PLANNING AND TRAINING REDUCE RESTORATION TIME FOR DAMAGED TRANSMISSION LINES IN INDIA

by

L. N. Agrawal
Power Grid Corporation of India Ltd.
India

Paul. E. Erickson, P.E.
Lindsey Manufacturing Company
United States

Abstract

This paper documents how Power Grid Corporation of India Ltd. (POWERGRID) has utilized an emergency restoration system for improving the availability and reliability of their transmission grid. Extensive planning and training by POWERGRID has taken place since the introduction of the emergency restoration system in India in 1995. Since its 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 details of the training and planning by POWERGRID personal. The benefits from utilizing a standardized emergency restoration system will be presented along with some of the many lessons learned from POWERGRID's experience.

1.0 Introduction

The Power Grid Corporation of India (POWERGRID) was incorporated in October 1989 with the mandate of construction and operation of EHV, AC and HVDC transmission lines, substations, load dispatch centers and communications facilities in a coordinated and efficient manner. POWERGRID presently is operating and maintaining 31,250 ckt km of transmission lines, mostly 400kV and 220kV AC transmission lines and $\pm$500kV HVDC systems that criss-crosses the entire length and breadth of India. POWERGRID's network possesses a transformation capacity of over 27,875 MVA distributed over more than 56 substations.

By developing techniques like hotline maintenance, emergency restoration systems for transmission lines, special earthing systems, EHV equipment condition monitoring etc., POWERGRID successfully maintains the transmission system at availability of over 98% since its inception and is ranked amongst the top transmission utilities in the world.

2.0 History

Due to the vast expanse of India (almost 3 million sq. km of land area including flat rolling plains, deserts and the Himalayas) and the variety of climatic conditions, POWERGRID is subjected to transmission lines that occasionally fail due to natural disasters. These natural disasters are a result of mudslides, heavy ice, high winds or floods. Traditionally, restoration of these transmission lines was accomplished using available spare towers. The typical self supporting lattice type towers used in India were erected using derricks and in many cases complete new foundations had to be constructed. These operations were very time consuming and often resulted in prolonged outages. Many of the sites of these damaged transmission towers were difficult to access. The loss of these towers would sometimes result in backing down the generation and load shedding at industrial centers in India. When this occurred, it was estimated that lost Gross Domestic Product for India could be "eighteen times the value of the power that was lost". It has been calculated that the loss of income across India on account of loss of power is equivalent to between 1% and 3.5% of the Gross Domestic Product[1].

To compound this difficult situation, massive amounts of inventory were required in order to have spare lattice towers available for emergency restoration. When POWERGRID was incorporated in 1989, they inherited more than 100 different designs of transmission suspension towers and 100 different designs of transmission tension or deadend towers.

Realizing these facts, POWERGRID embarked on a program not only to improve restoration time but also to reduce inventory levels.

3.0 Rapid Restoration Plan

In 1994 and 1995, POWERGRID acquired ten sets of emergency restoration systems (ERS) that were built in accordance with IEEE Standard 1070[2]. These emergency restoration systems consisted of lightweight modular aluminum structural components, insulators and hardware, anchoring systems, computer software for design and field training. This system is used to build light weight guyed transmission towers, not the traditional self supporting type towers used in India;

therefore, in 1995 and 1996, linemen from all of POWERGRID's regions were trained on the use and erection procedures of the modular, aluminum emergency restoration structures. The actual emergency restoration systems were stored in six strategic locations throughout India at Itarsi, Dehgam, Bhabrawati, Dalhousie, Hyderabad and Patiala. At each of these locations, POWERGRID field personnel were trained on the procedures for installing anchors and erecting several different types of suspension, angle and tension type restoration towers for both 220 and 400kV. To complete the training, twin conductor was strung between the restoration structures and tensioned. Each field training class took approximately two weeks.

Additional training on the use of the computer programs supplied with the emergency restoration system was conducted in New Delhi for transmission line design engineers and operating engineers. This training consisted of reviewing all the design assumptions for emergency restoration, applying these design parameters to the various types of restoration structures and interpreting the results.

4.0 POWERGRID's Experience with Rapid Restoration using the ERS

The following are but some of the experiences of POWERGRID utilizing the ERS and some of the many lessons learned during their deployment.

4.1 Emergency restoration of 400kV Maithon-Jamdeshbur transmission line

On May 28, 1997, heavy wind and rainstorms caused five double circuit 400kV suspension towers on the Maithon-Jamdeshbur transmission line in West Bengal State to fail. The five suspension towers were located between two tension towers. All five suspension towers collapsed and the resulting collapse caused cross-arms on both tension towers to be damaged. A typical span between each suspension towers was 400m. The terrain was relatively flat, rolling terrain. Failure of these towers did not cause any outages; however, due to the increase loads on other redundant lines, it was critical to restore these lines as quickly as possible. The closest emergency restoration system was located in Itarsi, over 1500km away; therefore, it took 3 days to transport the material to the restoration site. During this time engineers from POWERGRID surveyed the site and decided to restore one circuit of the 400kV with the emergency restoration system. Using the computer programs provided with the system, the engineers were able to locate each of the ERS towers and their anchors. Installation of the anchors was then begun immediately. Salvaged materials at the site were used to replace the damaged arms on the tension towers. Crews from both Itarsi and Faridibad were used to erect the ERS towers. It was decided to use a bypass restoration scheme on this double circuit 400kV transmission line. It was also decided to string new conductor in lieu of salvaging the old conductor, which lay under the damaged towers. To build a bypass transmission line four (4) ERS tension towers and three (3) ERS horizontal-vee suspension towers were built paralleling the damaged transmission line. During temporary restoration of this line, a total of 5 days were lost due to bad weather and transportation. The line was re-energized on June 12, 1997.

With this ERS bypass transmission line in place, POWERGRID was able to repair the damaged foundations and erect permanent steel towers in approximately one month. Due to difficulty of access at this site, only manpower could be used to build the emergency restoration system and the permanent towers. To build the ERS bypass, a total of two groups of 15 linemen each were used. In retrospect, POWERGRID believes the line could have been restored 3 days earlier if the old conductor had been used instead of stringing new conductor.

4.2 Preventative maintenance on the Bairasul-Pong 220kV Tower 59

A massive earth slide in June of 1996 triggered by the saturation of soil due to spillway discharge resulted in the destabilization of tower number 59 on the Bairasul-Pong 220kV double circuit transmission line, which is located just above the slide area.

After reviewing the damaged tower the PGCIL decided the best approach was to reduce the load on the damaged tower. This would be accomplished by removing the outside circuit on the 12 degree angle strain tower and moving it to a bypass ERS tower located above tower 59 (see figure 1).

Prior to the restoration in September 1996, POWERGRID Engineers developed bills of material for the proposed bypass towers and began to move the equipment from storage areas to the tower site. The closest road and staging area was approximately 2.5 km from the tower site. All of the equipment had to be hand carried from the staging area (see Figure 2). The site conditions were very difficult. The original tower was constructed on steep sloped terrain. The average slope of the terrain towards the river was 40 degrees.

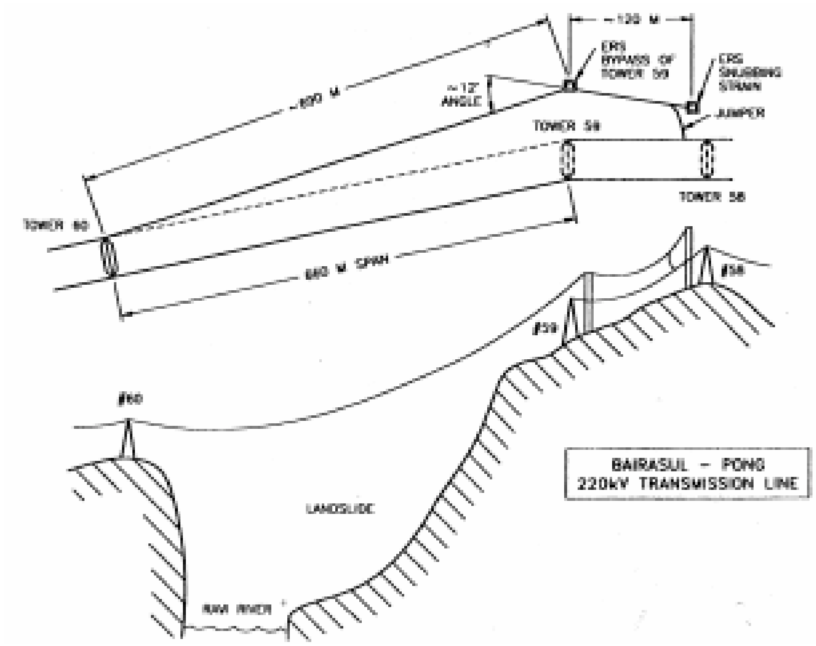

Figure 1
Profile of the Bairasul-Pong 220kV Towers 58, 59 and 60. Note the placement of the two ERS bypass towers.

Figure 2
Fourteen-foot ERS column section being hand carried to the construction site, along a typical trail.

POWERGRID Engineers determined that two, three phase tension structures would work best for the given site condition. The Engineers located the two foundation sites and the related anchor positions. Once the anchor plates were buried the actual construction of the towers began. ERS foundations were located and staked down, the ERS gimbal was bolted to the foundations and an aluminum gin pole or derrick, supplied with the ERS, was moved into place and each ERS tower erected (see Figure 3). Each tower was completed in approximately one day. Once both towers were completed, new conductors were strung between the ERS towers. An eight (8) hour outage was then taken to transfer the conductor from tower 59 to the ERS 12 degree strain tower. This was accomplished by using a block and tackle to lower the conductors from tower 59 to the ground and then pulling the conductors into position on the ERS towers. On September 20 the bypass transmission line was energized (see Figure 4).

The movement of material and construction of the bypass line took less than two weeks. Approximately 30 people were utilized in the bypass construction. The building of this bypass line was used by POWERGRID as a field training exercise. It is estimated that construction time could be reduced by 30% now that the linemen have been trained in the use of the ERS.

Figure 3
Erecting the bypass for Tower 59 using a Gin Pole and manpower to lift the ERS components.

Figure 4
Completed ERS bypass of towers 58 and 59.

4.3 Preventative maintenance on the Kawas-Nabasari 220kV double circuit river crossing

The Kawas-Nabasari double circuit 220kV transmission line connects the power plant at the Kawas substation site to a major load center at the Nabasari substation. Because of the heavy demand (400 megawatts are carried on both circuits), this line is critical and only one circuit can be taken out of service at a time.

Due to heavy flooding, the riverbanks on both sides of an 800m river crossing for the Kawas-Nabasari transmission line were badly eroding during the spring of 1997, endangering both 75m tall double circuit 220kV suspension towers that span the river. In April 1997, POWERGRID built three ERS single phase tension towers to the south of both endangered permanent towers to bypass one circuit. These six ERS towers were approximately 35m in height (see Figure 5). One circuit of the Kawas-Nabasari 220kV line was transferred to these six tension ERS towers.

Due to increased load requirements, in October of 1997, POWERGRID built two additional 3-phase deadend towers to the north of the endangered towers having a height of approximately 50m. These additional two ERS tension towers allowed the remaining conductor to be removed from the two endangered suspension towers. New permanent foundations were then constructed 25m further away from the endangered towers and the river banks thus allowing the 78m tall suspension towers to be dismantled and moved back on new foundations. In mid 1998, the conductors were restrung on the relocated 78m tall suspension towers.

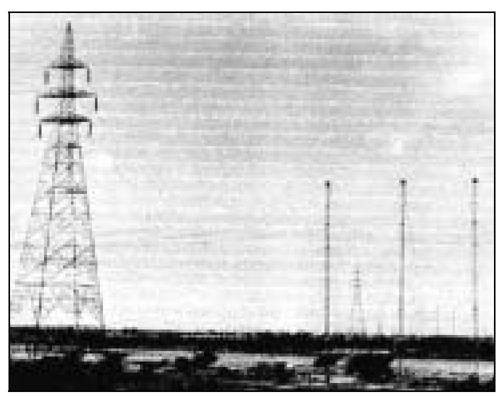

Figure 5
Three of the six 35m tall ERS river crossing towers used to bypass the 220kV Kawas-Navasari line.

All of this was accomplished utilizing only the existing tower steel (as they were moved prior to failure) and by taking only short outages on the critical Kawas-Nabasari 220kV transmission line using conventional methods and materials which could have taken up to 40 to 45 days. Loss of energy revenue of more than 1.5 million US$ was avoided through this effort.

4.4 Cyclone Damage in Gujarat State

On June 9, 1998 a severe cyclone hit the coastal area of Gujarat State on the Arabian Sea. Wind speeds were measured at 130 km/h and estimated to be much higher. The cyclone caused widespread loss of life and property in the coastal areas of Gujarat.

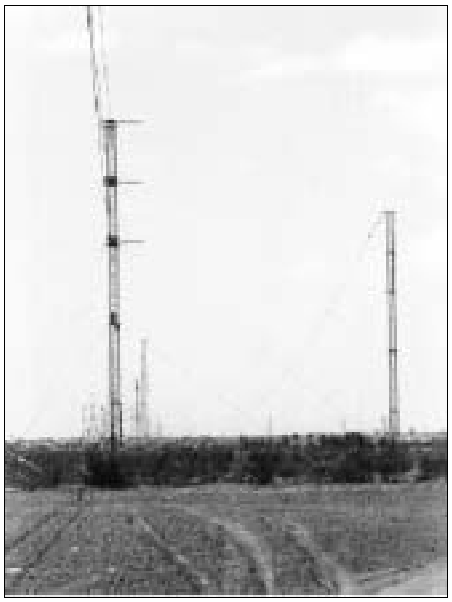

Figure 6
Temporary 220kV ERS tower used to restore the Panandru-Anjar line after the Gujarat cyclone.

This natural disaster could not have been predicted. Because of the high winds and severe flooding, several major transmission lines of Gujarat State Electricity Board were destroyed. Because of the much-needed requirement of power in the cyclone affected area, POWERGRID undertook the challenge of rapidly restoring several of the vital transmission lines. As an example, three towers were destroyed on the double circuit 220kV transmission lines from Panandru thermal power station to Anjar. These lines were rapidly restored using cranes and other heavy equipment along with POWERGRID's ERS. Power was restored on the first circuit on the 18th of June using four ERS towers while the second circuit was restored on the 23rd of June using another four ERS towers. These transmission circuits shown in figure 6, were restored in 5 to 6 days time under very adverse post cyclone conditions as opposed to restoration time

4.5 Cyclone Damage in Orissa State

On the early hours of the 29th October 1999, a massive and merciless cyclonic storm hit the coastal belt of Orissa killing thousands and displacing millions. Wind blew at a velocity of 250-260 km per hour and the sea rose up to 5-8 meters high with accompanying continuous rain sweeping hundreds of thousands of houses out of existence.

The worst affected districts ware Jagatsingpur, Kendrapada, Puri, Khurda, Bhadrakh and Balasore which were totally de-linked from the rest of the country. Bhubaneswar, the capital city, was in darkness and all possible links with the outer world were cut off by this Super Cyclone. Communication within the State was impossible due to complete ransacking of the electric and telecommunication wires and cables.

Figure 7
One of several ERS towers used to restore power after the Orissa cyclone.

Emergency restoration systems (ERS) and diesel generator (DG) sets were rushed by POWERGRID to help restore power in the severely affected coastal areas. Many of the lessons learned from the Gujarat cyclone were applied to the Orissa cyclone. Because of the standing water restoration of power was extremely difficult due to the difficulty of digging and anchoring of the towers. Even with this difficulty, POWERGRID crews restored all damaged transmission lines of 23kV and above (see Figure 7). Restoration of lesser lines was undertaken by Gridco, the major provider of electric power in the state of Orissa.

From these cyclone experiences POWERGRID is planning to strengthen its disaster management operations. POWERGRID chairman Mr. R. P. Singh stated " Delay in restoring power for a day means a loss of Rs 100 to Rs 200 crore (23 to 46 million US$)." Because of delays in moving emergency materials to the destination, POWERGRID is looking at purchasing heavy-duty helicopters for more rapid deployment.

These lessons were not lost on Gridco, as they have acquired two set of interchangeable IEEE Std. 1070 type emergency restoration systems, and have begun training in their deployment.

4.6 Restoration of Sabotaged Towers in the Kashmir Valley

Figure 8
Erection of the 400kV single circuit 15-degree tension ERS tower using manpower to pull the two conductors of the bottom phase.

A very recent example of successfully deploying ERS is on the 400kV double circuit Uri-Wagoora transmission line which carries the power from 480 MW Uri Hydro Project in Jammu and Kashmir. The entire Kashmir valley became almost dark after sabotage of two towers feeding power to the Kashmir Valley on 16th January 2000. Tower no. 268 on the 400kV Uri-Wagoora line (owned and operated by POWERGRID) and one tower on the 220kV Kishenpur-Pampore line (owned by PDD J&K). The only highway from Jammu to Srinagar was closed due to heavy snowfall. Thus, the ERS was transported in an AN 32 (Russian) Transport Air Force plane. The required material was transported in the above plane, which made several trips between Jammu & Srinagar.

Figure 9
Two views of the almost completed 400kV ERS tension tower showing the span over the double circuit 220kV line.

After transporting the ERS to location no. 268 of the 400kV Uri-Wagoora line, the actual work started on the 19th January under very adverse and cold and snow climate (see figure 8). One 15-degree in-line dead end structure (101 ft. high) supported by 18 guy anchors was used to bypass the damaged tower at location no. 268 (see figure 9). The two conductor bundle spans were 416m on one side and 300m on other side.

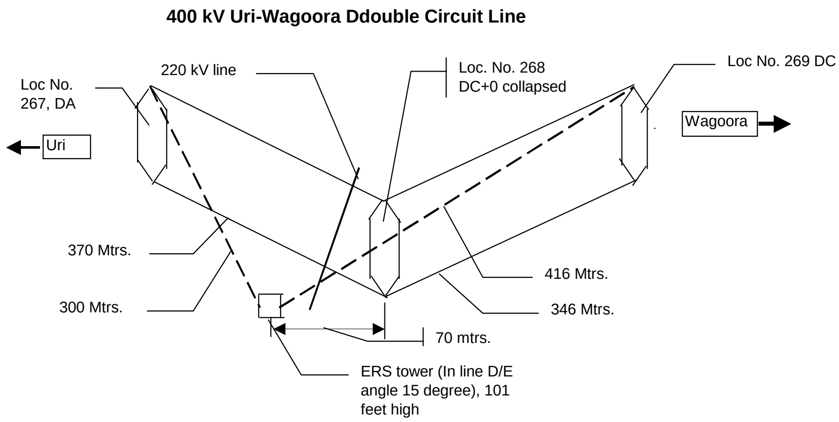

Figure 10
Plan view of the emergency restoration of Tower no. 268 of the 400kV Uri-Wagoora line.

There was also a 220kV line crossing between location no. 268 and 269, as shown in figure 10. For designing such an ERS tower, proper computer analysis and planning is essential, which was done by POWERGRID engineers. The restoration work was completed on 25th January and this circuit of the line was energized which could light the Srinagar area on the eve of Republic Day.

Similarly, the 220kV tower (66 meter tall), which also collapsed due to sabotage, was restored using the ERS. The type and configuration of ERS tower was similar to the ERS tower used for restoration of 400kV Uri-Wagoora line except the height of bottom conductor was increased by 14 ft. (total height of ERS tower became 115 ft.) to get adequate electrical clearance from 132kV line crossing beneath the 220kV line. In fact, it was not possible to achieve adequate clearance from the existing Double Circuit 132kV line. To achieve the clearances, the top earthwire and top phase conductors, were removed and the existing 132kV line was made to be operative as Single Circuit line which was sufficient to transmit the required load.

5.0 Conclusion

Even after carrying out condition monitoring and preventive maintenance, the break down of transmission lines cannot be ruled out, mainly because of natural calamities such as floods, cyclone etc. or unpredictable events such as sabotage. Restoration of damaged and collapsed transmission line tower can take a very long time which can vary from 3-4 weeks to 1-1.5 years depending on site conditions, availability of spare towers, requirement of pile foundation etc. Because of this POWERGRID has deployed the IEEE Standard 1070 Emergency Restoration System for restoration of collapsed towers. Manual erection of the ERS tower takes minimum of four days when restoring a collapsed tower. When hydraulic cranes or helicopters can be deployed, the restoration work can be done in 2-3 days time.

Since acquiring the emergency restoration systems, POWERGRID has used these systems many times for either emergency restoration on transmission line or maintenance activities. The results to date have met all of POWERGRID's expectations. As a result of POWERGRID's preplanning for potential emergencies on their transmission grid, significant savings have been realized by both POWERGRID and by the economy of India. From the experience to date, POWERGRID has modified their emergency restoration program in the following ways:

1. Emergency restoration materials have been made more decentralized throughout India in order to reduce deployment time.

2. POWERGRID has reduced inventory of permanent emergency towers to 5% to 10% of previous amounts, keeping only heavy tension towers in stock, thereby releasing critical funds for other projects.

3. POWERGRID plans to continue training with the emergency material including the erection of IEEE Standard 1070 emergency restoration towers thereby keeping field personnel and engineers well trained.

4. POWERGRID plans to reduce the time required to transport emergency materials to the job site by

utilizing heavy helicopters and other air transport equipment as required.

References

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[2] IEEE Guide for the Design and Testing of Transmission Modular Restoration Structure Components, IEEE Std 1070-1995, ISBN 1-55937-592-2.