International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 11 Nov. 2022, pp: 795-798 www.ijaem.net ISSN: 2395-5252

Prospective Study of Organic Rankine Cycle in Tripura and Determining the Efficiency of a Bio Gas Power Plant Using Organic Rankine Cycle as a Waste Heat Recovery System

Arup Datta[1], Johnson Debbarma[2], Sudip Bhowmik[3]
[1,2,3]Assistant professor, Tripura Institute of Technology, Agartala, Tripura

Submitted: 15-11-2022 Accepted: 25-11-2022

ABSTRACT: The demand of energy is gradually increasing with time. Since the energy availability is mostly dependent on non-renewable energy sources hence, it became very much important to reduce the consumption of non-renewable energy sources as soon as possible. This paper focuses on understanding Tripura's energy consumption and to find out whether organic Rankine cycle waste heat recovery system will be feasible to establish in Tripura based on the existing power generation scenario. As the energy demand will be increasing in the near future so any kind of wasted energy will impact a lot. Here the data of a bio gas plant has been taken for analyzing the efficiency with and without the waste heat recovery system. The modeling of ORC-WHRS has been done on DWSIM software. The ORC-WHRS used for the analysis have the certain components like pump, boiler, recuperator, cooler, turbine and economizer. R123 refrigerant has been used as a working fluid due to its low boiling point and highest gaseous heat energy. After the analysis has been done the result shows a promising increase of 17.2 % of efficiency of bio gas plant with ORC-WHRS.

KEYWORDS: ORC – WHRS: Organic Rankine Cycle- waste heat recovery system

I. INTRODUCTION

The population of India is generally increasing at a very faster rate. It has been studied that in the upcoming years the population of India will be more than that of China. So, as the population increases the demand of energy will be much higher than that of the previous years. As India almost gets its 60% energy from the fossil fuel like coal so it becomes more questionable that how the demand of energy can be reached.

The government of India has taken several steps to empower various renewable energy sources as it is much more sustainable than that of non-renewable energy sources. For this various energy sources like wind energy, solar energy and hydel energy are kept under the radar. In recent years as pollution level drastically increased a lot so, it is always been better to use certain energy source which is less harmful to the environment. Another option for fulfilling the energy demand can be the proper utilization of Organic Rankine Cycle as a waste heat recovery system. As ORC shows a promising result of generating electricity from waste heat [2]. A simple Organic Rankine Cycle generally consists of pump, Evaporator, Expander and condenser. One or two recuperators are also used in order to increase the efficiency. The main concern of ORC is to select the proper working fluid for its optimum working. At present Organic Rankine Cycle is used in India by several companies like Ultra Tech, Thermax and many more [4]. Various research and experiments are going on in order to reduce its complexity in terms of economic, efficiency and services point of view.

The aim of the study is to find the feasibility of Organic Rankine Cycle in Tripura as per the availability of heat sources and to determine the Efficiency of ORC – WHRS

Motivation:

As we know that the demand of energy will reach at a certain level where the existing generation of electricity in Tripura won't be sufficient. Due to the demographic condition of Tripura, establishment of nuclear power plants is not possible and it is quite obvious that any kind of wasted energy will impact a lot. So, in order to decrease the amount of wasted energy, ORC-WHRS can be used in the power plants which is being attached in the exhaust pipes and uses to recover the energy from the flue gases which should have been wasted otherwise.

Problems with the existing waste heat recovery system:

The existing waste heat recovery system is not suitable for every industry as high amount of temperature like 1500°C to 2000°C is required for proper recovering of energy by WHRS and the quality of waste heat is also not that much good.

Approach:

In order to counter the existing problems Organic Rankine Cycle- WHRS can be used rather than WHRS as it can function at low temperature due to the low boiling point of the working fluids. As Tripura mainly depends on four power stations and some renewable energy sources for the generation of electricity so finding the feasibility and utilizing the ORC-WHRS in any one of the plants will give a basic idea about the improvement of efficiency with and without the ORC-WHRS. This paper carries out about the feasibility of ORC-WHRS in Tripura and finding out the efficiency of the plants with ORC-WHRS.

Scope Of Waste Heat Recovery System

As Tripura have four power generation units for fulfilling the needs of the electricity. But as we have seen in table 2 that the need of electricity is not yet fulfilled at a great extent. So, for this reason each and every amount of energy is useful. For this Organic Rankine cycle can be applied as a WHRS in order to increase the efficiency of the plants and hereby decreasing the emission rates. As the Organic Rankine cycle WHRS generally uses the flue gases coming out of the power plants so automatically that wasted heat which should have been otherwise left outside is been utilized for other useful work.

SELECTION OF WORKINGFLUID

Several research has been carried for the proper selection of working fluid. Bipul et. al selected different working fluids based on the Indian Industrial plant working and found out that R21 working fluids shows a promising result [3]. Jahar et. al. also signifies two fluids which gave good results, ammonia which is said to be best for net power generation and n pentane signifies best for Thermal efficiency [4]. There are basically three types of working fluids which are mainly used. The fluids are wet fluids (water), dry fluids (Benzene) and isentropic fluids (R11). Out of the three fluids wet fluids are always been ignored due to the certain complications. Due to the wet property of water the efficiency always drops down and in order to increase the efficiency various heat exchangers are required. These fluids are also neglected as they might fill up ample droplets in the expander which ultimately can destroy the expander blades. So various researchers suggested to use the dry and isentropic fluids for the proper working of Organic Rankine Cycle.

Safety Criteria:

As the pollution level are increasing at a very faster rate so it is always been required to select the fluid in a proper manner. Various things like ODP (ozone depletion potential), GWP (global warming potential) are taken under considerations.

Certain things are kept in mind for proper selection of working fluids: 1. ODP level should be always zero. 2. GWP level > 150. 3. Boiling point should be low. 4. Ignition temperature should be high.

Suitable working fluid:

Kankeyan et. al. plotted different working fluids as per there feasibility at different heat source temperature [1].

Heat Source Temperature (K)	Different working Fluids
320	R143a, R32
420	R600a, R142b, Iso butane, Butane
445	R600, R245fa, Neo pentane, R245ca
500	R123, R141b, R601

Table 2: suitable working fluids as per the heat source temperature.

As the study will be carried out with the exhaust gases coming out from the power plants where the temperature of the flue gases will be in between 900 – 1000° C. So, for the analysis R123 working fluid has been selected as it shows a promising result of working at a temperature higher than 500 K.

MODEL DESCRIPTION

Various components of ORC WHRS:

The Organic Rankine Cycle waste heat recovery system is generally used to extract the heat energy from the working fluids which have low

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boiling point then that of water and then convert that energy into useful mechanical and electrical energy.

Modelling on DWSIM software:

The modeling of Organic Rankine Cycle waste heat recovery system has done on Open-Source chemical process flow simulation software, DWSIM. The modeling is done based on the exhaust flue gases coming out from the different power plants. For the analysis part the flue gases from the thermal power plant and engine exhaust gases are taken. The flow rate, Temperature, Pressure, Volumetric flow has been taken from the factory itself and from the several literature reviews. As the main objectives of the study is to calculate the efficiency, so the energy intensive part is only taken under consideration. The first analysis is done on the flue gases coming out from the thermal plant. The following data has been plotted below.

Configuration	V70
Electrical output	999 kW
Energy input	2459 kW
Efficiency	40.58%
Exhaust gases mass flow rate	5774 kg/h
Exhaust gases Temperature	920° C
Molar flow	199.37 k mol/h
Volumetric flow	14655 m³/h

Table 3: Technical data of a Biogas engine plant

After knowing the values, an ORC-WHRS is modelled for the exhaust gases coming out from the plant. As mentioned in the above table the flue gases coming out from the plant is 920°C. The flow rate values are also scaled down.

The exhaust gases first enter into the pipes of ORC-WHRS, which consists of superheater and boiler. The material streams in the ORC-WHRS are water, R123 organic fluid and air. Firstly, the exhaust gases are used to heat the water which transfers the heat energy to the working fluid. That working fluid is then used to transfer that energy to the turbine to convert it into electrical energy. After the working fluid lost its energy, it is been passed through the recuperator and the heat exchanger to cool it down before sending it back again to the boiler for the continuation of the process. The exhaust gases after losing maximum of its energy in the boiler is cooled down in the cooler to a certain temperature of 120°C by the help of a cooling water and is then returned to the atmosphere.

II. RESULT AND DISCUSSION

After the Biogas plant and ORC-WHRS are successfully being modelled in the DWSIM, an analysis has been done to get the exact data of energy inflow and outflow. Here The energy inflow and outflow can be used in order to determine the production efficiency of the system with and without the ORC-WHRS. So, in order to find the production efficiency of the system we can use the formula: [ŋ = energy obtained / energy supplied] or, we can say its Energy output / Energy input

Here, the efficiency of the thermal power plant without the Heat recovery system: 40.58 %.

As the software does not considers any equipment and mechanical process inefficiency, which does exist in the real world. So, the heater efficiency has been set 70 % as added parameter in the software, to make result more accurate considering different practicality.

Here, in the figure 5 all the energy streams had been plotted from the ORC-WHRS process which will be used in order to determine the production efficiency of the system.

Energy Obtained = Turbine + Air Preheater
= 201.37 + 405.81 kW = 607.18 kW
Energy Supplied = Heat Exchanger + Boiler + Pump
= 849.06 + 180.69 + 6.54 = 1045.13 kW
So, the efficiency of the ORC-WHRS is = Energy obtained / Energy supplied
= 607.18 / 1036.29 = 0.585917 = 58 %

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III. CONCLUSION

The main objective of the project is to determine the feasibility of Organic Rankine Cycle waste heat recovery system in Tripura and to model and simulate an ORC-WHRS in the DWSIM software and to find the increment of efficiency when being coupled with Bio gas power plant.

The modelling is done focusing just on the energy intensive process. The whole model was designed after identifying different processes and parameters. The heat recovery process is done by the help of different stages mainly in Boiler, Cooler, Condenser and Recuperator. After the analysis, it has been seen that the waste heat recovery system when coupled with the two bio-gas plant contributed an astonishing increase in the energy efficiency of it by 17.42% which might vary more.

The use of ORC-WHRS also helps the environment in the greater extent. The flue gases when entered has the temperature of 920°C at the rate of 75.8 kg/s and is switched with flue gases of 120°C at the same rate. It signifies that a large tone of harmful gases (greenhouse) can be prevented from being released which will ultimately reduce the carbon footprints of power plants at a great extent and hereby reducing pollution and Global warming.

REFERENCES

[1] Kankeyan Thurairaja, Anusha W, Saliya J, Chathura Ranasinghe, “Working Fluid Selection And Performance Evaluation of ORC,” CPESE, PP:19-21, Japan, 2018

[2] Kankeyan Thurairaja, Anusha Wijewardane, Chathura Ranasinghe, “Thermo- Economic Analysis of Organic Rankine Cycle for power Generation,” IEEE 7th international conference on power and energy (PEcon), Sri Lanka, 2018

[3] Bipul Krishna Saha, Bishab Chakraborty, Ashish Alex Sam, Parthasarathi, “Performance Analysis of Organic Rankine Cycle Technology to Exploit Low Grade Waste Heat to Power Generation in Indian Industry,” International Journal of Environmental Engineering, Vol: 11, No: 10, 2017

[4] Jahar Sarkar, Souvik Bhattacharya, “Potential of Organic Rankine Cycle Technology in India; Working fluid selection and feasibility study,” India, 2015

[5] Lorenzo Tocci, Tamas Pal, Ioannis, Benjamin Franchetti, “Small Scale Organic Rankine Cycle: A Techno-Economic Review,” energies MDPI, PP:413, Italy, 2017

[6] Sadik Ata, Ali Kahraman, Remzi Sahin, “Thermal efficiency evaluation of an Organic Rankine Cycle with n-pentane as working fluid,” International Journal of Energy Applications and Technologies, PP:31-38, Turkey, 2019

[7] Muhammad Imran, Fredrik Haglind, Muhammad Asim, Jahan Zeb Alvi, “Recent research trends in Organic Rankine Cycle technology: A bibliometric approach,” Renewable and Sustainable Energy Research, PP:552-562, 2017

[8] Murat erbas, Atilla Biyikoglu, “Design of low temperature Organic Rankine Cycle and Turbine,” 4th International conference on power Engineering Energy and Electrical Drives, PP:13-17, Turkey, 2013