# Digitally Transforming Offshore Oil and Gas Production with Topsides 4.0

Oil and gas may have been slow to realize the potential of IoT and digital transformation; however, in recent years as the industry has been forced to find new ways of improving profit margins in the face of sustained low prices, operators are quickly catching up. This is particularly true in the offshore sector, where an increasing number of producers are leveraging digitalization to help reduce breakeven prices and ensure profitability in a future defined by market volatility.

Despite the positive momentum, there are still significant opportunities for the industry to advance further along the digital transformation maturity curve by adopting a more holistic digital lifecycle approach to offshore production assets.

Today, most operators are incorporating digital technologies as part of a peripheral strategy, where solutions are unsystematically implemented (often at the plant level) and have little if any impact on operating or business models. In most cases, digital capabilities are simply “bolted on top” of equipment and facility systems after they have been installed rather than being integrated from the earliest phases of the project timeline.

While this approach has enabled many companies to achieve marginal efficiency gains, it largely fails to address the looming challenges the offshore industry faces, such as high capital and operating costs, and long cycle times. Failure to integrate digital capabilities early in the design/conceptual phase of a project also negatively impacts cybersecurity, making it more difficult to protect operational technology (OT) assets when the facility is in operation.

Digital solutions providers and original equipment manufacturers (OEMs) bear some of the blame for the current situation. For years, offshore producers had virtually no choice but to adopt digital solutions in piecemeal fashion because a more holistic approach did not exist. Siemens recognized this problem and set out to change the status quo by combining its deep expertise in digitalization, automation, and rotating equipment to develop Topsides 4.0 – the industry’s first fully integrated digital lifecycle solution for offshore oil and gas production.

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## What is Topsides 4.0?

When it comes to offshore installations, including floating, production, storage, and offloading (FPSO) vessels, the topsides packages that stand the most to gain from digitalization are rotating equipment and electrical, instrumentation and control systems. Topsides 4.0 is an integrated digital approach that focuses on supporting these packages throughout the entire project lifecycle – from concept and design into operation.

The approach focuses on applying digital technologies to reduce capital and operating expenses, shorten project development cycles, minimize interfacing risk, decrease offshore manning requirements, and ensure stable production throughout the life of the plant. This is achieved by enabling advanced capabilities, such as enhanced design, testing, manufacturing, and lifecycle maintenance through advanced virtualization (i.e., creation of an intelligent digital twin); remote monitoring and pre-emptive maintenance of mission-critical equipment; and cybersecurity.

The digital twin is a software model that not only mirrors the status and working condition of the offshore asset in near real-time, but also behaves like its real-world counterpart. In doing so, it gives operators the ability to perform design and testing in a risk-free environment and serves as an invaluable tool for lifecycle decision-making support and asset optimization.

With Topsides 4.0, an intelligent digital twin is constructed in parallel to the physical topsides during the design and build phases of the project. The digital twin then evolves with the facility as it moves through commissioning and eventually into operation.

The digital twin provides operators with the capability to run virtual what-if scenarios on the asset and better understand the impact of different operating conditions on the process, equipment, and maintenance. Its intelligence derives from the capability to interpret raw data through a variety of analytics, some of which are automated and others that are offered as an OEM service. The automated analytics are independent of equipment vendor and based on a statistical analysis of real-time data from the instrumentation and automation system. For critical equipment like compressors and turbines, Siemens supplements this layer of monitoring with OEM-connected services for predictive diagnostics, spare parts management, and outage planning.

## Harnessing the Power of the Digital Twin

Every offshore production facility is characterized by cumulative data evolution. Massive quantities of asset data are generated throughout all phases of the project lifecycle. The problem that many operators face is that this data is spread over a multitude of software applications, databases, and paper files throughout the enterprise and at the site. As a result, the information available to decision-makers is often inaccurate, out-of-date, incomplete, inconsistent, and poorly synchronized.

The digital twin in Topsides 4.0 solves this problem by bringing together process and plant engineering, physical layout modeling, project and construction planning, maintenance, and asset performance modeling. It also supports federating data from underlying sources to eliminate data duplication.

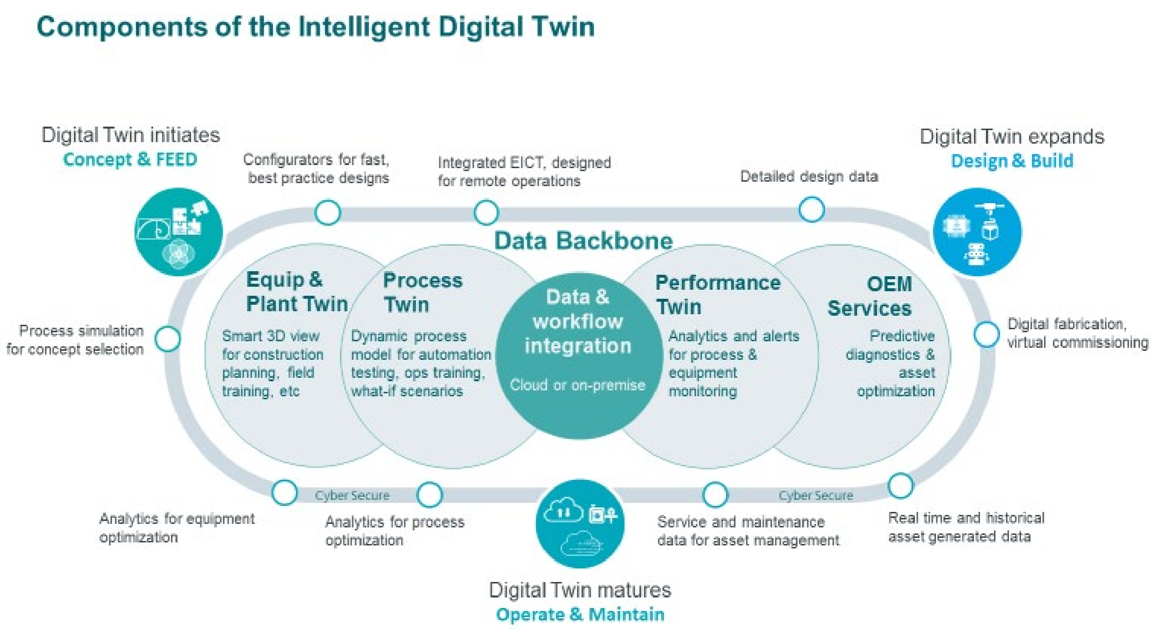


**Figure 1. Intelligent digital twin structure.**

The entire project lifecycle benefits from the digital twin, starting at its inception during the customer's concept development process. The model progressively matures into an as-is digital representation of the physical asset that provides operators with insight into the lifecycle performance of their assets.

**Key deliverables of the Topsides 4.0 intelligent digital twin include:**

1) **Integrated Digital Backbone**

   Topsides 4.0 begins during the conceptual phase of a project with the deployment of a comprehensive digital data hub (i.e., digital backbone). It is during this time that Siemens evaluates how the operator is using data, where the gaps are, and how best to fill them. With that knowledge, Siemens collaborates with the operator and tailors a specific solution.

   The digital backbone ensures data persistence and underpins the intelligent digital twin throughout the lifecycle of the asset by allowing engineering and maintenance contractors, along with equipment and other providers, to share the as-built and as-maintained data image of the offshore plant. Instead of delivering and attempting to maintain hard copy documentation, the different stakeholders deliver data records. This creates complete transparency of information for each plant object and optimizes the design process by:

   - Providing engineers with direct access to information changed by colleagues in other disciplines, which leads to an increase in the degree of parallel engineering, improved design quality, and a reduction in the time required to reach operational readiness.
   - Reducing engineers' time to enter and find information. The documentation provided at handover is an up-to-date 'as-built' asset database, that, when maintained, becomes the 'as-maintained' database.
   - Ensuring that the regulatory obligation of up-to-date plant documentation is always fulfilled.
   - Enabling quicker and more informed decision-making. In urgent situations, intelligent decisions can be made based on up-to-date plant information, thus reducing operational risks.

2) **Plant Twin: A Smart 3D Viewer for the Facility/Asset**

   The plant twin is a smart 3D viewer for the entire topsides that provides virtual access to equipment, maintenance, and real-time operations data for construction, commissioning, and maintenance planning. It provides a realistic viewer for very large 3D models, with fast navigation for non-specialists, such as operations or maintenance personnel.

   The plant twin enables back and forth navigation between the 3D representation and the 2D drawings in the digital backbone. For example, maintenance personnel on the platform can view in a 3D digital space where equipment is located and if it is accessible. Using the virtual environment, operators can directly access equipment characteristics, maintenance history and documentation by clicking through to engineering and maintenance data from the equipment in the 3D view. Similarly, if an engineer was working with 2D engineering and maintenance data, he/she can click through to the 3D view of the equipment and see the spatial context of, for example, locations where work permits are issued.

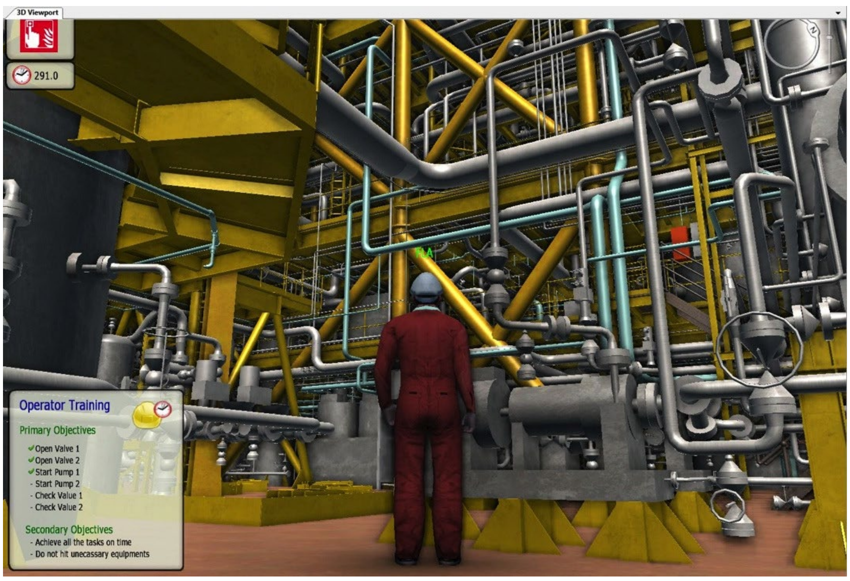


**Figure 2. Plant twin (i.e., Smart 3D-viewer).**

**3) Process Twin: A Dynamic Model of Operational Behavior**

The process twin is a dynamic model that mirrors the operational behavior of the entire topsides. The objective of the dynamic model is to realistically replicate the process and equipment behaviors of assets in the digital world. It also serves as a digital replica of the process and automation system and permits testing of the process and control infrastructure, safety logic, and operating procedures before the asset has been started-up.

This type of dynamic process simulation delivers benefits, from simple I/O and signal testing, to logic and functional testing, to dynamic process simulation for verification management, optimization, and training. It has been widely used over the past two decades in the downstream and petrochemical industries and has proved to be particularly beneficial for greenfield offshore facilities, where it serves as a key tool in reducing start-up risk.

**4) Performance Twin: Monitoring and Analytic Solutions**

The performance twin visualizes the performance of the topsides packages against key performance indicators (KPIs) specified by the operator. The performance twin comprises a range of potential applications, including artificial intelligence- (AI) and machine learning- (ML) based algorithms, which run analytics on equipment and on process performance to predict failures and optimize operations.

The primary objective is to provide operators with an early-warning system that can better predict degrading performance and provide insights into changes and conditions. With these insights, personnel can make more informed decisions about how to best manage equipment issues to minimize non-productive time (NPT), for instance, by taking immediate corrective action or alternatively managing the issue via specific operational interventions until the next planned shutdown.

Condition monitoring analytics detect abnormalities in operation – either in the form of an increasing (or decreasing) trend or drift from a normal operating condition. This is done with the help of statistical calculations on process data obtained from the historian. The analytics identify long-term performance trends and run comparisons from a wider perspective than what the equipment itself can provide in isolation. This approach provides wide-ranging benefits, including lower engineering and maintenance costs through condition-based maintenance (CBM); shorter repair times through advanced planning and spares availability; and a reduction of NPT through predictive maintenance.

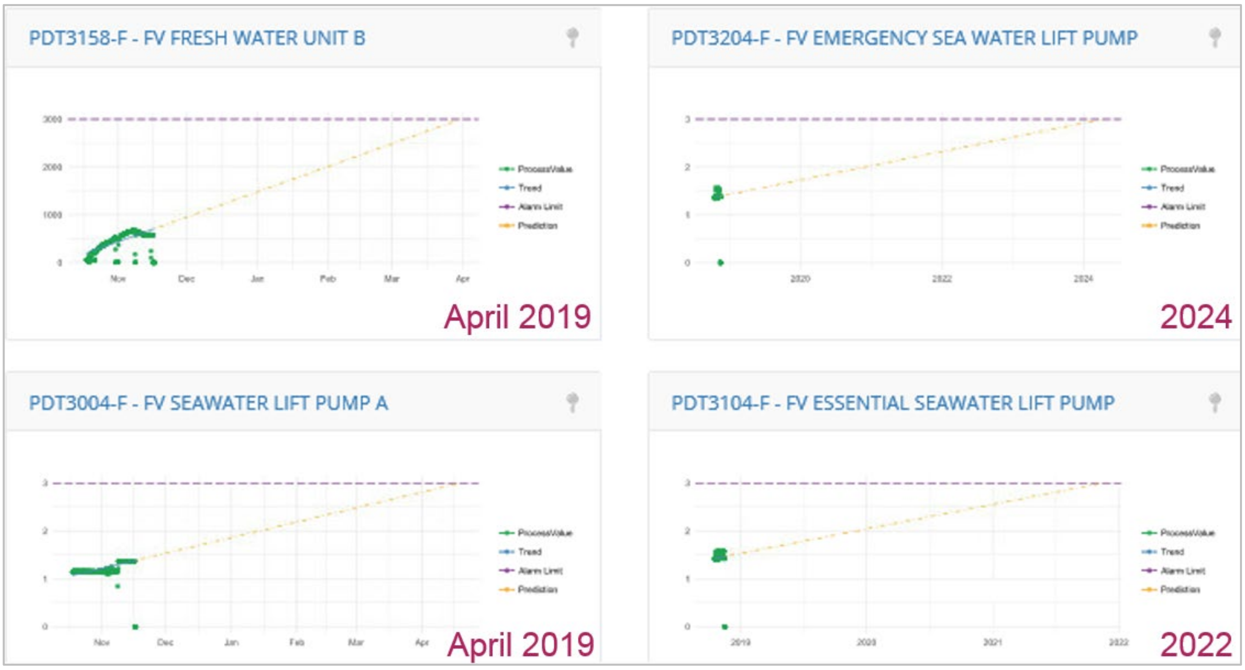


**Figure 3. Performance comparison example – predicted remaining useful life of sea water lift pumps.**

5) **OEM Services: Access to Expert Advice**

   Analysis of historical and current operational data is critical to optimize the performance of rotating equipment assets, but on more complex equipment, it is not a replacement for OEM subject matter expertise. To maximize the predictive window, it is beneficial for the OEM to support the operations and maintenance teams by providing expert advice and remote diagnostic services (RDS).

   RDS focuses on identifying "long cycle" issues and estimating time to failure, which helps determine whether problems should be addressed during the next maintenance campaign. RDS not only monitors deviations in machine performance but also identifies suboptimal operations, (e.g., anti-surge valve remaining open beyond what is deemed necessary, overly conservative alarm settings, deviations in following machine start-up procedures, etc.)

   The overall objective of the Topsides 4.0 maintenance approach is to leverage digitally enabled O&M services to create operator-specific KPIs aimed at reducing equipment total cost of ownership (TCO), maximizing production uptime, and de-manning platforms to the greatest extent possible. This contrasts with the traditional long-term equipment care models employed on many offshore facilities today, where OEMs provide close support to operators to facilitate equipment performance but have very little "skin in the game."

   Topsides 4.0 aims to transform the operator-OEM relationship from one that is highly "transactional" in nature, to a strategic partnership where both parties have a vested interest in meeting predetermined levels of performance and uptime.

6) **Workflow and Data Integration**

   The last component of the intelligent digital twin is workflow and data integration. If changes are made in any one of the digital twin components, these feed through to the others so that the digital twin model remains an accurate as-is representation of the installation.

## Equipment Selection

Optimizing the lifecycle performance of offshore production facilities, particularly FPSOs and FLNG facilities, is highly contingent on the incorporation of rotating equipment packages that can reliably deliver the horsepower to exploit resources located in a range of water depths and environmental conditions. At the same time, operators have become more cognizant of reducing emissions and minimizing the weight and footprint of topsides modules, the latter of which can substantially impact facility development costs.

Topsides 4.0 focuses on leveraging the recent advances in the design and engineering of equipment and associated systems to help operators meet these demands. Key areas of focus include:

**Maintenance and Serviceability –** Topsides 4.0 prioritizes serviceability and availability during equipment selection to minimize mechanical handling, extend service intervals, and where possible, facilitate "plug and play" maintenance.

"Plug and play" maintenance minimizes the requirement for engineers to go offshore and spend days on the platform trying to fix equipment. Instead, the unit can simply be removed, and a replacement installed to ensure uninterrupted operations. Executing maintenance on this basis allows for the adoption of low offshore manning concepts where OEM staff based onshore conducts specialist maintenance and overhaul activities, while providing remote, virtual assistance to offshore generalists.

**Digitally-enabled Equipment –** Selecting "digitally-enabled" equipment is also a key philosophy of Topsides 4.0. As a simple example, choosing the lowest cost pump for an offshore installation may add significant operating cost if the pumps must be manually reset before every restart. A pump that has monitoring and data acquisition capabilities built in may be more costly; however, these characteristics are a perquisite for leveraging analytics and conducting condition-based maintenance.

In addition to changing philosophies on equipment selection, the Topsides 4.0 approach aims to enhance automation and digitalize operational and maintenance processes. Digitalization covers a very broad range of solutions that can contribute to low manning, but at its core are two concepts:

1) Predictive maintenance to reduce unplanned downtime and enable condition- rather than time-based maintenance; and
2) Where possible, remote control of processes from either an onshore control room or another offshore hub.

Automation of repetitive and non-value adding activities is also an objective. An efficiency benefit that is often overlooked is that service staff are able to have the correct replacement parts and service equipment on hand before embarking on a maintenance campaign at the offshore installation, thereby preventing the regular, wasted mobilizations that operators see today.

To realize these benefits the automation system and digital solutions must be designed to provide the quantity and, most importantly, the quality of data required to feed the condition monitoring analytics. It is the norm that time series data is captured based on a present time interval, with interpolation of values in the white space between captured values. This may be sufficient for monitoring process trends, but it smooths out the rapid and small changes that give early indication of changes in equipment performance – for example, changes in the open/close profile of a valve. For equipment condition monitoring to be effective, it is imperative that data is captured and historized on change, rather than on time stamp.

**Leveraging Advanced Technologies, such as Additive Manufacturing –** Another core pillar of the Topsides 4.0 approach involves leveraging state-of-the-art technologies to improve rotating equipment performance and reduce lead times for spare parts. One technology, in particular, that is already generating wide ranging benefits for offshore operators in this regard is additive manufacturing (AM).

On the SGT-A35 aeroderivative gas turbine, for example, AM is being used to manufacture combustion systems (both DLE and non-DLE systems) and provides ways to improve the availability of spare parts, and at the same time enhance key product attributes, such as emissions and fuel flexibility. These have translated into numerous advantages, including improved gas turbine reliability and performance, as well as a substantial reduction in development cycle time and component lead time.

In the case of the SGT-A35 dual-fuel DLE combustion system, Siemens used AM to eliminate an operational limitation inherent in the original design. When the dual-fuel variant of the DLE combustor was initially developed, gas exit holes in the central injector needed to be moved slightly to make room for the liquid fuel injection system, which in turn changed the gas fuel placement. This resulted in higher levels of combustion noise during prolonged periods of low power, which increased the risk of vibration damage to downstream components in the turbine section.

By adopting AM methods, a revised design of the injector was possible, which maintained the liquid fuel capability, while also restoring the gas fuel capability and noise characteristics to that of the proven gas-only version. This solution has now successfully completed multiple combustion rig tests to validate the required dual-fuel operating range and confirm that combustion dynamics are in line with existing (i.e., well-established) gas turbine designs.

AM is also being applied to improve the repair of other offshore gas turbine models, including the SGT-750.

## Quantifying Topsides 4.0 Benefits

The foundation of Topsides 4.0 represents the workflow and data integration of solutions that Siemens has successfully delivered to the oil and gas industry over many years. Although the integrated approach is still relatively new, the digital solutions that comprise it have a strong track record of success.

The Topsides 4.0 intelligent digital twin is not yet a standard deliverable in offshore projects. As a result, monetary and operational savings claims from past implementations are not available. It is also important to understand that it is not practical to state generic value that can be generated from the digital twin because it can vary greatly depending on the baseline cost and performance of the asset to which it is being applied. For example, the digital twin can be applied to both brownfield and greenfield installation; however, developing it as a standard project deliverable is an order of magnitude less expensive than retrofitting it to an existing facility.

Overall, the various components of the Topsides 4.0 intelligent digital twin, including the dynamic process simulator (i.e., process twin) and 3D viewer (i.e., plant twin), have been deployed across the oil and gas industry with positive results. It is therefore possible to extrapolate these benefits and make educated claims regarding total savings, which are outlined below[1].

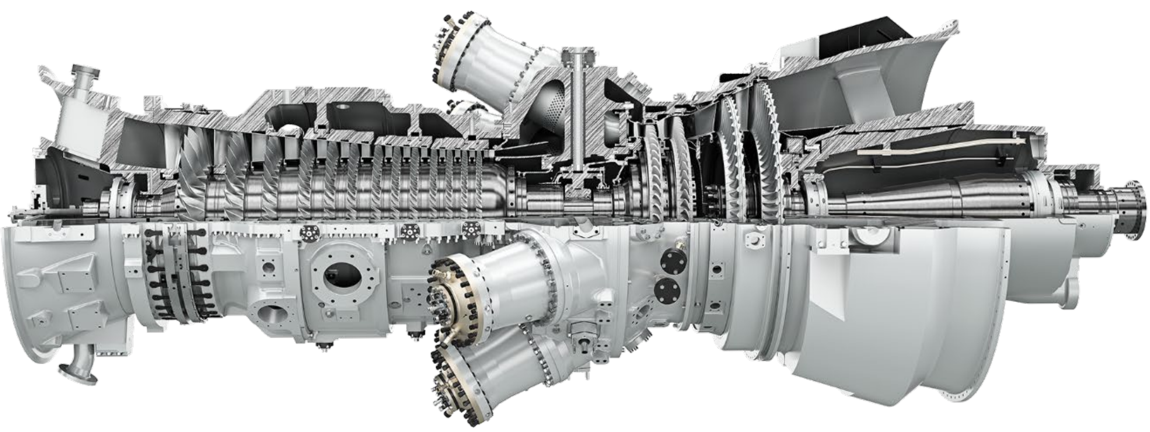

**Figure 4. Industrial gas turbine SGT-750.**

[1]All inputs were normalized against a mid-sized FPSO with production of 100k barrel per day (bpd) and then averaged. Where significant variance in data was reported, benefits were presented as numeric/monetary ranges. More operators / projects than those named as proof points in Fig. 5, Fig. 6, and Fig. 7 were included in the analysis. Where company/customer names are used as proof points, it does not imply that the customer confirmed the specific benefit of the value driver.

## Reduced Project Cycle Time

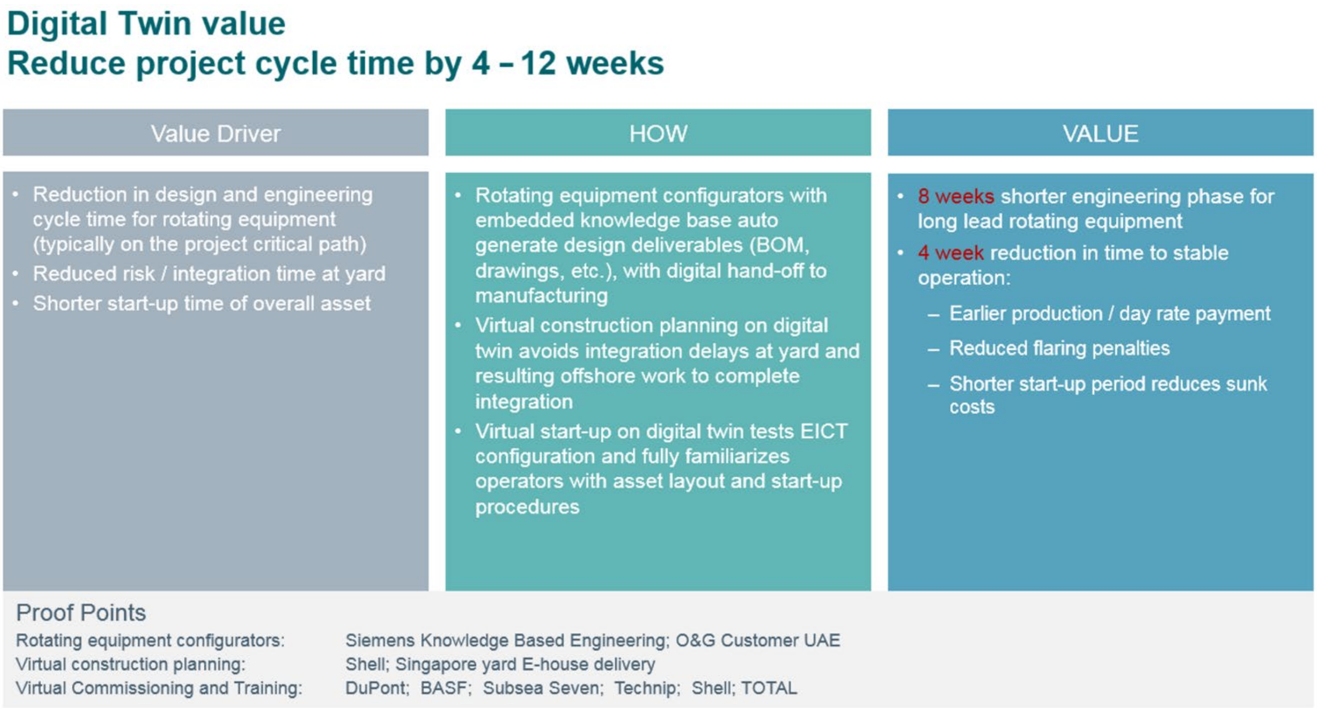


**Figure 5. Summary of how digital twins can reduce project cycle times.**

During the design phase, the biggest benefit lies in reducing the project cycle time. Various Topsides 4.0 elements contribute to this value driver. They can broadly be categorized into the following:

1) Engineering configurators and templates, with an embedded knowledge base, to auto-generate design deliverables like 2D, and 3D drawings, BOM, single line diagrams, etc. For rotating equipment, which directly impacts project critical path, OEM engineering teams report up to an eight-week reduction in engineering time.

2) Virtual interface management and construction planning to reduce integration delays in the yard. This benefit has been confirmed on real-world projects with various stakeholders but was not quantified. The Construction Industry Institute (CII) at the University of Texas reports a 10% savings in construction cost and time using construction planning software for work package data management and optimized work scheduling. Whether this applies equally to the oil and gas industry is yet to be determined.

3) Validation, testing, and training on the digital twin has been proven in the downstream and petrochemicals industry to shorten time to stable operation by 4 - 8 weeks. There is no reason why this benefit would not apply equally to upstream. As an example, the Ivar Aasen platform in the North Sea made extensive use of the process twin (dynamic simulator) for control system validation, controller tuning, and operator training. The platform started up in December 2016 and reached stable operation within one week. Only two of the control loops required retuning after start-up.

A combination of the above tools and capabilities results in faster time to first oil and a 4 – 12-week reduction in project cycle time.

## Lower CAPEX

### Digital Twin value
### Reduce CAPEX by ~ $7m

| Value Driver | HOW | VALUE |
|---|---|---|
| • Smaller living quarters<br>• Integration between data hub and ICSS engineering tools reduces engineering time and allows later start of automation work.<br>• Auto generation of Performance Twin reduces digitalization implementation effort | • Reduced offshore manning<br>• ICSS change orders typically increase contract value by 70%. A later design freeze date means design is nearer complete, with fewer change orders.<br>• Delivering a Performance Twin for an offshore facility will typically cost > € 3m. Auto generating condition monitoring typicals from automation schemas, specific for each asset type, reduces the engineering effort | • Weight reduction = 20 tons pp @ $12,000/ton = $3m<br>• ICSS change orders reduced by 50% = $2m<br>• Digitalization implementation effort reduced by more than 60% = $2m |

Proof Points

ICSS Change Control: AkerBP; FPSO Project (name withheld)

Digitalization implementation effort: FPSO Project, compared to standard digitalization implementation

**Figure 6. Summary of digital twins CAPEX savings.**

With Topsides 4.0, operators can use the digital twin to evaluate more design scenarios during the conceptual phase and identify the configuration that minimizes CAPEX. Smaller living quarters as a result of implementing low-staffing concepts is another tangible benefit. The industry rule of thumb is that each additional offshore resource will add 20 tons to topsides weight.

Another key advantage is that the use of engineering tools and automated workflows for the ICSS allows the later start of ICSS engineering, at which time designs are more mature. A 50% reduction in change orders, which is very typical in ICSS projects, has been observed in real-world projects.

To ensure the lowest lifecycle cost and ease of maintenance, the performance twin should be a standard project deliverable and generated with minimal manual configuration. With pre-existing predictive maintenance templates for each asset type that are auto-mapped to tags in the ICSS typicals and asset attributes in the digital backbone, experience has shown the engineering effort for developing a performance twin is reduced by up to 60% (performance twin for new build FPSO compared to retrofit of performance twin to brownfield platform).

Total CAPEX savings from all these benefits have been estimated on the order of ~$4 – $7 million.

### Reduced OPEX

**Digital Twin value**
**Reduce OPEX by $60 – 100m over 10 years**

| Value Driver | HOW | VALUE |
| --- | --- | --- |
| • Reduced manning for operations and asset monitoring<br>• Fewer unplanned shutdowns<br>• Shorter, safer turnaround times, better planned maintenance activities<br>• Less time spent on data management, fewer data errors<br>• Lower insurance rates | • Remote operations and monitoring reduces offshore resources. Digital twin enables multi-skilled maintenance personnel.<br>• Early warning of developing failures allows pro-active maintenance or worst case a planned shut down.<br>• Condition-based rather than time based maintenance reduces spares.<br>• Master data at hand in an integrated data hub prevents data errors | • 20-60% of maintenance and ops roles moved onshore after 2 years<br>• Reduce unplanned downtime by 2-7% per year<br>• 10% lower parts usage<br>• 10% improvement in engineering efficiency, fewer data mistakes<br>• Major shutdowns every 4 years with average 30 day turnaround time. 2 days savings on every major shutdown |

Proof Points

| | |
| --- | --- |
| Reduced Manning: | O&G customer 1 North Sea; FPSO Project; Woodside Australia; |
| Analytics & Predictive maintenance: | WINGAS; Bahrain Petroleum Co; Equinor Hammerfest; Siemens Remote Diagnostics Group, AkerBP |
| Integrated Data & Transparancy: | ENGIE E&P Norge AS; Tulip Oil BV; Siemens GP SDO |

**Figure 7. Summary of digital twins OPEX savings.**

The combination of an integrated control and safety system (ICSS) that is designed for remote control with predictive analytics allows operators to minimally staff their facilities once a "normal" operational baseline has been established. The extent to which this is possible does not only depend on the digital twin, but also on the design philosophy of the physical asset and the complexity of the facility. The wide range of potential benefits reflects this.

Although the idea of remotely controlled facilities is not, relatively speaking, new, it is certainly not yet the norm. This is primarily due to the cost of high bandwidth and low latency communication infrastructure, but 5G is expected to drive wider adoption. The concept of a normally unattended installation (NUI), on the other hand, is something that is currently being developed by several operators and engineering companies.

Predictive maintenance, enabled by the performance twin and OEM services, contributes to de-manning by preventing unplanned downtime. OEM data for rotating equipment shows an availability improvement of 2-7%, measured across 1,100 units. At the overall facility level, this information is less available in the public domain; however, one oil and gas facility confirmed no unplanned shutdowns during the past 30 months.

Benefits from data availability and accuracy are widely accepted as very real, but harder to quantify. An accepted rule of thumb is that nonconformance cost (NCC) contributes up to 10% of overall maintenance spend, with some estimates as high as 25%.

All these benefits combined indicate that OPEX reductions of USD 60 – $100 million over 10 years are achievable.

### Improved Safety

Topsides 4.0 enables companies to train operations and maintenance (O&M) personnel well before the asset is on location. This is made possible through a virtual "walk inside" of the topsides facility (i.e., the plant twin). Customers can locate valves, panels, and process equipment like coolers, separators, and filters in the digital twin and familiarize themselves with the switchgear and other electrical equipment. The opportunity to run various simulations and conduct "what if" scenarios also ensures that O&M personnel will react safely and productively when they are working onsite.

### Minimized Interfacing Risk

With Topsides 4.0, Siemens takes responsibility for the ICSS of the entire asset and natively integrates third-party package controls into its ICSS system. This minimizes interfacing risk, shortens testing and commissioning time, and reduces spares holding and maintenance costs. Integration also provides the capability to operate and maintain the ICSS for the entire topsides, which is a key enabler of remote operations.

### Cybersecurity Considerations

Despite the many benefits that digital transformation of offshore assets can provide, connecting critical equipment to cloud-based platforms does mean that the industry must be ready to respond to an evolving security landscape in which cyber threats are the norm. It is therefore critical that end-to-end security solutions are integrated to help clients secure, test, and monitor operating environments and raise organizational maturity as a prerequisite for digitalization. This is particularly critical when extending the operation of the platform to an onshore location, as is the case with Topsides 4.0.

A key differentiator of Topsides 4.0 is that all electrical, instrumentation, control, and telecommunications (EICT) systems and equipment are integrated into one solution. The EICT design establishes a secure, reliable, and scalable system backbone and architecture to enable safe operation of the topsides facility from an onshore control center.

Today, it is not a matter of whether companies are at risk of cyberattacks, but rather the degree of risk that they are exposed to. Like physical security, there is no "silver bullet" for cybersecurity. The starting point for operators is understanding where their vulnerabilities are. Only then can they develop a plan to become fully secured.

Cybersecurity is like HSE in that it must become part of the organization's DNA, with every individual practicing safe cyber work practices every day. However, it differs from HSE in that risks are constantly evolving. Cyber, like digitalization, is a journey, not an event. It is a continuous cycle of testing and securing the digital environment by detecting threats and hardening infrastructure. Like other industrial digitalization offerings, it is most effective within a trusted ecosystem with partners and OEMs who make it a priority. Companies are only as strong as the weakest link in their supply chain

## Conclusion – Making the Digital Leap

Although Industry 4.0 has the potential to produce unparalleled value for the oil and gas industry, organizations will first have to change the way they go about adopting digital initiatives. The piecemeal approach of deploying standalone digital tools that is prevalent throughout the industry today will have to be replaced by more holistic strategies that leverage digitalization to support the entire project lifecycle – from concept and design to end of operation.

To do this requires a combination of clients' domain expertise, along with OEMs' knowledge of equipment, automation, software, and data analytics. Getting to the point where oil and gas companies feel comfortable sharing data in a secure but open ecosystem will be critical as the industry forges ahead with Industry 4.0.

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For more information, please contact
our customer support center
Phone: +49 180 524 70 00
Email: support.energy@siemens.com