INTEGRATED CONSTRAINTS OPTIMIZATION FOR SURFACE AND SUBSURFACE TOWARDS CAPEX FREE MAXIMISING PRODUCTION

- Shahrul Azman Zainal Abidin
- Custodian Engineer (Process Simulation & Optimization)
- Group Technical Solution (GTS)
- PD&T, PETRONAS.

INTRODUCTION

- Conventionally a standalone topside process model can only achieve production increment of up to 1%. In order to achieve higher production increment, an integrated topside process and subsurface model is required (Zainal & Hussein 2014).
- This modeling technique requires the integration of different modeling platforms for wells, headers, topside facility, interconnecting pipelines between platforms and re-injection wells back to the reservoir. The main challenge is to develop a seamless interface communication between the different modeling platforms.
- In this work an integrated first principle compositional model from well to surface processes is developed in one single platform iCON.





The optimization objective function is to locate a CAPEX free operation settings by manipulating top site operating pressure and individual choke valve opening by satisfying surface facilities constraints. The model will create the operating profile to satisfy the maximum production envelope.

PROBLEM STATEMENT

✓ To generate Optimization Operating Envelope to ensure the optimized condition can be implemented in all range of active and inactive well configuration possible for the field.

SCOPES

The motivation and problem formulation for this study is to develop an integrated surface sub-surface optimization model in single operating platform with various active and inactive well scenarios to ensure optimization set points can be implemented at site within the optimization envelope. Specifically, :

- To generate individual well Inflow Performance Relationship (IPR) in iCON environment thorough translating PROSPER simulation results into Liquid Flow correlation as a function of Tubing Head Pressure (THP), Water Cut, GOR and Gas Lift flow.
- ✓ To develop iCON Steady State surface facilities model that include rotating equipment performance curves matching the actual operating condition. Advanced Peng Robinson equation of state is applied due to its robustness within the operating temperature and pressure region.
- ✓ To link individual well Vertical Lift Performance (VLP) correlation with iCON steady state model and test the integrated model to match the actual operation.
- ✓ To setup Optimization objective function with manipulative and constraints variables. Test various Optimization Techniques suitable for the study.
- ✓ To establish Optimization envelope considering active and inactive well situation.
- ✓ To locate the CAPEX free optimization envelope base on installed equipment constraints to maximize production.

MODELLING STRATEGY

- Establish single operating platform i.e iCON to accelerate the calculation and avoid the thermodynamic instability
- ✓ Develop iCON top side model using Advanced Peng Robinson with pseudo component characterization
 - pseudo component impact pipeline gas dew point
 - steady state pipeline network pressure correlation
- ✓ Link iCON with subsurface Vertical Lift Performance (VLP) and test the integration as a function of individual well water cut, gas lift, Tubing Head Pressure (THP) and Gas Oil Ratio (GOR)
- Setup optimization objective function and test various optimization techniques calculation performance i.e Interior Point, Nedler Mead, and Powell.
- Establish operating envelope base on active/inactive wells considering well line up configuration to locate maximum production point.
- ✓ Locate CAPEX free optimization envelope base on the above constraints
- ✓ Confirm the findings with iCON dynamic model

LITERATURE REVIEW ANALYSIS : INTEGRATED MODEL

Integrated model Coverage	Software	References	This Work :	Software	Work
Reservoir performance and production and surface network	ECLIPSE NETOPT	Hepguler, Dutta-Roy & Bard, (1997)	Integrated Model		Significant
solution	PVM		Individual well,	iCON –	Constraint
Reservoir performance and production and surface network solution	ECLIPSE FORGAS PVM	Trick, (1998)	well lineup, production and surface network	modeling and system integrator (SI) platform	Optimization Operating envelope at different well
Reservoir models, coupled with process and economics models	Not mentioned	Juell, Whitson, &Hoda, (2010)			configurations (lineup and active/inactive
Integrate well performance, gathering system calculation and process plant simulation	Commercial software and rabbit (in-	Sarra, et al. (2015)			well) to maximize production
I town I to to to to to to	house software)				
Integrate reservoir model, well model and surface facilities model in a single integrator.	SENSOR PROSPER HYSYS Pine-It	Rahmahwati,Whitson, Foss & Kuntadi, (2012)			

LITERATURE REVIEW : SCOPES ANALYSIS

	Area of Scopes	Past Works	Gap Analysis
1	Modeling Platform	Use System Integrator to link with multiple modeling platform	iCON is the System Integrator and the surface/ sub-surface modeling platform
2	Well Line Up Optimization	Based on Fixed well configuration	Base on possible well lineup configuration
3	Surface Pressure And Choke Valve	Influential variables are varied from well to reservoir configuration	Influential variables are varied from well to top side surface configuration
4	Surface Equipment Capacity and Control Valves Check	Equipment and Control valves have the capacity to cater for production increase	Considered as constraints to locate CAPEX Free Optimization envelope
5	Locate CAPEX Free Optimization Envelope	Single Optimization point to maximize production	CAPEX Free Optimization Envelope

WORK SIGNIFICANCE SCEMATIC

The Work Technical Gap Coverage

----Research -----Literature

Integrated Single Platform

100

80

70

60

50

40

30

20

With Locate CAPEX Free Optimization Envelope, the implementation strategy is within the operating envelope and well line up scenarios where value creation can be realized immediately. The findings from this work are considered reaping the additional gas and oil production just by changing surface facilities separators set points and individual choke valve opening without violating any process constraints. Locate CAPEX free

Optimization Envelope

With Surface Equipment Capacity and Control Valves Check, it checks whether processing facility can handle the capacity by operating closer to the process constraints with process disturbances such as slugging wells due to well pressure variations.

Surface Equipment Capacity

With Integrated Single Modeling Platform, it will ensure seamless data transfer, smooth thermodynamic translation among the models and efficient optimization iteration to locate the CAPEX free implementation region.

Well Lineup Optimization

With Well Line Up Optimization, it can avoid competing wells scenarios that have great economic potentials in term of operation efficiency especially with the number of feed conditions (wells, water cuts, GOR, WGR) and different pressure setting options to maximize production base on active/inactive well scenarios

With Simultaneous Surface Pressure And Choke Valve **Optimization**, it can cater for more representative in maximizing oil and gas production.

Surface Pressure & Choke Valve Optimization

WORK SCOPE : ICON STEADY STATE MODEL DEVELOPMENT



High and Medium Pressure Wells

Low Pressure Wells



Separator and Compressor Trains



WORK SCOPE : SUB SURFACE DATA CODING TO GENERATE INDIVIDUAL WELL PRESSURE FLOW RELATIONSHIP



нир_с 🚺 🔒 🦴 🔗 -V-500 Summary - Min pressure for V-500 is S0bar considering pressure drop for pipeline to Bokor around 5bar to reach 45bar for gas IR /Betty - Excel unit-op ? 조 – 🗆 > HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW DEVELOPER ADD-INS Acrobat Reconditional Formatting * Ensert General Σ **≜**▼ **#** Arial Unicode * 9 Eormat as Table V The Delete Sort & Find & r 📿 B 1 €.0 .00 Cell Styles 🗊 Format - 🧶 -Filter + Select + Clipboard Editina 013 - : X / fr Vie-3 G Strings Mode Flowfraction2 Flowfraction1 THP psig 768.69 1.0000 0.0000 768.7 4300 18 HHP 210.00 13L 0.0000 1 0000 210.0 1400 70 HP HP 60.00 21L HP 0.0000 1.0000 210.0 1400 70 **18S** HP 0.0000 1.0000 210.0 1300 70 291 HP 0.0000 1.0000 210.0 1440 70 learnetric-2 17L LP 0.0000 0.0000 60.0 48 00 \odot 11S IP 0.0000 60.0 58.2 0.0000 100 -**H** 21L_OI 15S LP 0.0000 0.0000 60.0 48 220 13 285 IP 0.0000 0.0000 60.0 200 52.2 7L IP 0.0000 0.0000 60.0 140 48 11 21S LP 0.0000 0.0000 60.0 80 48 0.0000 0.0000 60.0 49.52 12 281 IP 250 185 GM CN-13 13 201 IP 0.0000 0.0000 60.0 210 49.3 185_OI 18S Water Well Line-up IPR (+) 4 III III 29L_G 29L_ON In Fluid Liq0.viscosity 2.3261t-3 [Pa-s] In Fluid Liq1.viscosity 5.6412t-4 [Pa-s] Isometric-3

✓ Insert code in iCON software and link with iCON flowsheet via excel for interactive graphics

WORK SCOPE : LINK SURFACE AND SUB SURFACE MODELS IN ICON

	IP	R										
			1	2	3	4	5	6	7	8	9	10
						THP	Water Cut	GOR	Liquid	Oil	Water	Gas
	Fi	le Name	String			psig	%	mmscfd/bbl	bbl/d	bbl/d	bbl/d	mmscfd
18L	Г	-18ST1(S1.0)	18L	HHP		4300	0.00%	0.017	1,214.894	1,214.894	0.000	20.046
13L		-13L	13L	HP		1400	84.92%	0.046	630.857	95.129	535.728	4.344
21L		-21ST1(R3)	21L	HP		1400	8.02%	0.007	1,389.830	1,278.414	111.417	9.448
18S		-18ST1(P1.0)	18S	HP		1300	0.00%	0.017	437.125	437.125	0.000	7.249
29L		-29L	29L	HP		1440	75.00%	0.014	1,576.672	394.168	1,182.504	5.654
17L		-17L	17L	LP		90	86.98%	0.013	572.989	74.603	498.386	0.961
11S		-11S	11S	LP		100	85.03%	0.008	1,394.206	208.687	1,185.519	1.624
15S		-15S	15S	LP		220	76.03%	0.015	756.697	181.366	575.332	2.785
28S		-285	28S	LP		200	71.99%	0.002	3,417.113	957.191	2,459.922	1.575
7L		-7L	7L	LP		140	89.99%	0.007	1361.539	136.254	1225.285	0.928
21S		-21S(M5.0)	21S	LP		80	3.14%	0.017	188.668	182.742	5.927	3.091
28L		-28L	28L	LP		250	80.00%	0.011	405.400	81.080	324.320	0.912
20L		-20ST1(M5.0)	20L	LP		210	27.97%	0.001	1,050.261	756.518	293.743	0.945
									14,396	5,998	8,398	60
	18L 13L 21L 18S 29L 17L 11S 15S 28S 7L 21S 28L 20L	IP 18L 13L 21L 18S 29L 17L 11S 15S 28S 7L 21S 28L 20L	IPR File Name 18L 18L 18L 18L 18L 18L 18S 18S 18S 18S 18S 18S 18S 18S	IPR 1 File Name String 18L -18ST1(S1.0) 18L 13L -13L 13L 13L -13L 13L 21L -13L 13L 11S -11S 17L 11S 11S 15S 28S -28S 28S 7L -7L 7L 21S -21S(M5.0) 21S 28L 28L 28L 20L -20ST1(M5.0) 20L	IPRI12Image: IPR12Image: Image:	IPRI23I123IFILe NameStringI18LFILe NameStringI18L-18ST1(S1.0)18LHHP13L-13L13LHP21L-13L13LHP21L-13L21LHP21L-18ST1(P1.0)18SHP29L-17L29LHP17L-17L17LLP11S11SLPI15S15SLPI28S-28S28SLP21S-21S(M5.0)21SLP20L-20ST1(M5.0)20LLP	$\begin{array}{ c c c c c c } & \mbox{IPR} & \mbox{IPR} & \mbox{IPR} & 1 & 2 & 3 & 4 \\ \hline 1 & 2 & 3 & 4 \\ \hline 1 & 2 & 3 & 4 \\ \hline 1 & 2 & 3 & 4 \\ \hline 1 & 2 & 3 & 4 \\ \hline 1 & 2 & 3 & 4 \\ \hline 1 & 1 & 1 & 2 & 3 & 4 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1$	$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	IPRIntIn	$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	$\begin{array}{ c c c c c c c c c c c c c c c c c c c$

IPR Equation Setup

	THP	
		Copied
18L		= -0.0000000007933333333329980000x4 + 0.0000006516666666681460000000x3 - 0.00029366666666778800000000x2 + 0.2923333333698700000000000x + 2,918.80000000340000000000000000000000000000
13L		=0.0000001083333333334x3 - 0.00051392857142867000x2 + 0.04859523809553050000x + 1,272.85714285689000000000
21L		= 0.00000015365405429783300000000x3 - 0.0007528607548865360000000000x2 + 0.50908571951785400000000000x + 1,731.090837578350000000000000000000000000000000
18S		=-0.00000080266666666667x3 + 0.00024859999999999000x2 - 0.2324333333324100000x + 495.4999999993200000000
29L		=-0.0000008786883784820x3 - 0.00005417387926763550x2 - 1.49198854764436000000x + 4,099.8456072193100000000
17L		=-0.00000001180831826157x4 + 0.00000847968655726811x3 - 0.00306013562383397000x2 - 0.47253556356904900000x + 634.8971066890300000000
11S		= -0.000000022478439260995000000000x4 + 0.0000187238196310835000000000x3 - 0.006175414051992510000000000x2 + 0.0091334303441215100000000000x + 1,438.57092772563000000000000000000000000000000000000
15S		= -0.0000000025382399996x5 + 0.00000027256959994680x4 - 0.00010900469331478200x3 + 0.01926833599052070000x2 - 1.77540906312717000000x + 867.68271963254300000000
28S		=-0.00000248522666662643000000000x3 - 0.001351058285739230000000000x2 - 5.223920419040390000000000x + 4,535.821567999180000000000000000000000000000000000
7L		=0.0000000761438145869x5 - 0.00000534514819561238x4 + 0.00147957339239824000x3 - 0.2030741805908600000x2 + 11.75126054767340000000x + 1,280.53956684449000000000
21S		= -0.00015927145649168000000000000x2 + 0.0165908454021760000000000000 + 188.36049055193900000000000000000000000000000000
0 28L		=0.00000050666666665151500000000x4 - 0.0000467999999983065000000000x3 + 0.013913333326946000000000x2 - 1.6669999998889700000000000x + 485.89999999336500000000000000000000000000000
20L		=-1.09681663999237E-08x4 + 0.0000183800995165769x3 -0.0125487891157642x2 + 3.14617022983361x + 794.080168311003

SCOPES OF WORK (1/2)

Objective Function:	Maximize Oil Production
Manipulative Variables	: Individual Header Pressures (HP, MP and LP)
	Individual Well Choke Valve Opening:
	100 % < Valve Opening > 0%
Constraint Variables:	Compressor Capacity < 15.0 mmscfd
	HP Vent Capacity < 18.0 mmscfd
	MP Vent Capacity < 5.0 mmscfd
	Pump Capacity < 112 m ³ /hr
	800 psig < HP Header Pressure > 650 psig
	310 psig < HP Header Pressure > 120 psig
	100 psig < HP Header Pressure > 30 psig
	100 % < Choke Valve Opening > 0%

Optimization Techniques: Nedler Mead, Powell and Interior Point

iCON OPTIMIZER

lected (Case:	Optimizer1			Ŧ								New	1	Delete
					-								Clone		
Na	me:			Optim	zer1								CADINE	_	
Set Up	Status	Results	Settings	Notes											
					Apply	Optimizer \	alues as Spe	a							
Object	ive Funct	ion												1	
											A	dd.	Add Custom		Delet
Activo	Namo	Dath			Mada	Current	Value Sca	o Ontimizo	e Vak	n filaite	a 🗌				
- CUINE	Obi En 1	/\$35.In.F	luid Lie0 Vel	ume Elow	Maximize	current	669,234 1	00	5718.1	174 bbl/d	2				
0.5	opj ma	100000			- Aller and a second						-				
Manip	ulated Va	riables -									_			- 1	
											A	dd.	Add Custom		Delet
Active	Name		Path				Lower Limi	Current V	alue	Upper Lir	nit S	cale	Optimizer Value	[Unit	s]
×	Manipulat	ted Var 1	/Header_P	ressure.PC	alcMgr.Sh	1.E1.Value	120.0	0 27	70.00	310	.00	1.00	270.0	0	
8	Manipulat	ted Var 2	/Header_P	ressure.PC	alcMgr.Sh	1.H1.Value	30.0	0 4	ŧ0.00	100	.00	1.00	40.0	0	
	Manipulat	ted Var 3	/VIv-6.% 0	pening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
	Manipulat	ted Var 4	/VN-7.% 0	pening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
	Manipulat	ted Var 5	/VIv-8.% 0	pening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
	Manipulat	ted Var 6	/VIv-9.% 0	pening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
	Manipulat	ted Var 7	/Header_P	ressure.PC	alcMgr.Sh	1.81.Value	700.0	0 80	00.00	800	.00	1.00	800.0	0	
	Manipulat	ted Var 8	/VIv-5.% 0	pening			0.00	0 0	0.500	1.	000	1.00	0.52	5 [Frac	ction]
	Manipulat	ted Var 9	/Vhv-10.%	Opening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
	Manipulat	ted Var 10	/Vh-11.%	Opening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
	Manipulat	ted Var 11	/Vhv-12.%	Opening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
	Manipulat	ted Var 12	/Vh-13.%	Opening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
	Manipulat	ted Var 13	/Wh-14.%	Opening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
	Manipulat	ted Var 14	/Vh-15.%	Opening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
	Manipulat	ted Var 15	/VN-16.%	Opening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
2	Manipulat	ted Var 16	/Ww-17.%	Opening			0.00	0 0	0.500	1.	000	1.00	0.50	0 [Frac	ction]
Constr	aints														
											1	dd	Add Custom		Delet
Active	Name	P	ath			Lov	er Limit Cu	rrent Value	Uppe	er Limit	Scale	Opti	mizer Value [Un	its]	1
	Constrain	t Var 1 /	HHP_Gas.In.S	Std Gas Vo	ume Flow		1.50E+1	1.5868E+1	1	1.70E+1	1.00		1.6511E+1 [MP	ISCFD	1
	Constrain	t Var 2 /	HP_Vent.In.S	td Gas Vol	ume Flow		0.00E+0	1.8274E+0		2.00E+0	1.00)	1.8395E+0 [MP	ISCFD	1
×	Constrain	t Var 3 /	K-7000.1n.St	d Gas Volu	me Flow		4.00E+0	7.304E+0)	8.00E+0	1.00)	7.3084E+0 [M	ISCFD	1
	Constrain	t Var 4 /	P-801_802_8	03.In.Std I	ig Volume	Flow	5000.000	11507.547	7 15	000.000	1.00)	11555.512 [bb	(/d]	-
															_

OPTIMIZATION RESULTS AFTER 3 DAYS RUNNING

S Optimizer			(Process Calc	ulator)				
Selected Case: Optimizer1	New	Delete	PC-1	Description:				
- Optimizer1	Clone				Solved			
Name: Set Up Chatting Results Cattings Nates	Name:							
Set op Status Kesuits Settings Notes		1					Link	
Apply Optimizer Values as Specs						oppection		
Add	d Add Custom	Delete	U. Takama		- East Calar			
				• 8		Cell Color Notes		
Active Name Path Mode Current Value Scale Optimizer Value [Units]			В	C D	E	F G H	I	
			Well T	HP Liq Rate (IPR)	Oil Wat	ter Gas WC	GOR	
			p	sig bbl/day	bbl/day bbl/	/day MMSCFD Vol Frac	MMSCF/bbl =	
- Manipulated Variables			1.01	4204 90 1200 20	1177.60	0.00 16.27 0.00	0.0120	
Add	d Add Custom	Delete	13L	1410.78 622.73	91.09	381.63 3.84 0.8073	0.0422	
Active Name Path Lower Limit Current Value Upper Limit Sca	ale Optimizer Value [Units	sl	21L	1419.36 1376.33	1232.38	79.92 8.38 0.0609	0.0068	
Manipulated Var 1 /Header_Pressure.PCalcMgr.Sh1.E1.Value 120.00 270.00 310.00 1	.00 214.50		18S	337.31 420.00	408.60	0.00 6.25 0.00	0.0153	
Manipulated Var 2 /Header_Pressure.PCalcMgr.Sh1.H1.Value 30.00 40.00 100.00 1	.00 61.29		29L	1449.69 1555.37	377.30	842.16 5.02 0.6906	0.0133	
Manipulated Var 3 /Vlv-6.% Opening 0.000 0.500 1.000 1	.00 0.511 [Frac	ction]	17L	76.40 584.31	74.56	370.57 0.9767 0.8325	0.0131	
Manipulated Var 4 //lv-7.% Opening 0.000 0.500 1.000 1	.00 0.536 [Frac	ction]	11S	86.37 1404.11	205.12	867.10 1.62 0.8087	0.0079	
☑ Manipulated Var 5 /Vlv-8.% Opening 0.000 0.500 1.000 1	.00 0.511 [Frad	ction]	15S	210.00 761.52	178.07	420.29 2.78 0.7024	0.0156	
✓ Manipulated Var 6 /Vlv-9.% Opening 0.000 0.500 1.000 1	.00 0.511 [Frad	ction]	285	191.35 3469.37	950.20	1816.83 1.62 0.6566	0.0017	
Manipulated Var 7 /Header_Pressure.PCalcMgr.Sh1.B1.Value 700.00 800.00 800.00 1	.00 700.00		7L 21C	129.57 1383.88	135.58	907.35 0.9355 0.8700	0.0009	
			215	240.94 409.12	70.65	4.30 3.00 0.0230	0.0172	
			201	198 57 1050 87	737 30	212.95 0.9585 0.2241	0.0013	
Constraints			202	14434.66	5825.49	6140.17 52.73	0.0015	
Add	d Add Custom	Delete						
Active Name Dath Lower Limit Current Value Linner Limit Costs Onto	mizer Value [Unite]							
Constraint Var 1 /HP Cas In Std Cas Volume Flow 1 505+1 1 58695+1 1 705+1 1 00	1 6052E+1 [MMSCED]				kg/m3 API	[calculate API Chemsain		
Constraint Var 2 /HP Vent In.Std Gas Volume Flow 0.00E+0 1.8274E+0 1.00E-1 1.00	[MMSCFD]			Oil Density	870.34	31.08 31.86 865.35		
				Viscosity	3.72	3.04		
			111		· ·	I I I	•	
				d				
Run Done. Stopped by the user		Close	it				Ignored	

OPTIMIZATION RESULTS AFTER 8 DAYS RUNNING

🔀 Optimizer				alculator)							
Selected Case: Optimizer1		New	Delete	D	escription:						
Ontimizer1		Clone					Solved				
Set lin Statue Results Settings Notes				Settings	Notes Help	1					
Apply Optimizer Values as Spec	. 1		1								Link
Objective Function	·						Connection	1			
	Add	Add Custom	Delete			- East	Color Col	Color No	tes		
				na	• I C				//e5/		
Active Name Path Mode Current Value Scal				В	С	D	E	F	G	Н	A I
	0 5830.595 DDI/ d			Well	THP	Liq Rate (IPR)	Oil	Water	Gas	WC	SOR
					psig	bbl/day	bbl/day	bbl/day	MMSCFD	Vol Frac	MSCF/bbl ≣
- Manipulated Variables				101	4202.55	1000.00	1100 50	0.00	10.55	0.00	0.0120
	Add	Add Custom	Delete	18L	4293.56	1222.23	1190.53	290.20	10.55	0.00	0.0139
Active Name Path	Current Value Unper Limit Scale	Ontimizor Value [1]	nite]	211	1398.19	1424 31	1277 44	87.84	8.60	0.0609	0.0422
Manipulated Var 1 /Header Pressure PCalcMor Sh1 E1 Value 120 00	212.66 310.00 1.00	0 214.03	intsj	185	339.37	420.00	408.60	02.04	6.25	0.003	0.0153
Manipulated Var 2 /Header_Pressure.PCalcMgr.Sh1.H1.Value 30.00	67.47 100.00 1.00	0 68.64		29L	1392.30	1680.38	415.98	928.50	5.53	0.6906	0.0133
Manipulated Var 3 /Vlv-6.% Opening 0.00	0.503 1.000 1.00	0 0.511 [Fr	raction	17L	95.38	568.36	71.89	357.30	0.9417	0.8325	0.0131
Manipulated Var 4 /Vlv-7.% Opening 0.00	0.541 1.000 1.00	0 0.551 [Fr	raction]	11S	105.37	1390.10	202.44	855.78	1.60	0.8087	0.0079
Manipulated Var 5 /VIv-8.% Opening 0.00	0.497 1.000 1.00	0 0.473 [Fr	raction]	15S	223.79	754.84	176.08	415.60	2.75	0.7024	0.0156
Manipulated Var 6 /VIv-9.% Opening 0.000	0.562 1.000 1.00	0.572 [Fr	raction]	28S	203.35	3396.75	925.26	1769.14	1.57	0.6566	0.0017
Manipulated Var 7 /Header_Pressure.PCalcMgr.Sh1.B1.Value 700.00	705.32 800.00 1.00	0 707.78		7L	144.10	1352.69	131.53	880.22	0.9075	0.8700	0.0069
				21S	85.18	188.62	177.92	4.30	3.06	0.0236	0.0172
<u> </u>				28L	253.70	404.19	78.66	234.11	0.9046	0.7485	0.0115
- Constraints				20L	214.52	1049.74	736.42	212.70	0.9573	0.2241	0.0013
	Add	Add Custom	Delete	_		14484.44	5885.67	6129.77	53.63		
Active Name Path Lower Limit Curren	t Value Upper Limit Scale Optimiz	zer Value [Units]									
Constraint Var 1 /HHP_Gas.In.Std Gas Volume Flow 1.50E+1 1	6043E+1 1.70E+1 1.00	1.6038E+1 [MMSCFD]					ka/m2	API calculate	API Chomosin		
Constraint Var 2 /HP_Vent.In.Std Gas Volume Flow 0.00E+0 2	7477E+0 3.00E+0 1.00	[MMSCFD]				Oil Density	866 93	31 72	31.86	865 35	
			·			Viscosity	3 45	51.72	3.04	005.55	
						1.0000107	0.40		5.01		
											•
											4
Bun Dans Stannad by	the user		Class								·
Kun Done. Stopped by			Close								<u>I</u> gnored

INTERMEDIATE OPTIMIZATION RESULTS SUMMARY (NEDLER MEAD TECHNIQUE)

Optimization Period	Var 1	Var 2	Var 3	Var 4	Var 5	Var 6	Var 7	Production (bbl/d)	Delta
Initial Value	270	40	50%	50%	50%	50%	800	5669	-
After 3 days	214.5	61.29	51.1%	53.6%	51.1%	51.1%	700	5794	125
After 5 days	212.6	64.26	50.3%	54.1%	49.7%	53.%%	705.3	5809	15
After 6 days	212.6	64.26	50.3%	54.1%	49.7%	56.2%	705.3	5822	4
After 7 days	212.6	67.47	50.3%	54.1%	49.7%	56.2%	705.3	5826	4
After 8 days	214.0	68.64	51.1%	55.1%	47.3%	57.2%	707.8	5830	4



Production Optimization Increment versus Simulation Time

Var 1 : Medium Header Pressure (psig)
Var 2 : Low Header Pressure (psig)
Var 3 : Medium Well Valve Opening (%)
Var 4 : Medium Well Valve Opening (%)
Var 5 : Medium Well Valve Opening (%)
Var 6 : Medium Well Valve Opening (%)
Var 7 : High Header Pressure (psig)



FLOW GAINED SUMMARY

WithOut HP	HP	MP-A	MP-B	MP-A + MP-B	LP-A	LP-B	LP-A + LP-B
HP	0						
MP-A		295	388		441	319	273
MP-B			181		348	86	240
LP-A				104	164	181	
LP-B				412		55	
MP-A + MP-B							221
With HP	HP	MP-A	MP-B	MP-A + MP-B	LP-A	LP-B	LP-A + LP-B
HP	751						
MP-A		156	800		332	835	967
MP-B			389		178	762	915
LP-A				877	834	981	
LP-B				847		761	
MP-A + MP-B							313

FLOW GAINED OPTIMIZATION TECHNIQUE SUMMARY : Interior Point is more suitable to handle large optimization variables and Powell is suitable for small optimization variables

WithOut HP	HP	MP-A	MP-B	MP-A + MP-B	LP-A	LP-B	LP-A + LP-B
HP	-						
MP-A		Powell	Nedler Mead		Powell	Powell	Powell
MP-B			Nedler Mead		Powell	Powell	Nedler Mead
LP-A				Powell	Powell	Powell	
LP-B				Powell		Powell	
MP-A + MP-B							Interior Point
With HP	HP	MP-A	MP-B	MP-A + MP-B	LP-A	LP-B	LP-A + LP-B
HP	Interior Point						
MP-A		Nedler Mead	Interrior Point		Nedler Mead	Interior Point	Interior Point
MP-B			Interrior Point		Nedler Mead	Interior Point	Interior Point
LP-A				Interior Point	Interior Point	Powell	
LP-B				Interior Point		Interior Point	
MP-A + MP-B							Powell

INTEGRATED MODEL MATCHING

Case 1: All Wells are Flowing										
		Actual	Model	Deviation (%)						
Well	Unit	Choke Valve Opening	Choke Valve Opening	Choke Valve Opening						
18L	%	50	50	0						
13L	%	50	50	0						
21L	%	50	50	0						
18S	%	50	50	0						
29L	%	50	50	0						
17L	%	50	50	0						
11S	%	50	50	0						
15S	%	50	50	0						
28S	%	50	50	0						
7L	%	50	50	0						
21S	%	50	50	0						
28L	%	50	50	0						
20L	%	50	50	0						
HP Header Pressure	(psig)	800	800	0						
MP Header Pressure	(psig)	270	270	0						
LP Header Pressure	(psig)	40	40	0						
HP Gas	(kg/hr)	4418	4386	0.72						
HP Gas to Field B	(kg/hr)	10122	10518	3.91						
HP Vent	(kg/hr)	0	0							
MP Vent	(kg/hr)	496	493	0.60						
MP Fuel Gas	(kg/hr)	844	838	0.71						
MP Gas to Field C	(kg/hr)	20829	21043	1.03						
MP Gas to Field B	(kg/hr)	1317	1308	0.68						
LP Gas to Field B	(kg/hr)	6963	7010	0.67						
LP Vent	(kg/hr)	0	0							
LP Gas to Field C	(kg/hr)	7425	7521	1.29						
Oil Production	(kg/hr)	31961	31853	0.34						
Water Production	(kg/hr)	40184	39592	1.47						
Surge Vent	(kg/hr)	65	62	4.62						
				Average Deviation						
Mass Balance		124624	124624	1.46%						

	Unit	February 2018 (actual)	iCON Model (Calculated)	Deviation (%)
HP Gas	MMSCFD	15.5	15.87	2.50%
MP Gas	MMSCFD	23.8	24.02	0.83%
LP Gas	MMSCFD	13.5	13.68	0.99%
Oil	bbl/d	5,650	5669.23	0.34%
Water	bbl/d	6136	6047.05	1.47%

OPTIMIZATION CONTOUR FOR ALL WELL FLOWING CASE : Powell gives the highest objective function value compared to Nedler Mead and Interior Point



OPTIMIZATION RESULTS FOR ALL WELL FLOWING : Optimized set points for surface headers pressures and sub-surface individual choke valve opening

		Case	1-1-1			
Properties		Original Value	Optimized Value			
High Pressure Header	(Psig)	800	798.750			
Medium HeaderPressure	(Psig)	270	201.491			
Low Header Pressure	(Psig)	40	84.368			
18L Choke Valve Opening	[Fraction]	0.5	0.538			
13L Choke Valve Opening	[Fraction]	0.5	1.000			
21L Choke Valve Opening	[Fraction]	0.5	0.552			
18S Choke Valve Opening	[Fraction]	0.5	0.501			
29L Choke Valve Opening	[Fraction]	0.5	0.580			
17L Choke Valve Opening	[Fraction]	0.5	0.501			
11S Choke Valve Opening	[Fraction]	0.5	0.501			
15S Choke Valve Opening	[Fraction]	0.5	0.501			
28S Choke Valve Opening	[Fraction]	0.5	0.639			
7L Choke Valve Opening	[Fraction]	0.5	0.501			
21S Choke Valve Opening	[Fraction]	0.5	0.501			
28L Choke Valve Opening	[Fraction]	0.5	0.501			
20L Choke Valve Opening	[Fraction]	0.5	0.501			
Optimized Production	(bbl/d)	5669	5982			
Production Gain	(bbl/d)	31	13			
Otimization Method		Powell				

OPTIMIZATION RESULTS AT DIFFERENT WELL CONFIGURATION : Highest Optimized Set Points

	wc	GOR		1-1-1	1-1-H1	1-1-H2	1-1-0
Properties	(%)	(bbl/mmscf)		Optimized Value	Optimized Value	Optimized Value	Optimized Value
High Pressure Header			(Psig)	798.750	798.653	798.472	798.776
Medium HeaderPressure			(Psig)	201.491	269.987	269.980	269.991
Low Header Pressure			(Psig)	84.368	40.055	40.092	-
18L Choke Valve Opening	0	0.0165	[Fraction]	0.538	0.995	1.000	1.000
13L Choke Valve Opening	84.92	0.046	[Fraction]	1.000	0.509	0.727	0.636
21L Choke Valve Opening	8.02	0.007	[Fraction]	0.552	0.721	0.985	1.000
18S Choke Valve Opening	0	0.0165	[Fraction]	0.501	0.481	0.671	0.644
29L Choke Valve Opening	75	0.014	[Fraction]	0.580	0.617	0.946	0.497
17L Choke Valve Opening	86.98	0.013	[Fraction]	0.501	0.523	-	-
11S Choke Valve Opening	83.05	0.008	[Fraction]	0.501	0.343	-	-
15S Choke Valve Opening	76.03	0.015	[Fraction]	0.501	0.478	-	-
28S Choke Valve Opening	71.99	0.002	[Fraction]	0.639	0.605	-	-
7L Choke Valve Opening	89.99	0.007	[Fraction]	0.501	-	0.875	-
21S Choke Valve Opening	3.14	0.017	[Fraction]	0.501	-	0.496	-
28L Choke Valve Opening	80	0.011	[Fraction]	0.501	-	0.504	-
20L Choke Valve Opening	27.97	0.001	[Fraction]	0.501	-	0.593	-
Optimized Production			(bbl/d)	5982	5459	5175	4076
Production Gain			(bbl/d)	313	877	847	800
Otimization Method				Powell	Interior Point	Interior Point	Interior Point

OPTIMIZATION ENVELOPE for all well lineup configuration and control valve capacity checks

<u> </u>								Table	4.57: Overal	Optimzed S	et Points for	all possible w	vell lineups							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
\rightarrow	Case	jh Pressure Hea	dium HenderPress	uw Hender Press	Choke Valve Open	n Choke Valve Oper	h Choke Valve Oper	n Choke Valve Oper	Choke Valve Oper	n Choke Valve Oper	Choke Valve Open	Choke Valve Open	Ghoke Valve Ope	Choke Valve Oper	Choke Valve Open	. Choke Valve Oper	Choke Valve Open	ptimized Producti	Production Gain	Otimization Method
\rightarrow		(17119)	[17:19]	(Ping)	[Fraction]	[Fraction]	[Fraction]	[fraction]	[fraction]	[fraction]	[fraction]	[Fraction]	[Fraction]	[Fraction]	[Fraction]	[fraction]	[fraction]	(pps a)	(pps.d)	
	1-1-1	798 750	201.431	84 368	0.538	1.000	0.552	0.501	0.580	0.501	0.501	0.501	0.633	0.501	0.501	0.501	0.501	5982 266	313.000	Powell
2	1-1-H1	738.653	263.387	40.055	0.335	0.503	0.721	0.481	0.617	0.523	0.343	0.478	0.605					5458.674	877.000	Interior Point
	1.1.112	758 472	263 380	40.032	1.000	0.727	0.385	0.671	0.346					0.875	0.436	0 504	0 533	5175 015	847 000	Interior Point
47	1-1-0	738 776	263 331		1,000	0.636	1,000	0.644	0.437									4075 863	800.000	Interior Point
5	1-111-1	736 216	270.014	41 323	0.333	0.754	0.350			0.775	0.411	0.754	0 333	0 333	0.001	0 736	0 747	5318 843	367.000	Interior Point
6	1-112-1	773 686	271.808	41440	0.383	0.104	0.550	0 330	0.870	0.337	0.426	0.925	0.978	0.364	0.201	0.783	0.351	5305 616	315.000	Interior Point
2	1.41.41	713.000	149.363	40 133	0.565	0.623	0.635	0.330	0.070	0.357	0.420	0.325	1.000	0.304	0.201	0.705	0.001	4195 833	332.000	Nedler Mand
1.1	1.41.42	716.100	269.965	40.152	0.004	0.623	0.035			0.304	0.347	0.333	1.000	0.947	0.951	0.540	0 502	4100.002	835.000	Interior Deint
	1.42.41	707.450	203.303	40.000	0.555	0.043	0.700	0.194	0.535	0.477	0.510	0.513	0.548	0.347	0.001	0.040	0.002	3475 800	178.000	Nedles Mand
-	1-112-111	707,400	212.200	40.032	0.303			0.434	0.000	0.477	0.510	0.013	0.040	0.505	0.504			3473.000	170.000	Redier Mesa
10	1-112-112	797.324	263.336	40.200	0.335			0.435	0.634				•	0.929	0.506	0.511	0.510	2307.217	47.000	Nedler Mead
	1-11-0	720.358	225,356	•	0.538	0.707	0.634				•		•			•		2703.638	156.000	Nedler Mesd
12	1-H2-0	737.306	263.358		0.731			0.438	0.438									2377.751	389.000	Interior Point
13	1-0-1	700.000		100.000	1.000					1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.700	4642.000	381.000	Powell
14	1-0-H1	736.741		40.363	0.343					0.507	0.335	0.478	0.337					3403.006	834.000	Interior Point
15	1-0-H2	797.159	•	40.273	0.335		•		•	•		•	•	0.56470234	0.562035648	0.565307333	0.552171161	3083.678	761.000	Interior Point
16	1-0-0	797.394	•	•	0.335	•	•	•	•	•	•	•	•	•	•	•	•	1987.625	751.000	Interior Point
17	0-1-1	•	263.382	41.036	•	0.732	0.337	0.700	0.893	0.762	0.762	0.760523035	0.938042245	0.463303873	0.766706765	0.482334761	0.407151971	4662.881	221.000	Interior Point
18	0-1-H1		233.4658684	57.3852267		0.6	0.65125	8.42E-02	0.525	0.5	0.5	0.5	0.55125					3476.534	104.000	Powell
13	0-1-H2		203.3283713	36.7546573		0.572148317	0.337163038	0.330396084	6.76E-01					0.672330731	0.33778272	0.464452082	0.505053502	3527.442	412.000	Powell
20	0-1-0		208.0563705			0.551316144	1	0.573624173	7.62E-01									2420.062	388.000	Nedler Mead
21	0-H1-1		154.8620344	81.54867258		0.7	0.6	-		0.878407334	0.866611635	0.881331138	0.385178373	0.935111924	0.755383851	0.7618034	0.6	3332.042	273.000	Powell
22	0-H2-1		271	72.21148236	•			6.35E-02	0.6	0.884561752	0.866388413	0.873368501	0.388037075	1	0.5	0.5	0.5	3408.183	240.000	Nedler Mead
23	0-H1-H1		211.4050281	64.221919		1	3.35E-01			0.194202119	0.310200066	0.800081154	0.334418353					3086.319	441.000	Powell
24	0-H1-H2		191.1693564	100		0.6	3.65E-01	•	•					0.334210445	0.74550233	0.7618034	0.6	2708.785	313.000	Powell
25	0-H2-H1		250.5457113	57.51116258				0.331180321	0.336427631	0.632780643	0.734115137	1	0.337260005					2438.601	348.000	Powell
26	0-H2-H2		200.633628	76.02206438				0.313041554	1					0.518352374	0.544687885	0.510783433	0.48335563	1919.989	86.000	Powell
27	0-H1-0		207.7317084			0.354551751	1.00E+00											1595.827	235.000	Powell
28	0-H2-0		122.0041152					0.232303713	1									1763.147	181.000	Nedler Mend
23	0-0-1			100						0,700	0.5763932	1	1	1	0.7	1	0.7	2613,824	182,000	Powell
30	0-0-H1			57,55260812						0.332554633	0.967835845	0.356471612	1					1504.455	164.000	Powell
31	0-0-H2			100.000										1	1	1	0.7	1145,792	55,000	Powell
32	0-0-0																			

Equipment	Controller	Control Valve	Valve Opening	Valve CV	Flowing CV	Remark
V-100	LIC-100	LV-100	4.2	40	1.68	Ok, Flowing CV < Valve CV
(High Pressure Separator)	PIC-100	PV-100	55.7	125	69.63	Ok, Flowing CV < Valve CV
V-200	LIC-200	LV-200	6.5	220	14.30	Ok, Flowing CV < Valve CV
Medium Pressure Separator)	PIC-200	PV-200	44.4	1668	740.59	Ok, Flowing CV < Valve CV
V-300	LIC-300	LV-300	5.8	340	19.72	Ok, Flowing CV < Valve CV
Low Pressure Separator)	PIC-300	PV-300	40.2	732	294.26	Ok, Flowing CV < Valve CV

SUCCESSFUL IMPLEMENTATION CASE 1: 0-1-1 well lineup configuration of changing medium and low pressure header pressures and individual 12 choke valve opening from the same headers based on optimized set points. The delta of production before and after implementation was roughly 0.36 kg/s (7.43 kg/s – 7.07 kg/s) correspondingly to 225.3 bbl/d oil production measured at crude transfer pump. The model predicted 221 bbl/d of oil production increment translated to 1.9 % deviation from the actual value.



SUCCESSFUL IMPLEMENTATION CASE 2: 0-H2-1 well lineup configuration of changing medium and low pressure header pressures and individual 10 choke valve opening from the same headers based on optimized set points. The delta of production before and after implementation was roughly 250 bbl/d (3400 bbl/d – 3150 bbl/d) oil production measured at crude transfer pump. The model predicted 240 bbl/d of oil production increment translated to 4.0 % deviation from the actual value.



SUMMARY

- ✓ 31 possible well lineup configurations with optimized operating envelope have been successfully developed in this study using iCON modeling platform that link surface and subsurface models.
- ✓ 3 constrained optimization techniques were applied and compared to establish the optimization envelope to select the highest oil production (optimization objective function) by manipulating each header pressure and individual well choke valve opening.
- ✓ The optimization envelope generated then can be used as optimized set points or guidance for operation to maximize oil production. Operation team will follow the set points recommended in the optimization envelope table that matches their current well lineup configuration.

TECHNICAL GAP AND POTENTIAL FUTURE WORK



POTENTIAL FUTURE WORKS

Based on Figure 5.1, there are still technical gaps to be studied in integrated surface sub-surface optimization fields. For future works, several recommendations are suggested below:

- a. Take fluid sample at each well to determine individual well composition for more accurate fluid properties calculation and products distribution.
- b. De-lumping well bank simplification by using individual well flow correlation to generate maximum well lineup configuration for more granular operation matching.
- c. Apply hybrid constrained optimization technique via auto adaptive auto switching method to reduce optimization converging time.
- d. Verify individual well flow assurance at maximum surface production rate via OLGA modelling to confirm each well can deliver additional flow gain.
- e. Extend the optimization study by linking the integrated developed model with reservoir steady state model under one simulation and thermodynamic platform.

THANK YOU and In Memoriam for Professor Marco Aurélio Satyro



Thank You

with his favorite phrase that inspired me "how hard can it be..."