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Poly-generation energy system driven by associated geothermal water for oilfield in high water cut stage: A theoretical study

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ABSTRACT

Onshore oilfields are also geothermal fields. In order to reduce cost of geothermal wells and simultaneously improve the energy efficiency of geo-plants, a poly-generation energy system driven by associated geothermal water was established for oilfield in high water cut stage. The system consists of four parts: the power generation subsystem, the absorption chiller subsystem, the oil gathering and transportation heat tracing (OGTHT) subsystem and the radiant heating subsystem, and it realizes the combined cooling, heat, power generation, and oil recovery (CCHPOR), with the associated geothermal water ranging from 373.15 K to 423.15 K. The impact of the heat source temperature and the evaporation temperature on system performance was analyzed. The results show that the performances including net power output, thermal efficiency, exergy efficiency, of the TSORC (two-stage series organic Rankine cycle) are better than those of the ORC, and the total energy efficiency of the CCHPOR reaches 75%. Moreover, the CCHPOR system can prolong the effective life of oil wells, especially for those in high water cut stage, which can be adopted in engineering applications.

1. Introduction

China's energy demand is growing with the continuous economic development from 3.6 billion tons of standard coal in 2011 to 4.36 billion tons of standard coal in 2016 (National Bureau of Statistics of People's Republic of China, 2017). From the viewpoint of energy production, the energy structure of China still depends on coal. Although the production of renewable energy continues to increase, it accounts for a small proportion.

There has been a strong market demand for energy due to the rapid economic growth (Liu and Falcone, 2018). Renewable energy has become the focus of research due to the shortage of traditional fossil fuels and environmental issue. Geothermal energy, as huge reserves, no CO_2 emission, continuity and stability natural resource, has attracted more attention (Bahadori et al., 2013; Li, 2013). The high-temperature geothermal resources are the most suitable for commercial production of electricity (Barbier, 2002). However, China is deficient in geothermal resources of high-temperature, while medium-low temperature geothermal resources are abundant. Therefore, it is essential for China to develop medium-low geothermal power generation with a low cost and large scale (Zhu and Hu, 2015).

The associated fluid temperature from oil wells in high water cut stage is often between 65°Cand 150°C, the temperature level is very suitable for binary cycle power generation technology (Liu and Falcone, 2018). Moreover, the corresponding infrastructures already exist in oilfields, such as the drilling and fluid collection systems, therefore reducing the cost of investment. In addition, the geological data is very detailed to cut down the cost of exploration and appraisal.

Currently, many researchers have been focused on the power generation driven by geothermal energy. Kujawa et al. (2006) estimated the availability and usefulness of geothermal energy obtained from existing production wells Jachowka K-2, and they pointed out that the flow rates and insulation of existing well had important effects on the heat transfer process. Bu et al. (2012) proved the possibility of obtaining geothermal energy from the existing abandoned oil and gas wells. Guo et al. (2011) set up a novel type of cogeneration system driven by low-temperature geothermal sources. This system includes a low-temperature organic Rankine cycle (ORC) subsystem, an intermediate heat exchanger and a commercial R134a-based heat pump subsystem. Caulk and Tomac (2017) built an enhanced geothermal system (EGS) on abandoned wells in California. Moreover, the low temperature deep borehole heat exchanger (BHE) was applied to the

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Nomenclature

A	area (m^2)
c	specific heat (kJ/kg)
Ex	Exergy (kW)
h	specific enthalpy (kJ/kg)
I	irreversibility rate (kW)
K	heat transfer coefficient (W/(m2·°C))
M	molar mass (kg/kmol)
m	mass flow rate (kg/s)
P	pressure (MPa)
Q	heat transfer rate (kW)
r	latent heat of vaporization (kJ/kg)
s	specific entropy (kJ/(kg·°C))
T	temperature (K)
t	temperature (°C)
U	intrinsic energy (kJ)
W	power (kW)
ΔP	pressure difference (Pa)

Greek symbols

η	efficiency (%)
ρ	density (kg/m^3)

Subscripts

c	condenser
cri	critical
cw	cooling water
e	evaporator
ex	exergetic
g	generator
gw	geothermal water
m	mechanical
opt	optimal
p	pump
pp	pinch point
s	isentropic
t	turbine
th	thermal
wf	working fluid
0	environment
1 2, 3, 4	state points

Acronyms

ALT	atmosphere life time (yr)
GWP	global warming potential
ODP	ozone deletion potential
ORC	organic Rankine cycle
VFR	volumetric flow ratio

system. Cheng et al. (2016) used abandoned oil wells to generate electricity, and proposed a novel method of developing thermal reservoirs to improve efficiency, and they found that geothermal energy production increased about 4 times with thermal reservoirs. Cheng et al. (2014) used different working fluids (R134a, R245fa, R600a, R600) to study abandoned wells with different kinds of well depths and geothermal gradients. The suitable conditions of direct power generation system (DPGS) and flashing power generation system (FPGS) were also studied.

On the other hand, Noorollahi et al. (2017) simulated the multi-effect seawater desalination process in the Southern part of Iran, in “Ahwaz oil field”. The results showed the system can approximately produce 565 m^3/day of fresh water. Kiaghadi et al. (2017) uses geothermal resources from abandoned oil and gas wells to desalinate produced water, saving the use of traditional energy sources. So far, the lowest temperature of geothermal resources exploited for commercial power generation worldwide is only 57°C in Chena Hot Springs, U.S. (Erkan et al., 2008).

At present, the utilization of associated geothermal energy for oilfield in high water cut stage is mostly concentrated in power generation

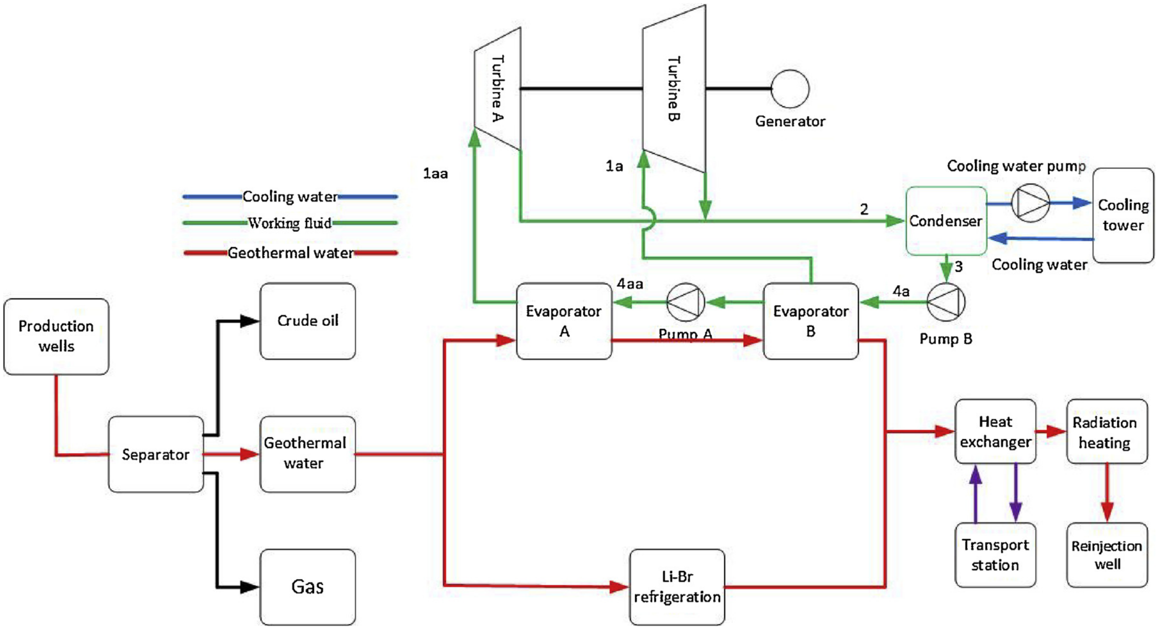

Fig. 1. Schematic diagram of the cascade utilization system.