POTENTIAL OF ORGANIC RANKINE CYCLE BASED HEAT RECOVERY SYSTEMS FOR POWER GENERATION

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DECLARATION

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ABSTRACT

Due to intense fuel dependency on energy production in the world, cost of energy has a greater bearing on the prices of fossil fuels. Most of the countries in the world are suffering due to this and Sri Lanka is no exception. It is in this context promotion of optimize the usage of thermal power generation, is so vital to the country. Even though fossil fuel base power generation plays a greater role as a source of primary energy in the country, major portion wasted to environment. WHR systems have been already introduced, but most of them are not performing effectively and efficiently. On other hand, novel systems and technologies required to investigate, to recovery most of the wasted heat of thermal plant while increasing the system efficiency and reducing the fuel cost. Conceptual thermodynamic cycles such as Trilateral Flash cycle, Organic Rankine cycle, Kalian cycle and Gaswami cycle, can be successfully incorporate for WHR applications. Hence, purpose of this research was to assess the amount of waste heat generated by thermal plants in the country while discussing the possible technologies that can be introduce for heat recovery. Further, discuss about selection of most suitable option and carryout thermo-economic analysis as a case study.

Fluid selection and system optimisation based on heat source temperature are two most critical aspect of Organic Rankine Cycle. Eleven fluids were investigated to optimize the work output by varying the evaporator temperature and varying the expander pressure ratio with theoretical model. In evaporator analysis, Heptane, Pentane and Decane shows favourable results in terms of work outputs while, in terms of efficiency, Decane and Heptane are better. Further it is recommended to use fluid Pentane, when source temperatures of WHR lies between 45 – 190 ^{o}C, while fluid Heptane is recommended when source temperature between 190 – 260 ^{o}C. Fluid Decane is recommended when temperature between 260 – 340 ^{o}C. Respective monographs were developed where one point on the graph can denote approximate work output, efficiency, pressure, temperature, etc. Based on expander analysis, Decane, Heptane and Toluene fluids have shown higher work outputs while, in terms of efficiency, Decane is better. In expander selection, when inlet/outlet pressure ratios are less than 10, fluid Decane is recommended. Further, when ratios are in between 10 – 13 and 13 – 20, fluid Heptane and fluid Toluene are recommended respectively. Refer to these 03 fluids, monographs were developed accordingly.

Refer to optimum working regions of temperature analysis; fluids were selected for economic evaluation. Waste heat recovery opportunities were selected from existing thermal plants for the case study and electric outputs were obtained for each plant, based upon selected fluids from theoretical model. Then maximum work out of each opportunity was selected for further economic evaluation under 07 different scenarios. Possible future economic situations of the country were predicted under those scenarios and carryout NPV calculations for each, to evaluate the investment feasibility. Scenario 2, 3 and 7 are the most possible situations of the country in future and for those conditions, WH opportunities at Supugaskanda, Lakvijaya, Keravalapitiya and Kelanithissa are most feasible to recover waste heat with ORC system.

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Most difficult part of this exercise was the collection of data related to waste heat energy of each thermal power plant in the country. My special thanks in this regard should go to my fellow engineers who have supported in data collection in various thermal power plants.

The biggest challenge I faced during this research was to find time for this and meeting the targets. I am sure if not for my wife, Nadeeka De Silva, my new born son Dihas and my mother I.D. Priyangani, I could not have completed this research on time. Hence, my gratitude should go to my beloved family members for the sacrifices they made during this research.

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LIST OF ABBREVIATIONS

CEB – Ceylon Electricity Board

NRE – Non-Renewable Energy

WHR – Waste Heat Recovery

IPP – Independent Power Producers

HSFO – High Sulfur Fuel Oil

LSFO – Low Sulfur Fuel Oil

SPS – Sapugaskanda Power Station

KPS – Kelanithissa Power Station

GT – Gas Turbine

ST – Steam Turbine

CCPP – Combined Cycle Power Plant

CCGT – Combined Cycle Gas Turbine

LPT – Low Pressure Turbine

HPT – High Pressure Turbine

IPT – Intermediate Pressure Turbine

CHP – Combined Heat & Power

ORC – Organic Rankine Cycle

TFC – Trilateral Flash Cycle

NPV – Net Positive Value

$\dot{W}_{exp}$ - Expander work

$\dot{m}$ - Fluid mass flow rate

h - Specific enthalpy

η_{is} - Expander isentropic efficiency

$\dot{W}_{exp.is}$ - Expander isentropic work

Q_{evap} - Evaporator heat energy addition

$\dot{W}_{pump.is}$ - Pump isentropic work

P - Pressure

ρ_{liquid} - Fluid density

$\dot{W}_{pump}$ - Pump work

η_{pump} - Pump efficiency

$\eta_{pump.is}$ - Pump isentropic efficiency

η_{cycle} - Cycle Efficiency

$\dot{W}_{in}$ - Work input

$\dot{W}_{out}$ - Work output

$Q_{evap.\ max}$ - Maximum available heat energy for evaporator

η_{evap} - Evaporator efficiency

P1/P2 - Expander pressure ratio between inlet and outlet

LIST OF APPENDICES