Transmitting Power in the 90s: Architectures and Systems

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Abstract

Powering is becoming an increasingly costly part of delivering communication services. With the advent of so much new technology, there are as many powering problems to accompany it. This paper deals with some of the problems associated with high power delivery and techniques to solve them. The bottom line is lower capital expenditure and lower operating costs.

Anyone who has attempted to design a broadband cable system capable of delivering dial tone service has already discovered the enormous appetite for power that such a design requires. Short of deploying a power supply at every other corner with a minimum of six batteries per cabinet, a new solution must be found. Many of the designers are searching for new techniques and answers for this problem.

The Problems

As cable systems have evolved, the powering needs have changed in step with many different elements of the broadband system. Power hungry amplifiers have changed the powering design such that for the first time, the network current (the power in one single power feed direction) has become the limiting factor. This coupled with the highly capacitive nature of the current consumption created by switching power supplies has created numerous problems for operating systems and power supply vendors. The actual current consumption provides an opportunity for the most improvement. Any line gear power supply will draw most of its peak current during the voltage peak of the waveform. In its worst case, a hypothetical 4 amp RMS load could produce peak currents of 24 amps. While this is alarming, the use of linear transformers in the older line gear resulted in a high loss of efficiency which was expended as heat in the amplifier housing, another situation that is not desirable.

Enter dial tone services. In addition to the power consumption of the line actives, a system that is delivering Dial Tone Service must also deliver 4 to 7 watts of power for each active dial tone customer to power a home device. The normal output wattage of a CATV UPS power supply is 900 watts. If we assume a 40% penetration of dial tone customers, the additional power required is upwards of 800 watts in a 500 home node. It is easy to imagine that with any actives, a single standard CATV product cannot deliver the powering needs of one fiber node.

When we consider the implications of 911 services on the hybrid system, it is important that the system be reliable. This reliability takes two different formats. The components must be redundant such that a component failure cannot stop the delivery of power. A failure must be serviceable so that it can be "hot swapped" while not producing an outage. The system must also provide a minimum of 8 hours of backup capability. Finally, there is a technology called "PCS" that will require 50 watts per transponder location. The net addition is somewhere between 150 watts and higher per node site. These challenges have led to what will be a drastic change in how we design and deliver power in the 90's.

90 Volt Powering

Anyone who has done design work knows that the biggest limiting factor in plant powering is the I^2R losses of conductors, more notably coaxial cable and it's loop resistance. The industry fought this battle years ago and moved from 30 VAC powering to 60 VAC powering to increase the distance that power could be delivered over. Now with today's loads, it is time to increase that voltage again. The National Electrical Safety Code (N.E.S.C.) will allow up to 90 VAC on the systems for communications. However, the National Electric Code (N.E.C.) will only allow 60 VAC on the communication carrier to the home. They will however allow a secondary carrier to transmit up to 100 watts into the home. By separating the power at the tap, voltage limiting devices in power passing taps will not be necessary as the voltage is passed on a siamese coaxial cable with a twisted-pair copper conductor. Once all the codes have been satisfied, it is time to examine the equipment that this 90 VAC will power. Most manufacturers will need to provide a new power module to facilitate the use of 90 VAC. While some of the models are capable of sustaining up to 94 VAC, they cannot deal with the peak voltages that accompany a ferroresonant waveform producing 90 VAC true RMS. These voltage peaks can theoretically approach 112 VAC. You either need to change the power modules in the amplifiers or select a powering system with a peak voltage below that of the module being driven. One key factor in selecting these modules is in the useful "rail -to-rail" capability of the module. When the peak voltage rises, the bottom rail must also follow after a moderate increase. Currently there is a useful range of 20 volts for design purposes with 60 VAC powering. When a ferroresonant device is utilized for 90 VAC, the rail moves up and the design window increases to 30 VAC. This is a moderate increase allowing a reduction in the overall number of power supplies until the current limitation problem peaks at 10 amps. With a controlled delivery source, the current power modules can be maximized to deliver a range of 48 to 50 VAC. And with the reduced current capability from a controlled source, either further distance or more power can be achieved.

Once the power modules have been selected, the equipment figures into the equation again. Most line gear is only capable of passing 10 amps true RMS. The passives and distribution equipment varies from 6 amps up to 7.5 amps depending on the vendor. While work is in process to increase these current capabilities, the selection of a power delivery system that minimizes current in the network will allow for longer runs where current is concerned. In reality, the design moves back to a current limitation before the full usefulness of the 90 VAC change can be realized.

Finally, safety issues must be addressed. The only aspect of 90 VAC powering that everyone can agree upon when it comes to safety is that training will be necessary. However, with the reliability demands of Networks in the 90's, great care will be exercised not to casually open the network path. Modules cannot be swapped unless the system they are deployed in is capable of "Hot Swapping". If a unit is to be removed, there must be an identical unit or system to take its place with no break in the network traffic. This type of training is long overdue in the cable industry.

The effective result of utilizing a 90 volt system is a reduction in the number of power supplies. Current designs with 750 MHz or 1 GHz spacing require power supplies at every 0.6 to 1.2 miles depending on the geographic area. One system completed an upgrade where they utilized twice as many power supplies as they had previously. However, when the first utility bill arrived, the total dollar amount was closer to triple of that which they had previously received. Obviously, the more efficient a system is at powering, the lower the operating costs for powering will be.

Express Power Feeders

When you examine any powering design, the highest losses occur in the cable segments closest to the power source. If you can reduce the amount of current flowing in these segments, the voltage drop decreases proportionally. One technique for maximizing the ability of any power supply, 60 VAC or 90 VAC, is to run an "express feeder" from the power supply past the first load point. For example, if the voltage drop in a 3000' segment is 12 VAC and the load is 4 amps, by utilizing a coaxial extension cord, the voltage drop can reduce the load to 2 amps on each segment. This results in a uniform 6 VAC drop on each leg. This would allow another section to be installed, again increasing the voltage drop on the express feeder to 12 VAC. This is a proportional gain that allows approximately only 40% of the segment distance to be gained. But sometimes that small amount is the difference between the need for an additional power supply.

Typically, .825 coax is utilized due to its ability to carry high current loads with nominal loop resistance. Different sizes of cable can be utilized depending on the desired end voltage or current load of the design. This technique could also allow a leg in a single direction to have a total current draw of 12 amps with the current splitting 3 amps to the first segment and 9 amps to the remaining plant. Typically there is no RF transmission on these express feeders. Typical gains in utilizing this technique are a 10-20% decrease in power supplies in the system or better. Again, the geographic layout of the system will determine the total benefit. The down side of this technique is in direct burial applications or where conduit systems are already full. The additional cost in these locations merits close examination of the costs. Don't forget the operating costs that will be attributable to another supply location such as fixed clerical fees or attachment fees.

Architectures

There are many system designs being deployed today for communication networks. With regards to powering, the only common thread seems to be the centralization of powering. There is a desire to locate the power source at a central area and deliver power to the system. Some designs will locate the unit at the fiber node. If a node size is large enough, it may be the only one connected to that power supply. Other designers will utilize smaller nodes and then interconnect them utilizing express feeders and 90 VAC systems. Yet other designers are looking for techniques to harden the network against the ever popular "Semi Fade". That's where a "Mack" truck takes out a line or an entire power supply. To accomplish this task, they want to utilize "smart" switches that will seek the first active line. When the primary line fails, the next active line comes up to feed the fiber node. This process must be accomplished in less than the hold-up time of the fiber node. Even when we strive to achieve near passive system designs, the powering of home devices and the possibility of powering "PCS" gear requires that we still reliably power the network.

Efficient Delivery

To address the capacitive nature of today's networks, a new form of delivery was needed. The **Unity Wave™** was designed to solve this problem as well as the problem of transmission efficiency and I^2R losses. A *trapezoidal waveform* proved to be the solution. The waveform has a controllable rise time which controls harmonic content for reduced hum modulation in the network elements. This waveform lowers the overall RMS current being required by the cable network by increasing the load power factor. This in turn *lowers the cable segment voltage losses* allowing a higher voltage at the end of line or a deeper penetration into the cable network. Also, the I^2R losses in each cable segment are minimized *lowering the overall system power requirements* and maximizing transmission efficiency. The flat crest or peak voltage allows the switchmode power packs to draw their current over a longer duration which is the mechanism for power factor improvement. An additional benefit is that the peak voltage of the output is virtually equal to the RMS voltage. A **Unity Wave™** product with a 90 VAC RMS output will have only a 91.5 VAC peak voltage. Standard CATV power supplies can have a peak voltage up to 40% higher than their RMS output.

The final improvement is the output frequency. A **Unity Wave™** product has an *adjustable output frequency.* DC to 60 Hz can be selected by programming the unit in the field through its status monitoring or network management system. Personnel safety is improved at frequencies below 5 Hz, but corrosion performance improves as the frequency increases. The **Unity Wave™** product permits the output frequency to be optimized to suit each customers requirements.

Higher Delivery Voltage and Current Capability for Increased Penetration

The need to minimize the number of locations for maintenance purposes first became clear when evaluating the maintenance of the batteries required to provide 8 hours of backup in a 500 home node. It is estimated that it would take from 4 to eight power supplies with 6 batteries each to provide the requirements set forward. This translates into 48 batteries every 3.5 years at a material cost of $4224.00. In addition, the human resources needed to maintain these batteries during their usable life overshadows the material cost. The solution was to create a product that *centralized the standby operations on a per node basis.* To facilitate this, a higher output voltage is required.

Each leg of the system is limited today to 10 amps RMS maximum current by the coaxial devices employed in the system. The *lower peak currents of the trapezoidal waveform allow more power to be delivered into the coax.* If only 60 VAC RMS is used, the maximum power per feeder would be 600 watts. By utilizing 90 VAC RMS, the maximum is increased to 900 watts per feeder. With a system design of 4 feeders per node, the power output available is 3600 watts into the feeders. This is a substantial gain over power supplies currently used in CATV systems.

Most of the line gear manufacturers are producing equipment that will operate on a "controlled waveform" 90 VAC RMS supply or are in the design stages of such a product. A "controlled waveform" refers to the fact that the peak voltage of the **Unity Wave™** products is only 2% greater than the RMS output voltage.

Increased Reliability Through Redundancy

An optional feature of the **Unity Wave™** power supply is its *"N+1" redundancy.* This means that no single failed module will prevent operation of the network. This will in turn signal the Network Management system to notify system personnel of the problem. The Network Management system can control and monitor numerous parameters of the system's operation.

Extended Standby Operation

When faced with the large number of batteries required to provide 8 hours of emergency service, it is apparent that there must be a better solution. The **Unity Wave™** system employs an optional *DC Generator* to provide long term uninterrupted backup at a lower cost than batteries. The generator can be fed from either bottled liquid propane or a natural gas hookup. It is designed into a *cabinet which may be located separately from the power supply* location. The **Unity Wave™** system will run from internal battery power for 20 minutes before switching the generator on. This will handle most nuisance outages. If a DC generator is not practical in a given area, a system utilizing additional batteries could be deployed for a total of eight hours of backup time or greater.