❖ Home Work 1

Prepare an engineering PV based power supply working layout diagram (indicating the size of PV modules/array, size of rechargeable battery/batteries, wire sizes fuses, etc.) to meet the following requirements for a remote area school:
Light load: 5 no of 15 W LED lamps for 5 different rooms
Computer Load: 50 desktop computers (Ten 80-Watt computers per room in 5 different rooms)

Given:
System Voltage: 220 Volts AC, 50 Hz
Solar Insolation Value: Min 4 kWh/m2/day (for 8 months); Max: 5.5 kWh/m2/day for 4 months
The efficiency of DC to AC inverter: 90?
Operation hours: 10 hours/day

Assume other data as required

Solution,
Here, first computing the power consumption by the bulbs and computer,

Total bulbs power consumption (P_B) = no. of rooms * bulb per room * power per bulb
= 5 * 5 * 15
= 375 Watt

Total computer power consumption (P_C) = no. of computer * power per computer
= 50 * 80
= 4000 Watt

Now the total power consumption is given by,

Total power consumption (P_T) = P_B + P_c
= 375 + 4000
= 4375 Watt

Before we go to further calculation, we require few more conditions. For that let us suppose the power requirement objectives given as following points:

- The devices are operated 10 hrs a day.
- The battery size is aimed to have a full-day backup capacity.
- The PV module is 20% efficient.
- The unit battery pack is 12V.

- The peak sun time is 4 hrs.

This gives us the total energy consumption per day as E,

E_T = Total power(P_T) * operating time
= 4375 * 10
= 43.75 K Watt/hr/day

This energy 'E_T' is the AC power and has to be converted from DC for the operation, which certainly has some power loss. So,

The total energy required/consumed per day (E_T) = actual energy required in battery (E_A) * efficiency

actual energy required in battery (E_A) = E_T / efficiency
= 43.75 / 0.9
= 48.61 K Watt/hr/day

Our system has to be operated throughout the year, hence the case for minimum Solar Insolation Value should be considered. Considering the Solar Insolation values given by the question,

Solar Insolation Value: Min 4 kWh/m2/day (for 8 months);
Max: 5.5 K Watt hr/m^2/day for 4 months

So the PV module efficiency will be,

Obtained Energy per m^2 per day (E_O) = 0.2 * 4
= 0.8 K Watt hr/m^2/day

Now, we can calculate the minimum size for the PV module since we have the energy required and energy obtained per m^2 of the available PV modules.

Hence,

the minimum size of the PV module (S) = E_A/E_O
= 48.61 / 0.8
= 60.763 m^2

The size of the battery in terms of Ah = E_A/V
= 48.61/12
= 4.05 KAhr
= 4050 Ahr

As per ELDORA VSP.72.AAA.03 PV module Spec:

Peak Power (Wp) = 300W

Total energy per day = power per panel * no. of panel * peak sun time
or, 48611 = 300 * no. of panel * 4
$\therefore$ no. of panels ~ 40 panels

As per 6LMS200L battery Spec:
Energy capacity (Ec) = 200Ah

So minimum no of batteries required = 4050/200 ~20 batteries

The size of the battery in terms of Ah (S_1) $= E_A / V$
= 48.61 /12
= 4.05 KAh
= 4050 Ah

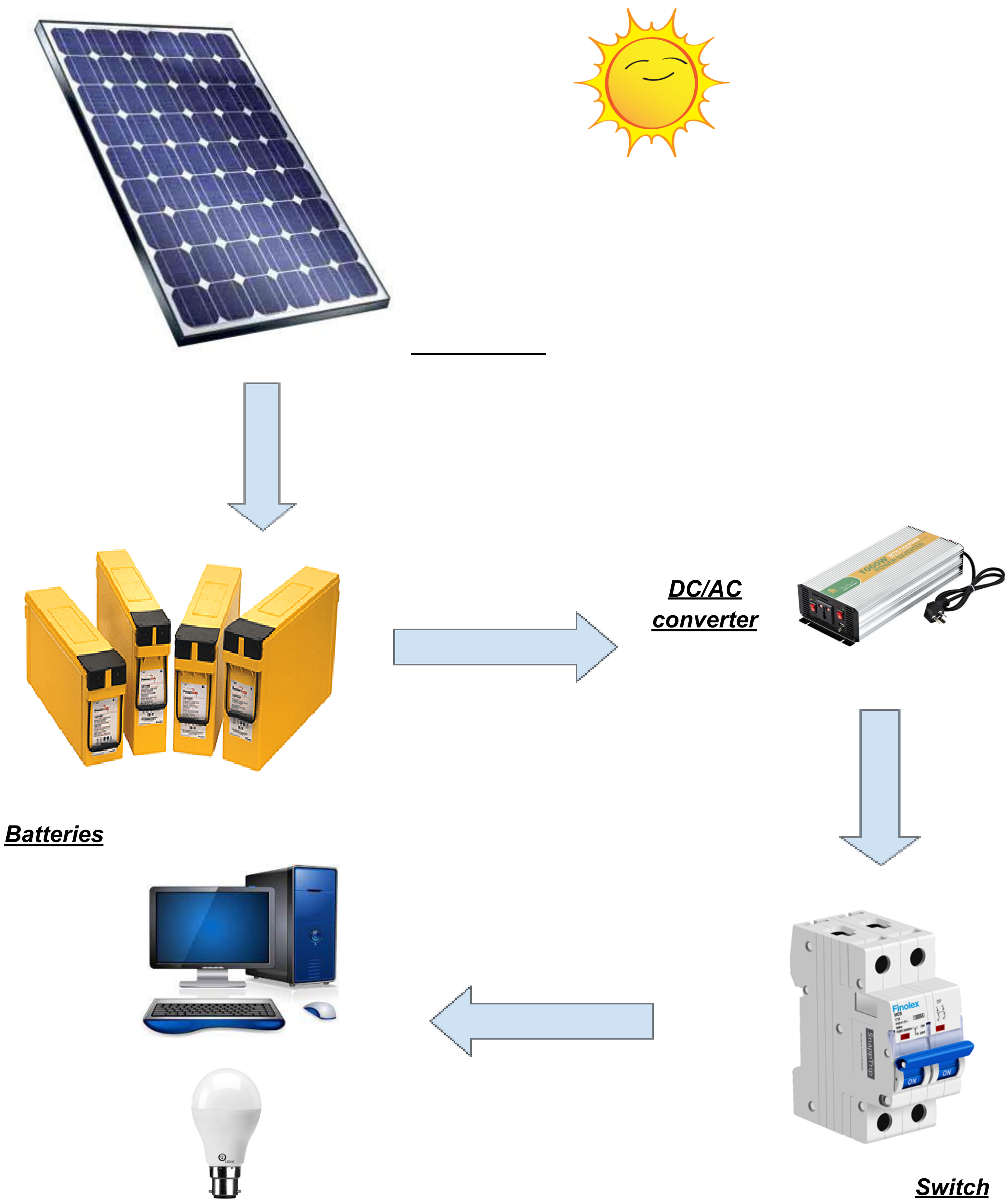
Power consumption per room (P) = Total Power (P_T) / no. of rooms
= 4375 / 5
= 875 Watt

Current consumption per room(C) = P / 220
= 875 / 220
= 3.977 Amp

The room's mains must have a wire gauge that can handle at least ~4 Amps, thus 1/18 Size Wire is suggested.

The required design for the given specification of the PV module is shown given below:

10m x 6m (40 units) PV module



Devices in parallel connection

❖ Home Work 2

Find out a simple payback period for homework no. 1 assuming the following given values:

- ***Cost of PV module Rs. 50/Wp***
- ***Cost of rechargeable battery Rs. 150/Ah of (12 V DC, DOD 80, at least 2000 Cycles)***
- ***Cost of sine wave inverter Rs. 20 /Watt (24V DC/220 V AC, 50 Hz, Sine Wave) (?)***
- ***Cost of diesel in a remote area: Rs. 200/liter***
- ***The benefit of CER (certified emission reduction, world bank rating, US$20/ton of CO2e) (?)***
- ***Simple payback period in years= (total cost of the RE based system)/(total cost of the traditional system/year)***

Solution,
Following assumptions are done for Diesel Equivalency

- Cost per liter of diesel (C) = Rs. 200/litre
- Energy generated per liter (E_2) = 3KWh/L
- CO2 emission per liter (P) = 2.5 Kg/L
- Total operational day in a year (T) = 280 days

diesel usage per day (V) = Total power consumed per day(E_A) / energy generated by diesel per litre (E_2)
= 48.61/3
= 16.20L

Cost of Diesel per day (C2) = V*C
= 16.20 * 200
= Rs. 3240

Cost of Diesel per year (C3) = C2*T
= 3240 * 280
= Rs. 907390

CO2 emission per day (P1) = P * V
= 2.5 * 16.20
= 40.5 Kg/day

Benefits due to CER of CO2 (B1) = 0.0405 * $20 * 280
= $226.8/year
= ~Rs. 27000/year

Total equipment expenditure (X) = Cost of PV module + Cost of Battery + Cost of Inverter
= 50 * 40 * 300 + 150 * 3800 + 20 * 4075
= Rs. 1251500

Total Cost Savings per Year (X1) = C3 + B1
= 907390 + 27000
= Rs. 934390

Total payback Period (T) (without considering the time value of money) = X/X1
= 1251500 / 934390
= <2 Years

❖ Home Work 3

Refer Home Work # 2

Find new answers to questions asked in homework 2 if a number of autonomy days are considered three.

Solution,

For 3-day Backup Calculation following assumption is made:

- The 3-day battery backup charging from 0-100 takes 6 full active usage days

Size of Battey module for 3 full day backup (S_2) = S_1 * 3
= 4050 * 3
= 12150 Ahr

As per 6LMS200L battery Spec:

Energy capacity (Ec) = 200Ah

So minimum no of batteries required = S2/Ec
= 12150 / 200
= ~60

As per the assumptions we have made earlier,

The total energy required in 6 days (E_2) = Active usage energy + Full battery energy
= E_A*6 + E_A*3
= 48.61 * 9
= 437.49 KWatt hr

Energy production per day (E_3) $= E_2/6$
$= 437.49/6$ F
$= 72.915$ KWatt hr

As per ELDORA VSP.72.AAA.03 PV module Spec:
Peak Power (Wp) = 300W

We have,
The total energy per day (E3) = power per panel * no. of panel * peak sun time
or, 72915 = 300 * no of panel * 4
or, no of panel = 72915/300/4
∴ no of panel = ~60 panels

❖ Home Work 4

A base transceiver station (BTS) is a fixed radio transceiver in any mobile network. The BTS connects mobile devices to the network. It sends and receives radio signals to mobile devices and converts them to digital signals that it passes on the network to route to other terminals in the network or to the Internet.

A BTS (Base Transceiver Station) is being planned to install at a remote area without INPS (Integrated National Power System). During active mode from 0600 hours to 2300 hours, the required current to operate the relevant equipment is 37 A and during sleep mode from 2300 hours to the next day 0600 hours, the required current is 10 A. The operating voltage is 48 V DC with negative grounding.

Design PV-based power system along with deep cycle battery bank with 50% DOD (depth of discharge) for a number of autonomy days considered as two. The average peak sun can be considered as 4 hours.

Solution,
Total energy in a day cycle (E_1) $= (37 * 17 + 10 * 7) * 48$
$= 33552$ Watt hr
$= 33.552$ K Watt hr

Since the total autonomy day is 2,
Total energy consumption in 2 days (E_2) $= E_1 * 2$
$= 33.552 * 2$
$= 67.104$ K Watt hr

Since DOD is 50%,

The total Energy Capacity of the battery is (E3) $= E_2 / 0.5$
= 67.104 / 0.5
= 134.208 K Watt hr

As per 6LMS200L battery Spec:
Energy capacity (Ec) = 200Ah Voltage (V1) = 12V

So, the size of the battery is (S1) = E3/V1 = 134.208/12 = 11.184 KAh = 11184 Ah

So minimum no of batteries required = S1/Ec = 11184/200 = ~56

As the operating voltage is 48V, the system requires 4 units in series and it's multiple in parallel to increase the energy capacity. Here, 56 is a multiple of 4 and so no extra battery must be added to attain 48V serial packs.

As per ELDORA VSP.72.AAA.03 PV module Spec:
Peak Power (Wp) = 300W

We have,
Total energy per day = power per panel * no. of panel * peak sun time
or, 33552 = 300 * no of panel * 4
or, no of panel = 33552/300/4
∴ no of panel = ~28 panels in parallel