UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Development
Rural Utilities Service

RUS BULLETIN 1724E-203

SUBJECT: **Guide for Upgrading RUS Transmission Lines**

TO: All Electric Borrowers, Consulting Engineers, and RUS Electric Staff

EFFECTIVE DATE: Date of Approval

OFFICE OF PRIMARY INTEREST: Engineering Standards Branch; Office of Policy, Outreach, and Standards; Electric Program

FILING INSTRUCTIONS: This bulletin replaces RUS Bulletin 1724E-203, "Guide for Upgrading RUS Transmission Lines," issued December 28, 1994.

AVAILABILITY: This bulletin is available at http://www.rurdev.usda.gov/RDU_Bulletins_Electric.html

PURPOSE: This bulletin provides engineering personnel with information for upgrading transmission lines.

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ABBREVIATIONS

AAAC-6201 — All aluminum conductor-6201 Alloy
ANSI — American National Standards Institute
ACCC — Aluminum Conductor Composite Core
ACCR — Aluminum Conductor Composite Reinforced
ACSR — Aluminum conductor steel reinforced
ACSS — Aluminum Conductor Steel Supported
BIL — Basic insulation level
EMF — Electric and magnetic fields
IEEE — Institute of Electrical and Electronic Engineers
kcmil — Thousand circular mils
kV — kilovolt
kV_{LL} — Line-to-line voltage in kilovolts
MSL — Mean sea level
NESC — National Electrical Safety Code
ROW — Right-of-way
RUS — Rural Utilities Service

DEFINITIONS

Isokeraunic Level — The average annual number of thunderstorm days used for lightning statistics.

1 INTRODUCTION

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

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

The primary purpose of this bulletin is to furnish engineering information for use in upgrading standard RUS wood pole type transmission lines in the 46 kV to 230 kV range. This publication is not intended to supersede RUS Bulletin 1724E-200, "Design Manual for High Voltage Transmission Lines," or any part thereof, for design of new transmission facilities; however, it does provide guidance and certain special design criteria for upgrading existing lines while maintaining NESC Grade B construction for transmission lines. Much of the information in this bulletin is also pertinent when upgrading a steel or concrete pole transmission line.

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

2 CONSIDERATIONS TO BE MADE IN LINE UPGRADING

Frequently critical transmission lines need to be upgraded to a higher power transfer capability or improved reliability. Once this need has been recognized, one alternative to be considered is whether or not an existing line can be modified to meet new system requirements. In many cases, the existing line can be upgraded; however, a hasty decision may result in an expensive temporary solution to a system load problem that might require long-term solutions.

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

In addition, some basic analysis can be done using the RUS bulletin 1724E-201, "Electrical Characteristics of RUS Alternating Current Transmission Line Designs." This publication provides a means for hand calculations of individual transmission line performance parameters and approximations of power transmission capabilities, line voltage drop, and power losses.

Conductor ampacity can be determined from various sources, such as conductor manufacturers, “Current Carrying Capacity of ACSR” (IEEE article, February 1959, House

and Tuttle), EPRI research, IEEE 738-1993 - IEEE standard for Calculating the Current Temperature of Bare Overhead Conductors (ISBN 1-55937-338-5) and the Aluminum Conductor Handbook by the Aluminum Association. Each utility will have to define its maximum operating limits given ambient temperatures and wind conditions.

Using one or more of the types of analyses described above, certain essential parameters of the proposed upgraded or converted transmission line should be defined, namely:

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

Other parameters may also be established but these four are essential for the transmission line analysis.

Table 2-1 provides a list of minimum recommended conductor sizes for various operating 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	4/0	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.

Prior to an upgrade, an environmental review of the project is required in accordance with 7 CFR Part 1794, RUS Environmental Policies and Procedures. Concerns on Electric and Magnetic Fields (EMF), clearance limitations due to airport approaches, increased audible noise in sensitive neighborhoods, and endangered species should be considered.

The borrower should investigate the existing electrical demand on the proposed transmission line to be upgraded. Discussions should be held with the construction and operation personnel on the duration, schedule conflicts, and limitations of an outage. Outage duration, availability of equipment, and schedule could impact the design and construction sequence of the line upgrade.

3 STEPS REQUIRED FOR LINE UPGRADE

a Clearances. The analysis of structure upgrading assumes conformity to the electrical clearances recommended by RUS Bulletin 1724E-200. Where the bulletin does not address clearances, the National Electrical Safety Code (NESC) or local code, if more stringent, is to be utilized. If the local code is more stringent than RUS Bulletin 1724E-200, then that code should be followed.

The latest edition of the NESC should be referred to for emergency and standard operating installations. Maximum operating temperature can be based on long term operating conditions. Rule 230A2 of the NESC is referred to concerning emergency installations.

The engineer should compare original design clearances and operating temperatures with current NESC requirements and RUS recommendations in Bulletin 1724E-200. Since NESC and RUS clearances have been redefined over the years, it may be possible to now operate an existing line at higher temperatures due to redefined clearance requirements. Also, older lines may have been designed for ice loadings and may have additional capacity available at high operating temperatures. Existing design drawings, specifically regarding structure information and conductor sags, should be compared to the actual installation to confirm existing conditions prior to performing analysis.

b Right-of-Way Width. Right-of-way width is one of the most important electrical clearance requirements and is sometimes overlooked in procuring of easements for transmission lines. The width of the right-of-way depends upon many factors, such as:

(1) Structure configuration (phase spacing)
(2) Conductor size and weight
(3) Structure span length
(4) Amount of conductor sag
(5) Amount of conductor blow out
(6) Operating voltage
(7) Elevation (MSL)

All of these factors should be considered before a transmission line is upgraded or converted. In the case of conductor blow out, RUS Bulletin 1724E-200 provides recommendations for ROW widths based on blow out calculations.

Typical right-of-way widths (predominantly H-frame structures) that have been used by agency borrowers in the past are shown in Table 2. The actual ROW width that is available for the existing line should be evaluated based on the various options for upgrading the line.

Table 2
Nominal Right of Way Widths

	Nominal Line-to-Line Voltage in kV				
	69	115	138	161	230
ROW Width, ft.	75-100	100	100-150	100-150	125-200

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

(1) 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.

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

(3) 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.

(4) "Permanent easements" should not be confused with "easements for construction."

(5) Some easements limit the wire size and line voltage.

(6) Encroachments may conflict with a line upgrading.

(a) 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.

(b) Ponds or lakes may have been created or expanded.

(c) New roads and/or driveways may have been built.

(d) 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.

(e) Irrigation systems may have been added.

(f) Utility or communication facilities may have been constructed since the transmission line was built which may impact clearance requirements. In addition utility pipeline systems on the ROW or adjacent to it may be affected due to grounding or corrosion. Fault or corrosion studies may be required.

(g) Commercial signs may have been installed.

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

(8) Existing "Blanket Easements" should be evaluated by legal counsel to see if they are still enforceable or if additional ROW documentation is required.

(9) 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.

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

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

d Analysis of Existing Lines and Structures. Before an existing structure or line becomes a feasible candidate for voltage conversion or improving the current rating, a thorough records search must be made, detailed field information obtained, and comprehensive engineering calculations made.

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

(1) Several essential facts about the existing facilities must be determined:

(a) 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?

(b) 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? What is the remaining strength of the existing structures and what strength values should be used in determining structure capability? 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?

(c) 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?

(2) A thorough survey will be required to check clearances, verify the profile, and accurately locate the existing structures. The field effort begins with determining the physical and mechanical condition of the existing line. This is in addition to or in conjunction with a survey of the existing centerline. An inventory of any changes to the physical features along the centerline should be recorded with corresponding elevations. Measurements should also include conductor attachment heights, wire sags, obstructions, right-of-way encroachments, clearance over and under utility crossings, and check of span lengths. All wire crossing heights should be measured during the field survey.

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

(3) Finally, the data should be analyzed to determine the optimal plan for improvement. Any design changes made to the existing line must comply

with the latest edition of the NESC. Sag and tension parameters of the existing conductor will have to be determined. Design tensions may not be very accurate if actual span lengths are not the intended design lengths or if the field sagging of the wire was not accurate. Raising structures, moving structures, etc., will change sag and tension characteristics. Raising a structure may gain clearance in one span but lose clearance in an adjacent span. Raising a line usually results in increased tension in the conductor and can put unwanted longitudinal forces in the new system. If a structure needs to be raised, the engineer should review the designed cold curve on the profile to check for a potential uplift problem.

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

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

e Methods of Upgrading/Using Existing Structures. When upgrading a line, the engineer should take advantage of local environmental experience concerning temperature, ice and wind loadings. For example, if a transmission line exists in a medium loading zone, but was designed for heavy loading conditions, the structures may have strength in excess of what the NESC required and which can be used in upgrading.

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

(1) Reconductor
(2) Bundle conductors
(3) Retension existing conductors
(4) Increase line voltage using existing conductors
(5) Increase operating temperature using existing conductors

These methods of line modification may be used individually or may be used in combination with one other. Each method has unique problems which need to be considered in upgrading.

(1) Reconductor. Removing existing conductors and installing a single larger conductor may be a valid line modification technique, provided the existing structures have adequate pole strength and ground clearance to accommodate the increase in vertical and transverse loads and increased conductor sag.

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

Another method of line upgrading/conversion utilizes the installation of a conductor which has certain vibration damping characteristics such as Aluminum Conductor Steel Supported (ACSS) or Twisted Two Conductor (T2) type of conductors. Each specialty conductor has unique installation and handling concerns.

Additional reconductoring options include the use of high temperature, low sag conductors such as Aluminum Conductor Composite Core (ACCC) or Aluminum Conductor Steel Supported (ACSS). These types of conductors typically offer greater ampacity compared to conventional conductors of similar size and weight. Additional benefits include the possibility of utilizing existing structures and ROW.

Among the items that need to be considered for a reconductor project are: clearances, shield angle, insulator strength, foundation capacity, conductor hardware, guy strength, pole and structure strength, anchor capacity, vibration, and galloping concerns.

(2) Bundle Conductors. The bundling of conductors to achieve voltage upgrading may be a valid technique. This method of line modification lends itself to structures that have excessive pole strength in their present configuration. Sufficient ground clearance will be required to offset any increase in insulator string length and voltage clearance requirements.

Horizontal conductor bundles usually consist of two conductors per bundle at voltages less than or equal to 345 kV. The horizontal bundle minimizes the amount of additional ground clearance required for voltage upgrading because the same wire size and resulting conductor sag may be utilized. One disadvantage to this technique is that a new conductor cannot be added to

form a horizontal bundle with an existing conductor (even if they are the same size) because of the difference in initial and final conductor sag and tension values.

Vertical conductor bundles may be utilized in most of the same situations as the horizontal bundle. The vertical bundle arrangement requires about 305 mm (12") to 356 mm (14") more height at the conductor attachment point than the horizontal bundle, due to the length of the conductor hanger. There are some advantages to the vertical bundle technique. One advantage is that a new conductor can be installed in the top position of a vertical bundle and the existing conductor installed in the lower position. Another advantage is that vertically bundled conductors may be installed on certain single-pole structures (e.g., horizontal line post construction).

(3) Retension. If conductors are resagged to higher line tensions, vibration dampers may be required. Guyed structure strength, guy strength, insulator strength, conductor hardware strength, foundation capacity, anchor capacity, and uplift capacity also need to be considered.

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

(5) Increase Operating Temperature. Prior to the release of the 1977 NESC, utilities generally were designing their transmission and distribution facilities to meet operating temperatures of 120°F. At high ambient temperatures with low wind speeds, this criteria does not provide for a high power transfer. With increasing electrical demand, many utilities are focusing on increasing the operation limits of existing transmission facilities. The utility should contact and/or follow conductor manufacturer's recommendations for maximum operating temperatures. Ampacity is limited by ground-to-conductor clearance and thermal properties of the conductor. Each utility should calculate its own conductor ampacity based on local ambient and operating conditions. The ground clearance for most lines with small conductor (4/0 ACSR and smaller) in the Heavy Loading District is controlled by the sag of the iced conductor, not the 120°F hot sag. During

summer peak, the transmission line should have additional capacity in those cases. A preliminary spot check can be performed by drawing the higher operating temperature curve over the existing profile. Generally, old transmission lines do not have reliable records due to inaccuracies of elevation measurements, addition of roadways, and new developments that have regraded the ground beneath the transmission line. Other utilities may have crossings that have not been documented on the utility's permanent records.

f Insulation Levels. In general, the shield angle for lightning protection should be 30 degrees. For a more detailed analysis on lightning performance, the engineer is referred to an April 1985, IEEE paper, "A Simplified Method for Estimating Lightning Performance of Transmission Lines," pages 919-932.

For horizontal post insulators, it is recommended that the BIL be approximately 20 percent above NESC dry flashover. For suspension insulators, it is recommended that insulator strings conform to the recommended insulation levels in RUS Bulletin 1724E-200, "Design Manual for High Voltage Transmission Lines." However, one bell less than standard may be used if the following criteria are met:

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

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

g Cost Factors. Up to this point, the considerations to be made in transmission line upgrading have dealt mainly with system operational requirements, electrical clearance requirements, and structural performance capabilities. Information presented in this section will direct attention to expenditures of resources involved in line conversion and upgrading. These expenditures include finances, time, manpower, environmental considerations, and material.

(1) Additional Right-of-Way Costs. Perhaps the most important questions to be resolved in any proposal for line upgrading or conversion concern the right-of-way affected by the line changes. Recommendations for calculating the minimum required right-of-way width are provided in Section 3b of this bulletin.

A critical question concerning right-of-way is whether or not additional right-of-way can be obtained if needed. Depending on the availability of

additional right-of-way, alternate methods of line construction may need to be considered.

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

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

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

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

Another item that should be considered is the availability of the types of material being considered for use in the proposed conversion or upgrading. Material lead times vary. The designer should check the supply or availability of materials needed in the time frame planned for line conversion.

(3) Labor Costs. The labor cost to convert or upgrade the proposed transmission line can be a significant expense item in the project. Labor costs may be several times as great as material costs.

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

If the proposed upgrade is a radial line, additional cost for "hot line work" should be considered if outages are not able to be taken.

(4) Technical Analyses. A complete analysis of the existing transmission line must be performed. An upgrading or conversion project will have preliminary engineering expenses that must be considered. The costs should include the time and expenses for the activities listed below.

(a) 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.

(b) 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 verification, and pole ground line circumference measurements.

(c) 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, and verification of the accuracy of engineering drawings.

4 IMPROVE RELIABILITY

There are several methods to upgrade a line and improve its reliability. The following methods may be used in combination with each other to decrease the number of outages to a line.

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

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

Improving grounding on a transmission line can decrease the number of outages on a shielded transmission line. Additional ground rods may need to be driven to reach lower resistivity soil layers. In high resistivity soil, counterpoise may be the best

solution. Chemically treated ground rod systems may be necessary in high resistivity soils.

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

An additional method of reducing outages due to lightning is the use of lightning dissipation devices. The basis of these devices is that they lower the voltage differential between the ground surface and the cloud charge below flashover levels. Sharp points of these devices ionize the surrounding air, allowing safe transfer of electrical charge to a grounding system. Since grounding is a key element in the performance of these devices, grounding techniques mentioned above may have to be used in highly resistive soils. There is some disagreement in the industry on the effectiveness of these devices.

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

(1) Increase conductor separation by raising or lowering crossarms.

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

(3) Reduce span lengths by adding additional structures.

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

(5) 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.)

(6) Add detuning pendulums to dissipate the low frequency energy.

c Improve Aeolian Vibration Performance. Aeolian vibration may cause conductor fatigue and eventually conductor breaks creating outages. Several measures may be taken in order to reduce aeolian vibration:

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

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

(3) Monitor vibration frequency and amplitude through current recording devices.

(4) 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.

(5) Add detuning pendulums to dissipate the mechanical energy.

5 DETERMINING THE BEST SOLUTION

a Factors to Consider. A primary factor in line conversion or upgrading is the total estimated cost of the proposed project. As described earlier, the estimated cost for each alternative method of line conversion should be carefully prepared. The estimated cost of a totally new transmission line and right-of-way should also be prepared for comparison of cost and public interest. The new construction alternative, even if it is more expensive, may be the desirable alternative if the additional service life of the line is considered to be worth the higher cost.

A second factor to consider is the time required to provide the needed system modifications. If the need for increased power requirements or system service is urgent and the time available to construct these system improvements is limited, then the construction alternative with the shortest timeframe may be the best alternative.

In considering system improvements, some factors can be somewhat subjective such as consumers' interests and public relations. Reliability of service and consumers' interests are obviously related. When system analyses conclude that a line conversion or upgrading is necessary to provide the desired reliability of service, the message should be communicated that consumers' interests are being supported. A proposal to utilize existing transmission line rights-of-way for needed system improvements could be an opportunity to promote good public and consumer relations in that the work would be done on existing rights-of-way with an effort to minimize impact to the public.

b Comparison of Alternatives. The purpose of information presented in this bulletin is to suggest alternatives for upgrading transmission lines. Comparison of the alternatives will require consideration of a number of different factors. It is important to prepare comprehensive cost estimates for each of the configurations to be considered for the upgrading project. Although minimizing construction costs is important, the need for system improvements may be so critical that more consideration may be given to selecting a higher cost option with a more compatible construction schedule.