AC POWERING FOR DIGITAL NETWORKS

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ABSTRACT

Network powering reliability is one of the most fundamental and unfortunately one of the most overlooked areas of system design and operation. Competitiveness with other service providers can be significantly affected by powering reliability, not only in the outside plant but in the office and headend as well.

This paper will explore the key issues facing operators today in terms of improving the powering reliability of their networks.

INTRODUCTION

The Cable Television industry has evolved rapidly into a complex infrastructure of broadband signal trunking and distribution networks for transmission of many different information services. The industry is poised on the threshold of the conversion to digital signal transmission of the majority of existing services. In addition, new services that are much more feasible due to digital technology are being implemented at an ever increasing pace.

The fundamental business issue facing the industry is the ability for Cable Television networks to be competitive in delivery of other services with the existing providers that are already firmly entrenched. One of the most important technical obstacles to the competitiveness of our industry is *network reliability.* Compared to existing providers of Alternate access, Telephony and Cellular, the Cable Television industry has to make significant progress in the design, construction and reliable operation of their systems in order to win over new customers from the competition. As one of the most fundamental issues facing operators for improvement of reliability, system powering is perhaps the area that deserves initially the most attention in the design of new communications networks.

DIGITAL SIGNAL POWERING REQUIREMENTS.

With the advent of digital signal transmission over the cable television network, reliable and uninterrupted powering of signal processing and transmission equipment has become extremely important.

Previously, minor signal interruptions to the cable system were somewhat tolerable because the information transmitted was entertainment video and not necessarily critical in nature (Although some subscribers would argue with this viewpoint). A slight picture roll, or a few second dropout was annoying but not necessarily critical to the subscriber.

In the past, power fluctuations, dropouts and transfer interruptions have been tolerated in many systems. Many locations had only limited or no back-up power capability for the outside plant or the headend. Some locations that had standby power equipment in place experienced poor equipment reliability, excessive maintenance requirements or budget limitations that limited repair or replacement activity.

BANDWIDTH, DIGITAL AND NEW SERVICES.

With cable systems upgrading and rebuilding for higher bandwidth and transmission of digital video and audio, Video on demand (VOD), PCS, pay per view, data networking and other digital signal delivery services, powering reliability is one of the most critical common denominators to the success of the system.

A key factor that has determined a difference in powering requirements is the volatile nature of digital data. Digital data using Asynchronous Transmission Mode (ATM) data protocol (even with error detection) can be very susceptible to power fluctuations that cause signal dropouts. Even if some form of error correction or packet delivery verification is employed, microsecond interruptions in signal flow result in reduced data throughput, higher bit error rates or complete data loss. Even the advanced synchronous "data packet" protocols that have effective error detection and correction can experience reduced data transfer speeds because of re transmission of the same data over again.

These interruptions can cause annoying visual and audible effects for entertainment transmission but can cause critical problems for other services.

SUSCEPTIBILITY TO POWER FLUCTUATIONS.

Several amplifier manufacturers have recently studied the effect of power interruption to their equipment in terms of effect on signal transmission. Their conclusion is that an interruption of power to active devices (or prolonged brownout) for longer than 20 to 25 milliseconds (.025 seconds) will cause a corresponding dropout in signal flow through the device.

AMPLIFIERS AND FIBER OPTIC RECEIVERS.

The problem in the outside plant is interruption of power to the signal processing and amplification circuitry in the active devices.

The "hold-up" time of the filter capacitors in the power supply within the amplifiers could provide several milliseconds of continued operation during a brief power dropout when new. But as they age, especially in warmer climates, the capacitance value typically decreases, and the hold-up time decreases as well. This often results in an amplifier hold-up time that is shorter in duration than the "transfer" interruption caused by of many of the standby power supplies. When certain types of standby power supplies change modes from line to standby or standby to line, an interruption in output power results. It is clear that any momentary power fluctuation that may occur on the utility input can cause standby power supplies to transfer to standby. This is what the power supply is designed to do, but if the transfer time is longer in duration than the hold-up capability of any of the amplifiers, a drop-out of data flow will occur.

Can you imagine a network that provides digital services such as telephony, dropping all phone calls in progress every time the power supplies transfer into standby?

It would be difficult to argue that such a system would be competitive with the existing Telephony providers that utilize DC Uninterruptible power systems in the central office and the outside plant.

An obvious conclusion is the importance of uninterrupted power output from the Cable Television standby power supply for reliable signal transmission. This is true not only in the outside plant but in the headend and office as well.

UNINTERRRUPTIBLE POWER SUPPLIES (UPS).

Uninterruptible power supplies (UPS) have been used by the telephone and computer industries for over 30 years for reliability reasons. These "Double Conversion" UPS units tended to be large, inefficient and expensive. For cable television applications, the typical standby power supply has been acceptable for years because of the aforementioned insensitivity of the network to minor interruptions.

DIGITAL COMPRESSION AND DATA LOSS.

With digital signal transmission, this has all changed. To give an example, any power interruption longer than a few milliseconds to any signal transmission device in a PCN or alternate access system could cause a complete drop and disconnection of all calls in progress within that cell. Any signal dropout of this duration to digital compressed video and audio can cause unpredictable, strange and annoying effects that are presented to the subscriber. Dropouts in other data services such as leased commercial data networks (service provided to inter-exchange carriers) can be catastrophic depending on the error correction system (or lack of), data transmission speed and duration of the signal loss.

Digital compression ratios in excess of ten to one have been advocated by several manufacturers of signal processing equipment. In conjunction with the compression system, high data transmission speeds are to be employed as well to provide the necessary video performance. At these high data rates, even a few millisecond interruption could result in data loss greater than all of the information contained in a several volume encyclopedia!

As many of the local area network engineers have concluded, it is imperative to the data integrity of the network that power be completely uninterruptible.

Many cable operators who are active in system planning for networks that will carry digital data in the near future have recognized the importance of UPS powering for all of the critical signal processing equipment from the headend to the subscriber. With the right design concept, uninterrupted output from a power supply does not require many additional components or extra cost.

POWER SUPPLY DESIGN

Single Ferroresonant

In cable television applications there are basically two standby power supply design approaches; the single ferroresonant transformer UPS and the "two-module" standby.

The single ferroresonant transformer concept for cable powering was introduced over 15 years ago and is available in outside plant standby power supplies as well as UPS for office or headend powering. The single ferroresonant design features two primary inputs (AC line and battery inverter) and one isolated resonant secondary winding output. The output is always connected to the transformer and is isolated from primary side transients and noise by 60 dB. The output voltage is regulated in both AC and standby modes and is consistent in voltage, waveshape, frequency and phase during AC and standby operation. Input power is routed either to the AC input primary from the utility or from the solid state crystal controlled inverter fed by the battery string when operating in standby mode. The circulating energy in the resonant tank circuit on the output winding provides continued output power during the transfer on the primary side from either line or inverter.
This energy storage provides the uninterrupted output in all modes of operation, during transfer from line to standby or standby back to line mode.

Two-Module Standby

The two module approach available from most manufacturers uses essentially two power supplies with their outputs connected to the contacts of a relay. The wiper of the relay is connected the cable system and selects from the output of one or the other power supply outputs depending upon AC or standby operation. In normal line operation, a non-standby ferroresonant transformer power supply provides output power to the cable system. When AC power browns out or completely blacks out the inverter module waits for the output voltage of the ferroresonant power supply to drop below the holding current of the transfer relay (or a sensing circuit) before the relay switches the cable system to the output of the inverter module output. This results in a significant brownout on the output (which can drop end of line actives out of operation) prior to a significant power output interruption of 35 to 70 milliseconds or more before the inverter starts to power the cable system.
According to the amplifier manufacturers, a 20 to 25 millisecond (or less in some cases) interruption is all that is required to drop signal. This effect is much worse at the end of cascade where the actives operate at a lower average voltage and have less hold-up time.
It is important to note that even if a power brownout occurs (not a complete drop-out), distortion levels in the amplifier circuitry can increase to such a level that data flow is interrupted or corrupted.

The other problem with this design is that the transfer from line to standby is not synchronized in phase. The output is switched by a relay with variable switching time and no means to synchronize to the AC line prior to re-transfer after an outage. The inverter frequency is free-running in many of these designs and can vary from 45 to 90 Hz depending on temperature, battery voltage and output load. When operating in standby, these designs can produce a high harmonic square wave output which can cause interference in the subscriber tap. This interference unfortunately also interferes with digital signal through the tap. The interference caused by the rapid rising and falling edges of the square wave output causes a signal blanking of up to 200 microseconds in the tap. This effect can occur in any device with capacitive or inductive elements that respond to the conducted harmonics at several frequencies. Devices designed for higher bandwidth such as 750Mhz to 1Ghz seem to be more susceptible to spurious noise generated by harmonics in the power supply output waveform. Or caused by transfer switching interruptions and phase changes.

OFFICE, CUSTOMER PREMISES AND HEADEND POWERING.

Power reliability is not only important in the outside plant. In most offices now, computers are an integral part in plant design, billing systems, addressability, status monitoring and other applications.

For Telephony and data network services, all of the network switching and routing equipment must be protected.

Cable network connection to local exchange carrier point of presence (POP) as well as connections to inter-exchange carriers require UPS powering for all of the multiplexers, routers, and other digital interface equipment. Usually most central office and customer premise equipment for commercial data services is powered by 48VDC UPS systems on site. A DC UPS system consists simply of a 48 volt DC (24 VDC for Cellular/PCN systems) rectifier with it's output connected in parallel to a string of Gel-cell batteries. In normal operation, the rectifier provides the operating power for the Telephony equipment in addition to "trickle charge" current to maintain the charge on the battery string. When a brown-out or blackout occurs, the battery system continues to power the equipment with no interruption. An inverter or transfer circuit is not necessary, and the corresponding potential transfer delays or interruptions are eliminated.

Even the office telephone system is critical in most systems for subscriber pay per view transactions and needs to be protected from power failure. A few minute power interruption during pay per view peak ordering time can easily result in enough revenue loss to pay for a UPS several times over.

In the headend, new digital equipment is being installed in many systems. From digital advertising insertion equipment, telephony switching and routing systems to microprocessor controlled modulators, receivers and digital music systems. Many of the computer controlled devices will not reset after a power interruption and may require manual reprogramming or fine tuning in order to restore correct operation after interruption. This clearly can be a problem in remote headend or telephony hub site locations where it can take a significant amount of time to get someone on site to correct the problem.

STANDBY GENERATORS

Even installations with standby generators are not immune from problems. It can take up to 50 seconds for an automatic standby generator to start and come up to stable voltage and frequency before transfer of the load to generator. This is assuming that the generator starts up properly the first time, many generators will re-try several times if they are having difficulty starting. This situation can occur often during cold weather in outdoor installations that can increase starting difficulties. Even if the generator starts up properly within 50 seconds or so, most computer based equipment has long since shut down. Interruptions of 8 milliseconds or less can drop out most computers.

In most high density locations, it would seem unacceptable to drop out service to all of the subscribers fed by a particular headend for 50 seconds. Add to this the interruption caused to telephone call routing systems and switching gear for commercial data customers for this duration. Our competition in the telephone industry employs dual redundancy in powering equipment in many locations that are critical to the network switching and routing activity.

Many of the newer cable television headend locations are being designed with power reliability in mind. One approach to powering in the headend is the use of both interruptible and uninterruptible branch circuits for equipment power.

The interruptible circuit is powered by the standby generator and usually consists of the devices that can withstand a momentary interruption in power with no ill effect upon operational reliability such as the following:

Interruptible Circuit;

Most lighting
Air conditioners
Circulating fans
Non-computer based equipment
Other non-critical electrical equipment.

The uninterruptible circuit is powered by a UPS that is also powered by the standby generator. When a power outage occurs, the UPS continues to provide uninterrupted output power to the headend equipment during the start-up delay of the generator. Even if the generator took several attempts to start up (or did not start at all) most UPS systems can provide continued output up to 30 minutes or longer. After the generator starts, the UPS is powered by generator and transfers out of standby mode and immediately starts recharging its battery bank. The UPS provides another significant function while operating from the generator; Voltage regulation and filtering. Most smaller generators that have been used for these types of applications are not very stable in terms of frequency or voltage regulation. When heavy electrical loads are suddenly placed on the generator such as an air conditioner, motor or lighting, the voltage and frequency can sag for many cycles until the generator speed governor and voltage regulator circuit compensate for the load change. The same is true when heavy loads are removed from the generator output, except in this condition frequency can increase and voltage can overshoot or spike until the governor can compensate. During generator operation, the UPS will filter the damaging voltage spikes and fluctuations from the generator output and provide clean power to the sensitive computer equipment connected to the Uninterruptible circuit such as the following:

Uninterruptible Circuit;

Satellite Receivers
Modulators
VTR's
Ad Insertion Equipment
Telephony switching equipment
laser transmitters and receivers
Computer Controllers
Microprocessor Based Equipment
Telephone System
Emergency Lighting

By implementing a dual circuit power system in the headend, the UPS need only be large enough in capacity to provide power to the devices connected to the uninterruptible circuit. This saves both cost and physical size with no sacrifice in reliability of the critical equipment. By coordinating this approach with the electrical contractor during the building design , maximum flexibility in installation of equipment racks powered by each circuit can be achieved. It is important for the designer to pay close attention to electrical grounding details to ensure that both the interruptible and uninterruptible circuits share the same "single point" ground location to eliminate potentially damaging ground loops.

HYBRID TELEVISION AND TELEPHONY NETWORKS.

In the U.K. many locations are currently under construction to provide video delivery as well as telephone service utilizing the same communication network. Traditional 60 volt Ac powered cable television amplifiers and fiber optic receivers are being co-located with 48VDC telephony multiplexers and switching gear. This design approach initially presented several challenges in terms of powering design. To eliminate the cost and size requirements for a dual AC and DC powering systems using traditional equipment, a new design was implemented;

A 60 volt AC output UPS was redesigned to operate from a 48 VDC battery string instead of the typical 36 volt systems used for cable television applications. The battery charger was upgraded for additional output current and to comply with the low ripple, low noise telephony specifications for 48 VDC power. A significant savings in cost was achieved by using one unit to provide both AC and DC UPS functions. The battery charger/ rectifier provides 48 VDC output for the telephony equipment at each node as well as to trickle charge the gel-cell batteries. The 60 VAC output powers the cable television equipment co-located at the node and continues to operate without interruption when utility power is interrupted. The internal DC to AC inverter converts the 48 VDC energy stored in the batteries to the 60 volt quasi-square wave output. With this approach, the cost and size of the equipment was significantly reduced. In all cases this implementation proved less expensive than the previous approach that did not provide any back-up for the 60 volt AC output.

Another power device was also implemented to improve reliability in this network; a "power multiplexer".

In the architecture used in these U.K. systems, there is a telephony node called the "Major Multiplexer" that feeds signal to all of the peripheral subscriber node locations. The Major Mux. is connected to the peripheral nodes via coaxial cable and thus can have access to the 60 volt AC UPS power from the peripheral node uninterruptible power supplies. The Major Mux. may not always be co-located with other node locations and as it is 48VDC telephony equipment it requires a rectifier / battery system to provide back-up power. To save the high cost of a separate utility power location (electrical meter, pedestal etc.) and the cost of a dedicated 48 VDC power supply, the "Power Mux." was designed. This device can accept 60 volt power from up to four directions fed via coax from the power supplies located out in the peripheral areas. The "power mux" selects AC power from one of the 4 input ports and rectifies, regulates and filters to provide a 48 VDC telephony grade power output to operate the major multiplexer. Since all four of the AC power sources are UPS, essentially "quadruple redundancy" for powering was achieved for the telephony node without installing an electrical service, large power supply or batteries. This design effectively increased reliability and reduced cost at the same time. Due to the nature of the telephony service carrying emergency (911 type) calls, the reliability requirements are much stricter than those typically considered for television service only.

CONCLUSION.

Due to the impending change in signal transmission to digital format and the new business opportunities for services in addition to television, the requirements for reliability have greatly increased. AC power problems in many locations can contribute to as much as 30 percent or more of the signal outages if not prevented by adequate power conditioning and protection systems. New services such as telephony, PCN, and data networking are far less tolerant of power related problems than the existing video service. UPS powering systems should be implemented for protection of equipment in all critical locations of the new communication networks. This will help to ensure powering reliability that will assist operators in being competitive in the new ventures.