U.S. NUCLEAR REGULATORY COMMISSION
REGION I

Report No. 50-311/86-29

Docket No. 50-311

License No. DPR-75 Category C

Licensee: Public Service Electric and Gas Company
P.O. Box 236
Hancocks Bridge, New Jersey 08038

Facility Name: Salem Nuclear Generating Station, Unit 2

Inspection At: Hancocks Bridge, New Jersey

Inspection Conducted: September 12-19, 1986

Inspectors: C J Anderson for — 10/17/86
S. V. Pullani, Lead Reactor Engineer — date

Also participating and contributing to the report were:

T. Koshy, Reactor Engineer
F. Paulitz, Reactor Engineer
C. Woodard, Reactor Engineer

Approved by: C. J. Anderson — 10/17/86
C. J. Anderson, Chief, Plant Systems Section — date

Inspection Summary: Inspection on September 12-19, 1986 (Report No.50-311/86-29)

Areas Inspected: This special inspection was conducted to followup on licensee's actions following an event due to failure of a load center transformer (LCT 2F) and a station power transformer (SPT 22) resulting in a reactor trip and consequent unit trip.

Results: No violations, deviations, or other unacceptable conditions were identified. Three items remained unresolved at the end of the inspection.

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DETAILS

1. Persons Contacted

1.1 Public Service Electric and Gas Company (PSEG)

C. Churchman, Assistant General Manager, E&PB
*L. Corleto, Principal Engineer, Plant Engineering
D. Dodson, Engineer, Licensing and Regulation
R. Dounges, Engineer, Licensing and Regulation
*L. Hajos, Lead Engineer, Plant Engineering
*L. Miller, Assistant General Manager, Salem Operations
P. Mirchandani, Senior Staff Engineer, EP&B
A. Nassman, Acting Manager, Plant Engineering
*R. Patwell, Licensing Engineer
*L. Reiter, General Manager, Licensing and Reliability
*J. Zupko Jr., General Manager, Salem Operations

1.2 Nuclear Regulatory Commission (NRC)

*C. Anderson, Chief, Plant Systems Section
*S. Ebneter, Director, Division of Reactor Safety
*R. Gallo, Chief, Project Branch 2
*K. Gibson, Resident Inspector
*L. Norrholm, Chief, Reactor Projects Section 2B
*T. Kenny, Senior Resident Inspector

*Denotes those present at the exit meeting.

2. Summary of the Event

At 1858 hours on September 11, 1986, Salem Unit-2 tripped from 75 percent power. The cause of the reactor trip was loss of reactor coolant pumps 23 and 24 because of de-energization of 4160 Volt group (non-vital) buses 2F and 2G. The reason for the de-energization of buses 2F and 2G was tripping of all circuit breakers around station power transformer (SPT) 22 including those which feed buses 2F and 2G, by protective relay action to isolate a fault within SPT 22. At the same time, load center transformer (LCT) 2F which is fed from bus 2F also had a fault which was automatically isolated by opening of its own feeder breaker. The license postulated that an incipient or gradually developing fault existed within SPT 22 prior to the event and the fault within the load center transformer aggravated the SPT 22 fault resulting in relay actuation and tripping of its breakers.

Vital buses 2A and 2C were on SPT 21 and vital bus 2B was on SPT 22 prior to the event. Upon loss of SPT 22, vital bus 2B was automatically transferred over to SPT 21 as expected.

All vital equipment operated as expected during the trip. The unit was subsequently placed in cold shutdown for replacement of the transformers and other corrective actions.

3. Description of the Event

For a better understanding of this event which involved several components in the Plant Electrical Power System, a summary description of this system is presented below before attempting to describe the event itself.

3.1 Plant Electrical Power System

Attachment 1 shows a simplified electrical one line diagram of Salem Units 1 and 2. With respect to Unit 2 side, the normal line up of the system is such that during startup and shutdown, 4 KV group buses 2E, 2F, 2G, and 2H and the vital buses 2A, 2B, and 2C are supplied from Station Power Transformers (SPTs) 21 and 22. After unit startup, the group buses are manually transferred to No. 2 Auxiliary Power Transformer (APT), which is the normal power supply for the group buses. On a unit trip, the group buses will automatically transfer to the SPTs (offsite source). When the unit is running, the vital buses continue to be supplied by SPTs 21 and 22. Normally two vital buses will be supplied from one SPT, while the third bus is supplied by the other, with complete transferability between the two. On simultaneous loss of both SPTs, the vital buses are automatically powered by the standby diesel generators to supply engineered safeguards loads.

The automatic transfer of the group and the vital buses are initiated by various sets of undervoltage relays with appropriate time delays to perform their functions in a coordinated manner.

3.2 Plant Conditions Prior to the Event

The plant was operating at 75 percent power, with all 4 reactor coolant pumps (RCPs) operating. RCPs 21, 22, 23, and 24 are powered from group buses 2H, 2E, 2F and 2G respectively. Group buses 2H and 2E were being powered from STP 21 and group buses 2F and 2G from SPT 22. With the unit on-line, this is not the normal lineup of group buses which was previously discussed in Section 3.1 of this report. The normal lineup with the unit on-line is such that all 4 group buses will be powered from No. 2 APT. The revised lineup was a corrective action to avoid a bus transfer from the APT to the SPTs in the event of a unit trip and consequent degraded voltage conditions on the vital buses and the resulting problems for the diesels to re-energize the vital buses, as was experienced during the event on August 26, 1986 (see Inspection Report 50-311/86-26 for details).

Prior to the event, vital buses 2A and 2C were on SPT 21 and vital bus 2B was on SPT 22. This configuration of the vital buses is their normal lineup with the unit on-line, as explained in Section 3.1 of this report.

3.3 Details of the Event

Attachment 2 shows how the two transformers which faulted and initiated the event are connected to their buses and their associated relaying schemes. The two transformers include load center transformer LCT 2F (750 kVA, 4160/230 V, Delta/Wye, ITE make, dry type, self-cooled with provisions for fan cooling, 6.7 percent impedance at rated kVA) and station power transformer SPT 22 (25 MVA, 1.38/4.16 kV, Delta/Wye, Westinghouse make, Class OA/FA/FOA, 5.7 percent impedance at 15 MVA) Attachment 3 shows the detailed trip sequence of the protective relays which had tripped during the event to clear the faults.

Summarizing the relay trip sequence, the instantaneous overcurrent relays tripped the feeder breaker 2F5D and cleared the fault on LCT 2F. This happened almost instantaneously as was evidenced by not having any flags on the time overcurrent relays which are the backup protection for the instantaneous overcurrent relays. In normal circumstances, the instantaneous clearing of the fault on LCT 2F should not cause tripping of any upstream breakers as the relay settings are supposed to be well coordinated to clear the faults selectively. However, several upstream breakers around SPT 22 tripped. It was concluded by the licensee that this was because of an internal fault within SPT 22 which caused its differential protection relays to trip the breakers around it within a few cycles and was not because of any problem with improper coordination of relay settings. After the event, the relay settings and proper functioning of the affected breakers were verified to be correct by the licensee.

The tripping of the breakers around SPT 22 de-energized group buses 2F and 2G which power RCPs 23 and 24. Because the reactor was operating at a power level greater than 36 percent, and there was a loss of two RCPs, this resulted in a reactor trip and consequently a unit trip.

Vital buses 2A and 2C continued to be on SPT 21 which was still energized. Upon loss of SPT 22, vital bus 2B was automatically transferred over to SPT 21 by the action of the transfer scheme described in Section 3.1 of this report.

All vital equipment operated as expected. The plant stabilized in Mode 3 (hot shutdown). The plant was later placed in cold shutdown to investigate the cause of the event and take appropriate corrective actions.

4. Apparent Cause of the Event

As discussed earlier in this report, the apparent cause of the event is believed to be a fault within LCT 2F which (although LCT 2F was isolated by opening of its feeder breaker) aggravated an already existing or gradually developing fault within SPT 22. This in turn tripped the breakers around SPT 22 and isolated its fault. The tripping of these breakers caused power failure to RCPs 23 and 24. This in combination with high reactor power caused the reactor trip and consequently a unit trip.

Thus the faults within LCT 2F and SPT 22 were determined to be the cause of the event. These two transformer failures are further discussed in the following sections.

4.1 Failure of LCT 2F

An examination of the faulted transformer LCT 2F indicates one of the primary phases (delta connected) had experienced a ground fault. There were also burn marks on the delta connections. The transformer feeder breaker (2F5D) appeared to have opened under heavy short circuit conditions. The burn marks on the breaker contacts and arc chutes indicated this. The cable connections on the load side of this breaker had burn marks and two of three cables opened up at their crimp connections to their terminal lugs, apparently due to strong magnetic forces induced by the short circuit current. The rear door of the breaker enclosure were blown open and there was hinge damage. There were signs that electrical current was induced into the breaker enclosure. There were burn marks around the door handle. All these observations indicate a heavy short circuit condition. However, the root cause of the short circuit will not be known, until the transformer is examined thoroughly in the manufacturer's (ITE) repair shop. The licensee is taking prompt action to identify the root cause of failure. The licensee is also examining similar previous transformer failures to identify any generic problem. This is an unresolved item pending completion of the above licensee actions and its review by NRC (50-311/86-29-01).

4.2 Failure of SPT 22

Subsequent to the event, several tests were conducted on SPT 22 to determine the nature and possible cause of its failure. The transformer gas and oil samples were tested, turns ratio checked, and winding power factor and excitation tests were conducted. The tests indicated a fault within the transformer, apparently on one phase. However, a visual examination of the internals of the transformer could not positively identify the location and nature of the fault.

The licensee plans to send this transformer to the manufacturer's (Westinghouse) facility for repairs and upgrading to the 1986 design standards. The upgrading should eliminate potential problems of a

degradation of winding insulation resistance due to circulating currents within strands, as was experienced within the Unit 1 Auxiliary Power Transformer which is currently being repaired. The licensee also expects to identify any similarity between the two transformer failures, possible root cause of the failures, and any generic implications. This is an unresolved item pending completion of the above licensee actions and its review by NRC (50-311/86-29-02).

5. Corrective Actions

Based on the apparent cause of the event discussed in Section 4 of this report, the licensee initiated several corrective actions, both short term and long term, which were under various stages of completion at the end of this inspection. The short term actions were generally complete at this time. The licensee plans to develop a schedule for the long term actions depending on the nature of the root cause of the problem (transformer failures) discussed in Sections 4.1 and 4.2 of this report.

5.1 Short Term Corrective Actions

The short term corrective actions fall under two categories: (1) actions to identify the cause of the problem and (2) actions to correct the problem itself. The actions under the first category included:

- Oil and gas sample test and turns ratio test for SPT 22;
- Winding power factor and excitation tests for LCT 2F and SPT 22;
- Hi-Pot tests for 13 kV cables to and from SPT 22;
- Testing of the relays and breakers associated with LCT 2F and SPT 22 (see Attachment 2 of this report) to verify their function and proper relay coordination.

The actions under the second category included:

- Replacement of LCT 2F, its feeder breaker 2F5D, the damaged load side cables and associated tests to verify their function. The replacement of LCT 2F was with an identical type and make (ITE).
- Replacement of the damaged SPT 22 (Westinghouse) with an electrically equivalent but of General Electric make and post installation testing in accordance with vendor recommended practices. The replacement and testing was in progress, but not complete at the end of the inspection.

In addition to the above actions, the licensee also performed certain tests (oil and gas sample) on SPT 21 (the sister transformer of SPT 22) which are possible while the transformer is energized.

This was to verify that a potential problem, similar to that in SPT 22, did not exist in SPT 21.

5.2 Long Term Corrective Actions

The licensee's long term actions include:

- Determination of root cause of the transformer failures (see Sections 4.1 and 4.2 of this report);

- Determination of any connections between various transformer failures in the plant and the degraded voltage conditions as a result of bus transfer transients during unit trips. This determination is expected, once the root cause of the transformer failures is known and the result of the bus transfer transient study for degraded voltage (presently in progress as a corrective action for the August 26, 1986 event) are available.

The licensee's corrective actions described in Sections 5.1 and 5.2 together is an unresolved item pending their satisfactory completion and review by NRC (50-311/86-29-03).

6. Conclusion

The inspector had no further questions regarding the licensee's evaluation of the event, the actions to determine root cause of the event, and the corrective actions. Upon completion of the short term corrective actions the licensee planned to restart the unit.

7. Unresolved Items

Unresolved items are matters about which more information is required to ascertain whether they are acceptable items, violations or deviations. Unresolved items identified during this inspection are discussed in Sections 4.1, 4.2 and 5 of this report.

8. Exit Interview

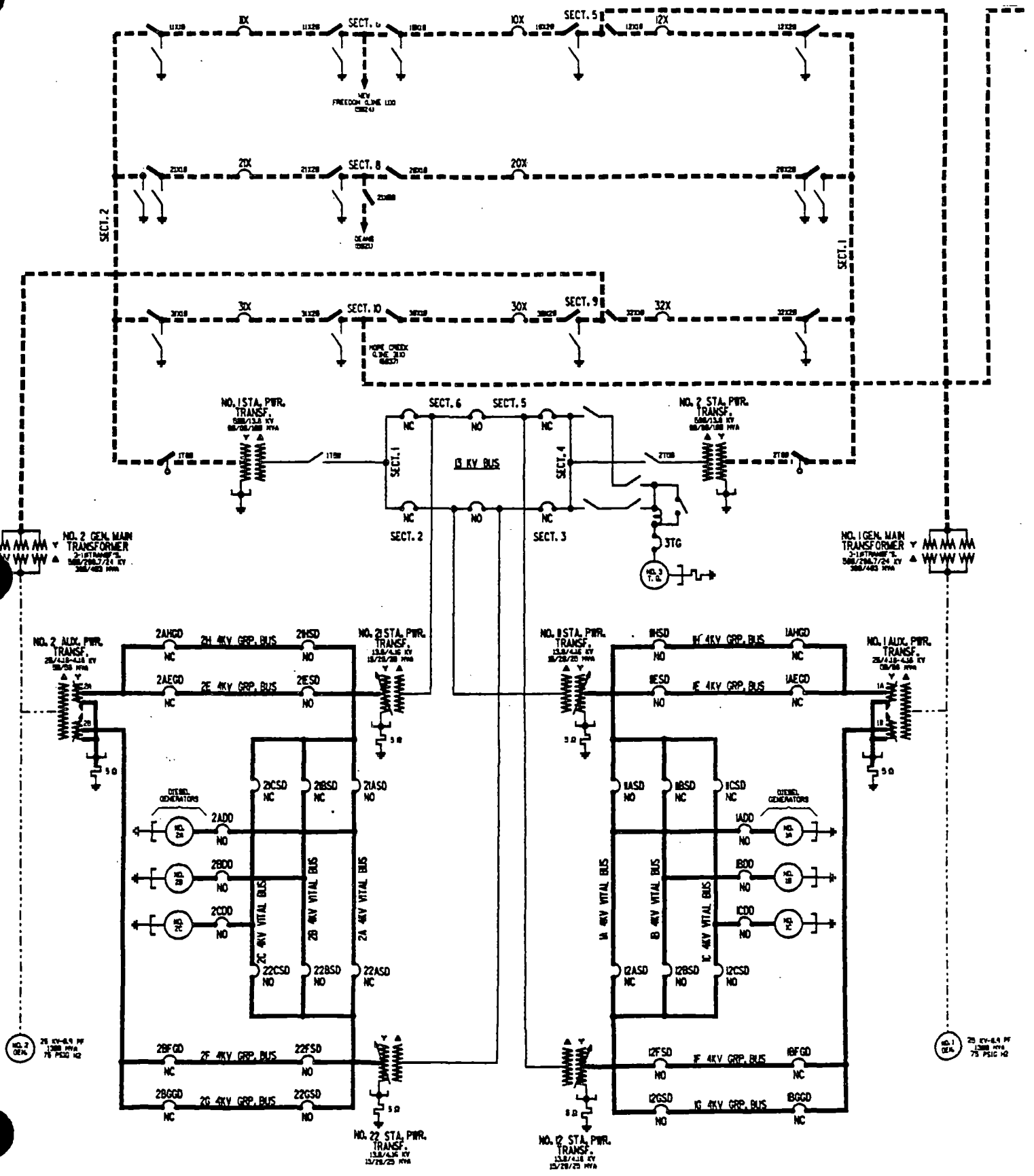
The inspector met with licensee management representatives (see Section 1.0 for attendees) at the conclusion of the inspection on September 19, 1986. The inspector summarized the scope and findings of the inspection at that time.

The inspector and the licensee discussed the contents of this inspection report to ascertain that it did not contain any proprietary information. The licensee agreed that the inspection report may be placed in the Public Document Room without prior licensee review for proprietary information (10 CFR 2.790).

At no time during this inspection was written material provided to the licensee by the team.

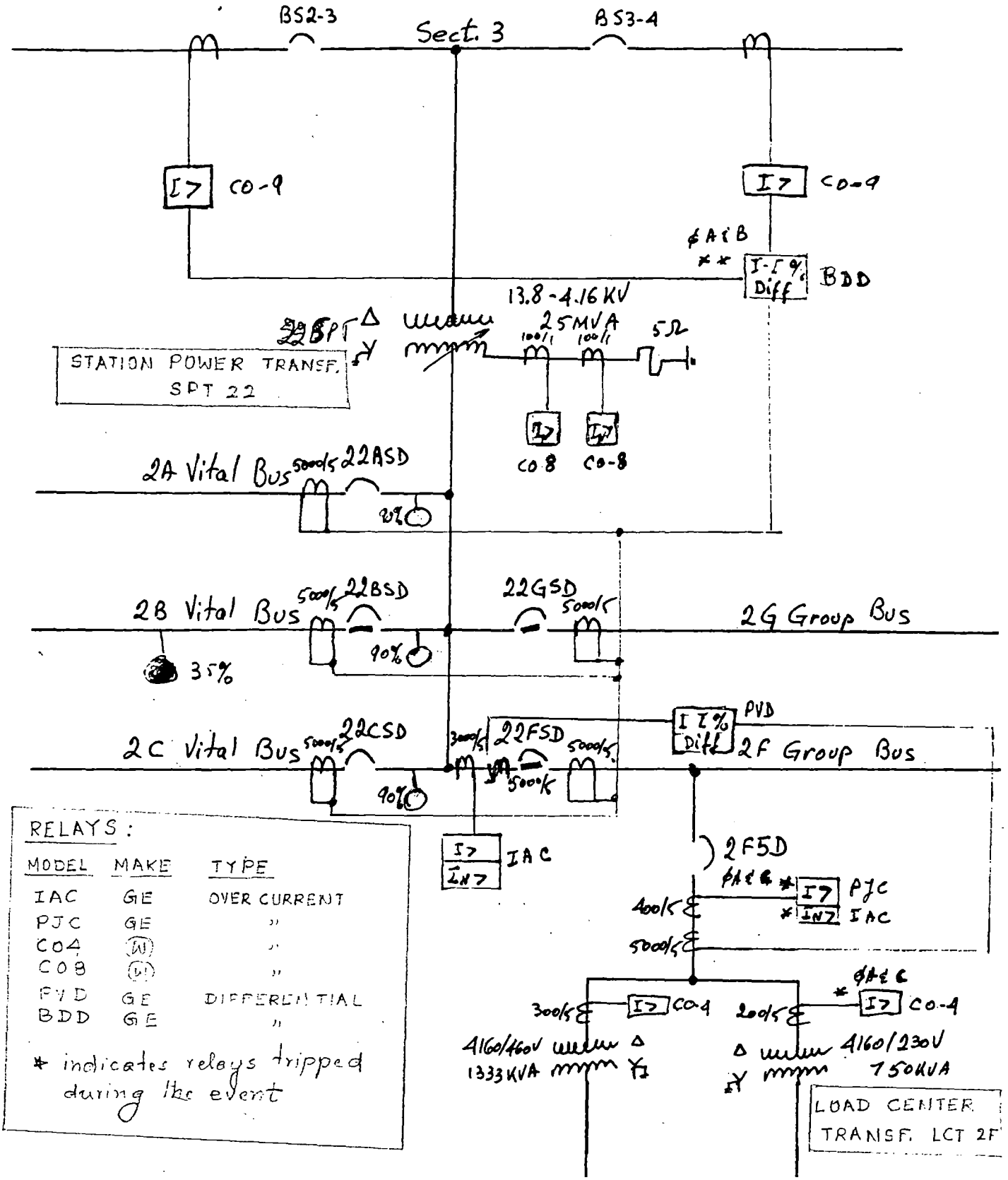
ATTACHMENT 1

Simplified Electrical One Line Diagram of Salem 1 and 2



ATTACHMENT 2

Protective Relaying Scheme for SPT 22 and LCT 2F



RELAYS :

MODEL	MAKE	TYPE
IAC	GE	OVER CURRENT
PJC	GE	"
CO4	(W)	"
CO8	(W)	"
PVD	GE	DIFFERENTIAL
BDD	GE	"

* indicates relays tripped during the event

ATTACHMENT 3

Trip Sequence During September 11, 1986 Event

of Protective Relays on SPT 22 and LCT 2F

Fault on a 4160/230V transformer fed from 2F group bus (breaker position 2F5D)

Relay operation determined from the relay targets found by the Relay Department.

1. Phase A & C overcurrent protection on the high voltage side of the 4160/230V transformer. Indicating Instantaneous Trip unit (IIT). No time-delay unit targets were found.

2. Neutral overcurrent protection on the 4160V feeder (IAC Relay-Instantaneous).

3. Phase A & C Instantaneous overcurrent protection (Relay type PJC) on the 4160V feeder.

   All these relays trip 2F5D circuit breaker. The PJC relays operate when the fault current is higher than 5760 amps.

2F group bus has overload protection, set very high both for current and time. However, if the 2F5D breaker should have not operated this protection would have cleared the 4160V group bus.

The transient data recorder tape indicates that 12 cycles later the bus breakers 22GSD, 22SD, and 22BSD tripped. Targets on phase A & B transformer differential protection were found.

2B vital bus was transferred from 22SPT to 21SPT (target on the undervoltage transfer permissive relay 35%). The transfer was initiated by the 70% undervoltage protection, but no target was found. Apparently, it is a problem with these targets.