Prediction of development potential in a certain well area

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ABSTRACT

The structure of a gas reservoir in a certain well area is complex, and the reservoir belongs to a medium low porosity and low permeability reservoir with poor physical properties. With the continuous deepening of development, contradictions in gas reservoir development have gradually been exposed. Therefore, a dynamic analysis of gas reservoir development has been carried out from four aspects: production capacity, pressure, reserves, and water production. Targeted research has been conducted on the development potential of well areas from five aspects: well network refinement, perforation and fracturing, repeated fracturing, reservoir unblocking, and composite drainage. A preliminary arrangement of 13 well measures has been made, and the total daily gas increase prediction after measures is 101.5×10^4 m^3, ensuring the reasonable development and stable production of the gas reservoir.

Keywords: Development contradiction, dynamic analysis, developing potential, predictive research, reasonable development; stable production and increased production

1. INTRODUCTION

With the continuous expansion of production scale and deepening of development level in a certain well area, some problems have gradually been exposed in production capacity construction and production: (1) Strong heterogeneity of gas reservoirs, large differences in single well production dynamics, and unbalanced exploitation seriously restrict the stable production capacity of gas reservoirs; (2) The degree of reserve utilization in the well area is low, the physical properties of the gas well reservoir are poor, the energy is insufficient, and the production dynamics such as pressure and production capacity change quickly. It is necessary to timely track and evaluate the dynamic characteristics of gas reservoir development and formulate reasonable development technology countermeasures; (3) The gas water relationship in gas reservoirs is complex, and the wellbore of gas wells is prone to liquid accumulation. During the development process, attention should be paid to drainage[1-3]. Therefore, it is necessary to timely evaluate the development performance of gas reservoirs, summarize the implementation experience of measures in the well network, combine the actual production performance of gas wells, reservoir conditions, process technology and other aspects, select potential wells for the next step of measures, thereby improving single well production capacity, enhancing development efficiency, and increasing reserve utilization[4].

2. OVERVIEW OF THE WELL AREA

2.1 Structure, reservoir and gas reservoir characteristics

A certain well area is located in the Xujiaweizi fault depression in the southeastern part of the Songliao Basin, with a Shengping Xingcheng nose shaped structure. It mainly produces volcanic and conglomerate rocks, with explosive and fan delta facies as the main lithofacies. The lithology is mainly rhyolite, tuff, conglomerate, and sandstone. The reservoir belongs to a medium low porosity and low permeability reservoir, with poor physical properties. The gas water relationship in the well area is complex, and it belongs to a normal pressure and temperature system. The natural gas properties are mainly methane, which is a typical dry gas feature. The formation water is $NaHCO_3$ type.

2.2 Development status

Production time of a certain well area: Starting from July 2008; Total number of wells: 12; Average daily gas production per well: 6.3×10^4 m^3; Average daily water production per well: 1.7 m^3; Daily production capacity: 76×10^4 m^3; Annual production capacity: 2.2×10^8 m^3; Gas extraction speed: 4.7%; Accumulated gas production: 13.4×10^8 m^3; Extraction

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degree: 28.3%.

3. DEVELOPING DYNAMIC ANALYSIS

6 gas wells are produced from the initial stage of production from 2008 to 2014 in this area. As the production capacity of the gas wells naturally decreases, the daily gas production gradually decreases. Since 2015, some new wells have been put into production each year, and the daily gas production has been increasing year by year. The development situation is good (Figure 1).

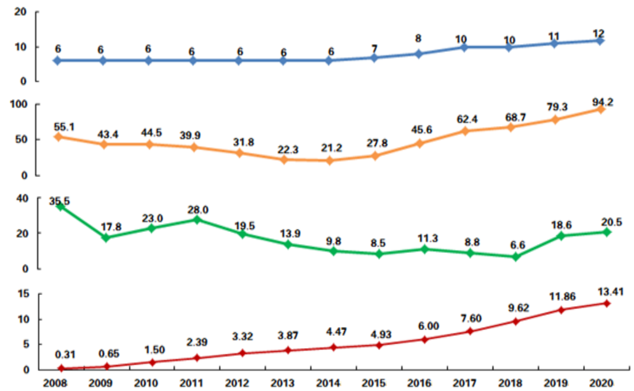


Figure 1. Comprehensive production curve of a certain well area.

3.1 Capacity characteristics

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

The production capacity of gas wells varies greatly[5], with a higher proportion of Class II gas wells (Table 1).

Table 1. Gas well classification evaluation and composition.

Category	**Formation coefficient (mD·m)**	**Initial stable production ($10^4m^3/d$)**	**Unit pressure drop gas production ($10^4m^3/MPa$)**	**Current average production capacity ($10^4m^3/d$)**	**Well**	**Accumulated gas production (10^8m^3)**
I (High production)	＞100	＞15	＞1000			
II (High production)	50-100	10-15	500-1000	10	M1-P4, M6-202, M6-301, M6-309, M6-313, M603	9.61
III (Medium production)	10-50	5-10	100-500	3.8	M6-101, M6-102, M6-308	2.88
IV (Low production)	＜10	＜5	＜100	1.5	M6-103, M6-X201, M6-X307	0.92

The production characteristics are characterized by a rapid decrease in production capacity in the early stages of production[6-7], which is currently stabilizing (Figure 2).

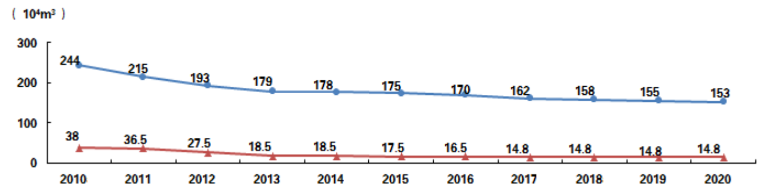


Figure 2. Changes in calibrated production capacity of a certain well area over the years.

3.2 Formation pressure

The formation pressure decreased rapidly in the initial stage of production and is currently stabilizing (Figure 3), while the gas production per unit pressure drop is relatively low (Figure 4).

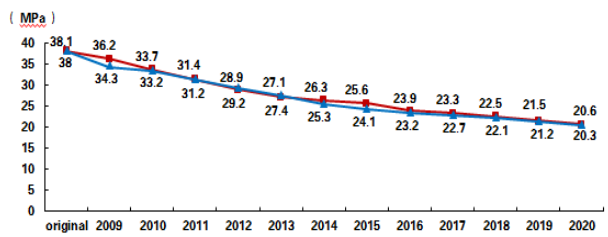


Figure 3. Formation pressure variation curve in a certain well area.

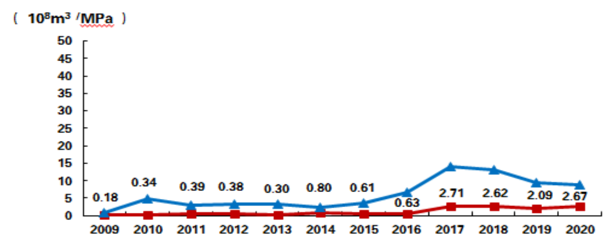
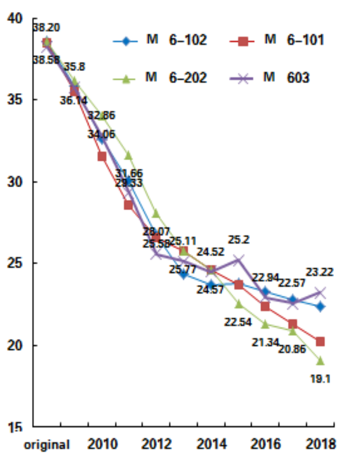


Figure 4. Variation curve of gas production per unit pressure drop in a certain well area.

Pressure monitoring shows that there is a connectivity relationship between wells M6-101, M6-102, M6-202, and M603 (Figures 5 and 6).



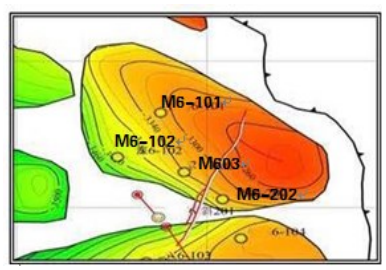


Figure 5. M6-101 volcanic rock pressure profile. Figure 6. Volcanic rock and structural overlay in block M.

3.3 Reserve characteristics

The dynamic reserves of single well control are low (Figure 7), and the degree of reserve utilization in the well area is low (Figure 8).

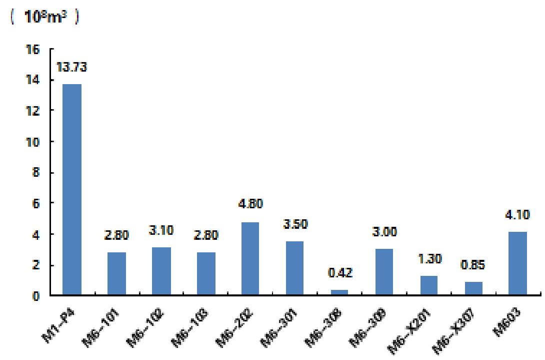


Figure 7. Schematic diagram of single well controlled reserves in a certain well area.

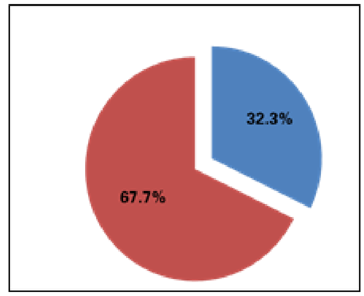


Figure 8. Schematic diagram of reserves utilization in a certain well area.

3.4 Produced water characteristics

At present, the main type of produced water in the well area is fracture type weak water channeling, with a water to gas ratio ranging from 0.1 to 0.9 $m^3/10^4$ m^3. Some gas wells have low production and are difficult to carry liquid. Currently, there are three wells producing layer water, all located in lower structural areas, adjacent to the same layer of gas and water (Table 2).

Table 2. Production situation and water quality analysis of a certain well area.

Well	Current oil pressure (MPa)	Current casing pressure (MPa)	Current daily gas production ($10^4m^3/d$)	Current daily water production (m^3/d)	Current water to gas ratio ($m^3/10^4m^3$)	Sampling date	PH	Salinity	Water type
M6-102	4.8	9.2	2.1	0.98	0.5	2019/11/20	8.4	12422.98	Sodium bicarbonate
M6-103	4.8	8.5	1.0	1.00	1.0	2014/3/20	7.1	6533.92	Sodium bicarbonate
M6-X201	5.5	10.0	0.9	0.98	1.1	2018/3/19	8.5	12057.76	Sodium bicarbonate
Regional water properties							7.7-8.9	5650-13300	

4. POTENTIAL ANALYSIS OF MEASURES

For a certain well area, it is necessary to have a refined development strategy. From a planar perspective, the well network should be encrypted in the unused area. From a vertical perspective, the unused layer should be subjected to perforating and fracturing. From a refined perspective, the underutilized layer should be subjected to repeated fracturing, reservoir contamination wells should be unblocked, and liquid gas wells should be treated with composite drainage to improve single well productivity, enhance development efficiency, and increase reserve utilization.

4.1 Well network encryption

From a planar perspective, the well network is encrypted for the unused area. A certain well area has strong heterogeneity in the reservoir and low degree of reserve utilization. By calculating the current well control area and remaining reserves between wells of the gas wells that have been put into operation (Table 3), the degree of reserve utilization can be improved by adjusting the well network encryption. The remaining reserves under well control between well groups are 5.1×10^8 m^3, with an area of 0.51 km^2. It is recommended to select a favorable location in the distribution area of remaining reserves and arrange a horizontal well to fully utilize the remaining reserves.

Table 3. Calculation of single well control area in a certain well area.

No.	Block	Well type	Well	Effective thickness h (m)	Porosity Φ (%)	Gas saturation Sgi (%)	Tsc (K)	Original pressure Pi (MPa)	Pressure under standard ground conditions Psc (MPa)	Original formation temperature T (K)	Deviation coefficient under original pressure Zi	Well controlled reserves G ($10^8 m^3$)	Well control area A (km^2)	Well control radius r (m)
1	X-block	Vertical well	M6-103	50	0.062	0.56	293	38.69	0.101	413.0	1.0878	3.04	0.7009	472
2			M6-202	90	0.085	0.65	293	38.58	0.101	413.0	1.0869	4.61	0.3718	344
3			M603	120	0.07	0.6	293	38.20	0.101	411.0	1.083	4.11	0.3275	323
4			M6-102	60	0.065	0.57	293	38.58	0.101	410.0	1.0858	2.5	0.4473	377
5			M6-X201	54.4	0.05	0.5	293	38.00	0.101	414.0	1.0828	1.43	0.4276	369
6			M6-101	70	0.069	0.59	293	38.49	0.101	414.0	1.0865	2.99	0.4227	367
7			M6-301	100	0.088	0.65	293	37.74	0.101	411.0	1.0795	3.47	0.2458	280
8			M6-309	70	0.068	0.58	293	38.11	0.101	411.0	1.0826	3	0.4373	373
9		Horizontal well	M1-P4	90	0.12	0.7	293	38.29	0.101	421.0	1.0885	19.67	1.0734	585
Average				78.27	0.075	0.6	293	38.3	0.101	413.1	1.085	4.98	0.495	388

4.2 Perforation and fracturing

Vertically, for gas wells with unused reservoirs, perform perforation and fracturing, summarize the experience of implementing measures in the well network, and select potential wells for the next step of measures based on actual gas well production performance, reservoir conditions, process technology, and other aspects[5-8] (Table 4).

Table 4. Situation of unused reservoir gas wells in a well area.

No.	Well	Gas production ($10^4 m^3/d$)	Effective thickness of unused reservoir(m)				
			Yingyi	Yingsi	Shahe	Denglou	Total
1	M6-308	6	46.8	4.4	37.4		88.6
2	M603	4	70		45.2		115.2
3	M6-101	3			20.6	13	33.6
4	M6-102	2.5			17.2		17.2
5	M6-202	6			38.4		38.4
6	M6-X307	3			38.2	12	50.2
7	M6-309	8	4.4			17.8	22.2
8	M6-301	13	4.8			22.2	27

No.	Well	Gas production ($10^4 m^3/d$)	Effective thickness of unused reservoir(m)				
			Yingyi	Yingsi	Shahe	Denglou	Total
Total		45.5	126	4.4	197	65	392.4

The drilling and fracturing of the gravel layer in well M1-4 have achieved increased storage and production of the gas well. After the measures, the well's controlled reserves have increased by 1×10^8 m^3, and the initial production has reached 10×10^4 m^3, with a cumulative increase of 2430×10^4 m^3.

The M6-308 well in the well area is used to extract the Shahezi Formation reservoir, while the adjacent M6-309 and M6-301 wells are used to extract the volcanic rock reservoir, which has good physical properties.

From the perspective of production dynamics, the stable production capacity of M6-308 well is 6×10^4 m^3/d, the daily production capacity of M6-301 well and M6-309 well are both above 10×10^4 m^3, and the peak shaving capacity can reach 18×10^4 $m^{3/}$d. The effective thickness of the unused volcanic rock reservoir in M6-308 well is 46.8 m, and it is predicted that the daily gas increase of the well after perforation and fracturing can reach 10.3×10^4 m^3.

It is predicted that the total increase in gas production through perforation and fracturing of unused reservoir gas wells in a certain well area is 86.2×10^4 m^3/d (Table 5).

Table 5. Prediction of gas increase in unused reservoir gas wells.

No.	Well	Gas Production ($10^4m^3/d$)	Effective thickness of unused reservoir(m)				Prediction of gas increase ($10^4m^3/d$)				
			Yingyi	Yingsi	Shahe	Denglou	Yingyi	Yingsi	Shahe	Denglou	Total
1	M6-308	6	46.8	4.4	37.4		10.3	0.4	10.1		20.8
2	M603	4	70		45.2		15.5		12.2		27.7
3	M6-101	3			20.6	13			5.6	0.8	6.4
4	M6-102	2.5			17.2				4.6		4.6
5	M6-202	6			38.4				10.4		10.4
6	M6-X307	3			38.2	12			10.3	0.7	11
7	M6-309	8	4.4			17.8	1.5			1.1	2.6
8	M6-301	13	4.8			22.2	1.4			1.3	2.7
Total		45.5	126	4.4	197	65	28.7	0.4	53.2	3.9	86.2

4.3 Repeated fracturing

In terms of precision, for gas wells with inconsistent dynamics and insufficient reservoir utilization, repeated fracturing was carried out. The M6-Xiang201 and M6-102 wells were affected by edge and bottom water, with an average perforation of only 15.4% of the effective reservoir thickness. The amount of sand added was less than 50 m^3, and the amount of liquid added was less than 400 m^3. It is predicted that the effective thickness of the unused reservoir is 52.6 m (Table 6).

Table 6. Insufficient utilization of gas wells in the edge and bottom water gas reservoir.

No.	Well	Effective thickness of reservoir (m)	Perforation thickness (m)	Perforation thickness ratio (%)	Sand addition amount (m^3)	Fracturing fluid (m^3)	Prediction of the effective thickness of unused reservoirs (m)	Recovery rate (%)
1	M6-X201	54.4	10	18.4	29.5	265	11.4	18.9

No.	Well	Effective thickness of reservoir (m)	Perforation thickness (m)	Perforation thickness ratio (%)	Sand addition amount (m^3)	Fracturing fluid (m^3)	Prediction of the effective thickness of unused reservoirs (m)	Recovery rate (%)
2	M6-102	80.76	10	12.4	40	352.8	41.2	38.1
Total		135.16	20	15.4			52.6	

The M1 Ping 1 well underwent repeated fracturing to improve the degree of reservoir transformation. During the gas testing, only 44 m^3 of sand was added, resulting in low fracturing fluid backflow rate and large leakage. In addition, there was a 448 m reservoir that was not used, and the daily gas production before the measures was only 3.2×10^4 m^3. In order to improve the gas well production capacity, 13 stages of fracturing transformation were carried out in 2017, with a sand addition of 372 m^3 and a liquid volume of 8260 m^3. After the measures, the well control reserves increased by 2.6×10^8 m^3, and the production increased by 6×10^4 m^3. The cumulative gas increase has been 2808×10^4 m^3.

It is predicted that the total amount of gas increase from repeated fracturing in a gas well with insufficient reservoir utilization in a certain well area is 3.1×10^4 m^3/d (Table 7).

Table 7. Prediction of gas well increment for underutilized gas reservoirs in the edge and bottom water gas reservoirs.

No.	Well	Effective thickness of reservoir (m)	Perforation thickness (m)	Perforation thickness ratio (%)	Sand addition amount (m^3)	Fracturing fluid (m^3)	Prediction of the effective thickness of unused reservoirs (m)	Recovery rate (%)	Gas increase prediction (10^4m^3/d)
1	M6-X201	54.4	10	18.4	29.5	265	11.4	18.9	0.6
2	M6-102	80.76	10	12.4	40	352.8	41.2	38.1	2.5
Total		135.16	20	15.4			52.6		3.1

4.4 Reservoir unblocking

There is a discrepancy between the dynamic and static conditions, and there is reservoir contamination in the gas well. Reservoir unblocking is carried out, and the M6-102 well is adjacent to the same gas and water layer, producing below the critical liquid carrying flow rate. The wellbore is prone to liquid accumulation, with a large production pressure difference, and there is “water lock” pollution in the reservoir. From the perspective of production dynamics, the daily gas production and water production of the well are low, with low wellhead pressure and a recovery rate of 34.5%. The remaining well control reserves are 2.03×10^8 m^3. It is recommended to perform reservoir unblocking on the well[9].

Taking the M6-103 well reservoir unblocking as an example, the daily production capacity of the well was low before the measure, and it could not continue normal production. After the measure, continuous production was achieved, with an initial daily gas production of 1.8×10^4 m^3 and a daily water production of 5.3 m^3. For reservoir unblocking wells (Table 8), timely acquisition of dynamic data, evaluation of production increase effect, summary of mature practices, identification of shortcomings, and reliable reference for the next batch of well measures are provided. It is predicted that the daily gas increase of M6-102 well after the measures will be 1.5×10^4 m^3.

Table 8. Statistical table of reservoir unblocking wells.

No.	Well	Calibrate production capacity ($10^4m^3/d$)	Operation data	Before operation				After operation				Current gas increasing (10^4m^3)
				Tubing pressure (MPa)	Casing pressure (MPa)	Daily gas production (10^4m^3)	Daily water production (m^3)	Tubing pressure (MPa)	Casing pressure (MPa)	Daily gas production (10^4m^3)	Daily water production (m^3)	
1	M605	3	2018.12	5.20	22.40	0.1011	1.18	13.90	14.40	4.2712	4.94	733.11
2	M6-103	1	2018.12	4.90	—	0.0100	0.01	5.70	9.40	1.8870	5.31	520.95
3	M3	1	2019.9	7.00	—	0.1019	0.08	4.70	—	2.5218	2.51	449.33
Total		5				0.2130	1.27			8.6800	12.76	1703.39

4.5 Composite drainage

In terms of precision, for the liquid gas well, composite drainage is carried out. The physical properties of the reservoir in M6 Xie201 well are poor, the daily gas production during gas testing is low, and the skin coefficient reflects that the reservoir has no obvious pollution. Small layer data shows that there is no potential layer above and below. It is recommended to improve the recovery rate of the gas well by implementing composite drainage measures on this well[10-12].

M6-101 has eddy current tools underground, with a large pressure difference in the oil casing, up to 3.5 MPa, and the wellbore is prone to fluid accumulation. The control measures of adjusting production and carrying liquid are taken for the well. When the inlet pressure is below 6 MPa, the instantaneous production is increased by 1000-1500 m^3/h until the inlet pressure rises to about 8 MPa and is adjusted to production allocation. Through the control, the cumulative gas increase of M6-101 well is 148.72×10^4 m^3 so far, and it is predicted that the daily gas increase of M6-XE201 well combined drainage is 0.7×10^4 m^3.

5. CONCLUSION

(1) A total of 12 gas wells have been put into operation in a certain well area, with an annual production capacity of 2.2×10^8 m^3. The gas reservoir has a complex structural shape, and volcanic rocks, conglomerates, and sand conglomerates are exploited. The reservoir belongs to medium low porosity and low permeability reservoirs, with poor physical properties and complex gas water relationships.

(2) The production capacity of gas wells varies greatly, and decreases rapidly, and the stable production capacity is poor. The formation pressure drops rapidly, and the gas production per unit pressure drop is low. The degree of reserve utilization in the well area is low, and some gas wells have low production, making it difficult to carry liquid. Currently, there are three wells producing formation water.

(3) In the well network of the well area, measures such as densification of the well network on the plane, perforation and fracturing vertically, repeated fracturing finely, and reservoir unblocking and composite drainage for low production and low efficiency wells are taken. The comprehensive decline rate is gradually controlled within 2%, and it is expected that the well area can achieve stable production of over 2×10^8 m^3 for another 10 years.

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