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Simulation of air in let cooling system of a Gas Turbinepowerplant

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ABSTRACT:
This research work focus on the simulation of air inlet cooling system of a gas turbine power plant using anASPEN HYSYS simulation software. ASPEN HYSYS is engineering software suite. The user interface is predicatedon a library of ready-made user editable component models based in FORTRAN. Operating data for gas turbineunit were collected in every two hours on a daily control log sheet for a period of one month.The daily averageoperating variable were statistically analyzed and mean values were computed for the period of collection. Theperformance of the plant was determine by simulation using ASPEN HYSYS software to obtain the compressorwork, turbine work. Other results such as Net-power, specific fuel consumption, heat Rate and thermal efficiencywas calculated in excel sheet. The results obtained show that decrease in inlet air temperature brings about anincreaseinpoweroutputandthermalefficiency.Also,retrofittingoftheexistinggasturbineplantwithmechanicalsystem give abetterperformance.
Keywords:ASPENHYSYSsimulationsoftware,GasTurbine, Airinletcooling,Temperature,

INTRODUCTION

The performance of a gas turbine powerplant is sensible to the ambient condition.Theambienttemperaturehashugeinfluenceontheperformanceofagasturbineplant.Astheambientairtemperaturearises,lessaircanbecompressedbythecompressor,thus,the gasturbine outputisreducedat agiventurbine entry temperature [1]. Besides, thecompressionworkincreasesbecausethelimitedvolumeoftheairincreasesinproportionalitytotheintakeairtemperature[2,3].Inletaircoolingandintercooling are two important methods forrisingpoweroutputofgasturbinecycles.
Gas turbine intake air cooling may cause asmalldecreaseinefficiencybecausealotoffuelisneededtomakecompressorexhaust gas [4]. Gas turbine makes use ofambientairforitsoperationanditperformanceisgreatlyaffectedbythesefactors(ambienttemperature,ambientpressure,relativehumidity)whichinfluence the flow rate of air delivered tothecompressor,intermsofweightandphysicalconditions[5].
Anincreaseincompressorinlettemperature brings about a correspondingincrease in the specific work required tocompresstheair.However,theweightdeliveredwillbeincrease(becauseofdecrease in specific weight). Consequently,thepoweroutput,turbineefficiencyandusefulworkdiminish[6].Ifthecompressorinlettemperaturesdecrease,thereverseprocessoccurs.Thistemperature dependsonthe airaspiratedby the compressor. Power and efficiencyvaries from turbine to turbine, according tocycleparameters,compressorandexpanded output and air delivery rate etc.Asaresult,thevariationratiosofgasturbineperformanceparameterareproportional to design point [7]. Figure 1showshowpower,heatconsumption,heat rate and the delivery rate of theexhaustgases are influence by ambient temperature[8].**(ReferFig. 1)**
The inability of agas turbine engines toperform to an optimum efficiency is as aresult of increase in compressor air aboveISOcondition(15^{0}C)[8].Thisresearchworkisaimedattheimprovingthegasturbine performanceand bring it neartoISO conditions.

METHODS AND MATERIALS SOFTWARE MODELLING AND SIMULATION TOOL

ASPENHYSYSisengineeringsoftwaresuite. The user interface is predicated on alibraryofready-madeusereditablecomponentmodelsbasedinFORTRAN.Byconnectingthesecomponentsbymaterialheatandworkstreamsandprovidingappropriateinputs,theuserisable to model complex processes. ASPENiscommonlyusedsoftwareplatformforprocessmodeling,particularlyintheoilandgasindustry,PowerGenerationCompanyetc.

DATAUSED

Operating data for gasturbine unit werecollectedineverytwohoursonadailycontrollogsheetforaperiodofone month.Thedailyaverageoperatingvariablewerestatisticallyanalyzedandmean values were computed for the periodofcollection **(ReferTable1).**

3.4 MODELLING OF GASTURBINEUNIT

ThebasicgasturbinecycleisBraytoncycle. Air enters the compressor where it iscompressedandheated.Itgoestothecombustion chamber; the fuel is burned atconstant pressure where the temperature ofair is fired to a high temperature (T_3). Theresulting high temperature gases enter theturbine where they expand to generate theuseful work and theexhaustgases leavetheturbine(open-cyclegasturbineengine).Figure2showstheschematicdiagramof simple Gas Turbine andfigure3 shows the flow chart of model SimpleGasTurbine. **(ReferFig.2)**

InFigure2,thecompressorinlettemperatureisequaltoambientairtemperaturesincethebase-caseneglectsthe cooling effect and simulate the cycleunderISOcondition(T_1 =15^{0}C,P_1 = 101.3kpaand □=60%).Thereis no pressuredropatinletandexhaustductsthus;pressuredropacrosscombustionchamber is taken to be 2% [9]. **(Refer Fig.3)**

Thegasturbineplantconsistsofcompressor,combustionchamberandturbine.Inthisresearchwork,theinletcoolingtechniqueproposedfortheanalysisismechanicalrefrigerationcoolingsystem.Theperformanceofthegas turbine is evaluated with the proposedcoolingtechniqueandcomparedwithvalues.Inthemechanicalrefrigerationsystem,therefrigerationvapouris compressedusingvapourcompression.The vapour passes through the condenserwhereexpansiontakesplaceintheexpansionvalve,thus,providingthecoolingeffect.Theevaporatorhelpstochills the incoming air before entering thecompressor. The gas turbine power plant ismodelbaseon the followingassumptions;

i. Allcomponenthasadiabaticboundaries
ii. PlantperformanceatISOconditions
iii. The air and the combustion products areassumeideal characteristics
iv. Kineticandpotentialcomponentsofenergyareneglected
v. The ambient conditions of temperatureandpressureareat27.63^{0}Cand101.3kpa
vi. The vapour entering the compressor isdrysaturatedandthereisnoundercooling
vii. Lowerheatingvalueoffuel(LHV)tobe50,000kJ/kg
viii. The pressure drop in combustionchamber2%
ix. Combustionefficiencyto be0.99
x. Isentropicefficiencyforcompressorandturbine100%
xi. Pressure and temperature of theevaporatorto be(2.4371bar, -5)
xii. Pressure and temperature of thecondenserto be(11.5447bar, 45)
xiii. Workfluidofrefrigerant134a

PROCESS SIMULATION

The first step in creating the model was theselection of a standard set of componentsand a thermodynamic basis to model thephysicalpropertiesofthesecomponents.The selected components data required forthe Gas Turbine simulation are shown in**(ReferTable 2).**

Whenthecomponentlistwascreated,HYSYScreatedanewcomponentlistcalled "Component List-1". The next stepwas the selection of a 'Fluid Package' forit.The'FluidPackage'whichisthethermodynamic system associated with thechosen list of components **(Refer Figure4).**

ToaccountforthereactionthatwillbetakingplaceintheCombustionChamber

thereactionmethanewasaddedtotheprocesssimulation**(ReferFigure5).**
Figure 6 shows the process flow sheet forGasTurbinewithMechanicalRefrigerationUnit. **(ReferFig 6)**

Therefrigerantiscompressedinthecentrifugalcompressorunitandthisisfollowedbycondensation.Thecondensevapour is expanded in the expansion valvewhere it provides the cooling effect. Thecoldaircompressedinthecompressorenteredthecombustionchamber.Hotgases produced in the combustion chamberare expanded in the turbine to produce thework,which drivethecompressors.

RESULTS AND DISCUSSION

Theperformanceoftheplantwasdeterminebysimulationusing ASPENHYSYS software to obtain the compressorwork, turbine work. Other results such asNet-power,specificfuelconsumption,HeatRateandThermalEfficiencywascalculatedinexcelsheet.Table3showstheresults obtained. **(ReferTable 3)**
Thesimulationresultsobtainedbyincorporatingairintakecoolingsystem(mechanicalrefrigerationsystem),theambient air temperature, pressure at inletandexit,massflowrateofrefrigerant, massflowrateofairenteringthemechanical refrigeration unit, the ambientairtemperaturevariedatdifferentconditionis showin **(ReferTable4).**
Figure7showsthegraphofnetpoweroutputagainstambienttemperature.Anincreasesinletairtemperaturefrom301kto313kdecreasesthepoweroutput.Thisleadtoapproximately0.135%dropinpowerloss,thislosscanbepreventedbycooling theinletairtemperaturefrom313kto301k,thus,anapproximately0.136%increase in power output. **(Refer Fig. 7)**Figure8showsthegraphofthermalefficiencyagainstambienttemperature.Itwas observed that as the inlet airtemperatureincreasefrom301kto313k,there was a decrease in thermalefficiencies.Therefore,anapproximately0.0605%dropinthermalefficiencywasrecorded.Thisdropcanbeincreasebycoolingtheinletairtemperaturefrom313kto301kwhichleadstoapproximately0.066%increaseinthermalefficiency.**(Refer Fig. 8)**

Figure 9 shows the graph of specific fuelconsumption against ambient temperature.Increase in ambient inlet temperature from301k to 313k brings about an increase inspecificfuelconsumption.Thisleadto approximately2.41%increaseinhighCOandHCemission.Theemissioncanbeprevented by cooling the air inlettemperaturefrom313kto301kwhichwillbring about an approximately 2.35%decrease in fuel burning. **(Refer Fig. 9)**Figure10showsthegraphofheatrateagainstambienttemperature.Anincreaseinambientairinlettemperaturefrom301kto313kincreasetheheatrate.Thisleadtoapproximately 0.460 drop in fuelefficiency.Thisdropcanbepreventedbycoolingtheinletairtemperaturefrom313kto301ktherebyincreasingfuelefficiencyby0.462%efficiency. **(Refer Fig. 10)**

CONCLUSION

Simulation model that consist of thermalanalysisofgasturbinecoupletorefrigerationcoolerwasdevelop.Theperformance analysis is based on couplingthe thermodynamic parameters of the gasturbineandcoolerunitwiththeothervariable.TheaugmentationoftheGasturbine plant performance is characterizedusingthepowergainratio(PGR)andthermal efficiency change term (TEC). Theperformanceanalysisofthegasturbineshowsthattheintakeairtemperaturedecrease by 27.63^{0}C to 17.79^{0}C while thePGRincreasetoamaximumof10.75%.
There was anaverage increase in poweroutputfrom33.794MWto37.425MWwith significant increase in plant thermalefficienciesfrom33.279%to36.855%.Therefore, decrease in inlet air temperaturebrings about an increase in power outputandthermal efficiency.

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LISTOFFIGURES:

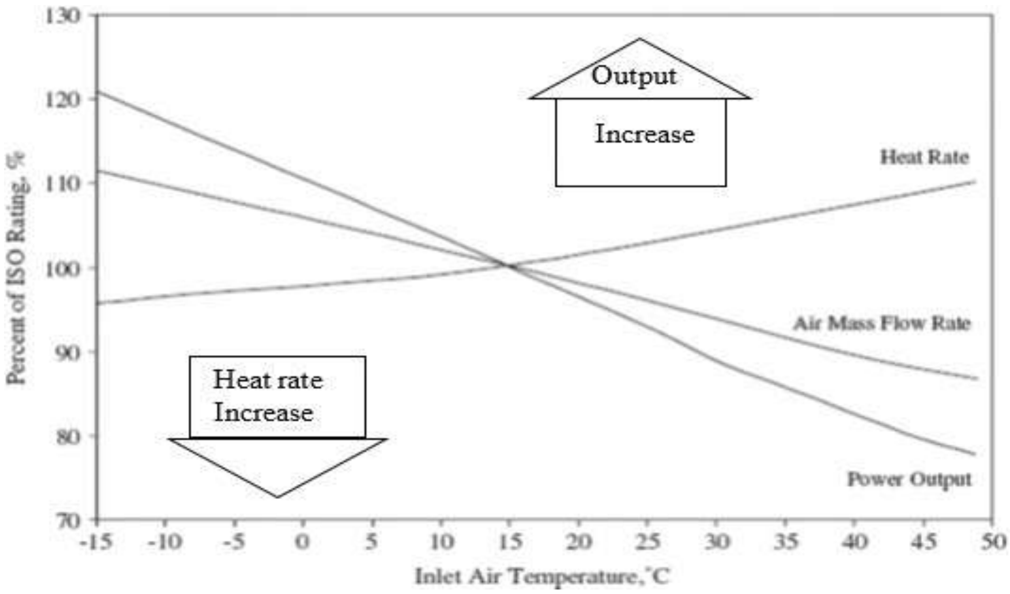

Fig.1.Influenceof externalfactor on gasturbineperformance[8].

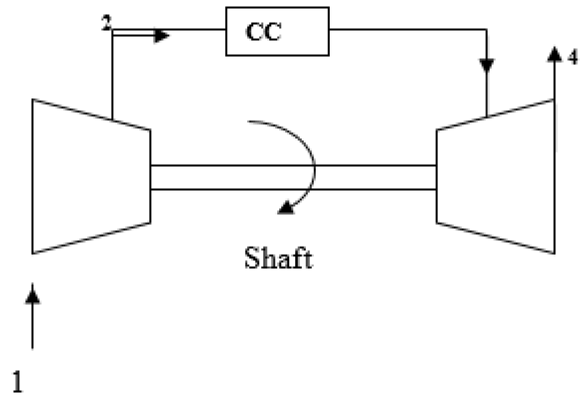

Fig.2Schematicdiagramofsimplegasturbineunit

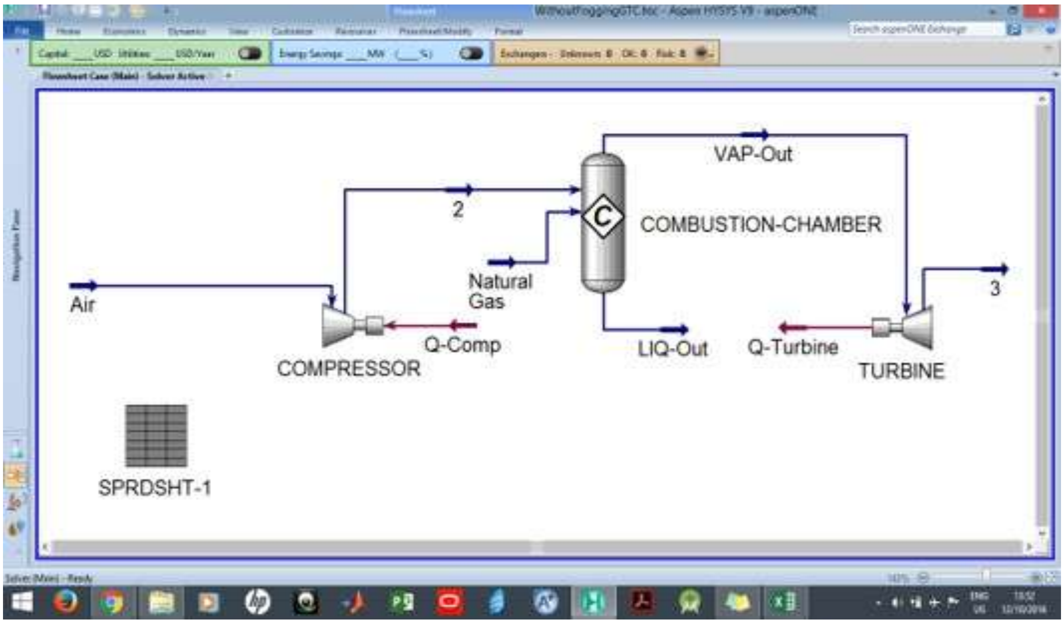

Fig.3Flowchartmodelof Gas Turbine.

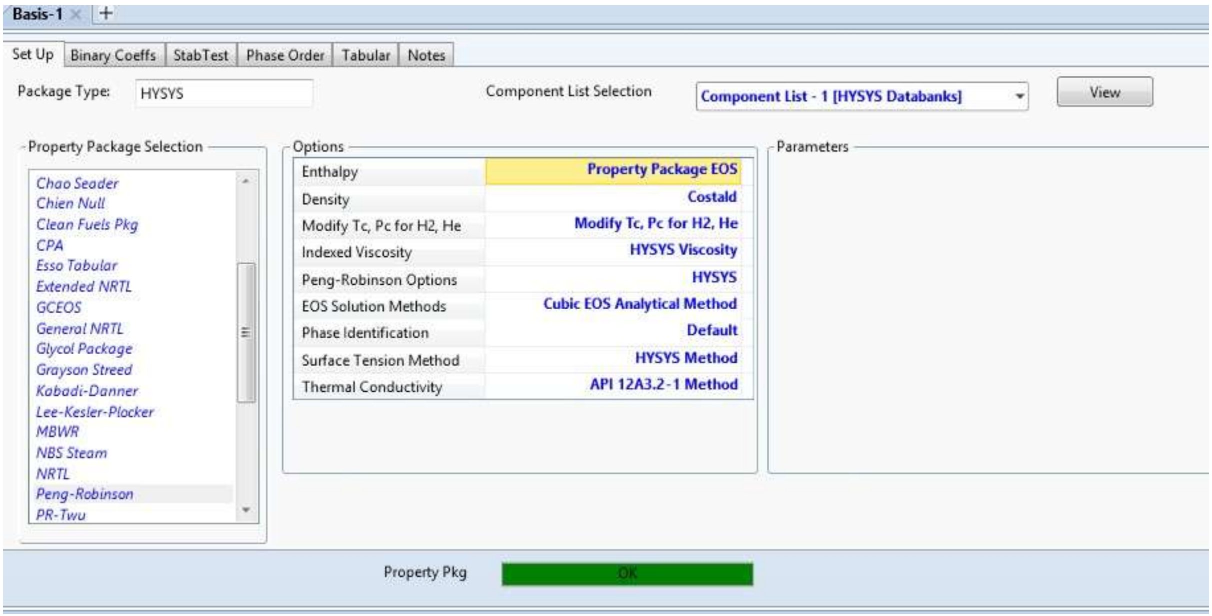

Fig.4 Selectthermodynamicsforfluidpackage

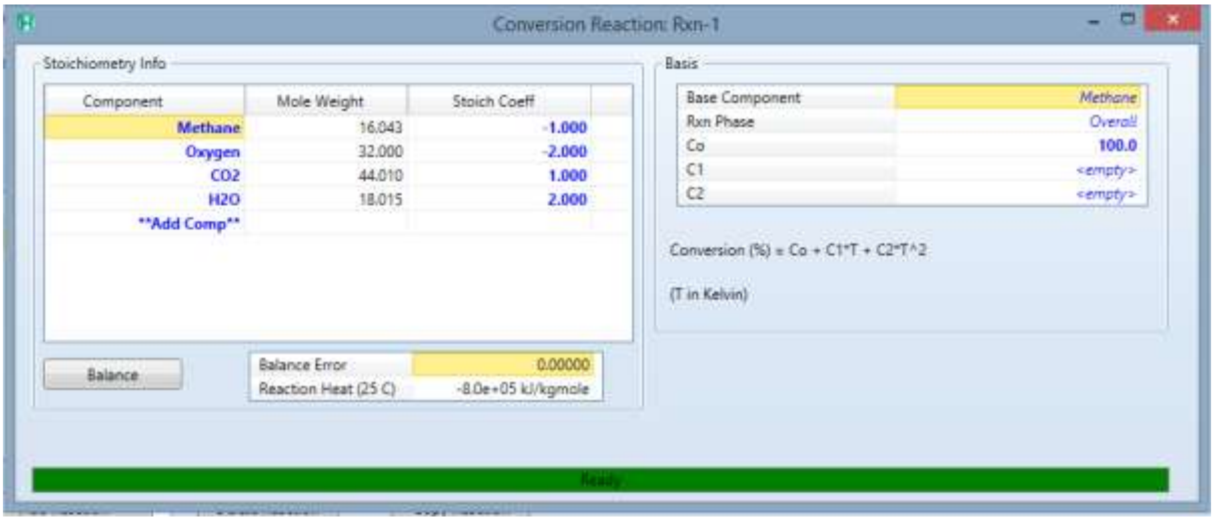

Fig.5Parametersforthereactioninthe combustion chamber

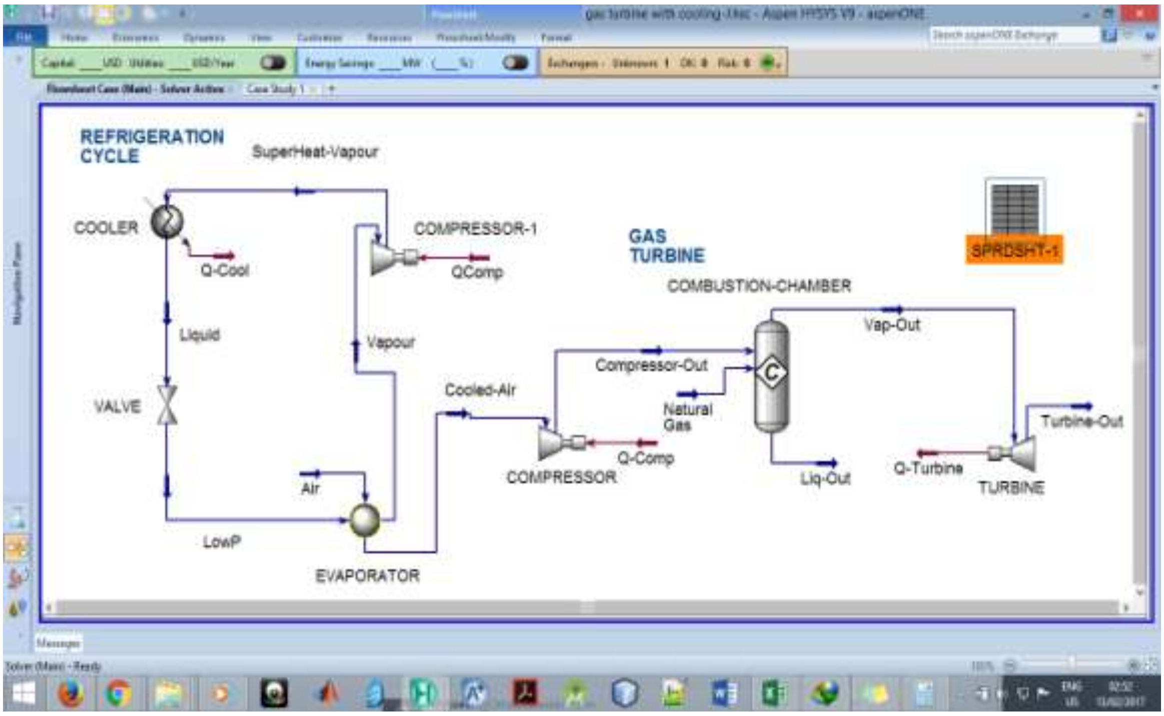

Figure6.ProcessFlowsheetforGas TurbinewithmechanicalrefrigerationUnit

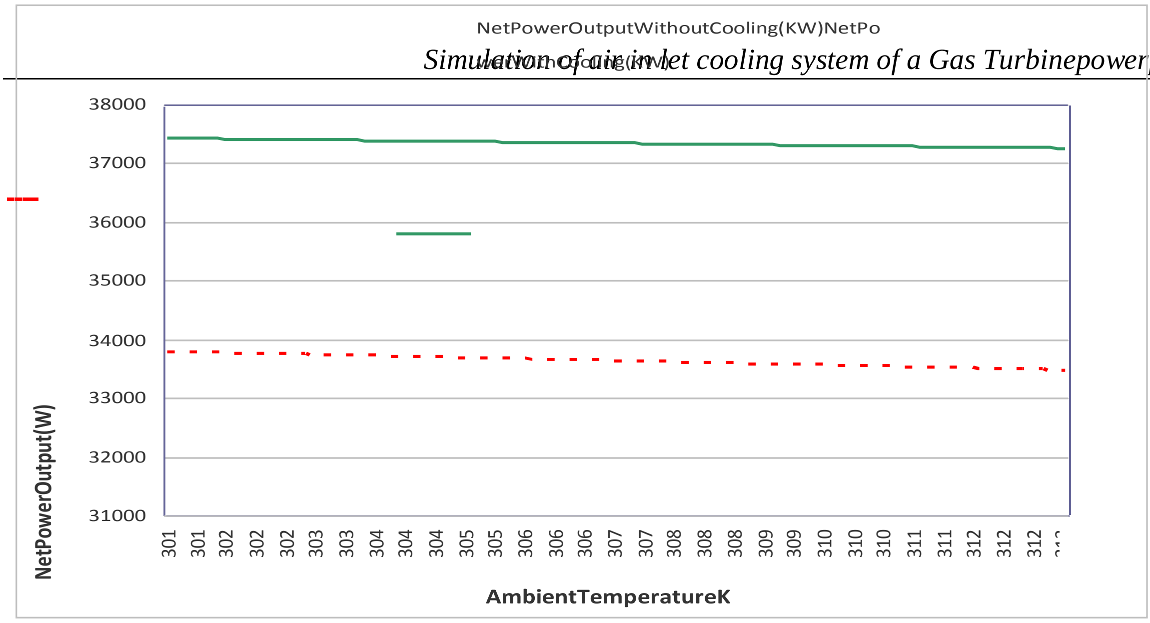

Fig.7Effect ofAmbientAirTemperatureonNetPowerOutput

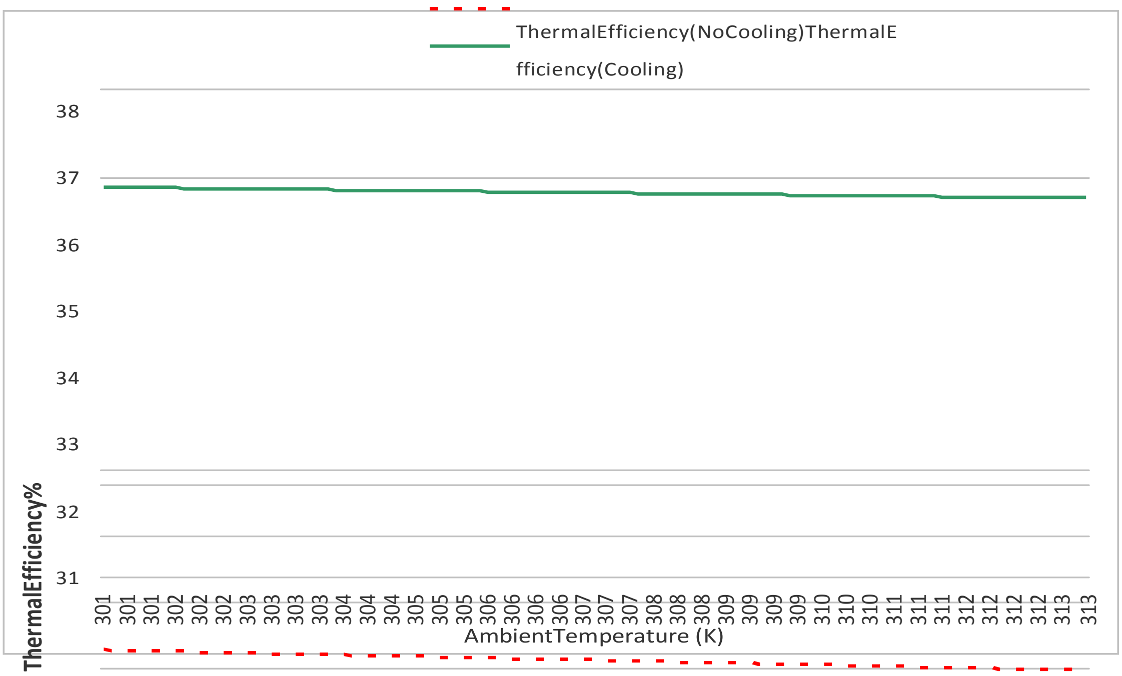

Fig.8.Effect ofAmbientAirTemperatureonThermal Efficiency

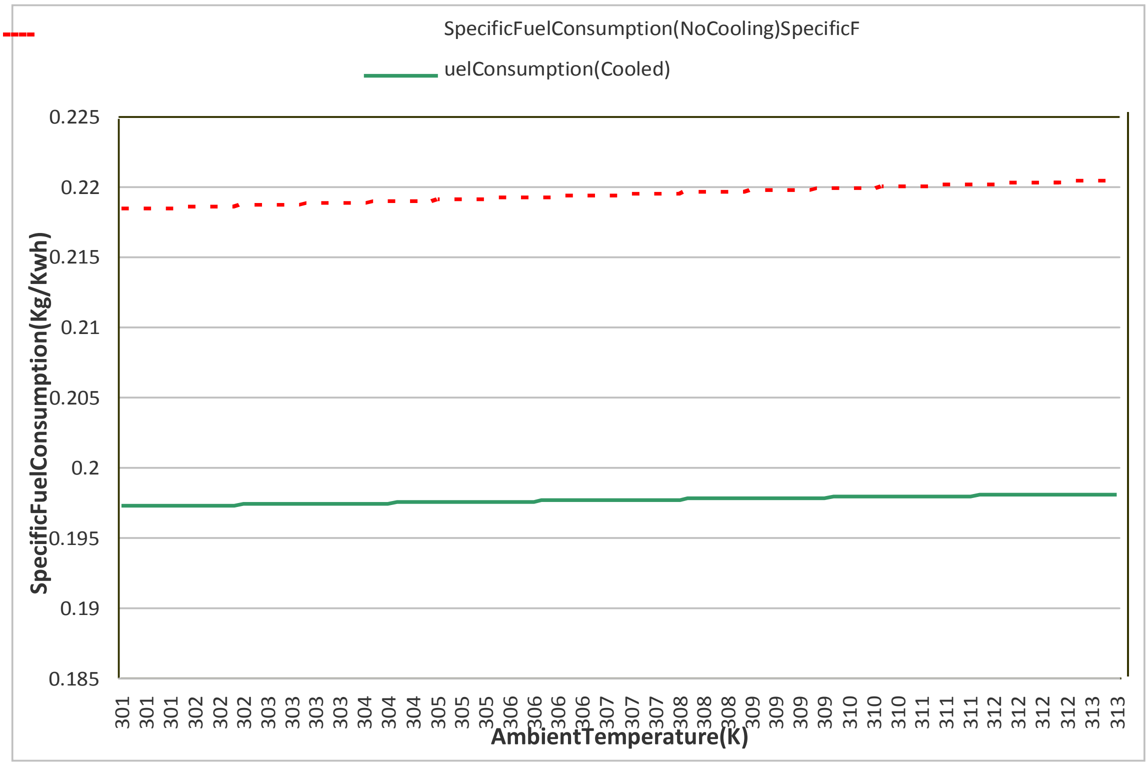

Fig.9Effectofambientairtemperatureonspecificfuelconsumption

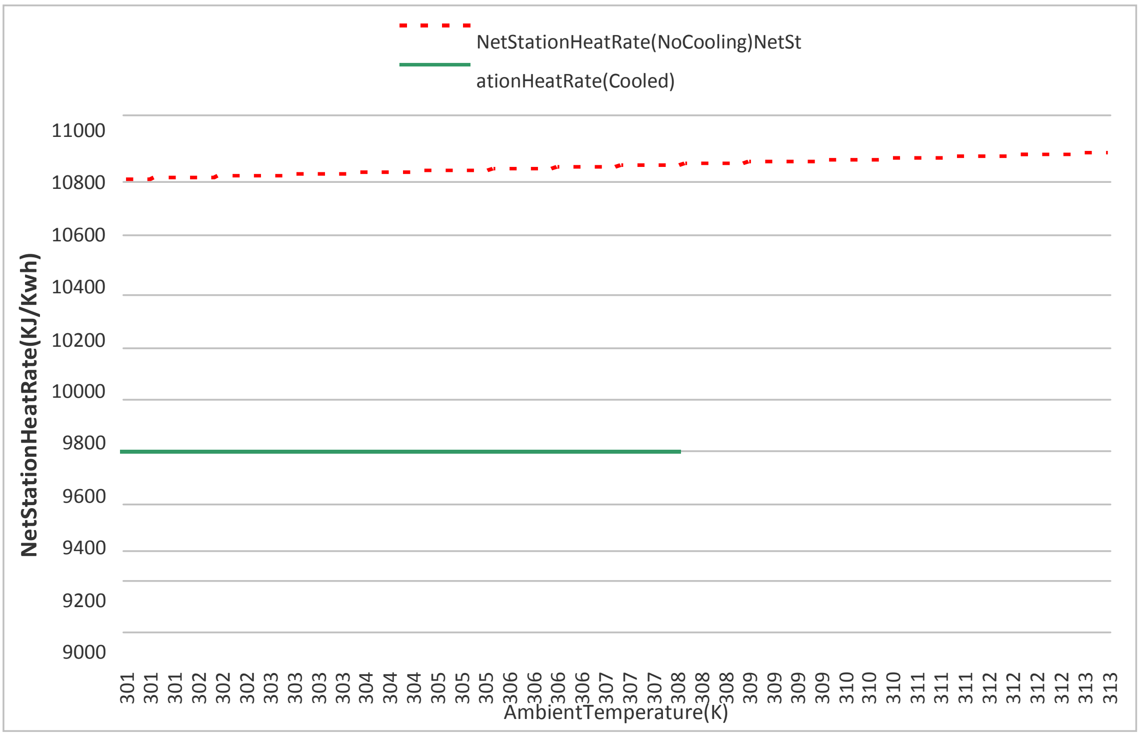

Fig.10Effect ofambientairtemperatureofheatrate

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Table 1.OperatingdataforGas TurbineUnit

Compressorinlettemperature(T1)	27.63°C
Compressor dischargepressure(P2)	6.4bar
Compressordischargetemperature(T2)	308.8°C
Exhaust temperature(T4)	365.31°C

Table2.DatauseinincorporatingMechanical RefrigerationSystemintoGasTurbine

S/N	OPERATINGPARAMETERS	VALUE	UNIT
1	Mass flowrate of air $\dot{m}_a$	208.69	Kg/s
2	Mass flowrata of fuel $\dot{m}_f$	2.050	Kg/s
3	Mass flowrate of exhaust$\dot{m}_{exh}$	210.74	Kg/s
4	Pressureoffuelgas p_f	2280	Kpa
5	Temperatureoffuel gas	328	K
6	IntaketemperaturetocompressorT_1	290.142	K
7	Intakepressuretocompressor	101.3	Kpa
8	Exittemperaturefromcompressor	491.7	K
9	Exitpressurefromcompressor	640	Kpa
10	TurbinepressureP_3	620	Kpa
11	TurbinetemperatureT_3	917	K
12	Exhausttemperature	577.9	K
13	Exhaust pressure	101.3	Kpa
14	Evaporatortemperature	298.1	K
15	Evaporatorpressure	243.71	Kpa
17	Centrifugalcompressortemperature	312.6	K
18	Condensertemperature	303.1	K
19	Condenserpressure	1154.47	Kpa
20	Expansionvalvetemperature	246.8	K
21	Isentropicefficiencyofcompressor	100	%
22	Isentropicefficiencyofturbine	100	%
23	Specificheat capacityofair	1.005	kJ/kgK
24	Specificheat capacityofexhaustgasC_{pa}	1.15	kJ/kgK
25	Pressureratio	6.317	
26	Lower heatingvalueoffuel	50,000	kJ/kg
27	Combustionefficiency	99	%
28	Pressuredropincombustion chamber	2	%

Table3.Simulatedresultobtainedatsimpletypegasturbineunit

S/N	Resultof simulatedsimple typegasturbine	Values
1	Compressorpower	50255.194kW
2	Turbinepower	84049.196kW
3	Netpower	33794.002kW
4	Specificfuelconsumption	0.2183819kg/kWh
5	Thermalefficiency	33.279%
6	Heatrate	10809.906kJ/kWh

Table 4. Simulation result of incorporating air intake cooling system (Mechanical Refrigerationsystem)

S/N	Resultsofsimulation	Value
1	Compressorpower	41338.639kW
2	Refrigerationcompressorpower	91.375kW
3	Turbinepower	80655.259kW
4	Netpower	37425.866kW
5	Thermalefficiency	36.855%
6	Specificfuelconsumption	0.197kg/kWh
7	Heatrate	9761.157kJ/kW
8	Regenerationheat effects	370.67KW