Nodal Analysis of Development Wells in Gelama Merah Oil Field

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***Abstract* — Nodal analysis serves as the predominant approach for assessing the effectiveness of integrated production systems. The crucial solution operating point is pinpointed at the juncture of two curves, each representing the inflow and outflow aspects. This study directs its attention to the findings derived from nodal analysis, specifically concentrating on actual reservoir pressure and well productivity parameters for the Gelama Merah Oil wells. The primary objective is to furnish valuable insights into the dynamic reservoir behavior, supplying practical data to inform decision-making and refine production strategies within the Gelama Merah Oil Field. Along the way, DST matching will be tested to determine the correlation for IPR and VLP.**

Keywords—Nodal Analysis, Inflow Performance Relationship (IPR), Vertical lift Performance (VLP), DST Matching.

I. Introduction

Exploration and optimization of development wells, particularly in offshore fields, need advanced reservoir engineering techniques to ensure optimal resource extraction. Hence, nodal analysis has come to serve as a method for analysing and improving well performance. This paper reviews the use of nodal analysis in the context of the development well in Gelama Merah Oil Field. Nodal analysis, a key method in evaluating integrated production systems (Mach et al., 1979), involves breaking down the system into elements like the reservoir, completion, and tubing string. Nodes are strategically placed to segment the system, each section defined by specific equations.

Identifying a solution node, often at the bottom hole, is crucial. Pressure changes from the starting point are tallied until reaching the solution node, revealing the inflow capacity (Inflow-Performance Relationship or IPR). The same process extends to the system's endpoint, revealing outflow capacity (Vertical-Lift Performance or VLP). The point where these curves intersect is the solution operating point, critical for optimizing system performance. In understanding inflow and outflow systems, Hagedon-Brown and Vogel correlations are vital tools in nodal analysis. They help unravel the complex dynamics of the production system, providing engineers and practitioners with key insights for informed decision-making and effective performance improvement.

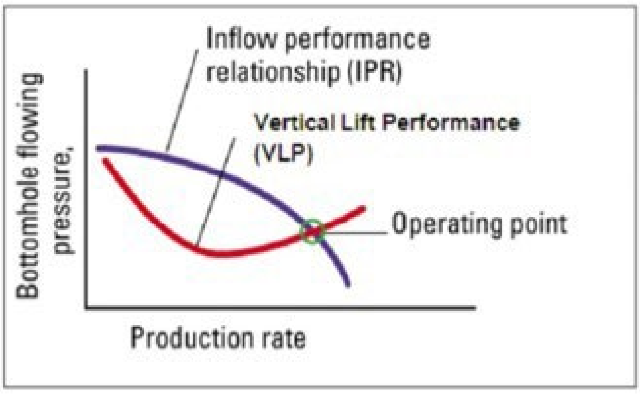

Figure 1 Nodal Analysis

Figure 1 shows the VLP (Vertical Lift Performance) and IPR (Inflow Performance Relationship) curves, representing a crucial aspect of petroleum engineering, particularly in the analysis of reservoir and well performance. These curves are essential for comprehending the connections between wellbore pressure, production rates, and reservoir characteristics. The VLP curve specifically illustrates a well's ability to lift fluids vertically, while the IPR curve demonstrates the relationship between reservoir pressure and inflow rate. These visual representations play a critical role in optimizing well production and making informed decisions during field development. Interpreting these curves aids in identifying optimal operational conditions, understanding reservoir behavior, and refining production strategies for effective reservoir management.

II. Literature Review

A. Drill Stem Test (DST) Matching

Dynamic Systems Theory (DST) Matching is an important approach used in the oil and gas sector to find correlations determining the Inflow-Performance Relationship (IPR) and Vertical-Lift Performance (VLP). DST Matching actively examines changing wellbore and reservoir conditions, using principles like attractors and self-organization to generate correlations that accurately reflect the complicated, time-varying interactions between reservoir and wellbore for IPR. Similarly, in the context of VLP, DST Matching directs the selection of correlations that adjust to changing parameters in the wellbore and surface facilities, resulting in a more precise representation of the well's vertical lift performance (Azim, R. A.,2019). This matching improves reservoir management by providing a comprehensive and adaptable method for selecting correlations that correspond to the dynamic nature of the oil and gas production environment, resulting in optimal decision-making and production strategies.

B. Inflow Performance Relationship (IPR)

Based on the works of (AL-Dogail et al., 2018) it defines that Inflow Performance Relationship (IPR) is the relation between well-flowing bottom-hole pressure (Pwf) and flow rate (Q_o) at a stable reservoir pressure. IPR is used to evaluate well productivity, and accurate estimates of well production that can assists operators to optimize production design and anticipate recovery for project planning.

C. Vogel's Inflow Performance Relationship

Vogel's Inflow Performance Relationship (IPR) is a practical empirical correlation developed in 1968 (Vogel J. V., 1968) for two-phase scenarios involving both oil and gas in the reservoir.

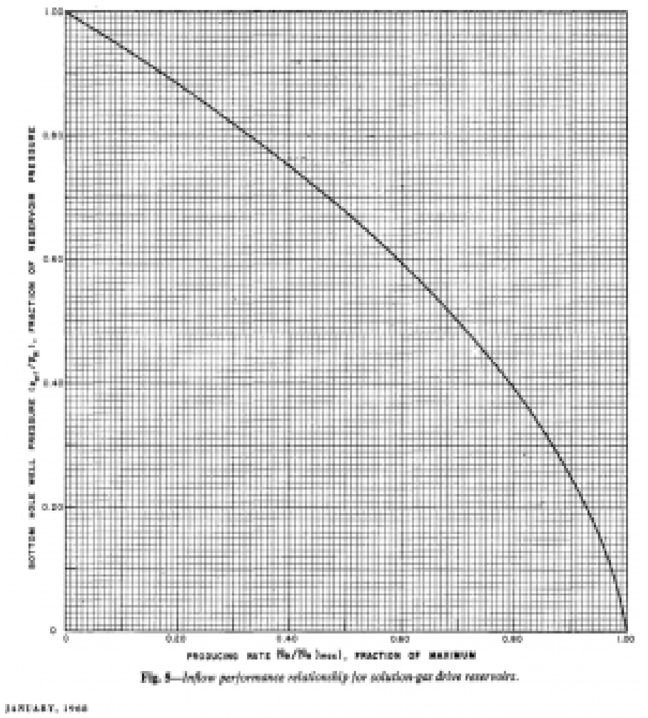

Figure 2 Vogel's IPR Curve

Figure 1 depicts the curve for Vogel's IPR. This correlation originated from extensive computer simulations conducted on diverse solution gas drive reservoirs, covering a range of fluid and reservoir relative permeability properties. Vogel's IPR, stemming from this empirical foundation, provides valuable and applicable insights into the intricate dynamics of fluid inflow. Widely utilized in reservoir engineering, it serves as a fundamental tool for predicting and optimizing well productivity when dealing with two-phase flow conditions.

The default equation for Vogel's IPR is;

$$\frac{q_o}{q_{omax}} = 1 - 0.2\frac{P_{wf}}{P} - 0.8\left(\frac{P_{wf}}{P}\right)^2$$

D. Vertical Lift Performance (VLP)

The Vertical Lift Performance (VLP) curve depicts the correlation between flow rate and pressure in the context of fluid elevation (Ghetto et al., 2019). This curve articulates the pressure needed to raise a particular volume of fluid to the surface under a specified well head pressure. In essence, the VLP curve visually represents the dynamic relationship between flow rate and the associated pressure demands, providing valuable insights into the effectiveness and functioning of the fluid lifting process in oil and gas wells.

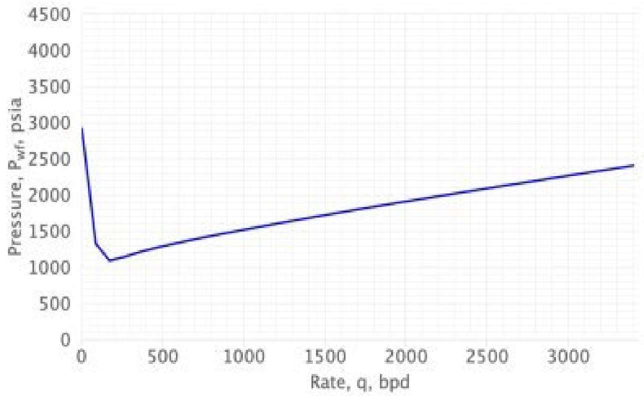

Figure 3 VLP Curve

Figure 2 shows the VLP Curve. It illustrates the correlation of VLP. Hence, as the flow rate increases, there is a corresponding rise in the necessary pressure, primarily due to friction forces. Simultaneously, the unique curvature in the curve, known as the "hook," is a consequence of liquid dominance over gas, influencing specific pressure characteristics during the vertical lift process.

E. Hedgedorn and Brown Correlation

Hagedorn and Brown, developed in 1965, is an empirical correlation tailored for two-phase flow involving both liquid and gas components (Hagedorn, A. R.; Brown, K. E.,1965). Notably, this correlation does not discern between different flow regimes. At its essence, the Hagedorn and Brown method relies on a specific correlation designed for liquid holdup (HL). This correlation is fundamental to the methodology, providing crucial insights into the quantity of liquid present in the two-phase flow system. The Hagedorn and Brown correlation has been a fundamental tool in fluid dynamics, finding valuable applications in situations where distinguishing between various flow regimes is not a primary concern.

III. Background

The nodal study of the Gelama Merah oil wells provided valuable insights into the performance dynamics of the integrated production systems. The solution operating point, defined as the junction of the inflow and outflow curves, offered crucial information for maximizing well production.

The genuine reservoir pressure data collected by nodal analysis provided a detailed insight of the reservoir's behavior. These findings help to provide a more accurate evaluation of the reservoir's current state, allowing for better judgments about reservoir management strategy. The nodal analysis results not only support the existing reservoir pressure predictions, but also reveal possible changes or differences from expected behavior. When assessing well productivity, the nodal analysis identified major parameters impacting the outflow capacity of Gelama Merah Oil wells. Understanding all these aspects is important for developing successful methods for production. The examination of well productivity also includes an assessment of how artificial lift systems, completion procedures, and reservoir characteristics affect whole system performance.

Furthermore, the nodal analysis results provide concerns on the possibility of implementing optimization methods like as adjusting surface choke settings, introducing artificial lift enhancements, or amending completion designs to increase well productivity. The issue will be crucial for operators and engineers who want to optimize Gelama Merah Oil Field's economic potential. In conclusion, the results and suggestions from nodal analysis give an in-depth understanding of the Gelama Merah Oil wells' performance. This understanding serves as the foundation for making prudent choices, executing targeted reservoir management practices, and improving production in response to the reservoir's unpredictable conditions.

IV. Results and Discussion

A. Drill Stem Test (DST) Matching

DST matching is required to determine the most suitable equation for the IPR and VLP. The default equation in the model for IPR is Vogel since the field containing oil and for VLP is Hagedorn and Brown. By using the data from well test report, the reference point for IPR and VLP is managed to be intersected at the reference point. Hence, this conclude that both correlations can be used for Nodal Analysis.

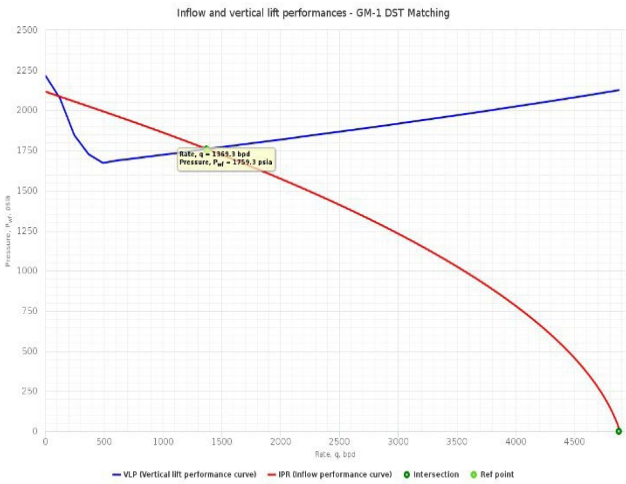

Figure 4 DST Matching

Figure 3 depicts the good match of DST Matching. The information utilized for achieving this correlation corresponds to the details provided in Table 1. This data can be obtained from Well Test Report.

Table 1 Well Test Data

P_b	2014 psia
SG_{oil}	23.3 API
SG_{gas}	0.748 Sp.gr.
SG_{water}	1 Sp.gr.
P_{res}	2116 psia
T_{res}	155 F
H_{tub}	4909 ft
ID_{tub}	2.75 in
OD_{tub}	3.5 in
ID_{casing}	8.681 in
H_{perf}	4987 ft
J	4 bpd/psia
THP	390 psia
THT	97 F
WCUT	0 %
GOR	400 scf/bbl

B. Nodal Analysis

Nodal analysis results for the five wells which are GM-T, GM-O, GM-K, GM-P and GM-I provides a comprehensive insight of their overall operating dynamics. Each well contributes to the ensemble in a unique way, with varying flow rates and bottom hole pressures. This extensive research digs into the complexities of their performance, assessing how changing reservoir conditions and production factors affect the system. This discussion lays the groundwork for an in-depth examination of reservoir behavior, potential optimization strategies, and the overall performance of the integrated production system that includes these five wells, GM-T, GM-O, GM-K, GM-P and GM-I, by determining the solution operating points through the interaction of inflow and outflow curves. The drop in pressure during depletion is revealed by the vertical gap between the initial IPR curve and its subsequent points. This decline is a consequence of the reservoir's diminishing energy, resulting in a decreased capacity to transport fluids to the wellbore at a consistent rate. Hence, when the VLP and IPR intersected at the lowest rate, the wells can produce more longer despite the dropping of pressure in the reservoir.

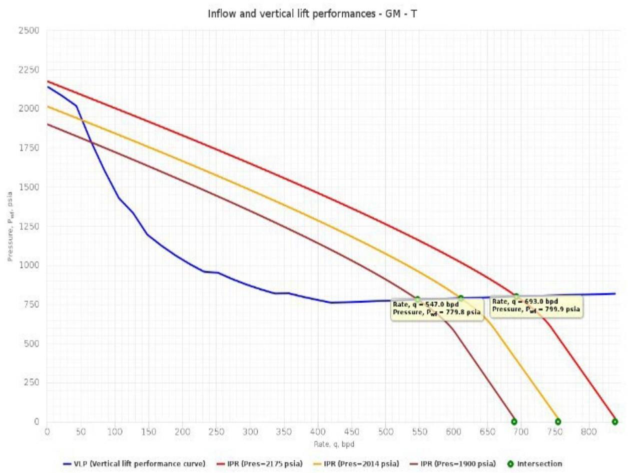

Figure 5 Nodal Analysis of GM-T

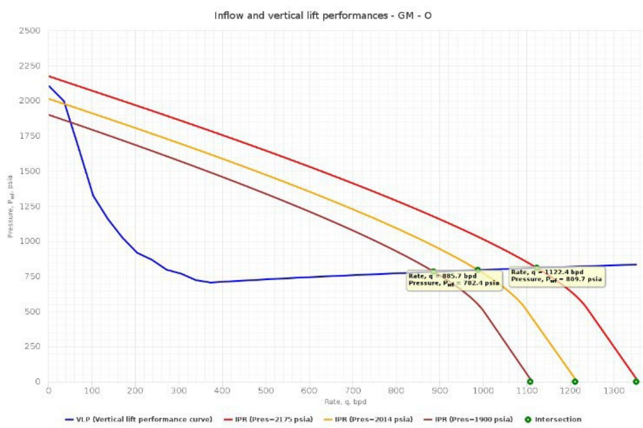

Figure 6 Nodal Analysis of GM-O

Figure 4 displays the Inflow-Performance Relationship (IPR) and Vertical Lift Performance (VLP) curves for GM-T. The intersection point on the figure indicates that the IPR and VLP curves converge precisely at the minimum point of the depletion pressure drop with the rate of 547 bpd and pressure Figure 5 shows the result of Nodal Analysis for GM-O where the rate of 885.7 bpd and pressure of 782.4 psia. Hence, this pressure will be tested in the model as a real data. 779.8 psia.

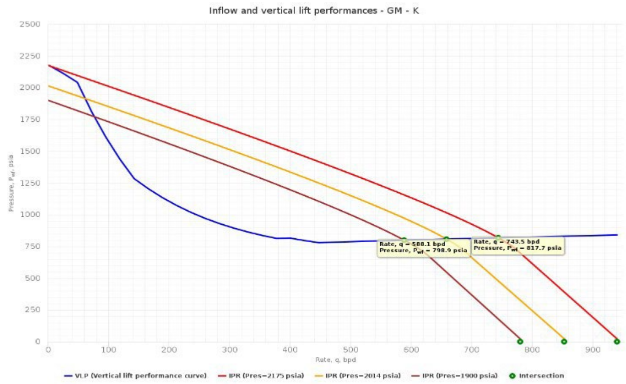

Figure 7 Nodal Analysis of GM-K

Figure 6 shows the result of Nodal Analysis for GM-K where rate of 588.1 bpd and pressure of 798.9 psia. Hence, this pressure will be tested in the model as a real data.

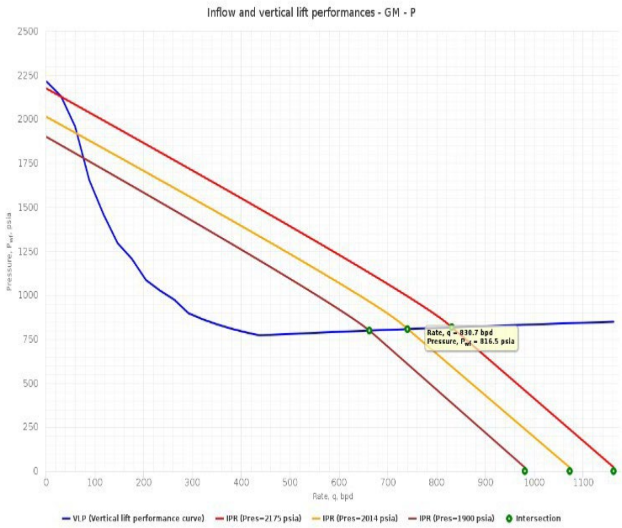

Figure 8 Nodal Analysis of GM-P

Figure 7 shows the result of Nodal Analysis for GM-P where rate of 830.7 bpd and pressure of 816.5 psia. Hence, this pressure will be tested in the model as a real data.

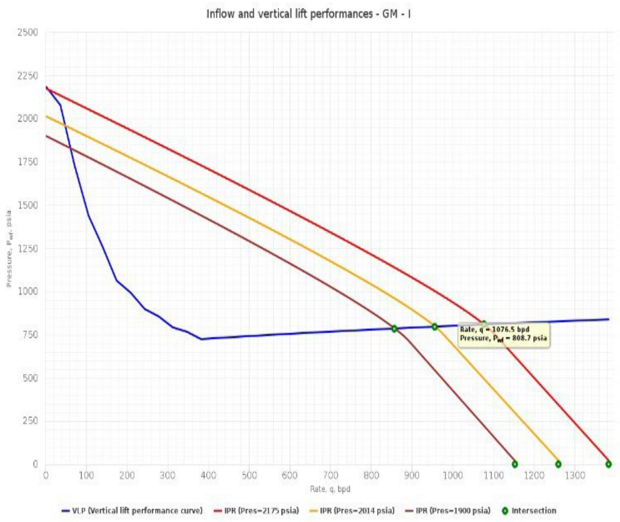

Figure 9 Nodal Analysis of GM-I

Figure 8 shows the result of Nodal Analysis for GM-I where rate of 830.7 bpd and pressure of 816.5 psia. Hence, this pressure will be tested in the model as a real data.

V. Conclusion

In conclusion, the utilization of nodal analysis has been paramount in dissecting the complex interrelations across reservoir, well, and surface facilities. Employing nodal analysis principles has afforded us a holistic grasp of pressure distribution within the reservoir, guiding optimal well positioning and informing our strategies for reservoir management. On the well front, this approach has yielded crucial insights into fluid flow dynamics, encompassing variables such as wellbore storage, skin factors, and completion design, thus allowing us to maximize our yield of hydrocarbon resources. Moreover, at the surface infrastructure level, nodal analysis has played a pivotal role in evaluating the efficiency of gathering networks, processing units, and transportation systems, pinpointing areas for improvement and enhancing the overall operational effectiveness of our project. The integration of nodal analysis techniques into our field development initiative has proven indispensable, guiding our decision-making processes, and contributing significantly to the sustainable and efficient exploitation of our hydrocarbon reserves.

Hence, the determined pressure values stemming from the Nodal Analysis of the Sumandak Oil Field serve as authentic indicators of reservoir behavior. These outcomes, encapsulating the nuanced interactions within the reservoir and are poised to play a crucial role in reservoir engineering. Specifically, the resulting pressure data will be meticulously provided to the Reservoir Engineer for integration into the reservoir model. This incorporation ensures an accurate representation of the real-world dynamics of the Sumandak Oil Field, enabling engineers to make informed decisions, optimize reservoir management strategies, and contribute to the sustainable and effective extraction of hydrocarbons from this dynamic reservoir.

References

Vogel, J. V. (1968). Inflow performance relationships for solution-gas drive wells. Journal of petroleum technology, 20(01), 83-92.

Brown, K. E. (1984). The technology of artificial lift methods, Volume 4.

Georgeson, V. U., Iledare, W., & Ajienka, J. A. A New Framework for the National Petroleum Production Capacity Determination.

Hagedorn, A. R.; Brown, K. E. (1965). "Experimental study of pressure gradients occurring during continuous two-phase flow in small-diameter vertical conduits"Free registration required. Journal of Petroleum Technology. 17(04) (SPE-940-PA): 475–484.

Economides, M.J.; Hill, A.D.; Economides, C.E.; Zhu, D. (2013). Petroleum Production Systems (2 ed.). Westford, Massachusetts: Prentice Hall. ISBN 978-0-13-703158-0.

"Turbulent Flow in Pipes, With Particular Reference to the Transition Region Between the Smooth and Rough Pipe Laws" Paid subscription required. Journal of the Institution of Civil Engineers. London, England. 11: 133–156.

Moody, L. F. (1944). "Friction factors for pipe flow" Paid subscription required. Transactions of the ASME. 66 (8): 671–684.

Lyons, W.C. (1996). Standard handbook of petroleum and natural gas engineering. 2. Houston, TX: Gulf Professional Publishing. ISBN 0-88415-643-5.

AL-Dogail, A. S., Baarimah, S. O., & Basfar, S. A. (2018, April). Prediction of inflow performance relationship of a gas field using artificial intelligence techniques. In SPE Kingdom of Saudi Arabia Annual Technical Symposium and Exhibition. OnePetro.

De Ghetto, G., & Di Lullo, A. (2019, March). A New Method to Calculate the Vertical Flow Performance in Well Production Studies. In Offshore Mediterranean Conference and Exhibition (pp. OMC-2019). OMC.

Azim, R. A. (2019). Full Field Production Optimization Study Using Nodal Analysis Technique. Petroleum & Coal, 61(3).

Trina, S. (2010). An integrated horizontal and vertical flow simulation with application to wax precipitation (Master of Engineering Thesis). Canada: Memorial University of Newfoundland.