ON THE USE OF HIGH EFFICIENCY POWER SUPPLIES

Dan Pike

PRIME CABLE CORP.

ABSTRACT

The effects of recent developments in power supply efficiency are examined, with particular emphasis on operating costs.

INTRODUCTION

In recent years rapid developments in semiconductor technology and computer memory requirements have led to some rapid advancements in power supply technology, particularly switching regulated supply technology. The linear series pass designs were too bulky and inefficient for those applications. For personal computers, peripherals and many other consumer and industrial applications small highly efficient power supplies were developed. Many of these units operate in the same ranges of voltage and power that amplifier stations in use in the CATV industry require, and lately some of these advanced designs have been applied to the CATV industry. It is particularly important to note that the efficiency of these supplies has a very significant impact on the operating costs of a cable television system.

RECENT ADVANCEMENTS

Today it is commonplace to see power supply efficiency in the mid-eighties and the present state-of-the-art of switching power supplies for the ranges of concern to the cable industry is about 90%. Traditionally, the series pass units used in many trunk stations and virtually all line extender stations operated in the range between 40 and 60% efficiency. The switching regulated supplies used in some trunk stations approach 70% but their use is limited to the trunk lines.

The recent achievements in efficiency are due to advancements in all switching architectures but particularly those involving off-the-line or transformerless topologies. They typically use highly optimized magnetics and power MOSFET devices, with elaborate sensing and control circuits.[1] These have gained a great deal of respect for price efficiency and reliability without forfeiture in key parameters of concern to the cable industry such as susceptibility to transients and isolation.[2,3] Developments continue at a strong pace in this area[4,5] and the cable industry can expect to take advantage of reliable, efficient designs in power supplies that develop from proven techniques in other industries where these supplies sell in the 50¢ per watt range.[6] Judicious design effort and attention to the advancements in other industries can achieve for our industry the benefits of these supplies while minimizing their disadvantages of ripple, EMI, and increased circuit complexity.

CASE STUDIES

The loading presented by CATV amplifiers to their central supply is represented by a complex piece-wise nonlinear network,[7] and attempts to judge the items of interest for this study are better done empirically. While others [8,9] have pointed out the advantages of careful attention to the original loading calculations and equipment selection, the present day effects of the highly efficient power supply is worth examining. Such an architecture has been employed in a CATV product with a successful history of about three years[10] and others now or soon will be offered to the industry[11].

Some test designs were done on large and varied samples of plant to see the significance of these power supplies when used in various applications typical of the industry. The results were quite favorable in every case.

Case 1 shows the influence of the high efficiency supplies when used in a typical urban plant. The influence of the high efficiency supplies is given for several criteria, but the one of most importance is that a 34% reduction in power costs is achieved. The comparison is one of a complete series regulated supply to a high efficiency unit and a number of typical operating variables might be influential in raising or lowering that percent savings. A plant with a higher feeder to trunk ratio would see a higher benefit since 60% of the power consumption in this case was in the line extenders. It is the power consumption of the line extender which has the greater effect on I^2R losses in the feeder cable, and the power lost in the power supply can equal or exceed the power required for the amplifier modules. Accordingly, it is in the feeder amplifiers where these power supplies can achieve their greatest savings.

In Case 2, an upgrade application is modeled and it is particularly important to note a 24% reduction in power usage even though the trunk line had been refitted with feedforward amplifiers and the actives count had been increased due to the necessary corrections required in such an upgrade.

Case 3 shows the contribution of the trunk and feeder system to the total reduction in power usage by the use of the higher efficiency supplies. The case shows a total reduction of power required of 30%, with the contribution of each section about 15%. This suggests that there are significant cost reductions still possible in the improvement of a trunk switching supply from present efficiencies, and also shows the significance of improving the line extender supply efficiency.

THE RELATIVE SIGNIFICANCE FOR CATV OPERATIONS

As the industry becomes more mature with fewer chances for new growth, continued improvements in operating efficiency are sought. Minimizing plant power costs represents a very significant opportunity for improvements to the operating margins of a cable company because power costs can easily approach 10% of the total direct operating expenses and 1 to 2% of the total expenses involved in the operation of a cable television plant. A 30% reduction in those expenses is quite significant. Assuming a pessimistic incremental cost estimate of $50 for a line extender supply and $100 for a trunk station supply and a power cost of 10¢ per kilowatt hour (slightly above the 8¢ per kilowatt hour national average), the results in Case 1 can be used to forecast about a 12 month simple payback for the additional costs incurred in the equipment. At costs of 12 to 15¢ per kilowatt hour (closer to typical urban plant costs) the payback reduces to 10 and 8 months. It is important to note that dual plants and higher bandwidth plants have an opportunity for much greater savings not to mention the effect of future power cost increases which grow steadily a few percent each year. It is interesting to note, however, that a return to solid copper center conductors would yield about a 15 year simple payback indicating clearly that the efficiency of the line extender supply is the major component to be dealt with. The simple paybacks suggest that initial cost alone is not the dominant feature in the selection of new equipment, and that among the more complex considerations of a rebuild that power supply efficiency would take high priority.

Various comparisons of the relative significance of these savings would indicate that these potential savings alone approximate the total of various other but less controllable expense items such as vehicle expenses, plant maintenance, copyright fees and pole rental. Further, it is interesting to note that the magnitude of these cost reductions can have the same net effect to the cable company as the results of the marketing efforts.

CONCLUSIONS

Improvements in the ubiquitous power supply haven't kept up with other amplifier advancements in our industry and an application of presently available technology to those components can show reductions in power costs of 30% or greater, regardless of whether the application is in new or refit work. Power supply efficiency should become a key consideration in equipment selection and application.

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CASE 1

HIGH EFFICIENCY POWER SUPPLY ADVANTAGE IN A TYPICAL URBAN PLANT

	POWER COST(1) PER MILE OF PLANT,$	ACTIVES PER SUPPLY	MILES OF PLANT PER SUPPLY	KWH PER MONTH(2)
Conventional	167.5	14.5	4	525
High Efficiency(3)	110.0	21.0	6	340

NOTES:

(1) Per year, assuming 10¢/kwh/month power cost.
(2) Per 60v power supply area, average.
(3) High efficiency assumes 85% efficiency on all actives; conventional used current specifications on series regulated power supplies for all actives.

CONDITIONS: 400 MHz; active reverse; single cable.

Design Sample:	100 miles
Density:	112 h/m
Cables Used:	750/500; 3rd generation GID
Feeder/Trunk Ratio:	3/1
Actives:	103 trunk; 248 line extender
Power Supply Loading:	80% of maximum

CASE 2

HIGH EFFICIENCY POWER SUPPLY ADVANTAGE IN AN UPGRADE APPLICATION

	KWH PER MONTH(1)	ACTIVES PER MILE(2)
Conventional	577	2.5
High Efficiency(3)	438	3.0

NOTES:

(1) Per 60 volt power supply area, average.
(2) Actives increase due to some necessary distribution rearrangement and corrections required to accommodate 300 MHz loading.
(3) High efficiency assumes 85% efficiency on all actives; conventional used current specification on series regulated power supplies for all actives.

CONDITIONS: 220 MHz plant upgraded to 300 MHz (single cable). Trunk amplifiers were changed to feedforward units.

Design Sample:	100 miles
Density:	52.3 h/m
Cables Used:	750/500; 3rd generation GID
Feeder/Trunk Ratio:	4.5/1
Actives:	220 MHz; 47 trunk; 207 line extenders 300 MHz; 57 trunk; 242 line extenders
Power Supply Loading:	80% of maximum

CASE 3

TRUNK VS TOTAL SYSTEM ADVANTAGE

	KWH PER MONTH(1)	NUMBER OF POWER SUPPLY AREAS(1)
Conventional	4,421	9
Trunk High Efficiency(2)	3,754	8
Total System High Efficiency	3,097	6

NOTES:

(1) For the total plant.
(2) High efficiency assumes 85% efficiency on all actives; conventional used current specification on series regulated power supplies for all actives.

CONDITIONS: 400 MHz; active reverse, single cable.

Design Sample:	37.5 miles
Density:	46 h/m
Cables Used:	750/500; 3rd generation GID
Feeder/Trunk Ratio:	3.4/1
Actives:	36 trunk; 89 line extenders
Power Supply Loading:	80% of maximum/ 400 MHz with active reverse.

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