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Computational Analysis of Natural Gas Fired Power Generation System

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Abstract
Performance of a thermal system is dependent upon many design and operating parameters. Theses parameters are decided upon many design and operating conditions. Design conditions are fixed upon operating conditions which are very dynamic in itself. Operating conditions keep on changing from place to place and time to time. As the operating conditions are changed, their impact comes upon efficiency and performance of the power generation system. In the present working a brief on the working of power generation system is presented. Working is comprising of different components of power generation system. Based upon the working of power generation system mathematical modelling is developed which is solved with the help of computer programming tool.

Keywords: *Computation, combustion, Gas Turbine.*

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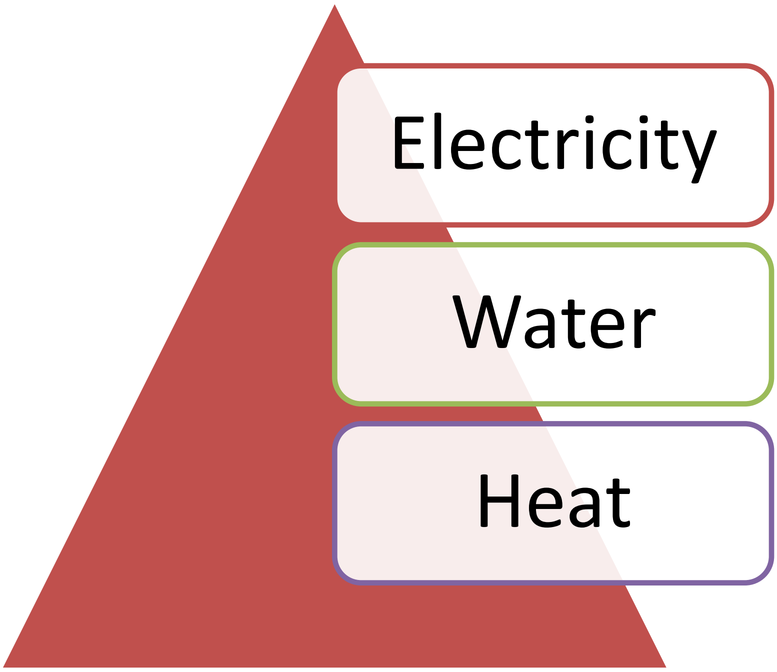
I. INTRODUCTION

Energy is used for all kinds of activities in life. It is of paramount use for society and its development. Energy is convertible in many forms. It is converted into many other useful forms with the help of energy conversion systems. Water which is available in liquid form is required very much for this.



II. METHODOLOGY

Methodology for the present work is based upon the following steps:
1. Define the problem
2. Literature review
3. Development of problem statement
4. Development of computer programming tool

```
function [Cpwv]=SpecificHeatWaterVaporP (T);
%18.02 is the mass of the water vapour
%function to calculate the specific of water at constant pressure and at
%elevated temperatures
%temperature T has to be entered
R=8.314;
a=4.07;         %constant value may change
b=1.108;        %constant value may change
c=4.152;        %constant value may change
d=2.964;        %constant value may change
e=.807;         %constant value may change
Cpwv=(R/18.02)*(a-(b*T/(10^3))+(c*(T/(10^3))^2)-
(d*(T/(10^3))^3)+(e*(T/(10^3))^4));
```

III. MODELING AND ANALYSIS

Based upon the mathematical equations described above a computer programme is developed in software engineering equation solver. It is as given below:

Pressure losses in different components of natural gas based gas turbine operated power plant is as following:

Plossregeneratorairside=5
Plossregeneratorgasside=3
Plosscombustionchamber=5
PlossHRSG=5

Efficiency and effectiveness parameter of natural gas based gas turbine operated power plant is as following:

Eregenerator=0.68
effcombustion=1
effcompressor=0.86
effturbine=0.86
effelectrical=0.85

Intial composition of air of natural gas based gas turbine operated power plant is as following:

x1N2=0.7748
x1O2=0.2059
x1CO2=.0003
x1H2O=0.0190

Compressor Inlet condition of natural gas based gas turbine operated power plant is as following:

h1N2=Enthalpy (N2, T=T1)
h1O2=Enthalpy (O2, T=T1)
h1CO2=Enthalpy (CO2, T=T1)
h1H2O=Enthalpy (H2O, T=T1)
h1totalair=x1N2*h1N2+x1O2*h1O2+x1CO2*h1CO2+x1H2O*h1H2O
s1refN2=Entropy (N2, T=T1,P=P1)
s1refO2=Entropy (O2, T=T1,P=P1)
s1refCO2=Entropy (CO2, T=T1,P=P1)
s1refH2O=Entropy(H2O, T=T1,P=P1)

Table 1: Mathematical expression used for the computational analysis

Components	Exergy Destruction Rate	Exergy Efficiency
Air Compressor	$e_{D,AC} = e_1 - e_2 + \dot{W}_{AC}$	$\eta_{ex,AC} = \frac{e_2 - e_1}{\dot{W}_{AC}}$
Combustion Chamber	$e_{D,CC} = e_3 + e_f - e_4$	$\eta_{ex,CC} = \frac{e_4}{e_3 + e_f}$
Gas Turbine	$e_{D,GT} = (e_4 - e_5) - \dot{W}_{GT}$	$\eta_{ex,GT} = \frac{\dot{W}_{GT}}{e_4 - e_5}$
Regenerator	$e_{D,R} = (e_2 - e_3) + (e_5 - e_6)$	$\eta_{ex,AP} = 1 - \frac{e_{D,AP}}{\sum_{i,AP} e}$
Process Heater	$e_{D,PH} = (e_6 - e_7) - m_w(e_9 - e_8)$	$\eta_{ex,PH} = 1 - \frac{e_{D,PH}}{\sum_{i,PH} e}$

IV. RESULTS AND DISCUSSION

In the present work gas turbine is simulated for the following parameters:
1. Efficiency of the cycle
2. Work output from the cycle

For this purpose a computer programming tool is developed as explained above. With the help of computer programming tool following operating conditions are analyzed:
1. Temperature of ambient air
2. Compression ratio
3. Composition of air
4. Fuel composition

Thermodynamic results which are based upon the mathematical modelling and computational results are listed in the forms of tables as following:

Table 2. Thermodynamic performance of natural gas based thermal power plant at inlet air temperature of 5°C

10	12	14	16	18	20	22	24	26	28	30
54.33	56.98	58.96	60.46	61.6	62.46	63.11	63.58	63.9	64.1	64.19
32.05	33.61	34.78	35.66	36.33	36.85	37.23	37.51	37.7	37.81	37.86
-5296	-5296	-5296	-5296	-5296	-5296	-5296	-5296	-5296	-5296	-5296
3137	4065	4886	5626	6301	6924	7502	8043	8552	9033	9489
211.1	1224	2123	2934	3676	4361	4999	5596	6159	6691	7197
-15959	-15923	-15815	-15661	-15480	-15282	-15072	-14855	-14634	-14410	-14187
-29192	-28147	-27219	-26382	-25617	-24910	-24252	-23636	-23055	-22506	-21984
356	353.5	354.7	358.2	363.3	369.7	377	385.2	394.2	403.8	414.1
6.402	6.103	5.898	5.752	5.646	5.568	5.511	5.47	5.442	5.426	5.418
362.4	359.6	360.6	363.9	368.9	375.2	382.6	390.7	399.6	409.3	419.5
169744	155473	145374	137870	132107	127581	123973	121071	118730	116844	115338
0.0314	0.0302	0.02913	0.02817	0.02729	0.02648	0.02573	0.02502	0.02435	0.02372	0.02312
0.08063	0.07825	0.07614	0.07423	0.07249	0.07088	0.06939	0.06799	0.06667	0.06542	0.06423
0.7507	0.7516	0.7525	0.7532	0.7539	0.7545	0.7551	0.7556	0.7562	0.7566	0.7571
0.1373	0.1399	0.1423	0.1444	0.1463	0.1481	0.1498	0.1514	0.1528	0.1542	0.1555

From the results it may be concluded that with increase in air temperature its density is changed and this change is not desirable for gas turbine system. It actually decreases the amount of air entering the system. By this system performance is affected. It can be summarize as bellow:

1. Higher air temperature is undesirable
2. Higher efficiency is desirable
3. Higher efficiency can be achieved with higher compression ratio.

Any part of the analysis which is presented above can be concluded as below

V. CONCLUSION

From the present analysis a lot of conclusions are obtained and these are summarized as below:

1. Gas turbine system is well established system.
2. Gas turbine is an efficient system.
3. It can be used for power generation.
4. Power generated from gas turbine system can be in the form of electricity.
5. There is a lot of scope for improving the efficiency of gas turbine system in future also.

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