DESIGN CHALLENGES FOR UNDERSEA SYSTEMS SERVING OFFSHORE PRODUCTION PLATFORMS

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Abstract: Different design priorities and requirements have evolved for undersea cable systems serving offshore production platforms which vary significantly from the requirements of traditional telecommunication cable systems. High survivability and platform independence, particularly in geographic areas subject to severe weather events, are critical and may outweigh pure cost considerations. Sharing a single cable system among the platforms of multiple operators requires additional technical, operational and political considerations.

This paper identifies key operational parameters, presents a set of design criteria specific to the offshore oil and gas industry then considers the tradeoffs of various system architectures.

1 INTRODUCTION

Offshore oil and gas production has moved farther than ever into deeper water. At the same time, oil companies require new, collaborative methods of operating these platforms to reduce personnel on board and bring control of offshore systems into onshore facilities thereby reducing operating costs and personnel risks. Today's operating models require large bandwidth with high reliability, high survivability and low latency. Traditional microwave systems will not reach newer deep-water platforms and satellite systems are expensive and cannot meet either the bandwidth or latency requirements at any price. As oil and gas companies turn to submarine cable systems for their offshore telecommunications needs they are finding that conventional thinking does not take into account some of their unique operating conditions; nor will it meet their operational needs, or yield the financial security they have targeted that these new systems should provide.

2 CONVENTIONAL THINKING

In the oil and gas industry, conventional thinking is that telecommunication systems are a necessary evil and, that as telecoms do not bring oil or gas out of the ground, these costs should be kept as low as possible. In the telecom industry, however, conventional thinking is that reliability is king and ring systems enhance reliability; that single catastrophic failures are rare, but real and multiple catastrophic failures are highly unlikely; that cost is an important issue and undersea repeaters are expensive.

In areas like the Gulf of Mexico, offshore platforms are numerous and close enough to each other that a ring of unrepeatered submarine cable systems can connect a number of platforms (possibly from several different operators) without any submerged repeaters. This configuration would seem to meet the reliability requirements using ring architecture and should have the lowest implementation cost. In the oil and gas industry where almost every major asset has multiple operators as investors with a single nominated asset operator, this model would seem to meet the gross business requirements as well.

3 DESIGN CHALLENGES

In areas like the Gulf of Mexico frequented with hurricanes, severe weather operating procedures present significant design and operational challenges. Platforms are abandoned during severe weather and production is closed in. One of the goals of submarine telecom systems to offshore platforms is to improve the ability of the operators to re-man the platforms following abandonment. With the new generation of deep-water platforms, a single platform may be producing as much as 200,000 barrels of oil per day. With the current price of oil, being able to bring one platform back into production a day earlier means a significant reduction in lost revenue to the operator and owners. Production may not resume until the platform is re-manned which may not take place until the platform is determined to be safe and habitable, and communications are established. Current operational procedures usually require an over flight of the platform and/or a day visit by inspection personnel to determine platform status. If adequate telemetry can be maintained through a survivable transmission link to a shore base, it would be possible to determine the status of the platform either as secure and habitable or as uninhabitable, but with information regarding the nature of the deficiencies and problems aboard. In either case, good and survivable telemetry would make it possible to re-man the platform or carry out repairs in a shorter time frame and reduce the time to resumption of production.

During abandonment, power generation aboard platforms is reduced to a few "storm generators" left running to power a few critical systems. Every operator and, in fact, every platform (even platforms under the *same* operator) have different storm power generation standards, procedures and fuel reserves in the day tanks of its generators.

In an unrepeatered ring system of 8, 10, 12 or more platforms, the failure of two nodes can cause loss of communications to multiple nodes in the ring. Many different scenarios may cause the failure of a node during a hurricane. The failure of storm power systems and the loss of entire platforms both occurred during hurricanes Katrina and Rita in 2005. In the telecom world, highly reliable power supported by battery backup with long reserve times is taken for granted. In the world of the offshore platform, topside real estate is scarce, valuable and planned for years in advance. There simply is no room for a massive battery plant to provide 24 or 48 hours of reserve time.

Network security becomes another design challenge in an environment where the platforms of multiple operators are expected to coexist on a common shared ring system. In the case of the traditional unrepeatered ring, traffic from all operators will pass through each operator's platform(s). Admittedly, all traffic may not drop to the electrical level and express traffic may pass through the node while local traffic is added and dropped, but this will be completely dependent on the type of terminal, add/drop multiplex, repeater or router equipment used in the network design. Only in the cases of the add/drop multiplex (which is much more common in traditional telecom architectures than in Ethernet architectures more suited to enterprise networks) or the repeater, will express traffic of one operator remain fully encapsulated as it transits another operator's node.

Further design challenges are encountered when working in hurricane prone geographic areas. As an example, storms in the Gulf of Mexico may affect several hundred kilometers of coastline with high winds and storm surge as was clearly demonstrated by hurricane Katrina.

In deep-water production areas, new reservoirs are constantly being brought into production and it should be anticipated that several new production assets will be brought on line during the design life of the submarine cable system. While these assets will be in the same general geographic area, many of the new fields may lay hundreds of kilometers from existing production platforms. Any system installed today should allow for expansion, both in the number of platform nodes and in the length of the overall system. This type of flexibility is exceedingly difficult to accommodate with a ring comprised of unrepeatered links.

4 DESIGN CRITERIA

While reviewing the operational requirements and operating environment of the offshore oil and gas industry, a specific set of design criteria quickly surface as imperatives:

Shore terminal stations must be separated by 400 to 500 km as a minimum

Each platform node must be completely independent of every other node

The system must survive the loss of several nodes and one terminal station

The system must accommodate expansion in the number of nodes and in total system length

In a multi-operator environment, with rare exceptions, traffic from each node should bypass all other nodes, or it must remain encapsulated and secure if it transits another node.

5 MEETING THE DESIGN CRITERIA – A COMPARISON OF SYSTEM ARCHITECTURES

In a traditional unrepeatered ring configuration, a single pair of fibers may be employed. The ring itself provides protection from individual equipment, fiber, or link failures. All traffic must pass through each node to be amplified and/or regenerated either through terminals, add/drop multiplexers (ADM), amplifiers or regenerators. Power failure at one node will affect traffic for all nodes. Power failure at two non-adjacent nodes isolates all nodes between them from the shore. Failure of one node and one terminal station will isolate all nodes between the failed node and the terminal station. Addition of new nodes will be dependent on the location of the new node relative to other nodes and be dependent on distance. This architecture fails to meet all of the stated design criteria except for the encapsulation and security of express traffic, which is dependent upon the type of transmission equipment used at the nodes.

To improve survivability, a modified unrepeatered ring configuration can be considered where each node is connected to both its adjacent nodes and the next nodes beyond. This configuration utilizes three fiber pairs in each link except the links from each shore terminal station to the first offshore node at each end of the system which use two fiber pairs. This configuration also employs twice the number of optical transmitter/receiver pairs, less two, compared with the traditional ring. This architecture can survive a single shore terminal failure, up to three simultaneous node failures (depending on location) or up to two node failures and a shore terminal failure (depending on node locations) without affecting traffic from the other nodes. This architecture also significantly improves survivability, but only in certain failure scenarios. This configuration also comes with a hefty cost increase for the limited improvement in survivability and may be difficult to implement by having to span longer distances between non-adjacent platforms. In the Gulf of Mexico, some of these distances approach 300 km. While these distances are achievable without submerged repeaters, they require special fiber types and specialized premium grade connectors to handle the high power levels. All of these factors add significant costs and system complexity for small benefits in survivability.

A further configuration option is the use of a repeatered ring system. Current technology can support connections to as many as 32 nodes from one fiber pair utilizing broadband optical add/drop multiplexing (OADM) which can allow the dropping/inserting of one or more multiplexed wavelengths at each node without accessing pass-through traffic from other nodes. This repeatered OADM architecture provides exceptional survivability in the face of multiple node failures, as each node's traffic is completely independent of every other node. The system can also sustain a single shore terminal station failure in addition to multiple node failures and maintain traffic to all other surviving nodes. By employing power switching branching units, repairs to, or expansion of, any part of the system may be accomplished without interruption of traffic to unaffected nodes.

The repeatered architecture adds power feeding and a more expensive cable structure as well as increased sparing costs to include repeaters and OADM branching units. While the cost of repeaters and power feeding equipment has been added, fewer fibers and transmitter/receiver pairs are used in the repeatered OADM ring compared with the modified unrepeatered ring. This reduction in fibers and transmission equipment largely offsets the added expense of repeaters, power feed and cable types, bringing the cost differential between the repeatered and modified unrepeatered rings to 10% or less with major improvements in system reliability survivability. The cost differential between a repeatered OADM ring and a simple unrepeatered ring is in the range of 20-25%.

While significant expansion may be sustained on a single fiber pair, if future expansion beyond 32 nodes is anticipated, additional fiber pairs may be added to the system with limited initial capital investment. Terminal equipment and branching units may be added as platform nodes are brought into service. Proper initial transmission design can provide extensions to the length of the overall ring totaling several hundred kilometers in any geographic area of the ring.

6 CONCLUSIONS

Several design criteria are critical to the operational requirements of submarine cable systems used for telecommunications for offshore oil and gas production platforms:

Shore terminal stations must be separated by 400 to 500 km as a minimum

Each platform node must be completely independent of every other node

The system must survive the loss of several nodes and one terminal station

The system must accommodate expansion in the number of nodes and in total system length

In a multi-operator environment, with rare exceptions, traffic from each node should bypass all other nodes, or it must remain encapsulated and secure if it transits another node.

A repeatered OADM ring system employing power switching branching units can meet al the critical design criteria with the additional benefit that repairs and system expansions may be accomplished without interruption to existing traffic. Cost differentials to deploy repeatered solutions compared with unrepeatered ring systems range from 10% to 25% with exceptional survivability. That survivability can pay back the increased cost of deployment by the reduction of lost production by one day on one platform during one hurricane event.