RELIABLE POWER FOR CATV SYSTEMS

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The trend to greater interactive use of today's cable systems requires power sources of greater reliability than the AC utility power line. The head end, outside plant, and subscriber each present unique power requirements to the system designer. The causes and effects of power line problems are defined and the various equipment choices to protect critical equipment at each location are analyzed.

The Need for Reliable Power

The capabilities of Cable TV are expanding every day. The systems are rapidly changing from an entertainment television distribution system to a true communications network. The bandwidth available on a cable system today allows the handling of data transmission, security information, and even telephone conversations in addition to the traditional television signals.

As the uses expand beyond entertainment services, the need for reliable system operation also increases. A key element in the system reliability is the power source for the various requirements.

Electrical power is required at three distinctly different locations within the cable system:

1. Head End
2. Outside (Trunk/Line Amplifiers)
3. Subscriber

The traditional source for power at each of these locations has been the commercial AC power line. Utilizing the power line directly offers three advantages:

1. In the United States today, commercial AC line power is readily available.
2. Utilizing the commercial line is inexpensive. Power conversion equipment cost is the lowest of any methods to be discussed.
3. The commercial AC line in the United States is generally reliable enough for most applications.

The commercial power line, however, offers certain disadvantages to today's interactive and expanded capacity cable systems.

Four potential problems with using the AC line are described below with the possible causes for each problem.

1. Blackout--A blackout is a complete loss of AC power and can last from a few seconds to many hours.
2. Interrupt--An interrupt is a momentary loss of power lasting from a portion of a cycle to several cycles.

   Interrupts can be caused by the utility company's switching of transmission lines, automatic closing circuit breaker operation, or switching to or from an on site engine-alternator under actual or test conditions.
3. Brownout--A brownout is a long lasting reduction of AC voltage.

   The reduction can be to a level that causes marginal operation of connected equipment.

   Brownouts are caused by the electric utility company intentionally reducing the voltage to reduce the load on generating units or by continuous overloads on the distribution systems.

4. Transients--Transients are momentary voltage excursions--either high or low. They may be of very short duration (millionths of a second) or of long duration (several seconds). A low voltage condition lasting from one cycle to several cycles could be called a dip while a high voltage condition could be called a surge.

   Transients can be caused by lightning strikes, switching of power factor correction capacitors, large load changes, or faults on other circuits in the same distribution system.

Each load connected to an AC power system should be investigated as to its response to each of these problems.

Each location in the cable system (head end, amplifier, and subscriber) may have different needs for power.

The Head End

The head end will have the highest power demand of any place in the system and may have the most critical power requirements due to the complexity and sophistication of the installed equipment.

Computers are most sensitive to power line anomolies and will often shut down for no apparent reason, yet the power line is often the culprit. The effects of a blackout are readily noticeable by operating personnel. An interrupt may appear as nothing more than a blink of the lights, but this is sufficient to shut down a sensitive computer. Transients are not noticed by operating personnel but may actually damage sensitive electronic components immediately or cause a degradation in a component which leads to failure at a later time.

The system designer should consider each piece of equipment installed at the head end individually and ask the following questions regarding that equipment's operation following a power line problem:

1. What effect does the loss of this equipment have on operating revenues?
2. What effect does the loss of this piece of equipment have on the safety of subscribers or operating personnel?
3. What is the cost to restore the unit to operation, such as reprogramming time?
4. What are the effects of subscriber complaints upon loss of that particular service?

The designer must then decide which pieces of equipment will need protection and the degree of protection to be provided.

The power line problems that are solved the easiest and most economically are brownouts and transients. Both problems can be protected against by simply employing a line voltage regulator; however, the regulator will offer no protection against blackouts or interrupts.

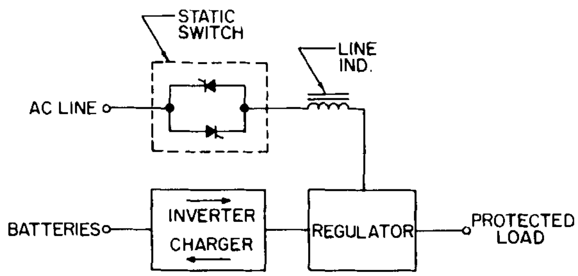
The simplest line voltage regulator is a ferroresonant transformer. Its energy consumption is low and the initial purchase and installation price are the lowest of any of the alternatives to solving power line problems.

The next highest level of protection is an engine alternator. The engine alternator by itself will offer protection against blackouts and brownouts but does nothing for transients or interrupts. A line voltage regulator would have to be used to protect against transients. The installed cost of an engine alternator is approximately 3 to 3½ times the cost of a line voltage regulator and the cost of the regulator would have to be added to it to offer protection against the three most common types of AC line problems--blackout, brownout and transient.

The combination of a line voltage regulator and an engine alternator still offers no protection against an interrupt in AC line voltage which may still cause problems with computer operated equipment. A time delay of many seconds to several minutes may be encountered as the engine alternator cranks, starts, and comes up to speed. Another interrupt will be experienced when the transfer switch reconnects the critical load to the commercial line following the use, during actual or test conditions, of the engine alternator.

Protecting the critical loads against the possibility of a power line interrupt requires the use of an energy storage device that can provide the energy immediately--unlike the start up time required in an engine alternator. The most common type of energy storage device available for this purpose is the lead-acid battery; however, the energy stored by the battery is not directly usable by most computer operated equipment; thus, the battery power must be converted by means of an inverter into usable AC power.

One type of Uninterruptible Power System (UPS) that can protect against all forms of power line problems--blackout, brownout, transients and interrupts--is depicted in the drawing below.



The heart of the system is the regulator which is a line voltage regulator that both regulates the line voltage for brownout protection and filters the line voltage for transient protection. A battery is provided as the energy storage device. A continuously operating inverter connected to the battery is also connected to the AC line regulator. If the line voltage should become unacceptable as a source of power for the regulator, the line is simply disconnected from the regulator by the static disconnect switch and the inverter, which has been running, simply supplies power to the regulator from the battery.

When the AC line voltage returns to normal limits, the control circuits will bring the inverter in step, or phase, with the AC line and reconnect the regulator to the line voltage. The control circuits then go one step further and allow the inverter to run slightly out of step, or at a different phase angle, with the AC line and draw a small amount of power from the regulator and feed it back to the battery to recharge it. Thus, the inverter is forced to "run backwards" to become a battery charger.

The installed cost of a UPS less the battery bank may be 1 to 1½ times in installed cost of the engine alternator. Adding a battery bank sufficient to operate a UPS at its full rated load for two hours can make the installed cost of the UPS and the battery approximately 2 to 2½ times the cost of an engine alternator.

Engine alternators are often installed of a size large enough to handle the complete requirements of the head end including the critical head end television processing equipment, computers, air conditioning, and lights. It is generally uneconomical to install a UPS large enough to handle all of these loads. The system designer should segregate those loads which are truly critical to the operation of the systems and operate only the critical loads from the UPS. It would not be unusual to have head end with a total power requirement of as much as 100 KVA, whereas the critical components of that load may easily be under 10 KVA. It would be far more economical to provide a 10 KVA UPS for the critical loads than try to install a 100 KVA UPS and battery bank.

Table A below illustrates the degree of protection offered by the various choices.

TABLE A

	Brownout	Transient	Blackout	Interrupt	Cost
AC Utility Service	None	None	None	None	0
Line Voltage Regulator	Good	Good	None	None	100%
Engine-Alternator	Good	None	Good	None	300-350%
Uninterruptible Power System with 2 Hour Reserve	Excellent	Excellent	Excellent	Excellent	600-800%

Outside Power Requirements

The outside plant (amplifiers and line extenders) power requirements are considerably different than the head end power requirements. The head end equipment is all designed to be operated from the 120 volt or 208 volt commercial AC service with its smooth sine wave voltage with low harmonic content.

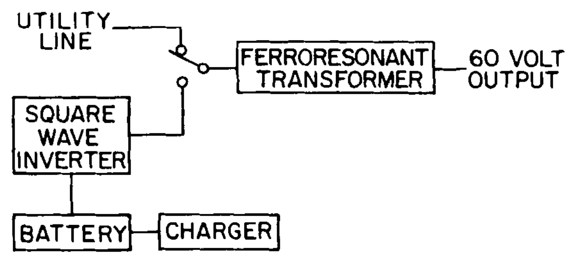
The traditional source of power for the outside plant equipment has been an unfiltered, line operated ferroresonant transformer with an output voltage of 30 or 60 volts and a harmonic content of 15 to 20 percent. The power supplies for the line amplifiers have all be designed to operate satisfactorily from this type of voltage and waveshape.

The 30 or 60 volt ferroresonant power supplies, because they are operating from a standard 120 volt commercial AC service, are all subject to the same power problems that the head ends are subject to. The ferroresonant power supply protects the line amplifiers from the effects of transients and brownouts. There is no protection against blackouts. The line amplifiers receive a limited amount of protection against short interrupts because the ferroresonant transformers contain a small amount of stored energy in the resonant circuit, and the line amplifiers' internal power supply has energy stored within its filter capacitors; thus, the line amplifiers can survive short power line interrupts without affecting the amplifiers operation.

It then becomes necessary to provide blackout and long interrupt protection only to insure continuous operation of the outside plants' electronics equipment. This will necessitate the use of a battery backed up Uninterruptible Power System instead of utilizing the simple ferroresonant power supplies.

The ideal UPS provides an output waveshape that is identical to the waveshape provided by the AC operated ferroresonant power supplies; thus, the line amplifiers will continue to receive the same waveshape in voltage whether it is being supplied by the utility service or by the back up batteries and inverter system.

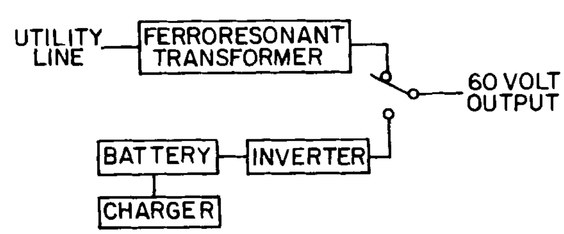
A typical equipment arrangement is shown below.



The utility line is the preferred source of power for the ferroresonant transformer. Should the utility line fail, the square wave inverter is caused to start and the transfer switch switches the output of the inverter to the ferroresonant transformer. Due to the energy stored in the ferroresonant transformer and in the line amplifier power supplies, it is not necessary to have a no-break or an instantaneous transfer from utility line to inverter power. This is unlike the situation at the head end where no energy storage devices are normally employed to keep the computer operated piece of equipment operating during a transfer. The output of the ferroresonant transformer will have the same waveshape and voltage characteristics whether the utility line or the inverter is providing the power to it. It is important, however, that the combination of the transformer and inverter be designed to provide the same level of voltage regulation as the utility line would provide as the battery voltage decreases. During a discharge, the ferroresonant transformer must maintain the output voltage within design limits to assure proper operation of the amplifiers powered by the system.

Following restoration of the utility line, the transfer switch will switch the ferroresonant transformer back to utility power and the battery charger will recharge and maintain the battery.

An alternative equipment arrangement is shown below.



The ferroresonant transformer is again powered by the utility line; however, the output of the transformer is now switched to the inverter and battery combination should the utility line fail. This arrangement does not take advantage of the energy stored in the ferroresonant transformer to help ride through the interruption of the transfer but relies entirely on the energy stored in the line amplifiers' power supplies. The inverter utilized may be one of two different types. The least costly type of inverter is a straight square wave inverter with no regulation. This subjects the load to a wide variation in voltage as the system switches from the regulation inherent in the ferroresonant transformer to the unregulated inverter. As the battery discharges, the output voltage of the inverter will decrease proportionally. An attempt to alleviate the regulation problem is made by utilizing a pulse width modulated (PWM) inverter where the output still is a square wave, but the width of the square wave is caused to vary as the battery voltage decreases in an attempt to maintain a constant output voltage. As the line amplifiers are designed to operate from the wave shape provided by a ferroresonant transformer and not the wave shape provided by a square wave or PWM inverter, the performance of the amplifiers may be adversely affected under worse case operating conditions.

The choice of the batteries and the battery charger employed in the system is vital to assure long term reliability and low cost operation. Two basic types of batteries are available.

1. Float Charge
2. Cycle Charge

The float charge battery is typical of those batteries used in communications service. The battery is designed to have a constant, well regulated battery charger connected to it at all times. The battery charger output voltage must be well regulated to assure that the battery is maintained at a high level of charge, but not at a level that would result in excessive water consumption and degradation of the life of the battery, nor at a level too low to maintain full charge.

An example of a cycle charge battery is the automotive battery. This type of battery is generally lower cost than the float charge battery and will not give long life under float charge conditions; thus, the battery charger must be designed to place a charge on the battery for a period of time, than allow the battery to self-discharge to a lower level, at which time the battery charger is turned on and the battery is cycled up to the fully charged condition. Thus, the state of charge of the battery is constantly changing.

Subscriber Power Requirements

The equipment that the subscriber connects to the cable will increase in complexity as the uses for the cable system increase. Ultimately, his equipment will require the same reliable source of power that the head end equipment requires. Fortunately for the subscriber, the power requirements are generally much lower than the requirements of the head end, but the power problems that the equipment is subjected to are identical. The choice for reliable power that the subscriber will generally make is a small Uninterruptible Power System in the 300 to 1000 watt range. A wide choice of equipment at low cost is available today to assure satisfactory operation of the connected equipment. One should select the UPS that supplies continuous output power without an interruption due to utility line failures and with an output that matches the voltage and waveshape supplied by the utility line to assure satisfactory operation of the connected equipment.

Conclusion

The above discussion has provided a system designer with a brief description of the types of power problems that he must anticipate when designing a total system and discussed the alternatives available today to solve those power problems. Only the system designer can determine which, if any, of the systems described are necessary in his installation , and he alone can select those solutions which exactly match his requirements.