Going Solar on the Farm: Basic Components & System Coordination

► Many options and variables should be considered before going solar in your operation. Proper understanding of the key components is important when planning your system or comparing bids from solar companies.

A solar power system is made up of many components working together in an electricity-producing unit. Basic components include the following:

- Photovoltaic (PV) solar cells, usually in panel form
- Racking system that holds the panels
- Associated power inverters, batteries, charge controllers, and wiring

For general agricultural application, the many types of solar cell technologies can be broken down into two main types: rigid silicon and thin film.

Rigid Silicon vs. Thin Film Solar Panels

The most common PV solar cell technology in use today is rigid silicon PV panels. These come in a few different varieties, but all are made with silicon and covered in tempered glass or other rigid protective covering and surrounded with a rigid frame (figure 1).

Figure 1. Close-up of typical rigid solar panel.

The basic rigid panels have proven highly durable and resistant to most weather events, including sizable hail. These rigid panels are modular and can be assembled to meet the desired production up to a utility scale of several megawatts. They can be mounted on multiple types of racking systems, either by ground or direct roof mount.

The second most common PV technology is thin-film solar panels. These are typically only a few micrometers thick, making them lightweight and flexible. Thin-film solar often is used in smaller-scale specialty applications where thin and flexible characteristics are needed, such as in mobile applications and in direct applications to uneven surfaces like the roof of a vehicle. They also can be used in larger-scale modular systems as rolls or sheets. Thin film is typically more expensive per watt of electrical production than most rigid types, which limits its widespread usage.

Several variations exist within these two main types of PV technology, with bifacial rigid panels becoming more prominent. Bifacial panels, as the name implies, collect radiation both directly from the sun as well as from reflected radiation on the backside of the same panel.

Research and development on new, more efficient, less expensive photovoltaic technology continues. Additional information on solar panel technology can be found under Solar Photovoltaic Technology Basics on the Office of Energy Efficiency and Renewable Energy website.

For the Alabama farmer today, rigid silicon solar panels, either single or bifacial, are appropriate for most applications and will be the assumed panel type for further discussion.

Mounting and Performance of Rigid Silicone PV Panels

The two types of mounting for PV panels are fixed mount and tracking mount. Fixed mounts are stationary, facing the same direction, at the same angle all the time (figure 2). This makes location of the PV system an important consideration. In the northern hemisphere, fixed-mount solar panels need to be facing a southern direction to get the most sun exposure during a normal day with limited shading from surrounding objects such as trees or buildings. The angle of the panels must be optimized for the specific latitude. In the proper configuration, fixed panels will get good sun exposure for 6 to 8 hours every day, increasing to maximum at noon and trailing off in the afternoon.

Figure 2. Fixed-mount PV panel array, single-axis tracking PV array.

Fixed-mount panels can be located on the ground or on roof structures. Roofs do not always allow for optimal direction or angle without additional mounting hardware. Roof-mounted systems also usually require piercing the roof envelope to properly secure them to the underlying structure; this adds the potential of future leaks. However, if simply mounted at the existing angle and direction of a roof, they can suffer reduced production, and this must be calculated into the overall system design. For this reason, ground-mounted fixed panels are often preferred.

The main advantage to fixed systems is low cost and the durability associated with zero moving parts on a sturdy rack. The disadvantage is that power production varies and is limited by the position of the sun. Tracking systems improve upon this shortcoming.

Tracking systems track the sun across the sky in one or both of two ways: on a single axis following the sun's east to west path or on a dual axis that tracks the sun's horizontal positioning as well as its east to west travels across the sky.

Single-axis tracking has proven to increase the production of solar panels up to 20 percent, while increasing cost less than 10 percent. Dual-axis tracking systems can increase production by 30 percent but cost significantly more. Practically, this means that fewer PV panels might be needed to supply the desired electricity when using a tracking system. For larger systems, the efficiency gains of solar tracking should be evaluated closely.

Tracking systems are most often ground mounted and will have some moving parts that require minimal maintenance. Tracking systems can be controlled either by simple timers preprogrammed to follow the sun's normal movement across the sky or by sophisticated sun tracking controllers that follow the sun and keep the panels pointed toward the brightest area of the sky no matter the time of day. Modern tracking systems have proven very reliable, and their cost is rapidly decreasing.

The area required for PV panels is based on the production rates of the particular PV panel and the desired total system output. In Alabama, a kilowatt (kW) of solar panel will produce on average 1,350-kilowatt hours (kWh) of electricity per year. A fixed-mount 200 kW system will need approximately one-half acre of land with unshaded southern exposure. This 200 kW system will produce on average 22,500 kWh of electricity per month, or 270,000 kWh annually.

All current PV panels have long life expectancies. The industry standard warranty is 25 years, guaranteeing 80 percent or better of their original electrical production rates. Many new panels are coming with 30-year warranties.

PV panels typically experience a half percent per year degradation in power production over their lifetime. However, panels have been tested at 30-plus years and found to be producing at better-than-expected rates; this is a main reason why panel recycling has been slow to start. There are not enough panels at their true end of life to supply the scale needed to make recycling economically feasible. However, it is expected that the problem of panel disposal will start to reach a critical mass in the next 10 years. In anticipation of this coming issue, there are now numerous efforts to encourage recycling and make it more economically appealing through research grant funding.

PV panels themselves have progressively decreased in price over recent years. Most single-face rigid panels can be purchased today at below $0.50 per watt retail cost (panel only). The cost just a few years ago was as high as $5.00 per watt. This decrease is solely the result of manufacturing innovations driven by world market demand. Because of the low cost of the PV panels, it is a good idea to oversize the panel component of a system to help ensure adequate PV energy will be available on less-than-optimal solar days.

Inverters and Connecting Switches/Wiring

PV panels produce direct current (DC) electricity. If you are powering DC equipment, then no electric current change is needed. However, most of the equipment that farmers use, such as lights, motors, and pumps, are typically powered by alternating current (AC). Therefore, they need a DC to AC power inverter to produce usable power out of the solar system.

Proper inverters are specifically designed for solar systems and come in many types according to the particular solar application. Solar inverters must be sized correctly to match the output of the system. It is a good idea to add some margin to the capacity to make sure nothing overheats and to account for any efficiency losses (figure 3). Inverters also must be matched to the peak amperage load they will be called to supply. This can be calculated by adding up all the loads of your system or by testing the main circuit with an amp meter while all expected loads are running at once.

The optimum inverter capacity typically will be less than the total PV panel array output capacity. For example, a system that has an output load capacity of 10 kW (the amount of power needed to run all the lights, motors, etc.) may need a 15 kW inverter that is supplied with 20 kW of PV panels. The reason for these mismatched capacities is that the system design must account for some loss of power at and between each stage. You also want to have enough PV panel capacity to capture enough solar on days with marginal sun (figure 3).

Figure 3. A DC to AC power inverter (blue and silver box) sitting on top of a deep cycle battery. These represent components typical of a small solar stand- alone application, such as an outbuilding or green house.

Solar power inverters are also improving in efficiency and decreasing in cost. A basic, small (less than 10 kW) direct-usage inverter costs $0.20 to $0.30 per AC output watt. Small inverter warranties vary with size and price, and the expected life will vary similarly.

Commercial-size inverters (10 kW-plus) typically cost $0.15 to $0.20 per AC output watt. Most commercial inverters come standard with a 10-year warranty, and replacement can be expected at 12 to 15 years simply due to wear. Commercial inverters with longer warranties can be purchased for an additional cost. The added cost typically does not make the best business sense because future replacement inverters are expected to continue to decrease in price and increase in efficiency.

Solar wiring, fuses, disconnects, and other interconnection components are similar to any other standard electrical component of equal power rating. All local and utility code requirements must be followed for any solar installation. It is always recommended that solar power installation be performed to NEC standards by a skilled technician familiar with solar.

Charge Controllers and Batteries

Farmers who utilize direct-usage solar usually need a battery and a charging system. Larger commercial-sized or whole-home-sized systems (10 kW-plus) will require sophisticated charge controllers that coordinate directly with the inverters and batteries. Specialized inverters often function also as the charge controller. It is recommended that a competent solar installer be consulted for these sizes/types of systems.

For most smaller farming applications, a specialized solar charge controller is still needed. The charge controller must match the output voltage of the selected solar panels and the input capacity of the chosen battery. The job of the charge controller is to monitor and maintain battery power with available solar without overcharging.

For battery sizing, you need to know how much power you need over time. For example, suppose you are powering a small greenhouse that has fifty 10-watt LED lights that must burn continuously for 10 hours a day. You will use the following calculations to determine the power needed each day:

> 50 LED lamps × 10 watts each = 500 watts of power used
>
> 500 watts × 10 hours per day = 5,000 watt hours per 24 hours

From there you will take the 24-hour usage and multiply it by the number of days you estimate may require battery power alone. This could be because of cloudy days or rain events that result in low solar production. For our example, we are using 3 days:

> 5,000 watt hours × 3 days = 15,000 watt hours

This gives you the basic battery capacity you need in kWh. You may want to add some additional capacity above this amount for added margin of error or to account for battery degradation over time.

Batteries must also be sized to match the maximum discharge rate of the powered loads. If all the components being powered by the system are on at once, the total load on the battery in watts per hour is the maximum discharge rate of the system. If a battery is not matched to this discharge rate, the system will not provide power as expected, and you could experience damage to the components or battery.

If the battery is not getting fully recharged during the day on a regular basis, it could be a sign that solar panel capacity is too small. If the system is unable to supply enough power to operate for the desired length of time, it is almost always the battery that is undersized for the job. Choosing the proper battery and matching it to enough solar PV is a "make or break" decision for a solar system's success.

Putting It All Together

Using our example greenhouse, here are the solar system calculations that give us the component sizing requirements:

> Discharge rate: 50 LED lamps × 10 watts each = 500 watts of power used
>
> Amp load: 500 watts ÷ 120 volts = 4.2 amps @ 120v AC
>
> 24-hour usage: 500 watts × 10 hours per day = 5,000 watt hours
>
> 3-day power capacity: 5,000 watt hours × 3 days = 15,000 watt hours
>
> Battery AH capacity: 15,000 watt hours ÷ 12 volts (battery voltage) = 1,250 amp hours

Given these parameters, the small greenhouse system would consist of the following:

- A minimum 1,250 AH battery capable of discharging at a rate of 500 watts per hour for 10 hours
- A 1,000-watt inverter (600 watts to power LEDs, 400 watts for battery charging) capable of 4.2 amps
- 2.5 kW of PV panels, which is sufficient to provide the minimum kWh per month for the location (per PVWatts.nrel.gov): 5 kWh/day x 30 days plus 25 percent margin of error = 190 kWh per month
- A capable charge controller (inverter combo or stand-alone)

At this time, a basic solar plus storage system like this should cost approximately $2.10 per watt of installed PV, which equates to $5,250.00 for this example. However, the price can vary greatly along with component specifications and outputs.

The best way to truly evaluate any system's cost is to compare cost per watt of used solar power to total cost per watt of purchased power. This is discussed in detail in "Going Solar on the Farm: Implementing Solar Power in Agriculture" (Extension publication ANR-2789).

Conclusion

The increased use of renewable energy holds many potential benefits for farmers. The most important business benefits to consider are improved economic returns, increased operational flexibility, and further control over required business inputs. The key to success is being able to capture this energy and economically convert it into usable electricity, when and where you need it.

Solar power systems have been around for many years. Currently available components have been proven robust, and the cost of a solar system is lower than ever for the person seeking to utilize our most abundant source of renewable energy.

If the bottom-line economics of direct-usage solar is positive for your situation, then choosing the correct components will help ensure success for your application.

References

- National Renewable Energy Labs. www.nrel.gov.
- US Department of Energy (DOE). "The History of Solar." Office of Energy Efficiency & Renewable Energy.

Dennis Brothers, *Associate Extension Professor*, Farm and Agribusiness Management, Auburn University