Estimation of the Regional Impact of Water-flood Reservoir*

YU Di[1,a], Song ShengYao[1,b]

[1] School of Electrical and Information Engineering, Northeast Petroleum University, Daqing Heilongjiang 163318, China;

[a]yudizlg@aliyun.com, [b]wojiushisong@163.com

Keywords: water-flooding; estimation of regional impact; ECLIPSE simulation

Abstract. Estimation of injection production relationship is discussed for multi-injectors and multi-producers of heterogeneous water-flood reservoir. The well pattern model is established and the definition of regional impact is proposed. In order to avoid the negative estimation parameter in the process of filtering, the optimal estimation of regional impact is obtained with modified extended KALMAN filter based on the oil field data. At last the results of ECLIPSE simulation research verify the effectiveness of proposed method for inverted nine spot well pattern within the river channel deposition in heterogeneous reservoir.

Introduction

As the world oil demand is increasing and the number of large oil fields found are declining, the importance of developed oilfield's economic and efficient exploitation is becoming more and more significant. Water flooding is currently the best comprehensive technical and economic mining method. Further improving the water flooding recovery is one of the important ways to keep water flooding oil production stable or slow down production decline. Water flooding management is a complex project involving many development activities, moreover, some activities are only once or twice in water flooding process, such as water flooding development design and well planning. However, there are a number of periodic activities, such as water quantity allocation of the injection wells. Successful water flooding management depends largely on the understanding of reservoir heterogeneity, According to water injection rate and oil production to determine the relationship between injection wells and production wells is an important method to infer the reservoir heterogeneity. Many scholars have gained many rich achievements[1-7] on the estimation of injection-production relationship in the case of multi injectors and single producer.

But a well pattern generally includes a group of injection wells and production wells, a region may be single or multiple well patterns. Flow rate change of an injection well has positive or negative effect on many oil wells. Therefore, effect of an injection well on a region may be more important than one on a single oil well. If the regional impact is obtained, better decision can be made to increase or decrease the water injection rate of a specific injection well so as to make the total crude oil production increase in the region. The optimal estimation of regional impact is obtained by Mendal[8,9] with extended KALMAN filter method in the case of multiple injectors and multiple producers. In order to avoid negative parameters in the process of filtering, Mendal[10] put forward the improved algorithm in the case of multiple injectors and single producer. In this paper, it will be extended to the case of multiple injectors and multiple producers, which not only avoids some practical difficulties in the process of the estimation of regional impact, but also is more close to the reality so as to enhance the applicability and practicality of the algorithm.

The paper is organized as follows, the model of reservoir is given in the case of multiple injectors and multiple producers. Then the improved filter algorithm is put forward. Furthermore, the validity

and effectiveness of the algorithm is verified using field measured data. Finally, the conclusion and future work directions are illustrated.

* The paper is supported by PetroChina Innovation Foudation (2012D-5006-0205) and Young Science Fund of Northeast Petroleum University in China.

The reservoir model of multiple injectors and multiple producers

The definition of regional impact

Based on the model of multiple injectors and single producer [8], the reservoir model of multiple injectors and multiple producers is obtained applying quasi reservoir method. Consider an example of injection wells and production well groups in an inverted nine spot well pattern, shown as in Fig.1. Four injection wells and five production wells are considered. The region impact of each injection well on the region around production wells is to be determined. The virtual injection-production relationship is represented by the dotted line between each injection well to regional production wells. Such reservoirs are defined as the virtual reservoir. The surrounding area of oil wells is defined as a quasi production well. Virtual channel is defined as a virtual reaction channel between injection well and quasi production well, which converts water injection rate into regional yield.

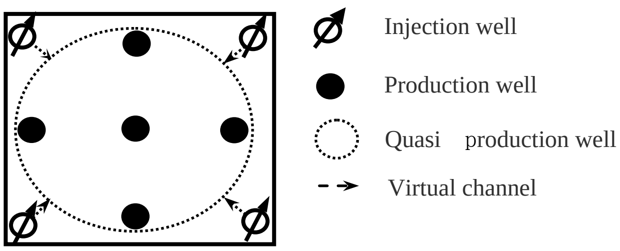

Fig. 1: Diagram of the relationship between the injection well and production well group

Without loss of generality, assume that there are N injection wells and M production wells, where N injection wells and each production well are seen as an independent subsystem. Therefore, the reservoir can be composed of M independent subsystems. Multiple production wells are considered as a region production well, then the actual reservoir model can be constructed as a virtual reservoir model, as shown in fig.2.

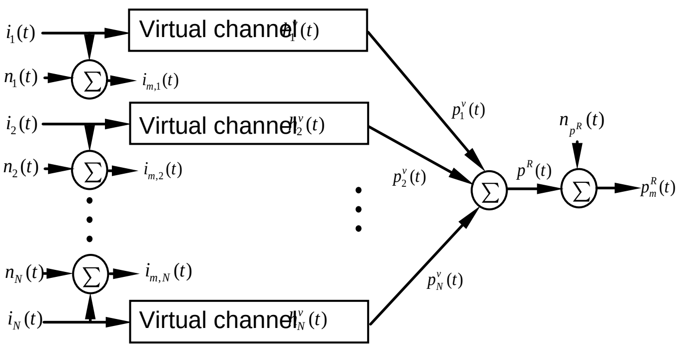

Fig.2: The virtual reservoir model with N injection wells and M production wells

Among them, $i_j(t)$ 、 $n_j(t)$ and $i_{m,j}(t)$ $(j=1,\cdots,N)$ are the actual water injection rate, the measurement noise and the measured water injection rate, respectively. Virtual channel $h_j^v(t)$ $(j=1,\cdots,N)$ considers influences of the channel function and the channel impulse response. Representation of Laplace transform to $i_j(t)$ by $I_j(s)$.Channel function $f(r_{j,l},k_{j,l})$ $(j=1,\cdots,N;l=1,\cdots,M)$ is linear or nonlinear scalar function of $r_{j,l}$ and $k_{j,l}$, where $r_{j,l}$ and $k_{j,l}$ are distance and permeability between the j injection wells and the l production wells, respectively. $f(r_{j,l},k_{j,l})$ is the decreasing function of $r_{j,l}$ and the increasing function of $k_{j,l}$; If the larger the values of $f(r_{j,l},k_{j,l})$, the connectivity between the injection and production well is better. Let $h_{j,l}(t)$ $(j=1,\cdots,N;l=1,\cdots,M)$ be a channel impulse response between the jth injection well and the lth production well, it can be used to model the continuous reaction channel between the jth injection well and the lth production well, $H_{j,l}(s)$ represents its Laplace transform. Then regional production can be given from fig.2,

$$P^R(s)=\sum_{l=1}^{M}\sum_{j=1}^{N}f(r_{j,l},k_{j,l})H_{j,l}(s)I_j(s)=\sum_{j=1}^{N}\{\sum_{l=1}^{M}f(r_{j,l},k_{j,l})H_{j,l}(s)\}I_j(s)=\sum_{j=1}^{N}H_j^v(s)I_j(s) \qquad (1)$$

Where $H_j^v(s)=\sum_{l=1}^{M}f(r_{j,l},k_{j,l})H_{j,l}(s)$ is the Laplace transformation of virtual channel between the jth injection well and regional production well, which can get from virtual pulse response $h_j^v(t)=\sum_{l=1}^{M}f(r_{j,l},k_{j,l})h_{j,l}(t)$. Let $p_j^v(t)$ is a virtual channel output generated by the jth injection well and the jth virtual channel, its Laplace transformation is $P_j^v(s)=H_j^v(s)I_j(s)$, thus the actual reservoir model can be expressed as

$$P^R(s)=\sum_{l=1}^{N}P_j^v(s)=\sum_{j=1}^{N}H_j^v(s)I_j(s) \qquad (2)$$

Let IP_j^R denote the region impact, it is similar to the injection production relationship,

$$IP_j^R=\frac{1}{T}\int_{t=0}^{\infty}h_j^v(t)dt\approx H_j^v(z)|_{z=1}=\sum_{l=1}^{M}f(r_{j,l},k_{j,l})H_{j,l}(z)|_{z=1}=\sum_{l=1}^{M}IPR_{j,l} \qquad (3)$$

The simulation research

Base on the above-mentioned definition of region impact and improved extended KALMAN filter[10], the inverted nine spot well pattern in river channel deposition hetero- geneous reservoir as shown in Fig.3.I1,I2,I3 and I4 denote four injection wells,P1,P2,⋯,P20 and P21 denote production wells. The distance from the injection wells to oil well of the edge is 500m.The red area is of high permeability channel deposition strip with permeability $5\mu m^2$.The blue area on both sides are edges of deposit with relatively low permeability with permeability $1\mu m^2$.The thick- ness of the stratum is 10m. The injection rate is 200m3/day, water injection well is suddenly closed in the 500th day.

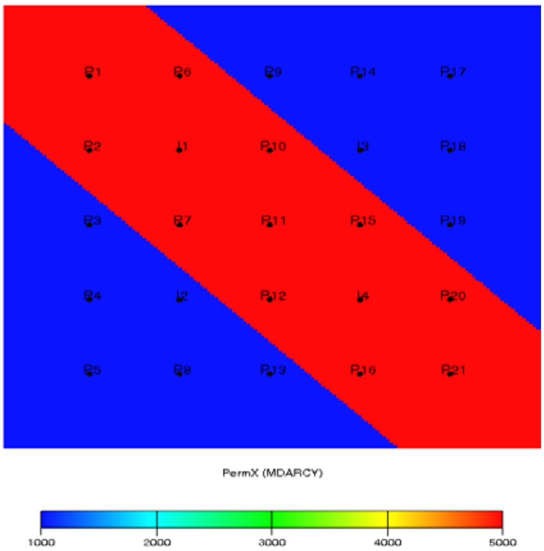

Fig.3: The inverted nine spot well pattern in river channel deposition heterogeneous reservoir

Based on ECLIPSE simulation data,the mean curve of the estimation of regional impact is shown in Fig.4. It can be seen the estimation method can fast track the regional impact change.The simulation results show that the proposed method is effective and feasible for estimation of regional influence.

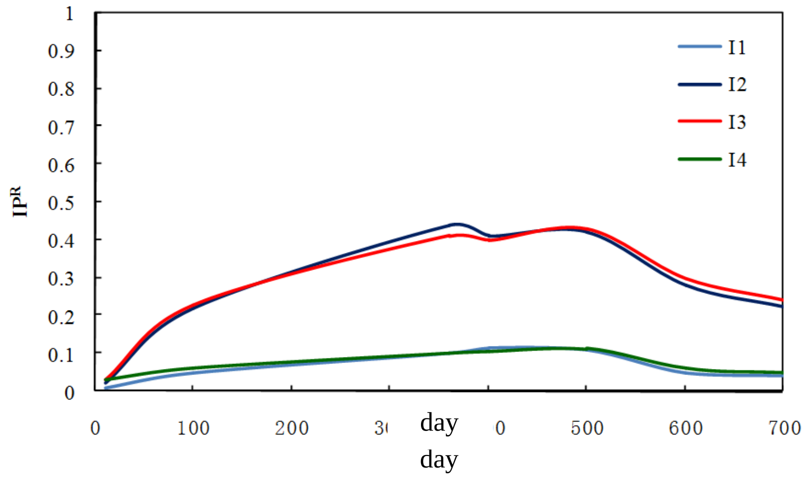

Fig.4 : Mean curve of the estimation of regional impact

Conclusion

The regional effects is considered for multi-injector and multi-producer of heterogene-ous water-flood reservoir.It is estimated using modified extended KALMAN filter method and quasi reservoir method. In view of inverted nine spot well pattern within the river channel deposition in heterogeneous reservoir, the regional impact is estimated based on simulation research data of ECLIPSE. The simulation results are consistent with the distribution of flow of streamline simulation. Obviously, the proposed method can effectively help engineer a better understanding of the regional reservoir heterogeneity.

References

[1] Alejandro Albertoni and Larry W. Lake, Inferring Interwell Connectivity only from Well-Rate Fluctuations in Waterfloods[C]. SPE 83381, 2003.

[2] A. A. Yousef, P. Gentil, J. L. Jensen et al.. A Capacity Model to Infer Interwell Connectivity from Production and Injection Rate Fluctuations[C]. SPE 95322, 2005.

[3] D.Zhai, J.M.Mendal,F.Liu.Robust Production-Rate Interpolation inWaterflood Management [C]. in SPE Western Regional Meeting, California, SPE 153896, May 2012.

[4] M. Sayarpour, E. Zuluaga, C. S. Kabir et al.. The Use of Capacitance-Resistive Models for Rapid Estimation of Waterflood Performance and Optimization[C]. SPE110081, 2007.

[5] M. Sayarpour, Development and Application of Capacitance-Resistive Models for Water/CO2 Floods[D]. the University of Texas at Austin, Austin, Texas, 2008.

[6] Weber D., Edgar, T. F., et al.. Improvements of Capacitance Resistive Modeling and Optimization of Large Scale Reservoirs[C]. SPE121299, 2009.

[7] Yousef, A. Y. and Lake L. W., A Capacitance Model to Infer Well Connectivity from Production and Injection Rate Fluctuations[J], SPE Reservoir Evaluation & Engineering, Dec 2006.

[8] F.Liu,J.M.Mendal,A.M.Nejad.Forecasting Injector-Producer Relationships from Production and Injection Rates Using an Extended Kalman Filter[C], in SPE Annual Technical Conference and Exhibition,Anaheim,2007, SPE110520.

[9] F.Liu,J.M.Mendal,A.M.Nejad.Forecasting Injector-Producer Relationships from Production and Injection Rates Using an Extended Kalman Filter[J], 2009,14(4):pp.653-644.

[10]D.Zhai, J.M.Mendal,F.Liu. A New Method for Continual Forecasting of Interwell Connectivity in Waterfloods Using an Extended KALMAN Filter [C], in SPE Western Regional Meeting, San Jose, SPE 121393, March.