

High Voltage Power Supply Technology for Use in Power Feed Applications

by
**Cliff Scapellati
&
Paul Treglia**

Background

The general technology area involving power supplies can be termed *Power Conversion Technology*. Within power conversion technology, there are many types of power supplies and devices for many varied applications. High Voltage power supplies are one of many niche markets existing in this broad technology area. Power Feed Equipment (PFE) is an even smaller niche within High Voltage power conversion technologies. For this reason, and others, PFE has traditionally been designed and manufactured by the captive manufacturers of undersea cable systems. Historically, this strategy was driven by the critical application knowledge required to design PFE, and the absence of this knowledge in the broader High Voltage power supply technology sectors. However, with power conversion technology advancing at a rapid rate, it is difficult for a systems manufacturer to devote the resources required to keep current on these advances.



Outsourcing Model Advances PFE Technology

In the early 1990's the strategy of outsourcing "non-core technologies" started to take off. Many large companies doing complex systems outsourced subsystem components to companies specializing in the applicable technology. This strategy was adopted back then by AT&T (now Tyco Telecommunications) for a new low-cost PFE project. By partnering with a manufacturer dedicated to High Voltage power supply manufacturing, paired with AT&T's application knowledge, unique solutions were implemented for PFE requirements. (Figure 1 shows a converter sub-system developed for AT&T in the early 90's).

To date, this type of partnership is leading the way for future advances in PFE technologies. Key benefits are in the areas of smaller size, lower price, lower cost of ownership, and higher system reliability.

High Voltage Technology Basics

Let's start off with a Warning: The High Voltage potential used in any PFE is Lethal! Only qualified operators and service personnel should be using or accessing any High Voltage equipment.



Figure 1

The High Voltage power supply as used in the PFE is often termed the *Converter*. Accurately so, because it converts one form of DC (-48 volts) to another form of DC (High Voltage DC). Within the converter there are a few basic building blocks:

Input Power processing: Provides input power filtering and circuit protection. Often in Telecom applications dual-input battery power sources (BAT A and BAT B) are used. This provides redundant input power sources for each device.

Inverter: Within any modern Converter is an Inverter. An Inverter "inverts" the DC power source to a high frequency ac power source. This allows for compact magnetic assemblies and high performance features such as ultra-low output ripple and fast output regulation response. The inverter uses high-speed transistors to "switch" the DC into

an ac signal. (Since Telecom power supplies are usually powered from 48 volts, MOSFET's are the best transistor technology to use).

High Voltage step-up Transformer: The high frequency ac power source is connected to a transformer with a high step-up ratio. In PFE applications, the transformer secondary winding needs to be isolated to voltages up to and greater than the output voltage rating of the PFE (typically 2x, to ensure high reliability)

Output rectifier: Since the application requires a DC source, yes, we need to invert that AC back into DC again. This is accomplished by high speed, high voltage rectifier diodes. (These multiple stages of inversion may seem like a silly process to someone outside the power supply field, but it is the best way to achieve the end goal).

Control: All of the building blocks of the Converter are monitored and controlled by control circuit electronics. In modern Converters, these circuits utilize advanced Digital Signal Processors (DSP) and Field Programmable Gate Arrays (FPGA). In PFE applications, the control circuits communicate to the PFE system controller for all control and monitoring.

The Converter is packaged into an easy to replace blind-mating unit know as a FRU, (Field Replaceable Unit). Most of the FRU's within the PFE are blind-mating which allows quick replacement in case of failure.

For PFE applications, multiple converters are often used to provide modularity to suit a variety of output voltage configurations, and for redundancy in the case of any individual converter going off-line.

PFE's Unique Requirements

In practice, the Converter is actually the most conventional component within the PFE. (Hence

it makes sense that the converter portion of the PFE was the first part of the PFE system to be outsourced). In addition to the Converter, PFE has many other functional building blocks:

Safety: Although somewhat an intangible item, Safety is the major building block consideration when designing the PFE. Because the cable can be powered from either end, (a term known as Double-end Feeding), there exists the possibility of High Voltage being present even if the local PFE is turned off. Significant safety systems are deployed in PFE. These typically involve high-level, redundant monitors, Fail-safe switching devices, protection barriers, key-lock interlocks and access systems.

Reliability: Since downtime is so costly, high reliability in Telecom equipment is mandatory and PFE is no exception. High reliability in the PFE is achieved via a combination of redundancy, high derating, and increased clearance spacing of all critical components. The margins are tested with a rigorous validation test plan to ensure the design performs as expected under all worst-case conditions in the field. Low Corona is also required in all High Voltage assemblies within the PFE and must be tested on every assembly built. Providing High Voltage assemblies with Low Corona is a daunting task. It is achieved by very specialized techniques utilized within the High Voltage Industry.

DC Distribution and Monitoring: Provides circuit breaker protection for each FRU and DC power distribution for the entire PFE.

PFE Local Controller: Provides Local control and monitoring of the PFE via a Graphical User Interface (GUI). The Local Controller typically consists of an industrial PC (server), a multi-channel Ethernet switch connecting all other modules within the PFE together, a keyboard, mouse, and LCD

display and/or touch-screen. The Local Controller directly communicates with the cable station's network management system for monitoring and limit control of the PFE. (For safety reasons, often controlling the PFE settings remotely is not done. However, modern PFE's can offer unique remote control features that facilitate remote diagnosis of PFE or cable problems).

Cable Monitoring and Access: The output of the Converters power the submarine cable via sophisticated monitoring and protection devices. Cable access and termination (shorting or opening) is also being provided at the PFE output point. This access point can be used to insert other ancillary cable testing devices into the cable path. Due to the dangers of High Voltage being present, significant safety features need to be incorporated at this point, and throughout the PFE. Figure 2 shows a PFE Cable monitoring FRU, with Cable access and terminating mechanisms.



Figure 2



Figure 3

Test Load: The Test Load unit allows testing of a Converter within the PFE cabinet while the Cable remains powered by the redundant Converters. Or similarly, both converters can be tested on the Test Load. The Test Load is a unique concept in deployed High Voltage systems, found only in PFE's. Traditionally, the Test Load was configured from an array of passive, fixed resistors. In order to change the load settings, high voltage relays were employed to select and reconfigure the fixed resistors. Nowadays, electronic test loads are available. These test loads use an array of active MOSFET transistors. The transistors can be programmed to offer an infinite range of load configurations within the PFE's capabilities. In addition, highly compact Test Loads can be achieved. These modern Test Loads do come at a premium price though. However, their small size can offer a massive reduction in the size of the cabinets used for just the Test Load. Indeed, modern PFE's can be realized within a single cabinet, including the Test Load! Figure 3 shows a modern 5kW Electronic Test Load, along with Figure 4, one of its MOSFET card arrays.

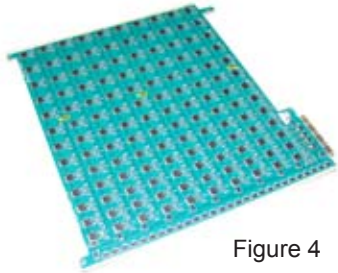


Figure 4

The Cabinet: Often referred to as "The Bay", a PFE cabinet has some conventional, as well as unique features. The complete PFE needs to meet seismic requirements per GR-63-CORE. The cabinet design is a critical factor in meeting this requirement. Due to the custom nature of the PFE hardware, the



Figure 5

cabinet too is a custom design. Safety interlocks and High Voltage cable routings need custom solutions. Modern single-bay PFE's incorporate unique "Trap Door" mechanisms that allow removal of the FRU's while High Voltage is present. The trap doors provide spring-loaded barrier protection so that live circuits cannot be touched if modules are removed. Figure 5 shows the innards of a PFE cabinet. Virtually all of the mechanics need to be custom designed.

PFE for Cable Laying Ships

A lesser known, but equally demanding need for PFE is in the cable laying ships. As a cable is placed, it is being tested with a Shipboard PFE system. During the cable laying boom of the 1990's, nearly 100 shipboard PFE systems were put into service. These shipboard PFE systems are functionally very similar to standard land based PFE, only with reduced functionality and requirements, (and a substantially lower price). The shipboard PFE can operate from 220 VAC supplied from ship generators, and generally can use more "Off the Shelf" High Voltage power supply units. (No need to carry all those batteries on board and hopefully no seismic events while out at sea). But reliability is still paramount for the shipboard PFE, as a PFE failure out at sea would stop cable deployment until help arrived.



Conclusion

It has been demonstrated with the bringing together of experts in undersea cable powering applications and High Voltage power conversion technology, that highly advanced PFE solutions have been designed and deployed. Future advancements

and solutions are in the works, which have the possibility of providing significantly smaller systems with higher voltage capabilities, as well as low-cost, lower-voltage units (e.g. for branching power requirements). Thanks and acknowledgement to Tyco Telecommunications for their contributions to PFE technology advancement by providing cable powering expertise, and for use of some photos herein.

