

REPORT
ON
SYSTEM DISTURBANCE
JUNE 28, 1974

FLORIDA POWER & LIGHT COMPANY

JULY 19, 1974

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TABLE OF CONTENTS

	<u>PAGE</u>
INTRODUCTION	1
SUMMARY	1
DESCRIPTION OF THE DISTURBANCE	2
SERVICE RESTORATION	3
SYSTEM CONDITIONS	4
CORRECTIVE MEASURES	5

LIST OF FIGURES

	<u>FIGURE</u>
AREA AFFECTED	1
SIMPLIFIED CARRIER CIRCUIT	2
TURKEY POINT PLANT 240 KV BUS VOLTAGES	3
DADE SUBSTATION FREQUENCY	4
SYSTEM LOAD	5
LOAD, GENERATION AND INTER-AREA FLOWS	6
UNDERVOLTAGE AND REACTOR COOLANT SYSTEM TRIPPING LOGIC DIAGRAM	7

LIST OF TABLES

	<u>TABLE</u>
SUMMARY OF RELAY AND BREAKER OPERATIONS	1
LOAD DATA	2
SUMMARY OF GENERATING UNIT OUTAGES	3

INTRODUCTION

Florida Power & Light Company (FPL) experienced an electrical power system disturbance on June 28, 1974, which resulted in the separation of the southern part of the system from the north. Load was shed due to the underfrequency that existed during the disturbance.

High-speed oscillograph records, recording charts and other data have been examined in order to reconstruct the sequence of events that occurred. This report documents the sequence of events and the corrective measures being taken.

SUMMARY

At 10:42 p.m., June 28, 1974, a phase to ground fault developed on the Laudania-Port Everglades 240kV line. Due to a malfunction of a protective relay, isolation of the faulted line was slow.

The delay in clearing the fault caused the system to become unstable. The fault and the consequent power swings resulted in low voltages over the southern part of the system. Protective relays operated to separate the portion of the system south of West Palm Beach from the rest of the system. (See Figure 1). Turkey Point No. 3 and No. 4 reactors were tripped by reactor protection. This 1425 MW loss of generation caused the frequency to drop rapidly. Underfrequency relays operated to shed approximately 70% of the load in the affected area. The frequency recovered and the system was tied back together in 11 minutes. Service restoration was complete in 56 minutes except for a few isolated cases.

DESCRIPTION OF THE DISTURBANCE

On a dead-end structure of the Laudania-Port Everglades 240 kV circuit, nine structures from Port Everglades Plant, a string of insulators supporting a jumper flashed over on B phase. The Laudania end opened at 21 cycles with a Ground Pilot target. The Port Everglades end opened at 41 cycles with a Ground Time target. The Laudania end reclosed at 43 cycles, re-establishing a B phase to ground fault. The Laudania end opened at 49 cycles to clear the fault from the system.

The fault persisted for 41 cycles because the contact of the carrier stop relay (GDX) in the primary directional ground relay (CLPG) scheme did not close to stop the carrier signal from Port Everglades. A simplified diagram of the carrier circuit is given in Figure 2.

The delay in isolating the fault caused power swings. The system split south of Ranch at 50 1/2 cycles, was tied back together at 64 1/2 cycles, by automatic reclosing, and split again at 79 1/2 cycles. The relay and breaker operations are summarized in Table 1.

At approximately 60 cycles Turkey Point No. 3 and No. 4 reactors were tripped by reactor coolant flow protection devices. The most probable cause of the reactor trip was the operation of the undervoltage relays on the 4 kV auxiliary bus. These relays are set to trip at 70% of normal voltage with a 1 second time delay. A plot of the Turkey Point 200 kV bus voltages is shown on Figure 3. Low reactor coolant flow, resulting from the low voltage, could also have tripped the reactor. The low flow set point is 90% of full flow with no time delay. The protective devices



at Turkey Point functioned in the conservative manner intended to protect the nuclear reactors. A simplified diagram of the protective devices is shown in Figure 7.

The generation lost at Turkey Point was 1425 MW. The loss of generation caused the frequency to decline to about 54.5 hZ at a rate of 5 Hz/second. Area frequency as recorded on the Dade Substation oscillograph is shown in Figure 4.

The underfrequency relays in the affected area operated between 59.2 Hz and 58.5 Hz to shed load. A total of 2250 MW of load was lost by load shedding, low voltage and low frequency. Load data is given in Table 2. The frequency recovered at a rate of about 1.5 Hz/second. The frequency was back to 60 Hz at 8.5 seconds, overshooting to 61.3 Hz at 10 seconds.

Lauderdale No. 4, initially carrying 115 MW, was tripped at 4 sec, 19 cycles by turbine thrust bearing protection. When the frequency increased to 62.5 Hz the auxiliary governor acted to reduce speed on the machine by closing the intercept valves and control valves. Closing of the intercept valves before the control valves caused the intercept valve interlocking relay to trip the turbine to prevent excessive thrust from developing. Closing of the throttle valves with the generator breakers closed initiated the unit lockout which tripped the generator. Cutler No. 6 initially carrying 72 MW, was tripped at 20 seconds by the operator.

SERVICE RESTORATION

The Power Coordinators quickly identified the affected area and proceeded to reconnect the system. The isolated portion was resynchronized at 10:53 p.m. with the closure of the Broward-Ranch 240 kV line. Distribution circuit restoration was begun immediately by use of supervisory

control and progressed rapidly, as shown in Figure 5. Restoration was complete except for isolated cases in 56 minutes.

There was no damage to any of the generating equipment or to the nuclear reactors. All units were returned to service as soon as safety inspections were completed. Duration of generating unit outages is given in Table 3.

SYSTEM CONDITIONS

Prior to the disturbance, the system load was 4870 MW, including 3210 MW in the affected area. System generating capability on line was 5486 MW. The capability in the affected area was 3458 MW. The system spinning reserve was 616 MW. Inter-area flows were well within limits. Area load and generation data and inter-area flows prior to the disturbance are given in Figure 6.



CORRECTIVE MEASURES

1. The contact of the carrier stop relay in the primary directional ground relay scheme of the Port Everglades-Laudania 240 kV line at Port Everglades Plant was adjusted. The line was returned to service on June 29.
2. At Turkey Point Plant on Units 3 & 4 the following measures are being undertaken:
 - a. To improve unit trip analysis:
 - a-1. A digital data processing system which includes discreet time sequence of events capability is now on order and should be operational this year.
 - a-2. A continuous recording high-speed oscillograph is on order for the nuclear units to record events prior to, during, and after a disturbance.
 - a-3. The auxiliary bus undervoltage relay operation indication to the "first-out" annunciator system is to be reconnected to give indication after the time delay relays have timed out.
 - b. To provide greater system reliability the nuclear safety committee will review the settings for the auxiliary bus under voltage reactor trips to determine if they can be reduced from 70% to 62% which is within the 60% setting allowed by the Technical specifications. The setting had been lowered in January 1974 from 75% to 70%, an adequate setting on the basis of analyses of system fault conditions. Subsequent faults on the transmission lines from Turkey Point had not caused reactor tripping.
 - c. The existing set points have been tested and found to be as follows:



Device	Unit	Set point	As found	
			min	max
4 kV undervoltage reactor	Volts	83	82	84
Trip relay	%	70	69.2	70.8
4 kV undervoltage reactor	cycles	60	61.3	62.5
Trip time delay				
Reactor Coolant Flow				
normal	%	100	97.0	100.8
trip point	%	90	89.5	90.5

3. Relays for out-of-step detection and blocking of reclosure of lines tripped due to stability swings are to be installed on 40 major line terminals. Engineering is in progress and is expected to be completed in six to nine months.

4. Power transfer capability between the West Palm Beach and Miami-Ft. Lauderdale areas has been increased by decreasing the second zone relay reach at Broward on the Broward-Ranch #1, 240 kV line. The mid-breaker of the Broward #1 and Ft. Myers line terminals at Ranch Substation is being operated open as an interim measure until transfer trip relays are installed at Ranch in December 1974 to provide local breaker failure protection. The transmission capability into the south area will be further strengthened by the addition of the Broward-Ranch #2, 240 kV line, scheduled for completion in August 1974, and the Ft. Myers-Lauderdale 240/500 kV line, scheduled for service in December 1974.

5. A Task Force has been formed with members from System Operations, System Protection, Power Resources, Engineering and System Planning to continue investigation of the disturbance and follow through with corrective measures. Some specific means under investigation include:

- a. Trip of Turkey Point No. 3 and No. 4 reactors by reactor coolant flow protection
- b. Implementation of measures to block reclosing following



out of step trip

c. Studies are being made to determine the requirements for high speed ground back-up relaying to assure that faults will be cleared fast enough to prevent system instability.

d. Trip of Lauderdale Unit 4

e. Governor response

6. The turbine manufacturer has been contacted regarding the loss of Lauderdale No. 4 unit to provide assistance in correcting the conditions which led to loss of the unit.

7. The relays (GCY) which operated at St. Lucie were tested and two were found to have defective capacitors in the potential circuit. These relays were repaired and returned to service.

8. Relay settings are being examined for proper coordination on the affected lines. Preliminary analysis indicates correct coordination for the ground backup relays presently in service.

FIGURE 1

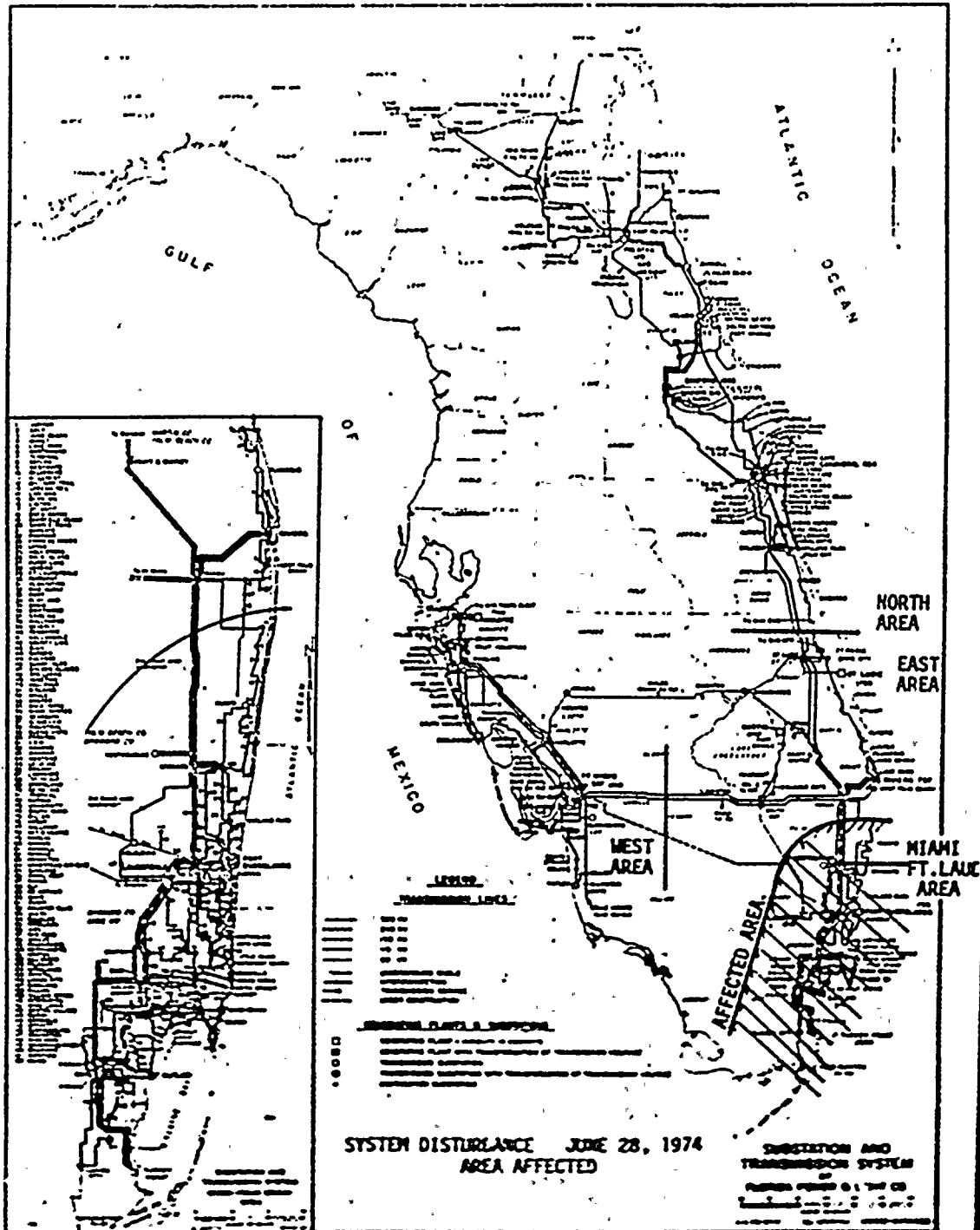
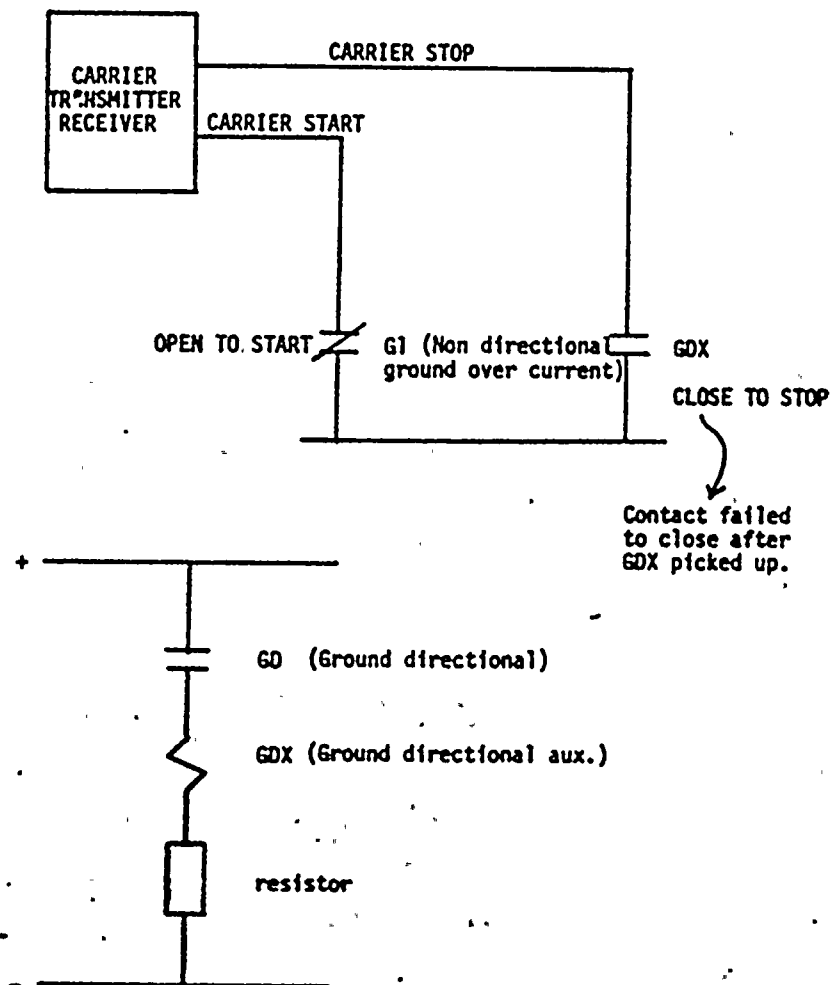
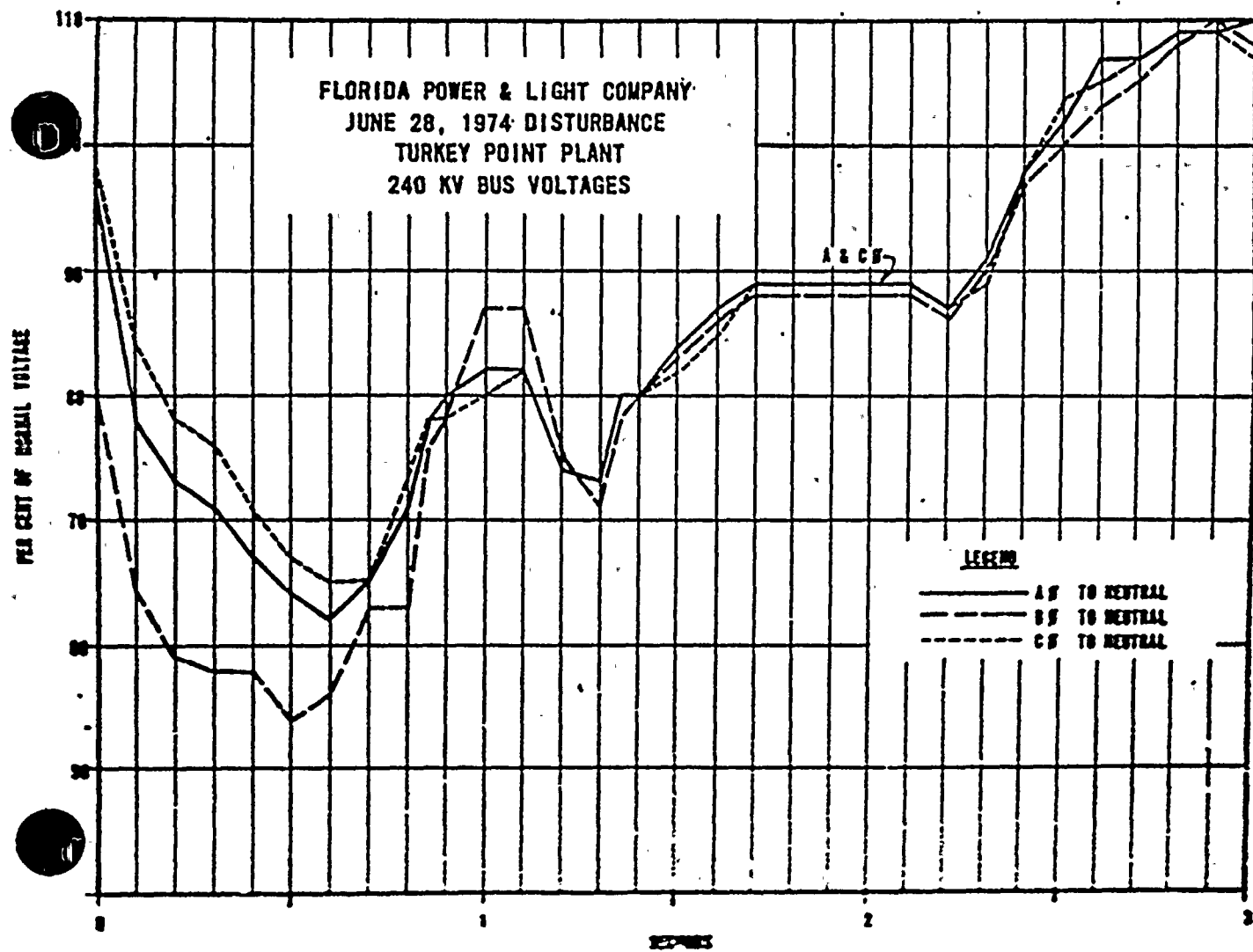




FIGURE 2
SIMPLIFIED
CARRIER CIRCUIT

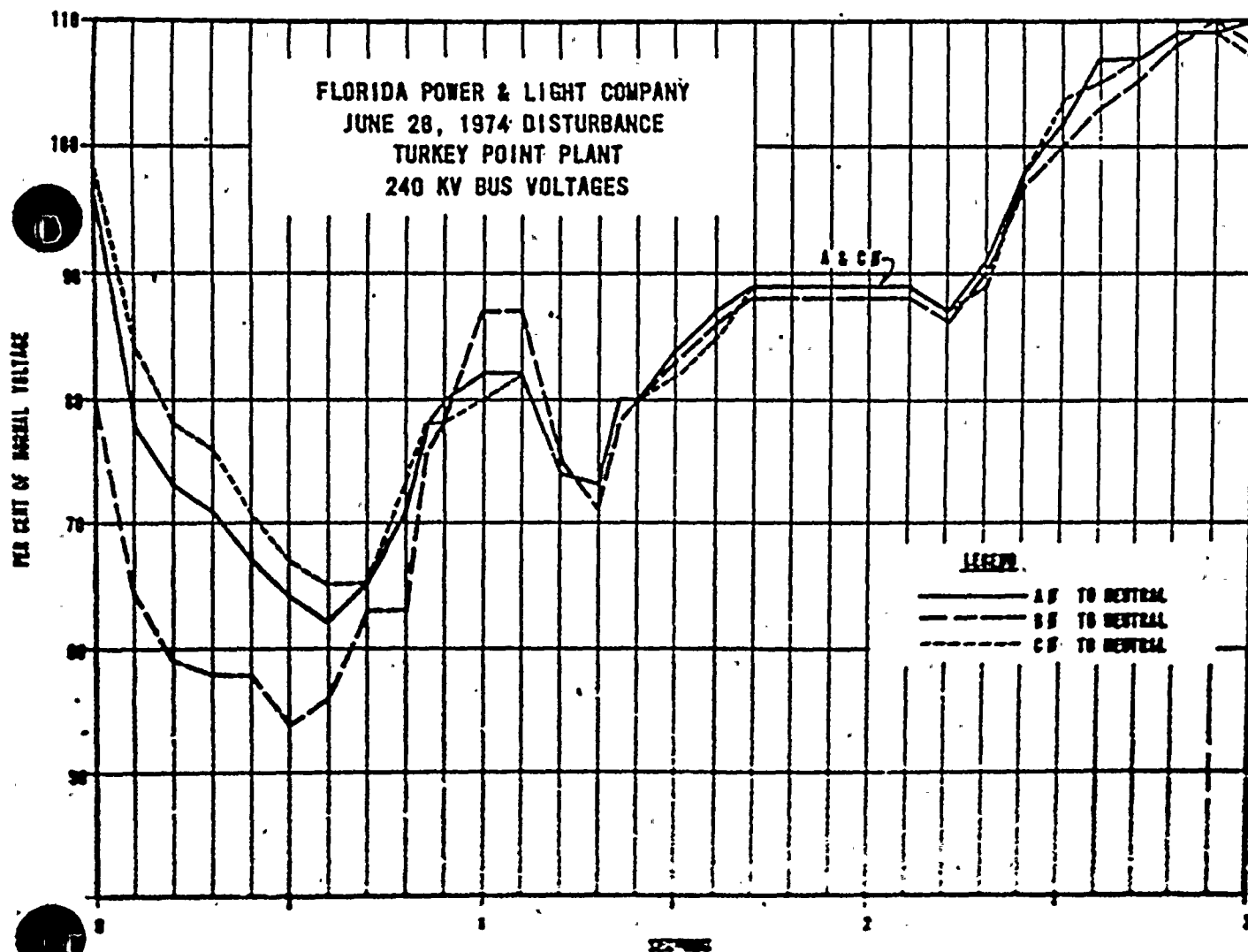


FLORIDA POWER & LIGHT COMPANY
 JUNE 28, 1974 DISTURBANCE
 TURKEY POINT PLANT
 240 KV BUS VOLTAGES



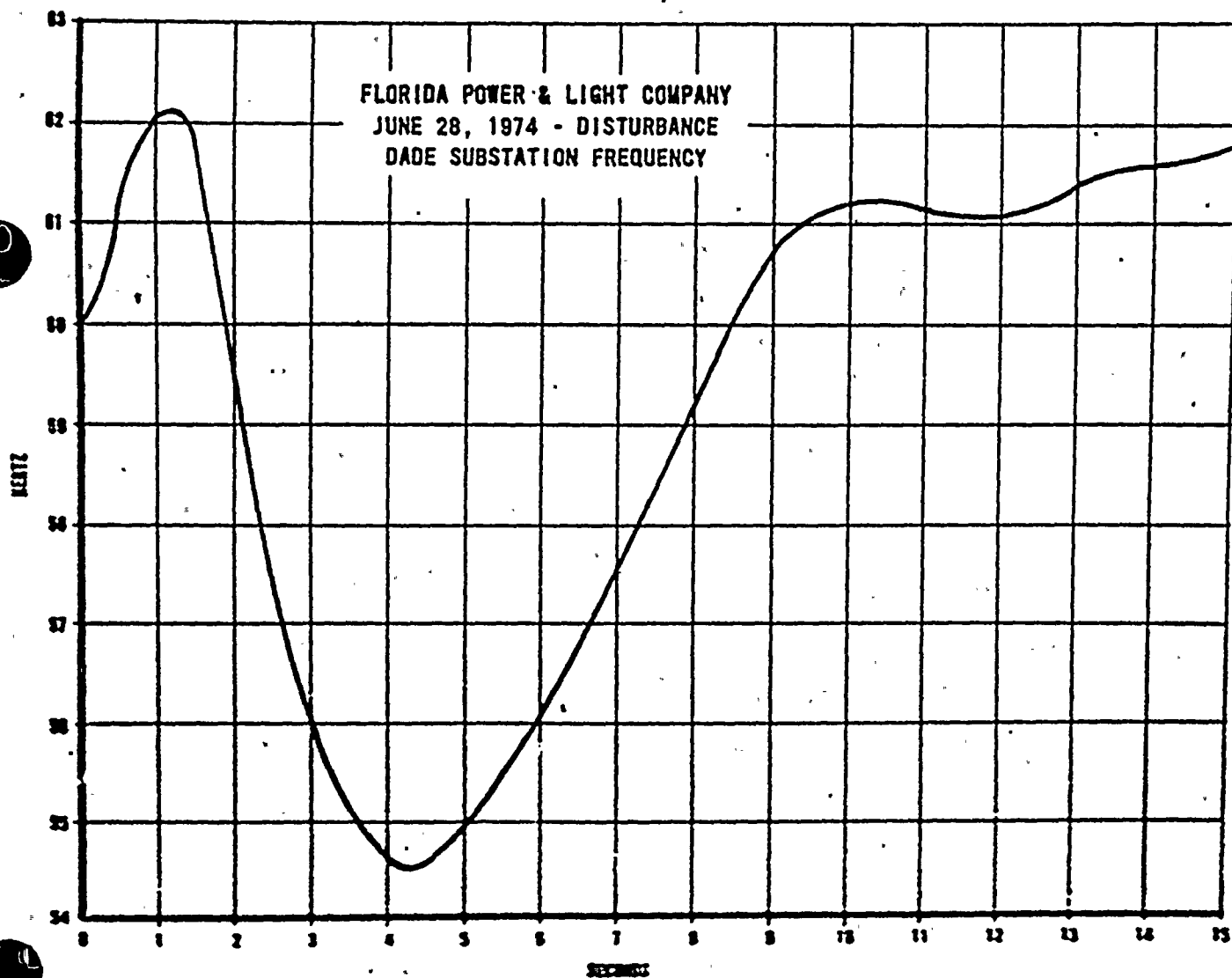
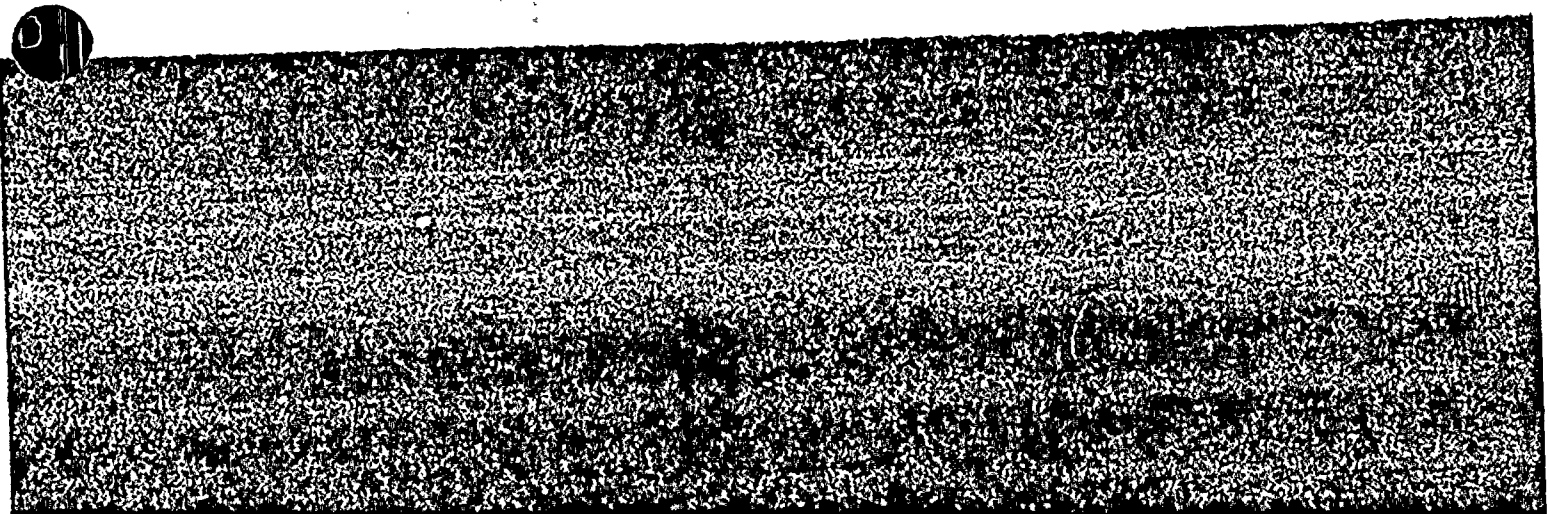


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TURKEY POINT PLANT
240 KV BUS VOLTAGES



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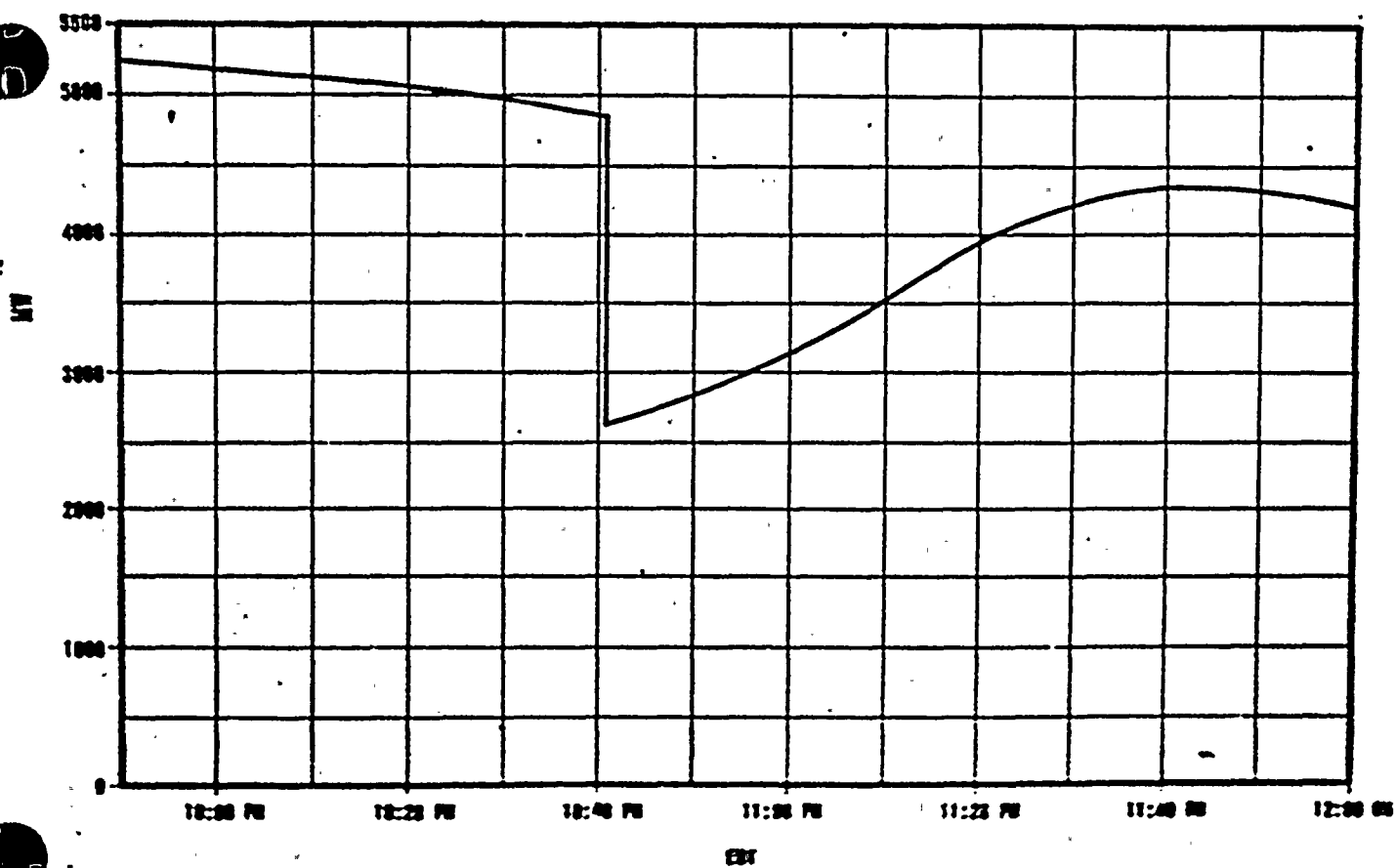




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FIGURE 5
FLORIDA POWER & LIGHT COMPANY
JUNE 28, 1974 DISTURBANCE
SYSTEM LOAD



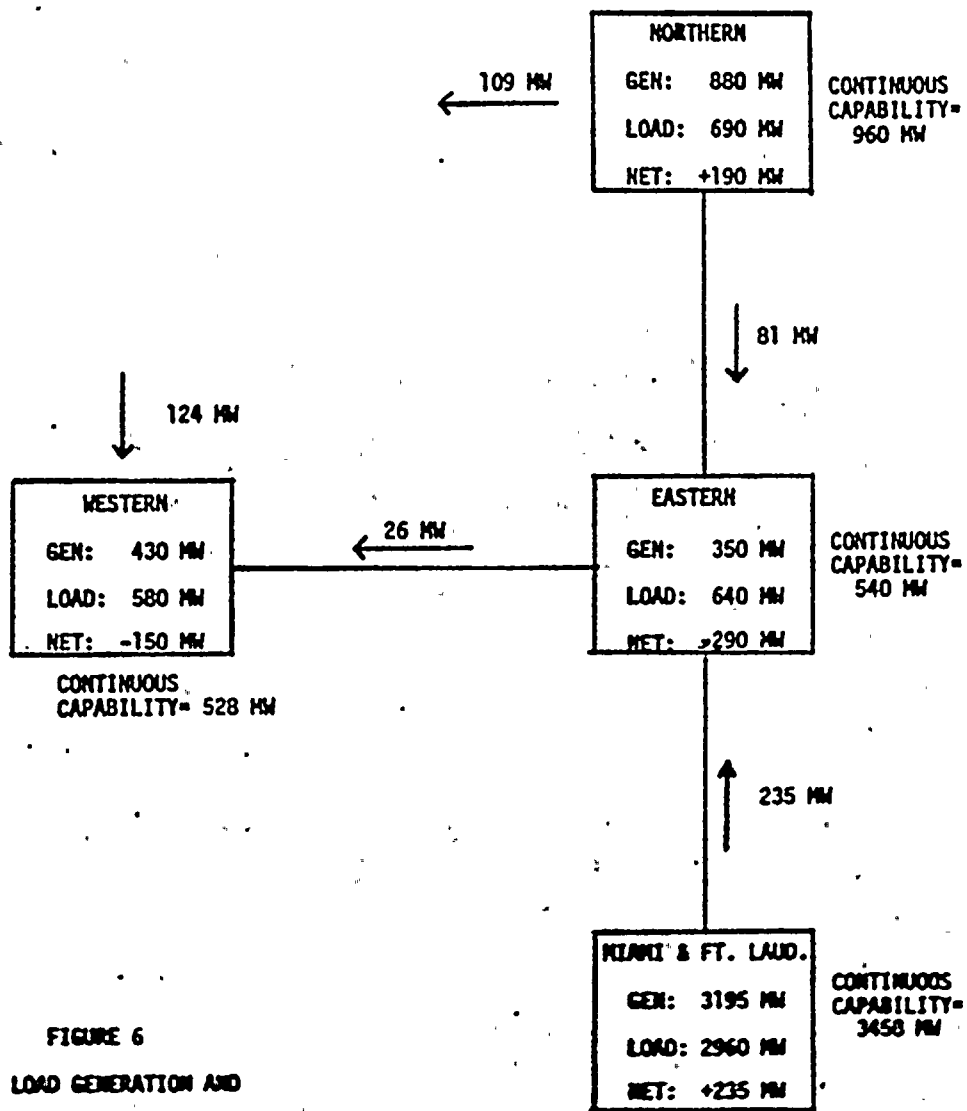
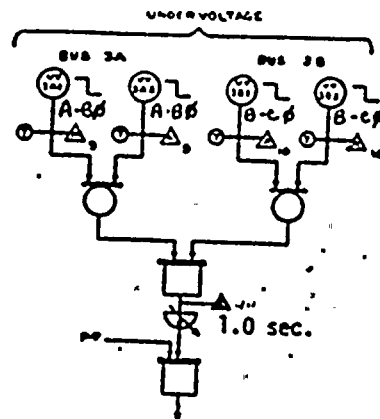


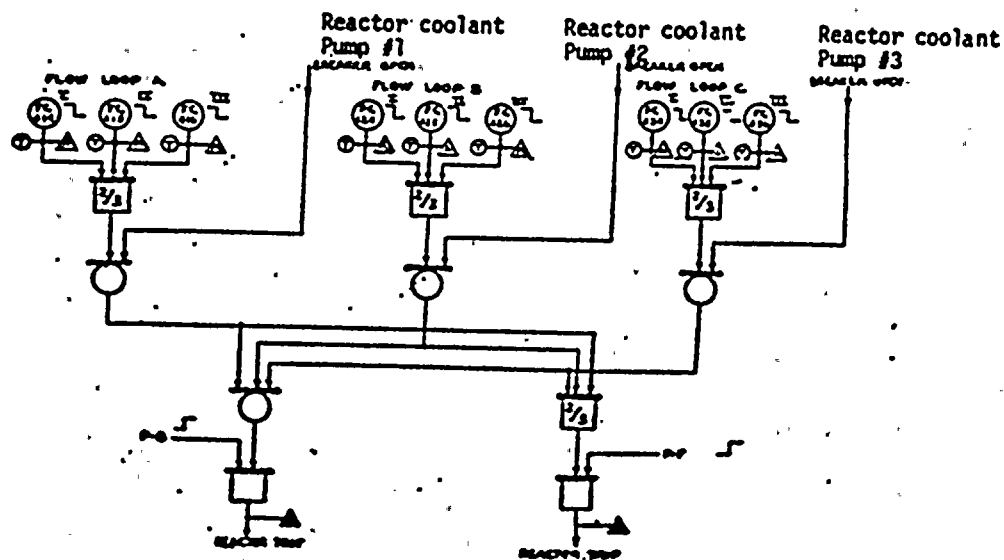
FIGURE 6
LOAD GENERATION AND
INTER-AREA FLOWS PRIOR TO
SYSTEM DISTURBANCE JUNE 28, 1974



Reactor trip

Legend

- protective device
 - ⊕ logic symbol "or"
 - ⊖ logic symbol "and"
 - ⊞ logic symbol "and" (2 out of 3 required)
 - ⊟ logic symbol time delay
 - ⊙ Trip status indicator
 - ⊠ Annunciator indicator
 - ⊡ Reactor "First out" annunciator
- 7-7, 3 From power level permissive circuit.



Undervoltage and Reactor Coolant System

Tripping Logic Diagram
Figure 7

TABLE 1

SYSTEM DISTURBANCE

SUMMARY OF RELAY AND BREAKER OPERATIONS

TIME	STATION	CIRCUITS	EVENTS	REMARKS
0 (10:42 p.m.)		Laudania-Port Everglades 240 kV	Fault on B8.	Flashover on deadend, 9 structures from Port Everglades. No damage.
21 ~	Laudania	Laudania-Port Everglades 240kV	Opened	GP
37 1/2 ~	St. Lucie	P&W #2-St. Lucie 240kV	Opened	B, Z1 (Defective relay)
41 ~	Port Everglades	Laudania-Port Everglades 240 kV	Fault cleared	GT
42 1/2 ~	Lauderdale	Lauderdale-Ranch 240kV	Opened	A, B, C, Z1
43 ~	Laudania	Laudania-Port Everglades 240kV	Reclosed	Fault re-established
44 1/2 ~	Broward	Broward-Ranch 240kV	Opened	A,B,C, Z2
45 ~	Lauderdale	Davis-Lauderdale 240kV	Opened	B, PZ3 (Reverse zone 3, tim delay 40 cycles)
49 ~	Laudania	Laudania-Port Everglades 240kV	Fault cleared	
50 1/2 ~	Broward	Broward-Ranch 138kV	Opened	A, B, C, PP, Z1
51 1/2 ~	Ranch	Broward-Ranch 138kV	Opened	A, B, C, Z1
56 ~	St. Lucie	P&W #1-St. Lucie 240kV	Opened	B, Z2 (Defective relay)
57 ~	St. Lucie	P&W #2-St. Lucie 240kV	Reclosed	
60 ~ (approx.)	Turkey Point	Units 3 & 4 reactors	Tripped	Reactor coolant flow protection



TABLE 1 (page 2)

TIME	STATION	CIRCUITS	EVENTS	REMARKS
64 1/2 ~	Lauderdale	Lauderdale-Ranch 240kV	Reclosed	
65 1/2 ~	St. Lucie	P&W #2- St. Lucie 240kV	Opened	
68 1/2 ~	Broward	Broward-Ranch 138kV	Reclosed	
72 ~	Ranch	Broward-Ranch 138kV	Reclosed	
79 1/2 ~	Lauderdale	Lauderdale-Ranch 240kV	Opened	
79 1/2 ~	Ranch	Broward-Ranch 138kV	Opened	
82 1/2 ~	Ranch	Lauderdale-Ranch 240kV	Opened	A, B, C, PP
83 ~	Broward	Broward-Ranch 138kV	Opened	
98 1/2 ~	Ranch	Lauderdale-Ranch 240kV	Reclosed	
4 seconds +19 ~	Lauderdale	Unit 4	Tripped	Turbine thrust bearing protection.
30.5 seconds	Turkey Point	Unit 4 240kV breakers	Opened	Intentionally delayed generator trip after reactor trip.
35.0 seconds	Turkey Point	Unit 3 240kV breakers	Opened	Intentionally delayed generator trip after reactor trip.

NOTES: 1. Ranch-Yamato 138kV circuit also opened, reclosed, and opened in the 40-80 cycle interval.

2. Cutler unit 6 tripped off by operator at approximately 20 seconds.



TABLE 2
SYSTEM DISTURBANCE
JUNE 28, 1974
LOAD DATA

<u>AREA</u>	<u>BEFORE (MW)</u>	<u>AFTER (MW)</u>	<u>LOST (MW)</u>
Miami & Southeast Division	2960	960	2000
Eastern Division	640	390	250
Western Division	580	580	-
Northern & North Central Division	<u>690</u>	<u>690</u>	<u>-</u>
Totals	4870	2620	2250



TABLE 3
SYSTEM DISTURBANCE
JUNE 28., 1974

SUMMARY OF GENERATING UNIT OUTAGES

<u>GENERATING UNIT</u>	<u>TIME OFF</u>	<u>TIME ON</u>	<u>HR:MIN DURATION</u>	<u>CAUSE OF UNIT TRIP</u>
Turkey Point 3	10:42 PM	12:43 AM (6/29)	2:01	Reactor low flow protection
Turkey Point 4	10:42 PM	12:47 AM (6/29)	2:05	Reactor low flow protection
Cutler 6	10:42 PM	1:35 AM (6/29)	2:53	Tripped by operator.
Lauderdale 4	10:42 PM	11:56 PM	1:14	Turbine thrust bearing protection