Model-Free Closed Loop Gas Lift Optimisation

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Background

Gas lift is a widely employed technique to facilitate the elevation of liquids, such as oil and water, to the surface when natural reservoir pressure is inadequate. This method involves injecting high-pressure gas into the production tubing, thereby decreasing the fluid column's density, reducing hydrostatic pressure, and enabling the reservoir pressure to efficiently drive the lighter fluids up the wellbore.

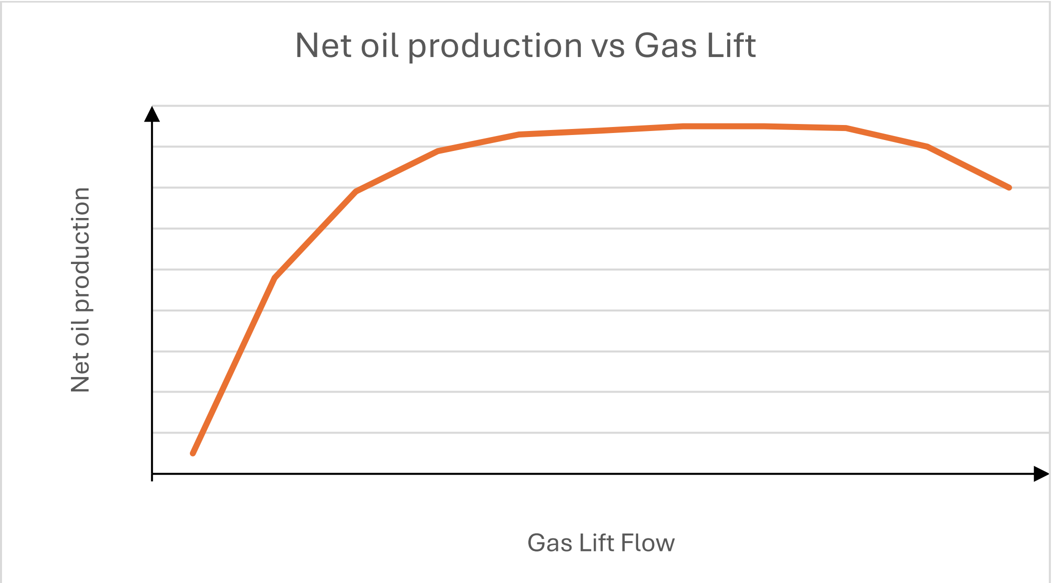


Figure 1 – Typical Shape of a Gas Lift Performance Curve

Increasing gas lift generally boosts production, but excessive gas lift eventually flattens or reduces output, as shown by the example gas lift performance (GLP) curve above. Each well will have its own GLP curve, the shape of which changes with time e.g. as the reservoir ages.

For a single well, the economic optimum will vary with changes in economics, reservoir conditions and equipment efficiency. The challenge is then to determine the optimum gas lift flow at any point in time.

For multiple wells, the impact of gas lift on production varies between wells. When the facility has multiple wells served by a common gas lift supply, e.g. on a common well pad, there is an additional challenge of determining how much gas lift should be used for each well. Where gas lift compression is limited, any gas lift optimization needs to distribute available gas lift (i.e. within compressor limits) to maximize total production.

Closed Loop Optimisation of Gas Lift

As outlined above, the relationship between gas lift and production for each well is non-linear. The optimum may be unconstrained or constrained (e.g. by gas compressor limits). Any generic approach must therefore be able to solve a non-linear optimization problem and honour a set of constraints.

Historically, closed loop optimizers have been model-based, where:

1. A linear model is used in a model predictive controller. The model is determined by plant tests. More recently these approaches have been extended by modelling non-linearity in gain.
2. A steady state non-linear model is used in a steady state RTO.

The challenge with all these approaches is expertise is needed to develop and maintain the model. Often these skills are not available within operating companies. In addition, there is significant cost incurred in developing the model which can make smaller projects uneconomic.

More recently, AI has been used to implement RTO. However, first principle models are still required, or large datasets covering the complete operating envelope, for training purposes.

To combat the 'model hurdle', a novel model-free closed loop optimizer has been released by ORTOmation. This optimizer "learns" how adjustments to the process impact operating profit or operating cost and uses the "learnings" to make further adjustments whilst ensuring constraints are not breached. No process model is required and thus expertise needed is significantly lower, costs are lower and payback time is improved.

Project Introduction

ORTOmation's closed loop optimisation technology has been applied an unconventional onshore oil and gas production facility in the USA. A depiction of a typical facility is shown in figure 2.

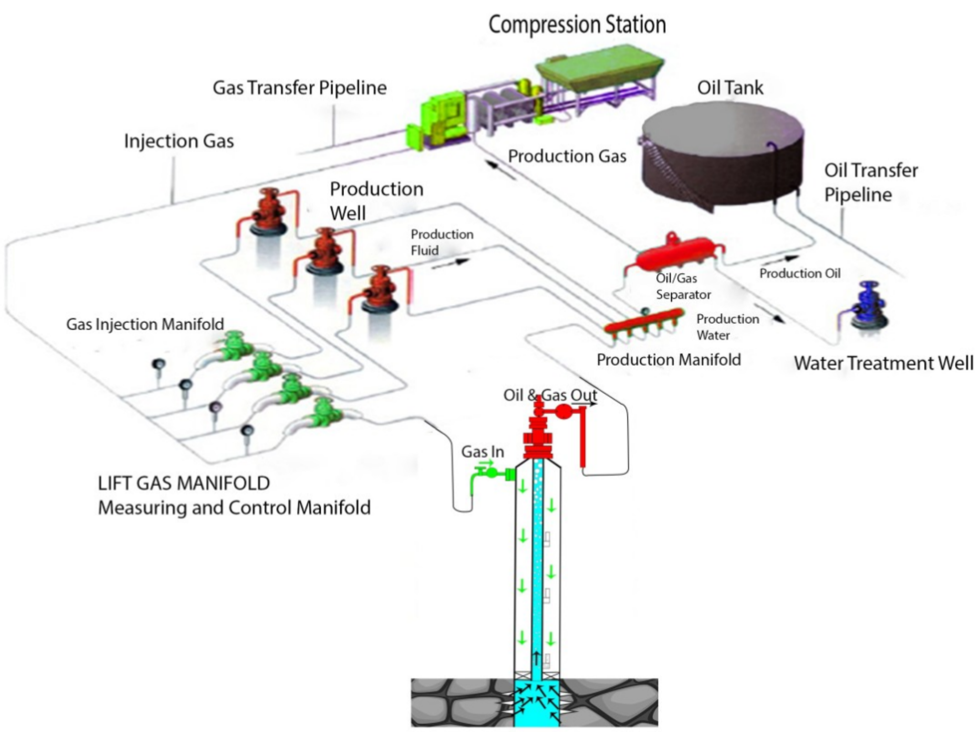


Figure 2 – Typical Oil and Gas Facility with Gas Lift

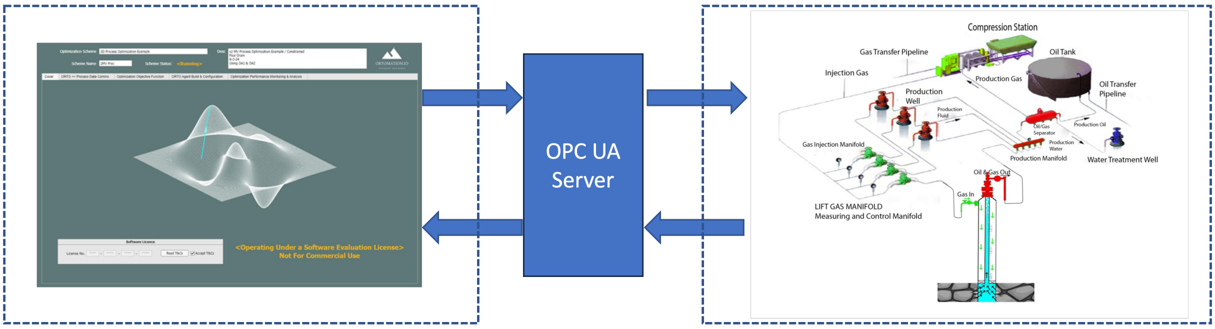
The facility comprises 5 wells. Gas, oil and water leave each well and enter a separator drum where the fluids are separated. Oil and water pass to storage. Some of the gas is recycled through a gas lift compressor and passes to the wells under flow control. The remaining produced gas is exported.

Project Execution

Upon approval of ORTOmation's proposal by the operating company, project execution commenced following these steps:

Software Installation

The ORTOmation software, ORTO™, was installed on a cloud-based server with secure access to the SCADA system. The connection to the measurement system and regulatory controls was built using OPC UA, as depicted in figure 3.



ORTO™ Application (OPC Client) Onshore Oil & Gas Facility

Figure 3 – OPC Communications

Training

Training covering how an optimization scheme is built, commissioned and then monitored using ORTO™ was provided to the operating company team via Microsoft Teams. The training took roughly 3 hours.

Define and Build the Optimization Scheme

The operating company team and ORTOmation had carried out some initial discussions prior to ORTOmation submitting the proposal. A further, more in-depth discussion was held to understand:

1. **The operation and economics of the wells at the facility:**
   The overall objective was to maximize produced gas from the well (and thereby liquids). A penalization function was designed to ensure the gas lift centred around a calculated 'critical rate'. It was also noted that the response time of the wells to changes in gas lift flow and pressure was very slow (days) and this led to a longer data scan rate (60s) being chosen.
2. **Manipulated variables to be used by the optimizer:**
   The manipulated variables were the gas lift flow rates on each well, i.e. x5 in total.
3. **Constraints that needed to be adhered to by the optimiser:**
   a. The key constraints were position of the flare pressure control valve (the optimiser must prevent flaring) and gas lift maximum and minimum flow rates to each well.

b. Any gas large gas lift flow deviations from setpoint were also added as constraints to ensure gas lift flow controllers were always in a controlling range.
c. The difference between gas production on each well was used to ensure gas lift flow balancing between wells and avoid high imbalances

4. **Optimizer pause flags:**
   It was decided that the optimizer should pause if:
   a. The gas lift flow controllers were not in the correct mode i.e. to receive a remote SP.
   b. The compressor trips, inferred by the total gas lift dropping below a defined limit.

Table 1 below summarises the final optimization objective function design.

<table>
<tr><th colspan="2">Optimization Variable (OV) Calculation:</th></tr>
<tr><td>(Vessel_Gas_Production_Rate-Gas_Injection_Rate)
(-4.0e-07(Vessel_Gas_Production_Rate-Critical_Rate)^2+1)</td><td>The overall objective is to maximize produced gas from the well (and thereby liquids).

The use of gas lift is penalized such that the search for the optimum gas lift rate is centred around the calculated Critical Rate.</td></tr>
<tr><th colspan="2">Manipulation Variables (MVs)</th></tr>
<tr><td>V101, V102, V104, V105, V106 gas lift flow SPs</td><td>To adjust gas lift flow to each well</td></tr>
<tr><th colspan="2">C1 Constraint Logic Expression (V106 example given):</th></tr>
<tr><td>(Gas_Injection_Pressure<600 || Pad_Flare_Meter_Rate>30)

&& ((V106_CR_Prod_Diff)>(V101_CR_Prod_Diff) &&
(V106_CR_Prod_Diff)>(V102_CR_Prod_Diff) &&
(V106_CR_Prod_Diff)>(V104_CR_Prod_Diff) &&
(V106_CR_Prod_Diff)>(V105_CR_Prod_Diff))

|| (GL_Valve_Pos>90)

|| ((-4.0e-07*(Vessel_Gas_Production_Rate-Critical_Rate)^2+1) <0.8
&& (Vessel_Gas_Production_Rate-Critical_Rate)>0)</td><td>To safeguard gas injection supply pressure and safeguard against flaring.

Ensures all optimizers work together to best utilize the available gas lift. This is achieved by ensuring that the well with the most excess gas lift available reduces its gas lift first, if either the gas injection pressure falls too low, or flaring occurs.
Note: (V106_CR_Prod_Diff)>(V103_CR_Prod_Diff) has been removed. V103 is currently not part of the scheme.

If GL_Valve_Pos > 90%, optimizer will wind down SP i.e. ensuring the valve is always in play and reducing the SP until it matches the PV.

Gas injection rate will be reduced if penalty factor is < 0.8 and the difference between total well gas production and the critical rate is positive. This helps drive the gas injection rate down, so that Vessel_Gas_Production_Rate moves closer to the Critical_Rate.</td></tr>
<tr><th colspan="2">P1 Pause Logic Expression:</th></tr>
<tr><td>Gas_Injection_PID_Mode~=1 || Total_Injection_Flow<100</td><td>Optimizer will pause if gas injection controller mode is incorrect OR if the compressor has tripped, inferred by the Total_Injection_Flow being less than 100.</td></tr>
</table>

Table 1 – Gas Lift Optimization Scheme – Objective Function

Summary of Benefits Achieved to Date

Review Regulatory Controls and Instrumentation

It was noted that the level of noise on the gas production flow was significant requiring effective noise management using ORTO technology signal processing capabilities.

Commissioning

ORTOmation technology allows for incremental commissioning. Commissioning was also cautious – limits on the high and low gas lift flow rates were initially close to the value when commissioning started and the maximum rate of change per optimizer scan was small. As confidence grew, the limits and rate of change that the optimizer could make were increased.

Monitor and Analyse Scheme Performance

As the gas lift optimizers were commissioned the ORTO analysis tools were used to monitor performance and make gradual adjustments to limits and tuning parameters. Data was exported every 24 hours from the ORTO™ software to allow for deeper off-line analysis.

Results

Following several weeks of ORTO agent deployment across the five wells, the resulting benefits were assessed and organised into four specific categories.

Reduction in Total Gas Lift Usage:

Prior to optimization, total gas lift usage was approximately 4700 Mscf/d . Following the switching on of the optimizers across the five wells, total gas lift usage fell by approx. 44% to 2640 Mscf/d, as detailed in Table 2 and plotted in figure 4.

Well	MV Bounds Low	Gas Injection – pre-optimization (approx.)	Gas Injection – after 14 Days (approx.)	Total Reduction in Gas Injection	Reduction %
1	300	1500	350	1150	23%
2	150	500	150	350	30%
4	300	900	510	390	57%
5	150	300	150	150	50%
6	350	1500	900	600	60%
	Totals	**4700**	**2060**	**2640**	44%

Table 2 – Well Gas Lift Usage Reduction

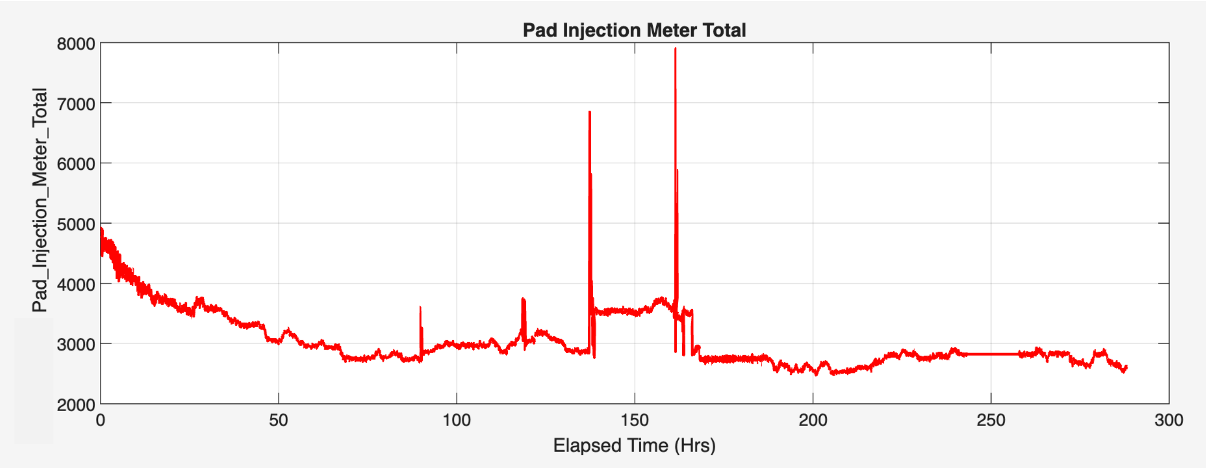


Figure 4 – Total Gas Usage

The energy needed to compress the gas, whether as electrical energy or gas consumption for operating the gas lift compressor, should therefore be reduced by roughly the same amount, delivering an OpEx saving and environmental emissions saving.

Note. The step increase in gas lift usage at ~130 hrs and subsequent reduction at ~165 hrs, was caused by the facility switching off optimization on one of the wells, and making manual gas lift adjustments, before switching optimization back on.

Increase in Production (when there is surplus gas lift available)

All ORTO optimizers worked as expected and performed well. As shown in figure 5, the assigned optimization variable (OV), inferring overall production is being maximized.

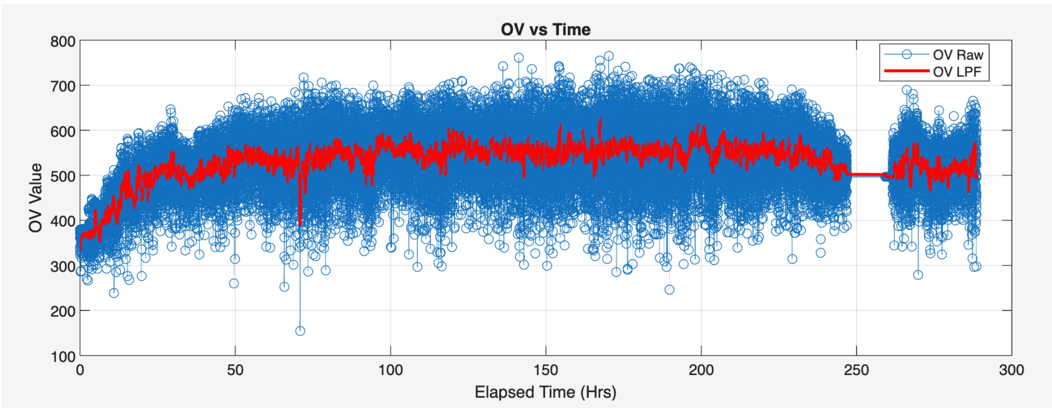


Figure 5 – Example well: OV Raw (Blue) and OV Filtered (Red)

The reduction in gas lift on each well has resulted in a reduction in tubing pressure. Fig. 6 shows how V106 622h tubing pressure has been reduced by approximately 8%.

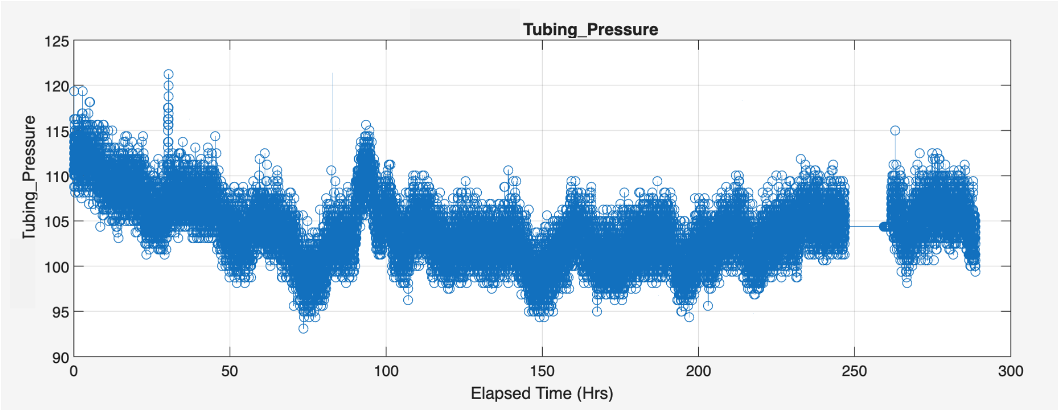


Figure 6 – Example well: Tubing Pressure

It has also led to a reduction in casing pressure, as shown in figure 7., by 1.5%.

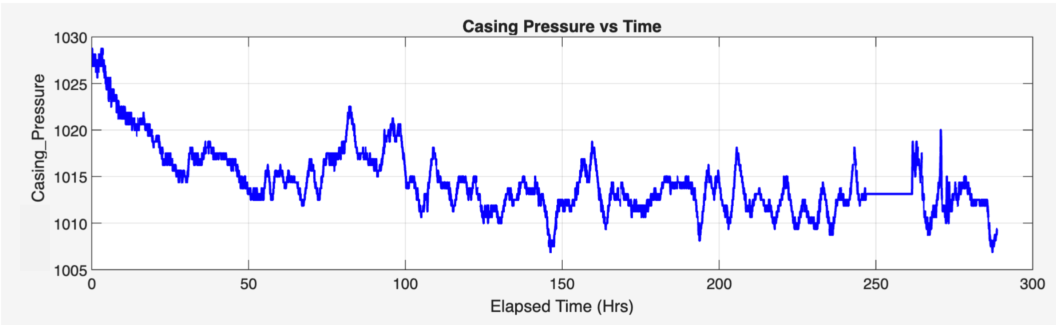


Figure 7 – Example well: Casing Pressure

Reduction in casing pressure may allow for lower gas lift injection and which may promote improved gas and liquids drawdown from the wells.

However, as shown in figure 8, at the end of the commissioning period production had not increased. Given the reduction in casing pressure, production may be improved over time.

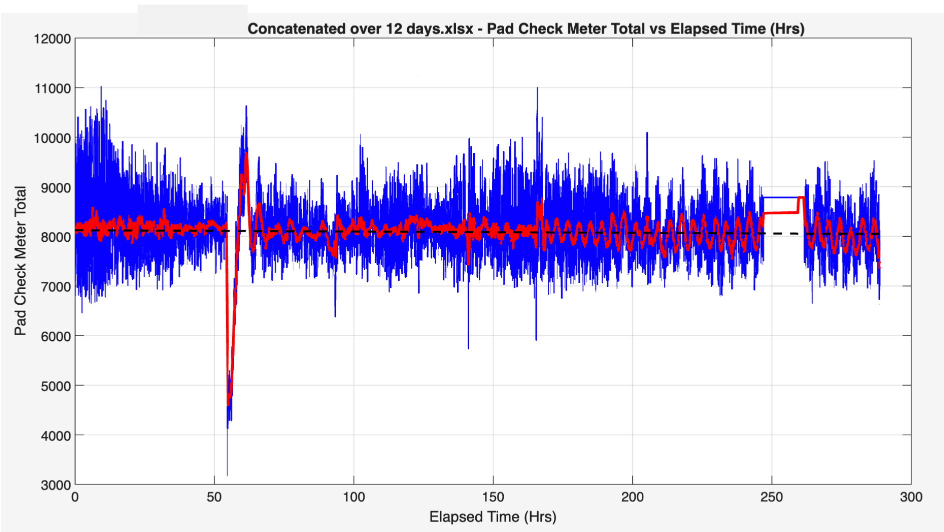


Figure 8 – Total Gas Produced Across all Wells (Blue) Hourly Moving Average (Red)

Note, the data in figure 7 includes production from a well not included in the optimization scheme. The period cycling from approx.160 hrs, is also being caused by this well.

Increase in Production (when there is deficient gas lift available)

Where gas lift is constrained i.e. the compressor cannot deliver enough gas lift to maximize production across all wells, then the ORTO™ optimization scheme is designed such that gas lift is made available from the well having the most excess gas lift at that given time. This is achieved by monitoring the gas lift supply pressure and if this supply pressure drops too low, then gas lift is reduced on the well operating the most above its calculated critical rate.

Over the analysis period, gas lift was readily available for all wells, as shown by the optimizers achieving a 44% reduction to meet all wells' needs. There is no indication however, that the configured ORTO™ agents would fail to optimise gas lift distribution if gas lift availability was constrained.

Ancillary Benefits

Reduced Process Variability

Reducing gas lift flow to each well improved well operational stability. As shown in figure 9, this resulted in a reduction of gas production variability (standard deviation around the mean), by ~40%.

This in turn may yield facility availability benefits as reduced variability should place reduced demands on safety systems and extend equipment life.

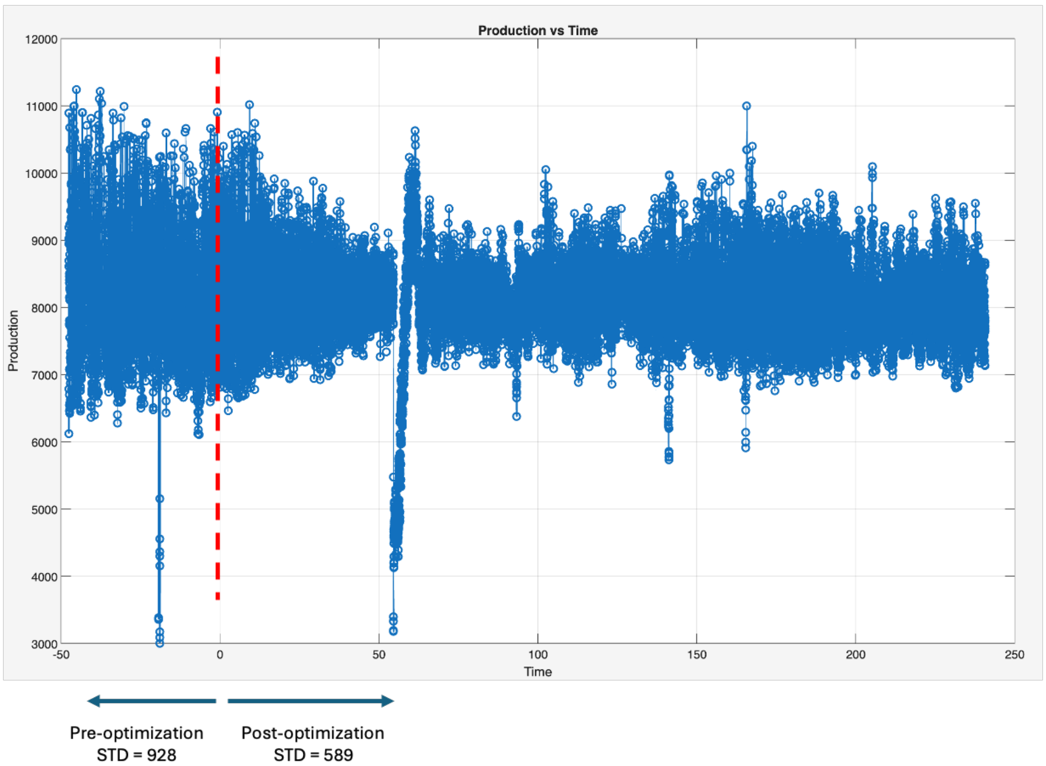


Figure 9 – Total Gas Production Pre and Post Optimizer Deployment

Possible CapEx Savings

Reducing gas lift requirements may result in reduced Capex spend, as associated equipment sizing can be reduced.

Benefits Summary

ORTOmation and the operating company collaborated to implement a self-learning closed loop gas lift optimizer successfully. The optimizer ran successfully, adjusting gas lift for several weeks and reduced gas lift usage by 44%, thereby reducing compressor OpEx costs by a similar amount.

Further savings may be achieved through greater facility uptime through stability improvements, and potential CapEx savings