COST EFFECTIVE HYBRID SUBMARINE CABLE SYSTEM SOLUTIONS

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Abstract: The submarine cable industry is currently riding out a demand wave. The new systems offer surplus capacity which needs to be filled. This in turn will create demand for smaller regional feeder networks, comprising elements of both repeaterless and repeatered technology. These hybrid systems are easier to finance, since the investment in comparison to trans-continental systems is considerably smaller. Time to market will be appreciably shorter, i.e. typically in the range of approx. one year from concept to supply contract, and another year for implementation. The hybrid networks have to be state-of-the-art but cost-effective, and no compromises to the security and performance of the network are permissible for either repeaterless or repeatered segments of the network.

1. CURRENT MARKET SITUATION

Newly built submarine cable networks such as Europe India Gateway (EIG), I-ME-WE, Asian-American Gateway System (AAG), Trans-Pacific Express (TPE) together with the existing networks form a belt of data highways around the globe, connecting a defined set of “hot spots”. The submarine cable industry is currently riding out a demand wave, the peak of which had already been reached in 2008. The end of this current wave of stimulus might be reached within 2010, by which time approx. 200,000 km of submarine long-haul systems will be in the water.

Of course there are many countries or regions which are not directly connected to the main data paths. Feeder networks will connect such ‘peripheral’ countries or regions to main data-paths and in turn generate traffic for the international networks.

In the aftermath of the market peak phase, with its big intercontinental submarine cable systems, we may expect numerous smaller projects.

These regional feeder networks are much smaller in their footprint. They may connect two countries or even several regions of the same country. Indonesia, for instance, is an extreme example with approximate 6,000 populated islands. There is just one single, or a small number of, customer(s) instead of multinational consortia to consider. Decision-making is accelerated and therefore time-to-market will be appreciably shorter, i.e. typically in the range of less than one year from concept to supply contract, and approximately another year for implementation.

The current economic downturn is increasing the cost pressure on the network operator as well as the system provider. Cost-effective solutions are therefore mandatory. At this point hybrid, repeaterless and repeatered submarine cable networks are coming into play. If smart solutions for both repeaterless and repeatered submarine cable systems can be provided, hybrid regional networks can offer a very attractive answer for the tasks involved.
Interlinked regional networks can even serve as alternative routes for international traffic. This may improve the business case, speed up return on investment and may make project financing less troublesome.

2. HYBRID SUBMARINE CABLE NETWORKS DESIGN REQUIREMENTS

The design requirements for Hybrid Submarine Cable Networks are simple: They need to be state-of-the-art but cost-effective, and no compromises to the security of the network are permissible for either repeaterless or repeatered segments of the network.

Of course there are differences between the repeaterless and repeatered segments in terms of technology, system design and transport logistics. For the project implementation phase, however, many aspects are common to both repeaterless and repeatered segments of a hybrid network.

![Figure 1: Examples for repeaterless and repeatered submarine cables](image)

2.1. REPEATERLESS SEGMENTS TECHNOLOGY, DESIGN AND TRANSPORT LOGISTICS

For system cost optimization it is mandatory to use submarine cable designs and their respective accessories that are optimized for repeaterless applications [1]. There is a need for neither 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. Cable fiber loss of less than or equal to 0.192 dB/km for G.652 fibers and less than or equal to 0.168 dB/km for G.654 fibers have already been supplied to the market.

Cost-effective SMF (G.652) and lowest loss fibers (G.654) 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 [2]. Provisioning of cable spars 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. Submarine cable systems which have been designed for 8 x 10 Gb/s in the year 2000 are now supporting in excess of 32 x 10 Gb/s. The technology for N x 40 Gb/s is just hitting the market for long distance repeaterless transmission systems. This has been enabled by improvements in the Raman and ROPA (Remotely Optical Pumped Amplifier) amplification technology, as well as by advances in the coding and forward error correction schemes.
With current transmission technology, these total link lengths can be reached at given design capacity per fiber pair:

- Approx. 375 km at 32 x 40 Gb/s,
- Approx. 425 km at 32 x 10 Gb/s,
- More than 450 km with some channels at 10 Gb/s,
- Around 500 km at 10 Gb/s single channel

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 layer.

2.2. REPEATERED SEGMENT TECHNOLOGY, DESIGN AND TRANSPORT LOGISTICS

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. 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.

Hybrid submarine networks 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 cost-efficient submarine grade fiber mix consisting of mostly reduced or low slope (negative dispersion type) and some portion of G.652 fibers for dispersion compensation will do the job nicely, even having 40 GB/s per wavelength system in mind, and there is no need for “dispersion managed fibers”.

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.

A black layer of high density polyethylene on top of the electrical insulation layer can provide additional abrasion resistance and UV-light blocking characteristics and therefore extra protection for the LW cable especially during loading, transport and installation, as well as depot storage. 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. A land based “terrestrial repeater” can add flexibility as well, and may even remove the need of additional terminal station close to the shore if the final destination is remote from the shore.

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 GB/s per wavelength and 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.

The repeatered sections of hybrid submarine cable systems are assembled and integrated at the cable factory. The most comfortable means of transfer is a direct load to the cable layer, yet this option in most cases is strictly prohibitive in terms of expenditure, in view of standard day rates of lay vessels. A much more cost-effective alternative is the use of a freighter vessel of opportunity. Utilizing custom-built cable cages and repeater storage racks inside the cargo hold allows considerable volumes of repeatered cable to be transported in specialized small vessels at a fraction of the cost of the main cable layer, not even necessarily compromising the transit speed of the transport. Cooperation with experienced logistic companies, coupled with strictly controlled procedures for industry-standard handling of the submersible plant, can make this approach an economically attractive alternative to conventional pick-up by cable layer.

3. 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.

3.1. 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.

3.2. 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 hybrid 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.

3.3. PERMITS

Full knowledge and early clarification of permit requirements are a critical factor in ensuring timely project completion. The process of permits for domestic or regional feeder systems is generally much more transparent and manageable than the cumbersome and time-intensive procedures
involved in obtaining installation permits from within a multitude of different countries. Such clearly defined permit structures, with liaison and permit support as a service from the supplier, offer a real advantage and opportunity in reducing time-to-market.

3.4. INSTALLATION

Cost creep as part of the installation phase can put a major strain on the project implementation as a whole. Close planning control at the outset and utilization of a survey and installation package which is fit for purpose are essential elements for keeping costs at bay.

Figure 2: Main-lay vessel during direct landing operation

A good cable route study is concise and to the point, combining the latest available data with a sound understanding of the requirements for a cable lay. In practice, fairly frequently such studies are overburdened with only marginally important information, such as seismic data of the upper kilometers of the seabed, or essays on the theory of plate tectonics. This tends to inflate the volume, whilst adding next to no useful information for the planning of the optimum cable route. Careful filtering of pertinent information by early involvement of installation expertise goes a long way to avoid nasty surprises in the later stages of the project. This also applies to the effective conduct of site visits. It pays to involve the staff tasked with the actual installation, rather than deploying a survey team with a GPS handset, but limited knowledge of cable-pulling operations.

The study concludes with a pre-selected route for survey, including armoring details, which is as far as possible free from risk to submersible plant. A properly executed study should reduce the amount of route development to be carried out during the survey.

A detailed electronic route survey, coupled with strategic geotechnical sampling, is money well spent and will bring dividends in the medium to long term. Whilst often stipulated in tender documentation, stoic and rigid adherence to a certain geotechnical sampling pattern, for instance, may prove to be less cost-effective than a strategic seabed ground-truthing exercise in support of sub-bottom profiling carried out by the trained eye of an experienced geophysicist. If the survey is further backed up by a combined PLGR and route clearance operation using local resources, chances are that the data so captured are much more useful, and much less repetitive.

Subsea cable integrity needs to be ensured by appropriate protection measures. The best protection is plough burial of the cable outside the grip of anchors or bottom fishing gear. There are no fool-proof guarantees and a certain risk of damage will remain, however, a properly buried cable of a carefully selected armor type – taking into consideration the most dangerous external aggressors to the cable - will reduce significantly any repair and maintenance costs to the system. A careful balance needs to be found in this respect with regard to the burial depth (unless it is stipulated by legislation), since cable buried too deeply may pose a challenge for recovery, if required.

Cable landings can be most effectively executed as direct landings from the main lay vessel, if the water depth allows for this. A clever selection of landing points, tying the cable into existing backbone networks, can be a huge cost saver in this
respect, since the expenditure of pre-laid shore ends can be considerable. Even with pre-laid shore ends, though, a small strategic spread utilizing local resources can be much more effectively and flexibly used in many instances than a fully equipped multi-purpose barge.

Figure 3: Installation of pre-laid shore ends

3.5. REPAIR AND MAINTENANCE

One area of significant importance is continued support for the cable system throughout its lifetime. Aside from re-routing and re-instatement considerations of commercial traffic, a fast response to cable outages is paramount. A large number of system operators are arranged in club-type agreements sharing a common, strategically stationed vessel resource. This may not always benefit the domestic carriers, since more often than not the larger, international consortium cable systems are able to dictate the agenda and enjoy privileged status of access to maintenance resources as a direct reflection of their agreement share. In this case, domestic maintenance solutions, tailor-made to the requirements of individual customers, should be given consideration. Depending on the requirements involved, these may actively involve the system owner as part of a knowledge transfer process between manufacturer / installer and customer, and could also be utilized to react flexibly to new-build requirements on a regional level.

4. SUMMARY

Optimized cable design is required for both the repeaterless and the repeatered segments. Local experience in cable route engineering is the key for both cost savings and submarine cable protection. Careful selection of landing points and utilization of most economic tie-ins into existing terrestrial networks are of similar importance and value. Direct landings might be favorable to lengthy pre-laid shore-ends, requiring additional installation equipment at significant add-on time and cost. Short repeatered systems could be converted into cost effective repeaterless systems without jeopardizing the network performance by utilizing high power repeaterless transmission equipment. Clever design and implementation concepts are required for cost effective yet fully-featured and well-protected hybrid submarine cable systems.

Hybrid regional submarine cable networks can offer state-of-the-art but cost effective solutions without compromises to the security or performance of the network for neither the repeaterless or repeatered segments of the network.

5. REFERENCES
