Solar PV Power Generation (ESL 855)

Minor: Part B

Department of Energy Science and Engineering, IIT Delhi

Submission deadline: 7.55 pm (IST)

Total marks: 50

(1) Consider a single module of SOMERA VSMH.72.455.05 which is operating at STC. The datasheet of it can be found from the following link: https://www.vikramsolar.com/wp-content/uploads/2020/07/Somera-6-144-E-2022-All-Channel.pdf. In an application, a DC-DC converter operating at CCM is used to charge a 48 V battery bank. The battery bank is charged with a current of 5 A and the internal voltage of the battery is 49 V. PV is delivering a current of 5.44 A.

(i) Out of the three types of DC-DC converter taught in the class which type of converter can be suitable for this application? Write with proper justification. [2]

(ii) What is the duty ratio of the converter at this operating point? [3]

(iii) Considering a safety margin of 2, determine the current rating of the switches of the DC-DC converter. [5]

The equivalent series resistance of the battery bank is 0.22 ohm. The terminal voltage of the battery can vary within the range 45 V to 51 V while charging. The losses of the DC-DC converter can be neglected.

(2) The IV characteristic of a PV module is provided in Fig. 1. Find the following:

(i) Calculate the series and parallel resistance of the module. [4]

(ii) Reverse saturation current of the diode in the equivalent model of the PV module. [2]

(iii) If for a particular load the module is operating at a voltage of 24 V, what is the voltage across the diode in the equivalent model of the PV module? [2]

(iv) Calculate the maximum power that can be delivered by the module. [2]

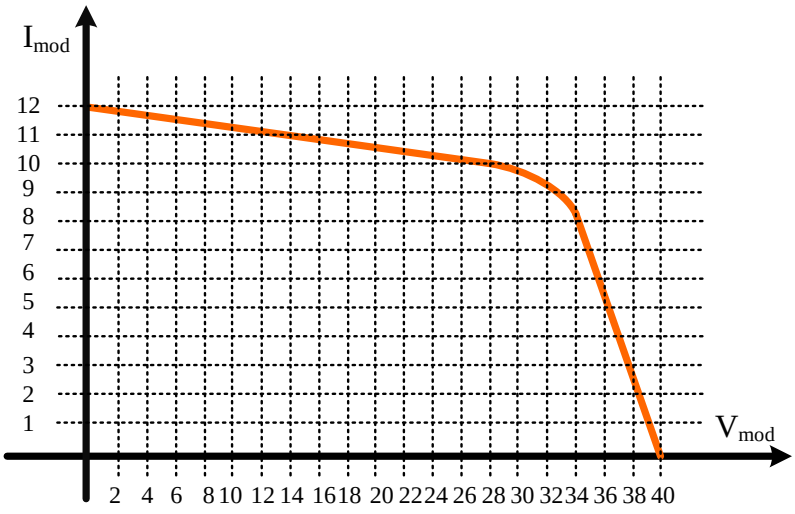

Fig. 1: IV characteristic of a PV module

(3) For an application the minimum PV side MPP voltage requirement is 200 V and the maximum allowable power that can be extracted from the PV array is 1300 W. Three modules whose data are mentioned in Table 1 are available with you. Consider the operation of the array in MPP throughout the operating range. As a design engineer which module will you choose to serve your purpose best? How many selected modules are required to be connected in series to form the array? It may be noted that the range of insolation variation and ambient temperature variation at the installation location are 400 W/m^2 – 800 W/m^2 and 5 ^{o}C – 40 ^{o}C respectively. Any combination of insolation level and ambient temperature is possible in this case. Give proper justification of your answer. [10]

Table 1: Module parameters (V, I and P values are mentioned in STC)

	V_{oc} (V)	I_{sc} (A)	V_{mpp} (V)	I_{mpp} (A)	P_{mpp} (W)	α_V (%/^{o}C)	α_I (%/^{o}C)	α_P (%/^{o}C)	NOCT (^{o}C)
Mod_1	35	7	30	6	180	-0.40	0.048	-0.70	45
Mod_2	40	8	35	7	245	-0.29	0.028	-0.40	45
Mod_3	45	9	40	8	320	-0.60	0.068	-0.89	45

(4) You have to design a 24 V DC standalone PV system with a PWM charge controller to meet a 2.4 kWh/d demand for a small, isolated cabin (block diagram is provided in Fig. 2). You want to size the PV array to meet the load demand of the cabin with average insolation equal to 5 kWh/m^2/d. Your chosen PV modules have their 1 sun MPP at Vr = 18 V and Ir = 5 A. Assume a 0.80 derate factor for dirt, wiring, module mismatch (i.e. 20% loss). You have to use 200 Ah, 12 V batteries with 100% Coulomb efficiency.

(i) How many PV modules are needed approximately (integer number) to configure the PV array? Sketch your PV array. You can neglect the effect of equivalent parallel resistance of the modules. [5]

(ii) How many 200 Ah, 12 V, deep cycle batteries would be required to cover 3 days of no sun if their maximum discharge depth is 75%? Show how you would wire them up. You can assume that the battery bank will be charged during partial loaded condition. [5]

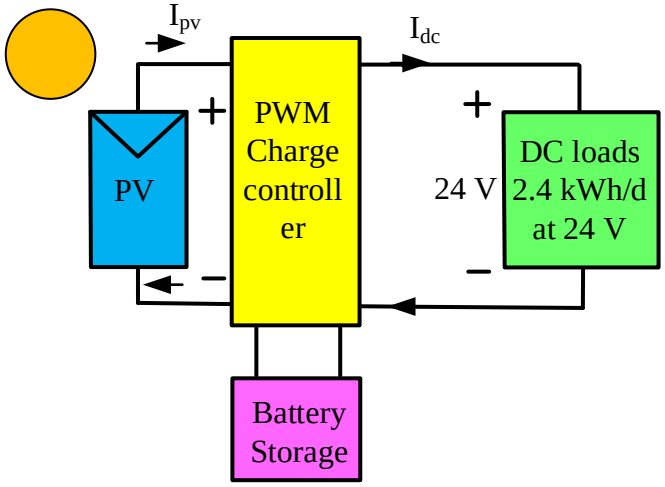

Fig. 2: Block diagram of the DC standalone system

(5) Consider a single 87.5 W, First solar CdTe module whose parameters are mentioned in Table 2. This module is used to charge a 12 V battery.

(i) If the battery is charged by a buck-boost converter in CCM with a terminal voltage of 14 V, what will be the duty ratio of the converter? Consider that the PV panel is operated at MPP at STC. How many Ampere will it deliver to the battery under those conditions? [5]

(ii) Suppose ambient temperature is 25^{o}C with 1-sun of insolation. Recalculate the Amperes delivered to the battery. [5]

Table 2: First Solar CdTe module, FS Series 3 parameters (values are mentioned at STC)

Efficiency	V_{oc} (V)	I_{sc} (A)	V_{mpp} (V)	I_{mpp} (A)	P_{mpp} (W)	α_V (%/^{o}C)	α_I (%/^{o}C)	α_P (%/^{o}C)	NOCT (^{o}C)	Dimensions (m)	Weight (kg)
12.2%	61	1.98	49.2	1.78	87.5	-0.27	0.04	-0.25	45	1.2x0.6	15