Parallel Computing in Optimal Design of Development of Multilayer Oil and Gas Fields

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Abstract: In this paper we consider problems of optimization and selection of development systems (technologies) of oil/gas fields, consisting of some disjoint oil/gas pools (in terms of hydrodynamics), tied by resource constraints or general oil/gas production plan. In order to solve these problems, formulated as MILP models, we have developed approximate algorithm using Lagrangian relaxation (see Mikhalevich V.S. and Kouksa A.I., 1983). Initially we consider the problem for oil fields and then for gas fields. Contrary to another models and techniques, used for solving the similar problems, our models and algorithms allow us to coordinate allocation of production volumes and reserves among the pools with selection of optimal development system, as well as optimization of technological parameters for each pool. We have also examined the perspective approaches, using both multilevel decomposition of oil reservoirs, and hierarchical splitting, and parallel computing on supercomputer for developing effective problem-solving procedures.

Keywords: Selection of development system, reservoir engineering, optimization, optimal allocation of scare resources, group of oil and gas pools, Boolean variables.

1. INTRODUCTION

In this paper we consider a pre-design stage of feasibility study of several oil (gas) pools development bounded by either scare resources or requirements on total production. The analysis and optimization of interrelated pools development is required when the pools belong to the same oil-and-gas producing company, for example. For this reason the company is interested to obtain the best results for not only a single pool but the whole group of pools. In that case one should choose the most effective field development system (reservoir engineering) for feasibility study, optimize process variables for each pool and allocate resources among several oil/gas pools.

Different technologies with various process variables values in different environmental conditions require different resource costs and provide various production levels. Therefore on the one hand you will be able to choose rational technologies only if you know process variables values of each pool, on the other hand the selection of optimal process variables values of each pool is available only if we know resources allocation for each pool and reservoir engineering. This means that resources volume, process variables values and numbers of chosen reservoir engineering technologies, i.e. basic characteristics, defining options of fields' development, should represent the components of a vector, which is a solution of the common optimization problem.

At present, the used algorithms of generation and selection of oil/gas pools group development methods do not meet the abovementioned requirements. They are only used to define optimal process variables values for each oil/gas pool at the given technologies allocation or optimal technologies allocation at the given process variablesvalues for each pool. That results in selection of development options with low performance indicators.

Hereafter we propose an approach based on mixed-integer programming models and methods, which is free of stated deficiencies. The approach's possibilities are shown by solving two problems related to generation of pre-design options of hydrocarbon accumulation development that allows proceeding to the stage of feasibility study for field development.

2. OPTIMAL PRODUCTION OF GROUP OF OIL POOLS

The problem of optimization and selection of reservoirs engineering when a total production plan of the whole group of oil pools is given will be considered. In this context the common resource constraint means the total volume of cumulative oil production of all pools, where pools are oil-bearing formation of multilayer field exploited separately.

We review the strategy of oil pools development that corresponds to constant drainage from formation per unit time. For each pool the list of initial preliminary options of development is assumed to be defined. These options include partial sets of technological parameters and differ from each other by field and intake wells outputs, their number and relative positioning (arrangement of wells and flooding pattern), i.e. defined by oil-reservoir engineering. Therefore, for the j-th oil pool, $j=\overline{1,J}$, the i-th option (technology), $i=\overline{1,I}$, is the set of $\{m_{ij}, n_{ij}, q_{ij}^{\mathrm{o}}, q_{ij}^{\mathrm{w}}\}$, where m_{ij} is the number of field wells, n_{ij} is the number of intake wells, q_{ij}^{o} is the debit of a field well, q_{ij}^{w} is the debit of an intake well. We assume that wells production rates, their amount, and position for each option have been chosen with regard to wells interference. We will consider the water drive of pool drainage, wherein the balance is realized:

$$m_{ij} q_{ij}^{0} = n_{ij} q_{ij}^{\mathrm{w}} \ . \qquad (1)$$

We will consider the situation that have been analyzed by Ermolaev (2001), when it should be taken into account that Backley-Leverett function $-f(\cdot)$,defining a part of oil in produced fluid, could depend not only on the cumulative oil production ($Q(t)$) in a period $[0,t]$, but on the number and arrangement of the wells. Then the aggregated model of the j-th oil pool development using the i-th option looks like

$$dQ_j / dt = q_j^l(t) f_{ij}(Q_j(t)), 0 \le Q_j(t) \le Q_{ijk}, Q_j(0)=0, \quad (2)$$

where $q_j^l(t)$ is the drainage per time unit from the j-th oil pool (total debit of all field wells equals to total chemical injection of all intake wells); $Q_j(t)$ is the cumulative oil production of the j-th oil pool in a period $[0,t]$; Q_{ijk} is the maximum possible oil production and $f_{ij}(Q_j(t))$ is a part of oil in produced fluid on the j-th oil pool development when using the i-th option.

We will use the minimum value of cumulative fluid production of all pools as a criterion of optimality. We chose this criterion as a criterion of efficiency because generally the minimum value of fluid production is equal to the minimum operation costs of oil production. Besides, the using of this method does not require recognizing of the economic standards, which are usually very difficult to obtain. As mentioned above the overall constraint, binding oil pools is the cumulative oil production of all wells. In consideration of these remarks we will formulate the task of optimization and selection of development systems as follows: to find such oil and fluid production volume, establish field development term and option for each accumulation of the group, which will provide minimum value of total fluid production from all pools provided that the total oil production requirements are fulfilled.

In order to formulate the problem mathematically we will introduce the following symbols. Let Q be the cumulative oil production task order of all oil pools, moreover

$$Q \le \sum_{j=1}^{J} \min_i \{Q_{ijk}\} .$$

Let $Q_j(t)$ be cumulative oil production volume for a period $[0,t]$ at j-th pool, $Q_j(0)=0$, and $f_{ij}(Q_j)$ – part of oil in produced fluid during development of j-th pool using i-th option.

Let us introduce required variables: T_j is the term of the j-th oil pool development; x_j is the fluid withdrawal from the j-th pool during a period of its development; $z_j = Q_j(T_j)$ is the cumulative oil production volume of the j-th pool during a period $[0,T_j]$. Besides these continuous variables $z_j, x_j, T_j \ (j=\overline{1,J})$, let us introduce some Boolean variables:

$$y_{ij} = \begin{cases} 1, \text{ if for the } j\text{-th oil pool was set the } i\text{- th option,} \\ 0, \text{ if otherwise.} \end{cases}$$

Now, in consideration of the expansions given in (2) our task takes the form of:

$$\sum_{j=1}^{J} x_j \to \min_{x,y,z} \qquad (3)$$

$$\sum_{j=1}^{J} z_j \ge Q \qquad (4)$$

$$dQ_j / dt = (x_j / T_j) \sum_{i=1}^{I} y_{ij} f_{ij}(Q_j), Q_j(0)=0, \ j=\overline{1,J} \qquad (5)$$

$$\sum_{i=1}^{I} y_{ij} = 1, \ j=\overline{1,J} \qquad (6)$$

$$z_j = Q_j(T_j), \ z_j \le \sum_{i=1}^{I} y_{ij} Q_{ijk}, \ j=\overline{1,J}, \qquad (7)$$

$$x_j \ge 0, \ y_{ij} \in \{0,1\}, i=\overline{1,I}, \ j=\overline{1,J}. \qquad (8)$$

Formulas (3)-(8) allow expressing variables x_j by other variables:

$$x_j = \int_0^{z_j} dz / \sum_{i=1}^{I} y_{ij} f_{ij}(z) = \sum_{i=1}^{I} y_{ij} \int_0^{z_j} dz / f_{ij}(z) . \quad (9)$$

Let us set:

$$\Psi_{ij}(z_j) \equiv \int_0^{z_j} dz / f_{ij}(z) \qquad (10)$$

Then taking into account (6), (8)-(10), and that $f_{ij}(z) \ge 0$, if $z \ge 0$, the original task (3)-(8) takes the form of:

$$\sum_{j=1}^{J} \sum_{i=1}^{I} y_{ij} \Psi_{ij}(z_j) \to \min_{y,z} \qquad (11)$$

$$\sum_{j=1}^{J} \sum_{i=1}^{I} y_{ij} z_j \ge Q \qquad (12)$$

$$\sum_{i=1}^{I} y_{ij} = 1, \ j=\overline{1,J} \qquad (13)$$

$$0 \le z_j \le \sum_{i=1}^{I} y_{ij} Q_{ijk}, \ y_{ij} \in \{0,1\}, i=\overline{1,I}, \ j=\overline{1,J}. \ (14)$$

In order to find an approximate solution of the problem (11)-(14) the algorithm that was developed by Ermolaev (2001) could be used. The detailed description and argumentation of this algorithm is shown in Ermolaev's investigation (2001).

So for a n-th iteration following manipulations should be done.

1. For each pair of indexes «i,j» there is a need to solve the problem with strictly convex function (because $f_{ij}(\cdot)$ is the decreasing function)

$$\varphi_{ijn}(z_j) \equiv \psi_{ij}(z_j) - \xi_n z_j \to \min \qquad (15)$$

and with the following constraint:

$$0 \le z_j \le Q_{ijk}. \qquad (16)$$

The function $\psi_{ij}(z_j)$ is expressed by (10), and $\xi_n \ge 0$ is the value of penalty coefficient (Lagrangian multiplier) for the n-th iteration (a selection of ξ_n is stated later). The problem (15)-(16) should be solved for each index j, i.e. for each oil pool separately, and for each index i. Let s_{ijn} be the optimal solution of (15)-(16). Then

$$s_{ijn} = \begin{cases} 0, & z_{ij}^{o} < 0, \\ z_{ij}^{o}, & 0 \le z_{ij}^{o} \le Q_{ijk}, \\ Q_{ijk}, & z_{ij}^{o} > Q_{ijk}, \end{cases}$$

where z_{ij}^{o} is a root of the equation

$$1 - \xi_n f_{ij}(z_{ij}^{o}) = 0.$$

In the problem Lagrangian multiplier means a variable inversely related to part of oil in produced fluid. It follows from the last equation. As $f_{ij}(\cdot)$ is decreasing function if ξ_n increases, then z_{ij}^{o} increases, as well as s_{ijn} increases. Therefore increasing of ξ_n will result in (12) constraint satisfaction.

2. The set of variables $\{y_{ijn}\}$ is defined, where $\{y_{ijn}\}$ is the n-th approximation of an optimal resolution in Boolean variables:

$$y_{ijn} = \begin{cases} 1, c_{ijn} = \min\limits_{1 \le l \le I}\{c_{ljn}\}, \\ 0, c_{ijn} = \min\limits_{1 \le l \le I}\{c_{ljn}\}, \end{cases}$$

where

$$c_{ljn} \equiv \varphi_{ljn}(z_{ljn}), l \in \{1, \ldots, I\}, j = \overline{1, J}, n = 1, 2, \ldots$$

If there are several c_{ijn} in the j-th column of the matrix $\{c_{ljn}\}_{I \times J}$, for which $c_{ijn} = \min\limits_{1 \le l \le I}\{c_{ljn}\}$, then one of them will be taken as a minimum element of the j-th column of the matrix $\{c_{ljn}\}_{I \times J}$, e.g. conformable to the $\psi_{ij}(z_{ijn})$ minimum. It is made to satisfy the (13).

3. Variables z_{jn} are defined, where z_{jn} is the n-th approximation in continuous variables:

$$z_{jn} = \sum_i y_{ijn} s_{ijn}, j = \overline{1, J}.$$

4. The constraint (4) satisfaction is verified for the set of $\{z_{in}\}$. If the constraint has been satisfied it is necessary to proceed to the point 5 of the algorithm, otherwise proceed to the point 6.

5. The optimum condition satisfaction is verified for permissible solution $\{z_{ijn}, y_{ijn}\}$:

$$(d_n - Q)\xi_n = 0, \qquad (17)$$

where

$$d_n \equiv \sum_{i=1}^{I} \sum_{j=1}^{J} y_{ijn} z_{ijn}.$$

If equality (17) is valid, then, according to the Mikhalevich and Kuksa work, (1983) the sets $\{z_{ijn}, y_{ijn}\}$ appears to be the optimal resolution of (11)-(14). And all the computing operations should be finished. Otherwise it is needed to proceed to the point 6.

6. The value of penalty coefficient ξ_{n+1} is defined using the rule proposed by Mikhalevich (1983):

$$\xi_{n+1} = \max\{0, \xi_n + \theta_{n+1}(Q - d_n)\},$$

where

$$\lim_{n \to \infty} \sum_n \theta_n = \infty, \theta_n > 0, \theta_n \to 0.$$

Then put $n \equiv n+1$ and return to the point 1. Besides optimum condition satisfaction there is another rule of stopping the iteration procedure, i.e. satisfaction of inequality for admissible decision $\{z_{jn}, y_{jn}\}$:

$$|F_n - F_{n-1}| \le \varepsilon, \quad \varepsilon > 0,$$

where F_n and F_{n-1} are the values of the target function (11) on the n-th and $(n-1)$-th iterations.

Thus, let us assume that the optimal (or approximate) solution of (11)-(14) is found and identified by means of the $\{z_j^*\}, \{y_{ij}^*\}$ sets. Then m_j^*, n_j^*, q_j^o, q_j^w are defined from following formulas:

$$m_j^* = \sum_{i=1}^{I} y_{ij}^* m_{ij}^*, \quad n_j^* = \sum_{i=1}^{I} y_{ij}^* n_{ij}^*,$$

$$q_j^o = \sum_{i=1}^{I} y_{ij}^* q_{ij}^o, \quad q_j^w = \sum_{i=1}^{I} y_{ij}^* q_{ij}^w,$$

where m_j^* is the number of field wells, n_j^* is the number of intake wells, q_j^o is the debit of a field well, q_j^w is the debit of an intake well for the j-th oil pool.

The fluid production volume x_j^* during the j-th oil pool development period is defined by (9):

$$x_j^* = \sum_{i=1}^{I} y_{ij}^* \int_0^{z_j^*} dz / f_{ij}(z).$$

Then the j-th oil pool development period is defined by the formula (see (1)):

$$T_j^* = x_j^* / m_j^* q_j^o = x_j^* / n_j^* q_j^w.$$

Using obtained values $m_j^*, q_j^w, j = \overline{1, J}$ we can plot the correspondence $Q_j(t)$, i.e. cumulative oil production versus time for each oil pool. Thus it is necessary to solve the differential equation similar to (2) using one of the known analytic or numerical approaches:

$$dQ_j / dt = q_j^l(t) f_j(Q_j(t)) \text{ at } t \in \left[0, T_j\right],$$

considering the following assumptions:

$$Q_j(0) = 0, Q_j(t) \le Q_{jk},$$

where

$$q_j^l(t) = m_j^* q_j^o,$$

$$f_j(Q_j(t)) = \sum_{i=1}^{I} y_{ij}^* f_{ij}(Q_j(t)),$$

$$Q_{jk} = \sum_{i=1}^{I} y_{ij}^* Q_{ijk}.$$

Moreover we can plot the $q_j^o(t)$, i.e. the total oil production of all field wells versus time that defined as (see (2)):

$$q_j^o(t) = q_j^l(t) f_j(Q_j(t)).$$

Thus the solution of (3)-(8) allows both to select an optimal development option for each oil pool, and to define rational values of oil and fluid production volumes over the whole period and each year of pool development period. It results in increasing of quantity of the initial design information and helps to make more well-grounded decisions while choosing the development systems of oil pools group.

3. OPTIMAL PRODUCTION OF GROUP OF GAS POOLS

We will consider the applicability of proposed algorithms for solving problems of optimization and selection of gas pools development systems. We will use the total gas production volume of all pools over the planned period T as a criterion of optimality of development systems. And we will use the constraint on allowable total costs – b, required for all gas pools developing over the planned period, as a resource constraint tieing the pools with each other.

As for the previous problem we will assume that for each gas pool the list of initial preliminary options of development (reservoir engineering) is defined. These options include partial sets of technological parameters, and differ from each other by a value of maximum permissible differential pressure drawdown (in absolute or relative terms), a minimum permissible well-head pressure, and a tubing size, i.e. they differ by used borehole equipment. There are no intake wells, what is typical for gas fields development.

We will formulate the task as follows: to find such gas production volume, amount of wells and option of development for each gas pool, which will provide the maximum value of total gas production of all gas pools over a planned period provided that the constraint on admissible total costs is satisfied.

Let us introduce the following notation. Let z_j be the j-th pool ultimate gas recovery, $j = \overline{1, J}$, x_j be the j-th pool number of wells, x_j is constant (the momentary bringing in a well is considered);

$$y_{ij} = \begin{cases} 1, & \text{if for the } j\text{-th gas pool was set the } i\text{- th option,} \\ 0, & \text{if otherwise.} \end{cases}$$

Let us introduce the following initial parameters notation. Let V_j be the j-th pool gas reserves; η_{ijk} is the j-th pool limit value of an ultimate gas recovery when the i-th option is chosen.

We will assume that the j-th gas pool development cost when the i-th option is chosen is a linear dependence:

$$g_{ij}(x_j) \equiv (\alpha_{ij}^b + \alpha_{ij}^o T) x_j + \beta_{ij},$$

where α_{ij}^b is a well construction cost, α_{ij}^o is a well servicing cost in a unit time when for the j-th pool development the i-th option is chosen, β_{ij} is fixed costs independent of number of wells.

We will assume that

$$\sum_{j=1}^{J} \max_i \{\beta_{ij}\} < b.$$

Put $\alpha_{ij} \equiv \alpha_{ij}^b + \alpha_{ij}^o T$. We will suppose that wells interference could be neglected. Such assumption is quite reasonable at the pre-design stage when there is wide well spacing in gas fields. As a gas pool development simulation model we can use the aggregated model, proposed by Ermolaev (2001) similar to (2):

$$V \frac{\partial \eta_j}{\partial t} = x_j q_{ij}\left(\eta_j(t)\right), \quad 0 \le \eta_j(t) \le \eta_{ijk}, \quad \eta_j(0) = 0,$$

where $\eta_j(t)$ is current value of a gas recovery of the j-th pool, $q_{ij}\left(\eta_j(t)\right)$ is a well debit versus gas recovery when for the j-th pool development the i-th option is chosen (see Ermolaev's paper (2001) for this function).

If the number of wells possesses great values, we may omit the integrality condition for x_j and replace it by the inequation $x_j \ge 0$. Then the mathematical formulation of the problem takes on the following form:

$$\sum_{j=1}^{J} V_j z_j \to \max_{x,y,z} \tag{18}$$

$$\sum_{j=1}^{J} \sum_{i=1}^{I} (\alpha_{ij} x_{ij} + \beta_{ij}) y_{ij} \le b, \tag{19}$$

$$V_j d\eta_j / dt = x_j \sum_{i=1}^{I} q_{ij}(\eta_j(t)) y_{ij}, \eta_j(0) = 0, \tag{20}$$

$$\sum_{i=1}^{I} y_{ij} = 1, j = \overline{1, J}, \tag{21}$$

$$z_j = \eta_j(T), 0 \le z_j \le \sum_{i=1}^{I} y_{ij} \eta_{ijk}, j = \overline{1, J} \tag{22}$$

$$x_j \ge 0, y_{ij} \in \{0,1\}, i = \overline{1, I}, j = \overline{1, J}. \tag{23}$$

We will express x_j through other decision variables using (20) and (21), (23):

$$x_j = \frac{V_j}{T}\int_0^{z_j}\frac{d\eta}{\sum_{i=1}^{I} y_{ij}q_{ij}(\eta)} = \frac{V_j}{T}\sum_{i=1}^{I} y_{ij}\int_0^{z_j}\frac{d\eta}{q_{ij}(\eta)}. \quad (24)$$

Put the (24) into the (19):

$$\sum_{j=1}^{J}\sum_{i=1}^{I}\left\{\alpha_{ij}\frac{V_j}{T}\left[\sum_{m=1}^{I} y_{mj}\int_0^{z_j}\frac{d\eta}{q_{mj}(\eta)}\right]+\beta_{ij}\right\}y_{ij} \le b. \quad (25)$$

Modify the obtained formula:

$$\sum_{j=1}^{J}\sum_{i=1}^{I}\left\{\alpha_{ij}\frac{V_j}{T}\left[\sum_{m=1}^{I} y_{mj}\int_0^{z_j}\frac{d\eta}{q_{mj}(\eta)}\right]+\beta_{ij}y_{ij}\right\} \le b.$$

From the (21) imposed on Boolean variables it follows

$$y_{ij}y_{mj} = \begin{cases}1, & m = i\\ 0, & m \ne i.\end{cases}$$

Therefore the (25) may be modified as follows:

$$\sum_{j=1}^{J}\sum_{i=1}^{I}\left\{\alpha_{ij}\frac{V_j}{T}\left[\int_0^{z_j}\frac{d\eta}{q_{ij}(\eta)}\right]+\beta_{ij}\right\}y_{ij} \le b \quad (26)$$

Put

$$\psi_{ij}(z_j) \equiv \alpha_{ij}\frac{V_j}{T}\left[\int_0^{z_j}\frac{d\eta}{q_{ij}(\eta)}\right]+\beta_{ij}. \quad (27)$$

In view of (21), (23), (24), (26), (27) the original task (18)-(23) takes the following form:

$$\sum_{i=1}^{I}\sum_{j=1}^{J} y_{ij}V_{ij}z_j \to \min_{z,y} \quad (28)$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} y_{ij}\psi_{ij}(z_j) \le b \quad (29)$$

$$\sum_{i=1}^{I} y_{ij} = 1,\ j = \overline{1,J}, \quad (30)$$

$$0 \le z_j \le \sum_{i=1}^{I} y_{ij}\eta_{ijk},\ j = \overline{1,J}, \quad (31)$$

$$y_{ij} \in \{0,1\},\ i = \overline{1,I},\ j = \overline{1,J}. \quad (32)$$

The abovementioned algorithm can be used in order to solve the obtained task (28)-(32). It should be slightly modified due to the fact that a maximum is to be found and there is a sign "≤" instead of "≥" in the binding constraint (29). It should be mentioned that implementation of the 1-st item leads to solving the problem for each pair of indexes «*i,j*» where a target function is strictly concave (since $q_{ij}(\cdot)$ is a decreasing function):

$$\varphi_{ijn}(z_j) \equiv V_j z_j - \xi_n\psi_{ij}(z_j) \to \max \quad (33)$$

$$0 \le z_j \le \eta_{ijk}, \quad (34)$$

where $\xi_n \ge 0$ is the penalty coefficient value (Lagrangian multiplier) for a n-th iteration.

Let s_{ijn} be an optimal solution of (33), (34). Then s_{ijn} will be defined by the formula:

$$s_{ijn} = \begin{cases}0, & \eta_{ij}^{o} < 0,\\ \eta_{ij}^{o}, & 0 \le \eta_{ij}^{o} \le \eta_{ijk}\\ \eta_{ijk}, & \eta_{ij}^{o} > \eta_{ijk}\end{cases}$$

where η_{ij}^{o} is a root of the equation

$$Tq_{ij}(\eta_{ij}^{o}) - \xi_n\alpha_{ij} = 0.$$

Since $q_{ij}(\cdot)$ is a decreasing function, according to the last equation, η_{ij}^{o} and s_{ijn} decreases as ξ_n increases. Therefore increasing of ξ_n in the result will lead to the (29) constraint satisfaction. Thus we may adjust the solution of (28)-(32) for the situation where bringing in well is not momentary. For example, let the number of wells of the *j*-th gas pool versus time ($x_j(t)$) be described by the following functional relation:

$$x_j(t) = \begin{cases}tx_j/T_j, & 0 \le t \le T_j;\\ x_j, & T_j \le t \le T,\end{cases}$$

where T_j is time of putting of a well on production for the *j*-th gas pool, x_j is a project number of wells (to be determined).

Then the (24) takes the form

$$x_j = \frac{V_j}{(T - 0{,}5T_j)}\sum_{i=1}^{I} y_{ij}\int_0^{z_j}\frac{d\eta}{q_{ij}(\eta)} \quad (35)$$

According to (35), in order to account the non-zero period of putting of well on production, the planned period T should be replaced with $T - 0{,}5T_j$ in all the previous formulas.

Thus, let sets of $\{z_j^*\},\{y_{ij}^*\}$ be obtained as exact or approximate solution of (28)-(32) using the basic algorithm. Knowing these sets and using formula (24) we can determine the rational number of wells and corresponding development costs. Then we can determine the variation of basic development parameters in time using the dynamics analysis algorithms.

Therefore, as well as the "oil" problem (3)-(8) solution, the solution of the "gas" problem allows choosing an optimal development option for each gas pool and completing the option by rational values of a gas production volume and development costs over the whole planned period and over every year.

Thus we can make more reasoned decision of problems related to distribution of investments required for implementation of development systems of gas pools group, tied by costs.

4. CONCLUSION (PERSPECTIVES OF RESULTS GENERALIZATION)

Suggested approach to solve the problem of selection of optimal strategies of oil and gas fields' development supposes absence of hydrodynamic connection between oil/gas pools (reservoirs). Such assumption is not always possible, thus fundamentally different approaches, like methods proposed by Akhmetzyanov A.V. (2008a), (2008b), Akhmetzyanov A.V. and Ermolaev A.I. (2008a), (2008b), should be used to evaluate J-function, gas recovery and oil recovery functions for each option of development of fields with filtration flows between contiguous oil/gas pools (reservoirs). In particular, the proposed problem formulation could be used for the concerned kind of gas fields if the current gas recovery factor would be evaluated by using multilevel simulation techniques of the real gas filtration through a porous medium, see Akhmetzyanov A.V. and Ermolaev A.I. (2008b). In a few words, for this purpose at first we will separate and will number the contiguous pools tied by filtration flows. We will number them in accordance with two- or three- or more colour reservoir decomposition if the filtration process is two- or three- dimensional. Then we will form two or four or more independent pools subsets. These subsets together with initially untied gas pools will form the upper level of gas field decomposition. The gas recovery functions for each subset may be computed independently and concurrently. Then for every element of these subsets of pools we can build Dirichlet domains (super cells) around all the wells of its element. Super cells after the similar two- or four- or more colour decomposition will make independent subsets of the next level of hierarchy of paralleling of calculating process. The gas recovery for each super cell could be evaluated using conservative quasiuniform multigrid methods, e.g. Control Volume Method.

When using this approach the problem of selection the strategy and its solution algorithms are naturally subjected to multilevel decomposition, which enable the decomposition and paralleling of calculations.

The highest efficiency and universalism of the proposed generalized approach is achieved by using the Perturbation Theory Methods for solving the nonlinear equations of real coercible gas filtration, taking into account its compressibility in the deformable porous medium of gas pools. In this case the initial nonlinear equation is replaced with sequence of linear equations among which are an unperturbed equation and a sequence of perturbed equations.

For oil fields the same results are achieved by using the decomposition method on physical processes. This technique allows proceeding to solving the sequence of linear sets of finite-difference equations instead of solving the set of quasilinear filtration equations.

In summary we have created all the necessary conditions to solve not only pre-project problems of the optimal strategy selection, but also problems of oil and gas reservoir engineering and management in general formulation. In particular, we could solve these problems taking into account the oil and gas reservoir geology and nonlinearity of filtration processes even in deformable porous medium.

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