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Study the Maximum Solar Radiation by Determining the Best Direction of the Solar Collectors

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Abstract— *Detailed information about the optimality of the direction for using the parabolic troughs solar collector for a particular installation site is important in the design and economic evaluation of solar power plants. This study developed simple relationships to predict the choice of solar power collector equipment in the city of Baghdad. The North-South tracking axis in the city of Baghdad represents the best performance for electricity generation over a longer period of the year. Such a constructive scheme of the parabolic troughs solar collector allows to tracking the trajectory of movement of the sun from east to west. Liquid heat transfer fluid circulates in pipes of a solar power plant is synthetic thermal oil.*

Keywords— *Solar radiation, solar power stations, parabolic troughs, axis tracking.*

I. INTRODUCTION

There are four different options that convert solar energy into heat when the concentration of solar radiation: parabolic troughs, linear Fresnel reflectors, central receivers and parabolic dishes. The most common of these are parabolic troughs, in these systems, mirror reflectors in the shape of a parabolic trough are used to concentrate sunlight on thermally efficient receiver tubes located in the focal line of troughs. The liquid is heated by concentrated sunlight and then pumped through a series of heat exchangers to produce superheated steam. The potential energy of steam is converted into electrical energy in a conventional steam turbine with a generator, which can be either part of a conventional steam cycle or integrated into a combined steam and gas cycle. The total radiation incident on the earth's surface consists of two forms: the first radiation is beam radiation, which has passed through the atmosphere without appreciable dispersion [1]. The second is the diffuse (scattered) radiation of the sky, which comes to the surface after it was absorbed by the atmosphere [2, 3]. The sum of beam radiation and diffuse radiation is called total radiation or terrestrial solar radiation [4, 5].

II. MATH

For solar power plants with parabolic trough beam radiation is required only on the collector aperture area, Ib,c, [6]. Beam radiation, Ib,c, is calculated by the formula:

$$I_{b,c} = (r_t \overline{H}_h - r_d \overline{D}_h) \frac{\cos i}{\sin \alpha} \quad (1)$$

where:

$r_t \overline{H}_h$ - the hourly beam solar radiation , MJ/ m2 h);

$r_d \overline{D}_h$ - hourly scattered solar radiation, MJ/(m2 h);

α - angle height of the sun, degree;

i - angle of incidence, degree, which depends on the tracking mode and the position of the sun.

In order to optimize Parabolic Trough Collector (PTC) performance, two different tracking modes are used (Figure 1): North-South (tracking the East-West axis) and East-West (tracking the North-South axis).

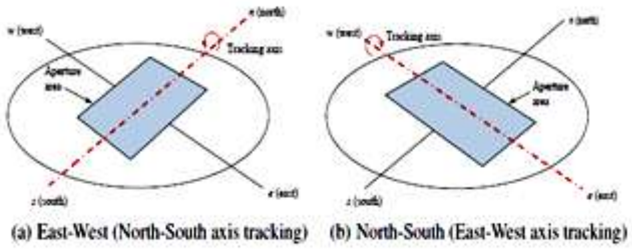

Fig. 1. Tracking mode for PTC

As noted earlier, PTC are designed to work with tracking along only one axis. The tracking system drive rotates the collector around the axis of rotation until the central beam of the sun and the normal to the area of the aperture match [7, 8]. Figure2 shows how the collector aperture rotates around the tracking axis r. The tracking angle, ρ, transfers the unit vector of the central beam S to the plane formed by the normal of the aperture and the axis of tracking. To write expressions for i and ρ in terms of the orientation of the collector and the angles of the sun, you need to convert the initial coordinates, x ', y', z ' into a new coordinate system, which has a tracking axis, as one of the three orthogonal axes [9.10]. The other two axes are oriented in such a way that one axis is parallel to the surface of the earth.

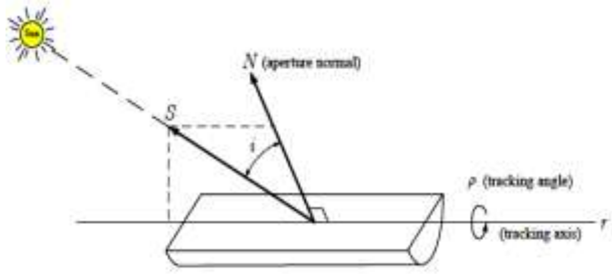

Fig. 2. One-axis tracking of the aperture [11].

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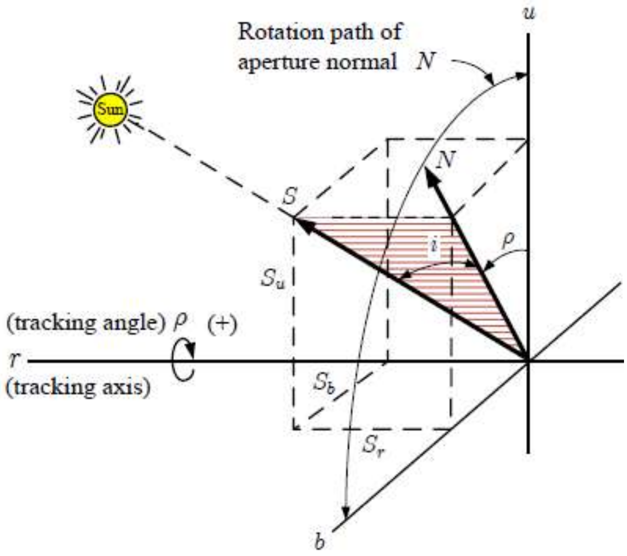

Fig. 3. Single-axis tracking coordinate system [12].

Figure 3 represents the new coordinate system, where r is the axis of tracking, b is the axis that always remains parallel to the earth's surface, and u is the third orthogonal axis. The normal of the aperture N rotates in the u-b plane. The quantities i and ρ can be defined in terms of the direction cosines of the unit vector S of the central ray along the u, b, and r axes. The tracking angle is determined based on the right-hand rule.

$$\tan\rho = -\frac{S_u}{S_b} \quad , \tag{2}$$

and the cosine of the angle of incidence, i, is defined as:

$$\cos i = \sqrt{S_b^2 + S_u^2} \tag{3}$$

or

$$\cos i = \sqrt{1 - S_r^2} \tag{4}$$

To describe this category, we must rotate the u, b, and r coordinates by an angle γ from z, w, and n coordinates, which were previously used to describe the unit vector of the sunbeam (Figure 3). Since the tracking axis remains parallel to the earth's surface, rotation occurs around the z axis, as shown in Figure 4. The direction cosines of the S (new coordinate system) are calculated according to the equation (this rotation in the negative direction, based on the right-hand rule):

$$\begin{vmatrix} S_r \\ S_b \\ S_u \end{vmatrix} = \begin{vmatrix} \cos\gamma & -\sin\gamma & 0 \\ \sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{vmatrix} . \begin{vmatrix} S_i' \\ S_j' \\ S_k' \end{vmatrix} \tag{5}$$

Substituting (5) into equation (2), we find that the tracking angle:

$$\tan\rho = \frac{\sin(\gamma - a_s)}{\tan\alpha} \quad , \tag{6}$$

where a_s - the angle of the solar azimuth.

The angle of incidence for a single axis horizontal tracking collector:

$$\cos i = \sqrt{1 - \cos^2\alpha\cos^2(\gamma - a_s)} \tag{7}$$

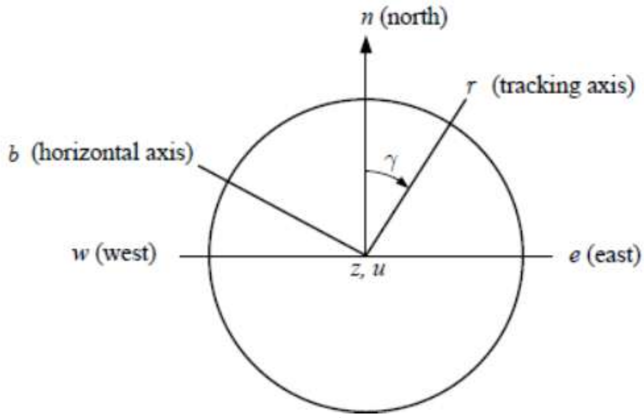

Fig. 4. Rotation coordinates u, b and r from z, coordinates w and n around the z axis [13].

If the tracking axis is oriented in the north-south direction (γ = 0), the above equations reduce to:

$$\tan\rho = -\frac{\sin a_s}{\tan\alpha} \tag{8}$$

and

$$\cos i = \sqrt{1 - \cos^2\alpha\cos^2 a_s} \tag{9}$$

If the tracking axis is oriented in the east-west direction (γ= 90), equations (6) and (7) take the form:

$$\tan\rho = -\frac{\cos a_s}{\tan\alpha} \tag{10}$$

and

$$\cos i = \sqrt{1 - \cos^2\alpha\sin^2 a_s} \tag{11}$$

III. RESULTS AND DISCUSSION

Figure 5 shows the effect of the tracking axis on the normal direct illumination of the collector at different times of the year. The North-South tracking axis for the city of Baghdad represents the best option for installing a solar collector for a longer duration of the year. For this reason, most PTCs are oriented along the tracking axis in the North-South direction. Therefore, in engineering practice, this configuration is adopted for the calculation of solar radiation.

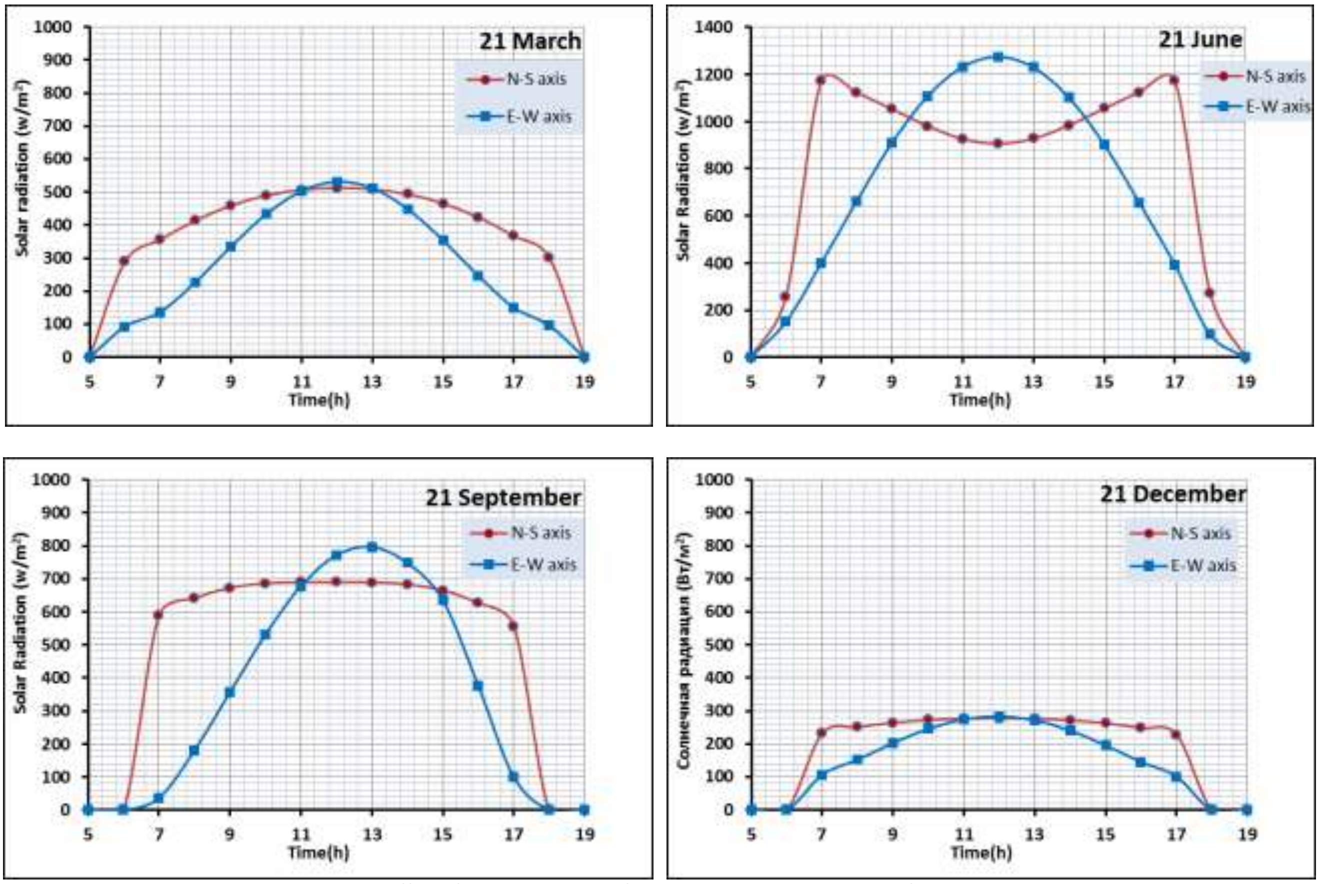

Fig. 5. The effect of the tracking axis of the normal direct illumination of the collector.

REFERENCES

[1] Iqbal, M., "An Introduction to Solar Radiation", Academic, Toronto (1983).

[2] Moafaq K.S. Al-Ghezi, "The Global and Scattered Radiation Evaluation for a Horizontal Surface in Baghdad City", *International Journal Of Computation and Applied Sciences IJOCAAS*, Vol. 3, Issue 1, ISSN:2399-4509, PP: 153-158, August 2017.

[3] Fayad, M.A., Fernández-Rodríguez, D., Herreros, J.M., Lapuerta, M. and Tsolakis, A., 2018. Interactions between aftertreatment systems architecture and combustion of oxygenated fuels for improved low temperature catalysts activity. *Fuel*, 229, pp.189-197.

[4] Donatelli M., Garlini L., and Bellochi G., "A software Component for Estimating Solar Radiation", *Environmental Modeling and Software* 21(2006) 411-416.

[5] Moafaq K.S. Al-Ghezi, "Calculate the Reflected Hourly Solar Radiation by Mirror Surfaces of Solar Concentrators Parabolic Trough," *International Journal of Computation and Applied Sciences IJOCAAS*, vol. 3, No. 3, pp. 256-260, 2017.

[6] Goswami, D. Y., Kreith, F., Kreider, J. F., and Kreith, F., 2000. *Principles of Solar Engineering*.second ed., Taylor & Francis, Philadelphia, PA.

[7] Moafaq K.S. Al-Ghezi, "Heat Accumulation System for Solar Power Station with Parabolic Trough Solar Collector," *Elixir International Journal, Elixir Renewable Energy* 119, pp.51122-51125, June 2018.

[8] Fayad, M.A., 2019. Effect of renewable fuel and injection strategies on combustion characteristics and gaseous emissions in diesel engines. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, pp.1-11.

[9] Moafaq K.S. Al-Ghezi, "Simulation Concentrator type of Compound Parabolic Trough Solar Collector in the Solar Thermal Power Plant (STPP) for Conditions of Iraq," *Elixir International Journal*, Elixir Thermal Engg.121, pp. 51589-51592, August 2018.

[10] Roshen Tariq Ahmed Hamdi, "Solar cell system simulation using Matlab-Simulink", *Kurdistan Journal for Applied Research (KJAR)*, Vol. 2, Issue 1, Sulaimani Polytechnic University, 2017/6/30.

[11] Stine, W. B., and Harrigan, R. W., 1985. *Solar Energy Fundamentals and Design: With Computer Applications.* Wiley-Interscience, Apr.

[12] Gueymard, C., 2004. "The sun's total and spectral irradiance for solar energy applications and solar radiation models". *Solar energy*, *76*(4), pp.23–453.

[13] Gueymard, C., 1995. SMARTS2: A Simple Model of the Atmospheric Radiative Transfer of Sunshine: Algorithms and Performance Assessment. Tech. Rep. FSECPF-270-95, Florida Solar Energy Center Cocoa, FL,USA.