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Original scientific paper

COMPARATIVE ANALYSIS OF SURFACE INFRASTRUCTURE MODELS FOR AN OIL FIELD IN THE PANNONIAN BASIN: EVALUATION OF ASPEN HYSYS AND GAP SOFTWARE

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Abstract: The Integrated Production Model (IPM) acts as a digital twin of the actual field, representing reservoir behavior, all wells and their equipment, as well as the entire surface infrastructure. This model allows for changes in parameters within the virtual environment, enabling the simulation of various scenarios to determine how these changes affect the entire system. Consequently, it is possible to select the most optimal scenario and validate its impacts. The development of the surface infrastructure model represents the final step in integrated production modeling, and this study focuses on creating a surface infrastructure model of an oil field in the Pannonian Basin using two software tools: Aspen HYSYS and Petroleum Experts - GAP. The goal is to compare the results obtained and identify the advantages and limitations of these software solutions. This analysis offers valuable insights into the capabilities of each program in simulating and optimizing oil operations. Engineers use a range of computational strategies and mathematical models to design and operate processing facilities. Aspen HYSYS is a widely recognized tool in the oil and gas industry for process simulation, allowing engineers to model various operational scenarios in detail and assess their impact on system performance. Aspen HYSYS is used for modeling the entire production process, including oil and gas processing, refining, and chemical plants, while GAP specializes in integrated asset modeling (IAM), modeling wells, flowlines, risers, and surface facilities, optimizing the entire production system from the reservoir to the processing plant. This paper first provides the theoretical background relevant to the research topic, including the basic concepts of process simulation in Aspen HYSYS and GAP. Following that, the research methodology is presented, including the steps of simulation and analysis. Finally, the simulation results are discussed, and conclusions are drawn regarding the applicability of both software tools for modeling surface infrastructure in oil fields.

Keywords: Integration Production Modeling, Oil and Gas Gathering and Stabilization, Aspen HYSYS, GAP – Petroleum Experts, Surface infrastructure

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1 INTRODUCTION

The gathering station is one production facility at the oil field that serves as a gathering place for several liquids produced from production wells to measure the production flow rate (Madonna et al., 2022). The development of surface infrastructure models in the oil and gas industry is a crucial step toward process optimization, increasing efficiency, and reducing costs. The application of software tools such as HYSYS and GAP enables engineers to simulate various operational scenarios, analyze performance, and identify potential issues before they arise in actual operations.

HYSYS enables precise modeling of various phases in the production cycle, particularly the separation of oil, gas, and water. Based on simulations, it is possible to reduce costs and increase efficiency (Elkamel et al., 2003). GAP software integrates surface gathering system components with subsurface simulations and enables the optimization of oil and gas transport, which is particularly useful in complex production systems (Petroleum Experts, 2010).

Aspen HYSYS is used as an integrated process simulator in both steady-state and dynamic modes. The simulation models created in HYSYS are utilized for various purposes: plant design, performance monitoring, problem-solving, operational process improvement, business planning, and asset management. The software offers an integrated set of intuitive and interactive tools for simulation and analysis, as well as real-time applications. It provides rapid evaluations of safe and reliable designs through the quick creation of interactive models for "what-if" studies and sensitivity analyses (Guo et al., 2007).

GAP's robust calculation engine can optimize highly complex networks consisting of thousands of components, such as wells, pipelines, compressors, pumps, heat exchangers, and more, interconnected in any configuration, including intricate loops with multiple control points throughout the system. This flexibility is complemented by GAP's state-of-the-art optimization engine, which is considered the most powerful and fastest in the industry, utilizing advanced non-linear optimization techniques (Petroleum Experts, IPM13).

The development of the surface infrastructure model in GAP requires the prior creation of the reservoir model in MBAL and the models of all wells in the observed oil field using PROSPER. All of these software tools belong to the group of Petex software for integrated modeling. The first step involves the preparation and verification of input data on pipelines and the creation of a custom database in Excel, which facilitates the automatic generation of the GAP model. Using a Python script developed through OPENSERVER, the automatic creation of the GAP model is enabled, significantly simplifying the process of building the surface infrastructure model compared to the model in HYSYS. The created script allows for the connection of multiple objects, pipe trimming and positioning, entry of data on wells and pipelines, pipe matching, and selection of the best correlation.

The following section provides a detailed description of the model development process in both software tools, including specific steps and methods used to optimize performance. Additionally, the results of the simulations are presented, offering insights into the efficiency and accuracy of each model, as well as an analysis that considers the advantages and disadvantages of the software solutions employed. Finally, conclusions are drawn that summarize the key findings and provide recommendations for future research and improvement of surface infrastructure models in the oil and gas industry.

2 METHODOLOGY

The analysis began with the development of a base model for the existing state of the surface infrastructure at oil field X using Aspen HYSYS and GAP software. When modeling surface infrastructure, it is crucial to accurately model the fluid, with the precision of the PVT model and the selection of the appropriate equation of state being the most important factors. To achieve alignment between the measured field data and the model data, the proper selection of correlations that describe pressure loss through the pipeline is essential.

The physical and chemical properties of crude oil vary significantly depending on the concentration of different types of hydrocarbons and minor constituents, as well as temperature and pressure. Accurate values of oil's physical properties and their changes during flow from the bottom of the well to the surface are essential as input data for fluid and heat transfer modeling (Martinović, 2022).

PVT properties of reservoir fluid are very important in petroleum engineering calculations, therefore, the accuracy of the calculations depends on the exactness of PVT properties. Ideally these properties are determined from laboratory analysis, of the samples (Kazemi, 2011).

A good PVT fluid model is crucial for successful modeling and simulation in the oil and gas industry.

In today's oil and gas industry, using a composite model and equation of state is increasingly important for accurately modeling the behavior of oil fluids. Black Oil correlations are typically used when limited information is available about the oil and gas in the system. The properties of oil and gas fluids are calculated from correlations with their specific weights, as well as several other easily measurable parameters (Honeywell, 2009).

The Black Oil fluid model assumes that the fluids consist only of liquid and gas phases, with the amount of gas dissolved in the oil depending on thermobaric conditions. The data necessary for creating the Black Oil fluid model includes: 1. oil density, 2. gas density, 3. gas-to-oil ratio (GOR), and 4. water saturation. This data must be obtained from laboratory flash analysis—analysis of multi-stage evaporation (usually three phases). The sum of the gases released from each phase of the laboratory evaporation is known as the production GOR. The density of oil produced from the last stage of evaporation defines the density of oil in the reservoir. The analysis should be conducted under conditions closely related to the operating conditions in the field (Zhao Y., 2016; Al-Safran Eissa & Brill P. James, 2017).

Compositional PVT models are developed based on reservoir fluid compositions and reservoir temperature. The mole fractions of hydrocarbon components (C_1, C_2, C_3, C_4, nC_4, C_5, nC_5, C_6, C_7, C_8, C_9, C_{10}, C_{11} and C_{12+}) and non-hydrocarbon components (H_2S, CO_2 and N_2), molecular weight (MW) of C12 and specific gravity (Sp.Gr) of C_{12+} are usually measured in the reservoir fluid compositions test. These parameters and reservoir temperature are used to prediction of bubble point pressure Pb, solution gas to oil ratio on bubble point - Rsb and formation volume factor for oil at bubble point – Bob (Kazemi, 2011).

When comparing Black Oil and the composite fluid model, it is evident that the composite model has greater accuracy in predicting the fluid properties of the hydrocarbon mixture. On the other hand, the Black Oil model requires only a few input data points (Mittbock, 2014). Due to the limitations of input data, the fluid model in the simulation was constructed as Black Oil.

The components that make up the oil were taken from the well model in PROSPER and selected when creating the component list, which effectively represents a starting step in the simulation itself. Pure components and pseudocomponents were selected based on the following parameters: critical temperatures, pressures, and volumes, molar masses, and acentric factors—as one of the parameters that provide information about the degree of polarization and interactions among molecules.

The equation of state is used to describe the thermodynamic behavior of fluids and enables engineers to understand and predict how fluids will behave under different conditions of pressure, temperature, and volume.

Equations of State (EoS) are becoming more prevalent for modeling the fluid properties of crude oil and gas reservoirs, providing a more accurate prediction of fluid behavior compared to traditional black oil models (Almehaideb et al, 2000).

In 1873, van der Waals proposed an EOS that represented non-ideal behavior by accounting for finite volumes occupied by molecules of substances and the repulsive and attractive forces between these molecules. The van der Waals EOS is shown as:

$$\left(p + \frac{a}{V^2}\right)(V - b) = RT \tag{1}$$

In Eq. 1, p is pressure; V is volume; T is temperature; a is the attraction parameter to correct pressures for attraction between molecules; b is the effective molecular volume to correct for volume occupied by the molecules; and R is the universal gas constant.

The equation of state applied in both software is the Peng-Robinson equation, which will be elaborated on later.

In 1976, Peng and Robinson introduced a new two-parameter equation of state developed primarily to improve calculations in the vicinity of the critical region and improve calculation of liquid densities. The PR EOS (Eq. 2) is expressed as:

$$p + \frac{\alpha(T,\omega)}{V(V+b)+b(V-b)} = \frac{RT}{V-b} \quad (2)$$

α – shape parameter in gamma function

ω – acentric factor. (Ezekwe, 2010)

The Peng-Robinson equation of state was used, which is applicable to single-component systems for defining the partial pressure of a component and its volumetric state. However, it is also utilized in two-phase or multiphase systems to describe the phase behavior of the observed thermodynamic system. This equation is an improved model of the Soave-Redlich-Kwong equation of state and demonstrates its greatest advantage in defining the density of the liquid phase (Grubač, 2019).

The advantage of using it in the simulation package is that it represents the most advanced model in Aspen HYSYS, providing high accuracy over a wide range of temperatures and pressures (Zhao, 2016). Additionally, the Peng-Robinson equation of state is also employed in GAP software.

2.1 Data Collection

All necessary data for creating the model were obtained from the technical regime in Šahmatka for April 2024. To create a model of the surface infrastructure in GAP, it is first necessary to develop the reservoir model in MBAL and the well models in PROSPER.

In this process, it is essential to collect data on oil, gas, and water production (Tables 1, 2, and 3), as well as pressures for a specific date that will be used to create the model. Additionally, data on pipelines, including their lengths and diameters, must be gathered from the pipeline database and GIS (Tables 4, 5, 6).

An Excel table has been created, customized for automatic data input into GAP through OPENSERVER, utilizing a developed Python script.

In addition to the previously mentioned data, it is necessary to enter the components that constitute the oil in HYSYS. The oil composition includes components C1 to C50+. For HYSYS, due to modeling fluids as Black Oil, the gas composition input is also required (Table 7).

Furthermore, data on oil density, gas specific gravity, water salinity, and the molar fraction of non-hydrocarbon components—H_2S, CO_2, and N_2 (Table 8)—are required. For the HYSYS model, the input of viscosity variation with temperature is necessary due to working with the Black Oil model of fluid, and this data is provided in Table 9.

All well pipelines connecting the wells at GS-1 and GS-2 are made of pipe material Φ73 mm x 5.2 mm API STD 5L GRADE B, buried and protected against corrosion. The fluid is transported via pipeline from GS-2 to GS-1, where the process of separating the liquid from the gas phase occurs, along with the dehydration of oil and its preparation for shipment, as well as the disposal of formation water into designated wells. The extracted dissolved gas is further prepared and delivered to end consumers, including shipments to JP Srbijagas, as well as for the operation of a cogeneration plant where electricity is produced.

The following tables present the input data that were used for model development.

Table 1 Input data for gathering station 1

Serial number	Parameter	Unit of measure	AMU-1	AMU-2	AMU-3	AMU-4	AMU-5
1	Qf	m^3/day	268	304	178,2	201	398,2
2	Qo	m^3/day	31	51	50	40,692	82,113
3	Qg	m^3/day	60	574	65	856	1248
4	p	bar	500	480	490	580	547
5	T	degC	20	20	20	20	20

Table 2 Input data for gathering station 1

Serial number	Parameter	Unit of measure	AMU-6	AMU-7	AMU-8	AMU-9	AMU-10
1	Qf	m^3/day	187,3	156,8	187,5	225,3	126,2
2	Qo	m^3/day	31,847	30,05	34,684	41,788	25,234
3	Qg	m^3/day	280	839	967	1464	427
4	p	bar	594	500	500	500	670
5	T	degC	20	20	20	20	20

Table 3 Input data for gathering station 2

Serial num.	Para-meter	Unit of measure	AMU-1	AMU-2	AMU-3	AMU-4	AMU-5	AMU-6	AMU-7
1	Qf	m^3/day	220,7	220,2	202,7	315	327	159,7	413
2	Qo	m^3/day	49,11	51,63	39,67	55,46	67	33,34	116
3	Qg	m^3/day	801	861	1160	914	104	2372	1521
4	p	bar	676	682	679	696	682	1063	976
5	T	degC	20	20	20	20	20	20	20

Table 4 Input data for pipelines on GS-1

Gathering station 1 (GS-1)							
Serial num.	**Parameter**	**Unit of measure**	**AMU-1**	**AMU-2**	**AMU-3**	**AMU-4**	**AMU-5**
1	Pipe length	m	10	10	10	530	130
2	Internal diameter of the pipeline	mm	156,3	156,3	156,3	156,3	156,3
3	Wall thickness	mm	6	6	6	6	6

Table 5 Input data for pipelines on GS-1

Gathering station 1 (GS-1)							
Serial num.	**Parameter**	**Unit of measure**	**AMU-6**	**AMU-7**	**AMU-8**	**AMU-9**	**AMU-10**
1	Pipe length	m	165	55	35	18	700
2	Internal diameter of the pipeline	mm	156,3	156,3	156,3	156,3	156,3
3	Wall thickness	mm	6	6	6	6	6

Table 6 Input data for pipelines on GS-2

Gathering station 2 (GS-2)									
Serial num	**Parameter**	**Unit of measure**	**AM U-1**	**AM U-2**	**AM U-3**	**AM U-4**	**AM U-5**	**AM U-6**	**AM U-7**
1	Pipe length	m	15	15	15	15	15	650	10
2	Internal diameter of the pipeline	mm	156,3	156,3	156,3	156,3	156,3	156,3	116
3	Wall thickness	mm	6	6	6	6	6	6	6

Table 7 Component composition of gas

Parameter	**Unit of measure**	**C1**	**C2**	**C3**	**iC4**	**nC4**	**iC5**	**nC5**	**C6**	**C7**	**N2**	**CO2**
Component participation	mol %	87	3,23	0,3	0,04	0,02	0,02	0,01	0,03	0,02	4,49	4,89

Table 8 Viscosity at standard conditions – input for Hysys

Serial number	**Parameter**	**Unit of measure**	**Value**			
1	Temperature	degC	25	35	45	60
2	Viscosity at standard conditions	mm	96,93	55,1	34,5	19,3

Table 9 PVT characteristics of fluids

Serial number	**Parameter**	**Unit of measure**	**Value**	**Parameter**
1	ρ_o	kg/m^3	914	ρ_o - oil density
2	ρ_{gr}	ρgr	0,687	ρ_{gr} - gas gravity
3	Water salinity	ppm	6221,8	Water salinity
4	Molar percentage H_2S	mol %	0	Molar percentage H_2S
5	Molar percentage CO_2	mol %	4,88	Molar percentage CO_2
6	Molar percentage N_2	mol %	4,49	Molar percentage N_2

2.2 Creating and matching the model

Simulation is the process of creating an operational model of a system and conducting experiments on that model to understand the system's behavior or evaluate alternative strategies for its development and operation.

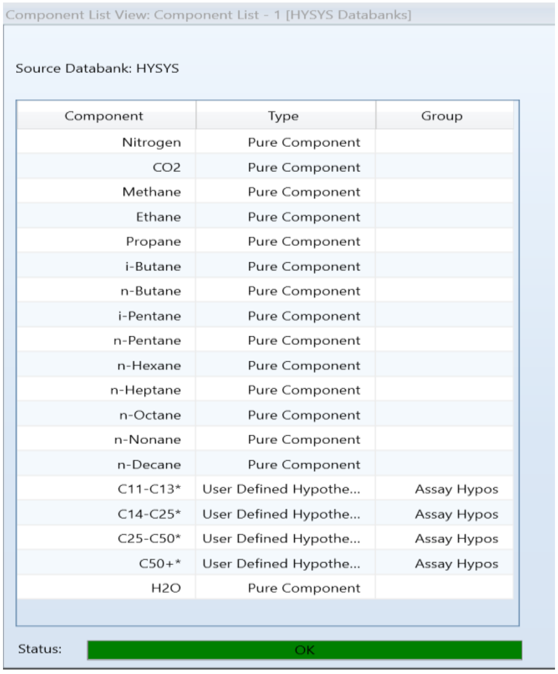
Models of the surface infrastructure for oil field X were created using Aspen HYSYS and GAP software, and the process of developing the models is described below.

Modeling in HYSYS

Considering that it is heavy oil composed of fractions up to C50+, the hydrocarbon components with more than 10 carbon atoms were grouped into pseudocomponents based on critical conditions: pressure, temperature, volume, acentric factor, etc., and entered into the software accordingly (Figure 1).

After defining the components that make up the oil, the next step involves selecting a thermodynamic model, i.e., an equation of state. Equations of state were developed to provide a mathematical relationship between pressure, volume, and temperature. Initially, they were introduced as a method to interpret the non-ideal nature of many pure substances. Later, the role of equations of state expanded to include the prediction of properties for both simple and complex mixtures. The equations used in PVT analysis are derived from the Van der Waals equation. In the software, the Peng-Robinson equation of state was used (Petroleum Experts, 2011).

The material streams, which represent automatic measuring units in the simulation, were modeled based on data on fluid production, system pressure, and temperature. Given that the base model was created using the Black Oil fluid model, input on the gas-to-oil ratio (GOR), water-to-oil ratio (WOR), water cut, oil density, viscosity changes with temperature, and the PVT composition of gas obtained from laboratory tests in the "oil and gas feed" section was also required. Based on the input data, the software independently calculated the molar fraction of each individual component in the fluid. Figure 2 shows the method of defining material streams in HYSYS and in Figure 3, the data input window for the Black Oil fluid model is shown.

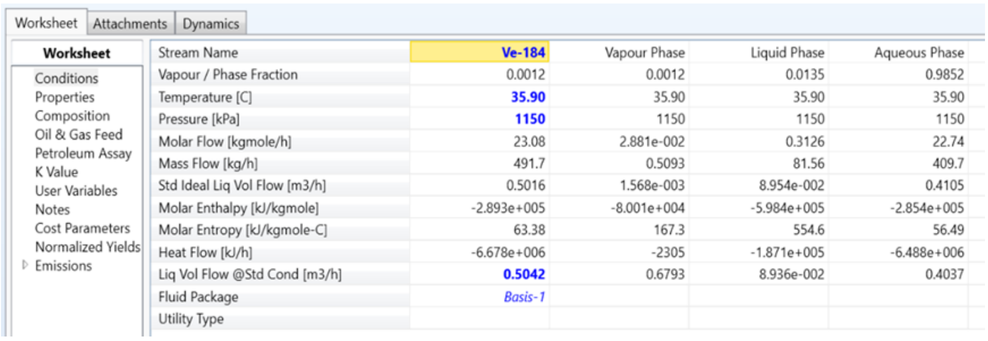

Component List View: Component List - 1 [HYSYS Databanks]

Source Databank: HYSYS

Component	Type	Group
Nitrogen	Pure Component	
CO2	Pure Component	
Methane	Pure Component	
Ethane	Pure Component	
Propane	Pure Component	
i-Butane	Pure Component	
n-Butane	Pure Component	
i-Pentane	Pure Component	
n-Pentane	Pure Component	
n-Hexane	Pure Component	
n-Heptane	Pure Component	
n-Octane	Pure Component	
n-Nonane	Pure Component	
n-Decane	Pure Component	
C11-C13*	User Defined Hypothe...	Assay Hypos
C14-C25*	User Defined Hypothe...	Assay Hypos
C25-C50*	User Defined Hypothe...	Assay Hypos
C50+*	User Defined Hypothe...	Assay Hypos
H2O	Pure Component	

Status: OK

Figure 1 Component List (Aspen Hysys V12)


Worksheet | Attachments | Dynamics

Worksheet: Conditions, Properties, Composition, Oil & Gas Feed, Petroleum Assay, K Value, User Variables, Notes, Cost Parameters, Normalized Yields, Emissions

Stream Name	Ve-184	Vapour Phase	Liquid Phase	Aqueous Phase
Vapour / Phase Fraction	0.0012	0.0012	0.0135	0.9852
Temperature [C]	35.90	35.90	35.90	35.90
Pressure [kPa]	1150	1150	1150	1150
Molar Flow [kgmole/h]	23.08	2.881e-002	0.3126	22.74
Mass Flow [kg/h]	491.7	0.5093	81.56	409.7
Std Ideal Liq Vol Flow [m3/h]	0.5016	1.568e-003	8.954e-002	0.4105
Molar Enthalpy [kJ/kgmole]	-2.893e+005	-8.001e+004	-5.984e+005	-2.854e+005
Molar Entropy [kJ/kgmole-C]	63.38	167.3	554.6	56.49
Heat Flow [kJ/h]	-6.678e+006	-2305	-1.871e+005	-6.488e+006
Liq Vol Flow @Std Cond [m3/h]	0.5042	0.6793	8.936e-002	0.4037
Fluid Package	Basis-1			
Utility Type				

Figure 2 Defining material streams in Hysys (Aspen Hysys V12)

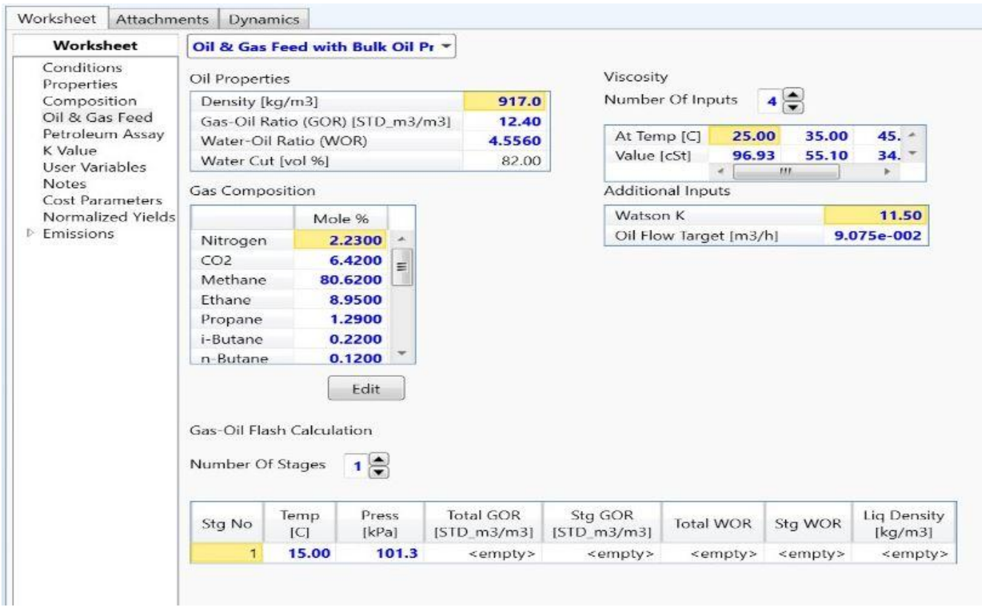


Figure 3 Defining material streams in HYSYS (Aspen Hysys V12)

The pipelines were modeled based on data regarding their length and diameters – both internal and external (Figure 4). This data was obtained from the pipeline database. The heat transfer coefficient (Figure 5) was determined using the "Estimate HTC" option based on data on burial depth and ambient temperature, as well as the soil composition at the burial depth, which is moist clay – data from the Republic Hydrometeorological Institute.

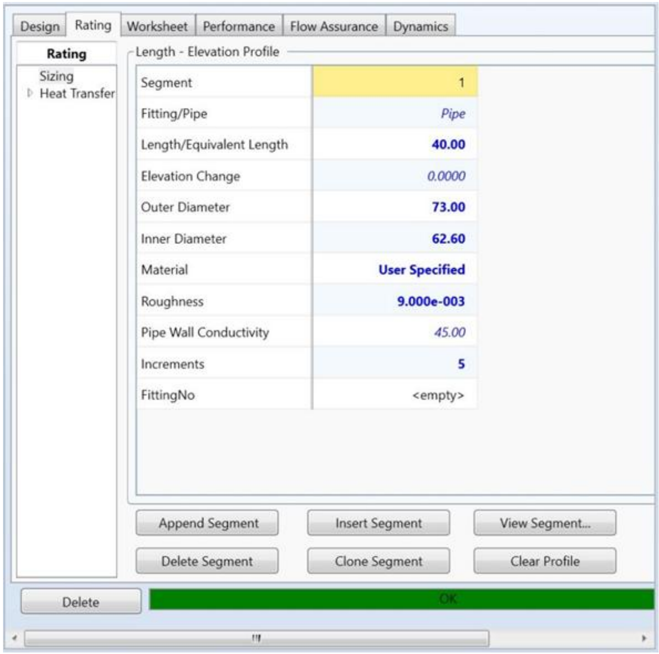


Figure 4 Defining pipelines in HYSYS (Aspen Hysys V12)

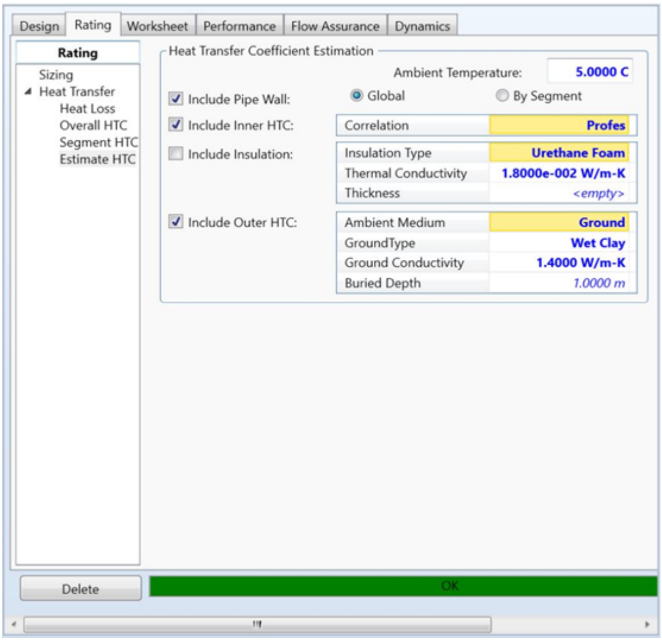


Figure 5 Calculation of the heat transfer coefficient (Aspen HYSYS V12)

Figure 6 shows the window in the software Aspen Hysys for selecting correlations.

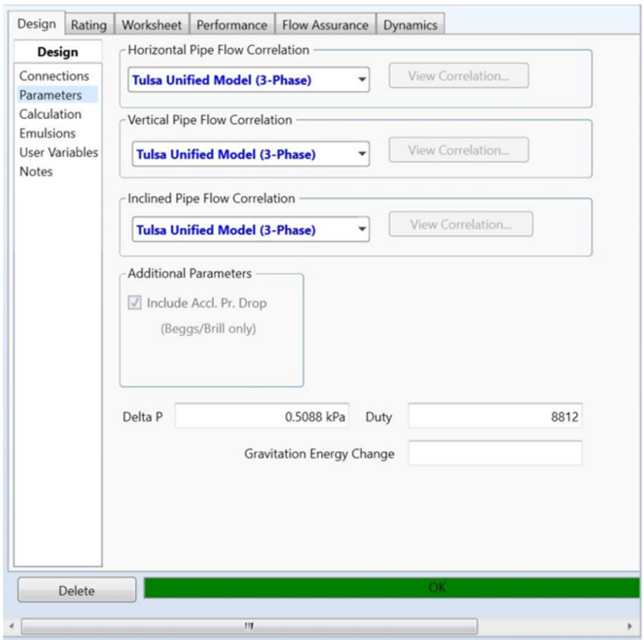


Figure 6 Selecting correlations for pipelines (Aspen Hysys V12)

By selecting the appropriate correlations, it was possible to achieve a match between the measured values from the field and the results of the base model. For this reason, special attention must be paid to the correlations. At the end of this chapter on models, the theoretical basis of the correlations used to define pressure drop through the pipeline in both software programs is presented.

In Figure 7, the base model of the surface infrastructure for oil field X created in Aspen HYSYS software is shown.

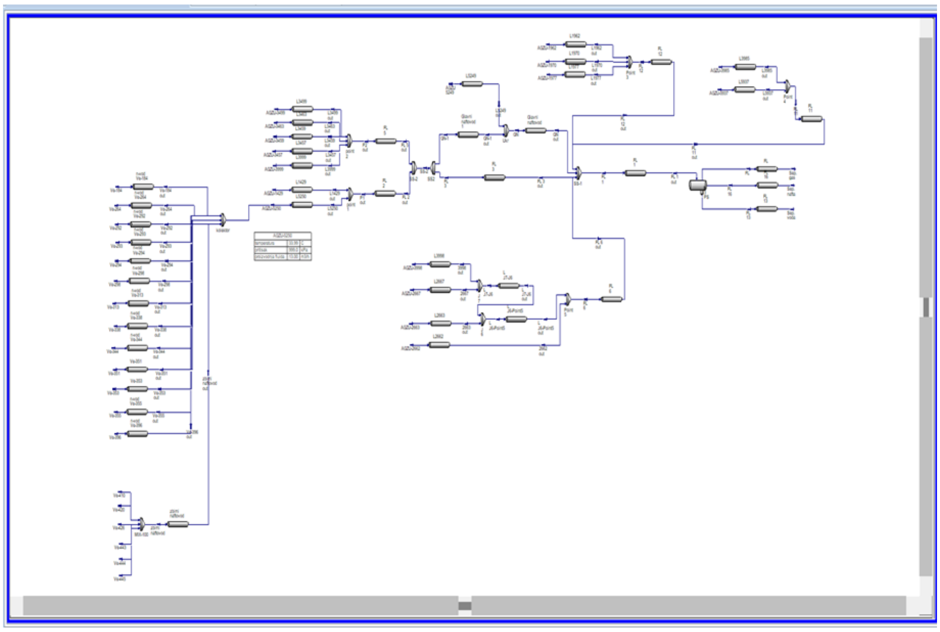


Figure 7 Base model of the surface infrastructure for oil field X (Aspen HYSYS V12)

Modeling in GAP

Before creating the surface infrastructure model in GAP, it is necessary to develop the reservoir model in MBAL and the well model in PROSPER, generate VLP tables from the well model, and import everything into GAP. The data required for the surface infrastructure model was obtained from the Pipeline Database (data on the diameter and length of pipelines), production data by well from the Sahmatka, pressure data from the SCADA system, and the GIS Odeon (pipeline situational map).

In this software, the Black Oil fluid model and the Peng-Robinson equation of state were also used.

The measured field data on pressures and production by wells, obtained from the Production Worksheet, are entered into the created skeleton of the surface infrastructure, which consists of wells, pipelines, and separators. To achieve a match between the model and the measured data, the correlation parameters that define the pressure drop through the pipeline are adjusted.

Figure 8 shows part of the surface infrastructure of this oil field, specifically one automatic measurement unit to which 16 wells are connected.

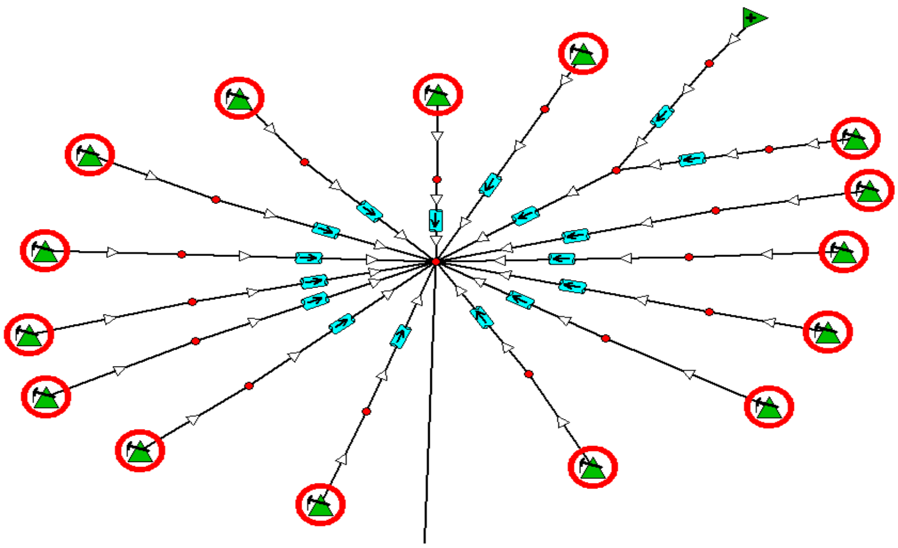


Figure 8 Automatic measurement unit – part of the surface infrastructure (GAP IPM13)

Figure 9 shows the input window for wells in the software – the corresponding PROSPER file with the previously created well model and the VLP table extracted from the model is imported.

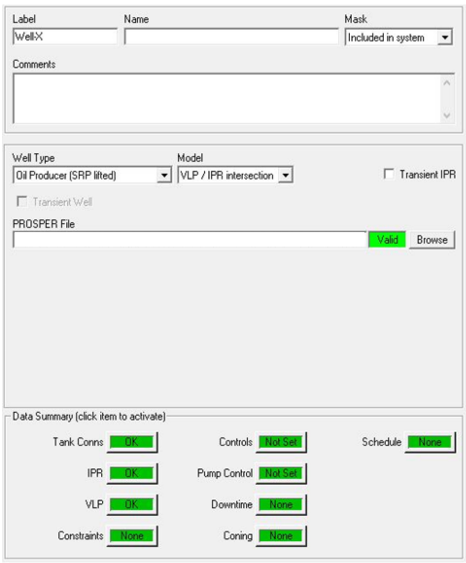


Figure 9 Input data for wells (GAP IPM13)

For pipelines, it is necessary to enter the length, diameter, roughness in the description window (Figure 10).

Figure 10 Description window for pipeline (GAP IPM13)

It is also necessary to enter the parameters for achieving a match between the model and the facts: molar fractions of nitrogen, carbon dioxide, and hydrogen sulfide, relative gas density, gas-oil ratio, water salinity, and inlet and outlet pressure in the matching window (Figure 11).

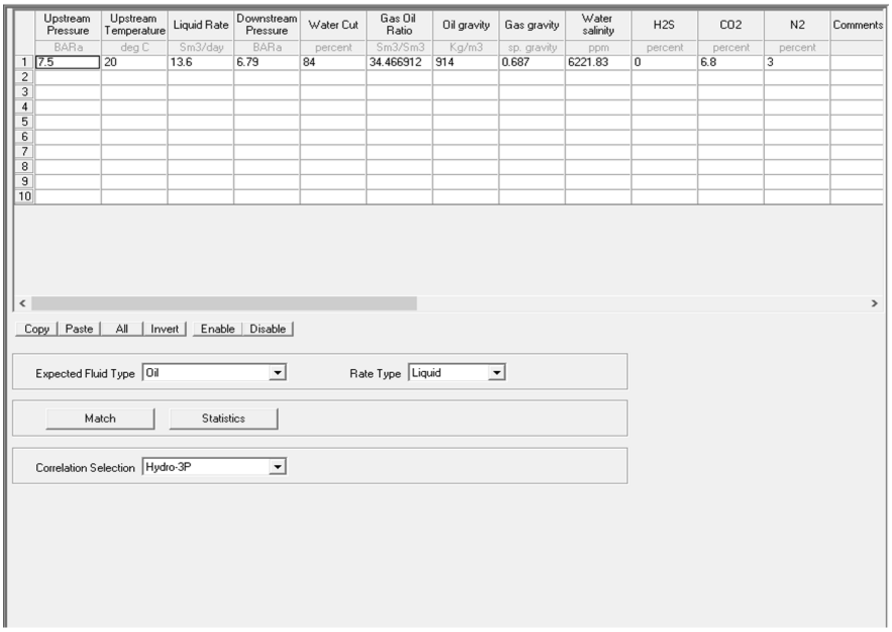


Figure 11 Matching window for pipeline (GAP IPM13)

Since there was an existing surface infrastructure model for oil field X in GAP, an update of that model was performed for April 2024. All necessary data has been entered into a unified Excel database, where, through the development of Python code, automatic data transfer to the model is carried out via OPENSERVER. This enables automatic communication between OPENSERVER and GAP.

The operational parameters of the wells in GAP have been updated, IPR data in PROSPER have been adjusted, new well models that were not included in the base model have been created, and changes in equipment in existing models have been made if maintenance is conducted. A review and verification of the production parameters of the wells have been performed, and all PROSPER models, as well as the necessary parameters in the GAP model, have been updated.

Models of gathering stations with corresponding wells for GS-1 and GS-2 have been created. Fluid is transported from GS-2 to GS-1 via two pipelines, and the station operates in a flow-through manner. GS-1 is equipped with a separation system where, after separation, gas and oil are transported further through separate pipelines.

A base model has been created with 248 wells that were operational on April 14th, 2024.

Figure 12 shows the surface infrastructure model of oil field X created in GAP software.

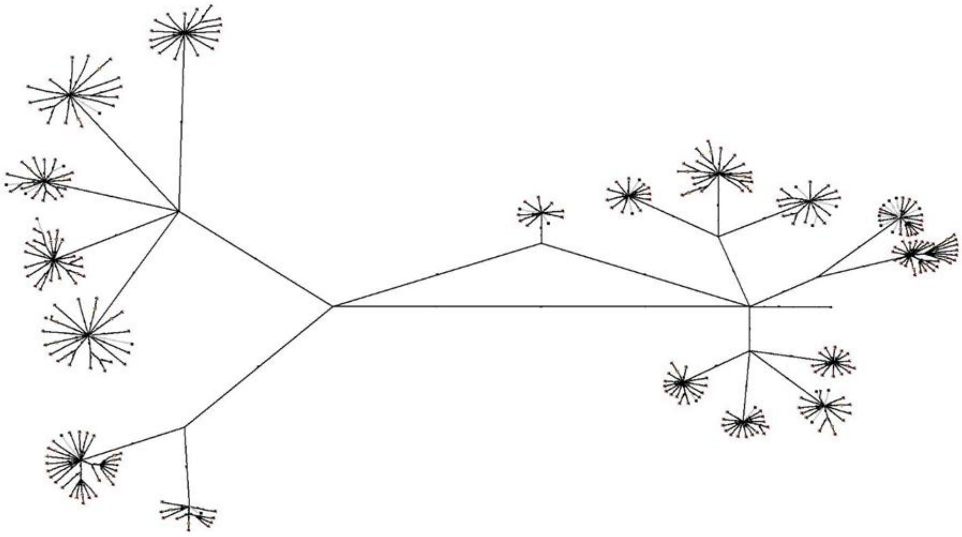


Figure 12 Base model of surface infrastructure of oil field X in GAP (GAP IPM13)

Model matching

The behavior of multiphase flow is significantly more complex compared to single-phase flow. When gas and liquid flow simultaneously, they tend to segregate due to variations in fluid properties. These fluids will experience different shear stresses as a result of their differing densities and viscosities (Brill and Mukherjee, 1999).

In the oil industry, multiphase flow models are often used to simulate the flow from the reservoir to the production unit. Flow simulations help monitor production and optimize processes to support decision-making. Despite the need for accurate simulations that support production operations, multiphase flow models are primarily developed using laboratory data and are rarely validated under field conditions (Chaves et al, 2022 & Xiao et al, 1990).

By matching pressure losses through the pipeline, an accurate integrated model is developed, starting from the reservoir, passing through the wells, gathering systems, and reaching the production separator.

It's crucial to carefully approach the pipeline matching process, especially when dealing with multiphase flows through long, undulating pipelines where field measurements have been taken over considerable distances. Pressure measurements may not align with production data due to the combined effects of fluid compressibility and the time required for the fluid to travel between measurement points.

The correlations used to achieve alignment with the measured data are: Beggs and Brill, Hydro 3P, and Petroleum Experts 5 in GAP, as well as Tulsa 3 Phase and Beggs and Brill in HYSYS. The following describes the correlations used.

The Beggs and Brill equation, first introduced in 1973 and later improved in 1979, is applicable to pipelines in horizontal, vertical, and inclined positions. This equation accounts for pressure drop due to friction and hydrostatic pressure changes. The first part of the equation addresses the determination of flow pattern and liquid holdup, followed by the calculation of the densities of the liquid and gas phases. Based on this, along with the flow pattern, the hydrostatic pressure drop is determined (Beggs & Brill, 1973).

Initially, the pipe was positioned horizontally, and the flow rates were adjusted to observe all horizontal flow patterns. Afterward, the inclination of the pipe was altered, allowing for the measurement of liquid holdup (HL(θ)) and pressure drop. This setup enabled the study of the effect of inclination on holdup and pressure drop. Beggs and Brill proposed the following equation for the pressure gradient (Eq. 3)

$$\frac{dp}{dL} = \frac{\frac{f\rho_n {v_m}^2}{2d} + \rho_m g sin\theta}{1 - Ek} \tag{3}$$

where Ek, dimensionless kinetic-energy pressure gradient, is defined by (Eq. 4)

$$Ek = \frac{v_m v_{SG} \rho_n}{p} \tag{4}$$

and mixture density should be calculated as (Eq. 5):

$$\rho_m = \rho_L H_{L(\theta)} + \rho_G \left[1 - H_{L(\theta)}\right] \tag{5}$$

Liquid holdup and friction factor should be found as described in the following.

Gravity forces act on the liquid, causing a decrease in the liquid velocity and thereby slippage and holdup is increased. By further increasing of the angle, liquid covers the entire cross section of the pipe. The slippage between the phases is reduced and liquid holdup reduces. Beggs and Brill observed that degree of holdup with angle varied with flow rates. To include effects of pipe inclination, it was decided to normalize liquid holdup. The following equation was proposed (Eq. 6):

$$\Psi = \frac{H_{L(\theta)}}{H_{L(0)}} \tag{6}$$

where Ψ is inclination correction factor, HL(θ) is holdup at angle θ from horizontal, and HL(0) is horizontal holdup (Fossmark, 2011).

On the other hand, the Tulsa 3 Phase correlation provides a unique methodology for hydrodynamic calculations, allowing for the prediction of flow patterns, pressure drop, holdup, and even the characteristics of slug flow in multiphase fluids. This model is applicable in horizontal, vertical, and inclined pipelines. The first step in solving the equation is defining the fluid flow pattern, followed by calculating the pressure drop through the system using the appropriate relationships (Grubač, B. 2019).

The TUFFP unified model for gas/liquid flow in pipes was designed to predict transitions between flow patterns, pressure drop, liquid holdup, and slug properties across all inclination angles from -90° to +90° relative to horizontal. The TUFFP unified model is based on the dynamics of slug flow. Because slug flow has transition boundaries with all other flow patterns, the equations of slug flow can be used not only to calculate the slug characteristics, but also to predict transitions from slug flow to other flow patterns. Therefore, flow pattern transitions and other hydrodynamic behaviors are all calculated within a single model. Oil and water can be found as a fully mixed pseudo-single-phase in a slug body and in bubbly, dispersed, bubble and annular flow. On the other hand, they may not be fully mixed, and the local holdups may not be the same as the input fractions. Presumably, the continuous phase is slower than the dispersed phase due to its contact with the pipe wall. The relative velocity between the continuous phase and the dispersed phase needs to be modeled under different flow conditions. As mentioned above, if the oil and water are fully separated, like in stratified flow or in the film region of slug flow, then the flow can be modeled with the three-layer approach. The model for predicting the transition from stratified to dispersed liquid-liquid flow can be developed based on the local turbulent intensity and the physical properties of the liquid phases. (Sarica & Zhang, 2006; Zhang et al, 2003; Al-Safran & Brill, 2017).

The upgraded Petroleum Experts 5 mechanistic correlation improves upon the previous Petroleum Experts 4. While PE4 exhibited instabilities (like other mechanistic models) that restricted its use, PE5 minimizes these issues by using a calculation approach that avoids flow regime maps as a starting point.

PE5 can model any type of fluid flow through various well or pipeline paths. It accounts for fluid density changes along both upward and downward trajectories.

Additionally, well stability can be assessed using PE5 by calculating gradient profiles, which also enable the modeling of liquid loading, slug frequency, and more (Fetoui, I. 2017).

The multiphase flow correlation is suitable for predicting and analyzing the behavior of three-phase flow in pipelines and wells. Applicable to both gas and oil fields, the "Hydro-3P" correlation offers accurate predictions for horizontal pipeline simulations across various flow regimes. It is particularly well-suited for stratified and annular flows, but it can also handle other flow regimes encountered in multiphase flow systems.

3 RESULTS AND DISCUSSION

The fluid production at the GS-1 facility, Field X, on April 14th, 2024, amounted to approximately 2233 m^3/day, with a water cut of 83.1%. Oil production on that date was 398 m^3/day, and gas production was 6780 m^3/day.

In the base model in HYSYS, the fluid production at GS-1 is 2159.8 m^3/day, of which 396 m^3/day is oil. The percentage difference in fluid production between the base model and actuals is 1.66%, the oil production difference is 0.52%, while the pressure difference at GS-1 is 0.21%. In the actuals, the pressure at GS-1 is 4.69 bar, while in the base model it is 4.68 bar.

On the other hand, the differences between the base model and actuals at GS-1 in GAP are as follows:

- Fluid production: $\Delta Qf = 3.06\%$;
- Oil production: $\Delta Qn = 4.52\%$;
- Pressure at GS-1: $\Delta p = 1.07\%$.

At GS-1 and GS-2, the temperature, according to actual data, varied between 19 and 22°C on the date the data was analyzed. A temperature value of 20°C was used as input for the models. In the HYSYS model, only the arithmetic value of the input temperatures can be obtained, slightly reduced due to the roughness of the pipelines through which the fluid flows and the chosen correlations, so the model was not matched based on temperature data.

Fluid production at GS-2, according to the actual data, is 1858.9 m^3/day, with oil production around 411.94 m^3/day. In the base model in HYSYS, the production values are as follows: fluid 1853.1 m^3/day, oil 411.12 m^3/day, and gas 7733 m^3/day.

In the base model in HYSYS, the fluid production at GS-2 is 1853.1 m^3/day, of which 411.12 m^3/day is oil. The percentage difference in fluid production between the base model and actuals is 0.31%, oil production differs by 0.2%, while the pressure difference at GS-2 is 3.33%. In the actuals, the pressure at GS-2 is 6.3 bar, while in the base model it is 6.09 bar.

On the other hand, the differences between the base model and actuals at GS-2 in GAP are as follows:

- Fluid production: $\Delta Qf = 2.32\%$;
- Oil production: $\Delta Qn = 4.96\%$;
- Pressure at GS-2: $\Delta p = 4.44\%$.

These deviations of the base model from the actual data in both software platforms are also presented in tabular form (Tables 10, 11 12 and 13), where the differences in values, not just the percentage deviations, can be observed.

Since all deviations are within the allowable limits of ±10%, the models in both software platforms are considered valid and can be used for various simulations and for monitoring system behavior due to certain changes made to optimize the process of crude oil and gas separation, storage, and transport.

Table 10 Value deviation of the model from the fact

Serial number	Parameter	Unit of measure	Hysys	Gap	Fact
1	Q_f	m^3/day	2159,8	2164,6	2254
2	Q_o	m^3/day	395,92	380	398
3	Q_g	m^3/day	6260	7272	6780
4	Q_w	m^3/day	1799,88	1784,6	1856
5	P_{GS-1}	kPa	468	464	469
6	T	degC	20	20	20

Table 11 Value deviation of the model from the fact

Serial number	Parameter	Unit of measure	Hysys	Gap	Fact
1	Q_f	m^3/day	1853,1	1815,8	1858,9
2	Q_o	m^3/day	411,12	391,5	411,94
3	Q_g	m^3/day	6609,6	7385	7733
4	Q_w	m^3/day	1442	1424,3	1446,96
5	P_{GS-2}	kPa	609	602	630
6	T	degC	18,84	20	20

Table 12 Percentage deviation of the model from the fact on GS-2

Gathering station 1						
Serial number	**Unit of measure**	**Parameter**	**Hysys**		**Gap**	
			Δ	**Δ(%)**	**Δ**	**Δ(%)**
1	m^3/day	Q_f	-37	1,66	-68	3,06
2	m^3/day	Q_o	-2	0,52	-18	4,52
3	m^3/day	Q_g	-520	7,67	492	7,26
4	m^3/day	Q_w	-56,12	3,02	-71,4	3,85
5	kPa	P_{GS-1}	-1	0,21	-5	1,07
6	degC	T	0	0	0	0

Table 13 Percentage deviation of the model from the fact on GS-2

Gathering station 2						
Serial number	**Unit of measure**	**Parameter**	**Hysys**		**Gap**	
			Δ	**Δ(%)**	**Δ**	**Δ(%)**
1	m^3/day	Q_f	-6	0,31	-43	2,32
2	m^3/day	Q_o	-1	0,2	-20	4,96
3	m^3/day	Q_g	-923	9,53	-348	4,5
4	m^3/day	Q_w	-20,33	1,39	-38	2,6
5	kPa	P_{GS-1}	-21	3,33	-28	4,44
6	degC	T	-1,16	5,8	0	0

4 CONCLUSION

In this paper, a comparative analysis of the software solutions HYSYS and GAP for modeling the surface infrastructure of oil field in the Pannonian Basin is conducted.

Error analysis shows that both software solutions provide reliable estimates, with deviations within acceptable limits of ±10%. At Gathering Station 1, HYSYS displayed a deviation of -37 m^3/day for the parameter Qf, with a percentage error of 1.66%, while GAP had a deviation of -68 m^3/day, with a percentage error of 3.06%. These deviations indicate that HYSYS provides more precise results for this parameter. Regarding oil production (Qo), HYSYS had a minimal deviation of -2 m^3/day (0.52%), while GAP showed a larger deviation of -18 m^3/day (4.52%), further confirming HYSYS provides better accuracy in its estimates.

However, in the analysis of gas production (Qg), GAP had a deviation of 492 m^3/day with a percentage error of 7.26%, while HYSYS recorded a significantly larger negative deviation of -520 m^3/day (7.67%), suggesting greater reliability of GAP for this parameter.

At Gathering Station 2, the results also showed similar trends. HYSYS had a deviation of -6 m^3/day for Qf, corresponding to an error of 0.31%, while GAP had a deviation of -43 m^3/day (2.32%). In terms of gas production (Qg), HYSYS had a larger deviation of -923 m^3/day, with a percentage error of 9.53%, while GAP recorded a deviation of -348 m^3/day (4.5%), indicating greater accuracy for GAP in this segment.

HYSYS excelled in estimates related to oil and fluid production, while GAP was more successful in analyzing gas production. This complementarity suggests that both tools can be used together to provide a comprehensive picture of the surface infrastructure system. It is recommended to use HYSYS when there are time constraints for model development, as it allows for modeling wells as material streams within the software itself. This functionality significantly reduces the time required for model development, making it suitable for quick analyses and simulations. On the other hand, GAP requires the initial creation of the model for the reservoir and all wells, which can significantly extend the modeling time.

The results indicate that HYSYS offers detailed simulation capabilities for the entire production process, whereas GAP offers integrated asset modeling that optimizes interconnected systems. The advantages of HYSYS include its versatility in various operational scenarios, while GAP excels various operational scenarios.

The comparison between HYSYS and GAP highlights that HYSYS is more suited for complex process simulations, while GAP excels in specific flow applications. HYSYS provides advanced capabilities for modeling multiphase flows, whereas GAP has limitations in this area. The user-friendly interface of HYSYS makes it easier for engineers to conduct simulations, while GAP requires a higher level of technical expertise. In terms of optimization and performance analysis, HYSYS offers broader options, while GAP focuses on specific flow calculations. Results obtained from HYSYS can be easily validated against real-world data, thanks to its advanced algorithms, whereas GAP is accurate for predefined scenarios. Additionally, HYSYS integrates well with various process units, while GAP is primarily geared toward pipeline flow analysis.

Overall, HYSYS is more applicable to refinery and chemical processes, while GAP is tailored for the oil and gas industry. Lastly, HYSYS tends to demand more resources and is better suited for larger systems, whereas GAP is simpler and more efficient for smaller-scale applications.

These findings are significant for the oil and gas industry, as they assist in selecting the most suitable software depending on the specific project needs. Further research is recommended to explore additional functionalities of these tools and their integration with modern technologies.

HYSYS allows engineers to explore various operational scenarios and optimize process units. On the other hand, GAP provides integrated modeling that focuses on analyzing the interconnections within the network, enabling the identification of potential bottlenecks and a better understanding of pipeline dynamics.

Although this study did not include optimization, the simulation results demonstrate the value of both software solutions in understanding the complexities of surface infrastructure. This study highlights the need for further research to explore additional functionalities of both tools, including possible approaches to optimization and the integration of modern technologies in future analyses.

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