FIBER-OPTIC CONNECTIVITY FOR OFFSHORE OIL & GAS APPLICATIONS: MORE BANDWIDTH, MORE POSSIBILITIES, MORE BENEFIT

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Abstract: The topic “communication” is an ever more critical business aspect. However, since it is not part of the core business of oil and gas producing companies, these companies are not interested in worrying about the technical details and other related problems. They require precisely tailored, i.e., engineered, highly reliable turnkey solutions. One recent trend is that oil and gas companies are outsourcing all communications-related tasks to independent service providers who are building, operating and maintaining those networks. As a result, the engineering quality of complex telecommunication services for the oil and gas business has received top ranking, in terms of value, for both the customer and the supplier. For the customer, it is the basis for gaining confidence in the solution. For the supplier, it serves as a shining example of his capabilities and performance. Once a platform is connected to a cable system, it can be used as a base station to connect surrounding platforms with cables or wireless technologies which will multiply the accessible users and improves the business case of the service provider.

1. INTRODUCTION

Communication plays an increasingly important role for oil and gas companies. New oil and gas fields are being developed at ever-greater distances from shore. As a result, these new oil and gas fields are located deeper than 2000 m with a clear tendency to 3000 m (and more). Such depths necessitate “free-floating” platforms. Until now, the preferred means of communications used microwave and satellite technology. Microwave links are limited to distances of about 80 km. These links have additional problems in that the platforms move slightly out of the focus of the microwave radio beam. On the other hand, satellites do not provide the bandwidth required by today’s applications at such a low cost level.

The engineer's new toys are data hungry applications like 4C (four component) / 4D (four dimensional) seismic surveying with real-time data delivery. Remotely supervised and controlled operations require huge data pipes and guaranteed “Quality of Services.”

Wireless communication systems like microwave and satellite rely on precisely aligned antenna systems placed on top of the platforms where they are directly exposed to the power of nature. Unlike these fragile structures, submarine cables enter the platforms well protected from below the water through steel I or J tubes.

Fiber optic submarine cable systems with this improved protection philosophy not only significantly improve the communication system uptime; they also provide the necessary bandwidth for tomorrow’s applications and services. Business-critical processes can be handled over a fiber optic submarine system due to the superior availability and reliability. Furthermore, huge OPEX savings are possible.

In addition to the described data and voice communication services, which can nowadays be combined via "Voice over IP," a fiber optic submarine cable system can handle extra "added value" services like

- Security and surveillance applications
- Backbone network for 3rd and 4th generation mobile telecommunication services
- Backbone network for "last mile" techniques
- And last but not least the entertainment system.

In this context, it is easy to understand why oil and gas companies are paying more and more attention to all communication-related aspects with special emphasis on fiber optic submarine cable systems and all their advantages [1].

As stated above, the topic "communication" is an ever more critical business aspect. However, since it is not part of the core business of oil and gas companies, these companies are not interested in worrying about the technical details and other related problems. They require precisely tailored, i.e., engineered, turnkey solutions. One recent trend is that oil and gas companies are outsourcing all communications-related tasks to independent service providers who are building, operating and maintaining those networks. As a result, the engineering quality of complex telecommunication services for the oil and gas business has received top ranking, in terms of value, for both the customer and the supplier. For the customer, it is the basis for gaining confidence in the solution. For the supplier, it serves as a shining example of his capabilities.

2. BUSINESS CASE

Anyone planning to provide communication services to oil and gas platforms is usually very interested to know all the pros and cons of the available solutions in order to balance their requirements with performance and costs:

Satellite

Pros

- Huge coverage, the user is not fixed to any infrastructure
- Very fast setup, there are solutions available which are up and running in less than one hour
- Low initial cost (CAPEX)

Cons

- Limited bandwidth
- Delays / echoes / distortion
- Very high latency in IP networks
- Increasing operational costs (OPEX) if more and more bandwidth needed
- Antenna exposed to harsh environment

Microwave

Pros

- More bandwidth than satellite
- Moderate initial cost (CAPEX)

Cons

- Bandwidth still limited
- Distance limitation (approx. 80 km)
- Possible antenna alignment problems with free-floating platforms
- Antenna exposed to harsh environment

Submarine Cable

Pros

- Virtually no bandwidth limitation
- No distance limitation
- System well protected on the ocean floor
- Only passive components used in the wet plant
- Different customers or applications can use separate fibers

Cons

- Most costly solution
- Longest time to implement

	Satellite	Microwave	Submarine Cable
CAPEX	☺☺	☺	☹☹
OPEX	☹	☺	☺
External hazards protection	☹☹	☹☹	☺☺
Quality of services	☹	😐	☺☺
Distance	☺☺	☹	☺☺
Bandwidth	☹☹	😐	☺☺
Scalability	☹☹	☹	☺☺

Figure 1: Business case summary

The three existing solutions do not necessarily compete with each other; usually they complement one another and are providing a very reasonable upgrade path to the customer.
A satellite connection can be used to cover initial communication needs. A microwave link (if technically feasible) can handle increased bandwidth needs, and finally a submarine cable can meet the highest reliability and performance demands.
In addition, the business case becomes more and more attractive with the number of platforms connected using a single cable system. Even multiple operators can share one single system without the need to share the communication media (i.e., the fibers).
Once a platform is connected to a cable system, it can be used as a base station to connect surrounding platforms with wireless technologies or short cable stubs which will multiply the accessible users.

Bigger networks can even connect different regions of a country, remote islands or even different countries. In this case, the potential of extra income from leasing dark fibers to telecom carriers might increase the attractiveness in the eyes of decision makers.

3. NETWORK DESIGN CONSIDERATIONS

Any kind of network configuration, such as star, collapsed ring, double ring or any combination, can be easily implemented. The basic network design usually contains a ring "trunk" submarine fiber optic cable system with branching units (BU) splitting fibers to the individual platforms. The platforms are connected via designated "jumper" and "riser" cables to the branching units and to the main network. A physical ring system is the best basis for an efficient network protection strategy [2]. If a physical ring system is not feasible, for example, due to economic considerations, a collapsed ring system should be set up in the beginning. This configuration provides basic protection against possible TR equipment failures. Later, the system can be extended to a physical ring system.

3.1. Repeaterless Segments Technology

For system cost optimization it is mandatory to use submarine cable designs and their respective accessories that are optimized for repeaterless applications [3]. There is neither a need for an outer copper layer nor for thick high voltage insulation. The cable design can accordingly be more compact, with less weight for more convenient transport arrangements.
Low cabled fiber attenuation is one of the key elements of repeaterless submarine cable system. The central metal tube, preferably made of copper, will provide a stress-free and hydrogen sealed environment in order to maintain lowest fiber attenuation even if the fiber count is high. The fiber count can reach up to 144 fibers. Dark fibers can be leased or sold to additional customers and sensitive applications can run on independent fiber pairs.

Cost-effective SMF (G.652D) and lowest loss fibers (G.654B/C) are the fibers of choice for repeaterless links since they can handle high optical power levels and are less prone to bandwidth limiting non-linear effects [4]. Provisioning of cable spares is simplified since cabled fiber dispersion management is not required, and a single fiber type can be used.

The branching units just need to provide flexible fiber management and routing features. Cost-driving features like optical add-drop multiplexers, power feed path support or even power switching are not required. Of course repeaterless submarine cables and accessories should support electrical fault localization techniques like DC-testing or electroding.

The progress in repeaterless transmission equipment technology in recent years has made repeaterless links even more attractive. The technology for N x 40 Gb/s or N x 100 Gb/s is available for long distance repeaterless transmission systems (approx. 400 km). This has been enabled by improvements in the Raman and ROPA (Remotely Optical Pumped Amplifier) amplification technology, as well as by impressive advances in the coherent transmission technology.

Innovative and efficient means of transporting repeaterless cables can greatly enhance turnaround time and significantly drive down cost. One such application with a proven track record is the use of containerized modular tanks, which enables the manufacturer / installer to transport the cable on standard container vessels, offering regular feeder services as well as fast and reliable turnaround. The modular tanks are lifted by crane onto the container vessel, eliminating the need for lengthy cable turnovers. On reaching its destination and depending on the lay spread involved, the cable can either be laid directly from the tanks, or alternatively coiled into the tanks of the cable vessel.

3.2. Repeatered Segment Technology

When crossing the limit of repeaterless systems, by distance and/or design bandwidth, repeatered transmission will be the technology of choice. Of course there will be a step-up of costs, especially of cable and transmission technology [5]. This increases the need for smart system design, which also includes a careful look at route engineering, cable protection measures, transport logistics and wet plant installation.

Repeatered submarine networks in the Oil and Gas sector have a more regional nature; they are not planned to bridge oceans. The link lengths of repeatered segments may vary between 500 km and 2000 km. For this type of system, a G.654B or even very cost-efficient G.652D fibers without any dispersion management are very well suitable due to the advances of the coherent transmission technology.
On the cable side the fully qualified, sea-trialed and field-proven 17 mm (LW diameter) standard design is the best compromise between compact design and robustness. A low resistance of 0.6 Ohms/km by using both a central copper tube and an outer copper layer above the strength members will reduce the overall power feed voltage and therefore the power consumption of the wet plant. A smaller and less costly power feed equipment could be selected, and the operational costs could be reduced.
The use of branching units will give ample flexibility in the system design. If possible the spur cables should be repeaterless to remove the necessity of an additional power feed equipment in the terminal station. The branching units would just provide fiber management or optical add-drop multiplexer features without cost driving power feed path switching options. Of course these options need to be available if

system design and system availability considerations permit.

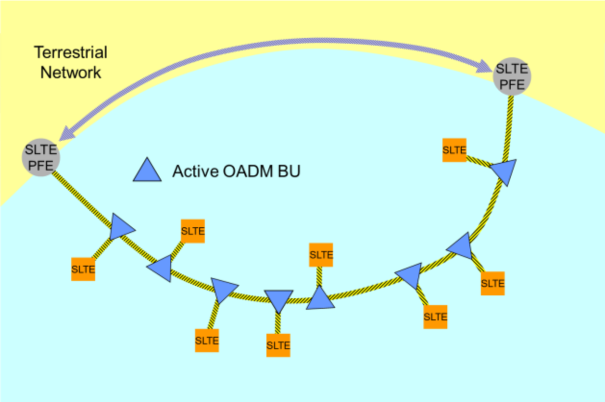

Figure 2: Typical repeatered system design

The Submarine Line Terminal Equipment should be set up in such a way that it can grow with the demand. System operators need to have the opportunity to start with a cost effective basic configuration. Feature and bandwidth upgrades can be added at a later stage without traffic interruption. 40/100 GB/s per wavelength and especially Ethernet capabilities have become a standard. These features will provide bandwidth in the terabit per second range per fiber pair. Network operators now may consider to reduce the fiber count e.g. from 4 pairs to 2 pairs, lowering repeater and cable costs, without the fear of lacking bandwidth in the future.

4. WET PLANT COMPONENTS, SUBMARINE CABLES

Of course, the most import part of the network is the submarine cable itself. Especially for oil and gas networks, the design requirements are both diverse and demanding. Therefore, the selection, design and engineering of the appropriate cable types require very close coordination with the customer. A typical fiber optic submarine cable network consists of several cable portions:

- Trunk cables, either repeaterless or repeatered, for the main "backbone" cable.
- Jumper cables connecting the platforms to the branching units.
- Static riser cables for fixed platforms.
- Dynamic riser cables for floating platforms for the last section from the seabed to the platform itself. The dynamic riser cables in particular will be engineered with tools for the design and analysis of flexible risers. These tools consider the ambient conditions like platform movements or other fixed or flexible elements in its environment.

Figure 3: Examples for repeaterless and repeatered submarine cables

- Branching Units (BU) are a fundamental part of the submarine cable network concept. Fibers can be routed straight through the branching unit or branched towards a platform (either existing or planned) or any other submersible device. BUs shall provide mechanical and optical continuity, pressure and hydrogen resistance and finally secure space for fiber and/or wavelength (OADM) management.

Figure 4 Branching Unit for MINISUB™ repeaterless submarine cable being deployed in the North Sea

- Pull-in Hang-off Assemblies are used to secure the submarine cable to the top of the J or I tube or other securing locations. The preinstalled Pull-in device is used to pull the cable through a J or I tube. The Pull-in Hang-off assemblies are specially designed for the individual I or J tube configuration and other unique conditions on the platforms.
- Cable-to-cable Joints are typically based on industry standard UJ or UQJ technology but sometimes tailor-made solutions are required for connecting special offshore cable types like umbilical cables or wet-mate connector systems.
- Lay-down Heads will be installed on submarine cables as the end seal. In addition, they are designed with some space for fiber management where the fibers can be spliced together to maintain optical continuity for data traffic or optical monitoring.

5. NETWORK EXTENSIONS AND SCALABILITY

Fiber optic submarine cable networks for oil and gas applications have to be as flexible as the business using them. New oil and gas fields will be developed, old platforms might be scrapped, new customers or applications might show up. Fiber optic submarine networks can easily be adjusted to these situations and can already be incorporated into future engineering concepts. Submersible fiber optic junction boxes with wet-mate connectors, which can be handled by "Remotely Operated Vehicles" (ROVs), can be preinstalled into branches of the network. New platforms or complete new network segments can be simply plugged into these underwater manifolds. No additional riser cables need to be installed on platforms which are already connected to the network and no additional slots in the limited J or I tubes are required. The transmission equipment can be preconfigured. In the best case, new links can be configured and managed completely remotely from the network management center. Another possibility to address future network extensions is the use of branching units with short jumper cables and Lay-down Heads with looped fibers. The Lay-down Heads can be recovered later and a new cable can be spliced onto the preinstalled cable tail. Both options are only a small advance investment and provide the network operator great flexibility for further extensions with considerable CAPEX and time savings when implementing these extensions in the future.

6. QUALIFICATION

Submarine cable design, together with all its accessories, must meet demanding requirements such as protecting single-mode fibers from excessive strain and lateral pressure during laying and recovery operations, from the effects of pressure on the ocean floor and from mechanical damage. Qualification tests are always part of the submarine cable system development and design program to demonstrate that all requirements including special project needs such as performance, reliability and service life, are fulfilled. All components of a complex telecommunication system for the oil and gas industry must be qualified by means of stringent qualification procedures under consideration of internationally accepted recommendations. Major cable manufacturers, academic experts and leading companies in the submarine telecommunications systems field created these standards to overcome the lack of a specification that accurately reflects harsh marine environments.

Continuous control tests are performed over the entire manufacturing process on incoming materials, semi-finished and finished products in order to assure a consistently high level of quality. Manufacturing control tests may include some or all of the following:

- Process qualification tests
- Manufacturing tools qualification
- Operator qualification tests
- Visual inspections.

This unmatched quality and performance have been confirmed by successfully implemented reference projects in the oil and gas industry in the Caspian Sea and the North Sea.

7. PROJECT IMPLEMENTATION

The implementation phase of the project can easily be as costly - or even more costly - as the production phase of a submarine cable project. Adequate experience in project execution, including sensible project and risk management, timely permitting and secure wet plant installation, is therefore mandatory for cost-effective planning of upcoming projects.

7.1. Project Management

The geographic extent of domestic or regional feeder networks allows the deployment of a small, dedicated project team with direct communication path to the System Owner, rather than a top-heavy administration and decision-making framework. A local project office offers fast and effective correspondence, regular exchange of progress in the same time zone and enables short-notice *ad-hoc* meetings to address the challenges of the project in face-to-face consultation with the system owner. This typically ensures a much better rapport and willingness to succeed together, thereby reducing friction and conflicts. This aspect, however benign it may seem, should not be overlooked, since it leaves precious time for the actual work in hand, and reduces greatly any delays arising from potential mis-communication spanning several different time zones and continents.

7.2. Risk Management

Early appreciation of project risk is one of the most critical aspects for maintaining a cost-effective solution towards the system owner. Whilst the majority of risks with respect to manufacturing are well-known and understood and there are usually well-established mitigation processes in place, the biggest uncertainty lies in assessing risk spanning a wide geographic area and a multitude of culturally diverse environments. With domestic or regional Oil and Gas cable systems, risk can be more readily assessed and mitigated, greatly reducing any knock-on effects on the implementation cost base, and enabling the turnkey supplier to reduce contingency mark-ups, passing economic benefits directly to the customer.

8. SUMMARY / CONCLUSION

The development of new oil fields is becoming more challenging. The new oil patches are more and more remote with simultaneously escalating external hazards. New technologies such as subsea exploration are already knocking at the door. Although the current price of oil is at a very high level, pressure continues to keep a tight rein on costs. Remote control, collaboration and automation are obvious trends in the industries. In this business, highly reliable telecommunication systems are becoming a key function for continuing success.

Repeaterless submarine cable networks for oil and gas have to be as flexible as the business using them. New oil and gas fields will be developed, old platforms might be scrapped, new customers or applications might show up. Due to the high fiber count, individual fiber pairs can be provided to different customers, user groups or applications. Unified data transport networks utilizing "Everything over Internet Protocol" form the basis for scalability and OPEX savings.

Fiber optic submarine cables do provide secure and reliable connections with virtually unlimited bandwidth. This massive bandwidth allows the operators to step into a new level of collaboration, distributed support services and centralized offshore assets management. This becomes even more important since more and more production equipment is operating directly on the sea bed instead of an accessible platform.

Access to information and communication everywhere and any time is a key necessity in today's life and submarine cable are the backbone of this system. The technology is available to bring this asset directly to even remote offshore places for the benefit of the Oil and Gas industry.

Fiber optic submarine networks can easily be adjusted to these situations and can already be incorporated into future engineering concepts

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