

# Adoption of solar thermal energy in the generation of electrical power in Iraq

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## Abstract:

Iraq is characterized by its location near the solar band, and so it is distinguished by the high intensity of solar radiation and high brightness during the months of the year. This property made him able to use renewable energy sources in the generation of electricity, especially solar energy, for being the best and have pure effect. Implementation of a planned solar system with PTC collectors With the Hilla Gas station in (Abu Ghraj), Iraq, this site is characterized by this site has large tracts of land and proximity to the transmission network.

The nominal value of solar thermal energy proposed by the plant is 10 megawatts operating in the Rankin cycle using threminol VP1 (HTF) thermal oil as a working liquid. The average factory's power monthly is 9.99 megawatts. Capacity factor 20.5 % proposed power plant comes out to be 36%. Four parabolic and twenty collectors were proposed to design power plant. In June, the production of system was 31.54 MW net on day. The electricity cost was 15.47 cents/ kWh. By comparing costs with traditional method based on fossil oils and renewable system previously working in Iraq, the suggested PTC system could vie well with the generation plants rest.

## Article History

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## 1. Introduction

Increasing the demand for energy for sake of essentials of the community in the present time has become a problem facing the community, so it can be met using a variety of sources of renewable energy [1]. As they have:

- To reduce fuel use.
- The calculated efficiency of energy transformations (electrical + thermal) can be said to be more than 85%, as compare to the value of 30-35% of traditional power system.
- Lower emission of unwanted gases
- lower costs.

But there is a bigger problem facing this solution for development is its impact on the environment and

climate in different forms leading to global warming [2].

Regardless of fossil fuels, nuclear power and large hydroelectric power, a number of energy sources are contributing little to the current demand and supply of energy worldwide. These include energy sources such as wind power, small hydropower, photovoltaic conversion, biomass, tides, geothermal and solar thermal power plants.. Figure 1 shows the schematic of solar power generation.. [3]

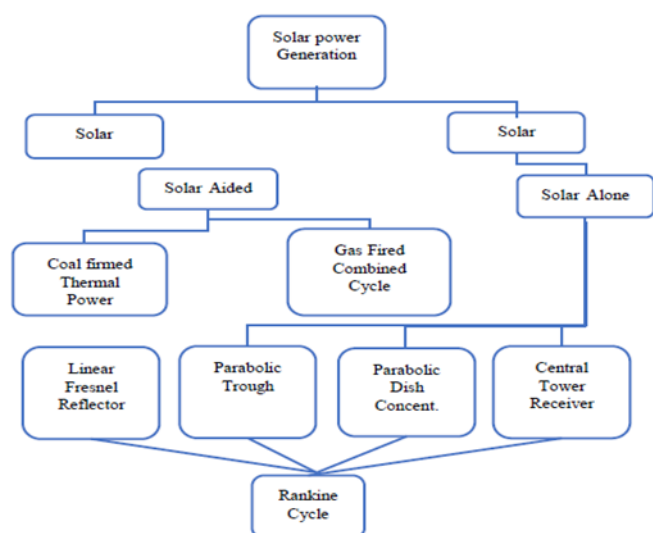


Fig 1: Demonstration of solar power generation methods

Among the most suitable solar technologies, concentrated solar energy (CSP) is the most widely used choice for being able to provide electricity and heat [4]. Equilateral aquarium field plants are the most reliable advanced solar technology .

One of the most important features of Iraq's climate is the high temperature in the summer and mild in the winter, and the highest temperature values are in June, July and August between 43 degrees Celsius and 50 degrees Celsius in the middle of the day. In January temperatures range from 1 ° C to 8 ° C [5], [6]. Sun brightness ranges between 2,800 and 3,300 hours per year. This enables Iraq to exploit solar energy [7]. Relative humidity ranges from lowest 25.5% in October to a January high of 73.8% [8].

Greater than seventy percent of the world's overall focused solar power system applied the technology of equivalent basin. The heat liquid will move to the turbine and transformed to electricity [9].

The aim of this paper is production of electricity by the concentrating power stations (CPS) . In this research, the design features of the solar thermal grid connected to the network were presented with the equivalent basin complexes for power station generation with 10 MW. The Hilla city was chosen because of the multiple studies of this area as well as the huge zone of land obtainability and the fact that

it is level land located near the electric gas station (AL-Khairat). In Abu Gharq area[10,11].

## 2. Choose the location of the data and properties

The geographical location of the Hilla City, Babylon, Iraq at 32.47° latitude and 44.41° longitude makes it a relatively sun-rich region with an annual solar irradiance of about 2200 kWh.m<sup>-2</sup>[10]. This implies that solar energy systems would be very efficient in this part of the world. . hilla city is located near the AL-hindiya River as shown in Figure 2.

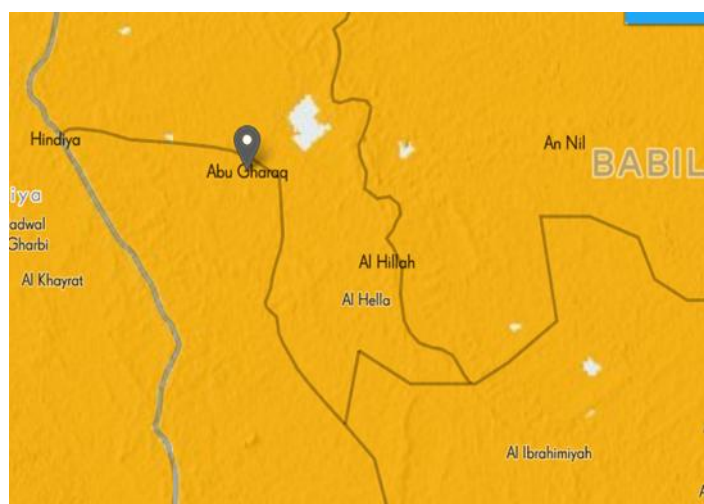


Figure 2 Hilla (Abo Gharaq) Location in the Map [13]

The site of the proposed system adjacent to the Hilla gas station (AL-Khairat) for the existence of large areas on which we can build a thermal station and support the station in case of failure in parts of the station .

The site selection that should be satisfied to certify the economic power plants [12].

The straight usual radioactivity (DNI) must more than 1900 kWh/m<sup>2</sup>/year (5.2 kWh/m<sup>2</sup>/day) and speed of wind must up to 15.64 m/s that is pragmatic to Hilla that has an annual straight usual radioactivity 2071 kWh/m<sup>2</sup>/year [13] as shown in figure 1 and speed of wind 1.7 m/s[14].

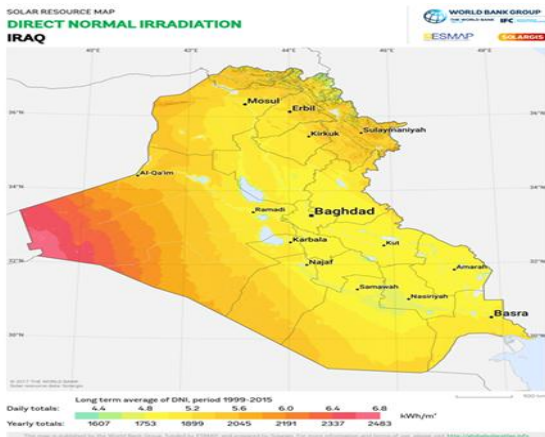


Figure 3 The direct normal irradiation

For the purpose of obtaining the greatest solar radiation, there must be one mechanism for tracking the sun.

- Flatland less than 1-3%. Hilla is one of the flat areas
- The availability of an appropriate network, and useful to suggested site because the availability is near to the community network of the city of Hilla.
- The proposed site in Hilla governorate contains adequate water incomes and worthy transportation abilities.
- Obtainability of standby gas.

### 3. Explanation of suggested System

There is a clear similarity between the work of a traditional fossil station with a solar system (STPP), but the dissimilarity is in the method of heat generation. Traditional power generation uses a warmth source from boiling fuels of fossil while STPP uses energy of radioactive depending on sun. The figure 2 illustrates the work of the STPP.

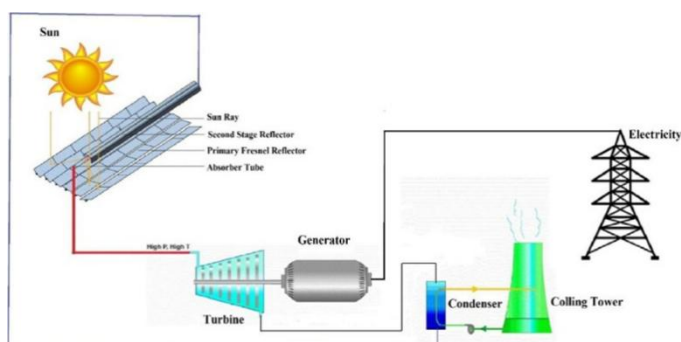


Figure 4 explanation of system

This system consists following parts: field of solar, energy block containing heat exchanger (eg steam boilers), turbine, condenser, pump and generator. After the production of electricity is completed, a standard condenser connected to a wetted steam post is started with a mechanical draft. The steam extracted from the turbine is condensed and then returned to the heat exchangers through pumps to convert them into steam [15].

### 4. Solar Thermal Plant Design

When designing the solar field, consideration must be given to the practical features of the designated collectors of the designated site and the climate. All of these data can be called design point conditions. Table 1 shows the data set for the design of the solar system

Table 1: the data of solar system

Power capacity of the solar thermal power plant	10 MW
The inlet temperature in the solar field	293°C
The outlet temperature from the solar field	393°C

The temperature of the heat transfer (HTF) portlets and TherminolVP-1 depends on its operation. In two phases

- The liquid phase is between (12 ° C to 400 ° C)
- Steam phase is located between (260 ° C - 400 ° C) [16].

When selecting a suitable temperature for the liquid at the outlet of the solar field, it must be at least 15 ° C higher than the steam temperature required to reduce loss of the thermal of the outlet for solar field with the producer input for steam of 5 ° -7 ° C [17]. In this research, high temperature steam was selected as a working fluid for mass energy at 378 ° C. The model that has been selected is the EUROTROUGH solar collector because of its high elasticity and elasticity, where it can work on many benefits and

can be applied in industry [18]. able 2 summarizes the characteristics of the proposed solar field.

**Table 2: Data of the Solar Field**

	EUROTROUGH
Thermal of fluid	Therminol VP-1
Fluid limit temperature	398°C
fluid Precise heat	2.436 kJ/kg°C
Positioning of the axis for collector	E-W
Structure of the supply for pipes	Central feeding
Insignificant mass flow	7 kg/s

**Table3 shows the technical characteristics of the cylindrical parabolic collector [19].**

Variables	Values	Unit
Length of collector	150	(m)
Opening width	5.77	(m)
Opening area	817.5	(m <sup>2</sup> )
Receiver (Outer diameter)	0.125	(m)
Receiver (Inner diameter)	0.115	(m)
Optical efficiency	0.77	
General thermal loss constant at Tabs=370°C and Tamb=20°C,	5.5	(W/m <sup>2</sup> C)
Dirt factor	0.97	
Occurrence angle modernizer for 18.7 °	0.97	
Receiver rugosity	4.6·10 <sup>-5</sup>	(m)
connection pipe Length between the collectors	11	(m)
Amount of 90° elbows between collectors	11	

The useful energy of the collector is calculated using eqn (1) [20], the step is to reduce the optimal design of the plant [21].

$$Q_u = F_R A_a \left[ S - A_r / A_a U_L (T_i - T_a) \right] \text{-----(1)}$$

which can be calculated using eqn(2)

$$S = E_b \rho (\gamma \tau \alpha)_n K_{\gamma \tau \alpha} \text{-----(2)}$$

Explaining eqn. (1) for the design point provides the suitable heat gain (Qu) to be 432 kW per collector.

The collector output temperature is written by [19],

$$T_o = T_i + Q_u / m c_p \text{-----(3)}$$

Where To is outlet temperature, Ti is inlet temperature, m is mass flow rate of HTF and cp is particular heat capacity of HTF. Equation 3 illustrate that a one collector provides a raise of 25°C in the temperature of HTF.

The values of these parameters are shown in Table 2, as the preferred outlet temperature of 393 °C (total rise is 100 °C)

$$\text{No. of collectors per loop} = 100 / 25 = 4 \text{-----(4)}$$

Number of collectors per loop = 4

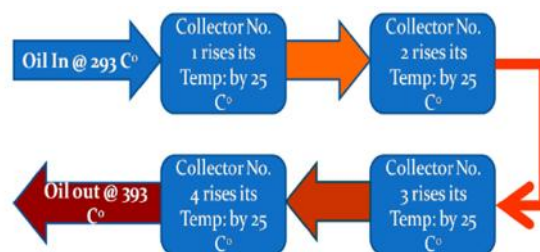


Figure 3. loop of collector rising the temperature of HTF by 100 °C

Figure.3shows the arrangement of collector loop to provide a total raise of 100 °C in the temperature of HTF , The thermal energy required from the solar field is 33MW net capability and efficiency of generator = 0.96 (nominal), efficiency of boiler = 0.90 [22], efficiency of turbine = 0.37 [22], the losses of piping of solar field = 6.2 MWth [23] needs 118.2 MW from the field of its solar collector. The

whole number of collector loops need to deliver this greatly of energy is assumed by [19], that can be written by the following equation

$$\begin{aligned} & \text{No. of loop srequired} \\ & = (P_{th}/\text{Output power per collector}) / \text{No. of collectors per loop} \end{aligned}$$

### 5 .Calculate the force for supply pump based on the solar fields

To get in the system the highest hydraulic equilibrium, we divided the field into 4 subfields, 3 with 32 loop and 1 with 30 loop. After this formation, two feeding tubes are used from the system (for cold liquids) and 2 from exhaust pipes from the field (hot liquids), one for each subfield. The length of each tube connecting the complexes and the energy block is 816.5 m (Fig. 4), the diameters decrease as it moves away from the energy mass.

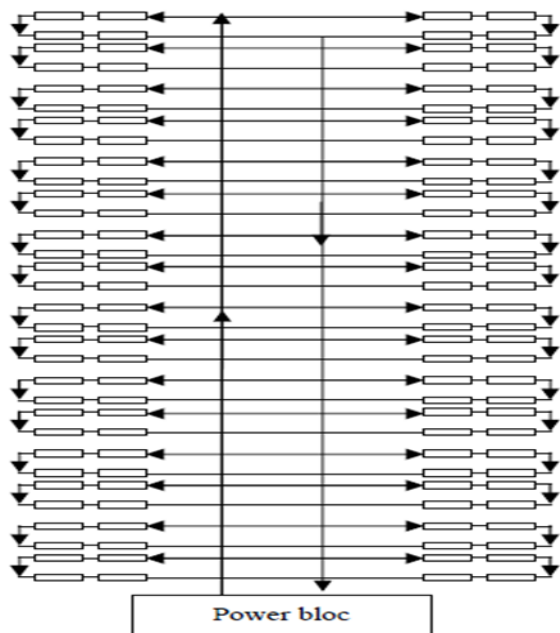


Figure 4 Solar field layout of the proposed design

Figure 4 illustrates the size of system, consisting of 126 EUROTROUGH collection rings and 4 compounds per loop.

Table 4 Physical properties of hot oil to obtain the average operating temperature value.

the fluid specifications		Unit
$C_p$	2436.65	J/(kg·K)
$P$	764.63	kg/m <sup>3</sup>
$M$	$165.54 \cdot 10^{-6}$	kg/(m·s)
$V$	2.81	(m/s)
$Re$	$844 \cdot 10^3$	
$F$	$4.64 \cdot 10^{-3}$	

In one episode:

$$P_{e,c} = 126P_{e,b} = 126 \frac{M \cdot \Delta p}{\rho \cdot \eta_b} \quad \text{---}$$

------(5)

For this there are used the correspondences obtainable in table 6.

Table 6 The corresponding lengths of the hydraulic solar field elements

	$L/D$	$L_{eq}$
Standard elbow	30	1.95
Standard "T" on the main branch	20	1.3

The length of Assembling loops for the system is 769.75 m because of to the receivers, and joining pipes and supporting elements of the circuit (table 7).

Table 7 The involvement to hydraulic length of a collecting loop.

Collectors	$L_c = 148.5 \cdot 4 = 594 \text{ m}$
Connection pipe	$L_t = 11(\text{m}) \cdot 4 + 18(\text{m}) = 62\text{m}$
Hydraulic elements	$L_{eq} = 22.75(\text{m}) \cdot 5 = 113.75\text{m}$
Overall length	769.75 m

The solar field will be built on perfectly flat ground, arranging all complexes on a level. The fact that electricity generated by solar thermal power plants does not produce large pollutant emissions compared to fossil-based thermal power stations can be confirmed. Table 8 shows the average monthly electricity generated from the proposed PTTP based on the direct natural rate Irradiation [31] and mean sun hours [32] via equation (6): -

Table 8 shows the average monthly electricity generated from the proposed PTTP based on the direct natural rate Irradiation

Month	Average Direct Normal Irradiation [kWh/m2]	Average Sun hours	Average Pout [MW]
January	87.3	5.7	6.43
February	116.4	6.7	9.60
March	174.3	7.9	9.1
April	168	9.9	9.56
May	202.2	10.1	11.1
June	236.7	12.6	13.20
July	219.9	12.3	11.4
August	206.7	12.1	12.22
September	171.9	10.5	11.23
October	113.7	9.2	7.82
November	86.7	7.7	9.84
December	78	6.3	6.23
Total	1837	9.25	9.99

$$P_{avg\_load} = Q_{th\_col} * total\ collectors * \eta_{elect.gen} * \eta_{turbine} * \eta_{Boiler} \quad (6)$$

the proposed STPP can be estimated using eqn.(7):

$$AEG_{csp} = (365 * 24)CF_{csp} P_{CSP} \quad (7)$$

### 8. Economic Practicality of STPP in Iraq

The level cost of energy (LCOE) is the most commonly used parameter for the feasibility study of

the solar thermal power plant, it can be estimated using eqn.(8)[25]. LCOE can be significantly affected by the inputs and assumptions proposed [25].

$$LCOE_{csp} = \frac{C_{csp} CRF + \xi C_{csp}}{AEG_{csp}} \quad (8)$$

and CRF the capital recovery factor which can be estimated as shown in eqn.(9).

$$CRF = \frac{d(1+d)^{t_{csp}}}{(1+d)^{t_{csp}} - 1} \quad (9)$$

in a CSP project can be determined using eqn.(10) [26].

$$DPP_{csp} = \frac{[\ln(B_i - C_i) - \ln\{(B_i - C_i) - dC_{csp}\}]}{\ln(1+d)} \quad (10)$$

the CSP project. Bi can be estimated using eqn.(11).

$$B_i = 8760CF_{csp} P_{csp} p_e \quad (11)$$

Where  $p_e$  is the purchase price of electricity delivered by the CSP system. The benefit to cost (B/C) ratio of the CSP system has been determined eqn.(12).

$$\left(\frac{B}{C}\right)_{csp} = \left(\frac{1}{C_{csp}}\right) \left[\sum_i^{t_{csp}} \left(\frac{B_i - C_i}{(1+d)^i}\right)\right] \quad (12)$$

$$NPV_{csp} = \left[\sum_i^{t_{csp}} \left(\frac{B_i - C_i}{(1+d)^i}\right)\right] - C_{csp} \quad (13)$$

The Electricity cost Levelized can be used as the standard for comparing various power systems generation equipment. Supposing the Suitable life time of CSP system of thirty years, rate of current inflation is 7.9%, actual reduction rate of 9.50%, finance rate of 9.5 % and combining these features in the Economic Model developing by Laboratory of

National Renewable NREL [28,29] provides a LCOE equal to 15.47 cents/kWh with 20.5 % of capacity factor.

The results of proposed system were good accordance by the distributed data of LCOE equal to 14-36 cents/kWh and 20-25 % of capacity factor [30]. The suggested system could produce 31536 MWh (gross) of electrical power each year. The cost of generation from Iraq's conventional power stations is significantly higher than the cost from solar power plants with unsubsidized fuel. Comparing the opportunity cost of offsetting the use of fossil fuels with solar energies.

## 9. Conclusion

In this paper, equivalent technology of solar thermal can be used as greatest solutions for a country such as Iraq to meet the power shortage and achieve green energy goals. It was found through the selected site that the number of sites in the country with exceptional solar resources similar to the mentioned site and other favorable characteristics most suitable for the development of STP generation. Places such as Baghdad, Najaf, Karbala, Maysan, Muthanna, Basrah and Diwania.. The financial investigation of the suggested PSTP plant demonstrates that solar system has the authority over traditional fossil fuels with renewable of power plants in the energy market in Iraq. Though no power plant been constructed, once Iraq studies this technology through training and enhancement, this proposed system could be applied on a large scale at a relatively cheaper cost to the country's conditions. The creation of STPP will be a milestone in the improvement of the solar thermal industry in Iraq. Also, it is expected that the wide commercial application of equivalent pond technology will be a new development point in Iraq's energy economy.

## REFERENCES

1. Sukhatme SP, Nayak JK. Solar energy: principles of thermal collection and storage. New Delhi: Tata McGraw Hill; 2011.

2. Prisyazhniuk VA. Alternative trends in development of thermal power plants. Applied Thermal Engineering 2008;28:190-4 .
3. V. Siva Reddy, S.C. Kaushik, K.R. Ranjan, "State-of-the-art of solar thermal power plants— A review". Renewable and Sustainable Energy Reviews Volume 27, November 2013, Pages 258-273.
4. Borello D, Corsini A, Rispoli F, Tortora E. A combined solar biomass Rankine cycle concept for small-size cogeneration. Proceedings of ECOS 2009, August 31- September 3, Foz do Iguacu, Paraná, Brazil .
5. Encyclopedia Britannica Online, —Tigris-Euphrates River System: Physical Features, 2009, available at: <http://www.britannica.com/eb/article-9110543/Tigris-Euphrates-river-system>.
6. W. C. King, J. Eugene, P. N. West Point, P. G. Anderson, D. D. Cowher, J. B. Dalton, J. S. Gloede, B. K. Herl, A. Lahood, A. D. Lohman, P. E. Mangin, J. C. Malinowski, E. J. Palka, R. P. Pannell, M. R. Sampson and W. C. Thompson, "Iraq: A Geography," Department of Geography & Environmental Engineering United States Military Academy Jon C Malinowski, Editor, 2003.
7. S. El-Kuwaz, "Rangelands management and development in Iraq," Proceedings of the expert consultation on range monitoring including under forest systems in the Near East, pp.177-188. FAO, Rome, 2007.
8. M. T. Chaichan, H. A. Kazem, A. A. Kazem, K. I. Abaas, K. A. Al-Asadi, "The effect of environmental conditions on concentrated solar system in desertec weathers," International Journal of Scientific and Engineering Research, vol. 6, No. 5, pp. 850-856, 2015.
9. Status Report on Solar Trough Power Plants, Pilkington Solar International GmbH, Sponsored by the German Federal Minister for Education, Science, Research and Technology,.
10. Ali Najah Al-Shamani, Mohd Yusof Hj Othman1, Sohif Mat1, M.H. Ruslan "Design & Sizing of Stand-alone Solar Power Systems A house Iraq" April 2015 with 2,967 ISBN: 978-1-61804-303-0 Reads Conference: Recent Advances in Renewable Energy Sources.

11. Wisam Shamkhi Jaber (2017) Analysis the availability of using concentrated solar Power (CSP) as electricity source in Al-Hilla City Journal of Babylon University/Engineering Sciences/ No.(1)/ Vol.(25)
12. Mingzhi Zhao; Zhizhang Liu; Qingzhu Zhang; Feasibility Analysis of Constructing Parabolic Trough Solar Thermal Power Plant in Inner Mongolia of China, APPEEC 2009, Asia-Pacific Power and Energy Engineering Conference, 2009.
13. Solar resource maps of Iraq 2017 The World Bank, Solar resource data: Solargis.
14. <https://weather-and-climate.com/average-monthly-Wind-speed,Babel,Iraq>
15. I.L. Garcia, J.L. Alvarez, and D. Blanco, "Performance model for parabolic trough solar thermal power plants with thermal storage: Comparison to operating plant data," Sol. Energy. vol. 85, pp. 2443–2460, 2011
16. Heat Transfer Fluid THERMINOL VP-1. <http://www.therminol.com/products/Therminol-VP1>, june 2015.
17. Keith Lovegrove and Wes Stein, Concentrating solar power technology Principles - developments and applications book, first edition, Woodhead Publishing Limited, 2012.
18. Michael Geyer, Eckhard Lüpfert, Rafael Osuna, EUROTROUGH - Parabolic Trough Collector Developed for Cost Efficient Solar Power Generation, 11th Solar PACES International Symposium on Concentrated Solar Power and Chemical Energy Technologies, Sept 4- 6, 2002, Zurich, Switzerland.
19. Spiru Paraschiv, Simona Lizica Paraschiv, Ion V. ION, Nicușor , Design and sizing characteristics of a solar thermal power plant with cylindrical parabolic concentrators in Dobrogea region, VATACHI, TERMOTEHNICA 2, 2010.
20. Engr. Shahrukh Saleem1 , Prof. Dr. Azzam ul Asar2 Analysis and Design of Parabolic Trough Solar Thermal Power Plant for Typical Sites of Pakistan IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 9, Issue 3 Ver. I (May – Jun. 2014), PP 116-122
21. Duffie, J.A. and Beckman, W.A., Solar Engineering of Thermal Processes, 3rd Edition New York, USA 2005.
22. Al-Nasser, A.M, Performance and Economics of a Solar Thermal Power Generation Plant in Jubail, Saudi Arabia: Parabolic Trough Collector, IEEE International Energy Conference and Exhibition (EnergyCon), 2010.
23. Frank Lippke , Simulation of the Part-Load Behavior of a 30 MWe SEGS Plant, Solar Thermal Technology Department, Sandia National Laboratories, 1995.
24. J. Dersch, et al., "Trough integration in to power plants-a study on the performance and economy of integrated solar combined cycle systems," Energy. vol. 29, pp. 947–959, 2004.
25. Kandpal, T.C., Garg, H.P., 2003. Financial Evaluation of Renewable Energy Technologies. Macmillan India Ltd., New Delhi.
26. C. Turchi, Parabolic Trough reference plant for cost modeling with the Solar Advisor Model (SAM), Technical Report NREL/TP-550-47605 July 2010.
27. System Advisor Model (SAM), URL: <https://sam.nrel.gov/>
28. International Renewable Energy Agency, Renewable energy technologies: cost analysis series, Volume 1: Power Sector, Issue 2/5, IRENA Working Paper, June 2012.
29. Genesis Solar Energy Project Datasheet. November 2010. <http://www.doi.gov/news/pressreleases/upload/Genesis-Fact-Sheet-20101104.pdf>. Accessed January 10, 2014.
30. National Renewable Energy Laboratory, Concentrating Solar Power Projects, [http://www.nrel.gov/csp/solarpaces/by\\_project.cfm](http://www.nrel.gov/csp/solarpaces/by_project.cfm).
31. Marcel Suri, Nada Suriova, Juraj Betak, Branislav Schnierer, Tomas Cebecauer, Artur Skoczek, Ivona Ferechova, Veronika Madlenakova, Atlas of Solar Resources, Palestinian Territories, Reference No 126-01/2014, Date 4 August 2014.
32. Miqdam Chaichan , Khalil Abaas" Practical investigation for measurment of concentrating solar power prototype for several target cases at Iraqi summertime weathers" Eng.& Tech. Journal ,Vol. , No. , 2011