

COMPARATIVE ANALYSIS OF METHODS FOR ASSESSING THE EFFECTIVENESS OF GEOLOGICAL AND ENGINEERING OPERATIONS

*Boris Ivanenko and Alexander Petelin*¹

National Research Tomsk State University, 634050, Tomsk, Russian Federation

Abstract. The paper presents a comparison of the methods for assessing the baseline oil production level based on the use of nonparametric statistics, integral and differential models, and neural network algorithms.

1 Introduction

As is known, geological and engineering operations (GEO) are directed methods of influencing the development of a field for the purpose of increasing the oil production. Depending on the action mechanism and the action object, the diversity of GEO can be divided into several groups: methods of oil production intensification, physicochemical methods, hydrodynamic methods, and gas methods.

GEOs are considered to be the most effective with the smallest discrepancy between the actual and basic (calculated) indicators that would be characteristic for the baseline level of the object development, i.e. the method used before the performance of GEO. Construction and further support of a special hydrodynamic model of the field can be used to calculate the baseline oil production level and assess the effectiveness of geological and engineering operations. However, this approach, in addition to substantial economic costs, requires special training of specialists in the area of physical process modeling. In other words, it is practically not suitable in production conditions when solving operational problems of optimization of the field development system.

2 Methods for forecasting the baseline oil production

The following methods for forecasting the baseline oil production level are common in modern practical oilfield geology [1, 2]:

- displacement characteristics (integrated models);
- decline curves (differential models).

Both methods are based on the regression analysis and are designed to forecast operational characteristics of oil production.

¹ Corresponding author: aepetelin@gmail.com

Displacement characteristics are used in the event if the development of oil wells is carried out by means of waterflooding. A reliable and a long-term forecast of oil production characteristics can be implemented only when the rate of change in the water cutting of oil wells is stabilized. It is believed that stabilization occurs at water cutting of more than 70%. At water cutting values from 50% to 70%, only a short-term forecast is possible. For values below 50%, the forecast cannot be consistent.

Decline curves are used when the depletion mode is the main method of developing oil wells, allowing to characterize the dynamics of decline in oil production rates.

Today, more than 70 kinds of displacement characteristics and decline curves are known. The forecast model of the baseline oil production level is selected based on the field description and the modeling purpose. The type of dependence is determined empirically [1].

3 Artificial neural networks

Methods of information simulation or mathematical modeling of processes and phenomena become relevant when assessing the baseline oil production level and the efficiency of geological and engineering operations. Artificial neural networks (ANN) is a convenient and a natural way of recording information models.

Information models can also be built on the basis of nonparametric statistics methods [2]. However, in practice neural network models are more preferable due to the low cost, the impossibility of obtaining a sufficient amount of experimental data, often high noise, and inconsistency of experimental methods.

An ANN can be quite formally defined as a set of neurons (simple processor elements with local functioning) and synapses (unidirectional links). An INS receives an input signal from the outside world. The signal passes through a network with transformations in each processor element. The signal is converted into certain output data when it passes through network connections. As is known, the neural network formulation of the problem consists of several stages:

1. Statement of the problem.
2. Selection of the algorithm for training the network and its architecture.
3. Construction of training samples. The following is used to create training samples:
 - 1) information from databases of the field development history, physical and chemical properties of fluids, geological and hydrodynamic characteristics of formations, etc.;
 - 2) the results of numerical modeling of processes and phenomena occurring in reservoirs.
4. Training and testing of the network.
5. Execution of the algorithm, obtaining of the result, and the analysis of the obtained data.

To determine the structure and the composition of the training sample fields for various input parameters (signals) of a neural network with their further detailing, the input signals are classified into the following groups:

- time and frequency of information selection (selected training period and dates of measurement taking);
- characteristics of injection wells (coordinates, operating time and number of wells, intake, injection volume, etc.);
- characteristics of production wells (well production volume, fluid extraction volume, well production rate, well operation time, location of producing wells, etc.);
- equipment parameters (pump capacity, pump immersion depth, etc.);
- geological and hydrodynamic characteristics of the formation (formation pressure, permeability, bottomhole pressure, dynamic level, porosity, etc.).

It is obvious that building of training samples is essential when solving problems of oilfield geology: determination of their composition and structure and division into subsets –

training and verification. In [3] it is proposed to conditionally divide them into two types – samples with a vertical and a horizontal structure (depending on the type of tasks being solved).

Before proceeding to the discussion of practical results, we shall note that the framework of this paper will not include the issue on the selection of a network architecture and algorithms for its optimization and training. It shall be noted that on the basis of our earlier studies [3], this paper will include only universal, multi-layer neural networks trained using the method of "back propagation" and linear neural networks.

The task of assessing the baseline production level in a neural network setting is the classical forecast problem, therefore, it cannot be separated into a separate class of problems. The difference is only in the method of specifying the appropriate parameters of the neural network model in the forecast period and the selection of the training period for the network, or the base interval. In practice, it is recommended to resort to two approaches of specifying forecast parameters of the model.

In the first case, the input of the trained neural network for the forecast period consists of some average characteristics of oil production obtained from the history of the formation development for the baseline interval. This approach is justified for short-term forecasts (in which the extraction dynamics is determined only by the rate of fluid extraction and the injection modes and, above all, the operation time of wells). In this case, it is enough to limit oneself to setting some constants for the forecast period, i.e. the average time of the well operation, the average fluid extraction, etc.

In the second case, when we are faced with a pronounced tendency to a decline or to an increase in the characteristics of oil production, it is recommended during the training period to construct regression curves for the corresponding engineering characteristics of each well (production rate, injectivity...), to prolong them for the forecast period and to submit to the input of the existing neural network that has been trained. These two methods are particularly effective in assessing the cumulative baseline production level simultaneously for several wells or for the entire field.

3 Analysis of the methods for assessing the effectiveness of geological and engineering operations

It is possible to do the same when solving the tasks of assessing the baseline oil production level for one well.

We shall consider two selected cells 2.2 and 3.2 of the formation U32 of the Severo-Vakhskiy deposit as an object of study (Figure 1). The total number of wells for two selected cells is 31. 18 of them are producing and 13 are injection wells. The data were collected from 01.01.1997 to 01.10.2000, i.e. over 58 months. Information content: current time, average monthly production and injection volumes, operating time and downtime, penetration depth of pumps.

GEOs, such as pump penetration and formation hydrofracturing (FHF) with simultaneous almost threefold increase in injection volumes, which significantly complicates the construction of the neural network model, were carried out in the period under the investigation in wells 1021, 1022, 1030 of the cell 2.2 (hereinafter referred to as intensified wells). Moreover, the complexity of building a neural network model is conditioned upon the presence in the database of a significant number of gaps and the lack of accurate data on the geological structure of the oil formation.

The calculations were carried out using a PC SNN and NeuroPro [4–6], developed using object oriented programming similar to [7]. Operating hours of production wells, time of information selection, well coordinates, submergence depth of the pumps, and liquid

calculated from the displacement characteristics, has a clearly pronounced tendency to increase, which in fact should not be the case.

Figure 3 presents the comparison results of neural network and non-parametric methods for estimating the baseline production level (taking into account the injection). The data on the injectivity of injection wells was specified in the training sample. It is easy to see that, in general, the results coincide quite well. Moreover, unlike conventional methods and methods of non-parametric statistics, the neural network methods have higher resolution capabilities and are capable to quickly solve the task of forecasting the baseline production level not only for several wells at the same time, but also for specific wells for any degree of flooding with a minimal set of input data.

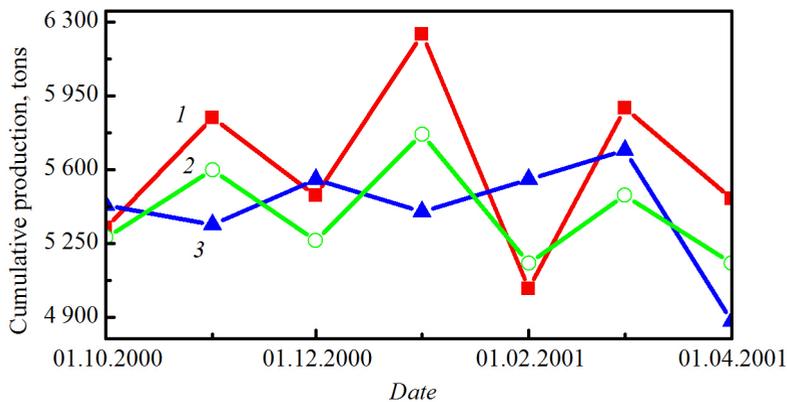


Fig. 3. Example of calculating the baseline level of the total oil production using various methods, taking into the account the injection: 1 (red line) – cumulative production; 2 (green line) – neural network forecast with injection; 3 (blue line) – forecast using the nonparametric statistics method.

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