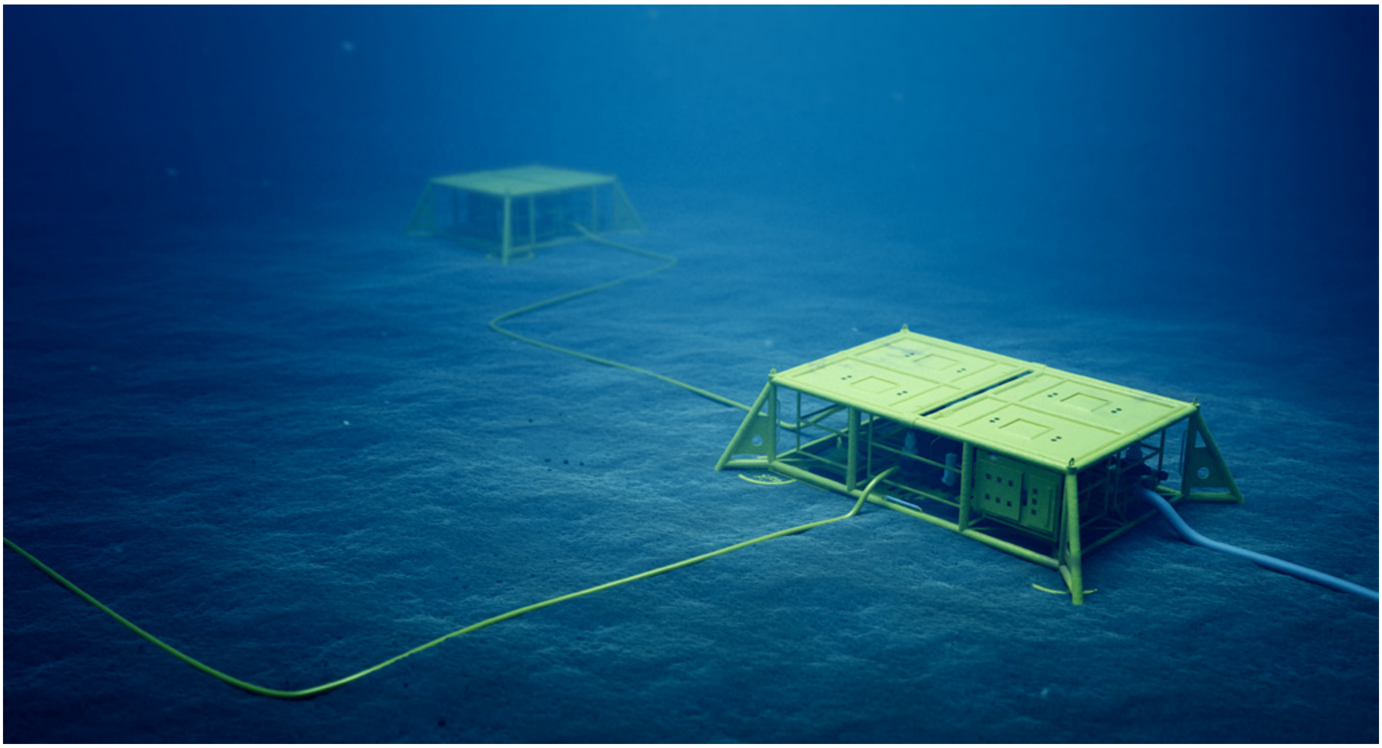

Subsea Power: the challenges in powering today's and tomorrow's applications!

Gleaned from the news and political debates, we are all aware that a significant number of offshore locations around the world are home to oil and gas fields. But the range and scope of subsea applications is much more than just those concerning oil and gas. From intercontinental communication cables making the WWW operate smoothly around the globe to deep-sea earthquake detection stations there are equipments installed on the seabed at depths of up to 4,000 meters (13,000 feet) and at pressures of up to 400 bar (5.816 psi), requiring safe and reliable power sources. So, in such highly demanding applications what factors does the power electronics engineer need to consider when designing power solutions?

Subsea power architecture
Most commonly, seafloor installations are powered from the shore or a platform via long-distance high-voltage transmission cables to floating or submerged transformation stations. Here, the voltage is stepped down locally to AC or DC within the range of 300 to 900VAC or 400 to 1500VDC to power local equipment and ultimately, lower DC voltages for the final application. This appears to be a standard approach just as it is for power grids and electronics equipment in industrial applications on terra firma. However, when the final equipment is located on the seabed and dealing with oil, gas or sensitive equipments, the level of quality and safety requirements are significantly higher.

The subsea power grid contains components such as switchgear, step-down transformers, energy distribution,

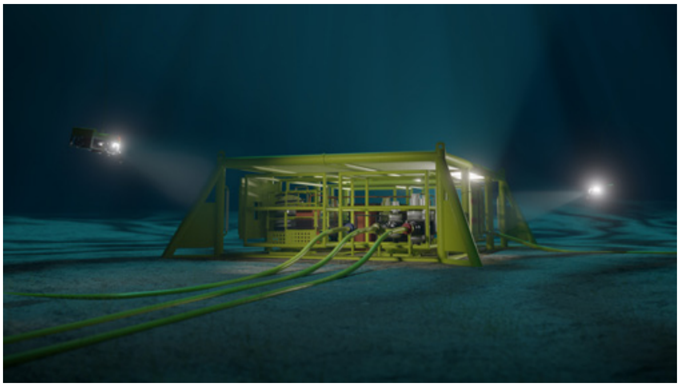

Figure 01: Common base frame for subsea applications with ROV interconnections (Source: PRBX/Shutterstock/Vismar UK)

and monitoring and control equipment serving several equipments such as pumps, compressors, water-injection systems and safety controllers. For efficiency and safety, the power components can be installed on a common base frame on the seabed (Figure 01) and interconnected through application specific connectors able to handle low voltage for signal use, and high voltage for power supplies, and able to sustain hydrostatic pressure and under-water connections. Also, for safety reasons and to guarantee uninterrupted operation, the local grid is secured by Uninterruptible Power Supplies (UPS), which could also be located on seabed.

All components within the grid are retrievable and are designed and constructed for normal and incidental operation. But because they are often deployed at depths below which humans can operate, they might require remotely operated vehicle (ROV) intervention and been designed in consequence

What's unique about subsea power supplies?
Subsea power supplies are classified in two major categories:

→ Standalone Container Power Supply Unit (SC-PSU)
SC-PSUs are designed to sustain very high pressures. They feature deep water connectors and build in removable chassis designed for ROV handling. SC-PSUs require very high levels of expertise in deepwater equipment design and are often designed and manufactured by the same companies who provide subsea transformers and sub-stations.

→ **Embedded Power Supply Unit (E-PSU)**
E-PSUs are integrated within the final pressurized equipment and not exposed to high pressure nor in contact with the liquid element. E-PSUs are closer to industrial power supplies but with extremely high reliability and dedicated functionalities relative to subsea operators' requirements.

Embedded Power Supply Unit (E-PSU) at a glance.
Power electronics designers dealing with subsea power supplies often describe their job as: "Designing a highly rugged power supply with extreme reliability and intelligence for one of the most hostile environments on Earth where failure is not an option." This is a good summary of the challenges faced by designers when developing power solutions that will be operated in deep seas where most of the time humans cannot access other than by using ROVs.

As mentioned in the introduction, the range of subsea applications is large, and depending on which segment the power supply will address, different standards and best practices apply, but for all of them there is a common approach to perform risk analysis to properly assess the technology and operational safety.

In cooperation with the equipment manufacturer, the electrical load calculation is one of the earliest tasks during the electrical power system design that needs to be considered. Engineers should estimate the required electrical load of all the subsea elements that will consume the electricity so that they can select an adequate power supply. Each local load may be classified into several different categories, for example, vital, essential, and nonessential:

→ **Vital:** Will the loss of power jeopardize the safety of personnel or cause serious damage within the platform/vessel/seabed equipment?

→ **Essential:** Will the loss of power cause a degradation or loss of the oil/gas production or, in the case of transcontinental cable, communication?

→ **Nonessential:** Does the loss have no effect on safety or production?

Depending on the final equipment and the level of risk, different technologies might be considered such as a redundant power solution, automatic load balancing or an emergency power resource switching to UPS. In all cases the power supplies must be able to communicate with the central monitoring system, where using the latest evolution of digital control and predictive algorithms, high levels of operational safety are achieved.

As certain parts of subsea oil and gas equipments migrate from full hydraulic operation to hybrid - for example motorized valves that electronically monitor and control - power supplies are required to be integrated within the pressurized cylinder. Also, when designing power supplies for transmission cables, e.g., signal repeaters, because space is critical, power designers must consider the volume available to shape the power supply in order to fit into the final application (Figure 02).

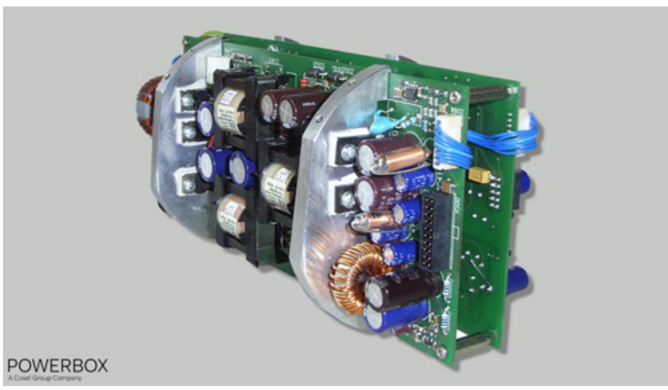

Figure 02: Power supply designed to fit into pressurized cylinder (Picture credits: PRBX/VB120-5)

Due to the compacity and high level of integration, another important point to take into consideration when designing a power supply for subsea operation is the electromagnetic compatibility within the embedded system. Extensive interoperability tests are performed during the design of the final equipment and sometimes this could require the adoption of a different topology e.g., multiphase with active phase-shifting to reduce EMI interference.

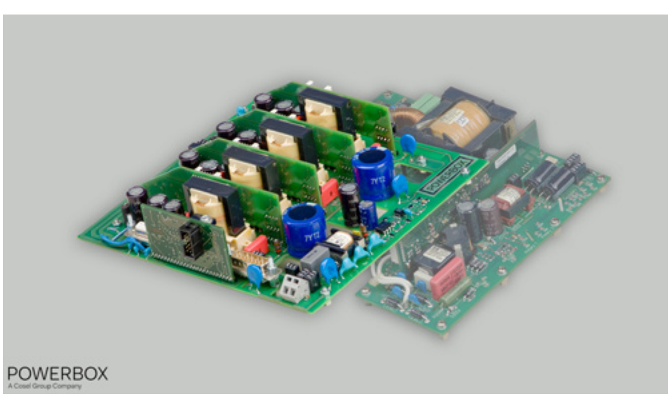

Figure 03: Power supply designed with high safety margin and reliability (Picture credits: PRBX/VB140-384)

In subsea applications it goes without saying that lifetime and reliability are very important. Power supplies must be designed with a high safety margin and with the lowest possible amount of stress - electrical and thermal - on every component (Figure 03). The selection of components is an important part of the design that might influence the choice of the topology and building practices. One example is the choice of the preferred switching transistors with a baseplate to facilitate conduction cooling.

American Petroleum Institute (API)	
API RP 14F	Recommended Practice for Design and Installation of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class I, Division 1 and Division 2 Locations
API RP 17A	Recommended Practice for Design and Operation of Subsea Production System
API RP 17H	Remotely Operated Tools and Interfaces on Subsea Production Systems
API RP 500	Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2
API SPEC 17D	Specification for Subsea Wellhead and Christmas Tree Equipment
API SPEC 17E	Specification for Subsea Production Control Umbilicals
API Standard 17F	Standard for Subsea Production and Processing Control Systems

International Standard Organization (ISO)	
ISO 13628-5	Petroleum and Natural Gas Industries – Design and Operation of Subsea Production Systems – Part 5: Subsea Control Umbilicals
ISO 13628-6	Petroleum and Natural Gas Industries – Design and Operation of Subsea Production Systems – Part 6: Subsea Production Control Systems

Figure 04 : Examples of AMI and ISO standards applicable to subsea oil and gas applications (Picture credits: PRBX)

Design considerations for different standards.
Most power supply designers are used to common standards for industrial, medical, transportation or defense applications, but when dealing with specific areas such as subsea oil and gas applications they must consider specific standards such as the one established by the American Petroleum Institute (API). As shown in Figure 04, the standard covers a number of specific areas and power supplies to meet different sections of the Standard for Subsea Production and Processing Control Systems (API 17F). This standard includes specific tests as well as communication protocols.

As well, with regards to subsea connectors we listed two of the ISO-13628 types. These provide the general requirements and overall recommendations for the development of complete subsea production systems, from the design phase to decommissioning and abandonment. This standard is not only for connectors and is often used in complement to the API.

Sustainable power to subsea applications.
Most subsea applications are powered from the shore through long distance power cables, or a platform via high voltage transmission cables often 10-100 kms, but there are several applications that require remote power solutions. Conventionally a vessel or floating platform with traditional power generators can be located above the field, but when considering the environment and sustainability this is not optimal, and accordingly the subsea engineering community has begun to consider alternative options.

Amongst many projects around the world, the Renewables for Subsea Power (RSP) project is one of the most interesting and promising. In answer to the question: How can green technologies be combined to provide reliable and continuous low carbon power and communications to subsea equipment, offering a cost-effective future alternative to umbilical cables? Scottish ocean energy pioneers Mocean Energy (who developed Blue X, a 20m-long, 38t, 10kW, wave energy converter machine (Figure 05)) and a group of partners specialized in subsea energy storage and energy management developed a business case which combines wave power, solar with energy storage to power subsea equipment for oil and gas projects (Figure 06).RSP test and evaluation process

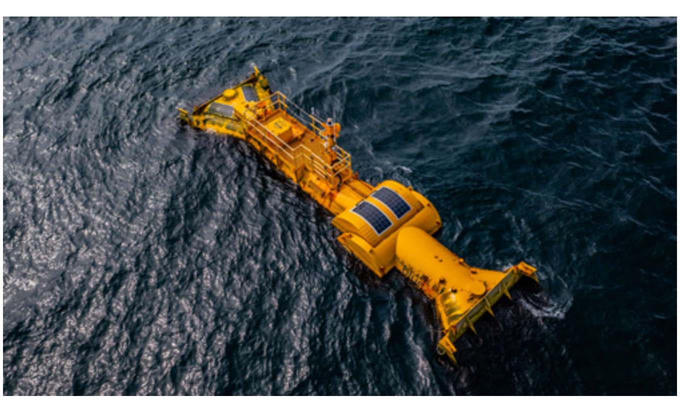

Figure 05: Mocean Energy Blue X Wave Energy Converter (WEC) - (Picture credits: With courtesy of Mocean Energy - Colin Keldie - EMEC)

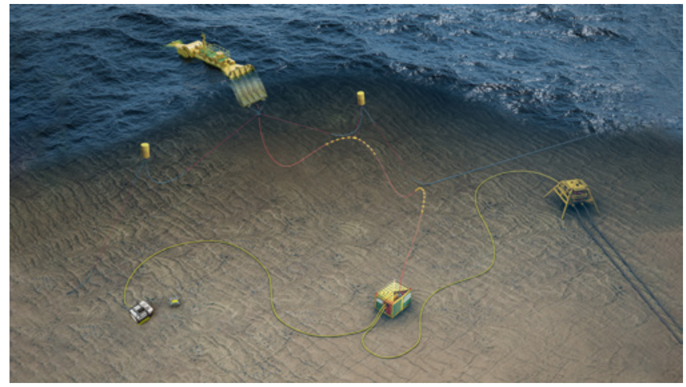

Figure 06: Wave energy converter provides renewable power for a range of subsea applications - (Picture credits: With courtesy of Mocean Energy)

has now completed and are ready for commercial deployment. This is very good example demonstrating that wave energy combined with solar-power capability and battery technologies can offer a reliable and cost-effective alternative to costly umbilical cables for subsea applications.

In conclusion:
Subsea power electronics is often considered as a niche industry but for a power designer developing power solutions for deep sea it is a great opportunity to learn about a very interesting range of applications that require advanced technology, extreme reliability and true innovation. That, combined with new ideas such as Renewables for Subsea Power (RSP) make our job very exciting and motivating, pushing the limits of our power supplies for even deeper explorations.

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Power Sources Manufacturers Association:
https://www.psma.com/

Sea Technology:
https://sea-technology.com/

About Powerbox
Founded in 1974, with headquarters in Sweden and operations in 15 countries across four continents, Powerbox serves customers all around the globe. The company focuses on four major markets - industrial, medical, transportation/railway and defense - for which it designs and markets premium quality power conversion systems for demanding applications. Powerbox's mission is to use its expertise to increase customers' competitiveness by meeting all of their power needs. Every aspect of the company's business is focused on that goal, from the design of advanced components that go into products, through to high levels of customer service. Powerbox is recognized for technical innovations that reduce energy consumption and its ability to manage full product lifecycles while minimizing environmental impact. Powerbox a Cosel Group Company.

About the author
Chief Marketing and Communications Officer for Powerbox, Patrick Le Fèvre is an experienced, senior marketer and degree-qualified engineer with a 40-year track record of success in power electronics. He has pioneered the marketing of new technologies such as digital power and technical initiatives to reduce energy consumption. Le Fèvre has written and presented numerous white papers and articles at the world's leading international power electronics conferences. These have been published over 450 times in media throughout the world. He is also involved in several environmental forums, sharing his expertise and knowledge of clean energy.

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