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Statistical Analysis for Parametric Optimization of Gas Turbine-Steam Turbine Combined Power Cycle with Different Natural Gas Combustion

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Abstract: ***The combined Gas Turbine (GT) and Steam Turbine (ST) power generation techniques plays important role in power production. The coal fired thermal power plants have maximum possible efficiency about 34-36% with all arrangements of reheating and regeneration thermal systems. The integration of GT power generation system with old coal based thermal power plant helps to re-powering of plant and utilization of exhaust energy of GT unit through heat recovery steam generator (HRSG) of ST plant. The proposed title of research deals two steps of analysis. Energy analysis is adopted as first step for performance and energy destruction evaluation purpose where as Multi Linear regression (MLR) method is introduced as second method for parametric optimization. The four natural gases have been considered in this analysis and investigate the suitable fuel gas performance as per operating condition of GT plant such as gas turbine inlet turbine temperature (GTIT), compression ratio (CR) and mass flow of gases. The result of this paper concluded as maximum exergy loss found in combustion chamber of GT system and exhaust flow system of ST system in terms of 41% and 8% respectively. The combined and exergetic efficiency of plant are estimated to be 41% and 38.5% respectively. In present statistical model 4 levels and 3 factors (Pressure ratio, operating temperature and type of fuel gases) have been considered. And overall efficiency, gas turbine efficiency, heat loss in GT plant, Exergy destruction in thermal utilities like Compressor, combustion chamber and gas turbine are investigated. The statistical modeling concluded that the comparative results of actual and predicted results at different compression ratio of combustible gases which is affects the overall performance of combined GT-ST plant. This study helps to justify possible efficiency improvement with identifying the irreversibilities of plant utilities.***

Keywords: ***Exergy Analysis, Irreversibility, GT-ST combined cycle, Statistical MLR Method.***

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I. INTRODUCTION

The precious quantity of heat is lost during the combining of two different power generation system which will affect the plant performance.

The First Law of Thermodynamic is defining the energetic criteria of system. It is incapable to give the information about thermal deficiency due to irreversibilities in process. The estimation of real performance of thermal system and quality of energy are

possible by the exergy analysis. The entropy generation approach established the energy-exergy analysis for the different thermal utilities of thermal power plant and statistical methodology helps to compare the performance parameters like power output, gas turbine thermal efficiency, fuel consumption and exergetic efficiencies at different combustible gases which are utilized in combustion process. The MLR optimization method is used for the parametric analysis in present work for findings of possible overall efficiency, heat loss, and gas turbine performance with the combination of operating temperature, pressure ratio and different fuel gases. The main objective of energy-exergy modeling is to identify losses in components and true performance of plant. The several researches have been conducted on performance analysis of power plant and parametric optimization by using statistical analysis tool. The authors conducted exergy destruction analysis of gas turbine based cogeneration thermal plant and observe the effect of compression ratio, steam pressure, turbine inlet temperature, refrigeration temperature, etc. The another research is analyzed the exergy performance of ejector-absorption refrigeration system which is efficient by 8% in the application of wastage heat combined power system with refrigeration effect [1-3].Sapele-Nigeria based low power generation category of steam power plant of 75Mega Watt (MW) is computed maximum exergy destruction as 87.3% in boiler, and plant exergy efficiency 11.03%.The higher energy loss in boiler signifies the treatment of boiler utilities. The exergonomic concept for different-different power generation techniques is reviewed. Authors addressed the boiler and condenser component have major exergy destruction in case of rankine power cycle, whereas combustion chamber has major exergy destruction in case of gas-turbine powers [5-6,8].Author explain about the exergy, exergy is the maximum rate of work, which is the theoretical limitation of system and undoubtedly shows that no real system can conserve exergy, it can be recovered only [7,22].The exergetic performance of the re-powered rankine cycle with gas turbine concluded that combustion chamber and boiler have more irreversibility in GT & ST plant respectively. Researcher developed a computational model for the parametric investigation. Their analysis involved the effect of compression ratio of used combustion gas, turbine inlet temperature, boiler pressure on the energetic and exergetic performance [9].The energy-exergy modeling the performance in terms of energy-exergy analysis of several thermal systems like ammonia–sodium thiocyanate absorption system, organic rankine cycle and combined cooling power generation plant (CCPP), and it provide the opportunity to improvement and identify the location of losses and losses mainly occurs during the operation and it remark as exergy destruction. The performance assessment of energy and exergy analysis of various configurations of the CCPP plant for waste heat recovery through HRSG and equivalent payback period also estimated [4,10-11].The physical systems simulation and quantitative modeling is mainly dependent on the mathematical models for accuracy and optimized design with multitude of parameters, furthermore, statistical mathematics implemented for error estimation, parametric comparison and optimization for both actual and model data examination.. For modeling and analysis generally traditional mathematical approaches have been incorporated, but complex problems can be solve by soft computing, fuzzy logic and neural networks approaches [13].The another type of plant data analysis is deals by statistical modeling techniques like regression model, least square method, Maximum Likelihood Estimator (MLE) method, Auto regression integrated moving average model (ARIMA),Multiple Linear Regression (MLR). Artificial Neural Network (ANN), Response Surface Method (RMS),Multivariate Regression (MVR), etc for error identification, parametric comparison and complex problem solving [14-19].The parametric analysis of geothermal power plant is estimated by using multiple linear regression method, and ANOVA-I&II mathematical tools have been conducted for organic rankine cycle performance analysis and compared with R-analysis tool for error estimation and parametric comparison in recent research work[20-21].

II. BRIEF OF COMBINED GT-ST POWER GENERATION SYSTEM

The proposed plant is integrated with Gas turbine and steam turbine with HRSG system. The exhaust temperature from gas turbine has potential to run the steam turbine plant through HRSG. The steam power plant thermal efficiency is fixed with maximum possible efficiency 36% because the gas turbine power cycle is works as toping cycle and the variation in GT plant will affect the overall performance of plant. The layout of proposed plant is made in AUTOCAD which is shown in fig-1; operational conditions and combustible gas properties have been listed in Table-1&2.

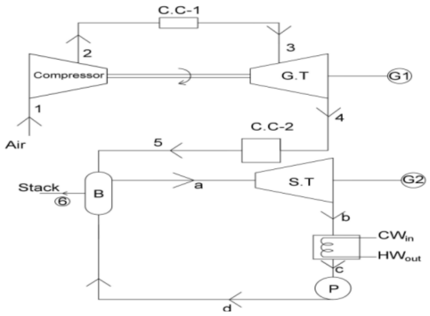

Fig.1. Thermodynamic schematic of combined GT-ST plant

schematic The combined GT-ST plant is integrated with GT power generation and ST power generation, the following process are given below as per the fig-1 mentioned plant.

Process: 1-2- Isentropic compression of atmospheric air in GT plant.
Process: 2-3-Combustion of gas in combustion chamber-1 of GT plant.
Process: 3-4-Isentropic flue gas expansion in gas-turbine of GT plant.
Process: 4-5-Combustion of flue gas in combustion chamber-2 of GT plant.
Process: 5-6-Stack flow out.
Process: 6-a-Steam generation in HRSG of ST plant by utilizing exhaust heat from GT plant.
Process: a-b-Isentropic steam expansion and steam-turbine work perform of ST plant.
Process: b-c- steam condensation and heat rejection of ST plant.
Process: c-d-pumping of condensed water & makeup water and supply to HRSG of ST plant.

III. PLANT OPERATION CONDITION AND COMBUSTIBLE NATURAL GAS PROPERTIES

Table 1. Operating Condition of GT-ST plant

Plant Components/Parameters	Unit & Value	Plant Components/Parameters	Unit And Value
Compressor Inlet condition (P1,T1)	1bar,25 ^{0}C	Specific heat ratio of air (γ_{air})	1.4
Compressor Pressure Ratio (P2/P1)	8	Steam condition at inlet of Steam turbine	40bar,425 ^{0}C
Gas Turbine Inlet gas temperature (T3)	900 ^{0}C	Condenser pressure	0.04 bar
Pressure drop in combustion chamber	3%	Feed water temp to HRSG	170.4 ^{0}C
Compressor Efficiency (η_c)- manufacturer efficiency	88%	ST Efficiency (η_{ST})	82%

GT Efficiency (η_{GT})- manufacturer efficiency	88%	Pressure Drop of gas in the HRSG	5kPa
Calorific Value of liquid Ethane as fuel (CV_f)	44.43MJ/Kg	Steam Flow rate= w_s	105 TPH
Specific heat of air ($Cp_{\_air}$)	1.006 KJ/KgK	GT outlet Pressure (P4)	1.05 bar
Specific heat of gas ($Cp_{\_gas}$)	1.148 KJ/KgK	Condenser Inlet staem or ST outlet flow	105TPH or 30Kg/s

IV. ENERGY ANALYSIS AND STATISTICAL MODELING OF COMBINED GT-ST POWER PLANT

The governing equation of analysis is based on energy-mass conservation and entropy generation principle of thermodynamics. The MLR method is used for parametric optimization for the GT-ST plant performance. Mass and energy balance equations has been applied in all thermal utilities. In order to simplify the analysis, some fundamental assumptions and proposed analysis is adopted from PK Nag combined GT-ST model [12]:

1. The thermodynamic process is assumed steady flow with consideration of control volume (CV) system.
2. The isentropic performance is considered for compressor, pumps and both GT& ST turbines.

4.1 Energy Analysis

Applying mass-energy and 1st law energy equation in all utility of GT plant. The thermodynamic relation and equations for power plant components are as follows

Compressor

The compressor work is function of operating condition of air intake; the compressor outlet temperature can be expressed as following thermodynamic relations-

$$\frac{T2}{T1} = \left(\frac{P2}{P1}\right)^{\frac{(\gamma-1)}{(\gamma * \eta c)}} \qquad (1)$$

W_comp= m_air × Cp_air (T2-T1) (1a)

Combustion Chamber

The pressure drop (ΔPcc) across the C.C as follows

P3/P2 = (1- ΔPcc) (2)

Assume flow rate of flue gas is 1Kg/s and that of fuel f Kg/s

The mass flow rate of air = (1-f) Kg/s (3)

Therefore $f\times CV_{f\,=}$ mf × $Cp_{\_gas}$ (T3-T4) – (1-f) Cp_air (T2-T0) (4)

$$\text{Air Fuel Ratio} = \frac{A}{F} = \frac{(1-f)}{f} \qquad (5)$$

Gas Turbine

The GT outlet temperature is estimated by isentropic efficiency (η_{GT})

$$\frac{T3}{T4} = \left(\frac{P3}{P4}\right)^{\frac{(\gamma-1)(\eta GT)}{(\gamma)}} \qquad (6)$$

Heat Recovery Steam Generator (HRSG)

The flue gas temperature at inlet of HRSG is calculated by Let the pinch point temp differences (T5-Tf) be 30 ^{0}C (pinch point at exit of GT and inlet of ST)

From Mass and Energy balance between GT and ST

m_gas × Cp_gas (T4-T5) = m_steam (h_a-h_f) (7)

And air flow rate entering the compressor = m_air = (1-f) m_gas (8)

Fuel mass flow rate m_fuel =w_f =f× m_gas (9)

Than energy interaction between HRSG and stack flow, and temperature of stack flue gas as follows

1.14 (482-T6) = 0.106 (3272-721.1) (9a)

Stack flow Temp= T6

Power Output of GT-ST Plant-

The combined GT-ST plant power output is achieved by the net work done by gas turbine and steam turbine both, total work of GT& ST plant is give by

$W\_total = W_{\_ST\ plant} + W_{\_GTplant}$

Energy equation for steam turbine work in terms of enthalpy across inlet and outlet of ST as follows

$W_{\_ST} = w_s\ (ha - h_{bs}) \times \eta\_st$ (10)

And Enthalpy at condenser line = h_{bs} = h_{f_b}+x_bs× h_{fg_b} (11)

Table 2. Properties of combustible gas for GT plant

S. No	Name Of natural gas	Chemical Formula	Heat Value (MJ/KG)	Cp/Cv	γ	Combustion Reaction (CaHb+c*O2-D*CO2+E*H2O)	Stoichiometric Combustion A/F(A/F=C*O_mol wt/(23.2% * Fuel _mol wt))
1	Methane	CH4	55.5	2.22/ 1.70	1.3	CH4+2O2-CO2+2H2O	17.24
2	Ethane	C2H6	51.9	1.53/ 1.48	1.03	C2H6+7/2 O2-2CO2+3H2O	16.09
3	Propane	C3H8	50.4	1.67/ 1.48	1.12	C3H8+5O2 - 3CO2+4H2O	15.6
4	Butane	C4H10	49.1	1.67/ 1.53	1.091	C4H10+13/2O2-4CO2+5H2O	15.45
5	Pentene	C5H12	48.6	1.66/ 1.52	1.092	C5H12+8O2-5CO2+6H2O	15.32

Work done by GT plant is depend on the difference between gas turbine work and compressor work consumption, the combine equation for $W_{\_GT}$ and $W_{\_COMP}$ as follows

$W_{\_GT}$ plant = $W_{\_GT}$ - $W_{\_COMP}$ (12)

$W_{\_GT}$ plant = m_gas × Cp_gas (T3-T4) - m_air × Cp_air (T2-T1) (13)

When two plants are combined, there is always some heat loss. If heat rejected by GT plant as topping cycle is absorbed by ST plant as bottoming cycle, The Lost heat as coefficient in the exhaust stack

$$X_L = \left(\frac{wg\times Cpg(T6-T1)}{wf\times CVf}\right) \qquad (14)$$

For the overall thermal efficiency with considering heat lost between topping and bottoming cycle. The overall efficiency of plant as follows

$\eta_{overall\ \ plant} = \eta_{STplant}+\eta_{GTplant} - \eta_{STplant}\times \eta_{GTplant} - \eta_{STplant} \times X_L$ (15)

The GT-ST combined plant efficiency is depend on work done by both turbines and heat supplied through combustion chamber and HRSG respectively in GT and ST plant. The equations for efficiencies are follows

$\eta_{STplant}$= (ha-hb)/(ha-he) (16)

put all values of enthalpy from equ. No 10-11-12-13

$\eta_{GTplant} = (W_{GT})/(w_f\times CV_f)$ (17)

From Equ No 15 $\boldsymbol{\eta_{overall}}$

4.2 Exergy Destruction Analysis

Assume exergy flux $\psi = (\Delta G_0 / \Delta H_0) = 1.0401 + 0.1728\ (h/c)$ (18)

Where $\Delta H_0 = w_f \times (CV)_0$

Compressor-

Rate of energy dissipation in compressor (I_{comp}) $= w_a T_0 \left(Cp_a \ln\frac{T2}{T1} - R_a \ln\frac{P2}{P1}\right)$ (19)

But $R_a = C_p \left(\frac{\gamma-1}{\gamma}\right)$

Combustion Chamber-

The irreversibility in CC is estimated by the energy balance between product, reactants, air and used fuel respectively.

$I_{CC}T_0\left[wg\left\{Cpg\ ln\frac{T3}{To} - Rg\ ln\frac{P3}{Po}\right\} - \left\{wgCpg\ ln\ \frac{T2}{T0} - waRa\ ln\ \frac{P2}{Po}\right\} + \Delta S\right]$ (20)

Gas Turbine-

Rate of energy lost or work lost in GT $= I_{GT} = w_g T_0 \left[Cpg \ln\frac{T4}{T3} - Rg \ln\frac{p4}{p3}\right]$ (21)

HRSG-

Rate of energy lost in heat recovery steam generator-$I_{HRSG} = T_0[ws(sa - se) + Cpg\ ln\frac{T6}{T4} - Rg\ ln\ \frac{P6}{P4}]$ (22)

Steam Turbine

Rate of energy or work lost in the steam turbine= I_{ST}

$I_{ST} = T_0\ w_s\ (s_b\text{-}s_a)$ (23)

Exergy Lost due to exhaust flue gas

$I_{EXHFLUEGAS} = \int_{T0}^{T6}\left(1 - \frac{T0}{T}\right) dQ = w_g \times Cpg\ \left[(T6 - T0) - T0\ ln\frac{T6}{T0}\right]$ (24)

Exergetic Efficiency$=\eta_{EX} = \frac{Total\ Output}{Exergy\ Input}$ (25)

4.3 Statistical Analysis-MLR Regression Method

The MLR method of statistical model is used in this analysis for overall and gas turbine both. The four different gases have been used in combustion chamber at different pressure ratio and operating temperature ranges.

This helps to identify the suitable combination of input factors for optimized result of plant operation.

The mathematical expression for expected value of performance parameters as follows which give the optimized result in all set of available factors and level of operating conditions.

Table 3. Factors and Level of combined GT-ST power plant

Factors (Input operational factor)	LEVEL 1	2	3	4
A-Compressor Pressure in Bar	6	7	8	9
B-Operating Temperature at inlet of GT in Degree C	600	700	800	900
C-Fuel Gases	Butane	Methane	Ethane	Octane

Above mentioned factors and its level analyzed by L16 model of MLR analysis.

MLR Regression Analysis-
Regression Equation

Overall Effi (%) = 36.62 + 0.428* Pressure +2.982*Temperature- 0.588 HC

(Neglecting effect of fuel gas composition, only compression pressure and GTIT consider)

where, Overall efficiency represents the gas turbines inlet temperature and gas turbines cycle pressure .

Coefficients

Term	Coeff	SE Coeff	T-Value	P-Value	VIF
Constant	36.62	2.48	14.79	0.000	
Pressure(Bar)	0.428	0.553	0.77	0.454	1.00
Temperature (Degree Celsius)	2.982	0.553	5.39	0.000	1.00
HC	-0.588	0.553	-1.06	0.309	1.00

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2.47505	71.93%%	64.92%%	51.99%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	188.405	62.802	10.25	0.001
Pressure(Bar)	1	3.668	3.668	0.60	0.454
Temperature (Degree Celsius)	1	177.817	177.817	29.03	0.000
HC	1	6.921	6.921	1.13	0.309
Error	12	73.510	6.126		
Total	15	261.916			

V. RESULTS AND DISCUSSION

The general output and exergy of components of proposed

Table 4. Observation Tables of GT-ST Plant performance (operated with octane gas)

Performance Parameters	Parametric Values	Performance Parameters	Parametric Values	Performance Parameters	Parametric Values
$W_{\_STplant}$	29MW	Gas Turbine Exergy Destruction	5646 KW	Exhaust Flue Gases Exergy Destruction	17760 KW
$W_{\_GT\ plant}$	53MW	HRSG Exergy Destruction	7583 KW	Total I_{LOSS} Or Destruction = $\sum Iloss$ =	132945 KW
$\eta_{STplant}$ & $\eta_{GTplant}$ & $\eta_{overall\ plant}$	38% & 27% & 41.7%	Steam Turbine Exergy Destruction	6412 KW	Exergy Input (ΔG_0)	212810 kW

Heat lost during combining of GT-ST cycle $=X_L$	35.40%	Compressor Exergy Destruction	6613 KW	Total Output	82,000KW
m_gas / m_air /m_fuel	275.4Kg/s /271.3kg/s /4.46 Kg	Combustion chamber Exergy Destruction	88661 KW	Overall Exergetic Efficiency= η_{EX}	**38.50%**

GT-ST combined plant are given in table-4. The present result is considering octane gas as a fuel gas in gas turbine plant with the all permissible operational condition for plant working.The performance of plant is observed by using energy analysis of different units of proposed plant. Efficiencies, Heat loss, mass flow of air & gas and exergy destruction are major performance indicators which are provided in table - 4. 38%,27% and 41.7 % of ST plant efficiency, GT plant efficiency and combined GT-ST plant efficiency are estimated respectively with the 35.4% of heat loss during the GT and ST cycle combination. The combustion chamber of GT plant has higher energy loss with 41.6%, where as GT is utilize maximum energy of input. The overall efficiency of plant is estimated as 41.7%, but the actual plant performance is calculated in terms of exergetic efficiency as 38.5%.

5.1 Effect of performance parameters:

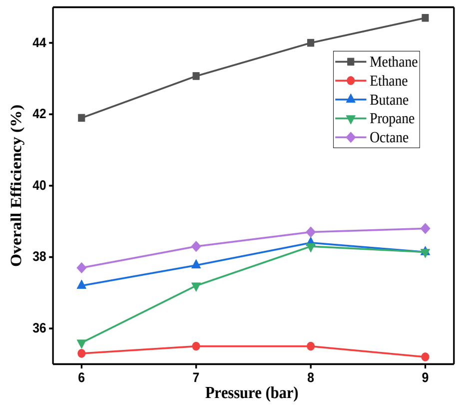

Fig 2(a).Effect of inlet pressure of GT on η_overall

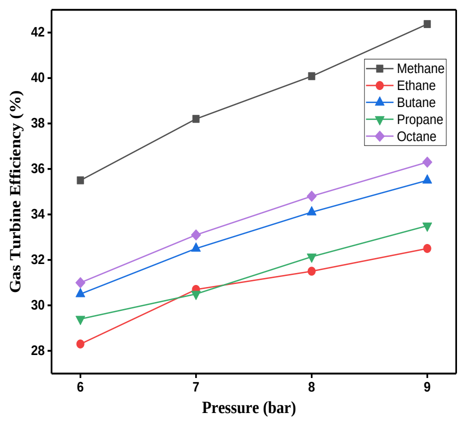

Fig 2(b). Effect of inlet pressure of GT on η_GT

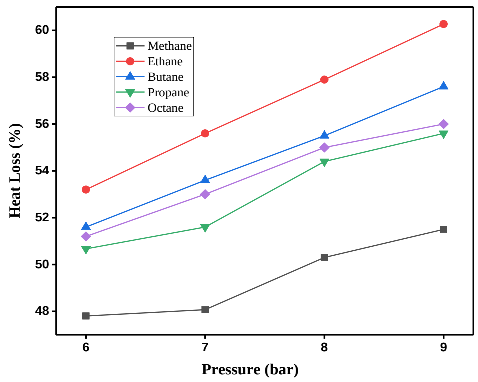

Fig 2(c).Effect of inlet pressure of GT on Heat loss between GT&ST

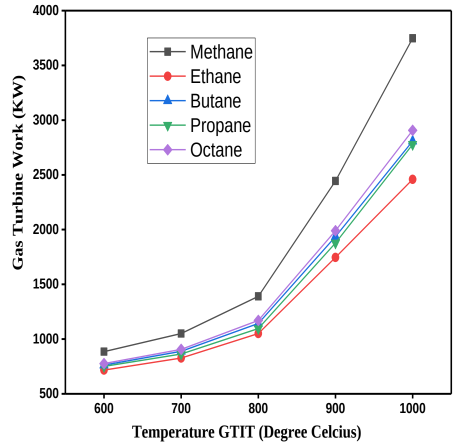

Fig 2(d). Effect of gas turbine inlet temperature in GT Work

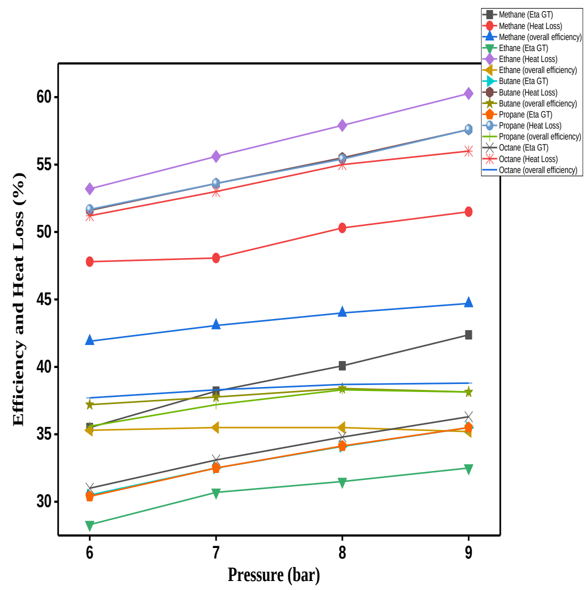

Fig 2(e) Effect of inlet pressure of GT in overall performance

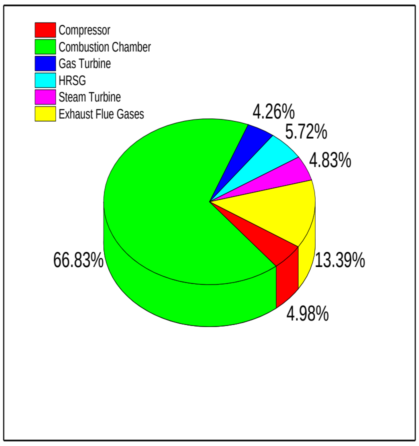

Fig 2(f). Exergy Destruction of Major component of combined GT-ST Plant

The more compression ratio enhances the GTIT and higher temperature of GT inlet gives higher thermal efficiency. Fig 2(a), 2(b), 2(c), 2(d) & 2(e) are showing the effect of compression ratio in overall efficiency of combined GT-ST plant with five different gas combustion in GT plant. The maximum GTIT taken 1000 ^{0}C, the metallurgical criteria of turbine material is main factor for limiting value of GTIT. Methane gas have higher efficiency with high CR and GTIT values, fig 2(c) clearly indicate minimum heat loss also, where as other gases have valuable output with all ranges of CR values. Overall performance of plant with all composition of natural gases is mentioned in fig 2(e).

The Total exergy loss of plant is estimated by 133MW with the 213 MW of input energy through CC and HRSG heat addition as mentioned in table-4, the component wise irreversibility is explained by fig-2(f) The maximum exergy lost 66.83% is found in CC of GT system and exhaust flue gas unit of ST system about 13.39%. Steam turbine also has more energy loss as compare to gas turbine.

5.2 Statistical modeling Result

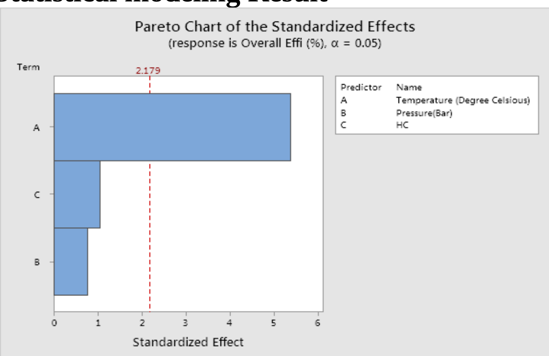

Fig-3(a). Pareto Chart of overall efficiency

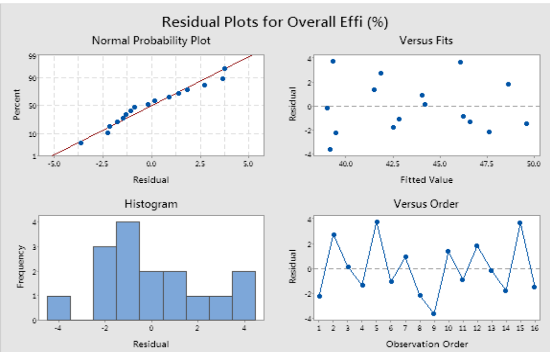

Fig-3(b) Regression Fit chart for overall efficiency

Table-5 L16 Regression model for Actual and Predicted result comparison

Compressor Pressure(Bar)	Temperature – GTIT (Degree Celsius)	Natural Gas	Actual Overall Efficiency (%)	Predicted Overall Efficiency (%) By DOE	Residual	% Deviation
6	600	Butane	37.2	40.03	-2.83	-7.607526882
6	700	Methane	44.6	43.012	1.588	3.560538117
6	800	Ethane	44.4	45.994	-1.594	-3.59009009
6	900	Octane	45.3	46.976	-1.676	-3.699779249
7	600	Methane	43.07	40.458	2.612	6.064546088
7	700	Butane	41.8	43.44	-1.64	-3.923444976
7	800	Octane	45	46.422	-1.422	-3.16
7	900	Ethane	45.5	49.404	-3.904	-8.58021978
8	600	Ethane	35.5	40.886	-5.386	-15.17183099
8	700	Octane	42.9	43.886	-0.986	-2.298368298
8	800	Butane	45.39	46.85	-1.46	-3.216567526
8	900	Methane	50.5	49.482	1.018	2.015841584
9	600	Octane	38.8	41.314	-2.514	-6.479381443
9	700	Ethane	40.78	44.296	-3.516	-8.621873467
9	800	Methane	49.8	47.278	2.522	5.064257028
9	900	Butane	48.19	50.26	-2.07	-4.295496991

% of Deviation = [(actual value – predicted value)/ actual value] × 100%

The MLR model summery measure the overall efficiency of the plant. The adjusted R-squared value of 64.92% and the Predict R-squared value of 51.99 % are fairly acceptable for this analysis. Furthermore, a value of R^2 on a higher side indicates that the results are close to the real data values. A comparison between the actual data and the predicted one is highlighted in Table 5. A set of data based on 16 runs were collected as per the operating gas turbine pressure, GTIT and combustible natural gases. The table was constructed which included the predicted responses from MLR analysis. The values seem to coincide with the actual data which is considered good. It also shows the residual by response surface and the percentage variation versus the run number in fig-4. A normal plot of residuals is shown in Figure-3(b). The graphs highlight one key fact, that is, the value of R^2 is 71.93%, shows minimum irregularity.

The linear model is statistically adequate. It can be seen that the best-fit line resembles the (Y=X) line when plotted on a data set of 16 points. This indicates that the predicted values and the real data are in close proximity to each other. The variation found in actual results from the predicted ones was between 2.612 and -5.386 showing only a minor dissimilarity. The pareto graph fig-3(a) well explained the GTIT is main factor for overall efficiency with the set of compressor pressure and fuel gases.

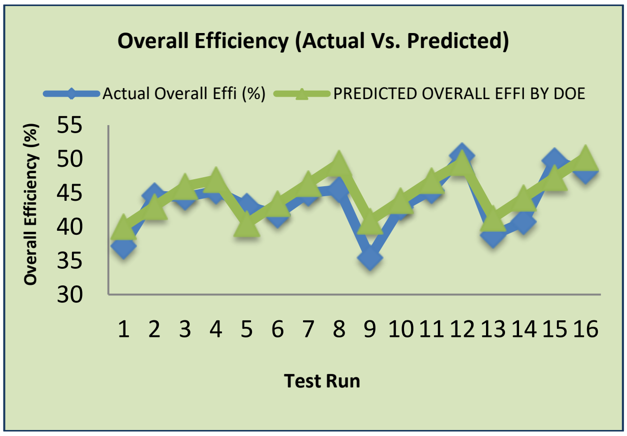

Fig-4 Overall efficiency (Actual Vs Predicted by DOE)

VI. CONCLUSIONS

The present analysis is carried energy and exergy approach of thermodynamics for actual performance where as MLR regression modeling is applied for comparison between actual and predicted experiments results. The highlights of this analysis have mentioned below-

1-The performance of combined GT-ST plant is influenced by gas turbine performance and as well as effected by heat loss. Steam turbine plant efficiency is fixed by 38% which is maximum possible efficiency.

2-The assessment of exergy destruction is important for actual plant performance. The determination of exergy loss estimation of various components helps to identify the components for control in heat loss or re-design of identified parts. Combustion chamber and heat recovery steam generator have major exergy loss in GT and ST plant respectively. Steam turbine exergy destruction is more than gas turbine destruction due to pressure reduction and steam condensation during the expansion of steam. It indicates the temperature at the inlet of steam turbine must be high as per materialistic temperature limit of turbine material. Superheated steam is required for the achievable turbine performance.

4. The MLR statistical highlight one key fact, that is, the linear model is statistically acceptable due to the best-fit line when plotted on a data set of 16 test runs. This indicates that the predicted values and the real data are in close proximity to each other. The variation found in actual results from the predicted in terms of average absolute residuals and average value of % deviation values are -1.328 and -3.371 respectively for the case of overall efficiency analysis of plant. It was due to cyclic variations that accounted for this minor difference between the real and the predicted data.

5. The overall plant output greatly affected by the heat loss. The maximum possible GT efficiency is achieved as 46% at higher CR value with methane gas combustion as shown in fig 2(a) & 2(b) .The heat supply through combustion chamber is converted in to GT work done and GT cycle heat rejection further, but rejected heat of GT cycle is utilize through HRSG of steam power plant for ST work output. If heat loss is more, than overall performance will decrease.

The both approach of analysis gives the comparative and optimized solution for plant operation at suitable operating condition. The present statistical model of DOE helps to compare the actual and predicted values for overall plant performance study, machinery optimization, components identification for controlling heat loss, best combination of factor with the large range of input operating parameters.

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