EFFICIENCY EVALUATION OF IMPLEMENTATION OF OPTIMIZATION METHODS OF OPERATION MODES OF THE "PLAST – GAS PIPELINE" SYSTEM BY THE METHODS OF MATHEMATICAL MODELING

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Abstract

To date, Ukraine's mature gas fields, which are being developed in the gas regime, are at the final stage of development, which is characterized by a significant depletion of reservoir energy. The final stage of development requires solving complex problems related to watering wells, destruction of the reservoir, removal of formation water and mechanical impurities, increasing back pressure in the system, as well as the moral and physical wear and tear of industrial equipment. In the conditions of falling gas production, a significant part of the operating well stock is unstable, in the mode of unauthorized stops due to the accumulation of liquid at the bottom and insufficient gas velocities for removal to the surface, and also the accumulation of the liquid phase in the lowered places of the gas gathering system.

Within the framework of the conducted studies, the gas dynamic models of the operation of the gas collection system of 3 oil/gas-condensate fields (OGCF) are created. A single model of the gas production system "reservoir – well – gas gathering system - inter-field gas pipeline – main facilities" is built. The current efficiency of the gas production, collection and transportation system is assessed. On the basis of model calculations, the current production capabilities of the wells are defined, as well as the "narrow" places of the system.

It is established that the introduction of modern technologies for the operation of watered wells without optimizing the operation of the entire gas production system is irrational, since the liquid that is carried out from the wellbore will accumulate in the plumes and increase the back pressure level in the ground part. In conditions of increasing gas sampling, liquid flowlines can be taken out of the loops and deactivated the separation equipment.

The feasibility of introducing methods for optimizing the operation modes of the gas production - gathering and transportation system is estimated, which allows choosing the optimal method for increasing the efficiency and reliability of its operation.

For the first time in the Ukrainian gas industry, an integrated model of the field is created as a single chain of extraction, collection, preparation and transportation of natural gas, which can be adapted for the development and arrangement of both new and mature deposits.

The main advantage of the application for the hydrocarbon production sector is the simulation of the processes, which makes it possible to evaluate the operating mode of the well in the safe zone while reducing the working pressure and introducing various intensification methods, and also to estimate the increase in hydrocarbon production. For the equipment of the ground infrastructure – "midstream" – the main advantage is a reduction in the time required to perform design calculations for gas pipelines, trains and pipelines for transporting multiphase media using public models.

The creation and use of integrated models of gas fields gives an understanding of the integral picture of available resources and ensures an increase in the efficiency of field development management.

The results of the calculation are clearly correlated with the actual data, which makes it possible to use the models constructed to obtain numerical results.

Keywords: gas production system, mathematical model, PipeSim, optimization, multiphase flow, hydrodynamics of gas-liquid mixtures.

DOI: 10.21303/2461-4262.2018.00717

1. Introduction

The efficiency of exploitation of hydrocarbon deposits is determined by the reliability of forecasting the technical and economic indicators of their development. Most of Ukraine's unique deposits are significantly depleted and are at the final stage of development, characterized by an increase in non-productive losses of reservoir energy in all elements of the gas production system. They are associated with the formation of sandy-clay and liquid stoppers at the bottom of the well, hydrate and liquid flowlines in gas collectors and inter-field gas pipelines, restriction of gas flow rates at wellheads by throttling devices and other factors.

The accident-free operation of the gas production system is an extremely important issue that the engineers face in the process of developing gas condensate fields. This is due, in particular, to the transition of most fields to the final stage of development. Therefore, it is the choice of the optimal operating mode for wells and the system for collecting and preparing gas products that can ensure the stable operation of the gas production system in the context of the "formation – well – flowline – gas processing facility (GPF) – booster compressor station (BCS) – inter-field gas pipeline – main facilities (MF)."The most significant factor complicating the operation of the well in such conditions is the accumulation of liquid at the bottom of the well, as well as in the lower sections of the flowlines and pipelines. That is why ensuring the delivery of liquid from the bottom of the well to the surface can significantly improve the operational characteristics of the wells and ensures its stable operation.

Modern hydrocarbon production systems require the creation of projects for the safe and cost-effective transport of extracted fluid from the formation to integrated production facilities. An important task of the operation of such systems is the optimization of hydrocarbon production to ensure maximum economic returns. The extensive capabilities of the modeling tools for pipeline gas gathering systems and the volume of functions inherent in them have made an advantage in selecting the tool for simulating the PipSim® Schlumberger multipurpose steady flow simulator.

2. Materials and methods of research

To date, due attention has been paid to the issue of mutual elements of the complex geological and technological system "formation – well – flowline – gas processing facility (GPF) – BCS – inter-field gas pipeline – MF". The consequence of this is irrational reconstruction of industrial systems in conditions of active watering of wells at the final stage of operation. In most cases, the development of a number of fields with significant reserves does not provide for the equipping of wells with means of instrumentation and automation, which considerably complicates the control and management of the hydrocarbon production process.

In such conditions, it is necessary to develop a set of models and algorithms for optimizing the management of the elements of the gas production system "formation – well – flowline – GPF – BCS – inter-field gas pipeline – MF" in fields with significant hydrocarbon reserves, taking into account the conditions of the final stage of development.

The object of research is three separate gas gathering systems of the Opishnia OGCF, the Western arch of the Berezivka gas condensate field (GCF) and the Kotelva gas condensate field, as well as the system of inter-field gas pipelines for gas supply to the final collection point of the Solokha MF (Solokha BCS) of JSC UkrGazVydobuvannya (Company) (Kyiv, Ukraine).

Systems of equations were used as a mathematical model of the geologic-technological model of the "formation – well – flowline – GPF – BCS – inter-field gas pipeline – MF" of the Opishnia, the Western arch of Berezivka and Kotelva fields. The solutions of these are implemented in the PipeSim® "Schlumberger" software. The well is modeled from the formation. The inflow equation is the flow inflow model to the "Jones" face [1]. As initial data, reservoir pressures and temperatures and the dependence of the dynamic bottom-hole pressure on the gas flow rate on the results of the latter at the time of the gas dynamic analysis of the wells are introduced.

The work of the wells is modeled on a segment from the middle of the perforation interval and to the wellhead nozzle. Enter the depth of the trunk, the diameter of the production string and tubing, the roughness, wall thickness, heat transfer coefficient (if necessary, calculated), the temperature of the environment around the barrel.

The gas gathering flowline appears approximately as a horizontal pipeline. The internal diameter of the pipe is introduced, the roughness, the wall thickness of the pipeline, the heat transfer coefficient (if necessary, calculated), the temperature of the environment in which the pipeline is laid, the gas pipeline profile.

GPF operation is modeled in a simplified form – the dropping liquid is separated before the BCS, based on the accumulated statistical information, the pressure loss and temperature values before the BCS and before connecting to the inter-field gas pipeline are entered.

BCS is represented by the following parameters: drive power, polytropic efficiency, gas flow rate at the compressor inlet, reduced polytropic pressure, compressor speed.

The system of inter-field gas pipelines is represented by a network of pipelines from three GPF to the MF.

Since the amount of gas coming from wells (gross production) differs from the amount of gas supplied to the inter-field gas pipeline (commercial production), it is therefore necessary to simulate pressure losses and gas volumes for the own needs of the fields. In the model, these losses are modeled using the "multiplier" module – on the basis of accumulated long-term statistics, a part of the gas is artificially separated from the inter-field gas pipeline.

Thus, the model of the gas production system of these deposits unites all elements of the geological-technological chain from the formation to the MF.

The component gas composition is set in accordance with the results of chromatographic analysis in the option "PVT file", it is unchanged throughout the area of the deposit. Here, the moisture content of the gas is also set depending on the thermobaric conditions in the borehole region.

The Peng-Robinson dependence [2] is used as the equation of state.

After building the model, its adaptation to the actual data is necessary. By this is meant the selection of equations, there is in the software PipeSim® "Schlumberger", which allow with the least error to calculate the pressure losses in the wellbore, the wellhead and the gas network.

Given that wells are not equipped with instrumentation and automation tools, adaptation of the model is extremely complex. Direct measurement of gas consumption is carried out only when carrying out gas dynamic studies of wells and the address scheme of the working flow, so these data form the basis of the methodology for adapting the model.

In [3, 4], an analysis was made of the methods for calculating the pressure gradient for the motion of gas-liquid mixtures and a conclusion was drawn on the complexity of choosing a universal equation for the entire variety of boundary conditions in the wells. Production of wells of selected deposits is a gas-liquid mixture with a variable volume content of water along the length of the tubing as a result of its condensation.

The PipeSim® "Schlumberger" software contains more than 20 methods for calculating the pressure gradient for vertical and slightly inclined (up to 45°) flow. When the water content in the stream in the estuarine conditions is less than 2000 mm^3/m^3 (they are in the range of 1400 mm^3/m^3 at the deposit), they give close results. For practical calculations, the "No slip Assumption" technique is used [1]. A low error is also provided when using the "Lockhart & Martinelli" and "Mukherjee & Brill" correlations [4–8].

For the selection of the equation, the gas flow rate is measured, which is measured by the diaphragm gauge of the critical current, and the slaughter pressure, measured by a deep gauge or calculated through the annulus pressure by the barometric formula for a real gas column in the annulus [9].

If the geological and technical state of wells is complicated (the inflow of bottom water into the face, the presence of a sandy-clay flowline on the face, the seizure of tubing, etc.), an addressable friction factor is used to adjust the model and take into account additional hydraulic resistances.

The PipeSim® Schlumberger software contains 3 equations for critical gas flow (for all wells in the field, the condition for critical gas flow in the fittings is maintained). The collection of the actual information for the selection of the equation for the critical gas flow is carried out according to the following algorithm:

1) measurement of pressures before and after the nozzle when working in the gas gathering network;

2) switching wells to the atmosphere through a diaphragm flow meter;

3) regulation of the well operation parameters by a corner fitting to the installation at the wellhead of the pressure equal to the wellhead during its operation in the gas gathering network (measuring the working flow rate of the well).

Thus, the information for the adaptation of the model is obtained. Further, the pressure is introduced into the model before and after the nozzle, its diameter (to regulation), and the gas flow rate is calculated. The equivalent diameter of the nozzle is determined by the marks on the needle of the union. In the case when a club is used as a chimney, its actual diameter is taken. This information is provided by the extraction department. By comparing the calculated and actual values, a conclusion is made about the correctness of the calculation.

3. Experimental researches

In this paper, simulation of a static multiphase flow in the PipeSim® "Schlumberger" software is performed.

PipeSim® "Schlumberger" provides the ability to optimize wells based on integrated modeling of the technology of opening the seams and mechanized mining systems. The software complex allows to diagnose complications limiting the producing potential of wells and optimize the operating mode of the mining fund using estimated measures to increase production.

The simulator implements the work of three separate gas gathering systems of the Opishnia OGCF, the Western arch of the Berezivka gas condensate field and the Kotelva gas condensate field, as well as the operation of the system between the inter-field gas pipelines of the gas supply to the Solokha MF. The created gas gathering network is linked to the GIS Map service area by real data, which reflects the actual location of the objects. Adaptation of working models is carried out on the basis of the analysis of the operation of industrial facilities and equipment according to the parameters specified in the technological regime and the report of field operations. The architecture of building models is shown in **Fig. 1** [1, 10].

The component composition and physicochemical properties of the producing gases along the wells of the group of deposits in question were determined on the basis of processing the results of gas condensate studies conducted by employees of UkrNIIGaz in the period from 2008 to 2018. For wells on which gas condensate studies were not conducted, the composition of the component mixture was adopted by analogy. The analogy was carried out taking into account the discovery of the same productive horizons with similar existing thermobaric conditions of occurrence [10].

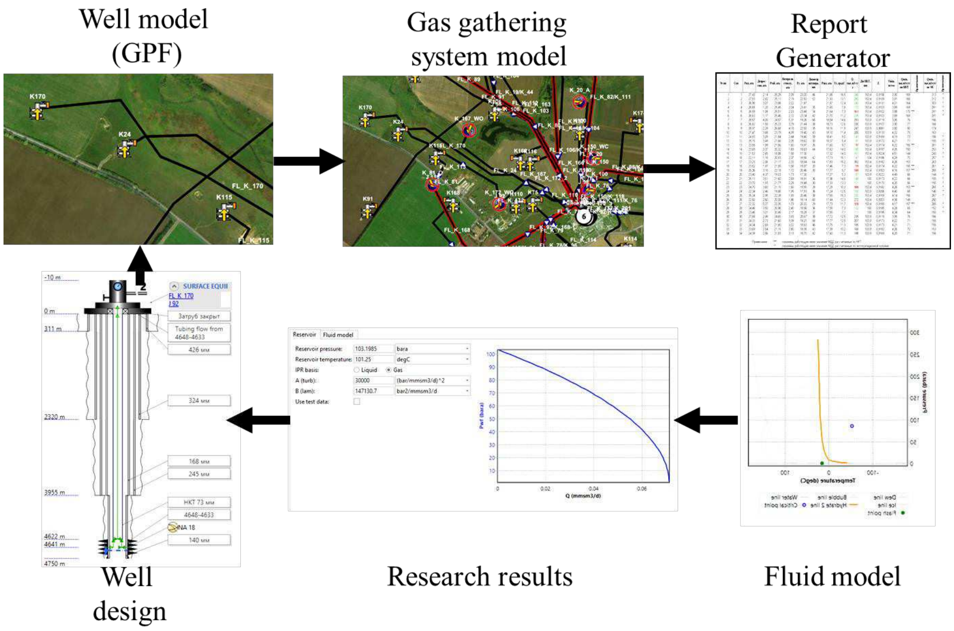


Fig. 1. The process of building models

The component composition of commercial gas was determined by the results of physico-chemical indicators of the quality of natural gas obtained in the physico-chemical laboratory of the GPD "PoltavaGasVydobuvannya".

In order to create a more accurate PVT model for the calculation of the formation – well – flowline – GPF – BCS –inter-field gas pipeline , the authors of this project, on the basis of well-known operating instructions and methodological guidelines [11–13], "breakdown" of the producing gases into heptane + above, and commodity – to n-deans + above.

Models of properties of well fluids in the Opishnia OGCF, the Western arch of the Berezivka gas condensate field and the Kotelva gas condensate field and fluids of the inter-field transportation system from the Opishnia GPF , Berezivka GPF, Kotelva cycling process unit (CPU) to Solokha MF were developed and adapted in the Fluid manager Compositional program module and physico-chemical properties of the gas, as well as taking into account the values of the gas-water factor presented in the report of the daily reporting of hydrocarbon production. As a basis for these deposits, a model of fluid inflow to the "Jones" face was applied [1, 10].

As a result of the work, the phase equilibrium curves found in the PipeSim® "Schlumberger" working models were obtained, which allows the creation of well models quickly and efficiently, which helps to maximize production and determine reservoir potential. The program simulates a multiphase flow from the formation to the wellhead, taking into account all the influencing factors.

Models of wells of the Opishnia OGCF, the western arch of the Berezivka gas condensate field and the Kotelva gas condensate field are constructed using the Well Editor built-in editor. Well construction data were used to construct the well design, as well as fluid models created in the PipeSim® Schlumberger software in the previous stage. Due to the availability of only obsolete data on well productivity, the coefficients of the filtration resistance A of productive horizons were listed and adapted to the operating parameters of the technological regime and the report of the daily reporting of hydrocarbon production for February 2018

The graph of the inflow function for the example of the No.1 well of the Opishnia OGCF is shown in **Fig. 2.**

The next step was the creation of a gas gathering network model. The gas gathering system is determined by the configuration and size of the deposit, the grid of placement and production rates of individual wells, the number and characteristics of productive horizons, the technological scheme of field gas preparation for transport, the requirements for reliability of gas supply from the fishery. At this stage of the work, the collection network was modeled in the form of complete systems, taking into account the interaction of various components, such as wells and trails, are involved in common collection systems. The wellhead pressure and the capacity of the gas gathering network are influenced by the counter pressure applied to the production system. Modeling of the collection systems allows to determine the effects from the change in the number of wells, increase in depression, looping of pipeline lines, changes in inlet pressure in the process line for gas preparation, and the like.

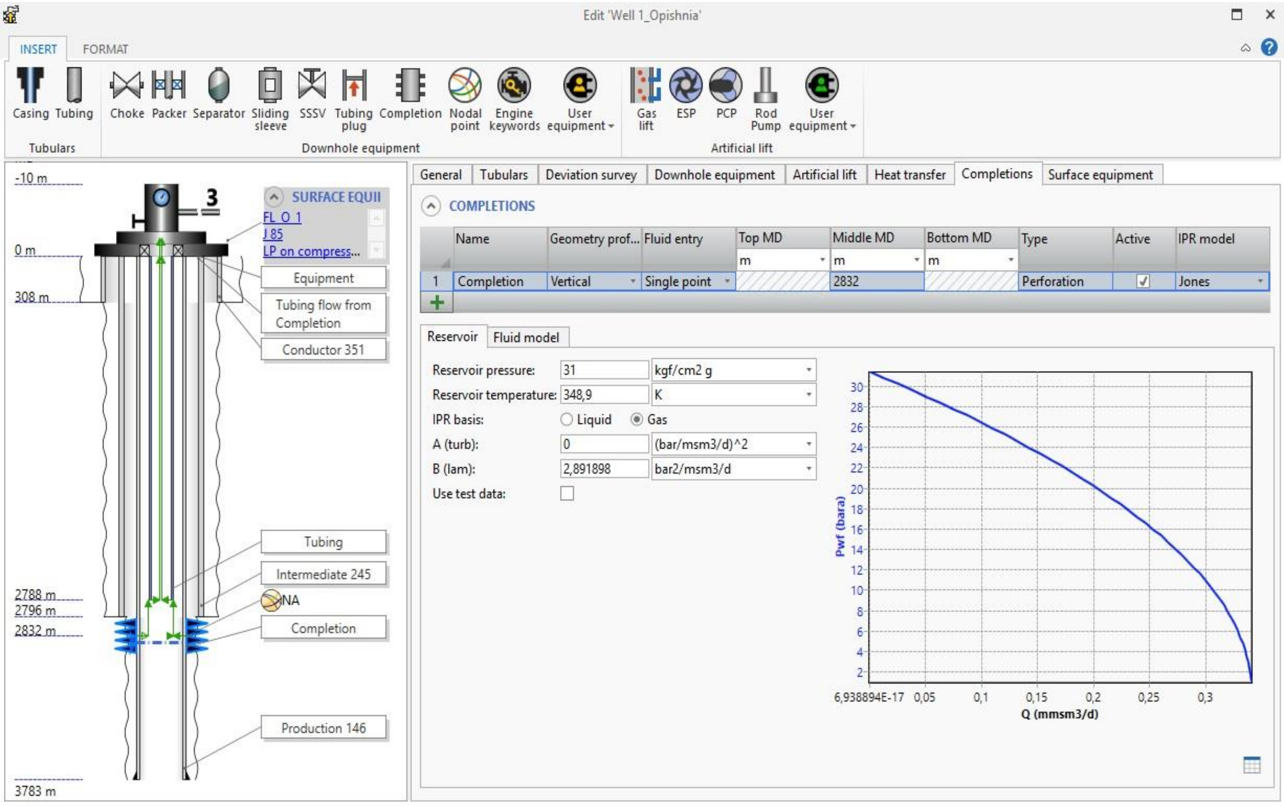


Fig. 2. Graph of the function of the inflow of well No. 1 of the Opishnia OGCF

In this module, the construction and calculation of the collection system are considered to evaluate the performance of a full-scale mining system.

The models are three separate gas gathering systems of the Opishnia OGCF, the western arch of the Berezivka gas condensate field and the Kotelva gas condensate field, where the network combines the producing gas wells into a closed collection system and delivers the combined stream to the final collection point. The previously created models of wells with a composite fluid were added to the network and connections (gas lines – flowline) were used, which allowed creating a gas gathering network with geo reference to the GIS Map service site based on real data that reflects the actual location of the objects (**Fig. 3**). The data of the geometric profile are shown in **Fig. 4** on the example of flowlines of wells No. 1 of the Opishnia OGCF.

The created models of gas pipeline-flowlines are adapted to the current state, characterized by the data of the technological regime and the report of the daily reporting of hydrocarbon production.

Based on the developed models of the gas gathering system of deposits in the program module Network simulation, the working parameters of the “reservoir-slaughter-estuary” system are calculated taking into account the counter pressure at the inlet of the GPF. The obtained results are compared with the data of the technological regime and the report of the daily reporting of hydrocarbon production.

In the subsequent authors, the models were linked to GPF. At its core, this system is a system of inter-field gas pipelines, for collecting gas from the GPF and submitting it for the integrated preparation of Solokha MF. In fact, the system consists of: – low-pressure gas pipelines for supplying gas from low-pressure wells without compressing the gas of the Opishnia OGCF and the Berezivka OGCF (operating pressure within 12 atm) at the Kotelva CPU – high-pressure gas pipelines for supplying gas from Berezivka, Kotelva and Opishnia gas wells and compressed gas at the BCS of the Opishnia OCGF and the Kotelva CPU on the Solokha MF.

A model of the system has been created between inter-field gas pipelines connecting Berezivka OCGF, Kotelva CPU, Opishnia OGCF and Solokha MF, Solokha BCS adapted to the actual state, characterized by summary data and is shown in **Fig. 5**.

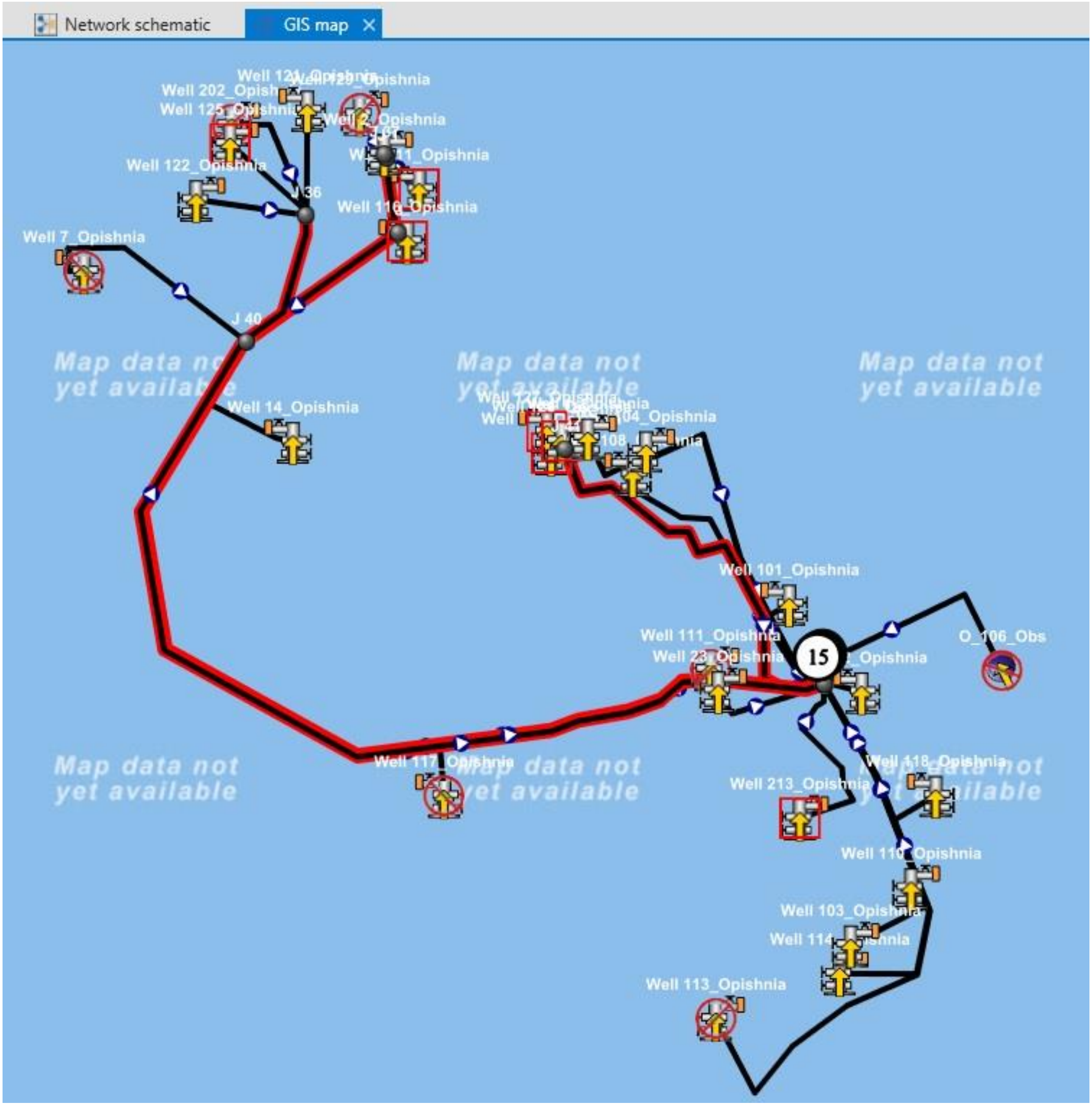


Fig. 3. The gas gathering system of the Opishnia OGCF

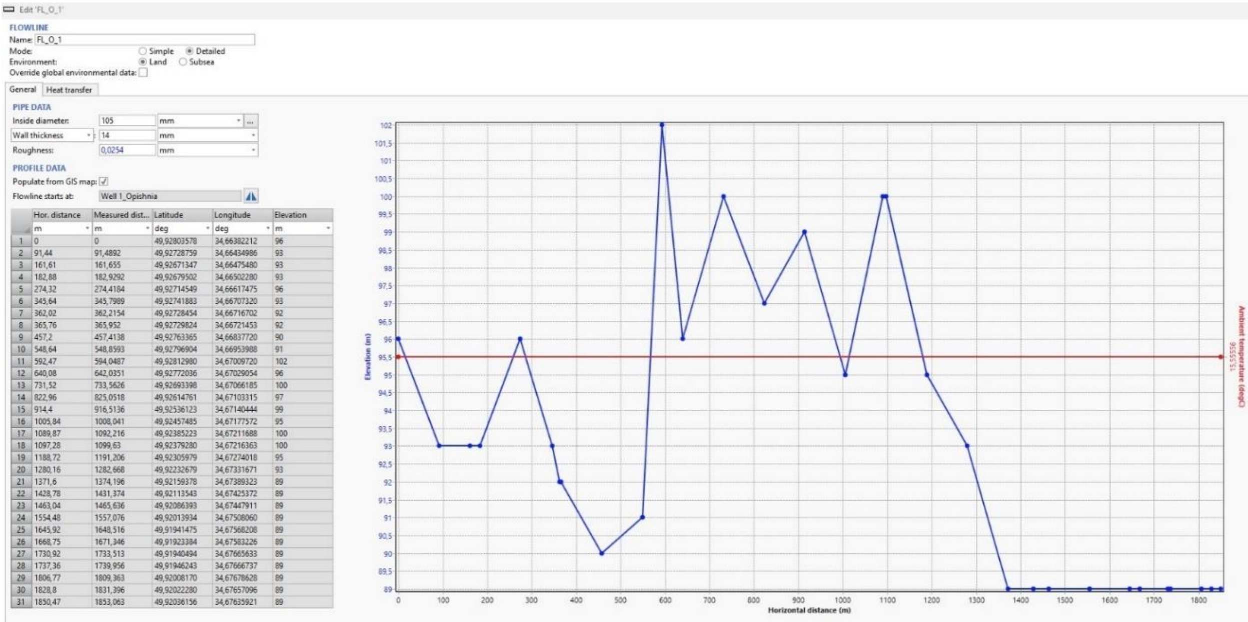


Fig. 4. Geometric profile of the route of laying the flowline No. 1 of the Opishnia OGCF

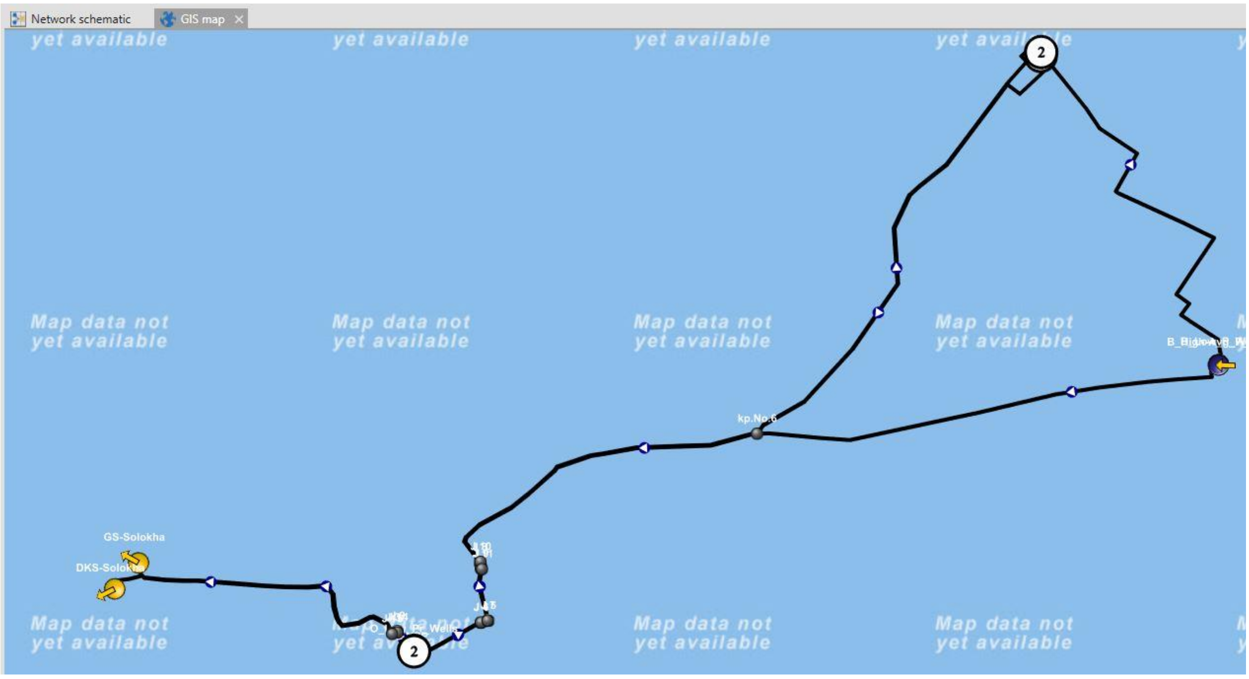


Fig. 5. A model of the system between inter-field gas pipelines connecting Berezivka OGCF, Kotelva CPU, Opishnia OGCF and Solokha MF, Solokha BCS with geo-reference

4. Analysis of the created models of the gas production system

After analyzing in the software modules Nodal analysis and P/T profile for each well of the Opishnia oil and gas condensate field, the Western arch of the Berezivka gas condensate field and the Kotelva gas condensate field, the following results were obtained:

– plots of inflow-outflow of fluid at the nodal point at the bottom of wells;
– well productivity;
– state of fluid flow regimes in wells;
– state of high-speed operation modes of wells;
– volumes of fluid accumulation at the bottom of wells.

Analyzing the results obtained for the well fluid injection of the above fields, it is clearly noted that 75 % of the Opishnia oil and gas condensate field are operating at gas velocities inadequate for fluid removal from the productive horizon to the tubing and 35 % in the tubing interval, 71 % of the wells of the Western arch of Berezivka GCF with gas velocities insufficient to carry out liquid in the interval from the production horizon to the tubing shoe, whereas in the coiled tubing interval, all wells operate at gas velocities sufficient to supply the liquid bones, 60 % of the wells of the Kotelva gas condensate field operate at gas velocities inadequate for fluid removal from the production horizon to the tubing shoe, 50 % in the tubing interval and 28 % of the wells operate in a single-phase flow in the interval from the productive horizon to the tubing.

A graph of inflow-outflow of fluid at the node at the bottom of well No. 1 of the Opishnia oil and gas condensate field, taking into account its safe operating conditions for the actual well design, is shown in **Fig. 6**.

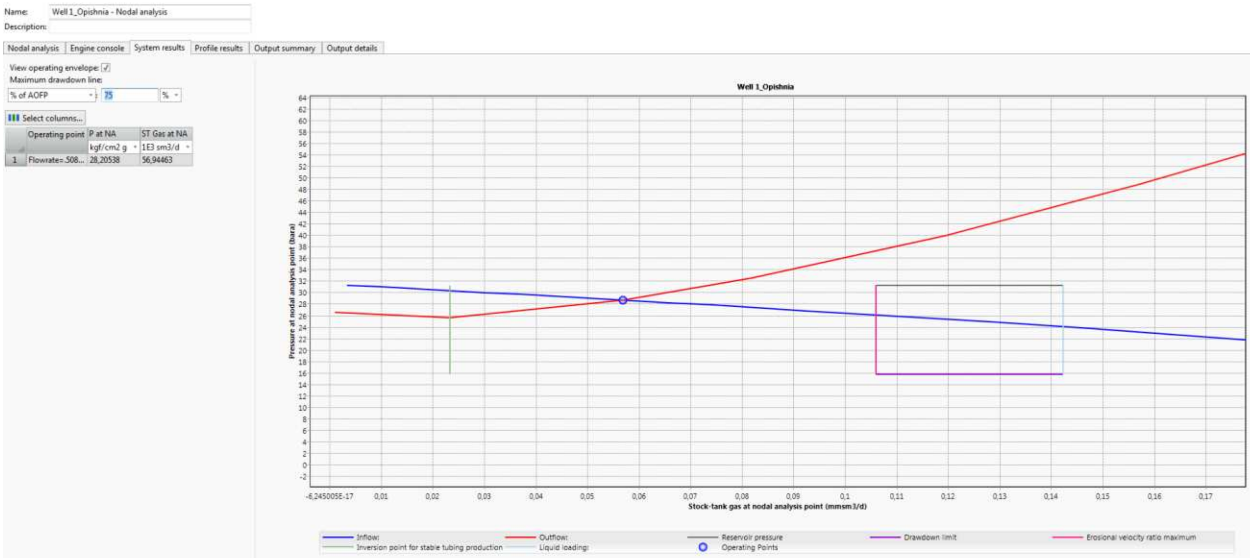


Fig. 6. Graph of inflow-outflow of well fluid of Opishnia oil and gas condensate field (Well No. 1) (base)

Analyzing graphs of inflow-outflow of fluid it is observed that the inflow-outflow node of the majority of wells of the group of deposits in question falls outside the safe range of operating conditions, primarily due to the insufficient gas flow rate in the wells. The required flow rates of the wells providing sufficient upstream velocity for complete liquid transfer are presented in the results of [10].

5. Optimization of the operating modes of the "formation-MF" system

Optimization of the system involves performing a nodal analysis at points in the system to obtain information about the behavior of the system in the following cases:

– optimization of the operation of the collection system and inter-field transportation of gas with a reduction in the back pressure of the Solokha MF (actually reducing the working pressure in the system) and withdrawing the work of the wells to reduce operating pressure;

– optimization of the operation of the collection system and inter-field transportation of gas with the reduction of hydraulic resistance (liquid withdrawal, prevention of hydrate formation) and reduction of the counter pressure of the Solokha MF and the working of the wells to reduce operating pressure.

To optimize the operation of the collection system and inter-field transportation of gas by reducing the counter pressure at the Solokha MF, the following scenarios are considered:

a) I scenario (input pressure on the BCS Solokha =12 kgf/cm², input pressure on the BCS fields =5 kgf/cm²):

– low-pressure gas of the Western arch of Berezivka GCF is supplied to the BCS of Kotelva CPU (inlet pressure =5 kgf/cm^2);

– part of the low-pressure gas of the Opishnia gas condensate field (going around BCS Opishnia) is fed to the Solokha BCS (inlet pressure =5 kgf/cm²);

– the entire gas of the Kotelva gas condensate field, the medium-high-pressure gas of the Western arch of the Berezivka gas condensate field, part of the low-pressure gas (passing through the BCS Opishnia) and the high-pressure gas of the Opishnia gas condensate field is fed through the high line of the Solokha MF (inlet pressure =12 kgf/cm^2);

b) II scenario (input pressure on the BCS Solokha =5 kgf/cm², input pressure on the DCS fields = 5 kgf/cm²):

– low-pressure gas of the Western arch of Berezivka GCF is supplied to the BCS of Kotelva CPU (inlet pressure =5 kgf/cm^2);

– part of the low-pressure gas of the Opishnia gas condensate field (going around BCS Opishnia) is fed to the Solokha BCS (inlet pressure =5 kgf/cm²);

– the entire gas of the Kotelva gas condensate field, the medium-high-pressure gas of the Western arch of the Berezivka gas condensate field, part of the low-pressure gas (passing through the BCS Opishnia) and the high-pressure gas of the Opishnia gas condensate field is fed through the high line of the Solokha MF (inlet pressure =5 kgf/cm^2);

c) III scenario (input pressure on the BCS Solokha =2 kgf/cm², input pressure on the DCS fields =2 kgf/cm²):

– dismantling of the Kotelvaand Opishnia BCS;

– all low-pressure gas of the Opishnia gas condensate field is supplied to the Solokha BCS (inlet pressure =2 kgf/cm²);

– all gas from the Kotelvaand Western arch of the Berezivka gas condensate field, as well as the high-pressure gas of the Opishnia gas condensate field is fed through the high line of the Solokha MF (inlet pressure =2 kgf/cm²).

Calculations to optimize the operation of the collection system and inter-field gas transportation were carried out for each scenario taking into account the actual hydraulic state and subject to the reduction of hydraulic resistance (reduction of the volume of liquid contaminants due to increased loading and reduction of operating pressures). The withdrawal of wells of the Opishnia oil and gas condensate field, the Western arch of the Berezivka gas condensate field and the Kotelva gas condensate field to reduce the working pressure in the above scenarios is presented in the results [10]. The volumes of gas production in the fields as a whole and their comparative analysis, as well as the withdrawal of well work for the introduction of optimization activities are presented in **Tables 1, 2**.

Table 1

Volumes of gas production under the scenarios of the Opishnia oil and gas condensate field, the Western arch of the Berezivka gas condensate field, the Kotelva gas condensate field and their comparative analysis

The actual state of the system of inter-field gas pipelines				
Solokha MF Pin=12 kgf/cm^2				
Deposit	**Technological lines**	**Base Pin GPF, kgf/cm^2**	**Solokha MF =12 kgf/cm^2 Pin GPF, kgf/cm^2**	**ΔQ, %**
1	**2**	**3**	**4**	**5**
Kotelva GCF	low-pressure	8	5,5	4,4
	medium-pressure	26	21,29	5,12
	high-pressure	38	21,29	55,27
	KarpatyGaz	38	21,29	17,32
Western Berezivka GCF	low-pressure	29	6,8	9,86
	medium-pressure	40	19,76	26,09
	high-pressure	52	19,76	20,71

Continuation of Table 1

1	2	3	4	5
Opishnia GCF	low-pressure on Opishnia BCS	9	5,5	15,45
	low-pressure on Solokha BCS	10	6,51	8,53
	high-pressure	29	18,01	22,41
Solokha MF Pin=5 kgf/cm²				
Deposit	**Technological lines**	**Base**	**Solokha MF = 5 kgf/cm²**	**ΔQ, %**
		Pin GPF, kgf/cm²	**Pin GPF, kgf/cm²**	
Kotelva GCF	low-pressure	8	5,5	4,4
	medium-pressure	26	18,19	7,35
	high-pressure	38	18,19	61,36
	KarpatyGaz	38	18,19	17,82
Western GCF	low-pressure	29	6,8	9,92
	medium-pressure	40	16,34	28,27
	high-pressure	52	16,34	21,89
Opishnia GCF	low-pressure on Opishnia BCS	9	5,5	15,45
	low-pressure on Solokha BCS	10	6,51	8,53
	high-pressure	29	13,91	28,03
Solokha MF Pin=2 kgf/cm²				
Deposit	**Technological lines**	**Base**	**Solokha MF = 2 kgf/cm²**	**ΔQ, %**
		Pin GPF, kgf/cm²	**Pin GPF, kgf/cm²**	
Kotelva GCF	low-pressure	8	15,09	–19,47
	medium-pressure	26	15,09	10,41
	high-pressure	38	15,09	70,01
	KarpatyGaz	38	15,09	18,51
Western Berezivka GCF	low-pressure	29	15,71	9,35
	medium-pressure	40	15,71	28,62
	high-pressure	52	15,71	22,08
Opishnia GCF	low-pressure on Opishnia BCS	9	7,33	8,59
	low-pressure on Solokha BCS	10	7,33	6,65
	high-pressure	29	11,12	31,05
The state of the system of inter-field gas pipelines, taking into account the decrease in hydraulic resistance				
Solokha MF Pin=12 kgf/cm²				
Deposit	**Technological lines**	**Base**	**Solokha MF = 12 kgf/cm²**	**ΔQ, %**
		Pin GPF, kgf/cm²	**Pin GPF, kgf/cm²**	
Kotelva GCF	low-pressure	8	5,5	4,4
	medium-pressure	26	15,36	10,23
	high-pressure	38	15,36	69,46
	KarpatyGaz	38	15,36	18,47

Continuation of Table 1

1	2	3	5	6
Western Berezivka GCF	low-pressure	29	6,8	9,92
	medium-pressure	40	14,95	29,05
	high-pressure	52	14,95	22,31
Opishnia GCF	low-pressure on Opishnia BCS	9	5,5	15,45
	low-pressure on Solokha BCS	10	6,51	8,56
	high-pressure	29	14,09	27,81
Solokha MF Pin=5 kgf/cm²				
Deposit	**Technological lines**	**Base**	**Solokha MF = 5 kgf/cm²**	**ΔQ, %**
		Pin GPF, kgf/cm²	**Pin GPF, kgf/cm²**	
Kotelva GCF	low-pressure	8	5,5	4,4
	medium-pressure	26	10,14	13,28
	high-pressure	38	10,14	79,26
	KarpatyGaz	38	10,14	19,2
Western Berezivka GCF	low-pressure	29	6,8	9,92
	medium-pressure	40	9,51	31,37
	high-pressure	52	9,51	23,65
Opishnia GCF	low-pressure on Opishnia BCS	9	5,5	15,45
	low-pressure on Solokha BCS	10	6,51	8,53
	high-pressure	29	8,08	33,63
Solokha MF Pin=2 kgf/cm²				
Deposit	**Technological lines**	**Base**	**Solokha MF = 5 kgf/cm²**	**ΔQ, %**
		Pin GPF, kgf/cm²	**Pin GPF, kgf/cm²**	
Kotelva GCF	low-pressure	8	8,13	–0,23
	medium-pressure	26	8,13	14,16
	high-pressure	38	8,13	84,02
	KarpatyGaz	38	8,13	19,78
Western Berezivka GCF	low-pressure	29	7,64	9,89
	medium-pressure	40	7,64	31,88
	high-pressure	52	7,64	23,98
Opishnia GCF	low-pressure on Opishnia BCS	9	7,33	8,59
	low-pressure on Solokha BCS	10	7,33	6,65
	high-pressure	29	5,38	35,28

Table 2

Response of the work of wells to the introduction of optimization activities

No.	**The actual state of the system of 8inter-field gas pipelines**				**Increase in production, %**
	Base		**Solokha MF Pin=12 kgf/cm²**		
	Wellhead pressure	**Depression**	**Wellhead pressure**	**Depression**	
	atm	**atm**	**atm**	**atm**	
Opishnia OGCF					
1	**2**	**3**	**4**	**5**	**6**
108	29,8	40,3	19,7	52,7	17,1
2	30	116,9	19,6	130,1	4,6
212	32,9	7,9	27,9	11	30,3
213	30	21,4	20,8	30,6	21,2
126/127	35,9/13,2	4,9/2,3	34,5/11,9	5,2/2,7	6,7

Continuation of Table 2

Western arch of Berezivka GCF					
1	**2**	**3**	**4**	**5**	**6**
136	54,6	43	31,8	66,8	34,6
200	54,1	178	27,3	212,1	9
201	52,5	121,5	22,3	163	17,6
202	51,8	23,6	46,7	29,5	22
Kotelva GCF					
174	38,2	16,6	22,1	30	63,1
168	51,7	13,7	47	15,9	14,7
75	38,9	66,2	23,5	88,7	19,3
103	40,1	34,2	27,3	52,5	36,7
114	26,8	106,2	22,1	111,7	2,8
115	26,9	82,4	22,4	87,4	3,6
116	26,9	82,5	22,9	86,9	3,2
104	32,3	81	29,1	84,6	2,9
170	27	47,7	22,6	53	7,4
44	27	35,9	22,8	41,5	10,6

As a result of simulation of the implemented methods for optimizing the operating modes of the system, the authors reproduce the inflow-outflow diagrams of the fluid at the node at the bottom of the Opishnia OGCF, the Western arch of Berezivka GCF and the Kotelva GCF, taking into account their safe operation modes for actual well designs (**Fig. 7**).

The results obtained in the nodal analysis from the recall of the wells satisfy the conditions under which the flow velocity does not exceed the rate of erosion wear (**Table 2**).

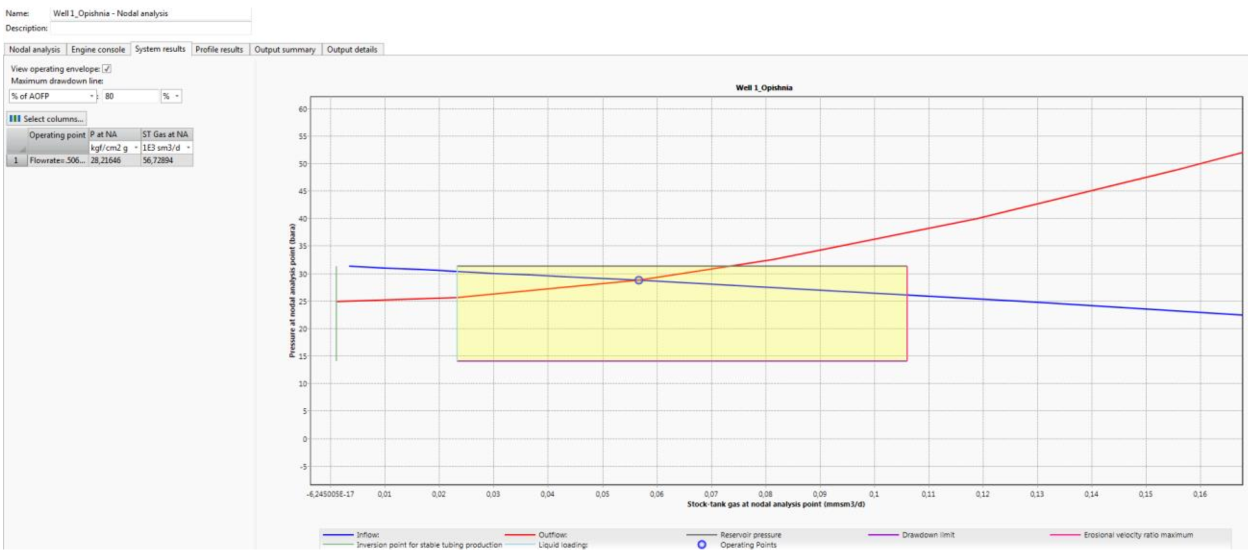


Fig. 7. Graph of inflow-outflow of the well fluid of the Opishnia OGCF (well No. 1) (taking into account the safe area of the well operation modes)

After modeling the pressure drop in the system, the authors assessed the movement of liquid stoppers and hydrate formation on the basis of the existing gas pipeline in PipeSim® Schlumberger.

To assess the movement of liquid stoppers in conditions of a decrease in the operating pressure in the system between industrial gas pipelines or changes in other operating conditions (in particular, the growth of the loading of the gas transportation system in conditions of increasing production from wells) is possible through the use of two or more simulations. The calculation was carried out for the of inter-field gas pipelines Berezivka-Kotelva-Opishnia in conditions of a decrease in the working pressure from 24 to 12 atm.

Estimation of contamination levels in the cavity of gas pipelines at a working pressure of 24 atm is shown in the column Total HoldUp Liquid (Total HOL) in **Fig. 8.**

It is taken into account in the calculation that when the working pressure is reduced and the loading is stable, the linear gas velocities increase substantially, which will lead to a redistribution of the liquid masses. In order to visualize them, let's consider the first section in front of the entrance to the Solokha BCS, namely Opishnia – Solokha, on which 19.76 m^3 of liquid is stored.

Estimation of contamination volumes in the cavity of gas pipelines at a working pressure of 12 atm is presented in the column Total HoldUp Liquid (Total HOL) in **Fig. 9.**

As can be seen from **Fig. 9**, the amount of accumulated pollution in the area will decrease to 5.08 m^3 or the approximate volume of the moving bag will be about 15 m^3.

The time required for this bag to be moved by the gas flow from the lowered location of the pipeline to the inlet to the separation equipment is shown in **Table 2.** The following estimates are used to estimate it:

– maximum speed, which is formed in the gas pipeline with a decrease in working pressure to 12 atm – 28 m/s;

– maximum speed, which is formed in the gas pipeline when working at pressures of 24 atm – 4 m/s;

– the average speed formed in the gas pipeline when the operating pressure drops to 12 atm – 16 m/s.

Table 3

Time required to move the liquid bag

Level	Volume of liquid bag, m^3	Site length, m	Linear speed, m/s	Time required to move the bag, min
minimum	15,0	7000,0	4,0	30
average	15,0	7000,0	16,0	8
maximum	15,0	7000,0	28,0	4

As can be seen from **Table 3**, the expected time of fluid intake will begin 4 minutes after the operating pressure has dropped and will end after 30 minutes, during which 15 m^3 of liquid will be trapped in the separators

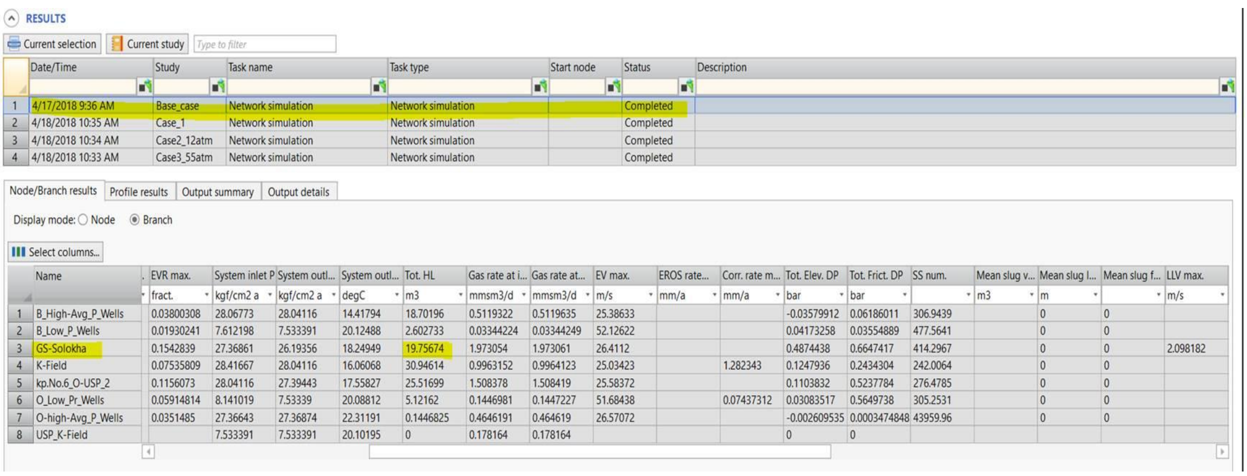
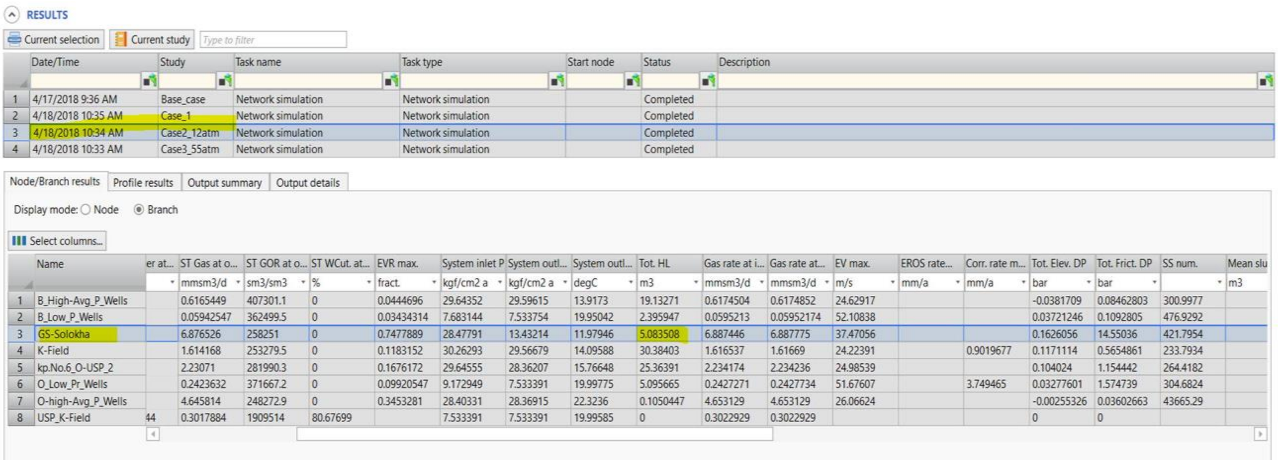


Fig. 8. Estimation of the approximate volume of contaminants in the cavity of the gas pipeline system at a pressure of 24 atm


RESULTS

Current selection | Current study | Type to filter

	Date/Time	Study	Task name	Task type	Start node	Status	Description
1	4/17/2018 9:36 AM	Base_case	Network simulation	Network simulation		Completed	
2	4/18/2018 10:35 AM	Case_1	Network simulation	Network simulation		Completed	
3	4/18/2018 10:34 AM	Case2_12atm	Network simulation	Network simulation		Completed	
4	4/18/2018 10:33 AM	Case3_55atm	Network simulation	Network simulation		Completed	

Node/Branch results | Profile results | Output summary | Output details

Display mode: Node Branch

Select columns...

	Name	er at...	ST Gas at o...	ST GOR at o...	ST WCut. at...	EVR max.	System inlet P	System outl...	System outl...	Tot. HL	Gas rate at i...	Gas rate at...	EV max.	EROS rate...	Corr. rate m...	Tot. Elev. DP	Tot. Frict. DP	SS num.	Mean slu
			mmsm3/d	sm3/sm3	%	fract.	kgf/cm2 a	kgf/cm2 a	degC	m3	mmsm3/d	mmsm3/d	m/s	mm/a	mm/a	bar	bar		m3
1	B_High-Avg_P_Wells		0.6165449	407301.1	0	0.0444696	29.64352	29.59615	13.9173	19.13271	0.6174504	0.6174852	24.62917			-0.0381709	0.08462803	300.9977	
2	B_Low_P_Wells		0.05942547	362499.5	0	0.03434314	7.683144	7.533754	19.95042	2.395947	0.0595213	0.05952174	52.10838			0.03721246	0.1092805	476.9292	
3	GS-Solokha		6.876526	258251	0	0.7477889	28.47791	13.43214	11.97946	5.083508	6.887446	6.887775	37.47056			0.1626056	14.55036	421.7954	
4	K-Field		1.614168	253279.5	0	0.1183152	30.26293	29.56679	14.09588	30.38403	1.616537	1.61669	24.22391		0.9019677	0.1171114	0.5654861	233.7934	
5	kp.No.6_O-USP_2		2.23071	281990.3	0	0.1676172	29.64555	28.36207	15.76648	25.36391	2.234174	2.234236	24.98539			0.104024	1.154442	264.4182	
6	O_Low_Pr_Wells		0.2423632	371667.2	0	0.09920547	9.172949	7.533391	19.99775	5.095665	0.2427271	0.2427734	51.67607		3.749465	0.03277601	1.574739	304.6824	
7	O-high-Avg_P_Wells		4.645814	248272.9	0	0.3453281	28.40331	28.36915	22.3236	0.1050447	4.653129	4.653129	26.06624			-0.00255326	0.03602663	43665.29	
8	USP_K-Field	44	0.3017884	1909514	80.67699		7.533391	7.533391	19.99585	0	0.3022929	0.3022929				0	0		

Fig. 9. Estimation of the approximate volume of contaminants in the cavity of the gas pipeline system at a pressure of 12 atm

6. Conclusions

These studies were implemented in the simulation simulator of static multiphase flow PipeSim® "Schlumberger" in order to evaluate the efficiency of engineering calculations in the process of production, collection and transportation of hydrocarbon products, as well as to determine the current state of the system "bottomhole – GPF" and the effectiveness of implementation of activities rationalization of three separate gas gathering systems of the Opishnia oil and gas condensate field, the Western arch of the Berezivka gas condensate field and the Kotelva gas condensate field, as well as the operation of the system of inter-field gas gas pipelines to a final collection point Solokha MF(BCS Solokha).

1. At the first stage, the authors created dynamic fluid models (P-T) for each well with the curves of condensation of heavy hydrocarbons and moisture, hydrate formation, ice formation. Well models with the technical characteristics of the casing string, tubing and well equipment, inclinometry and well flow curves are constructed on the basis of well research results. After that, models for gas gathering and gas transmission systems were created, linking to the GisMap service area, constructing route profiles, assessing the state of insulation, heat exchange with the environment in accordance with the actual depth of the pipelines. Then, the well models and the gas transmission system were reconciled at control points (in particular, the GPF) in accordance with the selected backpressure point. At the end of this stage, the models were calibrated in accordance with the data of industrial studies and current operating modes of the wells and gas gathering system.

2. Nodal analysis is performed to obtain the intersection point of the inflow curves and the outflow curves in accordance with the current or simulated technological mode of operation. The pressure and temperature (P-T profile) graphs are plotted along the wellbore height, along the length of the borehole and the inter-field pipeline. The structure of the multiphase flow is determined, the volume of liquid in the wellbore is determined, along its bottom (loading of the well through the liquid), in the lowered areas of the trains and inter-field gas pipelines. The high-speed mode of operation of the system with checking the speed of erosion and corrosion destruction of pipelines is determined. The optimal and safe operating conditions of the well in the envelope of permissible parameters are determined: depression, working pressure at the wellhead, erosion failure rate, liquid accumulation at the bottom.

3. In order to optimize the gas production, collection and transportation system, the reaction of the wells (gas, condensate and water productivity) is evaluated to reduce the working pressure in the gas transmission system (change in the backpressure in the system).

4. The review of the systems for collecting gas, its inter-field transfer, field preparation, compression and supply to the gas transportation system is estimated, and the following list of integrated measures is envisaged:

1) reduction of counter pressure at the final Solokha MF. Expected Result:

a) I scenario (input pressure on Solokha MF=12 kgf/cm², inlet pressure on the Solokha BCS=12 kgf/cm²): the additional estimated production is 0,294 million m^3/day;

b) II scenario (input pressure on the Solokha MF=5 kgf/cm², inlet pressure on the Solokha BCS=5 kgf/cm²): the additional estimated production is 0,326 million m^3/day;

c) III scenario (input pressure on the Solokha MF=2 kgf/cm², inlet pressure on the Solokha BCS=2 kgf/cm²): additional estimated production is 0,289 million m^3/day.

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