Latest Generation Subsea Observatory Standards – A Systems Architecture Review

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Abstract - **With the advent of the modern subsea observatory, two basic system architectures have emerged enabling the scientific community to study the oceans in an efficient manner for the region of interest, providing cost efficient, reliable, and proven solutions. Ethernet and optical networks dominate subsea communications architectures as utilized on programs such as MARS, VENUS, NEPTUNE, and NEMO due to the already developed and proven telecommunications hardware used in each application. With the two basic hardware configurations these observatories employ, a standard configuration has been generated that may enable experiments to be moved between observatories. This simple function of interconnectivity for experiments between observatories enables the study of oceanographic events on a global scale for the first time in history while creating efficiencies for funding. With currently planned hardware, a single experiment may study at least four different geographic regions with a minimum of three more locations available in the near future.**

The three main factors that define the architecture requirements of a modern subsea observatory are power, communication rate, and the distance required between regions of interest. Power defines the abilities of the node to support high wattage equipment like lights and other sensor arrays, while also affecting step-out distance due to the decrease in voltage based on resistive loads. Communication rates are vital as they define the systems ability to support instruments with high bandwidth such as cameras and remain competent over their design life spans. As the need increases for subsea information, so will the requirement for data rates. Observatories need to be able to upgrade throughout their lives to ensure they are able to meet the needs of future experiments. Subsea observatories also maintain the capability to be expandable into an entire subsea local area network (LAN) of sensors creating a need to evaluate step-out distances and repeaters. Ethernet-based communications have a maximum length of ~ 70 meters making them ideal for specific regions of interest. As some applications have found, the regions of interest can span many more square kilometers than is logistically viable for Ethernet-based communications architectures to support, leading to the need for an optically-based communications architecture which is able to support much longer step-outs. Using a standard set of existing equipment that is designed for, and can be configured for, each specific application's environment will minimize the cost and improve the reliability of the system by removing the need for engineering and qualification of new and unproven hardware.

This paper will present an overview of the latest generation of subsea observatories; focusing on the system architecture and discussing enabling interconnect hardware currently available, as well as highlighting future possibilities. Current technologies in each of the three main factors will be explored and discussed with special emphasis on how to design the most reliable system possible while reducing project costs due to design and development work. Specific examples from current subsea observatories will be cited, including their proven hardware choices, demonstrating they have achieved a subsea interface standard between programs providing a global solution to the scientific community.

I. INTRODUCTION

As the benefits of subsea observatories continue to surface within the scientific community more and more systems are planned and deployed. Understanding which technologies the existing observatories have pioneered, coupled with experiences from similar deepwater projects such as Oil & Gas and telecommunications, aid future projects by establishing a basic standard of existing and proven hardware. These standards create funding efficiencies by providing comparisons for estimated project costs, modularity of components, and possibly eliminating expensive design/development costs. This standard may also allow a single experiment to be deployed on multiple different observatories around the world enabling the global study of long-term deepwater events.

Taking advantage of equipment from the subsea telecommunications industry and the Oil & Gas Industry has always been part of the original intention of even the first subsea observatories. For example, in the early 1990's Japan's Venus project used a deployed electrical telecommunications cable which enabled scientists to do something that had never been done before while also not inventing the system from the ground up. The observatories underway today use the most advanced equipment available to them from the various subsea industries. The new optical/electrical based cable permits a level of communication with the observatory that is so high it can carry the signal from multiple experiments and high definition cameras while simultaneously supplying them with all of they power they require at a constant rate from the shore based station. The technology has been matured by the telecommunications industry to the point where a 25 year deployment is the acknowledged standard for the cable system.

Equipment pioneered by the oil and gas industry is employed to distribute the signal from the telecommunications cable to multiple experiments simultaneously. Cameron, GE Vetco, Aker Kvaerner, FMC, and many others have been using subsea control modules to distribute signals to valves and manifolds since the early days of the subsea well-heads. This technology is directly relative to an observatory as the control modules and power processing components emulate the requirements needed by an observatory. These same companies continue to pioneer other technologies that are in direct relationship to the oceanographic and renewable energy markets. High power subsea pumping and heating systems have grown tremendously over the last 5 years based on the global demand and elevated prices for hydrocarbons, making more of yesterday's questionable fields viable for production today. The high power connector originally developed for these oil and gas applications required only minimal qualification, primarily a DC rating, to be adapted to the original observatories. It has now become a standard when planning new observatories utilizing telecom style cables to provide power and data transmission.

Figure 1. Oil & Gas Communication Distribution Center.

Tying these two technologies together requires a final technology that was originally developed to support both of these applications. The electrical wet-mateable, high power electrical wet-mateable, optical wet-mateable and electrical/optical hybrid wet-mateable connectors are required to enable an observatory to adapt to the telecommunications line and pipe the processed signals out to either another secondary observatory or an individual experiment. A working knowledge of these technologies during the planning phases of a subsea system is imperative to reduce project costs and lead times while also improving project reliability figures. Using existing, proven, qualified hardware will immeasurably benefit the end users of the system by providing a dependable, upgradeable, serviceable, and competent research platform. This paper will review the current hardware slated for multiple projects and cite how existing hardware and architectures were adapted from various industries to provide a high reliability, low cost system. The use of Wet-mateable connectors has enabled observatories to combine the existing telecommunications hardware to an infrastructure capable of processing optical signals and voltages for multiple experiments or local area networks in a fashion that is both modular and expandable for considerations toward lowering total installation costs, total operations and maintenance costs and total life cycle costs.

II. ANCILLARY INFRASTRUCTURE ARCHITECTURE

The premise behind a subsea observatory is to study events in remote locations within the oceans and provide real-time data to scientists around the world. Once the data is received from the observatory it is piped via the Internet to computers around the world for analysis. To create this network of subsea information requires a support structure capable of retrieving the data from experiments and preparing it for transmission. A primary technology for this portion of the observatories comes from the telecommunications industry. Since the late 1980's communications companies have been using optical signals to transmit data across the Earth's oceans. Optical/Electrical cable, signal repeaters, shores stations, branching units, and cable terminations have all been manufactured and qualified for these applications providing proven solutions from which to build a subsea observatory. By using this existing hardware a solution for getting the information from a remote location to the Internet is provided, but it also comes with a standard set forth from the telecommunications industry for both optical signals and electrical power. Fortunately the power standard is large enough to enable observatories to run almost any experiment yet conceived but requires a step-down transformer to bring it to a more manageable voltage. Likewise, the optical signals have been a standard on-shore for over twenty years making supporting hardware easy to find and use.

To adapt the telecommunications industries technology to the requirements of the subsea observatory a system is needed to terminate a hybrid optical/electrical cable subsea. The termination must permit multiple instruments to send and receive data to a shore based station while also being manageable by either a ship or remote operated vehicle (ROV). In the interest of cost and modularity, most projects have chosen to have an ROV maintainable system instead of the alternate cable laying ship increasing maintainability/serviceability, and increasing the plug and play nature of the observatory. The enabling technology tying the telecoms industry to other technologies, while maintaining the premise of the observatory, is the wet-mateable optical and electrical connectors.

Optical connectors are used to bring the communications signal out of a standard repeater housing and a high power connector is used to bring the standard 10kVDC power from the same housing. These connectors may then mate to a standard, modular, node for processing and distribution. The connectors allow the cable termination and laying processes to be completely independent of the node and experiments. This allows the node for the observatory to be removed and upgrade or serviced without the need to retrieve the shore cable or trawl resistant frame.

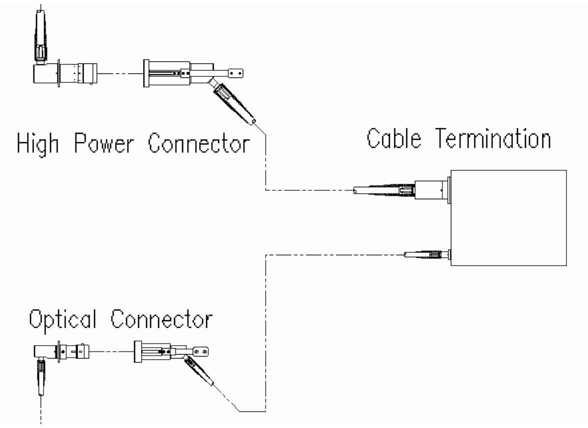

Figure 2. Connectorization of Telecommunications Cable Termination

The offshore Oil & Gas Industry began using optical connectors in the mid 1990's for communications to their subsea control modules. These control modules are similar to the observatories in that they retrieve information from many subsea wells, process the information, and communicate it to a surface control unit aboard the oilrig. For this reason, optical wet-mateable connectors were developed, qualified, deployed, and proven in field conditions. They continue to provide an off-the-shelf type solution to many other applications including the subsea observatory and have become the standard in the oil and gas industry. The Rolling-Seal optical wet-mateable connector was the original optical connector and has become the standard within the industry. It permits up to 8 optical circuits to be connected subsea a minimum of 100 times without any concern to the surrounding subsea environment with little optical loss (< 0.75dB).

In recent years the increased cost of petroleum has made the pursuit of deeper, more costly oil reasonable. Oil companies continue to move to colder, deeper climates with higher viscosity oil, driving the need for new technologies to aid in the retrieval of the oil. Subsea pumping and pipeline heating systems have driven the connector industry into developing wet-mateable connectors capable of handling many hundreds of thousands of watts to provide the power necessary for this type of hardware. These connectors become the enabling technology between the proven subsea control modules and the proven telecommunications cables providing a connection mechanism for the industry-standard 10kVDC to the subsea step-down transformer. Similar to the aforementioned optical connector, the high power connector permits the shore cable to be kept separate for the node reducing project costs and increasing maintainability, serviceability, and the nodes ability to be upgraded as the needs of the scientific community change.

By using a connectorized optical/electrical telecommunications cable, the subsea observatory now has the ability to remove the most complex part of the system and repair/replace as necessary. Connectors also lend themselves to providing an expansion port for the subsea node itself by allowing secondary observatories to branch off of a primary observatory as currently slated in the NEPTUNE program.

III. NODE ARCHITECTURE

An observatory's strongest point is its ability to collect data from, and provide power for, multiple instruments simultaneously while permitting those experiments to be changed/maintained as necessary. The node is required to receive the signals from the telecommunications cable and process them into a format that is easily used by various instruments. Anything from an analog instrument such as a hydrophone, pressure sensor, temperature sensor, or salinity monitor to more complex instrumentation such as a high definition camera must be able to be installed onto the node and work with the optical based shore cable. Similarly these experiments do not operate on 10kVDC so the node must contain a power processing facility capable of stepping the voltage down to a usable value while maintaining the required power.

Figure 3. Rolling-Seal Optical Connector.

Figure 4. High Power Connector.

A typical node consists of 4 main components: The power processing pressure vessel, the communications pressure vessel, the ROV deployable frame and cathode, and the wet-mateable connector suite. The power processing vessel and the communication pressure vessel clean the signals from the telecoms cable up to allow the science ports to communicate with the shore stations, the frame work aids in the deployment of the node to the already installed frame, and the connector suite provides the interconnectivity required to use the observatory. Currently there are only two basic architectures for the subsea node based on the use of existing telecommunications hardware. The power from the cable is the same in both cases at ~10kVDC so all that need be evaluated for this study is the communications signal. Logistically it is not reasonable to use electrically based communications signals over long distances, thus telecoms cable employs an optical based architecture. The deciding factor in the node is whether to process the optical signal to an electrical signal at the primary node, or to multiplex the signals to the various science ports and process the optical signal at a later date. Previously this decision was based on available equipment and estimated costs employing an integrated circuit technology within the communications pressure vessel to process the signal and use electrical wet-mate connectors to deliver the signal to the various experiments. This is a proven and deployed technology on projects such as the University of Victoria's Venus project, but has its limitations.

Figure 5. University of Victoria's Venus.

Once the signal is converted it cannot be transmitted over long distances before the signal degrades to an unrecognizable state. The optical signals provide increased bandwidth over their electrical counterparts and increased reliability within the node itself. The integrated circuitry lowers the overall reliability numbers of the node, as there are many components that may cause an issue. By using proven multiplexing equipment from the telecommunications industry the reliability of the node can be increased. The other direct benefit of an optical based system is the distance the signal is capable of traveling before requiring processing. It can be many kilometers from the main node opening the geographic region of study up from a few square kilometers to tens of square kilometers.

To enable the use of the optical architecture a wet-mateable connector is required to deliver both the optical signal from the communications pressure vessel as well as the electrical signal from the power pressure vessel. The typical requirement is for 2 optical fibers and 2 electrical conductors. One of the optical fibers is from communication to the shore, and the other is for communication from the shore. The electrical circuits are a requirement for DC power from the power processing pressure vessel to accommodate the needs of the experiment in lights, circuitry, etc. An adaptation of existing technology that is used in both the Oil & Gas Industry and the telecommunications industry is the NRH connector. This connector permits up to 4 optical circuits and 2 electrical circuits, providing sufficient power and communication for all scientific applications.

Figure 6. NRH Optical/Electrical Connector.

IV. EXPERIMENT ARCHITECTURE

Limits on a modern subsea observatory as to which experiments are able to be deployed have become increasingly difficult to define. Power does have a limit to the total simultaneously deliverable wattage, but contrary to previous battery powered assemblies that would perform similar studies; the power is continuous for the life of the observatory. Flexibility of what can be deployed and studied is paramount as there are so many unknowns to this relatively unexplored region. The power circuitry is, for the majority of observatories, set as a standard of either 400VDC or 48VDC with a few exceptions. The major choice of the experiment designer is the choice of how to process the optical signal from the node or how to process the Ethernet signal.

Ethernet appears to be the clear choice at first glance as it lends itself many monetary advantages over the optical systems and similarities to some experiments, but when compared to the compromises required to use the Ethernet based system the optical requirements begin to look more reasonable. Ethernet communication subsea has a limited distance of travel before the signal degrades due to the electrical characteristics of being subsea. Optical signals do not suffer this same affect as they are not influenced by things like capacitance or inductance. Similarly, if an optical fiber gets wet, it is not going to fail, adding an extra layer of reliability. This general inertness to the subsea environment yields a long-term reliable solution that has the benefit of increased step-out distance and the ability to be upgraded as needs evolve.

By designing the experiment with the required integrated circuit technology, the researcher may place the experiment in a location much further from the observatory while maintaining real-time, high bandwidth feedback. The inclusion of the circuitry into the experiment is an added benefit if the equipment should malfunction, only the experiment need be recovered. if the circuitry was in the node all of the attached experiments would suffer the failure and the node would have to be retrieved and repaired/replaced depending on the severity of the issue.

V. CONCLUSION

A subsea observatory is comprised of 3 main components: a telecommunications cable tying the observatory to the shore station, a node that processes and transmits signals from multiple points, and a suite of wet-mate connectors to enable the required interconnectivity. The wet-mate connectors are an important portion of the observatory as they permit the combining of existing, proven technologies and provides a configurable research platform. By using these existing technologies from industries such as Oil & Gas and Telecommunications Ocean Observatories may benefit from proven reliability, modularity permitting upgrades and servicing through reduced total life cycle costs and reduced engineering and qualification costs.

From the advent of the subsea node, researchers have always intended to use existing technology to enable the study of the ocean. The use of wet-mate connectors enables cables to be deployed separately from hardware, enables the hardware to be removed and maintained/upgraded if necessary, and removes the requirement to retrieve the node each time an experiment needs to be added/removed from the node. This function further reduces the project life cycle cost by allowing for the use of smaller ships of opportunity to service and maintain the node and the complete system. Wet-mateable connectors exist for the majority of the subsea configurations including electrical, optical, electrical/optical hybrid, and high power. Current observatories, both planned and deployed, use the wet-mate connector and established a de facto standard within the subsea oceanographic community. The establishment of this standard is a very positive step, towards reducing project costs by reducing engineering development and qualification costs, allowing components to be modular, and permitting research groups to study events in multiple regions on multiple systems without the need to reconfigure.

Knowing and understanding what technologies to use from the existing industries can save observatories time and money at the beginning of the project and through the project lifecycle. Understanding when to use optical and when to use electrical communications architectures is important to gain the maximum effectiveness for the study of the region of interest. As the observatory continues to grow, new programs should research and discuss architectures with some of the existing observatories like Neptune, Venus, and Mars as well as discuss the options with the manufactures of the hardware. Prudent planning at the onset of the project can limit the amount of delays in the project from design and qualification requirements as well as reduce the cost by providing existing and proven solutions.

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