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Memorandum

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To: All Regions
Attn: Manager, Airports Division

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Subject: Engineering Brief No. 76 Using Solar Power for Airport Obstruction Lighting

Engineering Brief No. 76 provides information and guidance on using solar power supplies for airport obstruction lighting.

Attachment

ENGINEERING BRIEF NO. 76

USING SOLAR POWER FOR AIRPORT OBSTRUCTION LIGHTING

January 11, 2008

PURPOSE: This Engineering Brief provides guidance and information to airports, Airport District Offices (ADOs), and Architectural and Engineering (A&E) companies on the use of solar power supplies for airport obstruction lighting applications.

BACKGROUND: Recent advances in light emitting diode (LED) technology for obstruction lighting have made the use of solar power systems an attractive option for many users. A direct current (DC) powered L-810 LED obstruction light may typically use one-tenth of the power required for an equivalent incandescent light. The innate power efficiency inherent to LEDs allows much smaller solar power systems than previously possible. When coupled with recent technology advances in photovoltaic solar panels (and associated components like batteries), solar-powered LED lights can become a cost-effective option. This is especially true for tower lighting applications when the distance from commercial power lines exceeds one-half mile. The cost for an extension of a commercial power line can range from $10,000 to $30,000 per mile, depending on location and terrain. In many cases, a solar power system can be designed for half the cost of a commercial power line. Many solar power systems designed to power obstruction lighting are already installed and operating throughout the United States.

Note: The use of a solar power system is not confined to DC-powered LED-based Type L-810 obstruction lights. However, powering other types of LED obstruction lights (for example, an LED L-864) designed for 120 volt AC operation may prove to be costly because of added system complexity.

A properly designed solar power system will be very reliable and require little maintenance throughout its lifetime. A typical, well-designed and properly maintained system can be expected to operate for at least 5 years, maximizing the return on initial investment.

APPLICATION: The Airport Lighting Equipment Certification Program (ALCEP) outlined in AC 150/5345-53 and equipment listed in the Addendum of the AC is established for airport projects receiving Federal funds under the grant assistance or passenger facility charge programs.

DESCRIPTION: This document provides guidance and information that is specific to solar-powered airport obstruction lighting equipment.

EFFECTIVE DATES: This Engineering Brief shall become effective 6 months after signature by the Manager of the Federal Aviation Administration (FAA) Airport Engineering Division, AAS-100.

APPLICABLE DOCUMENTS:

FAA Advisory Circulars
AC 70/7460-1, *Obstruction Marking and Lighting*

AC 150/5345-53, *Airport Lighting Equipment Certification Program*
AC 150/5345-43, *Specification for Obstruction Lighting Equipment*

RECOMMENDATIONS:

1.0 Solar Power System Components.

A solar power system is unique in that it requires no energy input other than ordinary sunlight. A solar power system is composed of four basic components:

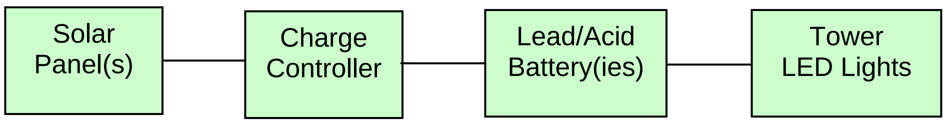

Figure 1. Basic Solar Power System Block Diagram

NOTE: *Some manufacturers may provide an obstruction light that integrates all the components shown in Figure 1into a single housing.*

1.1 Photovoltaic (Solar) Panel.

Sunlight is converted into electrical energy by the photovoltaic panel. The panel is made of many separate silicon photovoltaic cells typically connected in a series arrangement. It can be thought of as a direct current (DC) generator powered by sunlight.

When light photons from sunlight strike a photovoltaic cell, they free electrons in the silicon crystal structure, forcing them through an external circuit (battery or direct DC load), and then return them to the other side of the solar cell to start the process all over again. The voltage output from a single crystalline solar cell is about 0.5-volt DC with an amperage output that is directly proportional to the cell's surface area. Typically, 30 to 36 cells are wired in series (+ to -) in each solar module. This produces a solar module with a 12-volt DC nominal output (as high as 20 volts DC at peak power) that can then be wired in series and/or parallel with other solar modules to form a complete solar array to charge a 12-, 24-, or 48-volt DC battery bank.

Figure 2. A Typical Solar Panel

Solar panel wattages range from 15 to 200 watts—the higher the wattage, the larger the physical size of the solar panel.

1.2 Charge Controller.

When the solar panel charges the batteries, there must be some means of controlling its energy output to prevent damage to both the solar panel and the battery. If the peak output of a solar panel at 20 volts DC were directly connected to a 12-volt battery, it would seriously damage it. The charge controller protects the battery by regulating the amount of voltage and current applied. It is designed to optimally charge the battery and prevent any potential damage that may arise from excessive voltage and current. Many charge controllers also are designed to further protect the battery by limiting the voltage to which the battery can be safely discharged. If the battery is discharged too deeply, it may be damaged and not recharge. All well-designed solar power systems will use a charge controller that—

a. Optimally charges the battery based on the battery type.

b. Limits the lowest voltage to which a battery can be safely discharged.

c. Compensates for differences in battery charging due to temperature.

1.3 Batteries.

Batteries are the power source for the lighting load. The battery choice for a solar-powered lighting system is very important. Lead-acid batteries are most often used in solar power systems because they are readily available and relatively low priced. Anyone considering using a solar power supply should know both the type and capacity of lead-acid batteries.

1.3.1 Lead-Acid Battery Types

1.3.1.1 Shallow-Cycle Batteries.

These batteries are primarily used as starting batteries in automobiles and are designed to supply a large amount of current for a short time. They do not tolerate deep discharges, and if repeatedly discharged by more than 20 percent (below 12.5 volts DC for a 12 V battery) capacity, their life will be very short. These batteries are not a good choice for a solar power system.

1.3.1.2 Deep-Cycle Batteries.

A deep-cycle battery is designed to be repeatedly discharged down to as much as 80 percent (11.7 volts DC for a 12 V battery) of its capacity. These batteries are a very good choice for solar power systems. However, if the battery is not sealed, distilled water will need to be added to each cell about every 3 months, making them poor choices for solar power systems that are remote and require infrequent maintenance.

1.3.1.3 Sealed Deep-Cycle Lead-Acid Batteries.

These batteries are deep cycle and designed to be maintenance free. They will never require water and cannot freeze or spill acid. This type of battery is recommended for remote and unattended power systems.

1.3.1.4 Sealed Gel Cell (gelled-electrolyte) Batteries.

These batteries are also categorized as maintenance free. They can be used in any orientation since the electrolyte is in gel form. But extra care must be taken to ensure a gel cell battery is not charged above 14.1 volts (for a 12 V battery). When a gel cell is overcharged (just one time) over a long period, it will be irreversibly damaged. A solar power system using these types of batteries must have a charge controller with settings for sealed gel cell batteries to keep the charge voltage within safe limits. If expense is not a concern, then these batteries are desirable for a remote solar power system.

1.3.2 Battery Capacity.

Battery capacity is an extremely important consideration when choosing a solar power system. Battery capacity is measured in amp-hours. For example, for a lead-acid battery, the amp-hour rating indicates how much amperage is available when it is evenly discharged for 20 hours. The amp-hour rating is cumulative: to determine how many constant amps the battery will output for 20 hours, divide the amp-hour rating by 20.

For example, if a battery has a rating of 200 amp-hours, divide by 20. This particular battery can supply a 10-amp load for 20 hours before dropping to 10.5 volts (10.5 volts is the voltage at which the battery is considered to be fully discharged).

In reality, a battery is never discharged to 10.5 volts because it would drastically shorten the life of the battery. Most charge controllers will limit the battery discharge to 11.7 volts. This means that extra battery capacity is required to ensure that battery life is optimized; any well-designed solar power system will take this into account.

1.4 LED Light Fixtures.

Light fixtures using LED technology are the best choice for solar power systems. In most cases, an LED will have one-eighth to one-tenth the power requirements of an equivalent incandescent light. LED efficiency allows for a much smaller and lower-cost solar power system.

For any obstruction lighting requirement, it is important to choose a fixture that is certified and listed in Advisory Circular 150/5345-53, *Airport Lighting Equipment Certification Program*, Appendix 3, Addendum. LED obstruction lighting fixtures are certified by a third-party testing laboratory to perform to the requirements of Advisory Circular 150/5345-43, *Specification for Obstruction Lighting Equipment*. To be certified, a fixture must be tested at its operating voltage. It is important to realize that no solar power systems are certified to date.

2. Basic Solar Power System Design Considerations.

Paragraph 1 of this Engineering Brief provides some brief and basic information about the components of a solar-powered lighting system. However, there are many more considerations involved when choosing a solar power system that will be properly sized and reliable for the application. If your company or office does not routinely design solar power systems, we recommend that you contact a company that specializes in this type of design. Be prepared to supply the following information:

2.1 Site Location.

The specification should include the exact latitude/longitude of the site. This information will be helpful to the design activity to determine the maximum sun hours per day available (see Appendix 1). The sun hours per day will be less at more northern latitudes (Maine) and more at more southern latitudes (Arizona). There will also be differences in the sun hours available during the different seasons. Since all obstruction lighting applications will require year-round use, use the winter average for sun hours. Local weather also plays a part, so the engineering firm will also determine the average cloudy days for the site. Be prepared to supply additional details about the proposed location, including—

a. Whether the location is shaded by mountains or trees for part of the day.

b. Whether the site will be remote and receive infrequent maintenance. Is there easy access via paved roads? The accumulation of snow, ice, or dust on the solar panels will adversely affect their efficiency, so periodic maintenance to clean the solar panels might be necessary.

Ensure the engineering firm addresses all site-related considerations in their report prior to system delivery.

2.2 Power Demand.

Ensure the total power demand of the lighting system is known. This information can be calculated from the light manufacturer's specification sheets. For example, suppose a tower is 125 feet in height. AC 70/7460-1, *Obstruction Marking and Lighting,* requires the installation of dual L-810 obstruction lights at the top of the tower.

Example:

a. Refer to AC 150/5345-53, *Airport Lighting Equipment Certification Program,* Appendix 3, Addendum, L-810, to select a manufacturer. Confirm the availability of the part number listed with the manufacturer. This guarantees that a certified obstruction light is specified.

b. Refer to the manufacturer’s data sheet for the dual obstruction light chosen.

c. Calculate the daily amp-hours, assuming each light uses 8 watts of power. The current (I = P/E) for each light is 8 watts/12 volts or 0.67 amps. So the total current requirement for two lights would be about 1.3 amps. If the obstruction lights on the tower were operated 12 hours per night, the daily amp-hours would be—

1.34 * 12 = approximately 16.1 amp-hours

d. The engineering firm performing the solar power supply design will usually determine the information in paragraph 2.2c. However, it would be wise to check their data.

2.2.1 Batteries.

Determine what type of battery will be used. For example, assume a sealed lead-acid battery will be the power source. What is a quick method for determining the approximate size and number of batteries required to operate the lighting?

a. To prolong battery life, it is important that the battery not be completely discharged. Our example system will not allow the battery to be discharged below more than 40 percent of its capacity. This will greatly extend the life of the battery. Some simple calculations:

b. Based on paragraph 2.2c, the daily amp-hour requirement for the light is 16.1 amp-hours.

c. Per the system specification, the batteries must power the system for 7 days with no or reduced sunshine (winter - overcast skies with rain). This means it is necessary to multiply the number of amp-hours times the days desired to power the lights:

16.1 amp-hours * 7 days = approximately 113 amp-hours of battery capacity

d. Paragraph c is the calculated battery capacity. Remember the battery will only be discharged to 40 percent of its capacity. This means a larger battery will be necessary to power the system for 7 days. Take 113 amp-hours and divide by 0.4 (percent of discharge) equals approximately 283 amp-hours. This is a large difference from the original 113 amp-hours calculated. The approving activity should verify this calculation has been done in the design to make sure the batteries will last up to 5 years.

e. The impact of high and low temperature on the battery capacity should also be considered. The colder a battery becomes the less capacity it will have. During the winter time, when outside temperatures are 20 degrees F, a 283 amp-hour battery may not be able to power the system per the specification. The manufacturer of the battery will specify the temperature versus capacity change. For the example battery at 283 amp-hours capacity, the factor for a temperature of 20 degrees F will be 1.59. A 283 amp-hours capacity times 1.59 equals approximately 450 amp-hours. A battery of 450 amp-hours would be required to operate the tower lighting for one week without a charge at the low temperatures encountered during winter.

Conversely, when lead-acid batteries are exposed to high temperatures, although their capacity increases, the life expectancy decreases by half for every 18 degrees F rise over normal room temperature (72 degrees F).

When determining the impact of temperature, ask the following questions:

(1) When the manufacturer claims a 7-day capacity, is for the worst case cold temperature to be encountered?

(2) Will the battery cabinet be designed to prevent the build up of excessive heat during summer months? The cabinet should be painted white and vented or, if necessary, forced air cooled.

(3) Is the wiring properly sized to ensure the proper voltage is applied to the obstruction lights?

2.2.1.1 Number of Batteries.

In paragraph 2.2.1, a battery size of 450 amp-hours was calculated. This would translate into a very large and extremely heavy battery. It would make better sense to parallel wire batteries to achieve easy handling and perhaps lower cost. If a battery with a capacity of 103 amp-hours were selected (69 pounds), you can calculate the number of these batteries needed to achieve 450 amp-hours (450/103 = 4.4). Since you can only have whole batteries, round the number 4.4 up to 5. Five (5) 103 amp-hour capacity batteries would be required to power the lighting system on a worst-case basis.

Make sure the activity designing the solar power system includes the number of batteries required in their report.

2.2.1.2 Charge Controller.

Ensure the charge controller used for the solar power system has a feature to prevent excessive battery drain. In addition, the charge controller should be sufficiently rated for the maximum amperage expected from the solar panels. To facilitate easy maintenance, consider using a charge controller that has an integral display capable of displaying crucial system parameters like voltage, current, and solar panel output.

2.2.2 Battery and Tower Wiring.

Ensure that any wiring interconnecting the batteries is the correct gauge to reduce the possibility of excessive voltage drop. Connections to the battery terminals must use high-quality connectors to avoid problems with excessive voltage drop and possible corrosion.

The obstruction light must operate at its rated voltage for the correct light output. Ensure the tower wiring is the proper size (American Wire Gauge (AWG)) to avoid voltage drops that can adversely affect the fixture light output. See AC 150/5345-43, *Specification for Obstruction Lighting Equipment*, for details about light fixture voltage and control system voltage tolerances.

3. Solar Panels.

The size of the solar panels required to charge the batteries depends on the physical location of the panels. Make sure the solar panels are not shaded by vegetation or in the shadow of a mountain for part of the day on a seasonal basis. In addition, the optimum tilt angle of the solar panel array must be determined for the latitude of the site. It is best to perform a site survey before installation of the system to determine the best location for the solar panels and any associated equipment (batteries, wiring, charge controller).

3.1 Solar Panel Orientation.

a. The installing activity will be responsible for the correct orientation of the solar panels. To get the most output from solar panels, they must be pointed in a direction that will receive the most sunshine. The panels should always face true south or 180 degrees true.

b. To find true south, the easiest method is to use a compass. Be sure to find the correct magnetic declination for your particular location. The magnetic offset can be found on the National Geophysical Data Center (NGDC) website:

www.ngdc.noaa.gov/seg/geomag/jsp/Declination.jsp

c. Once true south is found, the optimum tilt angle of the solar panel can be determined. The winter season has the least sun, so the solar panel tilt should be optimized around this angle. To determine the angle, find your latitude, multiply by 0.9, and add 29 degrees. The result will be the angle from the horizontal to which the panel will be tilted.

For example, consider a tower located at latitude North 37.133 degrees—37.133 degrees times 0.9 equals 33.42 degrees; add 29 degrees to 33.42 degrees to produce a tilt angle of 62.4 degrees. This is the optimum tilt angle for winter. Since there will not be a seasonal adjustment of the solar panels, a 62.4 degree tilt angle should supply sufficient energy throughout the year.

3.2 Solar Panel Size.

The designer of the solar power system usually calculates the solar panel size. However, it is a good idea to use the following method as a check when reviewing the designer's data:

a. Find the daily amp-hour requirement of the installation per paragraph 2.2c.

b. Find your city (or the closest location) in the Solar Insolation Chart in Appendix 1. Use the "Low" value since the obstruction lighting system must be used all year.

c. Divide the daily amp-hour requirement by the value from Appendix 1. This will be the total amperage required from the solar panels.

d. Check the designer's solar panel type. Using the manufacturer's data, determine the peak amperage of the solar panel.

e. Divide the total amperage required from the solar panels (paragraph c) by the peak amperage of the solar panel (paragraph d). The result will be the number of solar panels required in parallel for a 12 V DC system. Check that the designer's number matches your calculations.

f. Example (using a site in New York):

(1) The daily amp-hours requirement from paragraph 2.2.1 is 16.1 amp-hours/day.

(2) Referring to the sun hours chart for Rochester, NY, find the "Low" value: 1.58.

(3) Take 16.1 and time 1.58 equals approximately 25.4, which is the amperage required from the solar panel array.

(4) From the designer's data, the solar panel selected supplies 4.47 amps peak.

(5) Take 25.4 and divide by 4.47 equals 5.6; round up to 6. This is the number of solar panels required.

3.3 Solar Panel Heat Fade.

During very hot days in the summer months, the solar panel output voltage may be reduced due to high temperatures on the silicon solar cells within the solar panel. As the temperature of the silicon solar cells increases, their voltage output decreases. This is why 12 volt solar panels are designed to output 17 to 18 volts at 77 degrees Fahrenheit (F) (25 degrees Celsius (C). A manufacturer of quality solar panels will publish the warranted minimum power output of the solar panel. If your installation is in an area of the country with extreme summer temperatures, be sure to check the minimum warranted power output of the solar panel.

4. Check List

Use the following check list in combination with the detailed explanations in paragraphs 2 and 3 when reviewing the designer's data:

a. Has a site survey been performed to determine latitude/longitude and maximize the output of the solar panels per paragraph 3?

b. Has a cost comparison been done for a commercial power line versus a solar power system?

c. Is the battery capacity sufficient to power the system for at least 7 days during the winter (see paragraph 2.2.1)? Check that the manufacturer's battery size is for the lowest temperature to be encountered at the site.

d. Is the battery cabinet well designed to prevent excessive battery temperatures during the summer months?

e. Is the charge controller designed to protect the batteries from damage that may arise from a full discharge to 10.3 volts?

d. Is the number of solar panels used sufficient to fully charge the system for worst-case winter conditions (see paragraph 3.2)?

e. Are the obstruction lights to be used listed in AC 150/5345-53, Appendix 3, Addendum?

f. Does the installing activity have all the information they need to perform the installation? For example, do they have the solar panel tilt angle, tools to determine true South, solar panel mounting location, site access (batteries are heavy), and lifting equipment?

Appendix 1. U.S. City Insolation in Kilowatt Hours per Square Meter

State	City	High	Low	Avg	State	City	High	Low	Avg	State	City	High	Low	Avg
AK	Fairbanks	5.87	2.12	3.99	KS	Manhattan	5.08	3.62	4.57	NY	Schenectady	3.92	2.53	3.55
AK	Matanuska	5.24	1.74	3.55	KS	Dodge City	6.50	4.20	5.60	NY	Rochester	4.22	1.58	3.31
AL	Montgomery	4.69	3.37	4.23	KY	Lexington	5.97	3.60	4.94	NY	New York City	4.97	3.03	4.08
AR	Bethel	6.29	2.37	3.81	LA	Lake Charles	5.73	4.29	4.93	OH	Columbus	5.26	2.66	4.15
AR	Little Rock	5.29	3.88	4.69	LA	New Orleans	5.71	3.63	4.92	OH	Cleveland	4.79	2.69	3.94
AZ	Tucson	7.42	6.01	6.57	LA	Shreveport	4.99	3.87	4.63	OK	Stillwater	5.52.	4.22	4.99
AZ	Page	7.30	5.65	6.36	MA	E. Wareham	4.48	3.06	3.99	OK	Oklahoma City	6.26	4.98	5.59
AZ	Phoenix	7.13	5.78	6.58	MA	Boston	4.27	2.99	3.84	OR	Astoria	4.76	1.99	3.72
CA	Santa Maria	6.52	5.42	5.94	MA	Blue Hill	4.38	3.33	4.05	OR	Corvallis	5.71	1.90	4.03
CA	Riverside	6.35	5.35	5.87	MA	Natick	4.62	3.09	4.10	OR	Medford	5.84	2.02	4.51
CA	Davis	6.09	3.31	5.10	MA	Lynn	4.60	2.33	3.79	PA	Pittsburg	4.19	1.45	3.28
CA	Fresno	6.19	3.42	5.38	MD	Silver Hill	4.71	3.84	4.47	PA	State College	4.44	2.79	3.91
CA	Los Angeles	6.14	5.03	5.62	ME	Caribou	5.62	2.57	4.19	RI	Newport	4.69	3.58	4.23
CA	Soda Springs	6.47	4.40	5.60	ME	Portland	5.23	3.56	4.51	SC	Charleston	5.72	4.23	5.06
CA	La Jolla	5.24	4.29	4.77	MI	Sault Ste. Marie	4.83	2.33	4.20	SD	Rapid City	5.91	4.56	5.23
CA	Inyokern	8.70	6.87	7.66	MI	E. Lansing	4.71	2.70	4.00	TN	Nashville	5.20	3.14	4.45
CO	Grandby	7.47	5.15	5.69	MN	St. Cloud	5.43	3.53	4.53	TN	Oak Ridge	5.06	3.22	4.37
CO	Grand Lake	5.86	3.56	5.08	MO	Columbia	5.50	3.97	4.73	TX	San Antonio	5.88	4.65	5.30
CO	Grand Junction	6.34	5.23	5.85	MO	St. Louis	4.87	3.24	4.38	TX	Brownsville	5.49	4.42	4.92
CO	Boulder	5.72	4.44	4.87	MS	Meridian	4.86	3.64	4.43	TX	El Paso	7.42	5.87	6.72
DC	Washington	4.69	3.37	4.23	MT	Glasgow	5.97	4.09	5.15	TX	Midland	6.33	5.23	5.83
FL	Apalachicola	5.98	4.92	5.49	MT	Great Falls	5.70	3.66	4.93	TX	Fort Worth	6.00	4.80	5.43
FL	Belie Is.	5.31	4.58	4.99	MT	Summit	5.17	2.36	3.99	UT	Salt Lake City	6.09	3.78	5.26
FL	Miami	6.26	5.05	5.62	NM	Albuquerque	7.16	6.21	6.77	UT	Flaming Gorge	6.63	5.48	5.83
FL	Gainesville	5.81	4.71	5.27	NB	Lincoln	5.40	4.38	4.79	VA	Richmond	4.50	3.37	4.13
FL	Tampa	6.16	5.26	5.67	NB	N. Omaha	5.28	4.26	4.90	WA	Seattle	4.83	1.60	3.57
GA	Atlanta	5.16	4.09	4.74	NC	Cape Hatteras	5.81	4.69	5.31	WA	Richland	6.13	2.01	4.44
GA	Griffin	5.41	4.26	4.99	NC	Greensboro	5.05	4.00	4.71	WA	Pullman	6.07	2.90	4.73
HI	Honolulu	6.71	5.59	6.02	ND	Bismarck	5.48	3.97	5.01	WA	Spokane	5.53	1.16	4.48
IA	Ames	4.80	3.73	4.40	NJ	Sea Brook	4.76	3.20	4.21	WA	Prosser	6.21	3.06	5.03
ID	Boise	5.83	3.33	4.92	NV	Las Vegas	7.13	5.84	6.41	WI	Madison	4.85	3.28	4.29
ID	Twin Falls	5.42	3.42	4.70	NV	Ely	6.48	5.49	5.98	WV	Charleston	4.12	2.47	3.65
IL	Chicago	4.08	1.47	3.14	NY	Binghamton	3.93	1.62	3.16	WY	Lander	6.81	5.50	6.06
IN	Indianapolis	5.02	2.55	4.21	NY	Ithaca	4.57	2.29	3.79					