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Thermal Analysis of Power Generation through Solar Pond in Dwarahat

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Abstract

In the present work, thermal analysis is done for the power generation of solar plant in dwarahat. A solar pond is created in dwarahat and power generation is calculated by mathematical formulation, Matlab computer software has been used to build a multi-scripts programs to solve ordinary differential equations by finite difference method for steady state models. For the performance of the solar pond, the first task is to determine the manner in which the radiation incident (solar radiation geometry) upon the solar pond is reflected, absorbed and transmitted through the water.The solar hour angle ω expresses the daily rotation of the earth. As the earth rotates 360° within 24 hours, every hour adds another 15° to the solar hour angle.The transmissivity based on absorption can be obtained by assuming that the attenuation due to absorption is proportion to the local intensity (Bouger's Law).According to a solar pond location, the sun path in the sky is changed seasonally thus the sun's altitude and azimuth angle and the daily sunshine period are varied and cause a great effect on the amount of the incident solar radiation and then on the performance of the solar collector.The calculation of the temperature distribution in a solar pond is rather involved since the pond consists of three zones.The single input (Latitude angle) is used to calculate the solar radiation in Dwarahat (India). The output of this script is done on the bases of solution given by Rabl and Knooi.

1. Introduction

The sun is the largest source of renewable energy and this energy is abundantly available in all parts of the earth. It is in fact one of the best alternatives to the non-renewable sources of energy. Solar energy, radiant light and heat from the sun, has been harnessed by humans since prehistoric times, but in a most primitive manner. Before 1970, some research and development was carried out in a few countries to exploit solar energy more efficiently, but most of this work remained mainly academic. After the dramatic rise in oil prices in the 1970s, several countries began to formulate extensive research and development programmes to exploit solar energy. Solar energy technologies include solar heating, solar photovoltaic's, solar thermal electricity and solar architecture, which can make considerable contributions to solving some of the most urgent problems the world now faces.**Solar thermal energy** (**STE**) is an innovative technology for harnessing solar energy for thermal energy (heat). Solar thermal collectors are classified by the United States Energy Information Administration as low, medium, or high-temperature collectors.A solar pond is simply a pool of saltwater which acts as a large-scale solar thermal energy collector with integral heat storage for supplying thermal energy. The saltwater naturally forms a vertical salinitygradient also known as a "halocline", in which low-salinity water floats on top of high-salinity water. The layers of salt solutions increase in concentration (and therefore density) with depth. Below a certain depth, the solution has a uniformly high salt concentration.

The solar pond is characterized by three zones:

- **Surface convective zone (SCZ)** usually has a small thickness, around 10 to 20 cm. It has a low, uniform concentration, which is close to zero, as well as a fairly uniform temperature, which is close to the ambient temperature.
- **Non-convective zone (NCZ)** is much thicker and occupies more than half the depth of the pond. Both concentration and temperature increases with depth in this zone. It serves principally as an insulating layer and reduces heat losses in the upward direction. Some of the heat collection also takes place in this zone and it serves also as of the thermal storage.
- **Lower convection zone (LCZ)** is comparable in thickness to the non-convective zone. Both the concentration and the temperature are nearly constant in this zone. It serves as the main heat-collection as well as thermal-storage medium. The lower convective zone is often referred to as the storage zone or as the bottom layer.

The concept of a solar pond is derived from the observation that in some naturally occurring lakes, a significant temperature rise (of the order of 40 degree to 50 degree centigrade) does occur in the lower regions.

2. Mathematical Formulation of Solar Pond

For the performance of the solar pond, the first task is to determine the manner in which the radiation incident (solar radiation geometry) upon the solar pond is reflected, absorbed and transmitted through the water.The solar hour angle ω expresses the daily rotation of the earth. As the earth rotates 360° within 24 hours, every hour adds another 15° to the solar hour angle. When the sun is in its highest point in the sky, the solar hour angle is zero. Angles before noon count negative, after noon positive.As the earth rotates, the angle between the sun and due south, the solar azimuth angle, γ, varies from -90° at sunrise (east) to +90° at sunset (west). The slope angle β is the angle made by the surface with the horizontal. It can vary from 0 to 1800.
The declination angle, δ, is the angular position of the sun at solar noon with respect to the plane of the equator. It varies from -23.45° at winter solstice to +23.45°at summer solstice according to

$$\delta = 23.45\ Sin\left[\frac{360}{365}(284+n)\right] \tag{1}$$

As before, *n* denotes the day in the year with n = 1…to…365.

3. Power Generation Through Solar Pond

The solar pond is considered one of the most reliable and economic solar systems. The collecting and storing of the solar energy is in one system, so the heat in summer can be utilized in winter in the same system.To predict the potential of solar pond at any place the mathematical formulations are solved by Rabl and Knooi equation to calculate the parameters affecting the performance of the solar pond.Here we can manufacture the solar pond for Power Generation in

Dwarahat (Distt. Almora). All the calculations are done by MAT LAB. For this first know the variation of temperature and Relative Humidity in the place where the solar pond site as per it's not possible to clearly predict the temperature. So the only solution is considering the last year temperature variation.

Table 1. Environmental Data for Dwarahat(Almora)

Latitude: **29.7833° N**
Longitude: **79.4333° E**
Elevation: **4,918 ft**

Month	Average Low Temperature ^{0}C	Average High Temperature ^{0}C	Extreme High Temperature ^{0}C	Relative Humidity %	Solar Radiation MJ/m^2/day
January	3	13	27	86	8.70
February	6	17	30	82	12.52
March	7	21	33	75	18.11
April	10	24	38	63	23.79
May	13	28	41	52	28.49
June	17	33	45	46	31.22
July	21	37	46	44	30.48
August	20	35	44	50	27.50
September	17	33	44	56	22.62
October	12	27	39	63	16.56
November	7	19	32	77	10.70
December	3	13	28	86	7.69

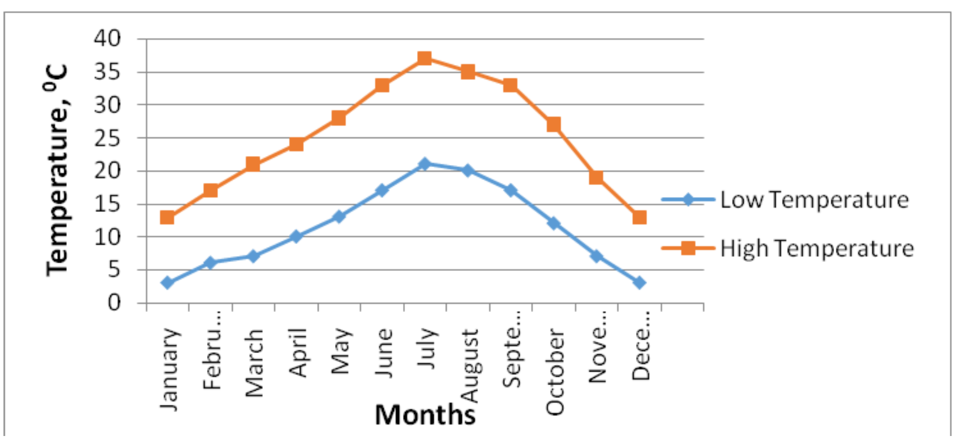

Figure1 – Temperature variation in Dwarahat, India, 2011.

Variation of Relative Humidity is also an important factor because of the extraterrestrial radiation is affected.

The electrical power generation system is based on a flash cycle that uses the pond brine as the working fluid. The flash distillation process was chosen because it was a known, simple, and successfully proven cycle.

4. Results and Discussion

The single input (Latitude angle) is used to calculate the solar radiation in Dwarahat (India). The output of this script is done on the bases of solution given by Rabl and Knooi and the results are really good and shown in Figure 2 for Dwarahat solar radiations.

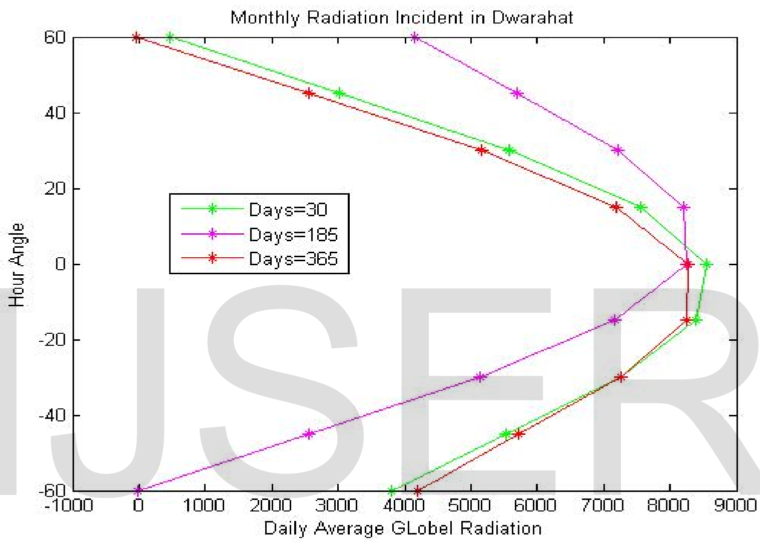

Figure 2.- The incidence over Dwarahat in 2011.

The obtained solar radiation data is used for one-dimensional time-dependent steady state equation to predict the solar pond temperature behavior in the storage zone during a year and an excellent agreement is obtained comparing with real temperature measurements by Rabl and Knooi and this output is illustrated in Fig.3.

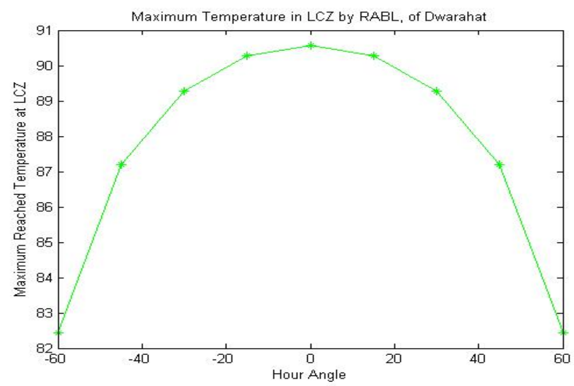

Figure 3- Maximum Temperature achieved throughout the year.

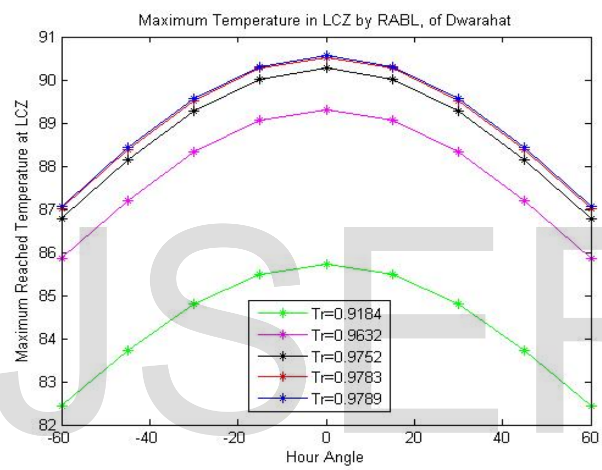

Figure 4- Maximum Temperature achieved throughout the year by Rabl.

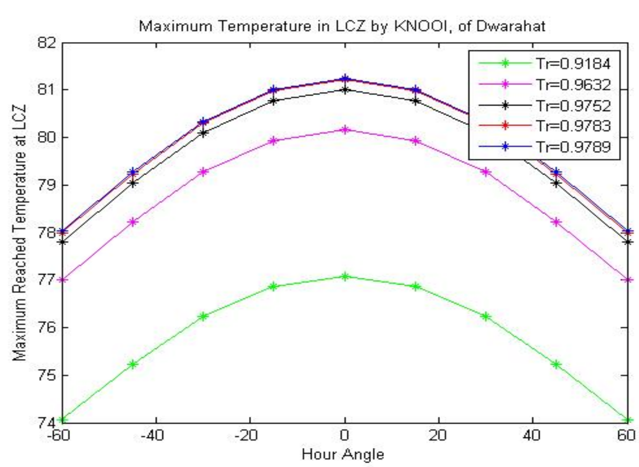

Figure 5 – Maximum Temperature throughout the year by the Knooi solution.

The above figures 3, figure 4, figure 5 results are based on the mathematical equations specified for the Solar pond calculated with the help of mathematical tool MAT LAB it's a single input method to find out the range of temperature achieved by the solar pond bottom (Lower Convective Zone) at the end of the year from the date of manufacturing.

5. Conclusion

The proposed method provides an accurate prediction of the solar radiation based on a single input data which is the location latitude. The predicted results are validated by comparison with NASA 22 years averaged data in three various locations in the Middle East, where very close agreement has been obtained. The one-dimensional time-dependent steady state model and transient model was investigated. However, it was found that the steady state model provided more realistic results. The solar pond performance in cold climate locations has been calculated and the pond temperature can reach 80 oC levels using some designs.Salinity gradient solar ponds, although not dramatically cheaper than other disposal methods, may still be a viable option especially in circumstances where the unit cost of power is very high or where access to a power grid is limited. Moreover, the actual cost of utilizing SGSPs may be lower than reported when other factors are taken into account, such as savings incurred by bypassing the waste disposal permitting process, the environmental savings associated with using a renewable fuel, or tax breaks that may be developed for facilities that use renewable fuels.The system outlined here did not explore every design parameter. Notably, little design work was actually performed in designing the pond itself. For instance, the brine temperature of 80°C was assumed as a conservative estimate of the temperature of the lower convective zone based on matematical calculations. Although our results show an acceptable efficiency to produce power, improvements could be made to the cycle by increasing the pond (and thus the feed) temperature or lowering the flash pressure. These changes would increase the efficiency of the flash separation process, and result in improved performance for the entire cycle.

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