VOL. 12, NO. 1, JANUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

GENERATED POWER PREDICTION BY SOLAR PANELS FROM THE ENVIRONMENTAL CONDITIONS OF CAJICÁ

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ABSTRACT

The constantly development of new technologies that are friendly with the environment has led to implement systems, models and even algorithms that improve the efficiency of themselves. This article has as objective to implement a prediction algorithm of the generated power by twelve solar panels installed in the campus Cajicá of Nueva Granada Military University (UMNG), this prediction will consider the solar panel efficiency, the time and environmental conditions that affect it. Obtaining as a result an application that allows the user to know the maximum load that the solar system can supply according with the weather conditions present in a specific hour and day.

Keywords: global solar radiation, prediction algorithms, solar systems.

1. INTRODUCTION

Worldwide, the shortage of resources for fossil fuels production has encouraged the development and implementation of technologies that use natural resources as a power generation source [1]. This tendency has led to recognize the production of renewable energy, as one of the major contributors in the world economy [2], [3].

The main drawback that currently own renewable energy, is the efficiency of their capture technologies [4]. To counter this problem different method, algorithms and even systems have been investigated to increase the efficiency of energy conversion [5], [6].

Among the most common solutions can be found the prediction of meteorological variables, due to these variables can be used to prevent and counteract fluctuations in power generation from renewable energy [7]. Moreover, have been designed elements for helping to increase the operation range of renewable energy technologies, such as solar systems with two degrees of freedom in order to extend the capture of solar radiation during the day [8], [9].

In the last decade the implementation of solar energy has increased by 60%, showing that the latest developments are being focused on increase the efficiency can have these systems [2]? Especially, solar systems made from solar panels, which commercially have an efficiency of 23%, as the case of panels made of polycrystalline silicon. But other panels made with different semiconductors have achieved efficiencies up to 30% [10], [11].

There are several ways to improve the efficiency of a solar panel, among them can find solar tracking systems, which ensure that the solar panel receive the maximum solar radiation during the day [12], [13]. It is also possible to find algorithms for predicting the possible generated power by solar panels, under some environmental conditions, this with the purpose of using control algorithms and energy management to have a better use and distribution of electricity [14].

According to the above, this paper proposes the implementation of a prediction algorithm, which determines the Gaussian bell hourly of solar radiation in Cajicá, based on information gathered from weather stations on the campus of the Nueva Granada Military University. With these data, was used an algorithm that identifies the amount of power generated by solar panels according to the predicted solar radiation. Obtaining as result a tool allows the user to identify the maximum load that could supply with the solar system for specific environmental conditions in a time frame.

2. METHODOLOGY

In the realization of this project was taken into account the methodology shown in Figure-1. Which begins with a compilation of data from meteorological stations located in Cajicá, specifically two located at campus of the New Granada Military University (UMNG).

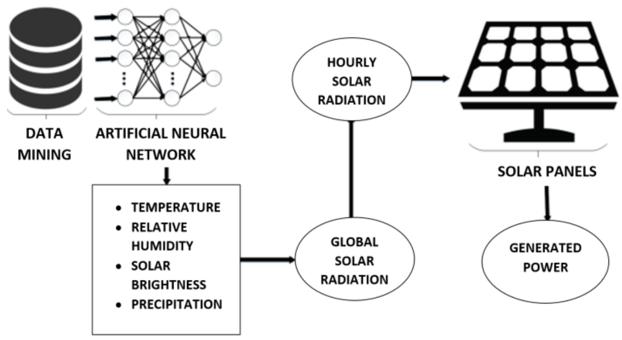

Figure-1. Methodology applied.

The weather stations recorded 14 environmental variables of Cajicá, since 2005. In order to predict the global solar radiation were taken 6 of these variables (relative humidity, average temperature, maximum temperature, minimum temperature, precipitation, solar radiation) for training two artificial neural networks.

With this information an array of size 37559 X 10 was created, that contain the variables of hour, day, month, year, average temperature, maximum and minimum temperature, relative humidity and precipitation. Subsequently a predictive algorithm based on artificial neural networks (ANN) was used, in order to predict these meteorological factors

With these factors, the daily extraterrestrial radiation (H_0) was calculated from the number of days in the year, latitude and longitude in Cajicá. Then, with this information three mathematical models were used in order to calculate the solar radiation.

The first model was developed by Reddy [15] related to equation (1), in which solar radiation is calculated from the temperature (*T*), hours of solar brightness $\left(\frac{S}{S_0}\right)$ and relative humidity (*R)* of the place.

$$H = K\left(0.6 + 0.02T\frac{S}{S_0} - 0.04\sqrt{R}\right) - R\left(4.3 - \sqrt{T}\right) \quad (1)$$

The second model was developed by Onyango [16] related to equation (2), in which involves the hours of solar brightness, the maximum temperature factor (T_{max}) and relative humidity in the calculation of the solar radiation.

$$H = H_0 exp\left[\varphi\left(\frac{S}{S_0} - \frac{R}{15} - \frac{1}{T_{max}}\right)\right] \quad (2)$$

The third model was developed by Angstrom [17] related to equation (3), in which is performed a polynomial regression involving the hours of solar brightness and astronomical day length, to calculate solar radiation in the desired location.

$$\frac{H}{H_0} = 0.348 + 0.320\left(\frac{S}{S_0}\right) + 0.070\left(\frac{S}{S_0}\right)^2 \quad (3)$$

Averaging the values obtained with the three mathematical models, the value of the average daily global solar radiation in Cajicá was obtained. Subsequently, the Gaussian function represented by Equation (4) [18] was used, to reconstruct the hourly solar radiation bell the desired future day, whose area under the curve corresponds to the value of calculated average daily global solar radiation.

$$Gf = e^{-\frac{(x-h)^2}{2N^2}} \quad (4)$$

Where to create the solar radiation bell were used the following variables, (h) which represents the astronomical day length, (N) representing the number of hours of sunshine and (x) represents 24 hours a day.

Subsequently, the predicted global solar radiation it relates to the efficiency that has a system of twelve polycrystalline silicon solar panels. This efficiency is given by Equation (5) [19].

$$\eta = \frac{V_{oc}I_{sc}FF}{P_{in}} \quad (5)$$

Where (V_{oc}) is the open circuit voltage (I_{sc}) is the short circuit current and (*FF)* is the filling factor. These factors are determined by the datasheet of each panel and the maximum power (P_{max})was obtained by equation (6).

$$P_{max} = V_{oc}I_{sc}FF \quad (6)$$

Finally, using the predicted solar radiation, is determined the input power (P_IN), which refer to the incident solar radiation in the area of the 12 solar panels [20]. Then through efficiency it determines how much electric power could generate the solar system for a specific day and time on campus Cajicá UMNG.

3. RESULTS

For the development of this project was used the solar system installed on the Cajicá campus UMNG, which consists of 12 solar panels connected in series as shown in Figure-2, in addition to have the weather station to confirm the predicted data.

Figure-2. Solar system of 12 solar panels at campus Cajicá UMNG.

Once trained the neural networks, prediction of weather variables for the month of September and October 2015 were made, taking into account the corresponding location of the solar station at campus Cajicá UMNG (length74.011W and latitude 4.939N).

This information was compared with the data obtained from NASA web application "Prediction of Energy Resource" (POWER) [21] for the same period.

Figure-3 shows the behavior of predicted solar radiation with the NASA application, which is in a range of 3kWh/m^2 to 7 kWh/m^{2}while with the prediction algorithm, is in a range of 2kWh/m^2 to 5 kWh/m^2. Although the ranges of predictions are different, both have the same increases and decreases in solar radiation.

VOL. 12, NO. 1, JANUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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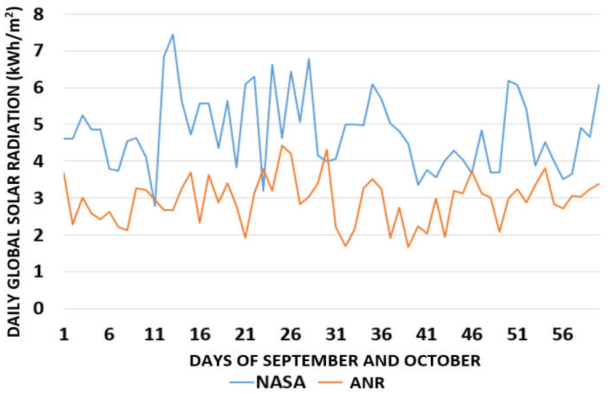

Figure-3. Behavior of predicted solar radiation with the NASA application and the algorithm.

The next compared factor with the NASA application was the predicted temperature, this behavior is shown in Figure-4. This shows that the variation in the average temperature is $\pm$ 3 °C, but the temperature range with the application of NASA is between 20°C and 25 °C while with the algorithm has a range of 10°C to 15 °C.

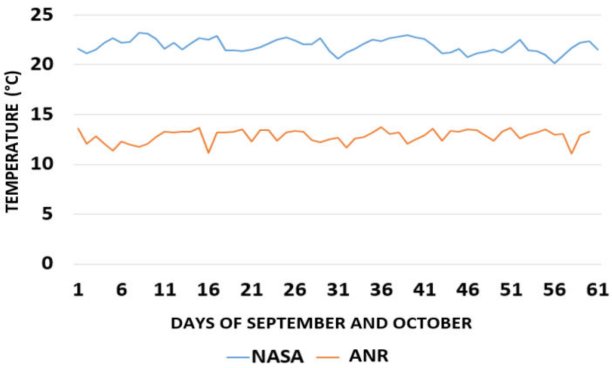

Figure-4. Behavior of the predicted temperature with the NASA application and the algorithm.

The behavior of relative humidity predicted through the NASA application varies in a humidity range of 50% to 80% while with the algorithm has a humidity range between 80% and 100%, as shown in Figure-5.

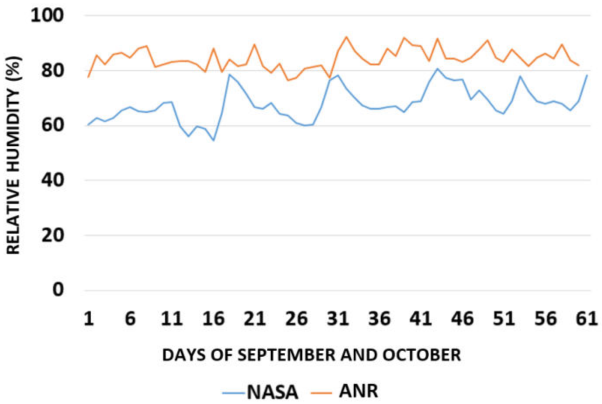

Figure-5. Behavior of the predicted relative humidity with NASA application and the algorithm.

Finally the precipitation factor was only compared for September, because the NASA web application hadn't data for the month of October. Obtaining as a result an equal number of rainy days in both applications, but with a different distribution of these during the month, as shown in Figure-6.

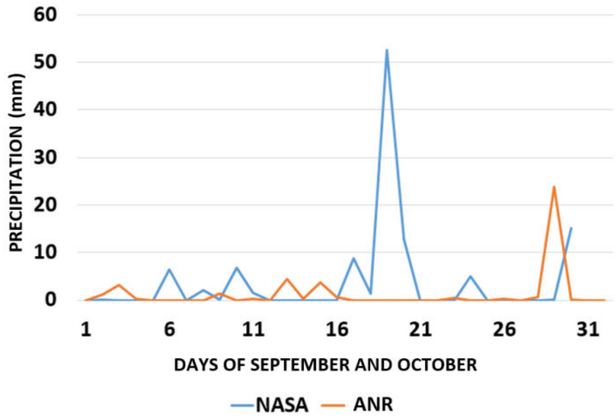

Figure-6. Behavior of predicted precipitation with NASA application and the algorithm.

Once validated the behavior of neural networks with application of NASA, they were used for the prediction of meteorological factors in Cajicá for a comprised period from 23 October since 23 November 2015.

Once defined the period, the data from the weather station located in the same area of solar panels were collected. In order to compare the predicted data with actual data, in this case the most important factor is solar radiation.

The Figure-7 shows, the behavior of predicted solar radiation and the solar radiation measured for the same period. In which an average error of 11.6% was obtained, due to the five overshoot that have the weather station data at comparison with the predicted data.

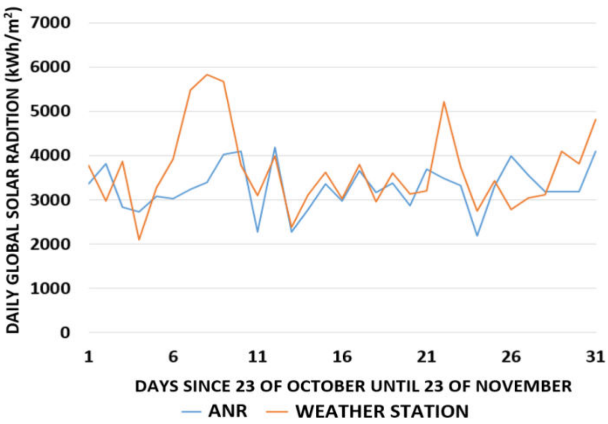

Figure-7. Behavior of predicted solar radiation and the solar radiation data from the weather station.

Moreover, the solar system comprised of 12 solar panels of 300 W from Solar Canadian brand, has a peak

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

power of 3600Wp due to they are connected in series and have an area of 23.025 m2. With this information it was determined that the solar system has an efficiency of 15.63%, because the material of the solar panels is polycrystalline silicon.

With this efficiency, the approximate values of generated power that produce the solar system were obtained. These values were compared with the generated power by the solar system in the same period, as shown in Figure-8. Obtaining as a result that the prediction results reached an 83% of electric generation that had the solar system in the 31 days selected.

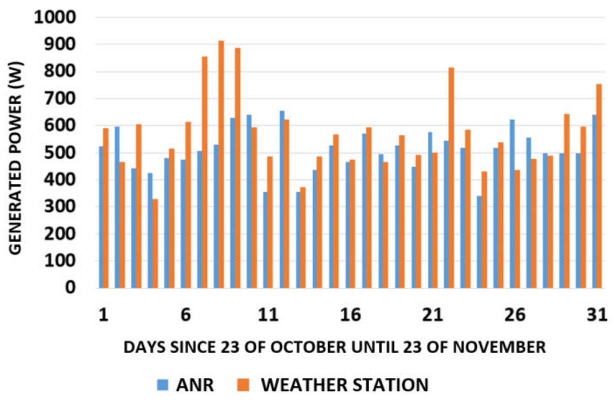

Figure-8. Generated power by the solar system and predicted power by the algorithm.

Finally for analyzing the generated and predicted power by hours, it took 1.2 days and 3 October period, to make the comparison made above, obtaining a relation of the predicted power by the algorithm with the power generated by the solar system, as it is shown in Figure-9.

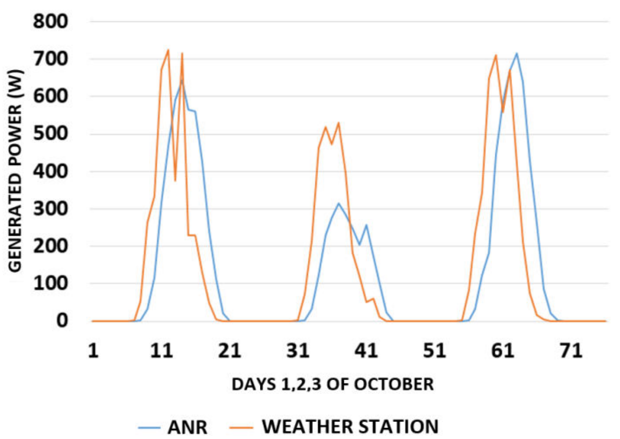

Figure-9. Generated power by the solar system and predicted power by the algorithm for 3 days.

Besides the Figure-9 shows that the data of the weather station haven't the ideal form, whichthe predicted data with the algorithm have.

4. CONCLUSIONS

The results of this study show that the prediction of meteorological variables in Cajicá, has low errors. Proof of this is the comparison made with NASA application for solar radiation, temperature, humidity, that had the same behavior although with a range more accurate at Cajicá.

The algorithm validated the predictions made comparing them with the collected data by the weather station, where the temperature has a variation of ± 4 °C and the relative humidity has a variation of ± 9.4%. Allowing an accurate prediction of solar radiation which presents ideal data, that approximating the data measured by the weather station.

With the verification of the algorithm in solar radiation prediction at Cajicá and the efficiency of the panels, the possible generated power by the solar system was calculated for specific environmental conditions. Proof of this is that the predicted data for the trial period reached an 83% of the measured data by the solar system.
Although the prediction algorithm of generated power provides approximate values, their behavior is similar to that has the solar system, allowing use this information as a reference for the user. In order to know what would be the maximum load with which the solar system can work in a specific period.

With the results of work, it may raise the possibility of using this prediction together with control algorithms and optimization techniques to improve energy efficiency obtained from polycrystalline silicon solar panels.

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