

Aloha Observatory Power System Description and Specifications

The fundamental problem of a power system that is powered from a constant-current DC source is that the load will almost invariably be a regulated switching converter for a number of reasons. Only a switching converter can provide DC isolation from the cable. It also provides impedance matching; transforming the high-voltage, low current source to a low voltage, high current load. Unfortunately, the switching converter presents a negative dynamic impedance at its input. The high impedance source combined with this negative impedance load always results in a negative node admittance, which is always unstable.¹ The situation is further complicated by the fact that the SL280 cable with its repeaters was designed for a strictly stable operation, while the science load tends to be variable and unpredictable by its very nature.

A shunt regulator provides the best solution simultaneously to a number of problems. 1) It converts the constant current source *locally* to a constant voltage source. 2) It provides a constant voltage drop load for the cable, thus “hiding” (regulating) the user fluctuations from the cable as well as regulating the cable voltage for the user. 3) In so doing, it provides a positive (stable) node admittance.

Since the current source is a constant 1.6 Amps, to get more power requires a larger voltage drop. The solution to this is to use *modular* DC-DC converters. The present power stack for the Aloha Observatory is 8 modules with 100 Volts input per power module. At a measured efficiency of 93-94%, this produces about 150 Watts of power per converter module.

The 48 Volt shunt regulator is placed on the secondary side. This provides ideal regulation directly on the power bus. The power modules are *unregulated* (proportional) DC-DC converters. The resulting simplicity produces an ideal combination or circumstance that actually simplifies the rest of the system greatly: 1) The converter reliability is enhanced by the simplicity of the circuit. 2) The converters’ primary-to-secondary voltage ratio is determined almost entirely by the turns ratio of the switching transformer. 3) Each power module is a completely independent switching converter. Since the switching is not synchronized, it has a “spread spectrum” noise characteristic that simplifies filtering. 4) There is minimal interaction between power modules. This greatly simplifies the analysis of potential failure modes. 5) Since the primary sides are all in series with the constant current source, current sharing on the secondary side is completely automatic. 6) Since the secondary sides are all in parallel with the shunt regulator, the voltage drops on the primary side tend to be remarkable equal. 7) Since the shunt regulator provides a constant-voltage load on the secondary, the overall voltage drop of the Observatory is nearly constant. 8) This modular approach is completely scalable, up to the dielectric voltage limits of the cable and power pack components.

Because the power converters function independently, the only probable consequence of a module failure is a unit-drop in input voltage and output current. This

¹ David W. Harris and Fred K. Duennebieer, “Powering Cabled Ocean-Bottom Observatories”, *IEEE J. Oceanic Eng.*, vol. 27, NO.2, pp. 202-211, April 2002.

makes the power stack *incremental failure tolerant*. By the same token, redundant spare modules can be “hidden” in the series stack by simply keeping their inputs shorted.

In a typical shunt regulator with multiple distributed shunt elements, there is the potential for one shorted element to bring down the entire power system. The Shunt Regulator is also modular like the power stack. The shunt elements consist of a power transistor and a power-dissipating resistor. The failure of one transistor (the most likely mode) simply results in one resistor permanently loading the bus (resulting in a reduction in total available power) and a unit reduction in regulator dynamic range. The sheer simplicity of the circuit ensures a good reliability performance.

The resulting Power System performance specifications derive directly from the above discussion:

- 1) Total power taken from cable: $100 \text{ Volts} \times 1.6 \text{ Amps} \times 8 \text{ modules} = 1200 \text{ Watts}$.
- 2) Secondary side power at 93% efficiency: $\sim 1116 \text{ Watts}$.
- 3) Shunt Regulator margin required for stable operation: $\sim 200 \text{ Watts}$
- 4) Power available to Hotel Load and users $\sim 916 \text{ Watts}$.