Recent Experience Restoring Damaged Transmission Lines by National Power Corporation of the Philippines

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1.0 Introduction

The National Power Corporation (NPC) of the Philippines was established as a non-stock corporation of the Republic of the Philippines in 1936 and was converted into a stock corporation in 1960. NPC has its head office in Quezon City, Metro Manila, Philippines.

NPC is responsible for the strategic and rational development of the Philippine power grids and the construction of generating facilities, the latter in cooperation with the private sector, and its success is therefore a key factor in assisting the country's economic growth. NPC's Power Development Plan sets out the proposals to meet future power demand through the coordinated addition of generation and transmission facilities, and sets out detailed proposals for the development of new plants in conjunction with the private sector.

Keeping pace with the country's continuing economic growth and the rising demand for power has resulted in several power plants being put on line in the last few years. With this addition, NPC's total generating capacity now stands at over 11,000 MW.

The addition of new power plants has required expansion of the transmission facilities and strengthening of existing transmission lines to ensure effective and reliable distribution of power to customers (retailers and distributors). A total of 637 circuit-kilometers (ckt-km) was constructed throughout the country in 1996 alone. There are currently over 17,000 ckt-km of transmission lines owned and operated by NPC.

These overhead transmission lines play an important role in the operation of a reliable delivery system. At the same time, because of their length and exposure to the elements, these transmission lines are vulnerable to catastrophic failure from a variety of initiating events, such as extreme weather, floods, vandalism and even volcanoes.

2.0 The Challenge

The Philippines lies between about 5^o and 20^o N. latitude, entirely within the humid tropics. Monsoon climates (large wind systems that reverse directions seasonally) predominate, so most of the islands experience distinctive wet and dry seasons. Most rain arrives in short, heavy showers, often causing severe flooding. The northern and eastern sections of the Philippines are exposed to violent tropical storms called bagyos, or typhoons. These storms originate in the western Pacific Ocean, normally during the summer and early fall months. There are, on average, twenty-two typhoons each year. These typhoons are characterized by extremely powerful winds, typically in excess of 100 miles (160 kilometers) per hour, and very heavy rains. One such typhoon in 1911 deposited 46 inches (117 centimeters) of rain on the upland resort city of Baguio, on Luzon, within a 24-hour period--a world record. The winds, heavy rains, and their associated high seas and flooding can be very destructive.

The southern part of the Philippines, the area south of 8^{o} N. latitude, is nearly free of typhoons; however, prior to the 1996 agreement between the Philippine government and rebels who had waged a 24-year rebellion in the southern island of Mindanao, many transmission towers were vandalized.

3.0 The Solution

These and many other types of problems present a significant challenge to NPC to adhere at all times to its vision statement of "providing quality and reliable electricity". In order to increase the reliability of NPC's transmission system and reduce the risk of catastrophic and costly outages, NPC has utilized a new technology for rapidly restoring damaged transmission lines since 1995. This new technology involves the use of a standardized, interchangeable design of universal modular emergency restoration structures, specified by ANSI/IEEE Standard 1070 (Reference 1). With the addition of insulators, hardware, anchors, crew training and application software, this universal modular emergency restoration structure, has become known in the Philippines as the Emergency Restoration System (ERS).

4.0 Examples of Utilizing the ERS

The remainder of this paper will present several unique examples of how NPC is utilizing this new technology.

4.1 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. Along with associated earthquakes, heavy accumulations of ash, and heavy rains, this volcanic eruption took 330 lives and destroyed much property.

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 (Reference 2). At that time these five circuits carried an average 1200Mw of power to Manila. Figure 1 shows a plan view of the five circuits affected by the lahar flow.

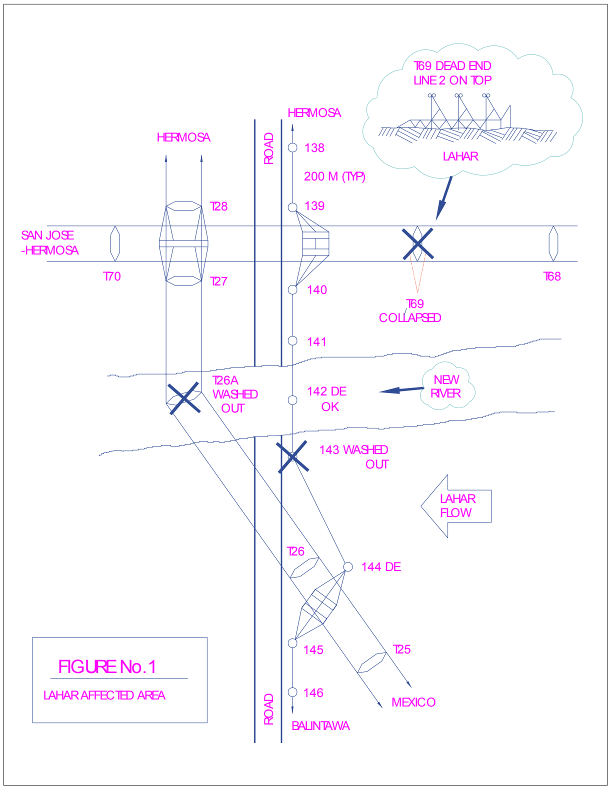

Figure 1

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.

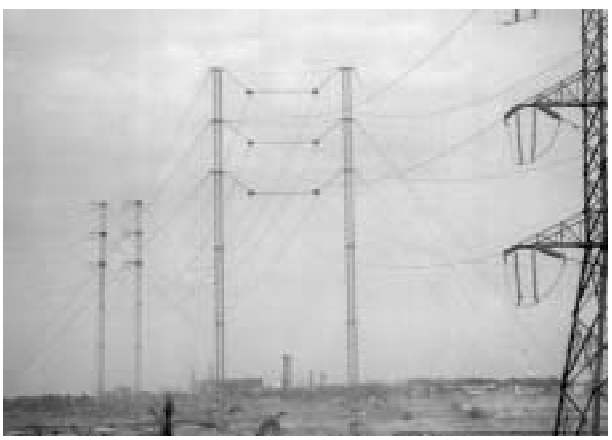

Figure 2

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 3

The two ERS tension tower and two ERS chainette tower 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.

The Northern Luzon power transmission group manager, Mr. Roque "Rex" Corpuz, area 6 manager, Mr. Wilfredo Mangulabnan and area 5 manager, Mr. Danilo P. Mercado, were given the responsibility of restoring the circuits. 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 2 shows a double circuit herringbone emergency restoration structure used for an in-line restoration of the double circuit 230 kV

Mexico-Hermosa line. Figure 3 shows a by-pass restoration using a deadend structure and two tangent chainette and deadend structures used 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.

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 for the last three years. 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 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. A plan and elevation of the failure site is shown in figure 4.

Mr. Roberto Marzo, transmission line manager, and Mr. Simeon Clerigo, Lanao area manager, were responsible for the restoration of this critical transmission line. 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 5 shows one of the circuits transferred and the ERS for the second circuit under construction. Both circuits were re-energized in seven days.

4.3 Mindanao: River flooding threatens previous wood pole restoration

In September 1997, swollen and flooding rivers threatened a wood pole bypass on the Aurora-Sta. Clara single circuit 138kV, a radial feeder in western Mindanao. A year earlier the flooding river had destroyed a river crossing tower No. 190. At that time a

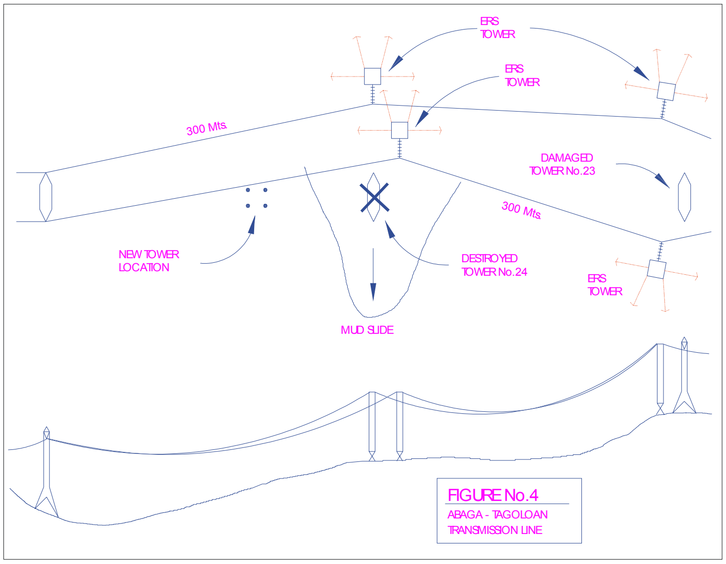

Figure 4

The drawing above shows the placement of the four ERS horizontal-vee structures. The mud slide destroyed tower No. 24 and damaged a suspension arm on tower No.23.

Figure 5

The photograph above 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 forground bypasses Tower No. 24.

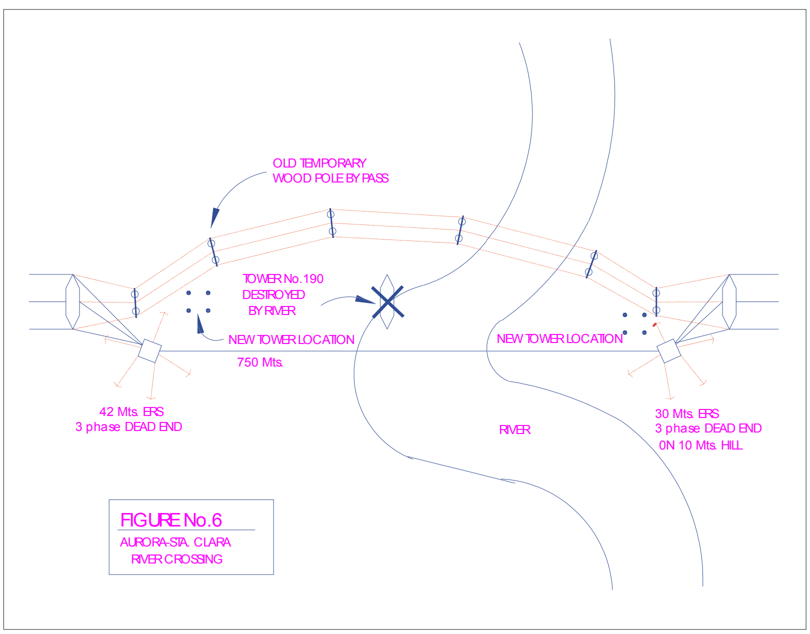

Figure 6

A 750m river crossing was constructed using two ERS tension structures. One was built 42m tall and the other, which was on a hill, only needed to be 30m tall.

Figure 7 `

All material had to be hand carried into the site, the aluminum ERS was carried through 3km of rice paddies.

Figure 8

The river was crossed by using the steel guy wire as a suspension cable and pulling the ERS across.

Figure 9

The photograph to the left shows the erected 43m tall ERS tension structure prior to string the conductor.

bypass was built utilizing six wood pole H-frame type structures. One year later the wood pole structures were failing for the same reason, the flooding and meandering river was washing out their foundations.

Mr. Ruben Conti, transmission line manager, and Mr. Lorrymir S. Adasa, North Western Mindanao area manager, were given the responsibility of building a new bypass that would allow construction of new permanent river crossing towers. It was decided to install two full tension ERS structures to span the approximately 750m river crossing. Due to the span a 43m tall ERS tension tower was required in order to maintain clearance. A plan view of the ERS bypass is shown in figure 6.

Access to site was through 3km of rice paddies. and the ERS equipment had to be transported across the river using temporary suspension cables and pulleys, as shown in figures 7and 8. An aluminum gin pole and a small portable capstan hoist were used to construct each ERS tension structure. Figure 9 shows final construction of the 43m tall ERS tension structure prior to stringing of conductors. Because of the critical nature of this radial feed transmission line, conductors were strung between ERS tension structures before taking a short outage to connect the slack spans to the permanent towers.

4.4 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. The plan and elevation of tower No. 44 is shown in Figure 10.

Mr. Ernesto Guinares, transmission line manager, and Mr. Emy Abellanosa, North Central Mindanao area manager, were given the responsibility of repairing this tower while always keeping one circuit energized. Their solution was to use two ERS horizontal vee temporary towers 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 5 to 10ft 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 11. In order to minimize outage time of transferring conductor from the lattice tower to the ERS

Figure 10

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.

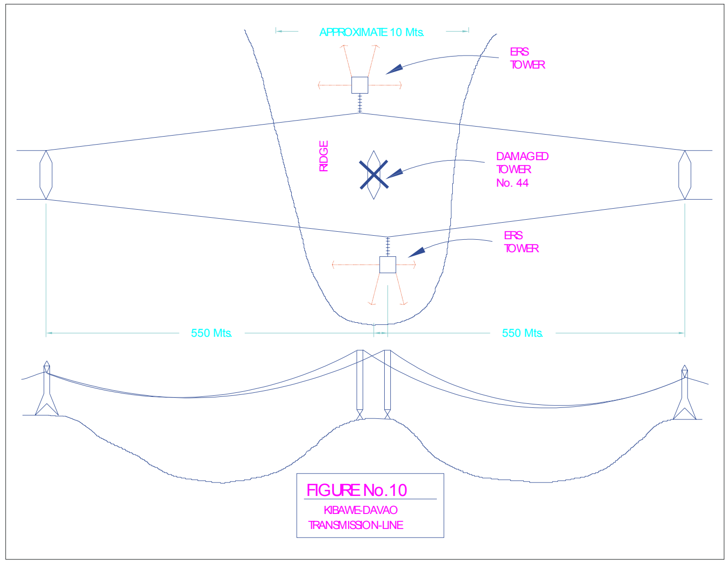

Figure 11

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 forground.

Figure 12

Mud slides destroyed tower No. 11 on the Palimpinon II-Amlan transmission line in the Visayas area. An ERS tension structure was erected to restore the second circuit.

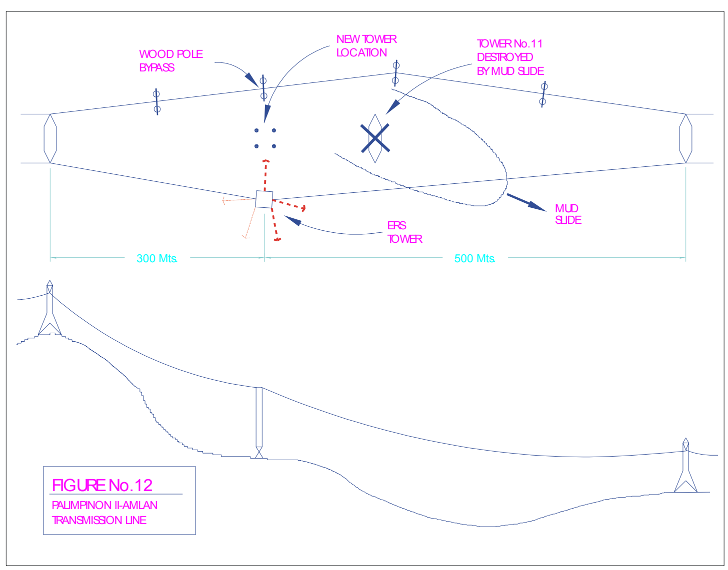

Figure 13

Visayas area field crews erected the ERS tension structure using only manpower and an aluminum gin pole. The erection of this structure was used as a training exercise by the field crews.

structure, the deadend insulators were tied together and the conductor with insulators were simply pulled to the side and attached to the ERS horizontal vee towers. The normal jumpers on the deadend hardware were tied to the insulator strings with small aluminum wires.

It took a total of four days to fly all the equipment in and erect the two ERS horizontal-vee towers. In addition, one day planned outage was given for each circuit to be transferred. The circuits were transferred one at a time over two days, therefore, one circuit was always energized during this restoration process.

4.5 Visayas: Floods destroy a double circuit 138kV suspension tower

Rain and heavy mudslides destroyed a 138kV double circuit suspension tower, Tower No. 11 on the Palimpinon II-Amlan transmission line, on the island of Negros, in the Visayas area of the Philippines. A temporary wood pole bypass had been constructed; however, this single circuit bypass was heavily loaded and was being threatened again by the mudslide.

Mr. Alfredo Arzaga, transmission line manager, and Mr. Manuel Terez, Central Visayas area manager, were given the responsibility of increasing the reliability of this line. As shown in plan and elevation view of tower No.11, figure 12, it was decided to erect an ERS full tension tower longitudinal, and outside of the mudslide area to carry one circuit of the 138kV line. The site was difficult to erect the ERS since it was located on a sloping hill. A gin pole was used to construct the ERS tension structure, as shown in figure 13. The line crews from the Visayas area used this for a training exercise and erected the ERS structure in only 2 days.

5.0 Conclusion

The Philippines is a chain of 7000 islands. The use of the Emergency Restoration System, ERS, has proven itself on both the large islands of Luzon and Mindanao as well as in the Visayas area. This is in large part due to the extensive field training conducted by NPC and the ERS supplier. From NPC's many applications of the ERS system, we have concluded that the ERS provides the most positive and cost effective means of limiting the risks of economic loss due to damaged transmission lines. By using a standard structure (ANSI/IEEE Standard 1070), which insures interchangeability, mutual assistance between the major transmission grids in the Philippines is possible. Structures from one area can be utilized in other areas, depending upon requirements.

NPC will continue to use the ERS, not only to restore damaged transmission lines, but is currently looking at using the ERS to help the construction of new lines in areas where right-of-way is difficult to obtain. The use of temporary bypass lines may be the only means to complete construction of vital transmission links on a timely basis.

References

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2. Joe. C. Pohlman, Dr. Keith E. Lindsey, R. "Rex" F. Corpuz, "Controlling the Economic Risk From Catastrophic Failure of Overhead Transmission Lines", ESMO '98 - 1998 IEEE 8th International Conference on Transmission & Distribution Construction, Operation & Live-Line Maintenance, April 26-30, 1998, IEEE Catalog No 98CH36230, paper 984-C-TPC-2.