American Railway Engineering and Maintenance of Way Association
Letter Ballot 38 21-09

1. **Committee and Subcommittee:**

   AREMA C&S Committee 38

2. **Letter Ballot Number: 38 21-09**

3. **Assignment:**

   MP's revised at Fall 2021 meeting.

4. **Ballot Item:**

   Ballot 38 21-09: This ballot contains the MP approved at the Fall 2021 meeting:

   9.4.1 - Recommended Guidelines for the Application of Solar Power Systems

   Rationale:

   Revised Manual Parts

Recommended Guidelines for the Application of Solar Power Systems

~~Reaffirmed~~ Revised 20~~22~~23~~18~~ (7 Pages)

A. Purpose

This Manual Part recommends guidelines for the purpose of providing general recommendations for the selection and sizing of solar (photovoltaic) power systems. They set forth specific areas of consideration for the design, sizing and component selection of solar power systems for both new and existing installations.

B. General

Solar power systems can be applied to a wide variety of railroad signaling and communication applications. It is most effective in remote areas where the installation of conventional utility power sources may be cost prohibitive. It can also be a reliable alternative in less remote applications to replace primary batteries and eliminate pole lines.

C. Typical Application Areas

Consideration of solar power is most appropriate where average system loads are typically less than 1KW and are predominantly or exclusively dc; and where there are high costs to install or maintain utility service or non-renewable energy sources such as primary batteries. Typical applications include:

1. Highway grade crossings and their approaches.
2. DC and Coded track circuits.
3. Signal and signal repeater locations.
4. Radio base stations and repeaters.
5. Microwave repeaters.
6. Emergency wayside telephones.
7. Defective equipment detectors.
8. Fiber optic cable systems.

D. Design and Sizing Considerations

Successful and reliable solar system design and engineering should consider a number of factors that affect system parameters.

1. Solar Radiation:

   The only available energy for a solar power system comes from the sun. "Solar Insolation" data is a measurement of the amount of that energy at specific sites throughout the country and world. This data is the fundamental basis for sizing solar power systems.

   a. Examine Several Insolation Data Sources:

      Solar insolation data is available from a variety of sources including the government, universities and solar panel manufacturers. Due to differences in measurement methods and sampling periods, several sources should be examined and the most appropriate utilized for system calculations.

      (1) National Renewable Energy Laboratory (NREL)

      (2) University of Wisconsin

      (3) University of Massachusetts

   b. Select a Data Site Most Similar to the Application Site:

      The data site utilized for calculations should be close in latitude and similar in climatic and geographical conditions to the actual installation site. If regional application of systems is being examined, several data sites within the region should be utilized in sizing.

   c. Adjust for Local Conditions:

      If necessary, adjust the solar insolation data to reflect any peculiar installation site conditions such as lake effects, snow belts or major differences in terrain and elevation.

   d. Use Monthly or Daily Long-Term Averages:

These provide the most accurate sizing basis and reveal important seasonal or monthly variances that can significantly impact system sizing.

e. Be Aware of Possible Variances:

Yearly insolation totals are fairly consistent for a particular site, but still can vary 10 % or more from long-term averages. Monthly values may vary 40 % or more. These variances need consideration when sizing the battery reserve.

f. Probability Analysis:

Computer software is available from private and public sources that provides a dynamic analysis of the probability of the system failing to support the load.

2. Site and Location Factors

a. Consider Daily and Seasonal Temperature Variations:

Identify the anticipated temperature extremes the system will be subjected to and their effect on both solar module and battery performance.

b. Consider Peculiar Weather Phenomena:

Special sizing and/or structural consideration may be required if a particular site is subject to frequent fog, excessively high winds, hailstorms or other adverse climatic conditions.

c. Adjust for Obstructions:

Trees, hills, poles and other obstructions can partially block the sun. The higher the latitude of the installation site, the more prevalent the problem since the sun will be lower on the horizon in winter months. Additional deration of the system or special considerations in the mounting of the system may be necessary.

d. Ensure Proper Alignment:

Make sure the array is aligned true south for proper operation. In many locations this requires an adjustment from "magnetic" (compass) south based on a current isogonic chart.

e. Protect from Vandals:

Special hardware covers and mounting considerations will be required for areas particularly prone to vandalism and/or damage from firearms.

3. Load Factors

a. Be Accurate:

In analyzing or detailing load requirements, include the current draw, operating voltage range, and expected duty cycle for everything to be connected to the solar power system.

b. Include Peak Current Loads:

For equipment loads that are variable or pulsating identify "peak" current levels unless definite patterns or duty cycles are determinable.

c. Consider Worst Case:

Since even a small increase in load can lead to a system unbalance or a cycling down of battery capacity make sure worst-case load scenarios are considered. This should include any variations that may result from seasonal conditions.

d. Plan for Future:

Consider the effect of equipment expansion or high usage that may arise in the future during the initial design of a system. The system should be capable of handling the increase or being easily expanded.

e. Check Compatibility:

All loads should be checked to ensure that they are capable of operating throughout the upper and lower voltage range of the solar power system.

f. Determine Design Margins:

If worst-case load scenarios and possible system expansion have been considered, additional design margins should be kept to a minimum so as not to reduce the cost effectiveness of the system.

4. Array Factors

The solar array is the system component that converts sunlight to electrical energy. An array is made up of one or more solar "modules" connected in a series and/or parallel arrangement.

a. Select Most Appropriate Module:

Solar modules are often rated on the basis of "peak watts" and their electrical characteristics are described in a current-voltage (I-V) curve. While both are important, more important is the module's behavior under expected operating conditions. Of particular concern is the module's charging voltage under expected high temperatures. It must be adequate to charge the battery while also overcoming system voltage losses.

b. Consider Effects of Dirt and Other Contaminants:

Dirt and other contaminants (i.e. bird-droppings) on the face of the solar array can reduce the power output. Site conditions should be assessed to gauge if contaminants might be a potential problem and whether special mounting considerations, system deration, or more frequent cleaning would be the best solution. If the tilt angle of the array is less than 30 deg.., buildup of dirt and other contaminants can be expected.

c. Optimize Orientation and Tilt:

The specification orientation and tilt of the solar array should be selected to optimize system power during the worst-case periods of the year when average solar insulation is lowest and load requirements are highest. It may be desirable in certain locations to increase the array tilt to aid the clearing of snow and ice.

d. Balance System Design:

Too large an array is unnecessarily costly, increases battery water consumption and risks possible damaging overcharge. Too small an array will have trouble supporting the load and sharply increases "winter deficits" in battery capacity. Try to achieve a system that attains a balance of array size and battery size.

e. Additional Reference Material:

Additional Photovoltaic battery sizing, installation and maintenance reference material can be found in the following:

(1) Institution of Electrical and Electronic Engineers (IEEE) Recommended Practice for Sizing Lead Acid Batteries for PV Systems, Standard 1013-(Current version).

(2) IEEE Recommended Practice for Sizing Industrial Nickel Cadmium Batteries for PV Systems, Standard 1144-(Current version).

(3) IEEE Recommended Practice for Installation and Maintenance of Lead Acid Batteries for Photovoltaic Systems, Standard 937-(Current version).

(4) IEEE Recommended Practice for Installation and Maintenance of Nickel Cadmium Batteries for Photovoltaic (PV) Systems, Standard 1145-(Current version).

(5) IEEE Guide for Array and Battery Sizing in Stand Alone Photovoltaic Systems, Standard 1562 – (Current version)

5. Battery Factors

Battery selection and sizing is critical to overall system performance and reliability. The battery serves as an energy "buffer," storing excess energy produced by the solar array and releasing that energy as required during darkness and periods of inclement weather when the array is unable to support the load.

a. Physical and Performance Requirements:

The battery should be capable of handling both the physical and electrical rigors of the application while providing the desired life expectancy and reliability. Specific key areas to consider include:

- Cycle life.
- Capability to withstand extended undercharged condition.
- ~~Capability to withstand extended overcharging when array output is not regulated~~[DW1].
- Charge efficiency and degree of self-discharge.

- Required need for equalization or a commissioning charge in accordance with the Battery Manufacturer's Installation & Operating Instructions.
- Performance and life effects of temperature extremes.
- Tolerance of abuse.
- Maintenance requirements.

b. Reserve Capacity

The capacity of the battery should be sized to override:

(1) The expected uncertainties in solar insulation and

(2) Any seasonal periods when the array power is unable to fully match the load requirements.

c. Temperature and Aging Deration

Battery performance is not static but will vary with age and environmental conditions. Battery performance should be derated to compensate for loss of capacity due to aging and the reduction in available capacity due to low temperature.

These factors will vary with battery type. An additional consideration for certain applications will be the life shortening effects of sustained high-temperature environments.

d. Regulation and Charge Control

A system regulator or charge controller ~~may be~~ is ~~necessary~~[DW2] required to prevent excessive overcharge during peak periods of solar radiation that could damage ~~some~~ the batteries~~, particularly flat plate lead acid batteries and "sealed" maintenance-free batteries~~. A regulator or controller ~~may also be desirable to~~ is necessary to reduce battery water consumption and extend required maintenance intervals when using flooded or vented batteries.

e. Battery State Of Charge (SOC)

All batteries, regardless of their chemistry, will self-discharge. Batteries should be installed fully charged and ready for service. If possible, apply a Commissioning Charge (NiCd) or an Equalization charge (Lead Acid) as defined in the Battery Manufacturer's Installation & Operating Instructions, prior to installation. In the case of remote areas, where the only battery charger available is the photovoltaic array, the batteries should be connected to the system with no connected load and allowed to recharge for 24 hours before connecting the loads and putting the equipment into service.