# SOLAR POWER SYSTEM DESIGN AND APPLICATION FOR SCADA SYSTEMS

**Michael A. Argo**
**Arco Oil and Gas Company**
**Midland, Texas**

## INTRODUCTION

Supervisory Control And Data Acquisition (SCADA) systems are frequently located in remote, environmentally hostile locations. Even in favorable conditions, the Remote Terminal Unit's (RTU) location often dictated function with a minimum of maintenance and routine oversight from operators. These criteria imply that these systems must be durable, reliable, and portable. Without an equally durable, reliable, and portable power source, these systems cannot carry out their intended functions. Photovoltaic (PV), or solar power, systems can meet these conditions.

This paper will present an overview of the steps involved in designing and installing PV power systems supplying RTUs. Reviews of two Arco systems are included.

## DESIGN OVERVIEW

### Load Sizing Calculation

Designing a PV system involves three basic steps: calculating the size of the load, the size of the battery, and the size of the solar panel or array (a group of panels interconnected to increase the available voltage or current). Designing a PV system for a typical RTU with radio communications will illustrate the process.

The initial stage in designing a PV power system is producing as accurate an estimate as possible of the site's power requirements. To begin sizing the power system, the designer must determine the power requirements of each component and the amount of time per day each component will require power.

The major power users at an RTU site are the process controller, its sensors, and the communications package. The process controller will typically have a nominal power supply requirement with additional power needs set by the input/output (I/O) configuration. For this example, select a process controller having an average current consumption of 300 milliamperes (mA) for internal use. A particular I/O arrangement might need another 100 mA. Using these numbers and assuming the controller remains active 24 hours a day, the total current requirement will be:

$$400 \text{ mA} * 24 \text{ Hours/day} = 9600 \text{ mA-H/day}$$

Expressed in more commonly used units, the process controller requires 9.6 Amp-Hours/day (A-H/d).

It is necessary to specify the operating time as continuous, as some manufacturers's equipment specifically designed for solar power applications will power down for short intervals to conserve as much battery capacity as possible. In addition to minimizing the battery requirement, this intermittent operation also minimizes the size of the PV panel or array.

Calculating the power requirement for the communication package involves repeating the previous procedure. In this case, the designer must estimate the time the radio will be transmitting and receiving each day. Occasionally, the radio also operates in a third mode called standby. This is an option where the radio provides power only to the minimum of the receiving circuit necessary to determine whether or not the base station is transmitting.

For this example, the radio will operate only in the transmit and receive modes. Typical values are two amps for transmitting and 75 mA for receiving. If the RTU is polled for information three times per hour, and each RTU transmission lasts five seconds, the power requirement for the radio will be:

Transmit 15 seconds/hour * 2 A * 24 H/day = 0.2 A-H/d

Receive 3585 seconds /hour * 0.075 A * 24 H/day = 1. 79 A-H/d

Totalling these two values shows that the radio will require 1.99 A-H/day. Round this value up to 2.0.

Combining the amp-hour requirements for the controller and the communications package gives a result of 11.6 A-H/d. This represents the amount of current that the battery must supply each day if the PV panels are not producing any electricity.

**Battery Sizing Calculation**

With the current requirement calculated, the next step is to determine the battery capacity. The term autonomy is used to describe the length of time the battery will carry the system load without recharging from the PV panel. Factors such as ease of access to the site, typical weather patterns, and the importance of maintaining operations influence the number of days of autonomy selected for each site. Values can range from five days to as long as thirty days. The penalty for selecting long periods of autonomy is increased cost for the batteries, enclosures, transportation, installation, and maintenance.

When sizing the battery, the designer must consider that lead-acid batteries cannot be completely drained of energy and then recharged without possibly damaging the battery. Lead-acid batteries built for PV service can tolerate repeated cycles where 80% of their rated capacity is used followed by recharging. Selecting seven days of autonomy and the maximum battery capacity used as 0.8, the required battery size will be :

11.6 A-H/d * 7 days of autonomy / 0.8 = 101.5 A-H

Referring to manufacturer's literature, the designer will find that batteries with approximately 100 A-H capacities are commonly available.

### PV Array Sizing Calculation

The final basic step in designing a PV power system is sizing the PV panel or array. First, the designer must determine the amount of solar energy available at the site. References that can be used to determine the solar insolation (amount of solar energy received at a site measured in kilowatt-hours per square meter) are insolation maps, insolation tables, and local weather service information. Insolation maps depict the data as broad areas receiving a particular amount of solar energy. The insolation tables generally provide data for specific sites, usually metropolitan areas. Also the designer must consider that the available solar energy is not constant year round. A conservative design would use the insolation values for the winter months at the site since these would be the lowest average values during the year.

Picking a site in the vicinity of Oklahoma City, Oklahoma, for this example gives a value of 3.5 peak sun hours per day. Divide the load current by the number of peak sun hours per day to determine the hourly current requirement.

11.6 A-H/d / 3.5 H/d = 3.3 Amps

From manufacturer's literature, select a PV panel that has a suitable operating voltage and current. A panel rated approximately 30 watts at 15 volts and 1.86 amps represents a typical product. To determine the number of panels needed divide the load current by the current output of a single panel.

3.3 load amps / 1.86 panel amps = 1.77 panels Round up to two panels.

This example illustrates one option requiring multiple panels. For this small system, a single panel with the correct voltage and current output could be another option.

## INSTALLATION OVERVIEW

Two considerations must be taken into account when installing a PV system. The installation must possess sufficient mechanical strength to survive the typical weather conditions onsite and the installation must meet electrical standards for personnel safety and equipment protection.

Physically, the installation must be strong enough to resist the expected winds at the site. The mounting will experience forces acting to push the panels upward as the wind strikes the rear of the assembly, and pushing downward as the wind strikes the panel face. The mounting must maintain the panel(s) at a specific angle above the horizontal to receive the optimum amount of sunlight. A rule of thumb for determining the necessary tilt angle in North America for best annual power production is to set the panel the same number of degrees above the horizontal as the number of degrees of latitude of the site. To optimize power production in the summer months use a tilt angle of latitude minus 15 degrees; for winter, an angle equal to latitude plus 15 degrees. For a site in Farmington, New Mexico, at 37 degrees latitude, the expected range of tilt angles could vary from 22 to 52 degrees above the horizontal.

In addition to being mounted at the correct angle, the panel(s) should also face true, not magnetic, south. Isogonic maps list the magnetic declination for various areas. The maps indicate the number of degrees east or west that magnetic north varies from true north. For a site located in the vicinity of Midland, Texas, the isogonic map shows an offset of approximately 11 degrees east. Correcting this offset requires shifting the panel's back, or north side, 11 degrees west of compass north.

Carefully consider the PV panel's location. They should not be shaded by trees, buildings, or other structures from 9:00 AM until 3:00 PM., the peak sun hours each day. Shading will dramatically reduce the panel's power output.

Electrically, the installation should conform to the requirements of the National Electrical Code (NEC). In particular, the installer should refer to NEC Article 690 that is specifically written for PV systems. This reference lists the requirements for wiring, grounding, and protecting a PV system.

## APPLICATION EXPERIENCE

### Block 31 Field, Crane, Texas

The gas well control and data acquisition at the Block 31 field consists of seven gas well RTUs and approximately 21 production battery sites. Only the gas well RTUs use PV power as utility power was available at the battery sites. In the event of a plant upset, the RTUs are capable of shutting in the wells by means of a pneumatically actuated shut-in valve. Pneumatic pressure is supplied from a high pressure nitrogen cylinder mounted on the skid. In an alarm condition, a solenoid valve activates and bleeds pressure off the shut-in valve which is a fail close design. The RTUs also monitor and report status points such as battery voltage, and nitrogen pressure. If required, the RTUs can also measure and total gas flow rates, report the well's operating pressures, and act as a stand-alone process controller.

The RTUs were designed to be truck portable skids to facilitate moving them from location to location. Standard rain-proof and dust-proof enclosures without additional thermal insulation were used for the electronic components and the batteries. Two 50 watt PV panels, two 80 A-H sealed, lead acid batteries, and a charge controller made up the 24 VDC system. The process controller operated directly from the 24 volt system while the radio was supplied 12 VDC from a DC to DC converter. Panel mounting was accomplished by a fixed tilt bracket attached to the radio antenna mast.

When the units were initially installed the battery fully discharged after only eight to ten hours operation without sun. Specifications had called for the RTUs to have a minimum of seven days of autonomy. The problem was determined to be the high power consumption of the DC to DC converter. The high power use by the radio was due to underestimating the transmit time per day. To solve the problem, the power system was divided into separate 12 and 24 VDC supplies. The original panels and batteries were dedicated to the process controller. An additional 50 watt panel and 80 A-H battery were added to provide 12 VDC to the radio. Making these modifications corrected the problem and the RTUs are now operating with seven to ten days of autonomy.

Normal maintenance consists of checking connections, battery voltage and cleaning the PV panels to remove dust and bird droppings.

**Ignacio Blanco Field, Farmington, New Mexico**

The Farmington automation project involves monitoring conventional and coal seam gas wells in the San Juan Basin. In addition to the gas wells, the system also monitors several facilities handling the gas production. In total, the system consists of approximately 140 RTUs and a single master station located in the Farmington office. Each RTU PV system consists of two 50 watt, 12 VDC panels, four 100 amp-hour, 12 VDC, lead-antimony, maintenance free batteries, and one charge regulator with battery temperature charge compensation and low voltage cutoff.

The system was specified to operate with 13 days of autonomy at an annual temperature range of -20 to +110 degrees F. The panels and batteries are configured to supply 24 VDC for the RTU and sensors. The 12 VDC required by the radio is supplied by a DC to DC converter. All components are mounted in a NEMA 4 (water-tight, dust-tight, sleet resistant) enclosure which is insulated throughout with one half inch foam insulation. The enclosure contains two separate compartments that are separately gasketed. The top compartment contains the process controller, the radio, and charge controller. The bottom section is reserved for the batteries. Even though the batteries are sealed units, the possibility of off-gassing was dealt with by providing for air circulation in the battery compartment. The PV panels are located on the top of the enclosure so that they are not shaded by the radio antenna mast which is mounted on the rear of the enclosure.

The two PV panels are mounted to the roof of the enclosure at an angle of 50 degrees. Although this is the expected tilt angle for a location at 36 degrees latitude, onsite personnel prefer a 60 degree tilt angle which allows snow to slide off the panels by itself. The lower angle tends to require some manual snow removal.

Operations have been successful with the system meeting design specifications. Improvements being implemented by the onsite personnel are remote monitoring of the battery voltage and control of the charging cycle to further reduce operator site visits. Also being implemented is a remotely initiated alarm that will reduce the number of routine status polls needed to verify proper RTU operation. Through reducing the number of polling cycles, the autonomy period should increase from the current 13 days to approximately 30 days.

Maintenance will be carried out as indicated by the status reports generated by the data acquisition system.

## REFERENCES

Architectural Energy Corporation: "Maintenance and Operation of Stand-Alone Photovoltaic Systems." Photovoltaic Design Assistance Center, Sandia National Laboratories, Albuquerque, New Mexico. 1991.

Post, H., Risser, V. V. , and Van Arsdale, A., editors: "Stand-Alone Photovoltaic Systems - A Handbook of Recommended Design Practices". Photovoltaic Design Assistance Center, Sandia National Laboratories, Albuquerque, New Mexico. 1991.

Roberton, E., editor: "The Solarex Guide to Solar Electricity." Tab Books, Inc. Blue Ridge Summit, PA, 1983.

## ACKNOWLEDGEMENTS

The author wishes to express his deep appreciation to Mr. Howard Limback, Arco Farmington, and to Mr. Terry Peeples, Arco Block 31, for sharing their experiences and the technical details of operating their PV systems. Great thanks are also due to Mrs. Lisa Gordy and Mr. James Curfew for their assistance in editing this paper.