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Fast-track conversion transforms supertanker into an intelligent FPSO

Integrated engineering, modular construction and advanced automation technologies make the world's largest "smart" FPSO possible.

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The world's largest Floating Production, Storage and Offloading (FPSO) vessel was put into operation in the Gulf of Mexico KMZ field by BW Offshore for Pemex in late June 2007. The 360,700-ton, single-hull supertanker *Berge Enterprise* was converted in less than two years into a mobile facility capable of processing 600,000 bopd and 120 MMcfd of gas, Table 1.

An integrated engineering and construction team for the vessel's process automation systems, led by BW Offshore and Emerson Process Management, maintained a fast-track schedule and achieved other significant goals. The "intelligent" FPSO uses a high degree of digital instrumentation, making maximum use of field diagnostics for operation and maintenance. Fabrication and installation costs were limited through tight management and modular construction of topside process units.

While modularization is not new, having the automation system built into each functional process unit during pre-fabrication was revolutionary. Each unit could then be tested on the fabricating site before transport to the shipyard in Singapore. System integration was then simply plugging modules into the established power and control networks—an important time-management factor.

In the beginning, BW Offshore's engineers expressed strong interest in integrating and using microprocessor-based field devices as a key part of the process control system. Advanced technologies were seen as the best means of implementing control and speeding the conversion process at the same time. For example, Emerson's PlantWeb digital plant architecture and DeltaV digital automation system with DeltaV digital safety system were implemented for the first time on a major FPSO to accommodate digital Foundation Fieldbus and Profibus-DP communication systems throughout the vessel. Of the more than 10,000 input/output (I/O) signals employed in controlling and safeguarding the process units, only 2,500 remained on conventional I/O. This contributed cost savings through reduced wiring.

TABLE 1. Specifications for *Yùum K'ak' Náab*

Client:	Pemex
Water depth:	80 m
Mooring:	Turret moored (STP)
Oil stabilization:	200,000 bopd
Gas compression:	120 MMcfd
Import of stabilized oil:	300,000 bopd of 21° API 250 bopd of 13° API
Total oil capacity:	600,000 bopd
Oil offloading to tanker:	1,200,000 bopd
Oil export via pipeline:	200,000 bopd
Gas export:	120 MMcfd
Cargo storage capacity:	2,200,000 bbl
Vessel's data	
Type:	Oil tanker (single hull)
Built by:	Mitsui (Japan)
Year:	1980
Class:	DNV
Propulsion:	Slow speed diesel engine
Cargo capacity:	407,000 m^3
Main Dimensions	
Length:	340.5 m
Width:	65 m
Depth:	31.5 m
Draft :	23.2 m
Dwt :	360,700 metric tons

The project was executed by international design and production teams in Norway, the Netherlands, India, Dubai, Singapore and Mexico. When an integrated team is brought together very early in project planning, greater efficiencies accrue.

Many activities were done in parallel to maximize efficiency and deliver the ship to Pemex in less than two years. New standards for FPSO control were developed and applied in a hardware concept that provided maximum flexibility for timely delivery and integration of the automation system on the ship's deck. The new FPSO was named *Yùum K'ak' Náab*, which is Mayan for Lord of the Seas, Fig. 1.

THE ORGANIZATION

The fast-track timeline could not have been accomplished without several teams, key suppliers and sub-contractors working cooperatively. Two design and engineering teams were based in Norway; project management, detail design, testing, HW assembly and staging teams were in Rijswijk, the Netherlands; and implementation teams were located in Pune, India. Topside module construction and commissioning took place in Dubai, installation and commissioning in Singapore and startup support was in Mexico.

The engineering and design team for automation systems created functional, integrated automation systems. The same team managed manufacturing, assembly, testing and installation. After selecting Kanfa Grenland Group of Sandefjord, Norway, as topside supplier, a second team was organized at Porsgrunn, Norway, to design the crude-oil processing modules. Because these teams were integrated, and aware of what the other was doing, their efforts were complementary.

By taking responsibility for the design and implementation of the essential process units, these integrated teams guided the project through to commissioning. In this way, concepts worked out by the designers and approved by BW Offshore officials were implemented without alteration or dilution by subcontractors.

AUTOMATION SYSTEM

The requirement for the extensive use of intelligent process instrumentation was well defined early in the planning phase and written as the Functional Design Specification for Automation during the FEED. Conventions for building the automation system were also defined. These became guidelines for the subcontractors, enabling them to deliver their automation design input in a consistent and correct form.

Emerson's digital plant architecture was written into the automation specs to bring intelligence from the field devices up to the highest level, where it could improve operations and contribute to the predictive maintenance of critical process equipment. This concept was ideal for the FPSO application and the designers used it wherever possible. Separate stand-alone systems using programmable logic controllers (PLC) were largely avoided.

Fig. 1. The new FPSO, *Yùum K'ak' Náab*, or Lord of the Seas in Mayan, was commissioned in late 2006 with first oil in late June 2007 and first offloads in early July 2007.

The digital architecture provides an elegant solution to communicating large amounts of data—both process measurements and diagnostics—between field devices and the control host. Because this architecture accommodates the "bus" method of communication, it offers substantial benefits in reduced wiring along with fast and reliable control-I/O transmission. As a result, operational costs are lower and product throughput is greater.

The DeltaV system was considered the ideal host to integrate automation, resulting in smooth-running, continuous production processes. The system accepts digital signals from fieldbus devices, 4-20 mA communications from Hart instruments, as well as inputs from the Profibus and Modbus systems. It also integrates data from Safety Instrumented Systems (SIS).

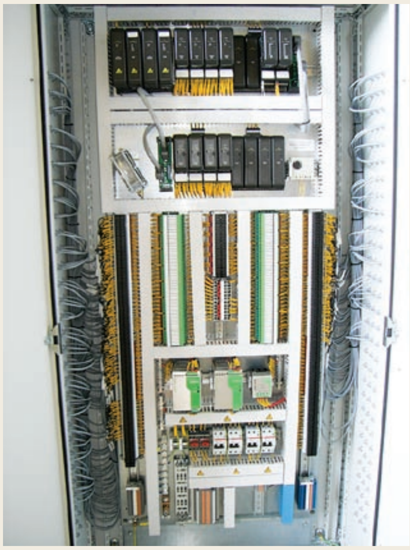

Fig. 2. The control package was integrated in the HPU package and underwent factory acceptance testing before being shipped.

In addition, Emerson's AMS suite of software obtains real-time diagnostic data from the control communications network and delivers never-before-available, field-generated information about instrument conditions, control valves and other devices. This information is processed, stored and made available in a useful format on an easy-to-navigate dashboard for operating and maintenance personnel to use. Improved diagnostics result in less downtime and lower maintenance costs.

In general, the integrated engineering and design teams drove procurement activities, so that as much equipment as possible could be compatible with the plant architecture and automation systems. Procurement decisions were generally not left to the discretion of sub-contractors, enabling the project to move forward efficiently.

Still, procurement of field instruments for some packages had progressed beyond the point-of-no-return, which prevented the bus systems from being implemented throughout the vessel. In such cases, diagnostics were accessed from hard-wired Hart instruments via multiplexers connected to the automation host. It was very important that this system be used rather than conventional PLCs, which would block the flow of intelligent information and limit the level of automation achievable with the specified systems.

THE SOLUTION

The automation system's most significant aspect included the development of Control Typicals for the various specific control applications and package units on board the FPSO. Each unit could then be pre-tested. This was an essential part of the fast-track plan.

Modules for separation, gas compression, fuel gas/amine generation, inlet heating, mixing, metering and offloading, power management, etc., were designed and constructed as stand-alone units capable of carrying out their specific missions without being part of a larger process. Each contained a built-in system connected to the module's internal instrumentation.

A typical automation cabinet prepared for installation in a package unit is shown in Fig. 2. In this case, the control package was integrated in the HPU package and subjected to complete factory acceptance testing in Nordfjord, Norway, before it could be shipped to the Singapore yard. The cabinets for the Kanfa process modules were certified in the Netherlands for placement in Zone-2 applications. In addition, the whole project, including the control system architecture, power and grounding, was certified by Det Norsk Veritas (DNV).

To maintain the fast-track concept, certain design preferences had to be abandoned. A case in point was the desire to include SIS in the Zone-2 modules containing a DeltaV controller, because at that time DNV was not ready to accept this design concept and technology. As a result, the DeltaV SIS was placed in safe areas on the vessel. The safety instruments and final elements on these modules had to be wired and tested during the yard installation and commissioning period. This was a disappointment, causing some inefficiency and delay to the original master plan, which had the objective to fully prefab and test the module. This SIS concept will be accepted by DNV for future projects under specific design requirements allowing improved efficiency and project runtime.

GLOBAL EXECUTION

As the design phase evolved into engineering and construction, the project took on global proportions with different activities occurring in the most appropriate locations. Much of the automation engineering was done at Emerson's Engineering Center in Pune, India. Some engineering leaders from India participated in detail design activities in Europe and then returned to India, where they implemented agreed-upon concepts. That process shortened the overall project completion time.

The power management system was built by Wärtsilä Corp., a provider of complete lifecycle power systems headquartered in Finland and alliance partner of Emerson for marine and offshore applications. Engineers from the two companies worked together in the power management module design. Factory acceptance testing was done in the Netherlands. Wärtsilä's engineers served on the commissioning team in Singapore and, more recently, in the GOM commissioning work.

The Daniel measuring skid was built by Emerson in Houston, using the design conventions and considerations prescribed by the automation design team in Norway. This was the first time an automation module was built into a Daniel metering skid. Acceptance testing was done on-site in Houston by the integrated engineering team before the skid was shipped to Singapore for installation.

After the topside hardware, manufactured in The Netherlands, had been tested and accepted there by BW Offshore engineers, all units were shipped to Dubai for topside module assembly and testing. The separate packages were brought together at the Sembawang yard in Singapore for vessel installation. The automation panels on each module were integrated, tested and commissioned before the ship was moved to the GOM in March 2007.

Effective communications are crucial in the global execution of any major project and Emerson provided high-speed networks for engineering purposes and rapid message and data transmission. A project database in the Netherlands served as the design and engineering repository, accessible from the other locations. Web-ex and conference calls were commonly used for voice communication, and remote desktop sessions were made possible via Windows Remote Desktop.

High-speed communications were used to complete acceptance testing remotely. In one case, a topside supplier was busy completing mechanical construction in Dubai, before doing acceptance testing. So, a test-system was set up in the Netherlands, executed remotely by the lead engineer in Porsgrunn, Norway, and observed via Web-ex by the customer in Dubai. This is typical use of communications technology to save travel time and money and keep the project on its fast-track.

IMPLEMENTATION

During the implementation phase, the modules were positioned on the ship's top side with appropriate connections to shipboard tanks and other modules. The internal control systems were plugged into the vessel's bus networks leading to the process control room. In addition, the proper electrical power connections were made as a part of the "plug and play" concept.

Every FPSO project tends to be a race against time because, once an operator like Pemex places an order for such a vessel, they want that ship delivered as soon as possible. On the other hand, the ship owner does not want to commit conversion funds until the contract is in hand and the actual processing requirements are known and understood. It's then a race against time to get the ship operational.

A head start was gained by obtaining a preliminary engineering contract without specific information on which to base the engineering. This allowed selection of the Main Automation Contractor and formation of the initial engineering and design team. That led to automation system selection and initiation of early-stage automation hardware construction. Even though the planners weren't quite sure where that hardware would be employed, they knew it would be needed. Rough estimates of control component's I/O requirements and locations enabled system designers to develop a cabinet that would allow I/Os to be assigned later. Many of the control system cabinets were constructed in this way and shipped to the yard for installation, providing the flexibility to move forward before all control requirements were fully defined. As a result, the time needed to develop and produce an automation system for a project of this magnitude was greatly reduced.

This technique, called MarineFlex and MarineSuperflex, was applied, making use of the DeltaV I/O termination properties and flexibilities. The upper rows of the cabinets were reserved for bus interface cards, and the next two rows were reserved for conventional I/O, i.e. analog I/O and discrete I/O. This cabinet design allows the backplanes and termination blocks to be used for whatever conventional I/O cards are needed. Once the I/Os have been defined, which depends on the instrumentation installed with each module, the assignment of I/O cards could then be designed and provided quickly from the factory in Singapore. In fact, they were delivered within days and installed in a very short time. In the meantime, shipyard technicians were installing the cross-wiring to integrate the automation islands into a total system. This approach allowed application engineering to move forward without actually knowing the real I/Os.

Integrating SIS was accomplished in the yard, so that both process control and system safety could be operated from one database. This also allows field instrumentation intelligence to be used for safety purposes. The C&E logic can incorporate diagnostics from instruments and valves in a voting configuration to determine if safety action is needed or not, depending on the device integrity. This can prevent unnecessary shutdowns and save the operator money, once the vessel is on station. The transparent system also allowed gas detector commissioning by one engineer at the AMS monitor, using the detector's diagnostic functionality instead of having multiple engineers climbing over the vessel to check detectors. This represented another big time saver.

Emerson's predictive maintenance software provides an effective means of identifying potential equipment problems in time to avoid failure-related shutdowns. This is a separate application built into the automation system that accesses diagnostic information from the smart field instruments and digital valve controllers by monitoring them full-time and generating Status Alerts, calling attention to instruments or equipment that may be in distress. Technicians can further evaluate alerts by interrogating the instruments online for more in-depth information. In this way, they can determine if an immediate repair/replacement is necessary, or whether the device can be allowed to operate until a more convenient time. This is the essence of predictive maintenance, which results in greater throughput, higher reliability, and lower maintenance costs.

DELIVERY

Commissioning of *Yuum K'ak' Náab* took place in Singapore in late 2006. By that time, the Norwegian, Indian, and Filipino crew had received basic training on the ship's operation, processes and automation system. The ship sailed from Singapore on February 2, 2007 and reached the KMZ Field in the GOM

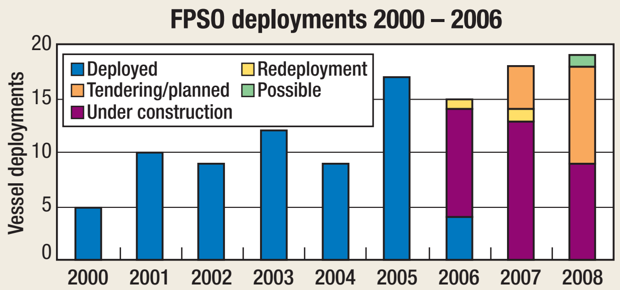

Fig. 3. Future projects will convert other oil supertankers to intelligent FPSOs.

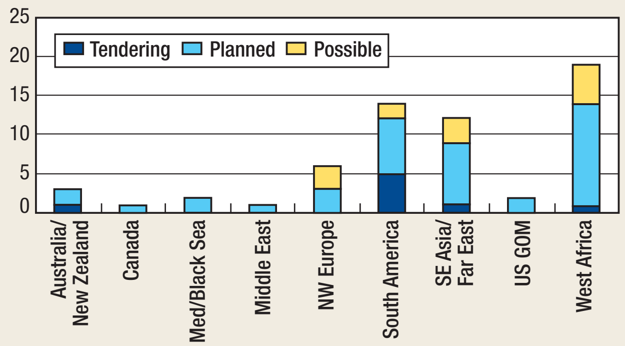

Fig. 4. Newbuild FPSOs will be placed around the world.

on March 16, where it is being operated by BW Offshore for Pemex. Emerson provided further training and support from its Mexican offices to assure a smooth transition from construction project to operational vessel. First oil was received in late June and the first off-loads were performed in early July.

FUTURE PROJECTS

BW Offshore and Emerson expect to apply the lessons learned in the fast-track conversion of this ship from oil supertanker to intelligent FPSO on future projects, Figs. 3 and 4. The two companies are discussing a partnership that will enable them to form integrated teams at the very earliest stages of future conversions to make the process as efficient and painless as the *Yùum K'ak' Náab* project proved to be. **WO**

THE AUTHORS

Wim Van Loon earned a BS degree in electrical and control systems engineering from Alkmaar Institute of Technology, the Netherlands, and is PMP certified, having progressed through Emerson's PMI training. He has over 17 years of experience in the process automation industry, including the last 10 years with oil and gas projects. He is based in The Netherlands and currently project manager in the EMA Northern Region organization for the Bergesen's Yuum K'ak Naab FPSO. Loon is presently project manager for the Bergesen's *Yùum K'ak' Náab* FPSO, and other similar projects in Norway.

Hans-Jacob Fromreide is an instrumentation lead engineer for BW Offshore. He has over 30 years of experience in construction, commissioning and engineering on development-projects for oil and gas world wide, including positions as subsea engineer, lead instrument engineer drilling, senior engineer process/utility, lead system engineer and commissioning manager. Fromreide's past eight years have been with BW Offshore, converting crude oil carriers into FPSOs. He has participated in bids, concept, engineering, commissioning and support to operation.