Energy Environment and Society Assignment

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PUL074BEX007

Problem 1

Prepare an engineering PV based power supply working layout diagram (indicating size of PV modules/array, size of rechargeable battery/batteries, wire sizes fuses, etc.) to meet the following requirements for a remote area school:

1. **Light load: 5 nos of 15 W LED lamps for 5 different rooms**
2. **Computer Load: 50 desktop computers (Ten 80-Watt computers per room in 5 different rooms)**

Given:

System Voltage (V)=220 V AC, 50 Hz

Solar Insolation Value=Min 4 kWh/m2/day (for 8 months); Max: 5.5 kWh/m2/day (for 4 months)

Efficiency of DC to AC inverter (η_i)=90%

Operation hours (O_H)= 10 hours/day

Assume other data as required

Solution:

Total number of rooms$(R) = 5$

LED lamps per room$(N_B) = 1$

Computers per room$(N_C) = 1$

Power consumed per bulb$(P_B) = 15$ W

Power consumed per computer$(P_C) = 80$ W

Total power consumption due to LED lamps$(P_1) = R \times N_B \times P_B = 5 \times 1 \times 15 = 75$ W

Total power consumption due to computers$(P_2) = R \times N_C \times P_C = 5 \times 10 \times 80 = 4000$ W

Total power consumption$(P_T) = P_1 + P_2 = 75 + 4000 = 4075$ W

$\therefore$ Total power consumed per room$(P_R) = \dfrac{P_T}{R} = \dfrac{4075}{5} = 815$ W

$\Rightarrow$ Total current requirement through wires$(I_W) = \dfrac{P_R}{V} = \dfrac{815}{220} = 3.7$ A

According to the reference for wire size and current carrying capacity relation, single strand wire of size 1/18 is required for 5 A current, which is sufficient for our requirement.
To proceed in solving the aforementioned requirements, some assumptions are made:

Peak sun time$(S_{peak}) = 4$ hours

Unit battery pack$(B_0) = 12$ V

Efficiency of PV module$(\eta_{PV}) = 20\%$

We can now proceed as,

Total energy requirement per day$(E_R) = P_T \times O_H = 4075 \times 10 = 40.75$ KWh/day

Total energy obtained per m^2 per day$(E_O) = \eta_{PV} \times \min\{\text{Solar Insolation}\} = 0.2 \times 4 = 0.8$ KWhm^{-2}/day

According to the problem statement, the efficiency of the DC to AC inverter is 90%, so the actual energy required in battery is given as,

Actual energy requirement per day$(E_A) = \dfrac{E_R}{\eta_i} = \dfrac{40.75}{0.9} = 45.27$ KWh/day

If we assume that the battery size is supposed to provide full day backup, from the *ELDORA VSP.72.AAA.03* PV module specifications,

Peak power per panel$(P_{peak}) = 300$ W

Number of panels required$(N_P) = ?$

We have the relation,

$$E_A = P_{peak} \times S_{peak} \times N_P$$

$$\Rightarrow N_P = \frac{E_A}{P_{peak} \times S_{peak}} = \frac{45270}{4 \times 300} = 37.725 \approx 38$$

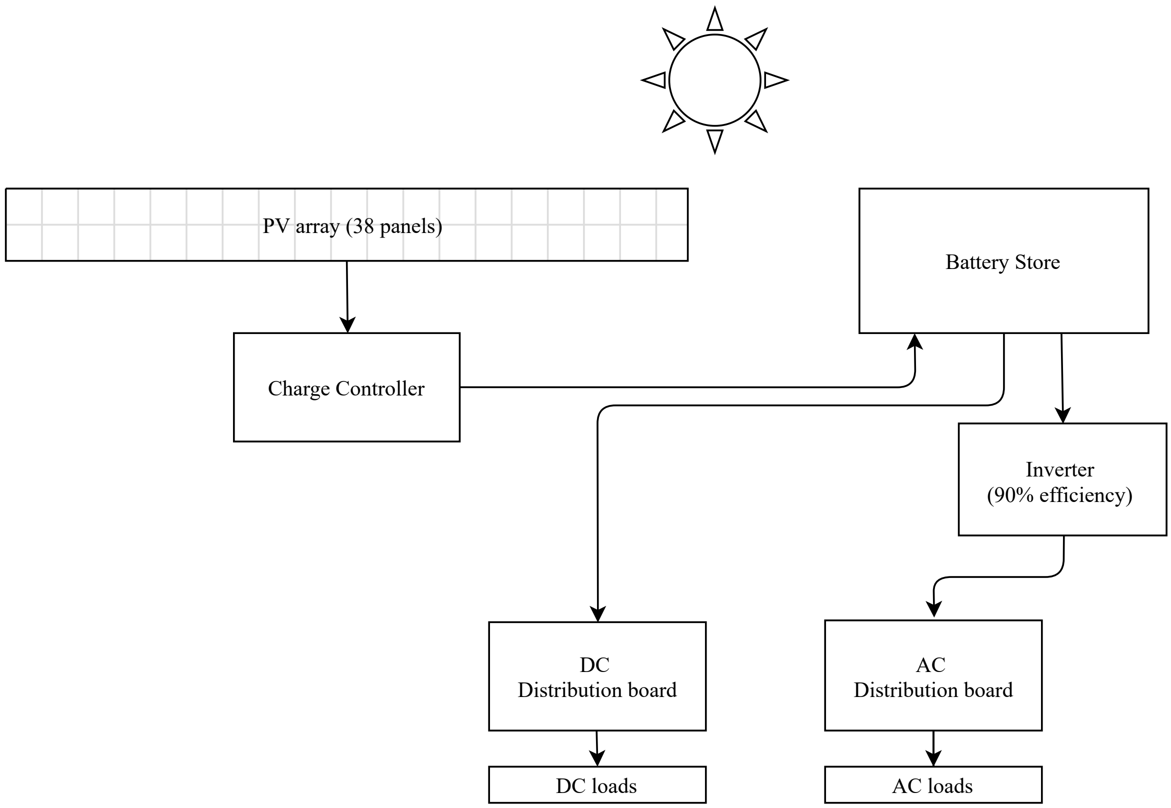

Figure 1: PV based power supply layout diagram

Problem 2

Find out simple pay back period for Problem 1 assuming following given values:

Cost of PV module (C_{PV})**= Rs. 50/Wp**

Cost of rechargeable battery (C_B)**= Rs. 150/Ah of (12 V DC, DOD 80, at least 2000 Cycles)**

Cost of sine wave inverter(C_I)**= Rs. 20 /Watt (24V DC/220 V AC, 50 Hz, Sine Wave)**

Cost of diesel in remote area (C_{RD})**= Rs. 200/litre**

Benefits of CER US $20/ton of CO_2

Solution:

Cost per liter of diesel$(C_D) = \text{Rs. } 108$

Energy generated per liter of diesel$(E_D) = 3$ KWh/L

CO_2 emission per liter$(W_L) = 2.5$ Kg/L

Operational days per year$(O_Y) = 280$ days

We can now calculate the diesel equivalency as,

Equivalent diesel requirement per day$(V_D) = \dfrac{E_R}{E_D} = \dfrac{40.75}{3} = 13.6$ L

Total cost of diesel per year$(C_{Diesel}) = V_D \times C_D \times O_Y = 13.6 \times 108 \times 280 = \text{Rs. } 411320$/year

CO_2 emission per year$(W_Y) = W_L \times V_D \times O_Y = 2.5 \times 13.6 \times 280 = 9520$ Kg/year $= 9.52$ ton/year

Benefits due to CER of $CO_2$$(B_{CER}) = W_Y \times \$20 = \$190.4/year \approx \text{Rs. } 22630.18$/year

Total cost saving per year$(C_{saving}) = C_{Diesel} + B_{CER} = 411320 + 22630.18 = \text{Rs. } 433950.18$/year

Total cost expense per year$(C_{expenditure}) = N_P \times C_{PV} \times P_{peak} + C_B \times 3800 + C_I \times E_R$

$C_{expenditure} = 50 \times 38 \times 300 + 150 \times 3800 + 20 \times 4075 = \text{Rs. } 1221500$

Total payback period$(T_{payback}) = \dfrac{C_{expenditure}}{C_{saving}} = \dfrac{1221500}{433950.18} = 2.84$ years < 3 years

Problem 3

Find new answers to previous problems if number of autonomy days is considered three.

Solution:

Let us assume that battery backup for three days, charging from 0-100% takes 6 full active usage days. So, according to *6LMS200L* battery specifications,

Energy capacity$(E_c) = 200$ Ah

Size of battery module for 3 full day backup$(S_{3days}) = 3772 \times 3 = 11316$ Ah

Minimum number of batteries required$(N_{battery}) = \dfrac{S_{3days}}{E_c} = \dfrac{11316}{200} = 56.58 \approx 57$

We have the relation,

Total energy required$(E_{6days}) = E_A \times 9 = 45.27 \times 9 = 407.43$ KWh

Energy production per day$(E_P) = \dfrac{E_{6days}}{6} = \dfrac{407.43}{6} = 67.91$ KWh

From the *ELDORA VSP.72.AAA.03* PV module specifications,

Peak power per panel$(P_{peak}) = 300$ W

Number of panels required$(N_P) = ?$

We have the relation,

$$E_P = P_{peak} \times S_{peak} \times N_P$$
$$\Rightarrow N_P = \frac{E_P}{P_{peak} \times S_{peak}} = \frac{67910}{4 \times 300} = 56.592 \approx 57$$

Problem 4

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, required current to operate the relevant equipment is 37 A and during sleep mode from 2300 hours to next day 0600 hours, 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 number of autonomy days considered as two. The average peak sun can be considered as 4 hours.

Solution:

Operation time in active mode$(T_A) = 17$ hours

Operation time in sleep mode$(T_S) = 7$ hours

Current requirement for active mode$(I_A) = 37$ A

Current requirement for sleep mode$(I_S) = 10$ A

Operating voltage$(V) = 48$ V

Total energy in a day cycle$(E_D) = V(I_A \times T_A + I_S \times T_S) = 48(37 \times 17 + 10 \times 7) = 33.552$ KWh

Total autonomy day$(T_D) = 2$ days

Total energy consumption$(E_T) = E_D \times T_D = 33.552 \times 2 = 67.104$ KWh

Depth of discharge$(DOD) = 50\%$

Total energy capacity of battery$(E_B) = \dfrac{E_T}{DOD} = \dfrac{67.104}{0.5} = 134.208$ KWh

According to *6LMS200L* battery specifications,

Energy capacity$(E_c) = 200$ Ah

Voltage$(V_B) = 12$ V

Size of battery module$(S_B) = \dfrac{E_B}{B_B} = \dfrac{134208}{12} = 11184$ Ah

Minimum number of batteries required$(N_{battery}) = \dfrac{S_B}{E_c} = \dfrac{11184}{200} = 55.92 \approx 56$

Since $V = 48$ V, and $V_B = 12$ V system requires $\frac{V}{V_B} = 4$ units in series and its multiple in parallel to increase the energy capacity. Here, $N_{battery} = 56$ is a multiple of 4,hence no extra battery must be added to attain 48 V serial packs. From the *ELDORA VSP.72.AAA.03* PV module specifications,

Peak power per panel$(P_{peak}) = 300$ W

Number of panels required$(N_P) = ?$

We have the relation,

$E_D = P_{peak} \times S_{peak} \times N_P$

$\Rightarrow N_P = \dfrac{E_P}{P_{peak} \times S_{peak}} = \dfrac{33552}{4 \times 300} = 27.96 \approx 28$