Analysis of Energy and Exergy and Modeling of Thermal Water Desalination Coupled with Combined Cycle and Solar Power Plant in Hot and Humid Regions

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Abstract:

In this study, firstly, A Multiple Effect Distillation (*MED*) thermal water heater system equipped with a thermo-compressor was selected as the most suitable and ideal system and was coupled and modeled in the Thermoflow software to the "Chabahar Port" power plant with the design conditions of an ambient temperature of 40 °C to provide and solve the problem of water shortage. Then, utilizing the potential and radiation capacity of the sun in the region, a solar farm was added to the system and modeled in Thermoflow software. For this selected system, analysis of energy and exergy had been studied. The results in the model made with the integration of the desalination system showed that by using solar energy, the power of the power plant was improved by 5.2 MW compared to the cycle without collector and it increased from 416.8MW to 422 MW. In other words, by using the solar energy potential in "Chabahar Port", in addition to fully utilizing the desalination system and daily supply of 4482 m^3 of water, the power of the power plant has also increased by 2 MW given the amount of electrical energy consumption in the hot days of the year.

Keywords: Thermal desalination system, Solar collector, Combined cycle power plant, Thermoflow

1. Introduction

Water and energy are one of the significant and vital resources for every life. Shortage of water and energy has always been one of the concerns of people, due to the significant increase and growth of the population, changes in lifestyle and living standards, environmental pollution, climate changes, and rapid development of the agricultural and industrial sectors [1]. Separating impurities and salt from salty water and converting it into drinking water has been one of the most promising solutions to solve the problem and challenge of drinking water shortage in the world [2]. Therefore, in recent decade, more and more attention has been paid to water desalination systems. Sadri et al. [3] investigated the optimization of a multi-effect desalination (*MED*) system with thermal vapor compression (*TVC*) system in Qeshm Island by using a genetic algorithm with the aim of increasing efficiency and performance and obtained favorable results such as increasing the coefficient of performance and reducing the level of heat transfer. Heck et al. [4] studied seawater desalination and its impacts on marine ecosystems in California. Ghorbani et al. [5] developed an integrated structure of cogeneration and freshwater production for residential complexes usage in the industrial town of Assaluyeh, in the south of Iran. Exergy analysis shows that the highest amount of exergy destruction on a specific day of the year, the percentage of the destructed exergy from the input exergy flow, occurs in the solar flat collectors and the auxiliary boiler, 54.72%, 21.89%, respectively. Junior et al. [6] studied on climate impact on combined cycle thermoelectric power plants in hot and humid regions. In their results, a strong correlation was between generation and the wet bulb temperature.

Due to the threat of running out of fossil fuels on the one hand and environmental pollution caused by fuel consumption and energy production, the need to increase efficiency in line with less fuel consumption is inevitable. Therefore, any solution that leads to the reduction of fuel consumption is considered by the industrialists. One of these solutions is the use of multiple production cycles. Over the years, intensive and extensive researches have been carried out by researchers on various types of desalination systems, connecting various types of water softeners with combined cycle power plants in dual systems with the aim of producing power and water. which is mostly in the field of connecting thermal water softeners to combined cycle power plants and less studies have been done regarding the use of solar energy alongside the combined cycle power plant at the same time for water softener systems. Hanafi et al. [7] theoretically studied a combined cycle power plant equipped with the *MED-TVC* desalination system from a thermo-economic point of view, and by developing a mathematical model, they analyzed the considered system separately and simultaneously produced in different operating conditions. Catrini et al. [8] investigated the thermo-economic costs of a combined cycle equipped with the *MED* thermal water softener system using the analysis of its exergy level. Their study showed that exergy analysis provides a principled method and a logical criterion for determining and allocating costs in dual simultaneous systems to produce power and water.

Nowadays, due to the high demand for water and energy production and the reduction of the carbon footprint, the integration of desalination systems using renewable energies is being considered and developed [9-12]. In addition, some researchers have carried out energy and exergy analysis of coupled solar power plants and thermal water desalination. Mibarki et al. [13] numerically investigated energy and exergy analysis of solar air gap membrane distillation (AGMD). The results indicated that the thermal and exergetic efficiency of the entire solar AGMD system decreases along with the rise of ambient temperature. It has become a significant solution in the countries of the Middle East region and the Persian Gulf. Shakib et al. [14] simulated coupled multi-effect evaporation thermal vapor compression desalination (*MED-TVC*) and gas turbine plant through a heat recovery steam generator. Emamdoost et al. [15] demonstrated a significant influence on increase in productivity and reduction of utility consumption of thermal desalination, considering a novel internally coupled multiple-effect distillation and reverse osmosis desalination process in a cogeneration of water and power plant.

Despite various researches carried out to optimization and exergy analysis of power plants or thermal desalination units, there is still a lack of studies on the evaluation of energy and exergy analysis of thermal water desalination coupled with combined cycle and solar power plant, especially in hot and humid regions.

In this study, At first, The combined cycle power plant of Chabahar city was simulated in Thermoflow software. Then, for providing drinking water to Chabahar City, A *MED* system (thermal water softener) was modeled and investigated at an ambient temperature of 40 degrees, after that, with the increase in the power and efficiency of the power plant, the *MED* system equipped with a thermocompressor (condensation of thermal steam) coupled to the desired model and was subjected to thermodynamic investigation. taking into account the location and potential and conditions of the sun's radiation in Chabahar city, the idea of designing and adding a solar farm of the type of linear parabolic collector to the power plant is simulated in Thermoflex software and to investigate the effect of the sun's radiant energy on power and efficiency. The power plant and its effect on the performance of the water-desalination system were investigated.

Chabahar combined cycle power plant has a nominal capacity of about 480 MW, which includes two V94.2 gas turbines, each with a capacity of 160 MW, and one vapor turbine with a capacity of 160 MW. The current fuel of this power plant is liquid. Given the problems of drinking water supply in the southern regions of Iran, especially in Chabahar City, this study was conducted to analyze a combined cycle power plant in Chabahar port with a thermal water desalination system. It also analyzes the whole system thermodynamically given the energy potential of solar radiation in this City by designing a solar farm and adding it to the combined cycle power plant integrated with the thermal water desalination system.

2. Energy and exergy equations for combined cycle power plant

For different parts of a power plant cycle, energy and exergy equilibrium are expressed in the form of the following equations separately.

The equation of the exergy rate of the work done in the air compressor [16]:

$$\dot{E}_{Wc} = \dot{w}_c = \sum_{out} \dot{m}_{ex} - \sum_{in} \dot{m}_{ex} - T_0 \dot{S}_{gen.c} \qquad (1)$$

Where $\dot{E}_{Wc}, \dot{m}, \dot{w}_c, ex, T_0$ and $\dot{S}_{gen.c}$ are the exergy rate, mass rate, power, specific exergy, reference temperature and entropy rate respectively.

The equation of the exergy destruction rate in the air compressor [16]:

$$\dot{E}_{Dc} = \dot{m}_{air}\left[h_1 - h_2 - T_0\left(S_1 - S_2\right)\right] - \dot{W}_c \qquad (2)$$

where *h* is the enthalpy.

The equation of the exergy rate of the work done in the gas turbine[16]:

$$\dot{E}_{WT} = \dot{W}_T = \sum_{in} \dot{m}_{ex} - \sum_{out} \dot{m}_{ex} - T_0 \dot{S}_{gen.tur} \qquad (3)$$

The equation of the exergy destruction rate in a gas turbine [17]:

$$\dot{E}_{DTur} = \sum_{in} \dot{m}_{ex} - \sum_{out} \dot{m}_{ex} - \dot{w}_{Tur} \quad (4)$$

The equation for the exergy rate of work done in a vapor turbine [17]:

$$\dot{E}_{WST} = \dot{W}_T = \sum_{in} \dot{m}_{ex} - \sum_{out} \dot{m}_{ex} - T_0 \dot{S}_{gen.tur} \quad (5)$$

The equation of the exergy destruction rate in the vapor turbine unit [17]:

$$\dot{E}_{DST} = \sum_{in} \dot{m}_g\, ex - \sum_{out} \dot{m}_g\, ex - \sum_{out} \dot{m}_w\, ex + \sum_{in} \dot{m}_w\, ex \quad (6)$$

The equation of exergy destruction rate in power plant condenser [18]:

$$\dot{E}_{D\,con} = \sum_{in} \dot{m}ex - \sum_{out} \dot{m}ex \quad (7)$$

- *MED* thermal water desalination:
The temperature difference of the adjacent stages in the water desalination system is the same and is obtained based on the following equation [19]:

$$\Delta T = T_1 - T_2 = T_2 - T_3 = \cdots = T_{n-1} - T_n \quad (8)$$

If we consider the temperature of the first stage of the water desalination as T_s and the temperature of the last stage as T_n, the temperature difference between the stages is obtained from the following equation [19]:

$$\Delta T = \frac{T_s - T_n}{n-1} \quad (9)$$

The sea feed water (F) in all stages of the desalination system is the same as the value F_i, which is obtained according to the following equation [19]:

$$F_i = \frac{F}{n} \qquad i = 1, 2, 3, \cdots n \quad (10)$$

The latent heat of water vapor in each stage of the water desalination system is obtained from the following equation [19]:

$$\lambda_i = 2589.583 + 0.9156 \mathrm{T}_i - 4.834 \times 10^{-2} T_i^2 \quad (11)$$

In the above equation, λ_i is the latent heat of vapor in each stage in kj/kg and T_i is the temperature in each stage in ${}^0C$.

The energy balance of the vapor produced for the boiling of salt water in the first stage of the desalination system is as follows [19]:

$$D_1 = \frac{\left(D_m + D_{ev}\right)\lambda_s - F_1 c_p (T_1 - T_f)}{\lambda_1} \tag{12}$$

In the above equation, D_m is driving vapor, D_{ev} is suction vapor, λ_s is the latent heat of evaporation at a temperature T_s, and c_p is the heat capacity of water.

The equation of output salt water mass residual of the first stage of the desalination system is expressed as follows [19]:

$$X_{b1} = \frac{F_1}{\left(F_1 - D_1\right)} X_f \tag{13}$$

In the above equation, X_f is the salt concentration in ppm.

From the second stage onwards (up to stage n-1), due to the presence of flushing boxes, the saturation temperature for each stage in the water desalination system is obtained using the following equation [20]:

$$T_{v_i} = T_i - BPE - NEA \tag{14}$$

In the above equation, NEA is the efficiency of the flushing process in the flushing boxes, which is obtained using the following equation [20]:

$$NEA_i = \frac{33\left(T_{i-1} - T_i\right)^{0.55}}{T_{v_i}} \qquad i = 2, 3, \cdots n \tag{15}$$

The amount of vapor obtained from the condensed fluid in the flushing process in the flush boxes is calculated using the following equation [20]:

$$y_i = \frac{C(\Delta T)}{\lambda_i} \tag{16}$$

where C is the heat capacity.

The energy balance of the vapor produced from the third stage onwards in the water desalination system is expressed in the form of the following equation [20]:

$$D_i = \frac{(D_{i-1}\lambda_{i-1} + d_{i-1}\lambda_{i-1} + d'_{i-1}\,\lambda'_{i-1}) - F_i c_p (T_i - T_f) + B_{i-1} c_p \left(T_{i-1} - T_i\right)}{\lambda_i} \qquad i = 3, 4, \cdots n \tag{17}$$

The equation for the amount of freshwater produced (total water produced in each stage) [20]:

$$M_d = \sum_{i=1}^{n} D_i \qquad i = 1, 2, 3, \cdots n \tag{18}$$

Investigating the exergy of the water desalination system equipped with a thermo-compressor:

The exergy of produced (fresh) water can be defined as follows based on the minimum theoretical work required for salt separation in the water desalination process [20]:

$$\dot{E}_{fresh} = \dot{N}_{fresh} \times \phi \times R_u T_0 X_{s.feed} \tag{19}$$

In the above equation, $\dot{N}_{fresh}$ is the molar flow rate of freshwater, ϕ is the separation coefficient of salts, R_u is the global gas constant, $X_{s.feed}$ is the molar fraction of non-dissolved salts.

The molar flow rate of freshwater is obtained by the following equation [20]:

$$\dot{N}_{fresh} = \frac{\dot{m}_{fresh}}{MM_{water}} \tag{20}$$

In the above equation, $\dot{m}_{fresh}$ is the mass flow rate of freshwater MM_{water} is the molar weight of water and is equal to 18 kg/mol.

The output salt water along with the wastewater disposed in the desalination system is useless. Also, the flow of input sea water is free. Thus, the exergy efficiency of the water desalination system can be defined based on the fuels, i.e., the necessary electricity flow, driving vapor, and the products, i.e., freshwater, and it is obtained using the following relationship [20]:

$$\eta_{ex} = \frac{\dot{E}_{fresh}}{E\dot{X}_s + \dot{W}_{MED/TVC}} \tag{21}$$

In the above equation, $E\dot{X}_s$ is the exergy of the driving vapor, $\dot{W}_{MED/TVC}$ is the consumed power (electrical energy).

Exergy of driving vapor is obtained using the following equation [20]:

$$E\dot{X}_s = \dot{m}_s \times \left[\left(h_s - h_0 \right) - T_0 \times \left(s_s - s_0 \right) \right] \tag{22}$$

In the above equation, $\dot{m}_s$ is the mass flow rate of the driving vapor and h_s is the enthalpy of the driving vapor.

Exergy loss per total mass flow of water produced for the system in question is obtained using the following equation [20]:

$$SED = \frac{E\dot{X}_s + \dot{W}_{MED/TVC} - \dot{E}_{fersh}}{D} \quad (23)$$

-Solar collector equation:

The production power and the energy used by the collectors are obtained based on the following equations [21]:

$$Q_s = N \times A_C \times DNI \quad (24)$$

In the above equation, Q_s is the production power or energy reached the surface of the collectors, N is the number of collectors, A_C is the cross-sectional area of the collectors, and DNI is the intensity of direct solar radiation to the collectors.

In a steady state, the energy used by the collectors is obtained using the following equation [21]:

$$Q_u = Q_a - Q_l \quad (25)$$

In the above equation, Q_u is the useful energy used by the collectors, Q_a is the energy absorbed by the absorber, and Q_l is the lost energy in the absorber.

The optical efficiency of the collectors is obtained using the following equation [22]:

$$\lambda = \frac{Q_a}{Q_s} \quad (26)$$

Where λ is the optical efficiency of the collectors, and Q_s is the production power or the energy reached the surface of the collectors.

The energy lost from the collectors is obtained using the following equation [22]:

$$Q_l = Q_{lk} + Q_{lc} + Q_{la} \quad (27)$$

In the above equation, Q_l is the lost energy in the collector absorber, Q_{lk} is the lost energy through conduction, Q_{lc} is the lost energy in the collector opening, and Q_{la} is the lost radiant energy in the absorber opening.

3. Numerical simulation

3.1 Modeling the integration of the MED desalination system into the Chabahar combined cycle power plant:

Chabahar power plant was modeled considering the conditions of power plant design, i.e. ambient temperature of 40 degrees Celsius, rated capacity of 480 MW, sea level height, and humidity of 60%.

A *MED* water desalination system of parallel feeding type, which includes 2 primary parts of condenser, and some evaporators, was integrated and simulated in a Chabahar combined cycle power plant with an ambient temperature of 40 °C. The vapor required for this system is taken from the flow rate of the low-pressure feed line of the vapor turbine.

Considering the purpose of this study, which is reducing energy consumption and increasing the efficiency of the water desalination system, the best place for vapor extraction for the water desalination with a thermo-compressor (low-pressure feed line of vapor turbine) was selected this place was used to provide thermal energy in simulations and all modeling. The integrated model of the power plant with details is shown in Fig.1. In this figure, *LP* and *HP* are low-pressure and high-pressure respectively. A *MED* thermal water desalination system was coupled in Chabahar combined cycle power plant at a temperature of 40 °C, and the simulated model is shown in Fig.2. Assumptions in this process are as follows:

1- Feed water was considered as parallel feed in all stages.
2- Lost heat was omitted in each stage.
3- Fresh vapor was considered salt-free in each stage.
4- The pressure drop inside the tube was neglected.
5- The temperature difference ΔT in each stage was considered 4.75 °C.
6- The system was considered stable.

Also, The considered parameters for the water desalination system are inspired by the data of the thermal water desalination, which are listed in Table 1. These parameters have been used in modeling considering the environmental conditions of Chabahar.

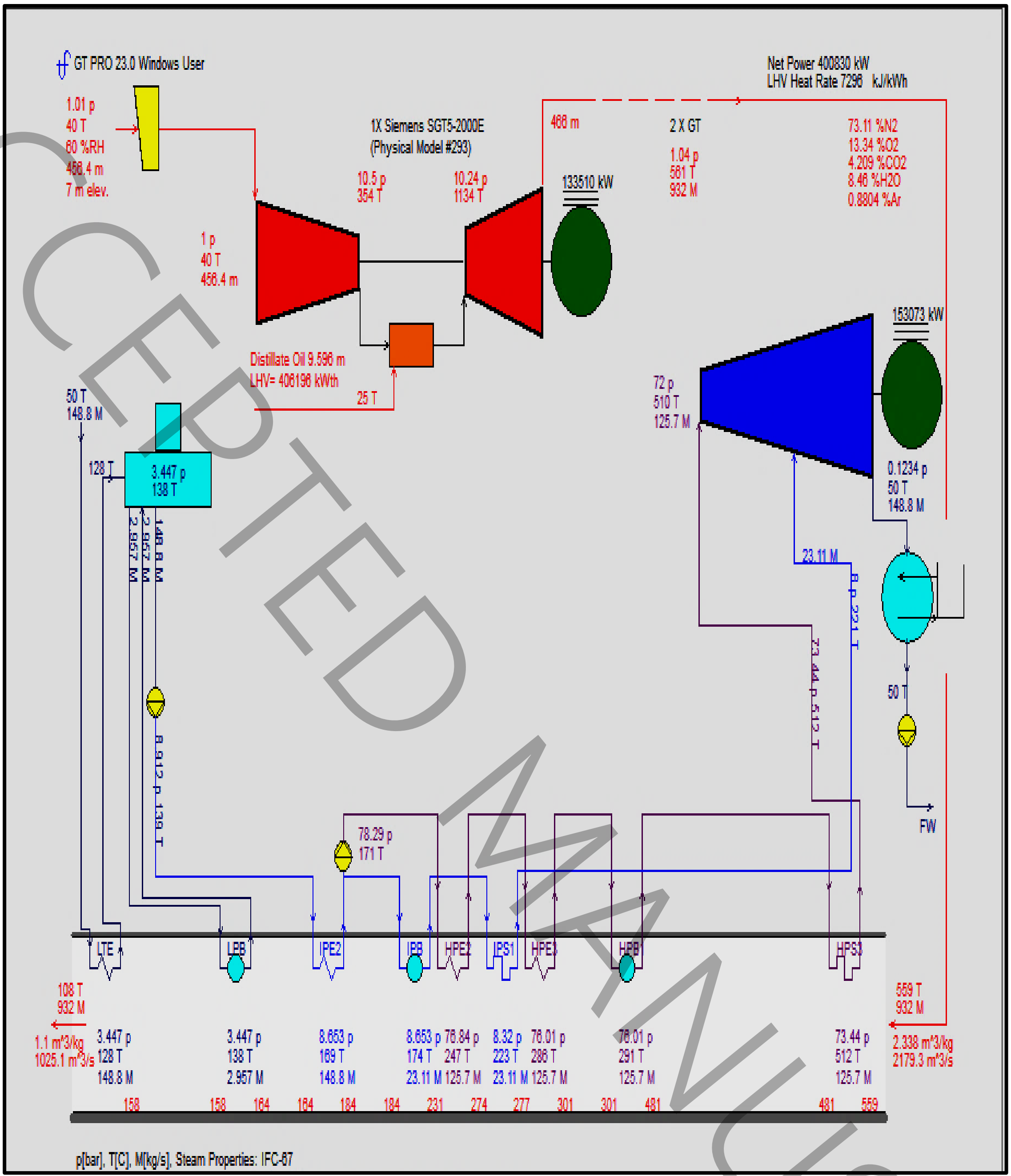


Fig.1- The integrated model of the power plant with details

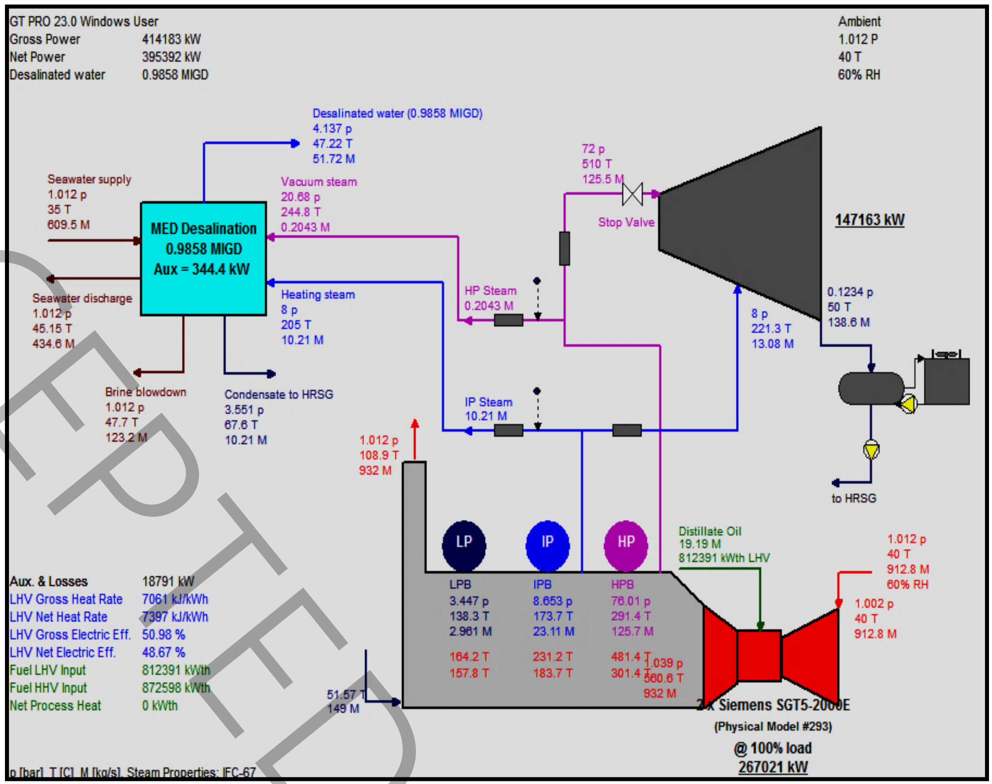


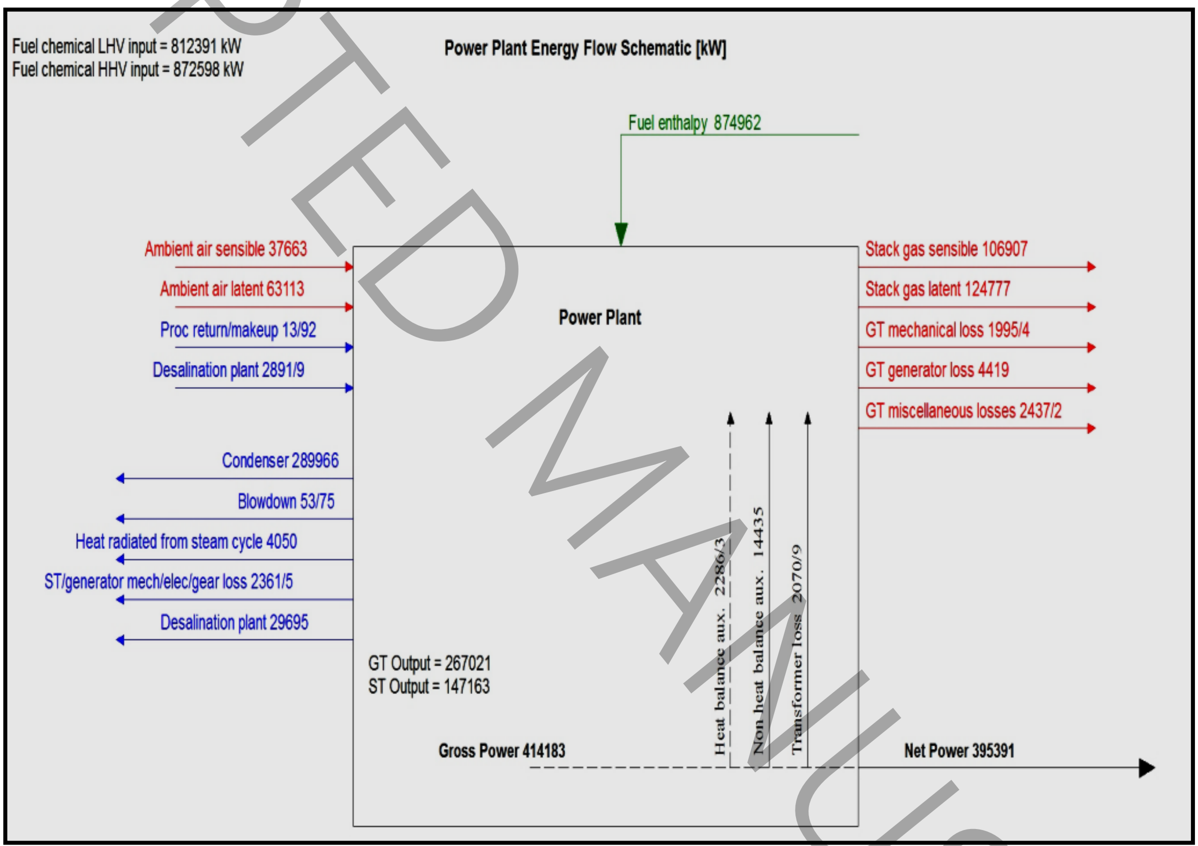
Fig.2- The output of the integrated model of the power plant with the MED desalination system in the design conditions of the ambient temperature of 40 °C

Table 1: Parameters considered for modeling and integration of thermal water desalination with power plant

Parameter	Value	Unit of measurement
The temperature of the seawater entering the condenser	35	˚C
Steam source for heating	Low-pressure feed line of steam turbine	-
Steam source to create a vacuum	High-pressure feed line of steam turbine	-
Heating steam temperature	205	˚C
Heating steam pressure	8	bar
The concentration or salinity percentage of the incoming feed water	35000	ppm
The concentration or salinity percentage of the effluent	49700	ppm
Salinity ratio	1.42	-
The percentage of vacuum steam to heating steam	2	%
TTD of condenser	2	˚C
Saturated steam temperature of the first stage	67.5	˚C
Evaporation temperature of the last stage	48.7	˚C
Number of MED stages	5	-
The maximum capacity considered for the MED system	4500	m^3/day

Diagrammatic analysis of energy and exergy model of desalination integrated into the power plant:

Fig.3 shows the diagram and distribution of energy flow in different parts of the power plant integrated with the *MED* desalination system in the design conditions of the ambient temperature of 40 °C in Chabahar City. The maximum thermal energy lost in the cooling tower of the primary condenser and the chimney of the power plant is about 29.63% and 23.67%, respectively. Also, the maximum thermal energy used for the water desalination system is about 3.03% of the total energy entering the system. The consumption power of the water desalination system is about 344.4 kW.



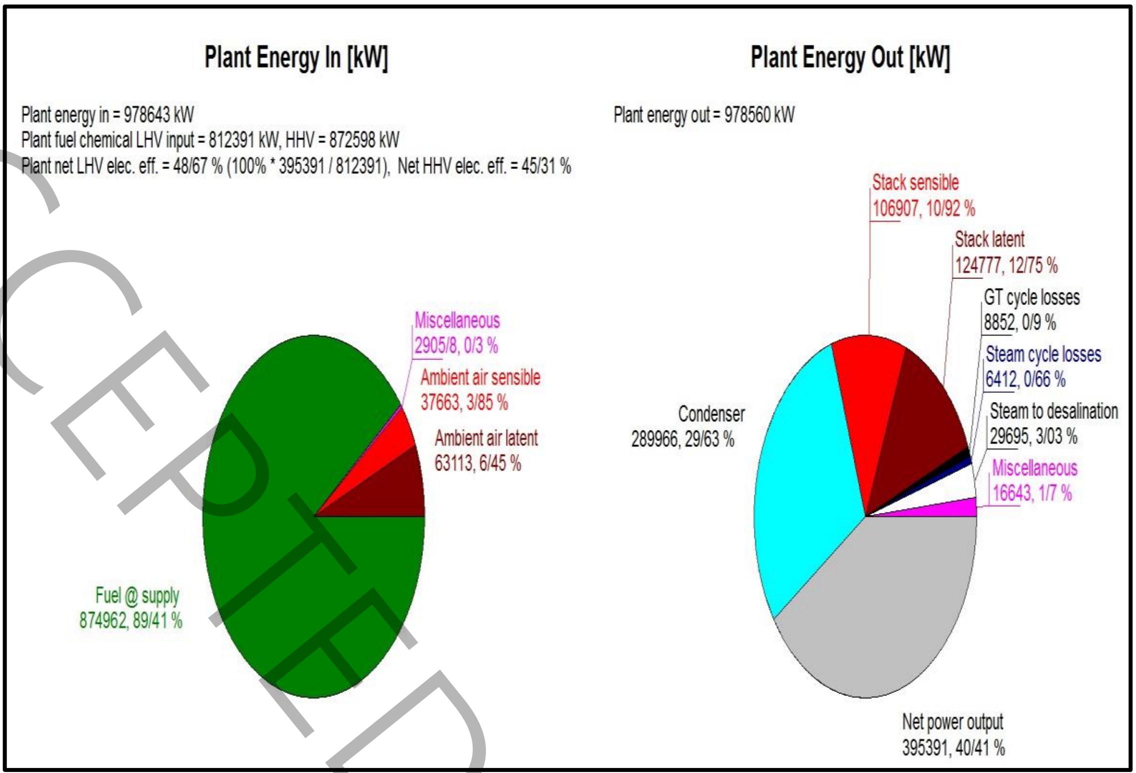


Fig.3- Input energy and its distribution in the integrated model of the power plant with the MED desalination system

Fig.4 shows the diagram and distribution of exergy flow in different parts of the power plant integrated with the *MED* desalination system in the design conditions of the ambient temperature of 40 °C in Chabahar City. The maximum exergy destruction is in the gas turbine set and in its combustion chamber, boiler, and vapor turbine of the power plant and it is about 19.37%, 4.06%, and 1.91% of the total input exergy, respectively. The most useful work after the net power is in the condenser of the power plant and is about 8.2%. The maximum exergy in the water desalination system is about 8524 kW and 0.95% of the total exergy entering the modeled cycle.

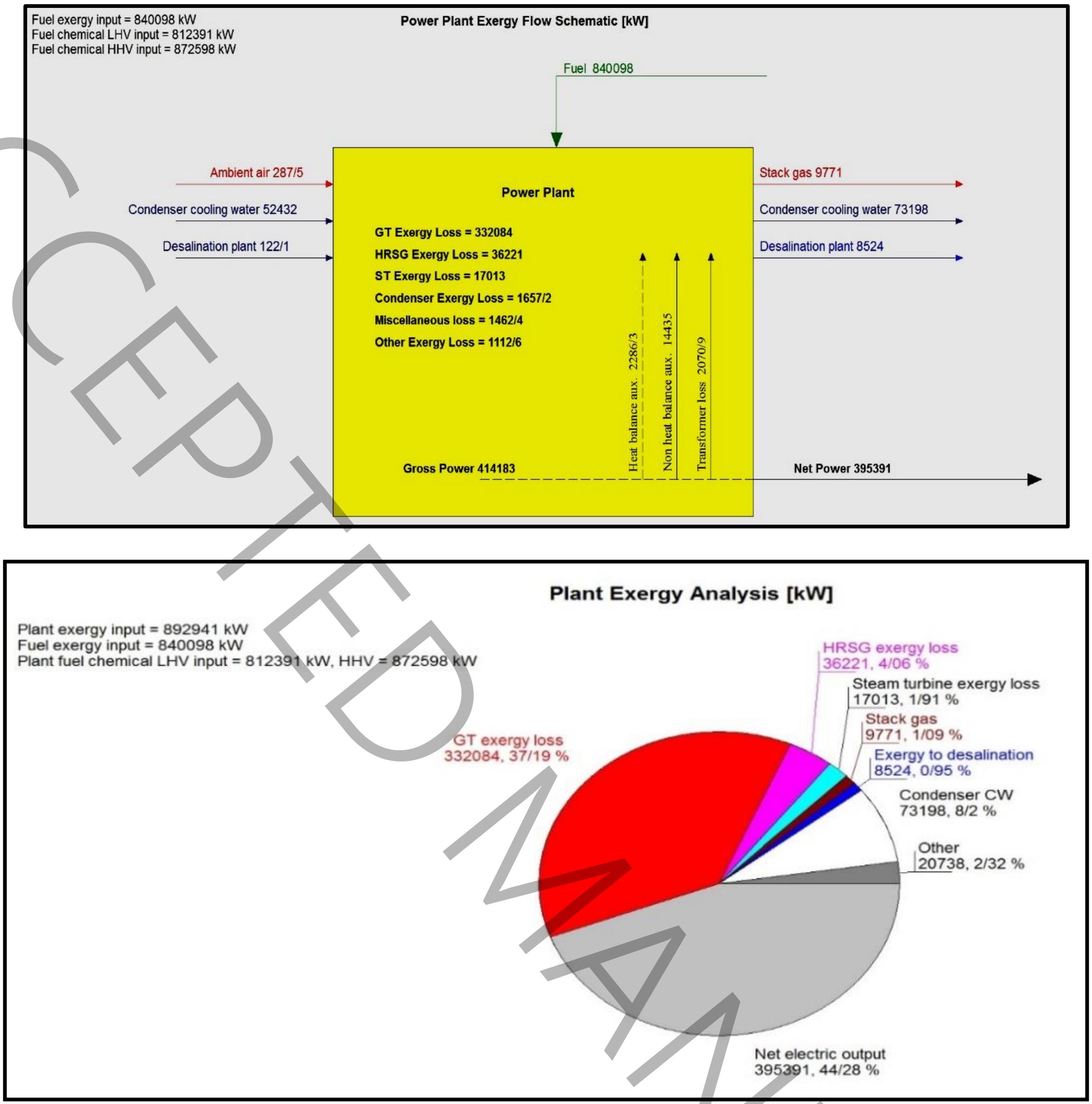


Fig.4- Exergy distribution in the integrated model of the power plant with the *MED* desalination system

Modeling of *MED* desalination water with *TVC* to Chabahar power plant in the design conditions of the ambient temperature of 40 °C:

It is possible to use the *MED* system equipped with *TVC* (thermal vapor condensation) to increase the performance ratio in *MED* systems. In this section, a combined cycle power plant with an ambient temperature of 40 °C was coupled with a *MED* water desalination system equipped with a thermo-compressor (thermal vapor condensation) of the parallel feeding type, which included three primary parts: a condenser, a thermo-compressor, and some evaporators, and was simulated according to Fig.5. The driving vapor and the source of thermal energy required for this system are taken from the flow of the low-pressure feed line of the vapor turbine.

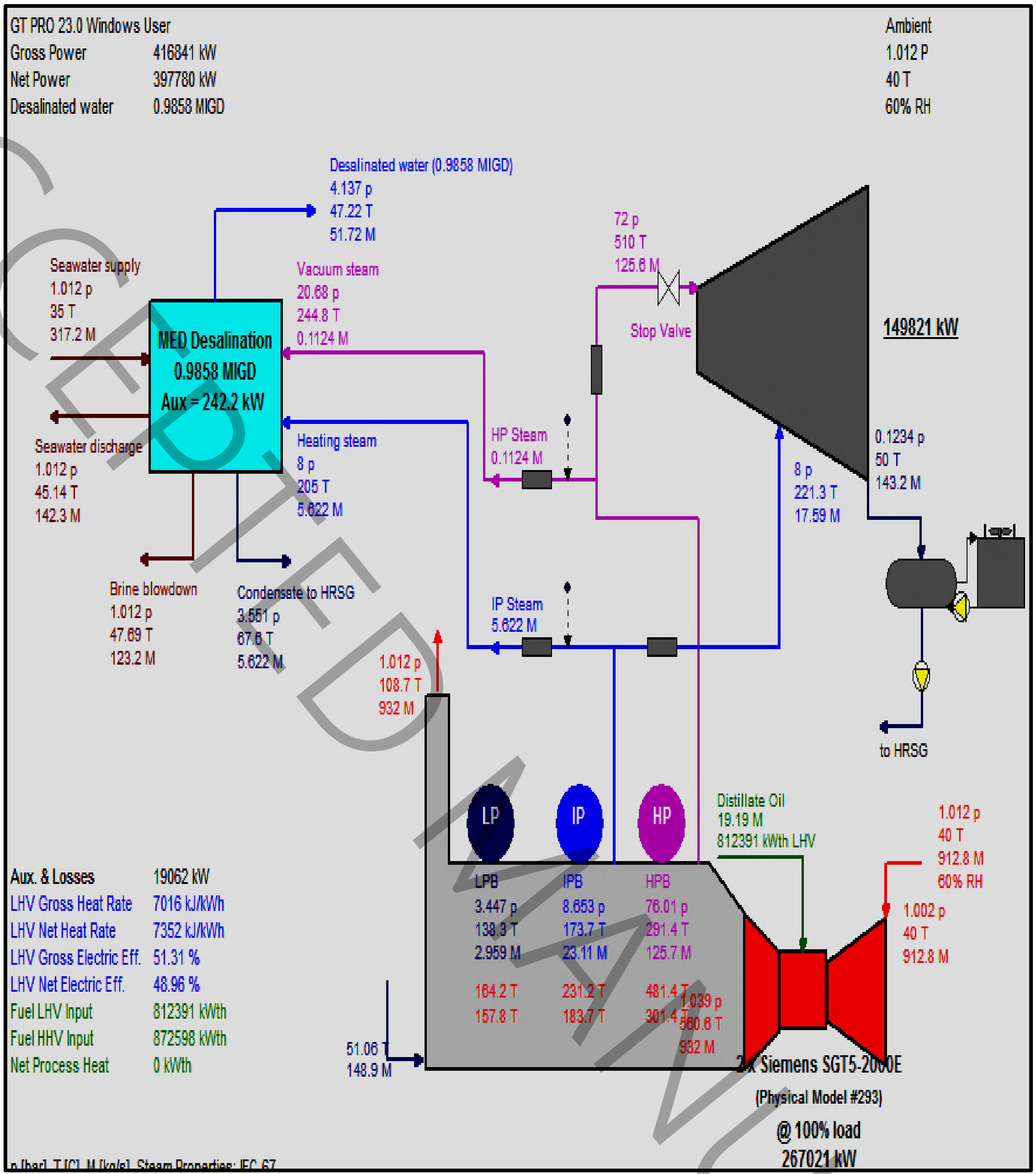


Fig.5- The output of the integrated model of the power plant with the *MED-TVC* desalination system in the ambient temperature of 40 degrees

Diagrammatic analysis of energy and exergy of the water desalination model integrated with *TVC* in the Chabahar power plant:

Fig.6 shows the diagram and distribution of energy flow in different parts of the power plant integrated with the *MED-TVC* water desalination system in the design conditions of the ambient temperature of 40 °C in Chabahar city. The maximum thermal energy loss is in the cooling tower of the primary condenser and the chimney of the power plant and it is about 30.66% and 23.68%, respectively, and the maximum thermal energy used for the desalination system is about 1.67% of the total energy entering the power plant. The consumption power of the water desalination system with thermo-compressor also decreased significantly from 344.4 to 242.2 kW.

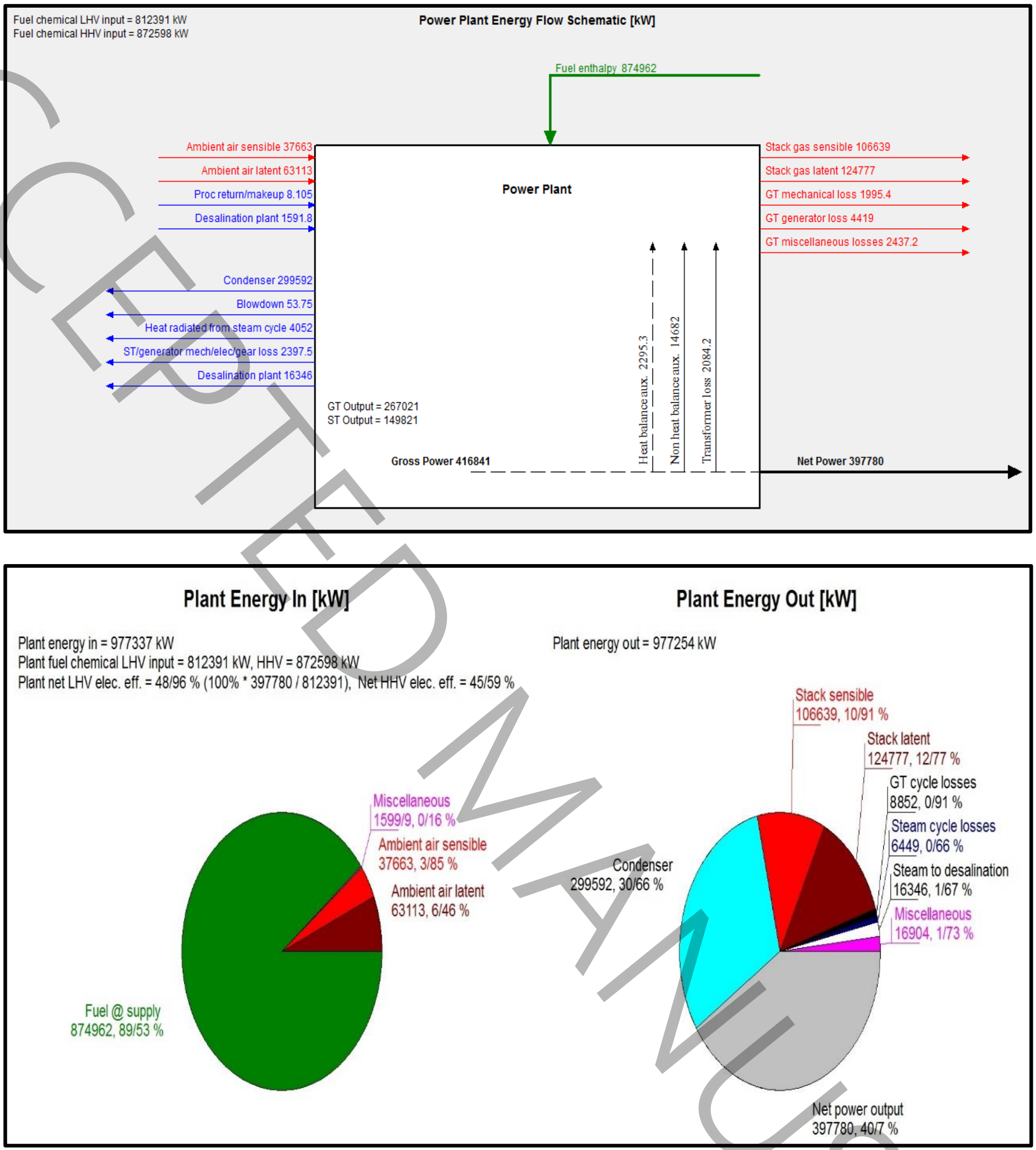


Fig.6 - Input energy flow and its distribution in the integrated model of the power plant with the MED-TVC desalination system

Fig.7 shows the diagram and distribution of exergy flow in different parts of the power plant integrated with the *MED-TVC* desalination system in the design conditions of the ambient temperature of 40 °C. The maximum exergy destruction occurs in its gas turbine set, and in the combustion chamber, boiler, and vapor turbine of the power plant, respectively, and is about 37.12%, 4.05%, and 1.95% of the total input exergy. The most useful work after the net power is in the condenser of the power plant, which is about 8.45%, and the maximum exergy in the water desalination system is about 4692 kW and 0.52% of the total exergy entering the modeled cycle.

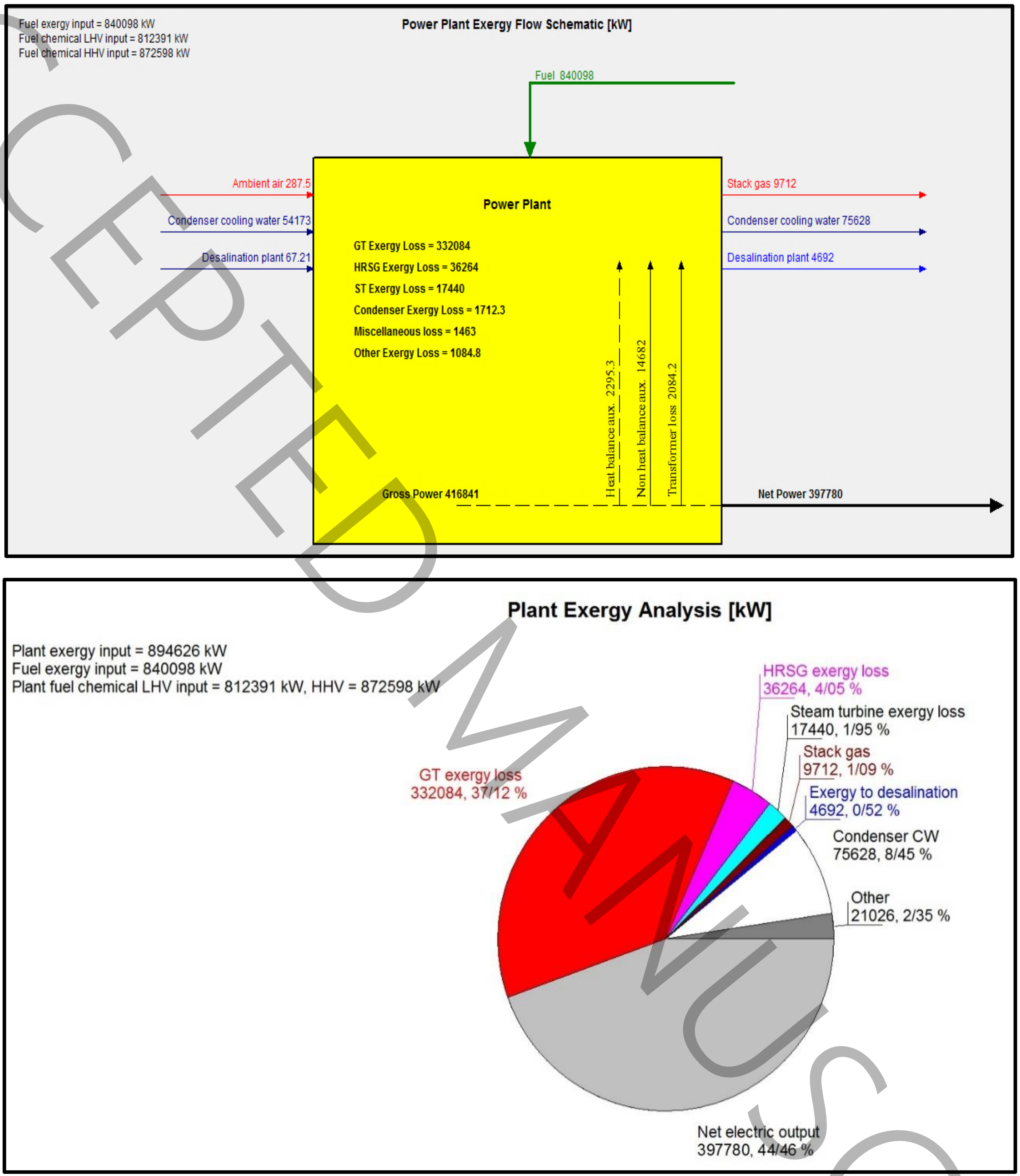


Fig.7- Flow diagram and exergy distribution in the integrated model of the power plant with the *MED-TVC* desalination system

4. Results

The simulated models of the power plant coupling with the water desalination system:

Based on the results of the simulated models, the total power of the Chabahar combined cycle power plant in the design conditions of the ambient temperature of 40 °C is 420 MW and its efficiency is about 49.34%. After coupling with the *MED* water desalination system, the power and its efficiency due to the extraction of vapor from the low-pressure turbine feed line as a source of energy and driving vapor for the water-desalination system decreased by about 0.67% and 6MW, respectively, and reached 48.67% and 414MW. Additionally, after integrating with the *MED-TVC* water desalination system (equipped with a thermo-compressor), its power and efficiency reached 416.8 MW and 48.96% with a drop of about 3.2 MW and 0.38%, respectively. Based on the obtained results, to compensate for the loss of power and efficiency of the power plant coupled with the desalination system, a solar farm can be added to the modeled power plant and simulated to compensate for the amount of extracted vapor and increasing power and efficiency, considering the location, conditions, and potential of the sun's radiation in Chabahar City.

Integration of solar farm to power plant coupled with *MED-TVC* in the software environment:

At this stage, in the environment of Thermo-flow software (Thermoflex module), the idea of adding a solar farm of the type of linear parabolic collector to the modeled combined cycle power plant of Chabahar was simulated to use the effect of the sun's energy as auxiliary thermal energy in the field of compensation and supply of vapor, used as a source of energy for the desalination system from the *LP* turbine feed line and the power loss and efficiency of the power plant. Also, the effect of solar radiation on the power and efficiency of the power plant and its effect on the performance of the desalination system was investigated.

The solar collector was thermodynamically simulated based on Fig.8 in the software by selecting the working fluid (Syltherm 800 oil with working temperature between -40 and 398 °C) and determining the mass flow rate along with the outlet temperature of the working fluid, and considering the temperature limit of the desired fluid.

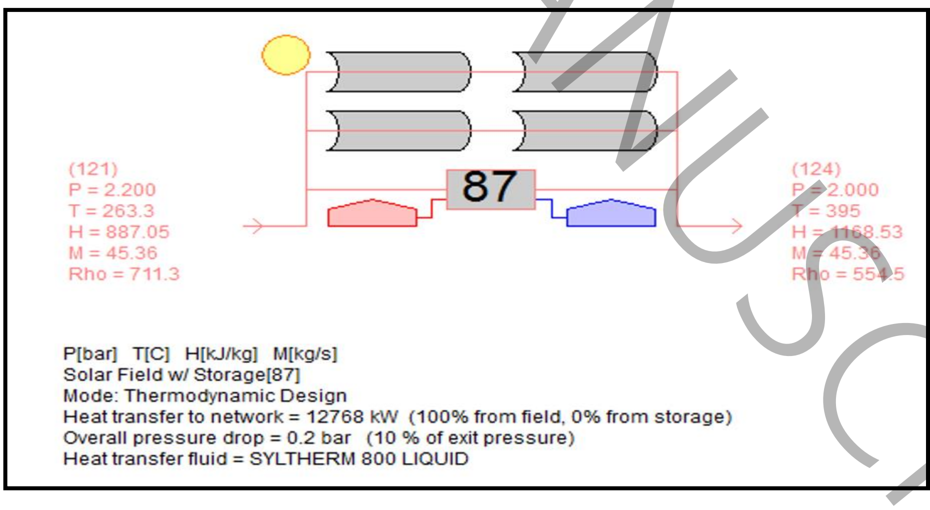
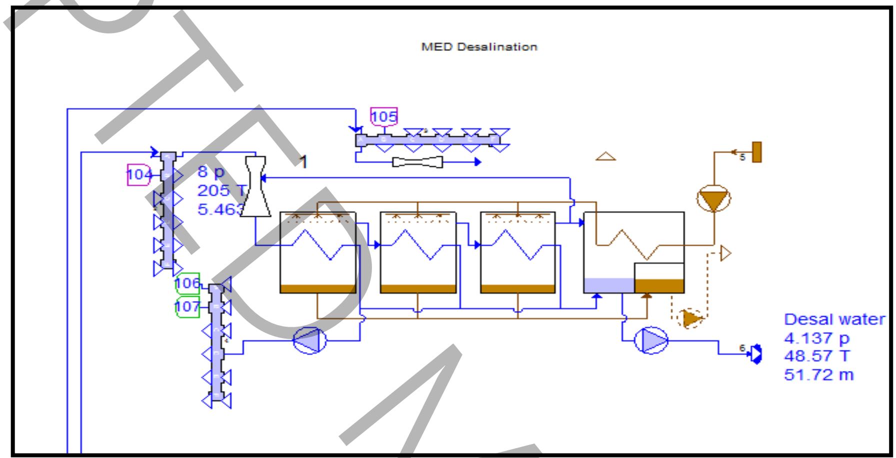


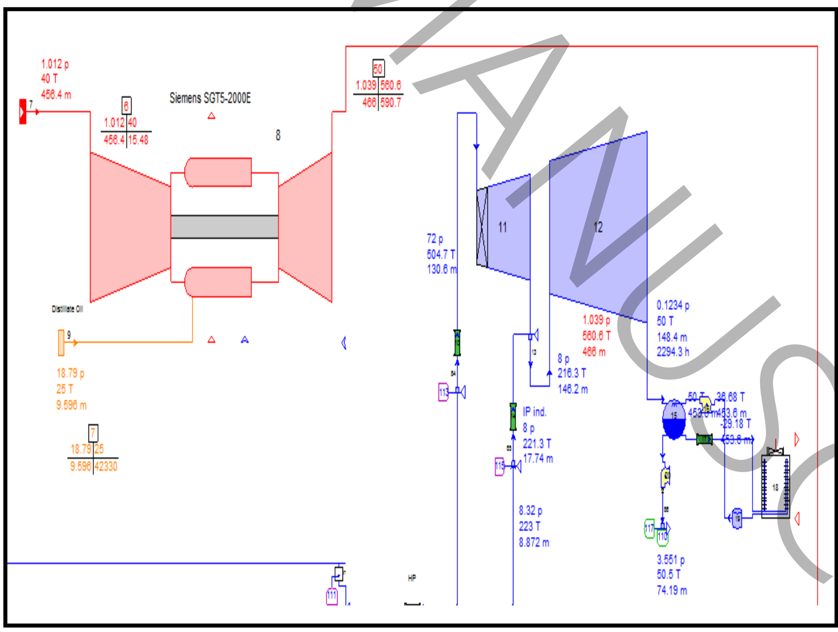
Fig.8- A view of the simulated solar farm in the software

In the present study, with the modeling done based on Fig.9, water (secondary fluid) was taken from the storage tank part of the power plant with a temperature of about 141.2 °C and a flow rate of 5.05 kg/s with a pressure of 73.65 bar for heat exchange with the primary fluid coming out of the collectors and converting it to the necessary vapor.

The water is taken from the power plant by passing through two heat exchangers of the economizer and evaporator, and heat exchange with the primary working fluid is converted into saturated vapor. Finally, by passing through the super-heater, it is converted into superheated vapor with a temperature of about 382.2 °C and is injected into the feed line of the high-pressure turbine with a pressure of 73.44 bars and a mass flow rate of 5.05 kg/s.

A view of the modeled cycle of the Chabahar power plant with adding a solar collector and the integration of water desalination in a cut form according to Fig.9





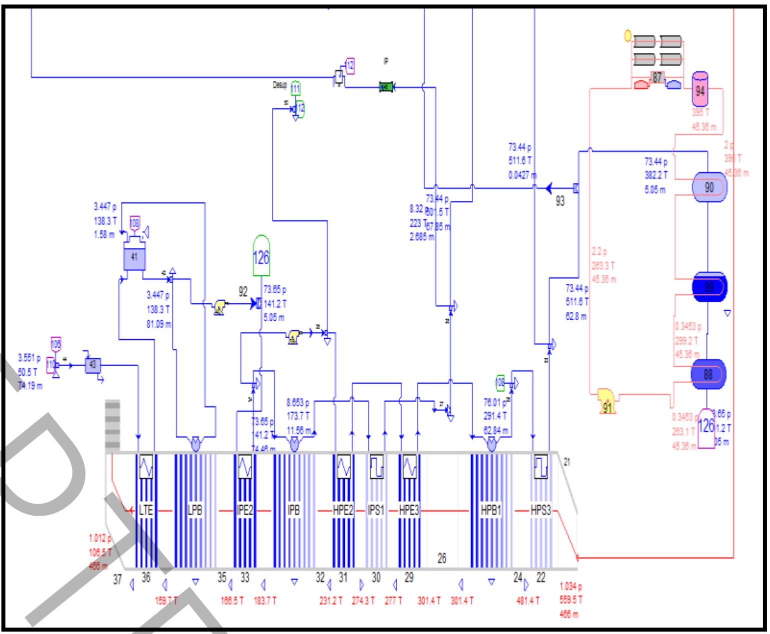


Fig.9- Cut view of the modeled cycle of the power plant with solar collector and water desalination MED-TVC

Results of a modeled power plant with a water desalination system in environmental conditions and adding a solar collector:

Based on the results of the simulated models, the idea of using the sun's radiant energy through designing and adding a solar collector to the Chabahar power plant, coupled with the water desalination system, has provided positive results. The total power and efficiency of the power plant have increased to 422 MW and 49.84% respectively. Thus, in addition to producing drinking water, it is possible to increase the power and efficiency of the power plant by adding a solar collector in the form of a solar farm and using the sun's radiant energy in the cycle of the modeled Chabahar power plant, given the hot and humid weather conditions and increased electrical energy increased during the hot seasons of the year.

5. Conclusion

In the first stage of the present study, energy and exergy analysis of the Chabahar port combined cycle power plant to a *MED* (thermal water desalination) system in ambient temperature conditions of 40 degrees was modeled and investigated, and the following results were obtained.

- The power of the plant reached 414 MW from 420 MW with a drop of 6 megawatts by coupling the *MED* desalination system to the power plant and using vapor from the low-pressure turbine supply line as the driving vapor and heat source of the desalination system.
- The vapor turbine output power decreased from 153 to 147.1MW.
- The efficiency of the power plant also reached 48.67% with a drop of 0.67%.
- The performance of the water desalination given the amount of vapor received and the amount of freshwater produced was about 5.08.

Then, to increase the power and efficiency of the power plant, the *MED* system was equipped with a thermo-compressor (thermal vapor condensation) that was coupled with the desired model and provided positive results as described below.

- By using the output vapor of the last stage of the water desalination as heating vapor in the first effect, the power of the power plant improved by 2.8 MW compared to the system without TVC, and it increased from 414 MW to 416.8 MW.
- The output power of the vapor turbine also increased from 147.1 MW to 149.8 MW with an increase of 2.7 MW.
- The efficiency of the water desalination also reached 9.2 with a significant increase due to the amount of vapor flow received.
- The efficiency of the power plant reached 48.98% with an improvement of 0.29%.

In the third stage, to compensate for the loss of power and efficiency of the power plant, the idea of designing and adding a solar farm of the linear parabolic collector type to the power plant was simulated in Thermoflex software considering the location, potential, and radiation conditions of the sun in Chabahar city and the effect of the sun's radiant energy on the power and efficiency of the power plant, and its effect on the performance of the water desalination system was studied, and the following results were obtained. The total power of the power plant was improved by 5.2 MW compared to the cycle without a collector by adding a solar collector and using the sun's thermal energy and increased to 422 MW from 416.8. Its efficiency also increased from 48.96 to 49.84% with an increase of 0.88%. There was no change in the performance of the water desalination according to the amount of received vapor flow rate and the constant production flow rate. Thus, the power of the power plant has also increased compared to the simulated model without the integration of the MW2 desalination system by adding a solar farm and using the sun's radiation while having a water desalination system with a daily production of 4482 m^3 of water. Based on the results of the performed models and the thermodynamic analysis of the extracted data, we conclude that the designed system that uses renewable energy sources and fossil fuel at the same time can supply the water and electricity of Chabahar City and have a favorable and effective performance in terms of efficiency. Thus, in addition to producing drinking water, it is possible to increase the power and efficiency of the power plant by adding a solar collector in the form of a solar farm and using the sun's radiant energy in the cycle of the modeled Chabahar power plant, given the weather conditions during these seasons of the year.

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