Incremental Deployment of Network Powering Infrastructure

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ABSTRACT

Delivery of network powered lifeline telephony service over existing HFC plant requires deployment of an infrastructure capable of providing reliable power to both system actives and telephony equipment.

This power must be available on a continuous basis during both momentary and extended utility outages. The need for continuous power requires deployment of alternate power sources. The economics of continuous power point to changes in the way power is distributed, The increased loads imposed by telephony equipment require commiserate increases in installed capacity.

These facts cause powering system enhancement to be the largest new plant cost item required in connection with telephony service. Because a certain amount of this new powering infrastructure must be in place before the first telephone customer is turned up, much of this cost is fixed.

The challenge before us is to deploy the lowest cost powering infrastructure which will meet the immediate needs of service launch, and to develop a plan to incrementally increase power capacity as the business grows. This paper will suggest network design techniques which address this incremental deployment.

INTRODUCTION

Preface

The analysis presented here is focused on the delivery of network powered lifeline telephony service. Conceptual descriptions of network powering design techniques are provided for universal application to HFC architectures. The powering infrastructure costs presented include provision of power to system actives, telephony network interface units, and the cost of long duration standby power sources. Cost models are based on the generic pricing supplied to Cable Labs and used by participating designers at the recent design conference.

Business Model

When telephony service is launched, the penetration rate will be zero percent. Power will be consumed only by system actives. As the service becomes more successful, the power consumption will increase. This is contrary to the predicament faced by our telco competitors, who must provide for 100% take rates up front with the expectation that market share will be lost as new players enter the marketplace. This business model offers an opportunity for significant reduction in the initial deployed cost of powering infrastructure.

OBJECTIVES

The following objectives have been identified as key to the control of capital expenditures and the provision of sufficiently robust powering infrastructure.

Minimizing Supply Locations

Long duration standby power systems are typically large, relatively expensive units that require easy maintenance access, and often need connections to natural gas and 240V secondary lines. Status monitoring is also required in these complex units.

Use of natural gas fired generators creates a situation where the materials cost of a supply is no longer a linear function of output capability. Basically, small generators cost nearly as much as large ones.

Time Warner's experience in Rochester NY has demonstrated the difficulty and expense involved in finding suitable locations and purchasing required easements.

For these reasons it is critical to minimize the total number of supply locations needed.

Localized Capacity Expansion

Because of the high cost of powering infrastructure, capacity increases must be separately deployable on an as-needed basis as the business dictates. This requires the discipline to monitor business success on a node by node basis, and a responsive design and construction operation capable of rapid network re-configuration.

A topology aware Operation and Support System capable of localized penetration reporting is an essential part of incremental power deployment. At a minimum, the OSS needs the capability to report the number of telephony devices deployed on a node by node basis. This provides for periodic comparison of existing power consumption (based on penetration level) to installed capacity. When existing penetration reaches a predetermined "alarm" point, power provisioning activities are initiated. These provisioning activities may alternately be triggered by remote monitoring and reporting of actual field power consumption, with the trigger based on a comparison of this reported consumption with the calculated consumption at the deployed capacity level.

Avoidance of Stranded Investment

The act of localized infrastructure capacity expansion will be repeated multiple times in the most successful service areas. This expected behavior makes it useful to examine in advance the network changes required beyond a given immediate business need. Such an examination will prevent stranded investment by revealing the nature of facilities which may be needed in the future, thereby minimizing the duplication of construction labor and the installation of undersized cables and other inadequate equipment.

CHALLENGES

Power Consumution Variables

Significant variables exist in expected power consumption in connection with telephony service offering:

- It is certain that some HFC service area nodes will be more successful than others.
- Telephony customer distribution will not be uniform along all streets in a given node, but is expected to be erratic in nature, with clusters of high penetration intermixed with lower penetration areas and areas without any subscribers.
- Telephony traffic levels will affect power consumption. Traffic effects will vary based on demographics and on the use and degree of RF concentration techniques.

The infrastructure design must be sufficiently conservative to accommodate these variables.

Stress testing techniques are available to examine the effects of traffic and subscriber distribution, but are beyond the scope of this paper.

60 Volt System Actives

In plant where upgrades have recently been completed, system actives will typically not be capable of operation above 60 Volts. The capital cost advantages afforded by the use of 90 Volt powering are unlikely to offset the cost of the needed equipment changeouts, particularly at low initial telephony penetrations.

The biggest liability of 60 Volt powering is the lack of "reach" compared to 90 Volts. This limitation creates two problems when compared to powering at higher voltages:

- A greater number of supply locations are needed, with the associated cost, reliability, and maintainability penalties.
- For a given service area, longer and/or larger coaxial cables must be added to attain a given design penetration level. This is both costly and time consuming.

90 Volt System Actives

Use of 90 Volt powering offers substantial deployment cost efficiencies compared to 60 Volts. However, caution must be used in design such that network instabilities such as multi-state oscillations ("motorboating") or network voltage collapse and lockup are avoided.

Effects believed to contribute to these undesired behaviors are:

- Low end of line design voltages
- Excessive total power source loading
- Excessive power dissipation in coaxial cables
- Switch mode power pack designs which continue to draw significant currents at very low ac input voltages before cut-off occurs and restart is initiated.

Variable Power Source Output Voltages

It has been suggested that the voltage of the power source could be adjusted such that the first amplifier would see only 60 Volts when fed by a long coaxial cable run. This technique appears to be attractive in cases where 60 and 90 Volt equipment is intermingled, or in upgrade scenarios where 60 Volt equipment is being progressively replaced with 90 Volt gear.

However, a closer examination of this technique reveals a serious flaw. If a portion of the load were to be lost, the voltage seen by all remaining devices could increase significantly, with potential damage to 60 Volt equipment. Safe application of the variable voltage technique will require a control system capable of protecting against equipment overvoltage. The added complexity and cost of this equipment is likely to negate the marginal advantages of variable voltage powering.

Power Provisioning Outage Reduction

Incremental infrastructure deployment must take into account potential interruptions in service during provisioning. Techniques such as temporary load segmentation and backup, and pre-placement of critical power inserters will minimize provisioning related outages.

TECHNIQUES

The following discussion illustrates how network powering infrastructure can be incrementally deployed in a typical service area node.

Samnle Node Characteristics

A sample node was selected to be representative of the "Fiber Rich" HFC architecture currently being deployed at Time Warner. The selected node has the following characteristics:

- 553 Homes Passed
- 6.59 Strand Miles
- 84 Homes per mile

- 37 Active Devices
- 5.6 Actives per mile
- A mixture of P-l and P-3 cables
- 750 Mhz upgrade with analog loading of 77 channels and 200 MHz digital.
- Minimum tap port outputs of +1 1 dBmV (virtual 750 MHz) over +8 dBmV (55 MHz).
- Cable sizes ranging from .4 12" to .875"
- Maximum RF cascade of one optical receiver/launch amp, two trunk amps, one terminating bridger, and three line extenders.
- A mixture of aerial and underground plant, mostly aerial.

Telenhonv Power Consumntion and Traffic Assumntions

While penetration is variable and is incremented in the design process, rules must be established to define how power consumption is allocated to each home passed. The following assumptions were selected to represent near term deployment of network interface units "NIUs" typically attached to the sides of single family residences.

Traffic assumptions:

- 3.6 ABSBHCCS. This is perhaps better explained as a design capable of a maximum of 10% of the deployed lines being off hook at any one instant.
- 2% Ringing.

Penetration assumptions:

- 10% of the NIU population has activated second line capability.
- Penetration is evenly distributed throughout the service area. This can be explained as follows: If a given pole location passes five homes, and the penetration is at 10%, then one half of one NIU power budget described previously is consumed at that pole location.

Power consumption:

- Idle State: 3 Watts
- Off-Hook: add 1 Watt per line to idle
- Ringing: add 10 Watts per line to Off-hook/idle combination.
- NIU design power allocated on a per telephony subscribing home basis: 3.63 Watts

Design Strategy

Powering designs were performed on the sample node using 60 Volt supplies, and again at 90 Volts. Real world active devices were selected with wide input voltage ranges, such that the same actives could be used in each case. The only specification difference was in the operating voltage range of the active devices. The voltage ranges used were as follows:

- 60 Volt design operated the actives (including NIUs) over an input voltage range of 40 to 60 Vac rms.
- 90 Volt design operated the actives (including NIUs) over an input voltage range of 45 to 90 Vac rms. The 45 Volt minimum was selected as a safety precaution against network stability concerns.

As stated earlier, an important objective is to avoid stranded investment. To this end, the design task is made considerably easier when the network is optimized at 100% telephony penetration initially, and lower penetration deployment strategies are developed based on the nature of the infrastructure needed at 100%. This conclusion was arrived at after considerable experimentation with designs starting at 0% and working upwards. When the next penetration level is already known, guesswork is eliminated as to cable sizes and service area segment boundaries.

The Design Process

The first step in powering design is driven by another of the objectives stated earlier, the need to minimize supply locations, The ideal node service area is fed from one location only.

A design at 0% telephony penetration is attempted, using a location central to the power load. The best site is not necessarily co-located with the optical receiver. If the entire node cannot be served from one location with minimal addition of coaxial power feeder cables, the node is then divided in half and the exercise repeated. This was the case for the sample node at 60 Volts, where two locations were needed.

Once the minimum number of supply locations is established, the most efficient layout capable of 100% telephony is determined for each supply location, using conventional design techniques. This design is then saved for future use.

Portions of the 100% telephony penetration design infrastructure are successively removed, and each power supply location service area is tested to determine its new, reduced penetration capacity rating. It becomes quickly evident to the designer which changes are associated with given penetration capabilities.

Each penetration level is saved with a unique name, and used as the basis to produce the next lower level. This process is repeated until all infrastructure other than that required at 0% penetration has been removed.

The 60 Volt Examples

Figures 1.) through 15.) illustrate the progressive penetration design technique applied to an actual HFC node service area design, using a supply voltage of 60 Volts. Multiple output ports are implemented at each power supply location to provide power into each power feeder cable, and to segment the load in order to avoid device current rating violations. In each figure, the thick black lines indicate power feeder cables that were required to attain the particular stated telephony penetration level. Tags attached to these lines indicate the type and length of cable needed. The squares containing a sine wave symbol are ports or modules at a common power supply location. The 60 Volt design, as stated earlier, required two such locations.

In Figure 2.), the replacement of a "weak link" of high resistance .4 12 cable, and the addition of one more output port were all that was needed to achieve 11% penetration capability. In Figure 3.), 15% was achieved by replacement of two other such weak links.

In Figures 4.) through 15.) power feeder cables and ports were added, and power stops moved to attain progressively greater capacities. Note that in Figure 15.), two power feeder cables were required in both the 1337 foot span and the 383 foot span. While this does represent labor cost incurred twice, It is possible that this particular node will never attain the penetration levels necessary to mandate the addition of these second cables.

Also note the long series of power feeder cable sections successively added in the trunk run at the bottom of Figure 15.). These power feeder extensions were required due to a voltage starvation problem in the longest cascade in this node. The underground sections of this run increased the cost substantially.

The 90 Volt Examples

Figures 16.) through 24.) illustrate the progressive penetration design technique applied with a 90 Volt supply. Note that the penetration jumps are larger, and the 100% configuration shown in Figure 24.) is no more complex that the 60 Volt version in Figure 15.), even though only one location was used.

Figure 1.60 Volts, 0% Penetration

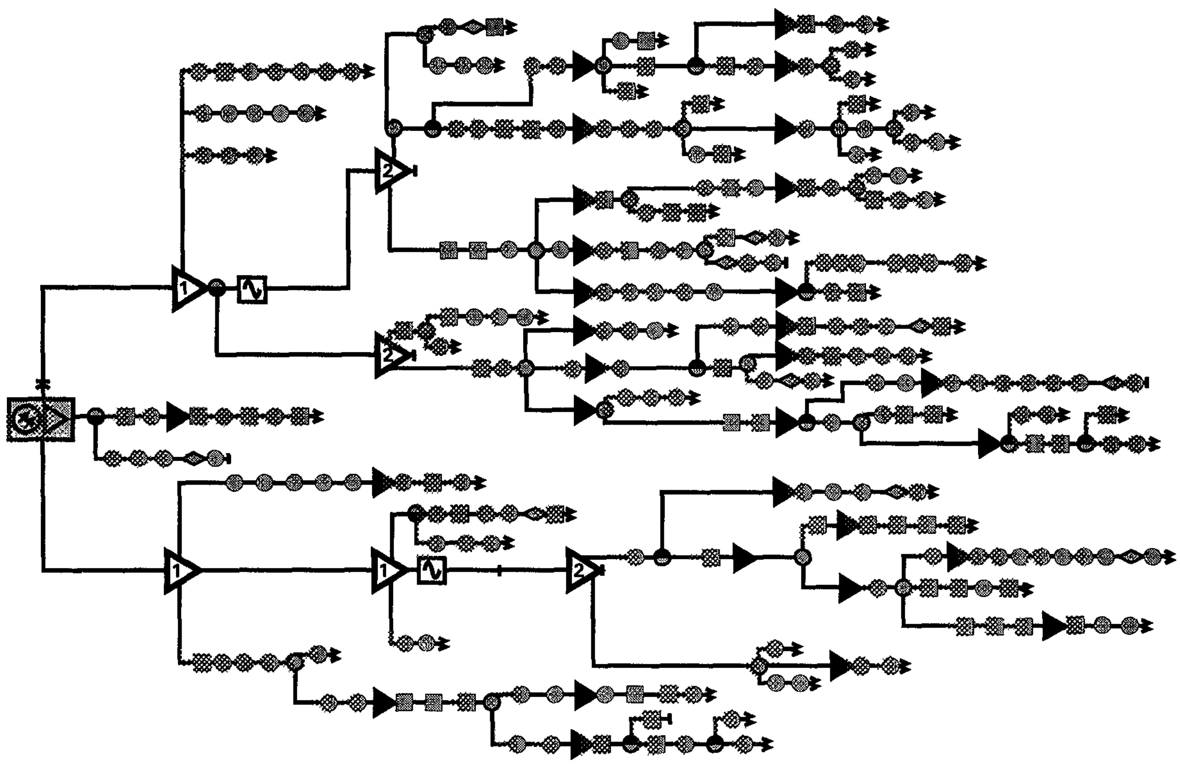


Figure 2.60 Volts, 11% Penetration

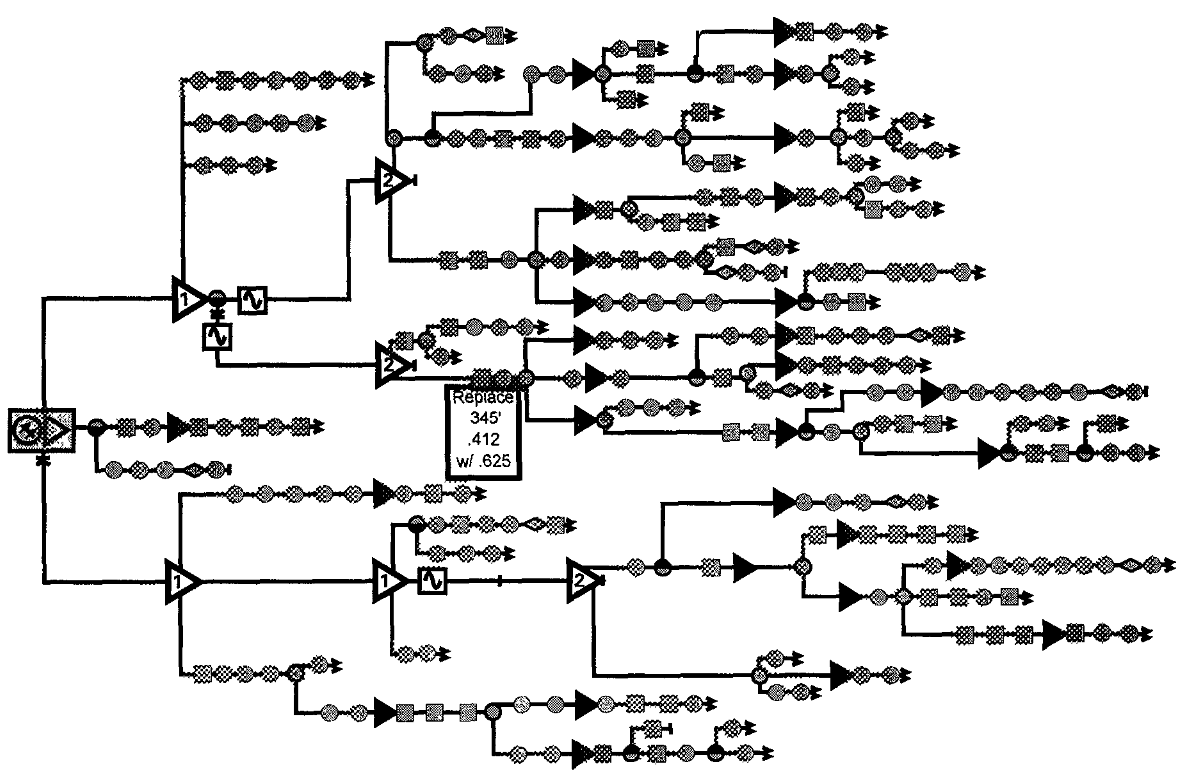


Figure 3.60 Volts, 15% Penetration

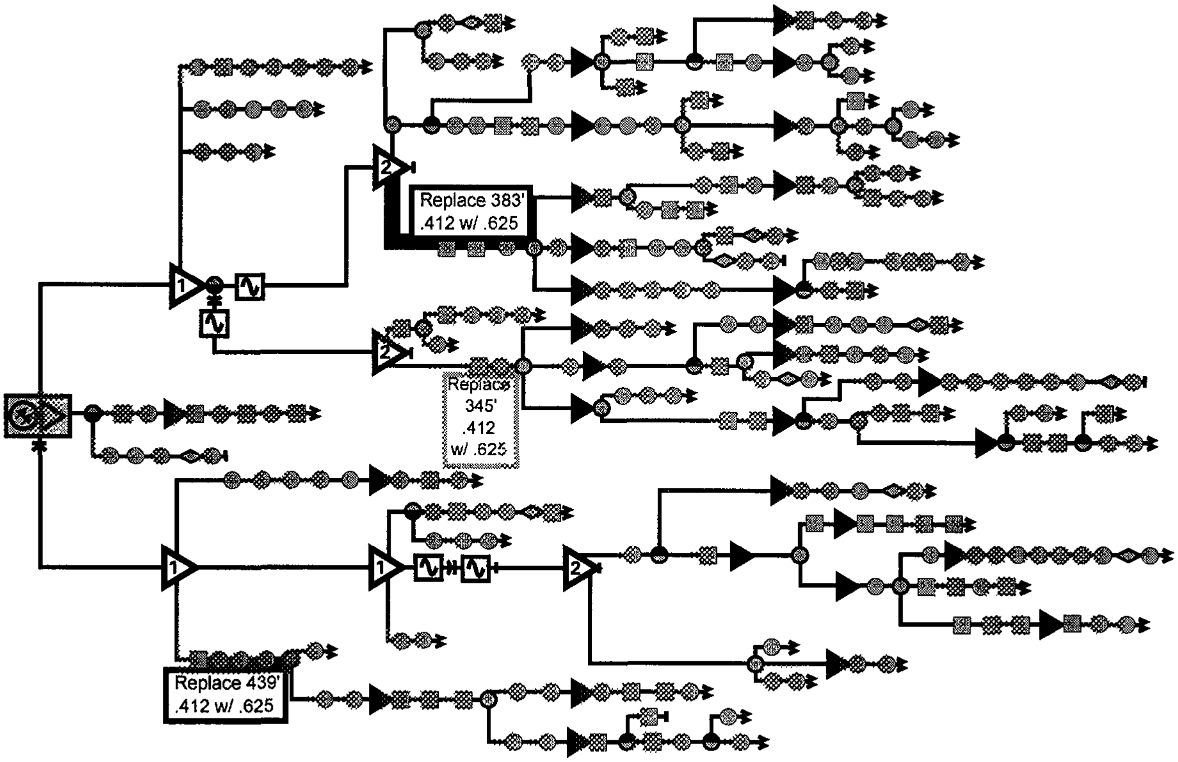


Figure 4.60 Volts, 21% Penetration

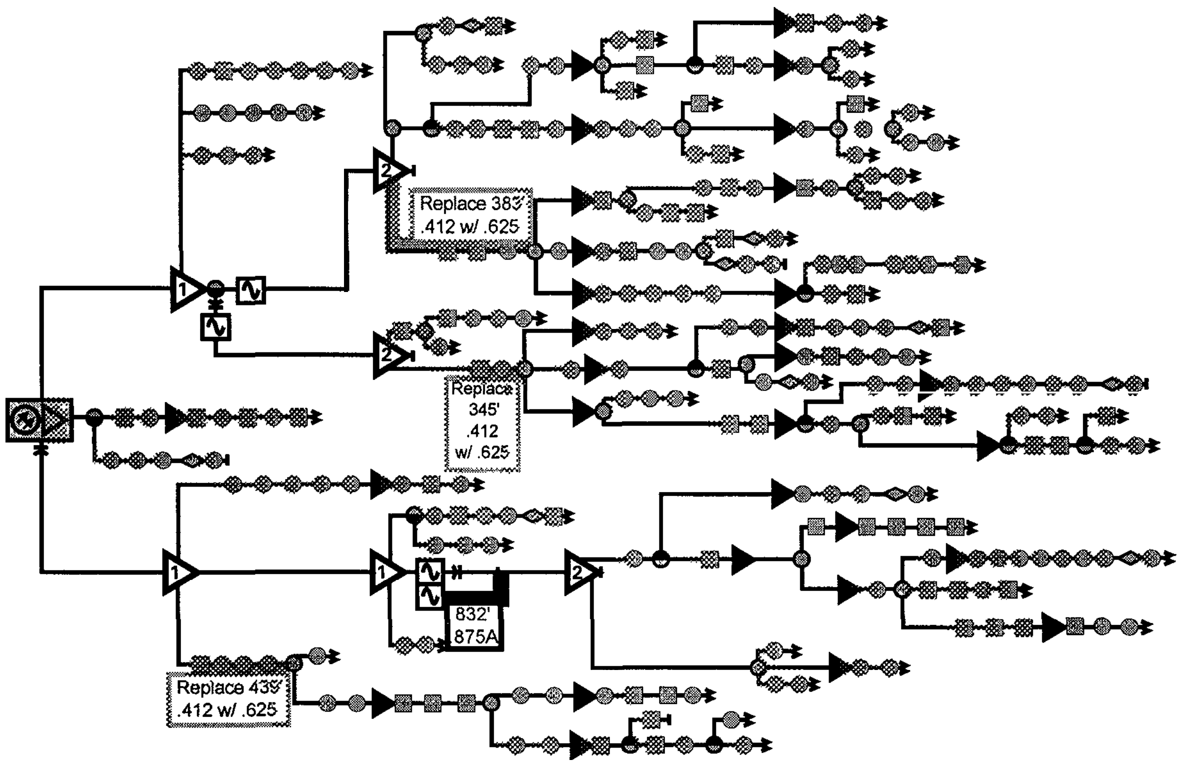


Figure 5.60 Volts, 25% Penetration

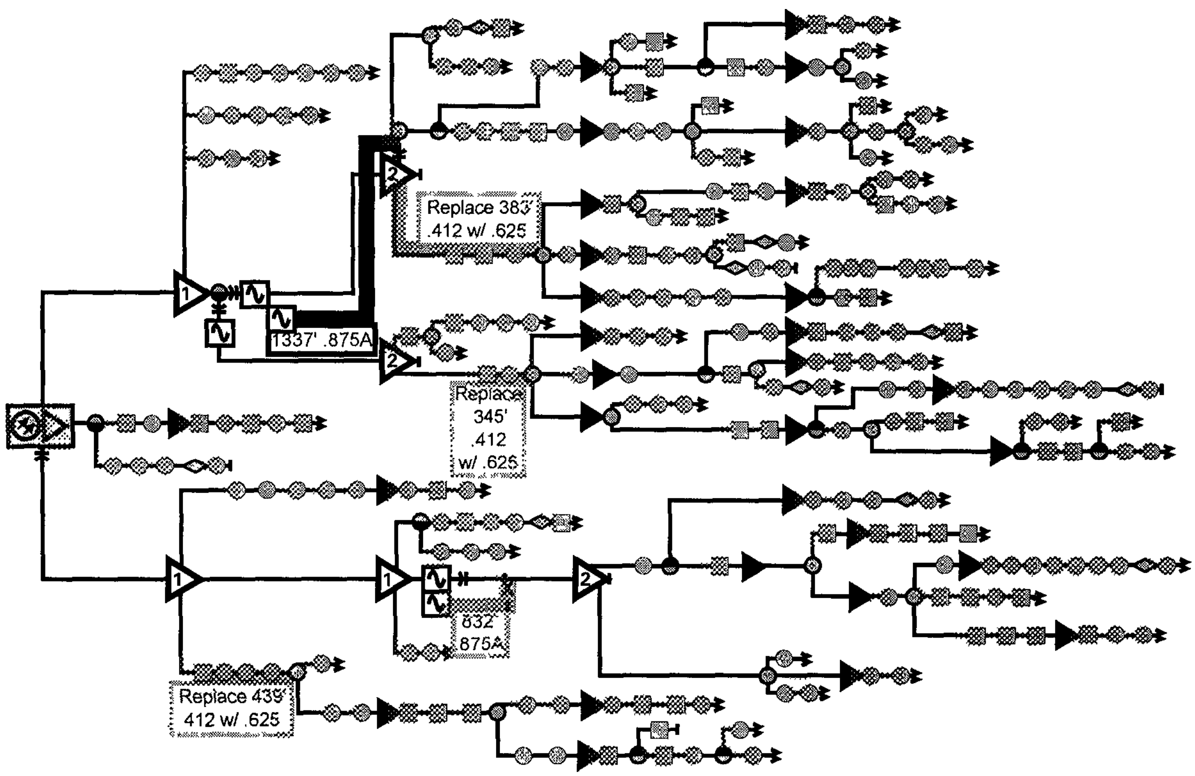


Figure 6. 60 Volts, 35% Penetration

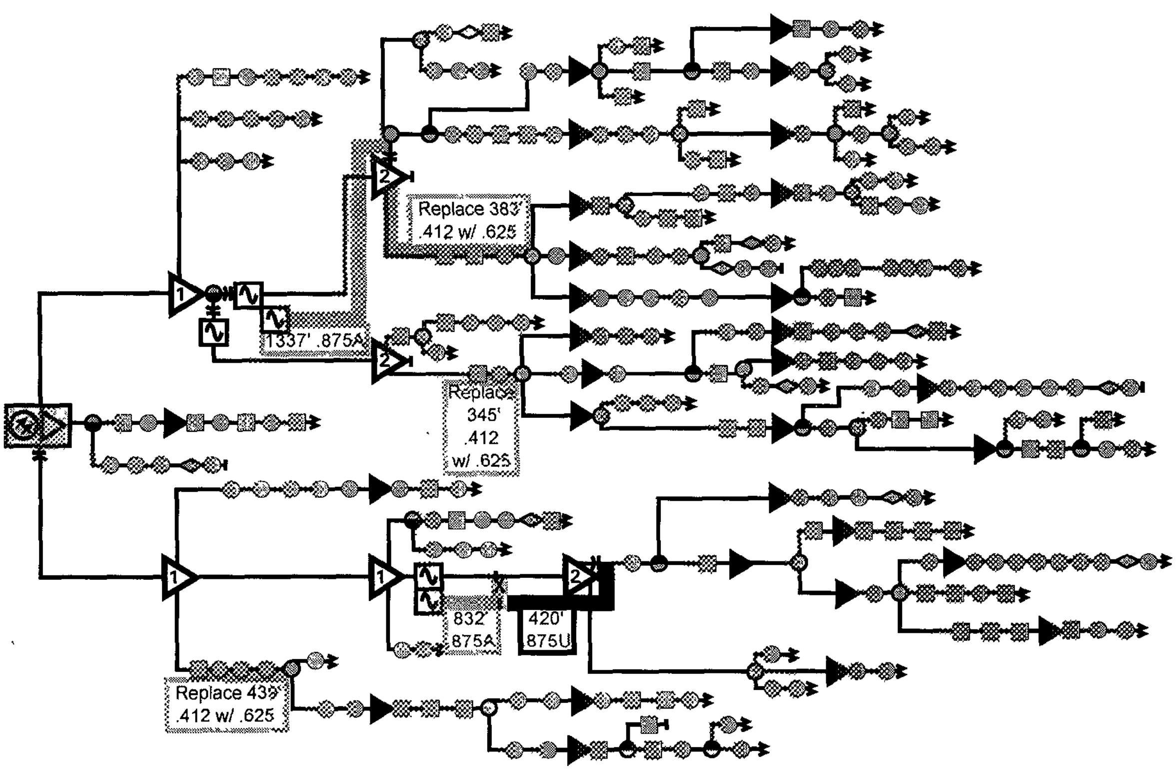


Figure 7.60 Volts, 46% Penetration

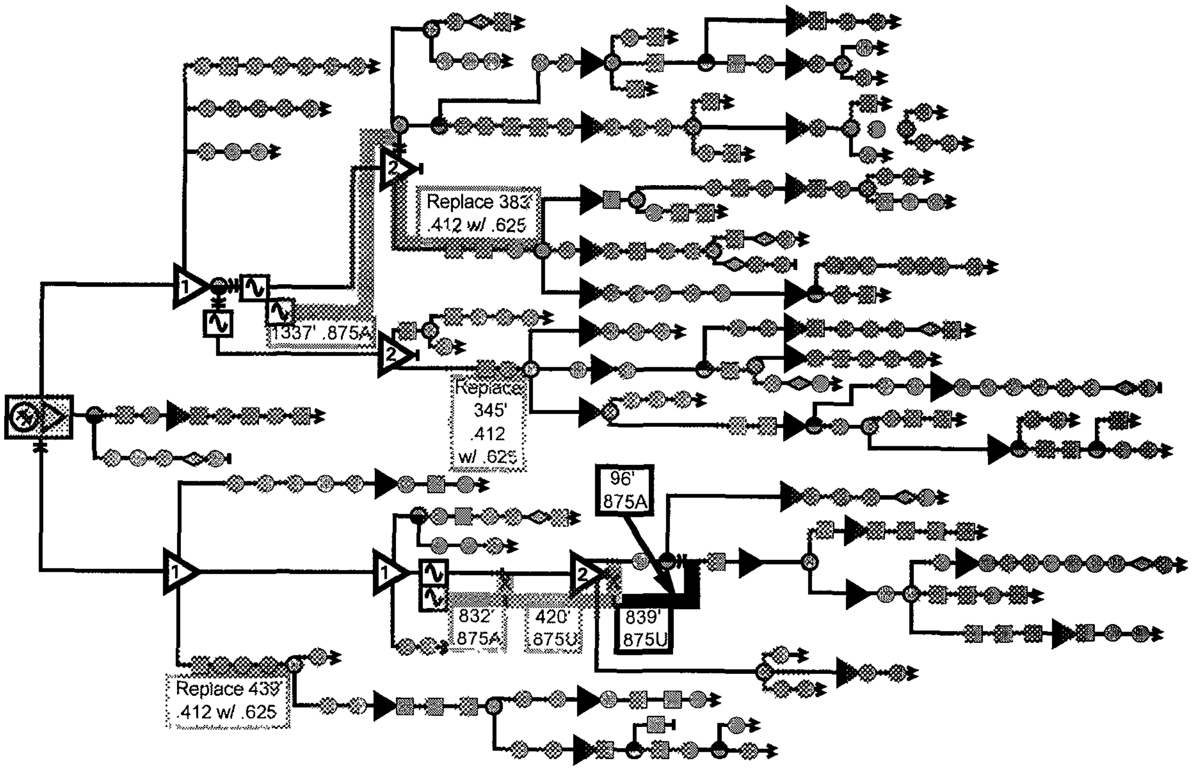


Figure 8.60 Volts, 48% Penetration

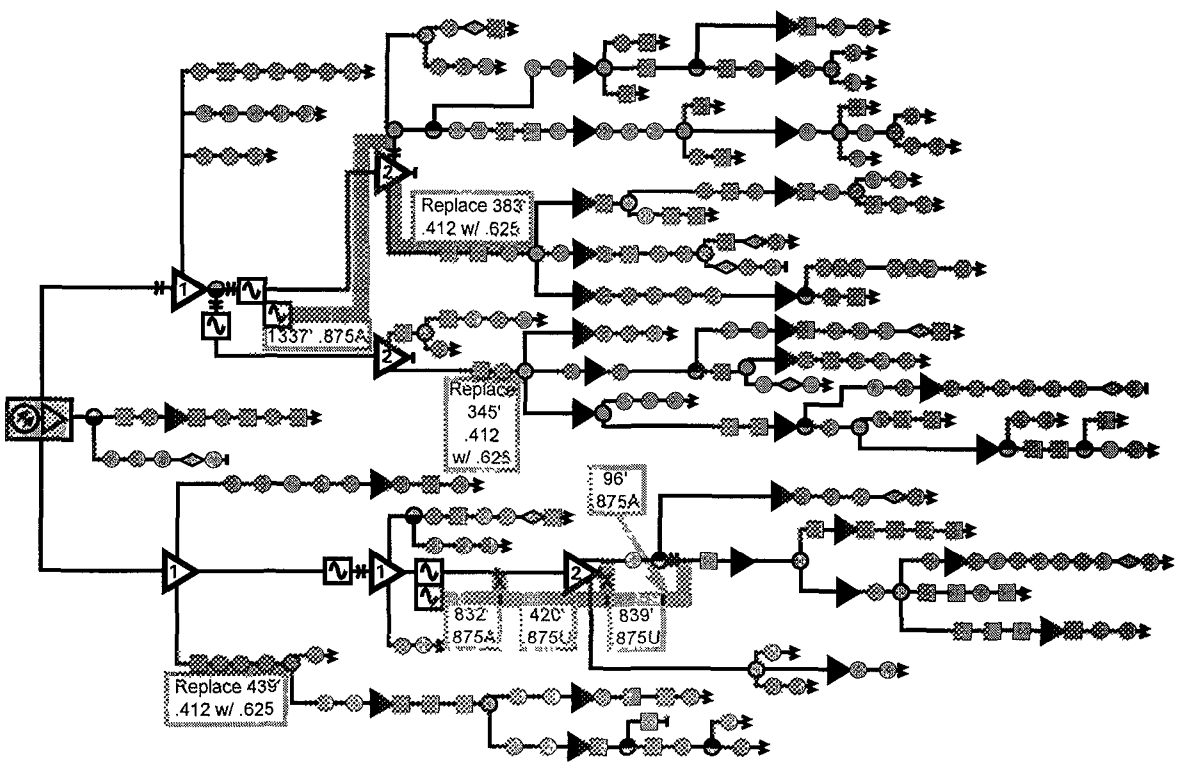


Figure 9.60 Volts, 52% Penetration

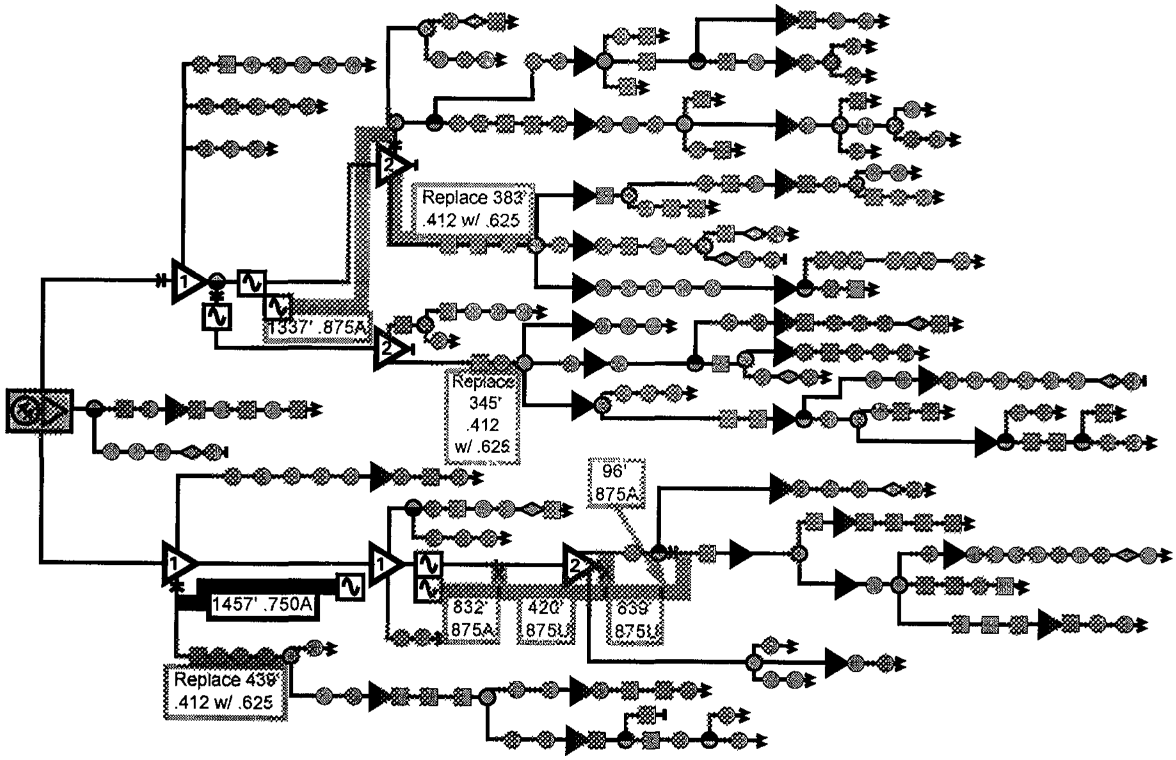


Figure 10.60 Volts, 57% Penetration

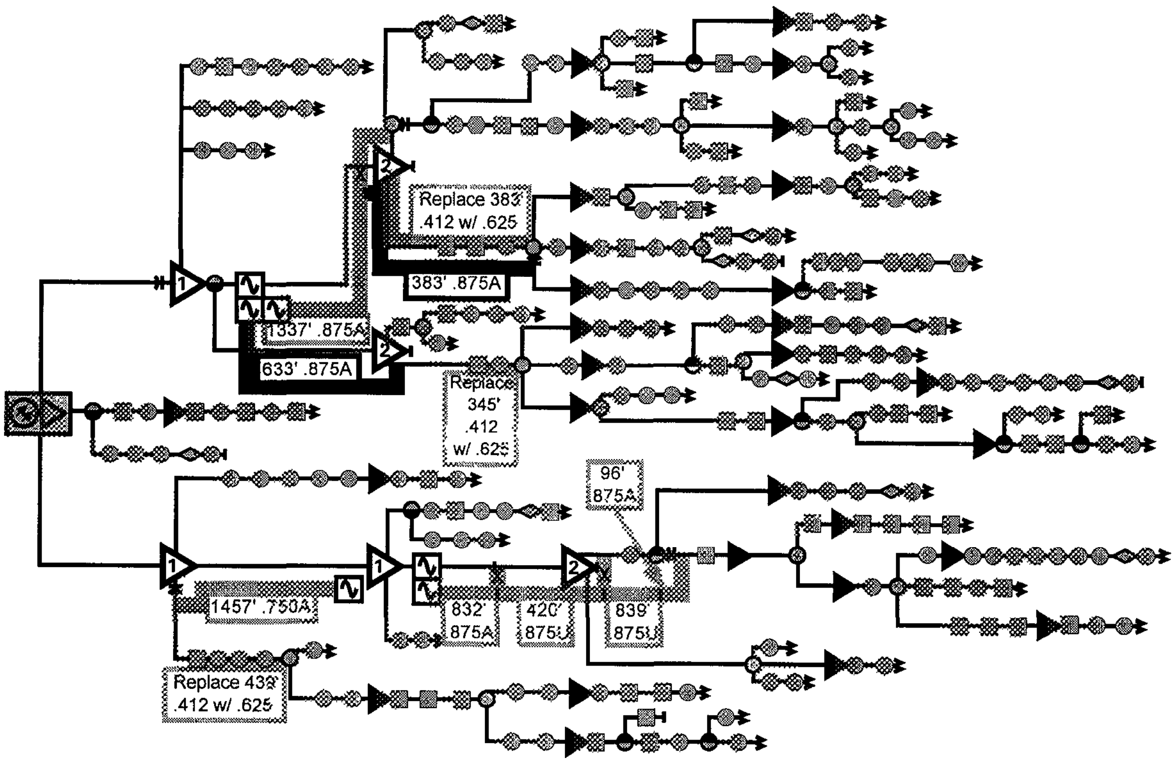


Figure 11. 60 Volts, 69% Penetration

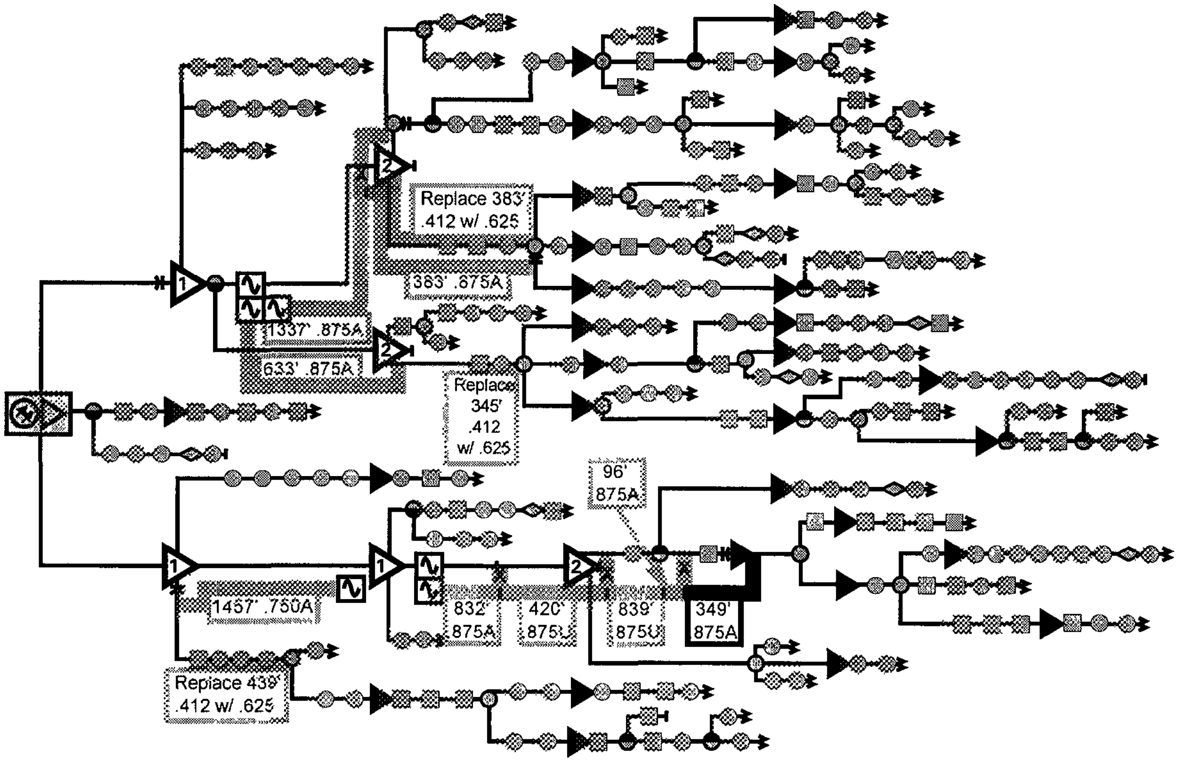


Figure 12.60 Volts, 71% Penetration

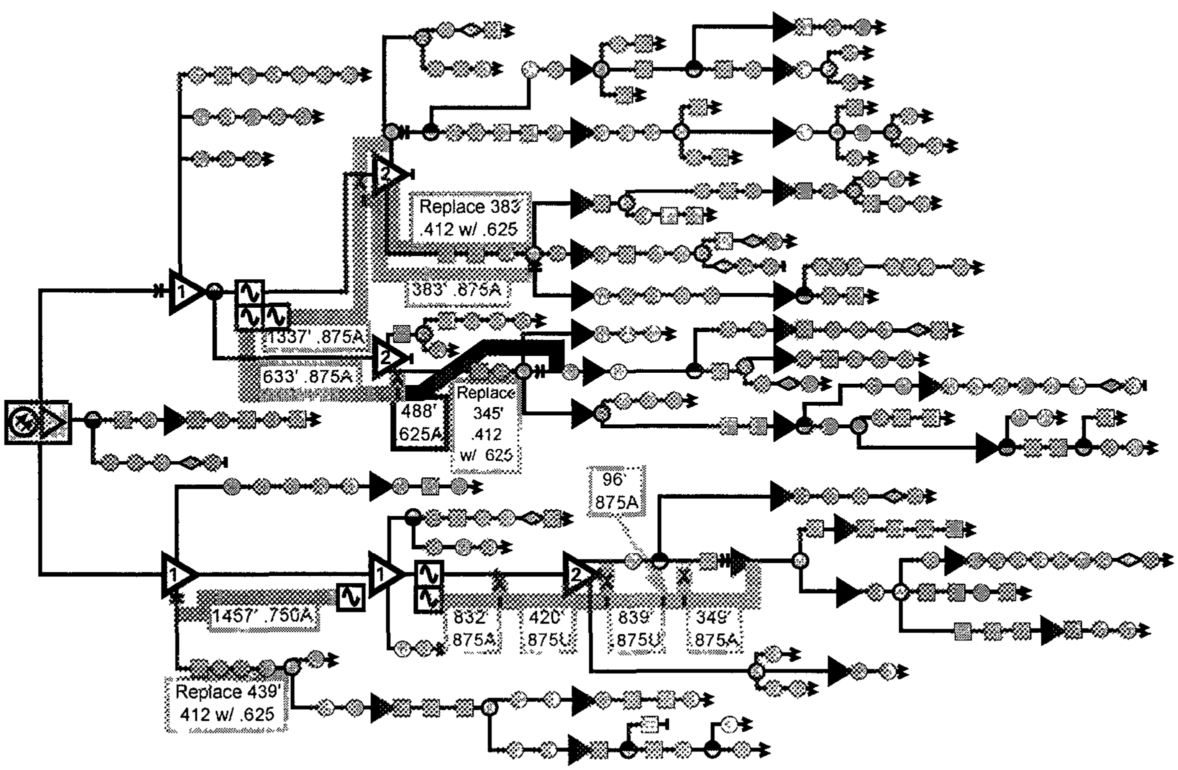


Figure 13. 60 Volts, 76% Penetration

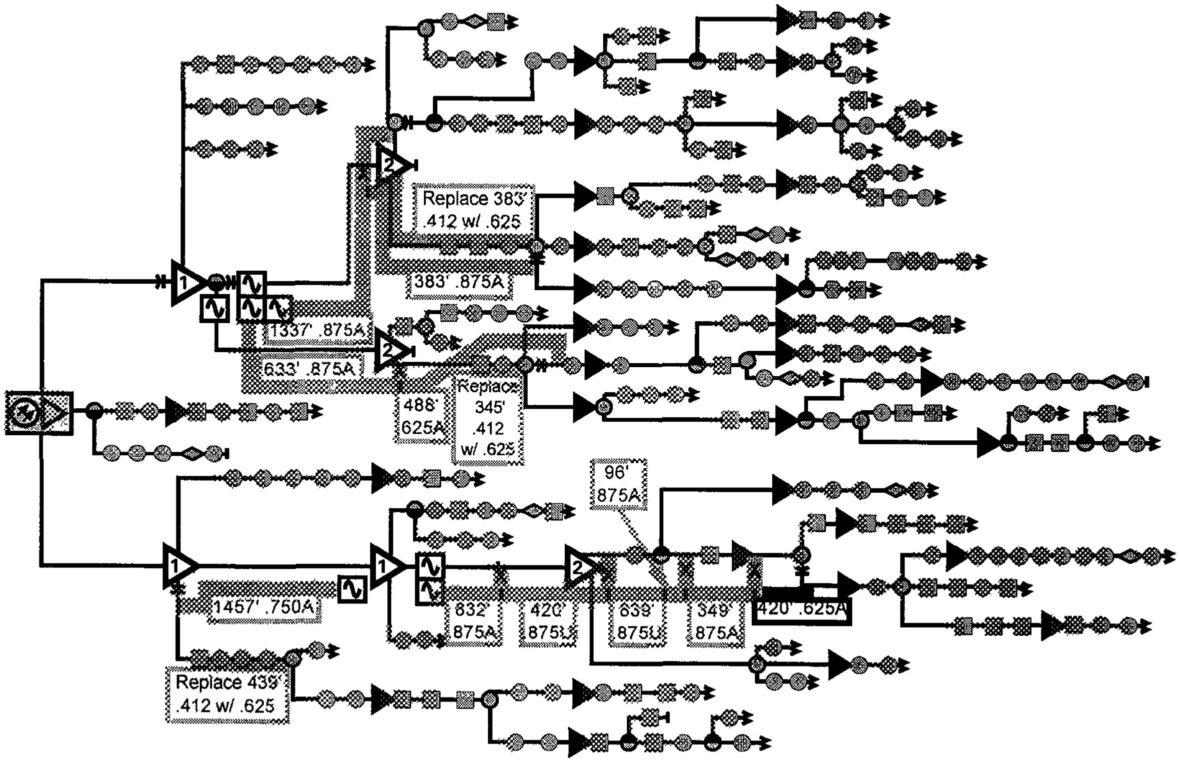


Figure 14. 60 Volts, 84% Penetration

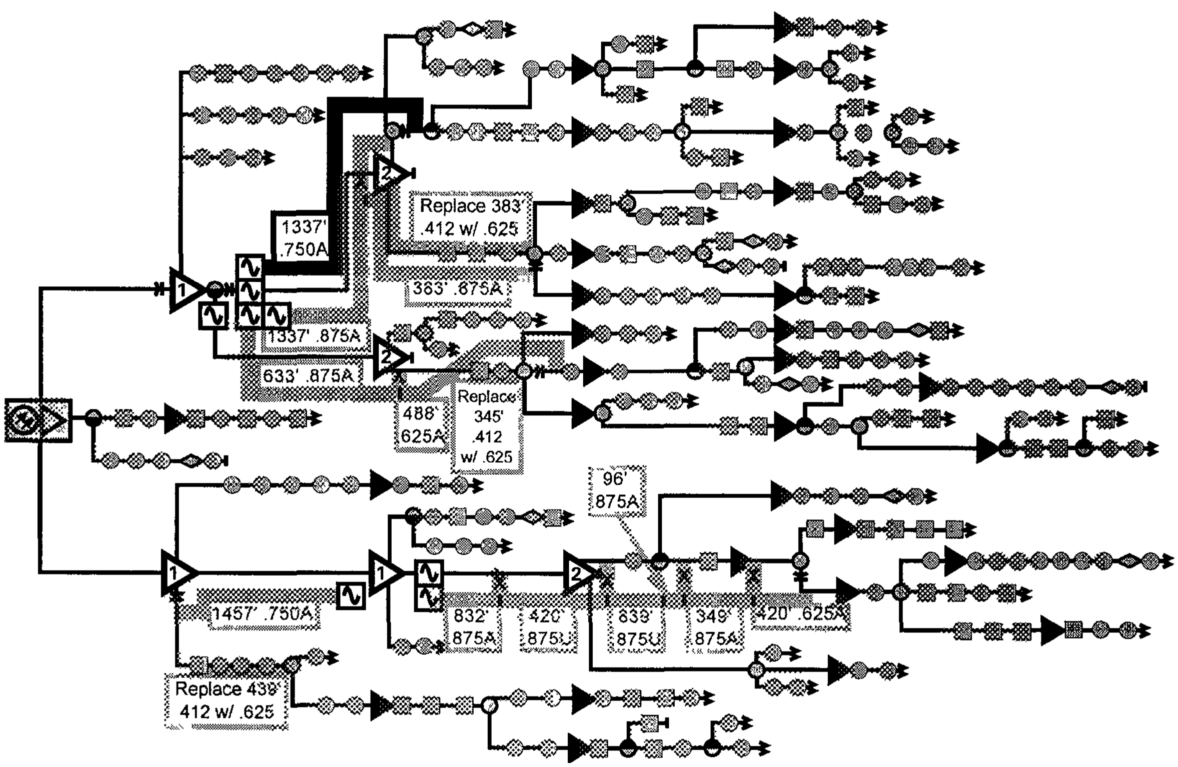


Figure 15. 60 Volts, 100% Penetration

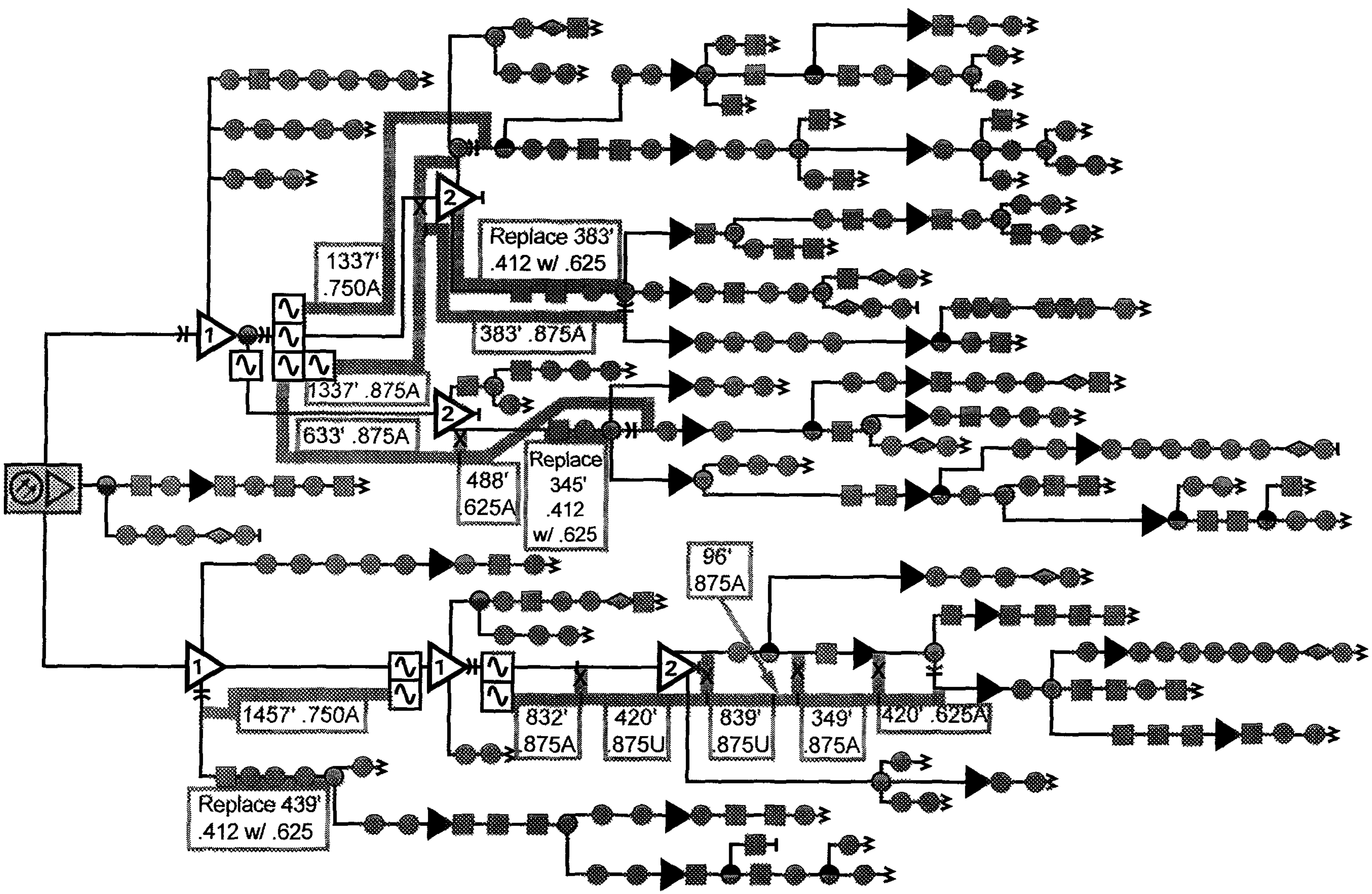


Figure 16. 90 Volts, 0% to 5% Penetration

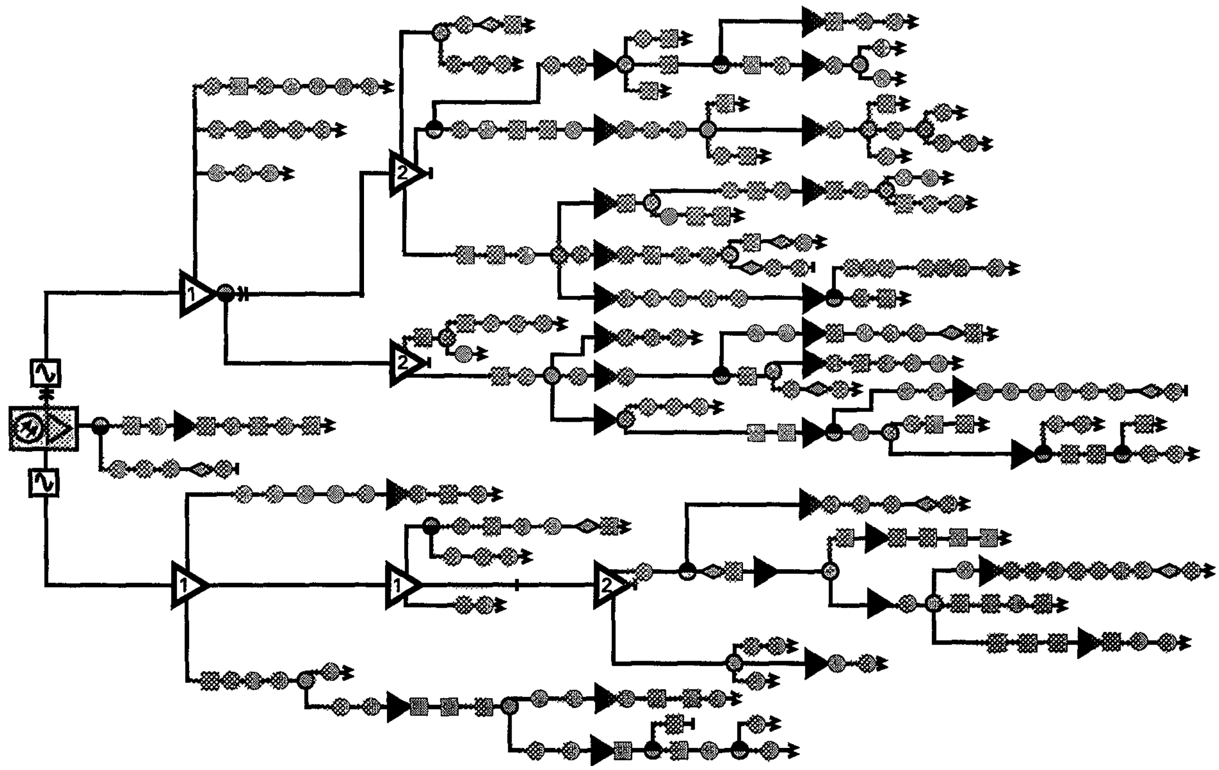


Figure 17. 90 Volts, 6% Penetration

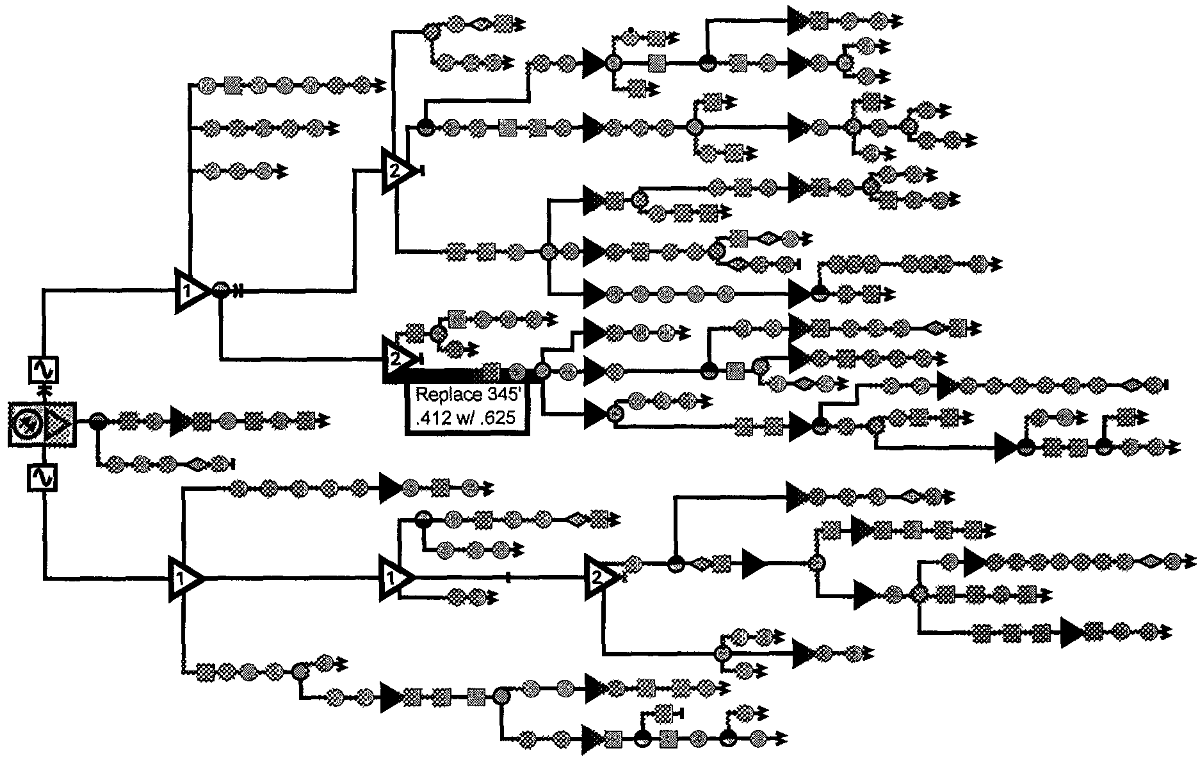


Figure 18. 90 Volts, 22% Penetration

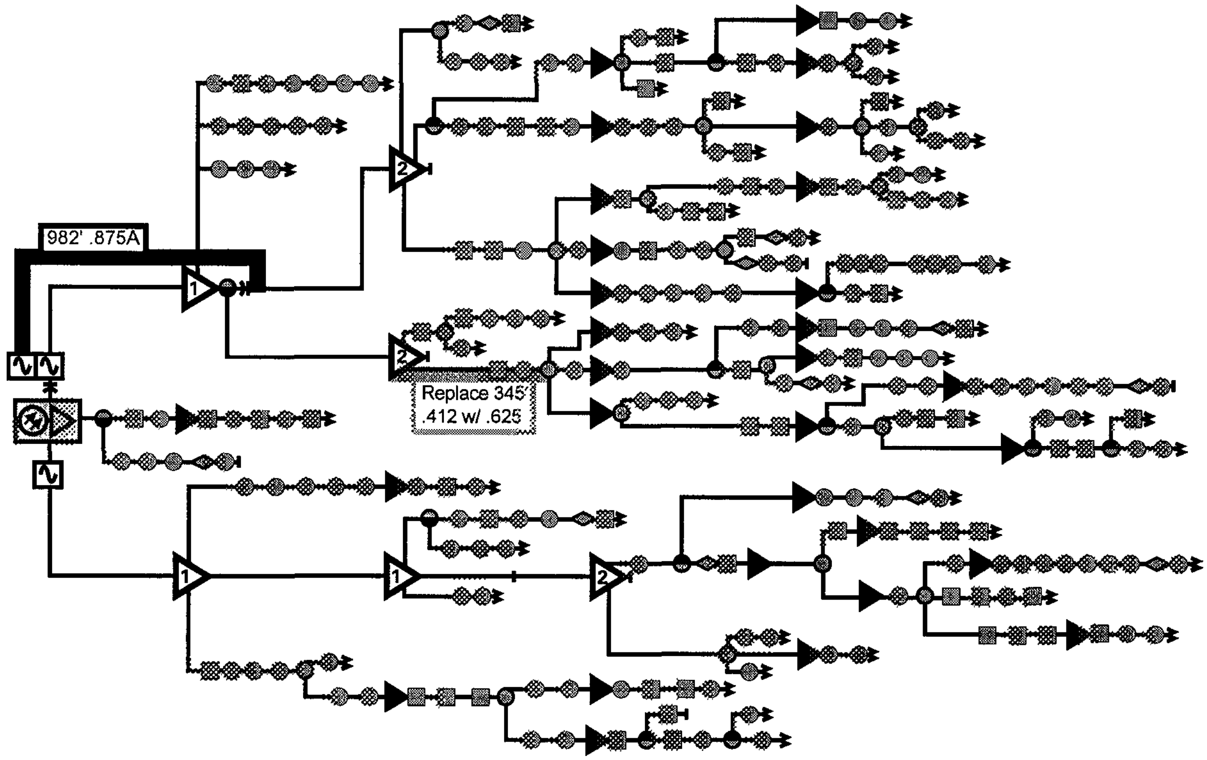


Figure 19. 90 Volts, 46% Penetration

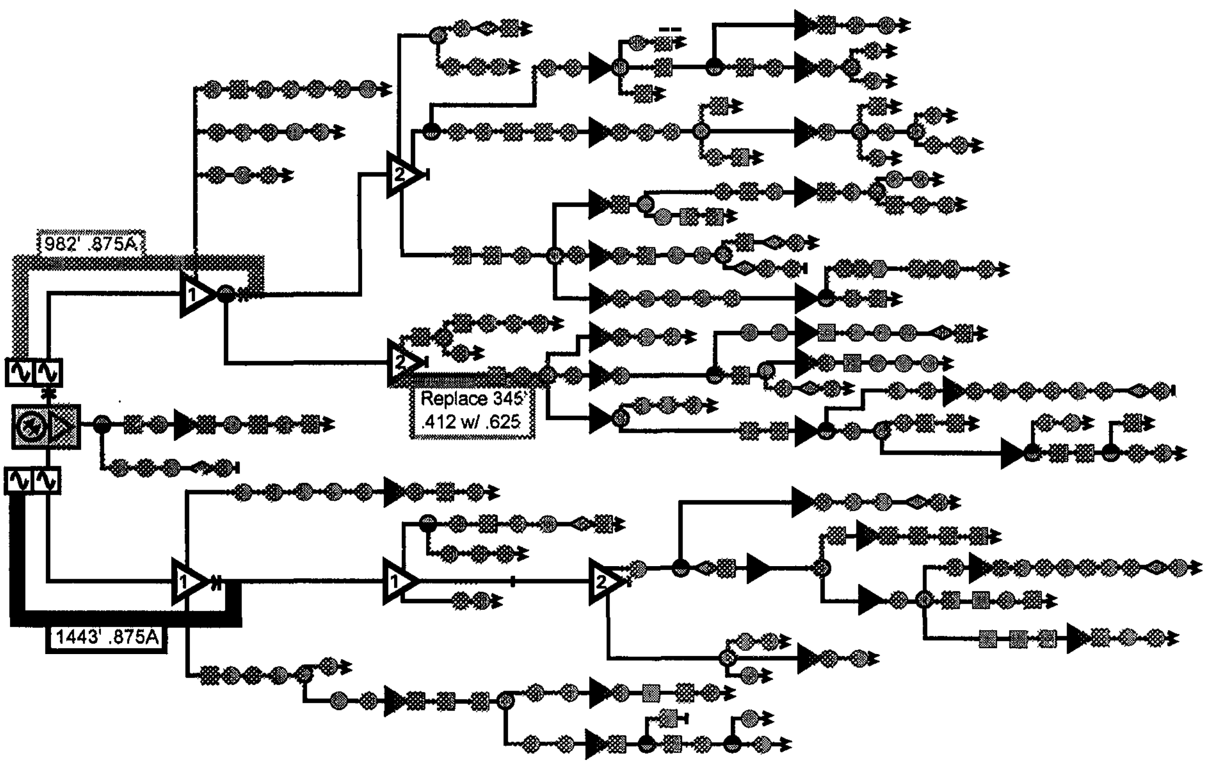


Figure 20. 90 Volts, 53% Penetration

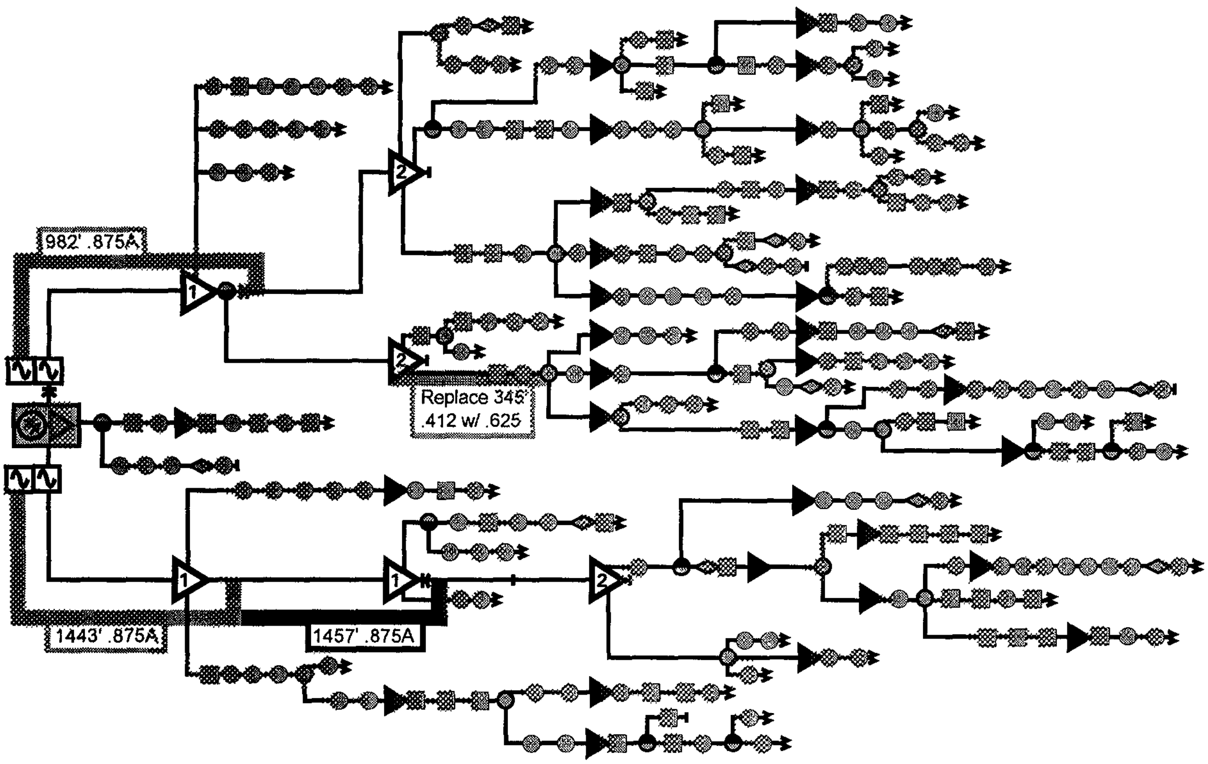


Figure 21. 90 Volts, 69% Penetration

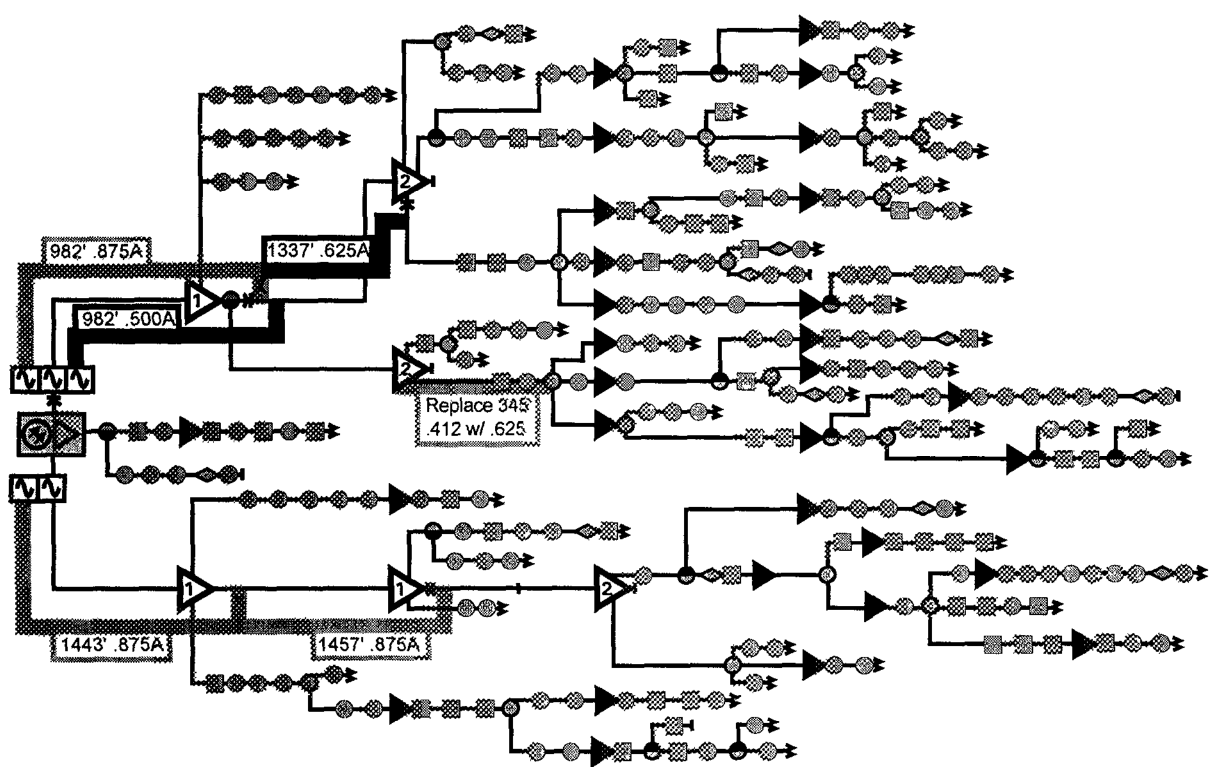


Figure 22. 90 Volts, 78% Penetration

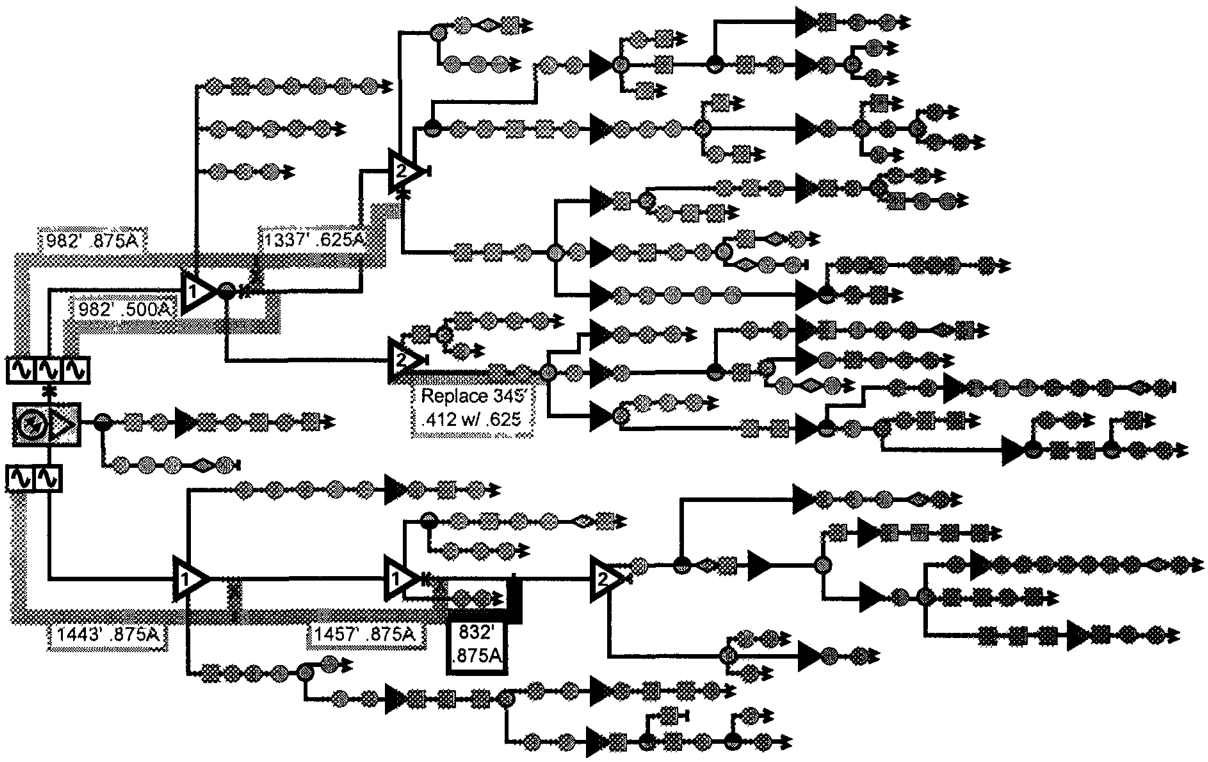


Figure 23. 90 Volts, 91% Penetration

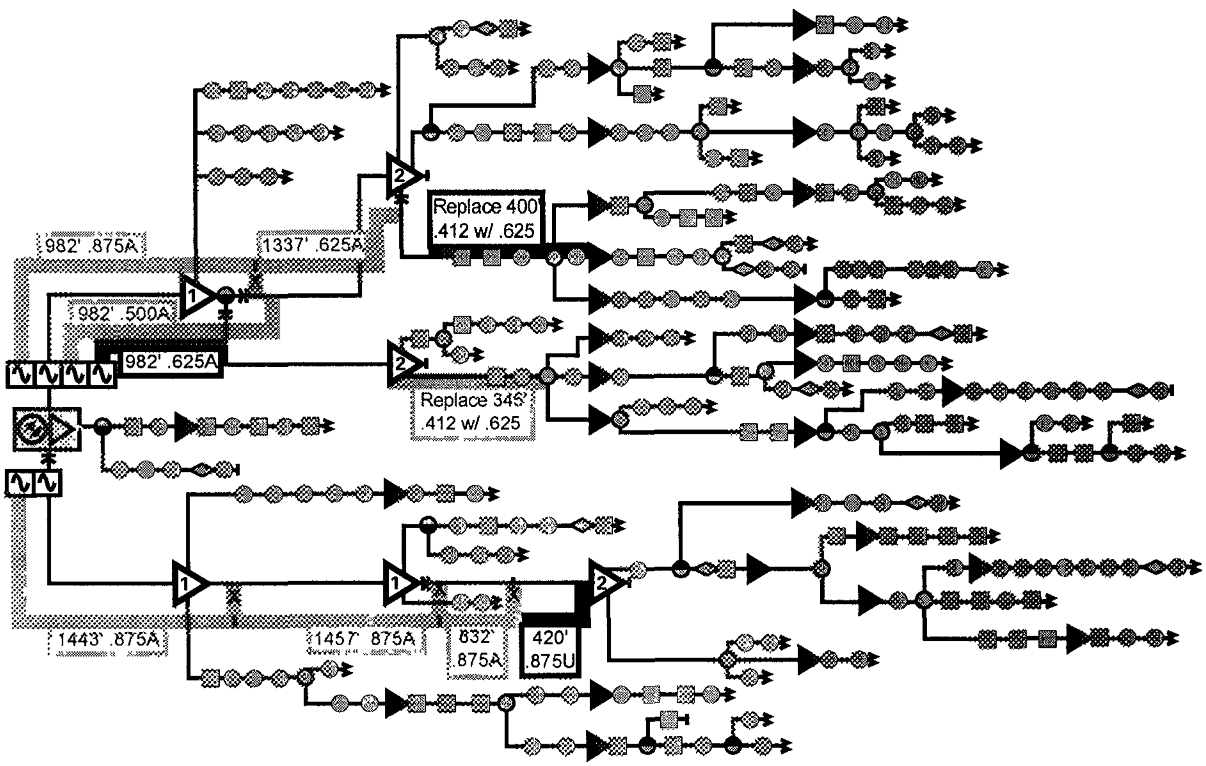


Figure 24. 90 Volts, 100% Penetration

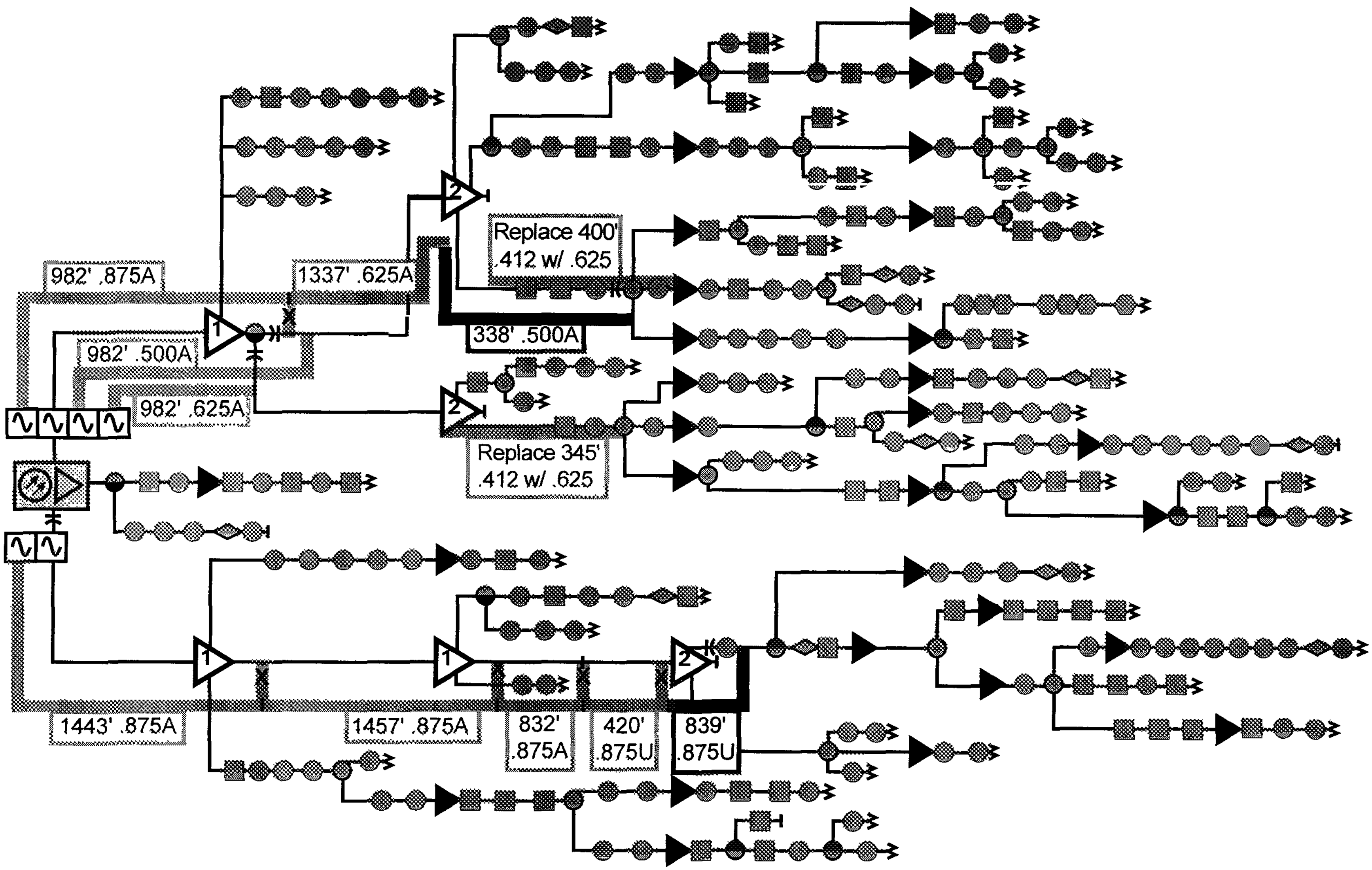


Figure 25. Infrastructure Cost Per Passing

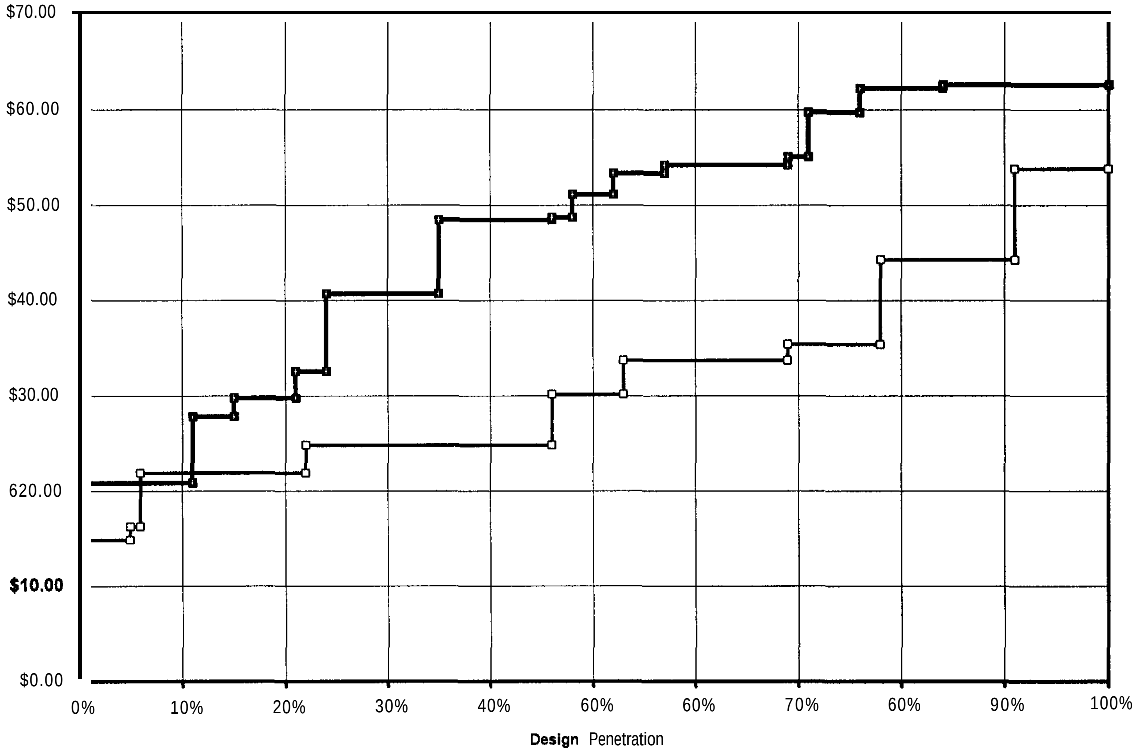


Figure 26. Power Consumption Per Passing

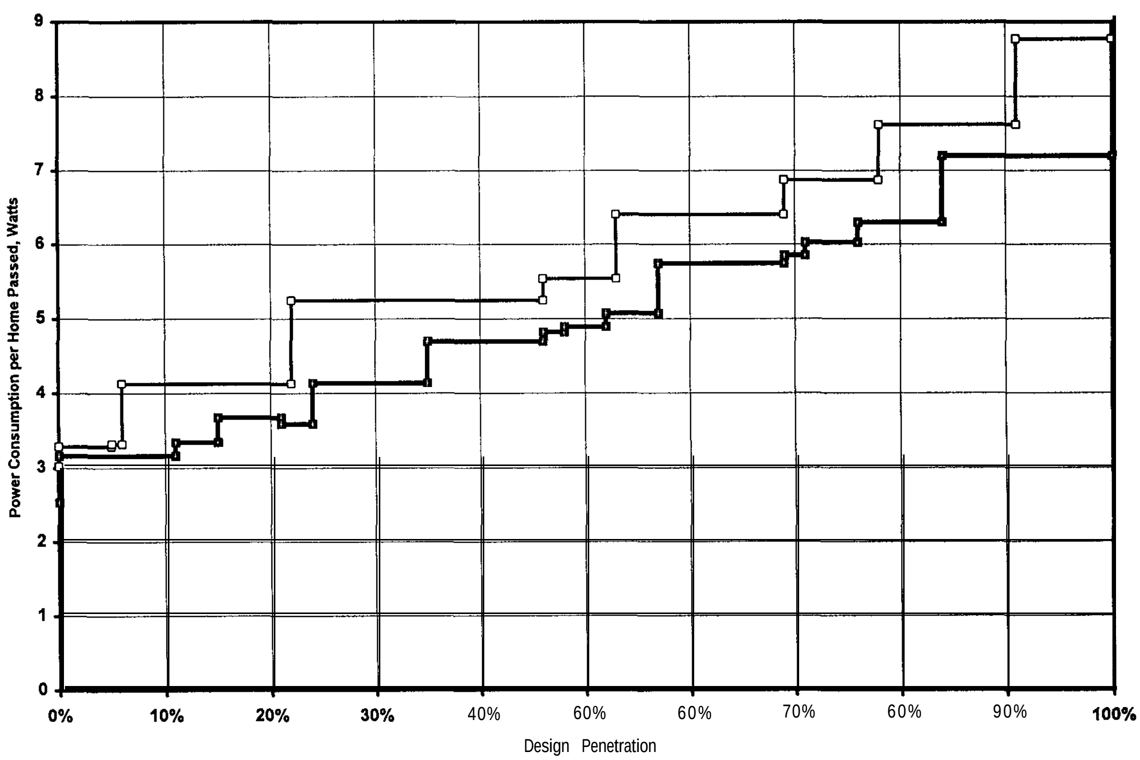


Figure 27. Cost Per Watt of Power Consumed

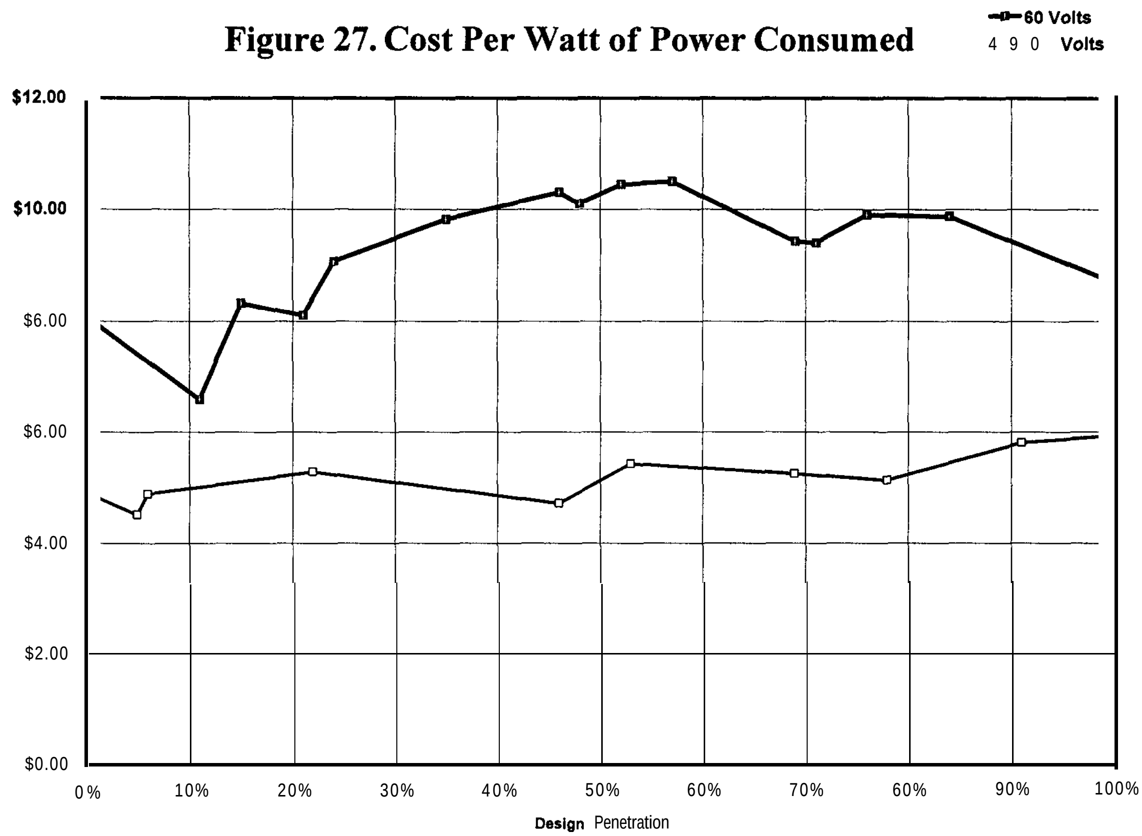
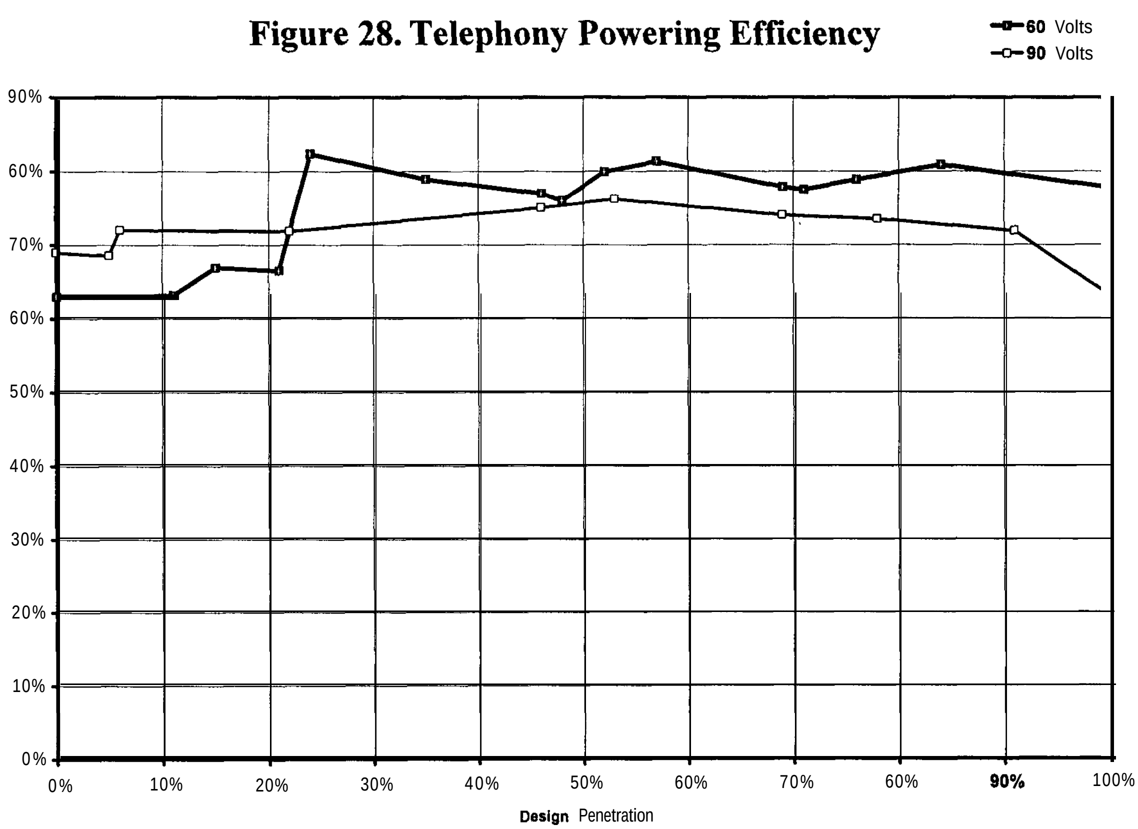


Figure 28. Telephony Powering Efficiency



Cost, Power! and Efficiency

Cost Estimation

Cost estimates were performed for the infrastructure added in Figures 1.) through 24.). These cost estimates were then combined and plotted against the associated penetration levels.

Deployment Cost Graph

Figure 25.) depicts the cost per passing of this incremental deployment. Note the stepwise function. The initially deployed capacity is determined based on the highest penetration number attained on a horizontal line that passes the minimum design requirement. For instance, If 30% penetration was selected as the minimum criteria, at 90 Volts a 30% design would actually operate to **46%.**

The high starting costs represent the initial installation of long duration standby supplies which are needed even at low penetration levels in order to power system actives.

Power Consumption Per Passing

Figure 26.) depicts the wattage consumed per home passed at various penetration levels. Note also the high starting levels due to amplifier powering.

Infrastructure Cost Per Watt

Figure 27.) shows the capital cost of deployed infrastructure needed per watt of installed design capacity. Note the cost advantage afforded by use of 90 Volt powering.

Network Power Losses

Figure 28.) displays network powering efficiency curves. Efficiency is calculated as follows:

1. The design power allocated to an NIU (3.63 Watts) is multiplied by the number of deployed NIUs at each penetration level.
2. The network power consumed by actives only (0% telephony) is subtracted from the total network power consumed at each penetration level.
3. Item 1. is divided by item 2., converted to a percentage, and plotted against penetration.

Note that use of 90 Volts does not offer a significant efficiency improvement over 60 Volt powering. This is due to the wider coverage area, and therefore greater resistive cable losses incurred as a result of selection of a single powering location.

CONCLUSION

Network powering design techniques are available which provide for incremental deployment of network powering infrastructure. Proper application of these techniques can result in substantial reduction in the investment needed to deploy network powered lifeline telephony services.

Use of these techniques requires the discipline to monitor service area penetrations and expand network powering infrastructure as needed.

Increased emphasis must be placed on the production of quality powering design. This emphasis will require a commitment to appropriate design staffing levels in order to benefit from the techniques described here.

ACKNOWLEDGMENT

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