Sudanese Oil Field Production Performance by Nodal Analysis Technique

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***Abstract* — The study has evaluated production performance of oil well by using nodal analysis for entire production system. The goal of this study is to analysis one of the Sudanese oil field using nodal analysis and to review the field completion strategy for the respective field. The study starts by collecting the data from oil Company and takes the X Field as case study. The X field consist of 18 well and four of them were selected for theanalysis namely X NW-1, X NW-2, X NW-3 and X NW-4. Operating pressure for each well are 2409, 2455, 2550 and 2420 psia, and operating flow rate are 3925.4, 1110.4, 2255.7, and 1387.2 STB/D respectively. Wellfl modeling used for this task, which permits the production optimization of oil well using the concept of nodal analysis.**

Several sensitivity analyses were conducted in order to get the production forecast. If assumed thatthe depletion in the pressure occur within 1 year, the pressure reduced to 2000 and 1000psia for each well; as can be seen, the production reduced rapidly inXNW-2 and XNW-4. However, 1000psia the production becomes zero for the four wells.

***Index Terms* — Nodal Analysis, Production Performance, Wellflo Progam.**

I. Introduction

Nodal analysis has long been a key method used to evaluate the performance of an integrated production system [1]. It has performed in the sixties and seventies by hand calculation, using vertical pressure traverse graphs generated in- house by big oil companies [2], and define the propositions that will be used to optimize a production system, for oil and gas well. Each component of the producing system is analyzed in order to reach the desired production rate as economical as possible [3].

- Determine the fluid rate that an oil or gas well will produce, taking into account the hole geometry and the completion boundaries.
- Optimize the system to produce an objective fluid rate as economical as possible [4]. Nodal analysis provides a method to determine the flow rate at which a producing system will perform under applied condition.

The node is placed into different location. The node is classified as a functional node when a pressure exists across it and the pressure or flow rate response can be presented by some mathematical or physical function [3]. Once the node is selected, the node pressure is calculated from the both directions stared at the fixed pressures. In other words, the flow into the node equals the flow out the nod [5].

Published on January 18, 2020.
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II. Application of Field X Nodal Analysis

A. Models and Correlations

The Wellflo computer program software was used for nodal analysis. For this study version (3.8) has been used. The computer program can conduct the nodal analysis calculations as well as (sensitivity analysis) and tested with actual field data.

Reservoir: The pressure drops across the reservoir porous media are computed by an inflow performance relationship (IPR) expressed by Vogel's [6].

$$\frac{q_o}{q_{0(\max)}} = 1 - 0.2\frac{p_{wf}}{p_R} - 0.8\left(\frac{p_{wf}}{p_R}\right)^2 \quad (1)$$

Perforation: The program computes the pressure drop across the perforations using Mc-Leod's method [7]. The equation for the pressure losses across the perforation is as follows:

$$p_{wfs-} p_{wf} = aq + bq^2 \quad (2)$$

The coefficient a and b are define as,

$$a = \frac{3.16 * 10^{-12} * \beta * \gamma * T * \left(\frac{1}{Rp} - \frac{1}{Rc}\right)}{LP^2 * \mu} \quad (3)$$

$$b = \frac{1.424 * 10^3 * T * \left(Ln\frac{Rc}{Rp}\right)}{K_P * L_P} \quad (4)$$

Tubing String: Hagedron and Brown correlation was used to compute the pressure drop across the tubing string.

Well Head Choke: Sechdeva, Adiatique expansion equation and Gilbert correlations used to compute the pressure losses across the wellhead choke [8].

Surface Pipeline: Hagedron and Brown correlation were used to compute the pressure drop across the surface pipeline, this equation considers slip condition and flow regime, used for all pipe size, and for the all fluids.

Fluid Properties: The correlations used to build the wellflo software program to estimate the properties of the fluids are listed in Table (1). These experimental correlations are function of temperature, pressure, type of fluid (gas, oil or water), and densities of the different phase which are present in the flow.

TABLE 1: CORRELATION FOR FLUID PROPERTIES

Fluid property	Correlation	Utilized
Solution Gas-Oil ratio	Glaso	Glaso
Formation volume factor	Laster	
	Standing	
Bubble point pressure	Vazquez- Beggs	
	Macary	
Surface tension	Advanced & Basic	Advanced
Oil viscosity	Beal +chew et al Beggs et al &Astm+cheqet al	Beal+chew et al

B. *Field X Data validation and Results*

4 wells namely XNW1, XNW2, XNW3, and XNW4 were selected, all of the four well open to production in 2009. X field data represent an ideal production data which is used to verify the robustness of wellflo software program. The characteristics of the reservoir as well as the completion, production, and fluid properties, for four well are summarized in following Tables 2-6.

TABLE 2: X FIELD RESERVOIR DATA

Well name	XNW-1	XNW-2	XNW-3	XNW-4
Initial pressure (psi)	2409	2455	2550	2420
Initial temperature (f)	186	179	180	179
Net pay (ft)	84.6	38	50.5	49.5
Porosity (fraction)	0.21	0.19	0.24	0.22
Permeability (md)	2400	212	2000	1800
Water saturation (fraction)	0.48	0.44	0.25	0.29

TABLE 3: X FIELD COMPLETION DATA

Well name	XNW-1	XNW-2	XNW-3	XNW-4
Casing diameter [in.]	6.267			
Perforated interval [ft]	131.2	55.8	62	57.4
Perforation density [SPF]	4			

TABLE 4: X FIELD PRODUCTION DATA

Well name	XNW-1	XNW-2	XNW-3	XNW-4
Well head pressure [psia]	390	265	235	280
Well head temperature [F]	164	150	155	143
Gas oil ratio (SCF/STB)	30	30	30	30
Water cut %	50	80	92	9
Liquid production rate (STB/d)	3925.4	1110.4	2255.4	1387.2

TABLE 5: X FIELD FLUID PROPERTIES DATA

Well name	XNW-1	XNW-2	XNW-3	XNW-4
Specific gravity of produced gas	0.65			
Oil density [API]	37.05	35.11	39.1	36.06
Solution gas/oil ratio correlation:	Glaso			
Oil formation volume factor correlation:	Glaso			
Bubble point pressure correlation:	Glaso			
Oil viscosity correlation:	Beal + chew et al			
Gas viscosity correlation:	Carr et al			
Surface tension	Advanced			
Water salinity (ppm)	5878			

TABLE 6: HISTORY MACH FOR THE FOUR WELLS

Calculated value	Well name	Calculated value	Actual value	Comment
Skin	Xnw-1	8.355	6.1	From well test
	Xnw-2	3.591	1.24	From well test
	Xnw-3	1.59	2.3	From well test
	Xnw-4	-1.128	-1.231	From well test
Productivity index (STB/d/psi)	Xnw-1	18.24	16.32	From well test
	Xnw-2	21.84	19.88	From well test
	Xnw-3	14.11	11.38	From well test
	Xnw-4	6.20	8.23	From well test

Sensitivity Analysis

Three cases were conducted to study the sensitivity of well flow rate to these cases. These cases are the pressure of the layer, the well head pressure and producing of water cut.

Layer pressure: The actual layer pressure of the well xnw-1 is 2400 psia. Therefore, layer pressure values of 2400, 2000 and 1000 psia are used for forecast computations for this well. The results show that when the layer pressure becomes 1000 psia, there is no operating point in well xnw-1. In other words, this well will not produce if the layer pressure decreases to 1000 Psia. Layer pressure value of 2455, 2400 and 2000 psia were used for forecast computation for well xnw-2 since the actual layer pressure of this well is 2455 psia. Simulation shows, this well has no operating point when the layer pressure became 2000 Psia. For well xnw-3 which it is actual pressure value is 2455, layer pressure values of 2455, 2400, 2000 and 1500 Psia were used. The results show that this well can produced for less than 2000 Psia layer pressure value but cannot produce if the reservoir pressure decrease to 1500 Psia. Reservoir pressure values of 2420, 2400, 2000, 1000 psia was used for well xnw-4 where the actual layer pressure value from it is 2420 psia. The well has no operation point in 2000 Psia. That means there is no flow rate at the surface and the operating of this well become uneconomic.

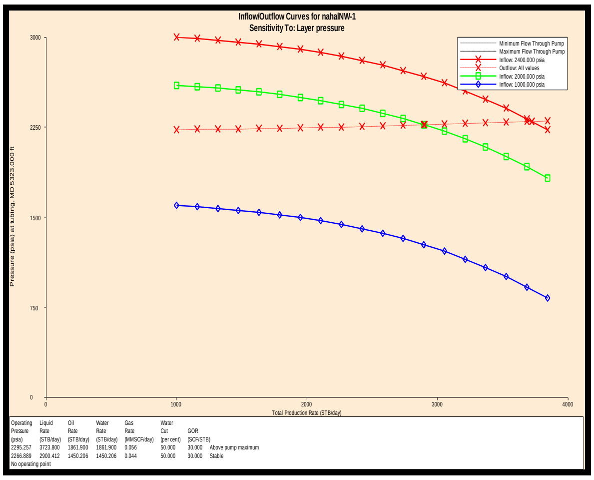

Fig. 1. Sensitivity of Flow Rate With Respect to Layer Pressure for (xnw-1).

DOI: http://dx.doi.org/10.24018/ejers.2021.6.1.1715

TABLE 7: SENSITIVITY OF LAYER PRESSURE

Xnw-1			Xnw-2			Xnw-3			Xnw-4		
Layer Pressure Psia	Gross STB/d	Oil STB/d	Layer Pressure Psia	Gross STB/d	Oil STB/d	Layer Pressure psia	Gross STB/d	Oil STB/d	Layer Pressure Psia	Gross STB/d	Oil STB/d
2400	3964	1982	2455	1141	228	2455	2107.4	163	2420	1335.8	996
2000	3190	1595	2400	789.7	157	2400	1939	155	2400	1094.8	927
1000	No operating Point		2000	No operating Point		2000	1043	83.5	2000	No operating Point	
						1500	No operating		1500		

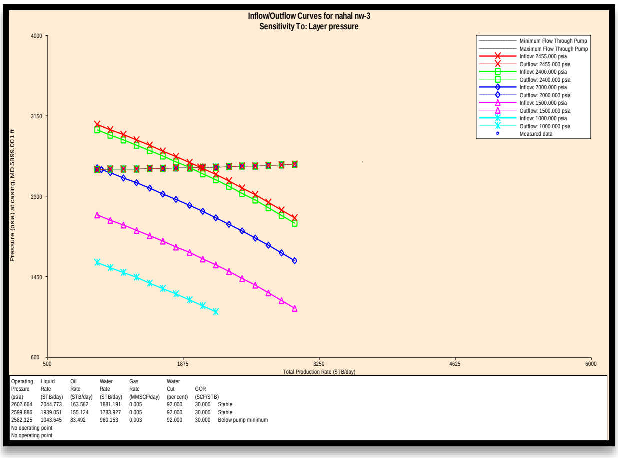

Fig. 2. Sensitivity of Flow Rate with Respect to Layer Pressure for (xnw3).

Well Head Pressure: The sensitivity of the four well shown in Table 8, the actual wellhead pressures of the four well are (380, 265, 235and 280 psia) respectively, different values of pressure were taken for the forecasting the four wells. The results show that the well performance improves as the well head pressure decreases. The decrease of wellhead pressure from 380 psia to 350 psia provided an increase in flow rate of about 288 b/d for the well xnw-1. However, a further decrease of well head pressure from 200 psia to 150 psia provided an increase of about 118 b/d. Moreover, the gain resulting from an eventual decrease of the well head pressure from 150 to100 psia provided an increase in flow rate of about 101 b/d. the decrease of well head pressure resulting in increasing the flow rate about 185 b/d for well xnw-3 and 174b/d flow rate was achieved for the well xnw-4.

TABLE 8: SENSITIVITY OF WELL HEAD PRESSURE

Xnw-1		Xnw-2		Xnw-3		Xnw-4	
Pressure Psia	Rate STB/d	Pressure Psia	Rate STB/d	Pressure Psia	Rate STB/d	Pressure Psia	Rate STB/d
380	3723	265	1141	235	2107	280	1335
350	4011	200	1365	200	2292	200	1509
300	4089	150	1484	150	2379	150	1596
-	-	100	1585	100	2467	100	1678

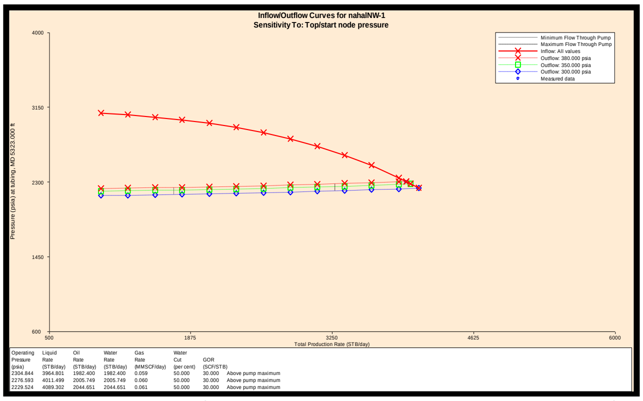

Fig. 3. Sensitivity of Flow Rate with Respect to Wellhead Pressure for (xnw-1).

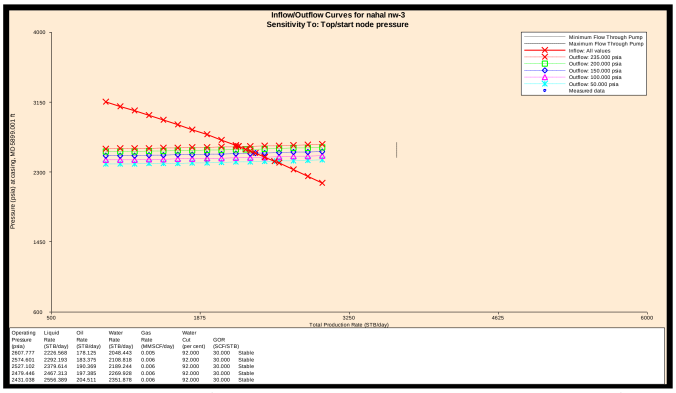

Fig. 4. Sensitivity of Flow Rate with Respect to Wellhead Pressure for (xnw-3).

Water Cut: In order to evaluate the viability of producing the four wells under increased water-cuts and reduced reservoir pressures, a number of sensitivity analyses were performed on the production from the four wells using WellFlo. The results summarized in Table 9. The actual water cut of the well xnw-1 is 50%. Therefore, a water cut values of 50%, 70%, and 90% are used for forecast computations for this well. The results show that when the water cut becomes 90%, the oil produced is 379 stb/b but it is reasonable comparing with other wells. Water cut value of 80%, 85% and 90% were used for forecast computation for well xnw-2 since the actual water cut of this well is 80%. Simulation shows, this well produced only 41stb/d when the water cut increasing to 90%. The same procedure was conducted for the other wells and the results shown in the following.

TABLE 9: SENSITIVITY OF WATER CUT

Xnw-1			X nw-2			X nw-3			X nw-4		
WC%	Goss Stb/d	Oil Stb/d	WC%	Gross Stb/d	Oil stb/d	WC%	Gross Stb/d	oil stb/d	WC%	Gross Stb/d	Oil stb/d
50	3723	1982	80	1141.7	228	92	2226.6	178	20	1276.7	1014
70	3881.6	1164	85	1060.8	159	95	2248	112	50	991.6	495.8
90	3790.5	379	90	961	41.5	98	2270.8	45	80	No operating point	

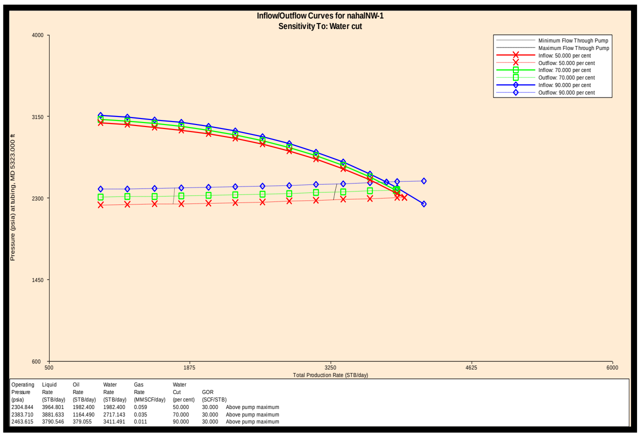

Fig. 5. Sensitivity of Rate with Respect to Water Cut for (xnw-1).

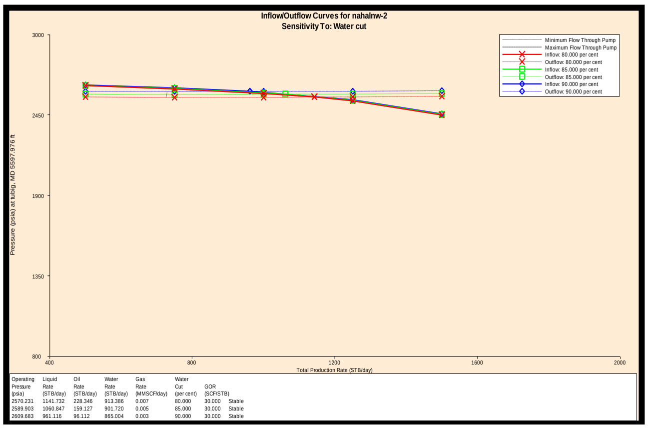

Fig. 6. Sensitivity of Rate with Respect to Water Cut for (xnw-2).

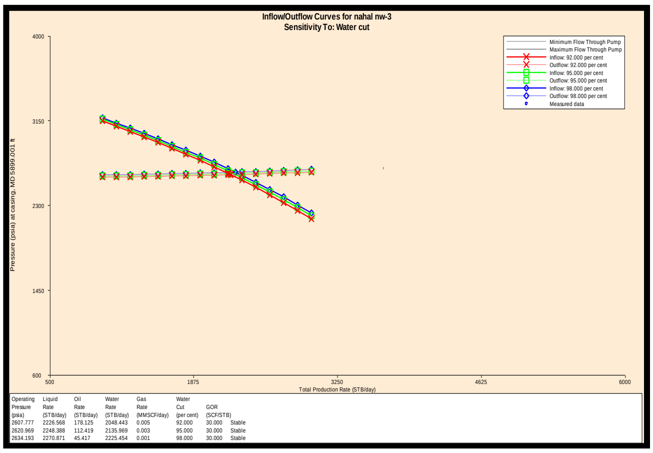

Fig. 7. Sensitivity of Rate with Respect to Water Cut for (xnw-3).

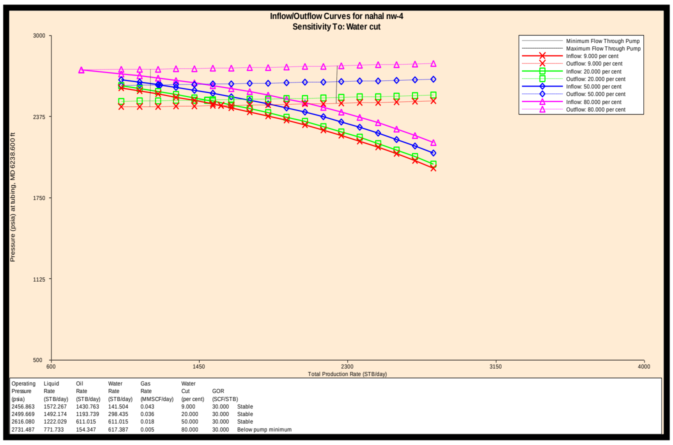

Fig 8. Sensitivity of Rate with Respect to Water Cut for (xnw-4).

III. CONCLUSION

Several innovative ideas during the courses of data collection, implementation in wellflo program, history matching, and sensitivity analysis are presented the finding prove that the nodal analysis provides valuable means to help the engineer in Decisions making. Opening oil well to production always involves considerable expenses whereas a model can be run many times at lower cost to try many different possible scenarios in order to make technical and economic decisions. The wellflo program presented in this study is capable of history matching the production data as well as predicting the performance under different scenarios. The program has been validated with the help of field data. The program definitely provides a logical improvement in nodal analysis.

IV. FURTHER WORK

For future researches is better to include the difference between the inflow and out flow due to friction through the production pipes which was not considered in this study, also there are so many factors can be considered in the coming researches such as GOR, inside diameter of all well node, Roughness of all well node, effective permeability, layer thickness, wellbore radius, external radius and total Darcy skin.

NOMENCLATURE

P_r – The reservoir pressure, psia
P_{sep} – The separator pressure, psia
q_o – Inflow rate corresponding to wellbore flowing pressure, STB
$q_{o\ max}$ – Inflow rate corresponding to zero wellbore flowing pressure, STB/d
$\overline{P_R}$ – Average reservoir pressure, psia

R_P – Radius of perforation, ft
R_C – Radius of compacted zone, ft
μ – Viscosity, cp
γ – Specific gravity, dimensionless
K_P – Permeability of compacted zone, md
L_P – Perforation tunnel length, ft
T – Temperature, R
P_{wf} – Bottom hole flowing pressure
P_{wfs} – Sand face flowing pressure
A_R – Laminar reservoir component
K_{OR} – Unaltered reservoir permeability to oil
S_d – Skin factor due to permeability alteration around the wellbore
K_R– Reservoir permeability
K_d – Alternated zone permeability
r_w – Wellbore radius
r_d – Alternated zone radius
B_R – Turbulent reservoir component
A_G – Laminar gravel-pack component
B_G – Turbulent gravel-pack component
N – Total number of perforation
L – Gravel-pack tunnel length
K_G– Gravel-pack permeability
P_{wh} – Wellhead pressure, psia
R – Gas/liquid ratio, MCF/STB
Q – Gross liquid rate, STB/D
S – Choke bean size, 64^{th} of an inch
C – Constant

References

[1] Beggs, H. (2003). 'Production optimization: using NODAL analysis'. 2nd Edition. (Tulsa, Okla.: OGCI and Petroskills Publications: Tulsa).
[2] Arslan, O., Wojtanowicz, A.K., and, White, C.D., (2004) "Nodal Analysis for Oil Well with down hole Water sink Completions". SPE The paper was presented at the petroleum society 5th.
[3] Awal, R. M; (2009). "Anew Nodal Analysis Technique Helps Improve Well Completion and Economic Performance of Matured Oil Fields," SPE 120632 university of Texas Tech.
[4] North, R., and, Lenn, C.P., "Managing Production in Maturing Assets: Increasing intervention Success by Combining Production Logging with Nodal Analysis". SPE 104629 The paper was presented at the SPE Middle East oil & gas (2007).
[5] Begges, D.H.; 1999. "Production Optimization Using Nodal Analysis," OGCI, Tulsa, Oklahoma.
[6] Ozdogan, U., Keating, J. F., Knobles, M. M., Chawathe, A., and Seren, D. (2008). Recent Advances and Practical Applications of Integrated Production Modeling. SPE Europec/EAGE Annual Conference and Exhibition, 9–12 June, Rome, Italy. (Society of Petroleum Engineers). 10.2118/113904-MS.
[7] Lorezo, A.C., "Anew Alternative in the Performance Monitoring and control of the Reservoir- Artificial Lift System for the Optimization of the producing Well", SPE 69463. Latin American and Caribbean Petroleum Engineering Conference held in Buenos Aires, Argentina, (25-28 March 2001).
[8] Perez, G. and Kelkar, B.G.; "A simplified Method to Predict Over-all Production Performance," Journal of Canadian Petroleum Technology, (January-February, 1990), Volume29, No.1.