Intelligent Power Management

The Need for Intelligent Power Management

Long-distance submarine cables make use of in-line optical repeaters spaced between 55 and 70 km apart, depending on the cable design. For reasons mainly of equipment reliability – simpler is better – these repeaters operate in constant power mode, in contrast to terrestrial repeaters that tend to include automated power control protocols whose job is to achieve as close to constant gain per channel as possible. Constant power mode means that the optical power load presented to a given fiber pair must be maintained as close as possible to the optimum level for total optical power (TOP). TOP can be made up of service wavelengths, or it can be augmented using optical power from amplifier spontaneous emission (ASE) devices or continuous wave (CW) idlers. The cable is initially loaded using ASE optical power, and as service wavelengths are added, the ASE spectrum is reduced to maintain the optimum TOP. In the event of the loss (either planned or unplanned) of transponder signals, the ASE can be extended to maintain optimum TOP. CW idlers can be used to provide power in a more precise part of the spectrum, and are particularly useful in branched cable topologies, as we will explain below. If optimum TOP is not maintained when signals are lost, since the repeaters will continue at the same total power level, the service wavelengths will receive either too much or too little gain. Either condition could result in service outages to some or all the service wavelengths, depending on how much the TOP deviates from the optimum value.

In the past, optical power management procedures were usually regarded as an ancillary part of service provisioning in a submarine cable, but the trend toward open cables and spectrum sharing means that the process of active and intelligent optical power management is now front and center in optimizing operational efficiency. Infinera’s Intelligent Power Management (IPM) solution is designed to:

- Automate the process of open cable characterization
- Stabilize services for the duration of the cable lifetime
- Help to automate service provisioning and maintenance
- Operate across point-to-point and branched subsea topologies
- Enable commercial spectrum sharing services
- Be an open, extensible platform that grows to include features such as seismic detection
Since the quality of the spectrum will vary across the amplified waveband and repeaters will include some amount of gain tilt, IPM also includes functions that assist with both coarse and fine pre-emphasis, which is the process of adjusting optical power at the transmit end of the fiber through a combination of ROADM and transponder adjustments.

The Building Blocks of IPM

IPM consists of four building blocks:

- The FlexILS Open Terminal System
- Active optical power generation devices, including ASE and CW idlers
- The IPM control function
- The IPM suite of software specifically designed to enhance cable operations

FlexILS Open Terminal System
FlexILS is a proven flexible-grid open line system that is deployed in hundreds of terrestrial and subsea networks around the world. Available in both compact and standard chassis sizes, FlexILS provides open cable demarcation, as well as potential spectrum sharing ports if this service is offered by the fiber pair operator. For spectrum sharing, FlexILS enables the policing of spectrum and protection against misconfiguration of transponders by other spectrum tenants.

Optical Power Generation
The optical power used to load the cable is housed within the FlexILS Open Terminal System. Both ASE and CW idlers are available to provide optical power. ASE is generally used to load large sections of spectrum, while CW idlers are used more surgically to protect individual bands, and in the case of branching unit spectrum.

IPM Software Suite
The IPM Software Suite is designed to operate and automate specific optical power management functions. It consists of the base software that is applicable across all repeatered submarine cables and optical features that may be required in specific deployments.
IPM Base Software

**Smart Shield.** This is the foundation of IPM, and it includes the software that drives the ASE and CW idlers. Smart Shield provides automatic spectrum protection for Infinera transponders and includes the ability to reinsert service wavelengths in a controlled manner after fault recovery.

**Smart Optimize.** This offers a range of optical power optimization features, including point-to-point link optimization to maximize Q values; viewability of the Tx spectrum, Rx spectrum and Q values of operating carriers; and the ability to perform coarse and fine pre-emphasis adjustments.

**Smart Express.** This contains the functions needed to integrate a terrestrial backhaul network into the optical path of the subsea fiber pair. This is increasingly necessary as fiber pair operators choose to optically express through the cable landing station and on to the nearest point of presence (PoP) or data center.

IPM Optional Features

**Smart Spectrum.** This module is designed to enhance **Smart Shield** to operate with third-party transponders, particularly in the context of spectrum sharing.

**Smart Service.** This module provides the features needed so that the fiber pair operator can create, modify, and deploy their own channel plans, as opposed to doing this via the Infinera installation service. In addition, **Smart Service** includes the ability to perform full capacity testing during the initial deployment of an open cable system.

**Smart Branch.** There is a trend toward the deployment of optically branched submarine cable systems in which an underwater optical switch is used to allow fiber pairs or spectrum to be sent to other locations, such as islands. Where wavelength-selective switches (WSSs) are used to provide dynamic bandwidth control in these cables, there can be special issues for optical power management if ASE is the only source of optical power loading. **Smart Branch** operates in conjunction with Infinera’s continuous wave idlers to maintain stable optical power levels even in cables that include branching units, and without the need for underwater WSS reconfiguration.

**Smart SNR.** Open cables offer the operator the ability to choose the best-of-breed transponder, but it can be a challenge to characterize the performance of a new open cable system. **Smart SNR** is designed to enable the characterization of parameters such as GSNR and GOSNR as defined in ITU-T G.977.1.

IPM Software Suite is designed as a modular system where new features are sometimes added as enhancements to the base software or can be added as optional features.

Emerging IPM Developments: Seismic Detection

Tsunamis are a real threat to life and property in many parts of the world, and they are caused by certain types of undersea earthquake. Today, tsunami warning systems rely mainly on land-based detectors and a small number of ocean buoys, but efforts are underway to enhance this detection network. One approach is to develop intelligent subsea repeaters that could be included in new cable deployments – so-called SMART Cables. These would offer a “gold standard” in instrumentation, including not just accelerometers and pressure sensors but also environmental sensors for monitoring marine life and deep ocean temperatures. The main issue with SMART Cables is that the first system is not scheduled to be deployed until 2025, and the rate of deployment thereafter (assuming all new cables are enhanced in this way) would be relatively slow.

In the interim period, an initiative is underway to enhance existing submarine cables with the goal of transforming them into seismic detection sensors. This initiative has four guiding principles:

- There must be measurable parameters at the end of the cable that are directly related to seismic activity somewhere along its length
- Ideally, we need to be able to localize the source of the signal along the cable, since cables can be thousands of kilometers long
- We need to keep the incremental cost of deploying such a system to a minimum to make it more acceptable for operators to deploy the feature on existing cables
- We need to leverage the cost reduction and enhanced precision aspects to promote the deployment of this capability over multiple submarine cables whose data can be networked and shared in real time
While the details of the technique are quite involved, Infinera has demonstrated the ability to detect seismic activity using state-of-polarization (SOP) data. Infinera is able to localize this activity to within the granularity of the repeater spacing on a given cable (typically 55-80 km). Currently an external test set is needed as the detector, but Infinera is planning to include this capability in a low-cost future transponder design that would be supported by a new IPM software module – Smart Cable. The quality of the data collected so far is so good that it justifies extending data collection to multiple cables, which would allow for far more accurate triangulation of an event.

With almost 500 submarine cables already deployed around the world, the opportunity to enhance them as seismic detectors at a relatively low cost per cable is extremely exciting. Note that this is not intended as a commercial service, but as an opportunity to enhance tsunami warning times and to help protect lives and property against this type of natural disaster.

Summary
Intelligent optical power management is a critical function in today’s submarine communication cables. Infinera IPM is an intrinsic part of our submarine network solution. It helps to enable automated fiber pair characterization, wavelength capacity optimization, ongoing service stability, and support for submarine WSS branched cables, and it is an open and evolving platform for future capabilities such as seismic detection.