Comparative study between the integrated solar combined cycle system and direct steam generation in solar aided power generation system

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Abstract **:** Parabolic trough power plants have been developed in the integrated solar combined cycle system (ISCCS) and the direct steam generation (DSG) ,each concept has their configuration due to solar energy combination .The technology for the Solar Aided Power Generation (SAPG) is appeared for optimizing this combination in solar contribution to cycle efficiency. The target of this work is to evaluate the thermodynamic performance on solar hybrid power plants system for ISCCS and DSG concepts, in comparison for a solar to electricity efficiency. The Solar Aided Power Generation is proposed to assuming the solar contribution with evaluation method, for to calculate the generation share of the solar power system in each concept. The study shows that the DSG concept is the best hybrid system to solar-electric efficiency .Further results obtained indicate that solar contribution increase to the DSG concept proposed , in the best extraction of solar thermal for to preheat the feed water heater. The performance of the SAPG estimate the effect of the solar collector area in each concept for annual solar thermal energy.

Keywords: combined, energy, generation, hybrid, power.

1 Introduction

The renewable energy in concentrating solar power now is the result for more than fifty years for researches and development at universities laboratories, and scientists experimented with ways to produce electricity via concentrate the solar ray, it because it is diffused in the nature under mild form, so it necessity to concentrate these rays to get the high temperature and pressure for the electrical productions. Many concepts for concentrate the solar ray is developed, but parabolic trough is the technology which is commercialized [2].

Algeria is oil state and has a large solar radiation from largest desert in world. So the New Energy Algeria (NEAL)
has programmed many power projects, the first project is the hybrid natural gas/solar power plant in Hassi R'male at 420 km south of Algiers is operational since 2011[1].

The solar power stations with parabolic trough collectors currently account for 94% of the power stations in activity. It is also the technology privileged for the majority of power stations [2]. The hybrid parabolic trough power plants were implemented for several concentrated solar power CSP technologies, actually two concepts for produce solar to electricity the integrated solar combined cycle system ISCCS and direct steam generation DSG. The parabolic trough power plants until now have several concepts in hybridization.

Hybridization is means the combination of different energy conversion technologies in one system, is the combination between solar-fossil, hybrid concept is called integrated solar combined cycle (ISCC), where the solar-produced steam is superheated through a waste heat recovery heat exchanger by making use of the heat energy of gas turbine exhaust gas [3].Therefore hybrid system is the weakness of solar energy because is a discontinuous production, for this reason the burner in the exhaust gas turbine may serve as back-up firing when solar power is not available but total plant capacity is demanded [4].Other target for improving the economics of the solar thermal energy systems, is the consideration of efficiently utilizing solar energy and reducing emission of the greenhouse gases in the near and mid-terms [5].

Hybridization is not enough for best efficiency, the solar contribution is the first factor in their development there are many works in this area. The solar contribution evaluation methods based on second law of thermodynamics and thermoeconomic theory was proposed [6].The evaluated solar contribution in a SAPG system based on exergy analysis ,instead for to determine the share of solar thermal in output cycle efficiency . They proposed a new evaluation method of SAPG system based on the exergy analysis and the characteristics of exergy flows crossing the boundary of the system. They showed with this evaluation method, the contribution proportion of solar energy in a SAPG system can be determined [7].

Nomenclature

A	area (m^2)
C	concentration ratio
DNI	direct normal irradiation (W/m^2)
E	total energy kJ
g	the gravity acceleration (m/s^2)
h	enthalpy (kJ/kg)
I	irreversibility (kW)
LHV	lower heating value (MJ/kg)
m	mass flow rate (kg/s)
Q	heat energy (MWth)
s	entropy(kJ/kg)
t	time
T	temperature (K)
U	heat transfer coefficient (W/m^2 K)
v	velocity (m/s)
Z	elevation (m)

Acronyms

CSP	concentrated solar power
CT	constant temperature strategy
DISS	direct solar steam
HRSG	heat recovery steam generator
HP	high pressure
HTF	heat transfer fluid
FWH	feed water heater
ISCCS	integrated solar combined cycle system
LEC	levelized electricity cost
LP	low pressure
PTR	parabolic trough receiver
SAM	system advisor model
NEAL	new energy Algeria
SAPG	solar aided power generation
SEGS	solar electric generating system
SGT	siemens gas turbine
SR	saving ratio
SST	siemens steam turbine
TRNSYS	transient system simulation program
X	share of solar

Greek symbols

η	efficiency
α	absorption coefficient
ρ	reflection coefficient
σ	stefan–boltzmann constant
ψ	exergy

Subscripts

a	absorber
ap	aperture
b	boiler
ccs	combined cycle system
cv	control volume
col	collector
el	electric
ex	exergy
exh	exhaust
f	multiplication coefficient
ff	fossil fuelled
i	inlet condition
sol	solar
m	ambient
o	outlet condition
r	aperture
th	thermique
0	ambient condition

The recent technology of commercial parabolic trough power plants have different concepts, the ISCCS use synthetic oil (Therminol VP-1) as working fluid for transformation the heat to heat recovery steam generator (HRSG) from collector receivers in solar field[8]. Another process without synthetic oil it the direct steam generation (DSG), this concept used steam in the collector receivers to feed the steam turbine.

However, all previous work their benchmark is coal- fired power plants, they analyse the solar contribution on hybrid power plant include the coal and oil like as heat transfer. In this new work we use gas fired power plants and water like as heat transfer in the solar hybrid.

In the present work, the first aim is to present the configuration DSG concept compared to similar concept ISCCS [22] in thermodynamic performance for cycle efficiency .The second aim are to compare both concepts for DSG and ISCCS with the combination of a SAPG plant, based on solar contribution method according to the first and second laws of thermodynamics, and the evaluation models based on energy balance and exergy balance. Finally we were evaluated the best parameters in output electricity production featuring these concepts in solar contribution .These parameters are analysed and simulated in the TRNSYS and SAM software.

2 The Concepts of Hybrid Parabolic Trough Power Plants

2.1Concept for Integrated Solar Combined Cycle System

The integrated solar combined cycle system ISCCS initially proposed by Luz Solar International is a typical hybrid system that integrates solar heat and fossil fuel [8]. The solar system produce the vapour that is supplier for steam turbine as well as production the electrical energy. The solar gas turbine system is another promising hybrid solar/fossil technology [9, 10].

This cycle is composed from two gas turbines SGT-800 has open cycle of Brayton type, whose waste thermal heat of gases is recovered in a system of heat exchangers, which is make the production of vapour in heat recovery steam generator (HRSG) [11].

The oil cycle thermal is composed from oil heated (Therminol VP-1) in collector recovers of solar parabolic trough, the energy of this recovered oil conducts to generate steam generator via heat solar steam generator (HSSG) included an economizer, an evaporator and a super-heater.

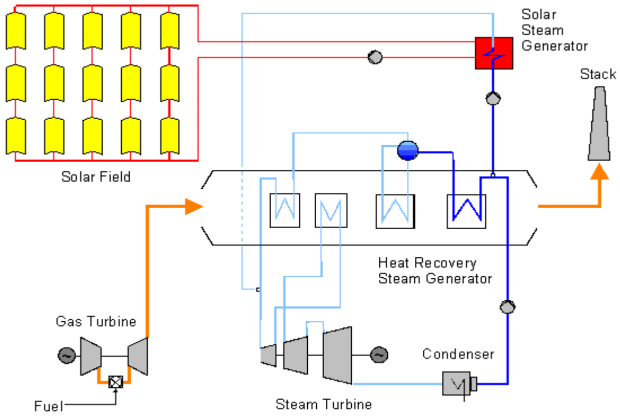

Fig. 1. Schematic of the integrated solar combined cycle systems (ISCCS) in conventional configuration, source: Dersch

In ISCCS the solar components are supplier to conventional power plant sometimes referred to height temperature; this heat can produce steam of pane in the heat recovery steam generator and can generate low pressure steam that is fed directly into the steam turbine [11].

2.2. Concept for Direct Steam Generation

The collectors of solar thermal power plants were used for to generate steam to power in thermodynamic cycle. The steam is generated directly into the absorber tube which is concentrated on sun ray. This concept is called Direct Steam Generation (DSG), so this technique is without Heat Transfer Fluid HTF “Fig. 2”.

Direct steam generation is considered a very promising option to increase the efficiency of parabolic trough systems, not only because there is no need of a heat exchanger between the solar field and the power block, but also to the high temperatures that can be attained in the collector receivers [12].This last reason is especially important at present, when new commercial absorber tubes, for working at higher temperatures, have been developed [13].

The DSG technology was tested at the DISS test facility in Almeria Spain [14]. Currently there is built commercially for the first time with parabolic troughs in Thailand [15]. Several of studies are realized the economic potential of DSG technology [16,17].Analyses results showed that live steam parameters of up to 500°C and 120 bar are most promising and could lead to reduction the levelized electricity cost (LEC) about 11% [18].

The concept of DSG is to use water as an HTF in the parabolic trough solar field, so that the solar field preheats, evaporates and superheats the water feed. Accordingly, steam can be expanded at a steam turbine directly. The benefits of this operation strategy are cutting capital and operation costs. Using water as an HTF results in eliminating the use of expensive synthetic oils and eliminating the heat exchanger from the power plant [19]. Furthermore the thermal efficiency of the thermal cycle is increased.

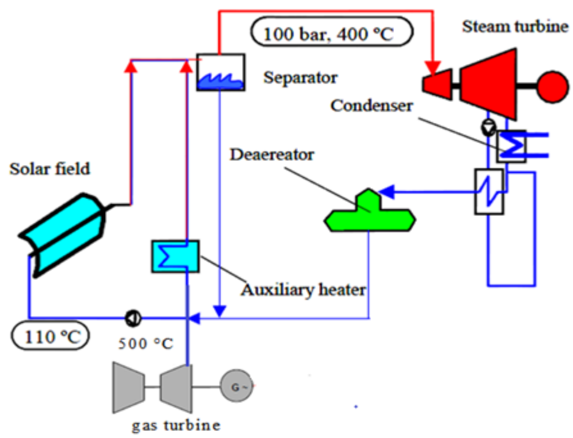

Fig. 2. Schematic of parabolic trough plant with the direct steam generation

There are different operation regimes were tested by the European project DISS. These experimental tests were carried out in southern Spain, in real solar radiation conditions and have proven the trough capability to generate steam with good conditions for the Rankin cycle operation. The three operation strategies are once-trough, injection system and recirculation system [21].

The description of the recirculation mode explained above is only valid when superheated steam is produced. In case the saturated steam cycle, the collectors after the steam drum are not needed. This is of particular interest for the present work. The step to higher temperatures has been demonstrated by the research project Real DISS with operation of the essential components at 120 bar/500 °C [21].

These models of hybrid power plants are operated under different concepts system, with fluctuating in power flows and efficiencies, e.g. the Sun position implies different optical efficiencies for annual production for each model. So this work is for to determine the best efficiency and the best concepts in hybrid power plants. Finally we assume the performance in solar contribution on the best concept for the solar hybrid power plants.

This work is divided into two section, firstly we evaluated the simulation of solar hybrid power plants in DSG system compared to ISCCS for validation the results, secondly we evaluated the model of hybrid power plant DSG on different cycle of steam parameters in several configurations for solar contribution . For found to reliable results the thermodynamic analyse and simulation in best configuration. We take into account the solar field and the cycle system concept, but the auxiliary electric consumption and costs of different installations are not considered.

3 System Descriptions and the Proposed Model

The model selected for simulation based on hybrid station (ISCCS) designs Hassi R'male [22] which includes Heat Transfer Fluid HTF , with actual operational condition taking into account the weather and the region, This reference plant is located at the south of Algeria in Hassi R'male, province of Laghouat at about 500 km from Algiers. The site is located at 33°7' latitude and 3°21'longittude, with elevation above the sea level is 750 m. The ambient temperature is varied from cold month on winter period between -10° C and 20°C and on the hot period between 21° C and 50°C in the summer, the solar in hot periods with Direct Normal Irradiation DNI can reach 930 W/m^2. The design of the power plant considered air ambient at 0.928 bars and 35°C with relative humidity at 24%.

The solar power plant was included the solar field and the power block. The power block of conventional combined cycle power plant with two gas turbine on 47 MW SGT-800 in Brayton cycle [22], accumulate with Rankin cycle for a steam turbine on SST-900[24]. The solar field for 183120 m2 comprises 224 parabolic collectors assembled in 56 loops, 4 collectors per loop and the heat transfer fluid HTF is the oil, it runs with PTR-70 receivers.

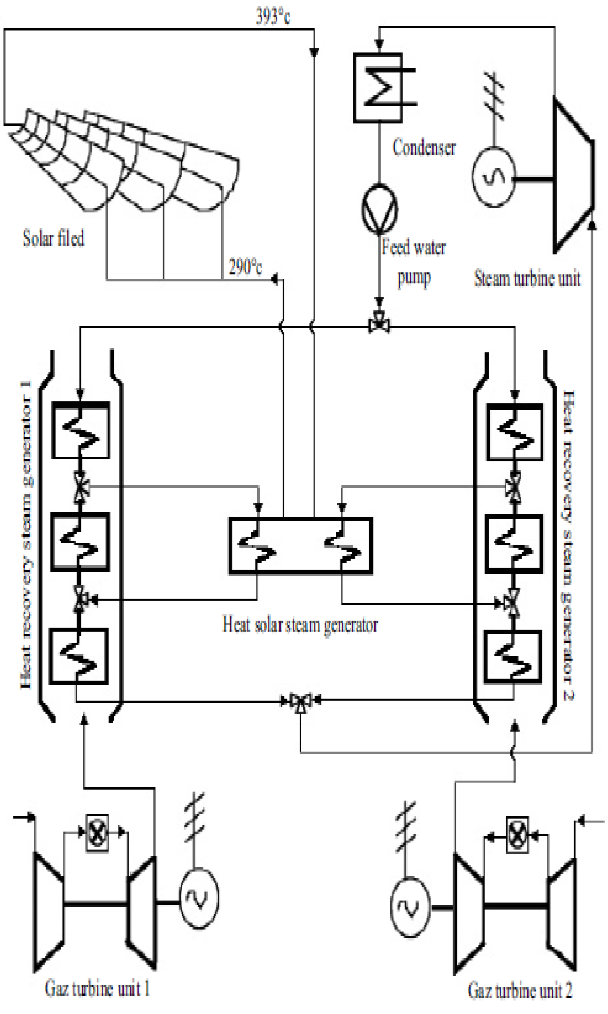

Fig. 3. HTF-ISCCS of Hassi R'mmel power plant with simple pressure level [22].

We consider the DSG plant basically similar to ISCCS plant in area of solar field size, gas turbine and steam turbine without the SSG system. These power plants are modelled and simulated in two commercial codes the SAM [26]and the TRNSYS [27] with a model library STEC developed by DLR, was used to model the solar components. The design parameters of the each solar power plants are summarized in Table 1.

Table 1 The parameters for each concept DSG and ISCCS

Production	ISCCS	DSG
Gas turbine		
Ambient temperature	35°C	35°C
Compressor pressure ratio	20.2	20.2
Compressor isentropic efficiency	0.88	0.88
Inlet turbine temperature	1200°C	1200°C
Turbine isentropic efficiency	0.88	0.88
Exhaust mass flow rate	120, 20 kg/s	120,20kg/s
Exhaust temperature	550 °C	550°C
LHV of natural gas	45778 kJ/kg	45778 kJ/kg
Net output power	40 MW	40MW
Gas natural mass flow rate	2.46kg/s	2.46 kg/s
Thermal efficiency	34%	34%
Steam turbine		
Inlet steam temperature	500°C	550°C
Inlet steam pressure	83 bars	120 bars
Steam mass flow rate	70 kg/s	70 kg/s
Condensate temperature	52°C	52°C
Isentropic efficiency	0.9	0.9
Full output capacity	80 MW	80 MW
HRSG		
Fuel mass flow rate	0.66 kg/s	0.66 kg/s
Approach temperature	25°C	25°C
Pressure losses	16 bars	16 bars
Inlet water temperature	60°C	60°C
Thermal efficiency	98.50%	98.50%
Solar Steam Generator		
Inlet water temperature	195°C	-
Inlet water pressure	90 bars	-
Water/steam mass flow rate	22.60 kg/s	-
Pressure losses	5.8 bars	-
Thermal efficiency	98 %	
Parabolic trough		
Area collector	183120 m^2	183120 m^2
Heat transfer fluid	oil	steam/water
The receivers type	PTR-70	PTR- 80
Outlet steam temperature	-	550 °C
Outlet receivers pressure	93 bars	120 bars
Outlet HTF temperature	392°C	-
HTF mass flow rate	205 kg/s	-
Pressure losses in HTF side	2 bars	
Water/steam mass flow rate		55 kg/s
Pressure loss in tube steam		0.5bars

4 Model of The DSG Concept in Solar Contribution System

The component of new concept DSG proposed to configuration is similar to the solar hybrid power plants of Hassi R'male, without solar steam generator and include the receivers for parabolic trough kind PTR-80.This concept is referred for validation the results of solar size initially to produce 200 MWth [38]. In order to evaluate the model in solar contribution to simulation, we selected the DSG concept in reference [38]. The solar field with 183120 m2 areas and 56 loops for each loop, and one axis involves 6 collectors from type of LS-3. This axis is aligned on the north south line and tracking the sun from east to west.

Two gas turbine units on 47 MW SGT-800 to provide a necessary flexibility in the operation in the night, day and cloudy day [23]. The steam turbine on SST-900 [24] and the system of heat exchanger included concept that is two heat recovery steam generator HRSG to generate steam and gas-boiled for thermodynamic cycle[25].

The new model of DSG concept proposed to include the grid of solar field in receivers PTR-80 which is composed of two parts preheater and superheated , these part loads the water or steam ,the model is presented in fig 7 . In the new DSG concept, liquid water from the deaerator is pumped to the proper pressure levels for to feed the feed water heater, in same times preheated on the first DSG solar field in the saturated case, and then vaporized in the second DSG solar field in superheated case (the solar field is not described in diagram below). When wet steam produced from the solar collectors it separated in a vacuum , the liquid returns to the solar fields, saturated steam is superheated by the gas turbine exhaust gas in HRSG before heading to the steam turbine. After high-pressure stage turbine, the steam returns to HRSG, to be reheated and feeds the next stage steam turbine.

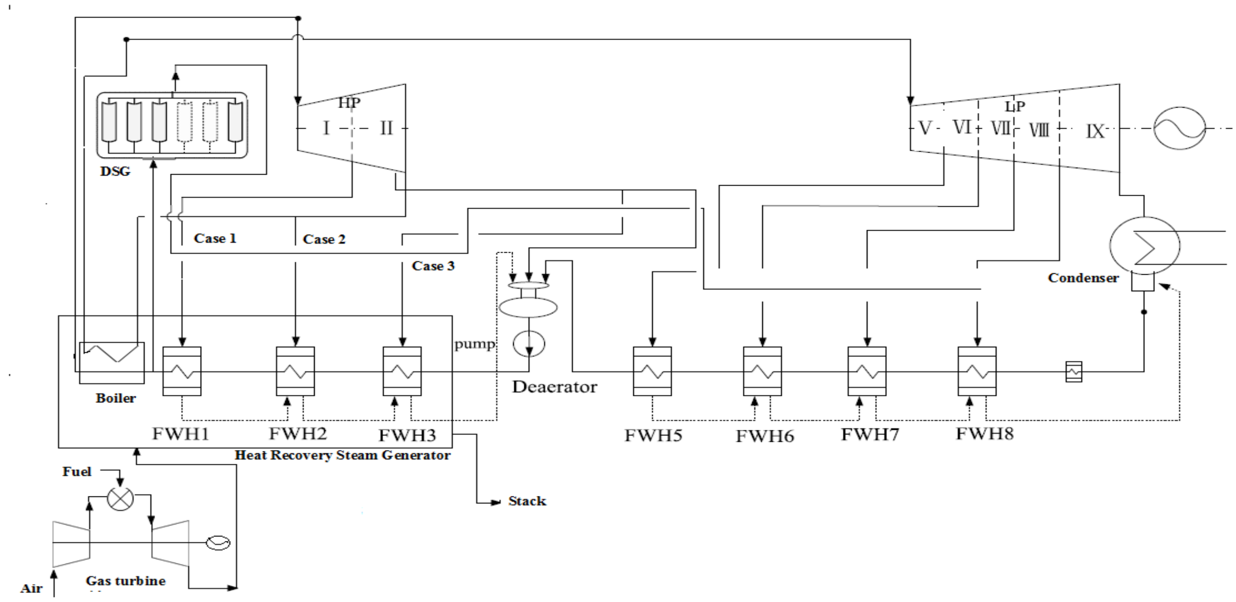

Fig. 4. Schematic diagram of a solar contribution on DSG concept, in which solar thermal energy used to preheat the feed water heater

The new DSG concept in configurations for simulation is presented in subsystems, each subsystem included extraction point of solar field for to heat the feedwater which is to feed the DSG solar filed . In this new concept DSG the feedwater is heated by solar thermal energy carried from parabolic trough, but there is a large loss of exergy. The exergy loss in the heaters can be reduced by increasing the number of extraction stages (and feedwater heaters), so we simulate the best way for extraction for to get the best performance efficiency.

5 Analyses for Combined Cycle System

The following model is evaluation for thermodynamic analysing of the solar integration system in each configuration. We use the first law of thermodynamics energy balance form should be used for control volume [28]:

$$\frac{dE_{cv}}{dt} = \sum \dot{m}_i \left(h_i + \frac{v_i^2}{2} + gz_i\right) - \sum \dot{m}_o \left(h_o + \frac{v_o^2}{2} + gz_o\right) + \dot{Q}_{cv} - \dot{w}_{cv}$$
(1)

The thermodynamic process of a steam turbine is an isentropic transformation. The ideal outlet steam specific enthalpy can be obtained from steam tables because the outlet steam pressure and steam entropy are known. For exergy balance in a control volume, the following equation has been used [28]:

$$\sum_r \dot{Q}_r + \sum \dot{m}_i \left(h_i + \frac{v_i^2}{2} + gz_i\right) = \frac{dE_{cs}}{dt} + \sum \dot{m}_o \left(h_o + \frac{v_o^2}{2} + gz_o\right) + \dot{W}$$
(2)

The control volume of irreversibility explanation, in the following equation is used [30]:

$$\dot{I}_{cv} = \left(\sum \dot{m}_i \,\psi_i - \sum \dot{m}_o \,\psi_o\right) + \sum (1 - \frac{T_o}{T})\dot{Q}_{cv} - \dot{W}_{cv}$$
(3)

In exergy calculation of all cycle equipment, we should calculate all exergy flows. The exergy calculation for single-phase flows such as water or steam to flow is carried out easily. For this action following relevance is used [28]:

$$\psi = (h - h_0) - T_0(s - s_0)$$
(4)

For transferred exergy by heat [30]:

$$\psi_Q = Q(1 - \frac{T_0}{T})$$
(5)

6 Efficiency of Collector Receiver for Solar Field

The DSG plant use the PTR-80 receivers because the higher temperature and pressure 550C° and 120 bars in recirculation mode as well as to minimize pressure drop over the collector loop.

The ISCCS plant use the PTR-70 receivers are commercialized in the world wide in this step we choose Algeria area with Tamanrasset city , other worth the area of Tamanrasset is the hot area in Algeria with direct normal irradiation 2600 kWh/m^2/ year .

The data onto weather condition is the climatological database from the TRNSYS, is for solar energy applications at every location on the globe.

The simulation model for the parabolic trough collectors using water-steam as heat transfer fluid, has already been developed and validated in other work [31].Another model for the parabolic trough, their cycle is activated in a central water boiler heated by the oil coming from the solar field [30].

The efficiency of collector η_{col} is given by the Hottel-Whillier Bliss equation [11], it was defined as;

$$\eta_{col} = \frac{Q_{col,net}}{DNI \cdot A_{col}} \quad (6)$$

$Q_{col,net}$ (kWth) is the net heat gain per collector loop is the energy balance applied to the troughs, it allows the calculation of the thermal power transferred to the fluid as a function of the impinging Direct Normal Irradiation (DNI) on the tube is defined as;

$$Q_{col,net} = [[DNI \cdot f\rho\alpha] - [U_A\,(T_b - T_m)/C] - [\varepsilon\sigma(T_b^4 - T_m^4)/C]] \cdot A_{col} \quad (7)$$

Where η_{col} is the collector efficiency; *DNI* (kWth) is the incident direct normal irradiation to the collector aperture area.

- A_{col} (m^2) is the total collector area of the solar field.
- ρ is the reflection coefficient of mirror 0.85.
- α is the absorption coefficient of pipe 0.96.
- U_A is the heat transmission index of the absorber 8W/m^2 K.
- T_b is the absorber temperature (K).
- T_m is the ambient temperature (K).
- ε is the emission coefficient of the absorber 0.15, σ is the Stefan–Boltzmann constant ($5.67*10^{-8}$/m^2K^4).
- C = A_r/A_a = 60 is the concentration ratio with A_r aperture area and A_a absorber area [32].
- The factor *f* is a multiplication coefficient to reduce the η_{col} of series parallel connected collectors as its efficiency is smaller than that for single collector where $0.85<f<0.95$ [33].

7 Efficiency of ISCCS and DSG power plant

Each configuration in concept of DSG and ISCCS systems have been analysed on the HTF in ISCCS and water in DSG, for same parabolic trough field about 183120 m2 but the concept with gas turbine. Firstly the modelling results are presented with tow last configuration.

For plant design and technologies (DSG and ISCCS) the total aperture area of the solar field was assumed equal to Aap =183120 m2, the total solar power production is:

$$Q_{sol-el} = Q_{ccs} - \dot{m}_{ff} * LHV_{ff} \quad (8)$$

Where:
Q_{ccs} is the thermal energy of output the combined cycle system (kWth).
$\dot{m}_{ff}$ is the mass flow rate of the fuel consumed in the gas turbine.
LHV_{ff} is the fuel's lower heating value from gas turbine.

For evaluate the cycle efficiency, we need to evaluate the electric power coming from the solar source and determined the thermal energy of the cycle, so this fraction between solar and combined cycle is the solar-to-electric efficiency are defined as:

$$\eta_{sol-el} = \frac{Q_{sol-el}}{DNI * A_{col}} \quad (9)$$

All previous works estimated that the coal-fired power plants are operating in the regenerative Rankine cycle. In a typical regenerative Rankine cycle power plant, some steam is extracted from the turbine to preheat the boiler feedwater, which can increase the overall thermal efficiency of the plant [34]. When the extraction steam in regenerative Rankine power cycle, is partly or totally replaced by solar thermal trough heat transfer fluid for to preheat the feedwater, this operation is the solar contribution in the hybrid power plant.

8 Analyses the Solar Contribution in DSG Concept

The solar contribution is the way to extract steam for preheating the feed water in hybrid power plant, there are many studies in this concept. The solar aided power generation (SAPG) concept, is to use solar thermal energy to replace the bled-off steam in regenerative Rankine power cycle. This extracted bled off steam is normally used to preheat feed water entering the boiler, it has the effect of increasing the thermal efficiency of the cycle [35, 36].

The thermal efficiency of the DSG system taking into account the solar heat contribution is defined as:

$$\eta_{th} = \frac{W_{net}}{Q_{ff} + Q_{sol,net}} = \frac{W_{net}}{m_{ff} * LHV + Q_{sol,net}}$$
(10)

where W_{net} is the system's total net power output including both from gas turbine and steam turbines, Q_f is the thermal energy provided from the fuel which is equal to the mass flow rate of the fuel m_{ff} consumed multiplies the fuel's lower heating value LHV, $Q_{sol,net}$ is the absorbed solar heat by water/steam.

The exergy efficiency is also calculated for the system performance evaluation. Assuming that methane's chemical exergy is approximately equal to 1.04 times its lower heating value LHV. The solar thermal exergy corresponds to the maximal work availability between solar collector temperature T_{sol} and ambient temperature T_0, so the definition of system exergy efficiency is given as follows [37]:

$$\eta_{ex} = \frac{W_{net}}{Q_{ff,ex} + Q_{sol,net}\left(1 - \frac{T_0}{T_{sol}}\right)} = \frac{W_{net}}{1.04 m_{ff} * LHV + Q_{sol,net}\left(1 - \frac{T_0}{T_{sol}}\right)} \quad (11)$$

The steam cycle thermal efficiency η_{steam} is defined as the ratio of steam turbine power output W_{steam} to the total thermal input to the steam cycle from solar field Q_{sol} and gas turbine exhaust Q_{exh}:

$$\eta_{steam} = \frac{W_{steam}}{Q_{sol,net} + Q_{exh}}$$
(12)

The contribution of the solar heat in the total heating load can be measured by its share in the system's total heat input:

$$X_{sol} = \frac{Q_{sol,net}}{Q_{ff} + Q_{sol,net}} = \frac{Q_{sol,net}}{m_{ff} * LHV + Q_{sol,net}}$$
(13)

The fossil fuel could be saved if the plant's power output remains unchanged as the same as the reference CCGT plant. The fossil fuel saving levels in comparison with the reference CCGT plant, for the same amount of electricity generated, is termed as the fossil fuel saving ratio:

$$SR_f = \frac{Q_{ccs} - Q_f}{Q_{ccs}}$$
(14)

9 Results and Discussion

9.1 Analyses the Concept of Hybrid Power Plants

Collector efficiency is an important parameter which directly influences on the thermodynamic performances of a solar thermal power plant, so in order to evaluate these performances we determine the heat output in solar collector and their efficiency.

Firstly we calculate the total annual of net heat gain per collector loop. The heat output of solar collector in each concept for the power plant is showed in "Fig. 4".

For different months in each power plant, there are a variations in solar field performance. The solar field output $Q_{col,net}$ increase according the solar radiation in each month until season of the summer when is reached the peak , due a high radiation and the solar field decrease when the summer it over . As well as there are a variations between the DSG and the ISCCS due a heat transfer fluid.

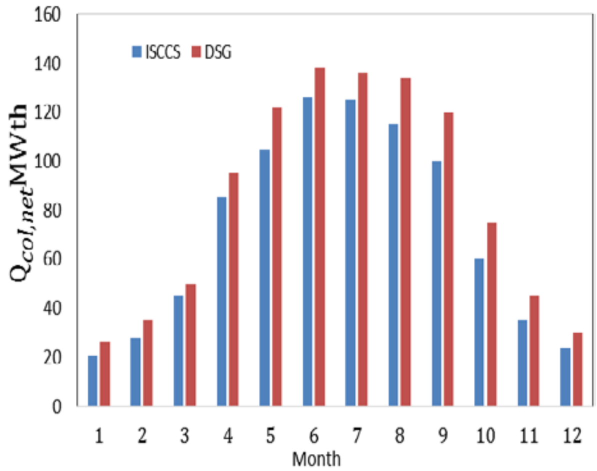

Fig. 5. The monthly power of solar field output in DSG and ISCCS

The DSG concept is used water like as a heat transfer fluid and it reached 500 C° and the peak value of midday is 138 MWth, while the ISCCS used oil (Therminol VP-1) as like as heat transfer fluid and it reached 400 C° and the peak value at midday is 124 MWth, therefore the water is better than the oil in the solar concentrating technologies.

Secondly we determine the increase effect of direct normal irradiation (DNI) in the efficiency of collector loop η_{col} for each integrated power plant, the results of simulation are set out in the following graph "Fig. 6".

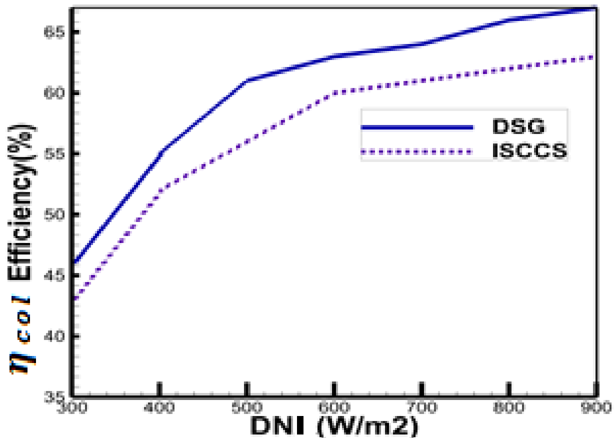

Fig. 6. The effect of direct normal radiation in DSG and ISCCS

The receiver tube efficiency is increased when the DNI is increased to each concept. The DSG concept is included water on low temperature and steam on high temperature in receiver tube, but in ISCCS concept the receiver is include only oil. The concept of steam is reached the efficiency for 67%, but the oil concept cannot be reaching 63%. For this reason oil and steam have a variation in efficiency η_{col} . Hence For same condition in direct normal irradiation DNI, the DSG is more efficiency than the ISCCS, as well as the HTF is making a loss for heat, because has a long cycle of generation and it cannot to use direct generation, while in the DSG concept is used direct system generation of short cycle, therefore the losses of efficiency in the HTF system are high than DSG concept, this loss is not to the fluid for heat transfer only, although is from the shape of heat process cycle.

When we were found the solar output in different concepts, we determined the annual solar-to-electric efficiency for each concept.

The ISCCS and DSG plants has been taken into account one-year period to determine the annual performance for both concepts, as well as this simulation is analysed in daylight when the sunrise until sunset ,table 2 as shown the overall annual power production. For to simplify the calculation, taken into account the daily light in power plant operation, the electricity production period must be considered and we have taken the average value all every month in one- year for annual production. The cycle of each power plant is analysed and simulates the solar-to-electric efficiency of the DSG and ISCCS is shown in the following chart.

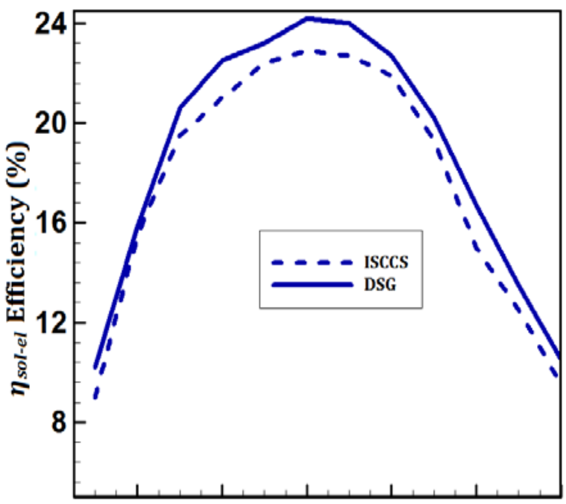

Fig. 7. The monthly efficiency power solar-to-electric

The simulation is explained, that the DSG and ISCCS concepts are able to have a very high efficiency in summer months, due to high percent of DNI in this month's .Whilst the efficiency of DSG concept is 6 % more than the ISCCS concept, this variation is from the kind of heat transfer fluid in receiver tube and their heat process. Conversely in winter the efficiency decays of the solar energy in both concept DSG and ISCCS, this variation leads to decrease from solar to electric efficiency, with less than 3% of the difference between each concept. Thereby DSG concept keeps their efficacy despite the lower DNI in winter. The results prove that the losses depending on heat transfer fluid, the component of cycle heat process of the thermal solar on generation cycle and weather condition. These losses decrease the efficiency of the in the ISCCS concept, except in the hottest months of the year but in winter this loses decrease due to low ambient temperature and low DNI value.

The average daily efficiency and the natural gas consumption are depending on the daily operation in each concept, we assumed that the gas turbine is operated only in daylight hours. The annual electricity production and annual natural gas consumption have been calculated in Table2 taking into account the monthly percentage of clear cloudy and overcast days. When comparing the ISCCS and the DSG plant, it can be found that the DSG concept work better than the ISCCS concept, this variation due of cloudy and overcast day, therefore the gas turbine is operated on balancing the shortage in heat losses as well as more fuel consumption (Table 2).

Table 2. The production solar combined system plant performance

Plant type	ISCCS plant	DSG plant
Gas turbine	47 MW	47 MW
Steam turbine	80 MW	80MW

Parabolic trough	30 MW	36 MW
Annual gas consumption	20845.43 m^3	12548.67 m^3
Gas percentage in electricity at day light	13.6%	8.7%

The results above show that the collector efficiency for DSG is better than the ISCCS, we choose the DSG concept for extraction the solar steam and their effect in cycle efficiency and exergy system.

9.2 Analyse the Performance for Solar Contribution in DSG Concept

In this work the analyse of the DSG concept is described. This new model proposed is validated to [38]. We assumed that the DSG concept is included two stage steam turbines in three extraction point from solar field for to heat the feedwater. In overall the extractions point in cycle configuration are divided into three subsystems. In the each subsystem the extraction steam is done bay solar thermal energy from receiver tube ,which included steam or vapour saturated for to preheat the feedwater fig4.We assumed that ,the amount of steam fraction of every extraction point in parabolic trough it same.

The extraction point of solar energy in high-pressure (superheated solar field), was supplied of sufficient heat to raise the feedwater temperature to the outlet temperature of (FWH 1, FWH 2, FWH 3), every extraction is one case;

- The first one scenario case 1: is the configuration with extraction from the superheated solar field , when the output steam leaving the solar field is directly preheat the feed water FWH1.
- The second configuration case 2: with extractions the steam from the superheated solar field to preheat feed water FWH2.
- The final scenario case 3: which is included the extraction of steam from solar field to preheat the FWH3.

These extractions are analysed in TRNSYS programme and compared to result in best performance for solar contribution in [38]. The results in reference chosen show that the plant with constant mass flow rate strategy could achieve higher annual solar power output and annual net solar thermal to power efficiency ,if the solar field area is oversized and plant located in the high solar resources area.

Firstly we determined the best case in analysing thermodynamic for all parameters, secondly we compared the solar contribution to best case simulated to the best case results from [38].

According the analyses and simulation of the model in each case of the TRNSYS software, the result is in the table below.

Table 3. Performance for solar contribution

Items	Case 1	Case 2	Case 3
Solar heat input, $Q_{sol,net}$ (MW)	96	84	73
Solar thermal share, X_{sol} (%)	29.2	26.5	24
Fossil fuel saving ratio, *SRf* (%)	29.5	26.7	24.2
Net power output, W_{net} (MW)	168	164	160
System thermal efficiency, η_{th} (%)	51.2	51.8	52.4
Steam cycle thermal efficiency η_{steam}(%)	26.5	26.2	26.3
System exergy efficiency η_{ex} (%)	52.1	52.9	53.3

We note that the performance of analyse thermodynamic in this concept is during two typical days: the day with relatively high solar radiation and the day with weak solar radiation. The results of this simulation show the best share of solar contribution to the hybrid power plant, when we was preheated the first feed water, the losses decreased of solar thermal energy, despite the legend decrease in thermal efficiency .The case 1 is the best way to preheat the feed water with X_{sol}=29.2%, almost the best way are to preheat the last feed water near the boiler.

Finally we compare the best concept simulated when we use the new DSG concept in effect of solar contribution to the results [38], when it used HTF like as oil for evaluation the solar contribution to best case.

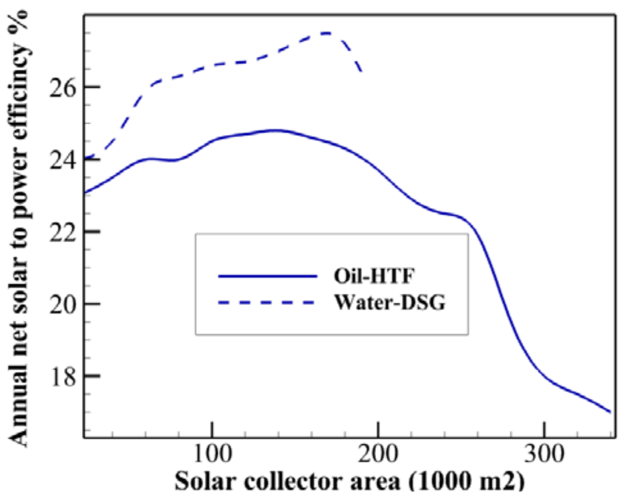

Fig. 7. The annual net solar to power efficiency

The solar contribution is varied from each concept, it can be seen that the new DSG concept had a large share solar in electric production, with the effect of best way for to reheat the feed water and decrease the losses. The annual solar to power efficiency in each concept increase when the solar collector area increase until a peak value 29% in the efficiency and 170000 m2 of solar collector area ,than the efficiency decrease when the solar collector area increase due for more losses to collect all collector area in parabolic trough.

Finally we are assumed the share of solar in the annual production electricity in new DSG concept simulated and the best case in reference system suggest.

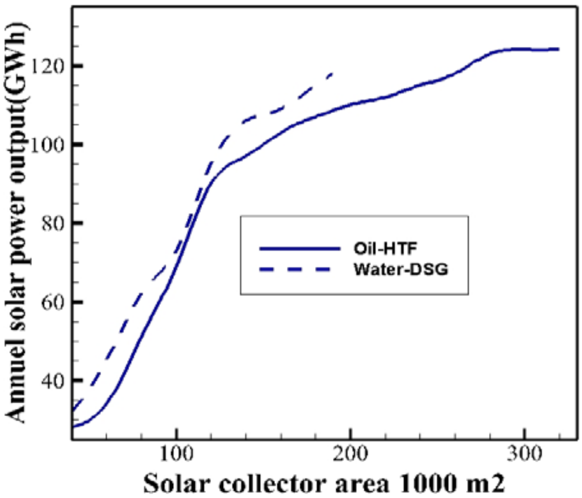

Fig. 8. The annual solar power output

The new concept DSG has high output solar thermal energy it can to reach 118GWh , but the reference HTF concept cannot to exec 114GWh in same collector area . Hence more solar collector area more solar output and more losses. Furthermore the DSG concept shows their performance in the solar efficiency.

According these simulations of the solar contribution to new DSG concept proposed, the output power increase when we preheated the last feed water (behind the boiler) from the superheated parabolic trough .Other words to heat the last feed water it mean less losses in heat and short way to feed the steam turbine . Furthermore the best way to increase efficiency are to decrease the losses.

10 Conclusion

The influence of the solar thermal on the annual performance of direct steam generation and integrated solar combined cycle system, is detailed whose system analysis has been performed .This analysis conducted to assess the efficiency of solar cycle and thermal cycle in both concepts DSG and ISCCS, each concept has their own process in power generation but the target is the best efficiency.

The DSG concept had the height efficiency after the development of new receiver. The ISCCS concept until now uses complex heat transfer system in the process while the goal of the manufacturing is the height performance .Therefore the result of this study indicated that the DSG concept in annual production is 4 % higher than the ISCCS concept with each parameter, same design and area condition of Algeria desert.

The DSG concept allowed to choose several mode extractions for solar contribution. The simulation result for solar aided power generation (SAPG) system in DSG concept, is showed that the extraction of solar thermal for to preheat the last feed water behind the boiler is the best performance in the DSG concept compared to the ISCCS concept .The efficiency of solar production is reached 29%.We conclude that the effect of solar contribution is to decrease the losses so more efficiency in solar to electric performance.

These results are a detail performance of the parabolic trough solar thermal power plants between the DSG and ISCCS. This work is not take the economic study, other word decrease the cost for this technology in future. This step is remained a critical point in the development of solar parabolic trough plant.

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