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Investigation on the HRSG Installation at South Pars Gas Complex Phases 2&3

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Abstract**—**In this article the investigation about installation heat recovery steam generation (HRSG) on the exhaust of turbo generators of phases 2&3 at South Pars Gas Complex is presented. The temperature of exhaust gas is approximately 665 degree centigrade, Installation of heat recovery boiler was simulated in ThermoFlow 17.0.2 software, based on test operation data and the equipments site operation conditions in Pars exclusive economical energy area, the affect of installation HRSG package on the available gas turbine and its operation parameters, ambient temperature, the exhaust temperatures steam flow rate were investigated. Base on the results recommended HRSG package should have the capacity for 98 ton per hour high pressure steam generation this refinery, by use of exhaust of three gas turbines for each package in operation condition of each refinery at 30 degree centigrade. Besides saving energy this project will be an Environment-Friendly project. The Payback Period is estimated approximately 1.8 year, with considering Clean Development Mechanism.

Keywords**—**HRSG, South pars Gas complex, ThermoFlow 17.0.2 software, energy, turbo generators.

I. Introduction

In this project, a feasibility study with Technical & Economical evaluation has been done to supply part of required steam in phase 2&3 of South Pars Gas Company (SPGC) by installing Heat Recovery Steam Generation Boilers on turbo generators & turbo compressors exhaust. This study was done in the following objectives:

- The possibility of installing HRSG Boilers according to ground & underground installations.

- The rate of generated steam by HRSG boilers according to load of turbo generators & turbo compressors. For this step two scenarios were investigated. The first one is the exhaust gas entered HRSG boiler only from one gas turbine and the second is the exhaust gas entered HRSG boiler from several gas turbines.

- The effect of environment and operating condition on performance of HRSG boilers.

- The evaluation of purchase, installation and perform plan costs.

- The profitability study of plan.

- The evaluation of payback time based on different price of natural gas and by considering the profit of clean develop mechanism (CDM) project.

Therefore, in this project, Thermoflow 17.0.2 software has been used to consider the condition accurately. This is one of the strongest software in the simulation of gas turbines operation and power plant cycles. Using this software, the effect of different environment and operating conditions on gas turbines performance and then, HRSG boilers would be possible accurately, based on the actual condition.

In order to accept and rely the results of simulations, it is necessary to compare different conditions and statistics in actual. In this project, results validation of simulation by this software in site condition and by using performance test data of gas turbines operating has been done. Confirming the results of gas turbines operating simulation, the possibility of designing HRSG boilers would be available.

Design of HRSG boilers using Thermo flow software has this advantage that different operating conditions of gas turbines and HRSG boilers would be considered simultaneously.

Economical study is done as an important measure in this project and payback period has been calculated based on different price of natural gas. Also the cost reduction of plan, while considering CDM, has been evaluated.

II. Plant Configuration

There are four gas turbine generators for electricity generation. Their type is GE PG6561B. Composition of their consumption fuel gas is mentioned in Table II and four steam boilers are available to generate high pressure steam (43 barg). Operation data related to Boilers are shown in Table III and operation data related to turbo generators in Table IV.

III. Methods

A. Method of Study

The first step of this study is considering operating condition of turbo generators and turbo compressors. This study for calculating the actual & operating condition is essential. Study of ground and underground installations impresses that enclosure of turbo compressors except in phase 2&3, has made restrictions for performing the plan.

At first the possibility of installing HRSG Boilers according to site condition, above ground and underground, installations was investigated. The underground around the gas turbine compressor do not allow installing any new component.

To design HRSG boilers two scenarios were investigated:

- The exhaust gas entered HRSG boiler only from one gas turbine.

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- The exhaust gas entered HRSG boiler from three gas turbines.

The advantage of first scenario is low initial cost and small structure of the designed HRSG boiler, while the greatest disadvantage is less using energy lost.

In the second scenario, initial cost is much more than the first one. Technical and economical study to design HRSG boilers represents that in viewpoint of energy conservation and optimization, the second scenario to design HRSG boiler is more economical. Simulation of second scenario is shown in Table V.

B. Thermoflow 17.0.2 Software

Thermoflow 17.0.2 software has been used to consider the condition accurately. This is one of the strongest software in simulation of gas turbines operation and power plant cycles. Using this software, the effect of different environment and operating conditions on gas turbines performance and then, HRSG boilers would be possible accurately, based on the actual condition.

C. Reliability of Simulation

The type of current gas turbines is GE PG6561B which is available in the library of this software. In addition to this to rely the results of simulations, it is necessary to compare different conditions and statistics with actual. In this project, results validation of simulation by this software in site condition and by using performance test data of gas turbines operating has been done. Confirming the results of gas turbines operating simulation, the possibility of designing HRSG boilers would be available. Design of HRSG boilers using Thermo flow software has this advantage that different operating conditions of gas turbines and HRSG boilers would be considered simultaneously. The performance test data and the result of simulation are shown in Table I, the maximum error of the current simulation is approximately less than one percent.

TABLE I
GAS TURBINE PERFORMANCE TEST DATA

Ambient condition	**Atmospheric Pressure**	**mbar**	1010
	Ambient Temp.	**ºC**	48
	Relative Humidity	**%**	80
Grid characteristics	**Power Factor**	**-**	0.8
	Net Frequency	**Hz**	50
Gas Turbine parameters	**Inlet losses**	**hpa**	10
	Exhaust static pressure	**hpa**	10
Fuel characteristics	**Natural Gas**		
	Temp.	**ºC**	35

TABLE II
GAS COMPOSITION (%VOL)

Component	**CH_4**	**C_2H_6**	**C_3H_6**	**C_4H_{10}**	**C_5H_{10}**	**N_2**	**CO_2**
% VOL	74.1347	10.7932	6.6375	3.3981	1.1353	2.0671	1.8334

TABLE III
OPERATION DATA RELATED TO BOILERS

Time period	**No. of working boiler**	**Generated steam temp.**	**Generated steam press.**	**boiler make up flow rate**
		°C	**barg**	**Ton/hr**
Summer	3-4	384	44.1	85-110
Winter	4	384	44.2	77-97

TABLE IV
OPERATION DATA RELATED TO TURBO GENERATORS

Time period	No. of in-service Turbo generators	Turbo generators power MW
Summer	3	12.9-16
Winter	2-3	14.2-16.8

TABLE V
SIMULATION OF SECOND SENARIO

Amb. Temp.	Load	Heat Rate	Turbine Efficiency	Fuel Consumption		Turbine Exhaust Gas Analysis				
	Gross	Gross	Gross	Kg/s	KWh (LHV)	N2	O2	CO2	H2O	Ar
°C	KW	KJ/KWh	%			%	%	%	%	%
30	15503	15335	23.48	1.472	66039	74.536	15.731	2.240	6.596	0.897

TABLE VI
RESULT OF HRSG SIMULATION FOR GTGS

				Summer	Winter
Ambient Condition	Temp.		°C	40	20
	R.H.		%	60	65
	Pressure		bar	1.01	1.01
Gas Turbine	Model		-	GE 6561B	
	NO. of GTG			3	3
	Output Power (Total)		KW	43507	46509
	Gross Heat Rate		KJ/KWh	15835	15339
	Gross Efficiency		%	22.73	23.47
	Fuel Consumption (Total)		Kg/s	4.267	4.418
	Emission	N2	%	73.118	75.361
		O2	%	15.360	16.082
		CO2	%	2.234	2.173
		H2O	%	8.408	5.477
		Ar	%	0.880	0.907
HRSG	Ex. Temp.		°C	224.5	228.5
	Ex. Flow		kg/s	317	341.6
	Steam Temp.		°C	384	384
	Steam pressure		bar	44	44
	Steam Flow		ton/h	100.3	90.45

D. Influence of Parameter

After designing HRSG boiler in 2nd scenario, the effect of different conditions on performance of HRSG boiler would be considered to determine effects of these conditions on flow rate of steam generating.

Influence of different parameters are investigated, environment temperature has a deep influence on the GTG efficiency, on the other side HRSG performance has close relation with GTG performance, so environment temperature on the performance of HRSG will have considerable effect. “Fig. 1” shows the influence on environment temperature on generated steam of HRSG and “Fig. 2” shows influence of GTG power on generated steam of HRSG. In these 2 figures, "Main IP process mass flow" presents the mass flow of generated steam in HRSG. As shown in Fig. 1, any increase in temperature causes efficiency reduction, while low efficiency leads to exhaust heat loss increase, and therefore the mass flow of generated steam in HRSG would increase.

Also as shown in Fig. 2, while the generated power of gas turbine increased, mass flow of exhaust gas and therefore mass flow of generated steam in HRSG would increase.

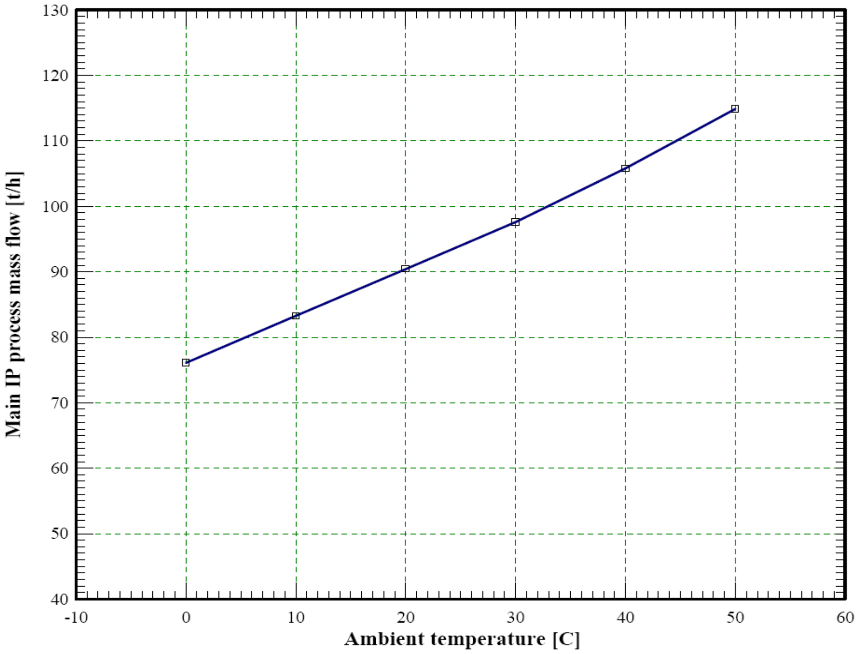

Fig. 1 Influence of environment temperature on generated steam of HRSG

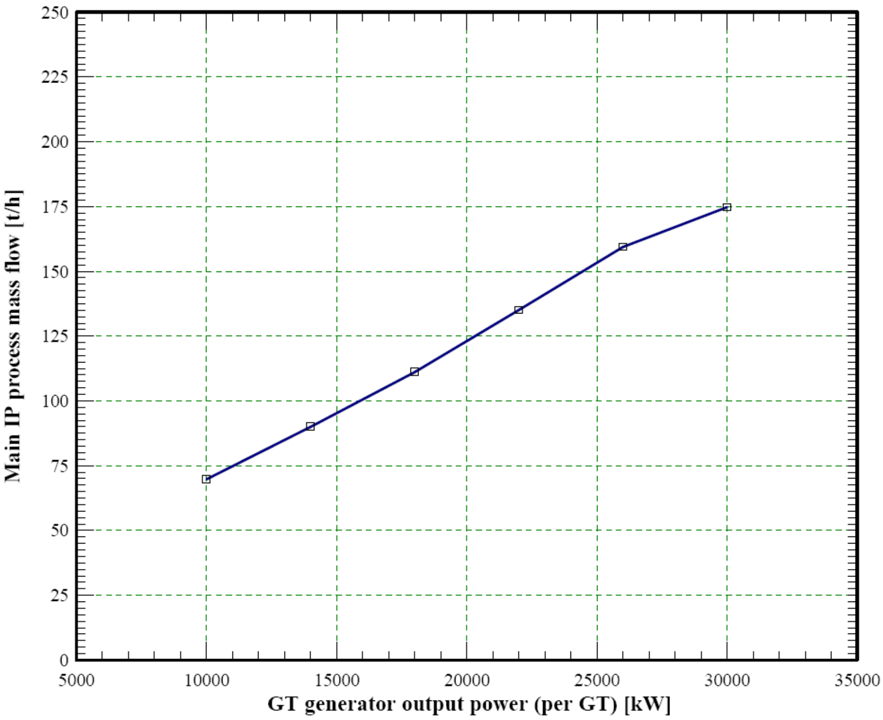

Fig. 2 Influence of GTG power on generated steam of HRSG

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IV. Financial Analysis

For cost estimation the rate of generated high pressure steam (as specification of header) by HRSG boilers is according to load of turbo generators & turbo compressors. The evaluation of purchase, install and perform plan costs. The evaluation of payback time based on different price of natural gas and by considering the profit of clean develop mechanism (CDM) project (appropriate methodology) [1,2,3].

The reduction of consumption fuel gas due to installation of HRSG was calculated by "(1)" for 330 work day.

$$Reduction\ in\ fuel\ consumption\ \left({}^{Rial}/_{Year}\right) = HRSG\ steam\ production\ \left({}^{Ton}/_{hr}\right) \times Specific\ fuel\ consumption\ \left({}^{Nm^3}/_{Ton}\right) \times \frac{24\ hr}{1\ day} \times \frac{330\ day}{1\ year} \times Fuel\ cost\ \left({}^{Rial}/_{Nm^3}\right) \quad (1)$$

It is necessary to calculate the amount of current boilers fuel consumption for generating one ton steam"(2)" as specific fuel gas consumption.

$$Specific\ Fuel\ Consumption\ \left({}^{Nm^3}/_{Ton\ of\ steam}\right) = \frac{Fuel\ Consumption\ \left({}^{Nm^3}/_{hr}\right)}{\text{Steam production}\ \left({}^{\text{Ton}}/_{\text{hr}}\right)} \quad (2)$$

By impose of HRSG to available system the turbine fuel consumption will increase, this cost is calculated by "(3)".

$$Increase\ in\ fuel\ consumption\ \left({}^{Rial}/_{Year}\right) = \left[Fuel\ consumption\ with\ HRSG\ \left({}^{kg}/_{s}\right) - Fuel\ consumption\ without\ HRSG\ \left({}^{kg}/_{s}\right)\right] \times \frac{1}{Density\ of\ Nat.Gas\ \left({}^{Kg}/_{Nm^3}\right)} \times \frac{3600\ sec}{1\ hr} \times \frac{24\ hr}{1\ day} \times \frac{330\ day}{1\ year} \times Fuel\ cost\ \left({}^{Rial}/_{Nm^3}\right) \quad (3)$$

Installation of HRSG besides the reduction in fuel consumption, due to increase of pressure drop in turbine gas exhaust its efficiency will be decrees so the fuel consumption of turbine will be increased in the constant load. The payback time is calculated by investment cost divided by reduction in fuel consumption (due to steam production) mines increase in fuel consumption.

As mentioned before, economical study is done as an important measure in this project and payback period has been calculated based on different price of natural gas. Also the cost reduction of plan, while considering CDM, has been evaluated (Table VIII).

V. Conclusion

Installation of heat recovery boiler was simulated in ThermoFlow 17.0.2 software, based on test operation data and the equipments site operation conditions in Pars exclusive economical energy area, Maximum error of the current simulation is approximately 1% or less. The affect of installation HRSG package on the available gas turbine and its operation parameters, ambient temperature, the exhaust temperatures steam flow rate and were investigated. Base on the results recommended HRSG package should have the capacity for 98 ton per hour high pressure steam generation in this refinery, Horizontal HRSG and the Pinch and Approach points respectively are 17 and 11 degree Celsius [4,5,6] is suitable. The designed HRSG specification is shown in “Table VIII”. Besides saving energy this project will be an Environment-Friendly project. The Payback Period is estimated approximately 1.8 years, “Table VIII”, with considering Clean Development Mechanism. This project will be cost effective and producing cleaner energy achieving more efficiency of our plant.

TABLE VII
Designed HRSG Specification

HRSG Steam Flow			HRSG Dimension			Reduction in fuel consumption (due to turn off boiler(s))		Increase in fuel consumption (due to reduction of GT efficiency)		Reduction in CO_2 emission
Design (30 ºC)	Summer (40 ºC)	Winter (20 ºC)	L	W	H	Summer	Winter	Summer	Winter	ton/year
ton/hr	ton/hr	ton/hr	m	m	m	Nm^3/month	Nm^3/month	Nm^3/month	Nm^3/month	
97.6	100.3	90.45	17.2	2.6	8.9	5.37×10^6	4.81×10^6	0.28×10^6	0.31×10^6	9.97×10^4

TABLE VIII
PAYBACK PERIOD CONSIDERING CDM

Investment Cost		sale of CER	Payback Time without CDM			Payback Time with CDM		
without CDM	with CDM		Fuel price: 700 Rial/Nm3	Fuel price: 1350 Rial/Nm3	Fuel price: 1000 Rial/Nm3	Fuel price: 700 Rial/Nm3	Fuel price: 1350 Rial/Nm3	Fuel price: 1000 Rial/Nm3
billion Rial	billion Rial	Million Rial/year	Year	Year	Year	Year	Year	Year
87.0	87.9	9772	2.2	1.1	1.5	1.8	1.0	1.3

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