A Yokogawa Company

Key Steps for Delivering Autonomous Operations

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KEY TAKEAWAYS

- ✓ Operations optimization approaches are often executed in a siloed and uncoordinated manner.
- ✓ There remain many uncertainties in achieving optimal performance due to the lack of integration and a holistic view.
- ✓ Advanced process control (APC) and real-time optimization (RTO) are proven to provide operational excellence.
- ✓ A single application that combines APC and RTO leverages the leading first principle, nonlinear process models.
- ✓ The single application performs dynamic optimization across the entire plant in real time.
- ✓ Dynamic real-time optimization ensures that the facility responds continuously to disturbances and market conditions.

Part 1 The Journey to Autonomous Operations

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> *Achieving autonomous operations is primarily about empowering the plant to run, learn, adapt and thrive in tomorrow’s environment...*

Achieving autonomous operations is primarily about empowering the plant to run, learn, adapt and thrive in tomorrow’s environment; whatever that environment might be. All process plants are pursuing the goal of enhanced plant stability, control-ability and predictability and for some, the first step involves equipping a relatively large frontline workforce with a collection of best practices to operate and optimize the facilities, supported by first principle models. Others may be further along in their digitalization journey and have embraced higher levels of automation. These plants typically have a smaller frontline workforce operating and optimizing facilities through advice-based actions in open-loop or closed-loop control, with procedure automation.

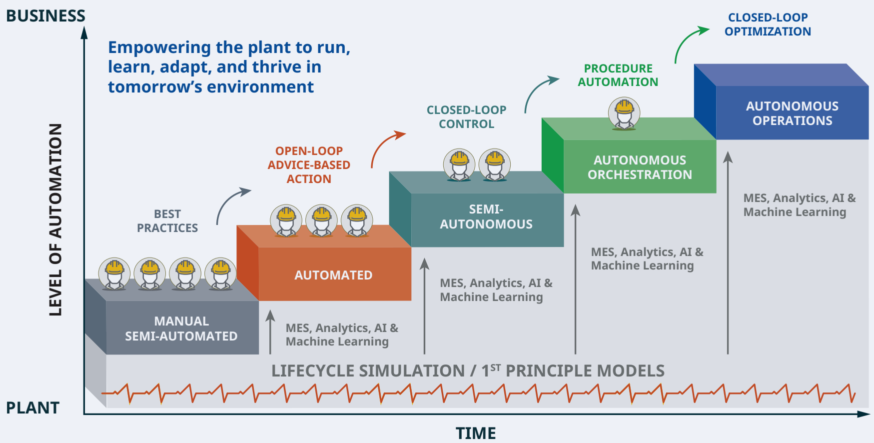


Figure 1 **–** Empowering the plant to run, learn, adapt and thrive in tomorrow’s environment.

Different parts of the Energy and Chemicals industry are further along in their journey than others. For example, discrete batch processes in specialty and fine chemicals have been able to advance faster than say, oil refining or liquefaction. Nonetheless, key to the progression towards autonomous operations is the implementation of manufacturing execution systems (MES), analytics, AI and machine learning technologies. Currently, advanced process control (APC) and real-time optimization (RTO) are proven in providing improved control-ability of plants and significantly contribute to the goals of operational excellence.

Part 2 Delivering the Operating Plan While Pursuing Autonomous Operations

Facilities need to be both operated (to maintain the status quo) and optimized (to improve). This is applicable across the fullstream:

- Aligning reservoir production potential vs facility capacity vs gas/oil ratio vs market demand
- Aligning LNG Annual Delivery Plan (ADP) obligations vs daily production volumes
- Aligning crude feedstock purchasing/volumes/quality vs processing constraints vs market demand
- Aligning petchem feedstock purchasing/volumes/quality vs processing constraints vs market demand

The problem with operations and optimization approaches undertaken to date across the industry is that they have typically been executed in a siloed and uncoordinated manner. This includes supply chain planning, production planning, production scheduling, process control, production accounting, and other business processes. The result is a collection of operations and optimization activities, all with limited scope, each with different objectives, often working against each other rather than being aligned. The outcome is uncertainty in achieving optimal performance due to the lack of a holistic view and integration. We can identify several factors that create this uncertainty (Figure 2).

FACTORS THAT CREATE UNCERTAINTY

Internal

- Poor estimation of non-linear effects
- Poor analysis that generates misleading insight
- Long workflows to exchange information
- Poor assessment and slow decision making
- Slow change tactic creation
- Plant upsets, slow-downs and other abnormal situations
- Maintenance of applications
- Limited scope
- Inability to adjust
- Slow execution

External

- Market dynamics
- Practical logistical constraints
- Weather

Figure 2 **–** Factors that Create Uncertainty

Part 3 The Vision

> “
> *The vision should be an entire facility or plant which continuously responds to market dynamics and live process conditions.*

The vision should be an entire facility or plant which continuously responds to market dynamics and live process conditions such as feed changes. This enables global optimization across the facility or plant on a minute-by-minute basis.

While the external factors are harder to control, there remains significant improvement potential when focusing on the internal factors. Over a shorter time horizon, internal opportunity areas include:

- Poor estimation of non-linear effects
- Maintenance of applications
- Limited scope
- Inability to adjust
- Slow execution

Each of the above opportunity areas can be addressed with the latest digital technology independently. However, to prevent the siloed situation as described above, then these must be considered together. The solution should calculate the optimal values for plant independent variables with a high level of accuracy using data through online connections to control systems and plant information management systems (PIMSs) and utilizing rigorous non-linear models to calculate additional inferred properties. Everything needs to be done quickly with the value chain boundaries and direction utilizing the most accurate data and equations where necessary.

In terms of applications, these should be completed by online runs of non-linear dynamic models every minute or using plant data from the DCS. These constitute the foundation of the dynamic real-time process optimization solution.

The scope of the dynamic real-time process optimization models should be greater than typical APC applications. The wider scope should encompass multiple process units or an entire facility/plant. These non-linear models should re-calculate the optimum dynamic changes to the independent variables every minute or so. In addition, the steady state gains should be updated by first principle process simulation when they differ significantly from the actual process. This can be achieved without re-initializing the controller.

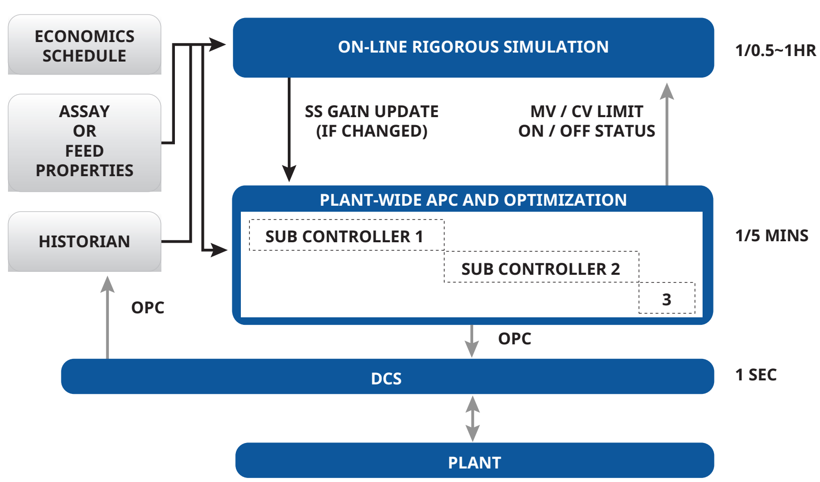
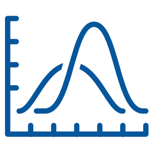


Figure 3 – Connected Applications

Part 4 Delivering the Vision

In 2015, Yokogawa released Platform for Advanced Process Control and Estimation (PACE). PACE is a new state-of-the-art multivariable model-based control technology, jointly developed by Yokogawa and Shell. In early 2019, KBC - A Yokogawa Company released the latest version of its rigorous steady state and dynamic fullstream process simulator, Petro-SIM®, which has been operationalized to consume real-time data for monitoring unit health and profitability. In 2019, Yokogawa merged the multivariable control technology of PACE with the non-linear process simulation technology of Petro-SIM to release a new Dynamic Real Time Optimizer, a solution in Yokogawa's OpreX™ Asset Operations and Optimization family.

Together, these applications are connected to the plant information management systems and are control system agnostic. It is this connectivity and combination of applications that addresses the aforementioned opportunity areas:

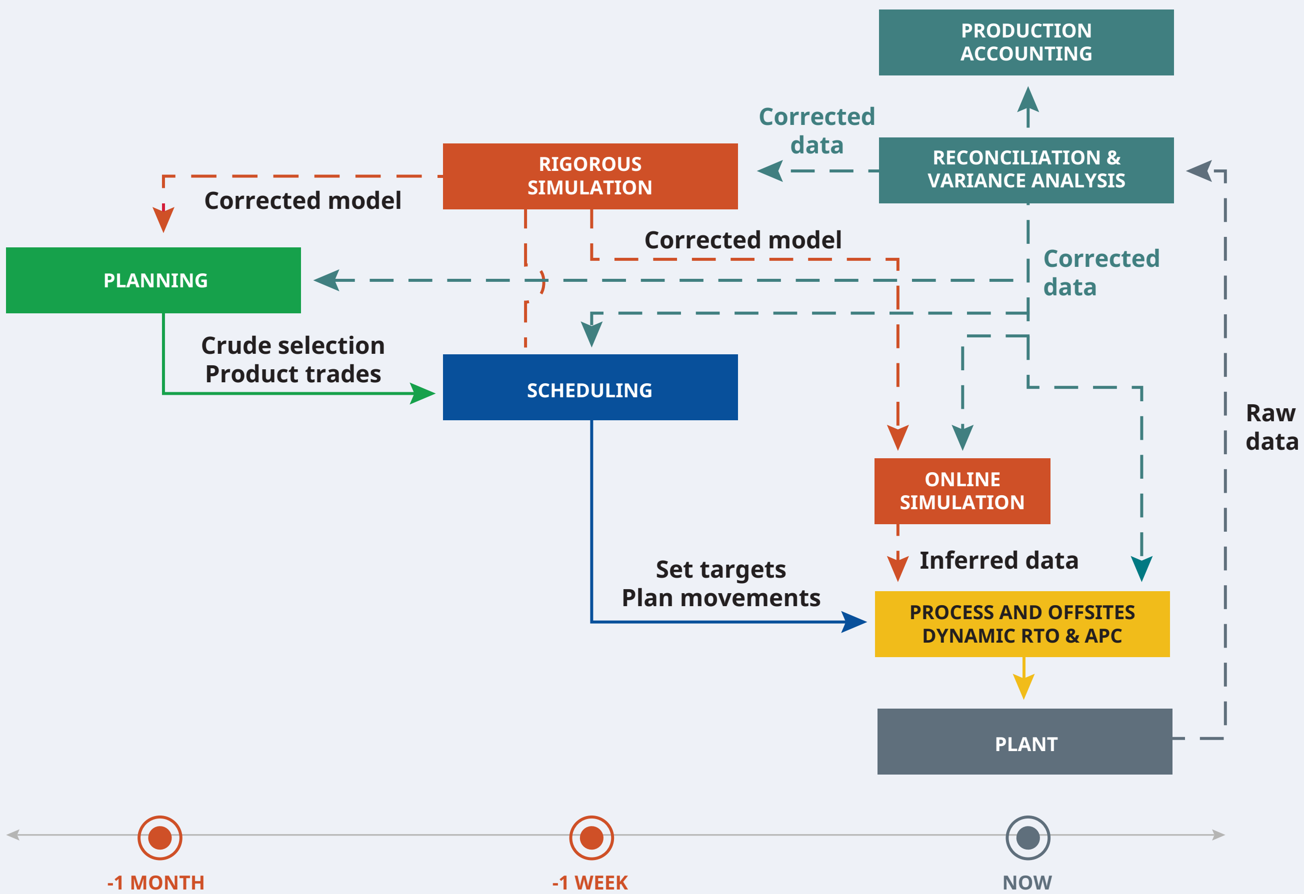


Poor Estimation of Non-linear Effects

Rigorous, non-linear facility-wide process simulation models are used today in planning and unit monitoring as a tried and tested means to generate inferential calculations (e.g. gas-oil ratios, separation efficiencies, furnace severity, catalyst degradation, catalyst circulation rate, distillation column tray loading). Connecting them online means that the outputs from these process simulation models can be used as inputs into the dynamic real-time process optimization, as extra targets and constraints.

Figure 4 – Planning, Scheduling, and Optimization Systems

Utilization of the business' rigorous simulation models that are used for the planning and supply chain can reduce the model update time. If the simulation is updated by expert users, a corrected model can be sent directly to the online simulation and the planning and scheduling systems all at the same time (Figure 4). This way the results and actions are consistent and reduce the time for manipulation before enactment.



Maintenance of Applications

Traditional real-time process optimization solutions have typically been implemented as an additional layer above the APC, which is itself a layer above the regulatory controls. This approach entails additional maintenance, integration, and usability challenges. However, dynamic process real-time optimization and APC can be achieved in a single layer, thereby addressing maintenance, integration, and usability challenges.

Limited Scope

Given the wide scope of process simulation models, dynamic real-time process optimization can accurately cover multiple process units such as a naphtha/isomerization/reformer/aromatics complex, residue hydrotreating and cracking complex, an entire ethylene plant, or an entire LNG facility.

For example, dynamic real-time process optimization can be used to optimize a complete ethylene plant including all the cracking furnaces and the recovery section. This provides the capability to maximize production (i.e. feed flow to the furnaces) up to constraints in the recovery section. As well as to shift selectivity between C_2 and C_3 olefins on a minute by minute basis to alleviate constraints in the refrigeration or a distillation column.

Not Adjusting to the New Envelope

The performance of advanced control and optimization systems tends to degrade over time due to changes in operating conditions, catalyst activity changes, and the aging of facilities. Matching the models often means downtime of applications and a period away from the operational optimum. Step tests to validate the new envelope can now be done automatically and online. Auto-Step, PACE’s automated step testing functionality, is embedded in the controller. The objective of Auto-Step is to provide an effective way to generate test data to re-estimate the controller internal model accurately. It is useful for a first application implementation and to maintain the reliability of APC models over the years with reduced engineering effort.

Slow Execution

One of the typical challenges in implementing APC is the often-complex integration process between APC and DCS. The PACE development team placed a large emphasis on eliminating this risk. The platform allows easy configuration of APC-DCS communication infrastructure according to DCS type with users selecting DCS company/type and required point extensions created automatically. This feature provides fast implementation to DCS and shortens the online commissioning period.

Connecting all applications online with access to real time data allows rapid execution, that leads to fast automated optimum control. This short-cuts the slow, often labor-intensive route, of variance analysis, model update and workflow validation. The online portion runs as robust technology enabled with closed loop, automated data, calculation and implementation. All these elements reduce the short-term uncertainty factors.

This automated step is connected with planning and scheduling optimization models that can, in a digital future, invoke machine learning and/or cognitive computing functions, using live data, to deliver step changes in optimization. AI application, coupled with intelligent, automated work processes can identify data driven optimization opportunities, that are executed with corrected models adjusting the controller’s operating envelope.

Part 5 Conclusion

The combination of Petro-SIM and PACE for dynamic real-time optimization ensures that the facility continuously responds to market signals and disturbances, on a few minutes' basis. The outcome is a fast automated response to dynamically changing plant and market conditions. Advanced control system optimization of the operation is in real time and based on the actual changes in raw material properties, product demand, and operating conditions.

The single application leverages the leading first principle non-linear process models to update the dynamic real-time process optimization gains and provide inferential calculations. The value addition is significant and provides a robust building block on which to build further in the pursuit of autonomous operations.

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