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Study on the 729 blackout in the Taiwan power system

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Abstract

This study surveys the power failure that affected the Taiwan electrical network on July 29, 1999 (729 blackout). The failure left approximately 82.5% of consumers without power. The first part of the investigation describes the general system characteristics and the condition of the network before the incident. Meanwhile, the second part describes the events during and after the failure. The third part then summarizes the lessons learned from the power blackout. Finally, the last part presents conclusions.

Keywords: Blackout; Outage; Restoration; Relay; Breaker; Transient stability

1. Introduction

A series of major blackouts recently have occurred around the world. These blackouts caused considerable panic and heavy losses for local residents and businesses. Examples include, the power blackout in Israel on June 8, 1995 [1]; the blackout in the United State and Canada on August 14, 2003 [2]; the blackout in South London, UK on August 28, 2003 [3]; power failure in Eastern Denmark and Southern Sweden on September 23, 2003 [4]; and the nationwide blackout in Italy on September 28, 2003 [5]. For comparison, the causes for the blackout and final suggested remedial actions of five other countries and Taiwan are provided in the Appendix.

This work represents an essential part of a research project supported by the National Science Council of Taiwan, and was conducted from August 2001 to July 2002. This study examines the 729 blackout accident in the Taiwan Power System, analyzes the causes of the accident, and makes suggestions for improvement. Hopefully this study can provide a valuable reference for the electric power industry and academia.

1.1. General system characteristics

The Taiwan Power Company, commonly referred to as Taipower, is a nationalized company responsible for the generation, transmission and distribution of energy throughout Taiwan.

The Taipower network is an isolated system, and in the year of blackout comprised:

2881 kM of 345-kV circuits
4324 kM of 161-kV circuits
5818 kM of 69-kV circuits

Installed generation capacity was 28,480 MW, and the peak load during the summer of 1999 was 24,206 MW.

The commonly used N-1 design criterion was applied to 161-kV network design, and the commonly used N-2 planning criterion was applied to 345-kV network design [6]. Owing to the strong demand growth during the past five

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List of Abbreviations

E/S	extra high voltage station
G/S	generation station
EHV	extra high voltage
#3 Nuclear	Third Nuclear Power Plant
Lungchi(S)	Lungchi(South)
Lungchi(N)	Lungchi(North)
For relay	
E/M	electromechanical relay
S/S	solid-state relay
21	distance relay
50	instantaneous over-current relay
85	carrier or pilot-wire receiver relay
G	ground
N	neutral
CT	channel trip
GC	ground channel trip
PG	pilot trip
PΦ	pilot trip phase

years (approximately 6% annually), and the expected continuation of such demand growth for the next several years, Taipower plans to rapidly increase installed generation capacity as well as transmission and distribution capability.

1.2. System condition prior to the 729 blackout

The Taipower system is a longitudinal system with a net power flow from south to north under normal conditions. That is, the north part of the island is seriously deficient in power, the central part of the island has a slight power surplus, while the south has a significant power surplus. On the day of blackout, just prior to the blackout, the Taipower system had total generation of 20,097 MW, with a reserve capacity of 1270 MW. The power generation of the area north of Lungchi E/S was 12,100 MW, and the load was 15,505 MW; that is, a 3405 MW power deficit existed in the area. This power deficit was supplied by the south and flowed from Lungchi E/S through four circuits (that is Chiamin E/S circuits I and II of 1883 MW, Chiamin E/S Sea Line of 733 MW, and Chungliao(S) E/S Mountain Line of 789 MW) to the north part of Taiwan; a pump storage unit at the Takung pump storage power plant was operating in pumping mode consuming power of 250 MW. Fig. 1 shows the power flow immediately before the blackout.

On the day of the blackout, the off-peak system demand occurred at 6:20 a.m., and total power generation at that moment was 14,900 MW; on the other hand, peak system demand occurred at 13:48, and total power generation was 23,110 MW. The blackout occurred at 23:31, when total generation was 20,097 MW, around 87% of the peak generation (namely 23,110 MW) on that day [7]. Before the power failure, the system was operating well at normal frequency and bus voltage.

2. Events during and after the blackout

2.1. Description of the events that caused the blackout

On the day of blackout at 23:31, The Chiamen E/S–Lungchi(S) E/S Sea Line and Chungliao(S) E/S–Lungchi (S) E/S Mountain Line tripped because a common extra-high-voltage electricity tower located near Lungchi suddenly collapsed, causing a ground fault which then led to successive relay trips. Following the trips, the Taipower system was separated into two systems at Lungchi, and the surplus power from the south system could not be delivered to the north system where power was insufficient. In the north system, a serious power shortage developed, further reducing system frequency. Low frequency protection devices were then actuated to cause the blackout of the north system, which had tripped the generators. In the south system, the frequency increased owing to the surplus power, causing the tripping of the first and the second generation units of the Third Nuclear Power Plant (#3 Nuclear), the five combined-cycle generation units of the Singda Power Plant, the fourth generation unit of the Talin Power Plant, and the first and the second combined-cycle units of the Nanhuo Power Plant. Other generation units maintained normal operations.

After the blackout, according to the failure-sequence record obtained by the Energy Management System installed in the Central Dispatch Room of Taipower, the tripping of the circuit breakers and the resulting protection relays are listed in Table 1 and illustrated in Fig. 2 [7].

Following this tripping of a series of breakers, the system became separated into two disconnected systems at Lungchi, the north system and the south system. Power from the south could no longer be delivered to the north. Moreover, the central and northern part of the system created an additional problem of low voltage profile. Owing to the serious deficit in the power supply, northern and central Taiwan experienced a power blackout regardless of the load shedding resulting from under-frequency protection relays.

2.2. System restoration

Power restoration began with starting a hydraulic unit of 12.8 MW at Shuili at 23:45, July 29. Within one hour after the blackout, the primary EHV station located in central Taiwan, Chiamin E/S, was energized at 23:52, July 29. Subsequently, at 00:33 and 00:36 a.m., July 30, two