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The Feasibility of Utilizing CSP and PV Applications at Sirte Oil Company site in Brega

Mohamed Elgabaili and Ahmed Tahir
[1]Department of Mechanical Engineering, University of Benghazi, P.O.BOX:9476, Benghazi, Libya
[2]Electrical & Electronics Engineering Department, University of Benghazi, P.O.BOX:9476, Benghazi, Libya, Benghazi, Libya

Abstract

This paper gives a glance at the potential of utilizing the renewable energy (RE) sources in gas and oil sector in Libya. Although, some oil companies see renewable energy resources as their direct competitors, many other companies have been investing in RE for many years to reduce their production cost and raise their revenue. The exploitation of RE in oil and gas production has proven to be more efficient and less expensive especially in remote areas or offshore applications. Therefore, the study considered herein sheds light on the RE applications used by Oil and Gas companies such as using wind turbines and PV solar systems to generate electricity. A proper control technique may be used to integrate these renewable energy resources to the main electric grid. For stand-alone applications, a battery storage system may be utilized. In addition, solar thermal system (solar collector) may be used for water heating and steam production required for the enhanced oil recovery (EOR) technique. Due to its high intensity in deserted area, solar energy can be very promising source of energy in Libya. Therefore, case study has been chosen to assess the potential of concentrating solar power (CSP) for steam and electricity generation and the photovoltaic (PV) system for electric power generation at Sirte Oil Company site in Brega. A comparison between the two technologies and the application of the solar power at Sirte Oil Company are also presented.

الملخص

هذه الورقة تعطي لمحة عن إمكانية استخدام مصادر الطاقة المتجددة في قطاع النفط والغاز في ليبيا. على الرغم من أن بعض شركات النفط ترى مصادر الطاقة المتجددة كمنافس لها إلا أنه هناك العديد من الشركات الأخرى التي تقوم بالاستثمار في الطاقة المتجددة لسنوات عديدة لكي تقلل تكلفة الإنتاج وترفع مستوى الدخل. عملية إستغلال مصادر الطاقة المتجددة في إنتاج النفط والغاز أثبتت أنها تؤدي إلى كفاءة أعلى وتكلفة أقل خصوصا في المناطق النائية والتطبيقات البحرية. وبناءاً على ذلك فإن الدراسة المستهدفة هنا تسلط الضوء على تطبيقات الطاقة المتجددة المستخدمة من قبل شركات النفط والغاز مثل استخدام تربينات الرياح و الخلايا الشمسية لتوليد الكهرباء. يمكن استخدام طريقة تحكم ملائمة لربط تلك المصادر من الطاقة المتجددة بالشبكة الكهربائية الرئيسية. في حالة التطبيقات المعزولة عن الشبكة يمكن استخدام نظام بطاريات تخزين. بالإضافة إلى ذلك يمكن استخدام النظام الشمسي الحراري لتسحين الماء وإنتاج البخار المطلوب في تقنية استخراج النفط المدعمة. بناءاً على ذلك تم تحديد دراسة محددة لتقييم مدى إمكانية استخدام نظام القدرة الشمسية المركزة لتوليد الكهرباء وأيضاً استخدام نظام الخلايا الشمسية لتوليد الكهرباء في موقع شركة سرت في مدينة البريقة. تم عرض المقارنة بين التقنيتين وأيضا تطبيقات الطاقة الشمسية في موقع شركة سرت للنفط.

Key Words: Renewable energy, photovoltaic (PV), CSP, oil and gas, solar energy.

1. INTRODUCTION

When oil price is low, oil and gas companies need to save more money in their production processes, and this can be achieved through reducing their energy spending. Thus utilizing renewable energy resources in oil and gas production is being the goal for oil and gas producer. In general, the growth in renewable investment is being in all sectors, due to, the escalated risks facing our environment from greenhouse gas emissions and conventional energy production. Particularly, after Paris environmental agreement, worldwide oil and gas companies were advised to follow certain regulations and limitations on gas emissions and fossil fuel productions. Driven by regulatory (biofuel content standards, renewable portfolio standards, feed-in tariffs, emerging GHG obligations), ideological (environmentally motivated customers, employees and project host communities), and simple public relations, oil and gas companies had to play an active role in renewable energy (Switzer, *et al*, 2012). Even though, some oil and gas producer may view renewable energy as threaten to their business, a big awareness has already grown among many companies that renewable energy applications can help in the flourishing of oil and gas sector.

Worldwide, oil and gas companies have already taken a great stride in utilizing renewable energy applications such as solar thermal energy, photovoltaics, geothermal energy, tidal power, wave power, wind power, hydropower, and biomass energy. For instance, Shell recently has new strategies to lower CO2 emissions and meet Paris agreement, the company has adapted a new transition plan toward energy production using RE to meet the changes in energy demands and CO2 regulations. Shell invested in areas such as wind power generation in the Netherlands. Moreover, the company used a co-generation facility at petrochemicals complex in Pennsylvania, USA to produce both heat and electricity for the plant, as well as surplus electricity that will be exported to the grid at a lower CO2 (Energiewende, 2016). The technology of renewable energy is being used to tackle problems of supplying electricity for remote or offshore oil and gas fields where connection to domestic grid is a huge obstacle. Southern North Sea offshore platform is using PV solar panels and wind turbines to generate their own electricity (Tiong, *et al*, 2015).

Libya has highly considerable amount of renewable sources, such as solar energy. According to data recoded and averaged by Solar GIS during 1994-2010 the country has an average annual of GHI (Global Horizontal Irradiance) in rang of 2000 kWh/m2/year in coastal region in the north part and over 2600 kWh/m2/year in southern region (Belgasim, *et al*, 2018). Despite of being rich in term of solar energy, the applications of solar energy in all industrial sectors across the country still at small scale. For instant, first use of PV systems applications in Libya was in 1976, the small PV system is to provide electricity for a small cathodic protection station to protect an oil pipe line connecting Dahra oil field with Sedra Port (I. M. Saleh, 2017). Moreover, oil and gas companies in Libya are using PV systems to electrify microwave repeater stations for communication purpose in deserted oil and gas fields. Despite all incredible efforts conducted by current National Oil Corporation to restore their daily oil production of 1.6 million as before 2011 political uprising, Oil and Gas sector in Libya, are facing great challenges; such as security in oil and gas fields, political disagreement, and most importantly shortage of governmental funds. Under these harsh circumstances NOC needs to save more in their production cost through investing in large scale solar projects.

The feasibility study and the performance evaluation of the PV system in different location has already been discussed. For instance, the potential and the viability of using the PV system in Bangladesh is presented in (Mondal, *et al*, 2011). The performance analysis of the PV system in the island of Crete is conducted in (Kymakis, *et al*, 2009).

This work will discusses utilizing of solar system such as PV and CSP system in oil and gas production at Sirte Oil Company site in Brega.

The simulation tool used in this study is called System Advisor Model (SAM) .SAM is a performance, design parametric, and financial software analysis for Renewable energy projects. The software is presented be NREL (National Renewable Energy Laboratory) in United State, and widely used with high reliability.

2. Site Assessment

Libya is located in the heart of North Africa, a region with highly considerable solar radiation plant (Belgasim, *et al*, 2018). The well-known hot Sahara Desert comprises more than 80% of the country area. A study conducted by the German Aerospace center, reveals that every 1 km^2 of this region is exposed to solar radiation per year, equivalent to 1.5 million barrels of crude oil plant (Trieb, 2007). Libya population is around 7 million and mostly concentrated in the north part of the country, leaving vast uninhabited areas in the middle and south of the country. Such an unexploited large land is highly candidate for large-scale solar systems project. Thus, the suggested CSP or PV plant will be located south of Brega airport at Latitude/Longitude 30.36, 19.615. According to PVGIS-5 geo-temporal irradiation database recorded during 2007-2016, the chosen site has an average annual of DNI (Direct Normal Irradiance) around 2300 kWh/m2/year. This value considered very high and suitable for economically efficient CSP or PV systems plant (Kaygusuz, 2011). Figure 1 depicts the monthly irradiation at Brega site.

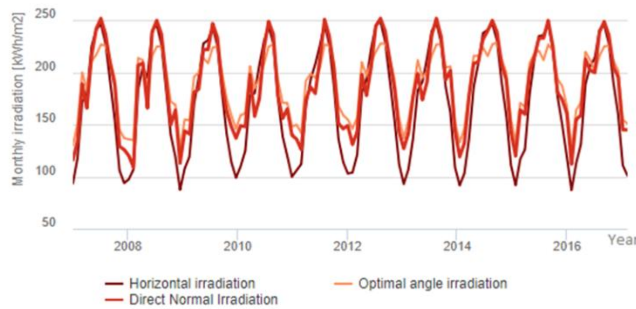

Fig. 1: Monthly solar irradiation at Brega selected site

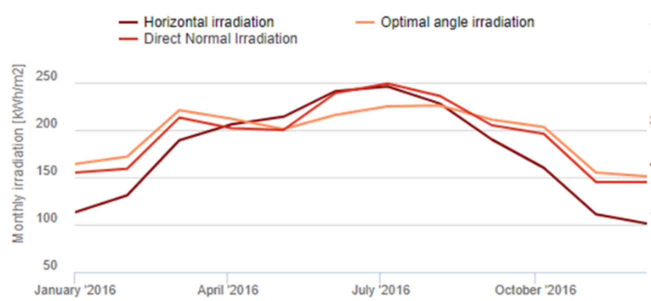

Fig. 2: Monthly solar irradiation observed in 2016 at Brega site

Solar irradiation in 2016 is estimated and recorded by PVGIS and exhibited in Fig. 2. It can be observed that July has the highest amount of solar irradiation with an average of 12 hours of sunshine daily as shown in Fig. 3.

The performance of CSP plants strongly depends on the meteorological conditions at the specific location of the plant. For instance, the direct solar irradiance DNI has a direct influence on the efficiency of the CSP plant. Other environmental factors such as ambient temperature and wind speed show an effect on heat losses from the different systems of the CSP plant (Belgasim, *et al*, 2018).

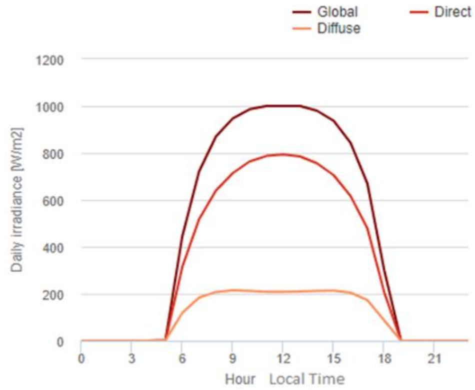

Fig. 3: Daily average irradiance in July for tracking plan

3. SOLAR ENERGY TECHNOLOGIES

In this section two different technologies of utilizing solar energy are discussed. The first technology is the concentrating solar power (CSP) and the second is based on using photovoltaic (PVP system. A comparison between the feasibility of each technique is also considered.

A. *Concentrating Solar Power (CSP) System*

Concentrating solar power systems utilize various types of mirror with different shapes to direct and concentrate the solar radiations onto a receiver and convert it into thermal energy. The generated heat is utilized to create a superheated steam, which can be used to drive steam turbine to produce electrical power or used as industrial process heat. CSP system can be equipped with thermal storage tank which allow for dispatchable generation of electricity in time of cloudy weather or after sunset and before sunrise. Based on the solar collector method of concentration, CSP system can be classified into two types. One type is line focus, concentrates and directs the sunrays along the focal length of the collector, such as parabolic trough and linear Fresnel reflector. Another type uses point focus collector that directs and concentrates the solar thermal radiations into central point, suchlike power tower and parabolic dish (Stein and Buck, 2017).

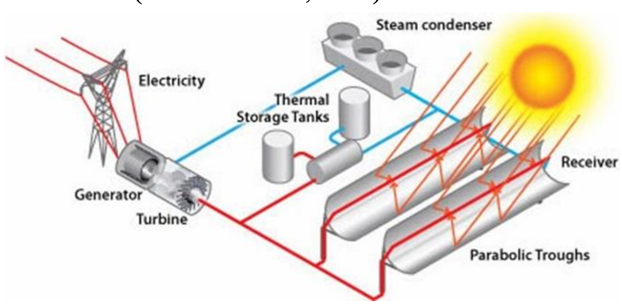

Fig. 4: Parabolic Trough CSP system

Parabolic trough CSP technology proven more successful in terms of installation and operating cost, and electrical power generations, thus more than 1220 MW of installed CSP used the parabolic trough technology (Turchi, *et al*, 2010). Therefore, parabolic collector is chosen in the suggested 160 MW CSP plant at Brega site. The simulation is carried out through SAM (system Adviser Model) to evaluate power production, general performance and cost estimations. To ensure and validate of the proposed study of the simulation results at Brega site, Noor I, CSP plant already in operation since 2015 with 160 MW gross capacity located in Morocco is taken as reference in this study. Similar technical design aspects for Noor I CSP plant are used in SAM for the suggested Brega CSP plant with taking into account weather and solar radiation data at the proposed site. The technical design parameters for the proposed Brega CSP plant is presented in table 1.

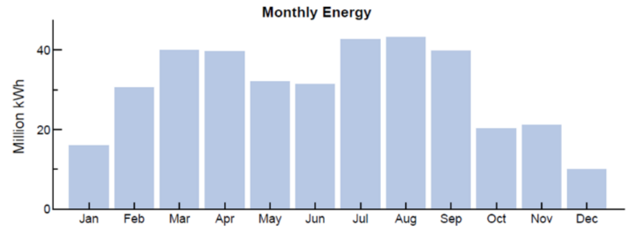

Fig. 5: Monthly energy harvested (CSP)

As shown in Fig. 5, the amount of energy harvested during the summer season (July) is much higher than the amount of energy harvested during the winter season (December). This variation between the two months may be explained comparing the power profile for two different months.

During the month of July, as depicted in Fig. 6, the sun radiation is relatively high and thus the generated power is high. In addition, the daytime is relatively longer (about eleven hours). Since energy is proportional to power and time, more energy is harvested during this month.

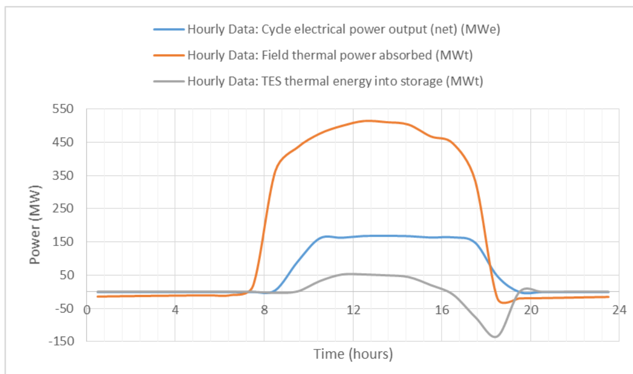

Fig. 6: July average daily power profile (CSP)

As shown, about 30% of the power generated is transferred to electrical energy. During the time with high radiation, some of the thermal power is stored in storage tanks and then reused during the low radiation hours when less harvested energy is produced. As a result, the generated electric power is kept almost constant for several hours.

On the other hand, during the month of December, the radiation is relatively low and the daytime is shorter as illustrated in Fig. 8. This justifies the low amount of energy harvested during this month.

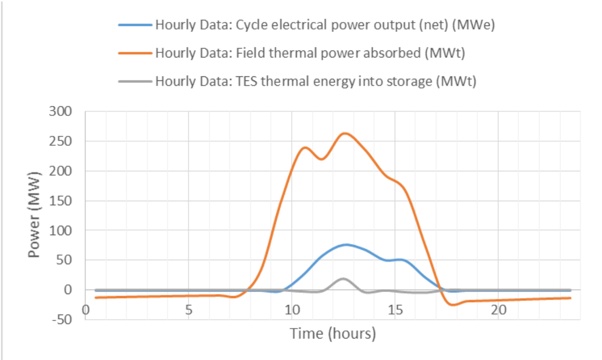

Fig. 7: December average daily power profile (CSP)

B. Photovoltaic (PV) System

In this technology, the electric power is generated using the photovoltaic phenomenon. When the sun light falls on the surface of the solar cell, electrons gain a kinetic energy and start moving. This movement of electrons establishes a potential difference between the cell terminals which cause the electric current to flow when a load is connected between these terminals. This is the concept of the solar photovoltaic (PV) phenomenon.

To establish a PV system with the desired rated voltage, several PV modules are connected in series to form a string. To obtain the required rated power, several strings are connected in parallel as depicted in Fig.8 [11]. Parallel inverters are used to transfer the DC power to AC power. The AC terminals of the inverter are connected to the medium voltage of the main grid through a three-phase transformer.

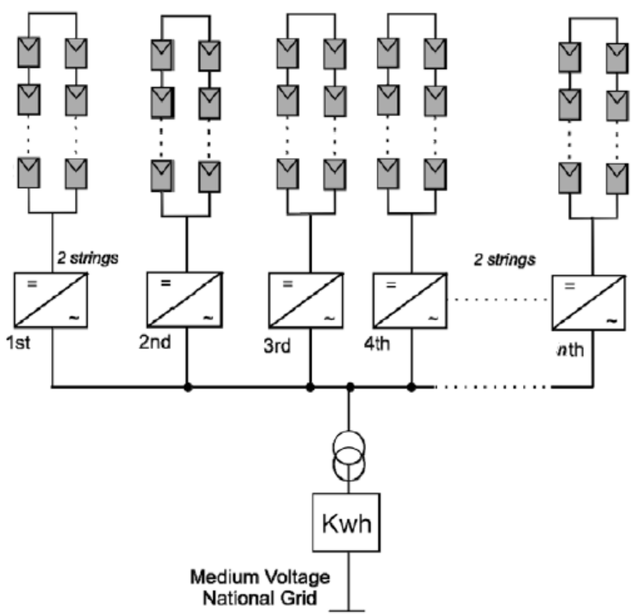

Fig. 8: Block diagram of the PV system

The number of parallel inverters is selected based on the maximum harvested power of the PV system. In this study, 28,512 strings with 22 modules per strings and 170 inverters are used to achieve the desired capacity of 160 MW. The parameters of the PV modules, inverters, and the PV array are presented in the Appendix.

The monthly energy harvested using the PV system is shown in Fig. 9. It is noticed that by comparing Fig. 5 and Fig. 9, more energy is harvested during the summer season using the CSP system but more energy is harvested using the PV system during the winter time. This is clearly caused by the fact that the CSP system relies mainly on temperature unlike PV system which rely on sun light.

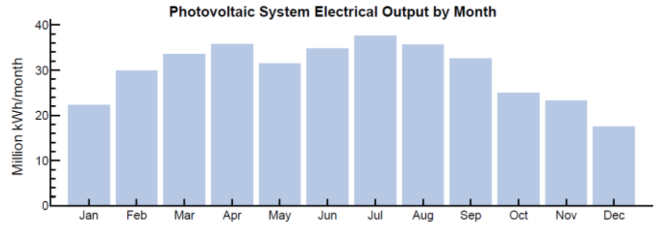

Fig. 9: Monthly energy harvested (PV)

As in the CSP technology, the monthly energy harvested depends on the daytime hours and the amount of radiation. Therefore, more energy is harvested during the summer (July) than during the winter (December) as depicted in Fig. 10.

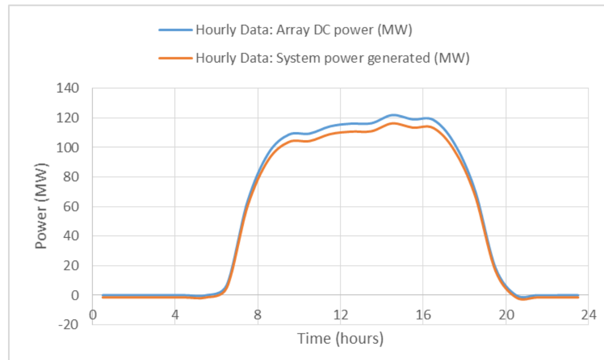

Fig. 10: July average daily power profile (PV)

One may notice that the electric power in generated using the CSP system, Fig.6, is more stable than the power generated using the PV system, Fig.10. This is may be associated to the fact that the thermal power may be stored and reused in the CSP system. A battery storage system may be used with the PV system to achieve similar performance.

Another advantage of the CSP system is that the value of the peak power is clearly higher than the corresponding value obtained by the PV system.

The average daily power profile during the month of December is shown in Fig. 11. By comparing Fig. 7 and Fig. 11, it is noticed that the opposite occurs compared to the month of July. The peak power obtained using the PV system is higher than the corresponding value obtained using the CSP system. Due to this variation between summer and winter seasons, the values of the annual energy harvested using both systems are very close.

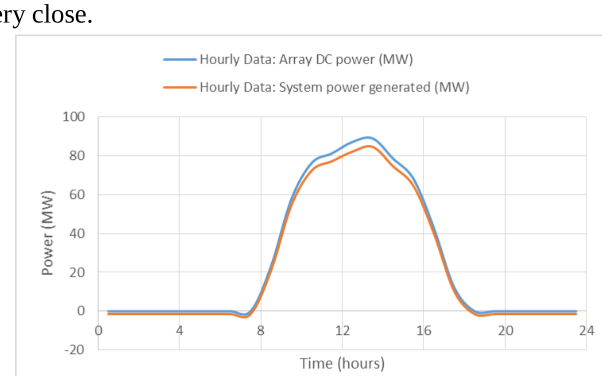

Fig. 11: December average daily power profile (PV)

C. Comparison between PV and CSP Metrics

A comparison between some metrics of the two proposed technologies is presented in Table I. One may notice that the CSP system has higher capacity factor and a little more energy harvested. On the other hand, the PV system is less costly and requires much smaller land area.

TABLE I

COMPARISON BETWEEN PV AND CSP METRICS

Metric	PV	CSP
Capacity (MW)	160	160
Capacity factor	25.5 %	29.0 %
Annual energy (kWh)	$357.62*10^6$	$365.80*10^6$
Total cost (million $)	273.96	773.97
Total area (Hectares)	102	339

4. Feasibility of Solar Power in Oil and Gas Industry

The simulation results for the Brega CSP plant are very promising with annually estimated produced energy of 365 GWh, a large amount of energy equivalent to nearly 224665 barrels of crude oil. Moreover, the suggested CSP plant will provide electricity for nearby oil and gas facilities. With this large amount of free and clean energy produced, Oil companies such as Sirte Oil Company they will not have to burn oil or gas to generate electricity, 145 MWe rated power will be generated by the proposed CSP system for almost 10 hours daily. Also the steam turbine can be operated at half load and the extra steam generated by solar thermal can by utilized in industrial heating at the Sirte company facilities.

5. Conclusion

In this paper, the feasibility study and the performance analysis of two different solar power technologies at the Sirte Oil Company site in Brega were considered. The two proposed systems at the site were 160 MW CSP system and a PV system with the same capacity. Using SAM software, the performances of the two systems were evaluated during the summer and winter seasons. The results obtained for the two systems were compared to each other. Finally, the feasibility of using the solar power system in oil and gas industry was discussed.

6. Appendix

The PV module parameters are illustrated in Table II

TABLE II

PV MODULE PARAMETERS

Modules	
Sunrise Solartech SR-M660255	
Cell material	Mono-c-Si
Module area	1.62 m²
Module capacity	255.07 DC Watts
Quantity	627,264
Total capacity	160 DC MW
Total area	1,018,676 m²

The inverter parameters are shown in Table III

TABLE III

INVERTER PARAMETERS

Inverters	
SMA America: SC800CP-US 360V	
Unit capacity	823 AC kW
Input voltage	570 - 820 VDC DC V
Quantity	170
Total capacity	139.91 AC MW
DC to AC Capacity Ratio	1.14
AC losses (%)	1.00

The PV array parameters are depicted in Table IV

TABLE IV

PV ARRAY PARAMETERS

Array	
Strings	28,512
Modules per string	22
String voltage (DC V)	663.30
Tilt (deg from horizontal)	30.00
Azimuth (deg E of N)	180
Tracking	1 axis
Backtracking	no
Self shading	no
Rotation limit (deg)	45
Shading	no
Snow	no
Soiling	yes
DC losses (%)	4.44

The technical design parameters for the proposed Brega CSP plant is presented in Table V

TABLE V

THE CSP DESIGN PARAMETERS

Brega CSP design parameters	**Value**
Total Capacity	160 MWe
Total estimated land area	340 Hectare
Collector type (SCAs)	EuroTrough ET150
Length of collector assembly	150 m
Number of modules per assembly	12
Number of SCA/HCE assemblies per loop	4
Number of loops	285
Optical efficiency	0.87
Collector tilt angle	30º
Collector azimuth angle	180º
Row spacing	15 m
Receiver (HCEs) type	Schott PTR80
HTF fluid	Therminol VP-1
Absorber material type	304L
Absorber tube inner diameter	0.076 m
Absorber tube outer diameter	0.08
Design loop inlet temperature	293
Design loop outlet temperature	393
Thermal storage Capacity	25 MWe
Full load hours of TES	6 h
Storage fluid	Molten salt

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BIOGRAPHIES

Mohamed Elgabaili received the B.S in Mechanical engineering from University of Benghazi in 2006. He received M.S, degree in Mechanical engineering from California State University Northridge in 2012. Since the fall of 2013, he has been a teaching staff member at University of Benghazi. His current research interests include thermal system, and renewable energy (solar and wind energy).

Ahmed Tahir received the B.S. (top of his class) in electrical engineering from University of Benghazi in 2006. He received the M.S., and Ph.D. degrees in electrical engineering from Purdue University, West Lafayette, IN, in 2011 and 2014, respectively. Since the fall of 2015 he has been a teaching staff member at University of Benghazi. His current research interests include electric machines, power electronics, and renewable energy.