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

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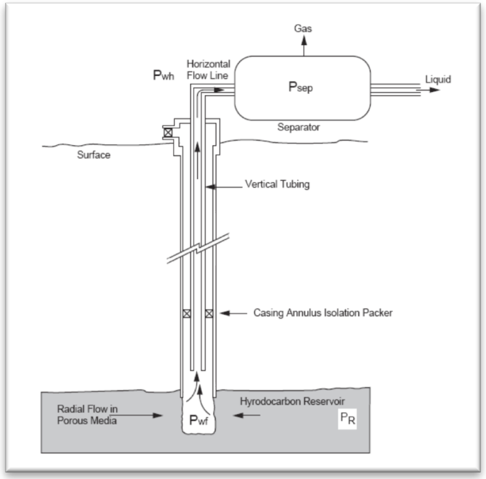
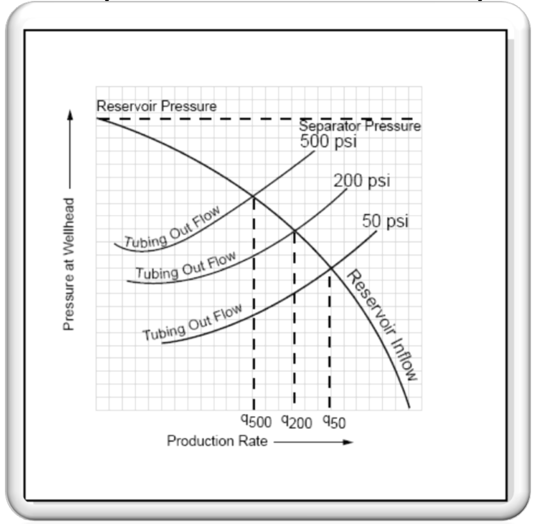
INTRODUCTION

- ✓ 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

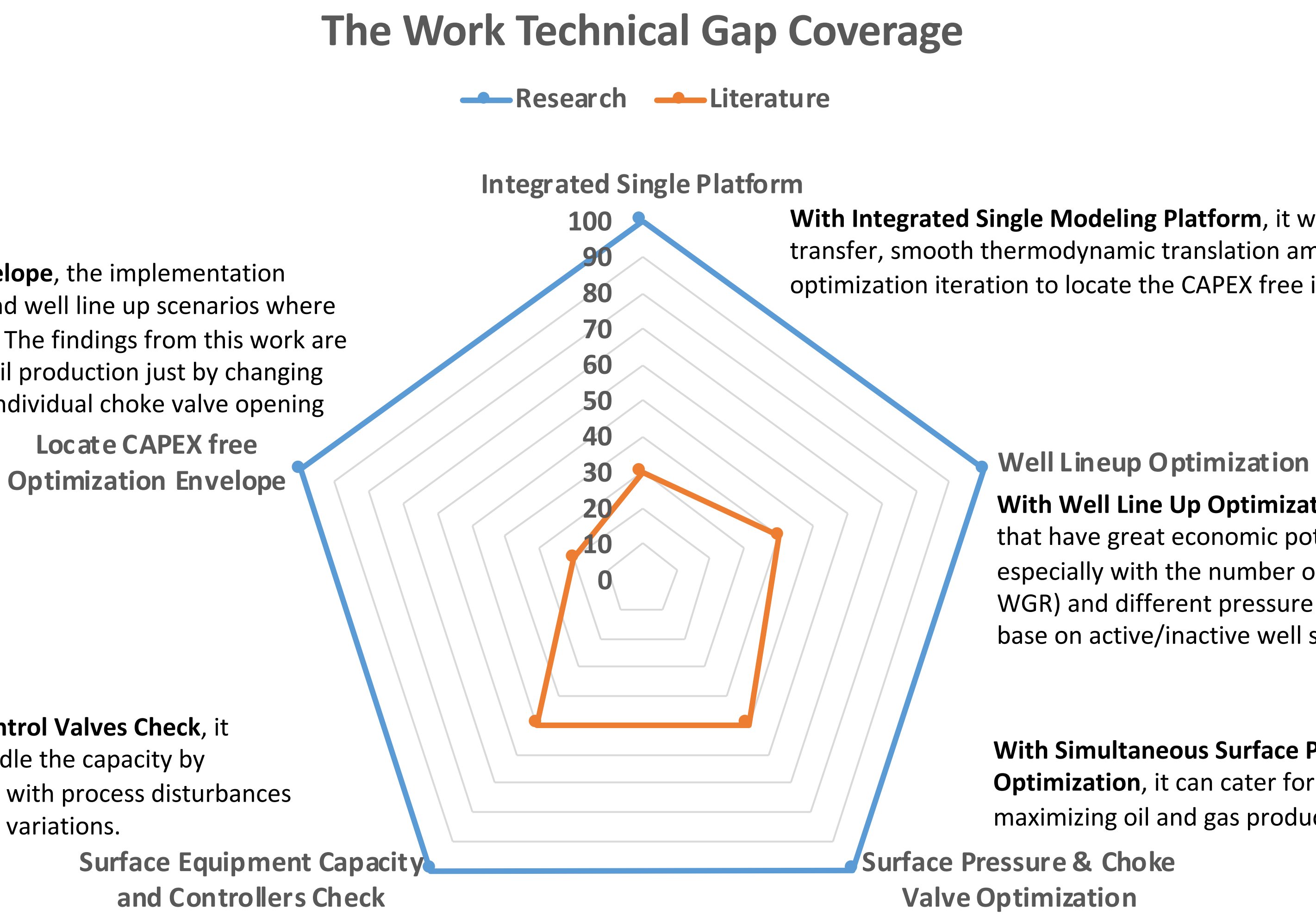
Integrated model Coverage	Software	References
Reservoir performance and production and surface network solution	ECLIPSE NETOPT PVM	Hepguler, Dutta-Roy & Bard, (1997)
Reservoir performance and production and surface network solution	ECLIPSE FORGAS PVM	Trick, (1998)
Reservoir models, coupled with process and economics models	Not mentioned	Juell, Whitson, &Hoda, (2010)
Integrate well performance, gathering system calculation and process plant simulation	Commercial software and rabbit (in-house software)	Sarra, et al. (2015)
Integrate reservoir model, well model and surface facilities model in a single integrator.	SENSOR PROSPER HYSYS Pipe-It	Rahmahwati,Whitson, Foss & Kuntadi, (2012)

This Work : Integrated Model	Software	Work Significant
Individual well, well lineup, production and surface network	iCON – modeling and system integrator (SI) platform	Constraint Optimization **Operating envelope** at different well configurations (lineup and active/inactive well) to maximize production

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



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.

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

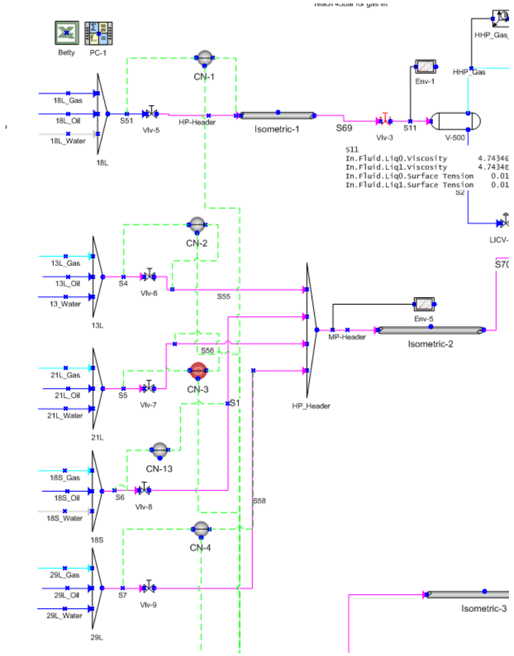
With Simultaneous Surface Pressure And Choke Valve Optimization, it can cater for more representative in maximizing oil and gas production.

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.

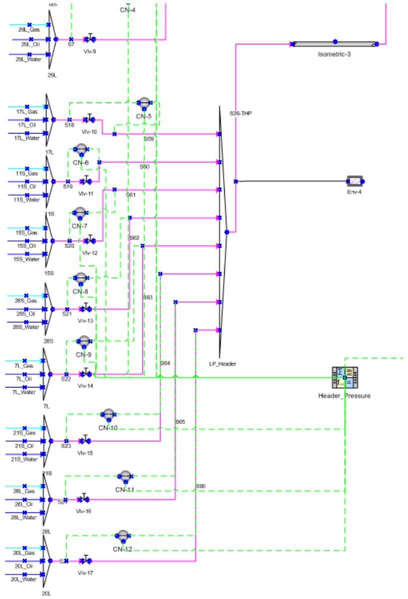
With Locate CAPEX Free Optimization Envelope, the implementation strategy is within the operating envelope and well line up scenarios where value creation can be realized immediately. The findings from this work are considered reaping the additional gas and oil production just by changing surface facilities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

WORK SCOPE : ICON STEADY STATE MODEL DEVELOPMENT

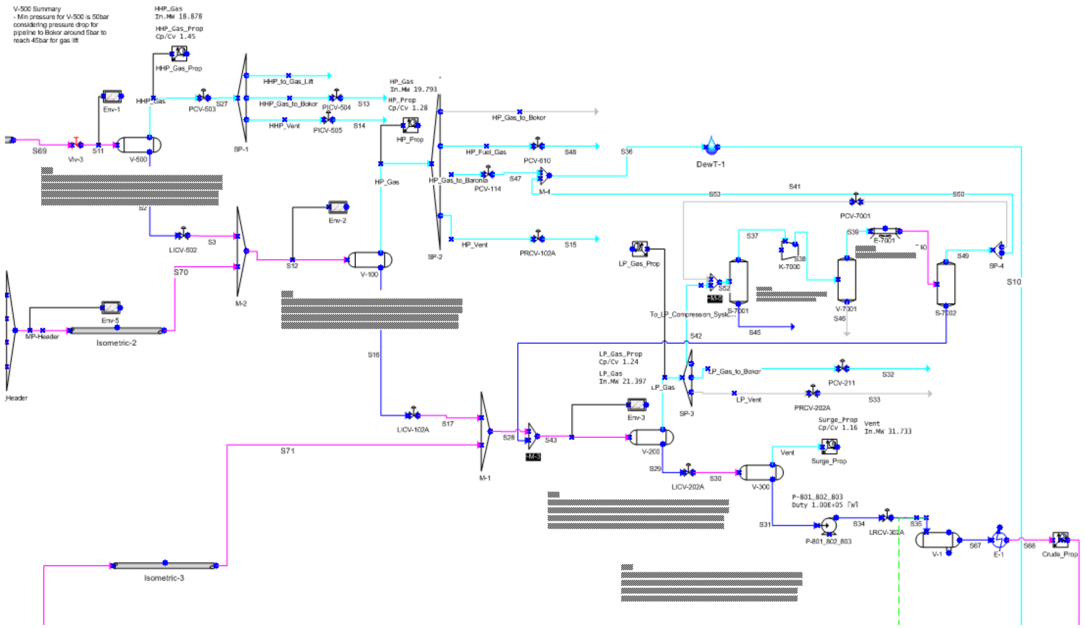
High and Medium Pressure Wells



Low Pressure Wells



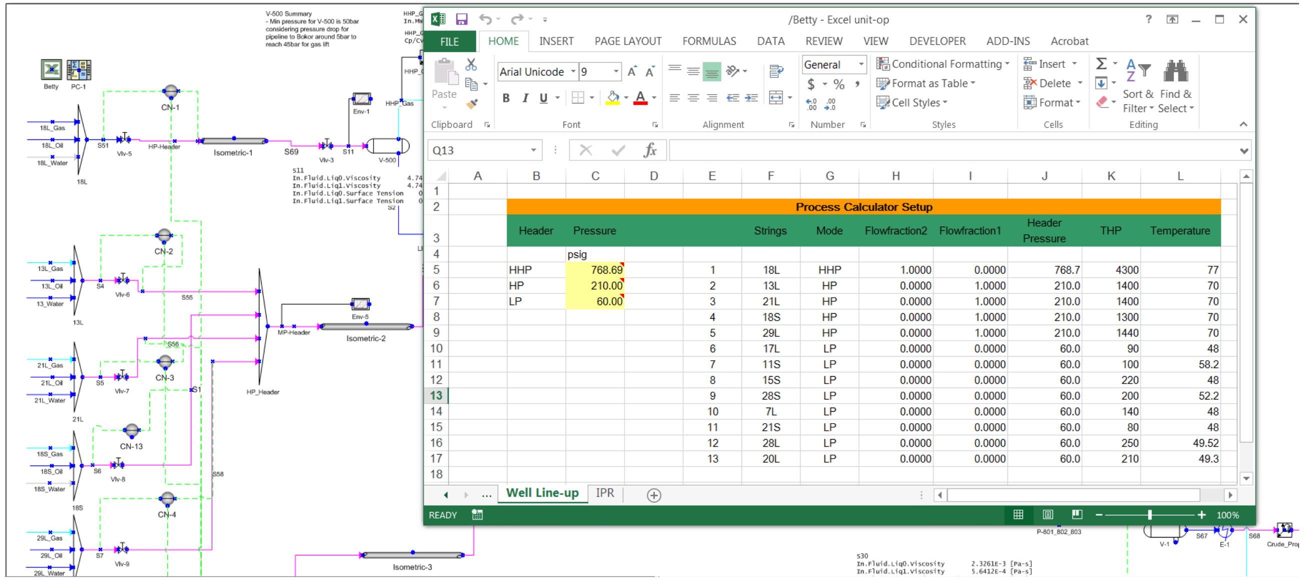
Separator and Compressor Trains



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

```
' Locating the water cuts and pressures data
Count = 0
For I = 1 To 1
    For J = 1 To Rpt(2)
        If ((Sheets(M).Cells(J, I) = "                    ++++++++++++++++++++++++++++++++++++++++" And Sheets(M).Cells(J + 3, I) = "
             (Sheets(M).Cells(J, I) = "                     ++++++++++++++++++++++++++++++++++++++" And Sheets(M).Cells(J + 3, I) = "
             (Sheets(M).Cells(J, I) = "                    +++++++++++++++++++++++++++++++++++++++" And Sheets(M).Cells(J + 3, I) = "
             (Sheets(M).Cells(J, I) = "                    ++++++++++++++++++++++++++++++++++++++++" And Sheets(M).Cells(J + 3, I) = "
             (Sheets(M).Cells(J, I) = "                   +++++++++++++++++++++++++++++++++++++++++" And Sheets(M).Cells(J + 3, I) = "
             (Sheets(M).Cells(J, I) = "                    +++++++++++++++++++++++++++++++++++++++" And Sheets(M).Cells(J + 2, I) = "
             (Sheets(M).Cells(J, I) = "                    ++++++++++++++++++++++++++++++++++++++++" And Sheets(M).Cells(J + 2, I) = "
            Count = Count + 1
            WCI(Count) = J
        End If
    Next J
Next I
For I = 1 To 1
    For J = 1 To Rpt(2)
        If ((Sheets(M).Cells(J, I) = "                    +++++++++++++++++++++++++++++++++++++++" And Sheets(M).Cells(J + 2, I) = "
             (Sheets(M).Cells(J, I) = "                    ++++++++++++++++++++++++++++++++++++++++" And Sheets(M).Cells(J + 2, I) = "
            GasW = 1
        End If
    Next J
Next I
If (Count = 0) Then
BlankP = 0
GoTo blankpage
End If
'-------------------------------------------------------------------------------------------
' To determine whether Water Cut first or NOT
For I = 1 To Count
    WCS(I) = Sheets(M).Cells(WCI(I) + 1, 1)    ' X = 1 for WC and X = 2 for P
Next I

For I = 1 To Count
    Varx = Split(WCS(I), " ")
    For J = 0 To UBound(Varx)
        If (Varx(J) = "Water" Or Varx(J) = "PVT") Then
            X = 1
        End If
```



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

Open

WORK SCOPE : LINK SURFACE AND SUB SURFACE MODELS IN ICON

	IPR										
		1	2	3	4	5	6	7	8	9	10
					THP	Water Cut	GOR	Liquid	Oil	Water	Gas
	File Name	String			psig	%	mmscfd/bbl	bbl/d	bbl/d	bbl/d	mmscfd
18L	-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	-28S	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**

IPR Equation Setup		
	THP	
		Copied
18L		= -0.00000000000793333333329980000x4 + 0.00000006516666666814600000000x3 - 0.00029366666667788000000000000x2 + 0.29233333333698700000000000000x + 2,918.80000000340000000000000000
13L		=0.000000108333333333334x3 - 0.000513928571428670000x2 + 0.048595238095530500000x + 1,272.857142856890000000000
21L		=0.00000015365405429783300000000x3 - 0.00075286075488653600000000000x2 + 0.50908571951785400000000000000x + 1,731.09083757835000000000000000
18S		=-0.0000000802666666666667x3 + 0.000248599999999999500x2 - 0.232433333333324100000x + 495.499999999932000000000
29L		=-0.00000008786883784820x3 - 0.00054173879267635500x2 - 1.49198854764436000000x + 4,099.84560721931000000000
17L		=-0.000000001180831826157x4 + 0.000000847968655726811x3 - 0.003060135623833970000x2 - 0.472535563569049000000x + 634.897106689030000000000
11S		=-0.00000002247843926099500000000x4 + 0.00001872381963108350000000000x3 - 0.00617541405199251000000000000x2 + 0.00913343034412151000000000000x + 1,438.57092772563000000000000000
15S		= -0.00000000025382399996x5 + 0.00000027256959994680x4 - 0.00010900469331478200x3 + 0.01926833599052070000x2 - 1.77540906312717000000x + 867.68271963254300000000
28S		=-0.00000248522666662643000000000x3 - 0.00135105828573923000000000000x2 - 5.22392041904039000000000000000x + 4,535.82156799918000000000000000
7L		=0.000000007614381458 69x5 - 0.000005345148195612 38x4 + 0.001479573392398240000x3 - 0.203074180590860000000x2 + 11.751260547673400000000x + 1,280.539566844490000000000
21S		=-0.00015927145649168000000000000x2 + 0.01659084540217600000000000000x + 188.36049055193900000000000000
28L		=0.00000000506666666665151500000000x4 - 0.00000467999999983065000000000000x3 + 0.01391333333326946000000000000x2 - 1.66699999998889700000000000000x + 485.89999999336500000000000000
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

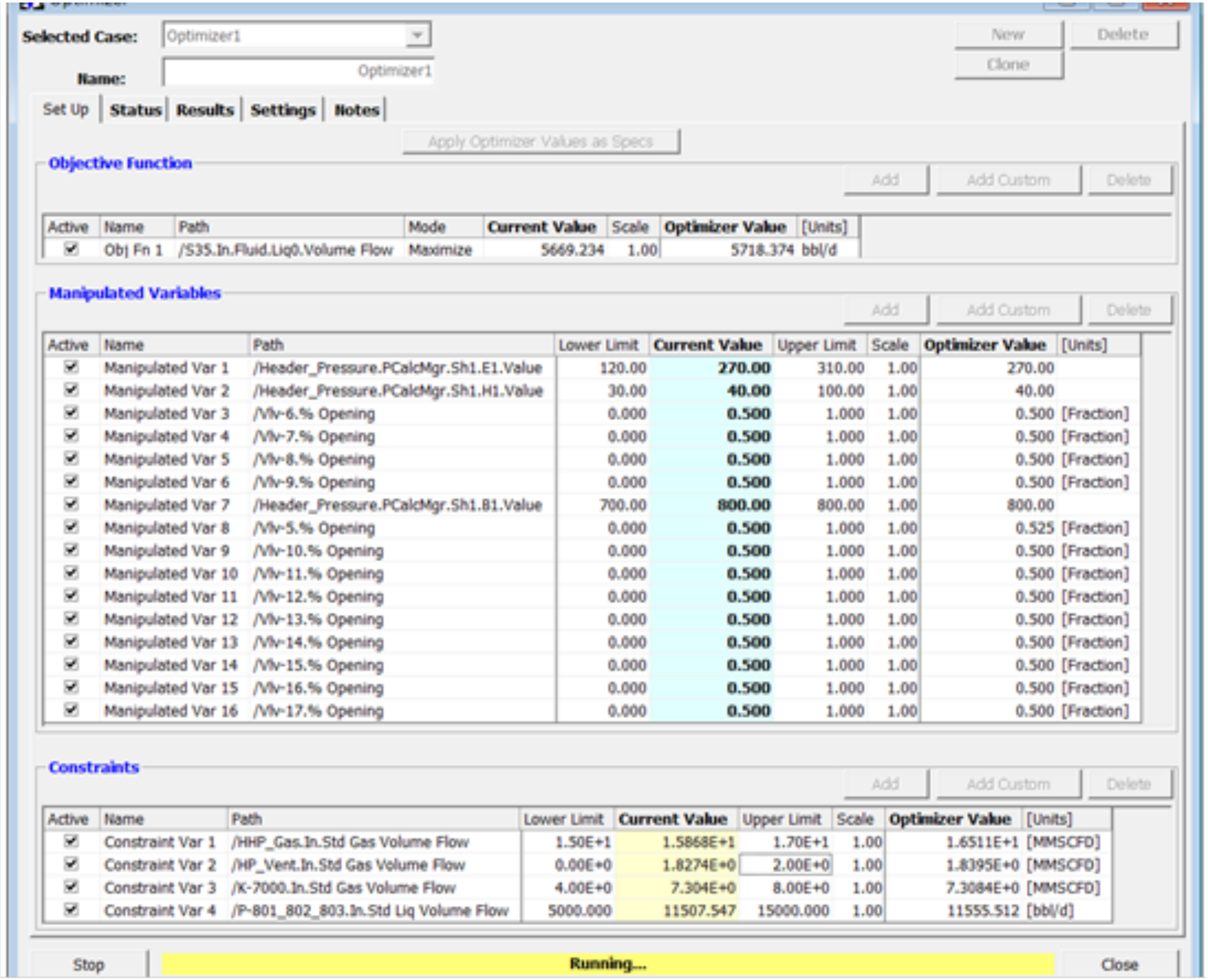
310 psig < HP Header Pressure > 120 psig

100 psig < HP Header Pressure > 30 psig

100 % < Choke Valve Opening > 0%

Optimization Techniques: Nedler Mead, Powell and Interior Point

iCON OPTIMIZER



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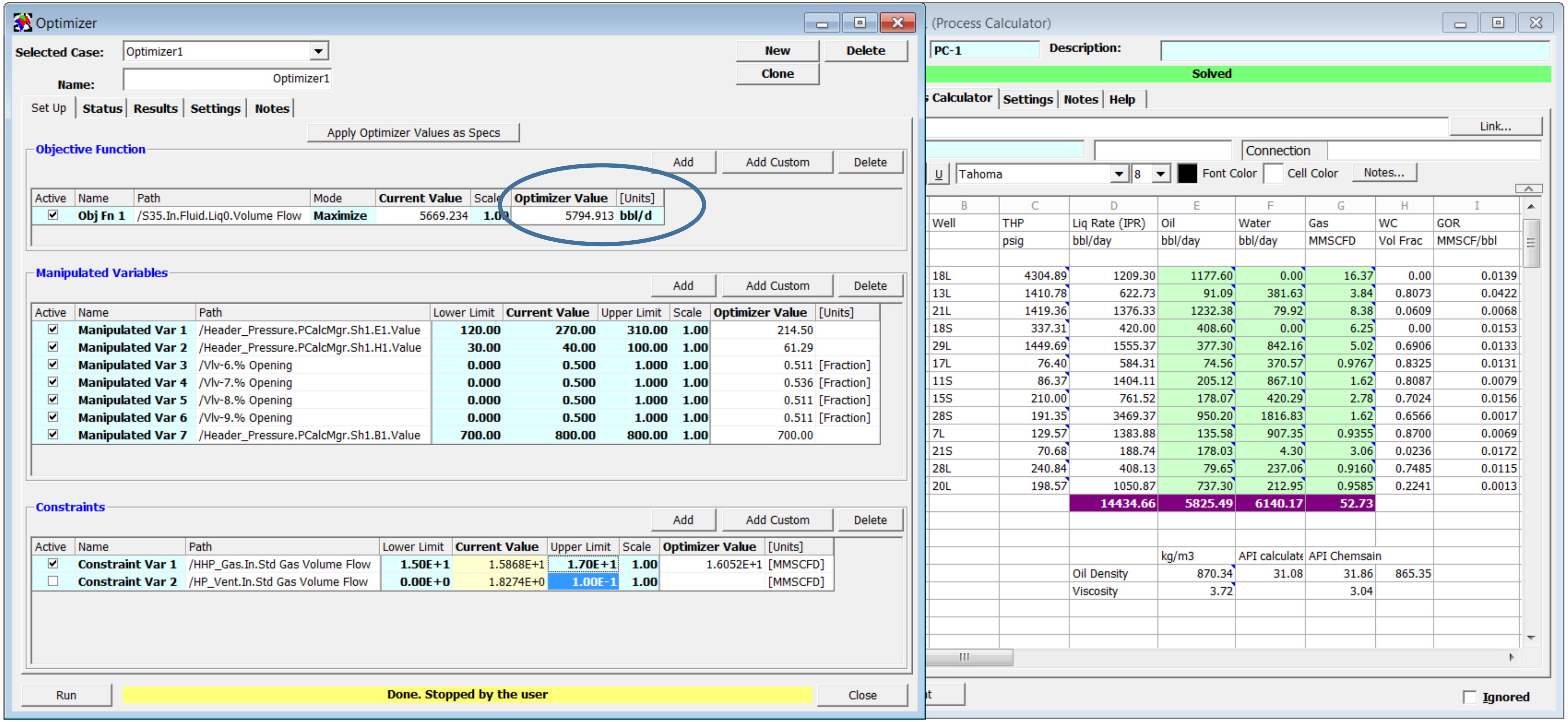
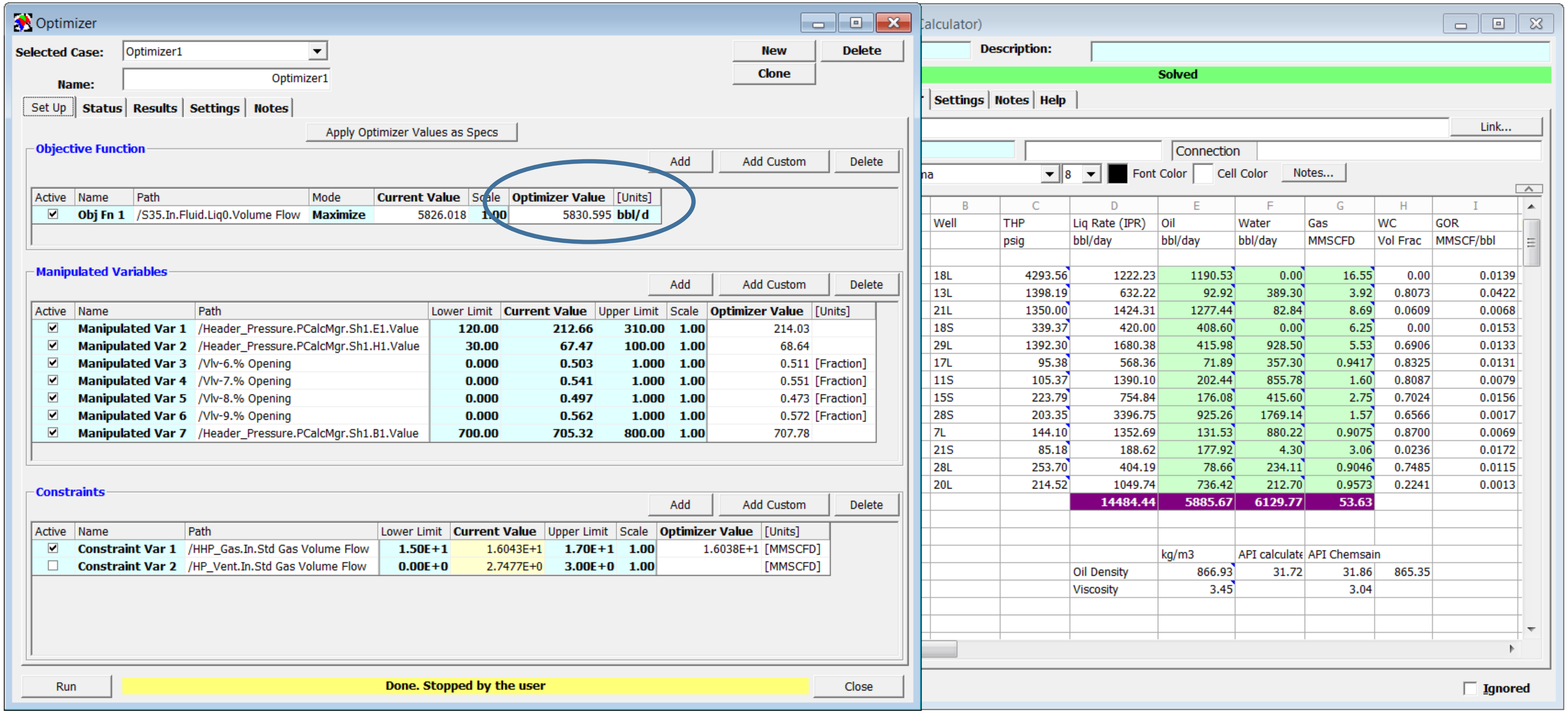
OPTIMIZATION RESULTS AFTER 3 DAYS RUNNING



OPTIMIZATION RESULTS AFTER 8 DAYS RUNNING



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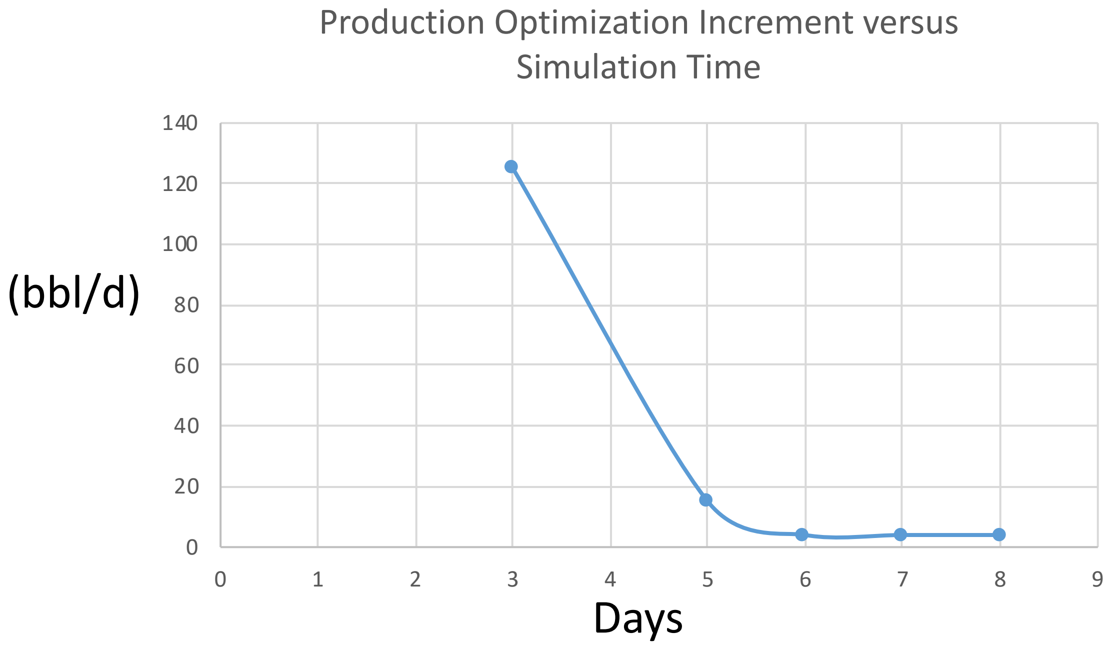
INTERMEDIATE OPTIMIZATION RESULTS SUMMARY (NEDLER MEAD TECHNIQUE)

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 increase :
(125+15+4+4+4)/5669
= 152/5669 x 100%
= 2.7 % (152 bbl/d)

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)



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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

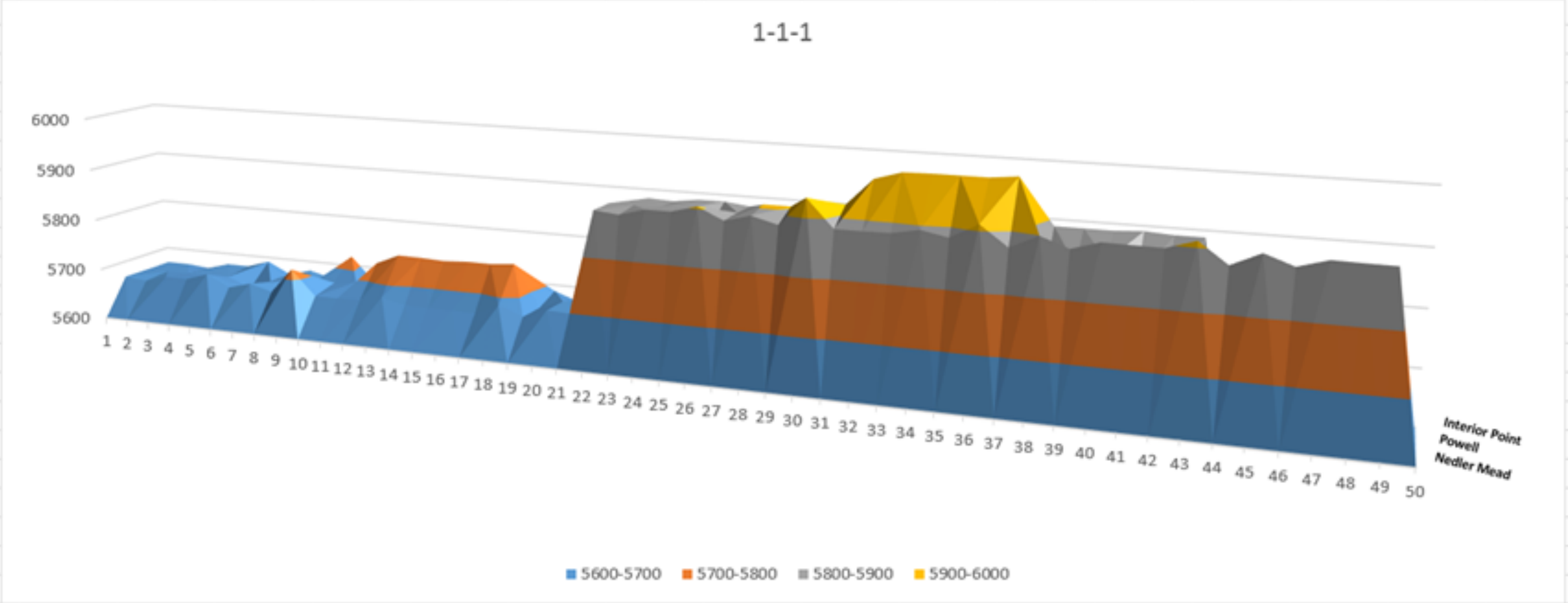
INTEGRATED MODEL MATCHING

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

Start	NM	PW	IP	Gain NM	Gain PW	IP Gain	
5669	5934	5982	5891	265	313	222	Powell



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)	313	
Otimization Method		Powell	

OPTIMIZATION RESULTS AT DIFFERENT WELL CONFIGURATION : Highest Optimized Set Points

Properties	WC	GOR		1-1-1	1-1-H1	1-1-H2	1-1-0
	(%)	(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

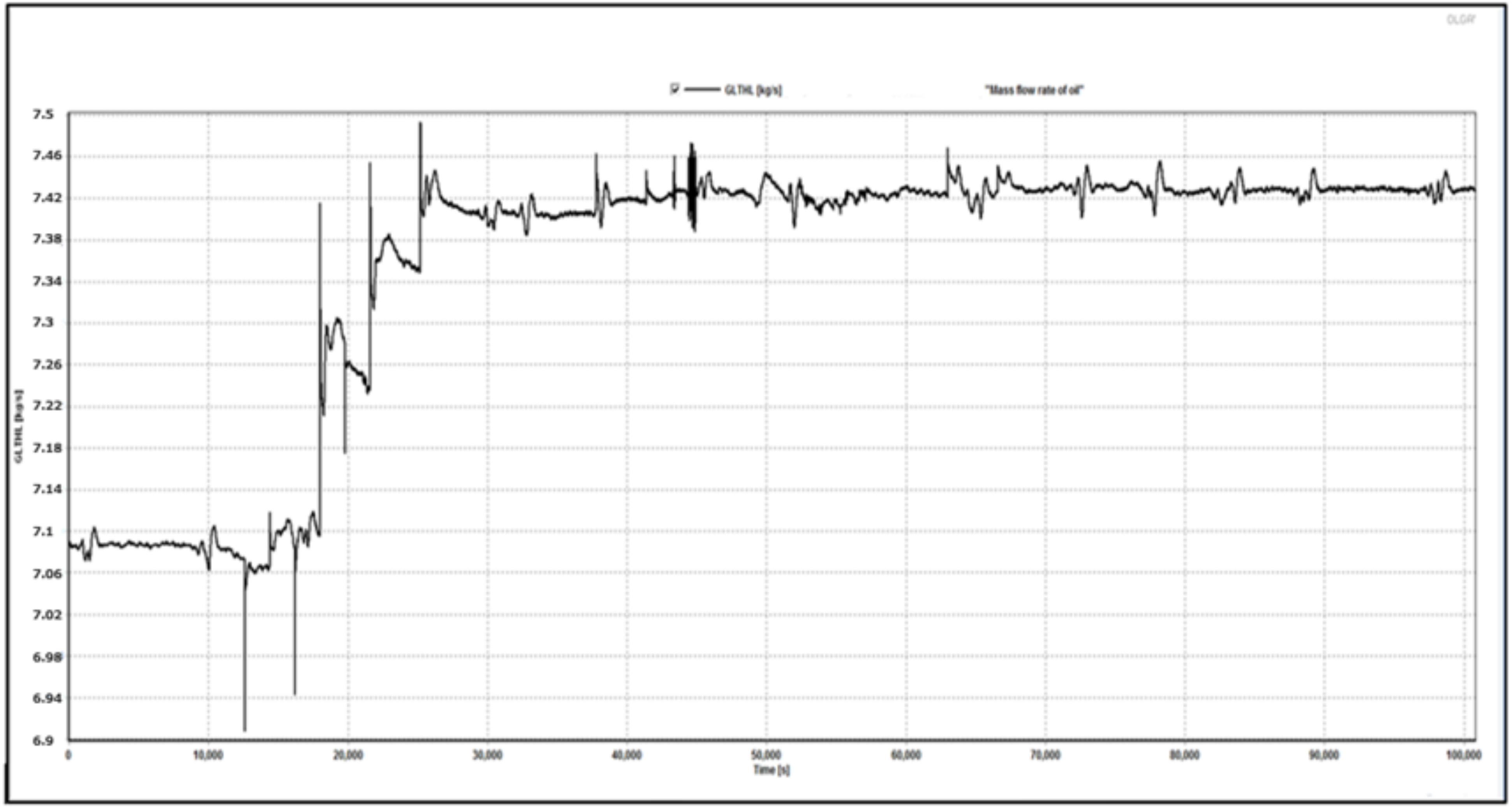
OPTIMIZATION ENVELOPE for all well lineup configuration and control valve capacity checks

Table 4.57: Overall Optimzed Set Points for all possible well lineups

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
	Case	h Pressure Hea (Psig)	dium HeaderPressu (Psig)	w Header Press (Psig)	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	Choke Valve Open [Fraction]	ptimized Producti (bbl/d)	Production Gain (bbl/d)	Otimization Method
1	1-1-1	738.750	201.431	84.368	0.538	1.000	0.552	0.501	0.580	0.501	0.501	0.501	0.639	0.501	0.501	0.501	0.501	5982.266	313.000	Powell
2	1-1-H1	738.653	269.987	40.055	0.395	0.509	0.721	0.481	0.617	0.523	0.343	0.478	0.605	-	-	-	-	5458.674	877.000	Interior Point
3	1-1-H2	738.472	269.980	40.092	1.000	0.727	0.985	0.671	0.946	-	-	-	-	0.875	0.436	0.504	0.593	5175.015	847.000	Interior Point
4	1-1-0	738.776	269.991	-	1.000	0.636	1.000	0.644	0.497	-	-	-	-	-	-	-	-	4075.863	800.000	Interior Point
5	1-H1-1	736.216	270.014	41.329	0.399	0.754	0.950	-	-	0.775	0.411	0.754	0.399	0.399	0.001	0.736	0.747	5318.849	367.000	Interior Point
6	1-H2-1	773.686	271.808	41.440	0.383	-	-	0.390	0.870	0.397	0.426	0.925	0.378	0.364	0.201	0.789	0.951	5305.616	315.000	Interior Point
7	1-H1-H1	712.156	149.363	40.132	0.564	0.623	0.635	-	-	0.384	0.347	0.399	1.000	-	-	-	-	4195.832	332.000	Nedler Mead
8	1-H1-H2	736.683	269.965	40.664	0.396	0.643	0.786	-	-	-	-	-	-	0.347	0.951	0.540	0.502	4449.863	835.000	Interior Point
9	1-H2-H1	707.450	272.268	40.092	0.563	-	-	0.494	0.539	0.477	0.510	0.513	0.548	-	-	-	-	3475.800	178.000	Nedler Mead
10	1-H2-H2	797.324	269.936	40.285	0.395	-	-	0.495	0.634	-	-	-	-	0.525	0.506	0.511	0.510	2907.217	47.000	Nedler Mead
11	1-H1-0	720.358	225.356	-	0.538	0.707	0.634	-	-	-	-	-	-	-	-	-	-	2709.638	156.000	Nedler Mead
12	1-H2-0	797.306	269.958	-	0.731	-	-	0.498	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	796.741	-	40.363	0.343	-	-	-	-	0.507	0.335	0.478	0.397	-	-	-	-	3403.006	834.000	Interior Point
15	1-0-H2	797.159	-	40.279	0.395	-	-	-	-	-	-	-	-	0.56470294	0.562035648	0.565307339	0.552171161	3089.678	761.000	Interior Point
16	1-0-0	797.394	-	-	0.395	-	-	-	-	-	-	-	-	-	-	-	-	1987.625	751.000	Interior Point
17	0-1-1	-	269.982	41.096	-	0.732	0.997	0.700	0.893	0.762	0.762	0.760529095	0.938042245	0.469909873	0.766706765	0.482334761	0.407151971	4662.881	221.000	Interior Point
18	0-1-H1	-	233.4658684	57.9852267	-	0.6	0.65125	8.42E-02	0.525	0.5	0.5	0.5	0.55125	-	-	-	-	3476.594	104.000	Powell
19	0-1-H2	-	209.9289719	96.7546579	-	0.572148317	0.997169038	0.330996084	6.76E-01	-	-	-	-	0.672990731	0.39778272	0.464452082	0.505059502	3527.442	412.000	Powell
20	0-1-0	-	208.0569705	-	-	0.551316144	1	0.579624173	7.62E-01	-	-	-	-	-	-	-	-	2420.062	388.000	Nedler Mead
21	0-H1-1	-	154.8620944	81.54867258	-	0.7	0.6	-	-	0.878407394	0.866611635	0.881391138	0.985178979	0.935111924	0.755383851	0.7618034	0.6	3992.042	273.000	Powell
22	0-H2-1	-	271	72.21148236	-	-	-	6.35E-02	0.6	0.884561752	0.866988413	0.873368501	0.988037075	1	0.5	0.5	0.5	3408.189	240.000	Nedler Mead
23	0-H1-H1	-	211.4050281	64.221919	-	1	9.95E-01	-	-	0.194202119	0.310200066	0.800081154	0.994418353	-	-	-	-	3086.319	441.000	Powell
24	0-H1-H2	-	191.1693564	100	-	0.6	9.65E-01	-	-	-	-	-	-	0.934210445	0.74550239	0.7618034	0.6	2708.785	319.000	Powell
25	0-H2-H1	-	250.5457113	57.51116258	-	-	-	0.331180321	0.996427691	0.632780649	0.794115197	1	0.997260005	-	-	-	-	2438.601	348.000	Powell
26	0-H2-H2	-	200.633628	76.02206438	-	-	-	0.313041554	1	-	-	-	-	0.518952374	0.544687885	0.510783439	0.48935569	1919.989	86.000	Powell
27	0-H1-0	-	207.7317084	-	-	0.954551751	1.00E+00	-	-	-	-	-	-	-	-	-	-	1595.827	295.000	Powell
28	0-H2-0	-	122.0041152	-	-	-	-	0.232903719	1	-	-	-	-	-	-	-	-	1763.147	181.000	Nedler Mead
29	0-0-1	-	-	100	-	-	-	-	-	0.700	0.5763932	1	1	1	0.7	1	0.7	2619.824	182.000	Powell
30	0-0-H1	-	-	57.55260812	-					0.992554699	0.967835845	0.956471612	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

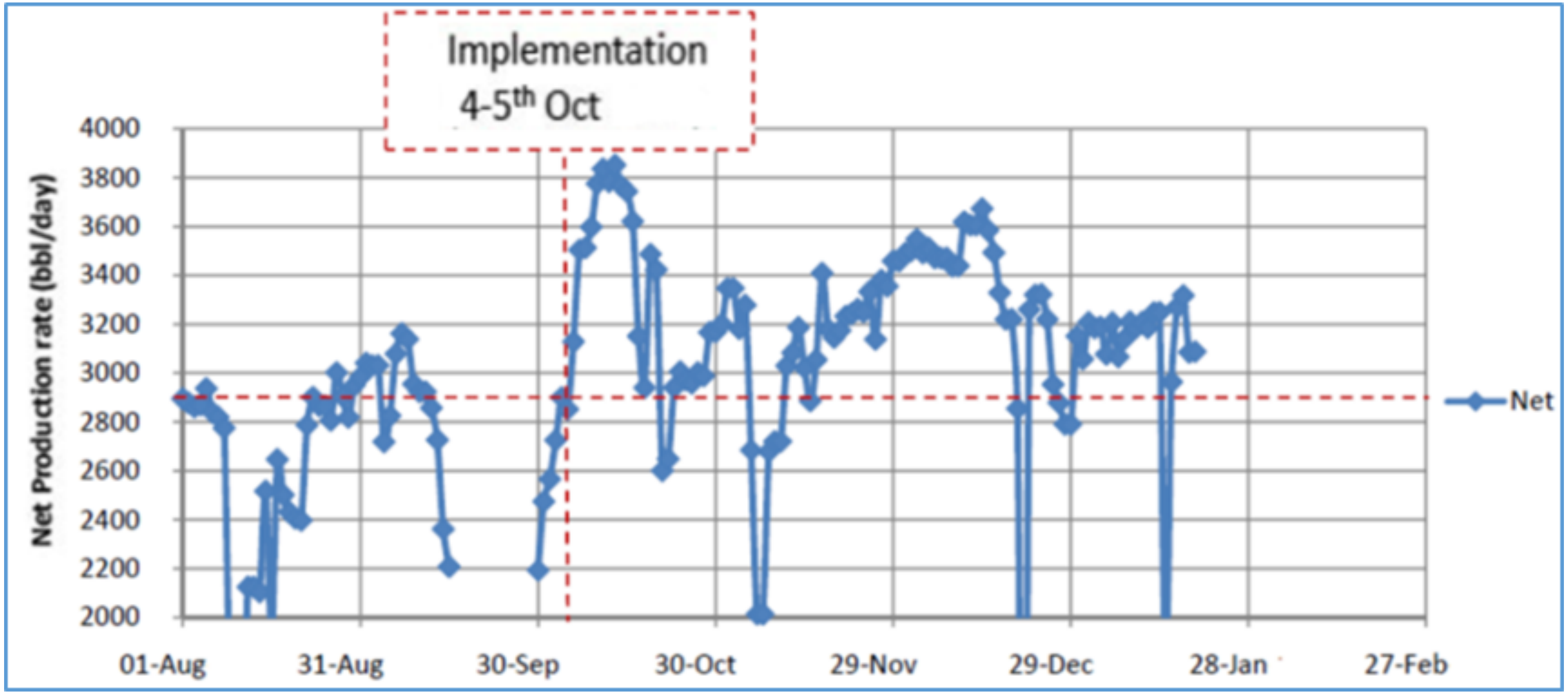
Equipment	Controller	Control Valve	Valve Opening	Valve CV	Flowing CV	Remark
V-100	LIC-100	LV-100	4.2	40	1.68	Ok, Flowing CV < Valve CV
(High Pressure Separator)	PIC-100	PV-100	55.7	125	69.63	Ok, Flowing CV < Valve CV
V-200	LIC-200	LV-200	6.5	220	14.30	Ok, Flowing CV < Valve CV
Medium Pressure Separator)	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.**



Open

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…"