جامعة فهد بن سلطان
FAHAD BIN SULTAN UNIVERSITY

MECH 453 Introduction to Renewable Energy

CHAPTER FIVE

Calculate photovoltaic power, battery AH, charge controller capacity and converter capacity for a given load

Course lectures Slides prepared by

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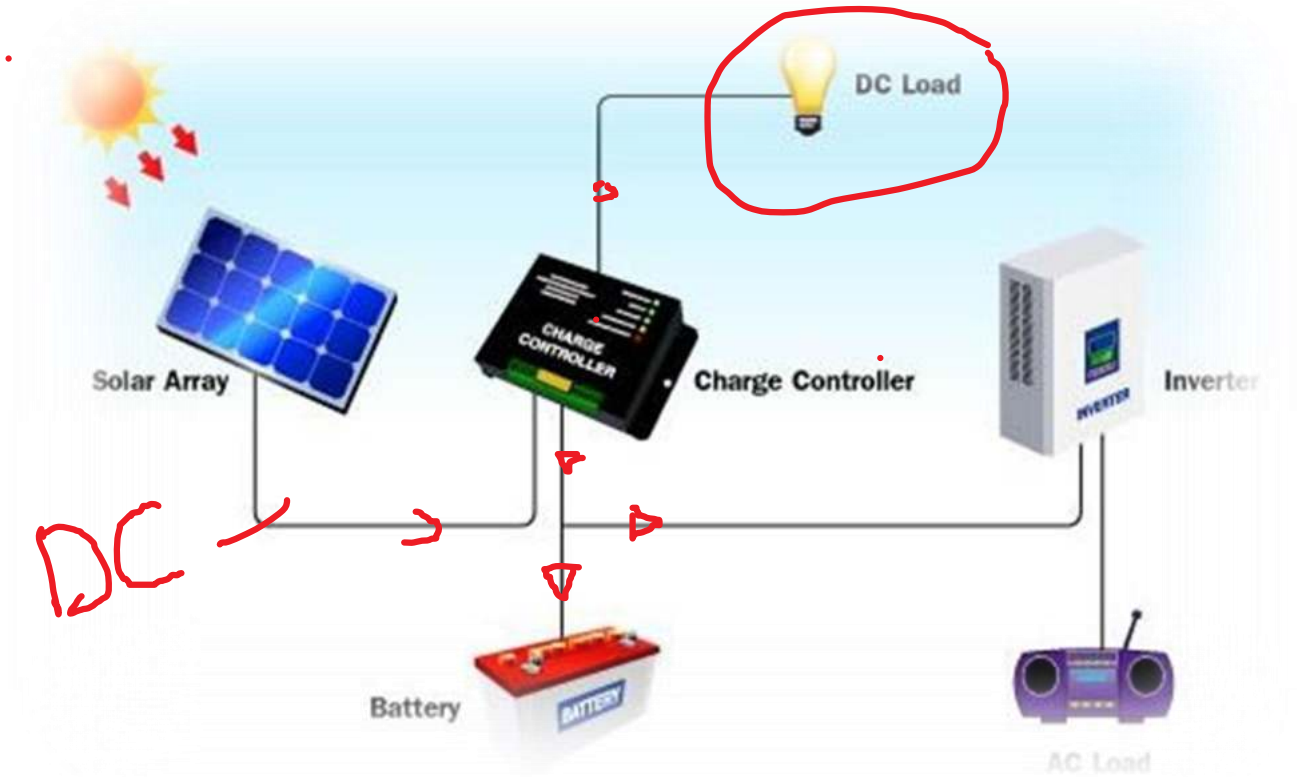
Sub-outcome 9: Calculate photovoltaic power, battery AH, charge controller capacity and converter capacity for a given load.

CALCULATE PHOTOVOLTAIC POWER, BATTERY AH, CHARGE CONTROLLER CAPACITY AND CONVERTER CAPACITY FOR A GIVEN LOAD.



With This section, Please use the provided Dynamic Spreadsheet

MAJOR SYSTEM COMPONENTS

1. PV module – converts sunlight into DC electricity.
2. Solar charge controller – regulates the voltage and current coming from the PV panels going to battery and prevents battery overcharging and prolongs the battery life.
3. Inverter – converts DC output of PV panels or wind turbine into a clean AC current for AC. appliances or fed back into grid line.
4. Battery – stores energy for supplying to electrical appliances when there is a demand.
5. Load – is electrical appliances that connected to solar PV system such as lights, radio, TV, computer, refrigerator, etc.

1 DETERMINE POWER CONSUMPTION DEMANDS:

The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as follows:

1 Calculate total Watt-hours per day for each appliance used.

Add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances.

2 Calculate total Watt-hours per day needed from the solar panels.

3 Multiply the total appliances Watt-hours per day times 1.3 (an estimated correction factor of the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels.

DETERMINE POWER CONSUMPTION DEMANDS:

(1) cont.

Example: A house has the following electrical appliance usage:

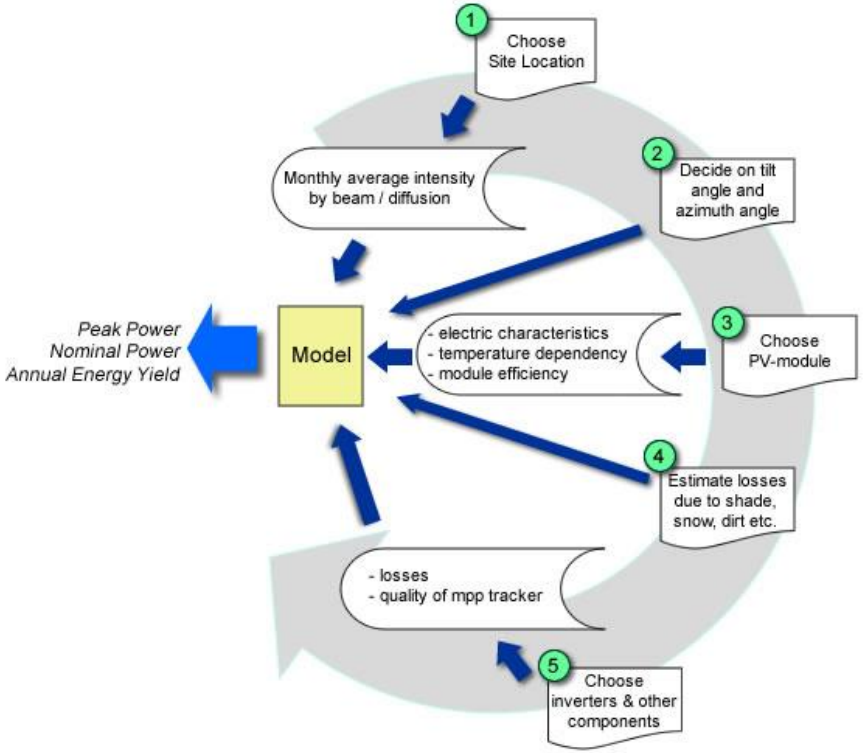
- **One 40 Watt fluorescent lamp with electronic ballast used 4 hours per day.**
- **One 60 Watt fan used for 12 hours per day.**
- **One 200 Watt refrigerator that runs 24 hours per day with compressor run 12 hours and off 12 hours.**
- **The system will be powered by 12 VDC, 110 Wp solar panel and Sun Hours is 8.8.**

1. Determine power consumption demands:

12/24

Total appliance W-Hours use
= (40 W x 4) + (60 W x 12) + (200 W x 24 x 0.5) = 3280 Wh/day

Total PV panels energy needed = 3280 x 1.3 = 4264 Wh/day.



2 SIZING THE SOLAR PANELS:

- Different size of solar panels will produce different amount of power.
- The peak watt (Wp) produced depends on size of the power solar panel and climate of site location – Sun Hours per day. For UAE, the suggested Sun Hours is 8.8.
- Calculate the total Watt-peak rating needed for solar panels, Divide the total Watt-hours per day needed from the solar panels (from previous item) by 8.8 to get the total Watt-peak rating needed for the PV panels needed to operate the appliances.
- Calculate the number of PV panels for the system Divide the answer obtained in the previous item by the rated output Watt-peak of the solar panels available to you. Increase any fractional part of result to the next highest full number and that will be the number of solar panels required.

Size the PV panel:

Total Wp of PV panel capacity needed in ONE Hour = 4264 / 8.8 = 484.5 Wp

Number of PV panels needed:
= 484.5 / 110 = 4.4 modules

Actual requirement = 5 modules
So this system should be powered by at least 5 modules of 110 Wp solar panel.

SIZING THE SOLAR STORAGE BATTERY:

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days.

To find out the size of battery, calculate as follows:

1 Calculate total Watt-hours per day used by appliances.

2 Divide the total Watt-hours per day used by 0.85 for battery loss (85% Efficiency).

3 Divide the answer obtained in item 2 by 0.6 for depth of discharge.

4 Divide the answer obtained in item 3 by the nominal battery voltage.

5 Multiply the answer obtained in item 4 with days of autonomy (the number of days that You need the system to operate when there is no power produced by PV panels) to get the required Ampere- hour capacity of deep-cycle battery.

SIZING THE SOLAR STORAGE BATTERY:

- **Battery Capacity (Ah) = (Total Load Watt-hours per day X Days autonomy)**

Divided By

(0.85 x 0.6 x nominal battery voltage)

- **Total appliances use = (40 W x 4 hours) + (60 W x 12 hours) + (200 W x 12 hours)**
- **Nominal battery voltage = 12 V**
- **Days of autonomy = 3 days**
- **Battery capacity = [(40 W x 4 hours) + (60 W x 12 hours) + (200 W x 12 hours)] x 3/ (0.85 x 0.6 x 12)**
- **Total Ampere-hours required 1607.8 Ah**
- **So the battery should be rated 12 V 600 Ah for 3 day autonomy.**
- **If 100 AH rated Battery is available:**
- **Number of Batteries = 1607.8/100 = 16.078 to be 17 Batteries.**

SIZING THE BATTERY CHARGE CONTROLLER:

For the Series Charge Controller type (PWM), the sizing of controller depends on the total PV Short Circuit current (Isc) which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration). According to standard practice, the sizing of solar regulator is to take the short circuit current (Isc) of the PV array, and multiply it by 1.25:

Solar Charge Controller Rating = Total short circuit current of PV array x 1.25.

If Solar Panel specification -
Pm = 110 Wp, Vm = 16.7 Vdc, Im = 6.6 A, Voc = 20.7 A, Isc = 7.5 A
charge controller rating = (5 strings x 7.5 A) x 1.25 = 46.87 A

So the solar Charge Controller should be rated 50 A at 12 V or greater.

SIZING THE BATTERY CHARGE CONTROLLER:

- Since most MPPT controls can take up to 600 VDC, on the solar panel input side, you can often connected in series two or more of the high voltage panels to reduce wire losses, or to use smaller wire.
- **MPPT Solar Charge Controller Rating**
- For 110 watt panel , 5 of them in series (Voc = 20.7V) would give you 103.5V volts at 7.6 amps into the MPPT controller, but the controller would convert that down to about 45.8amps at 12 volts.

In MPPT Charge Controller: Power in = Power out

110watt X 5= 12 X Amp = 45.8 Amp.....

Multiply by Tolerance 0f 25%..Hence 57A will be the one you use.

SIZING THE SOLAR POWER INVERTER:

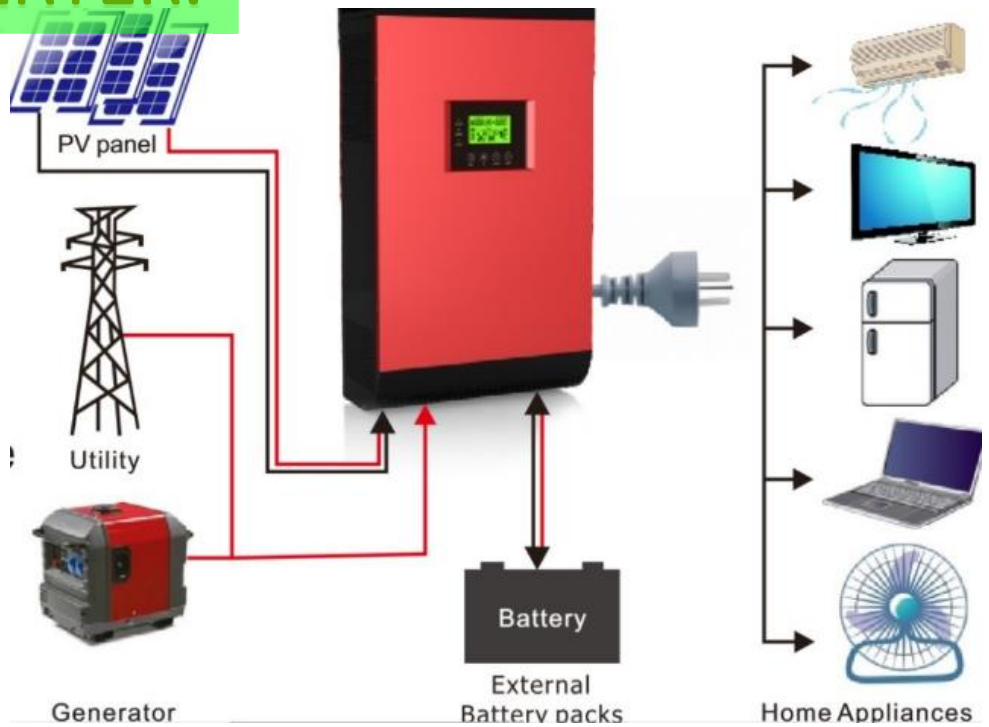
An solar power inverter is used in the system where AC power output is needed. The input rating of the solar power inverter should never be lower than the total watt of appliances.

The solar power inverter must have the same nominal voltage as your battery.

For stand-alone systems, the solar power inverter must be large enough to handle the total amount of Watts you will be using at one time.

The solar power inverter size should be 25-30% bigger than total Watts of appliances. In case of appliance type is motor or compressor then solar power inverter size should be minimum 3 times the capacity of those appliances and must be added to the solar power inverter capacity to handle surge current during starting.

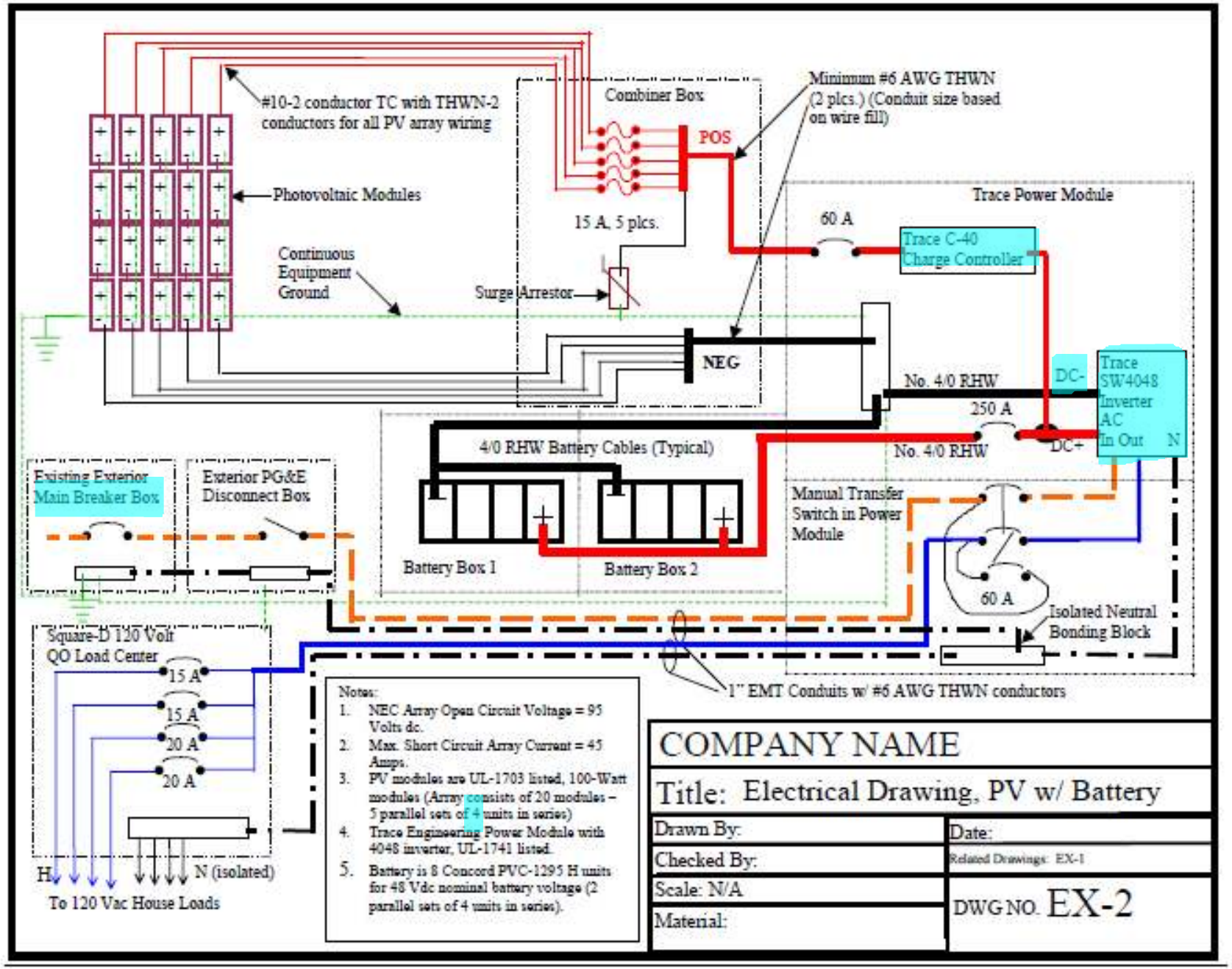
For grid tie systems or grid connected systems, the input rating of the solar power inverter should be same as PV array rating to allow for safe and efficient operation.



Total Watt of all appliances
= 40 + 60 + 200 = 300 W

For safety, the solar power inverter should be considered 25-30% bigger size.

The solar power inverter size should be about 375 W or greater.


#10-2 conductor TC with THWN-2 conductors for all PV array wiring
Photovoltaic Modules
Continuous Equipment Ground
Combiner Box
POS
15 A, 5 plcs.
Surge Arrestor
NEG
Minimum #6 AWG THWN (2 plcs.) (Conduit size based on wire fill)
Trace Power Module
60 A
Trace C-40 Charge Controller
No. 4/0 RHW
250 A
No. 4/0 RHW
DC-
DC+
Trace SW4048 Inverter AC In Out N
4/0 RHW Battery Cables (Typical)
Battery Box 1
Battery Box 2
Existing Exterior Main Breaker Box
Exterior PG&E Disconnect Box
Manual Transfer Switch in Power Module
60 A
Isolated Neutral Bonding Block
Square-D 120 Volt QO Load Center
15 A
15 A
20 A
20 A
H
N (isolated)
To 120 Vac House Loads
1" EMT Conduits w/ #6 AWG THWN conductors
Notes:
1. NEC Array Open Circuit Voltage = 95 Volts dc.
2. Max. Short Circuit Array Current = 45 Amps.
3. PV modules are UL-1703 listed, 100-Watt modules (Array consists of 20 modules – 5 parallel sets of 4 units in series)
4. Trace Engineering Power Module with 4048 inverter, UL-1741 listed.
5. Battery is 8 Concord PVC-1295 H units for 48 Vdc nominal battery voltage (2 parallel sets of 4 units in series).
COMPANY NAME
Title: Electrical Drawing, PV w/ Battery
Drawn By:
Date:
Checked By:
Related Drawings: EX-1
Scale: N/A
Material:
DWG NO. EX-2

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Sub-outcome 10: Design, simulate, implement and test a photovoltaic solar power generation system.

- Please refer to sample design questions