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# The Thermodynamic Analysis of New Combined Cycle Using Sabalan Geothermal Wells and Liquefied Natural Gas Cold Energy

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**ABSTRACT:** A new configuration base on the Sabalan geothermal wells is proposed to utilize two wells with different thermodynamic properties in Sabalan region in Iran and generate more power as well as supply of natural gas from liquefied natural gas. A Kalina cycle and Transcritical CO2 Rankine cycle are using Sabalan geothermal wells as a heat source and liquefied natural gas as a thermal heat sink. A comprehensive parametric study is investigated to understand the characteristics of the system. The results show that the thermal and exergy efficiencies can be increased by increasing separator 1&2 pressures. Also decreasing the higher pressure of the Kalina cycle and pinch point temperature of evaporators lead to increasing the net output power, thermal and exergy efficiencies. Additionally, exergy analysis results showed that the highest exergy destruction rate belongs to the heat exchanger 1&2. Optimization of the proposed cycle is performed by using genetic algorithm method, and it is observed in the optimal condition that the net output power, thermal efficiency, and exergy efficiency can be obtained as 30610 kW, 29.16%, and 56.92%, respectively. The results of this study indicate that the net output power and thermal efficiency is better performance compared to the previous studies.

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## 1. Introduction

The geothermal energies are stable, reliable, and unlimited sources that are used for power generation as an alternative scenario to fossil fuels in the world. In northwestern Iran and Sabalan Geothermal Power Plant (GPP), two wells with different mass flow rate and thermodynamic properties have been exploited [1,2]. Aali et al. [3, 4] studied the new configuration of integrated double flash/ORC with actual data for Sabalan GPP. The optimization results showed that the energy and exergy efficiencies calculated to be 20.57% and 63.72% with R141b, respectively. In Another work, they showed that for specific cost of output power is determined 4.766 $/GJ [5]. Abdolalipouradl et al. [6] studied a new integrated cycle (flash combined cycle with transcritical carbon dioxide and organic Rankine cycle) for power generation using real data of Sabalan GPP. The previous studies mostly have been conducted for power generation investigation of the Sabalan GPP however, in this work, a new configuration is proposed that can increase the net output power and use the waste heat to produce natural gas from Liquefied Natural Gas (LNG). Some main aims of the current study for the proposed system are as follows:

- Use of the waste heat of the transcritical CO2 and Kalina condensers for power and natural gas generation from LNG.
- A comprehensive parametric study.
- To carry out the optimization of the integrated cycle using a genetic algorithm.

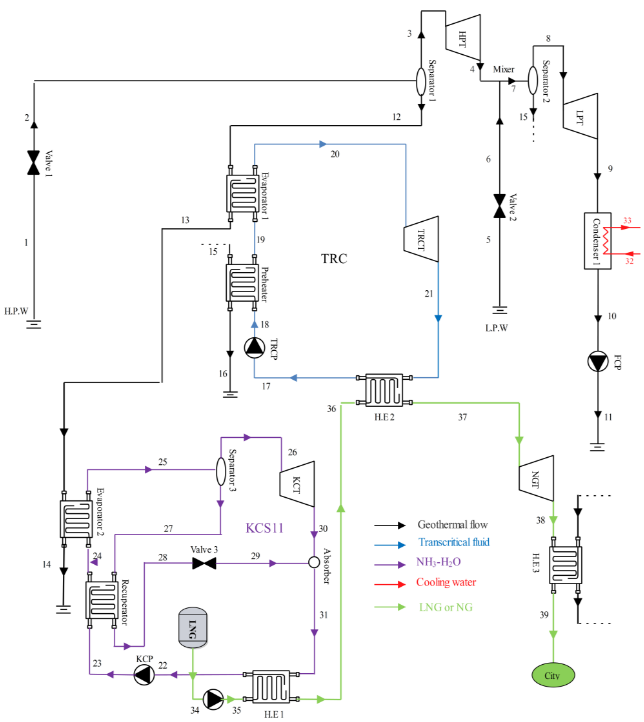


**Fig. 1. The new proposed cycle for the power and natural gas production**

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## 2. System Description

Schematics of the proposed cycles for power and natural gas generation from Sabalan GPP and LNG is shown in Fig. 1. The Kalina cycle and Transcritical CO2 Rankine Cycle (TRC) are using Sabalan geothermal wells as a heat source and LNG as a thermal heat sink. The simulation model is developed in Engineering Equation Solver (EES) software for the new configuration.

## 3. Results and Discussion

The influence of first and second separator pressures on the net output power, thermal and exergy efficiencies are demonstrated in Figs. 1 and 2, respectively. When and increase, the HPT and LPT power production increases as well, this trend leads to an increase in the net output power, thermal and exergy e efficiencies. By increasing the the high pressure of TRC rises. Thus, the power generation in the TRCT as well as the power consumption in the TRCP increase, and due to their opposing trend for the net power in TRC, the net output power, thermal and exergy efficiencies of combined cycle have optimum values as shown in Fig. 4. Fig. 5 shows the effects of the Kalian high pressure, on the net output power, thermal and exergy efficiencies of the combined cycle, the results showed that the net output power, thermal and exergy efficiencies decrease with increase.

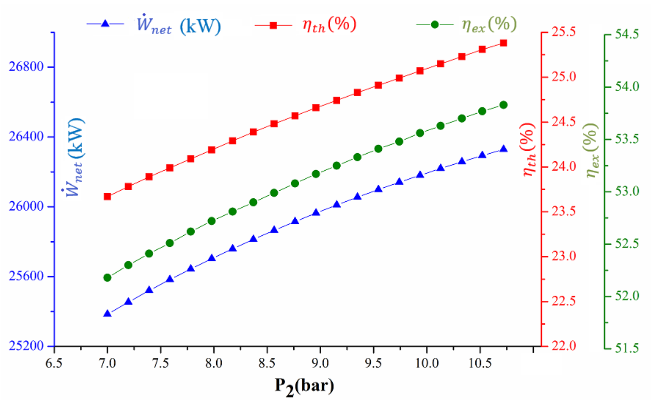


**Fig. 2. . Effects of the first separator pressure on the performance of proposed cycle.**

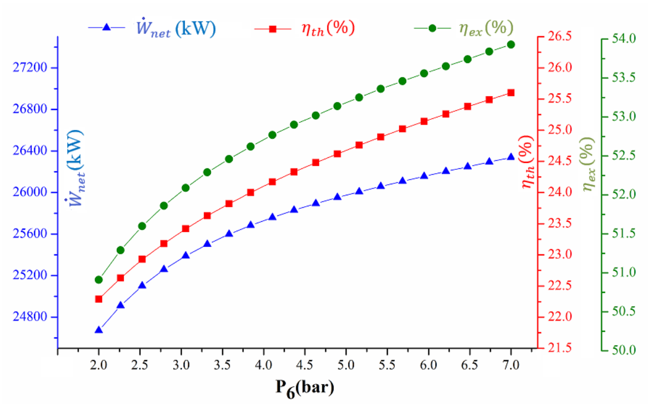


**Fig. 3. Effects of the second separator pressure on the performance of the proposed cycle**

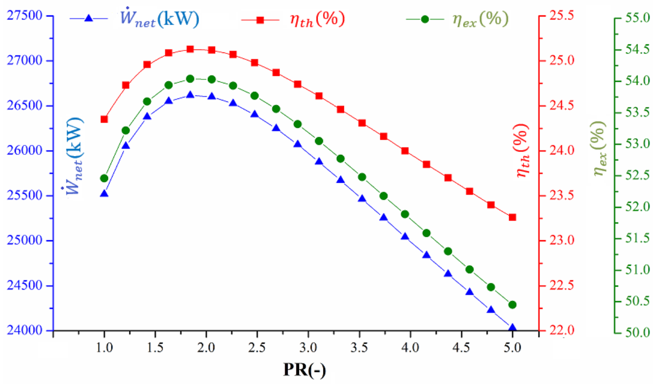


**Fig. 4. Effects of the CO2 cycle pressure ratio on the performance of the proposed cycle**

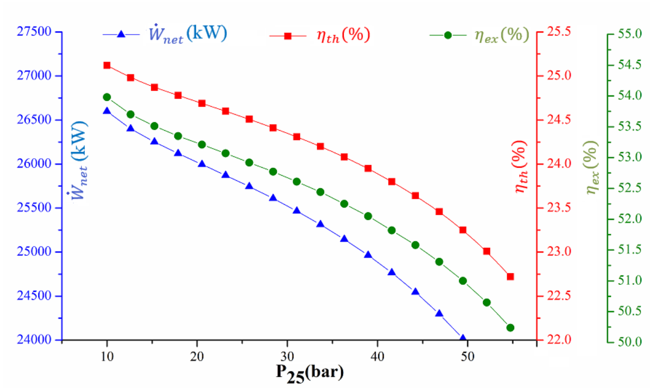


**Fig. 5. Effects of the kalian high pressure on the performance of the proposed cycle**

The results of optimization from the thermodynamic point of view (maximizing the net output power or thermal and exergy efficiencies) are outlined in Table 1. The optimization is performed for three different ammonia concentrations. According to the results of Table 1 for the highest amount of separator 1&2 pressures and LNG pump, ammonia concentration, the value of the net output power, thermal and exergy efficiencies of integrated system are obtained as 30610 kW, 29.16% and 56.92%, respectively. It can be seen from Table 2 that the maximum net output power and thermal efficiency are increased compared to the previous study [6].

**Table 1 The optimization results for the proposed cycle**

| | $x$=0.7 | $x$=0.8 | $x$=0.9 |
|---|---|---|---|
| $P_2$ (bar) | 10.72 | 10.72 | 10.72 |
| $P_6$ (bar) | 7 | 7 | 7 |
| $P_{25}$ (bar) | 10.4 | 10.05 | 10.1 |
| $PR$ (-) | 2.16 | 2.75 | 1.853 |
| $P_{2M}$ (bar) | 30 | 30 | 30 |
| $\dot{W}_{net}$ (kW) | 29668 | 30338 | 30610 |
| $\eta_{th}$ (%) | 28.43 | 28.89 | 29.16 |
| $\eta_{ex}$ (%) | 55.54 | 56.48 | 56.92 |
| $\dot{E}x_{D,tot}$ (kW) | 29236 | 28839 | 28631 |

**Table 2 Performance comparison of the proposed combined cycle in this work with [4]**

| | $\dot{W}_{net}$ ( kW) | $\eta_{th}$ (%) | $\eta_{ex}$ (%) |
|---|---|---|---|
| [4] | 20046 | 17.15 | 65.74 |
| This work | 30610 | 29.16 | 56.92 |

## 4. Conclusions

The main achieved results are as follows:

• Adding the LNG, in addition to increasing the net output power of the cycle, provides natural gas around the power plant.

• By increasing the separator 1&2 and LNG pump pressures, the values of the net output power, thermal and exergy efficiencies increase.

• For the optimum case, the net power of 30610 kW, the thermal efficiency of 29.16%, the exergy efficiency of 56.92% and exergy destruction rate of 28631 kW % are obtained

• The results of thermal efficiency are improved compared to the previous study with using LNG in the combined cycle.

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