PLANNING YOUR BATTERY BASED SOLAR SYSTEM

Loads

The first step in planning a photovoltaic (PV) system is to know something about the load. What is the power intended for? How much power will be required? There are many resources available in print and on-line to help determine average and peak load requirements we recommend using these resources to calculate anticipated load requirements. We also recommend that planners design for load growth. Experience has shown that loads rarely remain static and are reduced even less frequently. Once the load characteristics are determined the system planner may move to make decisions about the appropriate battery voltage.

Determining Battery Voltage

A major factor in making this decision is how much power will be required from the batteries. As power demands increase it is advisable to raise the battery voltage. A limiting factor in system design is current – it is expensive to move and provide circuit protection for large amounts of current (amps). A basic rule of electricity states “current = power/voltage”. This means that the higher the battery voltage the lower the current will be for any given load. For example a 96 watt load at 12 Volts draws 8 amps the same load at 48 Volts draws only 2 amps of current.

The table below shows rule-of-thumb recommendations for battery system voltage choices and maximum inverter sizes.

Load in kWh per day	Battery Voltage	Suggested Inverter Size
Under 2 kWh per day	12 Vdc	Up to 2.5 kW
2 to 6 kWh per day	24 Vdc	2-4 kW
Over 6 kWh per day	48 Vdc	3 kW and larger

Other factors in making this decision will include the size of the inverter.

A final factor in this decision is how much power will be required from the PV array. For example, the Apollo T80 TurboCharger™ is designed to produce 80 amps of output current. The amount of power this represents will be dependent on the output voltage (battery bank voltage). At 12 Vdc output 80 amps is 960 watts of power, at 48 Vdc output 80 amps is 3840 watts of power. The example above demonstrates that the amount of current or input power the TurboCharger™ will accept is limited by the system battery voltage.

Determining PV Array Voltage

Sizing a PV array is much like sizing a grid-tie inverter, the same questions apply: What is the max and min Vmp and Voc of each string, how many strings will be needed. One of the great advantages of the DC to DC converter design of the TurboCharger™ is that PV array voltages are no longer dictated by the battery voltage.

Maximum Voc

Each PV module has specific ratings for voltage and current at standard test conditions and temperatures, the manufacturers also publish current and temperature coefficients. The Voc for any PV module increases in cold temperatures. Modules are rated with an assumed cell temperature of 25^{o} C, when calculated at 0^{o} C there may be as much as a 25% increase in the rated Voc. The Voc voltage temperature coefficient for the specific location of the installation must be calculated from known weather data. Once the maximum Voc of the module is found a series string voltage may be determined.

Conversion Efficiency

The conversion efficiency, of the TurboCharger™ for example, in the proposed configuration must be considered. While it is possible to input 72 Vdc and output 12 Vdc, it is not the most efficient configuration for the controller. A system which had 36 Vdc input and 12 Vdc output would run more efficiently from the T80HV's perspective. The most efficient configuration is with 60 Vdc input and 48 Vdc output. Never-the-less, in many cases the savings in wire costs and the slight advantage of earlier wake up and shut down make the "inefficient" higher voltage to low voltage conversion the best system choice. Many systems input 72 Vdc for 24 and 48 Vdc batteries. The table below shows some recommended input to output configurations for a system using the T80 model.

Battery Voltage	Array Vmp Range
12 Vdc	16 - 83 Vdc
24 Vdc	32 – 136 Vdc
48 Vdc	70 – 150 Vdc*

* Never exceed 140 Voc in any T80 system design.

Wire Sizing

The distance between the PV array and the controller will be a factor in choosing an optimum string voltage for the charge controller. The higher the input voltage the smaller the wire can be for any given amount of power. For example, a system with a 12 volt battery and a PV array consisting of four 6.5 amp 12 Vdc nominal modules located at a distance of 40' from the batteries could have the modules wired in series, parallel or series and parallel. Input configuration possibilities in this example are 12, 24, and 48 Vdc. If the array was configured with the modules wired in parallel the input voltage would be 12 Vdc with an input current of 26 A. The same array wired in series would have an input voltage of 48 Vdc and an input current of 6.5 amps. In this example #1, the 26 amp 12 Vdc array #1/0 wire, which is prohibitively expensive, would be required to limit voltage drop to 2% which is recommended for 12 Vdc systems. The same array wired for 48 Vdc would only require a #8 wire. With the #8 wire the 12 Vdc array would have to be within 7' of the batteries. The distance that #8 cable can be used is over five times greater at 48 Vdc than 12 Vdc.

Of course, a final determining factor will be the number of modules available for installation. For example the optimum system design might call for six 12 V nominal modules in series, but the actual system to be installed consists of only 10 modules. It is not possible to wire strings of differing voltages to the TurboCharger™; therefore the number of modules available must be divided into even numbers. In the example given above each string would consist of 5 modules for a nominal voltage of 60 Vdc. The above noted system could be expanded by adding one module to each string for a nominal voltage of 72 Vdc or by adding an additional string of 5 modules and maintaining the 60 Vdc nominal input voltage.

Determining Maximum Current

The TurboCharger™ is designed to handle a maximum input current of 70 amps and a maximum output current of 80 amps – both of these ratings are continuous at 45^0 C. The Input voltage will be higher than output voltage hence input current (amps) will be lower than output current. For example, twelve 6.5 amp 12 Vdc nominal PV modules wired in series and parallel to produce 36 Vdc would equate to an input current of 26 amps – the rated current of each string times 4. (In series wiring the voltage increases and the current remains constant.) The output current of the controller will be dependent on the voltage of the battery bank. If the array in this example was connected to a 12 Vdc battery system the output current would be 78 amps. (Current in x V nom / V Bat = Current out).

When calculating the maximum input or output current, remember to add 25% to the rated current of the PV array, this is the NEC required “headroom” to account for the PV’s ability to produce more than the rated output under some conditions.

Circuit Protection

All electrical circuits require protection from over current and shorts. The charge controller should be installed with a circuit breaker or a fused disconnect on the input and output. The TurboCharger™ has a maximum current limit of 80 amps on the output. It is designed and listed to run at its maximum rating continuously. The continuous rating does not reflect the 80% derating required by the NEC for conductors, fuses, and many circuit breakers.

The NEC requires that the output conductors have an amperage capacity of 1.25 X the rated current after all temperature and fill corrections are calculated. This means conductors must be rated to carry 100 amps. The minimum cable necessary to carry the full rated output of both the T80 and T80HV is #3AWG, corrections for conduit fill and temperature could result in a large wire size being necessary.

Since the TurboCharger™ T80HV can accept a higher PV input voltage, a high voltage circuit breaker must be used. Apollo Solar offers circuit breakers that can accept up to 250VDC.

Apollo T80 Charge Controller:

In summary, Apollo Solar recommends that the input breaker be 90 amps rated for 150 Vdc and the output breaker be 100 amps rated at a minimum of 80 Vdc. Apollo Solar and it's distribution partners offer 90 and 100 amp breakers which are compatible with widely available PV system DC service entrance enclosures.

Apollo T80HV Charge Controller:

In summary, Apollo Solar recommends that the input breaker be 50 amps rated for 250 Vdc and the output breaker be 100 amps rated at a minimum of 80 Vdc. Apollo Solar and it's distribution partners offer 50 and 100 amp breakers which are compatible with widely available PV system DC service entrance enclosures.

For more details please contact our sales team at 203-790-6400, or email info@apollosolar.com.