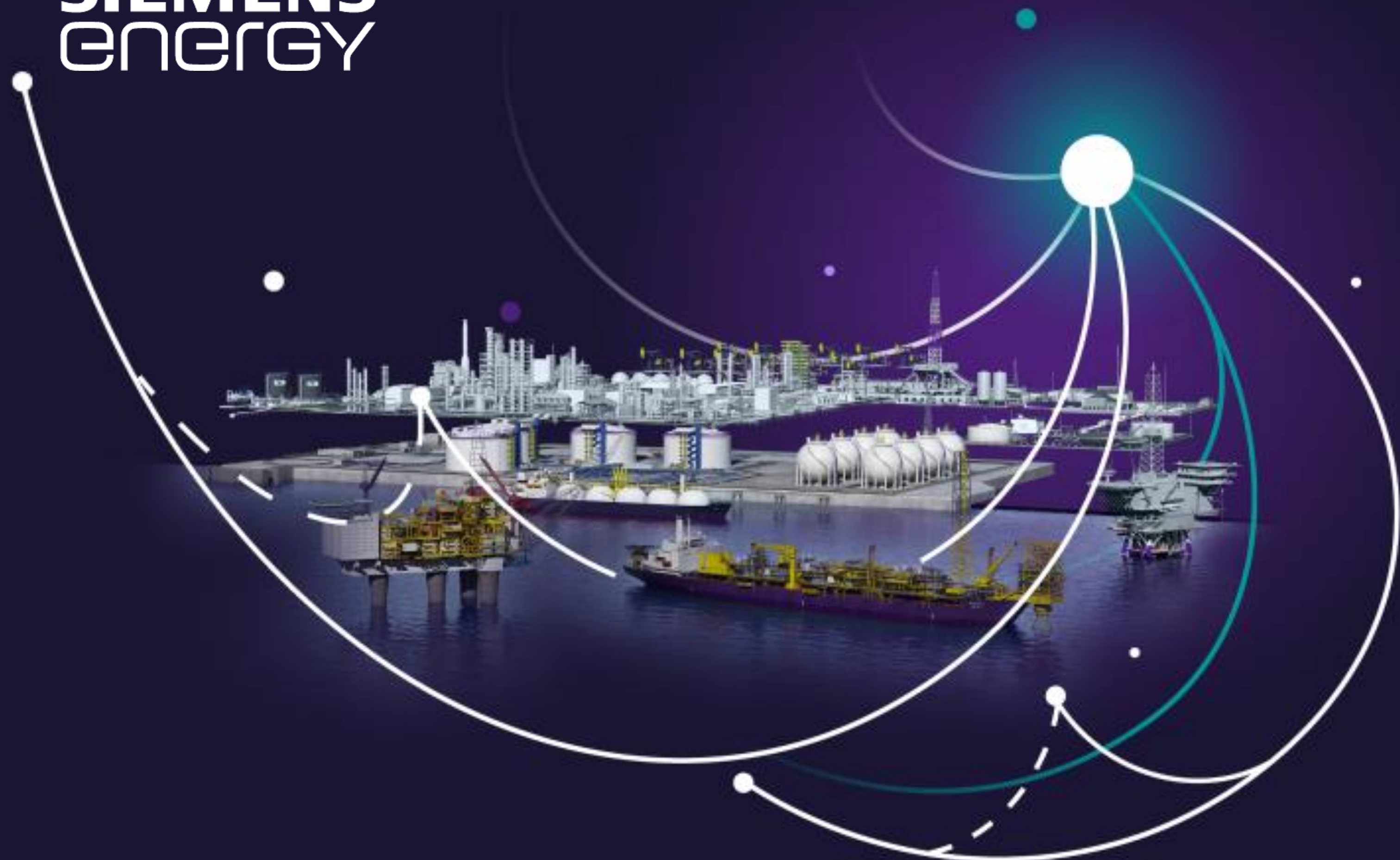

Digitalization Deployed: Enabling Real-time Production of a Gas-Lifted Field

In Canada, the implementation of Real-time Production Optimization (RTPO) enabled an operator to achieve full field optimization – increasing condensate production by 13% and reducing costs by $4.1 million USD annually.

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Introduction

In recent years, dynamic modeling and simulation has emerged as the least costly method of optimizing production operations. However, companies using simulators today face several challenges. Among these include the need to deploy separate models and offline workflows for various parts of the production value chain, including wells, gas-oil separator plants (GOSPs), electrical semisubmersible pumps (ESPs), etc.

Combining the results of these models can be a difficult undertaking that requires a great deal of manual intervention, time, and computing power. The results of one model often do not consider the constraints or outputs of the other, which means production engineers have to conduct numerous iteration runs to converge on optimal setpoints – a process that can take hours and even days for large, complex fields with multiple separators and associated equipment. The time delay associated with this approach makes closed-loop control infeasible because the setpoints generated do not reflect the current state of the well or field.

Additionally, with models generating a long list of control setpoints, field staff can be overwhelmed. In such cases, operators must manually prioritize which actions to take. But determining the right combination of actions to achieve KPIs is virtually impossible without automated prioritization based on impact.

The issue is often magnified when a field upset occurs, such as a process facility or compressor failure. Traditional sequential simulation solutions typically cannot perform optimization runs fast enough to determine what field changes are required to maintain high production levels while the condition is resolved. This is particularly the case with aging fields on artificial lift and large operations that include a wide array of new and old process equipment, gas lift compressors, sucker rod pump (SRPs), valves, complex piping networks, etc.

In 2018, Siemens Energy took a significant step toward addressing these problems with the release of Real-time Production Optimization (RTPO). RTPO is a "vendor-agnostic" equation-based modeling solution (delivered as-a-service) which enables whole field optimization -- from the sand face through central processing facilities to sale of the product.

In 2020, a Proof of Value (PoV) project with RTPO was initiated with a major Canadian operator on a gas lifted field (10 well pads, 135-150 wells). This paper discusses the motivation for the PoV and presents the results after a 12-month field test. Among the highlights of the project was a **13% increase in condensate production**. RTPO also demonstrated the potential for a **$4.1 million USD reduction in annual OpEx.**

RTPO Overview

RTPO differs from conventional sequential modeling tools used across the industry today in that it uses an equation-oriented optimizer based on Siemens PSE's gPROMS Oilfield software (PSE is a Siemens company).

Models are represented in the optimizer as a set of equations which are solved synchronously. The primary benefit of this approach is that it requires far less computing power and time to conduct optimization runs. Control setpoints in highly complex fields can be converged on within minutes as opposed to hours or even days. This provides several capabilities that are typically not available with sequential modeling simulations including:

- **Strategic optimization –** The unique equation-based approach made possible by the oilfield simulator provides the capability to optimize production based on multiple process constraints. Current field condition data such as well test results, flows, pressures, valve settings are fed into the model. The system then returns recommended setpoints that field operating staff can elect to implement. Any number of constraints can be entered into the optimization engine, giving operators and production engineers the ability to define a bespoke landscape for their optimization based on several KPIs related to production, process, economic, and environmental requirements.

- **Exploration of "what if" scenarios** – Operators can explore "what if" analysis scenarios, such as shutting in a group of wells, taking equipment down for maintenance, or changing constraints to see the impact on production

- **Real-time field upset** – In the event of an unplanned failure of critical equipment like a gas lift compressor, the equation-based modeler can be used to quickly re-optimize the field to minimize production losses until the upset condition is resolved.

- **Limited changes optimization –** In large fields with multiple separator plants, situations will inevitably arise when optimization requires numerous field changes. Perhaps to the point of overwhelming the operating staff. RTPO addresses this problem with a built-in function that can limit the number of setpoint changes. The optimizer prioritizes the selected changes based on their impact, thereby minimizing the need for operators' manual work.

- **Routing optimization –** With a single dynamic model, operators can optimize well and pipeline systems simultaneously. RTPO is able to handle not only continuous (e.g., ESP speed setting) but also discrete (routing and well status) decision variables -- a unique feature that is made possible because of the equation-oriented optimizer. Using discrete decisions, an optimum flow path can be identified within the framework of well dynamics, piping specifications, constraints of separators, etc. This capability reveals its true strengths in highly complex gathering networks, where millions of routing combinations are possible.

RTPO is offered as a full-service package and does not require an initial investment for deployment of the system (i.e., delivered 'as a service'). Recurring OPEX fees for the solution include all software and services for the duration of the contract. In this way, users pay for outcomes rather than for the technology itself.

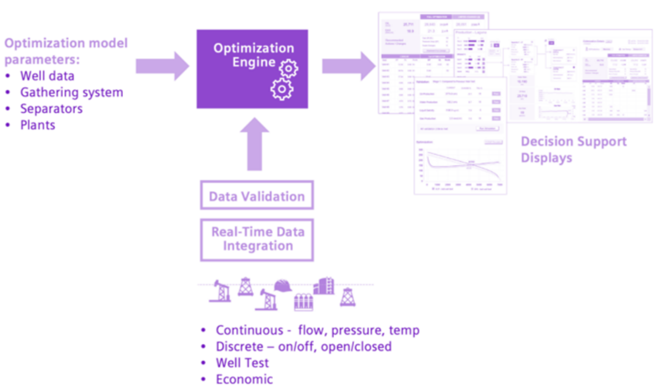

Figure 1: Overview of RTPO workstream

Implementation on a Gas Lifted Field

In 2020, Siemens Energy implemented RTPO as part of PoV project for a major Canadian operator on a gas lifted field in British Columbia.

The primary objective was to model and optimize the field, which initially consisted of 10 well pads and 134 wells and associated gathering lines. An additional 18 wells were added during the 12-month project (152 wells total).

Condensate production represents most of the operator's revenue in the field and gas lifting contributes heavily to operating costs. For this reason, maximization of condensate production and minimization of total gas lift rate were selected as the most important KPIs for the PoV.

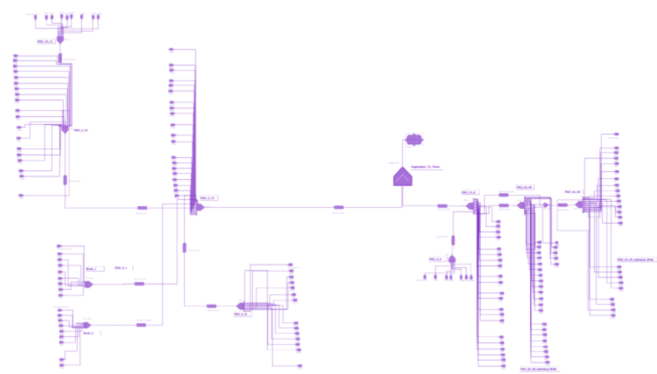

Figure 2: Example of RTPO model of a field representing wells and production network

Prior to RTPO's implementation, the operator was using several standalone software applications for optimization, including:

- A SCADA system for control of process and wells
- Hydraulic modelling software for the production network. The solution was not integrated with the existing IT/OT infrastructure. This required data input and output to be managed manually by a production engineer.
- Process simulator for the gas processing plant
- Well data management tool

Management of these applications to identify optimal field control inputs was a labor-intensive process that included the following steps:

1. Nomination of gas and condensate production (daily).
2. Definition of separator pressure.
3. Assessment of pressure drop in production network. An initial network flow (determine what pipes to switch on and off) according to production targets is defined. The network was checked on minimal velocity to avoid slug-ging. If necessary, the procedure needs to be repeated.
4. Define well pad flow to match nominations. For each pad, an estimated flow and pressure is determined. If necessary, the procedure needs to be repeated.
5. Individual well flow is generated as a result of well pad pressure. In addition, the desired well operation is defined (which wells flow, which wells to shut in, which wells to flow South etc.). If necessary, the procedure needs to be repeated.
6. Compressors, separator, gas treatment and gas lift are primarily controlled by the process control system. Fine-tuning of setpoints is done by operators.

In total, ~15 - 20 manhours were being spent weekly by production engineers and operators to complete the above tasks [1)]

POV Scope

The PoV consisted of implementing RTPO on the field and running it for a period of 12 months.

The IT architecture from RTPO is built according to a containerized or "Docker" structure. This supports fast development and flexibility. In this particular case, the solution delivered to the operator consisted of:

- Front end: A user interface (UI) which presents optimization results and allows for easy configuration of constraints/objectives, as well as exploration of "what if" scenarios
- Processing and analytics; including data cleansing and the gPROMS application
- Data storage component
- Connection to virtual machine (VM)
- Connection to all relevant existing data sources including process control (i.e., SCADA)

After data capture was secured, the process of aggregating, cleansing, and implementing handling logic for the data began. This is an extremely important task and is a prerequisite for "real time" generation of optimal setpoints. The initial setup took three weeks and subsequently eight weeks for fine-tuning to ensure a robust and accurate system.

After RTPO became operational, the operator was able to manually trigger optimization runs. The optimizer would return recommended setpoint changes to the oilfield operations team in under eight minutes. The team could then elect to implement the recommended changes.

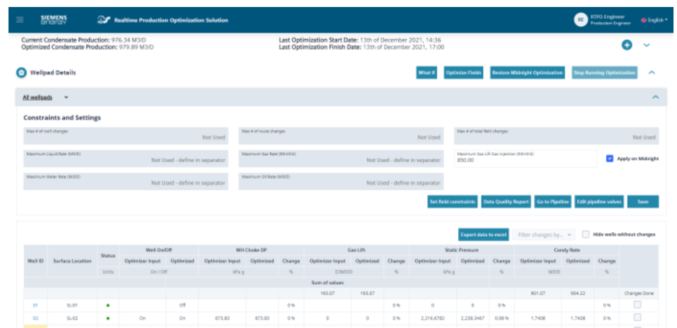

Figure 3: User interface showing results of a typical field optimization in RTPO

With RTPO, operators and engineers could also perform "what-if" runs. Example scenarios included (but were not limited to):

- Process plant constraint (gas, water, liquid, condensate) during planned maintenance
- Pressure-flow impact of new wells according to drilling campaign
- Potential addition of new pipelines
- Ability of wells to flow under different well head pressures

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1) Based on 1 upset every 2 months.
Managing an upset takes 16 hours across involved competences

Results

As with most unconventional wells, the operations team had to contend with two contradicting objectives: 1) maximize production of condensate, while at the same time 2) minimize back pressure for the wells. Previously, hydraulic modeling software was used to strike the right balance between these two constraints. However, it required significant manual effort.

This type of operational complexity can benefit from RTPO. The solution generates (at the push of a button) optimized settings for wells and the network in minutes by taking into account gas lift, minimal network velocity, and any other defined constraints.

Gas Lift System Optimization

Prior to the PoV, the operator had concerns about over-injecting and its associated costs (daily usage was from 0.6 million m3/day). To address the issue, remote terminal units (RTUs) were installed on each of the field's ~150 wells, each with a local gas lift control algorithm. The primary objective of the control logic was to keep the wells flowing slightly above their critical flow rate. This effectively solved the problem by cutting total injection volumes across the field by roughly half (saving $2.58 million USD in gas lift costs). However, it required operators to constantly fine-tune the algorithm manually, thus increasing labor costs and operational complexity.

During the PoV, it was discovered that the revenue-based (i.e., multi-objective) optimization functionality within RTPO could achieve a better result without the need for a control system upgrade or the addition of any new hardware or field instrumentation. Analyses showed that the implementation of RTPO alone would save $3.91 million USD per year in gas lift costs.

The better results can be explained by the fact that mild increases of lift gas (above critical velocity) make economic sense for some wells. RTPO takes into account the additional back pressure created by the lift gas in the whole network. In comparison to the current control system, RTPO showed it could produce gas lift cost savings of ~$1.33 million USD per year2. An additional $40,000 USD per year would also be saved by reducing the need for manual tuning/intervention[3].

"What-if" Scenario Analyses

The "what-if" feature of RTPO allowed production engineers to perform high-pressure (HP) analyses by defining a new flowing well head pressure. RTPO quickly indicates for all wells if the defined pressure will back out the well (i.e., no intersection IPR and VLP anymore). Engineers can also see the impact that a new HP well will have on mature low-pressure wells. The capability is especially useful for determining the optimal allocation of gas according to the drilling campaign.

Although it was not run, this same "what-if" analyses could be applied at the network level to see how increases in pressure at the well pad or separator impacts individual wells.

Well ID	Surface Location	Status	Well On/Off	Gas Lift	Well Head Pressure	Liquid Rate
			Optimized	Optimizer Input	Optimizer Input	Optimized
		Units	On / Off	E3M3/D	kPa g	M3/D
		Sum of values				
				253.85		
01	SL-01	●	Off			
02	SL-02	●	Off	0		
03	SL-03	●	Off			
04	SL-04	●	Off			
05	SL-05	●	Off	5.02		
06	SL-06	●	On	10.4	7,000	36.8733
07	SL-07	●	Off			
08	SL-08	●	On		7,000	36.1902
09	SL-09	●	On		7,000	13.1314
010	SL-010	●	Off			

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Figure 4: Results of a HP What-If analyses; only the blue marked wells will flow

2) Price condensate $320 USD per m3, price gas $33 USD per 1000m3/day, cost gas lift $24 USD per 1000m3/day
3) 8 hrs per week at production engineer hourly rate of $100 USD

The “what-if” feature was also used to optimize production in the field during potential upset scenarios.

Following a trip, wells are shut-in and a restart of production with a selection of “best” suitable wells is necessary. This well selection is currently an iterative process of picking the highest condensate producers according to the new temporary constraints, for example on water or gas. After implementation of chosen wells in the process control system, the selected wells ramp up production and results are evaluated. Often, a second and third round and third round of fine-tuning is necessary. During this iterative process the network must be checked in parallel on minimal velocities. Ensuring minimal network velocity is particularly challenging with reduced field capacity.

RTPO generates an optimized production upset regime within minutes. This enables a fast recovery of the plant and production. During the PoV, several upset scenarios were tested with constraints on reduced gas and water handling capacity of the facility.

As an example, using RTPO to evaluate a typical total gas flow restriction of maximum 1.4 million m3/day showed that a 13% increase in condensate production was possible when compared to manual optimization (644 vs. 571 m3/day) – equating to more than $115,000 USD/year [4)]

Conclusion

Upon completion of the PoV it was concluded that RTPO could provide significant value in comparison to the operator’s existing optimization strategy by:

1. Enabling quicker and more effective optimization
2. Reducing hours required for manual intervention
3. Eliminating licensing fees for several standalone software packages. The resulting monetary savings from these benefits are summarized in the table below:

Benefit	$USD per year
Gas lift optimization	3,910,000
Plant upset handling	115,000
Workflow optimization (reduction in man-hours)	75,000
Software redundancy (eliminating the need for separate modeling and simulation tools)	40,000
Safeguarding minimal network velocity (preventing slugging and corrosion)	Not quantified
Total value	**~$4.1 million USD**

[4)] Based on six days uplift of 60m3/day of condensate production. Price condensate $320 USD/m3

Additional RTPO use cases that were possible but not part of the PoV scope include:

- **Energy optimization** - RTPO can be expanded with a detailed model of the plant and compression station in order to create a real-time energy optimization platform. In such cases, the solution will be linked to real-time prices and forecasts of relevant parameters, such as electricity and ambient temperature. As an example, if there are extremely high ambient temperatures, RTPO could incorporate the degradation of equipment (e.g., coolers) into account during optimization runs.

- **Production planning** – The RTPO model can be expanded with future wells and network changes (i.e., addition of swinglines, compressors, parallel piping, etc.) according to the operator’s drilling campaign. Production engineers could use the platform to view the impact that these changes have on the existing network, thus streamlining production planning.

- **Nomination and trading** – RTPO can be used in conjunction with a sales application to take advantage of spot markets by routing gas and condensate to the most profitable markets. Balancing of daily nomination with actuals is also possible. In the event of imbalances, adjustments to compressor speed can be made to increase or decrease production.

Overall, the PoV project was a success. The operator (who is recognized within the industry as being best-in-class) was initially skeptical that software could deliver any measurable improvement to their operations. The implementation of RTPO changed that mindset. The positive results encouraged a full-scale deployment on the asset, along with others in both Canada and the US.

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