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Simulation of geothermal plant yield with organic fluid

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ABSTRACT

Geothermal energy used for heat and electrical power production; is part of concept for past many years, geothermal plants enable of renewable electricity production amounts with permanent production capacity. Therefore, our work is oriented towards the simulation of behavior power plant according to the temperature and pressure. objective of this work is to compare produced power from geothermal resources , function of geothermal temperature and organic fluid Butane, R245fa, and R11, used for organic Rankine cycle of thermal plant. For this, we choose "Thermoptim" software that allows in particular to thermodynamic cycles model, we introduce the necessary parameters and constraints, simulations and sensitivity studies to compare the results and represent curves trend. we compare different working fluids from energy performance, that is to say the production of electricity from geothermal low-temperature source, to determine reinjection temperature of geothermal water outlet of power plant cycle and evaluating recovered powers of different geothermal temperatures. Obtained results show that optimal power for maximum of 20kg/s, for Butane , is function of geothermal temperature resource; so for 90°C for geothermal temperature we can't produce more than 1MW, for 100°C power can be 1.3 MW; 120°C; it can produce 1.6MW, and 1.8MW can be produced for geothermal resource temperature of 140°C. And rei njected temperature is not very different for resource temperature; and this can be very important because this difference can be gained slowly and easy without a lot of loss.

محاكاة إنتاجية محطة الطاقة الحرارية الأرضية باستخدام السوائل العضوية

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الكلمات المفتاحية:

الطاقة الحرارية الأرضية
الموارد الحرارية
درجة حرارة إعادة الحقن
إنتاجية المحطة الكهربائية
دورة رانكين للسوائل العضوية.

الملخص

الطاقة الحرارية الأرضية المستخدمة في إنتاج الحرارة والطاقة الكهربائية؛ تعد محطات الطاقة الحرارية الأرضية جزءًا من مفهوم السنوات العديدة الماضية، حيث تمكن من إنتاج كميات من الكهرباء المتجددة بقدرة إنتاجية دائمة. ولذلك فإن عملنا موجه نحو محاكاة سلوك محطة توليد الكهرباء وفقا لدرجة الحرارة والضغط. الهدف من هذا العمل هو مقارنة الطاقة المنتجة من موارد الطاقة الحرارية الأرضية، وظيفة درجة حرارة الطاقة الحرارية الأرضية والمائع العضوي البيوتان، R245fa، و R11، المستخدم في دورة رانكين العضوية للمحطة الحرارية. ولهذا اخترنا برنامج "Thermoptim" الذي يسمح بشكل خاص بنموذج الدورات الديناميكية الحرارية، وإدخال المعلمات والقيود اللازمة والمحاكاة ودراسات الحساسية لمقارنة النتائج وتمثيل اتجاه المنحنيات. قمنا بمقارنة سوائل العمل المختلفة من أداء الطاقة، أي إنتاج الكهرباء من مصدر الطاقة الحرارية الأرضية منخفض الحرارة، لتحديد درجة حرارة إعادة حقن مخرج المياه الحرارية الأرضية لدورة محطة توليد الكهرباء وتقييم القوى المستردة لدرجات حرارة الطاقة الحرارية الأرضية المختلفة. تظهر النتائج التي تم الحصول عليها أن الطاقة المثلى

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بحد أقصى 20 كجم/ثانية، للبيوتان، هي دالة لمورد درجة الحرارة الأرضية؛ لذلك، عند درجة حرارة 90 درجة مئوية للطاقة الحرارية الأرضية، لا يمكننا إنتاج أكثر من 1 ميجاوات، ويمكن أن تصل الطاقة عند 100 درجة مئوية إلى 1.3 ميجاوات؛ 120 درجة مئوية؛ يمكن أن تنتج 1.6 ميجاوات، ويمكن إنتاج 1.8 ميجاوات لموارد الطاقة الحرارية الأرضية البالغة 140 درجة مئوية. ولا تختلف درجة حرارة الحقن كثيرًا عن درجة حرارة المورد؛ ويمكن أن يكون هذا مهمًا جدًا لأن هذا الاختلاف يمكن اكتسابه ببطء وسهولة دون خسارة الكثير.

1. Introduction

Thepaper Currently, 66.6% [1] of the electricity is produced by burning fossil fuels (coal 41%, natural gas 22% and oil ~ 4%). In contrast to the increase in electricity consumption, the reserve of fossil energy resources is limited and decreases. Power generation technologies based on the use of renewable resources therefore attracts much attention. In fact many renewable resources such as geothermal, solar, biomass or industrial waste heat is in the form of heat from low-temperature sources that cannot be economically used to produce electricity by conventional Rankin cycle because of the relatively high temperature boiling water[2]. In the field of the production of small and medium-power electrical energy from a heat source of lower quality, Rankin organic cycle with the same principle but using an organic compound (eg refrigerant.) as fluid work, a lot of interest. The CROs cycles always have a performance (of the order of 10 to 23% thermal efficiency and least 2MW of electrical power) much lower than the performance of conventional steam cycle. Several studies therefore focus today on improving the performance of the ORC cycle [3].

2. Geothermal energy

2.1. Origin

Geothermal energy comes from the increase in temperature as one penetrates deeper into the Earth's crust, either due to the natural gradient (3 °C/100 m, with an average flux of 60 mW/m2), or due to geophysical singularities (natural geothermal reservoirs of porous rocks at high temperature).

It is customary to distinguish three main categories of reservoirs, according to their temperature levels:

- high temperature (> 220 °C)
- intermediate temperature (100 – 200 °C)
- low temperature (50 – 100 °C)

In the first case, the geothermal fluid can consist mainly of water or steam, in the other two it is water, possibly under pressure. One of the particularities of geothermal fluid is that it is never pure water: it also contains many impurities, corrosive salts (the limit concentration for exploitation to be possible is equal to 1.5 mol/kg) and non-condensable gases (CNG) in variable quantities (0.1-10%). We will see that this particularity imposes specific constraints on the thermodynamic cycles that can be implemented. For environmental reasons, geothermal fluid must generally be reinjected into the reservoir after use, but this is not always the case [4].

3,Thermodynamic conversion

The thermodynamic conversion of geothermal energy uses four main techniques:

So-called "direct" power plants can be used if the geothermal fluid is superheated steam that can be directly expanded in a turbine. Historically, this type of power plant was the first to be implemented, in Larderello in Italy in 1904

flash vaporization power plants make it possible to exploit sites where the geothermal fluid is in the form of a pressurized liquid or a liquid-steam mixture. This is the most widely used type of power plant today. The geothermal fluid then begins to be expanded in a chamber at a pressure lower than that of the well, which allows part of it to be vaporized, which is then expanded in a turbine

So-called binary systems use a secondary thermodynamic fluid, which follows a closed Rankine cycle, the boiler being made up of a heat exchanger with the geothermal fluid

Fluid-mixed systems, such as the Kalina cycle, a variant of binary systems where the thermodynamic fluid is no longer pure but made up of two fluids in order to achieve a temperature glide during vaporization

Mixed or combined cycles can use both a direct or flash system and a binary system. [4].

3. 1. Organic rankine cycle conception

Organic Rankine Cycle machines are based on the same principles of thermodynamic steam Rankine cycle, they use an organic fluid (other than water, resulting from the carbon chemistry), which circulating in a closed cycle recovers waste heat of a heat exchanger vaporizes and then expanded in a turbine / expander associated to generator, thus converting thermal energy into electricity.

This technology originally developed for remote sites and for geothermal energy is deployed for 30 years and has proven itself with over 1500 MW of installed capacity.

Rankine cycle consists four transformations:

• 1 → 2: adiabatic and reversible compression (isentropic) to pump level

• 2 → 3: Spray isobaric level and irreversible exchanger

• 3 → 4: adiabatic and reversible relaxation (isentropic) at turbine.

• 4 → 1: Liquefaction isobaric and irreversible, at condenser.

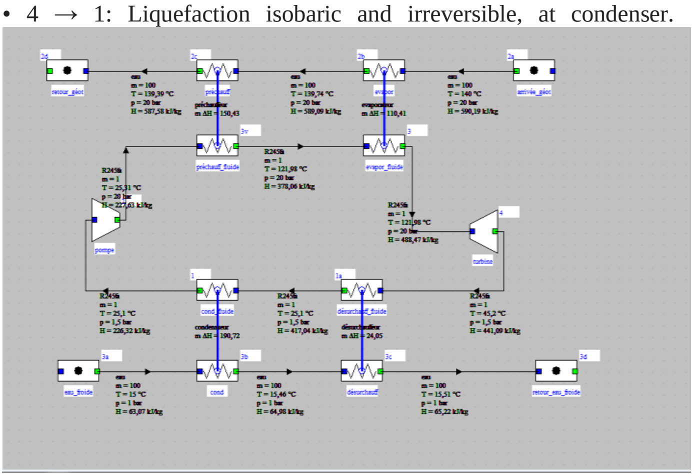
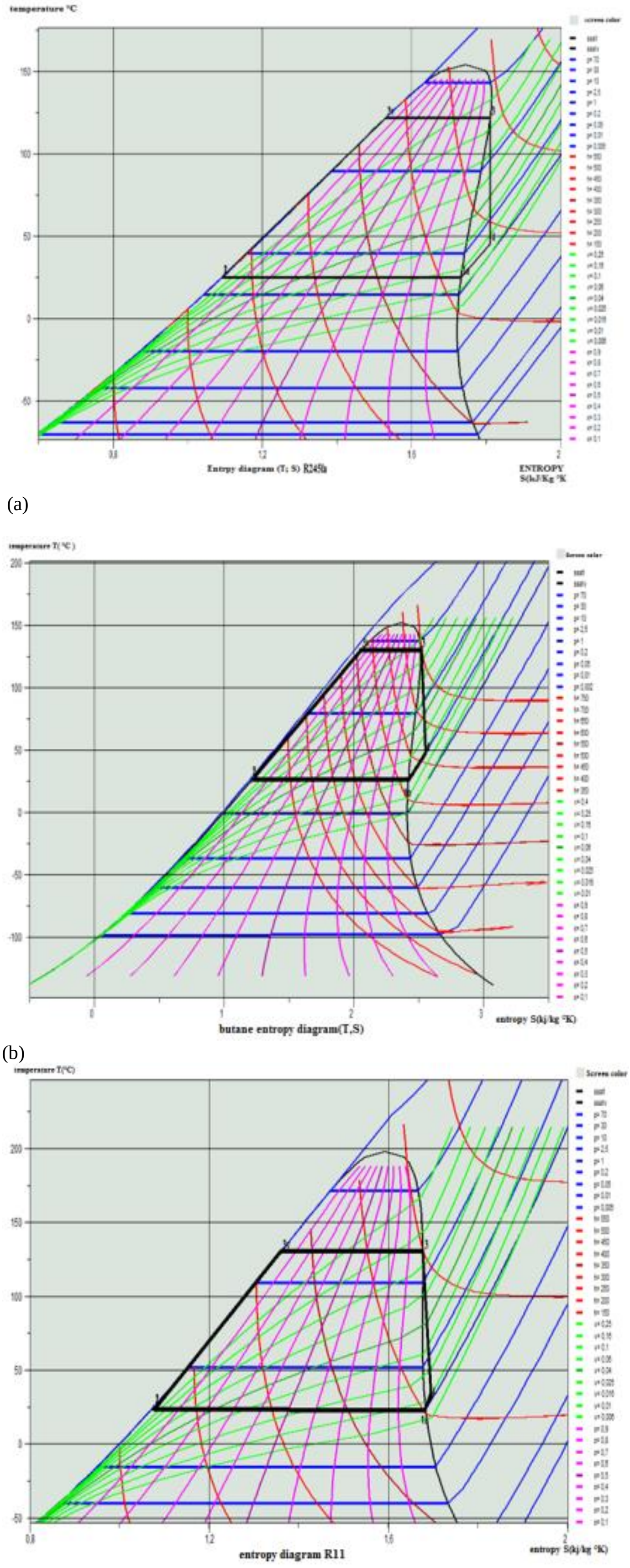


Fig.1: Geothermal Rankine Cycle plant

Isobaric evaporation of fluid can be divided into two stages: isobaric heating liquid only way then isobaric and isothermal evaporation. The schematic diagram of an organic Rankine cycle simply is given in figure1. It consists of: pump, steam generator, expansion machine and condenser.

3.2. Working fluid choice

To select working fluid for an application, it is generally desired to lead to high energy performance, it is adapted to cycle working conditions, it economically viable and meet the regulations. The criteria for fluids selection for refrigeration cycles can of course be different from those for Rankine cycles. Thermoptim does not have a large library of media work, we chose to study three fluids: butane, R11and R245fa.



(a) (b) (c)

Fig.2: Organic fluid entropy diagram

4. Materials and method

For doing our work we follow this steps:

- Choice operating constraints values: These values relate to regime; temperature geothermal water surface T = (90 ° C.100° C.120° C and 140 ° C); geothermal fluid flow rate = 100Kg / s
- Select the fluid and calculation method of its properties. Thermoptim don't have a library of thermodynamic properties of different fluids; they are calculated according to models that must be specified by the user. The choice of model has a critical impact on the validity of results.
- Design the cycle on Thermoptim interface.
- Set (hypothetically) the model design parameters.
- Eg Isentropic efficiency of turbine = 0.9.

4.1 Operating conditions

- Temperature of geothermal resource: 140 °C, 120 °C, 100 °C, 90 °C
- Geothermal Water flow (100 kg / s),
- Condensation temperature equal to 25 ° C
- Geothermal fluid assimilated to pure water maintained surface pressure of 20 bars.
- Heat flow rate = 100Kg / s)
- Temperature of cold source is 15 ° C
- Operation in subcritical regime
- Title steam at turbine inlet equal to 1
- Working fluid flow (= 1Kg / s)

Table 1: working conditions for organic fluid

	R245fa				R11				Butane			
T_{geot} C°	140	120	100	90	140	120	100	90	140	120	100	90
HP (bar)	14,9	10,14	6,60	5,23	14,9	10,14	6,60	5,23	26,37	18,47	12,50	10,12
BP(bar)	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	2,43	2,43	2,43	2,43
T_{vap} (°C)	130	110	90	80	130	110	90	80	130	110	90	80
T_{sur}(°C)	129,74	109,3	99,1	79,2	139,61	109	89,54	79	139,56	109,04	89,02	79,14
$T_{réinj}$ (°C)	139	119	98,2	88,3	139,33	119,3	99,12	89,01	138,80	119,10	89	79

4.2. Thermoptim software

The software is Thermoptim Primarily a systemic modeling environment very original and unique energy technology, it Makes possible to the introduction of new methods in pedagogy particularly fruitful, modeling and optimization. The same tool is now implemented by 60 users to 2 categories of applications: Either educational or industrial. By assembling predefined components or specifically developed models, it can easily represent very different energy systems, from easy to complex. As appropriate, the models of these components may be either purely phenomenological or more technology, that is able to dimensioning or simulate the operation, in non-nominal conditions. Thermoptim stands out more oriented software components with emphasis on linkages and interactions between components, That is to say on systemic properties of studied plants. It's complementary thus specialized tools developed by manufacturers of their devices.

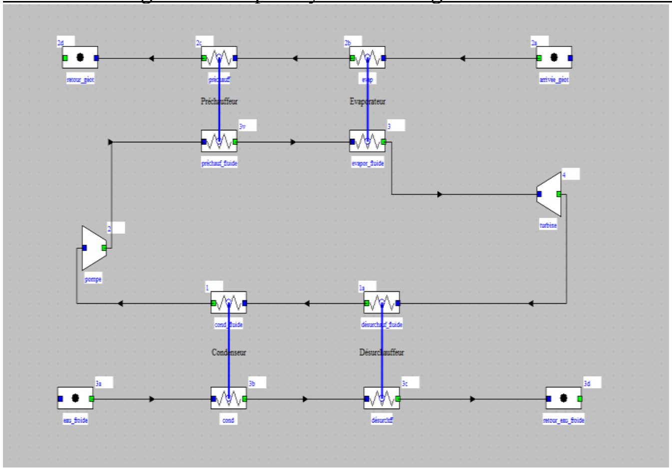


Fig.3: ORC Thermoptim

Thermoptim software gives study and design of favorite Organic Rankine Cycle power plant. To studying this installation shows in figure In the schematic editor on Thermoptim (figure3), are introduced cycle components with the selection of the working fluid and the names of exit points, and connected between the points of the cycle.

Table.2: geothermal plant parameters

		R245fa				R11				Butane			
T_{geot} °C		140	120	100	90	140	120	100	90	140	120	100	90
Turb	$\dot{W}_t = \dot{m}(h_4 - h_5)\eta_{m,t}$	50	41,40	32,01	26,2	39,70	33,17	25,56	20,52	97	84,44	86,14	51,03
Pum	$\dot{W}_p = (h_2 - h_1)\dot{m}$	1,31	1,19	0,95	0,83	0,72	0,66	0,53	3,47	6,64	4,45	2,7	1,4
Preh	$\dot{Q}_{pre} = (h_3 - h_2)\dot{m}$	110	99,77	84,13	76,15	81,15	79,12	70	61	184,16	176,42	161,51	140
Evap	$Qvap = (h_4 - h_3)\dot{m}$	150	141	130	119	100,01	92	88,41	83,21	296,94	275,5	232,71	202,06
yield	$\eta_{th} = \frac{\dot{W}_t - \dot{W}_p}{\dot{Q}_{pre} + \dot{Q}_{evap}}$	0,187	0,167	0,145	0,13	0,20	0,18	0,15	0,14	0,187	0,177	0,166	0,145
net	$\dot{W}_{net} = \dot{W}_t$	48,69	40,21	31,05	[illegible]	39	32,51	25,03	20,05	90,36	79,99	55,44	49,63
Mec	$\eta_{m,t} = 0,9$												

5. Results and discussions

Note on table (2), the temperature of geothermal water at the exit does not drop significantly in the case T_{geot}= 140°C (reinjection temperature =130°C) because too small working fluid flow relative to geothermal water flow (1Kg/s < 100 Kg/s).

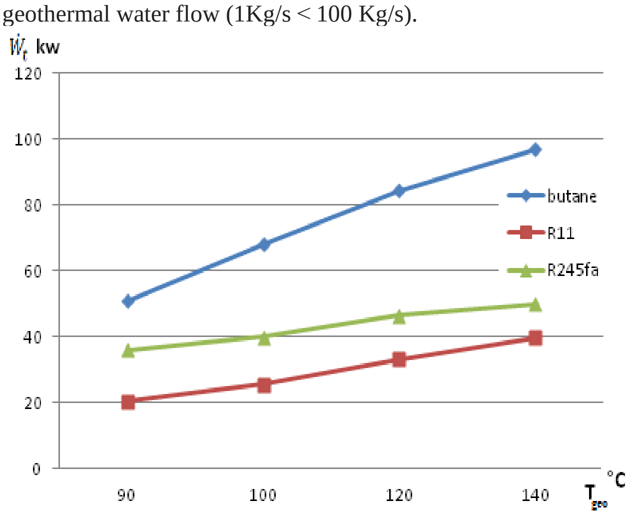


Fig.4. Turbine power for each fluid

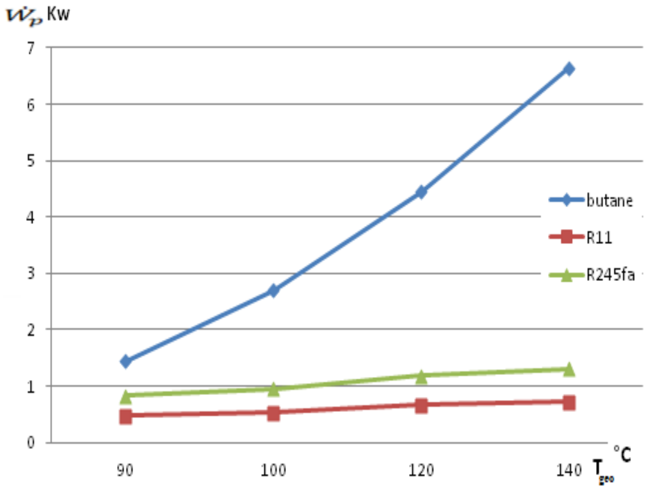


Fig.5: Pump power for each fluid

Figure 4 shows variation of turbine power as a function of geothermal temperature is noted that turbine power use butane as organic fluid is greater than R11 and R245fa.

This high power due to pressure difference HP-LP for butane which is greater than two other fluids (R11 and R245fa) and it's noted in TS diagrams for each fluid.

Figure 5 shows the variation of working pump depending on Tgeo is the same for the previous case we see that the (Wp) for butane is greater compared to that of the R11 and R245fa it known that each body fluid has its own thermodynamic properties, for example the butane that vaporizes at 130°C requires a pressure of 25 bar, by the R11 against to it just 18 bars.

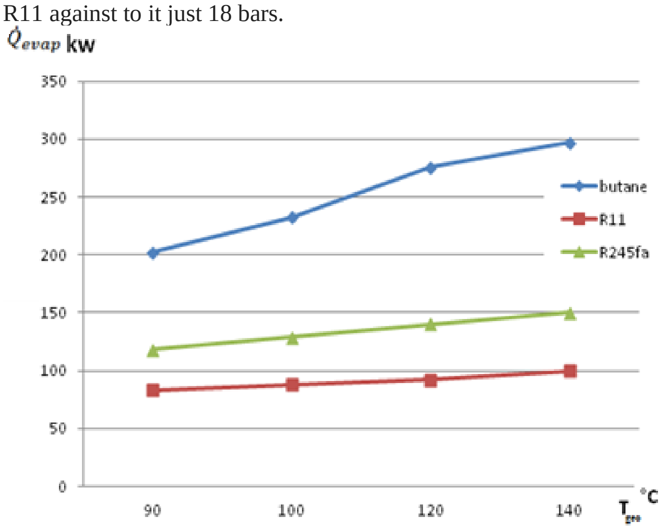


Fig.6: Heat vaporization for each fluid

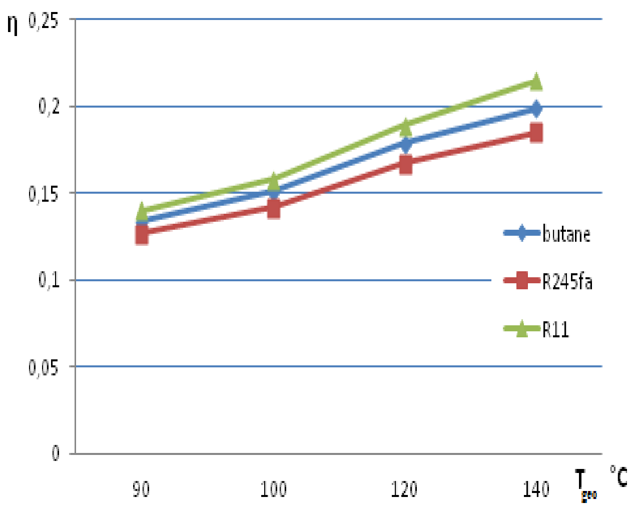
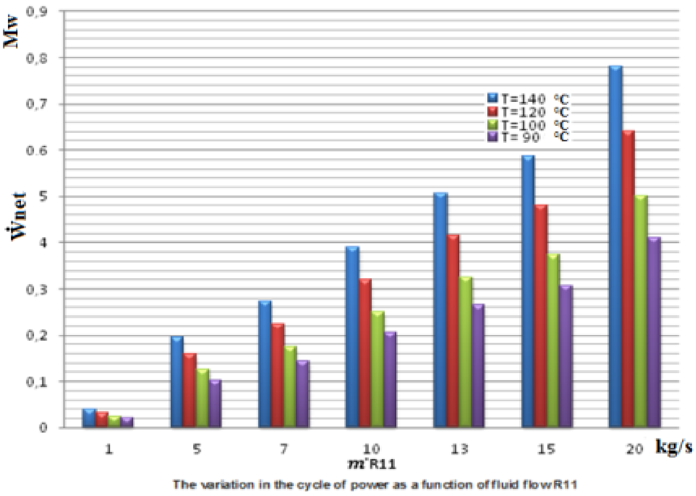


Fig.7: Cycle yield for each fluid

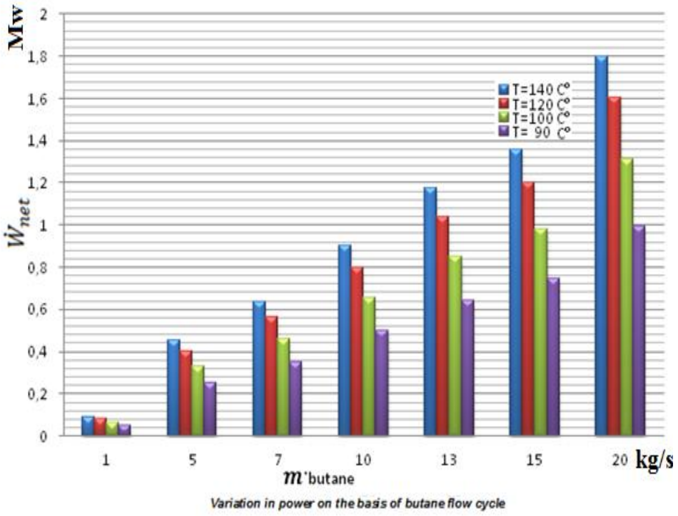
The evaporation temperature increases with the temperature of the geothermal water (figure 6), it is extreme using butane as the organic fluid, it is average using R245fa and minimum in the R11.

The cycle efficiency varies Labour fluid function (figure7), we see that the best performance is that of R11, by against his power is low compared to other fluids.

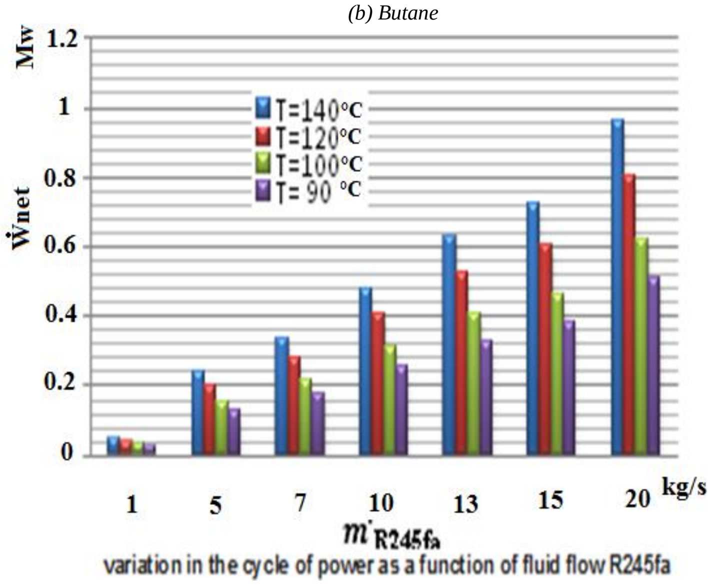
The performance of R11 is better than others because the work of the pump in the case of R11 is lower than the other two, we know that the energy consumed by the pump energy is a paid directly influences cycle's performance.



(a) R11



(b) Butane



(c)R245fa

Fig.8: Cycle power variation of each fluid flow

From figure 8 (a,b,c) we deduce that:

a) The power generated increases with the cycle speed except from a maximum value for each fluid, for example butane, flow cannot exceed 25 kg/s for T_{geot} = 140 °C because of 25Kg / if there is no sufficient exchange to vaporize organic fluid

b) whenever the T_{geot} increases cycle power also increases.

c) Even for a low temperature of geothermal source can have significant power eg butane T_{geot} the case = 90 °C power equal to 1 Mw.

6. Conclusion

From the results obtained we can conclude that: geothermal energy, power plants can produce significant power that can reach MW. Although the ORC cycle efficiency is low (0.10 to 0.23) the recovered power is always important.

The respect of fluid choice in features has direct impact on the power cycle. The cycle power for butane case is much better contribution than R11 and R245fa. Even for low temperature, geothermal water can produce high power.

In our work, we optimize the design of organic cycle Rankin power plants, it was noticed and proved that the yield depends on the organic fluid used, which we chose three, the most common and available on the software database used for simulation, named Thermoptim; are R11, R245fa, and Butane.

At the end of our study, we found that the best is good Butane. The power cycle is proportional to the temperature of the geothermal energy, and the flow rate of organic medium used.

Therefore, the results obtained, leading us to infer the optimal power for a maximum throughput of 20 kg / s, for Butane, and for each geothermal region in the following temperatures:

For tgeo zone of 90 °C, you cannot go more than 1 MW to 100°C, a power of 1.3MW; to 120 °C; is 1.6MW and 140 °C; is 1.8MW. This means that for th e Algerians websites

Meskhoutine in Guelma, you can install a 1.2MW plant, and that of Biskra, we can have a production of 1.7MW.

With these plants, we can supply 600 households in Guelma, and 850 households in Biskra, considering that each household consumes 2000kwh, knowing that the areas mentioned above have problems connecting to the national grid.

The economic and financial study has been initiated in this work, and it is considered perspective.

Regardless, we hope that this study will serve to think about integrating this energy source in the future production of electricity as compared to a central solar in concentration, it will be much less costly.

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