POTENTIAL OF EXERGY EFFICIENCY IMPROVEMENT OPPORTUNITIES OF COAL POWER PLANTS IN SRILANKA: A CASE STUDY

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Degree of Master of Engineering

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DECLARATION

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ABSTRACT

When considering global as well as local energy scenarios, it is required to consume energy in proper way and also required to harvest maximum possible output from the available energy source. Therefore analysis, monitoring and optimization of available power plants are major requirement in the sector. Generally the performance of power plant is evaluated by energy performance criteria based on 1st law of thermodynamics. However, as recent developments in thermodynamic studies exergy analysis was identified as a useful method to design, evaluation, optimization and improvement of power plants. It is based on 2nd law of thermodynamics.

Therefore in this thesis, it is tried to find out potential of exergy efficiency improvement opportunities in coal power plants through exergy flow analysis. A methodology was developed to calculate exergy values in major thermodynamics state in coal power plant and efficiency of major equipment in power plant. That was done according to general equations which are used in thermodynamics. As a result, set of thermodynamic equations were derived to analyze exergy flow in coal power plants.

The methodology which mentioned in above was applied to unit 01 of Lak Vijaya power station (LVPS) in Sri Lanka to validate it. In this calculation, thermodynamic properties of water-steam cycle of LVPS unit 01 under both design and actual calculation were used to evaluate exergy values of critical states of the cycle as well as exergy efficiencies of major equipment. The obtained results were used for the analysis of exergy of power plant. Then the exergy destruction, exergy efficiency of major equipment as well as the overall exergy efficiency of LVPS unit 01 was figured out under both design and operational conditions.

Boiler was identified as the major exergy destruction equipment in power plant and it has less exergy efficiency also. It is around 49% in design condition and 45% in actual operation condition. Also energy balance calculation was done for the boiler to identify the difference of exergy and energy efficiency of equipment. The boiler exergy destruction value is contributing extra percentage of total exergy destruction of power plant. Therefore the changes of boiler exergy destruction are directly affected to overall exergy efficiency of the power plant.

Hence boiler sub system was analyzed to identify potential of exergy efficiency improvement in coal power plants. The main variable parameters of boiler were used to identify the exergy flow behaviors of the boiler. The main steam pressure, main steam temperature, Feed water temperature, Gross Calorific Value of Coal and Load variation of power plant were considered as major variable parameters of the boiler. The above variables were taken individually to identify exergy destruction and exergy efficiency of boiler in LVPS unit 01. Then potential of exergy efficiency improvement in coal power plant was discussed using obtained results.

As per the results which were obtained from case study of LVPS unit 01, Coal power plant should run in full load (300MW) conditions as much as possible to improve its overall exergy efficiency. Also boiler main steam pressure should be kept in high pressure condition at least above 16.0MPa.Above working conditions were identified as better working conditions which will improve the exergy efficiency of overall power plant.

Also economic analysis was done for the boiler to identify the benefits of doing this kind of thesis. The steam generating cost was calculated in the thesis according to past actual operational data in LVPS unit 01. The cost saving due to the improvement of exergy efficiency also determined here. Not only steam generating cost saving in power plant but also reduction of hazardous CO_2 emission calculation was done here.

Key words: Exergy, Energy, Exergy destruction, Exergy efficiency, 1st law of Thermodynamics, 2nd law of Thermodynamics and Gross calorific value.

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Abbreviation	Description
CEB	Ceylon Electricity Board
CFC	Chlorofluorocarbon
LVPS	Lak Vijaya Power Station
NOx	Nitrogen Oxide
FGD	Flue Gas Desulphurization
SOx	Sulphur Oxide
N_2	Nitrogen
CO_2	Carbon Dioxide
H_2O	Water
PM	Particulate Matter
ESP	Electrostatic Precipitator
PW	Present Worth
CRF	Capital Recovery Factor
PEC	Purchase Equipment Cost
HP	High Pressure
LP	Low Pressure
IP	Intermediate Pressure
CP	Condensate Pump
BFP	Boiler Feed Pump
HTR	Heater
EIA	Environmental Impact Assessment
USD	United State Dollars
SH	Super Heater

RH	Re Heater
TMCR	Turbine Maximum Continuous Rating
FRP	Fiber Reinforced Plastic
CWS	Cooling Water System
VWO	Valve Wide Open
BMCR	Boiler Maximum Continues Rating
GCV	Gross Calorific Value
HHV	High Heating Value

Symbols	**Description**
E^{PH}	Physical exergy
E^{KN}	kinetic exergy
E^{PT}	Potential exergy
E^{CH}	Chemical exergy
e^{T}	Thermal exergy
e^{M}	Mechanical exergy
x^{n}	Mole Fraction of n^{th} gas mixture
$\overline{R}$	Universal Gas Constant
E_i	Exergy input
E_o	Exergy Output
E_D	Exergy destruction
C	Cost value
c	Unitary (specific) cost value
e	Product output
i	Feed input

k	Number of component
q	Heat
W	Work
E	Exergy
Z	Investment cost
$\dot{C}$	Exergy Cost
$\dot{E}$	Exergy Rate
c	Exergy Unit Cost
$\dot{Z}^{CI}$	Capital Investment Cost
$\dot{Z}^{OM}$	Operation and Maintenance Cost
i	Interest Rate
n	Life Time of Plant
j	Salvage Value Ratio
τ	Total annual operating hours
h	Enthalpy
s	Entropy
C_p	Specific heat
h_0	Reference environmental enthalpy
s_0	Reference environmental entropy
T_0	Reference environmental temperature

LIST OF APPENDICES