Transmission Emergency Restoration Systems For Public Power

by

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1.0 Introduction

Due to the vast expanse of Public Power's operating territory in the United States and the variety of climatic conditions that their electrical transmission lines are subjected to, these lines occasionally fail due to natural disasters. These natural disasters are a result of mudslides, heavy ice, high winds or floods. In addition to these natural causes, transmission lines have also been sabotaged.

Failures can occur due to:

- **high wind loading,**
- **storm damage,**
- **rock slides,**
- **mud slides,**
- **erosion of foundations,**
- **corrosion of towers, or**
- **vandalism or sabotage**.

Total losses resulting from an extended outage of a key transmission line is site specific and can be considerable. Depending upon the extent and resulting consequences of the transmission line failure, monetary losses can occur to the utility, their customers and local or national governments. The total losses may be more than just the direct losses of the utility, especially if the utility is answerable to customers and government entities [1], [2].

A few of the utility's direct losses are:

- cost of restoration (typically inversely proportional to the outage time)
- higher grid losses on alternate transmission lines
- contractual penalties for non-availability of the transmission line
- possible higher generation cost or costs for power plant reductions or shutdowns

If the transmission line failure results in power shortages at load centers, additional losses might also include:

- lost revenue from customers
- contractual penalties from performance base rate-making structures

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If power shortages at load centers do occur, direct losses will also occur to customers. Some or all of these losses may need to be added to the utility's losses if customers can demand compensation. These losses include:

- plant closings and lost business
- shut down and restarting of process equipment including lost product

One of the most serious losses from a power shortage is reduction of the gross domestic product (GDP) for a region or the nation. When this occurred, it was estimated that lost Gross Domestic Product (GDP) could be "eighteen times the value of the power that was lost"[3].

While the cost to rebuild or restore a failed transmission line is inversely proportional to the restoration time, the total losses are directly proportional to the outage time. In almost all cases, it is best to restore the transmission line as quickly as possible.

It has been found that the one of the longest lead-time items for restoration of a damaged transmission line is the tower steel for the damaged towers. To reduce this lead-time, massive amounts of inventory would be required in order to have spare lattice towers available for every emergency situation. Most Public Power utilities have many different designs of transmission suspension towers and transmission tension or dead-end towers. An effective transmission restoration system should not only improve restoration time, but also reduce inventory levels.

This paper documents how Public Power utilities can utilize a standardized system for emergency restoration of damaged transmission lines for improving the availability and reliability of their transmission grid. Extensive planning and training in addition to the required emergency materials are required to effectively implement a successful transmission restoration system. Several of these standard transmission restoration systems have been introduced into the United States and elsewhere in the world since 1982. Since their introduction, there have been numerous examples of its use in restoring critical transmission lines in difficult areas. Examples of these restorations will be presented along with a methodology for determining if there is a need for a Transmission Line Emergency Restoration System (ERS).

2.0 Economic Justification for an Emergency Restoration System

In the past, decisions on the management of overhead transmission lines were frequently based on the qualitative judgment of experienced individuals. The guides produced by CIGRE SC22 WG13 are an attempt to quantify this analysis [1].

2.1 CIGRE Approach to Management of Overhead Lines

CIGRE SC22 WG13 has assumed that one of management's top goals in today's Investor Owned Utility environment can be stated as follows:

"To minimize the net present value of annual expenditures over a given investment period."

In general terms:

$$NPV = \sum_{i=0}^{i=n} \frac{C_i}{(1+r)^i} \qquad (1)$$

Where:

- NPV is the net present value of the annual expenditures
- n is the period taken into consideration, where i = 0 is an initial investment
- r is the discount rate
- C_i is the annual expenditures in year i, and where:

$$C_i = E_i + R_i. \qquad (2)$$

- E_i is the deterministic costs, or planned expenditures, in year i, and
- R_i is the probabilistic costs associated with risk of failure in year i.

Sometimes the investment period (n) to be considered is low, i.e. the power plant at the end of the transmission line will shut down in 5 years. Sometimes the investment period is much longer, i.e. the lifetime of the asset.

For an overhead transmission line (OHTL) asset all relevant cost factors (deterministic and probabilistic) have to be taken into consideration during the investment period. According to the discounting principle, costs in the far future are less important than costs in the early years.

The deterministic cost factors are called “Planned Expenditures” (E_i). They consist of normal operations and maintenance costs, planned outages and investment costs accounted for in the year or at the time they are incurred.

The probabilistic cost factor is called “Risk of Failure” (R_i), and is chance times consequences. When the event is an OHTL failure, the chance is the probability of occurrence of the event initiating failure, and the consequences are the totality of resulting consequences from the failure. This risk of failure (R) can be stated in its simplest form as:

$$R = [\text{probability of failure}] \times [\text{consequences}] \qquad (3)$$

Risk of failure during a time interval may be defined in economic terms, such as net present value (NPV), and is a function of time since both the probability of failure and the consequences will vary as a function of time. Risk may also be defined in non-economic terms if strategic policy or political issues are involved. For Public Power utilities the risk and consequences must also take into effect these political issues and the GDP issues as outlined in the Introduction (section 1.0).

From the above equation, it is obvious that risk can be controlled by either:

- controlling the likelihood of occurrence of the failure initiating event, or
- controlling the magnitude of the resulting consequences

In general, the risk of failure (R) is also a function of planned expenditures (E), i.e.:

$$R = f(E) \quad (4)$$

2.2 Example: Calculation of Consequences, Risk of Failure and NPV

Assume that a Public Power's (PUD) OHTL grid provides an average demand of 250MW to a commercial and residential load center. Assume also that the transmission structures of this grid were designed and built several years ago with a normal design criteria of a maximum wind and ice loading capability for a 50 year storm. Also assume that these towers have been maintained properly, have not degraded over the years, and thus retained their original strength. Therefore, the annual risk of failure to this transmission grid is 2% (annual probability of failure = 1yr/50yr). This also assumes that there is no external threats such as sabotage that would increase this percentage.

The consequence of a large storm exceeding the 50 year limit could very well be the collapse of several of the towers in this transmission grid resulting in a partial or total blackout of the commercial and residential load center, this would mean almost a complete halt to the economic activity of this area. Table 1 presents some of the assumed economic and demographic facts for this assumed PUD blackout affected area.

Table 1
Demographics

United States Demographics (Approximate)	
US GDP (1999)………………………………………………..	\$ 9.3 x 10^{12} / year
US Population (2000)……………..………………………………	275 x 10^6
Avg. GDP/person/day = (\$ 9.3 x 10^{12} / 275 x 10^6 x365days)...	\$ 92.65/day
US Energy Usage……………………………………………...	3.6 x 10^9 MWh
Avg. Load/person = (3.6 x 10^{12} kWh/275 x 10^6 x 365 x 24h)...	1.49 kW/person
Avg. number of persons per household in US……………………	2.61
Assumed Demographics for the Affected Area of the PUD	
Average Load Dropped by PUD…..……………….……………	250 MW
Rate Charged by PUD…………………..……………………..	\$ 40/MWh
People affected by blackout = (250MW / 1.49 kW/person)……...	167,000
Households affected = (167,000/ 2.61)…………………………...	60,000
Daily GDP affected = (167,000 x \$ 92.65/day)………………….	\$ 15,470,000/day
Approx. Non-recoverable GDP = (20% x \$ 15,470,000/day).…..	\$ 3,100,000/day

If we assume that a mechanical collapse of the transmission grid results in a blackout for this area, and by reviewing the various affected economic sectors (i.e.: service, retail and wholesale trade, manufacturing, government, etc.) of the PUD, we might assume that between 20-25% of the Gross Domestic Product (GDP) generated in this area would be non-recoverable and thus lost. This would result in approximately a $3.1 million/day loss in local GDP. In addition to these losses, the average lost income to the Public Power District assuming an average rate of $40.00 per MWh would be $240,000/day.

If the Public Power utility was not prepared to handle this natural disaster, it might be reasonable to assume that the blackout could remain for as long as one week. If so, there would be additional losses due to the approximately 60,000 households in this area where food and other perishables (valued at $100 each) would be lost. In addition we could probably assume that other legal and political costs would occur due to the length of time of the outage. For this example, assume approximately $10 million for these legal and political costs. The total assumed costs for a one week outage is summarized in Table 2.

Table 2
Estimated Consequences and Annual Risk without an ERS
(A 7-Day Blackout)

PUD Lost Revenue = (250 MW x $ 40/MWh x 24h/d x 7day)….	$ 1,680,000
Lost GDP at 20% Non-recoverable = ($ 3,100,000/d x7day)……	$ 21,700,000
Household Losses = (60,000 x $ 100)…………………………....	$ 6,000,000
Legal and Political Costs…………………………………………	$ 10,000,000
Total………………………………………………………..	$ 39,380,000
Annual Risk = (2%) x ($ 39,380,000)…………………………....	$ 787,600/yr

Since the annual probability of this outage is 2% , the Annual Risk is $787, 600/year.

If management were to purchase an Emergency Restoration System that adequately recovered this electrical system in one half the time (or approximately 3.5 days), the results in Table 3 might be the anticipated.

Table 3
Estimated Consequences with an ERS
(A 3.5-Day Blackout)

PUD Lost Revenue = (250 MW x $ 40/MWh x 24h/d x 3.5day)..	$ 840,000
Lost GDP at 20% Non-recoverable = ($ 3.1 x 10^6/d x3.5day)…..	$ 10,850,000
Household Losses = (60,000 x $ 100)…………………………....	$ 6,000,000
Legal and Political Costs (assume proportional to outage time)….	$ 5,000,000
Total………………………………………………………..	$ 22,690,000
Annual Risk = (2%) x ($ 22,690,000)…………………………....	$ 453,800/yr

If the Emergency Restoration System were to cost $400,000 and annual inventory carrying costs for a system were approximately 25%, and training costs of the crew were approximately $24,000/year, then the first year investment would be $400,000 with an annual planned cost of $124,000; however, the risk and the consequences for a prolonged outage would be reduced. The net present value (NPV) of a management decision to make this investment over 3 and 5-year periods are given in Table 4. From this table it can be seen that there is a positive payback within 3 years for an investment in an Emergency Restoration System that could reduce the outage time if this disaster occurred. Over a 5-year period the difference in NPV is over $400,000.

Table 4
Net Present Value Analysis (in $1000)

Management Options	Annual Expenditures			**NPV** In 3 Years (at 8% Rate)	**NPV** In 5 Years (at 8% Rate)
	Planned		RISK After Investment		
	Investment Year 0	Annual Cost			
Do Nothing	$ 0	$ 0	$ 787.6	$ 2,005	$ 3,088
Add an Emergency Restoration System	$ 400	$ 124 *	$ 453.8	$ 1,871	$ 2,665

* Increased annual cost for inventory carrying cost and training.

The numbers presented in Tables 1 through 4 are typical numbers for the United States. Every Public Power District would have different numbers. However, an analysis similar to the one above could be performed for each PUD.

3.0 Components of an Effective Transmission Restoration System

There are three essential elements that are critical for an effective transmission restoration system. These are planning, availability of adequate emergency materials and training.

3.1 Planning

Before purchasing emergency materials utilities should first determine which transmission lines are their critical lines, what might cause them to fail and how to best restore them.

Each utility must develop an emergency plan for a number of failure scenarios for their critical lines. In any transmission line emergency restoration, there are usually three possible courses of action. The first is to replace the damaged structure(s) with permanent structures(s). This might be the fastest and least expensive option if no foundation damage has occurred and if sufficient quantities of permanent structures are available.

The second option is to build a temporary bypass or overbuild transmission line using the ERS. An overbuild restoration utilizes the existing right-of-way to erect temporary structures while a bypass restoration utilizes additional right-of-way adjacent to the damaged line to erect emergency structures.

The third available option, and most likely the preferred option, is to use a combination of both permanent and temporary restoration structures to restore a line to service as quickly and efficiently as possible in the event of a major line outage.

3.2 Emergency Materials

In order to perform any unplanned emergency work, critical materials must be on hand and available for restoration, for example, each utility should stock standardized wire sizes in appropriate quantities including all terminations and splices. However, this is not always the case especially when it comes to towers.

Since most Public Power utilities have a variety of different types of transmission towers, maintaining extra permanent tower steel for various types and classes of towers would require an extensive financial investment in inventory. One plan that has proved effective is to maintain only tower steel for the heavier types and classes of permanent towers and to use the temporary modular structures for restoration of all other damaged towers.

These light weight modular aluminum restoration structures and their associated polymer insulators, hardware and guying components, have become known in the industry as the Emergency Restoration System (ERS). Unlike typical permanent transmission structures, an ERS design is not driven by optimization, rather by flexibility, providing many different structural concepts.

The IEEE Standard 1070-1995, "IEEE Guide for the Design and Testing of Transmission Modular Restoration Structure Components"[4] was developed to encourage emergency preparedness. The purpose of this guide is to provide a specification that can be used by electric utilities for acquiring transmission modular restoration structure components. This particular design would then be compatible with the modular restoration structures presently in use within the industry and would allow the highly successful plan of transmission mutual aid to be greatly enhanced.

These restoration structures can be used either for emergency, temporary, or permanent installations. During emergency installation of restoration structures the following may be considered due to their relatively short exposure time.

- Clearances, including climbing spaces may be reduced considering the voltage involved and the probable lack of live line maintenance from these structures. Clearance reductions involving the public require barriers and or markers to restrict access.
- Structural loading criteria should be selected appropriately and should be designed to withstand expected loads, including those imposed by line workers and construction equipment. Designing for the requirements of a permanent installation may severely penalize the restoration structures and unnecessarily increase restoration time.

- Less than optimal electrical and mechanical designs (i.e. overhead ground wire shield angle and conductor clamping) may be acceptable due to limited exposure.

During installation of restoration structures used as temporary structures, the installation should meet the requirements for permanent installations, except structural loading criteria should be selected appropriately and should be designed to withstand expected loads, including those imposed by the line workers and construction equipment.

During installation of restoration structures used as permanent structures, the installation should meet the requirements for permanent installations [5].

3.3 Training

A critical part of any restoration is the training of field and office personnel in the erection and construction of the modular structures and in the use of the computer programs used to analyze the structures.

The training should include actual field training at the Public Power utility's site, imparting first hand knowledge about the assembly of the modular structures, fixing of foundation plates, erecting of structures on the foundation, guying the tower with anchoring arrangement and stringing of conductor. Specific instructions should be given for installation of modular structures using gin pole and hydraulic hoisting equipment.

4.0 Examples of the use of Emergency Restoration Systems

Since the concept of a standardized ERS was introduced to utilities in 1982, approximately half of the utilities that have acquired the IEEE Standard 1070 ERS have experienced subsequent OHTL failures that gave them the opportunity to apply the ERS to real emergency situations. The following is a description of two of these utilities.

4.1 Los Angeles Department of Water and Power

Between 1984 and 1986 the 500kV DC Intertie was uprated by adding mast sections and lengthening guy wires without moving guy footings. On three different occasions sabotage has brought down these guyed towers. But the most extensive failures began in January 1988 when sixteen guyed and one self supporting tower collapsed due to high winds and cascading. Both of these incidences have been discussed previously and will not be discussed here [2], [6].

In February 1989 eight more guyed and two self supporting towers collapsed again due to high winds and cascading. From 1990 to 1992 the DC Intertie line was upgraded by reguying, moving footings and replacing defective hardware. This upgrade has effectively prevented any further cascade type failures. However, isolated failures have still occurred. All of these failures were quickly restored by LADWP crews. The following is a brief summary of each failure and their restoration.

4.1.1 1989 Storm Damage

At 1:20 p.m. on Saturday, February 4, 1989, high winds again damaged the DC Intertie. Eight guyed towers, one self-supporting angle and one self-supporting suspension tower were destroyed. The 2312 kcmil conductor and static wires in those 11 spans were too damaged to be reused, requiring the installation of approximately 16 km of 2312 kcmil conductor and 8 km of static wire.

LADWP personnel immediately activated their emergency response plan. Supervisors started the transporting of material and equipment to the soon-to-be established marshalling yard. A remote command post was set up at the marshalling yard to control: material and equipment delivered from Los Angeles; supply and personnel needs; lodging; meals; crew assignments; timekeeping; and progress logs.

By 3:30 p.m. on February 4, the available on-duty Transmission Section personnel in Valley, Victorville and Los Angeles reported for instruction. The major tasks were divided into two areas: the Owens Gorge line restoration and the DC Intertie restoration which included the assembling and erection of eight in-stock guyed suspension towers, as well as anchor installation, pad development, and erection of three IEEE Standard 1070 ERS structures to replace the two self-supporting towers that were not in stock.

The DC Intertie transmission line was "Okayed for service" on Thursday, February 16.

The permanent restoration of the DC Intertie was contingent on delivery of self-supporting tower steel, and the availability of DC Intertie. During the week of March 27, the northern crew transported the tower steel to the site and assembled the tower for erection, completing the restoration (see Figure 1).

Figure 1
Permanent restoration of a self-supporting DC Intertie tower. The de-energized conductors are supported in the IEEE Standard 1070 ERS, the Owens line is shown at the right.

4.1.2 1998 Aircraft Collision with a Tower

On September 20, 1998, at 4:38 p.m., a twin-engine Cessna sliced through conductors and hit and destroyed a self-supporting tower on the DC Intertie. The aircraft burst into flames along the right-of-way just 20m from a housing development.

LADWP crews immediately responded. They grounded and snubbed the conductor to prevent further damage, and a roadway under the line was barricaded for public safety. As a similar self-supporting tower was not available, LADWP crews installed a temporary IEEE Standard 1070 ERS structure. Due to the close proximity of residential houses, a steep down guy angle was required (Figure 2),. This was quickly analyzed using the emergency restoration structure structural analysis computer programs.

Figure 2
An ERS Chainette type structure is used to support the 500kV DC Intertie. Note the residential area to the left of the damaged tower and the steep down guy angle of the ERS.

Crews work around the clock using night lights. Conductor hardware and insulators were replaced on the adjacent tension tower and new conductor was spliced in and sagged. Spacers were installed and the line energized within 36 hours after the start of the outage.

4.1.3 The 1994 Northridge Earthquake

At 4:31 a.m. on January 17, 1994, the 6.6 magnitude Northridge earthquake hit Los Angeles. For the first time in the history of LADWP the entire city of Los Angeles went black. Only one transmission line was operational. A four circuit 230kV transmission tower, that normally brings 1500MW of power from the Castaic pump storage generating station north of the city, was completely destroyed, and several other towers were severely damaged. It was vital to restore one circuit of this line to support the black start procedures for the fossil fuel generating stations. Adding to the difficulty was the damage to several roadways leading to the site.

Within eight hours after the earthquake, LADWP Crews were able to bring in a crane and assemble a vertical string of polymeric insulators and conductor travelers to lift one circuit and allow it to be energized.

In order to support the load that was being brought back on line, two more circuits of this critical 230kV line needed to be restored. In order to accomplish this a special double circuit narrow right-of-way ERS structure made from the same IEEE Standard 1070 components was erected next to the energized circuit in the crane (see Figure 3). By the morning of January 19, all three circuits were energized.

Figure 3
One 230kV circuit at the left is supported by the crane; two other circuits are supported by an IEEE Standard 1070 ERS. This double circuit 230kV ERS structure was designed for a narrow right-of-way.

4.2 National Power Corporation of the Philippines

The National Power Corporation (NPC) of the Philippines is the major provider of electricity on the island of Luzon, Philippines, and is responsible for the strategic and rational development of the Philippine power grids. NPC's total generating capacity now stands at over 11,000 MW.

4.2.1 Northern Luzon: Lahar Flow from Mount Pinatubo Destroys Five Circuits

In 1991 Mount Pinatubo, a 5,842-foot (1,781-meter) peak in central Luzon, erupted explosively after lying dormant for more than 600 years.

In October 1995 after a heavy tropical storm, a large flow of lahar (a mixture of ash and water from Mount Pinatubo) destroyed five circuits of 230kV transmission lines that supplied the city of Manila. At that time these five circuits carried an average 1200Mw of power to Manila. Figure 4 shows a plan view of the five circuits affected by the lahar flow.

In order to stabilize the system and prevent low voltage problems in the city of Manila, NPC purchased an ERS in order to restore four of the five circuits in the lahar affected area. Figure 5 shows a double circuit herringbone emergency restoration structure used for an in-line restoration of the double circuit 230 kV

Mexico-Hermosa line. Figure 6 shows a by-pass restoration using two tangent chainette and two dead-end structures to restore one circuit of the San Jose-Hermosa 230kV transmission line. Installation of the ERS required adding wood cross arms beneath the ERS foundation in order to increase the bearing area of the foundation in the soft lahar. Swamp type screw anchors were installed to guy the ERS structure. The foundations were tied to these anchors using steel guy wire, to prevent them from moving during additional new lahar flows.

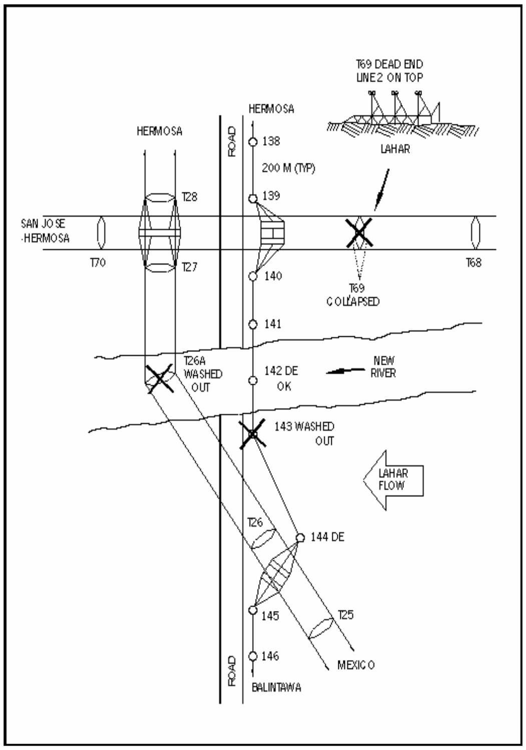

Figure 4

The drawing to the left shows the lahar flow from right to left. Tower T26A on the Hermosa-Mexico and tower 143 on the Hermosa –Balintawak lines were washed away. Tower T69 on the San Jose-Hermosa line collapsed. All other towers were buried in 6-8m of lahar mud.

Figure 5
The double circuit ERS suspension tower above and the two ERS tension towers were user to replace tower T26A on the Mexico-Hermosa line

Figure 6
The two ERS tension tower and two ERS chainette tower at the left, were used to bypass one circuit of the San Jose-Hermosa line. Tower T69 can be seen to the left. Another ERS bypass was eventually used to remove the energized circuit still attached to tower T69.

While an ERS system is typically meant to stay in service for only a short period of time, the unusual circumstances in the lahar affected area has required that these systems stay in place since 1995. Utilizing this technology, NPC has minimized the risk of line outages at their major load centers in Manila and provided a flexible restoration system capable of being moved as the lahar flow dictates.

4.2.2 Mindanao: Mud Slide Destroys Double Circuit 138kV Tower

In October of 1996, heavy rains caused a massive mud slide that completely destroyed a full tension tower No. 24 and damaged a cross arm on suspension tower No. 23 on the Abaga-Tagoloan double circuit 138kV transmission line in Mindanao, Philippines.

It was decided to restore both circuits with four horizontal-vee ERS structures. Due to the remote location, all ERS material had to be hand carried the last 2km to the site of the land slide. The four horizontal-vee ERS structures were built in five days using an aluminum gin pole and a small portable capstan hoist. The foundation of the ERS was placed on the sloping and unstable soil of the mud slide. It took an additional two days to transfer the conductor. Figure 7 shows one of the circuits transferred and the ERS for the second circuit under construction. Both circuits were re-energized in seven days.

Figure 7
The photograph at the left shows the first circuit to be repaired. The conductor is transferred from Tower No.23 to one ERS while the ERS in the In the foreground bypasses Tower No. 24, destroyed by a mud slide.

4.2.3 Mindanao: Vandals Cut Legs on a Double Circuit 138kV Tension Tower

Vandals cut two legs on a double circuit 138kV tension tower, No. 44, on the radial feed Kibawe-Davao transmission line. The tower listed at a 45° angle but did not topple. NPC braced the tower with several guy wires in order to maintain the energized line. This line is a radial feed into a major city and could not be de-energized. When one circuit was de-energized, a 50 megawatt diesel had to be started up in order to maintain voltage at the load center. To complicate matters, the tower was located on the top of a narrow ridge, and the only access to the site was by helicopter. See Figure 8.

Two ERS horizontal vee temporary towers were used to bypass both circuits around the damaged tower. With these in place, the damaged tower could be replaced, as the foundation was not damaged. Access to this site was difficult. All line crews and equipment had to be flown in by helicopter. It took one day and 18 trips (of 20km each) to get all personnel and equipment to the site. Helicopters were required to fly in supplies everyday and the line crew camped at the site. Approximately 25 linemen were involved. A gin pole and small portable capstan hoist were used to construct each ERS horizontal vee tower. The horizontal vee towers were offset longitudinally from the damaged tower approximately 2 to 4m on either side. Since the site was on top of a ridge, the back and side guys on the ERS horizontal-vees were two to three times longer than normal, as can be seen in Figure 9.

Figure 8
Vandals cut the legs of tension tower No. 44. This tower is located on the top of a narrow ridge. In order to keep the line energized, the conductor from one circuit was transferred to the ERS horizontal-vee structures while the other circuit was energized.

Figure 9
The photograph to the left shows the placement of the two ERS horizontal-vee structures directly on top of the ridge. Note that the dead-end insulators and hardware are in the span and to the left of the ERS in the foreground.

5.0 Conclusions

1. Public Power electrical utilities and their OHTLs are an essential part of the economy of the United States. If the service provided through these OHTLs is interrupted it will cause a loss in revenues to the utility and a much greater loss in GDP to the region or nation. If interruptions occur regularly, there will be a loss in investor confidence which will further damage the economic growth of the region. By their very nature, OHTLs are exposed to the risk of catastrophic failure from a wide variety of causes.

2. There are available technologies to limit the level of risk by controlling the probability of occurrence of the initiating event and/or limiting the total amount of losses that occur during the resulting outage period.

3. When OHTL failure does occur, rapid restoration is essential. Of the available technologies, the ANSI/IEEE Standard 1070, Emergency Restoration System (ERS) appears to provide the most positive and cost effective means to limit risk.

4. New CIGRE guidelines for the management of existing overhead transmission lines can be used to determine if an ERS is economically justified for a particular Public Power utility. In order to do so the probability of failure and the totality of all consequences from that failure must be estimated.

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