Enhancing Energy Recovery From Abandoned Oil Wells Through Geothermal Technology

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ABSTRACT

Finding alternative means of energy generation other than the use of fossil fuel-derived energy is imperative and requiring urgency, if we are to avoid doomsday predictions by climate change analysts. The objective is to identify the potential of utilizing abandoned oil wells through geothermal technology to generate electricity.

Current practices include the manipulation of non-traditional geothermal resources by enhancing the system. This involves the introduction of secondary fluids through an injection well into deep hot dry rock formations to extract its heat before being pumped out through a production well. Binary systems are suitable for use in such systems where temperatures are usually of low quality and fluids with low boiling points can easily vaporize in a heat exchanger, with the vaporized gas used to drive a turbine.

This article proposes an integration of Enhanced oil recovery and Enhanced geothermal systems principles to improve efficiency of energy output from abandoned oil wells. A new system was designed, the schematic illustrating the flow and interaction of geothermal fluids within the system units where heat is recovered from the reservoir to generate electricity.

Introduction

After an initial discovery of oil a new oil field is appraised to check if it meets the volume and production rate required for commercial viability. If it does, the oil field is then sanctioned for development, and this will take years. The first real celebration is the first drop of oil from the new facility. Gradually production is built up to a plateau rate as shown in the figure 1 below. With time the subsurface conditions will no longer be able to support the plateau rate of extraction, even with technological assistance, and then the "production decline phase" sets in. In many cases this decline is managed carefully to extract every last drop of oil possible, yet at a point, in every field, the economic limit will be reached thus ending the production process of the oilfield (ODR, 2014).

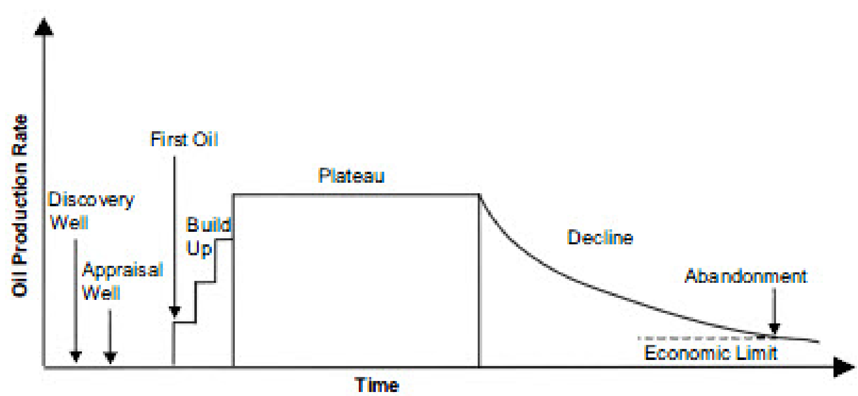

Figure 1. Typical oilfield production profile (Source: ODR, 2014).

When hydrocarbon reservoirs are depleted beyond their economic feasibility point, the wells are abandoned, decommissioned and then reclaimed. According to Kotler, about 20 to 30 million of such wells have been abandoned worldwide (Kotler, 2011).

These abandoned oil wells can be an enduring liability to communities where they are located and companies that own them as such companies will be responsible for any possible environmental contamination and any associating litigations that may follow especially in cases of a failed decommissioning of the well (Templeton et al., 2014).

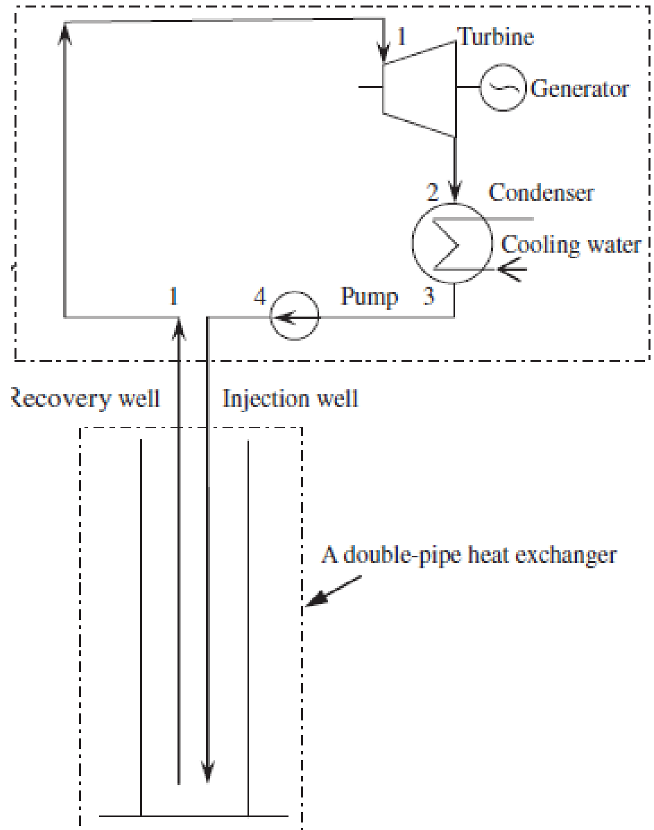

Figure 2. structure diagram of energy recovery from wells (source: Wen-Lon et al., 2013).

Current Technology

However, current technologies such as Enhanced Geothermal Systems (EGS) can be used to recover heat from abandoned oil wells. This involves passing a fluid (refrigerant) through a double-pipe heat exchanger (laid within the oil well) where it reaches supercritical state upon absorption of heat as it moves down the pipe. The supercritical refrigerant now flows upwards through the inner pipe and is then used to drive a turbine as shown in figure 2 (Wen-Lon et al., 2014).

This technology utilizes the principles of a binary cycle system and the fact that at oil reservoir depths from 3km and above, temperatures can reach as high as 100°C and increase higher within deeper wells (based on the Earth's subsurface average temperature gradient of 30°C/km) (Boyle, 2012).

An extensive review of existing technologies (in heat recovery from oil wells) which was considered as closed loop systems by nature especially where the double-pipe heat exchanger is used was made. Observations were that they are low in energy efficiency and it is not easy to commercialise beyond the experimentation or demonstration stages, therefore making it difficult to attract prospective investors. This to my view can be attributed to lower enthalpy status of oil reservoirs when compared to traditional geothermal reservoirs and also, the contact ratio between heat exchange medium and heat from the oil reservoir is limited which reduces the effectiveness of the system.

Proposed Technology

After primary extraction of oil from an oil reservoir, Enhanced Oil Recovery (EOR) is used to recover as much oil as economically possible from the reservoir. EOR as a process requires the drilling of another well called the injection well where a secondary fluid is pumped (forced) into the reservoir to dislodge and drive out crude oil towards the production well were the crude oil is then pumped out.

However, the percentage or recovery rate of oil will continue to drop until it is no longer economically viable as more of the injected secondary fluids (such as steam or light hydrocarbon gas) now form a greater quantity of fluid coming out from the production well (Schlumberger, 2014).

This process of oil recovery is similar to that of the Enhanced Geothermal Systems (EGS). Where fluid is pumped through an injection well into hot dry rock formations and retrieved through the production well after absorbing its heat. While both resources can be similar in the sense that they have features such as an overlying layer of impervious rock (cap rock) that traps fluids from escaping, permeable reservoir which aids the flow of fluids, presence of heat due to depth and both systems includes a production and injection wells. The difference however, is that while EGS is used to recover heat in a geothermal resource the EOR is used to recover oil in an oil reservoir.

The idea then is to identify a secondary fluid (like in the EGS system) based on its thermodynamic properties at liquid state with a boiling point temperature reasonably lower than what is obtainable within the identified oil reservoir as the geothermal working fluid. The fluid at liquid state is pumped into the oil reservoir through the injection well (now retrofitted with a geothermal system). A fluid with high thermal conductivity is ideal so as to absorb heat from the reservoir quickly as it moves towards the production well and raise its temperature above its boiling point.

Miscible gas flooding which is a method of EOR process has shown that lighter hydrocarbon gas can be used effectively to recover oil (Barrufet, 2001). It is therefore possible that after most of the oil has been recovered and well abandoned, that light hydrocarbons can continually be pumped into the abandoned reservoir to absorb heat within the rock formations. This heat can be utilized to drive a turbine by combining current principles of flash-cycle and binary cycle systems. More so the use of a light hydrocarbon as a working fluid will most likely eliminate the possibility of any chemical reaction within the reservoir which may lead to complications and loss of the refrigerant.

It will also be ideal to identify a suitable refrigerant which can adhere to the principles of green chemistry while effectively doing the work. This is necessary as to improve the environmental outlook of the system. Use of lighter hydrocarbon due to their lower density than the reservoir fluid (mainly oil and water) helps improve the vertical movement of the fluid as it absorbs heat (Mavor, 2014).

Considering the rock formations at such depths, any identified secondary fluid pumped into the reservoir should remain at liquid state due to pressure no matter the amount of heat applied as long as it does not attain its critical temperature and pressure. This is because pressure at oil reservoir depths is so high that despite the fluid reaching its boiling point it will still not vaporize.

More so, the secondary fluid at supercritical state is most likely to dislodge remnants of crude oil as they move through the reservoir formations. If so, can lead to a mixture of both reservoir fluid and the secondary fluid which is then pumped out the production well.

The Kalina cycle principles and fractional distillation of mixtures have shown that mixtures of different fluids can be separated due to their different boiling points. Applying this principle and that of single flash cycle, the fluid mixture under pressure on reaching the surface can be separated using a flash system (separator) allowing the secondary working fluid to vaporize. The vaporized fluid in gaseous state is then sent to a turbine to generate electricity.

The remaining fluid can still be sent to a heat exchanger where heat though of lesser quality can be extracted to drive a second turbine. Solar resource can be used to compliment energy supply especially during the day when demand is higher, as the energy can be used to power pumping and cooling equipment which can lead to 30% increase in efficiency (Boyle, 2012).

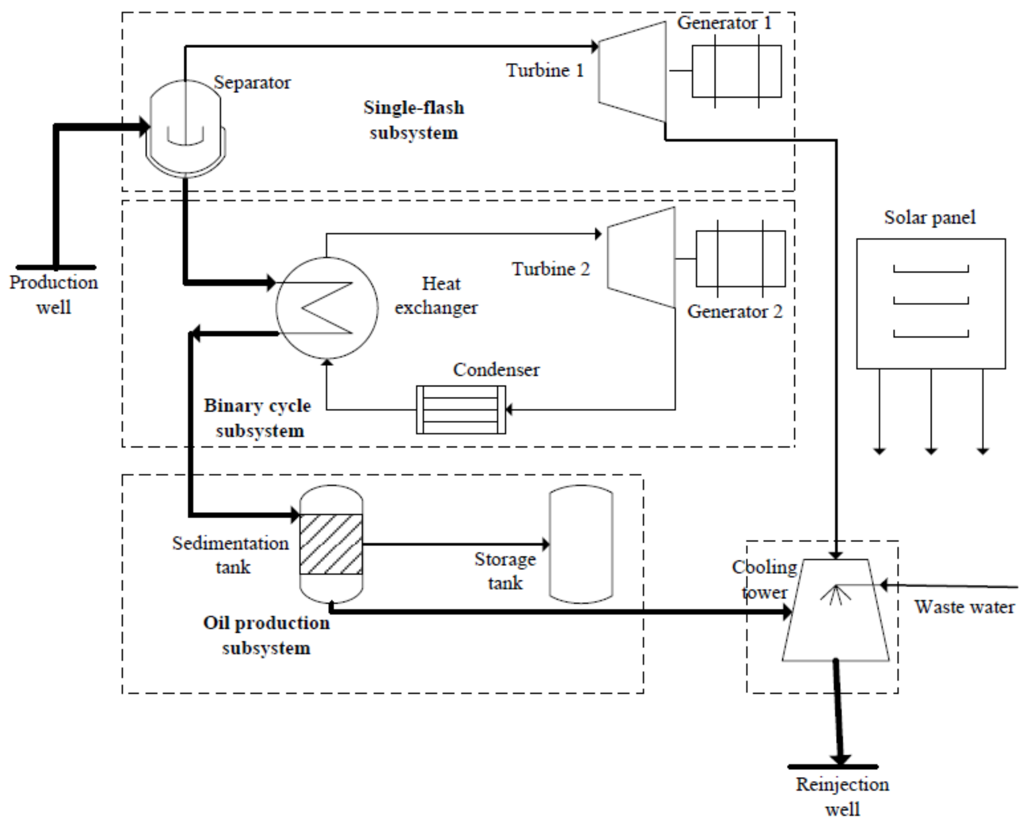

Figure 3. Proposed schematic diagram of heat and oil recovery system.

The diagram clearly shows the direction flow of the fluid mixture after they have been pumped to the surface and the various stages they undergo before heat and crude oil are extracted from them. The proposed design when retrofitted on an oil well incorporates the combination of a flash cycle and a binary cycle design to generate electricity before the remaining fluid is sent to an oil processing area to recover crude oil.

Conclusion

Exploitation of geothermal resources has been ongoing with technology advancements such as use of enhanced geothermal systems. Reservoirs that are not traditionally geothermal sources are now being exploited by ways of modification where in some instances fracturing of the reservoir pores and introduction of fluids are used to extract the heat locked within. An aspect that should be considered is how to retrofit the over 20 million abandoned oil wells worldwide for clean electricity generation. EGS have shown that secondary fluids can be used to extract heat from deep reservoirs.

EOR further supports this principle where practices such as injection of miscible gas flooding are used to retrieve petroleum product from oil reservoirs. Use of lighter hydrocarbons to retrieve oil in the EOR has shown that ordinarily a secondary fluid can be introduced safely without chemical reactions into the reservoirs. Use of ethanol as a refrigerant can retrieve both crude oil and heat from the oil reservoir, due to its low boiling point. Binary cycle systems use in EGS further confirms the use of such fluids due to their lower boiling point.

Recommendation is however made for further research and in-depth analysis of the thermodynamic interactions of identified working fluids at both the surface and subsurface levels. Also the suitability of an adopted system design is necessary as every reservoir has its distinct feature. Further research is required to identify how best to maximize efficiency of the adopted system and how to integrate a hybridized system to aid oil recovery.

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