POWER LINE CARRIER SIGNAL ATTENUATION

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Power line carrier (PLC) has been applied to utility transmission systems for many years and has historically provided a reliable means of communications over long distances. However, power line carrier is susceptible to line noise and its application requires careful signal-to-noise ratio analysis to ensure good performance.

Utility engineers designing power line carrier systems need to know the base frequency, power rating and coupling method for their transmitters/receivers. A critical input to this decision is loss attenuation of the carrier signal on the transmission system. This attenuation, in dB, can be adequately estimated via handbook methods for relatively short, untransposed, single circuit overhead lines with no intermediate connections. Handbook methods become unreliable for more complicated transmission systems. Without proper study, the designer could select equipment which will not work properly, if at all.

The transmission system diagram from a recent study is shown in Figure 1 where the PLC application is more complicated than normal. PLC is applied to a three terminal line where system requirements are such that the signal transmitted from each station must be heard with an adequate signal-to-noise ratio (SNR) at each of the other two stations. Most of this three terminal line is double circuit overhead construction. The tap to the third terminal is part overhead and part three phase pipe type cable. The line sections are of such a length that all reflections, refractions, resonances and quarter wavelength effects must be represented. Resonance effects can cause abnormally high attenuation of specific frequencies. Figure 2 shows one of the resulting scans depicting transmission loss as a function of frequency. Significant changes in attenuation can be seen to occur near three specific frequencies.

Figure 1. Transmission System (Continued on Page 2)

TRANSMISSION LINE UPRATING—A SYSTEMATIC APPROACH

R.E. Clayton, Manager Power Delivery

In today's monetary and regulatory environment, the uprating of transmission lines is becoming an increasingly attractive alternative for utilities. PTI and GA Consultants, Inc., are cooperating to offer engineering services in this area. GA's reliability based structural and foundation engineering capability complements PTI's electric power engineering expertise and, together, these two companies provide the utility industry with the most complete uprating services available.

Transmission line uprating ranges anywhere from simple reconductoring to a complete upgrading of the conductor, insulation, tower and foundation components. It can apply to a single line or to an entire class of construction. Studies on uprating have been reported with design options including:

- Current uprating
- reconductoring
- bundling
- additional circuits
- rerating
- Voltage uprating (AC and HVDC)
- voltage level increase
- High phase order uprating
- double three phase circuit to single six phase circuit
- HVDC conversion
- ac double circuit to hybrid ac/dc

These options, together with new conductor/hardware applications and design methodologies, make uprating a powerful alternative for system planners. A methodology for the development of uprating options is shown in Figure 1.

Key elements in this approach are:

- recognition of the interdependent nature of line design enhancements
- recognition of possible conservatism in the design criteria and methodology used during the construction of existing lines
- use of new design tools to evaluate the available options and provide the optimal solution.

An example of the interdependent nature of design enhancements is demonstrated by looking at reconductoring. An increase in conductor diameter increases thermal rating, reduces RI, AN, and line losses but increases material cost, ground level E-field, and could require strengthening of the tower/foundation system. All this must take place within the constraints imposed by the actual condition of the existing line which, unlike a new line, may be unknown and is physically more restrictive.

In the design of both the electrical and structural components, it is quite possible that the existing line design used criteria that would nowadays be considered unduly conservative. Electrical design considerations include:

- Ground/structure/phase clearances
- Ampacity
- Contamination
- 60 Hz, switching surge and lightning stresses
- RI/AN/E levels
- Visual corona

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TRANSMISSION ACCESS — NEW ARGUMENT, NEW MARKET

H.M. Merrill, Manager Planning

Transmission capacity is not usually thought of as a salable commodity, but nowadays economically motivated trans­fers are straining transmission capabilities to the point where loop flows through third parties' systems clearly affect their operations. Furthermore, federal and state rules, beginning with PURPA, now force utilities to provide transmission and distribution services to independent qualifying facilities. In fact, inter-utility wheeling arrangements increasingly involve use of others' facilities.

These factors suggest that transmission capacity be looked on as a commodity, and attach new importance to some old questions. How is use of transmission capacity to be priced? What if the utility owning the transmission has to change its operations to allow its use by others? In the extreme, how should a limited transmission resource be shared or allocated among competing users when they cannot all be satisfied?

Present methods of addressing these questions have major shortcomings. Postage stamp rates typically charge for trans­mission use on a MW basis, regardless of which way the power flows or how far. Such rates fail to recognize the wide variation in cost and impact of each transaction. A different approach was followed recently in California. The utility agreed to provide 1000 MW of transmission to qualifying facilities on a first come, first served, basis — but this may inadvertently allow one set of network users to tie up the network and freeze out later, more desirable, ones. Fully-allocated methods, where transmission charges are based on recovering the cost of an existing line, may unduly discourage use of the network by putting too high a price on it. Finally, ignoring the problem altogether, as is often done with loop flows, leads to continuing disagreements and inequities.

Economic theory says that, under well-defined conditions, the economically efficient and socially optimal price of a good is the incremental cost of providing it. For example, economic dispatch algorithms in utility control centers apply this theory. If output from a generating unit is priced above its incremental cost, it will tend to be under-utilized and replaced by more costly generation elsewhere. Similarly, if output is priced below its incremental cost, the unit will tend to be over-utilized, displacing less costly generation.

But the incremental cost of output from a generating unit is far easier to assess than the incremental cost of providing transmission service. However, there is a simple, economically efficient, method for allocating and pricing transmission capacity.

It recognizes four distinct situations:

Case 1 — no transmission constraints: with ample transmission capacity, there is no allocation problem. The optimal (economic­ally efficient) price for use of the network is the cost of the incremental losses due to a transaction. The cost of losses is reflected in the local incremental costs at the boundary buses between the systems involved.

Case 2 — transmission constraints are relievle by operating changes: for example, suppose that under certain conditions a wheeling transaction or a purchase from a cogenerator compete for a transmission line that a utility-owned coal-fired plant also needs. Every MW of power wheeled or purchased reduces the transmission capacity available for the coal plant by one MW and requires an operating change: the coal plant has to be backed down. The incremental cost of wheeling, or the price paid the cogenerator, should recognize that coal-fired power is being displaced (even if the system's incremental or swing fuel is oil). This can be done by basing the transmission use charge on a constrained local incremental cost. Note that this charge might fluctuate with system conditions: in some conditions operating changes might not be necessary, and the price should be computed as in case 1.

Case 3 — transmission constraints are relievle by network capacity additions: if a pattern of transactions requires that new facilities be built, it is appropriate for that pattern to be charged with the cost of the facilities. Even PURPA recognizes this, and FERC has stated that the facilities in question may be geograph­ically remote from the qualifying facility which caused the strain. Case 3 and case 2 are similar, and the choice of making operating changes versus upgrading the network must be based on a careful economic analysis from the viewpoint of those who will ultimately pay the bills.

Case 4 — unreleivable constraints: if a bottleneck cannot be removed with operating changes or reinforcements, then the transmission capacity available must be allocated among compet­ing users. But the incremental cost argument posed earlier in this article applies equally well to the buyer's side of the equation. Where there's not enough of a commodity to go around, its optimum allocation is to the users who can place the highest value on it. Thus, the suggested approach is to auction network access to the highest bidder. The parties for whom the network represents the greatest value will succeed in purchasing access. Once purchased, access rights may be sold or traded. They may also expire, as rights are likely to be auctioned for limited times only. The auction could even take place in real time, with access sold for, perhaps, a period of only an hour at a time.

This marginal cost pricing approach helps ensure that overall electrical energy needs are met at the lowest practical cost. It protects access to the transmission network so that the most attractive sources of power can be accommodated. It provides a framework for developing rational charges for use of a network to serve a utility's customers, to wheel for other utilities, or to accommodate qualifying facilities.


POWER LINE CARRIER SIGNAL ATTENUATION

(Continued from Page 1)

A new program developed by PTI, Carrier Signal Attenuation Routine, or CSAR, can make a PLC loss calculation for simple or complex transmission circuits. Single and multiple circuit trans­mission line sections are represented by full phase impedance matrices at the carrier frequency taking into account line and frequency dependent earth conductivity parameters. A signal injected on one or more phases (or shield wires) at a transmitter location can be detected at one or more remote receivers. Transmitter and receiver powers are calculated and the dB difference is the attenuation due to the transmission system.

![Figure 2. Attenuation with Transmitter at A1](Continued on Page 3)
CSAR calculates PLC transmitter/receiver voltages, currents and power from an impedance matrix comprised of transmission system elements which can include single phase lines and cables, three phase single, double or multiple circuit lines, transpositions, high phase order lines, HVDC lines, wave traps, substation stray capacitances, faults and open circuits. The impedance matrix approach can properly represent any complexity of transmission systems including radial lines, tapped lines and loop circuits. All reflections, refractions, resonances and quarter wavelength behavior shown in Figure 2 can be predicated and proper frequency, power level and coupling method chosen to ensure proper carrier system operation.

TRANSMISSION LINE UPRATING—A SYSTEMATIC APPROACH
(Continued from Page 1)

The possible options are often limited by the availability of design programs since a good deal of work and data is required to make a complete and systematic analysis. Often, only one option will be considered because of time constraints, etc. However, the use of the methodology described in Figure 1 and new design tools now available allow the designer to use experience in comparing different options and thereby achieve a true optimization.

The actual optimization of an alternative is achieved by equating costs vs. benefits as shown in Figure 2. This case is for conductor optimization.

In this example, conductor size was chosen as the independent variable since it is typically a major element in uprating. However, the independent variable could just as easily have been voltage level, number of conductors/bundle, etc. Figure 2 shows the means of choosing the optimum conductor size on an economic basis, within the framework of the constraints and trade-offs in the individual performance areas. The optimum will occur at the point where the slopes of the direct cost curve and the loss and maintenance cost curve are equal and opposite. The calculation of these curves is the key to a systematic uprating design. Recently developed programs permit this type of analysis. The loss curve is a function of the line electrical loading, demand and energy charges, etc., and decreases as conductor size increases. The direct cost curve is more difficult to define since it is a function of:
- structural modifications required to support the conductor
- structural reliability criteria
- tower "use factor"

The tower "use factor" is dependent on terrain and tower location. For example, it could be that an existing tower is located in such a position that it has a low "use factor" by virtue of short adjoining spans. Up to a point, this tower could accommodate larger conductors without any modification. In addition, wood poles have an inherent step function in capacity before requiring bracing, etc. Therefore, the structural component in the direct cost curve is a composite for the line of those towers/foundations requiring modifications and those that do not. Generation of this curve can be quite complicated, requiring input from reliability based structural analysis and tower spotting programs. Similarly, the tower "use factor" is dependent on terrain and tower location. For example, it could be that an existing tower is located in such a position that it has a low "use factor" by virtue of short adjoining spans. Up to a point, this tower could accommodate larger conductors without any modification. In addition, wood poles have an inherent step function in capacity before requiring bracing, etc. Therefore, the structural component in the direct cost curve is a composite for the line of those towers/foundations requiring modifications and those that do not. Generation of this curve can be quite complicated, requiring input from reliability based structural analysis and tower spotting programs. Studies of this type allow designers to react to the need for more transmission capacity within existing ROW constraints and by so doing fully realize the benefits of line uprating.

**References**


PTI STARTS EPRI TRANSMISSION LIMITATIONS STUDY

PTI is cooperating with EPRI staff in preparing a comprehensive survey to identify limitations inherent in today's high voltage transmission systems and to catalog both established and potential future means of overcoming these limitations. The study, scheduled for completion in mid '87, will concentrate on means of improving existing systems by modifications to or reuse of existing rights of way, by upgrading substations, by improved operating procedures or operator aids, and other means. It will also examine design and operating criteria as they affect transmission limitations.

By listing and evaluating the options for maximizing use of the in-place system while still meeting reliability, operational, and maintenance requirements, utility planners will have a better basis for gauging justification of new circuits. The study will give special consideration to the challenge of accommodating third-party transmission access at all voltage levels.

Inputs to the project will include an extensive literature search as well as interviews with electric utilities and manufacturers, both U.S. and foreign.

The work will be a joint effort of EPRI and PTI staff, the latter under direction of Lionel O. Barthold and the former under direction of Frank S. Young.

At the conclusion of the project, in June of 1987, a workshop will be scheduled to review the project. In addition, a panel session has been scheduled for the 1987 winter Power Engineering Society meeting in New Orleans.

SHORT COURSE SCHEDULE

To be presented at PTI offices in Schenectady, NY

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<th>Fee (per participant)</th>
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<td>Power Plant Performance</td>
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<tr>
<td>Sept. 22-26, 1986</td>
<td>Power System Planning Techniques</td>
<td>$1000</td>
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<td>Sept. 29-Oct. 3, 1986</td>
<td>Underground Cable Systems</td>
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<td>Utility Economics and Finance</td>
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<td>Oct. 14-17, 1986</td>
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<td>Oct. 15-17, 1986</td>
<td>Industrial Power System Harmonics and Power Factor Improvement</td>
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<td>Nov. 17-21, 1986</td>
<td>Power System Dynamics</td>
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<td>March 2-6, 1987</td>
<td>Power System Scheduling &amp; Operation</td>
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**********Special Presentations**********

Nov. 3-7, 1986 | Power Plant Performance — Salt Lake City, UT                        | $1000                 |

Nov. 17-21, 1986 | Power Distribution Systems — Boston, MA                                | $1000                 |

For further information or registration contact:
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