Thermodynamic and Efficiency Analysis of Solar Steam Power Plant Cycle

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Abstract- In this work, a study of solar power plant in Hassi - R'Mel, Algeria is proposed, according to the efficiency method. During this analysis the main parameters that govern the solar power plant were varied to provide the global behavior of the steam Rankine cycle system. The purpose of varying these parameters is to predict the influence of these on the overall performance of the power plant. Special attention is taken on the energy contribution of the solar field and its cyclical influence on the efficiency of the station. This study was conducted by the engineering equations solver (EES) software simulation; this software has enabled us to predict the evolution of the thermal system based on parametric calculations. The results obtained from this research show their accuracy by comparing with the theory and practice.

Keywords: Hybrid Solar-Gas Station, Steam solar power plant, parametric study, effeciency analysis, EES, Hassi r'mel.

1. Introduction

The world is experiencing major economic development. Industrial development and population growth have caused a significant increase in energy demand. This growth in demand was mainly covered by the source of fossil fuels. Other factors such as gas emissions greenhouse and environmental problems have pushed the scientific research and technological development to find new energy solutions based on the use and diversification of energy resources efficiently. Among the new resources renewable energy found that are now considered as the engine of development of new generation on the horizon for the coming decades. The development and implementation of renewable energy is essential, as these energy resources are unlimited and abundantly available. Solar energy is a clean and inexhaustible energy source. Currently solar concentration technologies, which are used to convert the incident solar energy into thermal energy, this energy is supplied for electricity generation through Rankine cycle. The latest advanced technologies open up interesting prospects for increasing the yield of the production of electricity, such as solar-gas hybrid systems makes the conjunction between the gas turbine combined cycle and solar field. The integration of solar energy in combined cycles present a very powerful advantage given the characteristics of solar energy, this yields reached up to 60% [1]. for a solar turnout defined, this technic is recently implanted worldwide. Algeria has put a special program to introduce renewable energy in the national electricity production. Based on the exploitation of solar energy in its various forms including concentrated solar power, new hybrid plants will be carried out on the horizon of 2030. The solar power plant on (SPP1) of Hassi - R'Mel is one of these projects. Several studies and research at the international level process performance combined cycle integrated by solar energy concentration, thermodynamic analysis, studies this type of cycle economically, environmental and technical. Most of these studies have demonstrated the potential and usefulness of the integration of solar energy in conventional cycles. The study of the steam cycle performance presents a necessary tool to determine weaknesses and inefficiencies due to the integration of solar energy. News articles discuss the performance of the first hybrid plant in Hassi - R'Mel from different sides, an energy and exergy based on the given operation of the hybrid plant is produced by Khalidi et.al [2], taking condition of the ambient air 35°C and 0.928 bars, with a superheated steam flow 560°C, 83 bar and 70 kg/s, the values included solar steam generated 22.5kg/s which matches the direct normal incidence equals 751W / m²; this amount expanded in the steam turbine producing 80 MW, the plant is capable of producing a net power of 160MW, 80MW from gas turbine and 80 MW from steam turbine. The solar field contribution is 14%, which is equivalent to 22MW. The thermal efficiency of the plant reached 56%, the

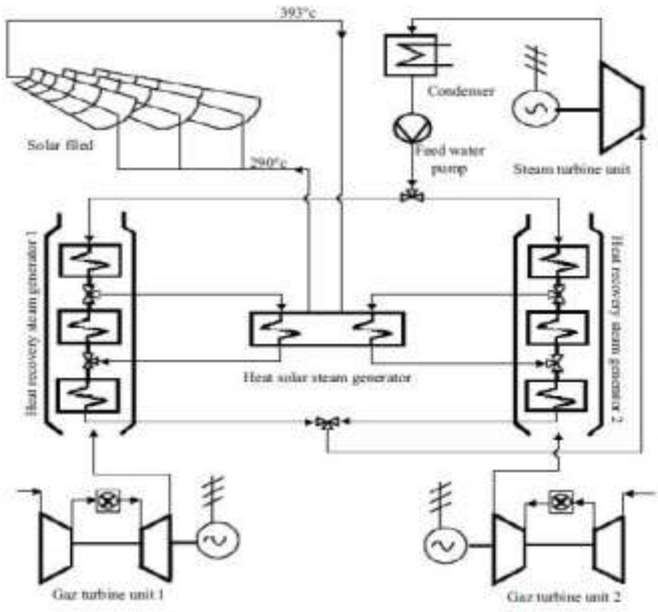

Figure 1: Block diagram of solar power plant of HassiR'mel.

thermal efficiency of combined cycle gas turbine is estimated at 35% separated from the plant. Miles et.al [3] have made an optimization of operating with solar simulation field parameters and its contribution in the combined cycle, it follows that the thermal efficiency in night mode is equal to 57%. The highest value reached is 68% in summer where the direct normal radiation is at its maximum almost 1200W/m^2[4]. Therefore, the integrated solar combined cycle system (ISCCS), capacity can reach the point of 158 MW. The increase in the solar field improves the thermal efficiency of the steam turbine where the gas turbine fuel consumption remains constant. Because of this improvement, the efficiency of the operation of ISCCS is improved. In this work, attention is paid only to the steam cycle system, it is assumed that the two gas turbine works regularly in single load, the two turbines delivers electrical power to a constant manner, steam engine cycle analysis part combined cycle. Several theoretical and experimental work are connected seeking ISCCS were presented. Most of them analysis of the various components of central mechanisms, including parabolic trough systems and combined cycle. With the construction of new hybrid plant combining solar and gas, scientific investigations concerning this type are growing. Recent papers published in international journals indicate the importance of this type of configuration of power plants. The articles analyze the concentrating solar power plant, a thermodynamic, environmental, economic and technical point of view. Some solar power plants similar to the hybrid plant SPP1 of Hassi - R'Mel are located in Morocco, Egypt, Mexico, and Iran. Optimization studies have found that the effective method of solar thermal energy integration in conventional combined cycles was to product steam at high pressure, the solar contribution may also be maximized, they indicated that the rate of annual participation in a solar hybrid plant has reached 12% greater economic benefits than the plants run by solar energy only. Dersch et.al [5] made a thermodynamic and economic investigation of solar power systems combined cycle and is presented the advantages and disadvantages of it compared with other solar energy only and conventional combined cycle. Ojo et.al [6] conducting a study of performance of solar combined cycle power plant, the plant operator has the option to compensate the variability of the solar energy with fossil fuel electricity production, to use the solar energy to save fuel and to boost the plant power output, while reducing the environmental footprint of the plant operation.

2. Description of ISCCS of Hassi r'mel

The SPP1 is the first one in Algeria, which uses solar-gas integration technology for electricity generation, located in the largest gas field of Hassi - R'Mel; Laghouat. The Solar power plant block diagram is showed in Fig. 1. The technology of parabolic trough (type LS – 3) aligned north - south pursuing the sun race east to West over two surfaces with a capacity of 25MW. Solar fields is arranged of 224 modules with six manifolds assembled in each module with 56 loops, whose total area is 183 120 m². The incident direct sunlight focused by the mirrors on a receiver located at the focal point of the parabola. The heat transfer fluid (HTF) circulating in a cycle, is a synthetic oil; Therminol the PV-1. Its physico - chemical properties are available in the reference [7,8]. Thermal energy from solar energy absorbed by the HTF is recovered by a solar steam generator (SSG), parallel to the two other heat recovery steam generator (HRSG). The SSG is an assembly of an economizer, an evaporator with a drum and a superheater. Two gas turbines (SGT 800) of 47 MW with open cycle, powered by natural gas, the residual thermal energy of the exhaust gas is recovered by two steam generators HRSG. Steam cycle, includes a steam turbine SST 900 with a maximum capacity of 80 MW at a single level of pressure. Since the area where the plant is located is arid, the air condensation system is chosen, this technic is applied to reduce water consumption to 90%[9]. There are two heat recovery exchangers HRSG, downstream of each gas turbine, each equipped with a low-pressure economizer, a low pressure evaporator, two superheaters, two burner pipe, the first is integrated behind the exhaust duct of the gas turbine to increase the temperature of the exhaust gases, the other is used to compensate the deficit of solar steam in low sunshine periods [2]. Note that the strength of this hybrid plant is the addition of the steam produced by the solar field that recovered gas turbines to power the steam turbine. The electrical power generated by the plant increases accordingly [4].

3. Modeling of the Solar Field

The total thermal power of solar radiation on the reflective surface of the solar field can be measured using the following equation:

$$\dot{Q}_g = A.\,DNI \quad (1)$$

$\dot{Q}_g$ is the global rate of heat of solar radiation on the reflective surface of the solar field (W), A is the total area of reflecting surface of the solar fields (m^2) and DNI is normal incident radiation on the collector (W/ m^2). The total power consumption of the fluid HTF is:

$$\dot{Q}_{abs} = \dot{Q}_g \,.\, \eta_{op} \quad (2)$$

$\dot{Q}_{abs}$ is the total rate of heat consumed by absorber(W) and η_{op} is the optical efficiency of the parabolic trough. Optical efficiency is defined by:

$$\eta_{op} = \rho.\,\tau_{env}.\,\alpha_{abs} \quad (3)$$

ρ is the collector surface reflectivity coefficient, τ_{env} is the transmissivity coefficient of the glass envelope and α_{ab} is the absorbitivité coefficient of absorber.

Due to thermal losses in the collector due to the phenomena of convection and radiation, the useful power will be less than that already absorbed; The thermal power gained by the HTF will be:

$$P_u = \dot{Q}_{abs} \,.\, \eta_{th.pt} \quad (4)$$

P_u is the useful power of parabolic trough (W) and $\eta_{th.pt}$ is the thermal efficiency of the parabolic trough.

Useful thermal power output of heat transfer fluid HTF transported to the SSG is calculated by:

$$\dot{Q}_{HTF} = \dot{m}_{HTF}.\,\Delta h_{HTF} \quad (5)$$

$\dot{Q}_{HTF}$ is the useful rate of heat output of HTF (W), $\dot{m}_{HTF}$ is the mass flow rate of HTF (kg/s) and Δh_{HTF} is the massic enthalpy change of HTF (kJ/kg).

$$\dot{Q}_{HTF} = \dot{m}_{HTF} \,.\, Cp_{HTF}.\,(T_i - T_o) \quad (6)$$

Cp_{HTF} is the specific heat of HTF $\left(\frac{kJ}{kg.K}\right)$, T_i is the inlet Temperture of HTF (K) and T_o is the outlet temperature of HTF (K).

The outlet temperature control HTF is effected by varying the output flow rate of HTF based on normal incident radiation per unit time, the temperature is set at 392 ° C .The yield of solar fields is defined by the following ration :

$$\eta_{sf} = \frac{\dot{Q}_{ABS}}{\dot{Q}_g} \quad (7)$$

η_{sf} is the solar field efficiency.

The solar steam generator SSG yield is:

$$\eta_{ssg} = \frac{\Delta H_w}{\dot{Q}_{HTF}} \quad (8)$$

η_{ssg} is the Solar steam generator efficiency and ΔH_w is the enthalpy change of water (kJ)

Fig. 2 shows the intensity of the direct normal incident radiation per time slot for the month of December and July. The data is taken for a 12h interval, from 06h to 18h in the morning to the afternoon,. it is observed in the month of July, the DNI begins to grow since the sunrise gradually to a maximum value of DNI 945 (W / m²) between 11h and 14h then it decreases by the change of the sun race that is longer than that of July, On the other hand, in December the intensity is the weakest of the year (477W / m²) recorded only between 12h and 14h, due to the change of the axis of earth, sun stroke is short compared to July where it is the hottest month of the year.

Fig. 3 shows that solar radiation depends on the month of the year for the months of November, December and January irradiation is minimal. The intensity of the DNI peaks in the months of May, June and July with direct normal radiation of respectively 926; 941; 945 W / m², this represented by the peak in the graph of the DNI, the incident overall energy strongly depends on the intensity of solar radiation, the total energy incident follows the same trend with variation DNI, the incident overall energy proportionally increases with the normal irradiation.

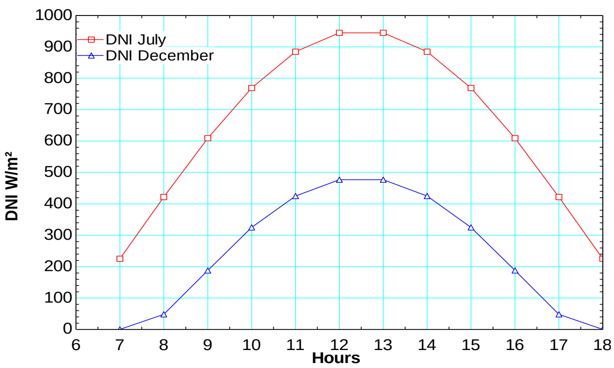

Figure 2 : Daily change of DNI For the July and december month.

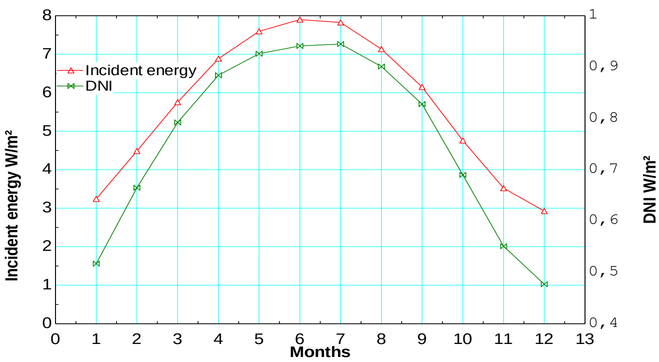

Figure 3 : Yearly change of DNI and incident energy.

From the graph of Fig 4, it is clear that the total power incident on the solar field is greater than the useful power transmitted by the heat transfer fluid (HTF), with the increase of the intensities of radiation, the output power increases in proportion to the DNI change, since the output power is the rate recovered by the heat transfer fluid (HTF) from the solar field. The two powers, absorbed and useful are linearly proportional to the DNI values. The difference between the two powers is due to the characteristics of solar concentrators and auxiliary. The solar concentrator is characterized by the thermal and optical performance that determines the effects of thermal losses due to natural phenomena such as heat transfer conduction and convection between the absorber tube and the reflective surface due to wind, therefore, heat losses are represented by the area between the two lines.

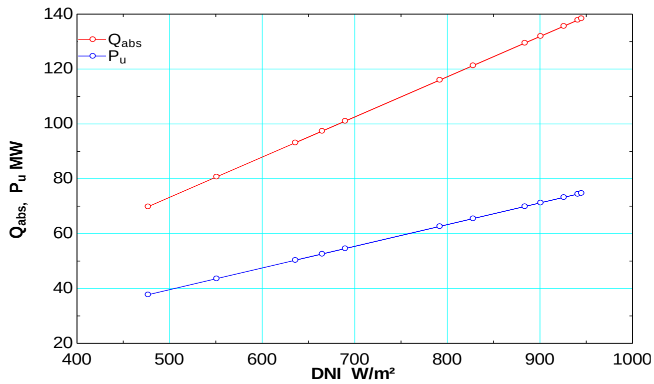

Figure 4 : Power absorbed and useful depending on DNI.

4. Thermodynamic Analysis of Power Plan Steam Cycle

It is assumed that the heat source of the steam cycle is the sum of the recovered thermal energy of the solar steam generator (SSG) and two heat recovery steam generators (HRSG), therefore, the overall thermal energy supplied to the steam generator (SG) is written:

$$\dot{Q}_T = \dot{Q}_{in} = \dot{Q}_s + \dot{Q}_{eg} \quad (9)$$

$\dot{Q}_T$ is the total rate of heat recovered from solar and gas turbine exhaust gases (W), $\dot{Q}_{in}$ is the total rate of heat supplied to the steam cycle (W), $\dot{Q}_s$ is the total rate of heat recovered from solar energy (W) and $\dot{Q}_{eg}$ is the total rate of heat recovered from gas turbine exhaust gases (W).

This amount of energy is variable depending on some factors, the daily intensity of DNI, output temperature and the mass flow rate of HTF from the solar field. It is assumed that the two gas turbines operating in steady state. So the thermal power generated at the HRSG is the same, and the performance of Rankine cycle is functions of operating parameters of the solar field and the solar steam generator that have influence on the power produced from the steam turbine. The net work produced by the cycle is determined by the following relationship:

$$\dot{W}_{net} = \dot{W}_t + \dot{W}_p \quad (10)$$

$\dot{W}_{net}$ is the total net rate of work of solar power plant (W), $\dot{W}_t$ is the turbine rate of work (W) and $\dot{W}_p$ is the pump rate of work (W).

So, thermal efficiency is :

$$\eta_{th.pp} = \frac{\dot{W}_{net}}{\dot{Q}_T} = \frac{\dot{W}_t - \dot{W}_p}{\dot{Q}_s + \dot{Q}_{eg}} \quad (11)$$

$$\dot{Q}_{eg} = \dot{m}_{eg} * \Delta h_{eg} \quad (12)$$

$\dot{m}_{eg}$ is the mass flow rate of exhaust gases (kg/s) and Δh_{eg} is the massic enthalpy change of exhaust gases (kJ/kg).

Depending on the analysis procedure ideal Rankine cycle with reheating, based on the first and second law of thermodynamics, using the power plant operating data, and using the engineering equation solver EES software, the results are presented in table 1.

From Fig. 5, the blue graph shows the Rankine cycle in real reheating, while the red graph represents the ideal Rankine cycle to reheating. Pressure levels are 8300 kPa and 13kPa. The Rankine cycle in real reheating (1 - 2 - 3 - 4 - 5 - 6 - 1), where the phase change process occur, the vaporization of liquid between the point (1) which represents the state variables at the input of steam generator with a pressure of 8300 kpa and the inlet temperature of 52°C, the pressure saturated liquid access economizer (1-2) and leaves at a temperature of 240°C and a constant pressure; the preheated liquid in the economizer is routed to the evaporator, the phase change process requires the supply of heat reaching solar fields, is that transmitted by the heat transfer fluid in (SSG) and the gas exhaust gas turbines, it is observed that the temperature change during vaporization of the liquid from $T_2 =$ 240°C to $T_3 =$ 315°C which results from irreversibilities phenomena by comparison with the ideal Rankine cycle reheating red graph, where the temperature remains constant.

Table 1: steam cycle operating parameters of solar power plant cycle.

state	P (kpa)	T (k)	h (KJ/Kg)	s (KJ/ Kg.K)	v (m^3/Kg)
1	8300	325	224.2	0.723	0.001
1_{REV}	8300	325	220.5	0.716	0.001
2	8300	513	1037	2.689	0.0012
3	8300	602	2900	5.973	0.026
4	8300	833	3518	6.887	0.044
5	13	325	2347	7.293	10.29
5_{REV}	13	325	2214	6.887	9.63
6	13	324.2	213.7	0.716	0.0010

The produced steam is fed to a superheater to maximize the inlet temperature of the turbine, to avoid low quality of steam to the turbine outlet (point 5 on the graph); the steam is superheated to the temperature of 560°C, which will be channeled with tubing to the inlet of the steam turbine (point 4), the steam expanded in the turbine and discharged to condenser pressure 13kPa and temperature of 52°C with steam quality (point 5) equal to 0.89 (89%), the wet steam enters condenser (13 kPa; 52°C), eliminating a portion of heat to the outside until one gets the saturated liquid in (point 6). the difference between the actual and ideal cycle is mainly due to the existence of irreversibilities in each element of the system. Irreversibility in the steam generator and condenser manifest as heat transfer, the irreversibilities in the pump appears as friction and compression, in the turbine side, they are characterized by mechanical friction between the bearings and the rotor and the heat transfer between the steam and the turbine blades.

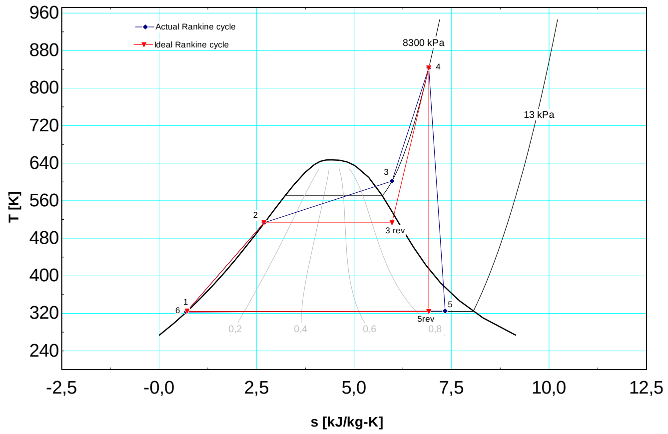

Figure 5 : (T, s) diagram of ideal and actual of Rankine cycle with over heat.

According to the second principle of the thermodynamics, the rate of generated entropy becomes important in the heat transfer process, therefore, the vaporization process (1-4) and condensation one (5-6) presented in the graph are the main steps of entropy changes. Irreversibilities are interpreted by entropy changes, the higher the irreversibilities important is entropy change [10].

(h, P) Diagram in Fig. 6 gives another point of view of cycle, the diagram (T s) performs the cycle in terms of temperature, while, the(h, P) diagram show the cycle in terms of energy. The exchange energy as heat between (1 -4) and (5-6) are significant compared to (4-5). The energy supplied to the phase change for vaporization Δh (4-5) or condensation Δh (6-1) is higher compared to the established operating conditions. Since the work of the pump is negligible compared to that of the turbine, therefore, points (6) and (1) appeared to be mingled.

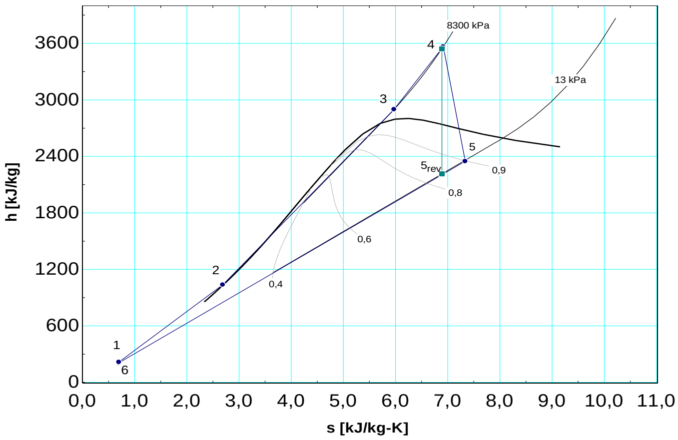

Figure 6: (h, s) diagram of actual Rankine cycle.

From the graph of Fig.7, every time whene the temperature and pressure is increased in the steam generator, the overall performance of the station increases, it follows directly from the first law of thermodynamics and the definition of thermal efficiency which is expressed by the ratio of Q_{1-4} , and Q_{5-6} and heat For different turbine inlet temperature values. By increasing the pressure the implications steam generator of temperature rise, therefore, the thermal efficiency of the cycle becomes large. The pressure of 83 bar is optimal in this case to ensure the operation of the plant without disturbance and maximize the life of the plant. But, unfortunately, it is not possible to raise the pressure at 150 bar, due to technical and security considerations as the material strength limit that can withstand high pressures and temperatures.

By setting the turbine inlet temperature and keeping at the same time the operating conditions, it is seen from Fig. 8 that the heat required by the steam generator depends inversely with the pressure P_1 of the steam generator, the heat input becomes minimum at the highest steam generator pressures.

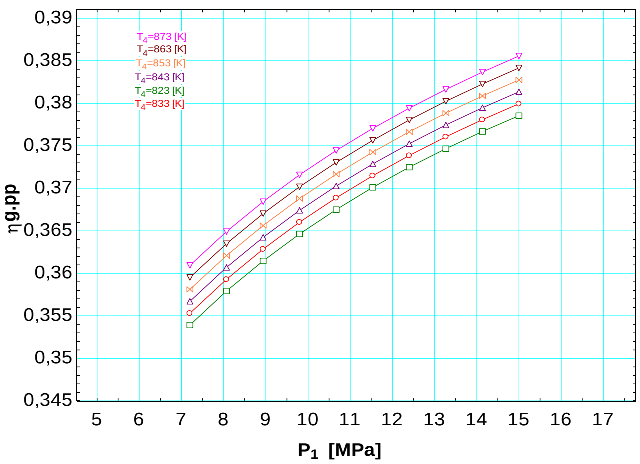

Figure 7: the change in global efficiency of power plant depending on HRSG pressure for different temperatures values of the turbine inlet.

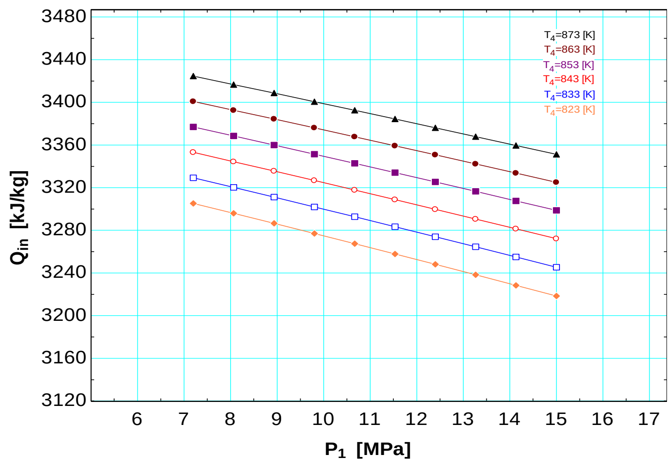

Figure 8: change in rate of heat supplied Q_{IN} depending in pressure change P_1 with different temperaures inlet values T_4.

According to the Fig. 9 graph, it is found that the quality of steam at the turbine outlet decreases with increasing pressure inside the steam generator, it is seen that the steam expansion process is skewed to the left until the pressure P_1 rises all keeping the inlet turbine temperature constant, the same for T_4 reheating temperature can observe that for higher temperatures, the quality of steam will be important for a set pressure, according to the results of the operating conditions of the plant. The quality of steam at the turbine output pressure of 83bar and T_4 = 560C ° is evaluated in this case at 0.89 (89%). This result coincides with the operating standards of the majority of thermal power plants [11].

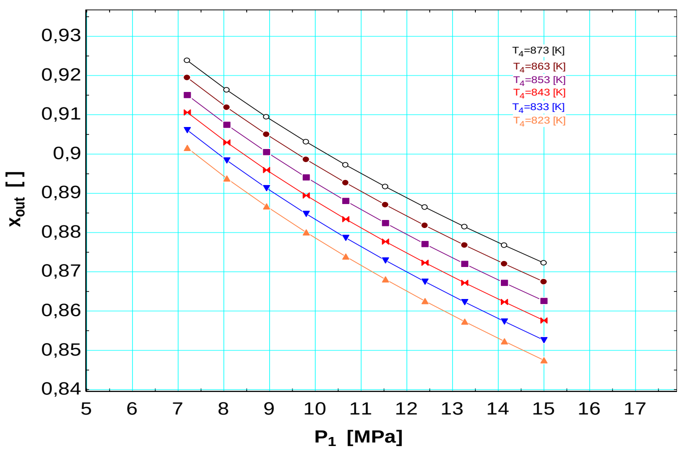

Figure 9: Effect of pressure change of the HRSG depending in steam quality at turbine outlet.

According to Fig. 10, the net work product increases with pressure, the linear dependence between the two can be translated by the area change [6 - 1 - 4 - 5 - 6], with higher temperatures turbine inlet, net working values obtained are greater, This has a direct influence on the thermal efficiency of the cycle, and from the thermodynamic point of view, the net work represents the difference between the heat supplied and rejected and since performance is the relation between what it is recovered and what was spent therefore, the greater the net work, important is the thermal efficiency.

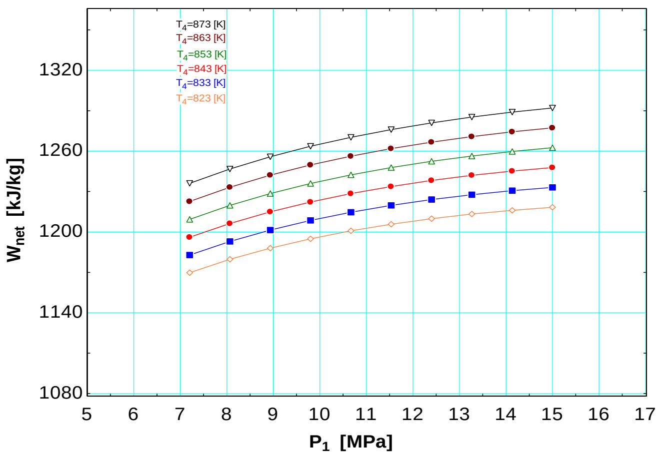

Figure 10 : Net work depending on P_1 HRSG pressure.

Note from Fig. 11, that at a constant temperature, the heat in the condenser is proportional to the condenser pressure. The condensation temperature associated directly with the cooling medium saturation pressure which transmitted the thermal energy released outside the plant, there are limitations to applications condensing pressures. The pressure must not be less than the saturation pressure corresponding to the coolant temperature.

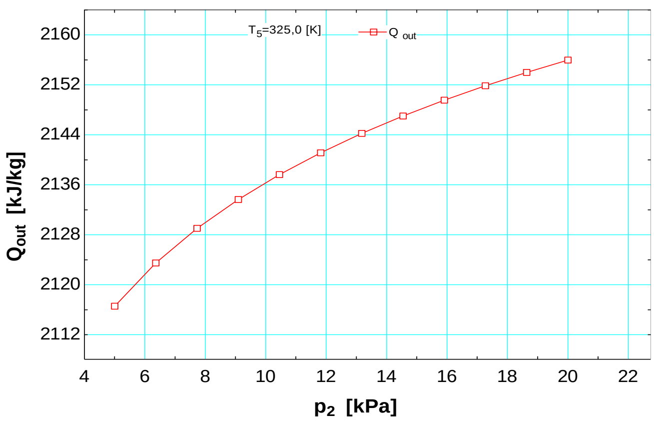

Figure 11: Condensation pressure influence on the heat rejected Q_{out}.

From Fig .12, the thermal efficiency of the plant is inversely proportional to the pressure in the condenser, this coincides with the return of the definition according to the first law of thermodynamics, more pressure is minimal in the condenser, more the cycle efficiency is maximum. The efficiency of a system depends on the temperature of the heat source when the plant operates, the condenser temperature influences the yield, the Carnot efficiency is higher when temperature is minimal, in the irreversible process it will ever work with process isothermal, and more recent technology used helps keep the minimum pressure levels corresponding to optimum condensing temperatures to minimize thermal regeneration steps.

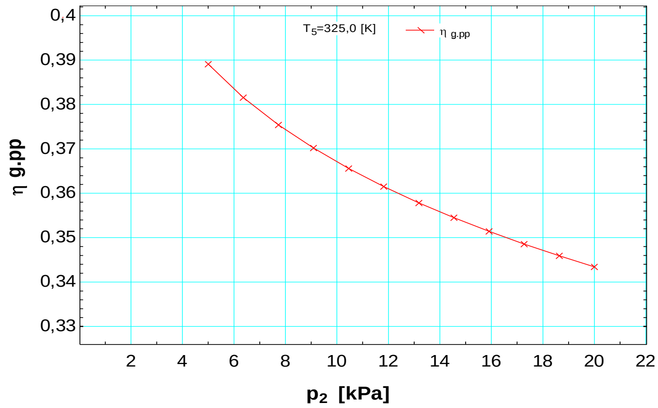

Figure 12: Effect of condenseur pressure change On power plant global efficiency.

5. Effeciency Analysis

The efficiency of carnot engine is :

$$\eta_{th.C} = 1 - \frac{T_c}{T_h} \quad (13)$$

$\eta_{th.C}$ is the thermal efficiency of Carnot engine and T_c, T_h are temperatures of cold and hot reservoires.

The thermal efficiency of all thermal engine is :

$$\eta_{th} = 1 - \frac{Q_c}{Q_h} \quad (14)$$

η_{th} is the thermal efficiency of all thermal engine and Q_c, Q_h are heats of cold and hot reservoires

Isentropic efficiency of turbine is:

$$\eta_{rev,t} = \frac{h_4 - h_5}{h_4 - h_{5,rev}} \quad (15)$$

$\eta_{rev,t}$ is the isentropic or reversible efficiency of turbine and h is the massic enthalpy in differents points see fig 4.

Isentropic efficiency of pump is:

$$\eta_{rev,p} = \frac{h_{1,rev} - h_6}{h_1 - h_6} \quad (16)$$

$\eta_{rev,p}$: Isentropic efficiency of pump and h is the massic enthalpy in differents points of Fig4.

Reversible work of cycle is :

$$W_{rev} = (h_4 - h_{5,rev}) - (h_{1,rev} - h_6) \quad (17)$$

W_{rev} is the ideal or reversible work.

Actuel work of cycle is:

$$W_{irr} = (h_4 - h_5) - (h_1 - h_6) \quad (18)$$

W_{irr} is the actual or irreversible work.

Thermal efficiency of the second law is:

$$\eta_{II} = \frac{W_{rev}}{W_{irr}} \quad (19)$$

Absolute efficiency of cycle is :

$$\eta_a = \eta_{th} \cdot \eta_{II} \quad (20)$$

Mechanical work of turbine :

$$W_{m.t} = \eta_m \cdot W_{rev\ t} \quad (21)$$

$W_{m.t}$ is the mechanical work of steam turbine (kJ) and η_m is the mechanical efficiency of steam turbine.

Global efficiency is :

$$\eta_{g.pp} = \frac{W_e}{Q_{in}} \quad (22)$$

$\eta_{g.pp}$ is the global efficiency of power plant, W_e is the electrical work of electric generator (kJ) and Q_{in} is the total heat supplied to the steam cycle (kJ).

Performance of the electric generator is :

$$\eta_{g.e} = \frac{W_e}{W_{m.t}} \quad (23)$$

$\eta_{g.e}$ is the performance of the electric generator.

6. Grassmann Diagram

The Fig. 13 above shows the Grassmann diagram. This diagram schematically a summary view of an energy system by showing the gains and losses in differents plant organs. In our case the most losses are localized to the condenser, in reality these losses are unavoidable because for a heat engine work product must inevitably lose energy (principle of Clausius). But obviously, heat transfer techniques can improve to minimize losses in the latter. Grassmann diagram shows that losses occurred in the steam generator, losses are estimated at 9%, as it designed with a very high efficiency. The energy lost in the pipes is very low because of advanced insulation techniques. Similarly electrical losses at the generator is very low. Finally the overall gain withdrawn from this station is estimated around 35%.

7. Conclusion

The combined cycles with the integration of solar energy for the electricity generation process are the more efficient and are the most effective method from a thermodynamic point of view, the exploitation of thermal energy recovered from solar fields, exactly from heat transfer fluid is used to generate steam, in order to maximize the power produced by the steam turbine cycle. The combination of the two forms of energy, the product of exhaust gas by the gas turbines, and heat transmitted from sun to the HTF is in scientific research stage to maximize efficiency combined cycle ISCCS and make these last competitive with conventional cycles. Analysis of solar fields parameters shows that the thermal power resulting from solar fields depends on direct normal irradiation, so the power produced by the combined cycle varies in same trend with the DNI, because the useful thermal power transmitted by the heat transfer fluid at the output of solar fields is strongly related to the change of DNI, in the practical case of the hybrid power plant of Hassi R'Mel, the electric power becomes maximum in the sunny days of June and July when the DNI reached its maximum, 941W/m² and 945W/m² respectively. The relationship of the electric power produced and the mass flow of the steam is linearly dependent on the thermal power delivered by the

HTF in the solar steam generator SSG, the thermal power transmitted by the fluid depends on some factors, such as, the solar field characteristic, daily DNI values, climatic conditions. The power provides from this combined cycle is 134MW in the night mode with a yield of 57%**.** During the day, solar energy can be converted into electricity with higher efficiency than combined cycle mode due to the most efficient method to convert solar thermal energy into electrical energy, the mode of operation ISCCS raises the capacity of the system to 158 MW and efficiency at 68%. Increasing the conventional combined cycle steam turbine capacity is a further advantage of the integration of solar energy, electric power of combined cycle remains constant. Solar electric power reach 24 MW and then decreases. For the steam cycle performance, different scenarios have been applied of operation of the reheating Rankine cycle, it was seen that the influence of the steam generator pressure on the thermal efficiency of the cycle (0.35 - 0.39) to pressures between (70 - 150 bar), net work increases also in other hand the steam quality decreases with increasing pressure, the pressure is applied in selected HRSG of the hybrid power plant is maintained to meet certain technical considerations and to straighten the pressures drops in the various cycle components. From the results obtained it is deduced that the condenser pressure of cycle plays an important role in the overall performance of the cycle, at low pressures in the condenser it will have the highest thermal efficiency. In general, the solar power plant integrated in the thermal power plant powered by fossil energy are recent technologies and solar energy conversion into electrical energy studies are growing to minimize thermal losses in solar fields and steam generators.

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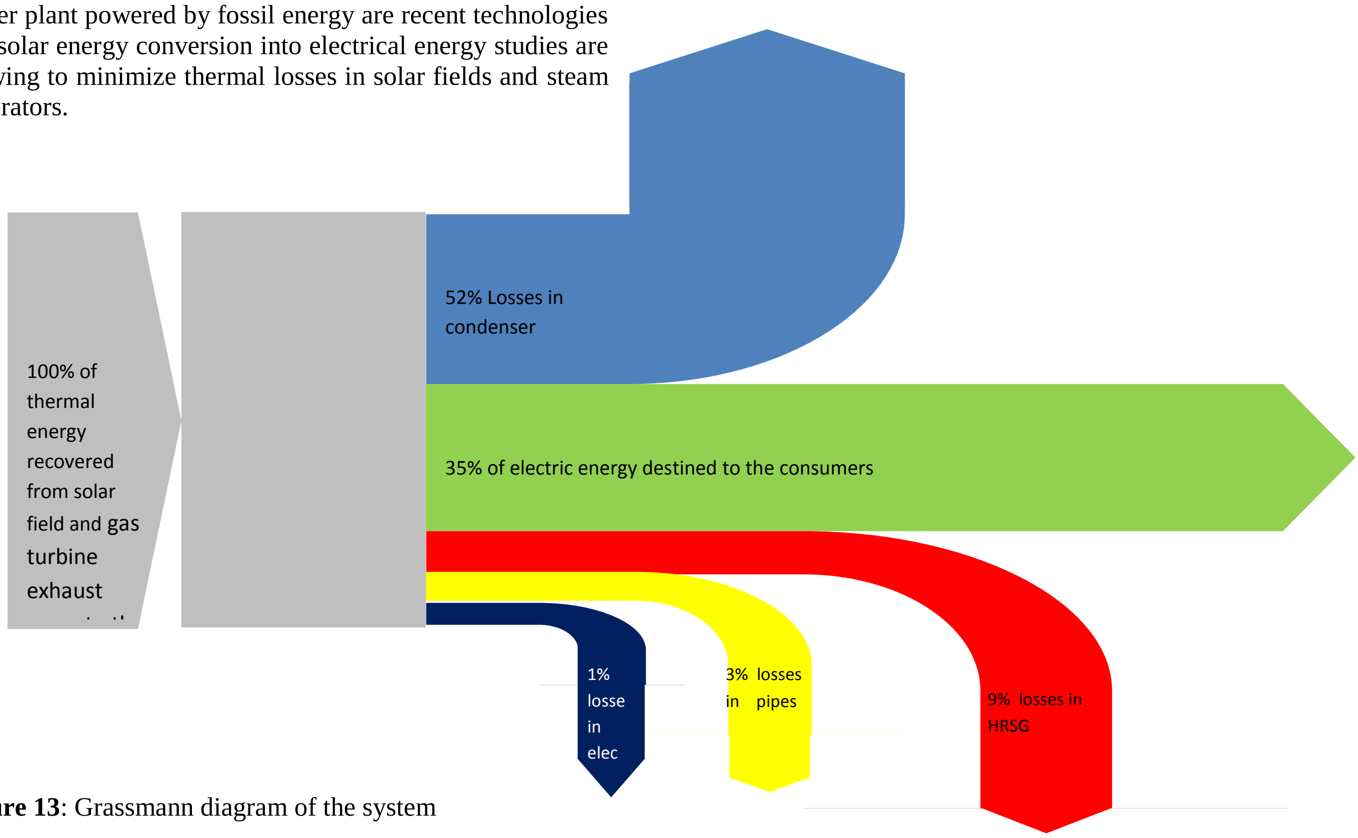

Figure 13: Grassmann diagram of the system

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