Engineering Bulletin

SunWize
Power & Battery

PV System Design, Load Voltages and Efficiency

Photovoltaics (PV) is a direct current (DC) power technology. The voltage of a solar module is the cumulative DC voltage of each cell connected in series in the module. This DC output makes a PV array an excellent power source for charging a nominal 12, 24 or 48 volt DC (VDC) battery bank.

The most efficient way to utilize the power from a PV system is by direct-powering a DC load. Why?

The first two laws of thermodynamics are inescapable. Basically, they state when energy is transferred from one form to another you can't gain energy in the process and you can't break even.

You will always lose. It's a simple fact that electrical energy transfer is always less than 100% efficient due to energy lost during the transfer process.

Specialized voltages are available with PV systems. Through the use of DC to AC inverters, DC to DC converters and AC to AC transformers, the DC output of a PV system battery bank can be transformed to any reasonable DC or AC voltage to match load requirements.

However, given those two pesky laws of thermodynamics, we know any transformation will result in energy loss. How does that loss impact the design of the PV system?

LOAD EXAMPLES

1. A load requires 24 watts of power continuously at a nominal 12 volts DC. Since PV systems rely on a daily energy budget for their sizing, a PV designer would consider this load as:

24 watts / 12 VDC = 2 amps of continuous current draw at 12 VDC
2 amps x 24 hours per day = **48 amp-hours/day @ 12 VDC**

2. Assume the 24-watt continuous load requires 115 volts AC. We now need to take our DC battery bank and feed it into a DC-to-AC inverter, which we will assume is 85% efficient. That means 15% of the energy we put into the inverter will be lost to heat generation. Our PV system design load becomes:

24 watts @ 110 VAC / 0.85 efficiency factor* = 28.2 watts @ 12 VDC
28.2 watts / 12 VDC = 2.35 amps
2.35 amps x 24 hours per day = **56.4 Ah/day @ 12 VDC**

If a device has 15% losses, we must divide by 0.85 (100% - 15%) to overcome the losses. If a load needs 24 watts of power, then we must feed 24/0.85 = 28.2 watts into a device that loses 15% of the 28.2 watts to heat, leaving 24 watts for the load.

3. Now assume the 24-watt continuous load requires an unusual DC voltage, such as 15 volts DC. We have to feed the battery output into a 12 volt to 15 volt DC-to-DC converter, which we will assume is 80% efficient. Our PV design load is:

24 watts @ 15 VDC / 0.80 efficiency factor = 30 watts @ 12 VDC
30 watts / 12 VDC = 2.5 amps
2.5 amps x 24 hours per day = **60.0 Ah/day @ 15 VDC**

4. Lastly, assume the 24-watt continuous load requires an unusual AC voltage, such as 24 volts AC required by many types of security cameras and agricultural instruments. We have to feed the battery output first into a DC-to-AC inverter to get 110 VAC, then we feed the 110 VAC into an AC-to-AC transformer to get our 24 VAC. Assume the inverter is 85% efficient and the transformer is 90% efficient. Our PV design load becomes:

24 watts / 0.85 efficiency factor / 0.90 efficiency factor = 31.4 watts @ 12 VDC
31.4 watts / 12 VDC = 2.61 amps
2.61 amps x 24 hours per day = **62.7 Ah/day @ 24 VAC**

If we introduce a voltage-conditioning device into the system (such as an inverter or a converter) that device becomes the load the PV designer has to power. The designer must feed that device with sufficient power so it, in turn, provides enough power to the load. The conditioner is inserted between the PV system battery bank and the load, so the battery supplies power to that device rather than directly to the load.

In the four examples at left, the load grows from 48Ah/day at 12 VDC to a worst-case of 62.7Ah/day when powering a 24 VAC load. The result is a 31% load increase to the PV system.

Since the size of both the PV array and the battery bank is directly proportional to the daily load, both components will have to increase by roughly 31% to keep pace with the load increase.

In conclusion, a load operated directly from the DC voltage of a PV system requires a smaller PV system than a load using an inverter, converter or transformer. This is an important factor when planning for solar powered remote site equipment. Whenever possible, consider load equipment requiring nominal 12, 24 or 48 volts DC.

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