Preliminary Study of Binary Power Plant Output Comparing ORC and Kalina for Low-Temperature Resources in Rusizi Valley, Burundi

Ferdinand Wakana

Ministry of Energy and Mines
Avenue of Revolution
P.O.Box 745
Bujumbura
BURUNDI

Phone:+25779977298

wakanafer@yahoo.fr

Abstract

Low temperature resources are located in many fields and represent high potential resources of energy. The most efficient and cost effective way to exploit this type of resources is based on the binary cycle technology. This study addresses the preliminary assessment of binary power plant output with low temperatures resources of geothermal water of Burundi in Rusizi valley. The focuses are the selection of working fluid, evaluate the net power output, the performance of working fluid, and comparison of Organic Rankin Cycle and Kalina cycle. The potential resource temperatures are in the range between 90°C and 140°C, and the mass flow of geothermal fluid ranging between 20kg/s and 80kg/s. The models of Organic Rankin Cycle and Kalina Cycle were developed and analysed by using EES program. The obtained results are for temperature of geothermal fluid in range between 110 to 140°C and show less power output for low resource temperature with a temperature below 100°C.

1. INTRODUCTION

The East Africa Rift System (EARS) have the largest geothermal potentials of the continent. It is one of the major tectonic structures of the earth where the heat energy of the interior of the earth escapes to the surface. Burundi is one of the countries located along in this system of East Africa Rift. According to the previous studies, 15 hot springs with the surface temperatures measured between 20 to 68 °C were found in western part of the Rift System at Burundi. The hottest geothermal system was expected in the Rusizi valley and the most likely reservoir temperature for these systems could be in range of 100 to 140°C (Fridriksson et al., 2012).

The electricity production in Burundi is totally dominated by hydro power and diesel generators. With climate change and oil price fluctuations, the country faced a serious energy crisis since 2010, because the power load shed. Thus paralyze businesses activities.

The electricity production is mostly handled by the national water and electricity utility REGIDESO, which has an installed capacity of 42.8MW, of which 32.8MW are hydropower plants and 10MW are thermal units, constituting 97 per cent of the national installed capacity. In addition to the capacity mentioned above comes the importation of 16.3MW from the Rusizi I and Rusizi II hydropower plant, through a purchasing contract between the REGIDESO and the Congolese National Electricity Company (SNEL), and the international society for electricity in the great lakes region (SINELAC).

The government of Burundi has decided to respond to those challenges by making long term investments in energy installations to ensure continuous economic growth and by developing the potential renewable energy. The development of geothermal energy is one of the sustainable solutions that the government has adopted. According of the preliminary available data reported by ISOR in 1982 and 2012, the binary power plant technology can be possible in the Rusizi valley System at Burundi if the detailed study is proven (Fridriksson et al., 2012).

This report concerns a tentative design of Binary power plant with consideration of Rusizi valley resource in the temperature range between 90 to 140°C. The design analyses the thermodynamic parameters of different ORC and Kalina Cycle, optimizing the net power output and comparing the output of these two cycles. As necessary data for this study such as fluid mass flow and the chemistry of the reservoir are not yet available, a calculation model was made by assuming some parameters.

2. OVERVIEW OF GEOTHERMAL RESOURCE IN BURUNDI.

Geothermal resources manifestations exist in many locations at the western part of Burundi. This western part of Burundi is connecting with East Africa Rift system (EARS) in western branch. Many reports have been done, describing the geothermal manifestation in Burundi since 1878 by Stanley, 1968, 1972 and 1981 by UNDP. Among them, the locations and chemical analysis have described. In 1981, by the request of the Ministry of Public Works, Energy and Mines of Burundi, the Icelandic International Development Agency carried out a reconnaissance survey in 1982.

During the reconnaissance mission, Ármannsson and Gíslason visited 14 geothermal sites, comprising all known geothermal locations in the country. These are all sites of hot springs with temperatures ranging from near ambient (22ºC) to 63ºC. All the geothermal sites are located in the western part of country; six (6) are located within the western branch of the Eastern Africa Rift valley. The hottest springs are all located in the Rift Valley and the three (3) hottest ones, Ruhwa, Gasenyi and Ruhanga, are located in the Rusizi Valley north of Lake Tanganyika (Fridriksson et al., 2012).

a. GEOLOGY CONTEXT.

The Rift System may be divided into two main branches, i.e. the eastern branch and the western branch. The western branch runs over a distance of 2100km, from Lake Albert in the north to Lake Malawi in the south. The central segment of the rift, trading NW-SE, includes Lake Tanganyika (773m a.s.l.) with a surface area of 32,600km^2, about 650 km long and up to 70km wide. The maximum thickness of the sediment fill is 4 to 5 in the Tanganyika basin. The sediments started to accumulate in Miocene or early Pliocene. The Tanganyika basin is divided western side by normal faults with a curved trace (Fridriksson et al., 2012). Into several asymmetric Sub-basins by NW-striking faults. The northern part of Lake Tanganyika, these faults is accompanied by geothermal activity.
In the western branch of East Africa Rift Valley, the Volcanism activity is much spread than the eastern branch. In the adjacent province of the Neighbours' countries of Burundi such DRC and Rwanda, the Geochronological and

petrological data suggest that volcanism associated with the western rift began ~11Ma ago in the Virunga region, north of lake kivu, ~10Ma ago in the Bukavu Province, south of Kivu; and 9 Ma ago in the Rungwe region, east of Lake Tanganyika. In each of these three provinces volcanism began before the initial subsidence of the local sedimentary basins. However, in the Tanganyika basin or Burundi, there are no subareas volcanism related, there are some indications of under plating of magma below the Tanganyika basin (Fridriksson et al., 2012) tholeiites originating in the Bukavu Province, south Kivu, are found in the north-western most part of Burundi, on the borders to Rwanda and DRC (Ármannsson and Gíslason, G., 1983).

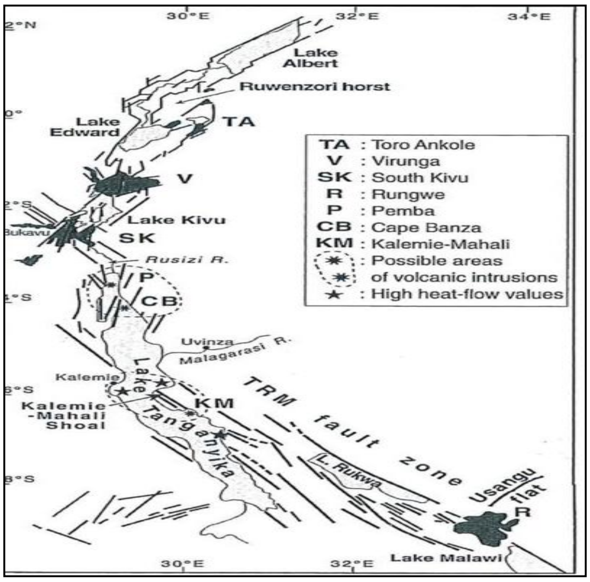


Figure 1: Distribution of Cenozoic lavas in the Kivu Province and neighbouring areas. (From Fridriksson et al., 2012)

Figure 2: Geothermal sites in Burundi and the main tectonic structure sites

The map on figure 1 indicates the lavas entered the NW tip of Burundi. The Burundian bedrock is mostly composed of Precambrian formation and complexes. Dominant rock types are quartzite, gneiss, granite, dolomite, schist, sandstone and conglomerate. The Rusizi valley is filled with thick sequences of alluvium formed during the Holocene. Sediments from Pleistocene, mostly lithified sandstone and conglomerates, are characteristic of the area east of the Rusizi valley, overlying Precambrian formations. A trip of Tertiary tholeiitic and alkali lavas is found in NW Burundi (covering some 30km^2), originating from the volcanic zone of south Kivu in Rwanda. The age of lava flows is estimated 6-8 Ma (Ármannsson and Gíslason, G., 1983).

According to several researchers, the hot spring in NW Burundi do not seem to be directly associated with the Cenozoic basalts found in that area, but they have inferred that under plating of magma might be an important process beneath the Tanganyika Rift (Fridriksson et al., 2012). On the western shore of Lake Tanganyika, along the N-S major faults with NW-SE trending faults (Fridriksson et al., 2012). The geothermal systems within sediments of the Tanganyika Rift in Rusizi are general more characterized by low porosity and permeability (Ármannsson and Gíslason,G., 1983).

b. GEOCHEMISTRY ANALYTICAL CONTENT.

The highest source temperature was suggested in the rift valley according the Icelandic GeoSurvey reports done 1983 and 2012. Three sites of highest temperatures were estimated at the locations in the Rusizi valley. All discharges in the Rusizi valley rising were carbon dioxide rich. This could indicate the presence of a powerful heat source. The high carbon dioxide concentrations lead to super saturation with respect to calcium carbonate in some cases, so that care would have to be exercised in avoiding calcium carbonate deposition in the event of exploitation.

The chemical compositions in Ruhwa are classified as CO_2–rich Na-HCO_3 waters and are very similar of the resultant of Mashyuza samples in Rwanda. Its chemical compositions are characterized all geothermal resources of Rusizi valley in Burundi, i.e. Ruhwa, Ruhanga, Cibitoke, and Gasenyi (Fridriksson et al., 2012).

Using chemical geothermometers to assess the likely temperature in the reservoir, the highest was found in Ruhwa with 102°C, slightly lower than the 110°C observed for 1983 sample. This temperature is low for electricity production with conventional flashing technology, but the binary unit is possible option.

3. GEOTHERMAL BINARY POWER PLANT DESIGN.

3. 1. Introduction

The low to medium temperature sources are unusable to generate electricity with conventional methods. In order to generate electricity from low-to-medium temperature sources, binary technologies have been developed. The binary plants technologies use a secondary working fluid. The intense research has done on Binary technologies and shows the promising resultant to convert the low and medium temperature resources into a useful work of electricity (Paci et al., 2009). This technology is based on conventionally binary power plant.

Generally, there are two main types of binary cycles, the Organic Rankin Cycle (ORC) and the Kalina cycle. The ORC commonly using hydrocarbons as the appropriate working fluid and Kalina cycle uses a water-ammonia mixture as a working fluid (85-15 weight %) (Kopunicova, 2009). The Kalina cycle achieves at thermodynamic efficiency (brine effectiveness) that is approximately 50% greater than that of standard binary Rankin plants (Dickson and Fanelli, 2003). The objectives of this design are:

- To analyse the net power output possibilities (efficiency) with an organic Rankin cycle and Kalina cycle with the Rusizi area parameters conditions;
- To compare a net power output (efficiency) by using an organic Rankin cycle and Kalina cycle.

3.2. Thermodynamic modeling of Organic Rankin cycle

In this study, the model presented in figure 3 is a simple binary cycle using an organic working fluid, as Isopentane, Isobutane, Propane and R134a. The working cycle components are preheater, evaporator, turbine, condenser and feed pump. The cooling system of the condenser uses a dry cooling system. The cooling system uses a fan and motor to supply and remove air in the cooling system. The cooling system is chosen regarding the Rusizi area conditions. In this area, there are two rivers, Rusizi River and Ruhwa River. These two rivers are shared by Democratic Republic of Congo and Rwanda respectively. The use of these rivers required an agreement between these countries.

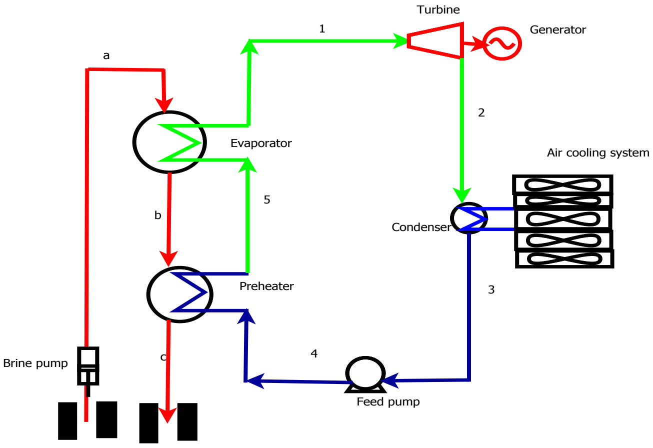


FIGURE 3: Binary cycle with air cooling system

The geothermal water is pumped from well in order to pressurize it. Using Engineering Equation solver (EES) software, a thermodynamic model of the binary plant cycle was developed for all working fluid and analyzed the parameters of the cycle. The objectives are optimization of the efficiencies of different working fluid and the net power output with the range of temperature and geothermal flow rate of 90 to 140°C and 20 to 80kg/s respectively. The ranges used refer to the reconnaissance study report of geothermal areas in Burundi done in September 2012. These ranges were estimated using the geothermometer analysis method. Many input data were estimated during development of the thermodynamic cycle of the binary, because the miss of sufficient data availability from the field. The following assumptions shown below in table 1 are made.

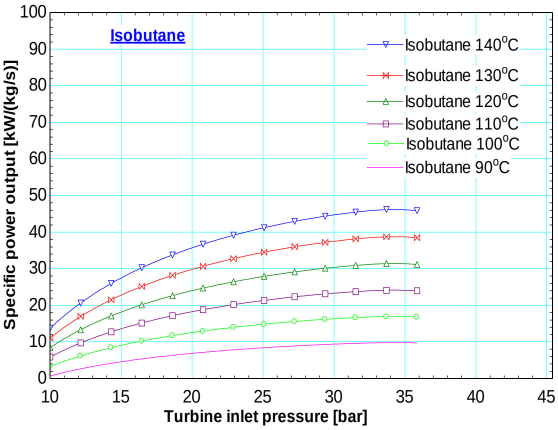
Table 1: Design parameters assumption of binary cycle power plant

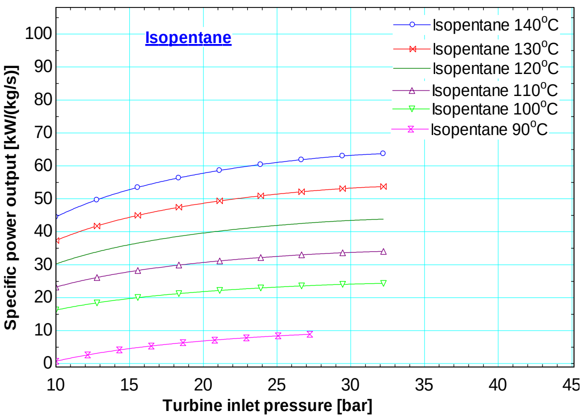
Parameters	**Unit**	**Minimum value**	**Maximum value**
Mass flow rate of geofluid	kg/s	20	80
Temperature of geoflud from the well	ºC	90	140
Pressure of geofluid from the well	bar	30	
Reinjection temperature	ºC	70	
Temperature of Rusizi area (Ndayirukiye, 1986)	ºC	30	
Turbine efficiency	%	85	
Feed pump efficiency	%	75	
Fans efficiency	%	65	
Atmospheric pressure	bar	1.02	
Relative humidity (Ndayirukiye , 1986)	%	70	
The pinch point of vaporizer	ºC	5	
Air temperature leaving the cooling system assumed equal ambient temperature plus 12ºC.	ºC	42	
Working fluids: Isobutane, Isopentane, propane and R134a	Kg/s		
The vaporizer pressure	Optimum pressure		
Temperature of condenser	ºC	45	

3.2.1. **Optimization of turbine inlet pressure of working fluid Cycle.**

The optimal design of a binary geothermal power plant can be considered as a multi objective, multivariable constrained optimization problem. Three main temperatures can be considered as constraints, i.e. the geothermal fluid, rejection, and ambient temperatures. The whole optimization problem can be reformulated into manageable size sub-problems. The results from the high optimization level represent the input data for the detailed design. The effects of the optimum component design (pressure losses, pumping power) are iterated at the system level (Franco and Villani, 2009).

In this study, the turbine inlet optimum pressure requires for every working fluid considered using for a temperature resource given in the range between 90ºC to 140ºC, we have optimized it for to get a good output of the binary power plant design. The turbine inlet pressure plays an important rule to produce a mechanical force for driving a generator. The net power output was considered as parameters in this optimization and the reinjection temperature in order to prevent calcite carbonate scaling possibility that can occur during operation. The optimization of inlet turbine pressure was done by a code create using computer. EES software is helpful to creating the code to resolve some thermodynamics problem. It is used in this study to optimize different parameters of our design cycle, including the pressure inlet in turbine for the range of temperature between 90ºC to 140ºC in respect of reinjection temperature. The optimization was done for all working fluid and analyse where the work output is highest. The behaviour work output of working fluid at different pressure was allowed us to choose the optimum pressure and the figure 4 below show the optimum pressure for each working fluid at different temperature.





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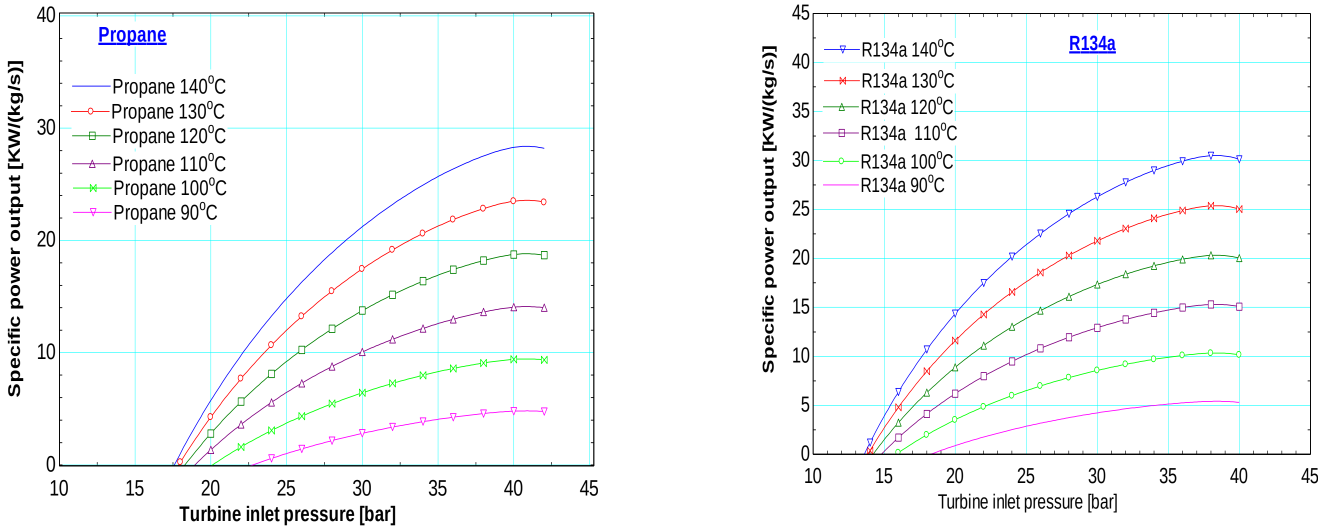


(c) (d)

FIGURE 4**:** power plant output with turbine inlet pressure

After optimization, we saw that some working fluid show the optimum pressure different at the different temperature or the same optimum pressure in certain range of temperature. One working fluid, R134a give an optimum output at the same pressure in all range of temperature considered and needs a high pressure to generated an optimum output. The summarize results of different optimum pressure for all working fluid and at various temperatures considered is shown in the table 7 below.

3.2.2. Power plant performance analysis.

The first and second law efficiencies are usually used to assess the performance analyses of binary power plants. These two parameters can help to compare the various available combinations of the source, rejection and condensation temperature, and give indications about of the specific power of the plant. Another parameter important to be considered is the mass flow rate used to generate a fixed power output.

In this study, the thermodynamic parameters of the binary model cycle were developed and EES programme used to estimate the parameters values of model binary cycle. Having pressure of turbine inlet, temperature of geothermal resource, ambient temperature, reinjection temperature and condenser temperature, other parameters could be calculated by EES helpful. The calculation was done with a geothermal mass flow input of 1 kg/s as source of heat. The reinjection temperature used in this study was fixed at 70°C considering the low enthalpy of the geothermal resource according to Alessandro and Marco Villani and the reconnaissance study report of geothermal resource in the Rusizi valley in Burundi September 2012. For the geothermal field that have temperatures between 110 and 160°C, it is difficult to use rejection temperatures lower than 70-80°C, the latter temperature is a crucial parameter in plant design(Franco and Villani,2009). The condenser temperature was fixed at 45°C because the ambient temperature is very high with average of 30°C. The analyses results of binary power plant model for all working fluid choose are presented in the tables 2 to 5 below. The performance analyses results give the value of exergy efficiencies with variation of temperature. The exergy efficiency is an indicator to assess the extraction of heat from geothermal resource by binary cycle through preheat and evaporator.

The first law efficiency and exergy efficiencies with the optimum turbine inlet pressure were calculated to assess the level of extraction of heat from the source and the level energy uses. This assessment allows to know the losses in the cycle. The results of analyses are illustrated in the table 2, 3, 4 and 5. The exergy efficiency, first law efficiency and mass flow of working fluid indicate thermodynamically the performance of a binary cycle. The objective is to extract more heat and gain a highest power output with less cost. The investment is another parameter to be considered in the decision maker for a binary power plant design. The results show isopentane is better than other working fluid utilized.

Table 2: Isopentane

Tgeo (°C)	**T_{inj}(°C)**	**Power Output(kW/kg/s)**	**n_{th}**	**n_{exerg}**	**m_{wf}(kg/s)**
90	70	12.57	0.14	0.50	0.17
100	70	22.7	0.17	0.68	0.255
110	70	31.8	0.18	0.78	0.338
120	70	42.6	0.20	0.85	0.424
130	70	52.2	0.20	0.86	0.511
140	70	62.0	0.20	0.87	0.599

Table 3: Isobutane

Tgeo (°C)	**T_{inj}(°C)**	**Power output(kW/kg/s)**	**n_{th}**	**n_{exerg}**	**m_{wf}(kg/s)**
90	70	8.2	0.096	0.32	0.34
100	70	15.8	0.125	0.487	0.33
110	70	23.8	0.141	0.58	0.56
120	70	30.09	0.146	0.55	0.70
130	70	38.13	0.149	0.57	0.69
140	70	45.4	0.152	0.58	0.81

Table 4: Propane

Tgeo(°C)	**T_{inj}(°C)**	**Power output(kW/kg/s)**	**n_{th}**	**n_{exerg}**	**m_{wf}(kg/s)**
90	70	3.8	0.045	0.15	0.28
100	70	9.07	0.071	0.27	0.43
110	70	14.05	0.083	0.34	0.60
120	70	18.7	0.088	0.37	0.76
130	70	23.4	0.091	0.38	0.91
140	70	28.3	0.094	0.39	1.078

Table 5: R134a

Tgeo (°C)	**T_{inj}(°C)**	**Wnet output (kW/kg/s)**	**n_{th}**	**n_{exerg}**	**m_{wf}(kg/s)**
90	70	5.4	0.064	0.21	0.56
100	70	10.3	0.081	0.31	1.14
110	70	15.3	0.09	0.34	1.03
120	70	20.3	0.095	0.36	1.42
130	70	25.5	0.099	0.38	1.71
140	70	30.3	0.101	0.39	2.01

3.3. Kalina Power plant principles and modelling.

The Kalina cycle is principally a modified Organic Rankin Cycle, and was developed in an attempt to reduce the losses incurred by the use of a pure substance working fluid. The goal of the Kalina cycle is that by using a mixture of ammonia and water as the working fluid, the temperature profile of the working fluid will more closely follow the temperature profile of the heat source or sink. There are several variations of the basic Kalina cycle based on the application (Jones, 2011).The ammonia in the mixture begins to vaporize first, and as it boils off, the liquid mixture ammonia concentration decreases, and the boiling temperature of the liquid mixture increases. By adjusting the mass fraction of ammonia in the mixture, the Kalina cycle can be optimized based on the input conditions. In order to fully appreciate the cycle, you must know before the number of additional steps and parameters of the model of cycle. The figure 5 shows a basic model of the Kalina cycle.

The working fluid (ammonia-water) leaves the evaporator or boiler as a saturated mixture. The quality of the mixture is a function of the concentration of ammonia in the working fluid mixture, the temperature of the heat source, and the pressure of the working fluid. Once the working fluid mixture leaves the evaporator, it enters the phase separator. The task of the phase separator is too separate the working fluid into two separate streams. The saturated vapour portion of the working fluid passes through the separator to state 1, and the saturated vapour is an ammonia rich mixture. The saturated vapour continues on to the turbine where it undergoes an isentropic expansion to produce work. The saturated vapour is expanded into a saturated mixture and exits the turbine. The saturated mixture is at state 2. The mass fraction of the working fluid that did not vaporize in the evaporator leaves the separator as a saturated liquid at state 3.

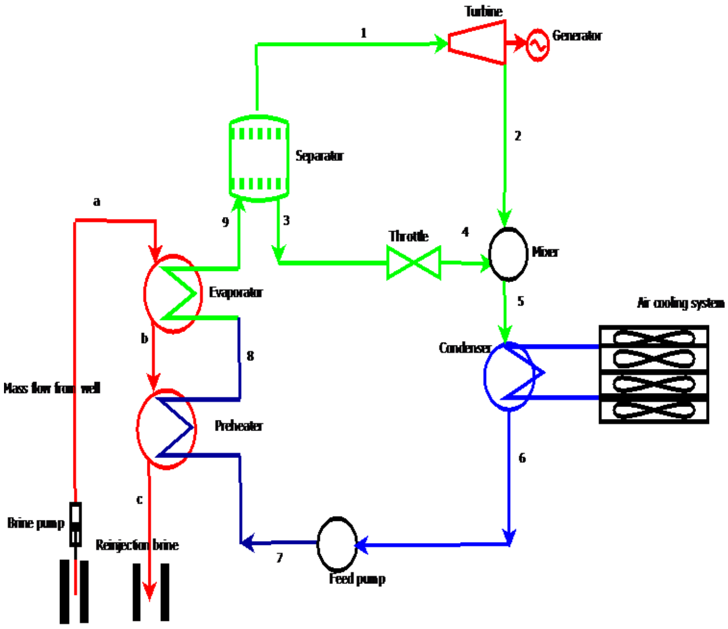


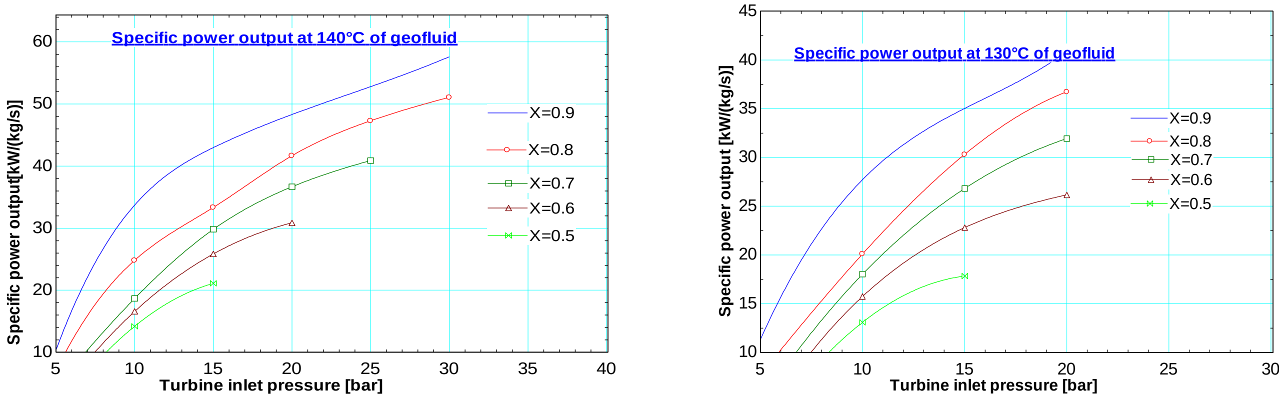
FIGURE 5: Schematic of Basic Kalina Cycle

The saturated liquid portion of the working fluid is a weaker ammonia mixture than the saturated vapour portion of the working fluid. The hot saturated liquid is sent to the absorber after to be brought at low pressure with a throttling valve, where it is mixed with saturated mixture leaving the turbine at the same low pressure. He recombined mixture leaves the absorber at state 5 and passes through the condenser where heat is rejected and the working fluid is brought back to a saturated liquid. The saturated liquid leaves the condenser at state 6. A pump is then used to isentropically compress the working fluid mixture to the maximum pressure of the cycle to state 7. The cold working fluid then enters the preheater in order to recover some of the thermal energy and leaves the preheater at state 8. The preheated working fluid mixture then enters the evaporator to start the process over again.

3.3.1. Thermal efficiency and net power output of Kalina cycle power plant

The thermal efficiency of the power plant cycle is of upmost importance in order to produce an economically viable system, and can be used as the primary evaluation parameter. The utilization of the first law efficiency of thermodynamics, allow measuring the cycle performance. A cycle with a high first low efficiency would have a much smaller boiler heat transfer area requirement per unit work output. However, several other factors such as the transfer coefficients and pressures play a role in the size of equipment.

The efficiency of Kalina cycle system was calculated by varying pressure and fraction of ammonia in water. The calculation concerned all range of temperature between 90°C to 140°C in order to find the optimum operation. The same procedure was used to calculate the net power output for different pressure and fraction of ammonia. The resultants show that ammonia water as a working fluid can be used at different pressure by changing the concentration of ammonia mixture in the water. The figure 6 .(a), 6.(b) ,6.(c) ,6(d),6(e) and 6 (f) show the behaviour of water ammonia mixture as working fluid in different pressure and different ratio of ammonia in the mixture.



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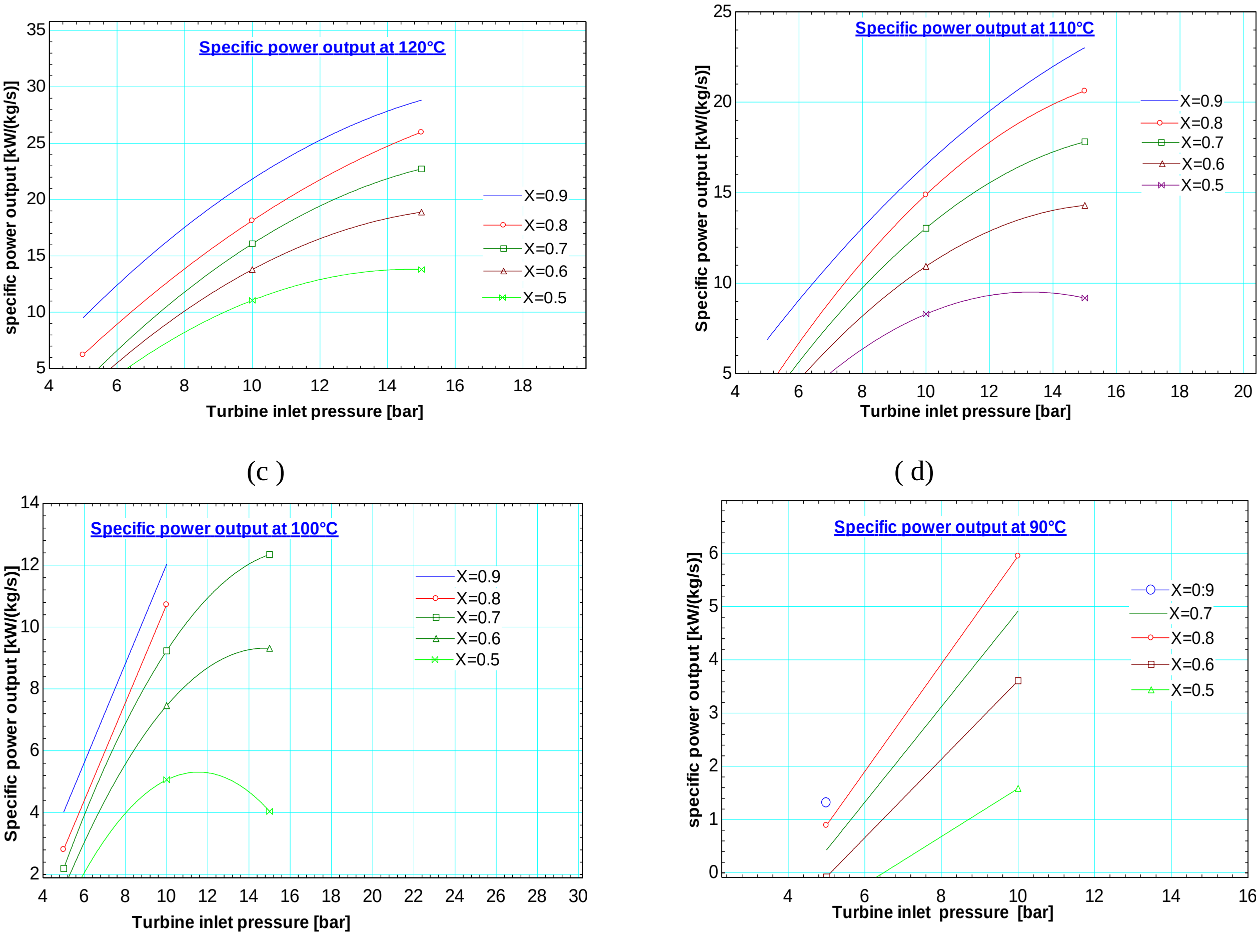

(c)

(d)

(e)

(f)

FIGURE 15: Comparison of net power output for different pressure and fraction of ammonia in mixture.

The optimum pressure regarding the pinch point of heat exchanger used is 30 bar for all range temperature considered with mixture fraction of 90% ammonia. The result is given in table below.

Table 9**:** optimum operation condition of power plant for range temperature resource

Temperature (°C)	Ammonia fraction	High Pressure (bar)	Low pressure (bar)	Cycle efficiency	Exergy efficiency	Specific power output(kW/kg/s)
90	0.8	15	5	3%	10%	2.5
100	0.8	15	5	6%	21%	6
110	0.8	15	2	12%	50%	20.6
120	0.8	15	2	13%	51%	25.9
130	0.9	20	2	16%	68%	40.4
140	0.9	30	2	19%	81%	57.6

4. COMPARISON OF ORGANIC RANKIN CYCLE AND KALINA CYCLE

The main comparison consists of power outputs and cycle efficiency. All two cycle utilize a secondary fluid for obtaining heat energy through a heat exchanger from a geothermal source. The difference between the ORC and Kalina cycle is in the working fluid and equipment component. Organic Rankin cycle utilizes hydrocarbon or refrigerant as a working fluid in a closed loop. Kalina cycle has specific parameters due to its mixture of ammonia and water. The optimum turbine inlet pressure in Kalina cycle depending the ammonia fraction in mixture water-ammonia and the temperature of geothermal fluid. The previous statement influences the optimum output and the heat extraction efficiency. The advantages on Kalina cycle are to increase or to decrease power output by adjusting only the fraction of ammonia in mixture without changing equipment. Theoretically, Kalina cycle has better high efficiency when the heat source stream has a finite heat capacity. But, ORC and Kalina cycles are similar when the source is condensing steam (Valdimarsson, 2003).

Regarding the first and second law efficiency results of ORC and Kalina cycle, the performance of Kalina is similarly with ORC.With low temperature below 100°C, Kalina Cycle give the less performance than ORC. However, the increasing of geothermal fluid temperature match with quick increasing of Kalina efficiency and power output. At 140°C, the efficiency and power output of Kalina are like to be the same with Isopentane that have a highest efficiency and power output. The behaviour of efficiency and power output with the increase of geothermal fluid temperature, shows the Kalina efficiency and power output might be very high than ORC at geothermal fluid temperature above 140°C. That means Kalina cycle performance at low temperature below 140°C, have the same performance of ORC if the working fluid is well selected. This result join the agreement of same authors that said the Kalina cycle permit a gain in performance with respect to ORC, the adoption of Kalina cycle, at least for low power level and medium- high temperatures thermal sources, seems not to be justified as the gain in performance with respect to a properly optimized ORC. It is very small and must be however obtained with a complicated plant scheme, large surface heat exchangers and particular high pressure resistant and no-corrosion materials, i.e. with an expensive and not proven (Bombarda et al., 2010).

Considering the models, Kalina cycle has many components than organic Rankin cycle and sometime very complex. Those increase cost of power plant.The calculation was done using the same baseline for ORC.Regarding power output for all ORC used and Kalina cycle, Isopentane give a highest output followed by Isobutane, R134a, propane and Kalina at temperature less than 100°C.But, between 100°C to 120°C, Kalina cycle produce higher power output than propane and R134a. At 130 to 140°C, it increase quickly and give highest power output of the working fluids considered except for Isopentane. At 140°C, Kalina gives a power output near the power outputgiven by Isopentane. This means if the temperature is high than 140°C, the Kalina cycle will give higher power output than Isopentane.Looking at the numbers of energy input and power output in the modelled systems the answersclear. Forlow temperature than 100°C, the performance ofKalina is less than ORC. But, for temperature between 100 and 140°C, the performance of Kalina and ORC is similarly, and depending the working fluid selected for ORC.

Again, Ammonia is toxic and highly corrosive, which has to be taken into account in material selection. In this study, ORC was appreciated regarding its efficiency if the working fluid is chosen properly. Isopentane show a good performance with this type of geothermal resource. It could be taken in consideration if all assumption done proven in future with detailed study.

5. CONCLUSION

After analysis several parameters of two cycle, the ORC was appreciated to be the best for use in Burundi for its low temperature resource. The ORC show the good efficiency and has used a long time and still showing the improvement with reliable and safety in operation. The Kalina cycle technologies are very complex and relatively new considering ORC. In many cases of research, the Kalina was shown the best efficiency. However, for the low temperature resource, this highest efficiency still in contradictor for some authors. The power output of ORC is very similarly of Kalina cycle for temperature of geothermal fluid in range between 110 to 140°C and show less power output for low resource temperature than 100°C.

Kalina cycle can be appreciated with its thermodynamic properties. It has several boiling temperature that allow it to decrease or increase the power output without change in equipment component. For higher temperatures than 140°C, the Kalina cycle might have a better performance than ORC regarding the behaviour of first law and second law of thermodynamics.In this study,the maximum power output at 140°C and geofluid mass flow rate of 80kg/s could reach 4,9MW and minimum at the same temperature with mass flow rate of 20kg/s is around 1.2MW using Isopentane as working fluid. At 90°C the maximum power output that could be reached is 1MW with mass flow of 80kg/s and minimum 0.3MW with mass flow rate of 20kg/s using Isopentane.

Regarding this study was done on assumption, the detailed exploration is needed to gather more information of subsurface. Only these information could help to improve the result of this work.

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