WASTE HEAT RECOVERY OPPORTUNITY FOR KENYA'S/AFRICA GEOTHERMAL POWER PLANTS AND THE MANUFACTURING SECTOR.

First Author (Patrick Kinyua Maina)[1], Second Author (Kelvin Muriuki Maina)[2]

[1] Graduate Electrical Engineer -patrickkinyua05@gmail.com
Coast Cables Limited
Electrical,I&C Engineer.
P. O BOX 87569-80100 Mombasa.

[2] Graduate Mechanical Engineer-muriukimaina254@gmail.com
Consol Glass Kenya Ltd
Forming Operator
P. O BOX 49835, Nairobi.

Abstract

Industrial waste heat refers to energy that is generated in industrial processes without being put to practical use. Industrial waste heat is a major challenge in manufacturing sector. Sources of Industrial waste heat in geothermal power plants include hot brine, hot condensate taken to cooling towers, hot flue/NCG gases discharged to the atmosphere,steam vented out and heat transfer from hot equipment surfaces.The paper hopes to give an overview of a proposal of how we can make our Geothermal Power plants more effective in energy conservation by embracing Waste heat recovery technologies to generate electricity for the auxiliaries especially.

This paper hopes to propose a wholesome approach of improving overall energy efficiency which is to capture and re-use the lost or "waste heat" which most of it is lost in the cooling towers for power generation. We will evaluate various waste heat recovery technologies for electrical power generation which can be practical in geothermal power plants which include but not limited to Organic Rankine Cycle, Thermo-electric generation and phase change material(PCM) Engine systems. The three methods will be given a keen focus in this paper because of they are Low temperature waste heat recovery temperatures which would easily be practical in our geothermal power plants.

We will also focus on newer waste heat recovery technologies for power generation as a new business opportunity in the manufacturing sector thus enhancing manufacturing processes which is one of the Big Four Agenda.

The paper gives just an overview of the waste to energy technologies we hope to put together in a utility model without going to specific thermodynamic details.

Keywords: NCG-Non -codenseable gases ,PCM-Phase Change Materials,Organic Rankine Cycle,Geothermal Power

1 Introduction

Geothermal energy is heat from the earth. A geothermal well has a depth of 950m to 3.65km deep to tap steam underneath. Hot fluids are obtained from below the earth's surface having been superheated from the core of the earth. These fluids are used to generate power in the form of electricity. The heated fluids are also used to heat water or other suitable fluids used to turn turbines. The turbine converts the heat energy to kinetic energy which is converted to electricity by the generator.

PROBLEM STATEMENT

According to the data from KenGen, the Olkaria I AU unit 4 and 5 for instance , vents out almost half of the steam that comes from the steam field. This vented steam is equivalent to approximately 70MW of power. Venting of steam is unavoidable because unlike hydro-power where there is a surge tank that accommodates for surplus water in cases of more demand, steam has to be supplied in excess in geothermal power plants to ensure that whenever demand is high, steam is readily available. Therefore, in times of low demand, a lot of energy is wasted.Other areas where energy is wasted is during brine extracted at the scrubber-to dry steam going to the turbine, is directed to the base of the cooling tower and non codenseable gases(NCG) extracted from ejector system.

2 Approach

WASTE HEAT RECOVERY LITERATURE REVIEW.

A substantial amount of energy used by industry is wasted as heat in the form of exhaust gases, air streams, and liquids leaving industrial facilities. Geothermal power stations are not any different.Hot brine, vented steam and hot Non non-condensable gases are the major waste heat streams in a geothermal power plant.

They are numerous waste-heat recovery equipments/technologies. However, for our review we will focus on Organic Rankine Cycle(ORC),Phase change materials and Thermoelectric generation.An increased use of waste-heat recovery technologies by industry would also serve to mitigate greenhouse gas (GHG) emissions.

ORGANIC RANKINE CYCLE (ORC)

The interest for organic Rankine cycle (ORC) systems is growing increasingly. The concept of using an organic fluid instead of water dates back from right after the invention of the Rankine cycle in 1859, yet it was not until the 1960s and 1970s that ORC technology got more prominent research attention. By today, ORC systems constitute a flourishing research field and its practical possibilities have been proven.

ORC utilizes organic compound instead of water as a working fluid, generally, a refrigerant, a hydrocarbon such as pentane, butane, and per fluorocarbon or silicon oil. The organic fluid's boiling point is much lesser compared to water and enable heat recovering at lesser temperatures instead of the steam Rankine cycle.

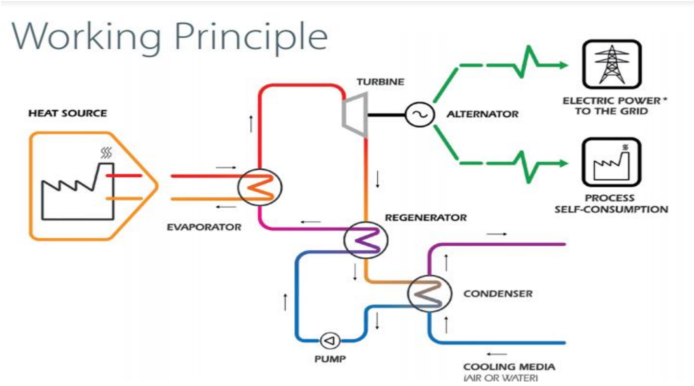
Organic Rankine Cycle can generate electricity from energy sources such as geothermal wells, biomass, solar and oceanic sources and industrial waste heat. Hence, ORC systems have potential to generate electricity from renewable energy sources as well as to enhance industrial energy efficiency. (3rd International Seminar on ORC Power Systems, October 12-14, 2015, Brussels, Belgium).

Details of the ORC Technology

The organic Rankine cycle (ORC) is a modification of the tradition steam Rankine cycle. This is a four stage thermodynamic cycle in which, first, a working fluid is pumped from a lower pressure to a higher pressure.

Then the high pressure fluid enters a boiler where it is heated at a constant pressure until it becomes a dry saturated vapor. Next, this vapor expands through a turbine where mechanical work is converted into electrical energy. The wet vapor, then, enters a condenser where it is condensed back into a saturated liquid and the cycle starts.

Overview diagram of working principle of an ORC system.



Adapted from www.turboden.com

Phase Change Materials (PCM)

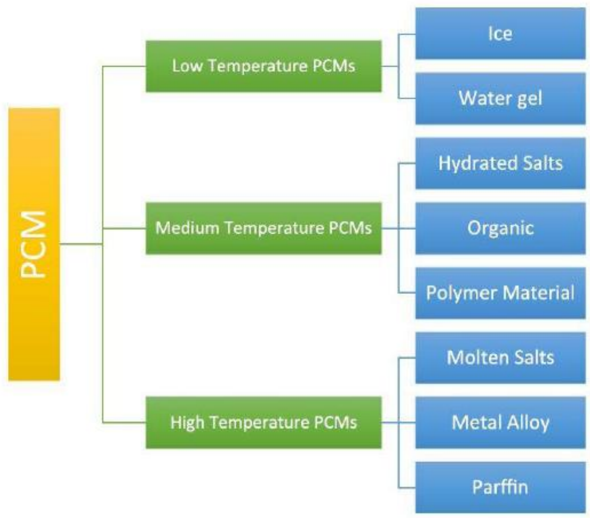
Batteries or PCMs can be used for energy storage However, as the energy storage capacity (kWh) of the batteries is very limited hence researchers and users are opting for PCMs as an alternative.

PCMs are more preferred for our application in this model because of higher storage capacity that is associated with the latent heat of the phase change and their capacity of storing heat at almost similar temperature range. SHS(Sensible Heat storage) materials which would be an alternative utilizes the heat capacity and change in temperature of the material during the process of charging or discharging so temperature of the storage material rises when energy is absorbed and drops when energy is withdrawn.

PCMs are different from Sensible heat Storage (SHS) materials ,However PCM will Initially, act like SHS materials in that the temperature rises linearly with the system enthalpy; however, later, heat is absorbed or release at almost constant temperature with a change in physical state.LHS is based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice versa.

PCM materials are broadly classified based on their physical transformation for heat absorbing and DE-absorbing capability. Solid–liquid PCMs, which are of interest to us are further classified into organic, inorganic, and eutectic materials.PCMs are also classified as different groups depending on the material nature (paraffin, fatty acids, salt hydrates, etc.)

The table below shows their classification based on waste heat stream temperature properties.

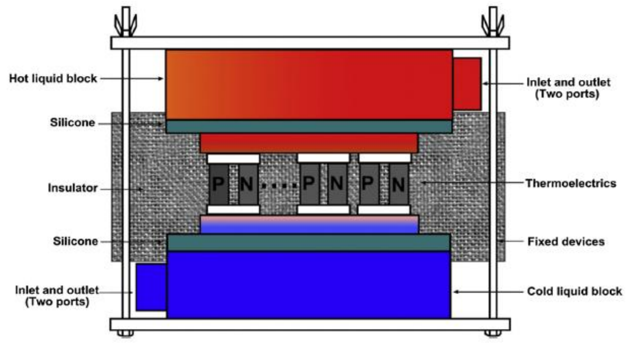


Types of PCMs.

THERMO-ELECTRIC GENERATORS

This entail a direct heat to electricity (DHE) technology using the thermoelectric effect, without the need to change through mechanical energy. This is a relatively new technology. However,The cost of the DHE power generator is lower than that of photovoltaics (PV) in terms of equivalent energy generated hence it is very promising especially in our application which is a low temperature waste heat recovery.

A thermoelectric power converter has no moving parts, and is compact, quiet, highly environmentally friendly and with minimal maintenance. This method of electricity generation could be used to compliment or in place of ORC technology where very low quality heat is the product of our waste heat recovery.Studies shows that therm o-electric generators are competitive with other renewable sources of energy like Solar and wind.



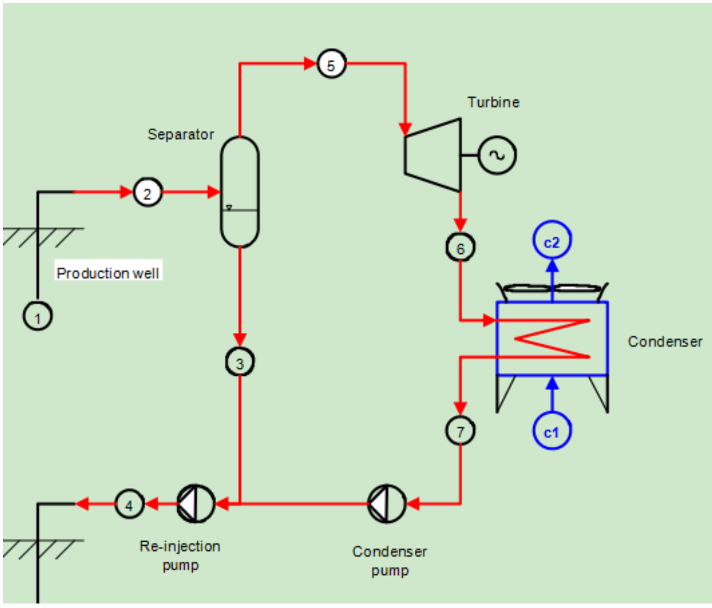
Schematic of a Therm-electric generator.

3 Findings

3.1 Status of Geothermal Power in Kenya

At present 45MW is generated at Olkaria I old station, 140 MW at Olkaria I Additional Units 4 and 5, 105 MW at Olkaria II, 140MW at Olkaria IV, 180 MW at Olkaria V and 80MW. There are a total of 14 wellheads that produce a total of 85 MW. An IPP (OrPower) produces over 50MW. Kenya is therefore producing about 745 MW of geothermal power, with a potential of over 10,000MW Olkaria geothermal power plants use single flash cycle system.

The geothermal fluid enters the cycle as shown in the schematic below. The reservoir is at a higher pressure than the surface and hence the geothermal fluid temperature increases and the fluid starts to boil. The hot fluid enters the separator where brine is removed at and pumped back to the reservoir. The dry steam from the separator then proceeds to the the turbine. In the turbine, steam will run the turbine then through the condenser to the cooling tower.



Single Phase Flow chart for Geothermal Power Plant

	T(Inlet) °C	T(Outlet) °C
Turbine	155.8	50
Condenser	50	10
Reservoir	200	165.2

Temperature values for Geothermal steam through the process.

4 Discussion

The proposed solution is utility model which is under review with prospect of being patented therefore the thermodynamic calculations and economic analysis have been deliberately left out.

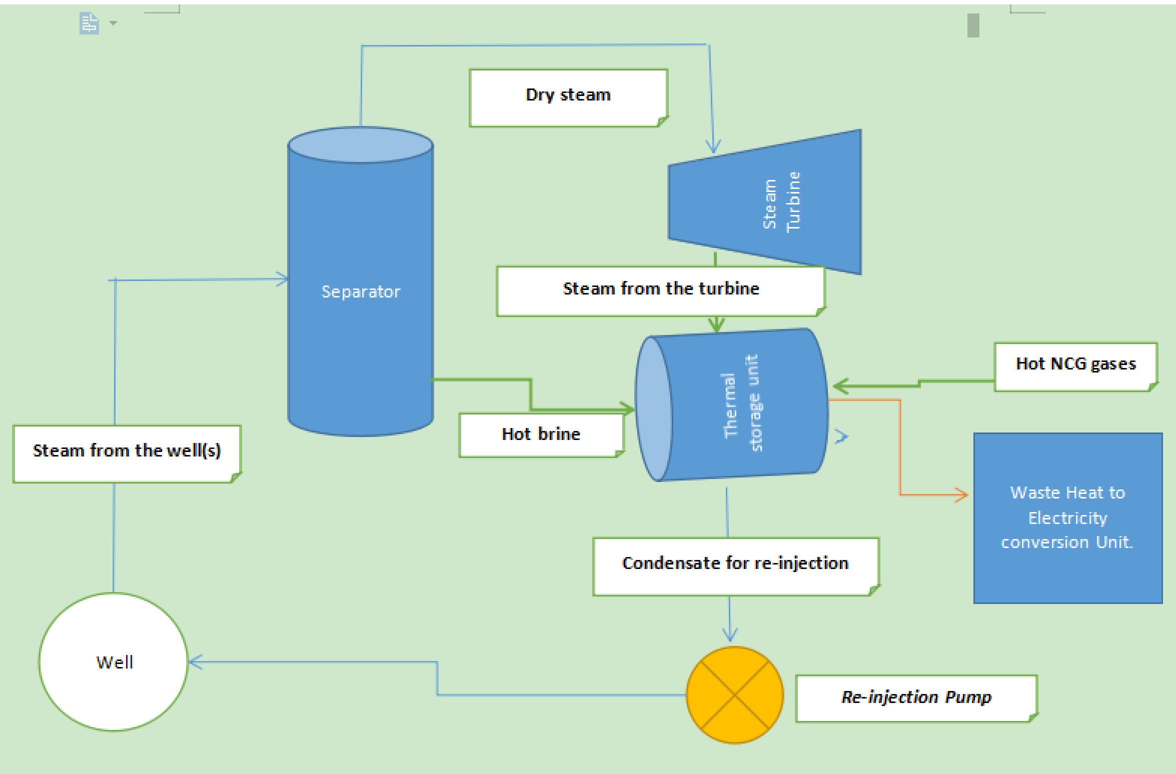
We propose a cascaded waste heat recovery system which is to be in-incorporated in the geothermal power plants already in existence/to be considered in the design for future geothermal power plants.The system will tap the waste energy lost during venting, hot brine from the separator and scrubber/demister and waste heat in the NCG gases lost into the cooling tower.

Waste Low pressure steam from either of the sources listed above will be compressed compressed very high-pressure steam to produce a medium pressure steam hence increased latent heat value which is paramount for waste heat recovery.

The medium pressure steam will be passed through a cascaded waste heat recovery system including but not limited to ORC, TEG and PCMs to generate electricity. The capability of PCMs offer an option of thermal heat storage which can be converted to electrical energy in future.

The proposed utility model should be able to power the power plant auxillaries and save cost of importing electricity from the grid during maintenance/Power plant overhaul.

The schematic below shows the modifications we propose in the single flash cycle system already implemented at Olkaria.



Schematic diagram of proposed the solution

5 Conclusions

The proposed concept will help to significantly address the problem of waste heat and conserve energy.This will have a significant impact in reducing the greenhouse gases.

The paper successfully presents a utility model for enhancing energy conservation thus efficiency in Kenya's geothermal power plants. The technologies outlined in this paper are low temperature waste heat recovery technologies which would also be applicable in many industries countrywide.

Our utility model has the capability of thermal energy storage and can be re-designed in regard to any industrial need.We therefore are also offering a solution which fosters energy conservation in our factories in the manufacturing sector thus contributing to suistable manufacturing practices which is in line with the Big Four Agenda.

We hope to find partners to work with in refining the utility model to a pro-type design hence actualize it into a practical solution.

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