CONSTRUCTING A CONVENTIONAL HARDENED TRUNK

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ABSTRACT

With higher bandwidths and increased gain, today's generation of active equipment consumes more power than the previous generation. The methodology behind powering this equipment, however, has remained essentially the same. Power supplies are added to the plant to compensate for the expected additional load or for potential future modifications. Along with additional power supplies, however, comes a decrease in system reliability. A power supply is dependent on the integrity of the local utility, and, based on our standard TREE AND BRANCH architecture and resistance to standby power, our reliability can never be better than theirs. To achieve satisfactory reliability, power supply cascades, or the number of power supplies serving a subscriber, must be reduced.

Headend operations are likewise impacted by power outages. In addition to the interruption in the cable service, the down time can contribute to headend equipment failures.

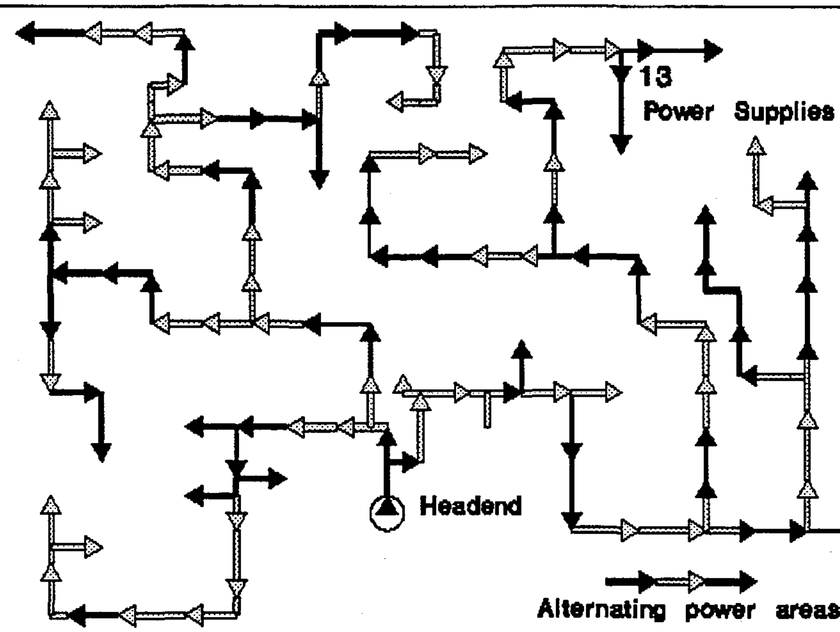
This paper introduces an alternative to the standard method of system powering. Described as a HARDENED TRUNK, it is a highly reliable, low maintenance, method of powering a cable plant. It offers relative ease of implementation, additional equipment protection, and, most of all, fewer power outages.

INTRODUCTION

The Nashua, N. H., system was recently upgraded from 300 to 450 Mhz. The system has 285 miles of plant and 85 power supplies. Trunk spacings and cascades remained the same as before, however, the heavier loads of the new equipment seemingly dictated that power supplies be added to the plant. The equipment vendor was instructed to design for complete two-way operation, maximum equipment loads, and to load the power supplies to no more than 80% of their maximum capacity. New power supplies were simply inserted into the plant where needed and none of the existing power supplies were moved. This is common practice for an upgrade throughout the industry.

The new system, however, was less reliable. The number of power supplies had increased by 40, or almost 100%. Cascades of 25 amplifiers had accompanying cascades of 13 under - loaded power supplies, none of which were equipped for standby operation. The picture quality in the system was judged by our customers to be very good, however, it did not make up for the fact that any isolated failure of the power grid resulted in catastrophic cable outages. In common with this plant problem was a power related trend that had developed at the headend locations: A loss of power, no matter how brief, would seem to coincide with equipment failures up to two weeks later. Headend equipment failures had previously been overlooked and/or accepted as the norm as long as they were not excessive. The headend was equipped with a diesel generator to provide emergency power

would be cost prohibitive and too difficult to maintain. Whatever was done, the end result had to be an actual improvement. It had to be both maintainable and reliable.



ORIGINAL DESIGN

during outages, however, the reason for the failures seemed to be the down time while the generator reached transfer speed.

SOLUTION

The plant had to be more reliable. To achieve a higher level of reliability, power supplies needed to be eliminated and cascades needed to be reduced. Fewer power supplies mean fewer problem areas and less reliance on the power company. Eliminating power supplies required starting over and re-powering the entire network.

To re-power the network, the contribution of each component had to be known. Cost was a factor, both the cost to implement and the cost to maintain thereafter. Simply changing all of the power supplies to standby

DESIGN PROCESS

Considerations - The upgrade to 450 Mhz required the use of three different types of amplifier: Push Pull, High Gain Power Doubling, and Feedforward. Switching regulated power packs had been installed to power the higher gain equipment. The RF portion of the design was similarly inefficient. Maximum cable losses had been used in the design, and because this was a "drop in" upgrade, the high gain Power Doubling amplifiers were used quite often; many times when they were not needed. The high gain version of the Power Doubling amplifier not only consumes more current but also has worse distortion specifications than a push Pull amplifier. To Achieve the higher gain, two Power Doubling stages are used and the advantage of Power Doubling technology is lost.

Switching regulated power packs had been installed in approximately 50% of the trunk stations. A switching power pack is approximately 90% efficient, compared to 50-60% with a linear regulated supply. Efficiency of the power pack is important, it determines the amount of AC current used by the trunk station, which determines the voltage drop, and, in turn, the load on the power supply.

Testing - Each type of active equipment was bench tested to measure the **DC LOAD CURRENT**. The DC load current is the current that the module requires from the power pack. The AC power differs from the DC current depending on the efficiency of the power pack.

$$\text{AC POWER} = \frac{\text{24VDC x DC LOAD CURRENT}}{\text{EFFICIENCY}}$$

The cable was then tested. The plant consists of several generations of air dielectric cable. A composite loop resistance was developed using the test data. The composite loop resistance was approximately 10% better than published specifications.

Design method - A **CONSTANT POWER** design method was chosen based on the existence of the switching regulated power packs, that is, the equipment consumed a constant wattage regardless of the input voltage, with higher voltages consuming less current than lower voltages. This method would more accurately reflect the operation of the switching power packs in the plant. The existing power areas were then tested using the new specifications and the numbers were adjusted to fit the real world accordingly.

Using the new specifications, the entire system was then redesigned on paper. Power supplies were loaded to 90-95% of maximum, 5 ampere power supplies were added to power the sub-trunk legs that branch off of the main trunk, and existing power supplies were moved to the most efficient location. Several other important steps were taken to improve reliability.

- During the initial redesign, and using actual field measurements, Push Pull amplifiers were moved to the main trunk and combined with a switching regulated power pack where the extra gain was not needed. This combination allowed for the most efficient design, low current consumption combined with a highly efficient power pack.
- A major focus was to stop power at the input of any trunk split. For example, each leg of a split is powered from a separate supply, eliminating the possibility that a power outage on one output leg would affect cable service on another. Each trunk section is therefore isolated from the others and responsible only for its own operation.
- Power supplies were moved to the location where they would have the greatest impact on the cascade and have a balanced load on either side of the power supply. Having a balanced load assures that voltage losses are kept to a minimum, and, as a result, the greatest efficiency is achieved.
- Standby power was then added to the longest trunk cascades. Having reduced the power supply cascade, a limited amount of standby power would greatly improve reliability.

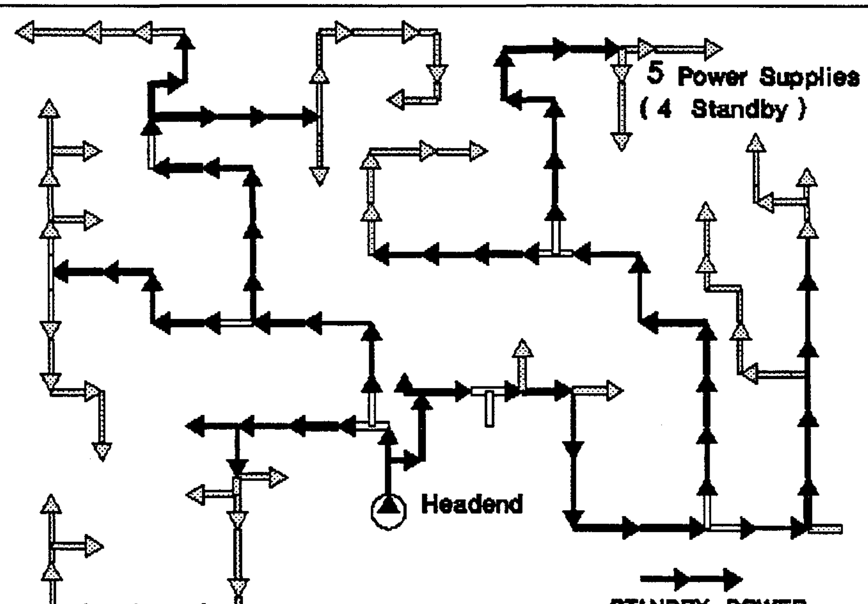
The result of the new design was a much more reliable network. Power supply cascades were cut in half. There were fewer critical power supplies and loads were brought to an efficient level. Despite installing only 4 standby power supplies in the first year of the project, the placement of the units greatly improved reliability.

IMPLEMENTATION

A three year implementation plan was developed. In the first year, 1991, 5 ampere power supplies were

took on a more significant role. The standby power supplies were placed where they would do the most good. Each one powers 6 to 7 trunk stations. The sub-trunk legs are powered by standard, non-standby power supplies which power 1 to 4 trunk stations.

This year, the second phase of the project, effort was placed on deeper penetration of the standby network, making most households no more than one power supply away from a standby. AMP CLAMP technology has been installed for the "hardened" portion of the trunk and the maximum power supply cascade has gone from 13 to 6.



FINAL DESIGN

installed on the sub trunk legs. Four 15 ampere standby power supplies were then installed on the "main" trunk, and 30% of the existing power supplies were moved.

The biggest impact to system reliability occurred during this phase of the project. The main trunk

80% of the households are now only one power supply away from a standby unit. This is reasonable, when the power is out in a neighborhood, there is no need for the cable service to be operable in the same confined area. With fewer than 12 standby units installed, the maintenance crew is able to perform regular maintenance on the standby power supplies.

The trunk network now has two unique identities, one a main trunk system composed of several long cascades of amplifiers powered by a limited amount of mostly standby power supplies, and another sub - trunk network composed of several short amplifier cascades branching off of the main trunk and without standby power.

Headend - Headend outages and equipment failures were occurring no more than in any other system, however, it was a problem worth correcting. Two problems existed relating to headend power outages and the delay until transfer to a generator. One, the cable service was interrupted to all subscribers. In the past this was acceptable, however, today we are more critically judged and we should not allow even the briefest outage if it can be prevented.

The second problem was related to equipment failures. The headend equipment is of various types and ages. The problems were varied and some were as common as modules becoming unseated in their housings and needing to be re-seated. This problem has been with us for years. The key factor is that the occurrences were traced to within two weeks of a power event. Adequate transient protection was in place and failures were not thought to be caused by line surges.

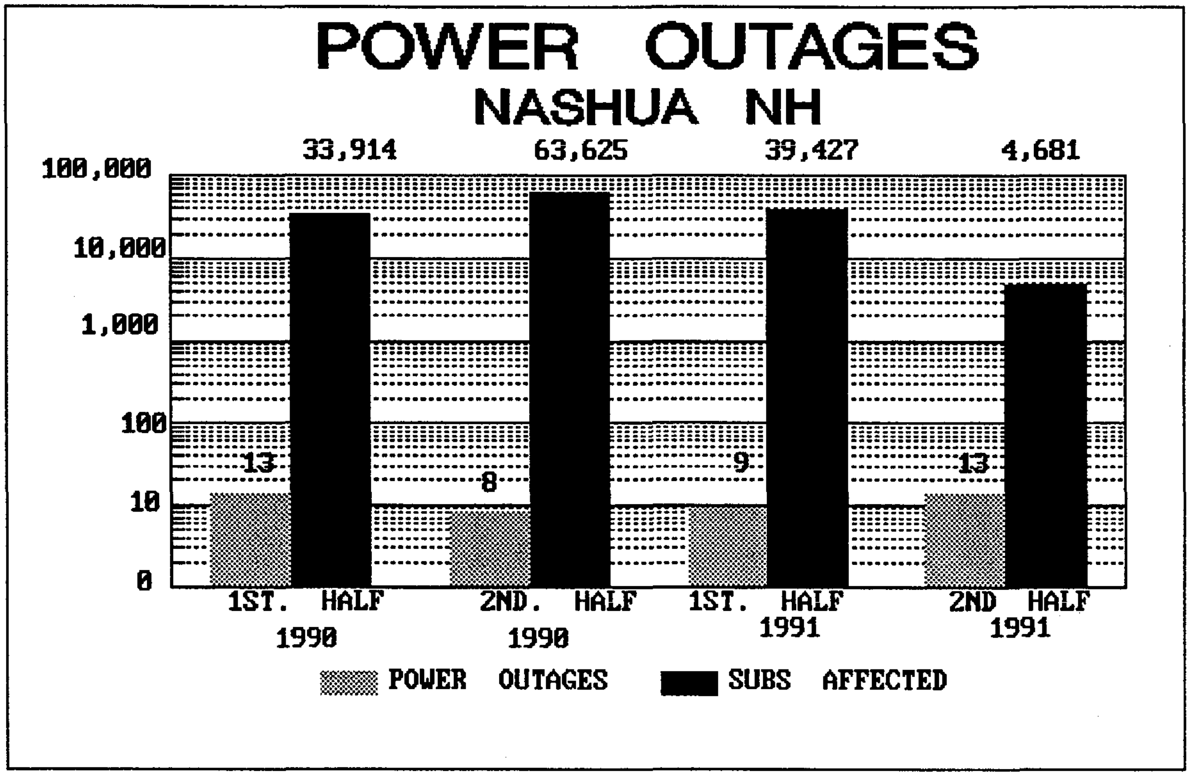
The cause of the failures was thought to be the equipment's inability to withstand brief losses of power. Equipment that had been working year in and year out developed a trend towards failure only after power was removed. The generator will transfer the load only after it has reached transfer speed, 5 - 10 seconds. If the lack of power was the cause, then eliminating the power outages in between would eliminate the corresponding equipment failures.

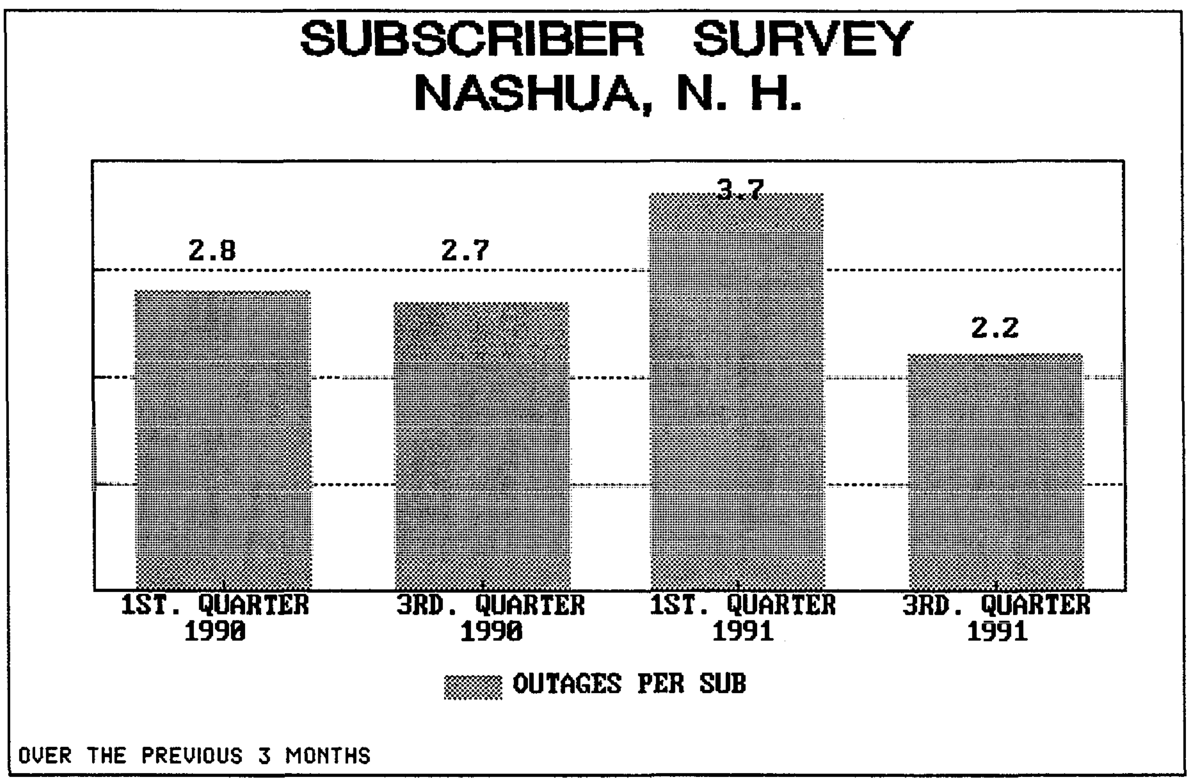
To solve this dilemma, uninterruptable power supplies were installed at one of the headend sites. An uninterruptable power supply, or UPS, is an instantaneous, battery powered AC source. It provides backup power when needed and is a source of additional over-voltage protection. The equipment would never notice a loss of power, nor would our customers ever see an outage. This was an enhancement to the existing backup generator. The UPS network only carries the load for the brief period between the time of utility power failure and the transfer to the diesel generator.

RESULTS

Two years after the concept was developed, the system is more reliable. Some power outages have been eliminated and the impact of each remaining occurrence is now limited in scope. No longer does a power outage result in catastrophe, and headend equipment failures seemingly have been eliminated. Because there are so few standby power supplies, each one is maintained properly and with far less effort.

One year after the UPS installation, March 1991 - March 1992, headend failures have been reduced to practically zero at the selected location. Despite power outages, numerous lightening storms, and a major hurricane, the headend has not gone off and the equipment has not failed. This is a difficult concept to visualize. The results are encouraging, but the theory would need to be tested in a controlled environment to prove a direct correlation.


POWER OUTAGES
NASHUA NH
33,914
63,625
39,427
4,681
100,000
10,000
1,000
100
10
0
13
8
9
13
1ST. HALF 1990
2ND. HALF 1990
1ST. HALF 1991
2ND HALF 1991
POWER OUTAGES
SUBS AFFECTED


SUBSCRIBER SURVEY
NASHUA, N. H.
2.8
2.7
3.7
2.2
1ST. QUARTER 1990
3RD. QUARTER 1990
1ST. QUARTER 1991
3RD. QUARTER 1991
OUTAGES PER SUB
OVER THE PREVIOUS 3 MONTHS

The first graph tracks the number of power outages versus the number of customers affected. This project was begun midway through the first half of 1991 and was completed late in the second half. During the second half of 1991, far fewer customers were affected by power outages than during any other time. This reduction occurred despite a hurricane in August that seriously damaged the power grid.

The second graph shows the results of a bi - quarterly survey of our customers. Again, despite the hurricane, outages were perceived to have been fewer.

SUMMARY

This paper outlines an approach towards system powering that can greatly increase plant reliability without consuming large sums of capital.

This trunk network is now **HARDENED** because it is better protected against outages, both power and transient related. It is **CONVENTIONAL** because it was constructed with off the shelf material and required no new technology. More than anything, it is an improved application of existing technology. It would interest those systems that are experiencing similar problems and will not be installing fiber in the near future. It can also be used as a first step towards a fiber optic installation. Regardless of the impetus, this technique is a simple solution to a problem that many system operators face.

Cost - It is important to mention that the switching power supplies had already been purchased and installed as part of the earlier upgrade project. For this project to be successful, it required that they be moved to the selected locations.

COST

INVESTMENT	TRUNK SYSTEM	HEADEND	PER PLANT MILE
1991 INVESTMENT	$14,000	$14,000	$ 98.00
1992 INVESTMENT	$10,000	$ 5,000	$ 52.50
PROJECTED 1993	$10,000	$ 5,000	$ 52.50
TOTAL INVESTMENT	$34,000	$24,000	$203.00

The basic premise is to construct a network which reflects the realities of the plant. Budgeting for the needs of tomorrow, which may never occur, requires that power supplies be added today. Standby power is an important asset, however, its use is limited due to the intense maintenance requirement. Many systems have standby power supplies that do not work because they could not be maintained.

The efficiency of the switching power supply is required to completely duplicate the results of this project. Without them, power supplies could still be moved to better locations, however, fewer of them would be eliminated because of the heavier loads. Purchasing new power packs for the main trunk will increase the cost by $100 - $200 per plant mile, effectively doubling the investment.