A STATIC LINEAR SIMULATION FOR THE THERMAL BEHAVIOR OF PHOTOVOLTAIC MODULES

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Abstract: This paper has as main goal to evaluate the quality of a model to describe the behavior of the thermal conditions of photovoltaic (PV) modules. The methodology consists in compare measured and calculated PV modules temperature values. As result, the maximal deviations are in a range of 12%.

Keywords: Photovoltaic modules; thermal behavior.

1. Introduction

The data used in this paper were collected in a PV powered reverse osmosis (RO) plant, installed in the community of Coité – Pedreiras, state of Ceará, Northeast Region of Brazil, where one finds yearly average temperature of 28ºC and a solar potential of about 2,000 kWh/m^{2}year. The main components of the plant are: 8 batteries (12V, 100Ah) with charge control, 1 RO unity (nominal drinking water product flow of 250 l/h) and 20 PV modules (55 W_p each). The plant is equipped with sensors for global radiation, ambient temperature, module temperature, wind speed, water flow and direct voltage and current for the PV modules and batteries. Figure 1 shows a view of the PV modules and figure 2 shows the basic configuration of the plant.

For this first project only power for the RO plant is supplied by the PV modules; power for the feed water pump is supplied by the electric grid (Carvalho et al., 2002). By a temperature increase of 2.7 K the PV-power output decrease on average 1% (Tegethoff, 1995). An important consequence of the influences of temperature is the variation of the MPP (Maximum Power Point).

Figure 1: View of the photovoltaic modules .

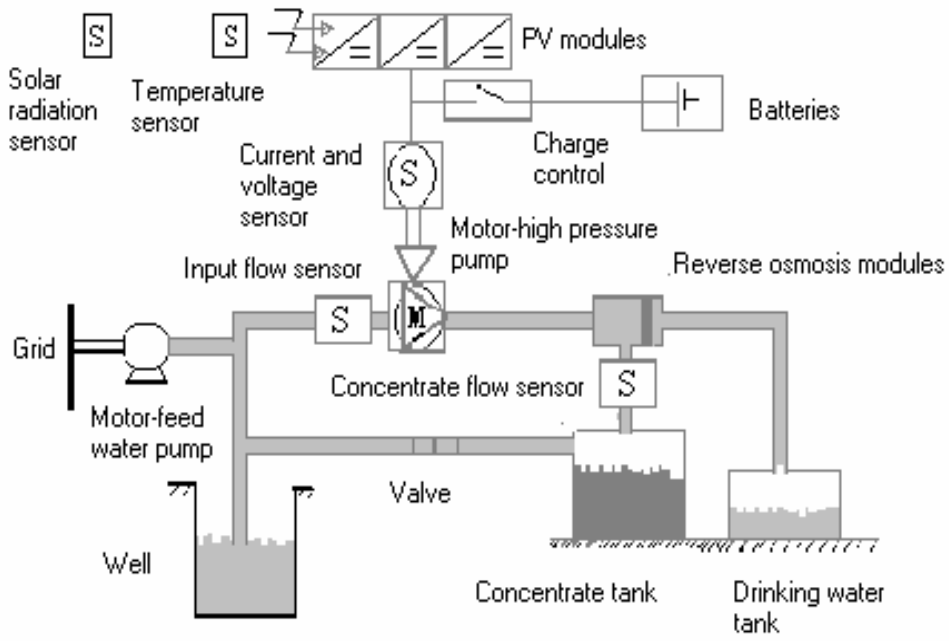

Figure 2: Basic configuration of a photovoltaic powered reverse osmosis plant

2. Collected data

The data collection was accomplished during the year of 2001 and includes data of ambient temperature, module temperature, solar radiation and wind speed. For the present calculation, data come from the dry and rainy season of the state of Ceará: March 30th, June 30th, September 28th, November 15th. Figure 3 shows data of ambient and module temperature for these days. Only data collected between the sunrise and the sunset were used and during operation of the PV-system.

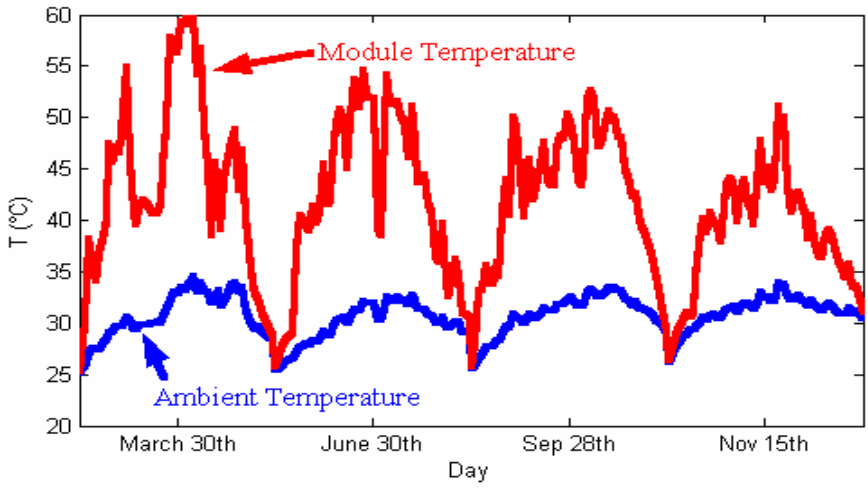

Figure 3: Data of ambient temperature and module temperature.

3. Results

The quality of simulation is evaluated with a static linear model of temperature (Duffie, 1991). The calculation of the relaxation time (T_r) for the modules results in simulation intervals of 8 min. After this time the system can be deemed to be static. For the simulation was used a higher value, with intervals of 10min and only the values during operation of the PV system in 2001. For the module temperature calculation it was used a static linear model:

$$T_c = T_a + m \cdot G(t) \qquad (1)$$

where:

T_c – Module Temperature;
T_a – Ambient Temperature;
G – Solar Radiation;
m – linear coefficient.

For the Equation (1) it is used a linear regression to evaluate the value of m. Figure 4 shows this linear regression.

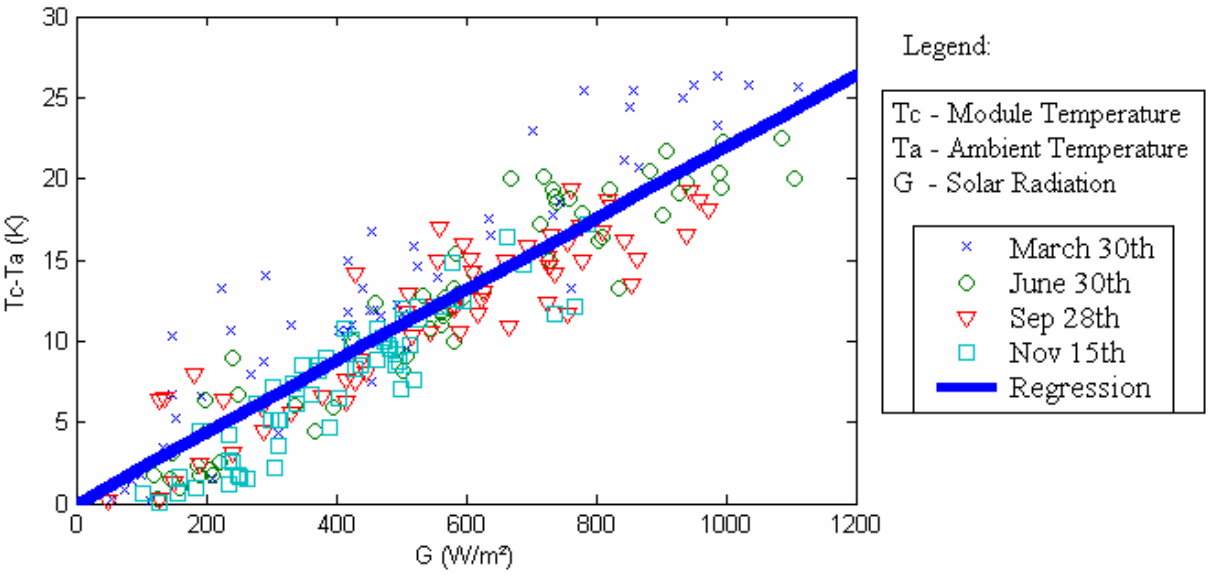

Figure 4: Determination of m through linear regression

Using the result of the linear regression, the calculated value is m = 0.022 m²K/W. In this way, the temperature of the module can be calculated as:

$$T_c = T_a + 0.022 \cdot G \qquad (2)$$

To compare, a similar study gives a value of m = 0.021 m²K/W. for a PV system in Lagoa das Pedras, Ceará (Tegethoff, 1995). By comparing measured and calculated values, the maximal deviation obtained was about ±12%. Figure 5 shows curves of measured and calculated by the static linear model temperatures, together with the deviation D *(%)* for each time interval.

4. Conclusion

This paper compares measured and calculated PV modules temperature values. The calculated values are found by the use of a static linear thermal model. Maximal deviation from both values are in a range of 12%. In this way, the linear model is acceptable and can used in MPP-Tracker programs or in PV systems simulations.

5. Acknowledgments

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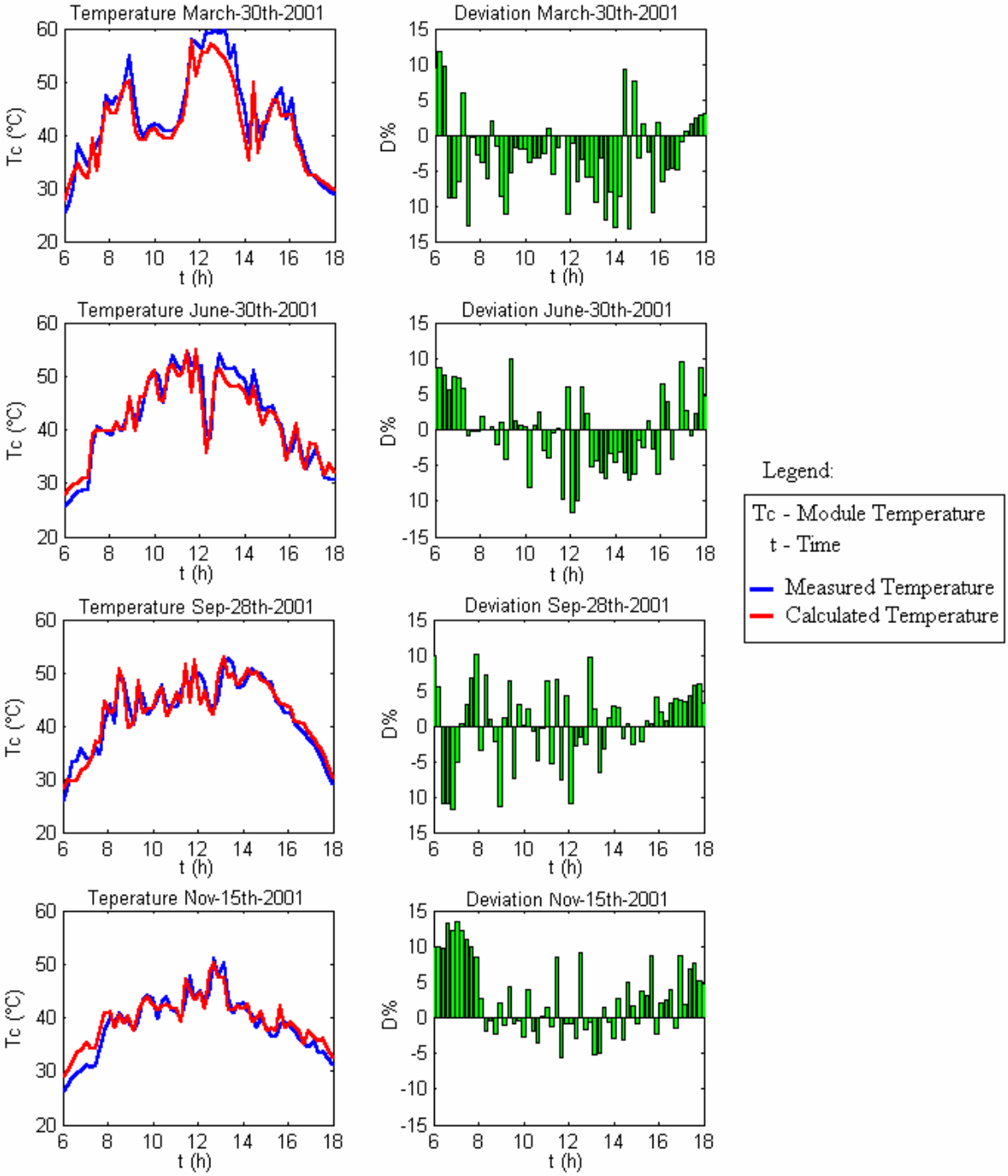

Figure 5: Measured and calculated temperature of the module.

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