UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Utilities Service

RUS BULLETIN 1724E-203

3JECT: **Guide for Upgrading RUS Transmission Lines**

: All Electric Borrowers

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/ision

ING INSTRUCTIONS: This bulletin replaces REA Bulletin 62-7, "Guide for Upgrading
Transmission Structures for Higher Operating Voltages," issued January 1981.

RPOSE: This guide bulletin provides engineering personnel with information for
grading transmission lines.

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ABBREVIATIONS

AC-6201 - All aluminum conductor-6201 Alloy
SI - American National Standards Institute
SR - Aluminum conductor steel reinforced
\- - Basic insulation level
\- - Electric and magnetic fields
EE - Institute of Electrical and Electronic Engineers
mil - Thousand circular mils
\- kilovolt
L - Line-to-line voltage in kilovolts
\- - Mean sea level
SC - National Electrical Safety Code
V - Right-of-way
S - Rural Utilities Service
AC - Steel supported aluminum conductor

INTRODUCTION: The increasing demand for power, coupled with the difficulty in taining new rights-of-way, dictates that the feasibility of upgrading the capacity an existing line be considered. In upgrading the capacity of a line, the possible tions include installing a larger conductor on existing structures, increasing the erating voltage, increasing operating temperature, increasing the reliability, or a mbination of above.

general, environmental problems will be less in upgrading an existing line than taining right-of-way for a new facility; however, upgrading is not necessarily the rrect or only solution for increasing demand or improving reliability.

e primary purpose of this guide is to furnish engineering information for use in grading standard RUS wood pole type transmission lines in the 46 kV to 230 kV nge. This publication is not intended to supersede RUS Bulletin 24E-200, "Design Manual for High Voltage Transmission Lines," any part thereof, for design of new transmission facilities; however, it does ovide guidance and certain special design criteria for upgrading existing lines ile maintaining RUS-NESC ade B construction for transmission lines. Much of the information in this guide lletin is also pertinent when upgrading a steel or concrete pole transmission line.

e borrower and its engineer are responsible to fully investigate the feasibility of upgrading project based on system load requirements, sound design practices, onomics of construction, operation, and environmental considerations.

CONSIDERATIONS TO BE MADE IN LINE UPGRADING: Practically every power system has und itself in the position of needing to upgrade a critical transmission line to a gher power transfer capability or improved reliability. Once this need has been cognized, one alternative to be considered is whether or not an existing line can modified to meet new system requirements. In many cases, the existing line can be graded; however, a hasty decision may result in an expensive temporary solution to system load problem that might require long-term solutions.

ery transmission line upgrading should be evaluated for adherence to system liability and planning criteria. The prime tool in performing this type of aluation is a system load-flow study.

addition, some basic analysis can be done using the RUS bulletin on "Electrical aracteristics of RUS Alternating Current Transmission Line Designs." This blication provides a means for hand calculations of individual transmission line rformance parameters and approximations of power transmission capabilities, line ltage drop, and power losses.

nductor ampacity can be determined from various sources, such as conductor nufacturers, EPRI research, the February 1959, IEEE paper titled "Current Carrying pacity of ACSR" by H. E. House and P. D. Tuttle, IEEE Standard 738-1993, IEEE andard for Calculating the Current Temperature of Bare Overhead Conductors (ISBN 1-937-338-5) and the Aluminum Conductor Handbook by the Aluminum Association. Each ility will have to define its maximum operating limits given ambient temperatures d wind conditions.

ing one or more of the types of analyses described above, certain essential rameters of the proposed upgraded or converted transmission line should be defined, mely:

- o Operating voltage.
- o Line current.
- o Proposed conductor size.
- o Maximum operating conductor temperature.

ner parameters may also be established but these four are essential for the ansmission line analysis.

ble 2-1 provides a list of minimum recommended conductor sizes for various erating voltages.

TABLE 2-1
RUS Recommended Minimum Conductor Sizes(1)

kV_{LL}	ACSR	AAAC-6201
34.5	1/0	123.3 kcmil
46	2/0	155.4 kcmil
69	3/0	195.7 kcmil
115	266.8 kcmil	312.8 kcmil
138	336.4 kcmil	394.5 kcmil
161	397.5 kcmil	465.4 kcmil
230	795 kcmil	927.2 kcmil

) The above minimum sizes are based on mechanical, corona and radio interference considerations. Larger conductors may very often be required because of the economics of power losses and other factors.

ior to an upgrade, an environmental review of the project is required in accordance th 7 CFR Part 1794, RUS' Environmental Policies and Procedures. Concerns on ectric and Magnetic Fields (EMF), clearance limitations due to airport approaches, increased audible noise in sensitive neighborhoods will have to be addressed.

e borrower should investigate the existing electrical demand on the proposed ansmission line to be upgraded. Discussions should be held with the construction d operation personnel on the duration, schedule conflicts, and limitations of an tage. Outage duration and schedule could impact the design and construction quence of the line upgrade.

STEPS REQUIRED FOR LINE UPGRADE

L **Clearances:** The analysis of structure upgrading assumes conformity to the ectrical clearances recommended by RUS Bulletin 1724E-200. Where the bulletin is lent on clearances, the National Electrical Safety Code (NESC) or local code, if re stringent, is to be utilized. If the local code is more stringent than RUS lletin 1724E-200, then that code should be followed.

e latest edition of the NESC should be referred to for emergency and standard erating installations. Maximum operating temperature can be based on long term erating conditions. Rules 230A2a and 230A2b of the NESC are referred to concerning ergency installations

e engineer should compare original design clearances and operating temperatures th current NESC requirements and RUS recommendations in Bulletin 1724E-200. Since SC and RUS clearances have been redefined over the years, it may be possible to now erate an existing line at higher temperatures due to redefined clearance quirements. Also, older lines may have been designed for ice loadings and may have ditional capacity available at high operating temperatures.

2 <u>Right-of-Way Width</u>: One of the most important electrical clearance requirements sometimes overlooked in procuring of right-of-way easements for transmission nes. The width of the right-of-way depends upon many factors, such as:

Structure configuration (phase spacing).
Conductor size and weight.
Structure span length.
Amount of conductor sag.
Amount of conductor blow out.
Operating voltage.
Elevation (MSL).

l of these factors should be considered before a transmission line is upgraded or nverted. In the case of item "e" above, RUS Bulletin 1724E-200 discusses conductor ow out and ROW widths based on blow out calculations.

e following nominal right-of-way widths have been generally proven to be tisfactory and, in most instances, provide sufficient clearance for a fallen ructure to remain within the right-of-way.

Nominal Line (kV)	ROW Width (Meters)	ROW Width (Feet)
69	23-30	75-100
115	23-38	75-125
138	30-46	100-150
161	30-46	100-150
230	46-61	150-200

3 **Right-of-Way Easements:** Easements and permits should be reviewed to determine / language that prohibits increased sag or ampacity across the described land. For ample, a river crossing may require revision of an existing Army Corps of Engineers ossing permit. Easements may have language that greatly restrict the use of the ght-of-way. It should be noted that a borrower may have owned and operated a 69 kV ansmission line within a 30.5m (100 ft.) easement for the past several years and t this same 30.5m (100 ft.) easement will not be sufficient for operating at a gher voltage. The following list is provided to assist the borrower and engineer foreseeing some of the common problems of reusing existing right-of-way.

Some easements may have restricted structure locations and/or line configuration. Thus in some localities, any change in the configuration or relocation of individual structures may require renegotiating the easement.

The centerline of construction does not always correspond to the centerline of the easement.

Some easements do not specify the right-of-way width. In these instances, legal counsel will be required to determine the right-of-way status for upgrading the line.

"Permanent easements" should not be confused with "easements for construction."

Some easements limit the wire size and line voltage.

Encroachments may conflict with a line upgrading.

- o Buildings constructed on or near the right-of-way of the line may be located such that horizontal and vertical clearances for an upgraded line cannot be met. In many instances, once the permanent facility is built within the easement or ROW and "Code Clearance" to the line is complied with, the borrower cannot force the owner to move the facility.

- o Ponds or lakes may have been created or expanded.

- o New roads and/or driveways may have been built.

- o In some areas a change in land use should be considered an encroachment. For example, undeveloped rural areas may have been converted to producing farmland. This may cause problems in providing adequate vertical clearance for the expected use of large harvesting combines and/or heavy farming equipment.

o Irrigation systems may have been added.

o Utility or communication facilities may have been constructed since the transmission line was built.

o Commercial signs may have been installed.

Easements may contain limitations on tree clearing and/or line accessibility.

"Blanket Easements" should be reviewed by legal counsel.

Line modification might be limited due to the construction of airstrip facilities or a radio/TV transmitter built nearby since the original line was constructed.

Public Utility Commission or Public Service Commission approval may have to be obtained.

Elevation or voltage changes for railroad crossings, highway crossings, aircraft approaches, or any other crossing may require a permit.

4 **<u>Analysis of Existing Lines and Structures</u>:** Before an existing structure or line comes a feasible candidate for voltage conversion or improving the current rating, thorough records search must be made, detailed field information obtained, and mprehensive engineering calculations made.

in-depth review of the design parameters and construction methods used for the isting transmission line must be conducted at the beginning of any proposed line nversion or upgrading project. The purpose of such a thorough study is to clearly fine the starting point and configuration before becoming committed to an pensive, time-consuming line modification.

4.1 Several essential facts about the existing facilities must be ascertained:

What basic design criteria was used? Is the original design data book available? What specific overload factors were used? Which version of codes or design manuals were used?

What basic electrical clearances (horizontal and vertical) were used in the original design? Are original construction drawings/contract documents available? Are existing plan-and-profile drawings up to date? Has a foot patrol been made to detect right-of-way encroachments, heights and locations of all utility crossings, and changes in ground elevations (cuts/fills)? Are pole heights, classes, and locations correct as shown on plan-and-profile drawings? Are all highways, streets, and railroads accurately shown? Have any airports or radio/TV stations been built in the general area since the original line construction?

Was the existing line designed for greater loads than necessary? Will the existing foundation and soil conditions sustain increased loads on the upgraded structure? What standard was used in selecting pole embedment depths? Do the existing structures have any surplus strength capabilities? What does the survey of the wood poles indicate concerning the condition of the existing poles? Is the groundline circumference in excess of the minimum dimension for the ANSI wood pole class? Is the wind span for the individual structure less than the maximum allowed for pole strength capabilities or uplift limitations? Does the existing line meet current NESC "when installed" criteria? What is the condition of the insulators, conductors, overhead groundwire, and conductor and pole hardware?

4.2 A survey will be required to spot check clearances and verify the profile. e field effort begins with determining the physical and mechanical condition of the isting line. This is in addition to or in conjunction with a survey of the isting centerline. A quick spot check of elevations will reveal if a full survey ll be required. An inventory of any changes to the physical features along the nterline should be recorded with corresponding elevations. Measurements should so include conductor attachment heights, obstructions, right-of-way encroachments, d check of span lengths. All wire crossing heights should be measured during the eld survey.

rial photography may be used to prepare new plan-and-profile sheets. The cost will crease with the level of accuracy desired for the aerial survey. A detailed cost mparison between aerial photography services and a ground patrol survey should be alyzed.

4.3 Finally, the data should be analyzed to determine the optimal plan for provement. Any changes made to the existing line must, as a minimum, comply with e latest edition of the NESC. Sag and tension parameters of the existing conductor ll have to be determined. Design tensions may not be very accurate if actual span ngths are not the intended design lengths or if the field sagging of the wire was t accurate. Raising structures, moving structures, etc., will change sag and nsion characteristics. Raising a structure may gain clearance in one span but lose earance in an adjacent span. Raising a line usually results in increased tension the conductor and can put unwanted longitudinal forces in the new system. If a ructure needs to be raised, the engineer should review the designed cold curve on e profile to check for a potential uplift problem.

the existing pole has adequate strength, conductors may be raised to permit eater sag or to increase clearances. The lower crossarm may have room to be raised foot or two depending on the original vertical spacing or line posts may be added existing crossarms to increase clearances. Caution should be exercised, however, at the solution to one problem does not create another. If the line has perienced galloping, changing the vertical spacing may introduce phase-to-phase ntact.

the field survey reveals a distribution line crossing is restricting the clearance derneath the transmission line, the owner of the conflicting line should be ntacted to remove the conflict. This approach may be less expensive than changing e transmission facilities.

5 Methods to Upgrading/Converting Using Existing Structures:

en upgrading a line, the engineer should take advantage of local environmental perience concerning temperature, ice and wind loadings. For example, if a ansmission line exists in a medium loading zone, but was designed for heavy loading nditions, the structures may have strength in excess of what the NESC required and ich can be used in upgrading.

the previous section, some items of review were suggested to help determine ether the existing structure configurations have any significant strength or ectrical clearance parameters in excess of that required by the NESC or recommended RUS Bulletin 1724E-200. If the existing structures are found to have certain rength or height advantages, an upgrading or conversion may be possible with a nimum of expense involved in material and construction. Some of the methods of ne modification that would fall into this category are:

- o Reconductor.
- o Bundle conductors.
- o Retension existing conductors.
- o Increase line voltage using existing conductors.
- o Increase operating temperature using existing conductors.

ese methods of line modification may be used individually or may be used in mbination with one other. Each method has unique problems which need to be nsidered in upgrading.

5.1 Reconductor : Removing existing conductors and installing a single larger nductor may be a valid line modification technique, provided the existing ructures have adequate pole strength and ground clearance to accommodate the crease in vertical and transverse loads and increased conductor sag.

larger conductor usually results in considerably higher line tension. Therefore, l conductor fittings, angle attachments, and deadend attachments will need to be viewed for the new strength requirement. Utilizing new or different conductor nfigurations will result in different galloping conductor ellipses. The revised nfiguration should be analyzed in the maximum, minimum, and ruling spans to termine whether the conductors will come in contact during galloping conditions.

other method of line upgrading/conversion utilizes the installation of a conductor ich has certain vibration damping characteristics such as Steel Supported Aluminum nductor (SSAC), Trapezoidal, or Twisted Two Conductor (T2) type of conductors. ch specialty conductor has unique installation and handling concerns.

e following items need to be considered for a reconductor project: clearances, sulator strength, foundation capacity, conductor hardware, guy strength, pole and ructure strength, anchor capacity, vibration, and galloping concerns.

5.2 Bundle Conductors : The bundling of conductors to achieve voltage upgrading y be a valid technique. This method of line modification lends itself to ructures that have excessive pole strength in their present configuration. fficient ground clearance will be required to offset any increase in insulator ring length and voltage clearance requirements.

rizontal conductor bundles usually consist of two conductors per bundle at voltages ss than or equal to 345 kV. The horizontal bundle minimizes the amount of ditional ground clearance required for voltage upgrading because the same wire size d resulting conductor sag may be utilized. One disadvantage to this technique is at a new conductor cannot be added to form a horizontal bundle with an existing nductor (even if they are the same size) because of the difference in initial and nal conductor sag and tension values.

rtical conductor bundles may be utilized in most of the same situations as the rizontal bundle. The vertical bundle arrangement requires about 305 mm (12") to 5 mm (14") more height at the conductor attachment point than the horizontal ndle, due to the length of the conductor hanger. There are some advantages to the rtical bundle technique. One advantage is that a new conductor can be installed in e top position of a vertical bundle and the existing conductor installed in the wer position. Another advantage is that vertically bundled conductors may be stalled on certain single-pole structures (e.g., horizontal line post nstruction).

5.3 Retension: If conductors are resagged to higher line tensions, vibration mpers may be required. Guyed structure strength, guy strength, insulator strength, nductor hardware strength, foundation capacity, anchor capacity, and uplift pacity also need to be considered.

5.4 Increase Line Voltage: Some structures may be upgraded/converted to higher ltage levels by raising the shield wire on a type of bayonet and installing new or dified crossarms or conductor attachment points to higher positions. Structures at may be modified in this manner must have a considerable amount of excess pole rength in their present configuration. Raising the shield wire and conductor cations will increase the ground line moment and other structure loadings. creasing line voltage may require increasing line insulation by adding additional rcelain bells or by changing out suspension or posts to longer units of porcelain polymers. If the existing conductor is to be utilized at a higher operating ltage, it must be capable of conveying greater electrical loadings. Conductor paration, insulator swing, corona, insulation level, and ground clearance must be nsidered.

5.5 Increase Operating Temperature: Prior to the release of the 1977 NESC, ilities generally were designing their transmission and distribution facilities to et operating temperatures of 120°F. At high ambient temperatures with low wind eeds, this criteria does not provide for a high power transfer. With increasing ectrical demand, many utilities are focusing on increasing the operation limits of isting transmission facilities. The utility should contact and/or follow conductor nufacturer's recommendations for maximum operating temperatures. Ampacity is mited by ground-t- conductor clearance and thermal properties of the conductor. ch utility should calculate its own conductor ampacity based on local ambient and erating conditions. The ground clearance for most lines with small conductor (4/0 SR and smaller) in the Heavy Loading District is controlled by the sag of the iced nductor, not the 120°F hot sag. During summer peak, the transmission line should ve additional capacity in those cases. A preliminary spot check can be performed drawing the higher operating temperature curve over the existing profile. nerally, old transmission lines do not have reliable records due to inaccuracies of evation measurements, addition of roadways, and new developments that have regraded e ground beneath the transmission line. Other utilities may have crossings that ve not been documented on the utility's permanent records.

5 **Insulation Levels**: In general, the shield angle for lightning protection should 30 degrees. However, the shield angle may be increased to 40 degrees based on the ne's loading, reliability, and the system integrity required by the individual line ing upgraded.

r a more detailed analysis on lightning performance, the engineer is referred to an ril 1985, IEEE paper, "A Simplified Method for Estimating Lightning Performance of ansmission Lines," pages 919-932.

r horizontal post insulators, it is recommended that a BIL be approximately 20 rcent above NESC dry flashover. For suspension insulators, it is recommended that sulator strings conform to the recommended insulation levels in RUS Bulletin 1724E-0, "Design Manual for High Voltage Transmission Lines." However, one bell less an standard may be used if the following criteria are met:

- o The line has an overhead ground wire.
- o The pole ground resistance is less than 10 ohms.
- o The line is located in an area of moderate isokeraunic levels*.
- o The line has no contamination problems.

polymer insulator should have electrical ratings equivalent to its porcelain unterpart. Usually the polymer insulator will have an increased length, reduced ight, and increased leakage distance. The reduced weight will affect the insulator ing clearances. Each manufacturer will have different levels of creepage, leakage, ashover characteristics, BIL levels, and strength ratings.

7 Cost Factors: Up to this point, the considerations to be made in transmission ne upgrading have dealt mainly with system operational requirements, electrical earance requirements, and structural performance capabilities. Information esented in this section will direct attention to expenditures of resources involved line conversion and upgrading. These expenditures include finances, time, npower, environmental, and material, to note only a few.

7.1 Additional Right-of-Way Costs: Perhaps the most important questions to be solved in any proposal for line upgrading or conversion concern the right-of-way fected by the line changes. The method of calculating the minimum required right--way width for the proposed structure was described in section 3.2, page 5.

other critical question concerning right-of-way is whether or not additional and jacent right-of-way can be obtained. If the existing line route crosses edominantly rural countryside, the chances are good that additional/adjacent right--way can be obtained. If, however, the existing line route crosses a developing sidential area or is restricted by other existing rights-of-way or geographical atures, it may be virtually possible to obtain additional/adjacent right-of-way. In that

sokeraunic level - The average annual number of thunderstorm days used for ghtning statistics.

se, alternate methods of line construction must be considered, e.g., tear down and build on existing right-of-way width.

the utility concludes that the additional/adjacent right-of-way width can be tained, the next question is the cost of the additional right-of-way in terms of me and money. Experience has proven that right-of-way negotiations, settlements, d condemnation actions require considerably more time and money to acquire than rst anticipated.

is suggested that an assessment of real estate values and properties affected by e line conversion be made by a private real estate broker or registered land praiser. It is further suggested that neighboring cooperatives and public ilities be contacted to gain information concerning their recent experience in time d expense involved in right-of-way procurement or condemnation proceedings.

firm commitment to proceed with line upgrading or conversion should be withheld til the utility is satisfied with the accuracy and adequacy of answers to the estions concerning additional right-of-way.

7.2 Material Costs: The cost of material involved in the proposed line conversion upgrading should be studied. There are at least three significant items that must ve value assessments made or derived. The first is the "book" value of the isting structure, items, or wires that will be affected by the line modification or tirement. (This may be obtained from the property accounting records.) Secondly, e salvage value of the removed materials must be estimated or otherwise defined. his value should be entered as a deduct item when estimating the total project st.) Thirdly, the cost of the material to be installed must be defined in order to tablish new structure costs for property accounting records.

other item that should be considered is the availability of the types of material ing considered for use in the proposed conversion or upgrading. Material lead time ries in an unpredictable manner; therefore, the designer should check the supply or ailability of materials needed in the time frame planned for line conversion. ems such as horizontal line post insulators, long-assembled crossarms, and shioned suspension units are usually long lead time items, and their acquisition y have a bearing on project planning.

7.3 Labor Costs: The labor cost to convert or upgrade the proposed transmission ne will probably be the most significant expense item in the project. The amount time and labor activities required in a line conversion will be substantial. bor costs may be several times as great as material costs.

e categories of labor costs that must be identified and tabulated are the labor to move specified items of existing line materials and dispose of as directed; dify/revise existing structures; install new line materials; clear additional ght-of-way.

the proposed upgrade is a radial line, additional cost for "hot line work" should considered if unable to take an outage.

7.4 Technical Analyses : A complete analysis of the existing transmission line st be performed. An upgrading or conversion project will have preliminary gineering expenses that must be considered. The costs should include the time and penses for the activities listed below.

) Record Search - A complete search of design records, drawings, and property records to determine the criteria used in design and construction of the existing line.

) Field Inspection - A complete and detailed inspection of the existing transmission line must be performed, including foot patrol, pole inspection, plan-and-profile verification, right-of-way encroachment inspection, pole height verifi- cation, pole ground line circumference measurements, etc.

) Engineering Analysis - Design analyses of the existing line and the upgraded structure must be performed including structure strength and hardware analysis, conductor galloping, electrical clearances, computation of overload factors, verification of the accuracy of engineering drawings, etc.

IMPROVE RELIABILITY: There are several methods to upgrade a line and improve its liability. The following methods may be used in combination with each other to crease the number of outages to a line.

1 Improve Lightning Performance: There are a number of ways to reduce the number outages due to lightning strikes to the phase conductors. One of the most fective ways is to attach an overhead ground wire to the structure such that the ield angle to the conductors is 30 degrees or less. If structure strength permits, bayonet may be added to the structure to either add an overhead ground wire or to ise the existing shield wire and decrease the shielding angle.

ghtning arrestors with proper grounding may be used to decrease flashovers due to ghtning. Design data and earth resistivity data should be provided to the nufacturer so that quantities and location of arrestors are properly determined. e benefit of lightning arrestors, as compared to the overhead ground wire, is that ey will not greatly increase the loadings on the structure.

proving grounding on a transmission line will decrease the number of outages on a ielded transmission line. Additional ground rods may need to be driven to reach wer resistivity soil layers. In high resistivity soil, counterpoise may be the st solution. Chemically treated ground rod systems may be necessary in high sistivity soils.

sulation should be considered to improve the BIL level of the line. In ntaminated areas, higher silicone rubber composition polymer insulators may also be nsidered. The silicone material provides a hydrophobic surface (water beading) ducing the deposits of contaminants.

e final method of reducing outages due to lightning involves lightning dissipation vices. The basis of these devices is that they lower the voltage differential tween the ground surface and the cloud charge below flashover levels. Sharp points these devices ionize the surrounding air, allowing safe transfer of electrical arge to a grounding system. Since grounding is a key element in the performance of ese devices, grounding techniques mentioned above may have to be used in highly sistive soils. Lightning experts disagree on the effectiveness of these devices.

2 Improve Galloping Performance: Outages may occur from phase-to-phase contact of lloping conductors. Outages from galloping conductors can be reduced several ways:

Increase conductor separation by raising or lowering crossarms.

Add air flow spoilers to break up the uniformity of ice buildup on the conductor.

Reduce span lengths by adding additional structures.

Reconductor with T2 type conductors. (Structure strength, guying, and other mechanical factors must be evaluated.)

Add mid-span spacers to eliminate conductor slap. (Conductor hardware should be reviewed closely to prevent conductor damage due to aeolian vibration or dynamic stress.)

Add detuning pendulums to dissipate the low frequency energy.

3 Improve Aeolian Vibration Performance: Aeolian vibration may cause conductor tigue and eventually conductor breaks creating outages. Several measures may be ken in order to reduce aeolian vibration:

Install spiral vibration dampers to conductor sizes not exceeding 19 mm (3/4") diameter. For larger conductor, a pendulum type damper should be used.

Use cushioned suspension or support hardware in place of conventional support clamps.

Monitor vibration frequency and amplitude through current recording devices.

Initiate a visual inspection program to review the conductor, armor rod, or tie wire damage. Check cotter key or hardware wear and look for the presence of black aluminum oxide.

Add detuning pendulums to dissipate the mechanical energy.

DETERMINING THE BEST SOLUTION

1 **Tangible Factors**: The primary factor in a line conversion or upgrading is the tal estimated cost of the proposed project. As described earlier, the estimated st for each alternative method of line conversion should be carefully prepared. e estimated cost of a totally new transmission line and right-of-way should also be epared for comparison of cost and public interest.

second tangible factor is the time element available to provide the needed system difications. If increased power requirements or system service is required and the me available to construct these system improvements is very limited, then the dification of existing power lines on existing rights-of-way can be a very tangible set.

third tangible factor is the electrical system capability. If additional service needed, or requested, in a part of the system which has marginal or limited pabilities, the necessity for system improvement becomes a tangible factor.

2 **Intangible Factors**: In developing any system improvement, there are a multitude factors to evaluate. Some of these are intangible items and thus cannot be aningfully evaluated in monetary terms. Two such factors are consumers' interests d public relations. Reliability of service and consumer interests are obviously lated. When system analyses conclude that a line conversion or upgrading is cessary to provide the desired reliability of service, the consumers' interests are ing supported, and the project warrants careful consideration.

intaining good public relations is a desirable posture for any organization. A oposal to utilize existing transmission line rights-of-way for needed system provements certainly is an attempt to develop good public and consumer relations. erefore, the upgrading or conversion of existing transmission lines within existing ghts-of-way or minimal increases in rights-of-way width is in the best interests of e general public where possible.

3 **Comparison of Alternatives**: The purpose of information presented in this cument is to provide various concepts for structure and line modifications. Each the available methods of line conversion or upgrading will involve differing penditures for materials, labor, rights-of-way, engineering analyses, etc. It is

portant, therefore, to prepare comprehensive cost estimates for each of the nfigurations to be considered for the upgrading project.

4 Selection of Alternatives: After comparing the various factors described above, e best overall solution can be determined. Although minimizing construction costs important, the need for system improvements may be so critical that an emergency tuation exists, and costs become less important.

ch situation must be evaluated independently and conscientiously. When this is ne, the owner can objectively determine the best solution for its system's needs d be confident that the interests of the consumers and the general public are also ing served.

5 Example: A borrower has operated and maintained 20.92 kilometers (13 miles) of kV transmission line, radial feed, that serves a 69/12.5 kV substation with six stribution feeders. The transmission line utilizes H-frame TH-1G structures with 6.8 (26/7) ACSR conductors and (2)-3/8" H.S. steel shield wires constructed within 30.48m (100 ft.) wide easement. The "Long-Range Plan" specifies the need to nvert the distribution feeders to 14.4 kV and the transmission/substation cilities to 138 kV with 795 (26/7) ACSR conductors and relocate the source bstation.

e initial investigation reveals the following facts:

It is currently the month of July with present peak loads already at the system's maximum capability with only a small unbalanced condition, thus, in-service for the 138 kV operation will be required within 11 months.

Alternative sources for the distribution loads are not available or they are impractical for long-term operation.

The weak link in the transmission/substation system is the 266.8 conductor. The 69/12.5 kV transformer has additional capacity for the distribution loads and space was provided for two additional 12.5 kV feeders.

The right-of-way contains numerous new crossings and encroachments, (utility, public, and private).

Part of the easements have been purchased by structure location and with limited right of access.

A metal plating company and railroad spur have since been located along .75km (1/2 mile) of this line.

The extremely harsh winters with unusually heavy ice have made construction impractical from November through January for the past 4 years.

The original line was designed with 198m (650 feet) ruling span, 274m (900 feet) maximum span, a conductor operating temperature of 48.90°C (120°F) hot and -17.8°C (0°F) cold, a basic structure of 60 feet Class 2 poles, one crossarm with some structures being X-braced, and the conductors were attached with cushioned suspension units. Dampers were not required as the 266.8 ACSR conductor was installed at a moderate tension. It was placed in service 9 years earlier.

The profile drawings are incomplete and all other design data has been lost.

Operations records show a high outage rate due to lightning, trees, and galloping conductors.

The 69 kV line can be taken out of service only during periods of low demand.

e following preliminary options must first be reviewed before the actual upgrading to be considered.

Determine all other feasible routes on both public and private properties. These routes shall include right-of-way widths of 15.24m (50 feet), 22.86m (75 feet), and 30.48m (100 feet) and a cost/mile for each.

Determine the relative cost of "new" single pole and H-frame construction with 795 (26/7) ACSR conductors.

Determine the feasibility of expanding the 69/12.5 kV substation by adding a second 69 kV line, possible loop feed.

Determine the cost of removing the existing line and building a new line in its place.

Determine if another conductor, 477 (26/7) ACSR or 636 (26/7) ACSR, can be used at 100°C (212°F) operation and calculate the losses.

l indications resulted in a common proposal, namely, that the existing line will /e to be converted to 138 kV on the existing right-of-way, with a minimum available :age time, using the same structure locations and reconductoring with 636 MCM 26/7 SR conductor to be operated at 100°C (212°F).

summary, the TH-1G to TH-VS (69 kV to 138 kV) conversion structure is recommended the detailed design considerations. Throughout the detailed design, the engineer st be aware of specific individual structure locations that cannot be converted by use of this structure. Those unique locations will require special design nsiderations and/or replacement with standard RUS 138 kV transmission structures.

general, the specific structure for this conversion is chosen for the following asons:

It is compatible with hot-line work.

It provides substantial increase in ground clearance to permit reconductoring to 636 conductor and operating at 100°C (212°F). If the ground clearance becomes a governing factor as the design progresses, consideration will have to be made as to the use of self damping conductors and/or installing dampers on a tightly strung 636 (26/7) ACSR.