Revue des Energies Renouvelables Vol. 16 N°4 (2013) 691 – 708

Effect of wind speed on the efficiency of the integrated solar combined cycle power plants SPP I in Algeria

A. Trad *, Z. Belgroun and A.M Djebiret

Unité de Développement des Equipements Solaires, UDES
Centre de Développement des Energies Renouvelables, CDER
42004, Tipaza, Algeria

(reçu le 24 Novembre 2013 – accepté le 30 Décembre 2013)

Résumé – *L'utilisation de la concentration de l'énergie solaire, 'CSP' avec système hybride pour la production d'électricité promet d'être l'une des options les plus viables pour remplacer les centrales à combustibles fossiles. En effet, les activités de recherche et de développement sur ses sous-systèmes de base ont connu un essor rapide depuis les années 1980. L'intégration de la technologie solaire cylindro-parabolique avec la technologie de la centrale à cycle combiné est appelée Integrated Solar Combined Cycle Systems, 'ISCCS', a prouvé un grand intérêt dans le développement des énergies renouvelables et plus particulièrement dans l'évaluation technique et économique des centrales solaires. La production nette d'électricité solaire, la consommation de carburant, l'efficacité thermique, les considérations environnementales, l'investissement et opérations et maintenance, 'O&M', les coûts sont les paramètres les plus importants pour évaluer la performance appropriée. La centrale SPP I sous le climat de Hassi R'Mel est une centrale hybride se compose d'un cycle classique combiné (TV-TG) associée à un champ solaire sans stockage thermique. Cette étude montre qu'une ISCCS permet d'économiser 20 millions de dollars de la consommation de carburant et réduit d'environ 1 million de tonnes des émissions de CO_2 en 30 ans période de fonctionnement.*

Abstract – *The use of Concentrating Solar Power, 'CSP' with hybrid system for electricity production promises to be one of the most viable options to replace fossil fuel power plants. Indeed, research and development activities on its basic subsystems have been booming rapidly since 1980s. The integration of parabolic trough solar technology with combined cycle power plant technology is referred to as integrated solar combined cycle systems, 'ISCCS', has been proven a great interest in the development of renewable energies and more particularly in technical and economic assessment of solar power plants. Net solar electricity, electricity production, fuel consumption, Thermal efficiency, environmental considerations, investment and Operations & Maintenance, 'O&M' costs are the most important parameters to evaluate suitable performance. The central SPP I under the climate of Hassi R'Mel is a hybrid plant consists of a conventional combined cycle (TV-TG) associated with a solar field without thermal storage. This study shows that an ISCCS saves 20 millions $ in fuel consumption and reduces about 1 million ton in CO_2 emission during 30 years operating period.*

Keywords: Concentrating solar power - Hybrid plant - Net solar electricity - Electricity production - Fuel consumption - Thermal efficiency - Wind speed - Environmental considerations – Investment - Costs.

1. INTRODUCTION

It is obvious that the origin of climatic change is CO_2, and at least 90 % of its emission amount results from fossil fuels burning for power generation and transport

* hotflow12@yahoo.fr

sector [1-4]. Recent studies and technology roadmaps published by the International Energy Agency, 'IEA', the German Aerospace Center, 'DLR' and the European Union, 'EU' have projected that 80 % of the CO_2 emissions, by 2035, will be from current industry based economy; so that changes in the climate will intensify if no decisive actions are undertaken [1, 4-6].

The progressive build up of CO_2 in the atmosphere is the undisputed cause for temperature rise accentuation, the melting of the polar ice caps and the increase in extreme weather events worldwide [1, 4-6]. As a result, many people around the World, mainly in Africa, face an increasing risk of hunger, water shortages, flooding, desertification, and severe environmental pollutions that are expected to cause about 150,000 additional deaths every year [3]. It has to be though stated that the fossil fuel era have resulted in an unparalleled standard of living and an increased life expectancy for part of the world's population [1, 5, 7].

Meanwhile, petroleum and natural gas prices are projected to move forward in the next 20 years (from $125/barrel in 2011 to over $215/barrel in 2035 [1]). This is due to increased demand which set to grow by over 50 %; from 87.4 mb/d in 2011 to 99.7 mb/d in 2035 [1].

Consequently, energy-related CO_2 emissions will then more than double by the year 2050 and concerns over supply security will surely heighten [1, 6, 8]. More than 7 billion people consume far more fossil resources and produce far more pollution than the Earth can accommodate [4, 5]. For instance, in the Mediterranean region energy consumption is raised by a factor of three between 1980 and 2005, and a further doubling is intended by 2020 [9].

For these reasons, more and more countries are mandating that a part of the electric power be from renewable origin, in particular solar energy. [10–17]. According to IEA, 50 % of the new power infrastructures will base on clean-sustainable energies. As a result, renewable energy will become the world's second-largest source of power generation by 2015; delivering about 30 % of the electricity needs by the year 2035 [1].

2. CONCENTRATING SOLAR POWER (CSP): HISTORIC AND CURRENT STATUS

2.1 Historic

Concentrating solar power, 'CSP' is not an innovation of the last few years. Records of its use date as far back as 212 BC when Archimedes used mirrors for the first time to concentrate the Sun's rays [22]. In the early seventeenth century, De Caux developed in 1615 a small solar powered motor consisting of glass lenses and an airtight metal vessel containing water and air [22]. More than a century later, in 1774, Lavoisier and J. Priestley developed the theory of combustion by concentrating solar radiation on a test tube for gas collection [23]. Next, A. Mouchot has devised a solar steam machine to run a printing press [24].

After that, in 1878, a small solar power plant made up of a parabolic dish concentrator connected to an engine was exhibited at the World's Fair in Paris [38]. In the early 1900s, although interest in solar power was then lost due to advances in internal combustion engines and increasing availability of low cost fossil fuel, the first CSP plant, powered by a parabolic trough solar field, was installed at Al Meadi (Egypt) [12, 25].

This first CSP plant, installed in 1913, was used for pumping water for irrigation [12, 25]. In the 1960s, with the focus on photovoltaic for the space program, interest in solar energy began to arise again. During 1970s the oil crisis boosted R&D activities on CSP and numerous pilot plants were built, tested and bringing CSP technology to the industrial and commercial level [26].

As a result, the first commercial plants had operated in California (USA) over the period of 1984 - 1991, spurred, more particularly, by federal and state tax incentives and mandatory long-term power purchase contracts. A drop in oil and gas prices has though driven many countries to retreat from the policy that had supported the advancement of CSP, and thus, no new plants have been built between 1990 and 2000.

It was not until 2006 that interest was once again rekindled for the development of large scale CSP plants. The market re-emerged more particularly in Spain and the United States, again in response to government measures such as the feed-in tariffs (Spain) and the policies requiring a share of solar power in their energy mix.

As of 2011, have been worldwide 1.3 GW of CSP plants in operation, 2.3 GW under construction, and 31.7 GW in the planning stage [20]. Nowadays, in 2013, 2.136 GW are operating, 2.477 GW under construction and 10.135 GW are announced mainly in the USA followed by Spain and China [19].

According to reference [21], about 17 GW of CSP projects are under development worldwide, and the United States leads with about 8 GW. Spain ranks second with 4.46 GW in development, followed by China with 2.5 GW.

The following figure 1 shows the amount of electrics MW produced and accumulated in the CSP around the world from the 80s.

2.2 Basic concept and current status

A typical CSP plant consists of three main subsystems: solar collector field, solar receiver and a power conversion system. In a hybrid plant, back-up and/or storage systems are added to enhance performance and increase capacity factor [13, 12, 27].

The solar receiver tube absorbs the concentrated solar radiation by collectors and transfers it to the heat transfer fluid (HTF) which is used to feed high temperature heat to a power conversion system. The subsystems are linked together by radiation transfer or fluid transport.

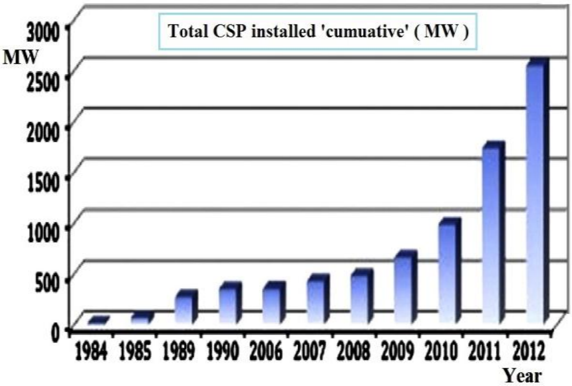

Fig. 1: Total solar thermal power plants installed [21]

Figure 2 shows the most important project of concentrating solar power technology (Parabolic trough) on the world.

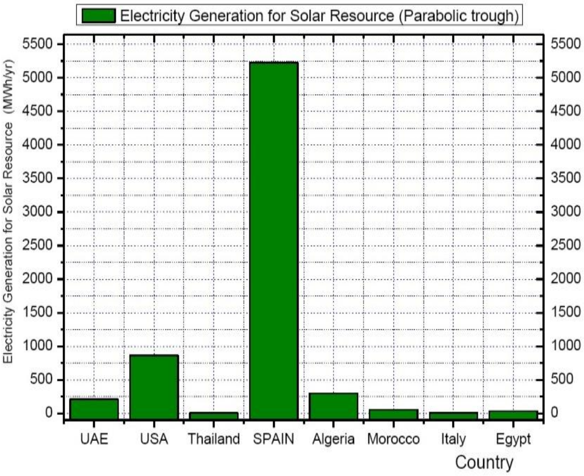

Fig. 2: Electricity Generation for different projects (Parabolic trough) in the world

There are four CSP families depending on the two major solar subsystems, i.e., the collector and the receiver: parabolic trough, solar tower also known as central receiver, linear Fresnel and dish Stirling [6]. They are classified according to the manner they focus the sun's rays and the receiver technology [15, 17, 20]. For each technology the overall efficiency of the whole system varies with the location, the time of day and the day of the year [28, 29].

In each CSP family, a variety of options is possible for solar field layout, tracking system, receiver type, heat transfer fluid (HTF), storage technology and power conversion system. North-South and East-West orientations equipped with single tracking mechanism are usually applied in trough solar field [18]. For central receiver, surrounded and North field configurations are the most proven technologies, while MTC (Micro Tower Configuration) is now under development [30, 31].

Whereas linear receivers are used for parabolic trough and Fresnel technologies, various configurations exist for power tower concept. Concerning heat transfer fluids (HTF), molten salt is widely used as HTF in commercial plants. Synthetic oil and saturated steam are also currently used as HTF's in commercial plants. Superheated steam has been recently introduced as HTF [34–35]. Pressurized air and other gases, in particular CO_2 and N_2, nano fluids, concrete and circulating particles are under development for both trough and tower, while helium or hydrogen is used in dish Sterling [36, 37].

Concerning storage, liquid molten salt is already proven storage medium for long time where as steam is typically reserved for short time storage [38, 39]. Phase change materials and compact heat storage (chemical reactions) are under development [38, 40]. Power conversion systems (thermodynamic cycles) are at present Rankine cycles (RC), Brayton cycles (BC), combined cycles (CC) for trough, tower and Fresnel types, and Stirling cycles (SC) for parabolic dish technology [42].

Advanced Brayton cycles, (BC) with pressurized air heated by volumetric solar receiver are nowadays an important issue [3]. Furthermore, supercritical steam and carbon dioxide cycles, air Brayton cycles are well positioned and promise to enhance solar power tower technology [17, 31, 41].

Besides activities in R&D and test and prototyping, numerous supports in various forms of incentives are playing a major role in the development of power generation through CSP. Incentives in the form of feed in tariff, tax relief, capital cost grants encouraging electricity export rates for CSP plants during recent years, in a lot of countries (Algeria, Egypt and Morocco in North Africa; Spain, Portugal, Italy and Greece in Europe; USA in North America; and India, China and Australia in Asia), has caused a rapid growth of these future power options. Likewise, other countries are in initiation phase or in the planning to set a favourable policy support for encouraging the development of CSP [10-16].

The overall experience in CSP technology development has been positive and new opportunities are opening. At the R&D and demonstration level, many projects have been carried out. At the configurations and component development projects, one can name DISS, SOLAIR, EURODISH and ECOSTAR projects. SOLGATE, SOLASYS and SOLHYCO are among the projects that have been carried out for the hybrid concepts implementation. DISTOR is a project worth citing for storage systems development [42, 43].

In this context solar thermal power plants will be capable of delivering efficiently more than 3 % of the EU's electricity by 2020, and at least 10 % by 2030 [45]. Moreover, it offers the opportunity to generate about 50 % of the electricity needs of the EU-MENA region [4, 5] and supply over 10 % of the world's electricity by 2050 [6].

3. PRINCIPLE OF OPERATION OF THE SOLAR POWER PLANTS

A typical hybrid central system, also known as a parabolic trough solar, consists of two major subsystems, namely the parabolic trough solar field and the power block conversion system. The solar field consists of numerous computer controlled mirrors that track the sun in one axe and reflect the solar radiation onto the tubular receiver located on the top of the parabolic trough.

The tubular receiver absorbs the reflected solar radiation and converts it into heat at high temperature levels. Depending on the tubular receiver design and the heat transfer fluid nature, the upper working temperatures can range from 250 °C to 400 °C.

A power conversion system is used to shift thermal energy into electricity in the same way as conventional power plants [11, 18]. In a power conversion system thermal energy can be converted into electricity with higher efficiency in Rankine cycle, Brayton cycle or combined cycle. These demonstration power plants have proved the feasibility and the economical potential of the parabolic trough technology.

They have also permitted the improvement in the design and performance of the parabolic trough for the Integrated Solar Combined Cycle, mainly its components, its hybrid concepts, its heat transfer fluids and storage system.

The development of Direct Steam Generation (DSG), which is currently in its early stage, as HTF is very promising for reducing costs and enhancing thermal efficiency by eliminating the heat exchangers network [35, 44].

4. PRINCIPLE OF OPERATION OF THE POWER BLOCK

Two gas turbines each coupled to a generator, producing electricity from the combustion of natural gas. The energy contained in the exhaust gas of gas turbine (TG) is recovered at a temperature of 550 °C and a pressure of 0.95 bar through two recovery boilers HRSG (Heat Recovery Steam Generator) which generate steam.

The steam so produced to a temperature of 560 °C and a pressure of 83 bars, feeds a steam turbine for driving a third generator. At the output of the steam turbine (TV), the steam is condensed in an air condenser to be fed back into the water-steam circuit.

During sunny periods (parameter: direct normal radiation), the solar field helps in the functioning of the plant involved in the production of steam at the GVS. A heat transfer fluid (HTF) is heated through tubular receivers with the concentration of solar radiation to reach a temperature of 393 °C and a pressure of 14 bars.

The heat thus acquired is used to produce steam at a temperature of 372 °C and a pressure of 87.2 bars with heat exchange oil (HTF) Water in a solar steam generator (GVS). This steam is injected into the HRSG recovery boilers. During these periods the plant operates in a hybrid cycle (Solar TV-TG-field).

The SPP1 operators manually control the flow rate of the Therminol VP-1 synthetic-oil heat transfer fluid (HTF) through the field of parabolic trough collectors. Normally, they adjust flow to maintain a roughly constant outlet field temperature, and this behavior was modeled. The required mass flow rate of HTF to achieve a user-defined outlet temperature Tout is calculated from a first law energy balance on the field:

$$\dot{M} = \frac{\dot{Q}_{net}}{C_p \times (T_{out} - T_{in})} \tag{1}$$

Where,

$$\dot{Q}_{net} = \dot{Q}_{abs} - \dot{Q}_{pipe} \tag{2}$$

$$\dot{Q}_{abs} = I \times A_{aperture} \times \left\{ LMS + A \times \frac{B}{(\Delta T_i + \Delta T_0)} \right\} + C \times \frac{(\Delta T_i + \Delta T_0)}{2I} + D \times \frac{(\Delta T_i + \Delta T_0)^3}{2I(\Delta T_i + \Delta T_0)} \tag{3}$$

The coefficients A, B, C and D are empirical factors describing the performance of the collector. The factor L is the incident angle modifier, M considers end losses and S considers shading of parallel rows. Evaluation of these parameters is described by Lippke (1995). ΔT_i, and ΔT_0 are the differences between collector inlet and outlet temperature and ambient temperature, and I is the direct normal isolation. $\dot{Q}_{pipe}$ accounts for losses in the piping

In periods of no sunshine (parameters not met), the solar field is not involved in the operation of the power plant. The contribution of the solar field is replaced by a gas supply to the burner's control (after burner) recovery boilers HRSG. During these periods the power plant operates in conventional combined cycle (TV-TG). Therefore the solar field reduces intake gas (fuel economy) during the periods of sunshine.

5. CASE STUDY

Considering the actual location of the first solar thermal power plant (SPP1) under the desert climate conditions of Hassi R'Mel (32° 55′ 48.0″ North, 3° 16′ 5.0″ East).

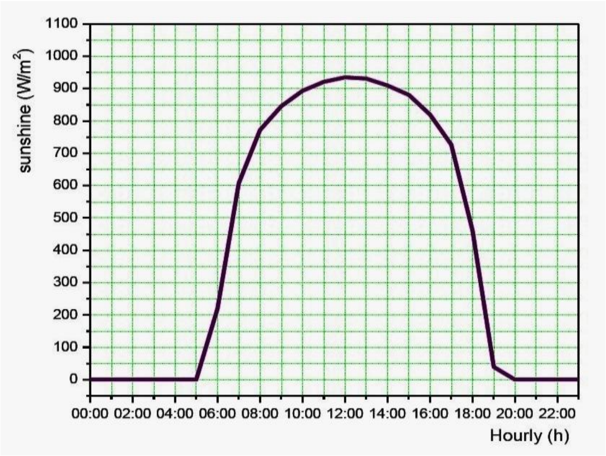

Fig. 3: Direct normal irradiation during hours of daylight in Hassi R'Mel

Solar Power Plant One consists of two solar fields, one in the north of the site and the other to the south with a surface opening mirrors 183,120 m^2 and a ground engaging over 600,000 m^2, the total area of the plant is 150 hectares. The two solar fields (North-South) include:

- 56 loops in a centralized provision;
- A loop has 4 sensors connected in series;
- A sensor consists of 12 modules in series;
- 2688 modules (module has 28 curved mirrors).

The orientation of the field (North-South), and tracking the sun is in (East-West). Collectors are equipped with tracking systems (tracking) on one axis and controlled from the control room. In case of maintenance or breakdown, it is possible to isolate a loop without affecting the operation of the rest of the field.

Also in the case of a minor operation or washing of a sensor, it can be put out of operation (defocused position) without affecting the operation of the rest of the loop. The washing operation is a systematic mirrors (15 to 20 days to perform the washing of all mirrors), it is done with the aid of a truck equipped with a system of osmosis water jet.

The two fields are interconnected by pipes, steel (carbon steel) carrying oil (HTF) (coolant) to the solar steam generator (GVS).

6. MATHEMATICAL ANALYSIS

6.1 Solar field analysis

The solar field is made up of a numerous parabolic trough collectors. The useful energy gained by each collector can be given as a function of absorber temperature [2]:

$$Q_c = A_c \times DNI \times \cos(\theta) \times \eta_0 \times K(\theta) - A_{abs} \times U_{abs} \times (T_{abs} - T_a) \quad (4)$$

The total useful energy gained by the heat transfer fluid in the solar field is:

$$Q_{SF} = N_c \times Q_c \quad (5)$$

The adopted methodology to estimate the direct solar irradiation intensity is the Hottel method. [2]

$$DNI = \tau \times I \times \cos(\alpha) \quad (6)$$

In the operation strategy, the inlet and outlet temperatures of HTF are set invariable. In this case, the mass flow is:

$$m = Q_{SF} / \{C_{pf} \times (T_{f0} - T_{fi})\} \quad (7)$$

Overall efficiency of the solar field is:

$$\eta_{SF} = Q_{SF} / (DNI \times A_c \times N_c) \quad (8)$$

6.2 ISCCS analysis

The most important factors to evaluate the ISCCS are the electricity production and the efficiency. The electricity production of the plant is best determined by calculating the instantaneous outputs of the gas turbines and steam turbine, and summing the results.

$$W_{ISCCS} = 2 \times W_{GT} + W_{ST} \quad (9)$$

The efficiency is then can be calculated:

$$\eta_{ISCCS} = W_{ISCCS} / (D \times f_{cv}) \quad (10)$$

The net solar electricity is the difference of the steam turbine outputs between sunny and night periods. Therefore, solar electricity ratio is:

$$\sigma = W_S / W_{ISCCS} \quad (11)$$

7. SIMULATION

In order to evaluate the instantaneous performance of the solar field, it is necessary to estimate the solar radiation intensity from sunrise to sunset. The DNI, of course, depends on the local weather conditions at the site where the power plant is built.

The SAM software (Solar Advisor Model) is used to evaluate the energetic performances to the solar power plants in the many sites proposed and also to study their economic feasibility. This investigation has been carried out using the National Renewable Energy Laboratory’s (NREL) SAM software [14, 47].

SAM provides modelling capability for several technologies including the CSP technologies. SAM combines an hourly simulation model with performance, cost and finance models to calculate energy output, energy costs and cash flows [46, 48]. Typical meteorological year (TMY) direct normal irradiation, ambient temperature, wind speed, sun angle, atmospheric pressure and solar azimuth angle and data for Hassi R’Mel were used as inputs to simulate the thermodynamic operation of the plants.

It should be noted that this software (SAM) and others such as DELSOL, TRNSYS and WINDELSOL have been used within previous studies of CSP technologies.

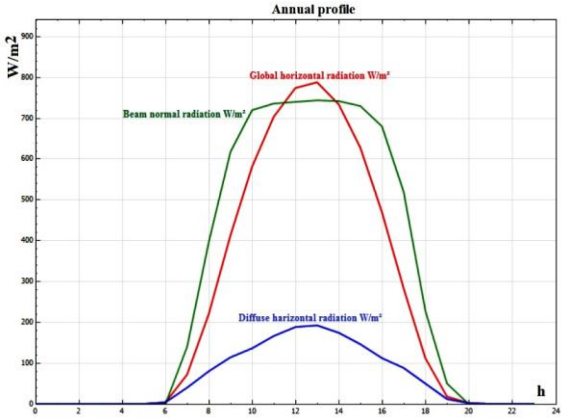

Fig. 4: Predicted annual profile of weather conditions to Hassi R'mel

Table 1: Different projects of CSP plant in the Algerian investment plan

Data	**Location**			
Technology solar-gas hybrid	Hassi R'Mel I	Meghair	Naâma	Hassi R'Mel II
	S-G-H	S-G-H	S-G-H	S-G-H
Name	SPPI	SPPII	SPPIII	SPPIV
Capacity (MW)	150	80	70	70
Estimated Cost $10^6$$	414	322	285	285

Nowadays many hybrid central projects are underway in Algeria and most of them will be operational in the shortest time. In the next, a detailed literature survey of the wind speed exceed negatively affected the functioning of the solar field of existing design comprising gain of fuel consumption and estimated cost, and techniques used to assess projects have been arranged in Algeria.

Table 2: Background of solar power plant I

Background	
Technology	Parabolic trough
Status	Operational
Country	Algeria
City	Hassi R'Mel
Region	Hassi R'Mel
Lat / Long location	32°55'48.0''N 3°16' 5.0''E
Cost (approx)	315,000,000 Euros
PPA/Tariff period	25 years
Project type	commercial

Table 3: Specification of solar field SPPI

Solar	Field
Solar-Field Aperture Area	183 860 m^2
N. of Solar Collector Assemblies (SCAs)	224
N. of Loops	56
N. of SCas Per Loop	4
SCA Length	150 m
Mirror Manufacturer	Rioglass
HTF	Thermal oil
Solar-Field Inlet Temp.	293 °C
Solar-Field Outlet Temp.	393 °C

Table 4: Specification of power block SPPI

Power Block	
Turbine Capacity (Net)	25.0 MW
Turbine Manufacturer	Siemens SST-900
Output Type	Steam Rankine
Cooling Method Description	Aero condensers
Cooling Method	Dry cooling

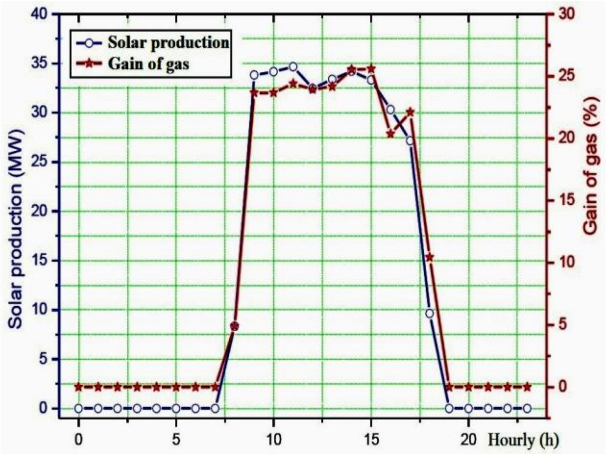

Fig. 5: Measured the daily gain in gas and solar production

Moreover, such a hybrid concept is able to save about 26 million m^3/year of fossil fuel, when the solar field is involved in the operation of the power plant during 8 hours/day.

8. BEHAVIOUR OF THE SOLAR FIELD AS A FUNCTION OF CLIMATIC CONDITIONS

In the operation strategy, the inlet and outlet temperatures of the heat transfer fluid remained constant and equal 290, 393 °C respectively. The following figures (6, 7, 8, 9, 10, 11 and 12) show the solar field production, gain of fuel and wind speed for the representative days of time standard. This day is chosen to illustrate the solar field performance, gas consumption and wind speed at different daytime. The selected days are 22st April, 25st May. The HTF mass flow rate, the thermal efficiency, solar field output and wind speed increase according to the increase in solar field production from sunrise till sunset of each day, where the operation duration varies for each daytime.

The amount of solar field output between 8a.m, 16p.m, is greater than for the other time of day due to the higher solar radiation intensity and longer solar radiation duration. The period of peak solar field output generally occurs between 10a.m to 16p.m of each day. In summer, the solar thermal energy is about 130 MW at midday. At this time, the HTF mass flow is in the order of 500 kg/s. As a result, the solar field efficiency reaches 80 %.

To illustrate the behavior of the solar field, and to quantify their contribution in the production of the plant, as well as the influence of climatic conditions, we take as an example, the results for two days, a perfect day in terms of solar power generation; according to the figures, we see that the operation of the plant through two phases (day and night):

- Between (12a.m, 9a.m) and from (5p.m, 12a.m), Sunshine is insufficient or no, the solar field is not involved in the operation of the plant, and the average gas consumption is 35000 m^3/h.

- Between (9a.m, 5p.m), the solar field is involved in the operation of the plant, and there is a fuel economy by reducing the average gas consumption of 35000 m^3/h to 27000 m^3/h an increase of 8000 m^3/h.

During this period, we see the curve an average contribution of 32 MW solar field. On this day the total production of electrical energy from the power station is 3618.29 MWh, the production of solar field represents 8.61% of the total production is 311.42 MWh.

During sunny periods (parameters together: solar field production, fuel consumption and wind speed), a brief comparison between these parameters is illustrated in after figure.

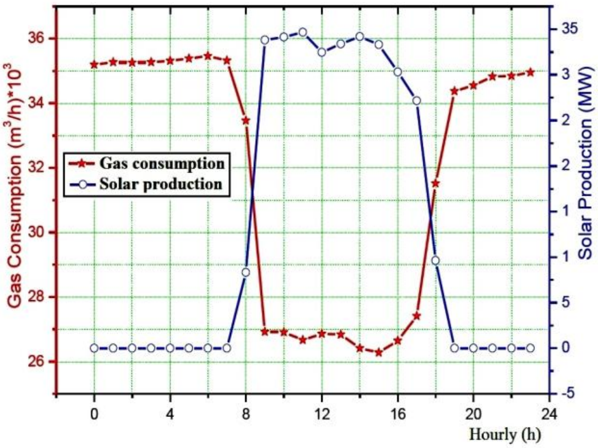

Fig. 6: Measured Gas consumption and solar
Field output during daylight hours (wind speed ≤ 8 m/s)

It may be noted that the solar electricity production is reached almost daily 35 MW at 8a.m to 4p.m when the value of wind speed is lower than 10 m/s throughout the daytime selected.

This hybridization allows the plant to operate as follows:

1. During the period of sunshine, the solar field provides a percentage of the energy cycle needs replacing fuel (fuel reduction).

2. During periods of no sunshine and night, the plant operates in conventional combined cycle (TV-TG).

According to the above figures, it is noted that the operation of the plant goes through several phases.

During the day we noticed that the contribution of the solar field is influenced by wind speed:

- Between (12a.m, 5a.m) and (7p.m, 12a.m), sunshine is zero, so the solar field is not involved in the operation of the plant, and the average gas consumption is 34 674, 28 m^3/h.

- Between (5a.m, 12p.m), sunlight is sufficient for the operation of the solar field, but the s the acceptable threshold set for the solar field operating position, in which case the plant operates in cycle conventional handset (TVTG), and solar mirrors are set dice focused position, and the average gas consumption is 34 884.23 m^3/h.

- Between (12p.m, 7p.m) the average value of the measured wind speed is 8.671 m/s, and the sun has reached the acceptable threshold for the steam generation solar function.

With these two parameters, the solar field is involved in the operation of the plant, and there is a fuel economy by a decrease in the average gas consumption of 34884.23 m^3/h to 29 200.98 m^3/h, gain 5683.24 m^3/h. During this period, the average contribution of the solar field is 21.163 MW. On this day the total production of electrical energy from the power station is 3568.3 MWh, the production of solar field represents 4.15 % of the total production is 148.14 MW.

A figure 7 shows the result of the simulation along a year of Incident energy on solar, solar field thermal output per area and solar field thermal output, without storage under the weather from a site in Hassi R'Mel.

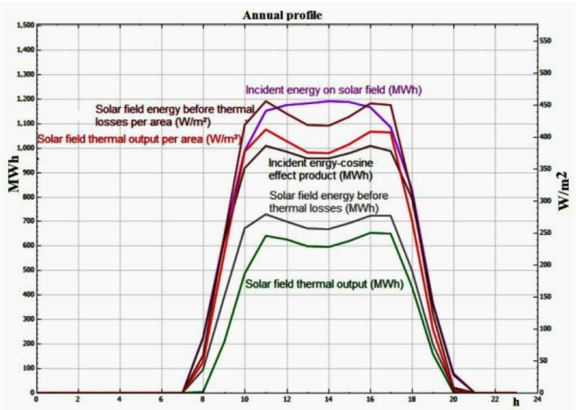

Fig. 7: Annual profile of Incident energy on solar, solar field energy before thermal losses per area, solar field thermal output per area, incident energy-cosine effect product, solar field energy before thermal losses and solar field thermal output.

But we can still see the profile of wind speed exceeds threshold 10 m/s in April, May, Jul, Aug and September that are almost always reached during few days of summer, constant spring and fall, much less in winter.

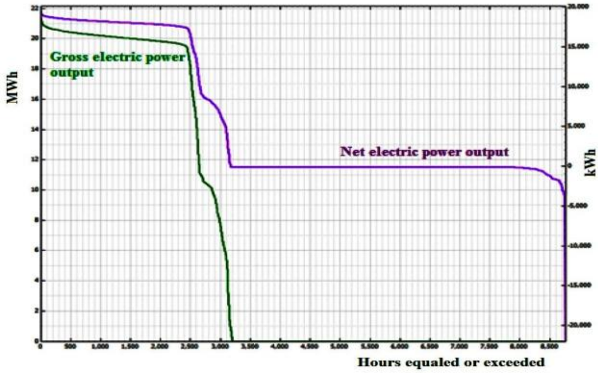

Fig. 8: Gross electric power output (MWh) and net electric power output (kWh)

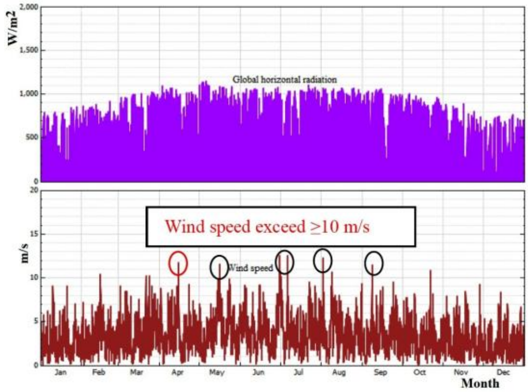

Fig. 9: Predicted annual profile of wind speed and global horizontal radiation

Indeed, the wind speed must not exceed the following thresholds:
- Current speed of 12 m/s.
- Average speed of 10 m/s over a period of 10 minutes.

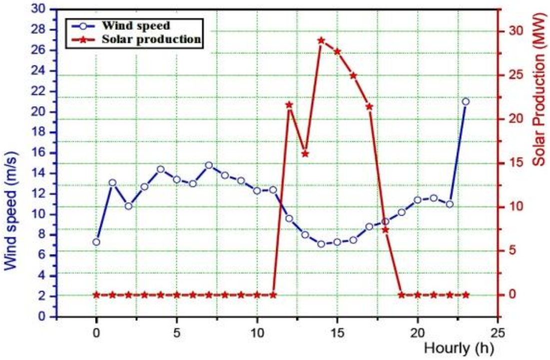

Fig. 10: Measured wind speed and solar field output during daylight hours

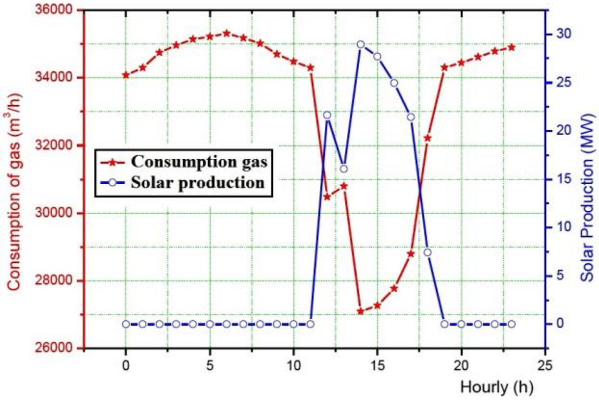

Fig. 11: Measured gas consumption and solar field output during daylight hours (wind speed ≥ 10 m/s)

The wind speed negatively affected the functioning of the solar field, despite sufficient sunlight. The value of electricity generated by the solar field is zero.

A figure 10 and 11 show the maximum point of solar production is 28 MW tends to 2 pm; this intervention of field solar into the electricity production is much lower along the daytime.

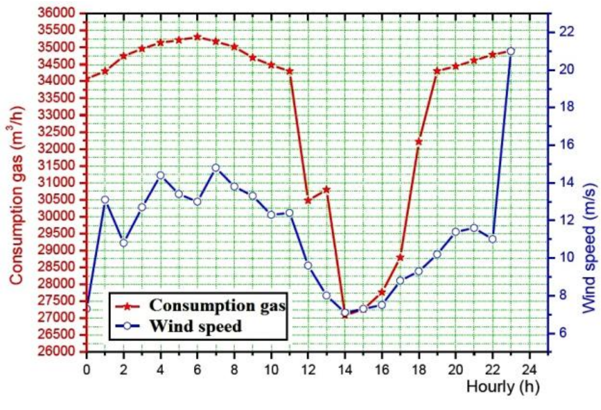

Fig. 12: Measured gas consumption and wind speed during daylight hours

Figure 12 shows the profile of the several points of measures along one day: The quantities of fuel consumed are very considerable during one day of measures when the wind speed exceeds the threshold of 10 m/s.

9. CONCLUSION

Is the growth in renewable energy self-sustaining and is it sufficient to put us on track to meet global climate goals. The major reason why the wide spread use of this power is variability which depends on meteorological factors and induces intermittent production.

The influence of wind speed on the performance of the first integrated solar combined cycle system in Algeria Hassi R'Mel under weather conditions is presented.

The simulation results show that the power plant responses sensibly to solar energy, where the electricity output increases accordingly to the solar radiation increase and sensibly to a conditional stability of the wind speed. The ratio gain of fuel can be very interested.

During the period when the wind speed exceeds the threshold of 10 m/s, the value of electricity generated by the solar field is zero. At daytime, solar energy can be converted to electricity with efficiency higher than at combined cycle mode because of the most efficient method for converting solar thermal energy to electric energy. Increasing the steam turbine capacity of conventional combined cycle by a half at the design point is other advantage of the integrated plant.

The installed solar field of the SPP I (183,860 m^2) surface has been designed for a production 16% solar without storage. The simulation showed that the possibility of storage is significant only if the area exceeds 300,000 m^2. This work has allowed us an introduction that we deem beneficial technologies SPP I plants and helped to highlight the contribution offered by this kind of thermodynamic plant. In the case study the effect economic and examination of parameters of weather conditions to the hybrid system installed in Algeria's energy sector in detail and the implications for the global cost of energy renewable.

NOMENCLATURE

A, Area, m^2	C_p, Heat capacity, J/kg K
CSP, Concentrating solar power	D, Fuel mass flow rate, kg/s
A, Area, m^2	C_p, Heat capacity, J/kg K
Dif, Diffuse radiation, W/m^2	f_{cv}, Fuel calorific value, MJ/kg
L, Incident angle modifier, °	I, Extraterrestrial radiation, W/m^2
I, Direct normal irradiation, W/m^2	N, Number of collectors
ISCCS, Integrated solar combined cycle system	m, Heat transfer fluid mass flow rate, kg/s s, Solar
Q, Useful energy, MW	SPPI, Solar power plant one
T, Temperature, °C	TMY, Typical meteorological year
W, Electricity production, MW	α, Zenith angle, °
σ, Net solar electricity ratio, % τ, Atmospheric transmittance for direct radiation	θ, Angle of incidence, ° η, Efficiency, % a, Ambient
abs, Absorber	c, Collector
f, Fluid	i, Inlet
o, Optical, outlet	SF, Solar field

REFERENCES

[1] Scientific Report, '*World Energy Outlook*', Executive summary, 2012. www.worldenergyoutlook.org/.

[2] O. Behar, A. Kellaf, K. Mohamedi and M. Belhamel, '*Instantaneous Performance of the First Integrated Solar*', Energy Procedia, Vol. 6, pp. 185 – 193, 2011.

[3] Scientific Report, '*An Overview of CSP in Europe, North Africa and the Middle East*', CSP Today, October 2008.

[4] S. Erdle, '*The Desertec Initiative, Powering the Development Perspectives of Southern Mediterranean an Countries*', Discussion Paper, December, 2010.

[5] Scientific Report, '*An Overview of the Desertec Concept*', Red Paper, Desertec Foundation, Initiative of the Club of Rome, Hamburg Office.

[6] Scientific Report, '*Technology Road Map Concentrating Solar Power*', IEA, 2010. http://www.iea.org/papers/2010/csp_roadmap.pdf.

[7] Scientific Report, '*Energy Revolution Report*', Green Peace, EREC January 2007. www.greenpeace.org/raw/content/international/press/reports/energy-revolution-a-sustainab.pdf.

[8] Scientific Report, '*Deploying Renewable in South East Asia Trends and Potentials*', Executive Summary, Working Paper, 2010.

[9] Scientific Report, '*Resources and Logistics, Identification Mission for the Mediterranean Solar Plan*'. Final report of FWC beneficiaries, Lot 4, N°2008/168828, January, 2010.

www.ec.europa.eu/energy/international/international_cooperation/doc/2010_01_solar_plan_report.pdf.

[10] Scientific Report, '*Evaluating Policies in Support of the Deployment of Renewable Power*', IRENA, 2012.

[11] Scientific Report, '*Renewable Energy Technologies: Cost Analysis Series*', Vol. 1: Power Sector, Issue 2/5, Concentrating Solar Power, IRENA, June 2012.

[12] J.A. Duffie and W.A. Beckman, '*Solar Engineering of Thermal Processes*', 2nd Edition, Wiley, New-York, 1991.

[13] J. Li, '*Scaling up Concentrating Solar Thermal Technology in China*', Renewable and Sustainable Energy Reviews, Vol. 13, N°8, pp. 2051 – 2060, 2009.

[14] M. Abbas, N. Kasbadji Merzouk, Z. Belgroun, Z. Tigrine and H. Aburidah, '*Parametric Study of the Installation of a Solar Power Tower Plant under Saharan Climate of Algeria: Case Study of Tamanrasset*', In the Proceedings of the First International Conference on Nanoelectronics, Communications and Renewable Energy, 2013.

[15] X. Py, Y. Azoumah and R. Olives, '*Concentrated Solar Power: Current Technologies, Major Innovative Issues and Applicability to West African Countries*', Renewable and Sustainable Energy Reviews, Vol. 18, pp. 306 – 315, 2013.

[16] A. Boudghene Stambouli, Z. Khiat, S. Flazi and Y. Kitamura, '*A Review on the Renewable Energy Development in Algeria: Current Perspective, Energy Scenario and Sustainability Issues*', Renewable and Sustainable Energy Reviews, Vol. 16, N°7, pp. 4445 – 4460, 2012.

[17] Ab.K. Mohd Zainal Abidin, Y. Rafeeu and A. Nor Mariah, '*Prospective Scenarios for the Full Solar Energy Development in Malaysia*', Renewable and Sustainable Energy Reviews, Vol. 14, pp. 3023 – 3031, 2010.

[18] M. Romero-Alvarez and E. Zarza, '*Concentrating Solar Thermal Power*', Energy Conversion 21, Plataforma Solar de Almeria, Ciemat, Taylor & Francis Group, 2007.

[19] F. del Sol and E. Sauma, '*Economic Impacts of Installing Solar Power Plants in Northern Chile*', Renewable and Sustainable Energy Reviews, Vol. 19, N°C, pp. 489 – 498, 2013.

[20] Scientific Report, '*Concentrating Solar Power: Its Potential Contribution to a Sustainable Energy Future*', The European Academies Science Advisory Council (EASAC), Policy Report 16, November 2011.

[21] www.renewableenergyworld.com.

[22] Report, '*Europe an Research on Concentrated Solar Thermal Energy*', Directorate-General for Research Sustainable Energy Systems, European Union (EU), 2004.

[23] D.Y. Goswami, F. Kreith and F. Kreider, '*Principles of Solar Engineering*', 2nd Ed. Philadelphia, PA: Taylor and Francis, 2000.

[24] A. Pifre, '*A Solar Printing Press*', Nature, Vol. 21, pp. 503 – 504, 1882.

[25] S. Rafaat, '*Maadi 1904-1962, Society and Historic in a Cairo Suburb*', Using the Sun's Force, Al Alhram News Paper, July 9, 1913, Maadi Introduces Solar Energy to the World in 1913, /http://www.egy.com/maadi.

[26] C.J. Winter, R.L. Sizmann and L.L. Vant Hull, Editors, '*Solar Power Plants*', Berlin: Springer; 1991.

[27] M.S. Jamel, A. Abd Rahman and A.H. Shamsuddin, '*Advances in the Integration of Solar Thermal Energy with Conventional and Non Conventional Power Plant*', Renewable and Sustainable Energy Reviews, Vol. 20, pp. 71 – 81, 2013.

[29] O. Behar, A. Khellaf and K. Mohammedi, '*Scaling up Hybrid Solar Gas Turbine: Simulation and Results*', SEN'2012, Alger, Algérie, 2012.

[30] M.A. Mustafa, S. Abdelhady and A.A. Elweteedy, '*Analytical Study of an Innovated Solar Power Tower (PS10) in Aswan*', International Journal of Energy Engineering, Vol. 2, N°6, pp. 273 – 278, 2012.

[31] R. Buck, A. Pfahl and T.H. Roos, '*Target Aligned Heliostat Field Layout for non-Flat Terrain*', 1st Southern African Solar Energy Conference, SASEC, pp. 1 – 9, May 21-23, 2012.

Available at: /http://researchspace.csir.co.za /dspace/bitstream/10204/5944/1/Buck_2012.pdf.

[32] G. Gong, X. Huang, J. Wang and M. Hao, '*An Optimized Model and Test of The China's First High Temperature Parabolic Trough Solar Receiver*', Solar Energy, Vol. 84, N°12, pp. 2230 – 2245, 2010.

[33] T. Tan and Y. Chen, '*Review of Study on Solid Particle Solar Receivers*', Renewable and Sustainable Energy Reviews, Vol. 14, N°1, pp. 265 – 276, 2010.

[34] M.J. Montes, A. Rovira, J.M. Martınez-Val and A. Ramos, '*Proposal of a Fluid Flow Layout to Improve the Heat Transfer in the Active Absorber Surface of Solar Central Cavity Receivers*', Applied Thermal Engineering, Vol. 35, pp. 220 – 232, 2012.

[35] W.D. Steinmann and M. Eck, '*Buffer Storage for Direct Steam Generation*', Solar Energy, Vol. 80, N°10, pp. 1277 – 1282, 2006.

[36] R. Tamme, D. Laing and W.D. Steinmann, '*Advanced Thermal Energy Storage Technology for Parabolic Trough*', Journal of Solar Energy Engineering, Vol. 126, N°2, pp. 794 – 800, 2004.

[37] O. Mahian, A. Kianifar, S.A. Kalogirou, I. Pop and S. Wongwises, '*A Review of the Applications of Nanofluids in Solar Energy*', International Journal of Heat and Mass Transfer, Vol. 57, N°2, pp. 582 – 594, 2013.

[38] T. Watanabe, H. Kikuchi and A. Kanzawa, '*Enhancement of Charging and Discharging Rates in a Latent Heat Storage System by Use of PCM with Different Melting Temperatures*', Heat Recovery Systems and CHP, Vol. 13, N°1, pp. 57 – 66, 1993.

[39] A. Gil, M. Medrano, I. Martorell, A. Lazaro, P. Dolado, B. Zalba and L.F. Cabeza, '*State of the Art on High Temperature Thermal Energy Storage for Power Generation- Part 1 Concepts, Materials and Modellization*', Renewable and Sustainable Energy Reviews, Vol. 14, pp. 31 – 55, 2010.

[40] A. Gil, M. Medrano, I. Martorell, X. Potau and L.F. Cabeza, '*State of the Art on High Temperature Thermal Energy Storage for Power Generation- Part 2 Case Studies*', Renewable and Sustainable Energy Reviews, Vol. 14, pp. 56 – 72, 2010.

[41] S. Rajinesh, S.A. Miller, A.S. Rowlands and P.A. Jacobs, '*Dynamic Characteristics of a Direct Heated Supercritical Carbon-Dioxide Brayton Cycle in a Solar Thermal Power Plant*', Energy, Vol. 50, pp. 194 – 204, 2013.

[42] Scientific Report, '*Concentrating Solar Power: from Research to Implementation*', European Communities, 2007.

[43] R. Pitz-Paal, J. Dersch and B. Milow, '*European Concentrated Solar Thermal Road Mapping (ECOSTAR): Road Map Document*'. SES6 – CT – 2003 – 502578, 2005. http://www.promes.cnrs.fr/uploads/pdfs/ecostar/ECOSTAR.Summary.pdf.

[44] Y. Tian and C.Y. Zhao, '*A Review of Solar Collectors and Thermal Energy Storage in Solar Thermal Applications*', Applied Energy, Vol. 104, pp. 538 –553, 2013.

[45] Scientific Report, '*European Solar Thermal Electricity Association, Solar Thermal Electricity European Industrial Initiative (Ste-EII) Implementing Plan*', 2010 – 2012, Brussels, May 2010. http://ec.europa.eu/energy/technology/initiatives/doc/implementation_plan_2010_2012_eii_solar.pdf.

[46] A. Ummadisingu and M.S. Soni, 'Concentrating Solar Power – Technology, Potential and Policy in India', Renewable and Sustainable Energy Reviews, Vol. 15, N°9, pp. 5169 - 5175, 2011.

[47] P. Gilman, N. Blair, M. Mehos, C. Christensen, S. Janzou and C. Cameron, '*Solar Advisor Model, User Guide for Version 2.0*', Technical Report, NREL/TP-670-43704, National Renewable Energy Laboratory, 2008.

[48] http://www.nrel.gov/analysis/sam