U. S. NUCLEAR REGULATORY COMMISSION

REGION III

AUGMENTED INSPECTION TEAM

Report No. 50-255/87019(DRP)

Docket No. 50-255 License No. DPR-20

Licensee: Consumers Power Company
212 West Michigan Avenue
Jackson, MI 49201

Facility Name: Palisades

Investigation At: Palisades Site, Covert, Michigan

Investigation Conducted: July 14-17, 1987

Team Members: B. L. Burgess, Team Leader, DRP-RIII

E. R. Swanson, Senior Resident Inspector-Palisades

Z. R. Falevits, Engineering Branch, DRP-RIII

J. L. Knox, Electrical Engineering Branch, DEST, NRR

Approved By: C. E. Norelius, Director
Division of Reactor Projects, RIII

10/7/87
Date

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1. General Discussion

a. Background

On April 2, 1987, the Palisades plant returned to power operation following an 11 month outage that had focused on upgrading the overall material condition of the plant. As a result of this effort, reoccurring and repetitive equipment and system deficiencies which had plagued plant performance and challenged plant operations were repaired. Additionally, a new attitude regarding plant reliability was instilled in plant staff as well as the establishment of higher expectations with regard to quality of corrective and preventative maintenance. As a result, the operating history subsequent to April 2 had been relatively trouble free, with only two manual plant trips. The first occurred on May 22 and was the result of an operator inadvertently closing the steam exhaust valve on the operating Main Feed Pump Turbine, causing a rupture disk to rupture. As a result of the amount of steam escaping from the blown rupture disk, auxiliary operators in the area concluded that a steam pipe had failed, and immediately informed the control room. Control Room Operators manually tripped the reactor from 40% power subsequent to the Shift Supervisor responding to the scene. The rupture disk was replaced and the plant returned to operation on May 24, 1987.

The second trip occurred on July 10, 1987, and was a manual trip caused by the failure of the backstop oil pump discharge pipe which supplied Primary Coolant Pump P-50C. The pipe had cracked, causing a loss of oil in the pump upper radial bearing, resulting in a bearing high temperature. In response to the high temperature the operators reduced power from 91% to 14%, and then manually tripped the unit after determining that the power reduction had no effect on bearing temperature. The pipe was replaced and the plant returned to service on July 12, 1986.

b. July 14, 1987 Event

On July 14, 1987 the Palisades Plant was operating at approximately 91% of full power. At 10:24 a.m. the deluge system for the main transformer was isolated to allow troubleshooting of Alarm C47 by I&C technicians. Isolation of this alarm requires the establishment of compensatory fire tours. In addition, security had been notified and was performing the requisite tours. At approximately 1:20 p.m., the C-47 alarm was received in the control room and investigation by the operators revealed that the deluge system for Transformer 1-2 had initiated. Two minutes later (1:22 p.m.) the rear bus or "R" bus isolated, the cause unknown at that time. The Shift Supervisor (SS) alerted to the event by the alarms received as a result of the loss of the "R" bus, responded to the control room. Subsequent to reviewing the status of offsite power and verifying the loss of cooling tower pumps and fans, the

SS ordered a manual reactor trip. Control Room Operators responded immediately and manually tripped the reactor. After a brief coastdown of the main generator, all five station power transformers were isolated from the main transformer as designed. This isolation resulted in the plant being without an offsite power source. In response to the loss of all offsite power, both diesel generators started, paralleled with the safeguards buses, and sequenced on their respective blackout loads.

As the loss of offsite power removed power from the primary coolant pumps, the plant was stabilized in hot standby by establishment of natural circulation flow. At this point, a review of the emergency plan was conducted, and at 1:30 p.m., an "Unusual Event" was declared as required for the loss of offsite power. Requisite notifications were made and a continuous open ENS communications established. Preparations were made to allow backfeeding of the main transformer by removal of the Turbine Generator disconnects. Subsequent to troubleshooting to assure that the offsite and plant electrical buses were normal, backfeeding began at 8:48 p.m. on July 20, 1987. The Unusual Event was terminated one minute later.

The NRC, in response to the event, activated the incident response centers at the Regional office and Headquarters. Immediate oversite of the event was accomplished by dispatching the D. C. Cook Resident Inspectors to the Palisades site. An Augmented Inspection Team (AIT) arrived onsite (5:00 p.m.) to oversee the licensee's actions and review the event. The inspection team consisted of a Projects Section Chief and an electrical engineer from Region III, the Senior Resident Inspector, and an electrical engineer from NRR. The team observed control room activities, monitored primary and secondary plant conditions, followed the licensee's analysis and evaluations regarding root cause and corrective actions to restore offsite power, and interviewed cognizant operators and plant staff regarding event sequence. The AIT concluded their inspection activities on the morning of July, 17, 1987.

2. Reactor Trip Review

a. Sequence of Events

The following edited sequence of events was derived by review of the plant Tennecomp Data Logger Printout and review of operator logs. The editing consisted of extracting selected significant data points and where data points did not exist, estimating approximate data points by the times documented in operational logs.

July 14, 1987

10:24	Deluge system isolated to Main Transformer to allow troubleshooting of Alarm C-47.
13:19:34	Main Plant Electric Fire Pump P-9A started (Indicating deluge system actuation).

13:20:55	Safeguards Buses 1F and 1G power supply breakers opened (Due to loss of switchyard "R" bus).
13:21:20	Reactor Tripped.
13:21:20	Charging Pump P-55A Stopped.
13:21:21	Turbine Trip Relays K-305L and K-305R Tripped (Turbine Trip).
13:21:22	Steam Generator E-50A Channel-A Water Level Low.
13:21:24	Feedwater Pump P-1B Turbine Tripped.
13:21:25	Charging Pump P-55A and P-55C Started.
13:21:25	Auxiliary Feedwater Pump P-8A Started.
13:21:31	Steam Generator Low Level Alarms.
13:21:33	Primary Coolant Loops A&B Low Flow.
13:21:34	Primary Coolant Loops C&D Low Flow.
13:21:52	Steam Dump Valves CV-0781 and CV-0782 Open.
13:22:36	Pressurizer Level Low.
13:23:10	Steam Dump Valves CV-0781, CV-0782, and CV-0779 Closed.
13:23:29	Primary Coolant Pumps P-50 A, B, C and D Stopped.
13:23:39	Condensate Makeup Valve Cycling (this valve will continue to cycle for approximately one minute as condensate hotwell level oscillates due to contraction of condensate water as condensate temp decreases).
13:26:22	Pressurizer Backup Heater On.
13:26:44	Pressurizer Level Normal.
13:28:19	Pressurizer Pressure Normal.
13:28:54-58	Steam Dump Valves CV-0781, CV-0779, CV-0780 Not Closed.
13:30:11	Steam Dump Valve CV-0780 Closed.
13:30:49	Steam Dump Valve CV-0779 Closed.
13:30:54	Steam Dump Valve CV-0781 Closed.
13:31:30	Boric Acid Pump P-56B Started.

13:36	Steam Generator Water Level Normal, Channels A, B, C and D.
13:37:24	Pressurizer Spray Valve CV-1059 Not Closed.
13:38:30	Pressurizer Spray Valve CV-1057 Not Closed.
13:39:17	Pressurizer Spray Valve CV-1057 Closed.
13:40:21	Service Water Pump P-7A Stopped.
13:40:23	Component Cooling Water Pump P-52A Stopped.
13:40:25	Component Cooling Water Pump P-52A Started.
13:40:58	Pressurizer Spray Valve CV-1590 Closed.
13:42:04	Pressurizer Backup Heater On.
13:44:10	Feedwater Valves CV-0703 and DV-0701 Closed.
13:59:41	Chemical and Volume Control Letdown Valve CV-2004 Closed.
13:04:25	Pressurizer Backup Heater Off (Backup Heater will continue to cycle to maintain PCS temperature).
13:011:06	Charging Pumps P-55 B&C Cycled On and Off to Maintain Pressurizer Level at Program.
13:28:18	Steam Generator E-50B Level Normal.
13:38:13	Steam Generator E-50A Level Normal.
13:39:05	Radwaste Isolation Normal.
13:04:42	Main Plant Diesel Fire Pump P-9B Stopped.
13:09:23	Auxiliary Feedwater Pump P-8C Started.
13:13:31	Auxiliary Feedwater Pump P-8C Stopped.
13:30:09	Turbine Coastdown Trip Relay Reset.
13:30:09	Bus 1C Fast Transfer Reset.

No discrepancies or peculiarities were noted during review of the data logger printout.

b. Plant Parameter Review

The following information was gained by review of selected strip charts and the printout of the date-logger.

Reactor coolant temperatures, pressure and pressurizer level decreased during the plant response to the manual tripping of the reactor. Pressurizer pressure decreased from 2013 psia to 1773 psia. Pressurizer level responded to the plant cooldown by decreasing from 56% to a low point of 32%. Hot leg temperatures decreased from 583°F to 533.3°F. Cold leg temperature initially increased from 539.9°F to 545.8°F and then started a slow decline to 518°F. Steam generator water levels decreased from a normal level of 67% to a minimum of 11% on "A" steam generator and 15% on "B" steam generator. Steam generator pressures initially increased from 759 psia to approximately 952.8 psia on "A" steam generator and 947.1 psia on "B" steam generator. At this time the steam dump valves opened to reduce pressure to about 860 psia at which time the dump valves closed. Steam generator pressure continued to decline to 800 psia and remained at this pressure until plant cooldown was commenced.

As steam generator pressure was stabilized, steam generator level returned to approximately 23-26%, normal levels for post trip conditions. Pressurizer pressure was returned to normal at 2000 psia and pressurized level responded to the stabilizing primary temperatures to return to 41%.

Primary and secondary plant response to the manual trip was considered to be normal. No abnormal equipment operations were identified with the exception of the quick open feature on the atmospheric steam dumps. Further review and testing of the relays associated with this feature could not determine the delay (approximately 17 secs) before the atmospheric steam dumps opened to control steam generator pressure. The licensee plans to continue to monitor these valves as a short term corrective action. Long term corrective actions will replace the valves with a valve more adapted to perform the desired operational functions required during all plant conditions.

c. Operator Actions

At the time of the transformer failure, the Control Room was staffed by a Shift Supervisor (SRO), a Shift Engineer (SRO), a Service Control Room Operator (CO1), and a Control Room Operator (CO2).

This staffing met facility minimum shift staffing requirements. The Shift Supervisor, responding to alarms alerting the operators to a loss of Startup Transformer 1-2, immediately left his office to observe plant conditions. After identifying a loss of condenser cooling by observing a loss of both cooling tower pumps and fans, and the loss of Startup Transformer 1-2, ordered Control Room Operators to trip the plant. By ordering a manual plant trip at this point, the shift supervisor limited the extent of the primary and secondary plant transients in response to the loss of all offsite power. Additionally, this action enhanced the establishment of primary cooling via natural circulation flow. These actions are considered by the AIT to be conservative and appropriate.

No adverse, unexpected or unplanned operator actions were identified.

3. Startup Transformer 1-2 Failure

a. Background

The Palisades offsite power system (Figure 1) consists of a switchyard, six transmission lines connecting the grid network to the switchyard, and an immediate and delayed access circuit connecting the switchyard to the onsite Class 1E distribution system. The immediate access circuit consists of a 345KV transmission line, 345KV to 24KV Startup Transformer 1-2 which failed July 14, 1987, and a 2400 volt bus duct. The delayed access circuit consists of 345KV transmission line, 345KV to 24KV main transformer, 24KV bus duct, 24KV to 2.4KV station power transformer (No. 1-2), and 2.4KV bus duct.

The 24KV bus duct associated with each access circuit (immediate and delayed) are routed in physically separate ducts through the Turbine Building to the Class 1E onsite power system. This aspect of the design was reviewed and found acceptable as part of the staff's evaluation of SEP Topic VII-3 dated December 31, 1981.

The 345KV transmission lines between the switchyard and startup and main transformers associated with each access circuit (immediate and delayed) are routed on the same towers for one-half mile. The staff's evaluation of this aspect of the design was included as part of a report to ACRS dated October 23, 1969. The staff concluded that in consideration of the slight increase in reliability which would result from adding another line between the switchyard and transformers and the low probability of a tower failure (which would cause loss of both of the lines), backfitting should not be required. This aspect of the design was not addressed in the staff evaluation of SEP Topic VII-dated December 31, 1981.

The startup transformer associated with the immediate access circuit and the main and station power transformers associated with the delayed access circuit are separated by about 25 feet and a cinder block wall. The adequacy of this separation was not included as part of the SEP review of Topic VII-3 dated December 31, 1981.

The delayed access circuit is established by removing disconnect links at the main generator. In accordance with GDC-17, this delayed access circuit must be designed to be available in sufficient time, following a loss of all onsite AC power supplies and the other immediate access circuit, to assure that specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded. In the Palisades design, the time required to remove the disconnect links is four to six hours. This design capability was accepted though not confirmed as part of the staff's evaluation of SEP Topic VII-3.

The Palisades DC battery system is designed to supply the required shutdown loads, with total loss of AC power, for more than six hours. The SEP review of this aspect of the design (as indicated in the staff's evaluation of SEP Topic VII-3 dated December 31, 1981), concluded that the DC design has sufficient capacity to permit establishment of the delayed access circuit in four hours without load stripping and that it also has sufficient capacity to permit establishment of the delayed access circuit in six hours if loads are stripped. Accordingly, the staff recommended (as part of the SEP review) that the licensee provide an operating procedure for stripping dc loads after a two hour loss of AC power in order to assure that GDC 17 can be met. The licensee's subsequently updated their procedures to include this recommendation.

In the Palisades design, station safety loads are normally supplied, during power operation, from the main generator through the station power transformer. On loss of the main generator there is an automatic transfer from this normal source to the immediate access circuit. The SEP review of this aspect of the design (as indicated in the staff's evaluation of SEP Topic VII-3 dated December 31, 1981) was limited to the design capability to test this automatic transfer during plant operation. The reliability and actual periodic testing of this transfer were not addressed. In addition, the susceptibility of the Palisades design to plant trip due to testing of the transfer during power operation was not addressed.

b. Detailed Event Description

To correct a problem with the main transformer deluge system alarm not alarming upon actuation, I&C technicians were in the process of calibrating the main transformer pressure switch and placing it in service. System air pressure for the cross connected main and startup transformers deluge systems was identified to be too-low. After adjusting the regulator, air pressure was too high, and to compensate, the technician adjusted the regulator and bled off the excess pressure. This rapid drop in pressure caused the heat actuated device to actuate and in turn initiated the deluge system.

A short time after deluge system actuation, a flash over arc jumped from the "Y" phase insulator bushing cap to the transformer case on the 1-2 Startup Transformer. The arc traveled through the conductive environment provided by corrosion and debris in the deluge spray. Through a combination of thermal and mechanical shock the initial fault caused a center section of porcelain insulator to separate at a segment joint or break establishing a path for fault current to the center tube of the bushing. At this time the porcelain catastrophically failed (exploded) before the fault could clear.

The ground fault was sensed by the differential relay scheme which initiated trips on the 345KV switchyard "R" bus and the startup power breakers. Since the sole source of power to the cooling towers is supplied by these transformers a manual reactor trip was initiated.

The normal fast transfer to the startup power transformers was blocked due to the ground fault and the emergency diesel generators were loaded on their respective buses by the normal shutdown sequencers.

The control room operators completed immediate actions and emergency procedures for plant shutdown and initiated the process for establishing the delayed access offsite circuit to safety loads. This process involved a tagging out procedure to assure 345KV transmission lines are deenergized and a procedure for removing the mechanical disconnect links located below the main generator.

The time required to complete this process was approximately 7.26 hours from initiation of the event to the time when power was reestablished through the delayed access circuit to safety loads. Because the plant was in a stable operating condition with shutdown loads being supplied from the onsite power system diesel generators, the licensee used additional time to allow the balance of switchyard breakers to be checked, verify status of the main transformer, and to assure all relaying had properly functioned. Also, additional time was used to investigate an omission in the procedure for loss of AC power which prevented reconnection of offsite power. Startup transformer auxiliary relays were not identified to be reset in the procedure. This omission was subsequently corrected.

The root cause of the fault was determined to be contaminants in the transformer deluge system water caused by combined buildup of corrosion products with wind currents which carried the water spray up to the transformer bushing cap. These contaminants provided a path to ground for the electrical arc. Upon inspection there was no indication that the insulator was degraded prior to the fault and prior power factor testing of the bushing had proved satisfactory. A survey by Doble Engineering indicates that nationwide one or two bushing failures are caused each year by deluge operation.

c. Corrective Actions

The startup transformer which failed (and the damage caused by its failure) was repaired. The repair included drainage of oil, inspection of internals, removal of some small pieces of the porcelain insulator found inside the transformer, replacement of failed insulator, repair of adjacent insulators damaged during event, and testing of the transformer. Additionally, quarterly deluge system flushes to reduce contamination and a test of the deluge spray pattern to verify that the spray was not directed towards the bushings were implemented.

Because it is believed that the root cause of the event was due to inadvertent actuation of the deluge system, the licensee is investigating (1) improvements for maintenance procedures and practices to minimize future inadvertent actuations of the deluge and (2) increased frequency of maintenance on the deluge system to

reduce contaminants in the deluge water which may have contributed to the likelihood of arcing and transformer failure. The licensee is also continuing their analysis of the failed porcelain insulator.

4. Operator Interviews

Licensed plant operators were interviewed to ascertain operator actions and response to the plant event equipment problems, management support and overall event response. The operators expressed opinions regarding plant response to the trip that were favorable, and stated the equipment performance (with minor exceptions) was very good. Additionally, operators felt that management support and attention to the plant event was excellent. The only concern operators expressed regarding the plant event involved the ability of a shift to establish backfeeding during a backshift. Because of the reduced complement of operations and maintenance personnel onshift, the time required to implement the actions necessary to establish backfeeding may be delayed until additional personnel arrive onsite.

Recommendations derived from operator interview included the following:

- A motor operated valve on the air ejector line to allow isolation of the condenser to help maintain condenser vacuum and reduce offsite released during a steam generator tube rupture.
- A blast proof wall between the startup and main transformers.
- Fast transfer features between the main and startup transformers (i.e., motor operator disconnects, breakers, etc.).
- Separate power supplies for the two cooling tower pumps.
- A ready made tagout for initiating backfeeding available to reduce administrative actions during loss of offsite power.

5. Persons Contacted

F. W. Buckman, Vice President, Nuclear Operations
D. P. Hoffman, Plant General Manager
W. L. Beckman, Radiological Services Manager
R. D. Orosz, Engineering/Maintenance Manager
R. M. Rice, Operation Manager
K. W. Barry, Director, Nuclear Licensing
J. G. Lewis, Technical Director, Palisades
T. J. Palmisano, System Engineering Superintendent
R. M. Hamm, Project Engineering
R. A. Vincent, Administrator, Plant Safety and Engineering
R. A. Fenech, Operation Superintendent
R. E. McCaleb, Quality Assurance Director
P. P. Margol, Quality Assurance Administrator
T. A. Buczwinski, Technical Support Supervisor

6. NRC/Licensee Meeting

On July 24, 1987 the NRC met with the licensee in Region III to discuss the progress and scope of its corrective actions in response to the July 14, 1987 loss of Startup Transformer 1-2 Event. During the meeting the licensee reviewed the event and outlined the status of its analysis and evaluations regarding acceptability of offsite power supplies. The licensee stated that several modifications were under consideration that will provide greater reliability to offsite power supplies.

7. Conclusion/Recommendations

At the termination of the Augmented Inspection Team's onsite review, event root cause determination was still in progress and the analysis of the failed insulator had not reached completion. However, the following conclusions and recommendations were reached:

Conclusions

(1) The offsite circuits between the switchyard and Class 1E safety buses marginally meet the design requirements of GDC-17.

(2) The single transmission tower line for both immediate and delayed access circuits between the switchyard and the startup and main transformers is vulnerable to a single event which could cause both circuits to be lost and does not meet current NRC standard review plan recommended practice for two physically separate lines.

(3) Operator response to the event was outstanding as evidenced by the operator initiated manual plant trip prior to the automatic trip which was eminent, thereby reducing the extent of the primary and secondary plant transients.

(4) Plant management and staff response to the trip was conservative, well thought out and appropriately planned. Although the current offsite configuration meets GDC-17, the licensee has initiated efforts to enhance offsite power supply reliability.

(5) The licensee's engineers and management personnel contacted during the inspection were receptive, solution oriented, and at ease. The needed documents and cognizant personnel were readily available.

Recommendations

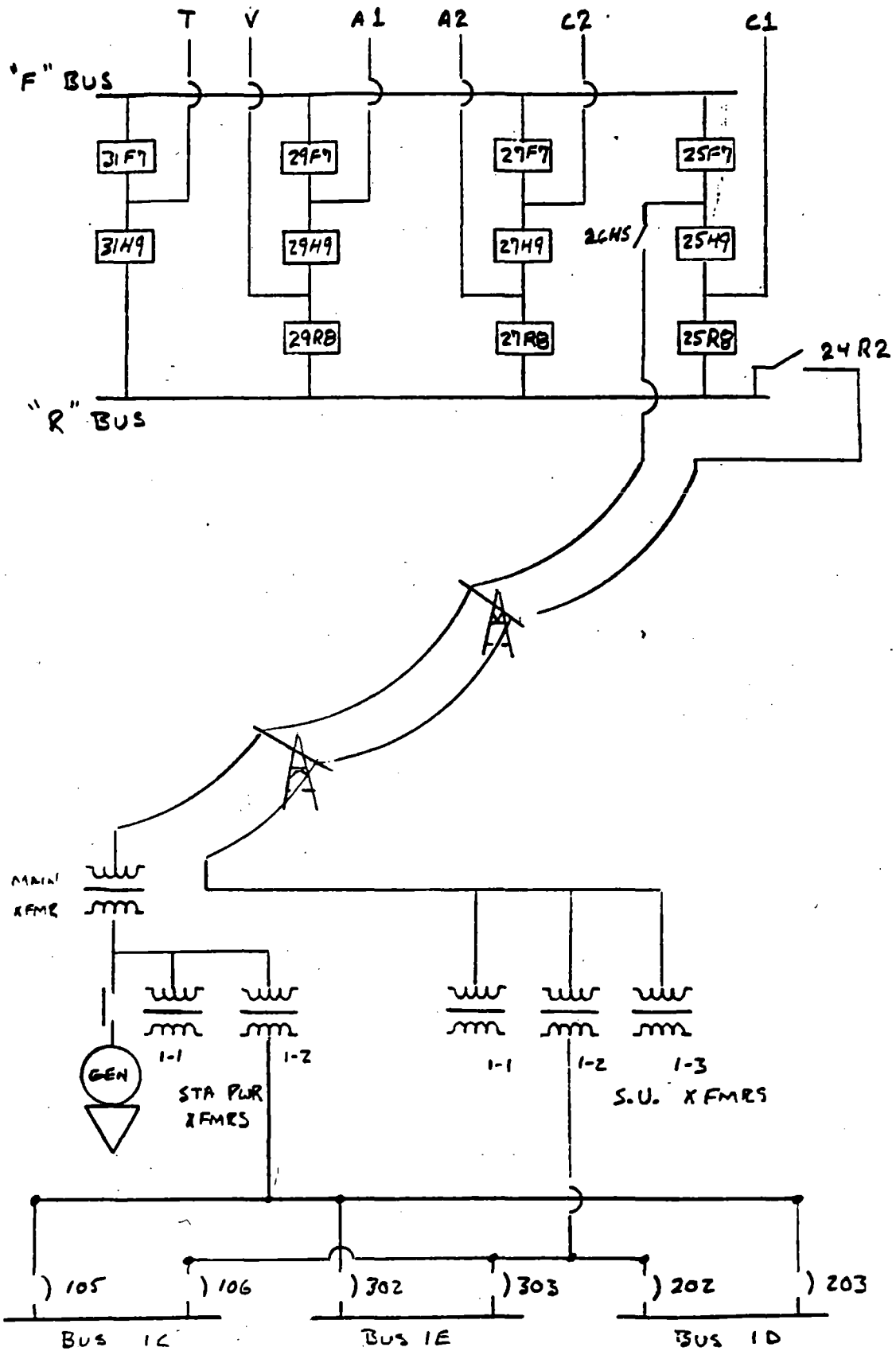
(1) Compliance with GDC-17 with respect to separation between main and startup transformers appears to be dependent on proper operation of the fire protection deluge system and the capability of the rock reservoir below the transformers to contain oil from the transformers and water from the deluge system. Periodic testing of the deluge system and an analysis of the design and capability of the rock reservoir should be considered as an operability requirement if required to assure adequate separation of offsite circuits.

(2) The cinder block wall between the main and startup transformers which may minimize the possibility of loss both offsite circuits due to missiles generated by failure of a transformer should be analysed to assure that it provides adequate separation.

(3) Testing of the procedure for establishing the delayed access circuit should be performed on a periodic basis in order to demonstrate the design commitment for its establishment in four to six hours. The procedure should be streamlined to the extent practical and be performed during each planned station shutdown or when station shutdown is greater than 30 days.

(4) Improvement of the four to six hour time required to establish the delayed access circuit should be considered as part of planned modifications to the offsite system. Each of the options being considered by the licensee for the planned modification (Figures 2, 3, 4) add additional circuits between the switchyard and the onsite Class 1E system. Each of the options removes the design requirement for the establishment of the delayed access circuit in four to six hours, meets the requirements of GDC-17, and is acceptable. Other options which should be considered include: (1) the use of a motor operated disconnect or breaker in place of the disconnect links and (2) an independent offsite circuit which is physically and electrically independent of the existing switchyard and circuits between the switchyard and Class 1E buses.

(5) The Commission's proposed station blackout rule would require that the Palisades design have sufficient capacity and capability to cope with a station blackout for a specified duration. The licensee may find it advantageous to consider this for plant modifications which are being planned for the offsite system.



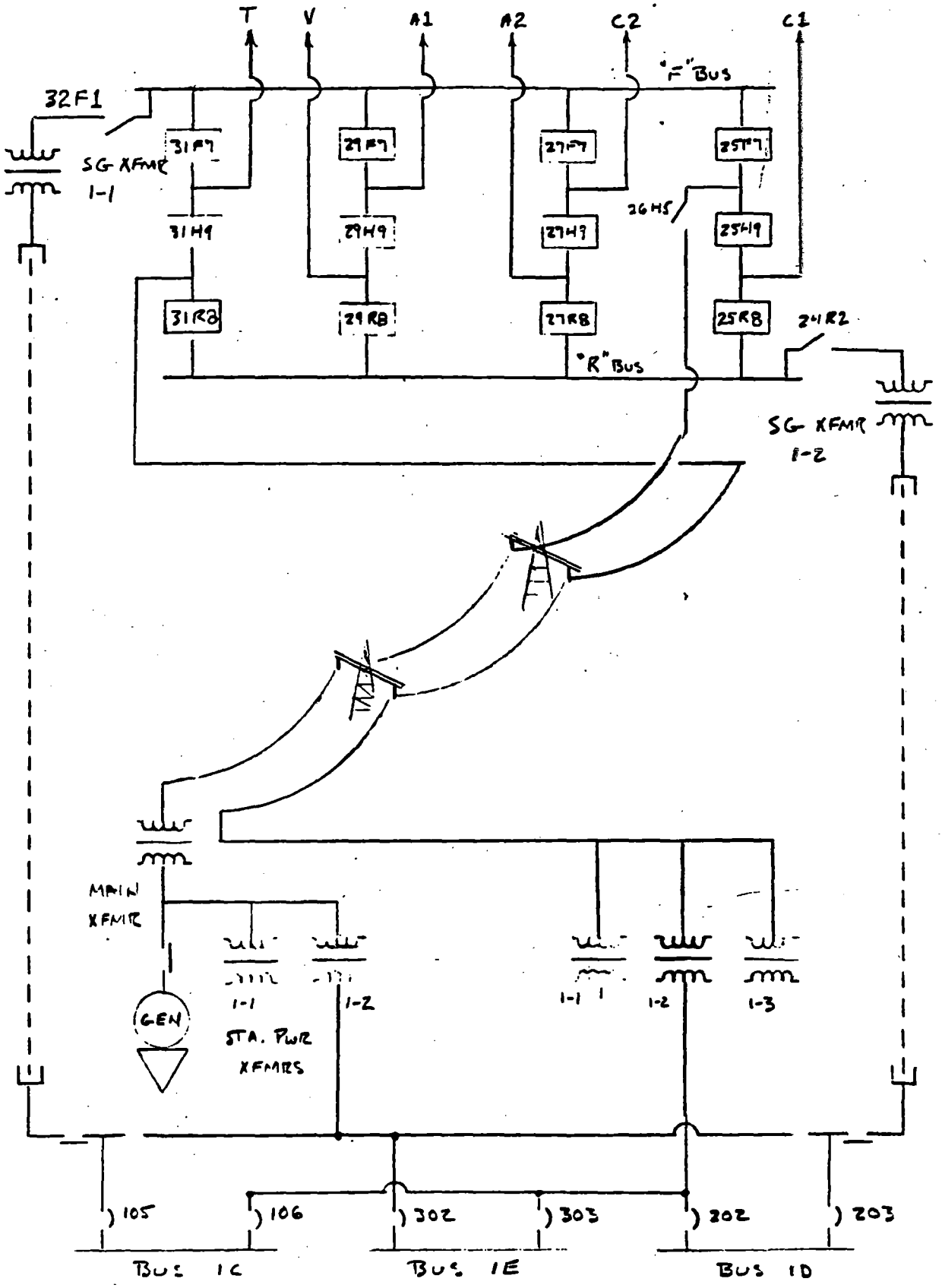

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FIGURE 3

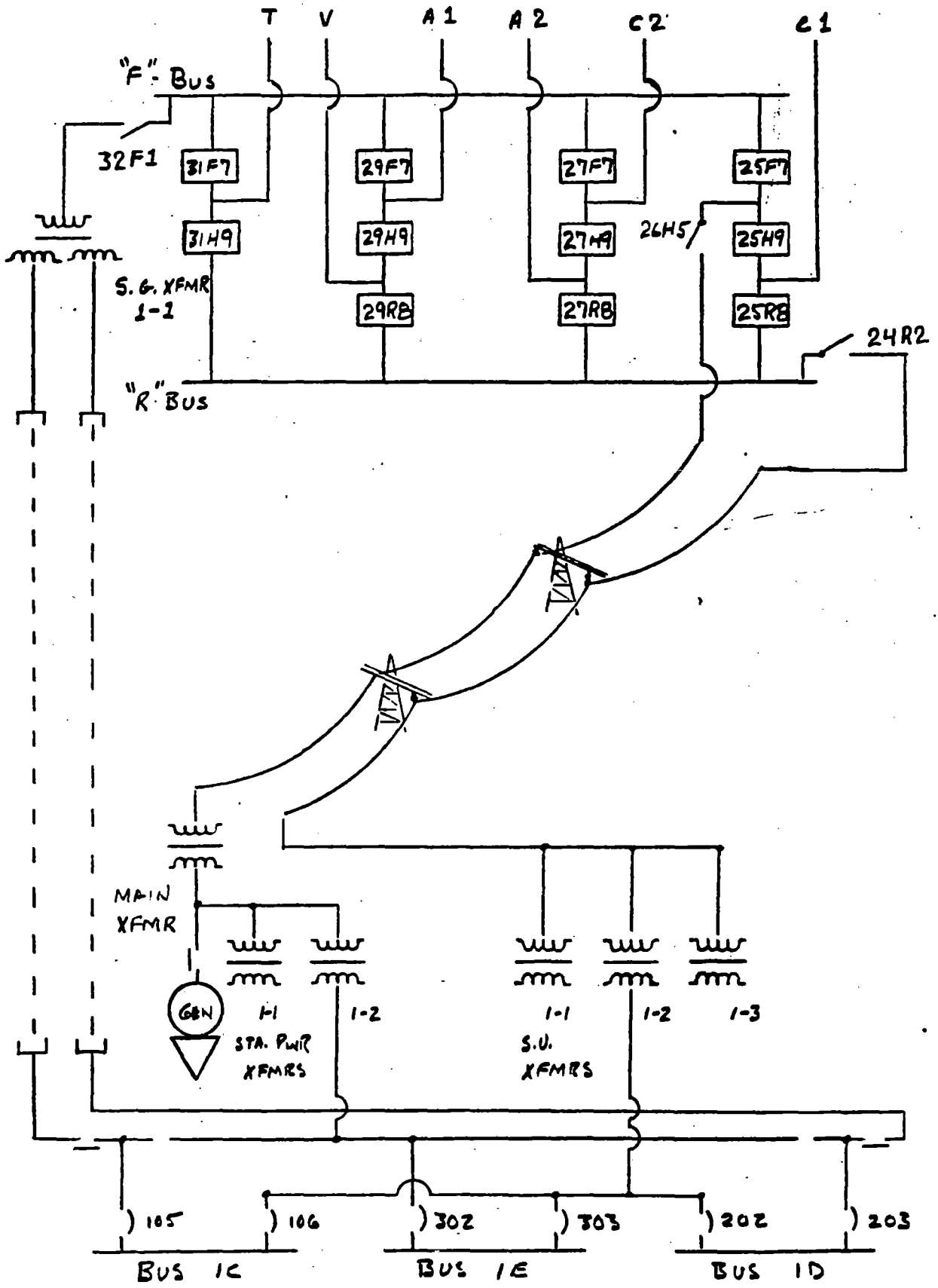

FIGURE 4