OPTIMIZATION OF GEOTHERMAL WELLS AND PRODUCTION SYSTEMS

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ABSTRACT

Maintaining geothermal well energy efficiency, as well as the efficiency of a production system, requires a detail analytical approach. One of the main conditions is to synchronize the performance of the surface system with the production well's operational conditions. Therefore it is essential to determine the most optimal duration of the wells flowing and the time of installation of the pump to achieve the required geothermal fluid quantities and operating pressure.

The surface system should be designed and constructed to provide the geothermal fluid of given parameters at any moment. The key condition is to eliminate both free and dissolved gases from the fluid, which are mainly of methane type in the Pannonian basin. As the production systems in the Province of Vojvodina are automatized, it is very important to know the well's performance type – whether it is flowing or working with submersible pump.

It is also very important to accurately determine the pump's installation depth, owing to the presence of free and dissolved gases, to achieve continuous operation and prevention of cavities.

1. SYSTEM ANALYSIS

System analysis may be used to optimize the system for the production of the geothermal energy. System analysis has been developed for the optimization of oil and gas wells and has been widely applied. It is based on collecting and analyzing a wide range of input data used to calculate output parameters and working conditions necessary for economic purposes.

Input data needed for system analysis are: reservoir characteristics (thickness, porosity and permeability), rheology, physical and chemical characteristics of the fluid, as well as flow and pressure at the well bottom and well head.

The following output data are obtained: quantity of the fluid and operational pressure for various types of well completion in order to choose the optimal production equipment, production as the function of pressure drop along the system and future production to foresee the end of natural flow and the best moment to introduce artificial lift (submerged pump).

The first phase of system analysis is to determine IPR curve (Inflow Performance Relationship). Darcy's method may be used to calculate IPR curve, under condition if valid reservoir characteristics are available. If not, Vogel's model may be used as it is quite reliable and gives results close to the actual. However, to use this relationship one measurement of production and pressure at the well bottom is available.

After IPR curve is obtained, the next step is to determine VLP curve that describes the vertical flow through the well and the horizontal flow through the pipeline to degasser and tank as the function of pressure at the bottom of the well. By using various models of equations for each part of the production system, VLP curve will be calculated. When optimum models are used VLP curve will intersect IPR curve at the value that matches the measured production.

After calculating the inflow and outflow curves at the well bottom nodal point, the same procedure is used to calculate curves at the well head nodal point. When these two pairs of curves are drawn on the same graph they should intersect at the same point as refers to x axis, i.e. the quantity of the produced fluid is the same, which is in agreement with the mass preservation law (Fig 1.).
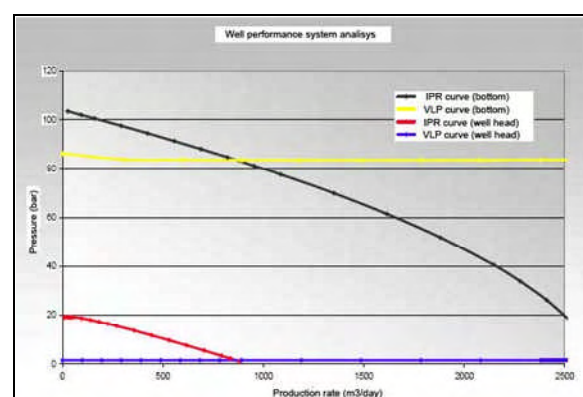

Fig.1. Well performance system analysis (solution at the bottom and the wellhead)

If there are two or more flow and pressure measurements at different bottom hole pressures, Fetkovich model could be used (based on the smallest square method) to obtain future IPR curves. Several IPR curves are constructed for various reservoir pressures, due to pressure decrease over a longer period of time (Fig 2.).

In this way the folowing could be estimated: future production, parameters of well completion and the performance of the entire system, and the moment when natural flow will end. Thus, it is possible to foresee the time when the artificial method of exploitation should be introduced.
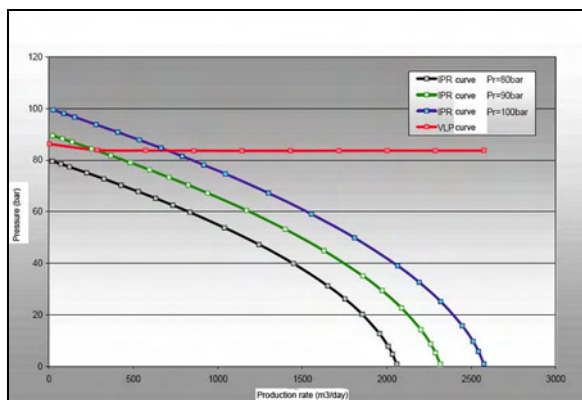
Fig.2. Natural flow well performance forecast

When installing the submersible pump into the well it is essential to define the optimal seating depth. The first prerequisite is that pump gets submerged into the fluid that is being produced, so the first criterium is obtained on the basis of the dynamic fluid level. The pump will be the most effective and will have the smallest losses when placed at the most shallow seating depth.

It is necessary to apply adequate artificial lift method when production rate drops bellow the minimal desired value to sustain functionality of the entire geothermal production system (Fig. 3).
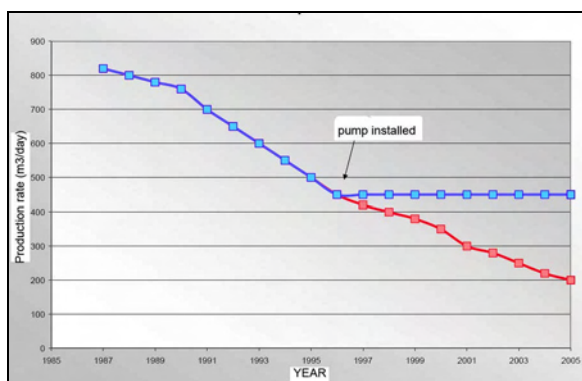

Fig.4 Pressure profile along well column

Fig 3. Production decline profile

It is also necessary to install the pump below the depth where bubble point occurs to avoid cavitation and pump damage. Depth where gas extraction from liquid occurs is determined on the basis of the pressure profile in the well, i.e. pressure drop is a function of the depth. It must be also taken into consideration that when the fluid gets into the pump a pressure drop occurs at the point of pump intake. This happens due to the change in flow pattern, thus this will also increase the depth of the pump seating (Fig.4).
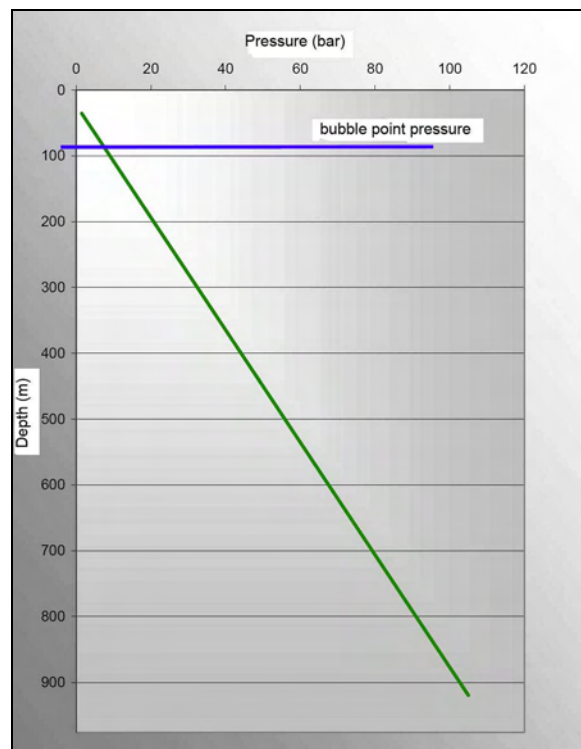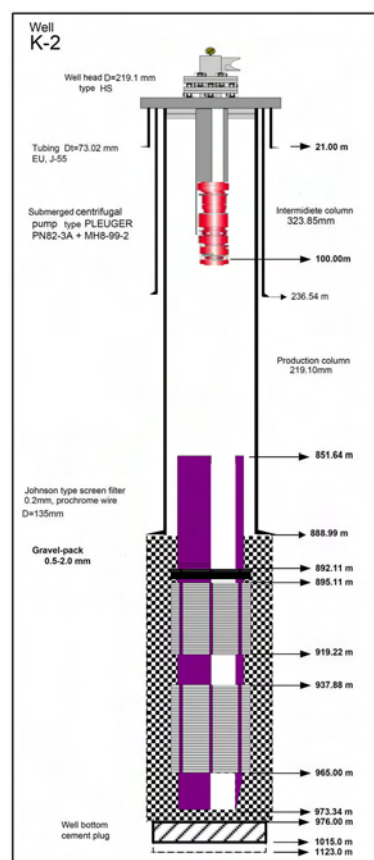

Fig 5. K-2 geothermal well schematic

If well K-2 is taken as an example it can be seen that after performing nodal analysis and on the basis of pressure data in the reservoir, as well as at the bottom of the well, initial production for the specified well completion is around $850m^3$ of fluid/day. Natural drop of the reservoir pressure decreased production up to 450 m^3 of fluid/day, after five years of natural flow production. By analyzing the graph showing the behavior of the IPR curves as a function of the drop of reservoir pressure it can be seen that the well could still produce in natural flow regime until the pressure in the reservoir drops up to 87 bars.

However the quantity of the produced fluid needed to achieve proper operation of the system requires installing of the submersible pump at the moment when the reservoir pressure reaches 90 bars. The submersible pump should be seated at the depth of around 100 m to satisfy the criterium of the mininimal allowed depth based on the dynamic pressure in the well and bubble point pressure. Production parameters of the submersible pump are adjusted to achieve the necessary quantity of the produced fluid and the pressure at the well head. The draft showing production geothermal well is show in Figure 5.

2. SURFACE SYSTEM

The basic characteristic of all built hydrothermal systems (HTS) in AP Vojvodina, built by NIS-Naftagas is that they operate without manpower. Produced quantities of geothermal water and pressures are occasionally monitored. The types of built HTSs depend on the production regime, i.e. natural flow or with artificial lift.

All geothermal waters in the Pannonic basin contain a certain quantity of free and diluted gas with methane content of over 90%. As this flammable gas may create an explosive mixture with air, water is flowing trough the degasser, an adsorptive column, where the gas is separated from geothermal water. Thus degassed thermal water, depending on the available quantities and temperature, can further be used for different purposes. Geothermal waters utilization structure in the area of Vojvodina is as follows:

- Spas and spa-recreational centers (heating and balneology): 43.6%

- Heating of various objects: 38.85%

- Technological needs in industry: 11.5%

- Recreation (open and closed swimming-pools): 6.1%

HTS production either from natural flow wells or with submersible pump, is synchronized with the consumer needs and the quantity of the geothermal water produced is in accordance with the needs of the moment. Built HTSs do not have large reservoir space, thus reliable equipment has to be used in order to secure a very acurate flow regulation quality as well as automatic pump control and regulation valves.

All electromotor valves for the regulation of flow and transport pumps operations are controlled by means of PLC units that have parameters specified in advance. Control of the submersible pump is achieved by means of frequency converter.

2.1 HTS with natural flow well

The mixture of water and gas from the geothermal well, due to the activity of the well working pressure, flows to the built in free gas separator, and then to the centrifugal pump.

The pump transports the mixture of water and diluted gas via transfer electromotor regulation valve into the two step atmospheric degasser. Thermal water degassing is performed in a cascade degasser. Separated free gas from the first and second step degasser is emitted into the atmosphere. Flow regulation depends on the consumer needs, i.e. on the level of the degassed thermal water in the storage tank.

Degassed water overflows by gravity into the storage tank which is equiped with a relief for the separation of the remaining gas. The tank is also equipped with overflow and drainage tube. Effective degassing of thermal water is achieved if the content of flammable gas in degassed water does not exceed 0.003 ms^3/m^3.

Water transport from the storage tank to the consumers is realized by means of a centrifugal pump placed behind the tank. Electromagnetic flow gauge is placed on the pipeline behind the pump. Automatic HTS running is managed via PLC unit and parameters that are specified in advance. The principle on which the HTS is constructed is given in Fig.6.
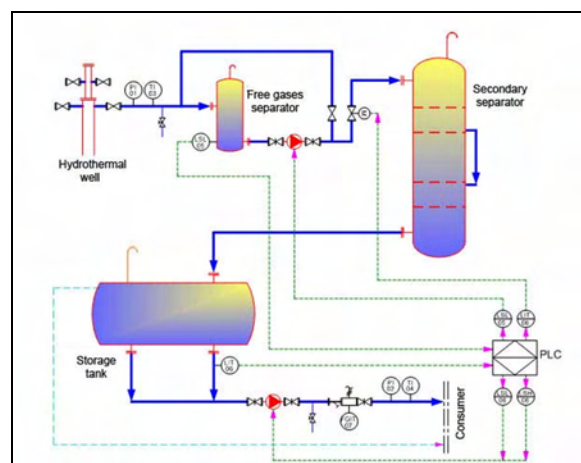

Fig 6. Hydrothermal production system with the natural flow well

2.2. HTS with submersible pump in the well

The submersible pump is installed into the well at the depth which makes impossible separation of free gas in the well, therefore a new externally isulated pipeline from the well to the inlet of the degasser is built. Connections for temperature and pressure control can be mounted on the pipeline. Degassing of thermal water is performed in the atmospheric two step cascade degasser. Separated free gas from the first and second step of degasser is emitted to atmosphere. Flow regulation is achieved by means of a frequency converter depending on the consumer needs, i.e. of the level of the degassed thermal water in the admitting reservoir.

Degassed water overflows, by gravity from the degasser into the storage tank that has a relief for the eventual separation of the remaining gas. The tank is also equipped with overflow and low-point drain pipeline. Transport of water from the storage tank to the consumers is done by means of a centrifugal pump. Electromagnetic flow gauge is placed on the pipeline, behind the pump.

All pipelines are made of steel and are placed on the ground surface. The pipeline is insulated with glass wool and placed inside the aluminum sheet lining.

Automatic managing of HTS is done by means of PLC units and parameters specified in advance. The principle on which HTS is constructed is given in Fig.7.
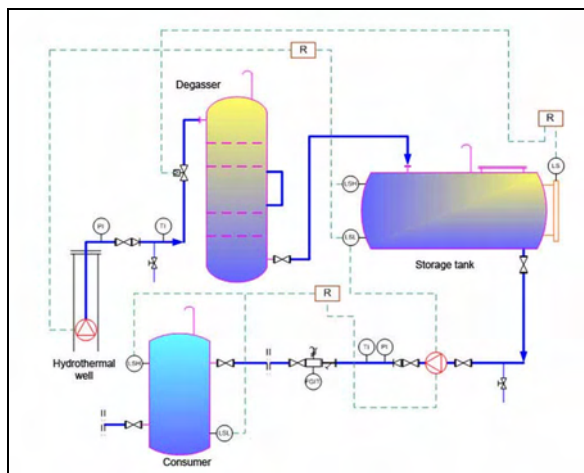

Fig 7. Hydrothermal production system with a submersible pump in the well

CONCLUSION

On the well K-2, as an example, system analysis has been applied to define the well equipment and to adjust the parameters for well production, i.e. the necessary quantity of fluid and operational pressure.

The surface part of the system has been designed to operate without manpower, in the automatic regime and in the starting with natural flow well, and later on with submersible pump installed.

An analytical approach has been used to make the concept and to design the system for the production of geothermal energy of crucial importance for the optimal functioning both from the technical and economic aspects.

REFERENCES

Soleša Mišo, Nenad Djajic, Ljubisa Paradanin, (1995), "Production and utilization of geothermal energy", *Faculty of mining and geology, Belgrade, SERBIA*

Soleša Mišo, Dusan Danilovic, Zsolt Buza, (1999), "System analysis of production of oil and gas of natural flow wells", *DIT Naftagas, Novi Sad, SERBIA*

Slobodan Vidovic, Sava Djuric, (2004), "Utilization of Geothermal Waters and Geothermal Energy in Vojvodina", *International Geothermal Days POLAND, Zakopane, September 13-17, 2004*

Djuric Sava, Slobodan Vidovic (2005), "Methods of Production and Possibilities of Determining Hydraulic Properties of Gas Saturated Water" *World Geothermal Congress 2005 Antalya, Turkey, April 24-29, 2005*

Kermit E. Brown, (1980) "The technology of artificial lift methods" vol 2, *Pennwell Books, Tulsa Oklaholma, USA*

Kermit E. Brown, (1984) "The technology of artificial lift methods" vol 4, *Pennwell Books, Tulsa Oklaholma, USA*

Technical documentation fund of NIS-Naftagas (1948 – 2006)