RESEARCH ARTICLE OPEN ACCESS

Effectiveness of The Development And Expansion of The Steam Power Station Condensate To Centers Thermoelectric Dedicated To The Production of Electric Power And Water Desalination

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Abstract
This research includes a mathematical form to study the effectiveness of development of basic design form condensation steam powers to dual pressure thermoelectric centers allocated for production of electric power and distillation water with the aspect of thermal effectiveness scale and preserving the lowest level of pollution for the surrounding media, in this study the scale of saving is used in the amount of fuel saved in the electric network due to the joint process of production for electric power and distillation water in suggested design compared to a separate production process for electric power and distillation water via a replacement station and distillation unit from the type of reverse osmosis. Hence the effect of design the multiple effect evaporation distillation unit and the gas turbine unit were studied, and so basic thermodynamic characteristics for this unit on the scale of effectiveness for development of basic design of steam station. Study findings provided the following:
The effectiveness of using the dual pressure process in development of steam condensation stations into thermoelectric centers. Where the minimum amount saving in quantity of fuel consumed 77.9 kg/hr for each MW of electric power produced in the basic design for the steam station. And hence the amount of decrease in the quantity of nitrogen dioxides (0.26 kg/MW.hr) and carbon dioxides (241.8 kg/MW.hr) presented to the surrounding media. And this is when the steam pressure prepared for the distillation unit 0.3 bar (and according to this, the design number for the effects of distillation unit 8 and amount of distillation water produced 15.7 ton/MW.hr).
The thermal and environmental effectiveness for using gas turbine units with sequential combustion in development of steam stations into thermoelectric centers. Where the minimum level of increase in saving amount consumed and above referred environmental indicators 14.9%.
Increase of the steam pressure prepared for the distillation unit from 0.3 bar to 0.38 bar leads to increase in the design number for effects of distillation unit from 8 to 10 and increase in the amount of distillation water produced with percent of 15.3% and so decrease in the electric power produced for each steam turbine unit with rate of 2.9%.
Keywords; Power plant ; steam turbine; gas turbine; pressure ratio ;fuel saving

1. Introduction

This It's well known that many in the world areas enduring scare resources of potable, irrigation and industrial water. And one of the scientific solutions for this problem is distillation of sea water by the thermal method [1]. Recent years were characterized by increase percent of thermoelectric centers for producing distillation water and electric power required to cover the electric network in most world countries and especially oil developed countries [1 , 2 , 3]. Beside this, the stations of producing steam electric power in most world countries are still covering high percent from the load of electric power consummation in the network. A great division of these stations became from the technical aspect not economic according to the new international standards of durability and rate of consuming fuel to produce electric power [4].

Modern study findings denote the economic effectiveness to use steam distillation units of multiple effect in the thermoelectric steam centers allocated for production of electric power and distillation water [5]. But in case of countries in which network of electric power depends mainly on condensation steam stations, it's necessary to think about preparing thermal power for distillation units aforementioned via using steam from condensation turbines or development of these turbines to work with the system of steam turbines of versus pressure. And this is when the distillation inside the electric station or near to it. It's notice worthy that this case must take into consideration the design ability and allowable increase in the power loaded on the phases of steam turbines [6]. And due to continuous scientific researches to submit what is more economically effective in the field of electric power production the researcher headed to adopt the idea of dual cycle in development and expansion of old steam stations [7, 8]. Upon the aforementioned, we shall tackle in this study the investigation of effectiveness of development of basic design for condensation steam station to the dual press thermoelectric center in which the electric power and thermal power are produced as required for units of evaporation distilling units of multiple effects.

2. Basic Design for the studied station

The basic design for the steam station (figure 1) in steam boiler (SB) with production capacity of (320 ton/hr) and unit of condensation steam turbine of one axis and design capacity of 84.65 MW and the steam turbine consists of two cylinders (HPT, LPT) to supply steam prepared by the boiler (TSB= 510 C ; PSB= 92.2 bar) and includes four points to exhaust steam from high pressure cylinder and low pressure cylinder for the objective of recovery heating for supply water (table 1).

Table 1. Properties of steam at various points of the turbine extraction

Extraction point	Turbine Extraction properties					
	0	**1**	**D**	**2**	**3**	**C**
P (bar)	**87.0**	**24.83**	**6.83**	**1.73**	**0.169**	**0.07**
T (°C)	**505**	**336.2**	**303.7**	**115.2**	**56.2**	**38.8**

3. Specifications of Studied Design

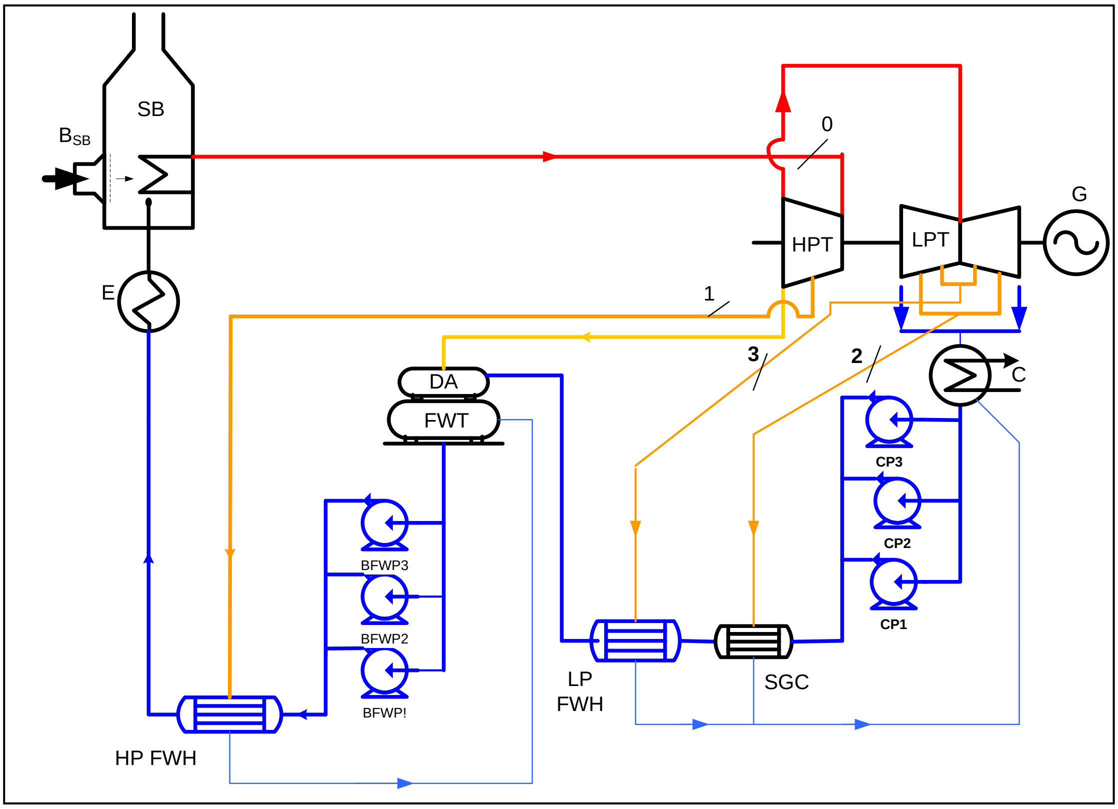
The suggested design for development of basic design of studied steam station provided in figure (2) where the design of the steam station is amended to the dual thermoelectric center in which the thermal power for the exhaust gases out of the gas turbine from the dual press steam boiler (HRSB) assigned to produce the amount of steam required for steam turbine in the basic design of the station in case of new operating system. Thereupon, the steam produced in the high pressure phase from the boiler after achieving a volume of work inside the cylinder of high pressure for steam turbine, shall be mixed with the steam volume produced in low pressure phase in the boiler. Where the quantity of steam produced in both phases of pressure in the boiler inside the low pressure cylinder till the preparation pressure for steam in the distillation unit.In the suggested design, the condenser and thermal exchangers allocated for recovery heating of supply water and main condenser were canceled. The design of condensation steam turbine is developed to work with system of thermal steam turbines of versus pressure.

Where the last three phases have been canceled for supplying the steam from low pressure cylinder so as to achieve the required steam specifications for distillation unit at the end of procedures of supplying steam inside the turbine and preserving the point of exhausting steam allocated for tank of extracting air in the basic design (which works according to the studied design at pressure of PD = 2.5 bar).

For the objective of decreasing the amount of steam exhausted for the tank of extracting air, the main condenser is heated (to the temperature less than the degree saturation corresponding to the pressure of air extraction tank with amount of 5°C) via putting a thermal exchanger allocated for this objective in the boiler. In addition to the aforementioned, it's considered the existence of supply tank (FV).

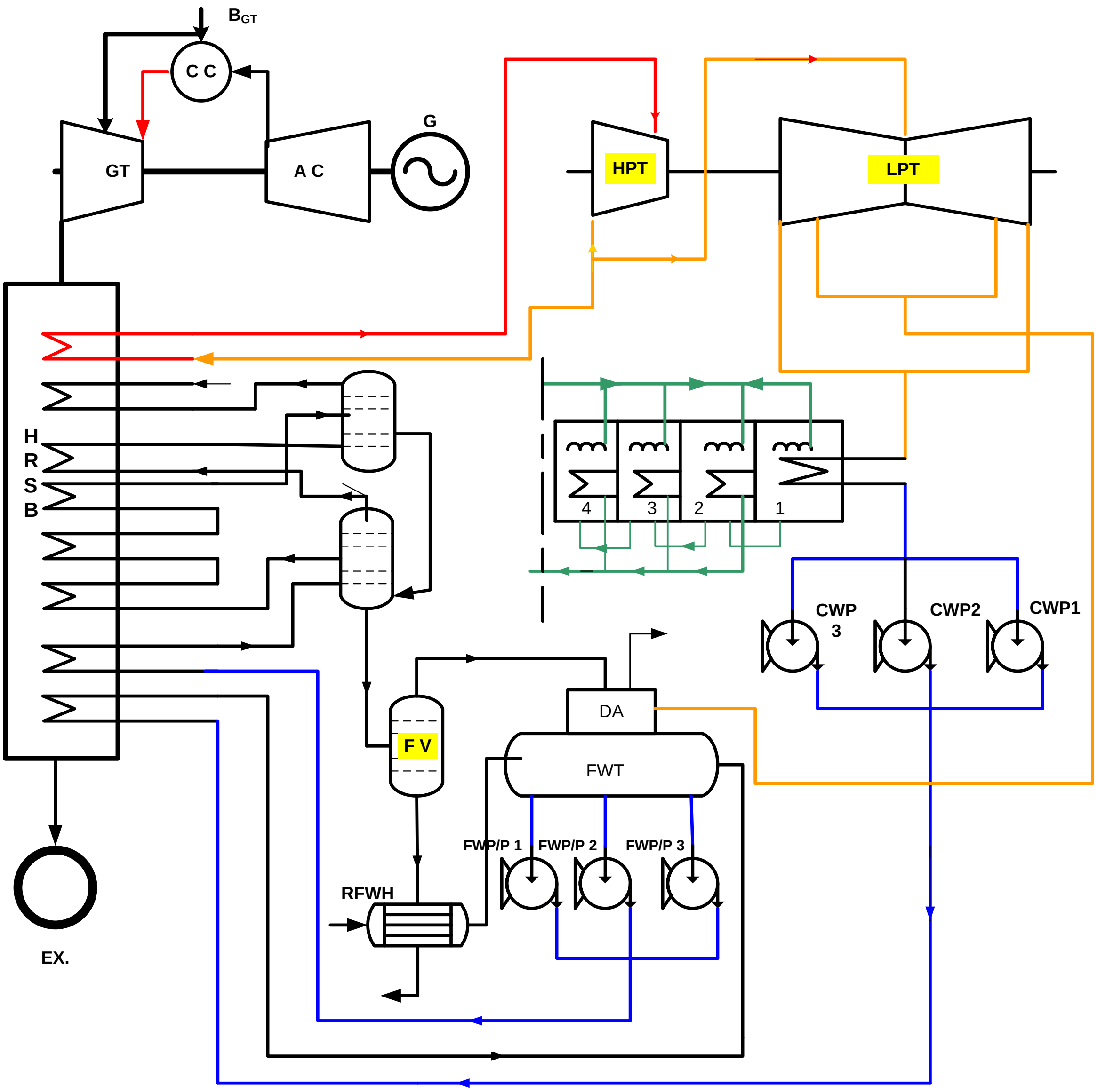
In which an amount of flash steam is produced via the exhausted amount of water from cylinders of both boiler phases, and so thermal exchanger (RFWH) to heat up the compensation water for the thermoelectric center via maximum use of thermal power remaining in the exhausted water from the supply tank.

As to the design of distillation unit (MED) it consists of a number of consequent steam condensers forming multiple effects for the distillation unit.



C: Steam condenser
CP :Condenser pump
DA : Deaerator
FP: Feed water Pump
FWT: Feed Water Tank
G :Electric Generator
HPT: High Pressure Turbine
LPT : low pressure Turbine
HP FWH:High Pressure
LPFWH: Low Pressure Heater
SB : Steam Boiler

Figure (1) Basic Design of the Steam Station



AC : Air Compressor	CP: Condensate Pump	FP : Feed Water Pump
CC : Combustion Chamber	D : Deaerator	FV : Flash Vessel
G : Electrical Generator	GT : Gas Turbine	ST : Steam Turbine
HRSB : Heat Recovery Steam Boiler	MED : Multi Effective Distillation Unit	REWH: Row Feed Water Heater

Figure (2) Suggested Design for Dual Thermoelectric Center

And the saline solution is prepared for these effects on parallel basis among them exhausting the concentrated saline solution from one effect to the other consecutively (according to hierarchy of pressure inside the effects) and so the design of distillation unit includes a separate condenser for the quantity of steam produced in the last effect from distillation unit. Where as part of cooling water is used for this condenser in preparing the amount of saline solution required for distillation unit.

It's notice worthy that in the current study two types of designs were used for gas turbine units:

First design (gas turbine unit designed with simple circuit and includes the following parts: air

compressor AC, circular individual combustion room CC, gas turbine GT, electric generator G).
Second design (gas turbine unit designed with simple circuit with consecutive combustion for fuel, and hence the gas turbine unit design shall include, in addition to basic parts aforementioned in the first design, a circular combustion room after the first phase of gas turbine).

4. Method of studying the effectiveness of studied design

To study the thermal and environmental effectiveness of thermoelectric centers of dual press, it's required to calculate the thermal design for a number of different alternatives for the studied design characterized from each other with change in the gas turbine design used and design characterizations studied forming a consecutive coordination for the objective of calculating the thermal and environmental economic indicators for these alternatives in each case.It's notice worthy that the basic design characteristics studied in this case: the primary temperature degree for gases before gas turbine (T3), air pressure percent in the compressor (PRC), steam pressure prepared for the distillation unit (PT) according to this, the design number for effects of distillation unit (N).Yet, the thermal and environmental effectiveness shall be defined in this case via the amount of saving in the quantity of fuel consumed from the electric network due to the joint production process for electric power and a distillation unit from type of Reverse osmosis for production of distillation water. Hence, the amount of saving in the fuel amount consumed in the electric network due to development of the basic design for the condensation steam station to a dual thermoelectric center allocated for production of electric power and distillation water:

$$DBST = \frac{3600 * [NST + NGT - (NEST)_O - NFP1 - NFP2]}{Qcv * EST} + (BSB)_O + \frac{3600 * DDW * [NRO - NMED]}{Qcv * EST} - BGT \quad (1) \quad \Rightarrow \max$$

Whereas:
BGT, NGT. The electric power produced (MW) and fuel consumption rate (ton/hr) for the gas turbine unit respectfully.
NST. Electric power produced (MW) for the gas turbine unit in case of new operation system.
(NEST), (BSB). Electric power produced (MW) and rate of fuel consumption (ton/hr) for the boiler in case of basic design of the station respectfully.
NFP2 , NFP1. Electric power consumed (MW) in the supply pump for the first and second phase from the boiler respectfully.
EST. Efficiency of dual recovery station for producing electric power in the network.
Qcv. Thermal value for qualitative fuel (Kj/Kg).
NMED, NRO. Rate of consumption of qualitative electric power (MW.hr/ton) for producing distillation water in the distillation unit from type of Reverse osmosis and evaporation unit of multiple effects respectfully.DDW. Quantity of distillation water produced (ton/hr).Hence, the proper alternative is to give the maximum value for equation (1) (any alternative which has the studied design for distillation unit and gas turbine unit and so thermodynamic characteristics studied for this unit gives the maximum effectiveness possible via the amount of saving in the fuel quantity consumed to produce electric power and distillation water).

It's notice worth in the process of building the sport model for calculating the thermal design for the dual thermoelectric center, the thermoelectric centers calculation method is used [9], and method of calculating the gas turbine units of high primary thermal degrees for gases [10], and method of calculating steam boilers allocated for using secondary resources for power [11], and method of calculating the evaporating distillation units of multiple effects [12]. In addition to the aforementioned, the method of calculating the gas turbine units aforementioned has been amended to deal with gas turbine units of consecutive combustion and defining the percent of gas expansion in the first phase of gas turbine from requirements of the number of phases in this turbine and equal distribution for amount of decrease in the gas power among these phases [13].

5. The results of study of the effectiveness of the design studied

The effect of design of gas turbine unit and basic design specifications aforementioned (paragraph 4) on the measuring the economic effectiveness of the studied design for dual thermoelectric center (amount of saving in the quantity of fuel consumed in electric networks and distillation water) - has been studied. Figure (3) demonstrating the effect of air pressure percent (PRC) on the amount of saving in the quantity of fuel in relation (1) at different primary temperature degrees for gases (T3) before gas turbine. The amount of steam required for the steam turbine unit by an amount which is larger than the increase in the qualitative job of gas turbine unit.The effect of the properties of gas turbine unit on the quantity of steam produced in the two phases of the pressure of the boiler was also studied; where it was noted of figure (5) that, at a fixed ratio of air compression and an increase of initial temperature of gases, the amount of steam produced in the high-pressure stage of the boiler DSB1 is rising because of the increased amount of thermal power available to produce steam at this stage due to the high temperature gases after the gas turbine . It was also observed that the amount of steam produced in the phase of the low-pressure of boiler DSB2 is declined together with an increase of the initial temperature of gases before the gas turbine. The reason for this could be attributed to the low temperature of the combustion gases after the provider of high-pressure phase of the boiler as a result of increasing the amount of thermal power required to heat the feed water for such phase of the boiler. At the increase of the compression ratio of air temperature and fixing of the initial temperature of gases, it was observed of Figure (5) that the quantity of steam produced in the high-pressure stage of the boiler is declined, because of the low amount of thermal power available to produce steam at this stage. The quantity of steam produced in the low pressure phase of the boiler increases with higher ratio of air compression. The reason for this is due to the low amount of water needed to feed the high-pressure-phase of the boiler, and then the high temperature combustion gases after the provider of this stage of the boiler and thus an increase of the amount of thermal power available to produce steam in the low pressure phase of the boiler.The effect of vapor pressure prepared for PT desalination unit and efficiency of the compensatory EST plant for the production of electric power, as well as the rate of electrical power consumption for the production of desalinated water in the desalination unit of reverse osmosis type on the amount of savings of the quantity of fuel consumed DBST as shown in Figure 6, where it is noted the drop in the amount of savings of the quantity of fuel consumed (DBST1) together with an increase of steam pressure prepared for desalination unit in the case of recovery of the hydraulic power of water drained from the reverse osmosis unit (NRO = 6 kW.hr / ton). The reason for this is due to a drop in electrical power produced of the steam turbine unit (NST, (Figure 7)) in a greater amount than the increase of the rate of consumption of electrical power of the compensatory desalination unit as a result of the high amount of desalinated water produced for the electro-thermal center (DDW, (Figure 7). In the case of non-recovery of hydraulic power for water drained from the desalination unit (NRO = 15 kW.hr / ton), it is observed of Figure 7 the high amount of savings of the quantity of fuel consumed (DBST2) together with an increase of steam pressure prepared for the desalination unit, because of the high rate of electrical power consumption for the production of desalinated water in the reverse osmosis unit, and then an increase of the rate of fuel consumption on the production of desalinated water in the separated production process in an amount that is greater than the rate of fuel consumption in the double electro-thermal center for the production of thermal power for the desalination unit. On fixing the vapor pressure prepared for the desalination unit and an increase of the efficiency of the compensatory desalination plant, it is noted of Figure (6) that the amount of savings of the quantity of fuel consumed is declined because of the low rate of fuel consumption for the production of electric power in the compensatory station.

The effect of vapor pressure prepared for desalination unit PT on the designed number of effects of desalination unit N as shown in Figure 7; where it is noted that an increase of steam pressure prepared for desalination unit leads to a rise in the designed number of effects of the desalination unit; and then the low rate of qualitative thermal power consumption of desalination unit (QR) as a result of the high amount of thermal power recovery of desalination unit, and therefore a high amount of desalinated water produced (DDW).

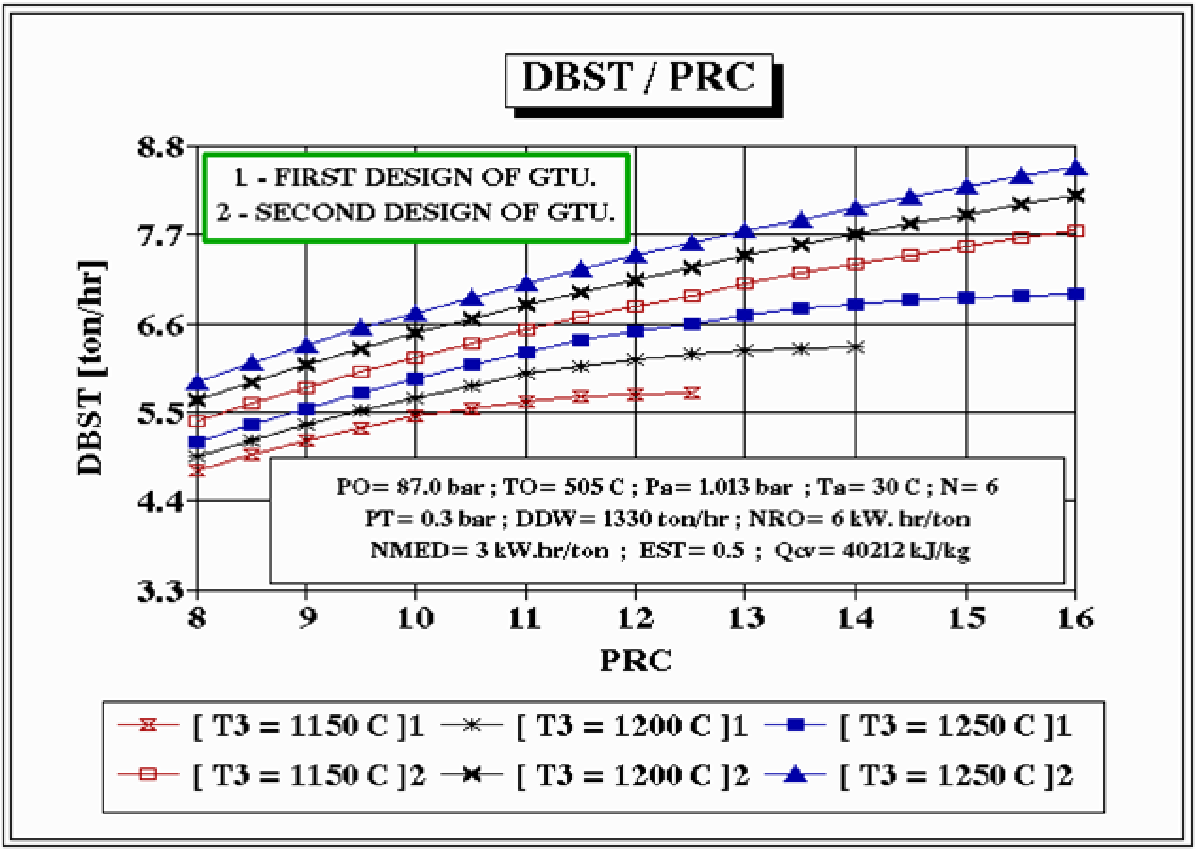
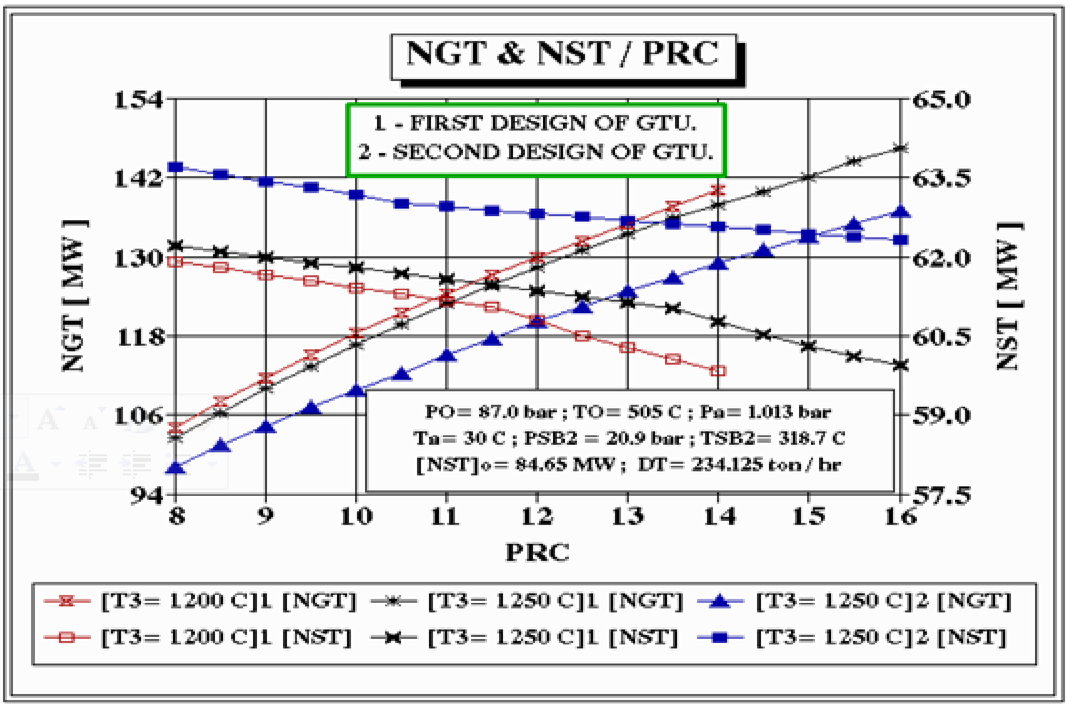


Figure (3) Relationship of the amount of savings in the amount of fuel consumed (DBST) with a compression ratio of air



(Figure 4) relationship with the amount of electricity produced per unit of steam turbine (NST) and gas ,(NGT) with a compression ratio of air in the gas turbine unit (PRC) at different values The temperature of the primary gases (T3).

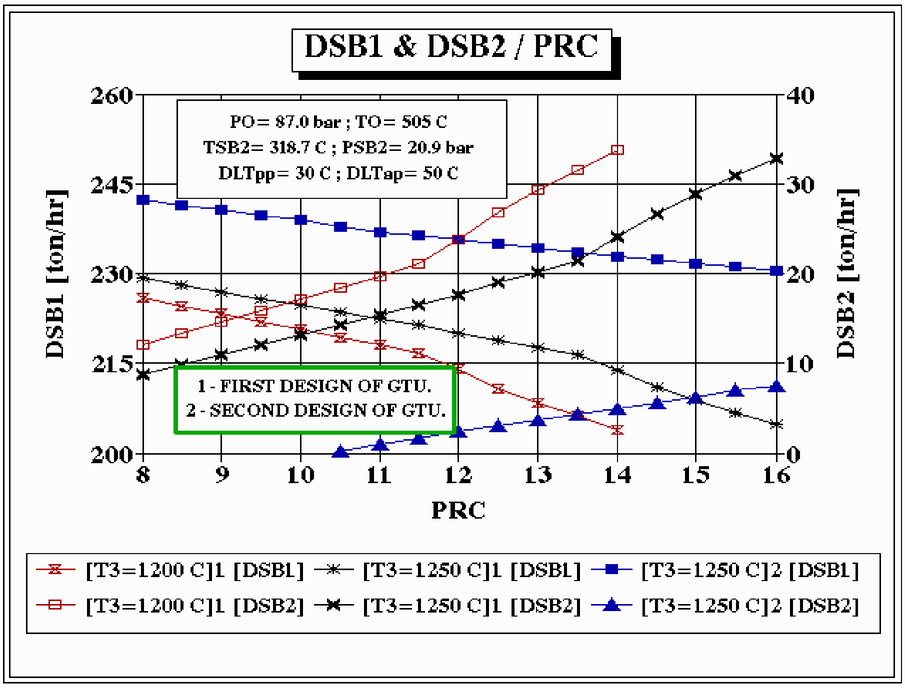
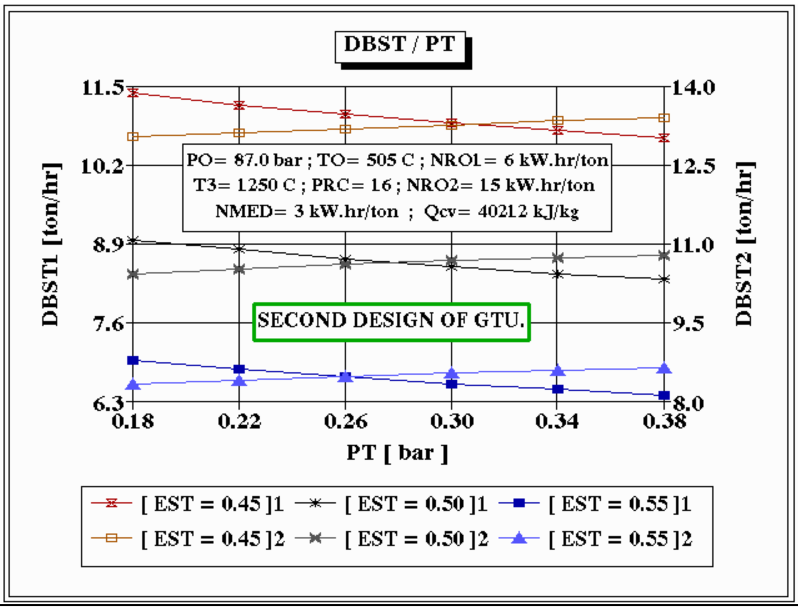
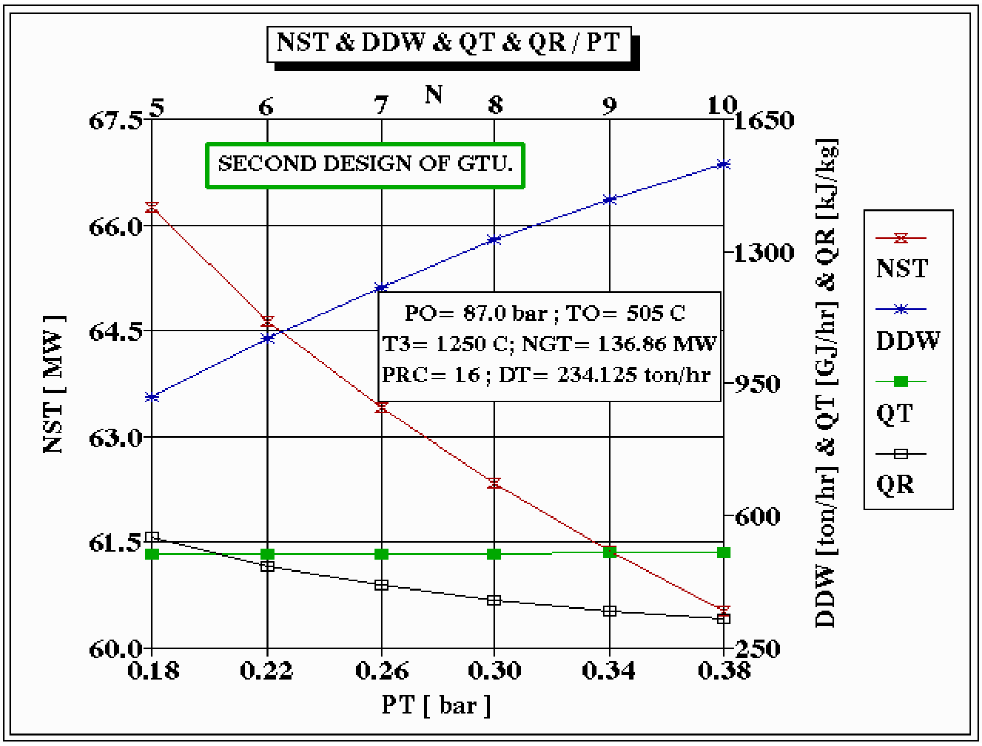


Figure (5) Relationship of the amount of steam produced in the two design with the compression ratio of the air in the unit Gas turbine (PRC) at different values of the gas turbine inlet temperature of the gases (T3).

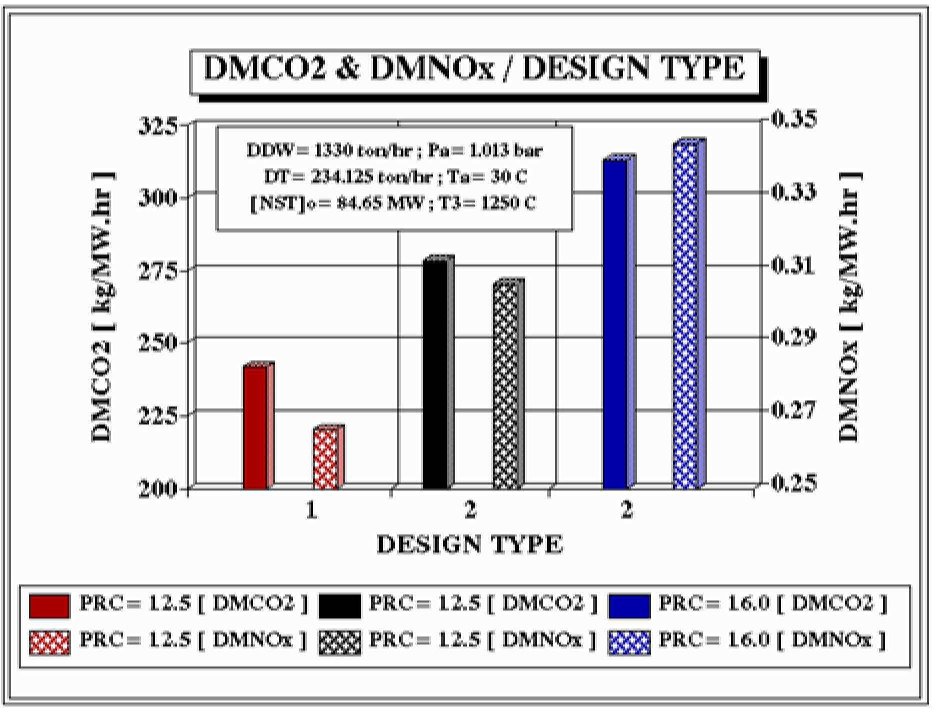


(Figure 6) ; Relationship with the amount of savings in the amount of fuel consumed (DBST) with steam pressure unit distillation (PT) at different values of the efficiency .



(Figure 7), Relationship between the amount of electricity produced per unit of steam turbine (NST), the amount of thermal energy to the desalination unit (QT), The rate of consumption of thermal energy quality desalination unit (QR)

Figure (7) also shows a slight increase in the amount of thermal power prepared for the desalination unit QT with a high steam pressure prepared for the desalination unit. This is because of the high temperature of condensed steam coming from the desalination unit and the fixed amount of steam prepared for this unit. The environmental effectiveness of designing the double electro-thermal center has been studied together with the impact of gas turbine unit on such effectiveness; where it is noted of Figure (8) the amount of decrease in the quantity of nitrogen oxides (DMNOx) and carbon dioxide (DMCO2) exposed to the surrounding environment as a result of the use of the design proposed for the double electro-thermal center compared with the separate process of production of electric power and water desalination. The reason for this can be attributed to the decline in the rate of fuel consumption for production of the two types of power (electrical and thermal) in the thoughtful design of the double electro-thermal center and low the amount of combustion gases exposed to the surrounding environment. It is also noted of Figure (8) the increase of the amount of the decrease in the quantity of nitrogen oxides and carbon dioxide exposed to the surrounding environment with a high ratio of air compression in the gas turbine unit, because of the increase in the amount of electricity produced and the high efficiency of the double electro-thermal center for production of this power, and then an increase in the fuel consumption rate for production of electric power in the compensatory unit which leads to an increase in the amount of combustion gases exposed to the surrounding environment in the separate production process of electric power and desalinated water.Figure (8) also shows environmental effectiveness of the use of gas turbine units of sequential combustion. Figure (7) also shows a slight increase in the amount of thermal power prepared for the desalination unit QT with a high steam pressure prepared for the desalination unit. This is because of the high temperature of condensed steam coming from the desalination unit and the fixed amount of steam prepared for this unit. The environmental effectiveness of designing the double electro-thermal center has been studied together with the impact of gas turbine unit on such effectiveness; where it is noted of Figure (8) the amount of decrease in the quantity of nitrogen oxides (DMNOx) and carbon dioxide (DMCO2) exposed to the surrounding environment as a result of the use of the design proposed for the double electro-thermal center compared with the separate process of production of electric power and water desalination. The reason for this can be attributed to the decline in the rate of fuel consumption for production of the two types of power (electrical and thermal) in the thoughtful design of the double electro-thermal center and low the amount of combustion gases exposed to the surrounding environment. It is also noted of Figure (8) the increase of the amount of the decrease in the quantity of nitrogen oxides and carbon dioxide exposed to the surrounding environment with a high ratio of air compression in the gas turbine unit, because of the increase in the amount of electricity produced and the high efficiency of the double electro-thermal center for production of this power, and then an increase in the fuel consumption rate for production of electric power in the compensatory unit which leads to an increase in the amount of combustion gases exposed to the surrounding environment in the separate production process of electric power and desalinated water.



(Figure 8) Relationship with the decrease amount of the quantity of nitrogen oxides (DMNOx) and carbon dioxide

(DMCO2) exposed to the surrounding environment with the design of gas turbine unit at different values of the ratio of air compression (PRC) in this unit.(Thoughtful Design II) in the double electro-thermal plants and centers, where the lowest level of increase in the amount of decrease in the quantity of nitrogen oxides and carbon dioxide exposed to the surrounding environment reached to 14.9% compared with the use of 1st thoughtful design of gas turbine unit. The reason for this is due to the high efficiency of the double plant or the double electro-thermal center, and then a drop of the rate of fuel consumption at the double plant or the double electro-thermal center for production of electrical power.

6. Summary findings and recommendations

The study results indicate the effectiveness of the proposed design to :

1. The minimum amount of savings of fuel consumed is 77.9 kg / hr for each MW of electrical power produced by the steam plant. Accordingly, the amount of the decrease in the quantity of nitrogen oxides is 0.26 kg / MW.hr and carbon dioxide is 241.8 kg / MW.hr exposed to the surrounding environment. That is when the vapor pressure prepared for desalination unit is 0.3 bar and accordingly the designed number of effects of desalination unit is 8 and the amount of desalinated water produced is 15.7 ton / MW.hr.
2. The amount of electricity produced for the electro-thermal center depends mainly on the design of electric power for the steam turbine unit as well as on the design of this unit.
3. The thermal and environmental efficiency of the electro-thermal center increases with the increase of basic thermodynamic properties of gas turbine unit. The use of gas turbine units of initial high temperature of gases leads to an increase in the efficiency of electro-thermal center for production of electrical power, and then an increase in the amount of savings of the quantity of fuel consumed despite the decline in the amount of the increase in the quantity of

electrical power produced by the electro-thermal center.

4. The thermal and environmental efficiency of the use of gas turbine units of sequential combustion in the development of steam-powered stations into thermoelectric centers. The lowest level of increase in savings by the quantity of fuel consumed and environmental indicators (paragraph 1.6) mentioned above reached to 14.9 %.
5. The increase of steam pressure prepared for desalination unit from 0.3 bar to 0.38 bar leads to an increase in the quantity of desalinated water produced by 15.3 % (as a result of low rate of thermal power qualitative consumption of desalination unit) as well as the decline in electrical power produced for steam turbine unit at a rate of 2.9%.
6. The need of an economic thermal study to determine design specifications and ideal thermodynamic properties for the proposed design which gives the maximum possible economic efficiency, taking into account the amount of change in the cost of the gas turbine unit and the boiler dedicated to the exploitation of thermal power of the exhaust gases together with the properties and design specifications for this unit; this is for the effect of these properties and specifications on the quantity of steam produced in the two pressure phases of the boiler, and then surface areas of the heat exchanger required to produce these quantities of steam.

*** Symbols used in tables and illustrations**

D, C : condenser and air removal tank.
DDW : quantity of desalinated water produced for the double electro-thermal center.
DLTpp, DLTap : the smaller temperature difference on hot end of steam roasters and cold end of evaporators in boiler, respectively.
PT, DT : quantity and pressure of vapor prepared for desalination unit, respectively.
EST : efficiency of double compensation plant for production of electrical power.
CP, FP : feeding water pump and basic condenser, respectively.
FV : expansion tank of water drained from the two cylinders of boiler.
FWHi : heater of feed water or main condenser No. (i).
HRSB : boiler of exploited thermal power of exhaust gases coming out of gas turbine unit.
HPT, IPT, LPT : cylinder of low, medium and high pressure of steam turbine, respectively.
MED : multi-effect evaporative desalination unit.
NMED, N : design number of effects of evaporative desalination unit and the consumption rate of qualitative electric power.
NRO : rate of qualitative electrical power consumption of desalination unit of reverse osmosis type.
Qcv : thermal value of qualitative fuel used in the study.
RFWH : Heater of compensatory Water of double electro-thermal center.
SB : steam boiler.
T, P : temperature and pressure, respectively.
To, Po : temperature and primary steam pressure before steam turbine, respectively.
Ta, Pa : temperature and air pressure in the surrounding environment, respectively.
TSB2, PSB2 : temperature and steam pressure produced in the second phase of boiler, respectively.
[NST] o : electricity produced in the case of basic design of steam plant.

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