Solar Flashers: Too Cloudy for You?

by Joseph Wise

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Quite often I'm told by DOT people that "...solar-powered traffic systems are a great idea for the Sunbelt states but they won't work in my area because of the cloudy weather." Cloudy weather should not preclude the use of solar electric in your next project.

Only by careful analysis of solar radiation data for a project's site; tabulation of the loads; and a thorough grasp of the operational requirements (duty cycle) can the user determine if a solar electric system is a practical alternative to a utility or hardwire system.

A properly-designed solar flasher system can function in a cloudy environment and supply enough power to run the equipment for its duty cycle. To substantiate this claim, you only need to analyze the power production characteristics of a solar module. For example, Figure 1 depicts what is known as a current-voltage (IV) curve which details the electrical performance of a solar module. The curve represents full sunlight on the modules which by standard testing methods is 1000W/sq-m.

The IV curve in Figure 1 illustrates the electrical characteristics of an AstroPower AP-120 solar module. If the output of a solar module is shorted, the maximum current output is realized at Point A-known as the short circuit current-and in this case, equal to 7.7 amps. If the output is left open, the maximum voltage is produced-shown as Point B-or about 21VDC for this module. The point where the curve bends is known as the knee of the curve-Point C-and considered to be the maximum power point. The power at the maximum power point is the value used to define the module's output wattage.

If you know the basic electrical performance of the solar module in full sunlight, you can calculate its productivity in cloudy weather. While it's true there is no direct sun on a cloudy day, sunlight penetrates the clouds in the form of diffused light. The cloud density dictates the percentage of sunlight which reaches the solar module. On a lightly overcast day, there may only be a loss of 10 percent. On a heavily overcast day, there may be only 50 percent of the equivalent solar radiation reaching the module. Nevertheless, there is some sunlight coming through which will produce electricity.

To substantiate this statement, please examine the electrical performance curves for the AP-120 module in Figure 2. Curve 1 is identical to the curve in Figure 1 when exposed to full sunlight. Curves 2 through 4 represent solar module output under conditions of reduced sunlight, such as those found in overcast conditions. Curve 2 displays the module output at 800W/sq-m, which is equal to a 20 percent reduction in sunlight. Curves 3 and 4 depict even lower levels of light. The main point to note-even at the reduced levels of irradiation-the solar modules still produce enough electricity to recharge the batteries but at a reduced rate.

Typical System Design

Armed with the knowledge that solar modules will provide an electrical output in cloudy weather, a school-zone flasher system is used to demonstrate how the solar module and battery requirement change from location to location yet at the same time, will properly power the same basic system. The flasher has the following parameters:

Load: Dual 8-inch, amber DC LED lamps (Precision Solar part number 1384) Control circuit consisting of a programmable time switch and an integrated charge/flasher control.

Duty Cycle: Lamps - 50 percent flash rate, bouncing ball configuration, 6.5 hours per day, school days Controls-continuous

Three data points (or locations) have been selected to show how a system's size will change with the climate.

Please note that latitude does have an impact on the amount of sunlight received at a location. The farther north from the equator, the shorter the days. Hence, less total hours of sunlight per day in the winter months.

To ensure a fair illustration of the systems, all of the sites are at approximately the same latitude. This rules out any variances in the hours of sunlight impacting the size of the solar arrays. A solar sizing report for each location using its solar radiation data1 and the electrical draw of each load was drawn to illustrate the power necessary to run the defined system.

An acceptable minimum array/load ratio for a school-zone system is 1.05.2 In each of the designs, all solar modules were placed at a 45 degree angle due south. Please note: the column headed "Global KWh/sq-m" represents the equivalent number of full sun hours on a flat surface at the site and the "@Tilt" column shows the equivalent full sun hours on a surface at the module tilt angle which is 45 degrees in this case.

Results for three data points

The first data point-Boulder, CO-a relatively sunny location. In Figure 3, the sizing shows that a solar flasher system with the given parameters would require a 55-watt solar module and a single battery to ensure proper operation. A Shell (formerly Siemens) SM-55 solar module was used.

The second location-St. Louis, MO-has a much different climate as can be seen in the equivalent number of sun hours for each month in Figure 4. The same system configuration in this location requires a 75-watt module and a single battery to power the system. A Shell SP-75 solar module was used.

The third site-Pittsburgh, PA-is a much cloudier climate due to influences on its weather from the Great Lakes. The sizing for this location, Figure 5, requires a 120-watt solar module and two batteries for the system to produce enough power. An AstroPower AP-120 solar module was used in the design.

Summary

Clearly, the data presented shows that solar modules do produce charging current even in cloudy weather-at reduced rates. When all the system parameters are considered-solar radiation, load, duty cycle- it's possible to make an informed decision on the practicality of using solar flashers. Systems for "cloudy" climates will obviously require larger solar arrays and battery banks than "Sunbelt" areas, yet may still offer a viable option over a traditionally hardwired system. Continuing improvements in solar module and LED technology will continue to decrease the costs of the systems and expand their useful range throughout all climates in the United States.

End Notes

1 Solar Radiation Data Manual NREL/TP-463-5607, National Renewable Energy Laboratory

2 IMSA Journal, July-August 2002, "Wireless Traffic Control Solutions" pp 48-52; 59

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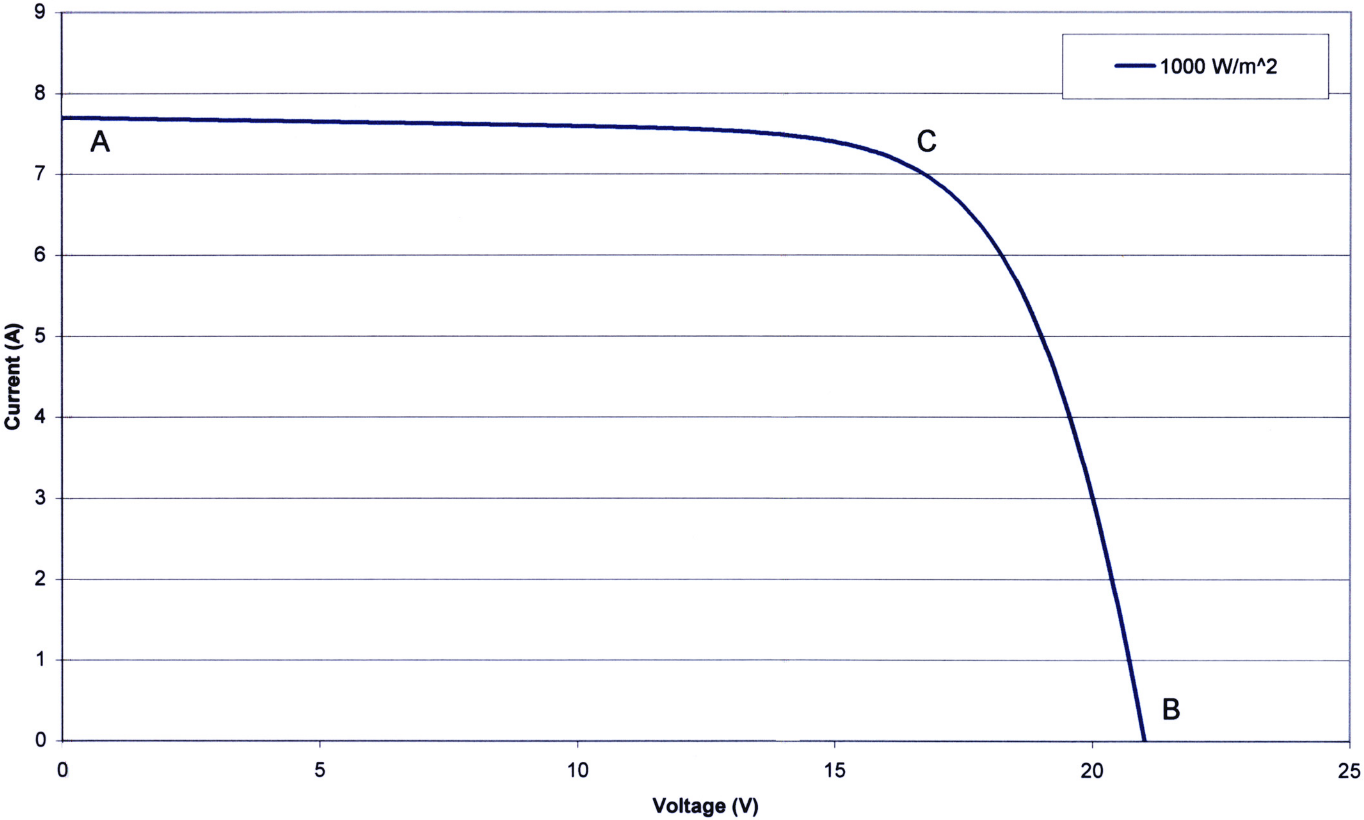
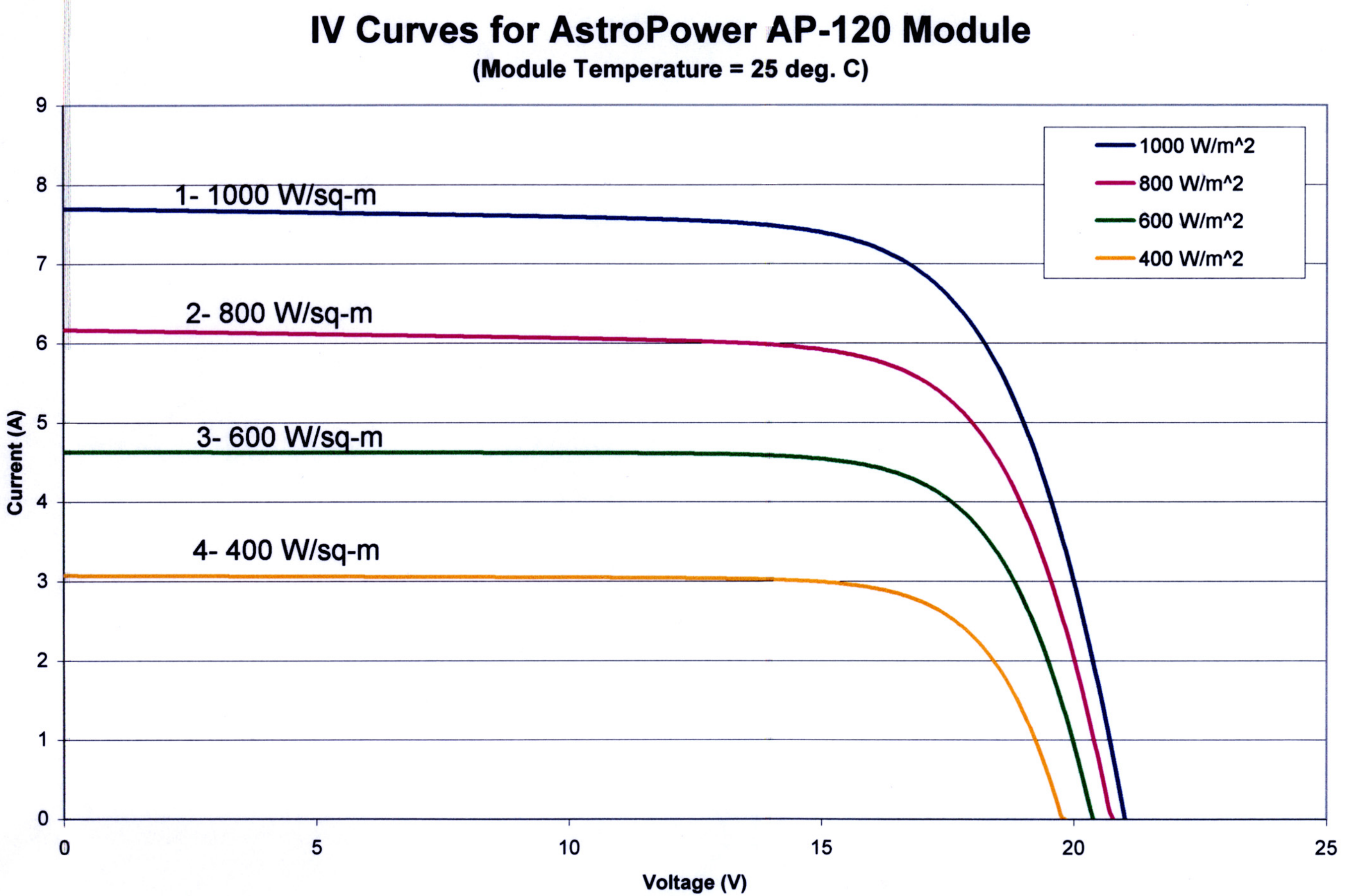
IV Curves for AstroPower AP-120 Module

(Module Temperature = 25 deg. C)




IV Curves for AstroPower AP-120 Module
(Module Temperature = 25 deg. C)
1000 W/m^2
800 W/m^2
600 W/m^2
400 W/m^2
1- 1000 W/sq-m
2- 800 W/sq-m
3- 600 W/sq-m
4- 400 W/sq-m
Current (A)
Voltage (V)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
25

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PVCAD VERSION 2.10

Load	Description	Load Profile	Amperes	Average Hours/day	Weekly Profile Days of Week On
1	2X8 AMBR FLSHR	24 hours	1.830	6.50	1 2 3 4 5 - -
2	DPC	24 hours	0.050	24.00	1 2 3 4 5 6 7
3	TIMER	24 hours	0.050	24.00	1 2 3 4 5 6 7

Nominal PV System Voltage: 12 Array mounting = Fixed tilt Array
Power system type: DC System with battery , NO maximum power tracker

Solar data and temperature location: BOULDER, COLORADO, U.S.A.
Latitude= N 40:01 Longitude= W105:11 Elevation= 1634 N (M)
Azimuth = 0 Albedo = 20%

- - - - - - - - - PV ARRAY DESCRIPTION (ratings at 25°C)- - - - - - - - - - -
Modules: SIEMENS, SM55 Total Modules = 1
Series = 1 Parallel = 1 Power = 55 Peak Watts
Max. power voltage= 17.4 Max. power current = 3.2
Open circuit voltage= 21.7 Short circuit current = 3.5
Mismatch loss(%)= 3 Dirt loss(%)= 5 Wiring loss(%)= 2

- - - - - - - - - - BATTERY SUBSYSTEM (ratings at 25°C) - - - - - - - - -
Battery: CONCORDE, PVX-840T Amp-hr/ea = 95 Volts/ea = 12
Series = 1 Parallel = 2 Total= 2 Max. month daily DOD =
Total Amp-hrs.= 190 Battery Charge Efficiency = 95% Weight= 52 Kg
Equivalent to 12.12 days at highest monthly load to 80% DOD

- - - - - - - - - - - - - - - ESTIMATED PERFORMANCE - - - - - - - - - - - - - -

Month	Global kWh/M²	Tilt	@Tilt kWh/M²	Mean °C	Gross A-hr/d	Array Net A-hr/day	Load A-hr/day	Deficit A-hr/d	SOC	Array/Load Ratio
Jan	2.40	45	4.39	-2.7	13.83	13.23	10.90		94-100	1.21
Feb	3.30	45	5.08	0.8	15.99	15.38	10.90		94-100	1.41
Mar	4.40	45	5.66	3.9	17.83	17.19	10.90		95-100	1.58
Apr	5.60	45	6.03	9.0	19.00	18.39	10.90		95-100	1.69
May	6.20	45	5.86	14.0	18.45	17.80	10.90		95-100	1.63
Jun	6.90	45	6.07	19.4	19.12	18.42	10.90		96-100	1.69
Jul	6.70	45	6.06	23.1	19.10	18.33	10.90		96-100	1.68
Aug	6.00	45	6.08	21.9	19.14	18.40	10.90		95-100	1.69
Sep	5.00	45	6.02	16.8	18.97	18.37	10.90		95-100	1.69
Oct	3.80	45	5.51	10.8	17.37	16.84	10.90		95-100	1.55
Nov	2.60	45	4.43	3.9	13.96	13.40	10.90		94-100	1.23
Dec	2.10	45	3.90	-1.4	12.29	11.72	10.90		94-100	1.08

Lowest array to load Amp-hr/day ratio is 1.08

(Array Gross: 25°C, no losses. Array Net: All losses and temperature effects.)
Saved as: X0804D2A.SSS Calculated by PVCAD

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Load	Description	Load Profile	Amperes	Average Hours/day	Weekly Profile Days of Week On
1	2x8" AMBR FLSHR	24 hours	1.830	6.50	1 2 3 4 5 - -
2	DPC	24 hours	0.050	24.00	1 2 3 4 5 6 7
3	TIMER	24 hours	0.050	24.00	1 2 3 4 5 6 7

Nominal PV System Voltage: 12 Array mounting = Fixed tilt Array
Power system type: DC System with battery , NO maximum power tracker

Solar data and temperature location: ST. LOUIS, MISSOURI, U.S.A.
Latitude= N 38:45 Longitude= W 90:24 Elevation= 172 N (M)
Azimuth = 0 Albedo = 20%

- - - - - - - - - PV ARRAY DESCRIPTION (ratings at 25°C)- - - - - - - - - - -
Modules: SIEMENS, SP75 Total Modules = 1
Series = 1 Parallel = 1 Power = 75 Peak Watts
Max. power voltage= 17.0 Max. power current = 4.4
Open circuit voltage= 21.7 Short circuit current = 4.8
Mismatch loss(%)= 1 Dirt loss(%)= 5 Wiring loss(%)= 2

- - - - - - - - - - - BATTERY SUBSYSTEM (ratings at 25°C) - - - - - - - - - -
Battery: CONCORDE, PVX-1040 Amp-hr/ea = 117 Volts/ea = 12
Series = 1 Parallel = 1 Total= 1 Max. month daily DOD =
Total Amp-hrs.= 117 Battery Charge Efficiency = 95% Weight= 30 Kg
Equivalent to 7.45 days at highest monthly load to 80% DOD

- - - - - - - - - - - - - - - - - ESTIMATED PERFORMANCE - - - - - - - - - - - - - - -

Month	Global kWh/M²	Tilt	@Tilt kWh/M²	Mean °C	Gross A-hr/d	Array Net A-hr/day	Load A-hr/day	Deficit A-hr/d	SOC	Array/Load Ratio
Jan	2.20	45	3.55	-2.5	15.61	14.90	10.90		91-100	1.37
Feb	2.90	45	3.96	1.1	17.43	16.72	10.90		91-100	1.53
Mar	3.90	45	4.63	7.3	20.36	19.60	10.90		92-100	1.80
Apr	5.00	45	5.15	13.7	22.65	21.87	10.90		93-100	2.01
May	5.90	45	5.48	18.9	24.11	23.13	10.90		93-100	2.12
Jun	6.40	45	5.60	24.1	24.64	23.46	10.90		93-100	2.15
Jul	6.40	45	5.75	26.6	25.29	23.94	10.90		93-100	2.20
Aug	5.70	45	5.68	25.3	24.99	23.77	10.90		93-100	2.18
Sep	4.60	45	5.28	21.2	23.21	22.28	10.90		93-100	2.04
Oct	3.50	45	4.74	14.7	20.87	20.11	10.90		92-100	1.85
Nov	2.30	45	3.37	7.9	14.81	14.15	10.90		91-100	1.30
Dec	1.80	45	2.75	1.1	12.11	11.46	10.90		91-100	1.05

Lowest array to load Amp-hr/day ratio is 1.05

(Array Gross: 25°C, no losses. Array Net: All losses and temperature effects.)
Saved as: X0806D2A.SSS Calculated by PVCAD

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Load	Description	Load Profile	Amperes	Average Hours/day	Weekly Profile Days of Week On
1	2X8 AMBR FLSHR	24 hours	1.830	6.50	1 2 3 4 5 - -
2	DPC	24 hours	0.050	24.00	1 2 3 4 5 6 7
3	TIMER	24 hours	0.050	24.00	1 2 3 4 5 6 7

Nominal PV System Voltage: 12 Array mounting = Fixed tilt Array
Power system type: DC System with battery , NO maximum power tracker

Solar data and temperature location: PITTSBURGH, PENNSYLVANIA, U.S.A.
Latitude= N 40:30 Longitude= W 80:11 Elevation= 373 N (M)
Azimuth = 0 Albedo = 20%

- - - - - - - - - PV ARRAY DESCRIPTION (ratings at 25°C)- - - - - - - - - - -
Modules: AstroPower, AP-120 Total Modules = 1
Series = 1 Parallel = 1 Power = 120 Peak Watts
Max. power voltage= 16.9 Max. power current = 7.1
Open circuit voltage= 21.0 Short circuit current = 7.7
Mismatch loss(%)= 3 Dirt loss(%)= 5 Wiring loss(%)= 2

- - - - - - - - - - - BATTERY SUBSYSTEM (ratings at 25°C) - - - - - - - - -
Battery: CONCORDE, PVX-840T Amp-hr/ea = 95 Volts/ea = 12
Series = 1 Parallel = 2 Total= 2 Max. month daily DOD =
Total Amp-hrs.= 190 Battery Charge Efficiency = 95% Weight= 52 Kg
Equivalent to 11.87 days at highest monthly load to 80% DOD

- ESTIMATED PERFORMANCE - - - - - - - - - - - - - - - - - - -

Month	Global kWh/M²	Tilt	@Tilt kWh/M²	Mean °C	Gross A-hr/d	Array Net A-hr/day	Load A-hr/day	Deficit A-hr/d	SOC	Array/Load Ratio
Jan	1.70	45	2.44	-4.7	17.33	16.02	10.90		94-100	1.47
Feb	2.50	45	3.32	-2.2	23.56	21.99	10.90		94-100	2.02
Mar	3.50	45	4.15	4.1	29.48	27.76	10.90		95-100	2.55
Apr	4.60	45	4.78	9.8	33.95	32.15	10.90		95-100	2.95
May	5.50	45	5.16	15.3	36.62	34.65	10.90		96-100	3.18
Jun	6.10	45	5.40	19.9	38.33	36.19	10.90		96-100	3.32
Jul	5.90	45	5.34	22.3	37.94	35.70	10.90		96-100	3.28
Aug	5.20	45	5.16	21.4	36.67	34.49	10.90		96-100	3.17
Sep	4.20	45	4.75	17.7	33.71	31.88	10.90		95-100	2.93
Oct	3.00	45	3.87	11.3	27.47	25.95	10.90		95-100	2.38
Nov	1.80	45	2.35	5.7	16.69	15.48	10.90		94-100	1.42
Dec	1.40	45	1.88	-1.7	13.38	12.29	10.90		94-100	1.13

Lowest array to load Amp-hr/day ratio is 1.13

(Array Gross: 25°C, no losses. Array Net: All losses and temperature effects.)
Saved as: X0804D2A.SSS Calculated by PVCAD