Calculating control area and reserves of single well by triangulation method

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Abstract. The arithmetic average method is a conventional method to calculate the geological reserves. However, it ignores the influence of heterogeneity in the block, especially the faults. The calculated single well controlled reserves are often quite different from the actual status, which can’t guide the development actions accurately. Therefore, it is necessary to introduce a more accurate calculation method. The triangular network method introduced in this article can improve the accuracy when calculating the control area of single well in fault area, support to evaluate the control reserves of single well, and reflect the changes of geological reserves near each well point accurately.

1. Introduction
By calculating the control area of a single well near the fault, and then calculating the control reserves, the triangular network method can quantitatively refine the reserves distribution, which can lay the foundation for the remaining oil research and lower potential tapping.

2. Calculation method of control area of single well
In order to clarify the controlled reserves of single well around the fault and the controlled reserves of fault area, the breakpoints on the fault are treated and optimized in this article, and each fault is regarded as a virtual well point. When the triangulation network is constructed, the virtual well points also participate in the formation of the triangulation network, which can effectively analyze the controlled reserves of the breakpoints and intuitively describe the remaining oil situation at the edge of the fault.

The trigonometric network method is used to calculate the control area of single well in fault area. In this method, each injection production well and breakpoint are connected in turn through the point by point insertion algorithm, and the triangular network structure is constructed through the basic principle of triangular network, and then the midpoint of the connecting line between the well point and the adjacent well is taken, and then the outer center of the triangle connected with the well point (the obtuse angle triangle can take its center of gravity) is obtained, and the outer center and the midpoint are connected into a closed area, which is the well scope of control\[1-3\]. Refer to Figure 1.
When calculating the control reserves, there are still some geological reserves in the control range of the water injection well. Even if the water injection well does not produce oil, these reserves will flow in the process of water injection development, and can be recovered from the surrounding production wells. Therefore, when the central well is a water injection well, the control area of a single well of the water injection well needs to be split proportionally to each production well around the well, so as to ensure that all areas around oil and water wells participate in production. Accordingly, the following principle of well control area splitting is formulated:

a). When two adjacent wells are injection well and production well respectively, the control area of the wells on both sides of the oil-water well connection line needs to be split to the wells on the connection line. Refer to Figure 2.

Figure 2.Split diagram of control area of water injection well

Figure 2 is a schematic diagram of well control area splitting in a well control unit, in which L1 is the oil well, L2 is the well connected with L1 well, and the blue area is the control area of L1 well. According to the principle of area splitting, the brown area is the control area split by surrounding wells to L1 well, forming a single well control area.

b). When two adjacent wells both are water injection wells, it is necessary to divide the control area of wells on both sides of the connection line between wells to the adjacent wells.

c). When the water injection well in the area is a transfer well, if the well is still injected water in the production stage, it is necessary to regard the transfer well as a water well, and divide the geological reserves and production controlled by the transfer well to the adjacent oil wells. If the well stops injection in the production stage, its control area is divided to the adjacent oil wells, but it does not participate in the later reserves division.

For each breakpoint on the fault line, i.e. virtual well location, the calculation method of control area is the same as that of well point, and a triangular network is constructed together with the surrounding well points and breakpoints. In the early stage of development, there are few wells in the
fault area and the well location is far away from the fault. Therefore, the control area of single well in the fault edge area should be adjusted. Scaling the breakpoint and the control range of single well is more in line with the actual situation, and the calculation is more reasonable\cite{4-9}.

After the construction of triangulation network, the control area of well point is divided according to the attributes of the triangle well point, so as to determine the area of each small triangle in each well point and breakpoint control area, then the control area of a single well can be calculated by stacking all the small triangle areas\cite{10}. Refer to Formula (1).

\[
A = \sum_{i=1}^{n} A_i
\]  
\[
A_i \quad \text{— area of triangles around well point.}
\]

3. Calculation method of single well controlled reserves\cite{10}

After the control area of single well in fault area is calculated by triangle network method, the control reserves of each single well and breakpoint in the area are determined by volume method. Refer to Formula (2).

\[
N = Ah\omega_{\theta}
\]

\[
N—\text{Geological reserves of crude oil, } 10^4t; \quad A—\text{Oil bearing area, } km^2; \quad h—\text{effective thickness, m;}
\]

\[
\omega_{\theta}—\text{Single storage coefficient, } 10^4t/(km^2 \cdot m).
\]

After calculating the control area of single well in each sub layer in fault area by triangle network method, according to the reserve calculation parameters of main control well, the attribute parameters are interpolated and weighted average with the attribute values at triangle vertex, and then the control reserves of single well in each sub layer are calculated. The total reserves are the sum of the single well controlled reserves of each sub layer. Refer to Formulas (3), (4).

\[
N_i = \sum_{j=1}^{n} M_j \cdot A_i \cdot h_i
\]

\[
N = \sum_{i=1}^{n} N_i
\]

\[
N—\text{Geological reserves of crude oil, } 10^4t; \quad M—\text{Single storage coefficient}; \quad A—\text{Control area of single well and small layer, } km^2; \quad h—\text{Average effective thickness of single well, m.}
\]

4. Calculation method of single well controlled remaining reserves\cite{10}

Based on the controlled reserves and production of a single well in the fault area, the remaining reserves in the controlled area of a single well can be calculated, and then the remaining reserves can be subdivided according to the triangulation method, and finally the distribution of the remaining reserves can be obtained.

\[
N_i = N - Q
\]

\[
N_i—\text{Remaining reserves, } 10^4t; \quad N—\text{Geological reserves of crude oil, } 10^4t; \quad Q—\text{Cumulative oil production, } 10^4t.
\]

In the process of calculating the remaining reserves of a single well, it is necessary to split the controlled geological reserves of wells and the cumulative oil production of oil wells to ensure the accuracy of the calculation of geological reserves. Considering the effective thickness of oil layers, effective permeability, interlayer interference, distance between injection and production wells, connectivity and measures, a specific split formula is established. Refer to Formulas (5), (6), (7).

\[
R_j = \frac{K_i h_i C_i M_j / \ln d_j}{\sum K_i h_i C_i M_j / \ln d_j}
\]

\[
Y_j = K_i h_i l_j
\]
\[ I_j = \frac{K_j}{K_{\text{max}}} \]  \hspace{1cm} (7)

\( R_j \) - Split coefficient of geological reserves;
\( K_j h_j \) - Formation coefficient, Product of effective thickness and effective permeability;
\( C_j \) - Connectivity coefficient of oil and water wells, Let 1 be connected, 0 if not connected;
\( M_j \) - Oil well measure coefficient, 0 for water shutoff, Take 1 without fracturing, Take 2 fracturing measures;
\( d_j \) - Distance between oil and water wells, m;
\( I_j \) - Interlayer interference coefficient;
\( Y_j \) - Yield split coefficient, 10^4t.

According to the partition coefficient of well reserves, based on the established triangle network, the well reserves are split into the surrounding oil wells, and then the oil well production is split into the triangles of each small layer, so as to refine the distribution of the remaining reserves of a single well, and then guide the measures for the lower part of a single well.

5. Conclusion

Compared with the arithmetic average method, the triangulation method considers the heterogeneity of strata in the block, especially the influence of faults, when calculating the reserves of a single well. Its calculation results have been proved to be more accurate in practice, and it has more guiding significance for the formulation of measures for the lower part of a single well.

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