Refitting oil wells for geothermal uses

Alimonti Claudio, Gnoni Angela

Sapienza University of Rome, DICMA - Via Eudossiana, 18 – 00184 Roma (Italy), Tel. +39 44585.628

claudio.alimonti@uniroma1.it

Keywords: waste heat; co-produced water; mature hydrocarbon fields.

ABSTRACT

In current energy outlook and oil price trends any operation in extending the life of oil&gas fields is welcome. Mature oil fields are characterised by a large amount of co-produced water. Oil dewatering and water injection operations tend to increase operational expenditure (OPEX).

Often, produced fluids have a high temperature and cooling is adopted. The waste heat recovery from the produced stream could be a quite interesting option. Increase in profitability of small oil and gas producers as well as possible reuse of an oil filed as a geothermal field are possible goal. Considering the large number of oil wells that are abandoned every year around the world that could be potentially exploited to produce energy again, reuse becomes a need.

The present study analyses different implementation scenarios of geothermal uses of oil wells in a depleting field. Scenarios assume to implement possible solutions during the oil production field life up to its complete conversion to a fully geothermal field.

Three different scenarios considering the possible use of hot stream from the wells have been studied. A first scenario concern the direct use in district heating; a second option of exploitation is in electric power generation through an Organic Rankine Cycle (ORC) plant; finally, a possible cogeneration scheme of electric power and heat have been assumed.

The comparison of the different scenarios highlight an optimal configuration of the exploitation of the field, a combination of electrical generation and district heating. The choice to operate in cogeneration, in fact, allows to maximize overall system efficiency, reducing heat loss. The produced heat and electricity will be supplied to the nearby community, through a district heating network, extending the service to a large number of buildings.

1. INTRODUCTION

An oil reservoir is assumed to be economically depleted when the sale of its products is less than production costs. This condition arise when hydrocarbons are present in the reservoir rock yet. The residual saturation in hydrocarbons could be high and the recovery factor is often less than 50%. Several oil reserves are abandoned having raised their economical limits in coincidence of a very high production of water (90-95% in water). The produced water must be treated and could not be delivered to the environment. Frequently the production water is re-injected into the reservoir. The produced fluids have a temperature higher than the ambient one.

Several studies on waste heat recovery in oil field application have been conducted (Zhang 2008, Davis, 2009, Bu 2012, Barbacki 2000. Limpasurat et al. 2010, Sanyal et al. 2010, Xin et al. 2012). Recently a demonstration project has been conducted to prove the feasibility to interface an ORC machine with a producing oil or gas well (Dalheim and Pike, 2012).

The main advantages are: the improvement of the entire economic cycle of oil production processes; reduction of the reservoir abandonment costs; increase of the life time and the recovery factor of the reservoir; improvement of the economic feasibility of the geothermal plant having avoided drilling costs (generally corresponding to the 50% of total costs of the project).

The present study is based on a real field case. Has been assumed a single well producing oil and gas with an increasing water cut (fraction of water). Thus, a reduction of the production capacity in hydrocarbons and an increase in production costs.

Different scenarios of use of the well have been analysed in order to produce thermal and electrical energy. The different models of well use are based on the direct use of the produced fluids: first scenario is only thermal use in a district heating scheme; a second scenario is the production of primary energy using an ORC binary cycle plant; third scenario is concerned by cogeneration of thermal and electrical energy.

The main critical issues in this kind of projects are the well integrity of existing wells, the appropriate condition for water injection and the proximity of final users.

2. CASE STUDY

The Villafortuna-Trecate oil field is located in the North Italy, in the Padana district. The reservoir has been discovered in the eighties and the site is

characterised by a normal geothermal gradient (2,8°C each 100 m depth).

The Villafortuna-Trecate field consists of an alpine compressional structure involving a pre-existing Mesozoic extensional relief. The petroleum system is wholly developed inside a Triassic depositional sequence: two reservoirs, made of dolomitized carbonate platforms rocks (Monte San Giorgio Dolomite, Anisian; Dolomia Principale, Campo dei Fiori Dolomite and Conchodon Dolomite, Norian-Rhaetian) and the source rock deposited in an anoxic intra-platform basins. The hydrocarbons were produced from Middle Triassic source rock formations (Besano Shales and Meride Limestone) which lie inside the Villafortuna-Trecate structure.

The field is already producing but at end of its life. Several wells are always open and only few are producing. From its current status arise the idea to provide a refitting well systems in order to extent well life.

The reservoir is characterized by the main parameters reported in table 1.

Table 1: Reservoir main parameters

reservoir depth: 5700-6100 m
reservoir temperature: 166 °C
average reservoir pressure: 850 bar

A study of well performance has been conducted using Prosper software. The well completion design has been assumed as described in Botto and De Ghetto (1994).

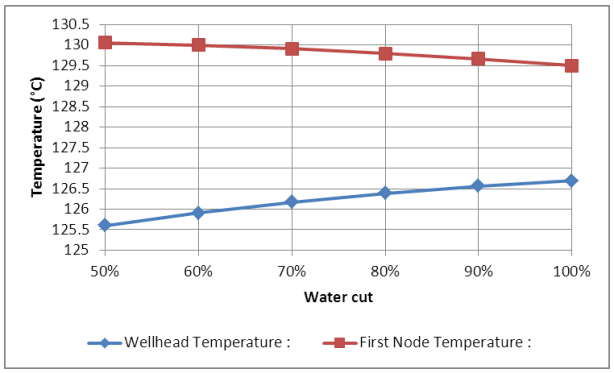

Figure 1: wellhead and downstream choke temperatures vs. water cut

The main results of the study show that is possible to have a fluid production of 850 m^3/d with wellhead pressure and temperature respectively 250 bar and 125 °C. Downstream the choke the fluid temperature assume a quasi-steady value of 130 °C, independent from water cut (Fig. 1).

Throughout the production life of the reservoir, main parameters have been assumed to be steady. Only water cut is increasing.

The field has eight active production well. More wells have been drilled and are available for production. Injection wells are also available.

In order to have a field evaluation the results from the well sample have been extended to eight wells at least.

To evaluate the closeness of possible final users the surrounding region has been analysed. Two municipalities have been considered. The municipality A is 1 km far from the field and has 5400 people. Meanwhile, the municipality B with 15500 people is located 3 km far from the field.

2.1 Thermal energy production option

The possibility to use hot fluid produced from the reservoir in an heating district plant for neighbouring municipalities has been evaluated. (Fig. 2)

The following main hypothesis have been assumed: maximum efficiency of the heat exchanger between geothermal fluid and heating district fluid, the single well production flow rate is 9,8 l/s (850 m^3/d), the heat exchanger inlet temperature is 130 °C. Decreasing the reinjection temperature, thermal power increases. A maximum temperature difference of 60°C has been fixed corresponding to a 70 °C injection fluid temperature. The corresponding maximum thermal power is 2,5 MW (Fig. 2).

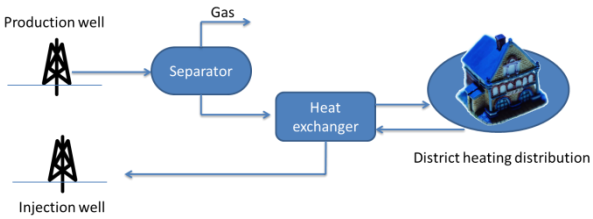

Figure 2: Scheme of thermal energy production plant

The supply temperature of heating district plant is 90 °C and the return temperature 60 °C. The flow rate in the heating district plant has been evaluated in 19,7 l/s flowing in a main pipe of DN 150 mm diameter with an insulation coating of 39 mm thickness. The power of circulation pump based only on the main distribution pipes is 15,5 kW with a pressure difference of about 5 bar. Pressure drops in the network have been calculated as concentrated as well as distributed. The total length of the main piping has been assumed to be 3 km. In mean time, to allow underground fluid reinjection the pump will require about 80 kW.

Estimating the possible user coverage, a medium insulation factor of 48 W/m^3 for houses has been assumed. More than 51.000 m^3 could be served by district housing plant per well. Fixing the reference volume of an housing at 300 m^3 and the number of

habitant per house at 2,5, about 233 housing could be fed per well corresponding to 583 people.

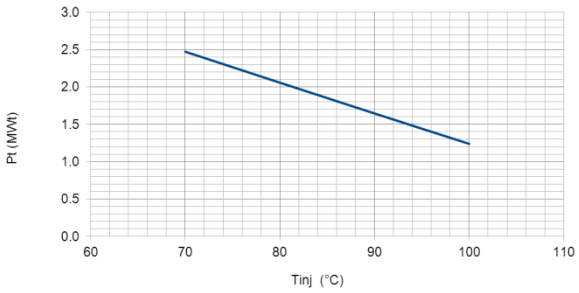

Figure 3 – Thermal power installed vs. injection temperature

2.2 Electrical energy production option

In order to evaluate the possible production of electrical energy from the produced fluids has been chosen to use a binary cycle plant based on an Organic Ranking Cycle (ORC). This plant allows to use thermal sources with medium temperature, often less than 150 °C. Plants are often designed on the plant size and requirement. Some interesting plants are those produced by Pratt&Whitney, each unit could generate 280 kW gross electrical power (265 kW net). More units could be used in parallel in order to produce the requested power. The major weakness of an ORC plant is thermal efficiency. This is quite low, in average 10% has presented in the MIT report (2006).

The electrical energy production is based on the scheme reported in Fig.4

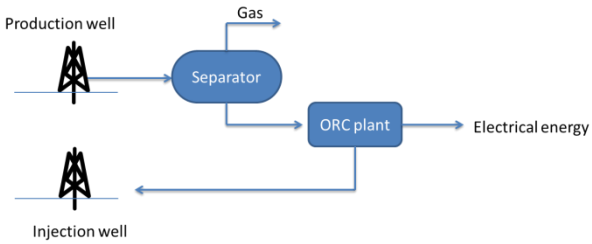

Figure 4: Scheme of electrical energy production plant

The produced stream need a separation stage in order to remove gas phase. The liquid stream then flows through the ORC plant. The inlet temperature is 130 °C and the flow rate will be 9,8 l/s. The exit temperature from ORC plant has been evaluated based on PureCycle unit data with the following relationship:

$$T_{ex} = T_{in} - 427.7q^{-0.8} \qquad [1]$$

where Tin (°C) is the inlet temperature and q is the flow rate (l/s).

Thus, the exit temperature from the ORC will be equal to 61,8°C. The thermal efficiency has been set to 9,2% based on the following MIT relationship:

$$\eta = 0.0935T_{in} - 2.3266 \qquad [2]$$

The electrical power output of the ORC plant is 260 kW. One ORC plant unit per well is required. The needed power supply for water re-injection (80 kW) must be fed by ORC plant. Thus, the net electrical power will be 180 kW per well.

Using an ORC plant unit with lower exit temperature electrical power increases up to 430 kW (20 °C).

2.3 Cogeneration of thermal and electrical energy option

A most interesting application concerns the cogeneration of heat and electricity. The production unit will supply the heating district network as well as the ORC binary cycle plant.

The geothermal fluid, coming out from the well, will enter the binary cycle plant. After this first heat exchange, the fluid will flow through its valorisation path entering a second heat exchanger to transfer the residual thermal power to the heating district plant. The fluid exit temperature has been fixed at 60°C. Thus, it will be re-injected underground.

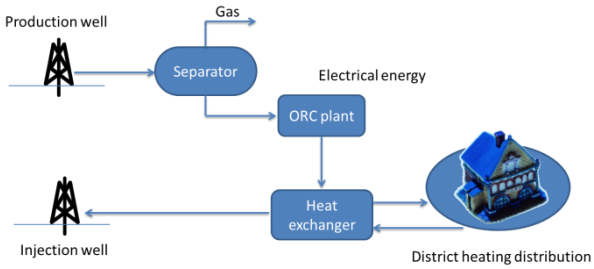

Figure 5: Scheme of cogeneration energy production plant

The optimal condition to exploit the geothermal resource has been determined finding the same number of utilities served with district heating service as well as electrical energy supply.

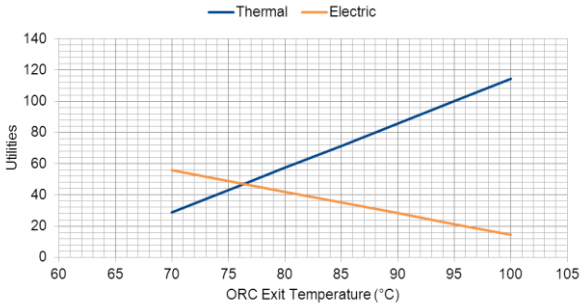

Figure 6: Electrical and thermal utilities vs. ORC exit temperature

The electrical energy production could be obtained with the same unit as in previous scenario but with a

less net power, about 143 kW per well. The district heating plant will have installed about 660 kW per well. This choice allows to obtain the same number of housing and give a coverage of about 46 utilities per well (Fig. 6).

3. DISCUSSION

The evaluation of the different scenarios must be extended to the available wells and to the utilisation scenario over the entire year.

On the field have been drilled about 50 wells. Only 8 are in production. Therefore, in the following analysis have been decided to assume 8 wells available as worst case and 40 well as best one.

District heating application are effective for six months. The rest of the year is not needed. Instead, air cooling systems are needed during the summer season. Therefore, the heating/cooling plant is the most interesting for municipalities and thus for public acceptance. During the winter season the operative scenario is the first one and in the summer is the second. Heating is ensured by district heating plant and cooling by conventional air conditioning systems using the produced electrical energy.

The cogeneration option is not interesting and promising. Therefore the alternative scenario is electric power generation.

In table 2 are summarised the main data with worst and best case.

Table 2 – Results summary

	Worst case	Best case
Electrical power generation	1,9 MW	7,5 MW
Heating/cooling	515.000 m3	2.000.000 m3

4. CONCLUSIONS

The waste heat technology applied to the oil&gas reservoirs becomes an interesting strategy to implement clean energy production techniques as well as extent the life of a depleted reservoir.

The paper presents a particularly interesting scenario concerning the extension of the life of an oil field in the northern Italy via a refitting of the plant in a geothermal energy plant. This is quite interesting considering the number of oil wells that are present and are abandoned in all the world. A lot of them could be used to produce again energy but in a cleaner way.

Obviously it is necessary to analyse a lot of factors that influence the feasibility. Geology, physic-chemical properties of the fluid, municipalities in the neighbours.

In the present case study have been considered different scenarios in order to find the most promising for the municipalities. A more deep analysis in terms of more defined heating district network, types of cogeneration unit could give a more improved project.

From an economic point of view the start-up of the refit project during the active life of the field could ensure in a very short time the investments cost recovery.

REFERENCES

Barbacki A.P. The use of abandoned oil and gas wells in Poland for recovering geothermal heat. *Proceedings World Geothermal Congress 2000*, Kyushu - Tohoku, Japan, (2000).

Bu X.B., Ma W, Li H. Geothermal Energy production utilizing abandoned oil and gas wells. *Renewable energy*, **41,** (2012), 80 – 85

Davis A.P., Michaelides E.E. Geothermal power production from abandoned oil wells, *Energy*, **34** (2009), 866–872

Zhang L, Yuan J, Liang H, Li K. Energy from Abandoned Oil and Gas Reservoirs, *Asia Pacific Oil and Gas Conference and Exhibition*, Perth, Australia, (2008)

An assessment by an MIT-led interdisciplinary panel, The Furture of Geothermal Energy – Impact of Enhanced Geothermal System (EGS) on the United States in the 21th Century, *MIT-Massachusetts Institute of Technology*, (2006).

Bello, M., and Fantoni, R.: Deep oil plays in Po Valley: Deformation and hydrocarbon generation in a deformed foreland, *AAPG Hedberg Conference*, Milano, Italy, (2002).

Botto, G., and Ghetto, G., Using Downhole Pressure Gauges in Hostile Deep Wells, Villafortuna-Trecate Field, *Journal of Petroleum Technology*, (1994), 594-598.

Sanyal, S., and Bulter, S., Geothermal Power Capacity for Petroleum Wells-Some Case Histories of Assessment, *Proceedings World Geothermal Congress 2010*, Bali, Indonesia, (2010).

Limpasurat, A., Falcone, G., Teodoriu, C., and Barrufet, A.: Unconventional Heavy Oil Exploitation for Waste Energy Recovery, *The SPE Latin American and Caribbean Petroleum Engineer Conference*, Lima, Peru, (2010).

Xin, S., Liang, H., Hu, B., and Li, K.: Electrical power generation from low temperature co-produced geothermal resources at Huabei Oilfield, *Proceedings of Thirty-Seventh Workshop on Geothermal Reservoir Engineering 2012*, Stanford, USA, (2012).