ABOUT DECISION-MAKING IN CONTROL OF SELECTION AND DISTRIBUTION OF GAS ON GAS FIELDS AND UNDERGROUND GAS STORAGES

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1. Introduction. Optimum decisions made in control of operating modes of wells are developed according to pre-chosen parameters of field development and operation of underground gas storages **(**UGS**)**. The decisions-making process is put together on the basis of stratigraphical parameters: scheduled sizes of total takeoff or pumping of gas for one or several seasons and the setting of short-term strategic parameters of productivity distribution at time steps. This, in turn, is related to registration of gas consumption dynamics in the region, and characteristics of underground gas storages and, first of all, changes of seam pressure distribution in gas pools.

The kind of made technological decisions is such that the choice of type and parameters of the technological action directed on increase of productivity individually on each well, generally speaking, is not possible due to their big quantity, and they are appointed for groups of wells as a whole, incorporated on the basis of the degree of affinity of technological parameters. Therefore actions carried out more or uniformly for all wells of a group, but due to their individuality it is not possible to expect identical effect, and in such circumstances planned actions are aimed at gain on average in a group, rather than on each chink.

2. Statement of the problem. The control problem consists, at this step, of a choice of the set of working wells and, hence, in determination of the configuration of a gas-gathering network. At occurrence of deviations from technological modes predicted for the given step, or at transition of the object into a new condition, parameters planned for the following period or the type of control for the next step can be subject to update.

It’s obvious that, generally, the problem of the choice of the optimum decision will be determined by several criteria and will be reduced to multi-criterial to a problem. However, there should also be a possibility of carrying out multiple calculations for comparison of various variants by any criterion.

3. The solution method. Consideration of the gathering system without taking into account its interrelation with other technological subsystems (units, objects) allows generation of hydraulic losses minimization as criterion of control [1]. Mathematically the specified condition is expressed as follows:

$$K = \sum_{i=1}^{N} q_i \ln \frac{P_{pl}}{P_{sp}} \to \min , \qquad (1)$$

Where q_i is productivity of $\boldsymbol{i}^{\text{th}}$ well;

P_{pl_i} is seam pressure in a working zone of $\boldsymbol{i}^{\text{th}}$ well;

P_{sp} is Target pressure of the assembly point;

N is number of wells.

Control by criterion (1) allows providing the best operating conditions of gas preparation system [2].

The factor of rational operation of subsoil can be taken into account at the same time. One of such criteria is formulated as follows:

$$R = \sum_{i=1}^{N} q_i \frac{P_{\max} - P_{pl_i}}{P_{\max}} \to \min \qquad (2)$$

Use of (2) allows conducting gas takeoff while minimizing pressure differences in a layer.

Criteria (1) and (2) are individual criteria describing various technological subsystems. Other technological-economic criteria can be considered as well, including those taking into account other technological subsystems. The most acceptable mode should be determined in view of interaction of all these subsystems, in particular, to calculate technological parameters with the best combination, for example, of values of criteria (1) and (2).

One of universal methods of formation of multicriterion criteria is summation of the "weighed" normalized parameters. According to the given method we shall introduce the criterion:

$$I = \gamma_1 \hat{K}(\hat{q}) + \gamma_2 \hat{R}(\hat{q}), \tag{3}$$

Where $\hat{q}$ is a control vector;

γ_1, γ_2 are "weight" factors describing "importance" of the criterion;

$\hat{K}, \hat{R}$ are normalized values of criteria determined from parities:

$$\hat{K} = \alpha_1 K, \quad \hat{R} = \alpha R;$$

α_1, α_2 are normalization factors.

Thus, the problem of optimum distribution of wells productivity of a gas gathering point (GGP) will be presented in the following form: to find such values output q_i at which the minimum of function (4) is achieved:

$$I = \sum_{i=1}^{N} q_i \left(\alpha_1 \gamma_1 \ln \frac{P_{пл_i}}{P_{пл_{min}}} + \alpha_2 \gamma_2 \frac{P_{макс} - P_{пл_i}}{P_{макс}} \right) \tag{4}$$

Under connection conditions:

$$\sum_{i=1}^{N} q_i = Q \tag{5}$$

And restrictions:

$$0 \le a_i q_i + b_i q_i^2 \le D_{макс}, \tag{6}$$

$$P_{min} \le P_{сп} \le P_{мах} \tag{7}$$

Normalization factors can be introduced, for example, as follows:

$$\alpha_1 = \frac{1}{\ell n \dfrac{P_{пл\ max}}{P_{пл\ min}}}, \quad \alpha_2 = \frac{P_{max} - P_{min}}{P_{max}}. \tag{8}$$

The problem of the choice of the set can be formulated, for example, like follows:

$$I = \sum_{i=1}^{M} \xi_i q_i \quad \text{at} \quad \sum_{i=1}^{M} q_i = Q_П, \ q_i \le \hat{q}_i, \ q_i \ge 0, \tag{9}$$

Where the parameter ξ_i and productivity of wells q_i depend on pressure upon the central platform or on GCP.

For complex gas collection systems (for example, collector or ring, which are more reliable on sea fields and UGS) it appears that productivities of wells are interconnected. In this case procedure of a choice of working wells inevitably should provide a choice of pressure on the central platform or GGP, the choice of the current variant of set working wells, hydraulic calculation of system in view of the set of working wells, calculation of value of optimality criterion for the given variant of control, the analysis or comparison of the value of criterion for the current variant with best of already computed.

Generally the problem of hydraulic computation of the network consists of the decision of the following system of equations [3]:

$$\begin{cases} \sum_{i\in M_j^+} q_{ij} - \sum_{i\in M_j^-} q_{ij} = \begin{cases} Q_j, & j\in R_1\cup R_2 \\ 0, & j\in R_3 \end{cases} \qquad j=\overline{1,M} & (10) \\ P_i^2 - P_j^2 = a_{ij}q_{ij}^2 & (11) \end{cases}$$

Conditions (10) express balance of pumping and takeoff in the nodes of the network, and M_j^+ is set of units from which arches come into unit *j*, M_j^- is set of units into which arches from unit *j* come; Q_j is inflow of gas to the source node or takeoff in the consumer node. According to the set inflows to source nodes and takeoffs in consume nodes the number of the equations of a kind (10) is equal to the number of nodes of the network *M.* However, the number of the linearly- independent equations equals *î-1* i.e on of the equations follows from others. The number of equations of a kind (2) is equal to the number of areas of network *N.* So, the overall number of the equations equals *N+M+1.* Unknown values are: *N* - expenses q_{ij} , on network areas (arches) and *M-1* pressures P_i, since in one of the points the pressure is set. The number of unknown values equals *N+M+1,* which coincides with the number of equations. The system (10) - (11) is linear - quadratic and, generally, is not analytically solvable.

Analysis of methods used for realization of each step of iterative process of the solution of the problem of flux-distribution, has shown, that in present there are various methods of amending all network contours simultaneously, consecutively, and selectively. However, despite of variety, the choice of computation contours from all possible in itself is very labour-consuming and exact and good recommendations do not currently exist. These methods requie diverse computation operations and hardly have advantages in comparison with Lobachyov - Kross method.

In this case for the solution of the problemk the method of hydraulic coordination of ring networks of Lobachyov – Kross is used, which is reduced to iterative process of specification of gas expenses q_{ij} in areas of each ring till achievement of the set accuracy.

The idea of a method of Lobachyov - Kross consists in the following. Initial estimation of gas expenses in areas of a network is selected and their coordination is made. For this purpose the system of equations (10) - (11) will be transformed to:

$$\begin{cases} \sum_{i\in M_j^+} q_{ij} - \sum_{i\in M_j^-} q_{ij} = \begin{cases} Q_j, & j\in R_1\cup R_2 \\ 0, & j\in R_3 \end{cases} \qquad j=\overline{1,M} \\ \sum_{(i,j)\in E_k} (Siqn\, q_{ij}) a_{ij} q_{ij}^2 = 0 \end{cases} \qquad (12)$$

Where E_K is set of all sites (*i*, *j*), forming k^{th} ring. For flat and connected graphs quantity of rings is equal to *K=N-M+1*, $Siqn\, q_{ij}$ equals 1, if the direction of gas flow in area (*i, j*) counter-clockwise, and equal (-1) if clockwise. Initial approximation is chosen so that the equations (10) - material balance in nodes – are fulfilled. For each ring (contour) the amendment Δq_k to expenses is determined, such that the sum of misalignments on ring E_K is equal to zero:

$$\sum_{(i,j)\in E_k} (Siqn\, q_{ij}) a_{ij} (q_{ij} + \Delta q_k)^2 = 0 .$$

Removing the brackets and rejecting component containing $[\Delta q_k]^2$ in view its negligibility, we receive the formula for calculation of the amendment to expenses in areas of the ring ring on *a* n^{th} calculations step:

$$\Delta q_k^{(n)} = -\frac{\sum_{(i,j)\in E_k} (Siqn\ q_{ij}^{(n-1)}) a_{ij} \left[q_{ij}^{(n-1)}\right]^2}{2\sum_{(i,j)\in E_k} a_{ij}\left|q_{ij}^{(n-1)}\right|},$$

where $q_{ij}^{(n-1)}$ is value of the expense of gas in area (*i*, *j*), received on (n-1)th step. For areas which are borders of adjacent rings K_1 and K_2 value of the expense on *a* n^{th} step of calculations looks like:

$$q_{ij}^{(n)} = q_{ij}^{(n-1)} \pm \Delta q_{k_1}^{(n)} \mp \Delta q_{k_2}^{(n)} .$$

For other areas:

$$q_{ij}^{(n)} = q_{ij}^{(n-1)} \pm \Delta q_k^{(n)} .$$

Signs on amendments depend on the direction of gas flow in area (*i*, *j*) in contour E_K; "+" if clockwise, "-" if counter-clockwise. The authors of the method have shown, that the method converges. Speed of convergence of computing process substantially depends on the choice of initial approximation. For calculation of values $q_{ij}^{(0)}$ the method of equal division of overall gas inflow into the area between the participants leaving the node is used, hence the conditions are satisfied.

Algorithm of calculation it is represented by the following sequence:

- The choice of initial approximation of gas expenses in areas of the network is made. Here either setting, or calculation of initial approximation are possible;
- Hydraulic computation of system is carried out in view of set of working wells by multistage iterative process of correction of these expenses up to achievement of the set accuracy. Here factors a_{ij} are calculated, defining the gas flow equation for each area of the network. For this purpose the values of diameters, lengths of areas, number of pipes in an aree, average temperature, densities of gas by air, factor of super-compressibility, the data on structure of a ring (collector) network are used;
- Calculation of pressure in all nodes of a network is carried out on the basis of the coordinated expenses in areas and rings (collectors) of a network;
- Values of criterion of optimality for the given variant of control are computed, the analysis or comparison of values of criterion for the current variant with best of already computed is carried out.

Numerical calculations of a specific target have confirmed practical suitability and efficiency of application of the described algorithm.

4. Conclusion. Presented approach can be applied for optimization of technological modes of ring and collector networks for well clusters and groups as a whole, incorporated on a degree of affinity of technological parameters on fields and underground gas .storages.

Literature

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