Introduction

Due to increasing complexity and cost of project implementation, decision-making process in field development and management has a particular value. Traditional dynamic models of fields, where only reservoirs and wells are considered, have a number of disadvantages. Even in those cases when the models are reliable and well matched to the production history, they do not always reflect the interaction between different parts of the entire system «reservoir-wells-gathering system-processing facility». The relationship between the design solutions for surface facilities and reservoir development is poorly ensured with this approach, as a result of which the predictive calculations of dynamic models may not be synchronized with the parameters of surface facilities. This leads either to non-compliance with the expected production profiles, or a field may have unrealized potential, which entails certain financial losses. The current situation requires the implementation of complex flexible tools that take into account the limitations of both surface and subsurface facilities, as well as backpressure effects of surface systems on reservoir energy and well productivity.

Integrated asset modelling is a holistic approach to model the development of oil and gas fields, which allows reproducing the behaviour of the entire chain of production system objects. Taking into account the interference of individual parts of the production chain integrated asset modelling allows the correct optimization of the whole production system.

Integrated asset models (IAMs) have particular importance when developing deep offshore and arctic fields in extreme conditions. This is due to high impact of surface facilities, inaccessibility and significant cost of drilling wells, production and transportation of hydrocarbons, as well as the need for uninhabited technologies application. When developing such fields, it is an extremely challenging task to control technological conditions along the entire path of gathering, processing and transporting hydrocarbons. Automation of production processes along with IAM implementation creates a digital copy of a field and infrastructure, with which it is possible to solve the problems of monitoring and development management.

Recommendations for IAM conceptual design and creating process

Most of oil and gas companies are creating dynamic models for its assets for planning reservoir development. Some disadvantages were mentioned above. In other cases when dynamic models are the parts of IAMs, the models become too complex and require a long time of simulation, what mostly is not very convenient.

IAMs can be presented in various versions depending on the purposes: long-term strategic or short-term operational planning. To solve the problems of each area, it is necessary to select the appropriate modelling tool that satisfies the specified criteria of accuracy and efficiency [Sodi Toby, 2014]. Further there are some recommendations for choosing the conceptual design of IAMs and suggestions for process of IAMs creating based on the Company experience.

For long-term planning IAMs are used to describe flow processes from the reservoir to the consumer in as much detail as possible, to take into account the characteristics of all surface facilities, to calculate the economic efficiency of the project and to make long-term predictions considering limitations at all levels of the system. Creating the detailed IAM requires significant time and human resources, however the presence of such model makes it possible to predict reliably various changes in the system, which is guaranteed to pay off at the stage of field development. The model is designed to solve long-term tasks, taking into account the geological and physical characteristics of the object and real physical processes occurring in the reservoir, wells and the gathering system. The reservoir model should be presented in the form of most detailed model (corresponding to the input data), which allows to describe the processes occurring in the reservoir as accurately as possible. History matching of the IAM is necessary for the entire amount of available data for the whole historical period. When matching the IAM for long-term predictions a less accurate quality of history matching is allowed than for the model used for short-term predictions.
To solve the current problems of field development, monitoring and management, identifying system bottlenecks and reducing operational cost, simplified IAMs are used, where the inflow from the reservoir is described using material balance models or inflow performance curve (IPR). The relatively high simulation speed allows a large number of calculations of development options for the object in acceptable time, which significantly increases the practical value of such models. When solving operational production problems, the main requirement for the model is the calculation speed. Moreover, the requirements for detailing description of the physical processes of the reservoir are lower. The model is designed to predict the technological modes of wells and the gathering system and not to predict reservoir development characteristics and energy conditions in detail. The main task during history matching is to match well models and the gathering system model for actual data for the last period, which is comparable with the duration of the forecast calculation. For short-term calculations it is recommended to match actual data with higher quality than for long-term predictions. IAMs for short-term predictions should have the ability to match quickly based on operational data and to describe correctly development conditions for the short-term period.

The level of IAM complexity should also be selected depending on the stage of field lifecycle. The next recommendations should be followed:

- At the initial stages (exploration, appraisal, conceptual design) it is sufficient to use a simplified reservoir model, a model of the gathering system in the form of VFP tables (Network option), a model of the processing plant in the form of pressure limit at the entrance to the plant;
- When moving to development stage it is recommended to specify a reservoir model, to use a steady state simulator (multiphase flow correlations) for the gathering system model and to make a simplified model describing the main stages of product processing for the processing plant;
- At the stage of full-scale production it is recommended to use a detailed reservoir model, a gathering system model in a steady or unsteady state simulator (depending on tasks), a detailed model of the processing plant with all processing facilities (depending on the task, if it is necessary).

One of the most important stages of IAMs creating is matching to the history data. For each of IAM components, different historical parameters are required. To simplify the history matching process and avoid unnecessary mistakes, it is recommended to perform matching separately for each element and then to make coupling and to analyse the need of the entire IAM additional matching. The recommended history matching scheme for IAMs, as well as the necessary data for creating and matching of IAM components models are presented in Figure 1.

![Figure 1 IAM creating and history matching scheme](image)
Successful examples of IAM projects

Several different IAM projects implemented by our Company that allowed getting real economic profit are considered. The conceptual design of IAMs was determined based on the stage of field lifecycle, initial data and modelling purposes.

The first considered IAM project was large oil-gas-condensate field in the conditions of low reservoir quality, permeability at 0.5-1.5 mD, abnormally high reservoir pressure and condensate content of gas varied in the range of 270-320 g/m3. The main purpose of this work was to justify the optimal technological conditions to maximize condensate production. The simplified IAM (dynamic model in Eclipse format with Network option) and the third-party optimizer (MEPO) were used. Various options for optimizing technological conditions of wells were considered, and the optimal option for optimizing technological modes by changing well chokes was proposed. On the basis of the proposed technological modes field test was conducted, which resulted an increase in gas-condensate ratio by 2.5% after optimization (Skvortsov and Glumov, 2014). Also after optimization there was a decrease in the intensity of the drop of gas-condensate ratio (Figure 2).

![Figure 2](image)

**Figure 2** CGR behaviour after field test

Another successful IAM project in the Company was carried out in two offshore gas fields with the common gathering system, compression and pre-processing facilities. The purpose of the project was to fulfill contractual obligations for gas production and supply, as well as to delay water breakthrough of production wells as much as possible. There was a need for direct and optimization calculations taking into account the technological limitations of the production, gathering and pre-processing facilities:

- The target annual gas rate must comply with the supply contract;
- Water production is limited by the capacity of separators located on the platform;
- The gas production is largely determined by the performance curve of the compressor located on the platform;
- Maximum gas rate restriction.

According to the noted features of the project, the purpose was to create a tool for searching optimal technological modes of wells, taking into account all these limitations. IAM consisted of detailed dynamic models (Eclipse), the gathering and pre-processing system model (Gap) and the integrator Resolve.

As a result of optimization, the optimal ratio of gas allocation between two fields and between wells for each field was obtained, which allowed achieving maximum gas production. Selected technological modes of wells allowed to extend the "plateau" of gas production and to minimize the risks of water breakthrough. It became possible to fulfill the obligations for gas production, to supply and to extend the period of waterless production for 3 years with the help of optimized technological modes of wells.

IAM implementation for the offshore oil and gas condensate field allowed us to estimate interference of wells at the surface system level, to estimate switching of wells to the new pipeline, to reveal incorrectness of measuring sensors. IAM consisted of detailed dynamic models (Eclipse), the gathering system model (Gap) and the integrator Resolve.
The wells of the license area were drilled from the shore into the oil rims of the reservoirs. The considered field was an element of the total system of hydrocarbon production, which included two other fields. Multiphase products (crude oil with gas and water) from all fields were transported to the processing plant, where the oil was prepared to salable products. Field development was carried out by natural flow and gas lift methods. Gas reinjection was implemented to maintain reservoir pressure in the field. Field development was complicated by gas breakthrough from the gas cap. Measurement of production rates was realized using the separator by switching wells alternately from the oil gathering pipeline to the measuring pipeline.

The estimation of wells interaction at the level of the gathering system was made using IAM. The simulation of the measuring separator was performed reproducing the process of measuring the production of wells from the bottom to the separator. The objective of the simulation was to quantify the discrepancy between the production measurements of wells, in the case when the measurement was performed individually and in conjunction with another well. Figure 3 shows the comparison of oil rates for individual and group well tests. In addition the estimation of wells interaction was performed by comparing the performance of wells when one of the wells started to operate after stop. When opening the well, there was increase in wellhead pressure for other wells, which led to decrease of their production.

Figure 3 Results of separator test simulations
The calculation of various scenario cases «what-if» was provided with IAM. For example, this allowed us to assess the effect of switching wells to the new pipeline, taking into account the expected technological conditions of wells and drilling schedule.

Another important task solved with IAM was the validation of actual measurements of product rates, pressures and temperatures. IAM based on the physics of flowing processes in the system «reservoir-wells-gathering system» allowed us to identify incorrect measurements and make recommendations for finding alternative data sources.

Conclusions
The abstract presents the description of integrated asset modelling approach. Based on the Company experience practical recommendations for IAM creating and matching and IAM conceptual design depending on the stage of field lifecycle and modelling purposes are given. Three examples of successful IAM application in real projects allowed to increase economic efficiency are described.

References