LCC Evaluation of a High Efficiency Combined Cycle Power Plant Installed In Rio de Janeiro City With a TIC – Gas Turbine Air Inlet Cooling System Implementation

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1. INTRODUCTION

A Life Cycle Cost evaluation will be performed of a high efficiency 110 MW Combined Cycle Power Plant operating in Rio de Janeiro City with the implementation of a TIC - Gas turbine air inlet cooling system. It will be determined the NPV for 20 years, considering: the extra power provided by GT and pricing under ANEEL fees [15], the ST power losses, and all costs involved for TIC system implementation.

The GT – Gas turbine performance is expressed in terms of net power available on the GT output shaft and heat rate. [2] [3] In GT at nominal speed the air volume flow remains approximately constant, however, the mass flow will vary depending on the air inlet temperature and humidity. Each increment of 1 ^{o}C in the GT incoming air temperature results in a loss of 1% in GT output shaft power, and increasing in 0,031% the heat rate. AC – Absorption chiller – TIC technology was elected as being the best technology to be applied.

1.2 A schematic diagram of the CCPP system + TIC

Figure 1. CCPP system schematic diagram to be installed in Rio de Janeiro City. The GT packages performance will be improved using 2 x 50% configuration AC - Absorption Chillers. These chillers will produce chilled water. Each AC uses heat input from a low-pressure steam (about 4.2 bar) from HRSG. The chilled water storage tank – TES will be installed between the AC and the chiller coil module. The primary pumps circulate chilled water between the chilled water storage tank and the absorption chiller, and the secondary pumps circulate chilled water between the TES - storage tank and the chiller coil module installed in front of GT air inlet filters.

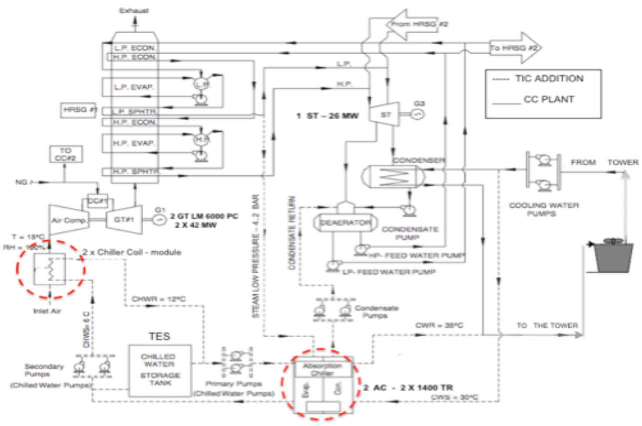

Figure 1 - CCPP + TIC schematic diagram

2. METHODOLOGY

2.1 On site ambient temperature election

For a 10 years scenario, 2007-2016, a temperature database was developed based on the collection of the hourly temperature measurements of the automatic meteorological station of Seropédica – RJ.

In one day the air temperature and humidity can vary greatly. Comparing a large number of the thermal amplitude samples during the days, it was observed a relative number of hours for the maximum, minimum and average temperatures, as given: 00:00 am to 8:00 am – minimum records, from 12:00 am to 6:00 pm – maximum records, and 9:00 am to 12:00 am / 7:00 pm to 11:00 pm – average records. [14] Therefore, for a same day, during the GT power calculation it will be considered the machine operating a amount of hours in maximum, avarage and minimum temperatures.

Figure 2. Meteorological station of Seropédica - RJ, located in the industrial area of Rio de Janeiro City.

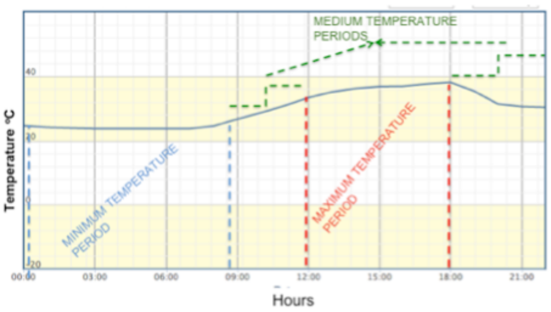

Figure 2. A day thermal amplitude [14]

2.2. Load calculation - cooling system dimensioning

The inlet air-cooling system, with absorption chiller (AC), will be dimensioned to cool the GT inlet air mass flow temperature from 32 ^{o}C to 15 ^{o}C. Table 4. THERMOFLOW® software simulates the necessary total cooling load by using the energy balance formula:[6]

$Q_{CL} = m_{air} [(h_a - h_c) - hf_{g,c} (\omega_a - \omega_c)]$[6] (1)

Description	Unit	Value
Air mass flow rate to be cooled at GT inlet (M_a)	Kg/s	115
Air temperature – site condition – RH = 70 %	^{o}C	32
Enthalpy – Inlet air - h_a	kJ/kg	86.26
Air temperature after coil	^{o}C	15
Enthalpy – air after cooling - RH = 100 % - h_c	kJ/kg	42.20
Heat to be removed per machine - Q_{CL}	kW	4.560
Heat to be removed per machine - Q_{CL}	TR	1.420
Total heat to be removed - 2 machines	TR	2.800

Table 1. Absorption chiller-dimensioning

Chilled water capacity THERMOFLOW® simulation based on heat transfer formula:

$Q_{cw} = M_{cw} * Cp_{cw} * (T_{cw2} - T_{cw1})$ [6] (2)

Description	Unit	Value
Mass flow rate for 1 TR	Kg/s	0.139
Vol flow for 1.420 TR + 10%	M^3/h	752
Total Vol flow – 2 machines	M^3/h	1.500

Table 2. Chilled water capacity [5]

3. GT - EXTRA POWER CALCULATION & ECONOMIC ANALYSIS & RESULTS

The AC needs a constant (4.2 bar) low-pressure steam, with a mass flow rate of 3.5 kg/s (4.5kg/h-RT) in accordance with AC manufacturer specs. THERMOFLOW® software simulation indicates that the ST power output decreases by around 1.82 MW. This is a very conservative calculation. Table 3. LCC evaluation results.

Premises & LCC Evaluation Results		
Interest rate - Brazil		15 %
Currency exchange rate - Real /US$	08/01/2017	3,11
MWH Price - Rio de Janeiro + taxes	ANEEL – R$ 628,00	$201.58
Life time service	Years	20
ST losses + Auxiliary electric load	MWH per/year	17.243
TIC capital cost		$14,700.000
GT system availability record		95 %
TIC system O&M cost	Per year	$965,000
CCPP extra power delivered	Per year	69.248
Net Present Value (NPV)		$67,263.511
Payback period	Year	1.5

Table 3. LCC evaluation results

4. CONCLUSIONS

The TIC - turbine inlet air-cooling system application is feasible and very attractive. Nowadays, the AC – absorption chiller technology can be considered as a reliable alternative with several successful applications worldwide.

The estimated net electric power production would increase by 69.248MWh/yr. The payback period is 1.5 years, and the net present value (NPV) is 67.26 MUS$.

5. REFERENCES

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