WHITEPAPER

Building a process Digital Twin for your plant with Unified Lifecycle Simulation

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Executive summary

Since the 1970s, process simulators have become an invaluable tool for designing and operating process plants. The new normal in the oil industry, the continuous need to innovate chemical industry and energy alternatives, is driving a need for a new approach. Any new process simulation platform must support the entire plant lifecycle in one single environment; it must be open enough to be extendable while enticing the next generation of engineers.

Process simulation today

Process simulators are irreplaceable tools for every process engineer. Since the nineteen seventies, process simulators have found widespread adoption within operating companies in oil & gas, refining and chemical industries, as well as the engineering companies and equipment manufacturers that service these industries. The tools available in the market today have incrementally improved over the years to provide more features and functionality. However, they trace their origins to legacy architectures, operating systems and aftermarket user interfaces, which create inherent limitations:

- They cannot support the full plant lifecycle as they are limited by their single-purpose architecture such as steady state process simulation, dynamic simulation, optimization, or flow network analysis for which they were originally designed
- Extending their functionality can be performed by a very small number of software developers with chemical engineering knowledge, software programming skills, and/or knowledge of that particular specialized program
- They are often based on decades old programming code that cannot leverage the more recent technological developments within the software industry

Global competition, pricing pressure and energy alternatives are now driving the need for a new approach. The oil & gas industry has seen high volatility and the lower price level of today is seen as the “new normal”. The chemicals industry has a continuous need to innovate for greater agility and lower costs.

The next generation of workers also expects a modern, scalable and easy to use solution with technology they now take for granted – high speed internet access, mobile devices, touch screens and virtual reality. New concepts like the Industrial Internet of Things (IIoT), Industry 4.0, and Artificial Intelligence have created greater opportunities with a new next generation platform that provides a “Digital Twin” of the plant through the process lifecycle that cannot be provided with today’s tools.

Unified Lifecycle Simulation

Today's simulators typically only support a single phase of the lifecycle and are often based on thermodynamics of different simulation vendors and different calculation methods. This not only leads to lack of trust in the results, but causes substantial rework by having to build a new simulation model in each new tool. And the results are hard to compare.

Unified Lifecycle Simulation means that one process model is extended throughout the entire lifecycle of the plant, from concept through to operations. This requires a process design mode, a fluid flow/rating mode and a dynamic mode, in combination with the ability to toggle back and forth between modes. Optimization may be provided to any mode. Table 1 describes each phase of the project lifecycle, and how a maturing Digital Twin develops and provides benefits for each phase.

Lifecycle Phase	Model	Benefits
Conceptual Engineering	The Digital Twin of a process plant is "first born"	• Fast evaluation of design alternatives due to continuously solved and flexible specifications • A native cloud application that protects IP to reduce IT costs • Open modeling for first-of-a-kind processes and equipment
Front End Engineering and Design (FEED)	The Digital Twin grows to represent all plant process equipment	• One product with one learning curve for multiple applications, such as process, process utilities, and relief and flare • Integrated Asset Modeling of interacting but separate systems, such as, an oil field gathering and topsides processing, or the process and its flare system • Automated population of an engineering database • Automated creation of FEED engineering deliverables • Multi-user collaboration of a single simulation
Detailed Engineering	Simulation-Driven Engineering: The Digital Twin grows to also represent the mechanical design and the control strategy	• Other disciplines, such as controls, mechanical, piping, all contribute to the engineering database • Simulation takes information from the engineering database to test the Digital Twin continuously as it is designed • Process engineering trends towards new agile software engineering practices with a test-driven development now made possible because of the existence of the Digital Twin
Startup and Commissioning	The Digital Twin is used for Operator Training and Controls Checkout	• The actual DCS logic can be integrated to the Digital Twin • Operators are trained without a separate operator training simulator investment
Operations	The Digital Twin is a master simulation model for process improvement, equipment monitoring, optimization, and more	• One master Digital Twin model can be spawned to many applications, such as, training, equipment monitoring, and real time optimization to reduce the sustainment costs associated with separate point solutions • No longer need to maintain several process simulation models for a plant – design model, operator training simulator (OTS) model, unit performance monitoring and real-time optimization (RTO)

Table 1: How a maturing Digital Twin develops and provides benefits for each phase.

Extendability and open environment

A next generation process simulation platform should allow for the design of new processes and first of a kind plants, not limit the user to the processes and equipment envisioned by the simulator vendor. The end user should have the ability to extend the process model, if desired, within an intuitive open model writing environment. This will allow you to:

- Expand problem solving capabilities. For example, many of today's specialized problems are handled by a specialized tool (that is infrequently used) or in Microsoft Excel which is user error prone
- Enable simulation of equipment for which standard simulation models are not appropriate, especially for dynamic simulation where equipment geometry may make a significant impact on the transient results
- Protect proprietary intellectual property (IP) to be incorporated directly or through external DLLs
- Leverage 3rd party applications where desired

Millennials coming

A new generation of workers that has grown up with the Internet is entering the workforce. Millennials expect immediate feedback and they will not accept user interfaces that hold them up or prevent a mobile lifestyle. New entrants will need guidance to check results for plausibility.

Ease of use needs to be radically rethought

New requirements arise for process simulators, including:

- A high level of rigor for the power user and enabling new engineers to benefit from experienced engineers
- A highly responsive and interactive graphical user interface, attractive to millennials
- A continuously-solved engine producing immediate results for optimized designs
- Flexible specifications
- Undo / redo ability where mistakes do not lead to lost work

Leveraging modern IT developments

A new simulation infrastructure must provide:

- Faster calculation speed, enabled through parallel computing
- Programs built to run in the cloud accessible from any networked device

Collaboration

Collaboration is particularly important to this generation

- Programs must enable collaboration between engineering departments and companies. Integrated companies that handle the entire plant lifecycle within their own organization especially benefit
- Provide opportunities for completely new work processes

Agile process design with the Digital Twin

Simulation-Driven Engineering provides an automated design test vehicle

In another engineering discipline, software engineering, work practices have changed significantly over the last 15 years. Previous software development followed a "waterfall" process of design specifications, component development, integration, in a sequential process with exit stage gates similar to the process engineering lifecycle stages. Now, software engineers embrace a new work process known as agile software development with test-driven development at its core.

Agile development plans small amounts of work with continuous integrated testing to reduce development cost while eliminating surprises at the end of the project. But, as plants are made of steel and concrete it is not easy to test a process design until it is procured, constructed, and started, at which time it is too late. Accordingly, engineering companies have numerous design reviews and use simulation as appropriate in dedicated studies to ensure design.

Next generation simulation software must allow process facilities engineering to move towards agile software development concepts using the Digital Twin during the design of the process plant. This First Born Digital Twin during design provides an opportunity to test new design and to continuously check inconsistencies at minimum cost.

For example, a process engineer of the future needs to design the emergency depressuring system for an offshore system. The engineer specifies a dynamic simulation from the engineering database. The valve C_v, and equipment volumes are taken from the engineering database. The engineer confirms the valve C_vs, that the depressuring time meets requirements, and that the temperatures are not too cold for the metallurgy. The emergency controls are integrated so that the volume between isolation valves is used for the calculation. Instead of doing this one time, the test is automated to confirm that the design continues to be adequate as the plant is further designed. Future changes to vessel size, control size, valve C_v will create a warning to the engineer. This depressuring test is one of hundreds of similar design tests necessary to prove the plant can start, operate, and shutdown properly given its feedstock, equipment design, and control design, as specified by the owner operator, and process, mechanical, and control engineers.

When the design basis changes due to unforeseen market events–for example, due to a new crude being selected–the impact of the change is known in hours through possibly failing tests, not through months of engineering rework.

Digital Twin model of a process plant

During operations, the Digital Twin used during design can evolve into a master model for:

- Controls checkout
- Operator training (OTS)
- Unit performance monitoring
- Real time optimization (RTO)
- Look ahead modeling
- Dynamic optimization

A single master simulation model can be leveraged to significantly reduce both financial and time investments. Today, each activity (in Figure 1) in an operating plant is an individual point solution. Although each item is justified by itself, plants sometimes do not sustain them adequately and they quickly become out of date. With a new platform, simulations for each of these applications can be spawned from the same master simulation. The availability of increasingly detailed process information can be used to compare the real plant status against the simulation model in a sense of unit performance monitoring and real time optimization.

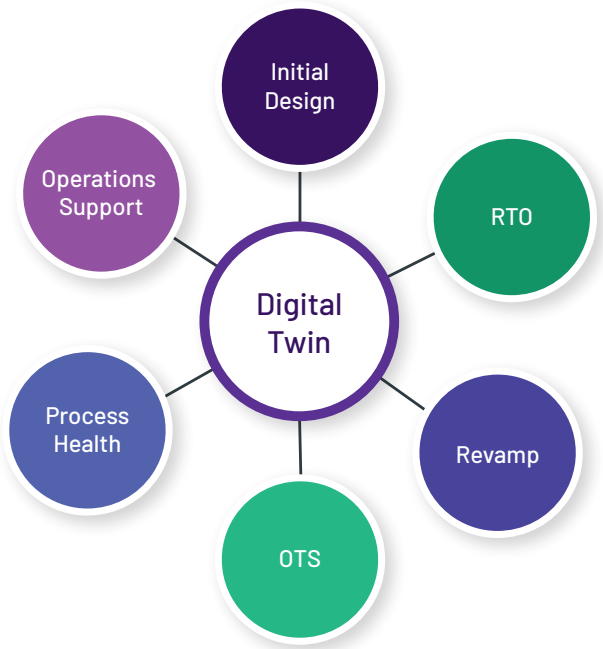

Figure 1: Applications of a Digital Twin process model during the lifecycle of a plant

AVEVA™ Process Simulation

AVEVA Process Simulation is the next generation process simulation platform, developed from the ground up, leveraging 50 years of process simulation experience by AVEVA. It provides these outstanding functionalities to become the Digital Twin during design and operations.

Unified Lifecycle Engineering

- First industrial simulation platform developed from the ground up
- Supports Steady State, Fluid Flow and Dynamic modeling.
- Interoperating libraries for Process Utilities, Flares, Oil Field Gathering Networks, and Process Plants
- Integrated asset modeling on one platform such as Process and Utilities, or oilfield gathering network and topsides processing
- Models are developed in a single environment for unified lifecycle support

Agile process development

- Changes the engineering workflow by promoting collaboration
- Enables user to work concurrently on the same model across departments, regional time zones, and between Engineering Procurement and Construction organizations
- Open model writing environment that allows the simulation of custom and proprietary models
- Will be integrated with engineering databases and control system emulation tools as engineering companies adopt simulation-driven engineering

Enabling the next generation

- Embraces modern software structure
- Intuitive user interface
- Reduces learning curve by replacing multiple point solutions with one unified platform

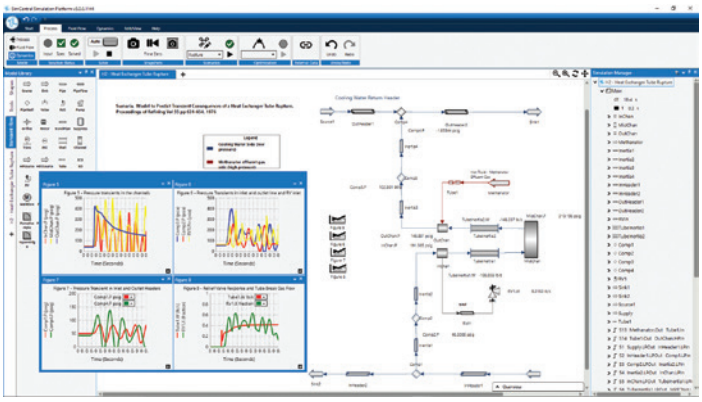

Figure 2: AVEVA Process Simulation user interface with Process, Fluid Flow and Dynamic modes, the Process library opened up and showing a dynamic trend while in process mode. A snapshot manager helps manage scenarios.

Best practice workflows

For the adoption of AVEVA Process Simulation (formerly SimCentral), the value-driven adoption process may be prioritized differently by each customer. While the ultimate goal is to fully leverage the Unified Lifecycle Simulation platform, opportunities for early adoption initially exist in:

Single-purpose (point) solution consolidation

Today, point solutions often exist in the form of specialized programs, proprietary in-house developed code, Microsoft Excel spreadsheets, and specialized custom solutions, that are all fit for a single purpose. All these tools can be consolidated using the Open Model Writing capability of AVEVA Process Simulation, providing an opportunity to reduce the number of tools and suppliers used. As well, users no longer need to adapt to many different user interfaces or rely on a small group of engineers trained on a specialized program.

Leveraging Unified Lifecycle Simulation for new process developments

AVEVA Process Simulation will drive increased process operability, better and easier modeling of steady state situations, higher process stability via better modeling of dynamic situations, better collaboration between modeling experts and control experts by early understanding of process controllability, and new insights into utility systems by network simulation.

Migration

The adoption of AVEVA Process Simulation, and the migration from existing AVEVA tools and alternative suppliers will be a gradual, value-driven process. As a rule of thumb, AVEVA will provide tools that help migration enabling a smooth migration path within one year after the capability becomes available. Migration from competitive packages will be based on customer requests. AVEVA's flagship products have strong, long-term roadmaps that will continue to see strong investment for at least a decade.

Benefits

AVEVA Process Simulation was first commercialized in March 2017 with an initial release for Process Utilities. Here is some anecdotal evidence from EPCs already available in the brief time it has been available.

One Global EPC has publically stated at the 2017 AVEVA User Conference (for a cooling water revamp project at a North American refinery) that if a customer asked "what if we completely remove this area or switch this equipment?" Previously, we had to say "give us two weeks." In AVEVA Process Simulation, with a simulation up and running, we can say "give me two hours." They also stated that the "learning curve is not steep, even for engineers who have no prior experience using process simulators."

Hyundai Engineering Co. said "We chose AVEVA Process Simulation after seeing how quickly and efficiently complex processes could now be modeled." Simulating how to best design, engineer and build vacuum transfer lines can be challenging given their high velocity and two phase flow, which can lead to poor separation in the vacuum tower that it feeds. The value AVEVA Process Simulation brings is the ability to quickly handle and avoid critical velocities, helping process engineers to find the right design, faster. Conventional simulation tools fall short with longer procedures, adding time and cost to these simulation exercises.

In workshops with **chemical companies,** the following AVEVA Process Simulation benefits were noted:

- Improved process operation, startup procedures, and relief system safety through unified dynamic simulation
- Better collaboration between modeling and control experts by early understanding of process controllability through unified dynamic simulation
- Debottlenecked process utility systems by fluid flow network simulation
- Better allocation of expert engineering resources through the use of the same tool set with an easier learning curve
- Delivery of models for OTS systems for demographic changes in plant staff causing personnel shortages
- Integration with cost estimation tools
- 50% reduction in simulation effort across the plant lifecycle
- Value in having a single tool to support Process Design, OTS and equipment performance monitoring
- By adopting early, partner companies have a high influence on AVEVA development plans that suit their business
- AVEVA Process Simulation is a really modern solution compared with tools in the market

Although premature, AVEVA Process Simulation is the ideal environment to fulfill the vision of Integrated Asset Modelling (IAM) in the upstream segment. Previously, benefits from IAM represent a 2 - 7% increase in production from existing fields. There are inherent advantages when well, network, and processing facility simulations can be handled in one equation-oriented environment. Today's approaches are typically not robust and sustainable because several tools need to be knitted together.

It is easy to extrapolate benefits to many other industries and applications, such as power generation and distribution (conventional and renewable), sea-water desalination, waste water treatment, and many more.

Conclusion

Lifecycle process simulation has been a vision for process simulation providers and their customers for a long time. Today's simulators cannot leverage the rapid developments occurring in the software industry due to legacy architecture. The next generation Unified Lifecycle Simulation platform AVEVA Process Simulation is a brand new offering in the market. Being built from the ground up, it offers many advantages as this paper has outlined.

To see how companies are already embracing AVEVA Process Simulation, watch our video on Covestro's reasons for switching:
sw.aveva.com/videos/covestro-optimizes-process-simulation-for-digital-twin

Resources

- AVEVA Process Simulation web pages on AVEVA Software
  aveva.com/discover-simcentral-simulation-platform
- AVEVA Process Simulation 3min overview video
  www.youtube.com/watch?v=1WEAKDTw3C4
- WorleyParsons press release
  www.aveva.com/en/Resources/News_Centre/Press_Releases
- Hyundai press release
  www.aveva.com/en/Resources/News_Centre/Press_Releases
- Collaborative Engineering whitepaper by ARC
  (available upon request)

About the author

Dr. Ian Willetts is the Vice President, Process and Simulation at AVEVA. He is responsible for the global management of the Design, Simulation and Training business within AVEVA including R&D, Product Management, Services and all other aspects of the business. Ian has thirty years experience applying process simulation and optimization solutions in the process industries. Ian is an established industry thought leader who has published dozens of articles in industry leading publications over the years. Ian graduated from Oxford University in the United Kingdom with a PhD in Engineering Science and recently returned after many years to complete his MBA at the Said Business School, Oxford University.

Cal Depew is the Product Director for AVEVA Process Simulation, AVEVA's next generation AVEVA simulation product. Previously, Cal was the dynamic simulation product director. He designed the process models for a first principles dynamic process simulator for engineering studies and operator training simulators. He was senior project manager for a 700 MW coal-fired power operator training simulator. Prior to joining AVEVA, Mr. Depew led Fluor's dynamic simulation group where he conducted over seventy studies which pioneered new applications for dynamic simulation for process engineering. He has a Chemical Engineering degree from the University of California at Berkeley.