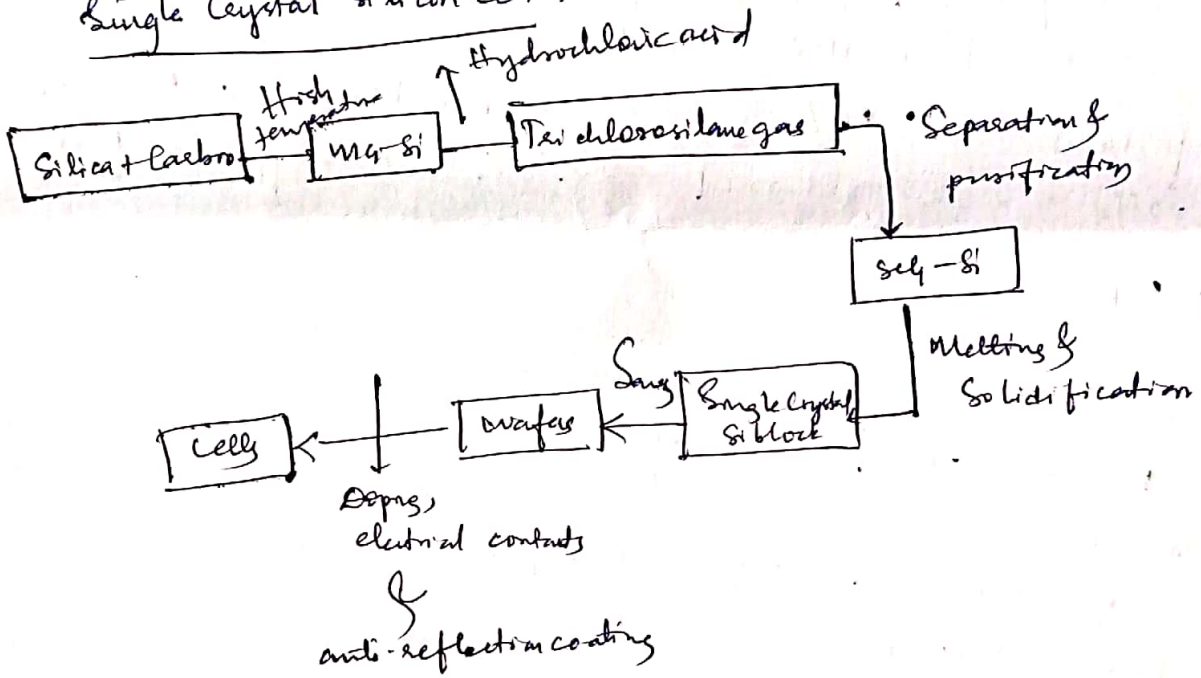
→ 1) c-Si 2) a-Si 3) GaAs 4) CIGS 5) CdTe 6) Organic



1) c-Si Technology :-

+ 80% crystalline market
* Cost reduction by using multi-crystalline cells
* 25 years lifetime
* 22-5% efficiency of monocrystalline cells
* Upto 20% efficiency of polycrystalline cells

Single Crystal Silicon Cell :-



Multi crystalline Silicon Cell :-

* Same process as that of single crystal with conversion of multicrystal to single crystal step being eliminated.
* Wafers can be cut from an octagonal tube of multicrystalline silicon with average wall thickness of 200 μm.
* Wafers are of square shape
* They allow higher packing density of cells in the module
* Efficiency is about 20.3%.
* Low cost

2) Amorphous Silicon (a-Si) :-

* Cheaper & uses thin film technology
* Electronic properties of a-Si is improved by alloying it with H_2 to get a Si:H material.
* The cell consists of 3 layers P-i-N.
* The cell is manufactured by chemical vapor deposition technique
* Silane gas dissociates allowing silicon to deposit on a glass substrate.
* Typical deposition temperature ranges from 150°C to 250°C.
* Less efficient.

3) (GaAs) :-

* GaAs has direct band gap of 1.43 eV.
* Uses thin film of n-type & p-type GaAs grown on suitable substrate
* Can also be produced by cascading many layers of p & n type materials using impurities from III-V elements.
* Fill factor is about 80% with V_{oc} ranging b/w 0.8 V to 0.9 V.
* $\eta = 20\%$ & highest obtained is 28.8% with single junction GaAs cell.
* Very expensive.

4) CIGS :-

* CIGS has direct band gap of 1 eV
* Uses sodalime glass as substrate
* Back contact is 1 µm molybdenum film.
* This forms an heterojunction.
* efficiency is about 14.7%.
* CdTe has direct band.

5) CdTe :-

* CdTe has direct band gap of 1.5 eV
* EVA is used for encapsulation
* $\eta = 10\%$ with V_{oc} of 0.8 V.

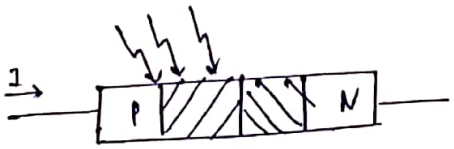
6) Organic :-

* Fabricated out of Carbon based dyes & organic polymers
* Electron acceptor layer has high electron affinity & ionization potential
* Low efficiency, Light weight, cheap & rugged, flexible

8.7) Explain how the variation of insolation and temperature effects the I-V characteristics of a solar PV cell.

→ $I = I_0 \left\{ e^{\frac{V}{\eta V_T}} - 1 \right\}$

where I_0 is the reverse saturation current $= 1.5 \times 10^5 e^{-\frac{E_g}{KT}}$



when pn junction is illuminated

$$I = -I_L + I_0 \left\{ e^{\frac{V}{V_T}} - 1 \right\}$$

* When junction is left open at terminals, $I = 0$ & open ckt voltage V_{oc} is given by

$$V_{oc} = \frac{KT}{q} \ln \left\{ \left(\frac{I_L}{I_0} \right) + 1 \right\}$$

For $I_{sc} = 2A$, $I_0 = 1nA$; V_{oc} is found to be 0.54 V.

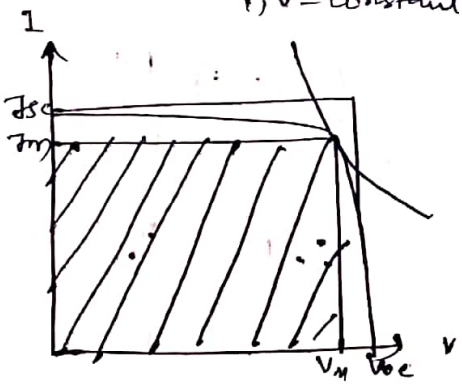
* Hence an illuminated pn junction is an energy source with V_{oc} & I_{sc}

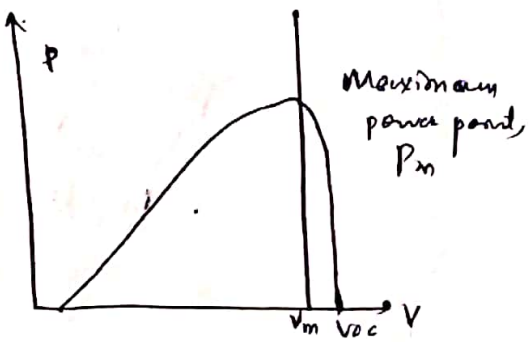
* Mathematically I-V characteristics is

$$I = I_L - I_0 \left\{ e^{\frac{V}{V_T}} - 1 \right\}$$

$$I = I_{sc} - I_0 \left\{ e^{\frac{eV}{KT}} - 1 \right\}$$

P, V = constant





8e) A PV system feeds a dc motor to produce 1 HP power at the shaft. The motor $\eta = 85\%$. Each module has 36 multi crystalline silicon solar cells arranged in 9 X 4 matrix. The cell size of 125 mm x 125 mm & cell $\eta = 12\%$. Calculate the no. of modules required in the PV array. Assume global radiation incident normally to the panel as 1 KW/m². Take 1 HP = 746 W.

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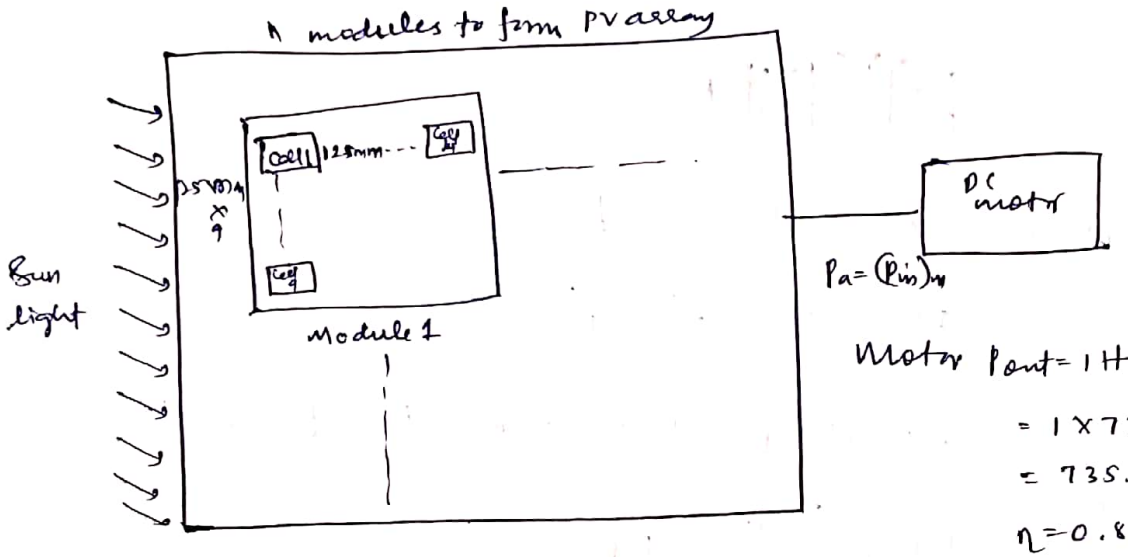

Motor P_{out} = 1 HP

= 1 X 735.5

= 735.5 W

$\eta = 0.85$

Area of 1 module = $125 \times 10^{-3} \times 9 \times 125 \times 10^{-3} \times 4 = 0.5625\ m^2$

$\therefore$ I/P power of motor $(P_{in})_m = \frac{P_{out}}{\eta} = 865.3\ W$

Area of PV array having 'n' modules $S = 0.5625n\ m^2$

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

$\therefore$ Power I/P to solar array

$P_{in} = E \times S = 1000 \times 0.5625n = 562.5n$

$\therefore$ O/P power of array -

Given $\eta_{cell} = 0.12$ $P_a = P_{in} \times \eta_{cell} = 0.12 \times 562.5n$; $P_a = 67.5n$

As $P_a = (P_{in})_m$; $67.5n = 865.3$

$\therefore n = 12.82 \sim 13$