

Network Powering Strategies and Alternatives

As new communications systems architectures are being introduced and as cable operators continue their thrust into telephony markets, reliable powering of networks is increasing in importance.

Powering Alternatives

Network powering can be implemented in two fundamental ways - either centralized or distributed. A typical centralized power node includes multiple power supplies, single or multiple strings of batteries and often an integrated standby generator. These installations are typically ground mounted, serving densely populated areas using relatively short, high power coax cabling. Distributed network power systems include single power supply configurations along the cable run, either pole or ground mounted.

The predominant power supply for both standby and non-standby network powering solutions remains the ferroresonant power supply as illustrated in Figure 1, with typical power ratings between 1,000 and 2,000 VA. Ferroresonant designs achieve very high reliability, with mean-time-between failure (MTBF) rates in excess of 250,000 hours or 28 years. The simplicity of the design, the avoidance of silicon in the direct power path, and the inherent lightning and short circuit protection enable this reliability performance despite the harsh outside operating environment. As shown in Fig. 1, during a power outage, the load power is taken over by the battery bank, coupled into the transformer via an inverter circuit. In order not to back-feed the line side fault, the input is disconnected via a relay. Transfers occur within a sub-cycle and well within load hold-up times, leading to non-interrupted load operation. The standby inverter design is a trade-off between cost and reliability, given that the system only operates in standby or self-test for a few hours per year. Recognizing the relative vulnerability of electronics when compared to the transformer assembly, the industry standard today is an economically attractive power supply featuring field-replaceable inverter electronics modules.

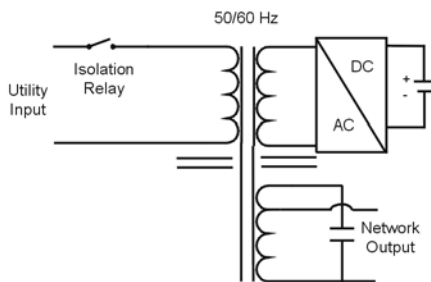


Figure 1. Typical Ferroresonant Backup Power Supply

Most modern power supply architectures for computers and other electronic systems employ switchmode power supply designs. This technology is also making its way into the CATV arena; the topology is illustrated in Figure 2. As shown, the power is now processed continuously through power electronic conversion stages. This approach has several advantages, including unity power factor operation, fast power transfer and high frequency operation (light weight, low volume, low audible noise). However, in order to achieve the required reliability in the harsh outside plant environment, the design needs to employ significant component derating, coupled with redundant power conversion paths. Consequently, for a given reliability objective, switchmode approaches are higher in cost than the conventional ferroresonant transformer. For this reason, applications to date have been limited to high density residential and multiple dwelling areas, where acoustic noise and physical size are prime concerns. Switchmode applications may also make inroads in central plant designs, where n+1 redundancy can be achieved at the overall system rather than stand-alone supply level, thus significantly reducing the cost burden on the individual power supply.

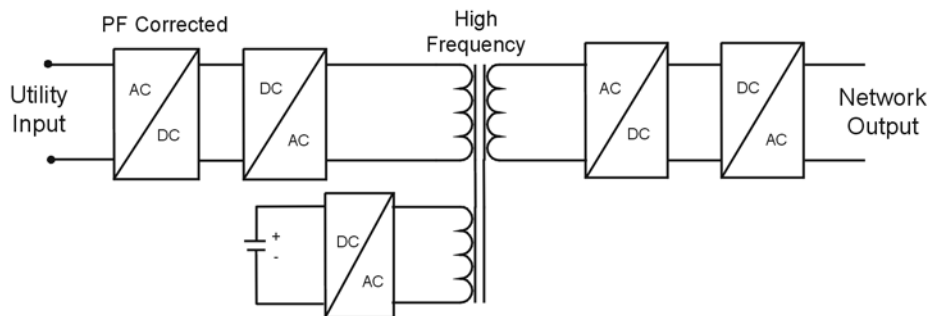


Figure 2. Switchmode Backup Power Supply

There have been attempts at creating hybrid approaches, combining a ferroresonant stage with in-line power electronic converters. Based on the cost/reliability discussion above, these implementations have not been successful either technically or economically.

No matter what the power supply topology, ferroresonant or switchmode, ac power supplies for network powering applications continue to provide square wave output voltage waveforms. For active front end amplifier loads, this enables optimum power factor operation and consequently the best power system utilization.

In the recent past, as fiber has gone deeper in the loop, many operators have provided local telephony service with a battery backed up power supply on the customer premises. While attractive from a signal security point of view and while requiring capital expenditure only upon subscriber sign-up, powering fiber-to-the-home installations is on the order of three to four times more expensive per customer than network powering. While the power supply is housed in a more benign indoor environment, maintenance complexities and costs increase significantly since the power supply is not readily accessible to the system operator. As subscriber concentration increases, most operators are scaling back local powering installations in favor of traditional network power or emerging solutions for deep fiber architectures. Table I summarizes some application scenarios and the appropriate emerging power supply solution.

Table I. Emerging Power Supply Solutions

Application	Power Supply Solution
Fiber-to-the-Curb options	Out- or indoor utility powered dc power supply; up to 200W rating; significant cost advantage over customer premise power supply; power supplies with integral batteries are small and unobtrusive.
Cable powering in deep fiber networks; small or fragmented service areas	Outdoor 60/90V ac network power supply at 200 to 400VA; utility powered with battery back-up.
Powering optical nodes using network power	Outdoor dc power supply powered off the 60/90V ac network supply; requires no new utility connection; can be collocated with network power supply

Energy Storage and Conversion Technologies

Lead acid batteries have been the backbone of energy storage for CATV and telephony networks. While battery technology continues to mature with the attendant performance improvement and cost decrease, lead acid batteries are and will remain a weak link in the power system due to the inherent maintenance requirements and need for replacement. Optimizing battery performance in outdoor applications requires thorough design at the system level. On the power supply side, the battery charging algorithms have to be compensated for temperature variations in order to match charging voltage to the state of the battery. While enclosures are often seen as a commodity, a well-designed cabinet, addressing both ambient temperature and solar loading effects, contributes significantly to battery life by lowering both absolute and relative battery temperatures. Batteries marketed to the broadband industry today include both gelled electrolyte as well as absorbent glass mat (AGM) technologies. While both offer comparable run times and shelf life, the improved heat transfer of gel batteries makes them superior for outdoor plant applications, especially in hotter climates.

Many equipment suppliers and network operators are recognizing the need for advanced battery management and several versions of charge management (CM) devices are being introduced into the broadband market. Fig. 3 illustrates a typical application of a CM system in a CATV power supply. These devices in general promise to balance the voltages in a series connected string, thus enhancing battery life by avoiding over- or undercharging of individual batteries. In addition, employing voltage-balancing techniques enables the replacement of individual batteries in a string, avoiding the need to replace an entire string with a new balanced set when a single battery fails. While battery management techniques have been available for some time, pricing has been too high for broadband markets. Today, a CM system is available for retrofit into existing installations at the price of a single battery, making the application economically attractive. Table II lists some of the more important features to consider when evaluating battery management systems. In addition, the actual circuit implementation should be evaluated carefully. Some circuit topologies rely on simple charge exchange

using intermediate energy storage elements, i.e. inductors or capacitors. This makes CM functionality subject to component variability, along with temperature and ageing effects.

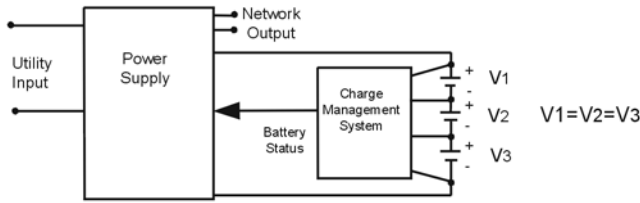


Figure 3. Charge Management System

Table II Charge Management System Considerations

Speed of Balance	Current rating should be high enough (2A or greater) to enable fast charge balance.
Final Balance	Should be 60mV or less per battery; higher imbalance renders the CM device useless.
Efficiency at Final Balance	Should be extremely low (5W or less) to avoid cabinet heating and an impact on operating costs.
Low Voltage Cut-off	Required to protect batteries from permanent damage during long outages.
Electromagnetic Compatibility	Most implementations use high frequency circuits along with long battery leads with the potential for interference.

For long standby times, natural gas powered curbside generators continue to be the choice of the industry. While local building ordinances are often a significant hurdle to overcome, generator systems with a one hour battery pack offer both initial and operating cost advantages over an eight hour battery installation; depending on the power level, the battery-only system can be more expensive by a factor of two or more.

Fuel cell technology has received much press coverage in the recent past and can be seen as an attractive alternative to batteries and generators for extended run-time applications. However, most of the current work is focused on hydrogen-based systems for automotive applications. Since there is no in-ground hydrogen distribution system and since on-site reformation technologies suffer from significant cost, complexity and reliability problems, the fielding of hydrogen fuel cells today requires truck based fuelling, an unattractive proposition for system operators. Coupled with the fact that cost and reliability figures are still an order of magnitude off the pace set by natural gas powered curbside generators, commercial application of fuel cells in communications power systems is years away.

There are also significant research and development activities addressing other energy related technologies, including advanced batteries, metal-air fuel cells, flywheels and ultracapacitors. While much of this technology is still pre-commercial, there will no doubt be several field trials in the coming months, giving the industry at large an opportunity to evaluate these future energy storage and conversion products.

Status Monitoring

System operators are placing a renewed emphasis not only on power system reliability, but also on dependable and affordable health and usage monitoring. Consequently, status monitoring systems have been undergoing the most significant update since their original introduction. A subcommittee of the Society of Cable Telecommunications Engineers has created a standard for interfacing between powering elements of a cable system. This Hybrid Management Sub-layer (HMS) standard allows for compatibility and interchangeability between vendors, and yields improved data acquisition and management capability. On the hardware side, interfaces are transitioning to robust serial communication links and transponders are increasingly being integrated directly with the power supply, yielding a robust, compact and cost effective status monitoring solution.

Bottom Line

The communications power industry is responding to the deployment of new fiber architectures and the continued push into advanced services. New power supply technologies are being introduced for last mile powering, offering battery-backed up ac or dc outputs in a mid-power range, filling the void between the traditional solutions of network and home powering.

With the changing network infrastructure, the application of local powering solutions on the customer premises is waning, while network powering applications remain strong. On the network side, the traditional ferroresonant power supply remains the topology of choice, with a significant emphasis being placed on system reliability and predictability. In turn, this is giving impetus to new developments in battery management and status monitoring.

Lead acid batteries will remain the energy storage backbone of standby power systems, aided by natural gas powered generators. While novel energy technologies are being introduced at the field trial stage, the fielding of a commercially viable product is still a long term proposition.

René Spée, Ph.D.
Alpha Technologies
Vice President, Engineering
rspee@alpha.com

Thanh Le
Alpha Technologies
Director of Power System Development
tle@alpha.com