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Smart Well Modelling for As Reservoir in AG Oil Field

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Abstract

Intelligent or smart completion wells vary from conventional wells. They have downhole flow control devices like Inflow Control Devices (ICD) and Interval Control Valves (ICV) to enhance reservoir management and control, optimizing hydrocarbon output and recovery. However, to explain their adoption and increase their economic return, a high level of justification is necessary.

Smart horizontal wells also necessitate optimizing the number of valves, nozzles, and compartment length. A three-dimensional geological model of the As reservoir in AG oil field was used to see the influence of these factors on cumulative oil production and NPV. After creating the dynamic model for the As reservoir using the program Petrel (2017.4), we improve the robustness of forecasting production from smart wells using reservoir simulation. High-level details in the rock and fluid flow properties are required in the horizontal well region to capture the flow dynamics accurately. Thus, the study offers an enhanced method for predicting the performance of intelligent or smart wells in reservoir modeling.

This model was history matched for a period of 20 years for three horizontal wells by using program Petrel (2017.4) and ECLIPS (2011). After successful validation of model on a field scale and well level, performance prediction was carried out to see the effect of (number of valves, number of nozzle and compartment length) using PICD/AFCV completion. Optimizing well performance entails lowering water-cut. From an economic viewpoint, the goal is to maximize NPV or profit, depending on the situation, from PICD wells, which compared to other wells.

Keywords: Field development, PICD, AFCV, Tornado plot, Net Present Value.

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1. Introduction

As reservoir conditions become more challenging, operators are increasingly utilizing "smart" or sophisticated wells. A variety of smart devices have been installed in the wells to fulfill a variety of objectives. Inflow Control Devices (ICDs) are used in long horizontal wells to decrease water or gas coning effects. These are passive devices that can selectively allow the selected phase to pass. The machines automatically generate a greater pressure drop to minimize excessive water or gas production in parts of the well that lack surface control. These are incredibly significant when considering reservoir heterogeneity; in some situations, greater permeability areas will enable massive water-cuts, substantially impacting well output as well as reservoir management owing to inadequate reservoir sweep. In addition, the deployment of the devices can postpone the commencement of the artificial lift necessary for the well, improving cash flow by deferring capital expenses.

Inflow Control Valves (ICVs) are another common type of valve that allows for dynamic down-hole control. These are controlled down-hole valves, and the valve setting may be adjusted to meet various goals. They may also be utilized to mitigate coning effects, regulate commingled production from different levels for equalizing injection rates, and sweep through all layers in multilayered wells [1].

Smart Wells, also known as Intelligent Wells, have downhole instrumentation (nozzles and valves for inflow control) placed on their tubing, allowing monitoring and production/injection control of the well without the need for conventional well intervention. This type of equipment allows for greater flexibility in the operation of these wells [2]. The principle underlying the use of flow control valves in horizontal wells is the imposition of an additional pressure drop, typically proportional to flowrate squared (Addagio- Guevera et al. (2008) [3], which equalizes the skewed drawdown along the lateral to promote more uniform

fluid front movement [4] demonstrated a great notion of entirely using a long horizontal well if it is created from both ends, i.e., from the heel and toe. Oil recovery is enhanced by selecting the right ICD, which also prevents the flow of undesired water and gas production. The results of field and modeling investigations reveal that the production of

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oil, gas, and water is highly reliant on the type of ICD and the number of ICD used [5]. According to Dosunmu and
[6] oil viscosity, horizontal permeability, and well diameter all have a substantial impact on horizontal well productivity .

The advantages of Intelligent Completions, particularly flow control valves, have been proven in several earlier publications through case studies and theoretical research. Improved reservoir management (e.g., production from stacked pay, thin oil rims and multiple reservoir compartments, managing water/gas coning in wells, etc.), reservoir diagnostics and formation evaluation [7] (flow profiling in horizontal/, downhole production testing), and more efficient clean-up/flow-back of complex wells [8]. Intelligent completions have also been shown in studies to be beneficial in dealing with geologic/reservoir uncertainty. [9] Conducted an NPV study of installing flow control valves in a synthetic reservoir with numerous realizations at varying degrees of confidence and discovered that the NPV was positive in the majority of situations .

To achieve these technological benefits in practice and properly value the additional expenditure, the location and inflow settings of the ICVs must be optimized. Optimization may also be required due to technical constraints (maximum number of ICVs operable in a single well). To optimize the additional value created by the deployment of flow control valves, appropriate screening of reservoir type [10] (for the application of smart completions) and kind of flow control technology [8] is necessary for addition to optimization.

Because of the number of factors involved, determining the placement and number of wells is not a straightforward operation. The well behavior is determined by reservoir characteristics and interactions with other wells, and it can only be predicted numerically. As a result, engineers must test each combination of number and well position.

Many studies advocate for the adoption of an optimization algorithm to decrease the work required by engineers. Because of its capacity to work in a solution space with non-smooth and non-linear topology, the Genetic Algorithm (GA) has been utilized globally for this purpose. The GA is a natural evolution-based optimization approach. It

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works by defining an initial population of N people. Then, the fitness function value is used to evaluate each individual [11].

Optimal reservoir management is a critical subject in the petroleum business. The majority of reservoir performance improvement studies concentrate on well location. [12] utilized a genetic method to decrease the computing burden in a well location optimization issue with uncertainties.

The study aims to conduct a sensitivity analysis for compartment length, the number of valves, and the number of nozzles in a three-dimensional numerical simulation model (AFCV/PICD). Optimizing well performance entails lowering water-cut and increasing NPV.

2. Methodology

This paper aims to make a 3D smart model using the Petrel (2017.4) [13] program for three horizontal wells in the As reservoir in AG oil field. To digest the performance of these smart wells, a reservoir simulation model is necessary. The smart model's goal is to find a design that optimizes NPV by evaluating different well layouts. The petroleum-physical. The approach described in this paper is used to maximize production strategies in a realistic reservoir model by specifying the number and location of production wells and the production flow rates. Some generations were also changed to assess the algorithm's effectiveness.

One of the most intriguing aspects of is Genetic Algorithm its parallelization. Each generation's simulations utilize distributed computation. The process is used in software that calculates NVP.

3. Application of the reservoir and well model

The As reservoir in AG oil field with an area of 106.8 km^2 was utilized in this study to show the implementation of the approach. After upscaling, the reservoir was discretized using a grid of (32x32x30) blocks, of which 29760 are active cells. It is possible to see two major lithofacies (Dolomite and Limestone) as well as the permeability distribution.

In this study, the As reservoir in AG oil field was employed. The model is made up of two dome-shaped structures. The model is bordered on the east and south sides by impermeable faults, and on the north and west sides by powerful water. The model is

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taken into account. The model's heterogeneous permeability is thought to be modest. Figure-1 depicts the reservoir model's top layer permeability and the position of the three horizontal production wells. Tables 1 and 2 show the model's data for rock and fluid characteristics, as well as the distribution of permeability and porosity.

Table (1) Properties of Rock and Fluids

Reference Pressure of Rock (bars)	400
Compressibility of Rock (bars^{-1})	3.44 x 10-5
Density of Water (Kg/m^3)	1170
Heavy oil has a density	30.11°API

Table (2) Distribution of permeability and porosity

Permeability in x normal (mD)	(mean=884.9706mD;σ =732.37mD)
Permeability in y (mD)	(mean=884.9706mD;σ =732.37mD)
Permeability in z (mD)	10 % of permeability in x
Porosity Normal (%)	0.1800 (mean=0.0745; σ =0.0467)

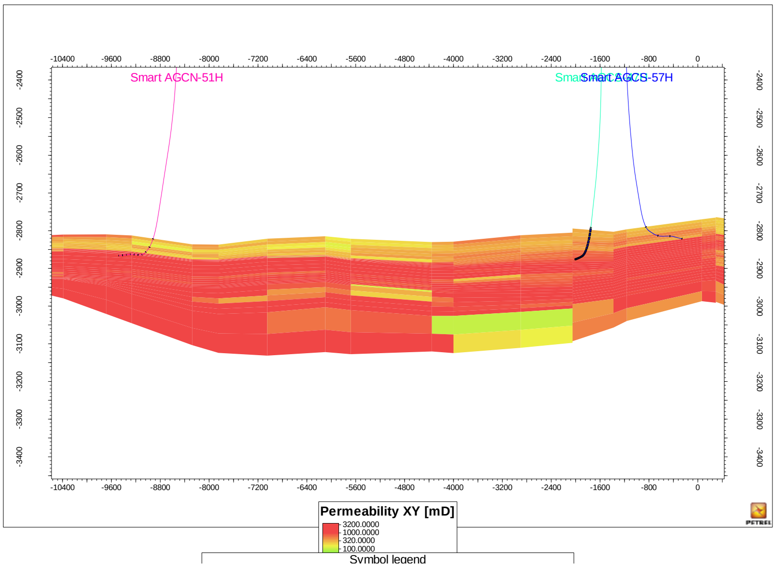

Fig. (1): Cross section showing permeability distribution and well location

4. <u>Intelligent Design Model</u>

4.1 Simulation Intelligent Model Integration

In horizontal wells, inflow control valves (AFCV) and inflow control devices (PICD) can be utilized to balance inflow along the horizontal portion. AFCV and PICD can aid

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to reduce the high flux at the heel of the horizontal well or from the highly permeable zone by regulating the pressure drop. This can help to postpone gas and water breakthrough, allowing oil reserves to be maximized. Using field dynamic reservoir simulators, the influence of (AFCV and PICD) on inflow throughout the horizontal length and over the whole well life may be modeled. The process of gathering all reservoir dynamic data in order to construct a suitable

AFCV and PICD design model for each horizontal well is known as simulation model integration. Petrel (2017.4) [13] was used to implement the As reservoir dynamic model, in which each horizontal well was loaded by the intended trajectory and corrected position for the heel and toe. Nozzle PICD and AFCV were chosen to be utilized for the necessary design, and a library of variable nozzle PICD and AFCV was produced. The library was mainly filled with various PICD/AFCV nozzle diameter sizes and compartment length between two packers. Furthermore, the anticipated casing and tubing parameters for each horizontal well were input into the model. For each horizontal well, a cross section map along the horizontal section was generated. The permeability profile along the horizontal portion served as the foundation for determining compartment length or packer spacing for PICD/AFCV intervals. Water flow along a horizontal portion was studied in order to further optimize the location of PICD and AFCV compartments. For modeling, one to four PICDs/AFCVs per compartment were employed, allowing for a more accurate assessment of the influence of PICD and AFCV on horizontal well performance. For each horizontal well model, a multi-segmented well model was constructed in order to accurately simulate the AFCV/PICD. The multi-segment technique requires the well to be divided into a number of segments along its horizontal length, with fluid characteristics, pressure, and flow rate determined in each segment. This will result in proper estimations of each segment's flow contribution. The multi-segment well model (MSW) was employed, which took into account all pressure drop components such as (phase slip, friction and acceleration). The MSW features might range from a minimum segment length of 50 meters to a maximum segment length of 200 meters.

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4.2 Sensitivity and Optimization

Because of the varied well architecture design and placement techniques in the proposed region, there are numerous possible characteristics that impact well performance. The first stage is to do a sensitivity analysis to determine the factors that have the greatest influence on well production performance; the purpose of this phase is to reduce the search area for subsequent optimization. The most sensitive factors are, in general, the number of compartment lengths, nozzles, and valve PICD/AFCV in each lateral segment. The method may evaluate geological sensitivity in the geological and petrophysical characteristics that are disseminated. The simulator ECLIPS [14] is used to evaluate various parameter combinations and uncertainty ranges. The producers are finished at all layers (A1, A2 and A3) for these wells. The inner diameters of PICDs and AFCVs available on the market are 1.6, 2.5, and 4 mm (Schlumberger Completions). Each PICD/AFCV can have 1 to 25 nozzles and 1 to 10 valves. During each simulation run, an optimization process optimized the flow area of the smart well (PICD and AFCV examples). 150 runs were created in order to investigate the effect of increasing/decreasing the number of (PICDs and AFCVs). This was accomplished by adjusting the compartment length, which is defined as the distance between two packers; having chosen the number of (PICDs and AFCVs) per compartment during the well completion design, a different number of compartments will automatically vary the number of (PICDs and AFCVs). After performing tens of reservoir simulation instances, the process generates a tornado chart to highlight the most sensitive factors on well production performance. The objective function, which might be the maximum cumulative oil output or the Net Present Value, is defined in this procedure.

The optimization techniques available (Evolution Strategy or Genetic Algorithm), the workflow will create and test alternative designs in good architecture and completion until it discovers the ideal solutions. The simulation times of 150 simulation runs with varied parameter combinations largely determine the turnaround time of this procedure.

Three horizontal wells were subjected to optimization techniques, and the Net Present Value (NPV) was the objective function evaluated. The (NPV) method was computed using a 10% annual discount rate, a $60 per barrel oil price, and a $3 water handling cost.

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4.3 Smart Model Results and Discussion

All of the PICD/AFCV simulation runs were compared to the base run, which assumes that the horizontal well would be constructed via casedhole completion and without the use of the PICD/AFCV program. The January 2020 cutoff date was discussed (well on production for 20 years). The horizontal well (AGCS- 47H Smart) with a horizontal length section of 275 m is shown in Figures (2) and (3). Based on the well permeability profile throughout horizontal length, simulation sensitivities for well PICD/AFCV compartments were taken.

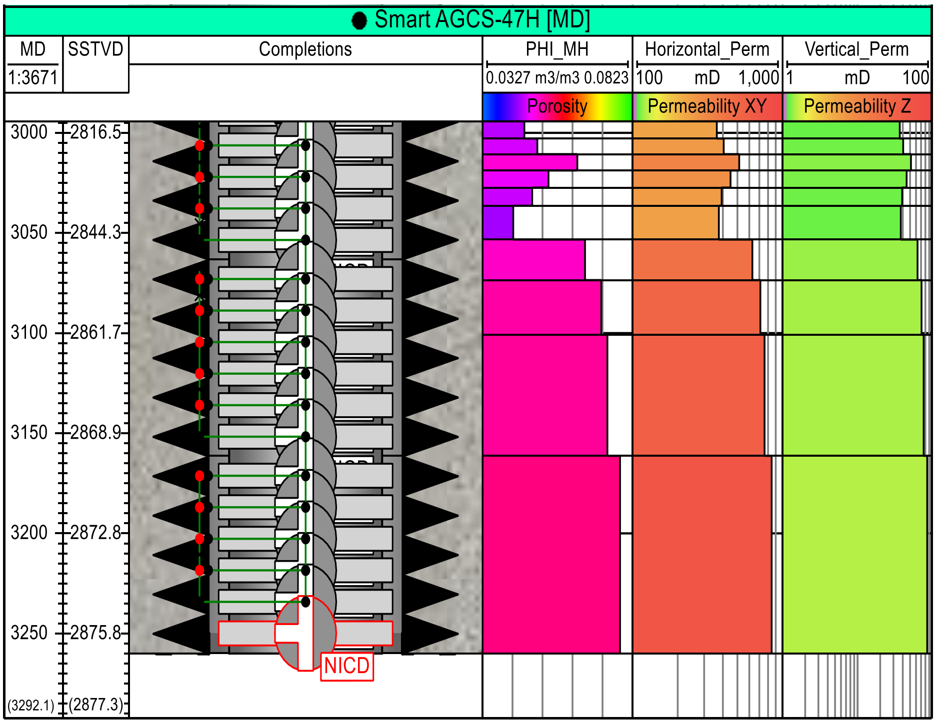

Fig. (2): AGCS_47H_Smart completed with six PICD

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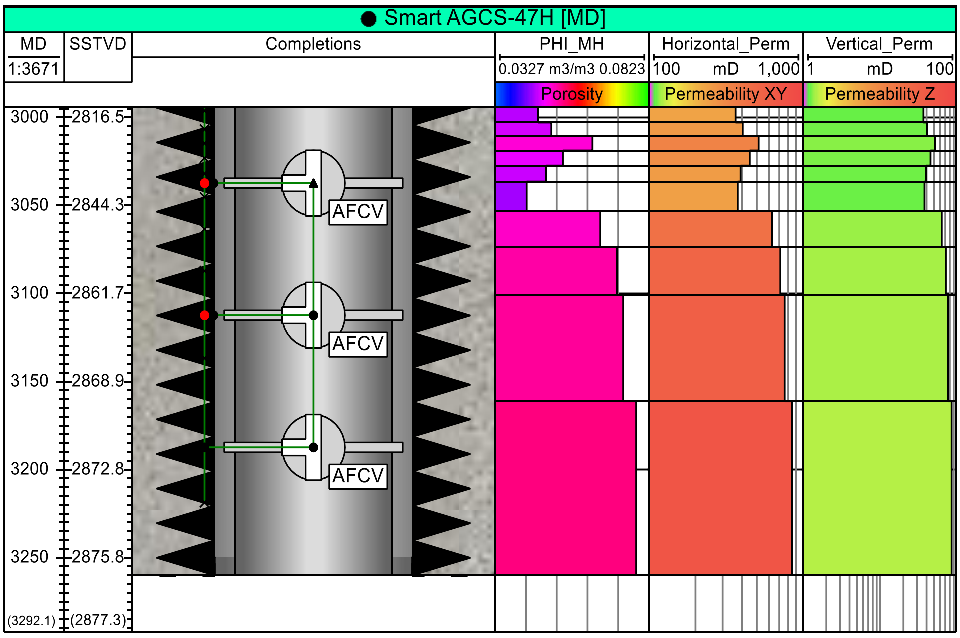
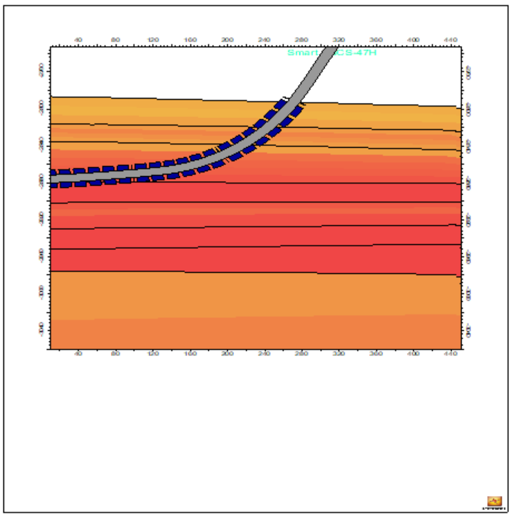


Fig. (3): AGCS_47H_Smart completed with one AFCV

Simulation sensitivities were supplied by the number of 18 PICDs dispersed along the compartment length, beginning with the first compartment at the horizontal well heel and ending with the third compartment at the horizontal well toe. As this smart well was producing simulated sensitivity by 3 AFCVs number (along the compartment length) dispersed throughout the three-compartment length see in Figure (4).



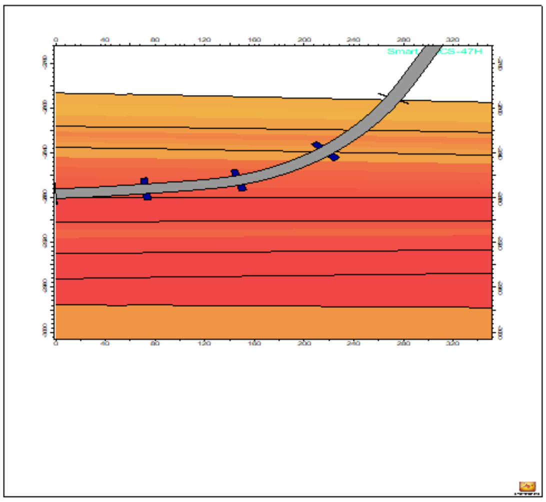


Fig. (4): Cross section of (AGCS_47H) smart model showing permeability distribution (AFCV to right and PICD to left)

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After performing tens of reservoir simulation instances, the process generates a tornado chart to highlight the most sensitive factors on well production performance. To maximize cumulative oil output and NPV from PICD/AFCV, compartment length, number of valves, and number of nozzles in each (PICD/AFCV) must be determined. Initially sensitivity on these variables has been carried out and it is observed from Figure (5) that, 100m compartment length, 6 valves and 12 nozzles with cross section area A= 0.00026 m^2 for PICD which case maximized cumulative oil production and NPV. For optimum AFCV, 429 m compartment length, 3 valves and 7 nozzles with cross section area A= 0.000157 m^2.

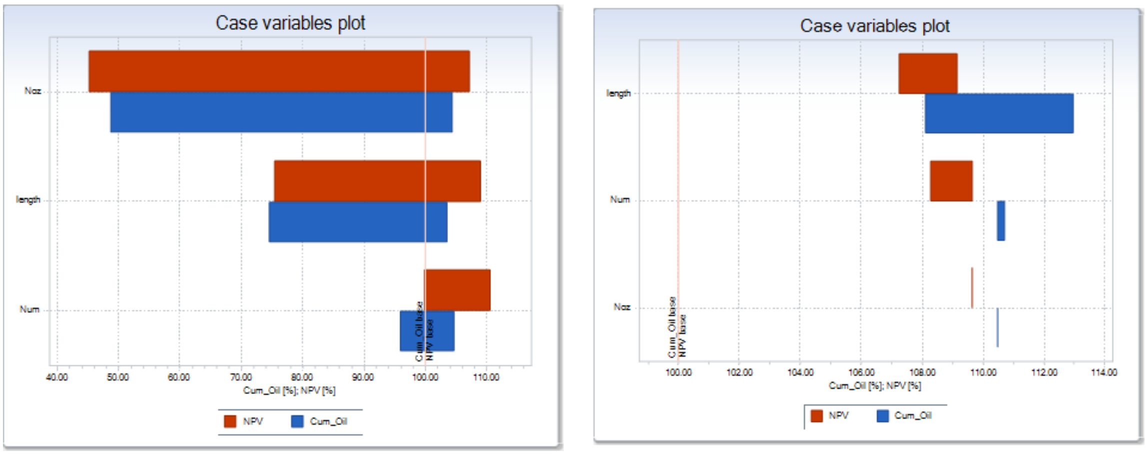

Fig. (5):- Tornado plot showing the effect of (Noz, Num and compartment length) on the cumulative oil production and NPV for AGCS_47H_Smart (AFCV to right and PICD to left)

The optimum (PICDs / AFCVs) distribution group was submitted to evaluate the effect of (PICDs / AFCVs) number from assume the developed creaming curve, as shown in Figure-6, shows the effect of each (PICDs / AFCVs) distribution group on the ultimate well recovery in comparison to the case assuming no (PICDs / AFCVs) application.

The creaming curve confirmed that, the use of 18 PICDs along the compartments length, is the optimum PICDs number and distribution group for this well as the incremental of accumulative oil production and Net Present Value will be appeared in Table 3 while decrease in cumulative water production compared to conventional case of value of accumulative oil production and Net Present Value.

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Furthermore, the simulation results showed that by using AFCV, it can also be observed that AFCVs can enhance cumulative oil output and NPV when compared to conventional wells.

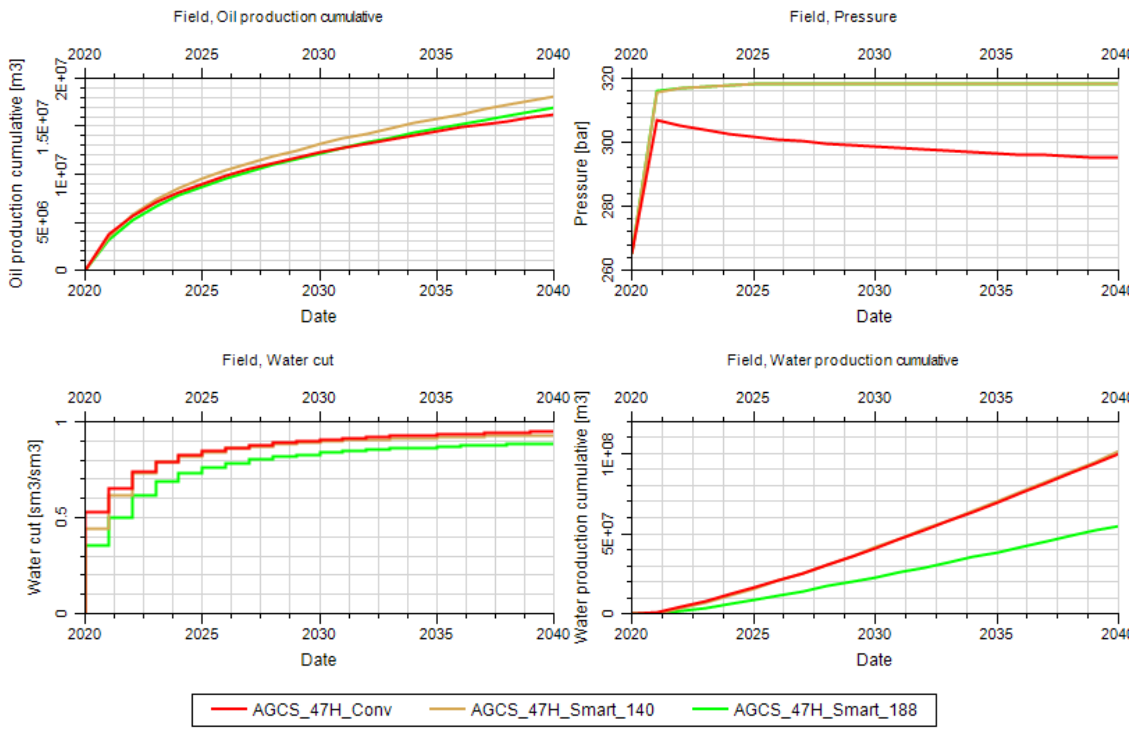

Fig. (6): Field Oil Production cumulative, field Water Cut and field water Production Rates with for CW and SW for AGCS_47H_Smart

Table (3) Comparison of the results obtained from optimization runs with the Base Case scenarios.

Item	**Probable Scenario**	**Cumulative Oil Production (*10^6 std m^3)**	**Cumulative Water Production (*10^6 std m^3)**	**NPV (*10^8 \$)**
Conventional case	AGCS-47H_Conv	16.329091	101.280664	4.85025055
PICD	AGCS_47H_Smart	17.050942	56.021920	5.33957820
AFCV	AGCS_47H_Smart	18.202092	102.456056	5.29232645

The horizontal length section of the second horizontal well (AGCS-51H _Smart) is 902.05m, as shown in Figures (7) and (8). Based on the well permeability profile

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throughout horizontal length, simulation sensitivities for well (PICD/AFCV) compartments were taken as shown in Figure (9).

For this smart well, simulation sensitivities were supplied by ten PICDs spread along the compartment length, beginning with the first compartment at the horizontal well heel and ending with the compartment at the horizontal well toe. As this well-made simulated sensitivity by 18 AFCVs (2 for one compartment length) spread along nine compartment lengths, see in Figure (9).

The process generates a tornado chart to highlight the most sensitive factors on well production performance after performing tens of reservoir simulation instances. Initially, sensitivity testing on three factors was performed, and it is evident from the results. Sensitivity analysis was testing on these factors and discovered that 62m compartment length, 1 valve, and 9 nozzles with cross section area A= 0.000205 m^2 for PICD maximized cumulative oil output and NPV. 68 m compartment lengths, 2 valves, and 3 nozzles with a cross section area of A= 6.94E-05 m^2 for optimal AFCV, as shown in Figure (10).

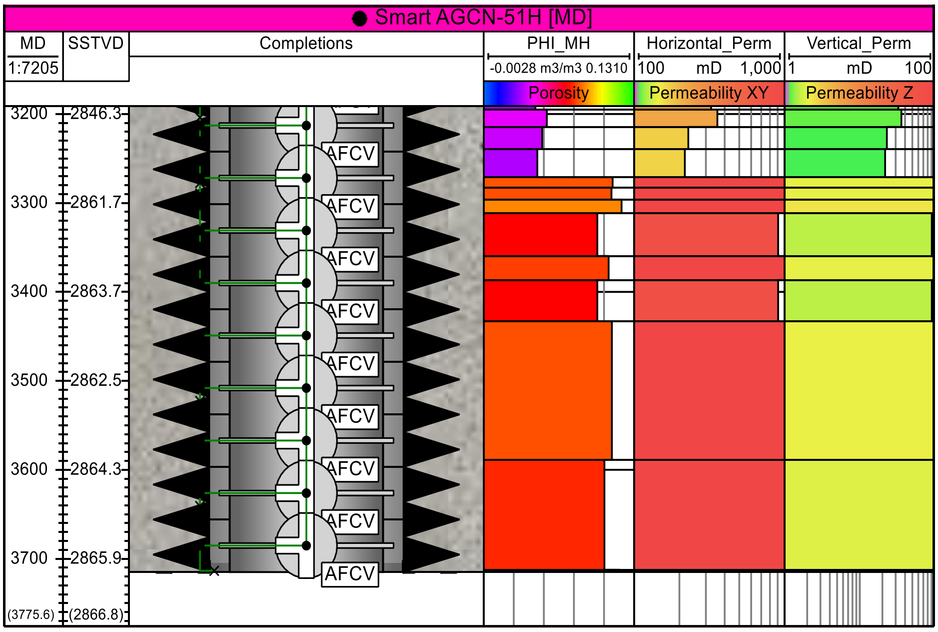

Fig. (7): AGCS_51H_Smart completed with one PICD

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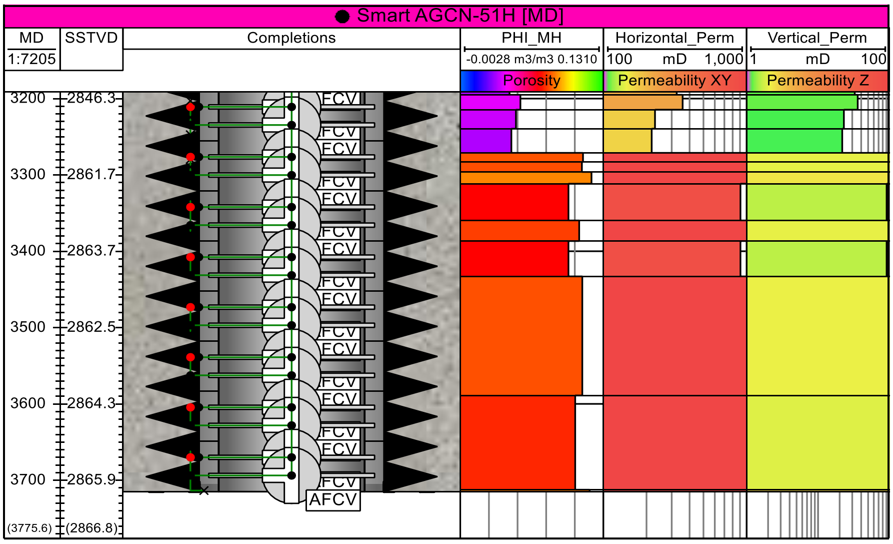

Fig. (8): AGCS_51H_Smart completed with two AFCV

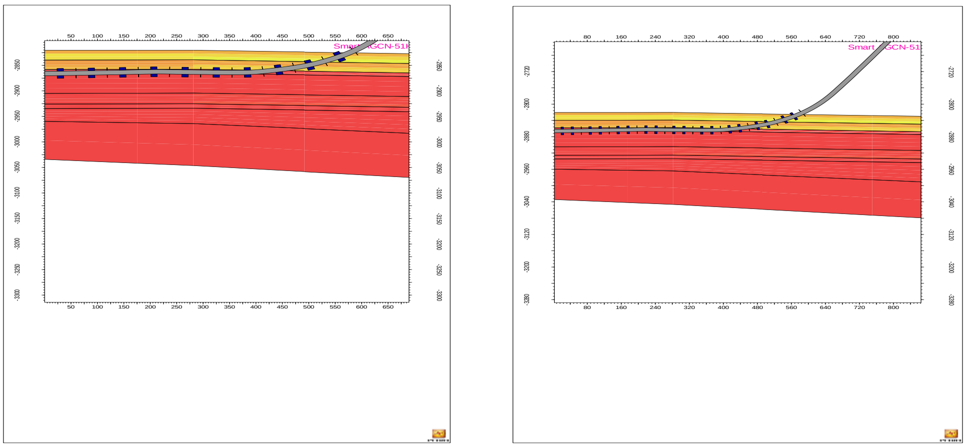

Fig. (9): Cross section of (AGCS_51H) smart model showing permeability distribution (AFCV to right and PICD to left)

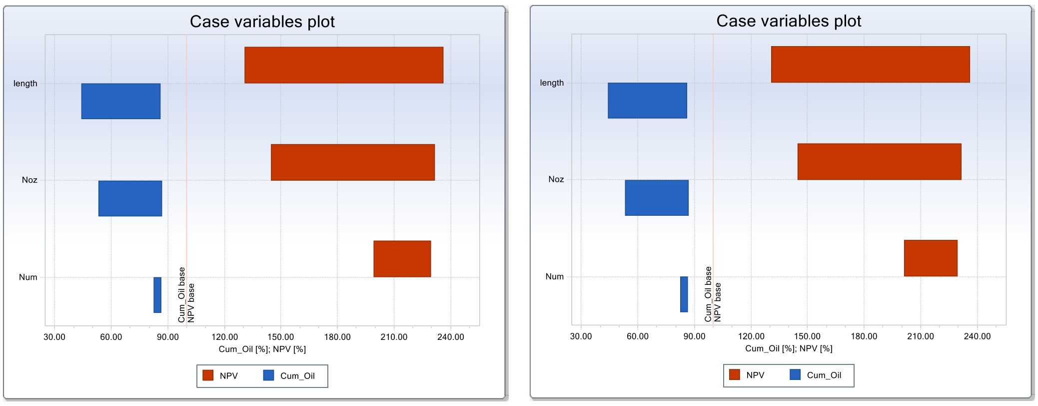

Fig. (10): Tornado plot the effect of (Noz, Num and compartment length) on the cumulative oil production and NPV for AGCS_51H_Smart (AFCV to right and PICD to left)

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To evaluate the effect of (PICDs / AFCVs) number from assume the developed creaming curve, the optimum (PICDs / AFCVs) distribution group was submitted the effect of each (PICDs / AFCVs) distribution group ultimate well cumulative water production and water cut compared to the case assuming no (PICDs / AFCVs) application, show in Figure (11).

The use of 10 PICDs along the compartments length is the optimum PICDs number and distribution group for this well as the incremental of Net Present Value while decrease in cumulative water production compared to base case, see in Table 4. Furthermore, the best AFCVs distribution group was provided to assess the influence of AFCVs number from 18 AFCVs. When compared to a conventional well, AFCVs for the well (AGCN-51H Smart) maximized NPV. Reduced cumulative water production, on the other hand, is a significant element in this field due to the necessity to conduct water treatment, becoming highly important since it decreases water production

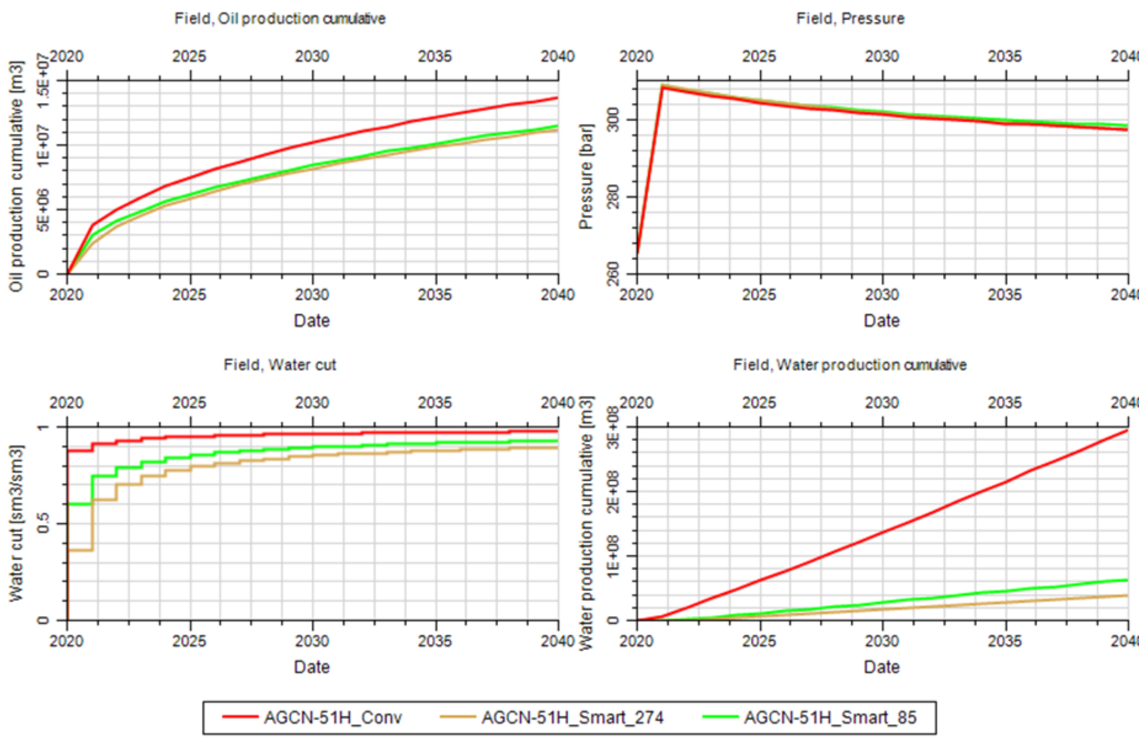

Fig. (11): (Field Oil Production cumulative, field Water Cut and field water Production Rates with for CW and SW for AGCS_51H_Smart)

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Table (4) Comparison of the results obtained from optimization runs with the Base Case scenarios.

Item	Probable Scenario	Cumulative Oil Production (*10^6 std m^3)	Cumulative Water Production (10^6 std m^3)	NPV (*10^8 \$)
Conventional case	AGCS-51H_Conv	13.815558	298.573984	1.438710561
PICD	AGCS-51H_Smart	11.606997	66.096140	3.414644387
AFCV	AGCS-51H_Smart	11.332860	42.067912	3.530106215

The third horizontal well (AGCS_57H _Smart), as given in Figure12 and13, has 837m horizontal length section. Simulation sensitivities was taken for well ICD compartments based on well permeability profile along horizontal length, as shown in Figure (14).

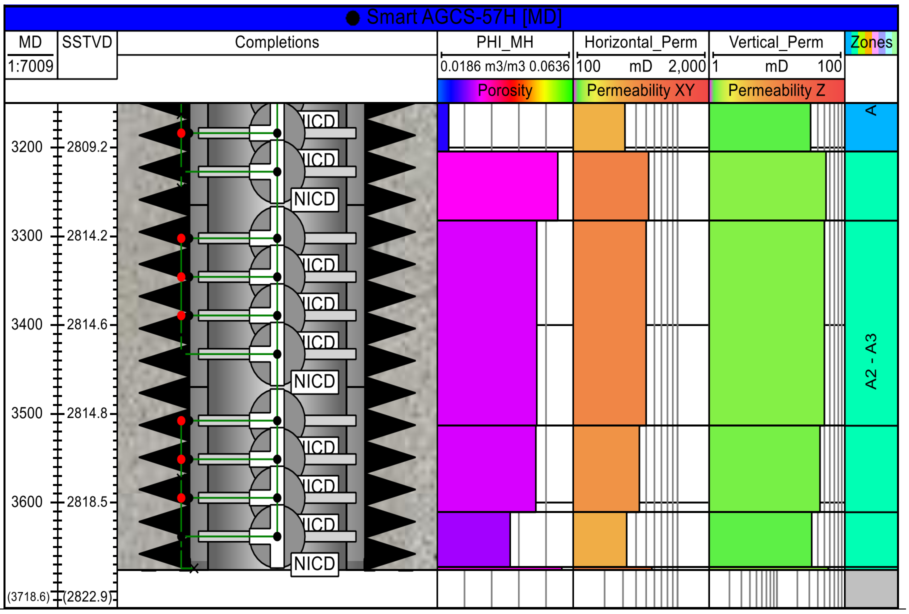

Fig. (12): AGCS_57H_Smart completed with four PICD

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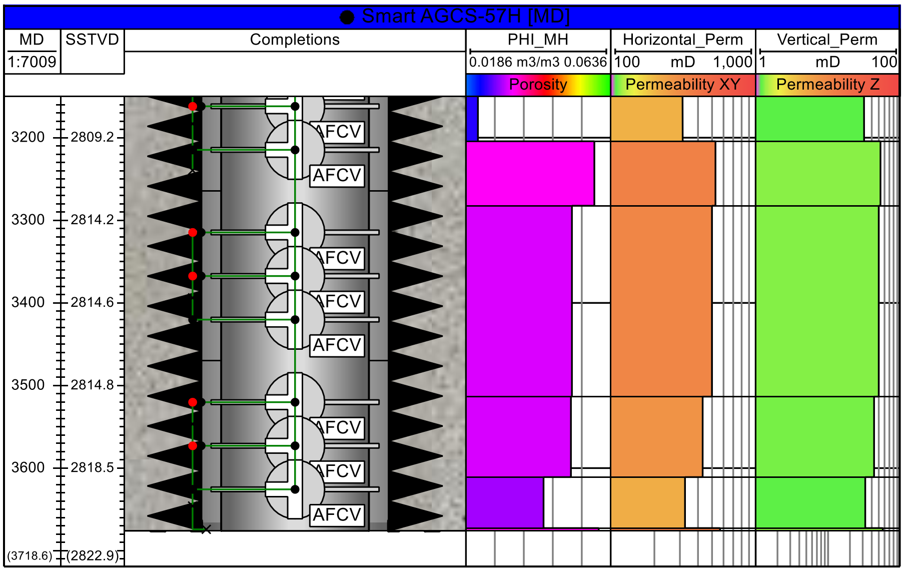

Fig. (13): AGCS_57H_Smart completed with three AFCV

Simulation sensitivities were supplied by 12 PICDs (four for each compartment length) spaced throughout the compartment length. This smart well was increasing simulated sensitivity by 9 AFCVs (3 for one compartment length) spread over nine compartment lengths as seen in Figure (14).

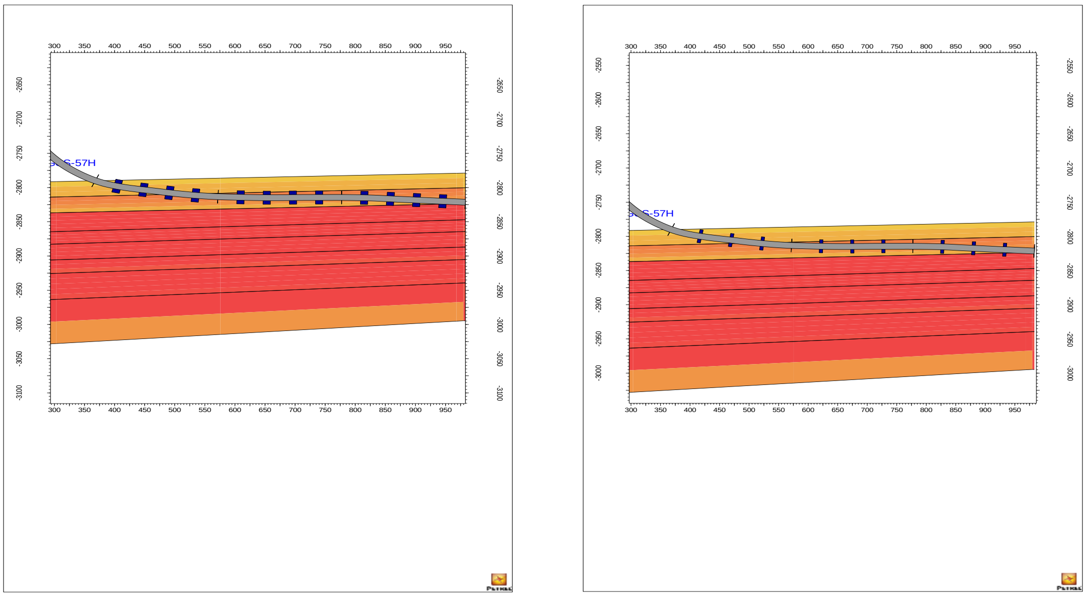

Fig. (14): Cross section of (AGCS_57H smart) showing permeability distribution (AFCV to right and PICD to left)

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The tornado chart is provided by the workflow to identify the most sensitive parameters on the well production performance. The effect sensitive parameters for PICD/AFCV in each lateral segment is shown in Figure (15). Sensitivity on these variables has been carried out and it is observed from Figure-5 that, 240m compartment lengths, 4 valves and 25 nozzles with cross section area A= 0.000541m^2 for PICD which case maximized cumulative oil production and NPV. For optimum AFCV, 209 m compartment lengths, 3 valves and 23 nozzles with cross section area A= 0.000506 m^2.

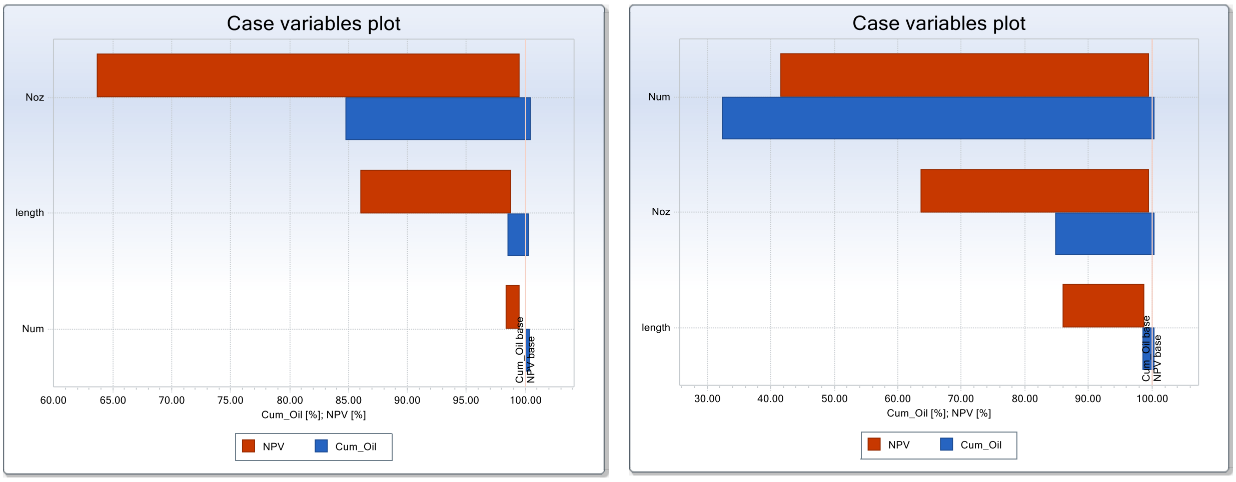

Fig. (15): Tornado plot showing the effect of (Noz, Num and compartment length) on the cumulative oil production and NPV for AGCS_57H_Smart (AFCV to right and PICD to left)

There is no effect of optimum (12PICD/9AFCV) along the compartment's length on Net Present Value, accumulative oil production and accumulative water production for this smart well, see in Table (5) and Figure (16).

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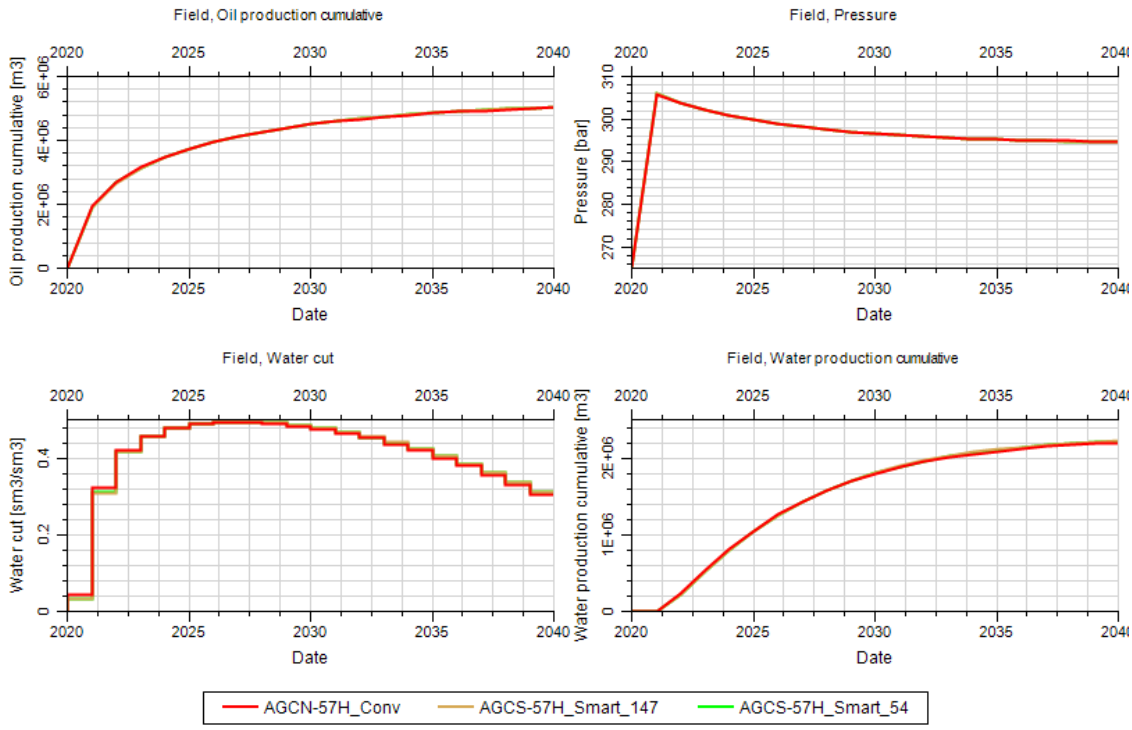

Fig. (16): (Field Oil Production cumulative, field Water Cut and field water Production Rates with for CW and SW for AGCS_57H_Smart)

Table (5) Comparison of the results obtained from optimization runs with the Base Case scenarios.

Item	**Probable Scenario**	**Cumulative Oil Production ($*10^6$ std m^3)**	**Cumulative Water Production ($*10^6$ std m^3)**	**NPV** ($*10^8$ \$)
Conventional case	AGCS-57H_Conv	5.071497	2.21365575	2.162035506
PICD	AGCS-57H_Smart	5.087945	2.23389775	2.158895215
AFCV	AGCS-57H_Smart	5092136	2.2401735	2.159081834

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5. Conclusions

The goal of the present work include optimizing NPV or profit, as well as reservoir management and inflow equalization along the wellbore through analyzing PICD/AFCV. Using the smart completion results of three horizontal wells in areas of different petrophysical properties, the following remarks can be drawn;

1- The overall effect of both NPV and cumulative oil output was often positive, although this was not true for all wells. It is not uncommon for smart wells in each case that produced less oil than conventional wells.

2- The reported results demonstrate that a smart well may be utilized to manage water and enhance oil production in a well with high permeability zones. After 20 years of production of the studied wells in As reservoir in AG oil field, the optimum PICD lowered cumulative water production by 77.8 percent in the well of higher permeability.

3- For the horizontal well in low porosity-permeability area, the optimal PICDs/AFCVs produced mediocre advantages, suggesting that it may not be justified for water management.

4- The length of the compartment, the number of valves and the number of nozzles all have an influence on the NPV of a smart horizontal well using PICD/AFCV.

Abbreviations:

ICD	Inflow Control Device
ICV	Inflow Control Valve
PICD	Passive Inflow Control Device
AFCV	Active Flow Control Valve
NPV	Net present value
MSW	Multi-Segmented Well

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