The Effects of Intermittent Solar Radiation in Off-grid Solar Power System

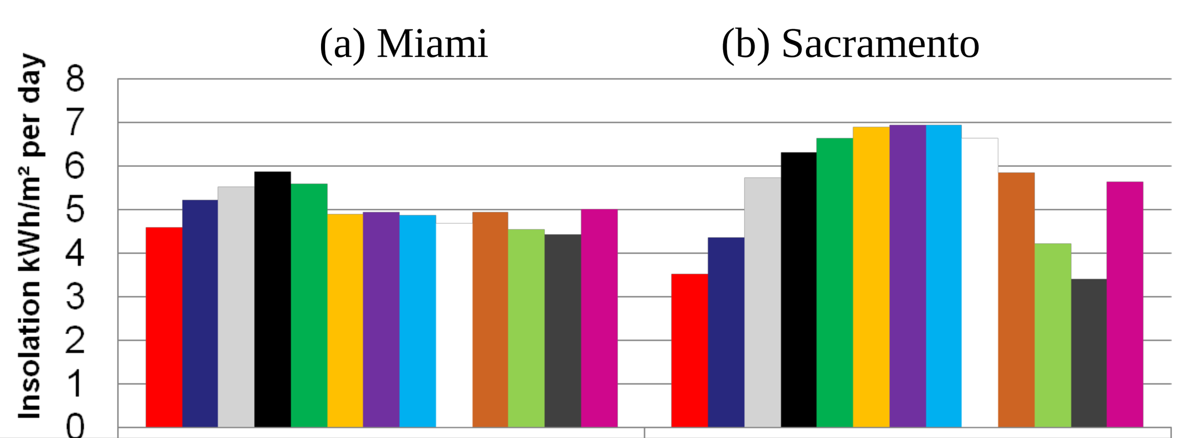
A Case Study of Two Cities; Sacramento, CA and Miami, FL
'Worst Month' method

Taleb H. Al-theanat, Maram A. Al-daraiseh , Mhd Aymen Lpizra
Department of Electrical and Computer Engineering, University of Bridgeport, CT.

1 Abstract

This study illustrates the impact of the solar radiation by comparing the design of two off-grid PV systems installed in two different locations have same annual average solar irradiation (insolation) values at fixed tilt angle. The case study selected the city of Sacramento, CA and Miami, FL. The monthly average Irradiation values in Sacramento are very diverse where the minimum, average and maximum values are spaced compared with the values in Miami which have no significant variation of solar irradiation from month to month. Comparing the Design of the two different systems will reflect the impact of the sporadic solar insolation on the rating values for the components of each system, which is affecting PV system cost. The design assumes the same load based and the worst case scenario of the solar irradiation. Each system will consist of PV modules, charge controller, power inverter and batteries.

2 Solar Information



	(a) Miami	(b) Sacramento
January	4.59	3.52
February	5.23	4.36
Mach	5.53	5.72
April	5.87	6.32
May	5.58	6.64
June	4.9	6.9
July	4.94	6.95
August	4.86	6.95
September	4.69	6.64
October	4.95	5.85
November	4.55	4.22
December	4.42	3.4
Annual average	5.01	5.63

Figure 1-2 : Insolation values represented as a chart for the location at : (a) Miami city at 25° tilt; and (b) Sacramento city at 38° tilt angle.

3 Standard deviation of the Insolation values

Standard deviation (S) @ Sacramento = 1.3717 kWh/m²
S @ Miami = 0.4538 kWh/m²
These values shows that the insolation values at Miami has less variation than in Sacramento.

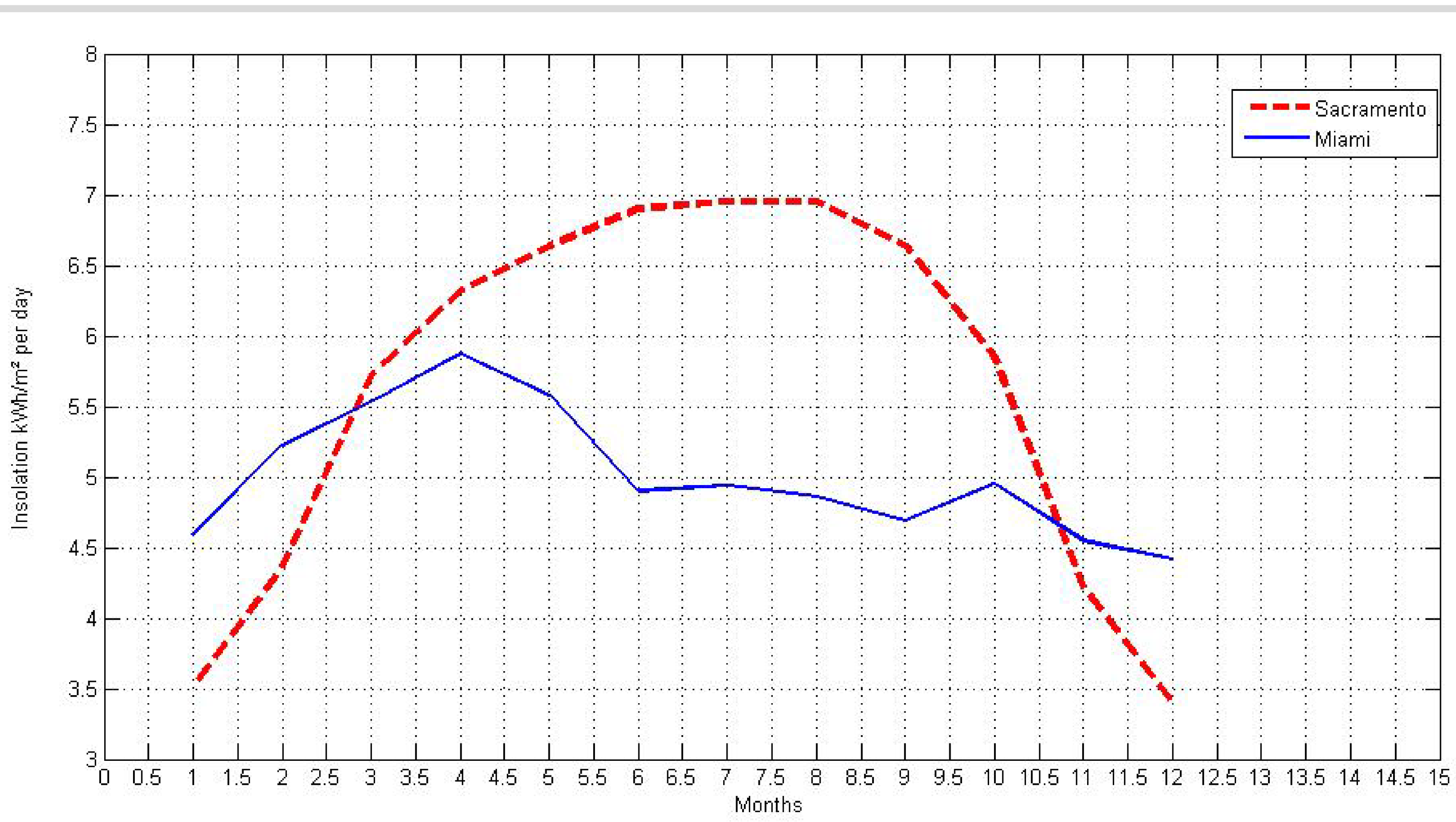


Figure 1-3 : Insolation vs. months

4 Temperature Information

The highest and lowest air temperature at Miami are 102°F (≈ 39°C) in 1983 and 30°F (≈ -1°C) in 1985, respectively. Also, the highest and lowest air temperature at Sacramento are 111°F (≈ 44°C) in 1944 and 16°F (≈ -9°C) in 1990, respectively. The impact of the temperature is presented in the designing process.

5 Off-grid Solar Power System

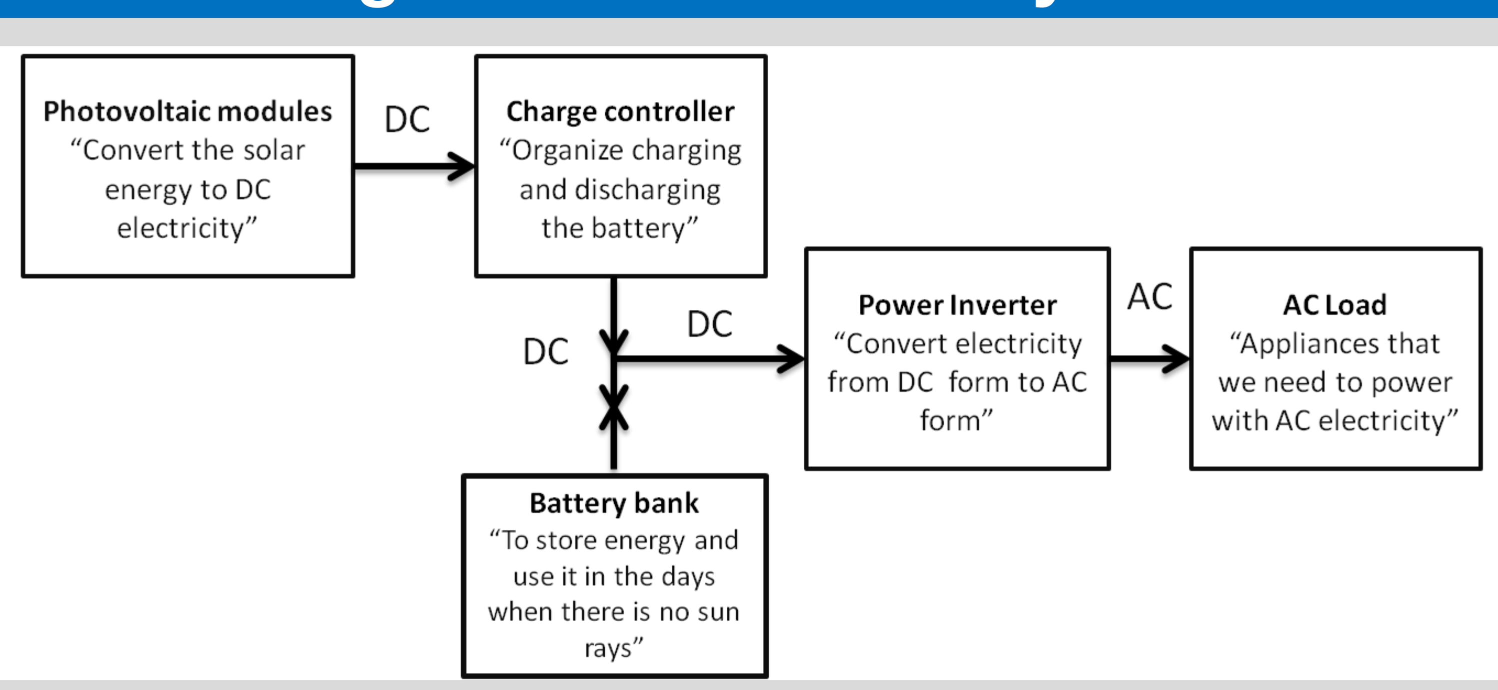


Figure 1-5 : Block diagram of an Off-Grid Solar Power System.

6 Load Estimation

Table 1-6 : Power and energy of the load.

Appliance	Quantity (Q)	Power (W) (P) each	Power (W) (P) Total	Usage time(hrs)/day (T)	Energy (Wh/day) E =Q× P ×T
Light	4	25	4×25= 100	4	4 ×25×4 = 400
TV	1	100	1×100= 100	3	1×100×3 = 300
Laptop	1	95	1×95= 95	4	1×95×4 = 380
small stove burner	1	1000	1×1000=1000	0.2	1×1000×0.2 = 200
Microwave Oven	1	1200	1×1200=1200	0.15	1×1200×0.3 = 180
Phone Charger	2	5	2×5= 10	4	2×5×4 = 40
Total	10	-------	**2505 W** [Max]	--------	1,500 Wh/day

We assumed that each location has the same electric load.

7 The Results

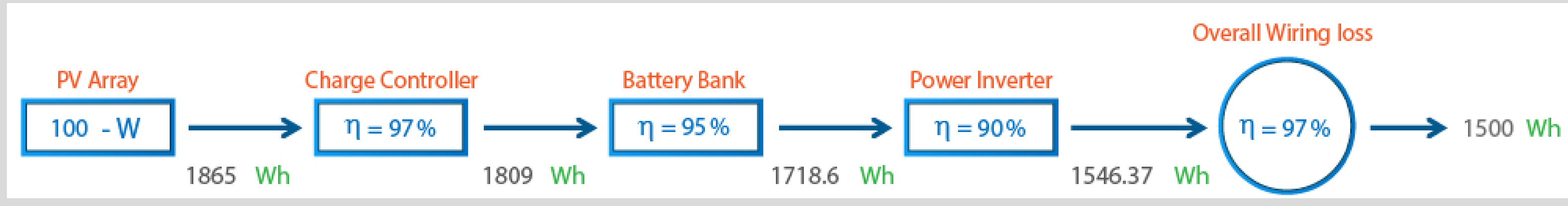


Figure 1-7 : Overall losses in the system.

Table 1-7 : Main components of each system.

	Sacramento	Miami
Temp (C)	Max/Min: 44/-9	Max/Min: 39/-1
Avr. Annual Insolation	5.63 kWh/m²	5.01 kWh/m²
Standard Deviation	1.3717 kWh/m²	0.4538 kWh/m²
PV Modules	Quantity : 8 / P = 100 W each	Quantity : 6 / P = 100-W each
Power Inverter	Quantity : 1 / P = 3000W	Quantity : 1 / P = 3000W
Batteries	Quantity : 7 / C = 100 Ah each	Quantity : 7 / C = 100 Ah each
Charge Controller	Quantity : 1 / Irated = 50 A, Vnominal = 12V, Vmax = 30V or greater	Quantity : 1 / Irated = 40 A, Vnominal = 12V, Vmax = 30V or greater

8 Discussion

This study has presented the effects of intermittent solar radiation in off-grid solar power system design, where the worst month of the average irradiation during the year method has been employed. However, After designing the two systems in both cities, the results showed that the cost of the system at **Miami** is cheaper than the system at **Sacramento**, and the components of **Sacramento's** system have higher rated values than **Miami's** system. These differences occurred due to the variation of solar irradiation from month to month at the location of **Sacramento**, unlike **Miami** irradiation. So, it is critical to study the monthly average insolation values at the required location, and take into consideration the variation of these values in order to make the right decision and the right location before investing money in an off-grid solar power system.

9 Conclusion

If two locations have the same (or very closed values) average annual solar insolation, where location **A** has higher standard deviation than location **B**, then we say:

- The system at location A will require more PV modules = Standard Deviation at A × # of PV modules at B.
- The ratio of the number of PV modules in A to B will equal the highest standard variation (in this case S @ A). In another words, # of PV @ A/ # of PV @ B = S @ A.
- Components of system A will have higher rated values than the components of system B.
- The System at B has more reliability that system A has. Where the insolation values at B have less variation and the system is more stable.
- The cost of system A will be higher than system B.
- Building an off-grid PV system at location B is more economical than A.

In this study, location A represents Sacramento and B is Miami. Where the ratio of the number of PV modules in Sacramento to Miami = 8:6 = 1.333 ≈ the standard deviation of Sacramento = 1.37, and the ratio is not the exact number same as the standard deviation due to the temperature effect where both locations have different temperature profile.