
Improving Operations, Maintenance, Planning and Training at Oil and Gas Companies
Companies in the global energy industry are under intense pressure from all directions. Power demand is growing exponentially and must be met. Compliance with increasingly stringent health, safety and environmental regulations is mandatory. New facilities must be brought online quickly, an aging infrastructure must be upgraded and modernized, retiring workforce with the potential loss of know-how and experience, must be replaced, — all with minimal service interruptions.

All the while, companies with trillions of dollars of assets in the field need new solutions to keep a lid on staggering operations and maintenance costs. According to a NIST* study, nearly $16 billion is lost annually in the industry due to interoperability challenges. No segment of the energy industry is exempt. Organizations face these challenges across the industry’s diverse segments, including nuclear and fossil power generation and distribution, petroleum exploration and refining, mining, and alternative energy sources including wind, solar and geothermal.

The oil and gas segment in particular has significant challenges. Refineries, offshore rigs and other processing plants are some of the world’s largest, most complex facilities, operating around the clock at peak capacity under some of the harshest conditions on the planet. Many upgrade, refurbishment and maintenance projects involve hundreds of workers who must be thoroughly trained — especially in safety-related operations such as handling fires, toxic chemicals, high-pressure leaks and other emergency incidents. Scheduling requires precise choreography to ensure each step occurs on time and in proper sequence — critical in limiting outages and meeting budgets and deadlines. All processes must be optimized for maximum efficiency, with no delays or downtime. Inefficiency must be squeezed from every activity.

Uptime is critical at oil and gas installations, where the cost of developing a well is $10 per second ($864,000 per day), shutdowns can cost up to $5 million per day and nonproductive time (NPT) costs can exceed $500 million a year. With capacities that barely outstrip demand, delays that extend shutdowns and reduce uptime are unacceptable. Yet manual, paper-based planning processes and schedules may be difficult to interpret and not closely related to actual plant operations, so they often contribute to unanticipated problems and complications. Workers may discover that equipment cannot be moved as planned because of clashes, interferences and insufficient clearance, for example, or that equipment blocks a crane operator’s line-of-sight for hand-signal directions from co-workers below. Moreover, activities in these complex sequences of procedures may not be optimized, with workers performing redundant tasks or waiting idly as other work is completed. It’s not surprising, therefore, that numerous studies indicate that almost 40% of all mega projects in oil and gas exceed their budgets and cycle times by more than 10%.

Many companies typically have mandatory training for their workers and subcontractors a few weeks a year. Challenges to meet training requirements are compounded at offshore oil and gas rigs accessible only by helicopter or boat, which drives up transportation costs for personnel and equipment. Teams of crews generally are replaced every six weeks on offshore drilling platforms, where on-site training is hugely expensive and highly disruptive to routine work. Conducting training exercises on-site using actual equipment presents a higher risk of damage to valuable equipment and the safety of the crew, especially subcontractors and new personnel who are unfamiliar with the site. On the other hand, off-site mock-ups are expensive to construct and often do not realistically replicate the real-world scenarios on the job.

In short, the oil and gas segment faces virtually all of the challenges inherent in the rest of the energy industry, plus a few uniquely its own. From maintenance planning, scheduling and sequencing to worker training and safety, the inherent complexity of oil and gas installations cries out for innovative new solutions to improve accuracy and reduce risk. The industry needs capabilities that allow owner/operators to execute programs safely, on time and on budget, ensuring both continuing supply for an energy-hungry world and a fair margin for those who meet the demand.
A growing number of companies in the energy industry are addressing these challenges through the use of innovative 3D virtual planning, simulation and visualization technologies. Such systems allow people to plan and schedule operational procedures, train workers and meet health and safety requirements by interacting with a computer simulated 3D environment, including cranes, plant assets and workers to determine the best process to minimize costly project delays and mitigate project execution risk.

By studying procedures in this virtual world, engineers, planners, safety experts and workers can identify problems, explore options and determine the best remedy – all without disrupting actual plant operations with traditional trial-and-error guesswork and avoid costly mistakes that could pose safety hazards, lower productivity or damage equipment. With lifelike 3D models, simulations and visualizations, planners can test their project plans virtually, and workers can see precisely what they need to do before they attempt it on the job. In this manner, optimal procedures and scheduling of operations can be worked out before projects are started in the plant or on the drilling rig, and workers can be trained off-site safely without disrupting normal work routines.

Typically, digital models are created from a combination of plant drawings, CAD geometry, 3D master models of the plant and laser scans of the facilities. Such digital models are highly detailed and significantly more accurate than physical mock-ups, which in most cases can be no more than rough approximations of the actual environment. Digital models also can be enhanced to incorporate representations of equipment such as cranes and the movement of such equipment in relation to interaction with the human workers and surrounding environment. In addition, the inclusion of physics representations can be used to simulate the realistic action of equipment such as the resistive force workers would encounter in turning a valve. All of this contributes to a virtual environment that not only looks real but also behaves realistically.

“Simulators not only provide a great way to train the next generation of operators; they also provide a great way to keep the current workforce performing at a high level of proficiency. Preventable human errors cause approximately 40 percent of all abnormal situations. Better-trained operators make fewer mistakes; recognize process upsets earlier; and can initiate the appropriate steps and actions to mitigate any potentially harmful, wasteful, or detrimental effects.”

Thomas J. Fiske, Ph.D.
Senior Analyst
ARC Advisory Group
Oil and gas companies can leverage simulation, visualization and virtual reality technologies in obtaining significant business value by accelerating throughput, reducing expenses and working more effectively in the critical areas of operations and maintenance planning, scheduling and training. And because these technologies have been proven in other segments (such as mining and power generation) of the energy industry with challenges and requirements similar to those present in oil and gas installations, owner/operators can have confidence that these solutions are equal to the complex challenges of their industry.

**Leverage Virtual Ergonomics to eliminate the need for physical mockups and ensure health safety requirements.**

These simulations also can include lifelike models of humans or manikins for a wide range of virtual ergonomics or human factors studies. These 3D manikins are more sophisticated than the commonly known human avatars used in Virtual Reality (VR) or gaming systems. These manikins are built using anthropometric specifications for male and female (Name, Gender, 5th, 50th, 95th percentile.). The manikins possess fully articulated hand, spine, shoulder, and neck models to accurately reproduce natural movement such as reaching, grasping, walking, picking, placing, climbing and lifting. For example, users can simulate activities such as ascending or descending stairs or ladders, moving from one posture to another, following the trajectory of a kinematic device or path of an object, or picking up objects and placing them in another location. The choreography of multiple workers working in tight spaces can be evaluated and biomechanics tools can be used to examine worker posture, comfort, safety, strength, fatigue and efficiency in performing required tasks.

Virtual ergonomics simulations can be validated against ergonomic requirements for compliance with US Occupational Safety and Health Administration (OSHA) and Quality Health and Safety Environment (QHSE). In this manner, operations and maintenance procedures can be thoroughly analyzed to ensure they are safe for workers, protect the public from potential hazards and lower the risks of damaging expensive equipment. Human factor studies are also useful in evaluating equipment layouts and accessibility, plant workflow, lifting requirements, and more. Such capabilities are often used in analyzing aspects of posture to determine worker comfort, safety, strength and performance when interacting with equipment. Static strength can be studied, along with comfort and joint analysis with fully articulated pelvic, neck, spine, shoulder and hand models.
In this way, it becomes possible to predict with a high degree of accuracy how people and machines will interact on the job site and the stresses each will experience. Such capabilities to simulate and assess these scenarios can help companies achieve a “zero incidents” with the potential to avoid on-site worker injuries and associated losses — expenditures that for oil and gas installations comprise a substantial portion of the $20 billion annual cost of worker injuries across all industries in the US, as reported by OSHA. The technology also has the potential to reduce offshore operations and maintenance expenditures, which could total more than $330 billion over the next five years, according to the Douglas-Westwood Offshore Operations and Maintenance Management Report 2010-2014.

**Increase productivity and lower costs by better planning operations and maintenance procedures.**
Planning for operations and maintenance procedures in the oil and gas industry encompass a wide range of diverse tasks. Major pieces of heavy (several tons) equipment such as generators, coolers, valves and piping must be installed, replaced, inspected and repaired. Operational tasks such as crane operation and valve actuation must be performed. Complex sequences of actions must be completed quickly and flawlessly.

The traditional ways of planning rely on the experience of the workers and subcontractors to execute the required maintenance tasks. Supporting 2D drawings and historical information are often inaccurate and outdated. This often leads to miscommunications between the various project teams during the actual execution, resulting in expensive delays to the project, unsafe working conditions, and costly project rework.

3D Simulation-based systems for planning scheduled maintenance, or new operational procedures provide an effective way for engineers to develop precise and detailed plans to execute work “right the first time” by studying various scenarios and performing what-if evaluations well before tasks are attempted with actual equipment. This capability to digitally plan and optimize processes lowers the risk of mistakes, delays, and rework and increases over all performance for operations and maintenance procedures.

Simulations can be performed to detect clashes, for example, or determine optimal paths for removing or installing equipment, minimize interferences and identify areas where structures or piping must be removed to clear the path of obstacles. Software developed specifically for such studies provides visual alert notices during the simulation, and detailed clash reports listing all interferences. In this way, engineers can study and modify motion paths until a feasible plan is determined. Likewise, the kinematic motion of cranes, robotics or other equipment can be accurately simulated to check that the devices can perform the required operations. In addition, a company’s valuable know-how and intellectual property (IP) can then be captured and retained in the 3D environment for future project planning.
Companies in the oil and gas industry using simulation to study and optimize operations and maintenance procedures are achieving significant benefits. The state-of-the-art software used by many of these companies and others in aerospace, automotive, nuclear and shipbuilding, employs advanced process simulation software integrated with PLM software, including CAD, providing an extremely accurate and efficient way of importing geometric data on facilities and equipment into the process simulator for modeling and effectively managing this critical data.

Maximize workflow and utilization of resources with detailed planning and coordinated work schedules. Properly executing planned operational and maintenance procedures is the critical function of scheduling – that is, the development of timelines, asset utilization resource allocations and personnel requirements.

Scheduling takes this into account as a basis for construction and process planning, operations and maintenance tasks, and personnel assignments. Effective scheduling requires output on individual task durations, equipment needs, and resource requirements. Leverage existing schedule and resource information created in standard applications (such as Primavera* or MS Project*) by importing it to the project’s 3D work breakdown structure (WBS), which combines information on timelines, activities and resources. Linking the schedule to the 3D WBS and the 3D process simulation model creates an animated, time-based 4D representation (3D plus the variable of time) that enables users to more easily visualize and understand operations and timelines. In this way, scenarios can be rearranged to more readily spot conflicts, find an optimal critical path and develop an optimized schedule taking all interrelated operations and processes into account. This approach is far better than conventional static, paper-based scheduling schemes that are difficult to interpret and hard to relate to actual plant operations. Cost as a 5th dimension can be added to the simulation.

In advanced systems, scheduling software is often coupled with process planning simulations in an integrated solution that optimizes schedules for day-to-day plant operations as well as periodic maintenance tasks. By iterating with process planning in evaluating various ‘what-if’ scenarios, the scheduling solution analyzes alternative sequences and arrives at an optimized master schedule. This output is invaluable to project managers and others in determining budgets, manpower requirements, critical timelines and operating efficiencies.

“Harvesting the use of 3D along with laser scanning technology is as transformational to the engineering and project management disciplines as moving from the slide rule to calculators were in the late 1960s and early ’70s. Combining scanning and modeling with up-to-date, advanced planning allows processes that could dramatically reduce the old industry-wide steam generator replacement average of 78.5 days. In some cases that time could be reduced by nearly 20%.”

John Mahoney, Innovations Leader for Nuclear Operations, Entergy Nuclear

Digital technologies, such as DELMIA’s Virtual Maintenance solutions can simulate and validate critical operations in a 4D environment to optimize project schedule and mitigate project execution risk.
In an industry where time is measured in hundreds of thousands of dollars an hour, scheduling – in conjunction with 4D process planning, simulation, and often, project management tools – performs vital functions in maximizing workflow to arrive at optimal utilization of all available resources, avoiding expensive downtimes and delays.

**Promote safety, lower risk of mistakes and eliminate disruption of work with virtual training.**

After optimal maintenance scenarios and related work schedules are developed, companies can save and capitalize on this captured knowledge: replaying the simulations as needed, easily making changes to adapt to different conditions, and leveraging the information throughout the entire lifecycle of the plant.

Reusing and leveraging the operations and maintenance planning simulations for virtual training purposes is of particular value. Planning and training can be done separately, but tightly integrating these two functions within a single-platform vendor environment is the most efficient approach for creating training scenarios and ensuring they reflect current operations and maintenance planning procedures.

Simulation-based training using specialized visualization software represents workers (either individually or in teams), who have the ability to interact with the scenario in lifelike realism. From basic PC-based packages to immersive theaters – simulation shows the consequences and points out on-screen when faulty decisions are made, with workers able to learn from mistakes and retry procedures immediately in a safe environment. Virtual reality guides workers through procedures interactively, indicating when they’re wrong and showing them correct sequences of operations.

Virtual Reality (VR) training systems create a lifelike, immersive environment that adds another dynamic dimension to 3D simulations. VR technologies enable users to interact with computer-simulated equipment and surroundings in lifelike realism. Most of these applications are used in worker training, where some of the most advanced systems use 360-degree wrap-around theaters with photorealistic imagery viewed with stereoscopic glasses. Multiple speakers generate high-fidelity sound effects to familiarize workers with the harsh and sometimes subtle sounds found on the actual jobsite.

Head-mounted goggles track head and eye movements, allowing the system to recognize where users are focusing their attention in the overall scene. In this way, workers can be trained off-site using VR without disrupting normal work routines or exposing them to the hazards of performing an untried or unfamiliar task in a real-life setting.
One of the most sophisticated immersive virtual reality training systems in the energy industry was developed at the University of New South Wales for training coal miners (shown below). A hemispheric, 360-degree wrap-around curved screen with surround sound immerses trainees in a virtual world with high-fidelity, 3D representations of actual problems in a dynamic, hostile mine site. The system is used daily to educate and test trainees in truck and shovel operations, rib and roof instability and unaided self escape.

In any of these systems, different maintenance and operations scenarios can be easily performed without workers being on the actual plant/rig site. Workers can gain familiarization with the plant/rig layout, equipment operation, walking paths and evacuation routes and memorize the location of fire extinguishers, masks and other safety devices. Workers can learn specific operations and maintenance procedures such as plant start-up and shut-down, crane operations, and drilling tasks as well as equipment maintenance, inspection and replacement. Workers are productive immediately when arriving at the plant/rig. A report issued at the end of virtual reality training indicating which tasks were successfully performed and which mistakes were made is useful in individual skills assessment as well as documentation for regulatory compliance on worker training. Overall, this ensures that workers are well prepared with the skills and knowledge necessary to work safely in an unforgiving real environment.

“VR adds another dimension of realism to simulation. VR technology – whether 3D graphics with avatars that interact with the plant and each other or a whole host of other immersive technologies that use stereoscopic 3D goggles and gloves – has the potential to significantly change the way operators in the process industries train.”

Thomas J. Fiske, Ph.D.
Senior Analyst
ARC Advisory Group
Real-World Benefits

Some of the most successful companies are reaping these benefits through the use of a unified platform that integrates design modeling, process planning, simulation, visualization, virtual reality (VR), capital project management and PLM in an integrated solution from a single vendor. An integrated solution, in fact, ensures compatibility between the different software packages, facilitates the exchange of data, leverages the extensive expertise of the vendor in working with a wide range of companies, and helps institute best practices and knowledge capture of IP from energy and a wide range of other industries.

Benefits of such unified solutions, like the Dassault Systèmes PLM offering, are impressive:

**Entergy Corp. anticipates $1 million per day savings.** Entergy Corp. – the second largest nuclear power operator in the U.S. that manages 10 commercial sites with a total of 12 reactors – expects to save up to $1 million per day by minimizing plant outages using Dassault Systèmes solutions for 3D digital modeling, planning, and simulation of maintenance tasks.

At Entergy’s Waterford 3 plant near New Orleans, Louisiana, the company simulated multiple maintenance projects, including analyzing the impact of a fire on equipment located in key areas of the plant, replacing the in-core instrumentation sensor system that monitors reactor fuel conditions, and removing and replacing a 57-ton reactor coolant pump motor.

Entergy implemented a combination of Dassault Systèmes technologies to prepare for these maintenance tasks, including CATIA for modeling the plant and DELMIA to simulate the actual project work. To ensure the team had accurate dimensions of the plant, Entergy used scanning and digital photogrammetry from Dassault Systèmes’ partner Areva NP.

Modeling and simulating the replacement of the reactor coolant pump motor was particularly important since any unanticipated delays during the project could result in high costs for replacement power purchased from other utility companies. CATIA digital 3D models made it possible to find equipment and structural conflicts when studying removal of the coolant pump motor. Two interferences were detected by modeling and simulating the task in DELMIA that might have caused major delays.

**Hydro-Québec saves 200 weeks and CAN$50 million.** Dassault Systèmes technologies were also used to assess the time and cost of refurbishing a hydroelectric power generating plant at Hydro-Québec, which generates, transports and distributes almost all the electricity consumed in Québec, Canada. Over 96 percent of the generated power is hydroelectric, making the company one of the largest renewable energy producers in North America.

To optimize refurbishment of its Manic-3 hydroelectric generating station and shorten the time the plant would have to be taken off-line, Hydro-Québec performed a feasibility study in a 3D virtual environment using Dassault Systèmes PLM solutions. In this way, it could outline all the necessary project steps, foresee eventual problems and optimize each refurbishing phase before starting the actual renovation.

Engineers used laser-scan data and original drawings in conjunction with the CATIA design system to create a virtual model of the station and all the equipment it contained. They then used the DELMIA process simulation to study the various refurbishing tasks, which included disassembling, moving and reassembling equipment such as a large alternator. This required highly accurate scheduling and strict safety precautions.
With DELMIA, interferences were clearly visible in a virtual simulation on screen. This helped engineers adjust the trajectory of the movement of parts and avoided encountering such issues in a real situation. Each piece of equipment is a complex assembly of different parts that can weigh hundreds of tons. Thanks to DELMIA, engineers were able to simulate each movement with a precision of a couple of centimeters, which is exceptional for equipment of this size.

The virtual simulation refurbishing study took six weeks to complete, saving 200 weeks of time and reducing expenses CAN$50 million. As a result, Hydro-Québec plans to deploy similar simulations on other refurbishing projects. The Hydro-Québec Estimation Team has already started using DELMIA to calculate concrete volume estimation and to optimize the sequences of concrete placement in its plants.

**Yantai Raffles Shipyards builds offshore structure 70% faster, increases design productivity 30%, saves two million man-hours.** In the oil and gas industry, Singapore-based Yantai Raffles Shipyards (YRS) Ltd. is a leading manufacturer of offshore and marine equipment such as jack-up drilling rigs, semi-submersible drilling rigs, pipe lay vessels, and floating production, storage and offloading vessels (FPSO).

To further strengthen its leadership position, YRS has a strategy in continuing to demonstrate consistency in innovation, product quality and customer service. Like its competitors, YRS is also under pressure to deliver vessels faster and at a lower cost. To address these challenges, the company is working to optimize work process and resource allocation through the use of a unified suite of PLM technologies from Dassault Systèmes including CATIA for offshore structural design, SIMULIA for stress analysis on parts and assemblies, ENOVIA for collaboration and decision-making, and DELMIA for process simulation and resource allocation.

YRS uses DELMIA to simulate manufacturing processes in 3D and derive test cases on which designs are analyzed. Using this tool, engineers can accurately determine what resources are needed for each production scenario, identify the best procedures and fastest way to fabricate vessels and pinpoint possible problems before they occur. This virtual design approach helps YRS avoid the cost and delays of unforeseen errors that previously resulted in up to 30% rework due to engineering changes and design problems.

Such capabilities have helped YRS improve vessel design and optimize manufacturing processes. They also enabled the company to design and build its own mega-structure – Taisun, the world’s largest crane, with a lifting capacity of 20,000 metric tons. By simulating the entire design and manufacturing process, YRS was able to design the crane in just six months rather than the two years it otherwise would have taken. Using the crane in its construction operations, YRS will be able to build offshore structures by as much as 70% faster and see increases in design productivity of as much as 30%. The company anticipates saving over two million man-hours on each semi-submersible drilling rig built as well as increasing its overall construction capacity.
Meeting Pressing Business Demands

Companies in the diverse energy industry are leveraging simulation technology in meeting the intense business challenges for greater savings and efficiency. These organizations are increasing productivity and lowering costs by better planning operations and maintenance procedures, maximizing workflow and utilization of resources with detail and coordinated scheduling, and making plants safer and more efficient with comprehensive simulation-based training. The business value of these applications are immense in reducing the costs of nonproductive time measured in hundreds of millions of dollars annually and avoiding the billions of dollars lost every year in this complex industry due to operating inefficiencies.

At stake for these companies is their viability in operating in a highly competitive market in which energy consumption continues to grow, consumers demand lower prices, stockholders expect greater profitability and regulatory agencies impose more stringent operating requirements. Clearly, companies implementing the simulation-based approaches have the potential to be some of the most successful elements in the energy industry as they face some of the most challenging and complex demands in the coming decades.

For more information on Dassault Systèmes solutions for the energy industry, please visit www.3ds.com/energy.
About Dassault Systèmes

As a world leader in 3D and Product Lifecycle Management (PLM) solutions, Dassault Systèmes brings value to more than 100,000 customers in 80 countries. A pioneer in the 3D software market since 1981, Dassault Systèmes develops and markets PLM application software and services that support industrial processes and provide a 3D vision of the entire lifecycle of products from conception to maintenance to recycling. The Dassault Systèmes portfolio consists of CATIA for designing the virtual product - SolidWorks for 3D mechanical design - DELMIA for virtual production - SIMULIA for virtual testing - ENOVIA for global collaborative lifecycle management, and 3DVIA for online 3D lifelike experiences. Dassault Systèmes’ shares are listed on Euronext Paris (#13065, DSY.PA) and Dassault Systèmes’ ADRs may be traded on the US Over-The-Counter (OTC) market (DASTY).

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