International Journal of Petroleum and Geoscience Engineering (IJPGE) 2 (2): 130-137, 2014
ISSN 2289-4713

Research paper

Underground Gas Storage in Gas Condensate Reservoir

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A b s t r a c t

Keywords:

UGS,
Gas condensate,
Dew point,
retrograde condensation.

In this paper a gas condensate reservoir with 33Gscm initial gas in place with total production of 15.8Gscm from 7 producers within 19 years production history is studied. The result of simulation study shows the reservoir can be appropriate candidate for underground gas storage execution. The result of the study also shows gas injection in the reservoir, significantly prevents condensate loss. It is also possible to inject 20MscmD in 8 months and produce 40MscmD in 4 cold months. The model is well fitted with 95 percent level of confidence.

Accepted:05 June2014

1. Introduction

Underground gas storage (UGS) is one of the important parts of natural gas industries. Normally, Gas demand varies from time to time as a function of weather, gas price and other affecting factors. The most common variation is increasing gas demand in winter. As a result, pipelines cannot transport enough gas to fulfill the needs of the customers whenever needed especially in winter. During the summer, pipeline can transport more gas amount than required. This situation normally results in an inefficient gas transport system. Therefore, In order to resolve this issue, the UGS has been applied. Natural gas may be stored in number of different ways. The common ways of underground gas storage are given below:

- Depleted oil and gas reservoirs
- Aquifers

- Salt cavern formations

2. Literature Review

In 1915, natural gas was first successfully stored underground in reservoir in Ontario, Canada. In 1916, Iroquis Gas Company placed the Zoar field, south of Buffalo, New York, USA into operation as storage site and it is still in operation. Before 1950, essentially all of the UGS projects consisted of reused partially or fully depleted gas reservoirs [1,2].Injection of gas into an aquifer, the salt cavern, abandoned mine and lined rock cavern were in 1946 (Kentucky, USA) 1961 (Michigan, USA), 1963 (Colorado, USA) and 2002 (Skallen,Sweden) [3]. The first UGS facility in the USSR was constructed in Bashkatovskoye depleted gas field. Gas injection commenced on 5 May 1958 [4] and the gas, in 1959, into a new water bearing structure not far from Moscow [1].

At late 1950s it was believed that nuclear energy was the most promising future source of energy. The first energy crises in 1973 and the second few years later changed this situation. There is a growing awareness that nuclear energy would not play the role that was hopped for (Harrisburg, Chernobyl) [5]. As a result the gas demand was grow up rapidly.
In 2008 gas storage facilities were operating in 33 countries [6]. Based on CEDIGAS analyses [7] of the latest developments (2013) storage facilities are operating in 48 countries all over the world. There are 688 existing facilities in the world and 236 projects are under construction and planned for construction. Global gas storage capacity is reported 377 Billion cubic meters. According to report presented by EIA [8] working gas in underground storage in lower 48 states of USA is 3776 Billion cubic feet (109.6 Gscm) in November 2013. In UK, up to 1950s coal mines supplied almost 90 percent of the energy needs. With nuclear power crises and the discovery of North Sea gas the "dash for gas" in 1980s, coal fired power stations were replaced with gas fired equivalents. UGS is relatively new in UK [9]. In China the demand for natural gas increased dramatically over the past years. In 2010, domestic gas consumption exceeded 100 billion cubic meters and by 2020 it is estimated to reach 450 billion cubic meters. CNPC plans to build 10 gas storage facilities by 2015 with a total storage capacity of 22.4 billion cubic meters [10]. Natural gas plays an increasing role in meeting the world's energy because of its abundance, versatility and its clean burning nature [11]. In the next 20 years the average growth rate of actual gas demand is over 1.8% per year [9, 12].

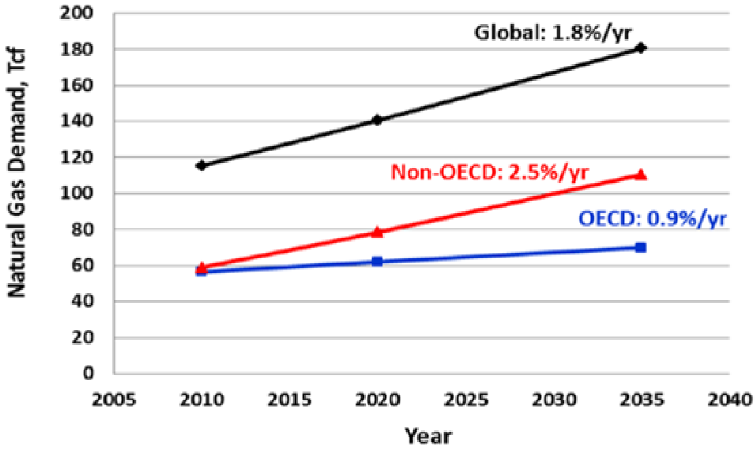

Fig.1: Demand trend for natural gas

As below figure shows, natural gas will have very important role in future world's energy, IEA Energy Outlook 2013[13].

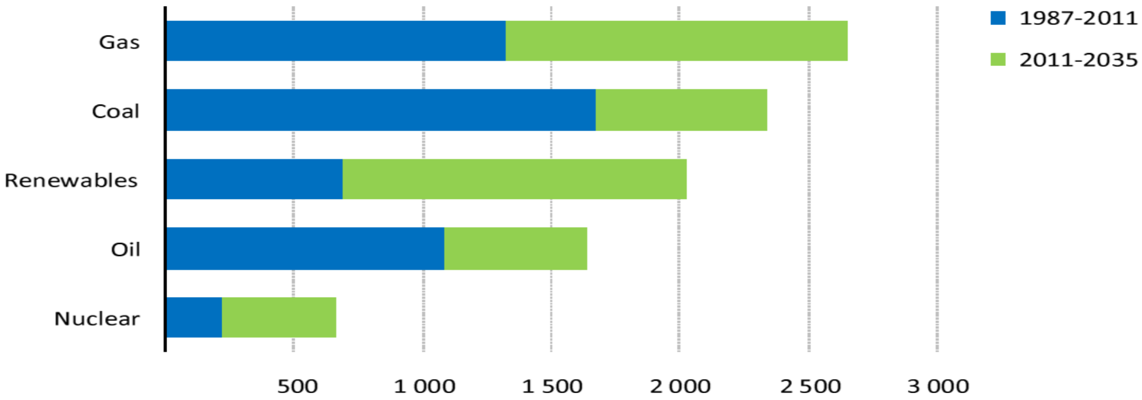

Fig.2: Comparison of different types of energy [13]

As it is indicated, according to the above figure, gas usage trend up to 2035 would be doubled in comparison with what previously used. Therefore, special concentration on gas production and underground gas storage would be highly beneficial. Here, as a research gap, underground condensate gas storage is focused which has been ignored in the literature. The importance of the topic comes from the fact that gas condensate compared with dry gas has different characterization which in this paper is focused. To the best of our knowledge, there is no other relevant research which incorporated underground condensate gas storage.

3. Problem Statement

In this paper we discuss UGS in a gas condensate reservoir. In gas condensate reservoirs, as a result of gas production, reservoir pressure gradually declines. When the reservoir pressure declines to dew point pressure, condensate drop out will occurs in the reservoir. It increases with decrease in reservoir pressure [14]. The saturation of the liquid condensate out of the reservoir fluid is low, therefore it adheres to the walls of the pore spaces of the rock, and thus the gas produced at the surface will have lower liquid content. If gas injection started in the vicinity of dew point pressure in the gas condensate reservoir, the amount of working gas is not the maximum, but it has the advantage of preventing condensate loss.

4. Reservoir Modeling

4.1 Reservoir description

This paper is about a gas condensate reservoir in Middle East. The field was discovered by drilling well-1. The reservoir rock is mainly consisting of consolidated sandstone with clay, carbonate and small amount of anhydrite. Initial reservoir pressure and temperature at datum depth of 2591 MSS has been 354 Bara and 122 degree centigrade. Initial gas in place is estimated 33 Gsm3 (1.165 TCF). Total of 7 production wells are gas producers. The condensate to gas ratio is measured 56.14 Sm3/Msm3 (10 STB/MMSCF). Total gas and condensate production from 7 wells during 20 years is 15.84 Gsm3 (.559 TCF) and 882 Ksm3 (5.55 MMSTB) respectively. The maximum daily gas production rate has been 6 McmD. As a result of production the reservoir pressure is declined to 214 Bara. Based on available PVT data the dew point pressure is 243 Bara.

4.2 Model Initialization

4.2.1 Static Modeling

A model is used to build three dimensional geological model of the reservoir. Structural model of the reservoir is based on the latest underground contour map (UGC map) of the top of reservoir.UGC map and all of the available rock properties in the wells were input to the model. The reservoir was sub divided into small cells and the rock properties between wells for different cells was interpolated. Reservoir model was constructed by a 51*34*5 network grid.

4.2.2 Dynamic Modeling

A 3D dynamic model is a reservoir simulator which is used to simulate the reservoir utilizing compositional modeling.

4.2.2.1 Grid Block Properties

After building 3D geological static model using geological and petro physical data, all the reservoir rock properties including porosity, water saturation and net to gross thickness ratio were upscale in 51×34×5 grid dimensions and necessary outputs was developed. Figures 3, 4 show porosity and water saturation distribution.

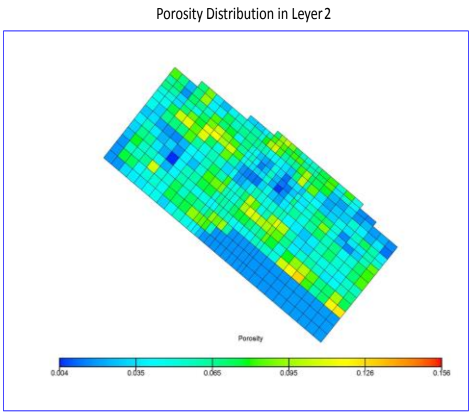

Fig.3: Porosity Distribution

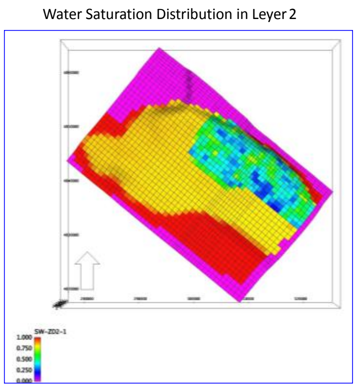

Fig.4: Water Saturation Distribution

4.3 History Matching

The reservoir has been on production for 19 years. The effort was to fit well static pressures and production rates generated by numerical method with actual field data, by adjusting critical parameters such as rock permeability, transmissibility multipliers and aquifer strength. The results of different simulation were compared with actual data and the best fit with actual data was observed. Figures 5, 6 show the result of matching.

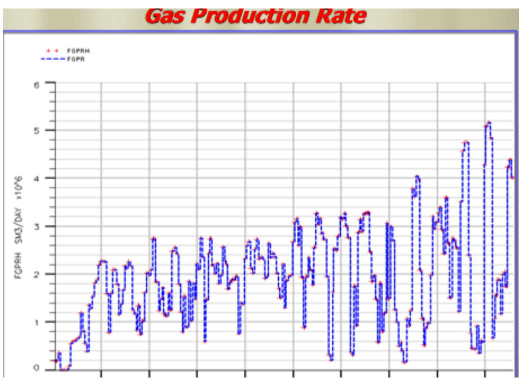

Fig.5: Gas Production Match

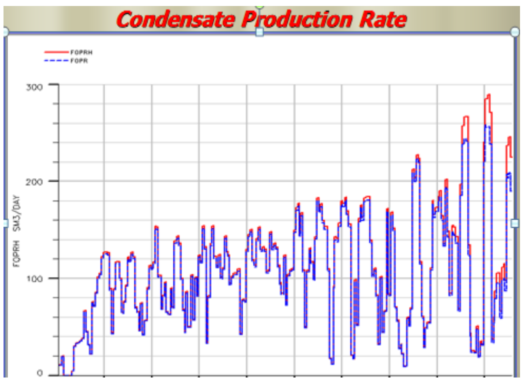

Fig.6: Condensate Production Match

4.4 Model Prediction

The tuned model was used to find out maximum possible working gas storage. For this purpose different predictions were run and in each of them the maximum reservoir pressure at the end of injection was estimated. As the initial reservoir pressure has been 354 Bara and, after taking into account the safety factor, the constraint for pressure assumed 300 Bara. The injection and production cycle is 8 month injection and 4 month production. The maximum daily injection is 20 MscmD for 8 months and 40 MscmD production amount for 4 cold months. The estimated injectors- producers by model are 20 plus 19 vertical production wells. Figure-7 shows result of the study. The study shows that drilling slanted well with 70 degree and horizontal well with 300 meters leg will increase the rate 1.4 and 1.7 times the vertical well. Figure 8 shows the result of this investigation.

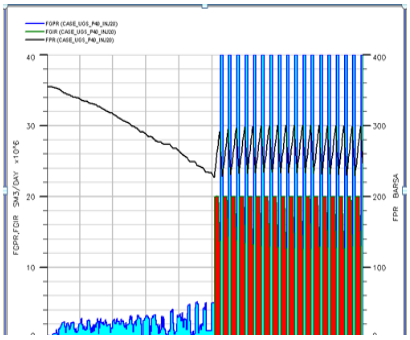

Fig.7: Maximum Gas Storage

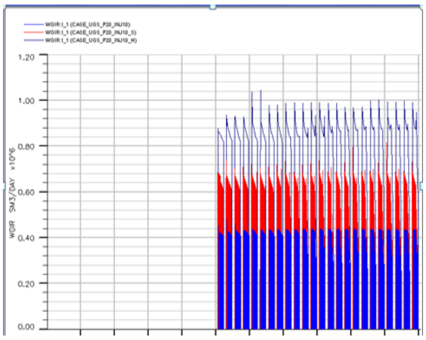

Fig.8: Gas rate in vertical, slanted and horizontal wells

Figure 9 shows the difference between condensate production in UGS and natural depletion. As the figure shows, in the case of UGS the condensate recovery is higher.

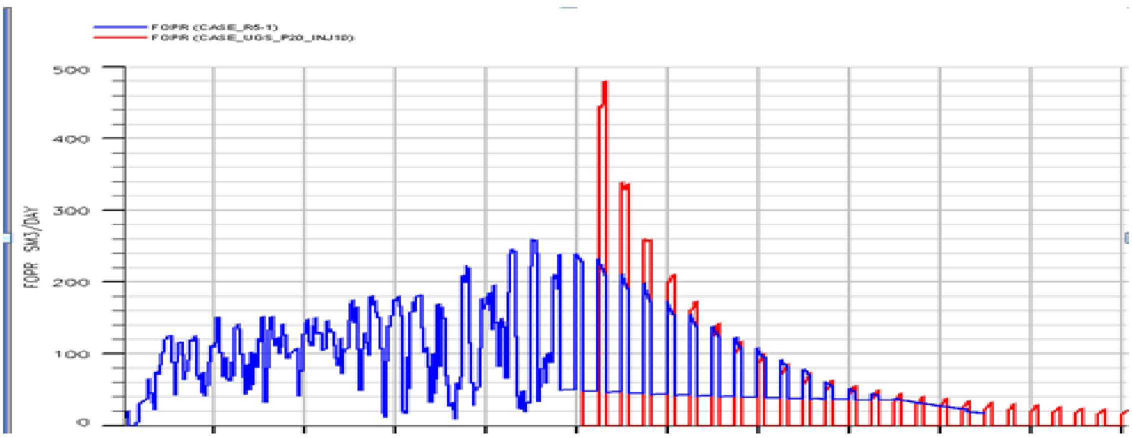

Fig.9: Comparison between Condensate production in do noting and UGS.

5. Conclusion

The conclusion and research findings are given below:

- The original gas in place calculated by material balance, static and dynamic model are 33, 33.15 and 33.0 Gsm3 respectively.
- Also, using reservoir as underground gas storage was studied. The result of the study shows that by drilling 20 new injector-producer and 19 new producers, it is possible to inject 20 million cubic meters of sweet gas during 8 months and produce up to 40 million cubic meters in four months.
- The result of study showed that in using gas condensate reservoir for UGS if the gas injection pressure is close to dew point pressure the condensate recovery will be high.
- The result of study showed that the production and injection rate of deviated and horizontal well is about 1.4 and 1.7 times the production rate of vertical well.

6. Recommendations

It is recommended to get production and reservoir engineering data from the first future 3 new wells to modify the rock and fluid properties.

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