International Journal of Natural and Engineering Sciences
E-ISSN: 2146-0086 12(3): 56-58, 2018

The Effect of Steam Injection that is Applied to Increase Performance of the Gas Turbines

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Abstract

This Electricity demand increases with each day in the developing countries with the strong economic growth; however the power producers are trying to find cost efficient methods in order to increase power efficiency and reduce generation costs, respond more quickly to the change in the market conditions due to liberalized electricity markets and gas prices with their high volatility.
Especially gas turbines are often used to meet the peak loads in the combined cycle power stations used commonly for power generation. In this study, the changes that occur in the station general power output and performance by injecting a certain amount steam that is taken from the steam turbine to the combustion chamber of the gas turbine by a computer supported analysis programme at a combined cycle power station. The optimum amount of steam that can be injected into the gas turbine was determined by computer aided modeling. With this steam injection, the change in the power output of the plant was found..

Keywords: A Gas turbines, Steam injection, Performance analysis, Optimisation, Power output

INTRODUCTION

For the last fifty years, various studies have been performed to increase the performance of gas and steam turbines. The most common practice is the execution of combined-cycle where gas turbine cycle (Brayton cycle) is coupled with the steam turbine cycle (Rankine cycle) and a waste-heat boiler [1]. During such execution, increasing the performance of gas turbine or steam turbines also increases the performance of combined-cycle power plants. In this study, the change in both gas turbine and the power plant's total performance due to some amount of steam's being drawn from the steam turbine was investigated.

Historical Background

In combined heat power generation systems, power generated from the gas turbine increases when steam is injected to the combustion chamber, but since the steam injected to the combustion chamber is drawn from the steam that will work at steam turbine, total performance of the system decreases [02].

It is important to consider when deciding in which level the steam will be drawn from the steam turbine that, the pressure of the steam which will be sprayed to the combustion chamber cannot be less than the compressor discharge pressure [03].

It is important to consider when deciding in the amount of the steam to be drawn from the steam turbine that, the amount of steam should be equal or less to the %5 of the amount of air passing through the compressor [04].

MATERIALS AND METHODS

Gate Cycle

Gate Cycle is an engineering application developed for the design and analysis of power plants. Gate Cycle software provides the designers ease of modelling a plant with design parameters, understanding and guessing the alternating loads, ambient conditions, equipment distortion and changes in the performance of the plant [05]. It is possible to design and analyse almost all power plants including combined-cycle, cogeneration, traditional coal-fired, fluidized bed power plants with this program. Program is a flexible and complete package integrated to a built-in database, solid engineering models, and customizable calculations.

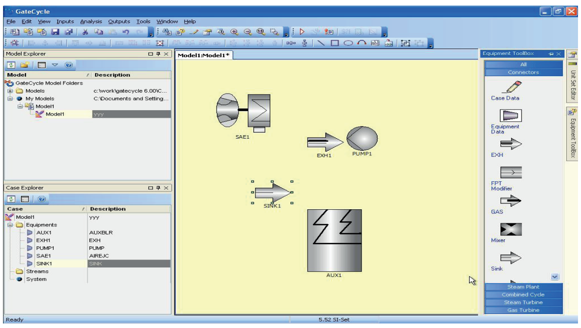

Figure 1. Gate Cycle screenshot

Alstom 13E2 Gas Turbine

13E2 model gas turbine by Alstom company was chosen for the modelling. Specifications of Alstom 13E2 model turbine are summarized below.

Table 1. Alstom 13E2 Gas turbine features

Turbine Model	Producer	Power (MWe)	Efficiency	Compression Rate	Heat Rate (Btu/kWh)
13E2	Alstom	165	35.7	15.4 : 1	9376

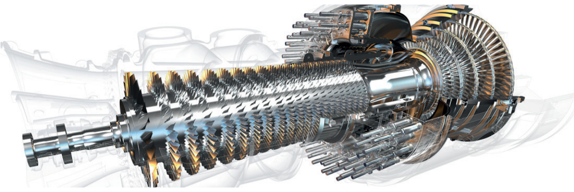

Figure 2. Alstom 13E2 general view

Thermal Model

A combined-cycle power plant consisting of an Alstom 13E2 model gas turbine, a steam turbine and a heat recovery steam generator is modelled. Two-stage steam turbine was designed to contain one low pressure and one high-pressure chamber. Design was planned such that the low pressure is 6 bar and high pressure is 60 bar at the heat recovery steam generator.

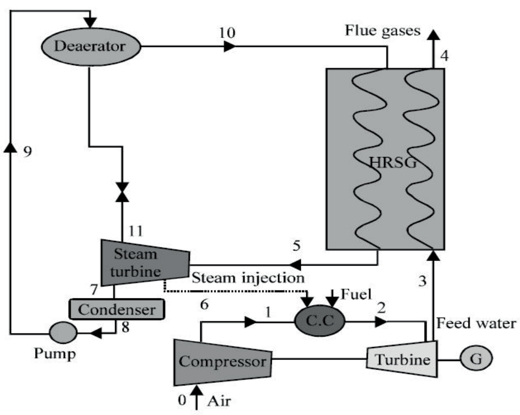

Figure 3. Overview of the designed model

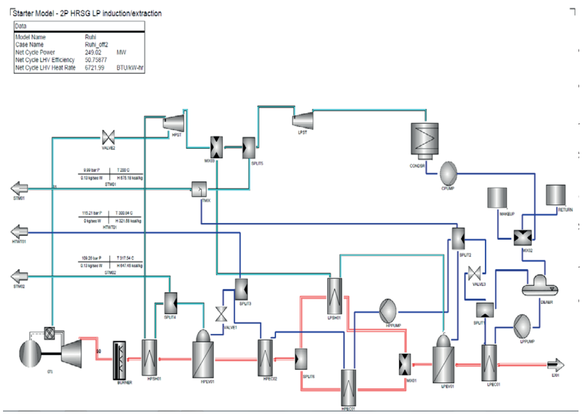

Figure 4. Designed thermal model with Gate Cycle

RESULTS AND DISCUSSION

In order to determine the optimum steam injection amount to be sent to the gas turbine in the modelled combined-cycle plant, trials were made in 0, 1, 5, 10, 13, 14, 15, 20 kg/sec intervals with computer aided analysis program. Results are summarized in the table below.

Table 2. Gate cycle results for modeled power plant

	Steam Injection	ST Shaft Power	GT Shaft Power	Overall Power	Ex-Gas Out Flow	Fuel Inlet	Ex-Gas Out Temp.	Ex-Gas Enthalpy	Cycle Efficiency	Cycle Heat Rate	Steam In Press	Comp Disch Press
	kg/sec	MW	MW	MW	kg/sec	kg/sec	°C	kcal/kg	LHV	BTU/kW-hr	bar	bar
HP	0	72,02	164,47	236,49	520,48	9,71	530,01	133,81	51,28	6653,92	0,00	15,10
HP	1	71,48	165,89	237,37	521,52	9,75	530,00	134,04	51,25	6657,06	19,62	15,16
HP	5	69,41	171,05	240,46	525,68	9,91	529,98	134,95	51,08	6679,12	18,44	15,35
HP	10	66,99	177,65	244,64	530,89	10,12	530,04	136,10	50,91	6701,98	17,03	15,59
HP	13	65,59	181,64	247,23	534,01	10,25	529,96	136,75	50,82	6714,08	16,20	15,73
HP	14	65,15	182,91	248,06	535,05	10,29	530,01	136,98	50,78	6718,74	15,94	15,78
HP	15	64,72	184,30	249,02	536,10	10,33	530,04	137,21	50,76	6721,99	15,68	15,83
HP	20	62,61	190,93	253,54	541,31	10,55	529,96	138,28	50,63	6739,15	14,37	16,06

When the results were examined, it is seen that mass flow rate of the fluid increases with the increasing percent of the steam injected therefore the power output of the gas turbine increases. However, the power output of the steam turbine decreases since the steam sent to the gas turbine is drawn from the steam turbine. Results reveal that, total power output of the plant increases with the increasing steam injection to the gas turbine.

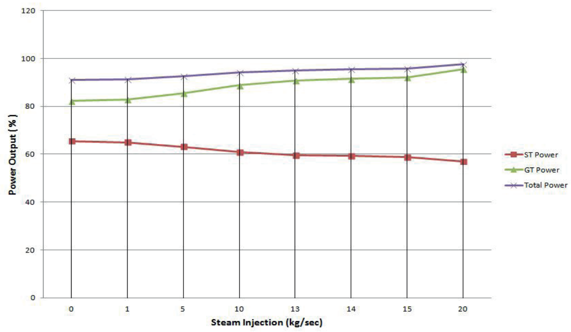

Figure 5. Power output chart

Since the control system was modelled to keep the temperature of the combustion chamber constant, temperature of the combustion chamber decreases due to steam injection, and control system sends additional fuel there to keep the combustion temperature constant. When additional fuel is sent to the combustion chamber, compressor is forced to send an additional amount of air, thus the outlet pressure of the compressor increases. Increasing steam injection increases the outlet pressure of the compressor and decreases the injection pressure of the steam. Consequently, steam injection pressure should be more than the outlet pressure of the compressor and at maximum level in order to increase the outlet power of the gas turbine.

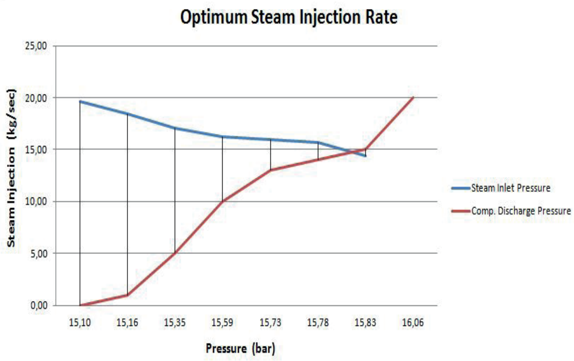

Figure 6. Optimum steam injection rate

When the results of the model designed according to this table is analyzed, it can be said that when the steam injection amount exceeds 15 kg/sec the pressure of the steam entering the combustion chamber stays below the compressor outlet pressure. Therefore, the amount of injected steam is optimal at 13 kg/sec which is equal to the %2.5 of the amount of air passing through the compressor.

CONCLUSION

It is possible that if the steam injection's effects on operational costs like fuel and water and maintenance costs are considered, and if the total costs are compared to the current sale price of electricity, the profit/loss scenario of the plant can be determined.

Considering the profit/loss scenarios, steam injection system can be operated with regard to daily sale price of electricity and gas, this system provides flexibility to plant operations.

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