Introduction

The experience and result of creating a full-scale integrated model of gas layers and gas caps of a large oil and gas condensate field in Russia will be highlighted, and, accordingly, the search for optimal solutions to the problem of optimizing the joint development of oil rims, gas caps of productive layers and dry gas layers, taking into account the influence of the restrictions of the collection and preparation network.

The peculiarity of the development of the considered large multi-layer oil and gas condensate field is in the complex structure of oil reserves, which are enclosed in relatively narrow, except for the deposits of the Tyumen formation, rims, overlapped by a gas cap and underlain by water. In total, 81% of oil reserves are concentrated in sub-gas zones (Fig. 1). In such conditions, the gas breakout from the gas cap, 87% of which is concentrated in 6 development reservoir formations, is a complicating factor in the development process.

As part of Phase 1 of the Gazprom Neft gas project, it is planned to develop the field under consideration with the useful use of associated oil and natural gas. The structure of a large gas project is necessary for the phased development of the group of oil and gas condensate fields on the Yamal Peninsula.
Theory and technology of integrated modeling

The integrated field model (IM) is a single digital model consisting of linked reservoir models, wells, and a detailed surface development model designed to optimize the entire system, taking into account the interaction of its components. IM takes into account both restrictions on depression, well design, fluid velocity in the tubing, the level of production, and restrictions on speed in the pipeline loop, the capacity of the booster compressor station, the pressure at the integrated gas treatment plant (GPP), etc.

The reservoir in the system must operate with a flow rate that is compatible with the well flow conditions described in the IM models of pressure and temperature losses along the wellbore (VFP model). Thus, production levels and operating modes of wells are calculated taking into account the impact of restrictions, both from the reservoir and from the production collection network, which allows increasing the accuracy of forecasting.

Among the advantages of creating an integrated model of the field, we highlight:
* The impact of the network on indicators of well operation
* Identify problem areas (bottlenecks) in the collection network
* Accounting for restrictions on the gas injection network and the speed of gas flow through pipelines
* Accounting for the interaction of wells with different characteristics located on the same cluster site.
* Correct accounting of the maximum GF for well operation
* Correct accounting of group restrictions on hydrocarbon production

Disadvantages include:
* The increase of requirements to the source data
* Increased time of making the model and need more computing power
* Low speed of model calculations in comparison with GDM calculations

To create an integrated gas model of the field, seven full-scale hydrodynamic models of the main objects were built. To start adapting gas wells, it is necessary to prepare models of well lifts for calculating well pressures at the wellhead and starting operation of gas wells in a model with control over the wellhead pressure.

A model of the field's gas collection network was created based on the IPM GAP software. The collection network model includes models of production wells, well clusters, and pipelines. The final node in the integrated gas model is the GPP.

The model of the collection network is represented by the above-ground part of the collection system and models of vertical lift (pressure and temperature losses along the wellbore from the bottom to the mouth) for 38 gas wells in the basic version of 6 cluster sites. Multiphase flow correlations were used to calculate the collection network model.

The integrated model is a combination (in IPM Resolve) of seven full-scale hydrodynamic models performed in the RFD tNavigator simulator, with models of different number of wells (depending on the calculation option – basic/upsides/scenario) and a model of the product collection network performed in IPM Prosper and GAP software. The integrator program mentioned above allows you to manage the calculation using a strategy. This tool allows you to set the production control mode for a well / group, change the configuration of the collection network (enabling / disabling wells, pipelines), parameters of objects (for example, the diameter of the fitting, pressure, flow rate and gas velocity at the entrance to the collection system, parameters of downhole and ground equipment, etc.).

Integrated into the calculations of the total produced fluid (SDF), i.e. introduced a method for calculating the commodity product based on the data of the 3-phase hydrodynamic model of “black oil” (oil, water, gas) and PVT modeling, since using standard tools of Black Oil model it is impossible to calculate the production of a commodity product. The use of this method has a strong advantage in the calculation speed compared to composite modeling due to the very low speed of joint calculation of a multi-component system (in this case - C1-C13 components) in the case of forecasting.
development indicators on a composite GDM in comparison with the "black oil" model. According to the method, the creation and matching PVT models of layers on the experiment CVD (Constant Volume Depletion) is performed to create condensation curves for each HC-component (C5-C13). Then dry (C1-C4) gas production profiles and reservoir pressure are unloaded from the model in the area of gas well drainage. The data is entered in a VBA macro in Excel, where the extraction profiles are decomposed by components (de-lumping), and then the flow is run (with data on the flow temperature from the IPM GAP) through the preparation system in the Hysys Software. And already at the output we get production of commercial gas and commercial condensate.

Results and Conclusion

The use of integrated modeling made it possible to translate the detected uncertainties [1] into the category of project risks at the early stages, perform an assessment of these risks and get the opportunity to lay solutions to avoid or significantly reduce the negative impact of these risks on the project's effectiveness, thereby increasing the stability of project decisions and the overall effectiveness of the project.

As a result of calculations of the basic version of the integrated model, the profiles of gas production and C5+ components, pressure at the wellsites and GPP, and other parameters required for the project development were obtained.

In addition to the basic version, we also searched for additional features (Up-Side) in order to optimize the business case of the project:

1) Upside #1 - expansion of cluster sites for drilling additional wells on the Yu2-6 formation. In the Up-side 1 variant, the increase in the project value for the gas production increase parameter was 24.0 %, and for the condensate production increase parameter – 27.6 %.

2) Upside #2, which involves the involvement of natural gas production at secondary development sites (NP4, TP1-4) (Fig. 2). Also, variants involving NP1, NP5-2, and NP8 layers were calculated. In the Up-side 2 variant, the increase in the project value for the gas production increase parameter was 14.7 %, and for the condensate production increase parameter – 13.5 %.

![Figure 2](image_url) **Figure 2** Production profiles for hydrocarbon (HC) components a) C1-C4 and b) C5 + components in the up-side №2 version of IM.
The result of the performed work is a full-scale integrated model of gas production of the field, synchronized with the integrated model of oil production and including:
- Seven hydrodynamic models of the main development objects;
- Models of production and injection wells;
- A model of a ground-based product collection network that includes models of pipelines from wellheads to GPP.

All the components of the model were adapted to the actual technological indicators of production. On the created integrated model, calculations were made on the forecast of gas and condensate production component-by-component (C1—C13+) using the method of calculating the commodity product based on data from three-phase hydrodynamic models and PVT-modeling, which allowed to significantly increase the calculation speed while maintaining accuracy in comparison with composite (multi-component) modeling.

Based on the results of calculations and sensitivity analysis, a factor analysis was performed to optimize oil production when extracting gas from gas caps with an assessment of current risks on the impact of infrastructure on the production profile. The integrated calculations made it possible to consistently identify and minimize the risks associated with the geological potential of productive layers and the capacity of the gas pipeline system at the early stages of project development.

Due to the update of the collection network model, the speed of gas movement through the system nodes was reduced to the necessary limit to ensure reliability, avoid vibration and equipment destruction. This update has increased the capacity of the network capacity at the same pressure in the collection system (at the GPP and wellsites) by 30 %. The input dates and parameters of the booster compressor station are also defined.

The assessment of involvement in the development of the gas cap of the Yu2-6 formation was performed, taking into account the minimization of oil production losses during free gas sampling (up-side 1). The estimation and integrated calculations of gas production from secondary gas layers of the field, the development of which does not entail additional losses of production of liquid hydrocarbons (up-side 2), were performed.

These options for optimizing the business case for calculations based on the integrated model allowed us to achieve a potential increase in gas and condensate production at the site, which increased the value of the project. In the Up-side 1 variant, the increase in gas production was 24.0 %, and condensate production was 27.6 %. In the up-side 2 variant, the increase in gas production was 14.7%, and condensate production was 13.5 %.

The results of the work performed confirm the need to use integrated modeling technology at the field level to improve the quality of decisions made during the implementation of a large gas project.

References

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