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DEVELOPMENT OF A NOVEL FRAMEWORK FOR SEQUENTIAL COUPLING OF RESERVOIR, WELLS, AND SURFACE FACILITIES

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Abstract. Petroleum production systems consist of three individual elements that are operating together: reservoir, wells, and surface facilities. Design, construction, and maintenance of surface facilities for hydrocarbon production require realistic simulation studies. These studies become much more realistic when well and surface facilities are simulated together with the reservoir. In this work, a literature survey was performed and different coupling approaches were discussed. Then, the new framework was introduced as a tool for coupling the reservoir, well and surface facility using the in-house UTCOMP simulator. UTCOMP is a compositional simulator, which has been developed at The University of Texas at Austin. This formulation is designed to use flow tables in order to compute wells and surface facility interactions. The presented framework enabled UTCOMP to read surface facilities data, which were generated by a commercial simulator. Some new software was developed to read and compare the flow table's data and enable surface facility option within UTCOMP. In this study, the new features added to UTCOMP were: (a) inserting a new flow table option, (b) including surface pipelines length and diameter, (c) calculation of operational condition like gas-oil ratio and water-oil ratio at the surface condition and (d) an output file for surface facilities information. Also, we show results of two case studies. Using the developed tool, we are able to understand the behavior of petroleum production systems and identify the main factors that affect production operations.

Keywords: Compositional Simulation, Surface Facilities, Sequential Coupling, Wellhead, Separator

1 Introduction

Fossil fuels are still the main source of global energy. Because of the increase in energy consumption, management of conventional petroleum reservoirs is crucial. In the earlier stage of production of petroleum reservoirs, the available information are limited to exploration and drilling data, seismic operations, logging tools, and initial reservoir simulation models. In the next stages, solo reservoir simulations studies are not sufficient due to development and construction of surface facilities equipment. As the petroleum productions developments plans become mature, it is essential to have simulators that enable the handling of both sub-surface and surface facilities simultaneously. From numerical point of view, development of such models is not easy. The number of associated variables, operational conditions, different production scenarios, different time scale windows, different type of fluid flows, uncertainties of physical properties of porous media, and complex phase behavior of hydrocarbons fluids are examples of reasons why numerical development of such integrated models is such a difficult task. Here, Petroleum Production Systems (or PPS) are referred to systems that consist of reservoir, well, and surface facility equipment. Another concept that is important for integrated modeling of PPS is the coupling point. According to nodal analysis of PPS, each section of the model could be treated as a node of pressure and flow rate. Hence, coupling point is referring to the point in which the total PPS is divided into two sub-systems for analysis of inflow and outflow performance of hydrocarbons fluids. Nodal analysis can be done at any location of integrated model, but generally, there are three preferred locations for coupling point: (a) bottom hole (b) wellhead (c) riser base (for offshore systems). Various numerical strategies have tried to tackle integrated simulation of sub-surface and surface models. The following describe the literature survey of previous studies.

During 1970s, as the earlier stages of development of integrated models, single-phase flow, such as network facilities of water distribution by Shamir *et al.* [1] and steady state natural gas distribution systems by Wylie *et al* [2] were developed without considering reservoir or wellbore sections. The work presented by Dempsey *et al.* [3] is one of the earliest works that addresses elements of PPS. They considered reservoir, tubing and surface pipeline for single phase (gas) and two-phase (gas and water) systems. Following that, Emanuel and Ranney [4] introduced a new approach of coupling of surface and subsurface facilities by flow tables for tubing. Flow tables are typical tables that are holding information and interactions of bottom hole and wellhead of wells. This concept is also known as VLP, or Vertical Lift Performance tables, by Schlumberger simulators, such as Eclipse and Pipesim [5,6], tubing performance tables by CMG [7], and hydraulic tables by Rossi *et al.* [8]. These tables do not only apply for tubing, but also can be used for surface facilities equipment as well [6, 9]. Barroux *et al.*[10] tried to extend the framework of Emanuel and Ranney (1981) for multiple wells. Their framework determined total system potential, number of drilled wells required, location of drilled wells, network constraints, etc. Schiozer [11] discussed three types of coupling strategies including explicit, implicit and full implicit. Trick [12] presented a procedure of coupling Eclipse with FORGAS commercial simulators, Byer's dissertation [13] was focused on improving computational efficiency of fully coupled reservoir-surface facilities, Barroux [14] used two commercial simulators to study several case studies and discussed four coupling configurations, Ghorayeb et al [15] presented a general purpose multi-platform reservoir and network coupling controller, Zapata *et al.* [16] coupled CHEARS and PIPESOFT-2 simulators . CHEARS was a fully implicit 3D reservoir simulator with black-oil, compositional, thermal, miscible, and polymer formulations, while PIPESOFT-2 was a multiphase wellbore-surface network simulator. Hence, in that work, wells were considered as a part of surface facilities equipment (not reservoir). Coats *et al.* [17] replaced a conventional well model with a generalized network model. Besides, they included downhole equipment, and it was the first time that advanced well models were discussed. Jiang [18] developed a framework, which extended Stanford General Purpose Research Simulator capabilities by adding unstructured models and advanced wells. He also discusses the details of derivatives of global Jacobian matrix for full implicit coupling of reservoir, well, and surface facilities. Killough *et al.* [19] introduced a new capability that was based on well-head pressures (WHP) and producing water-cut for automatically switching of the flow line. Olivares [20] implemented a fully coupled compositional simulation for surface facilities. In his work, he also modeled asphaltene precipitations. Cao et al [21] reviewed methodologies of coupling of reservoir-surface facility network simulators and discussed pros and cons of all of aforementioned works. Seth et al. [22] tried to extend Oilvera's work and included pumps, seafloor manifolds and determined optimal well operating rates in explicit formulation. Using of surface response functions and sub-surface response functions, Boogaart [23] tried to couple surface and subsurface models. Those functions were used to balance the proper rate and pressure of the integrated model, which were generate by two set of tables for Inflow Performance Relationship and Tubing Performance Relationship models. Zhou *et al.*'s work [24] was developed for coal bed methane reservoirs. They tried to optimize coupled surface and sub-surface model by considering length, diameter and layout of pipeline networks as optimization factors. More recently, Zaydullin *et al.* [25] introduced a new framework that enables their simulator to generate dynamic flow tables. In that framework, they introduced additional coupling steps, and a pipe flow simulator updates values of the tables during the simulation. Also, they pointed that generation of flow tables are based on mean average of auxiliary parameters such as input temperature. As for the generation of such tables, auxiliary variables were assumed to be constant and this increased inaccuracy of the tables. Secondly, generation of such flow tables are time consuming. Additionally, in order to have accurate sets of data, density of table should be increased, however, from numerical point of view, the increase of density of tables may resulted in increase of the computational efforts consequently. Finally, readers should pay attention that dynamic flow tables were developed for black oil reservoir simulator. In nutshell, according to above survey, three class of coupling strategies could be summarized as follows:

First Coupling Strategy- Decupled: in this strategy, fluid flow equations from reservoir-wells are considered together. Then one reservoir simulator solves the equations for reservoir-well and separately another simulator solves the equations of surface facilities network. This is mainly due to different types of fluid flow and time scale windows of surface and sub-surface facilities. In this approach, a third party software is acting as communicator of these two simulators (one for reservoir-well and another for surface facilities network) at the coupling point. The advantage of this approach is accuracy of surface facilities information. Nevertheless, this approach is not numerically stable. Additional details can be found in Cao *et al.* [21].

Second Coupling Strategy - Iteratively Coupling: the second approach tries to solve reservoir and facilities equations iteratively. When the reservoir equations are solved, the constraints are passed to the wells. Then the surface facilities equations start to be solved based on these constraints. . This approach keep iterating until convergence is reached. Further details regarding this approach can be found in the work of Emanuel and Ranney [4].

Third Coupling Strategy - Fully Implicit Coupling: the third, and most difficult, approach is fully implicit coupling. In this strategy, all of reservoir, wellbore and surface facilities equations are solved simultaneously. Since this approach solves all the equations implicitly, it is much more accurate than other strategies. However, it is difficult to implement such models and this approach is more time consuming. Additional information about fluid flow equations and their derivatives for global Jacobian matrix can be found in Olivares [20].

In this study, based on the literature survey, a new framework was developed for UTCOMP simulator to include surface facilities options. The presented framework enables our simulator to sequentially consider interactions of surface facilities information with reservoir condition and increase the simulator's flexibility for various production scenarios.

2 Motivation and objective

Compositional simulation of multiphase, multi-component fluid flow problems can be much more realistic when surface facilities models are included. Hence, in order to increase the flexibility, in this work, we included surface facility equipment in our in-house simulator called UTCOMP. The simulator was developed at the Center for Petroleum and Geosystems Engineering at The University of Texas at Austin for decades and it can simulate various enhanced recovery processes.

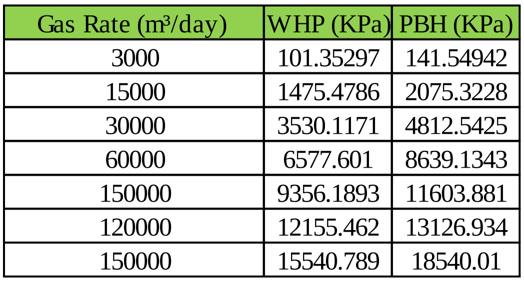
The main objective of this work is to develop a new framework for surface facility equipment by considering flow table options for well section. The flow tables were generated using a commercial simulator and are used as input data for the UTCOMP simulator.

3 Methodology

This section will demonstrate two groups of numerical packages that we designed and implemented regarding surface facility equipment option for UTCOMP simulator. The first package is named simplified flow tables, or SFT, while the second package is called advanced flow tables, or AFT. SFT were used as an initial pattern for development of AFT.

3.1 Simplified Flow Tables (SFT)

Figure 1 shows an example of a simplified flow table.



Gas Rate (m³/day)	WHP (KPa)	PBH (KPa)
3000	101.35297	141.54942
15000	1475.4786	2075.3228
30000	3530.1171	4812.5425
60000	6577.601	8639.1343
150000	9356.1893	11603.881
120000	12155.462	13126.934
150000	15540.789	18540.01

Figure1: Example of SFT.

As shown in Fig. 1, these tables consist of three group of information: flow rate, Wellhead Pressure (WHP) and Bottom hole Pressure (BHP). The values in each row are increasing from top to bottom; hence, there was no need for any sorting algorithm in the simulator. Once the tables were generated, they were passed as input data to the simulator, together with the original input with reservoir description. When using the flow table option, the user must also provide the initial well pressure, bottom hole or wellhead, depending on the chosen coupling point. This initial pressure will be used as an initial guess for the calculation of the reservoir section. After that, the calculated flow rates are used as input parameters for the flow table section. It was developed an algorithm to make the interpolation and to find the corresponding pressure inside the table based on these flow rates. If the pressure found in the table is close enough to the initial pressure, within a certain tolerance factor, the calculation is finished, and the simulator goes to the next time step. If not, the well pressure is updated and a new iteration is performed. This process goes on until the convergence is achieved. Figure 2 shows the algorithm.

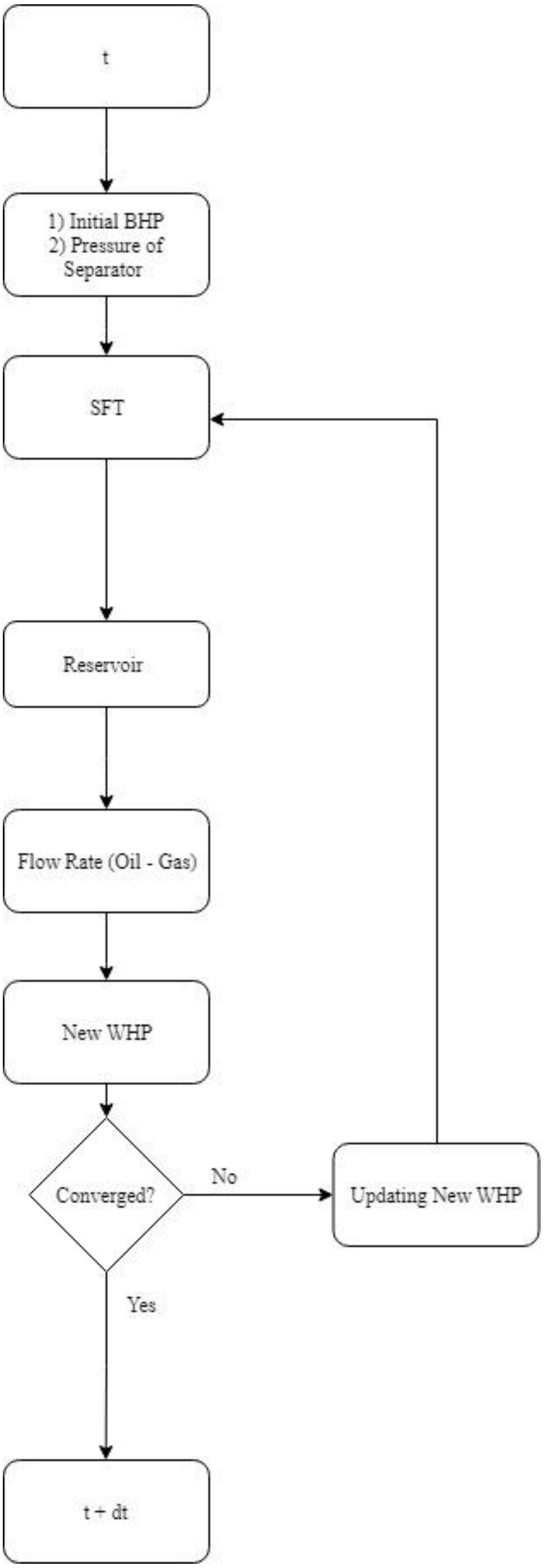
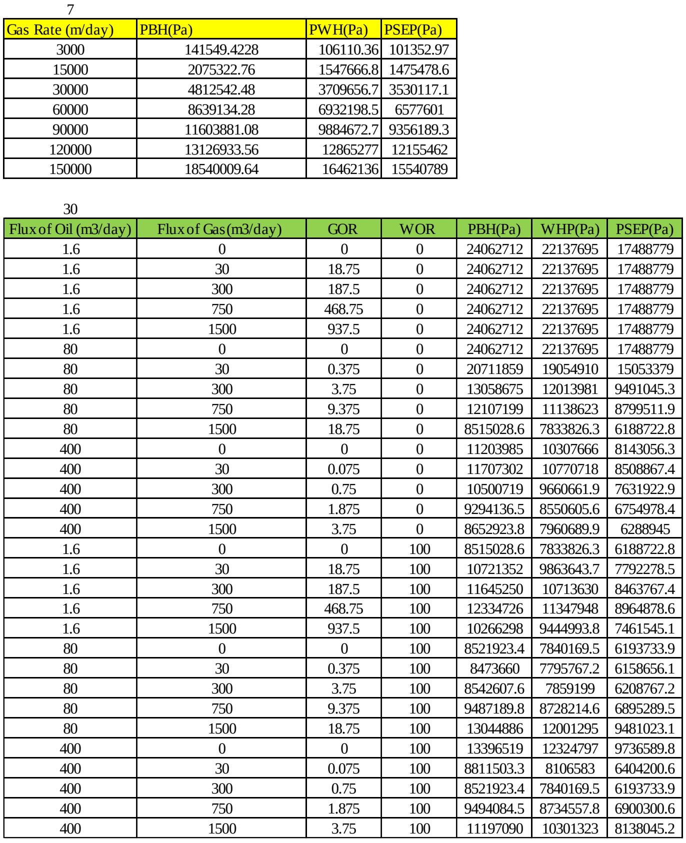


Figure 2. An algorithm that was designed for implementation of SFT inside the UTCOMP

Here, we describe the algorithm for wellhead, nevertheless, the process for bottom hole as coupling point is the same. This approach keeps iterating until both reservoir and well sections converge. If desired, the simulator can also print an output file showing the number of iterations, and the wellhead and bottom hole pressure achieved in each time step. It is important to mention here that in this approach, the separator pressure is constant. The only varying parameters are the wellhead and bottom hole pressure, both calculated based on the flow rate provided by the reservoir section.

3.2 Advanced Flow Tables (AFT)

Although it was possible to include new framework for surface facility information by using of SFT, those tables had some limitations. Firstly, they did not consider many of the operational constraints, for example WOR (water oil ratio) or GOR (gas oil ratio). Secondly, those tables were generated for black oil models using a commercial simulator. Finally, when the wellhead was specified, it was necessary to insert a pipeline equation. Because of that, the pipe equations had to be used to calculate pressure drop of surface pipeline with a fix separator value in each iteration. Hence, the values of separators could not change as a function of dynamic behavior of WHP. The AFT were a new set of tables that were designed to overcome all of limitations aforementioned. A sample of such tables is shown in Fig. 3.



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Gas Rate (m/day)	PBH(Pa)	PWH(Pa)	PSEP(Pa)
3000	141549.4228	106110.36	101352.97
15000	2075322.76	1547666.8	1475478.6
30000	4812542.48	3709656.7	3530117.1
60000	8639134.28	6932198.5	6577601
90000	11603881.08	9884672.7	9356189.3
120000	13126933.56	12865277	12155462
150000	18540009.64	16462136	15540789

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Flux of Oil (m3/day)	Flux of Gas (m3/day)	GOR	WOR	PBH(Pa)	WHP(Pa)	PSEP(Pa)
1.6	0	0	0	24062712	22137695	17488779
1.6	30	18.75	0	24062712	22137695	17488779
1.6	300	187.5	0	24062712	22137695	17488779
1.6	750	468.75	0	24062712	22137695	17488779
1.6	1500	937.5	0	24062712	22137695	17488779
80	0	0	0	24062712	22137695	17488779
80	30	0.375	0	20711859	19054910	15053379
80	300	3.75	0	13058675	12013981	9491045.3
80	750	9.375	0	12107199	11138623	8799511.9
80	1500	18.75	0	8515028.6	7833826.3	6188722.8
400	0	0	0	11203985	10307666	8143056.3
400	30	0.075	0	11707302	10770718	8508867.4
400	300	0.75	0	10500719	9660661.9	7631922.9
400	750	1.875	0	9294136.5	8550605.6	6754978.4
400	1500	3.75	0	8652923.8	7960689.9	6288945
1.6	0	0	100	8515028.6	7833826.3	6188722.8
1.6	30	18.75	100	10721352	9863643.7	7792278.5
1.6	300	187.5	100	11645250	10713630	8463767.4
1.6	750	468.75	100	12334726	11347948	8964878.6
1.6	1500	937.5	100	10266298	9444993.8	7461545.1
80	0	0	100	8521923.4	7840169.5	6193733.9
80	30	0.375	100	8473660	7795767.2	6158656.1
80	300	3.75	100	8542607.6	7859199	6208767.2
80	750	9.375	100	9487189.8	8728214.6	6895289.5
80	1500	18.75	100	13044886	12001295	9481023.1
400	0	0	100	13396519	12324797	9736589.8
400	30	0.075	100	8811503.3	8106583	6404200.6
400	300	0.75	100	8521923.4	7840169.5	6193733.9
400	750	1.875	100	9494084.5	8734557.8	6900300.6
400	1500	3.75	100	11197090	10301323	8138045.2

Figure 3. Schematic of AFT. The table consists of two distinguished section, one for single phase gas (yellow section) and one for multiphase (green section) condition.

As it can be seen, these tables contain, both single gas and multiphase conditions. The information in each section is passed to the simulator by two numbers (7 and 30) located above of each section of AFT. In the AFT, the GOR, WOR, and pressure of separator for different flow rates are included. Additionally, this table is generated for compositional fluid, and with fixed pipeline diameter and length. Compared to SFT, AFT are much more accurate tables. It was developed a new algorithm, which can read, locate and interpolate new information within AFT. This algorithm is shown in Fig 4.

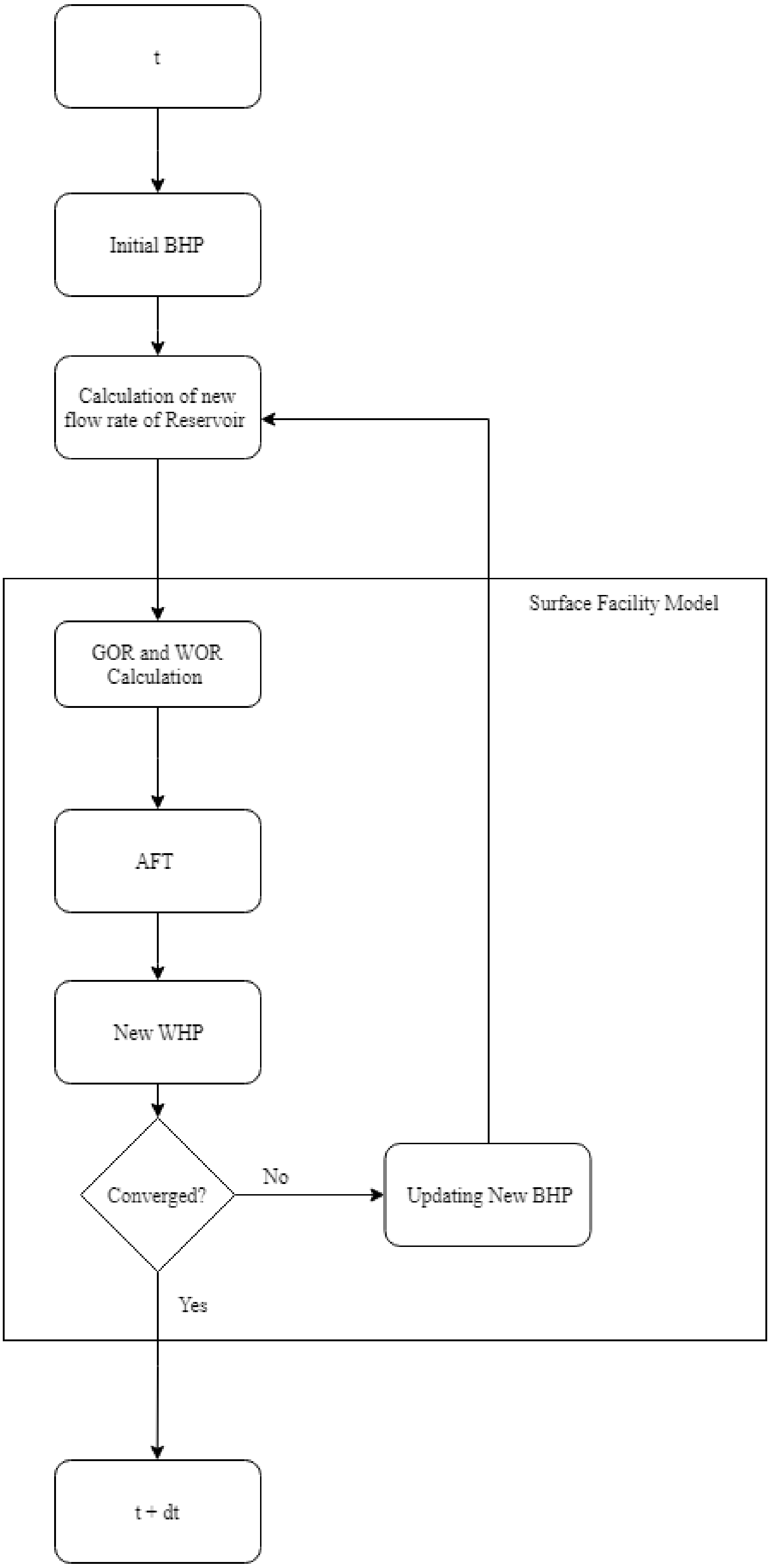

Figure 4. AFT algorithm. This algorithm can be used for both of WHP and BHP as coupling point.

As in the initial algorithm, here the user must also provide the initial BHP. This BHP is passed to the simulator and it calculates the rates of oil, gas and water. Thus, GOR and WOR are calculated next.

Based on the information, the algorithm will search and calculate the appropriate pressures. First it will search in the WOR section, then in the oil rate section, and finally in the GOR section. Almost always, the calculated values from the reservoir section do not match any exact value inside the table; so it is necessary perform a linear interpolation with the appropriate values from the table. Subsequently, it is possible to find the new wellhead, bottom hole, and separator pressures. Here, as in the SFT algorithm, a comparison is made between the pressure from the previous time step with the new pressure from the flow table. If the difference is within the tolerance, the simulator proceeds to next time step. If not, the BHP is updated, and a new iteration is performed. Based on Emanuel and Ranney's [4] work, the tolerance is 103.4 kPa, (or 15 psi). Also, it is important to mention that the algorithm switch from multi-phase to single phase in two conditions: A) when the oil rate becomes zero, B) when the value of calculated GOR goes higher than the highest GOR of multi-phase section of AFT. In both conditions, the subroutine switches to single phase section of AFT, and the value of BHP, WHP and PSEP are adjusted based only on gas rate (instead of oil rate, GOR and WOR). In single-phase section, if the gas rate value becomes greater than the highest value in the table, the simulation stops and a new AFT should be provided.

This algorithm is more complex than the first one in two ways. First, it needs to perform the interpolation in three different sections: WOR, oil rate and GOR. And second, it switches from multiphase to single phase. Of course, the computational effort is higher when compared to the first algorithm, but it results more accuracy, since the simulator will be able to handle more realistic cases, and support more operational parameters, as GOR and WOR.

The number of iterations and the pressures are monitored and reported, if desired, in an output file, as seen in Fig. 5.

Time (Day)	PBH (KPa)	PWH(KPa)	PSEP(KPa)	WOR	GOR	P Inj (KPa)	Oil Rate (m3/day)	Niter
0.04274	23435.26	7960.69	628.8945	0	111	39178.73	485.8512	1
0.13611	23435.26	7833.826	618.8723	0	111	39178.73	365.9168	1
0.23611	23435.26	9863.644	779.2278	0	111	39178.73	323.0208	1
0.33611	23435.26	10713.63	846.3767	0	111	39178.73	300.8944	1
0.43611	23435.26	11347.95	896.4879	0	111	39178.73	286.568	1
0.53611	23435.26	9444.994	746.1545	0	111	39178.73	276.1936	1
0.63611	23435.26	7840.169	619.3734	0	111	39178.73	268.1968	1
0.73611	23435.26	779.5767	615.8656	0	111	39178.73	261.7984	1
0.83611	23435.26	785.9199	620.8767	0	111	39178.73	256.5632	1
0.93611	23435.26	872.8215	689.529	0	111	39178.73	252.232	1
1.03611	23435.26	1200.13	948.1023	0	111	39178.73	248.6352	1
1.13611	23435.26	1232.48	973.659	0	111	39178.73	245.6544	1
1.23611	23435.26	810.6583	640.4201	0	111	39178.73	243.1984	1
1.33611	23435.26	784.0169	619.3734	0	111	39178.73	241.2	1
1.43611	23435.26	950.3755	690.0301	0	111	39178.73	239.6	1

Figure 5. Example of extended format of output file for AFT.

This output table has information for dynamic separator pressure, WOR, GOR, pressure of injector, and oil rate. The user can use this data to monitor the well behavior along the simulation. The next section will discuss results and conclusion of this study.

4 Results and discussion

In this section, we demonstrate the result of AFT for two cases. The first case is a 2-D reservoir with three components, and the second case is the same reservoir with six components.

4.1 AFT for 2-D Reservoir model with 3 Components fluids

A two dimensional reservoir was constructed for the first case study of AFT. In order to decrease the uncertainties, we assumed a homogeneous and isotropic reservoir. Detailed information of the reservoir and fluid properties can be found in Tables 1, 2, and 3. Table 4 shows the information of well section. The information for surface facilities is also presented in Table 4. Readers should pay attention that all of the information fed into UTCOMP simulator are given in field units.

Table 1. Reservoir information

Reservoir Parameters	Value
Grid Blocks	8 x 8 x1
Grid Blacks Size in X direction	69.9 m
Grid Blacks Size in Y direction	69.9 m
Grid Blacks Size in Z direction	24.3 ft
Porosity	0.1
Permeability in X Direction	9.86e-15 m^2
Permeability in Y Direction	9.86e-15 m^2
Permeability in Z Direction	4.93e-15
Formation Compressibility	4.e-6
Initial reservoir Pressure	3.1026e+4 KPa
Reservoir Temperature	76.66 °C
Simulation Run Time	100 Days

Table 2. Reservoir and injection fluids composition for first case study

Reservoir components (Case1)	Initial Concentration	Injection concentration
CO2	0.010	0.95
C1	0.19	0.05
NC16	0.8	–

Table 3. Reservoir and injection fluids composition for second case study

Reservoir components (Case2)	Initial Concentration	Injection concentration
C1	0.50	0.7
C3	0.03	0.2
C6	0.07	0.01
C10	0.20	0.01
C15	0.15	0.005
C20	0.05	0.005

Table 4. Technical information of wellbore Section

Wellbore Parameters	Value
Tubing Diameter	2.61 m
Casing Diameter	12.77 m
Tubing Length	661.4 m
Casing Length	762.3 m
Perforation location	680.6 m
Packers Location	637.3 m

Table 5. Technical information of surface facilities section

Surface facilities information	Value
Pipeline Diameter	0.15 m
Pipeline Length	2235. 7 m
Surface Temperature	21.1 °C
Coupling Point	Wellhead

In this study, it was assumed that the separator is able to receive all of the produced fluid, thus, no controlling device was considered. As it can be seen from Tables 1, 3 and 4 there are 25 variables associated for this integrated model. Based on composition of reservoir fluids and all of the associated variables, the corresponding AFT was generated and inserted into UTCOMP simulator. Figure 6 is shows oil rate and gas rate over time for the first case study. As it can be seen from Fig. 6, the trend of oil and gas are the same and this is why GOR value was constant in Fig 7. During the early stage of production, oil and gas production curves declined in the third day of production. Then injection of gas increased rate of oil and gas and maintained the rate of production.

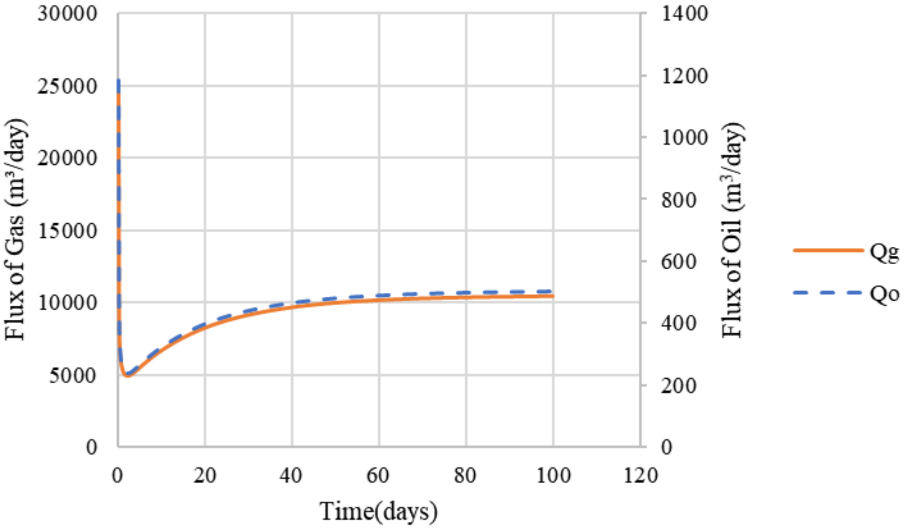

Figure 6. Production curve of oil and gas of the first case for 100 days.

Figure 7 shows the change of BHP and GOR over time. Two important operational parameters (GOR and BHP) were kept at constant rate in the first case study.

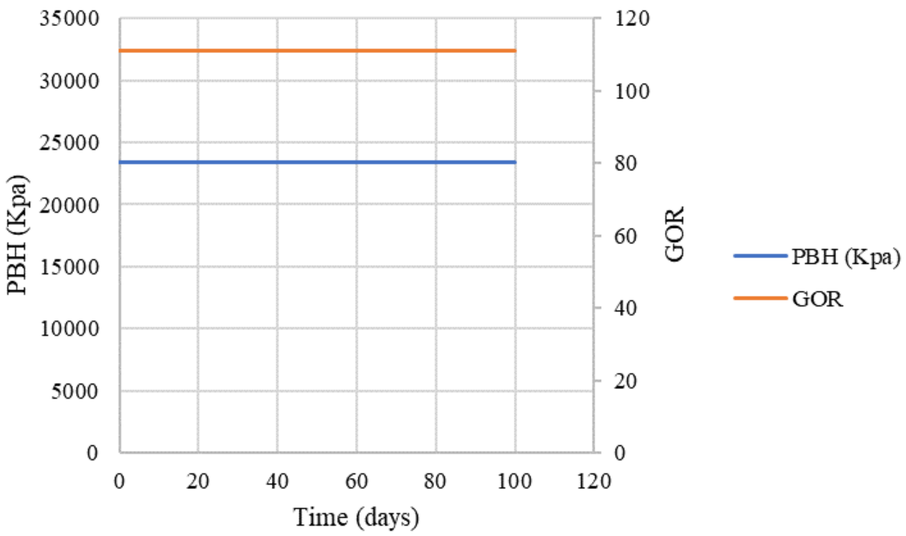

Figure 7. BHP and GOR over time

And finally, Fig. 8 shows the pressure change of injector, WHP and PSEP and average pressure of the reservoir over time. According to Fig. 8, wellhead and separator pressures are following the same trend. The dynamic changes of separator pressure, as an advantage of using AFT, is shown by Fig. 8. Also, it is worthwhile to mention that since the pressure of injector is high and the size of the reservoir is small (2-D reservoir model) the average pressure of the reservoir increase (orange curve in Fig. 8). Additionally, there was not any constrains for operating wells (injector and producer), thus, this is another reason why the average pressure of reservoir increased.

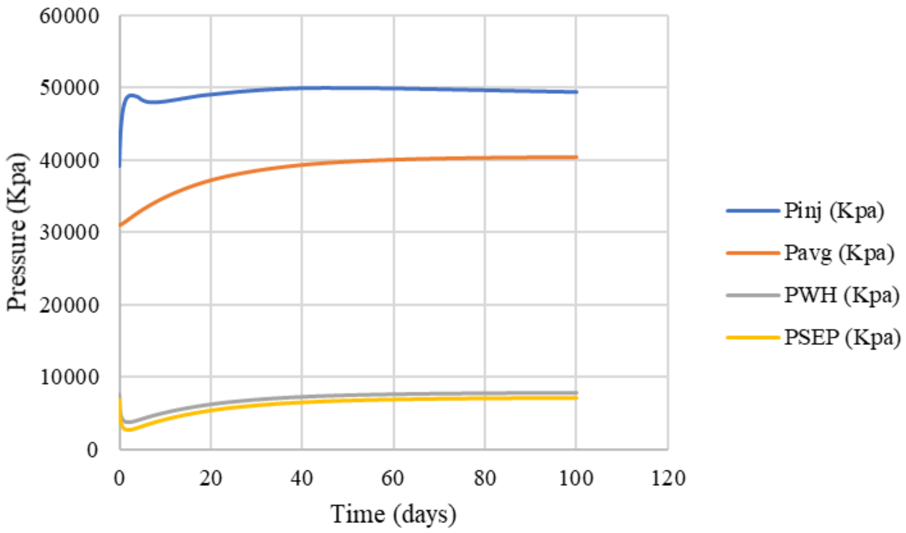

Figure 8. Different pressure changes of case one for 100 days of production.

As it can be seen in Fig.8, the order of magnitude of pressure are as follows, Pressure of injector, average pressure of reservoir, WHP and PSEP for each time step. Readers should also pay attention that the values of WHP and PSEP are generated using the commercial simulator, and UTCOMP simulator only reads, interpolates and compares them with current GOR, WOR and oil rates values. UTCOMP simulator is not able to generate individual values of WHP and PSEP by itself.

4.2 AFT for 2-D Reservoir model with 6 components fluids

The second case was designed to investigate the same 2-D reservoir model, but now with 6 components. Therefore, the operational conditions, such as temperature, initial BHP guess and the rest of reservoir properties, well and surface facilities were kept the same. Figures 9, 10, 11 show the same results that were demonstrated for the first case. Trends of oil and gas production are the same for 6 components. However, the oil rate is less decreased for the second case studies. Figure 9 illustrates this information.

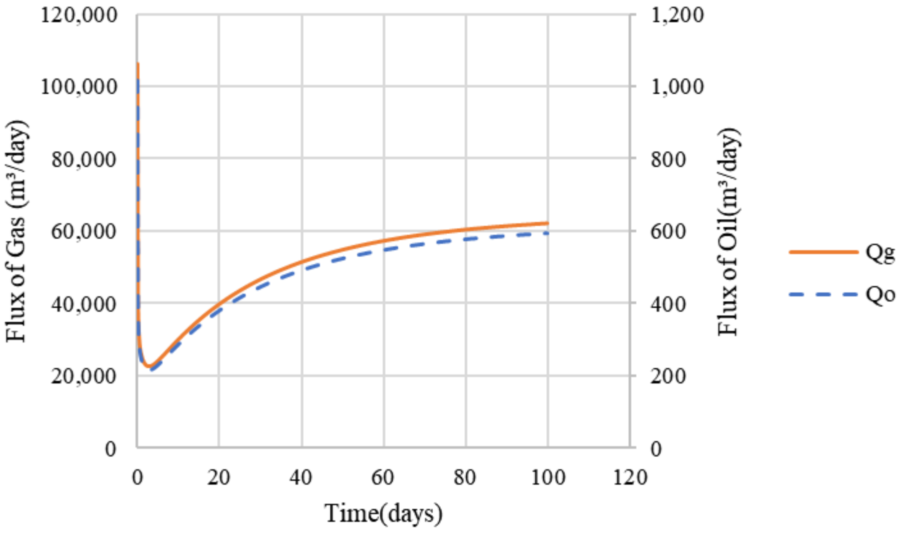

Figure 9. Production curve of oil and gas of case two for 100 days. The blue dash line indicates flux of the oil and orange curve is for gas production.

The changes of BHP and GOR for the second case are presented in Fig 10. As it can be seen, in the second case, the BHP of the producer has increased 55.6 kPa (or 8 Psi) during the production. This information indicates that the constraints of the well should be monitored and controlled precisely. Also, compared to case one, case two has greater GOR values. They are 111.1 and 558.56 for case one and two, respectively.

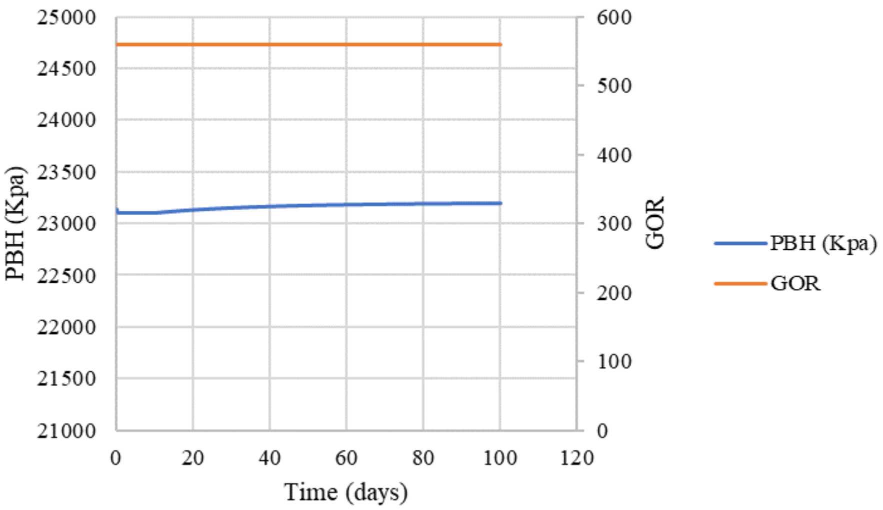

Figure 10. BHP and GOR change of case two for 100 days of production. BHP increases 55.6 kPa during the production

Finally, Fig. 11 shows the same trends for change of different pressures for second case. Similar to case one, average pressure of the reservoir and pressure of injector of the second case increased and both of them have sharper increase in the final days of production. The trends of changes of WHP and PSEP are not the same as case one. They were constant for almost the first ten days of production. This information reveals that the change of surface condition is a function of fluid type that exist in the reservoir.

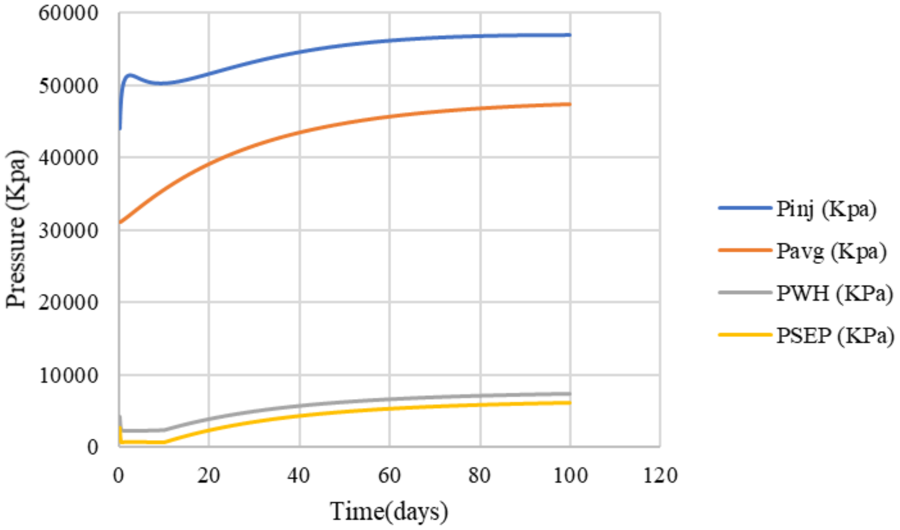

Figure 11. Different pressure changes of case two for 100 days of production.

The two case studies presented here show that the new sequential coupling strategy was implemented successfully. UTCOMP simulator was able to read, compare, and update surface facilities information that was generated by a commercial simulator. The simulator reported WHP and Dynamic PSEP properly.

5 Summary and Conclusions

Compositional simulation of integrated models for surface and sub-surface facilities requires robust and flexible simulator. The main objective of this work was the development of a new framework that can include surface facility section for UTCOMP by considering flow tables option for well section. Hence, we developed two series of flow tables, a simplified and an advanced flow table type. Some numerical software were designed and implemented for reading, comparing and updating information of surface facilities and location of coupling point for UTCOMP. The key findings of this study are summarized as follows:

1- Surface facilities option was included in the input files of UTCOMP.

2- Both of SFT and AFT were implemented successfully.

3- AFT enables the simulator to compute, current GOR, WOR, and based on them reports BHP WHP, and PSEP.

4- Simulation results of integrated models were sensitive to information of AFT. If the values are not suitable for the model, the old table should be replaced with new tables.

5- The presented framework enabled us to understand the behavior of the integrated system and identify the main factors that affect production operations the most.

By implementation of surface facilities option through AFT, we can have better prediction for full implicit coupling of surface and sub-surface facilities for our future works.

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