LIFELINE DAMAGE: ELECTRIC POWER SYSTEMS
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The September 21, 1999 earthquake in Taiwan severely impacted Taiwan Power Company's ability to transmit and distribute electric power to its customers. The authors visited Taiwan Power Company on October 4 (3:30-5:00 p.m.) where Mr. Sheng-Nan Lin, Chief Engineer, and his staff briefed us on the state of damage, repair and restoration of the system. The highlights of the briefing are provided below, followed by the authors' interpretations, observations and tentative recommendations for short-term actions.

Regarding the 345 KV transmission system (Figure 1), a significant number of transmission towers suffered from structural problems, and were tilted and displaced causing a large number of transmission lines to fail (marked with an X in Figure 1). This in turn caused the initial blackout throughout the middle and north of Taiwan. In addition, 161 KV (Figure 2) and 69 KV transmission systems in the affected area also suffered from similar failures. Some substations and switchyards were also damaged, although the impact of their damage on the entire power system was much less direct than the failure of transmission and distribution systems. A notable exception was the two switchyards at Chung-Liau (the south yard and the north yard) that were both significantly damaged. In fact, the loss of 53 potential transformers, 46 lightening arresters, and many bushings on buses, in addition to other equipment, rendered the yards inoperational. The functionality of these two yards is pivotal to power transmission in Taiwan, as can be seen from Figure 1, and hence the functional loss of these yards was at least partially responsible for the post-earthquake power interruption.

As for repair and restoration, effort was made to transmit power from southern Taiwan to the north, which is highly dependent on the power generated in the south and elsewhere. This was done first by systematically completing emergency repair of transmission/distribution lines, substations and generating stations that were initially damaged, and then transmitting the power by bypassing the Chung-Liau switchyards. The rationing of electric power to industry customers was lifted at the time of this writing (October 5, 1999) and it is expected that restrictions imposed on residential customers will also be lifted on October 10, 1999, a few days earlier than targeted. Construction of the third 345 KV transmission line between Chung-Kang and Auh-Mei may be accelerated due to the government emergency decree that resulted from this earthquake. However, it was reported that other options are also under consideration by Taiwan Power, for example, to construct additional power generating plants serving primarily regional areas, which may provide a socio-economically more viable solution to the need of enhancing its network reliability and redundancy.

RECOMMENDATIONS FOR SHORT-TERM RECOVERY

The following observations and tentative recommendations seem to be in order for short-term actions:

1. A large number of transmission tower failures were apparently due to the fact that they are constructed, obviously by necessity, over rugged mountainous areas with steep slopes susceptible to...
ground failure. It might be well advised to design, construct, and retrofit tower foundations with this in mind.

2. Enhanced measures of seismic protection, including base isolation, for generating plant equipment, switchyards and substations appear to be equally important.

3. A systems analysis capability should be developed for both pre-event estimation of seismic reliability of transmission and distribution networks, and socioeconomic decision support to optimize post-event recovery and restoration processes.

While item 1 above would be an interesting joint project for the immediate future, the current MCEER-NCREE collaborative research is already addressing items 2 and 3.