Final Precursor Analysis

Accident Sequence Precursor Program --- Office of Nuclear Regulatory Research

Dresden Unit 3	Unit 3 Scram Due to Loss of Offsite Power and Subsequent Inoperability of the Standby Gas Treatment System for Units 2 and 3	
Event Date 5/5/2004	LER 249/04-003	CCDP[1] $=2.8\text{x}10^{-6}$

June 30, 2005

Event Summary

On May 5, 2004, Dresden Unit 3 was at full power and Dresden Unit 2 was shut down. Offsite power Line 1223 in the Unit 3 switchyard ring bus was out of service for scheduled maintenance. See Appendix D Drawing 1 for information on the switchyard configuration. Operations personnel were implementing a switching order which cross-tied the Unit 2 and Unit 3 switchyard ring busses to provide an alternative source of power to the Unit 3 Reserve Auxiliary Transformer. Operations personnel manually opened Switchyard Breaker 8-15 in accordance with the switching order. However, when the ‘A’ and ‘B’ phases of Breaker 8-15 opened, the ‘C’ phase of Breaker 8-15 failed to fully open within the required time frame. This failure caused current imbalances in both the Unit 2 and Unit 3 switchyard ring busses. The current imbalances in the switchyard first resulted in a Unit 3 automatic scram due to a turbine load reject. The continued current imbalances then caused a loss of power to the Unit 3 Reserve Auxiliary Transformer which resulted in a Unit 3 Loss of Offsite Power (LOOP) to the safety-related Emergency Core Cooling System (ECCS) Busses.

The licensee declared an Unusual Event in accordance with the Emergency Plan and exited the Unusual Event approximately two and a half hours later following the restoration of offsite power to one onsite safety-related electrical bus. During the event, the licensee also experienced several other anomalies which included the following: the inadvertent opening of a diesel generator output breaker upon unexpected restoration of offsite power to the first safety-related electrical bus; the inability of the standby gas treatment system to maintain the proper differential pressure in secondary containment; and the inability to initially close a bus cross tie breaker needed for the restoration of the condensate system.

The sequence of key events is included in Appendix A.

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[1] For the initiating event assessment, the parameter of interest is the measure of the CCDP. This is the value obtained when calculating the probability of core damage for an initiating event with subsequent failure of one or more components following the initiating event. The value reported here is the mean.

Analysis Results

- **Conditional Core Damage Probability (CCDP)**

The CCDP for this event is 2.8E-006. The acceptance threshold for the Accident Sequence Precursor Program is a CCDP of 1.0 x 10^{-6}. This event is a precursor.

	Point Estimate
CCDP	**2.8E-006**

The unmodified Dresden SPAR model's CCDP for a LOOP event is 3E-6. This reflects probabilistically-weighted contributions from scenarios having significantly longer durations than the present event, in which offsite power was available in the switchyard early in the event. Correspondingly, most of the changes made to reflect the present event tend to drive CCDP down from the above value.

Uncertainty analysis was not performed because the CCDP differs minimally from that of the base model, and is reduced from the CCDP calculated for the Dresden model without the specific conditions obtaining in this event.

- **Dominant Sequences**

The dominant sequences are LOOP-40-05 (30% of the total CCDP), LOOP-40-27 (23% of the total CCDP), LOOP-10 (20% of the total CCDP), LOOP-39 (15% of the total CCDP), LOOP-38 (2% of the total CCDP), LOOP-42-02 (2% of the total CCDP), LOOP-40-14 (2% of the total CCDP), LOOP-41-06 (1% of the total CCDP), and LOOP-43-06-18 (1% of the total CCDP).

LOOP-40-05: One SRV sticks open; containment heat removal fails. This sequence did not change significantly in frequency as a result of the current assessment.

LOOP-40-27: One SRV sticks open; high-pressure makeup and depressurization fail. This sequence did not change significantly in frequency as a result of the current assessment.

LOOP-10: The isolation condenser fails and containment heat removal fails. This sequence did not change significantly in frequency as a result of the current assessment.

LOOP-39: The isolation condenser fails, high-pressure makeup fails, and depressurization fails. This sequence did not change significantly in frequency as a result of the current assessment.

LOOP-38: The isolation condenser fails, high-pressure makeup fails, and low-pressure makeup fails. This sequence increases in CCDP relative to the default model as a result of the way in which power recovery has been modeled (refer to the human error worksheets in Appendix B; as a result of issues mentioned in the event description above, increased values were assigned to human error probability in bus recovery). In the SPAR model, most crosstie possibilities are modeled but given probabilities of unity; this treatment was extended to crosstie of the SBO busses, which the default SPAR model credits. (Note that a more detailed model of this action would need to reflect dependence with other recovery actions modeled.)

LOOP-42-02: In the current assessment, this sequence decreased in frequency relative to the frequency calculated in the default model. Contributors to this outcome are the following. (1) The other unit did not suffer a LOOP, so the swing diesel did not need to align to the other unit. The default model conservatively assumes that the swing diesel ALWAYS aligns to the other unit. (2) Offsite power was available in the switchyard early in the event, and the present result is conditioned on that circumstance. The default model applies a more generic power recovery model.

LOOP-40-14: One SRV sticks open; HPCI succeeds, but the safety-class low-pressure injection paths fail. Alternate low-pressure makeup succeeds but containment heat removal fails. This sequence increases in CCDP relative to the default model as a result of the way in which power recovery has been modeled (refer to the human error worksheets in Appendix B; as a result of issues mentioned in the event description above, increased values were assigned to human error probability in bus recovery). In the SPAR model, most crosstie possibilities are modeled but given probabilities of unity; this treatment was extended to crosstie of the SBO busses, which the default SPAR model credits. (Note that a more detailed model for this action would need to reflect dependence with other recovery actions modeled.)

LOOP-41-06: Two or more SORVs stick open; low-pressure makeup succeeds, but containment heat removal fails (including venting). This sequence did not change significantly in frequency as a result of the current assessment.

LOOP-43-06-18: Scram fails; the power conversion system is unavailable and manual depressurization fails. This sequence did not change significantly in frequency as a result of the current assessment.

- **Results tables**

  – The CCDP values for the dominant sequences are shown in Table 1.
  – The event tree sequence logic for the dominant sequences is presented in Table 2a.
  – Table 2b defines the nomenclature used in Table 2a.
  – The most important cut sets for the major dominant sequences are listed in Table 3.
  – Table 4 presents names, definitions, and probabilities of (1) basic events whose probabilities were changed to model this event, and (2) basic events that are important to the CCDP result.

Modeling Assumptions

- **Analysis Type**

This analysis is an "initiating event" analysis.

- **Unique Design Features**

Features of Dresden affecting the assessment include:

  ‣ Swing diesel shared between units
  ‣ Each unit has a "SBO" diesel generator, in addition to the diesel generators tied directly to safety busses
  ‣ Numerous crossties linking Unit 2 busses to Unit 3 busses

Modeling Assumptions Summary

This event was modeled as a loss of offsite power initiating event (IE-LOOP). The frequency of IE-LOOP was set to 1.0. The frequencies of the other initiating events were set to 0.0. The duration of the LOOP is taken to be that of the actual event. The LOOP initiating event and its duration are the key boundary conditions for this analysis.

Equipment and operator actions that were successful during the actual event are assigned their normal failure probabilities. Equipment and operator actions that failed during the event are failed (set to TRUE) in the analysis.

For this analysis, the statistically based non-recovery curves contained in the SPAR model are replaced with specific human actions in order to analyze a LOOP event of known duration. LOOP recovery basic events that are required to occur at a time before offsite power was actually available in the event are set to TRUE (failed). (Possible examples: recovery actions that need to succeed early because of a transient-induced LOCA). These events cannot be successful, because the known duration of the LOOP is greater than the time available for the recovery action. LOOP recovery basic events that occur after offsite power is available are set consistent with the human error probabilities associated with re-energizing the ESF buses.

Since the LOOP duration is known, the status of power to the switchyard is known at any given time. However, the failure probabilities of the actions to re-energize the ESF buses, given that switchyard power is available, need to be determined. The human error likelihood is determined using the SPAR-H methodology (Ref. 5).

The EDG run mission times have been adjusted consistent with the time it took to re-energize the first ESF bus from offsite power following the event.

The other key modeling assumptions are listed below. Refer to Appendix A for a summary of the key events on which these assumptions are based.

Offsite power was available for recovery immediately following the initiating event. In order to support testing on Line 1223, the Unit 2/3 Switchyard Tie Breaker 4-8 was closed to power Unit 3 ECCS buses from Unit 2's switchyard. Breaker 8-15 was then opened to complete the isolation of Line 1223. See Appendix D Drawings 1 and 2. However, the ‘C’ phase failed. This occurred at 13:27:31. Due to the resulting switchyard current imbalances, Line 1222's switchyard breakers open. Unit 3 scrammed at 13:27:40 due to turbine load reject since its output to the grid was only through Line 1222. The current imbalance continued until protective relaying isolated the Breaker 4-8 fault by opening the Unit 2/3 tie breaker at 13:27:54. This resulted in the loss of offsite power to Unit 3 ECCS and also isolated the Unit 3 fault from Unit 2. Power to Unit 2 remained available. A manual cross-tie was available during the entire event between Unit 2 and Unit 3, through the Unit 2 Reserve Auxiliary Transformer TR-22. The cross-tie was safety-related and capable of supplying offsite power to one Division of accident loads for Unit 3 and both Divisions of Safe-Shutdown loads for Unit 3. Therefore, power was available for recovery from Unit 2's switchyard immediately. (Reference 2)

The trip of the EDG 2/3 (a swing EDG) output breaker did not adversely impact the plant’s response to this event. Following the manual closure of Switchyard Breaker 4-8 which re-energized Reserve Auxiliary Transformer TR-32 with offsite power, EDG 2/3 output breaker opened on reverse power. This occurred at 15:38 (Reference 2). Although this resulted in an unanticipated EDG breaker trip, the associated ECCS buses, Bus 33-1 and Bus 33, remained energized.

The failure of cooling to Reserve Auxiliary Transformer (RAT) TR-32 did not adversely impact the plant’s response to this event. During the recovery, Unit 3 Station Blackout Diesel was manually started and Bus 34 was energized at 13:40. Licensee personnel attempted to re-energize onsite Bus 36 from Bus 34 but the 4 kV cross-tie breaker tripped open. An important load on Bus 36 is power for cooling RAT TR-32. As a result, cooling was not available when RAT TR-32 was re-energized at 15:38. At 21:17 licensee personnel replaced the Bus 34 cross-tie breaker and energized Bus 36. This action restored the plant’s remaining internal loads including cooling to RAT TR-32 (Reference 2). As a result of the cross-tie breaker fault, power for RAT TR-

32 cooling was not available for some hours. However, no adverse consequences to the RAT TR-32 were noted during this event.

The inability to maintain secondary containment differential pressure does not contribute to the risk of core damage. Because Unit 2 was in a forced outage prior to the event, both Unit 2 drywell fans were running. The discharge from these fans goes into a common header shared with Unit 3 and contributed to the inability of Unit 3 to maintain secondary containment differential pressure (Reference 2). The secondary containment function is associated with barrier integrity in that it contributes to protection of the public from radionuclide releases caused by accidents or events. Since this analysis does not address radionuclide releases, this unit-to-unit interaction is not evaluated.

Modifications to event trees and fault trees

Note: the SPAR model event nomenclature is for Unit 2. This nomenclature was preserved although the event occurred at Unit 3.

The existing SPAR model contains logic reflecting considerations relevant to a generic loss of offsite power event, namely, gate "ROOP" (Recovery of Offsite Power) within the EPS fault tree. This logic contains basic events corresponding to nonrecovery within 1 or 10 hours; sequence-specific flag sets toggle this logic so that the appropriate nonrecovery event appears in any given sequence's cut sets. In order to reflect the specific characteristics of this event, this generic ROOP logic is replaced with event-specific, safety-bus-specific logic, as summarized in tabular form below and presented in Figures 3-8 (Appendix C).

Actions taken to reflect these considerations in the fault trees are the following.

Action	Rationale
Develop safety-bus-specific Recovery of Offsite Power (ROOP) tree logic	Preferred restoration path different for different safety busses
Change the operator failure event within ROOP logic to more complex, bus-specific events	Condition the analysis on the characteristics of this specific event. Address diagnosis, execution, and breaker failures. Reflect inspection report observations on procedural issues in human error probability assessment (Appendix B).
Capture dependency between restoration of different busses by incorporating a common "diagnosis" event for all busses	Some dependency is appropriate.

- **Basic Event Probability Changes**

Table 4 includes existing basic events whose probabilities were changed to reflect the event being analyzed. Some of these events were created anew per the above discussion, and others (the initiating events) are changed as part of the initiating event assessment process.

Following is a summary of basic event probability changes made for this analysis.

Hardware Failure of Breakers Linking ESF Busses to Offsite or to SBO Bus (ACP-BKR-23-1-1, ACP-BKR-24-1-1H, ACP-BKR-61-23, ACP-BKR-61-24). Typically either 2 or 3 breakers are required to change state in order to align ESF Busses to other sources. Each breaker failure is assigned 5E-4 (Ref. 4).

Hardware Failure of Breakers Linking ESF Busses to Offsite or to SBO Bus, and failure to recover (ACP-BKR-24-1-10H, ACP-BKR-61010H, ACP-BKR-23-1-10). Typically either 2 or 3 breakers are required to change state in order to align ESF Busses to other sources. Each breaker failure is assigned 5E-4 (Ref. 4). Within 10 hours, however, recovery of breaker hardware failure is possible (such a recovery took place within this event, though not on a safety bus), so a factor of 0.5 is applied to the hardware failure.

Event defined to toggle analysis between event analysis and unmodified model (ASP-ANAL-Case). This event switches on the fault tree modifications needed for this analysis, and is set to "TRUE" for the ASP case.

Operator Failures to Crosstie Busses (EPS-XHE-XM-S3XTIE, EPS-XHE-XM-U3D1X2, EPS-XHE-XM-U3D2X2). Two of these are set to "1" in the base model, and for this analysis, the other was set to "1" as well. In this analysis, all non-SBO bus recoveries for a given time frame (1 hour or 10 hours) have been given a common basic event for failure to diagnose (OEP-XHE-NODIA-10H or OEP-XHE-NODIA-1H, as appropriate), reflecting a conservative assessment of dependence between recovery events for different busses. If these events were not set to "1", they would also include this logic, and the dominant contribution to the failure of recovery of all busses would continue to be this basic event.

Swing diesel aligns to other unit (FLAG-SWING-EDG-TO-U3). In the base model, this event is set to 1, conservatively assuming that the DG will always align to the other unit. In this event, the other unit did not lose offsite power, so the event was set to "FALSE." (The DG can, of course, still fail.)

Initiating Event Frequencies (IE- ....). For this analysis, all initiating event frequencies except IE-LOOP were set to 0. IE-LOOP was set to 1.0.

Operator Failure to Execute Bus-Specific, Time-Frame-Specific Recovery Actions (OEP-EX-23-1-10H, OEP-EX-23-1-1H, OEP-EX-24-1-10H, OEP-EX-24-1-1H, OEP-EX-

61-10H, OEP-EX-61-1H, OEP-EX-61-23-1H, OEP-EX-61-24-1H). These basic events model failure of the execution portion of the recovery actions. Refer to the worksheets in Appendix B.

Blackout-related recovery actions (OEP-XHE-ASP-NR01H, OEP-XHE-ASP-NR10H, OEP-XHE-ASP-NR30M). These actions have been specialized from the base model to reflect the point that offsite power was in principle available. Refer to Appendix B.

Operator Failure to diagnose need to recover power to safety busses in 1 hour or 10 hours (OEP-XHE-NODIA-10H, OEP-XHE-NODIA-1H). These time-frame-specific basic events reflect the failure of the "diagnosis" portion of the operator action within the indicated time frame in non-SBO sequences. In this ASP analysis, these events are common to the ESF busses and the SBO bus, and are single-element cut sets for the joint recovery failure within the indicated time frame.

Diesel Generator Fails to Run (template event ZT-DGN-FR-L). The mission time for this event is set to 1.5, reflecting the present mission time of 2.5 hours. The first hour of the mission is reflected in another template event (ZT-DGN-FR-E).

Other basic event changes shown in the GEM file are applied to basic events that do not figure in the present analysis, and have correspondingly been eliminated from Table 4.

- **SPAR Model Corrections**

While this analysis was underway, a new version of the SPAR model became available (3.11). It has been confirmed that the results of the present analysis are not affected by the model changes resulting in the 3.11 version. First, the present analysis has been carried out in such a way that the event-specific modifications can be toggled off, so that the modified model can be driven as the original SPAR model. The results of such a run were obtained and compared with an unmodified version of the 3.11 model, yielding consistent results. Moreover, the Activity Log on the SAPHIRE web site indicates that the changes resulting in the 3.11 version "did not impact CDF," and would affect only uncertainty analysis or the modeling of large common cause groups, neither of which has been a factor in this analysis.

- **Analysts**

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References

1. *Licensee Event Report 249/04-003-01, Unit 3 Scram Due to Loss of Offsite Power and Subsequent inoperability of the Standby Gas Treatment System for Units 2 and 3, event date October 29, 2004*

2. *NRC Special Inspection Report (IR) 05000249/2004009, and Preliminary White Finding - Dresden Nuclear Power Plant Unit 3*, June 21, 2004 (ADAMS Accession No. ML041730504).

3. John A. Schroeder, *Standardized Plant Analysis Risk Model for Dresden 2 and 3 (ASP BWR C)*, Revision 3.10, December 10, 2004.

4. Steve Eide, *Generic Component Failure Data Base for Light Water and Liquid Sodium Reactor PRAs*, EGG-SSRE-8875, 1990.

5. Idaho National Engineering and Environmental Laboratory, “The SPAR-H Human Reliability Analysis Method INEEL/EXT-02-01307", May 2004.

Table 1. Conditional probability associated with the highest probability sequences.

Event Tree Name	Sequence Number	CCDP[1]	% Contribution
LOOP	40-05	8.4E-007	30
LOOP	40-27	6.3E-007	23
LOOP	10	5.6E-007	20
LOOP	39	4.1E-007	15
LOOP	38	5.1E-008	2
LOOP	42-02	4.9E-008	2
LOOP	40-14	4.7E-008	2
LOOP	41-06	3.5E-008	1
LOOP	43-06-18	3.3E-008	1
Total (all sequences)[2]		**2.8E-006**	**100**

1. Values are point estimates
2. Total CCDP includes all sequences (including those not shown in this table).

Table 2a. Event tree sequence logic for the dominant sequences.

Event Tree Name	Sequence Number	Logic ("/" denotes success; see Table 2b for top event names)
LOOP	40-05	/RPS /EPS P1 /HC1 /LCS SPC CSS CVS
LOOP	40-27	/RPS /EPS P1 HC1 DE2
LOOP	10	/RPS /EPS /SRV ISO /HCI SPC /DEP SDC CSS CVS
LOOP	39	/RPS /EPS /SRV ISO HCI DEP
LOOP	38	/RPS /EPS /SRV ISO HCI /DEP LCS LCI
LOOP	42-02	/RPS EPS /SRV /ISO /SEALS AC-04H
LOOP	40-14	/RPS /EPS P1 /HC1 LCS LCI /VA SPC CSS CVS
LOOP	41-06	/RPS /EPS P2 /LCS SPC CSS CVS
LOOP	43-06-18	RPS /PPR /RRS PC2 /SLC /NX /TAF DE1

Table 2b. Definitions of fault trees listed in Table 2a.

Top Event	Definition
AC-04H	Developed Event
CSS	CONTAINMENT SPRAY
CVS	CONTAINMENT VENTING
DE2	CONTAINMENT VENTING
DEP	MANUAL REACTOR DEPRESS
EPS	EMERGENCY POWER
HC1	HPCI FAILS TO PROVIDE SUFFICIENT FLOW TO RX VESSEL
HCI	HPCI
ISO	ISOLATION CONDENSER
LCI	LOW PRESS COOLANT INJECTION
LCS	CORE SPRAY
NX	OPERATOR FAILS TO INHIBIT ADS
P1	ONE SORV FAILS TO CLOSE
P2	TWO SORVS FAIL TO CLOSE
PC2	POWER CONVERSION SYSTEM IS UNAVAILABLE
PPR	SAFETY RELIEF VALVES FAIL TO OPEN
RPS	REACTOR SHUTDOWN
RRS	RECIRC PUMP TRIP FAILS
SDC	SHUTDOWN COOLING
SEALS	RECIRC PUMP SEALS SURVIVE
SLC	STANDBY LIQUID CONTROL FAILS
SPC	SUPPRESSION POOL COOLING
SRV	SRVS CLOSE
TAF	OPERATOR FAILS TO CONTROL LEVEL TO TAF
VA	LONG-TERM LOW PRESS INJECTION

Table 3. Conditional cut sets for dominant sequences.

CCDP	Percent Contribution	Minimal Cut Set (of basic events)
		Event Tree: LOOP, Sequence: 40-05
7.9E-007	94.24	PPR-SRV-OO-1VLV RHR-XHE-XM-ERROR CVS-XHE-XM-VENT2
1.6E-008	1.85	CVS-XHE-XM-LOOP PPR-SRV-OO-1VLV RHR-XHE-XM-ERROR
8.4E-007	**100**	**Total (all cutsets)[1]**
CCDP	Percent Contribution	Minimal Cut Set (of basic events)
		Event Tree: LOOP, Sequence 40-27
3.70E-07	59.39	PPR-SRV-OO-1VLV ADS-XHE-XM-MDEP1 HCI-TDP-TM-TRAIN
8.10E-08	12.91	PPR-SRV-OO-1VLV ADS-XHE-XM-MDEP1 HCI-TDP-FR-TRAIN HCI-XHE-XL-RUN
3.10E-08	4.95	PPR-SRV-OO-1VLV ADS-XHE-XM-MDEP1 HCI-XHE-XO-ERROR
3.10E-08	4.95	PPR-SRV-OO-1VLV ADS-XHE-XM-MDEP1 HCI-MOV-CC-F035
3.10E-08	4.95	PPR-SRV-OO-1VLV ADS-XHE-XM-MDEP1 HCI-MOV-OO-F006
3.10E-08	4.95	PPR-SRV-OO-1VLV HCI-MOV-CC-F036 ADS-XHE-XM-MDEP1
1.60E-08	2.47	PPR-SRV-OO-1VLV ADS-XHE-XM-MDEP1 HCI-TDP-FS-TRAIN HCI-XHE-XL-START
7.10E-09	1.13	ADS-SRV-CF-VALV1 PPR-SRV-OO-1VLV HCI-TDP-TM-TRAIN
6.3E-007	**100**	**Total (all cutsets)[1]**
CCDP	Percent Contribution	Minimal Cut Set (of basic events)
		Event Tree: LOOP, Sequence 10
2.8E-007	49.91	RHR-XHE-XM-ERROR ISO-VCF-FC-FTO ISO-XHE-XL-FRFTO CVS-XHE-XM-VENT2
2.6E-007	45.88	RHR-XHE-XM-ERROR ISO-VCF-FC-FMU ISO-XHE-XL-FRFMU CVS-XHE-XM-VENT2
5.6E-007	**100**	**Total (all cutsets)[1]**

CCDP	Percent Contribution	Minimal Cut Set (of basic events)
		Event Tree: LOOP, Sequence 39
1.30E-07	32.18	DCP-BAT-CF-ALL
7.70E-08	18.93	DCP-BCH-CF-ALL
6.50E-08	16.06	ADS-XHE-XM-MDEPR HCI-TDP-TM-TRAIN ISO-VCF-FC-FTO ISO-XHE-XL-FRFTO
6.00E-08	14.76	ADS-XHE-XM-MDEPR HCI-TDP-TM-TRAIN ISO-VCF-FC-FMU ISO-XHE-XL-FRFMU
1.40E-08	3.49	ADS-XHE-XM-MDEPR HCI-TDP-FR-TRAIN HCI-XHE-XL-RUN ISO-VCF-FC-FTO ISO-XHE-XL-FRFTO
1.30E-08	3.21	ADS-XHE-XM-MDEPR HCI-TDP-FR-TRAIN HCI-XHE-XL-RUN ISO-VCF-FC-FMU ISO-XHE-XL-FRFMU
6.00E-09	1.48	DCP-BAT-LP-UNIT3 ADS-XHE-XM-MDEPR
5.40E-09	1.34	ADS-XHE-XM-MDEPR HCI-XHE-XO-ERROR ISO-VCF-FC-FTO ISO-XHE-XL-FRFTO
5.40E-09	1.33	HCI-MULTIPLE-INJECT HCI-XHE-XL-INJECT ADS-XHE-XM-MDEPR HCI-MOV-CC-IVFRO ISO-VCF-FC-FTO ISO-XHE-XL-FRFTO
5.00E-09	1.23	ADS-XHE-XM-MDEPR HCI-XHE-XO-ERROR ISO-VCF-FC-FMU ISO-XHE-XL-FRFMU
5.00E-09	1.23	HCI-MULTIPLE-INJECT HCI-XHE-XL-INJECT ADS-XHE-XM-MDEPR HCI-MOV-CC-IVFRO ISO-VCF-FC-FMU ISO-XHE-XL-FRFMU
4.1E-007	**100**	**Total (all cutsets)**[1]

1. Total includes all cutsets (including those not shown in this table).

Table 4. Definitions and probabilities for modified or dominant basic events.

Event Name	Description	Probability/ Frequency (per hour)	Modified
ACP-BKR-23-1-1	FAILURE OF BKRS OFFSITE =>23	1.5E-003	Yes[1]
ACP-BKR-23-1-10	FAILURE OF BKRS OFFSITE=>23-	1.5E-004	Yes[1]
ACP-BKR-24-1-10H	FAILURE OF BKRS OFFSITE => 2	1.5E-004	Yes[1]
ACP-BKR-24-1-1H	FAILURE OF BKRS OFFSITE =>24	1.5E-003	Yes[1]
ACP-BKR-61-10H	FAILURE OF BKRS OFFSITE=> 61	1.0E-004	Yes[1]
ACP-BKR-61-1H	FAILURE OF BKRS OFFSITE=>61	1.0E-003	Yes[1]
ACP-BKR-61-23	FAILURE OF BREAKERS LINKING	2.0E-003	Yes[1]
ACP-BKR-61-24	FAILURE OF BKRS LINKING 61 TO 24 AND NO REC	2.0E-003	Yes[1]
ADS-SRV-CC-ERV3B	ELECTROMATIC RELIEF VALVE 203-3B FAILS TO OPE	2.5E-003	No
ADS-SRV-CC-ERV3C	ELECTROMATIC RELIEF VALVE 203-3C FAILS TO OPE	2.5E-003	No
ADS-SRV-CC-ERV3D	ELECTROMATIC RELIEF VALVE 203-3D FAILS TO OPE	2.5E-003	No
ADS-SRV-CC-ERV3E	ELECTROMATIC RELIEF VALVE 203-3E FAILS TO OPE	2.5E-003	No
ADS-SRV-CC-TRV3A	TARGET ROCK RELIEF VALVE 203-3A FAIL TO OPEN	2.5E-003	No
ADS-SRV-CF-VALV1	ADS VALVES FAIL FROM COMMON CAUSE	1.90E-05	No
ADS-XHE-XM-MDEP1	OPERATOR FAILS TO DEPRESSURIZE THE REACTOR	1.00E-03	No
ADS-XHE-XM-MDEPR	OPERATOR FAILS TO DEPRESSURIZE THE REACTOR	5.00E-04	No
ASP-ANAL-CASE	TRUE IF DOING THE ASP EVENT,	1.0E+000 TRUE	Yes[1]
CVS-XHE-XM-LOOP	FAILURE TO RESTART IA FOLLOWING LOOP (REQUIRE	1.00E-03	No
CVS-XHE-XM-VENT2	DEPENDENT OPERATOR ACTION TO VENT CONTAINMENT	5.10E-02	No
DCP-BAT-CF-ALL	STATION BATTERIES FAIL FROM COMMON CAUSE	1.30E-07	No

Event Name	Description	Probability/ Frequency (per hour)	Modified
DCP-BAT-LP-UNIT3	UNIT 3 250 VDC BATTERY IS UNAVAILABLE	1.20E-05	No
DCP-BCH-CF-ALL	CONTROL POWER BATTERY CHARGERS FAIL FROM COMM	7.70E-08	No
DCP-BCH-LP-UNIT2A	UNIT 2 STANDBY BATTERY CHARGER 2A IS UNAVAILA	1.20E-04	No
DCP-BDC-LP-BUS3	DIVISION II (BATT BUS 3) 125 VDC BUS IS UNAVA	4.80E-06	No
DCP-XHE-XM-BCHGR	OPERATOR FAILS TO ALIGN STANDBY BATTERY CHARG	1.00E-03	No
EPS-DGN-CF-RUN	COMMON CAUSE FAILURE OF DIESEL GENERATORS TO	3.10E-05	No
EPS-DGN-FR-DG2	DIESEL GENERATOR 2 FAILS TO RUN	4.20E-03	Yes[2]
EPS-DGN-FR-DG23	DIESEL GENERATOR 2/3 FAILS TO RUN	4.20E-03	Yes[2]
EPS-DGN-FR-SBODG2	SBO DG-2 FAILS TO RUN	4.20E-03	Yes[2]
EPS-DGN-FS-DG2	DIESEL GENERATOR 2 FAILS TO START	4.00E-03	No
EPS-DGN-FS-DG23	DIESEL GENERATOR 2/3 FAILS TO START	4.00E-03	No
EPS-DGN-FS-SBODG2	SBO DG-2 FAILS TO START	4.00E-03	No
EPS-DGN-TM-DG2	DG 2 IS UNAVAILABLE BECAUSE OF MAINTENANCE	9.00E-03	No
EPS-DGN-TM-DG23	DIESEL GENERATOR 2/3 UNAVAILABLE DUE TO TEST	9.00E-03	No
EPS-DGN-TM-SBODG2	SBO DG-2 UNAVAILABLE DUE TO TEST AND MAINTENANCE	9.00E-03	No
EPS-XHE-XL-NR04H	OPERATOR FAILS TO RECOVER EMERGENCY DIESEL IN 4H	5.00E-01	No
EPS-XHE-XM-S3XTIE	OPERATOR FAILS TO CROSSTIE SBO DG-3 TO BUS 61	1.0E+000	Yes[1]
EPS-XHE-XM-U3D1X2	OPERATOR FAILS TO CROSSTIE U3 DIVISION 1	1.0E+000	No
EPS-XHE-XM-U3D2X2	OPERATOR FAILS TO CROSSTIE U3 DIVISION 2	1.0E+000	No

Event Name	Description	Probability/ Frequency (per hour)	Modified
ESW-MDP-FS-23	DIESEL GENERATOR SERVICE WATER MDP 23 FAILS TO START	1.50E-03	No
ESW-MDP-FS-2B	DIESEL GENERATOR SERVICE WATER MDP 2B FAILS TO START	1.50E-03	No
ESW-MDP-TM-23	DG SERVICE WATER MDP 2/3 UNAVAILABLE DUE TO TEST AND MAINTENANCE	2.00E-02	No
ESW-MDP-TM-2B	DG SERVICE WATER MDP 2B UNAVAILABLE DUE TO TEST AND MAINTENANCE	2.00E-02	No
FLAG-SWING-EDG-TO-U3	SWING EDG 2/3 IS ALIGNED TO	+0.0E+000 FALSE	Yes[1]
HCI-MOV-CC-F035	TORUS SUCTION VALVE 2-2301-35 FAILS TO OPEN	1.00E-03	No
HCI-MOV-CC-F036	TORUS SUCTION VALVE 2-2301-36 FAILS TO OPEN	1.00E-03	No
HCI-MOV-CC-IVFRO	HPCI INJECTION VALVE FAILS TO REOPEN	2.0E-002	No
HCI-MOV-OO-F006	CST ISOLATION VALVE 2-2301-6 FAILS TO CLOSE	1.00E-03	No
HCI-MULTIPLE-INJECT	MULTIPLE HPCI INJECTIONS REQUIRED	6.0E-002	No
HCI-TDP-FR-TRAIN	HPCI PUMP TRAIN FAILS TO RUN	4.1E-003	No
HCI-TDP-FS-TRAIN	HPCI PUMP FAILS TO START	6.0E-003	No
HCI-TDP-TM-TRAIN	HPCI TRAIN IS UNAVAILABLE BECAUSE OF MAINTENANCE	1.20E-02	No
HCI-XHE-XL-RUN	OPERATOR FAILS TO RECOVER HPCI FAILURE TO RUN	6.30E-01	No
HCI-XHE-XL-START	OPERATOR FAILS TO RECOVER HPCI FAILURE TO START	8.30E-02	No
HCI-XHE-XO-ERROR	OPERATOR FAILS TO START/ CONTROL HPCI INJECTION	1.00E-03	No
IE-LOOP	LOSS OF OFFSITE POWER	1.0E+000	Yes[3]
ISO-VCF-FC-FMU	MAKEUP TO THE ISOLATION CONDENSER FAILS	4.00E-02	No
ISO-VCF-FC-FTO	ISOLATION CONDENSER FAILS TO	6.40E-02	No

Event Name	Description	Probability/ Frequency (per hour)	Modified
	OPERATE		
ISO-XHE-XL-FRFMU	FAILURE TO RECOVER FROM FAILURE OF MAKEUP	2.50E-01	No
ISO-XHE-XL-FRFTO	FAILURE TO RECOVER FROM FAILURE TO OPERATE	1.70E-01	No
OEP-EX-23-1-10H	OPERATOR FAILURE TO EXECUTE	1.0E-003	Yes[1]
OEP-EX-23-1-1H	FAILURE TO EXECUTE RESTORATI	1.0E-002	Yes[1]
OEP-EX-24-1-10H	FAILURE TO EXECUTE PROC TO R	1.0E-003	Yes[1]
OEP-EX-24-1-1H	FAILURE TO EXEQ PROC TO RECO	1.0E-002	Yes[1]
OEP-EX-61-10H	OPERATOR FAILURE TO EXEQ REC	1.0E-003	Yes[1]
OEP-EX-61-1H	FAILURE TO EXEQ RESTORATION	1.0E-002	Yes[1]
OEP-EX-61-23-1H	FAILURE TO EXEQ ALIGNMENT OF 61 TO 23 IN 1 H	1.0E-002	Yes[1]
OEP-EX-61-24-1H	FAILURE TO EXEQ ALIGNMENT OF 61 TO 24 IN 1 H	1.0E-002	Yes[1]
OEP-EX-SBO-23-1-1H	FAILURE TO EXECUTE ALIGNMENT	1.0E-002	Yes[1]
OEP-XHE-ASP-NR01H	OPERATOR FAILS TO RECOVER AC	4.0E-002	Yes[1]
OEP-XHE-ASP-NR04H	OPERATOR FAILS TO RECOVER OFFSITE IN 4H	4.0E-003	Yes[1]
OEP-XHE-ASP-NR30M	OPERATOR FAILS TO RECOVER OFFSITE IN 30M	2.2E-001	Yes[1]
OEP-XHE-NODIA-10H	FAILURE TO DIAGNOSE NEED TO RECOVER OFFSITE IN 10H	5.0E-004	Yes[1]
OEP-XHE-NODIA-1H	FAILURE TO DIAGNOSE NEED TO RECOVER OFFSITE IN 1H	5.0E-003	Yes[1]
PPR-SRV-OO-1VLV	ONE SRV FAILS TO CLOSE	3.10E-02	No
PPR-SRV-OO-2VLVS	TWO OR MORE SRVS FAIL TO CLOSE	1.3E-003	No
RHR-XHE-XM-ERROR	OPERATOR FAILS TO START/ CONTROL RHR	5.00E-04	No
RPS-SYS-FC-CRD	CONTROL ROD DRIVE MECHANICAL FAILURE	2.5E-007	No
RPS-SYS-FC-PSOVS	HCU SCRAM PILOT SOVS FAIL	1.7E-006	No

Event Name	Description	Probability/ Frequency (per hour)	Modified
RPS-SYS-FC-RELAY	TRIP SYSTEM RELAYS FAIL	3.8E-007	No
ZT-DGN-FR-L	DIESEL GENERATOR FAILS TO RU	1.2E-003	Yes[2]

Notes:

1. Changed to reflect actual plant conditions during the event.
2. Changed total mission time to 2.5 hours to reflect time of restoration of offsite power to safety bus.
3. All other initiating event frequencies set to 0.0.

Appendix A

Sequence of Key Events

<u>Key Events</u>
<u>(Excerpted, Summarized, and Paraphrased From Inspection Report)</u>

Note: The event description reflects the Unit 3 nomenclature (Bus designations, etc.) (the event occurred at Unit 3). The model's nomenclature is based on Unit 2.

Time	Event	Significance
13:27: 31-54	- Failure of C phase of breaker 8-15 leads to a series of events culminating in LOOP to safety buses of Unit 3 - U-3 DG starts & energizes Bus 34-1 - DG 2/3 starts and energizes Bus 33-1	Initiating LOOP, successful diesel starts on both safety busses
13:29	HPCI, Isolation condenser, LPCI for torus cooling	Successful inventory control and DHR
13:40	SBO diesel started, Bus 34 energized	Successful SBO diesel start
14:03	Licensee personnel attempted to energize onsite Bus 36 from Bus 34, and the 4kV crosstie breaker tripped open.	This obliged the operators to remain on HPCI rather than restoring condensate. Restoring condensate, though preferred by the operators, is not credited in the SPAR LOOP model anyhow, so this impact is not considered significant. However, lack of power to Bus 36 also meant that Reserve Auxiliary Transformer (RAT) had no cooling. See 19:44 entry.
15:38	Reserve Auxiliary Transformer (RAT) TR-32 Reenergized	Ultimately, offsite was restored from this source. But it could have been recovered earlier.
15:58	RAT "automatically energized the 4kV Busses 33-1 and 33 unexpectedly. Emergency Diesel Generator 2/3 output breaker tripped open on reverse power. Bus 33-1 and 33 remained energized via offsite power through RAT TR-32."	Offsite power was recovered to safety bus 33-1 from this time forward. By convention, this defines the end of the mission time for the diesel generators. This recovery sequence was abnormal, but culminated in no equipment damage and left offsite power on the bus. Increased conditional CDP associated with this abnormality would be associated with conjunctions of failures, such as: losing power to the bus AND failure to restore (as a result of newly damaged components, independent component failures, or operator error) AND failures in the other division. These

Time	Event	Significance
		contributors appear to be higher-order than those already modeled.
17:29	RAT paralleled with U3 SBO diesel	
17:31	Bus 34 energized via offsite	
18:59	Bus 34-1 separated from DG U-3 and connected to Bus 34	The other safety bus (34-1) is now also on offsite power.
19:44	The RAT was “identified as having no cooling because Bus 36 remained de-energized.”	See next entry. This related to a breaker failure preventing recovery of power to Bus 36. Staff replaced a breaker.
21:37	Licensee personnel noted that all RAT TR-32 auxiliary systems, including cooling, were restored and normal.	Lack of RAT cooling had not caused failure up to this time in the sequence. Conditional CDP associated with a postulated failure of the RAT at some later time would entail a chain of additional failures, since many options were available by then, so this possibility is not considered risk-significant.

Appendix B

Human Error Modeling

For this analysis, the failure probability of recovery of offsite power to selected busses during non-SBO, non-SORV sequences was estimated using the standard SPAR Model Human Error Worksheet. The worksheet used to determine the value is included below.

Although this action for a single bus would be considered primarily “action,” this recovery action is modeled as having both a “diagnosis” contribution and an “action” contribution, and the first two pages of the worksheet are filled out correspondingly. The diagnosis contribution is then applied as a common basic event to each of the three busses to which this class of recovery events applies. The dependency between different busses’ recoveries is deemed to have been captured in this way. Separate basic events then reflect the “action” contributions and the hardware (breaker) contributions.

SPAR Model Human Error Worksheet (Page 1 of 3)

Plant: Dresden 3 **Event Name**: OEP-XHE-NODIA-10H (sheet 1), OEP-EX-23-1-10H,OEP-EX-24-1-10H, OEP-EX-61-10H (sheet 2)
Task Error Description: Failure to recover power to 4160 kV busses in 10 hr

Does this task contain a significant amount of diagnosis activity ? YES ✓ NO __
If Yes, Use Table 1 below to evaluate the PSFs for the Diagnosis portion of the task before going to Table 2. If No, go directly to Table 2.

Table 1. Diagnosis worksheet.

PSFs	PSF Levels	Multiplier for Diagnosis	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	Significant time available in Non-SBO, non-SORV scenarios to which this action applies (the SPAR model event is “failure to recover in 10 hours”)
	Barely adequate < 20 m	10	
	Nominal ≈ 30 m	1	
	Extra > 60 m	0.1 ✓	
	Expansive > 24 h	0.01	
2. Stress	Extreme	5	
	High	2	
	Nominal	1 ✓	
3. Complexity	Highly	5	
	Moderately	2	
	Nominal	1 ✓	
4. Experience/ Training	Low	10	
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	This factor has been assessed because symptoms of loss of power are considered straightforward.
	Available, but poor	5	
	Nominal	1	
	Diagnostic/symptom oriented	0.5 ✓	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

SPAR Model Human Error Worksheet (Page 2 of 3)

Table 2. Action worksheet.

PSFs	PSF Levels	Multiplier for Action	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	Significant time available in Non-SBO, non-SORV scenarios to which this action applies (the SPAR model event is “failure to recover in 10 hours”)
	Time available ≈ time required	10	
	Nominal	1	
	Available > 5x time required	0.1 ✓	
	Available > 50x time required	0.01	
2. Stress	Extreme	5	
	High	2	
	Nominal	1 ✓	
3. Complexity	Highly	5	Power recovery is moderately complex.
	Moderately	2 ✓	
	Nominal	1	
4. Experience/ Training	Low	3	
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	Procedure issues were cited in the inspection report related to breaker manipulation specifically in the context of switchyard breakers.
	Available, but poor	5 ✓	
	Nominal	1	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

Table 3. Task failure probability without formal dependence worksheet.

Task Portion	Nom. Prob.	Time	Stress	Compl.	Exper./ Train.	Proced.	Ergon.	Fitness	Work Process	Prob.
Diag.	1.0E-2	x 0.1	x 1.0	x 1.0	x 1.0	x 0.5	x 1.0	x 1.0	x 1.0	5.0E-4
Action	1.0E-3	x 0.1	x 1.0	x 2	x 1.0	x 5	x 1.0	x 1.0	x 1.0	1.0E-3
Total	Note: diagnosis contribution and execution contributions applied in separate BE’s									1.5E-3

SPAR Model Human Error Worksheet (Page 3 of 3)

For all tasks, except the first task in the sequence, use the table and formulae below to calculate the Task Failure Probability With Formal Dependence.

Table 4. Dependency condition worksheet.

Condition Number	Crew (same or different)	Location (same or different)	Time (close in time or not close in time)	Cues (additional or not additional)	Dependency	Number of Human Action Failures Rule
1	s	s	c	–	complete	If this error is the 3rd **error in the sequence**, then the dependency is at least **moderate**. If this error is the 4th **error in the sequence**, then the dependency is at least **high**. This rule may be ignored only if there is compelling evidence for less dependence with the previous tasks.
2	s	s	nc	na	high	
3	s	s	nc	a	moderate	
4	s	d	c	–	high	
5	s	d	nc	na	moderate	
6 ✓	**s**	**d**	**nc**	**a**	**low**	
7	**d**	**s**	**c**	**–**	**moderate**	
8	**d**	**s**	**nc**	**na**	**low**	
9	**d**	**s**	**nc**	**a**	**low**	
10	**d**	**d**	**c**	**–**	**moderate**	
11	**d**	**d**	**nc**	**na**	**low**	
12	**d**	**d**	**nc**	**a**	**low**	
13					**zero**	

Using P = Task Failure Probability Without Formal Dependence (calculated on page 2):

For Complete Dependence the probability of failure = 1.0
For High Dependence the probability of failure = (1 + P)/2
For Moderate Dependence the probability of failure = (1 +6P)/7
For Low Dependence the probability of failure = (1 + 19P)/20
For Zero Dependence the probability of failure = P

Task Failure Probability With Formal Dependence = (1 + (*)) / =

Additional Notes:

SPAR Model Human Error Worksheet (Page 1 of 3)

Plant: Dresden 3 **Event Name**: OEP-XHE-NODIA-1H (sheet 1), OEP-EX-23-1-1H,OEP-EX-24-1-1H, OEP-EX-61-1H (sheet 2)
Task Error Description: Failure to recover power to 4160 kV busses

Does this task contain a significant amount of diagnosis activity ? YES ✓ NO __
If Yes, Use Table 1 below to evaluate the PSFs for the Diagnosis portion of the task before going to Table 2. If No, go directly to Table 2.

Table 1. Diagnosis worksheet.

PSFs	PSF Levels	Multiplier for Diagnosis	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	
	Barely adequate < 20 m	10	
	Nominal ≈ 30 m	1 ✓	
	Extra > 60 m	0.1	
	Expansive > 24 h	0.01	
2. Stress	Extreme	5	
	High	2	
	Nominal	1 ✓	
3. Complexity	Highly	5	
	Moderately	2	
	Nominal	1 ✓	
4. Experience/ Training	Low	10	
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	This factor has been assessed because symptoms of loss of power are considered straightforward.
	Available, but poor	5	
	Nominal	1	
	Diagnostic/symptom oriented	0.5 ✓	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

SPAR Model Human Error Worksheet (Page 2 of 3)

Table 2. Action worksheet.

PSFs	PSF Levels	Multiplier for Action	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	
	Time available ≈ time required	10	
	Nominal	1 ✓	
	Available > 5x time required	0.1	
	Available > 50x time required	0.01	
2. Stress	Extreme	5	
	High	2	
	Nominal	1 ✓	
3. Complexity	Highly	5	Power recovery is moderately complex.
	Moderately	2 ✓	
	Nominal	1	
4. Experience/ Training	Low	3	
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	Procedure issues were cited in the inspection report related to breaker manipulation specifically in the context of switchyard breakers.
	Available, but poor	5 ✓	
	Nominal	1	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

Table 3. Task failure probability without formal dependence worksheet.

Task Portion	Nom. Prob.	Time	Stress	Compl.	Exper./ Train.	Proced.	Ergon.	Fitness	Work Process	Prob.
Diag.	1.0E-2	x 1.0	x 1.0	x 1.0	x 1.0	x 0.5	x 1.0	x 1.0	x 1.0	5.0E-3
Action	1.0E-3	x 1.0	x 1.0	x 2	x 1.0	x 5	x 1.0	x 1.0	x 1.0	1.0E-2
Total	Note: diagnosis contribution and execution contributions applied in separate BE's									1.5E-2

SPAR Model Human Error Worksheet (Page 3 of 3)

For all tasks, except the first task in the sequence, use the table and formulae below to calculate the Task Failure Probability With Formal Dependence.

Table 4. Dependency condition worksheet.

Condition Number	Crew (same or different)	Location (same or different)	Time (close in time or not close in time)	Cues (additional or not additional)	Dependency	Number of Human Action Failures Rule
1	s	s	c	–	complete	If this error is the 3rd **error in the sequence**, then the dependency is at least **moderate**. If this error is the 4th **error in the sequence**, then the dependency is at least **high**. This rule may be ignored only if there is compelling evidence for less dependence with the previous tasks.
2	s	s	nc	na	high	
3	s	s	nc	a	moderate	
4	s	d	c	–	high	
5	s	d	nc	na	moderate	
6 ✓	**s**	**d**	**nc**	**a**	**low**	
7	**d**	**s**	**c**	**–**	**moderate**	
8	**d**	**s**	**nc**	**na**	**low**	
9	**d**	**s**	**nc**	**a**	**low**	
10	**d**	**d**	**c**	**–**	**moderate**	
11	**d**	**d**	**nc**	**na**	**low**	
12	**d**	**d**	**nc**	**a**	**low**	
13					**zero**	

Using P = Task Failure Probability Without Formal Dependence (calculated on page 2):

For Complete Dependence the probability of failure = 1.0
For High Dependence the probability of failure = (1 + P)/2
For Moderate Dependence the probability of failure = (1 +6P)/7
For Low Dependence the probability of failure = (1 + 19P)/20
For Zero Dependence the probability of failure = P

Task Failure Probability With Formal Dependence = (1 + (*   )) /   =

SPAR Model Human Error Worksheet (Page 1 of 3)

Plant: Dresden 3 **Event Name**: OEP-XHE-ASP-NR01H (SBO Recovery)
Task Error Description: Failure to recover power to 4160 kV busses

Does this task contain a significant amount of diagnosis activity ? YES ✓ NO __
If Yes, Use Table 1 below to evaluate the PSFs for the Diagnosis portion of the task before going to Table 2. If No, go directly to Table 2.

Table 1. Diagnosis worksheet.

PSFs	PSF Levels	Multiplier for Diagnosis	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	
	Barely adequate < 20 m	10	
	Nominal ≈ 30 m	1 ✓	
	Extra > 60 m	0.1	
	Expansive > 24 h	0.01	
2. Stress	Extreme	5	SBO scenarios; power available offsite but multiple failures in plant, including the ones (SRV) that drive 1-hr time scale
	High	2 ✓	
	Nominal	1	
3. Complexity	Highly	5	SBO scenarios; power available offsite but multiple failures in plant, including the ones (SRV) that drive 1-hr time scale
	Moderately	2 ✓	
	Nominal	1	
4. Experience/ Training	Low	10	
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	This factor has been assessed because symptoms of loss of power are considered straightforward.
	Available, but poor	5	
	Nominal	1	
	Diagnostic/symptom oriented	0.5 ✓	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

SPAR Model Human Error Worksheet (Page 2 of 3)

Table 2. Action worksheet.

PSFs	PSF Levels	Multiplier for Action	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	
	Time available ≈ time required	10	
	Nominal	1 ✓	
	Available > 5x time required	0.1	
	Available > 50x time required	0.01	
2. Stress	Extreme	5	SBO with multiple failures
	High	2 ✓	
	Nominal	1	
3. Complexity	Highly	5	Power recovery is moderately complex (note there were issues in this event).
	Moderately	2 ✓	
	Nominal	1	
4. Experience/ Training	Low	3	
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	Procedure issues were cited in the inspection report related to breaker manipulation specifically in the context of switchyard breakers.
	Available, but poor	5 ✓	
	Nominal	1	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

Table 3. Task failure probability without formal dependence worksheet.

Task Portion	Nom. Prob.	Time	Stress	Compl.	Exper./ Train.	Proced.	Ergon.	Fitness	Work Process	Prob.
Diag.	1.0E-2	x 1	x 2.0	x 2.0	x 1.0	x 0.5	x 1.0	x 1.0	x 1.0	2E-2
Action	1.0E-3	x 1	x 2.0	x 2.0	x 1.0	x 5	x 1.0	x 1.0	x 1.0	2E-2
Total										4E-2

SPAR Model Human Error Worksheet (Page 3 of 3)

For all tasks, except the first task in the sequence, use the table and formulae below to calculate the Task Failure Probability With Formal Dependence.

Table 4. Dependency condition worksheet.

Condition Number	Crew (same or different)	Location (same or different)	Time (close in time or not close in time)	Cues (additional or not additional)	Dependency	Number of Human Action Failures Rule
1	s	s	c	–	complete	If this error is the 3rd **error in the sequence**, then the dependency is at least **moderate**. If this error is the 4th **error in the sequence**, then the dependency is at least **high**. This rule may be ignored only if there is compelling evidence for less dependence with the previous tasks.
2	s	s	nc	na	high	
3	s	s	nc	a	moderate	
4	s	d	c	–	high	
5	s	d	nc	na	moderate	
6 ✓	**s**	**d**	**nc**	**a**	**low**	
7	**d**	**s**	**c**	**–**	**moderate**	
8	**d**	**s**	**nc**	**na**	**low**	
9	**d**	**s**	**nc**	**a**	**low**	
10	**d**	**d**	**c**	**–**	**moderate**	
11	**d**	**d**	**nc**	**na**	**low**	
12	**d**	**d**	**nc**	**a**	**low**	
13					**zero**	

Using P = Task Failure Probability Without Formal Dependence (calculated on page 2):

For Complete Dependence the probability of failure = 1.0
For High Dependence the probability of failure = (1 + P)/2
For Moderate Dependence the probability of failure = (1 +6P)/7
For Low Dependence the probability of failure = (1 + 19P)/20
For Zero Dependence the probability of failure = P

Task Failure Probability With Formal Dependence = (1 + (*)) / =

Additional Notes:

SPAR Model Human Error Worksheet (Page 1 of 3)

Plant: Dresden 3 **Event Name**: OEP-XHE-ASP-NR30M (SBO Recovery)
Task Error Description: Failure to recover power to 4160 kV busses in 30 min

Does this task contain a significant amount of diagnosis activity ? YES ✓ NO __
If Yes, Use Table 1 below to evaluate the PSFs for the Diagnosis portion of the task before going to Table 2. If No, go directly to Table 2.

Table 1. Diagnosis worksheet.

PSFs	PSF Levels	Multiplier for Diagnosis	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	
	Barely adequate < 20 m	10	
	Nominal ≈ 30 m	1 ✓	
	Extra > 60 m	0.1	
	Expansive > 24 h	0.01	
2. Stress	Extreme	5	SBO scenarios; power available offsite but multiple failures in plant, including the ones (SRV) that drive 1-hr time scale
	High	2 ✓	
	Nominal	1	
3. Complexity	Highly	5	SBO scenarios; power available offsite but multiple failures in plant
	Moderately	2 ✓	
	Nominal	1	
4. Experience/ Training	Low	10	
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	This factor has been assessed because symptoms of loss of power are considered straightforward.
	Available, but poor	5	
	Nominal	1	
	Diagnostic/symptom oriented	0.5 ✓	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

SPAR Model Human Error Worksheet (Page 2 of 3)

Table 2. Action worksheet.

PSFs	PSF Levels	Multiplier for Action	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	Need to recover within 30 min when this event is invoked
	Time available ≈ time required	10 ✓	
	Nominal	1	
	Available > 5x time required	0.1	
	Available > 50x time required	0.01	
2. Stress	Extreme	5	SBO with multiple failures
	High	2 ✓	
	Nominal	1	
3. Complexity	Highly	5	Power recovery is moderately complex (note there were issues in this event).
	Moderately	2 ✓	
	Nominal	1	
4. Experience/ Training	Low	3	
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	Procedure issues were cited in the inspection report related to breaker manipulation specifically in the context of switchyard breakers.
	Available, but poor	5 ✓	
	Nominal	1	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

Table 3. Task failure probability without formal dependence worksheet.

Task Portion	Nom. Prob.	Time	Stress	Compl.	Exper./ Train.	Proced.	Ergon.	Fitness	Work Process	Prob.
Diag.	1.0E-2	x1.0	x2	x2	x 1.0	x 0.5	x 1.0	x 1.0	x 1.0	2E-2
Action	1.0E-3	x 10	x2	x 2	x 1.0	x 5	x 1.0	x 1.0	x 1.0	2E-1
Total										.22

SPAR Model Human Error Worksheet (Page 3 of 3)

For all tasks, except the first task in the sequence, use the table and formulae below to calculate the Task Failure Probability With Formal Dependence.

Table 4. Dependency condition worksheet.

<table>
<tr><th>Condition Number</th><th>Crew (same or different)</th><th>Location (same or different)</th><th>Time (close in time or not close in time)</th><th>Cues (additional or not additional)</th><th>Dependency</th><th>Number of Human Action Failures Rule</th></tr>
<tr><td>1</td><td>s</td><td>s</td><td>c</td><td>–</td><td>complete</td><td rowspan="13">If this error is the 3rd error in the sequence, then the dependency is at least moderate.

If this error is the 4th error in the sequence, then the dependency is at least high.

This rule may be ignored only if there is compelling evidence for less dependence with the previous tasks.</td></tr>
<tr><td>2</td><td>s</td><td>s</td><td>nc</td><td>na</td><td>high</td></tr>
<tr><td>3</td><td>s</td><td>s</td><td>nc</td><td>a</td><td>moderate</td></tr>
<tr><td>4</td><td>s</td><td>d</td><td>c</td><td>–</td><td>high</td></tr>
<tr><td>5</td><td>s</td><td>d</td><td>nc</td><td>na</td><td>moderate</td></tr>
<tr><td>6 ✓</td><td>s</td><td>d</td><td>nc</td><td>a</td><td>low</td></tr>
<tr><td>7</td><td>d</td><td>s</td><td>c</td><td>–</td><td>moderate</td></tr>
<tr><td>8</td><td>d</td><td>s</td><td>nc</td><td>na</td><td>low</td></tr>
<tr><td>9</td><td>d</td><td>s</td><td>nc</td><td>a</td><td>low</td></tr>
<tr><td>10</td><td>d</td><td>d</td><td>c</td><td>–</td><td>moderate</td></tr>
<tr><td>11</td><td>d</td><td>d</td><td>nc</td><td>na</td><td>low</td></tr>
<tr><td>12</td><td>d</td><td>d</td><td>nc</td><td>a</td><td>low</td></tr>
<tr><td>13</td><td></td><td></td><td></td><td></td><td>zero</td></tr>
</table>

Using P = Task Failure Probability Without Formal Dependence (calculated on page 2):

For Complete Dependence the probability of failure = 1.0
For High Dependence the probability of failure = (1 + P)/2
For Moderate Dependence the probability of failure = (1 +6P)/7
For Low Dependence the probability of failure = (1 + 19P)/20
For Zero Dependence the probability of failure = P

Task Failure Probability With Formal Dependence = (1 + (*)) / =

Additional Notes:

SPAR Model Human Error Worksheet (Page 1 of 3)

Plant: Dresden 3 **Event Name**: OEP-XHE-ASP-NR04H (SBO Recovery)
Task Error Description: Failure to recover power to 4160 kV busses in 4H

Does this task contain a significant amount of diagnosis activity ? YES ✓ NO __
If Yes, Use Table 1 below to evaluate the PSFs for the Diagnosis portion of the task before going to Table 2. If No, go directly to Table 2.

Table 1. Diagnosis worksheet.

PSFs	PSF Levels	Multiplier for Diagnosis	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	4-hour time frame
	Barely adequate < 20 m	10	
	Nominal ≈ 30 m	1	
	Extra > 60 m	0.1 ✓	
	Expansive > 24 h	0.01	
2. Stress	Extreme	5	SBO scenarios; power available offsite but multiple failures in plant
	High	2 ✓	
	Nominal	1	
3. Complexity	Highly	5	SBO scenarios; power available offsite but multiple failures in plant
	Moderately	2 ✓	
	Nominal	1	
4. Experience/ Training	Low	10	
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	This factor has been assessed because symptoms of loss of power are considered straightforward.
	Available, but poor	5	
	Nominal	1	
	Diagnostic/symptom oriented	0.5 ✓	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

SPAR Model Human Error Worksheet (Page 2 of 3)

Table 2. Action worksheet.

PSFs	PSF Levels	Multiplier for Action	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	4-hour time frame
	Time available ≈ time required	10	
	Nominal	1	
	Available > 5x time required	0.1 ✓	
	Available > 50x time required	0.01	
2. Stress	Extreme	5	SBO with multiple failures
	High	2 ✓	
	Nominal	1	
3. Complexity	Highly	5	Power recovery is moderately complex (note there were issues in this event).
	Moderately	2 ✓	
	Nominal	1	
4. Experience/ Training	Low	3	
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	Procedure issues were cited in the inspection report related to breaker manipulation specifically in the context of switchyard breakers.
	Available, but poor	5 ✓	
	Nominal	1	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

Table 3. Task failure probability without formal dependence worksheet.

Task Portion	Nom. Prob.	Time	Stress	Compl.	Exper./ Train.	Proced.	Ergon.	Fitness	Work Process	Prob.
Diag.	1.0E-2	x0.1	x2	x2	x 1.0	x 0.5	x 1.0	x 1.0	x 1.0	2E-3
Action	1.0E-3	x 0.1	x2	x 2	x 1.0	x 5	x 1.0	x 1.0	x 1.0	2E-3
Total										4E-3

SPAR Model Human Error Worksheet (Page 3 of 3)

For all tasks, except the first task in the sequence, use the table and formulae below to calculate the Task Failure Probability With Formal Dependence.

Table 4. Dependency condition worksheet.

<table>
<tr><th>Condition Number</th><th>Crew (same or different)</th><th>Location (same or different)</th><th>Time (close in time or not close in time)</th><th>Cues (additional or not additional)</th><th>Dependency</th><th>Number of Human Action Failures Rule</th></tr>
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<tr><td>4</td><td>s</td><td>d</td><td>c</td><td>–</td><td>high</td></tr>
<tr><td>5</td><td>s</td><td>d</td><td>nc</td><td>na</td><td>moderate</td></tr>
<tr><td>6 ✓</td><td>s</td><td>d</td><td>nc</td><td>a</td><td>low</td></tr>
<tr><td>7</td><td>d</td><td>s</td><td>c</td><td>–</td><td>moderate</td></tr>
<tr><td>8</td><td>d</td><td>s</td><td>nc</td><td>na</td><td>low</td></tr>
<tr><td>9</td><td>d</td><td>s</td><td>nc</td><td>a</td><td>low</td></tr>
<tr><td>10</td><td>d</td><td>d</td><td>c</td><td>–</td><td>moderate</td></tr>
<tr><td>11</td><td>d</td><td>d</td><td>nc</td><td>na</td><td>low</td></tr>
<tr><td>12</td><td>d</td><td>d</td><td>nc</td><td>a</td><td>low</td></tr>
<tr><td>13</td><td></td><td></td><td></td><td></td><td>zero</td></tr>
</table>

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For Moderate Dependence the probability of failure = (1 +6P)/7
For Low Dependence the probability of failure = (1 + 19P)/20
For Zero Dependence the probability of failure = P

Task Failure Probability With Formal Dependence = (1 + (*)) / =

Additional Notes:

Appendix C

Event Tree and Fault Tree Figures

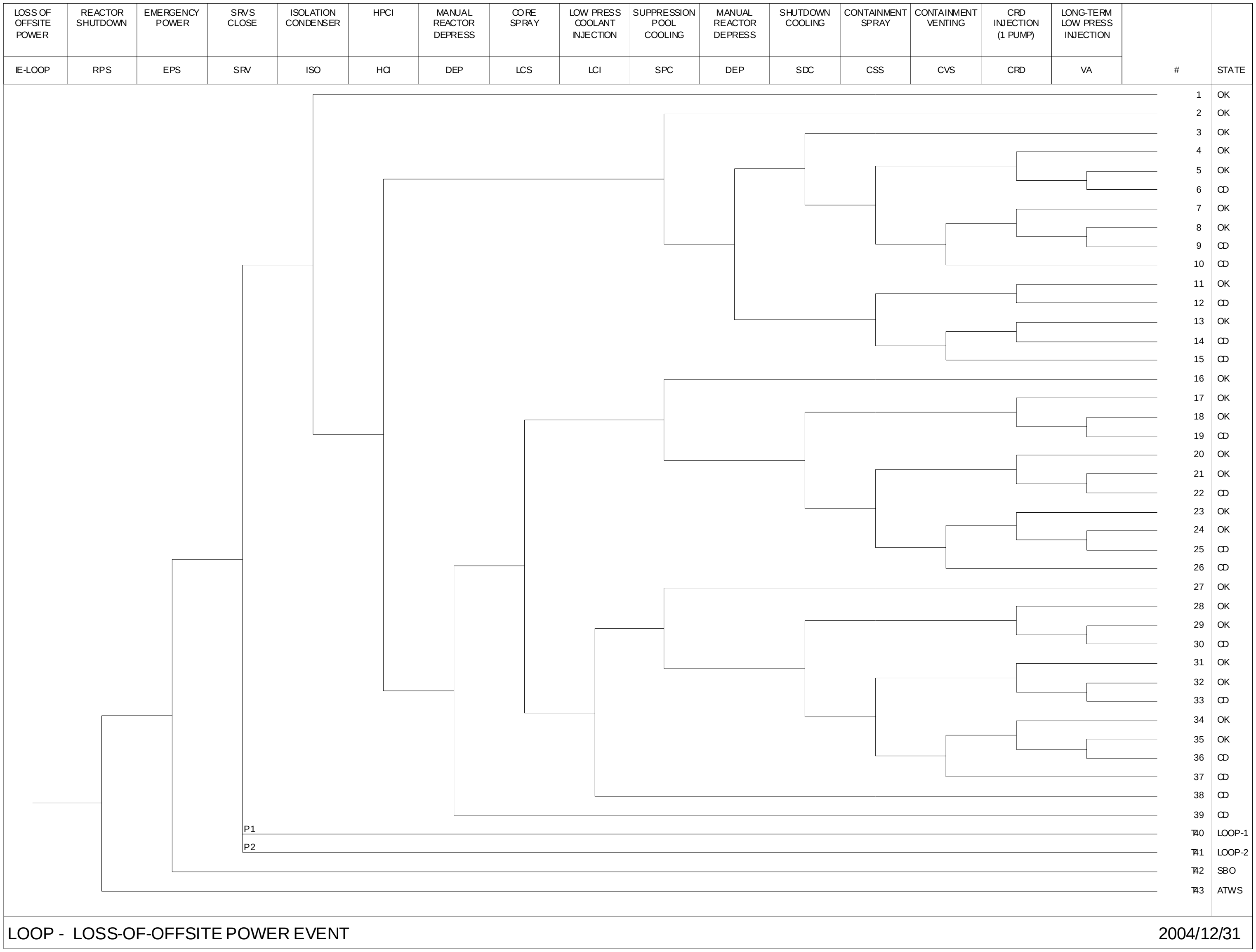


Figure 1. Event Tree for Loss of Offsite Power

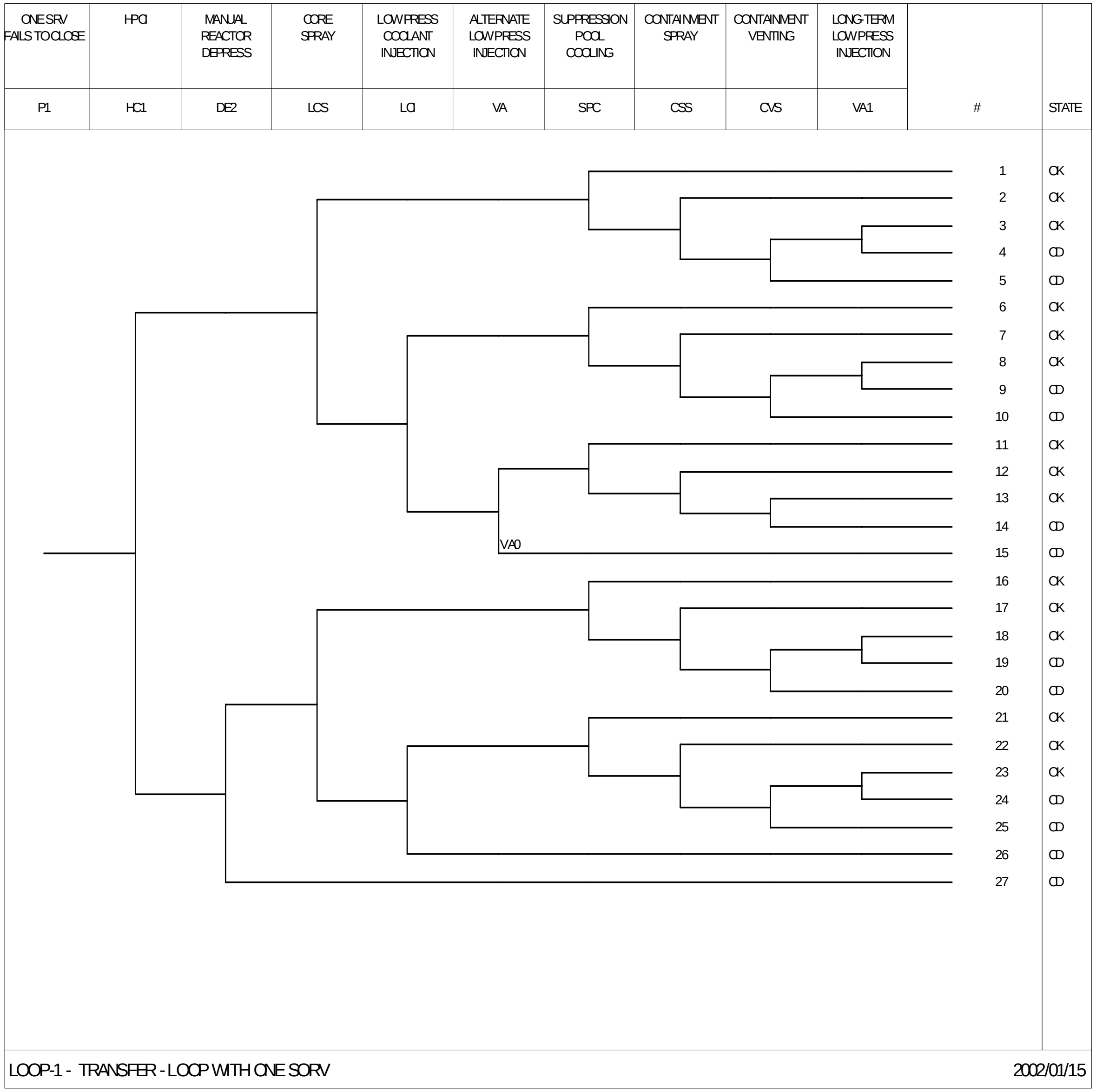


Figure 2. Transfer from LOOP Event Tree: LOOP with One Stuck-Open SRV

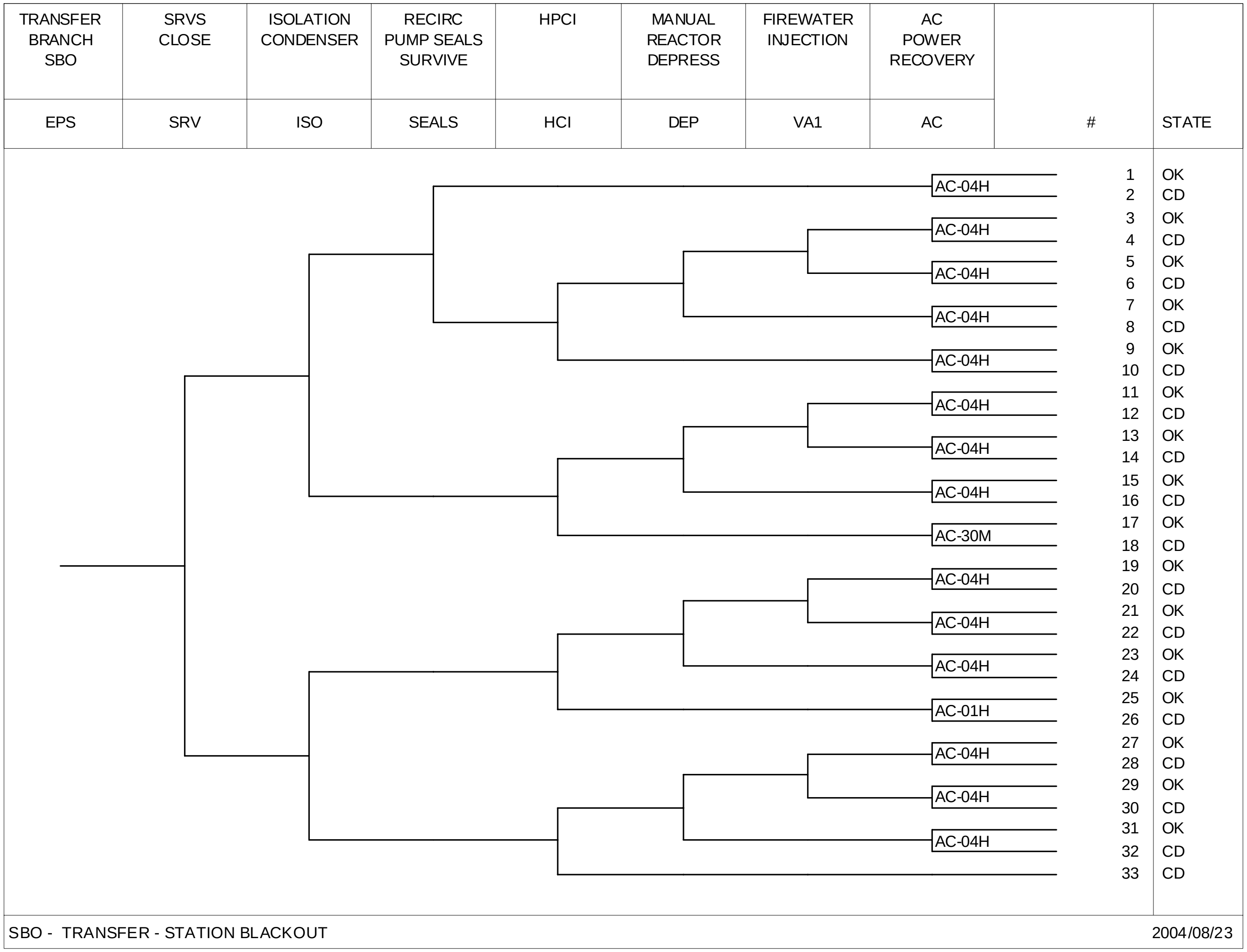


Figure 3. Transfer from LOOP Event Tree: Station Blackout

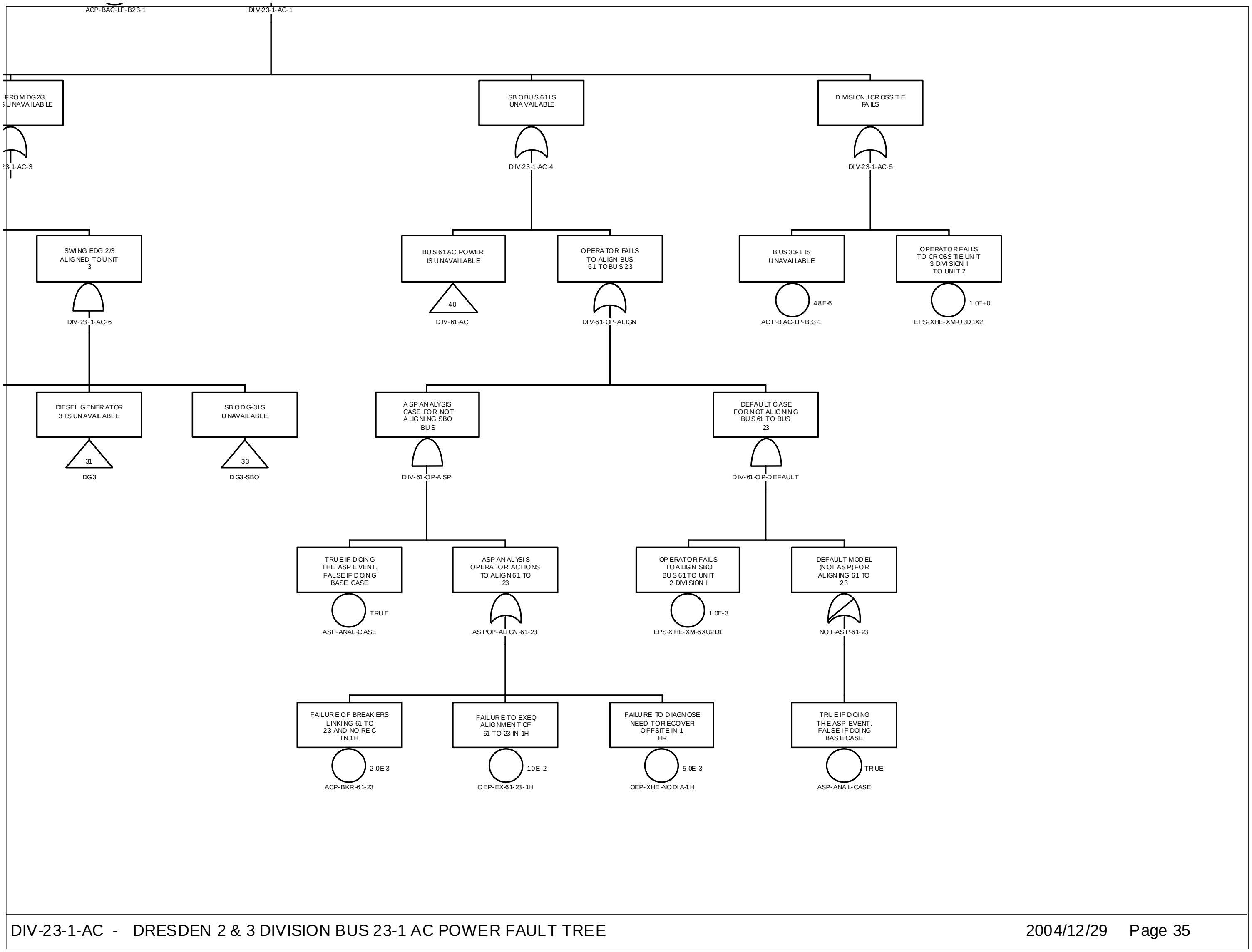


Figure 4. Portion of Fault Tree for AC Power at Bus 23-1

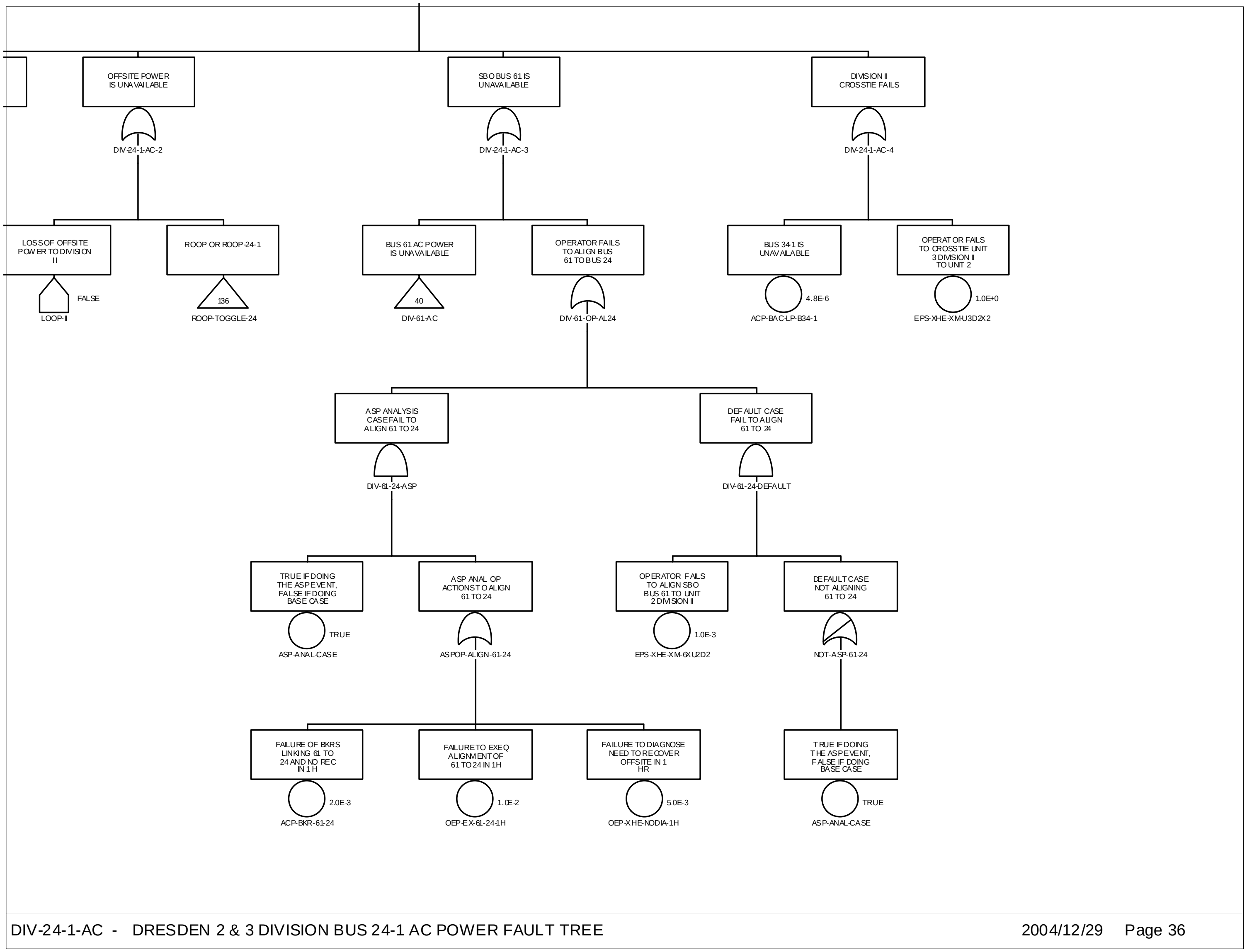


Figure 5.

Portion of Fault Tree for AC Power at Bus 24-1

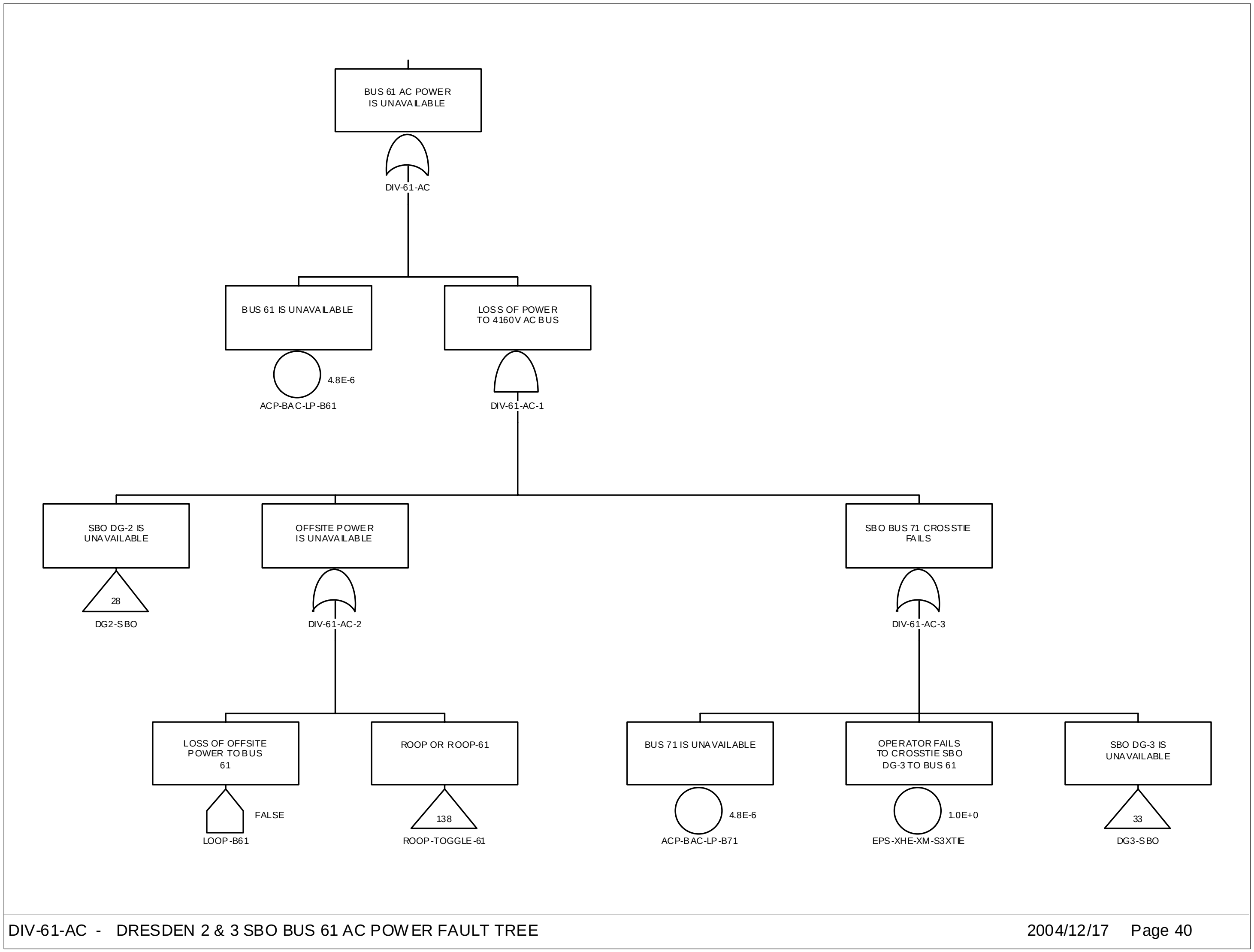


Figure 6. Portion of Fault Tree for AC Power at SBO Bus

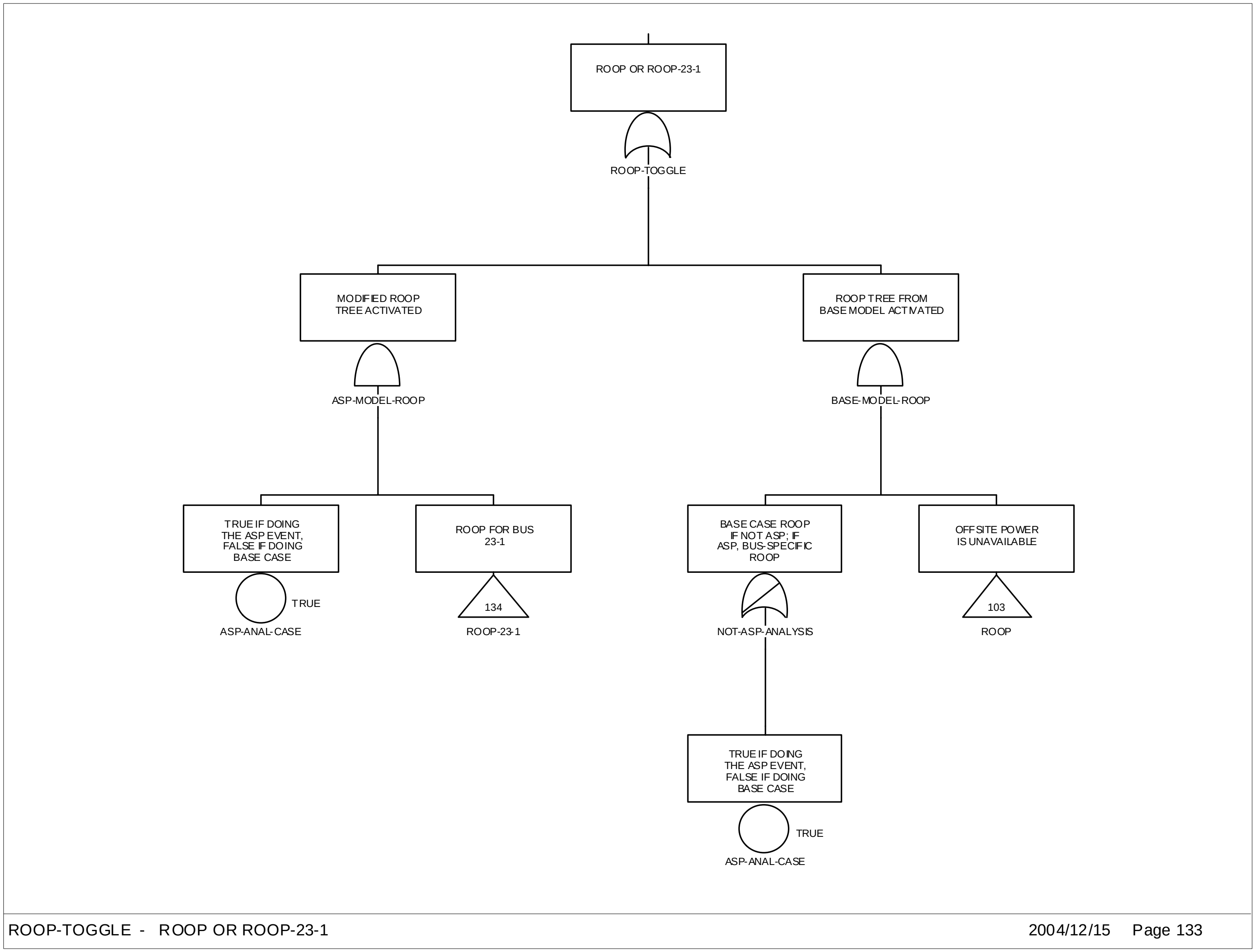


Figure 7. Portion of Fault Tree Logic Determining Recovery Actions to be Applied at Bus 23-1

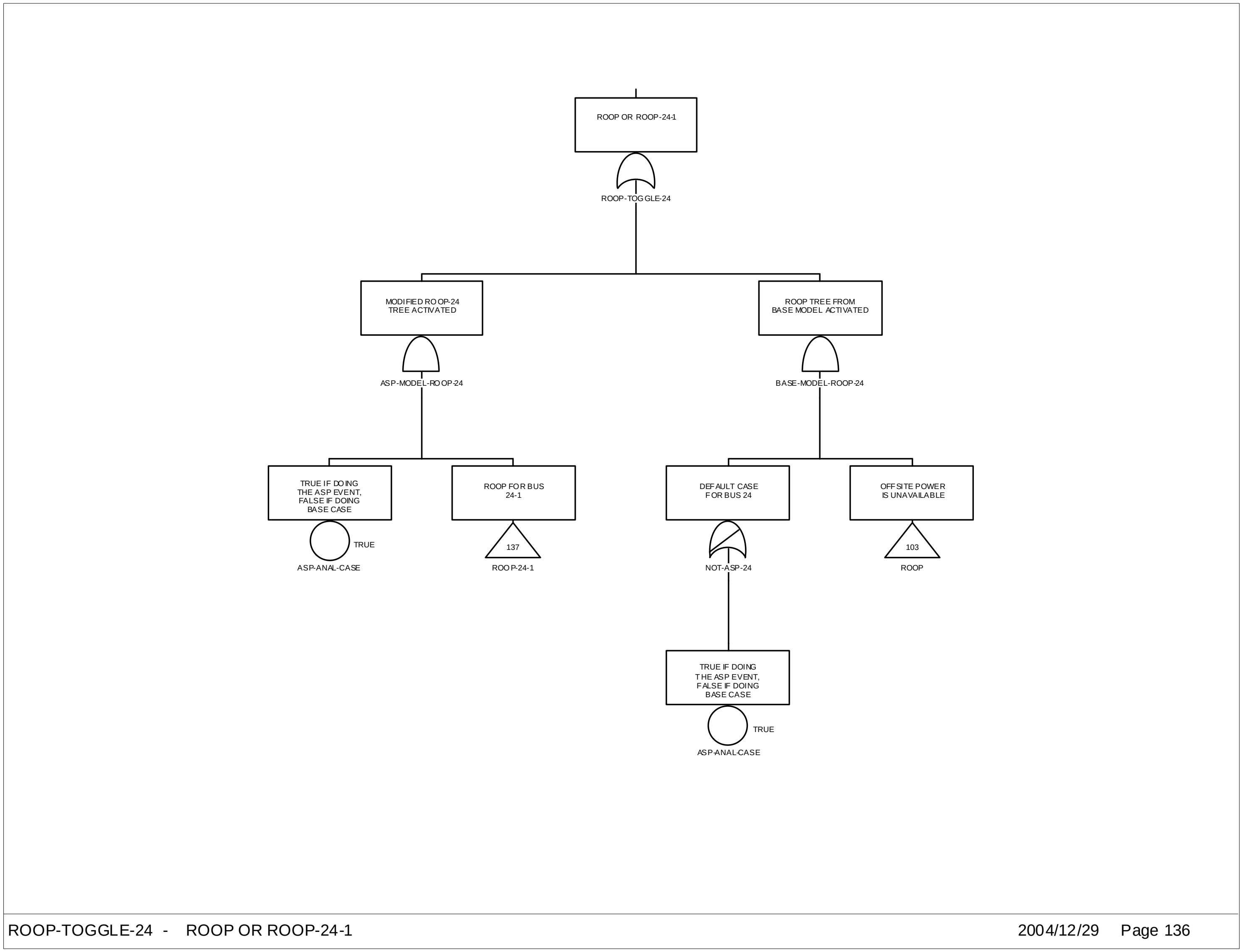


Figure 8. Portion of Fault Tree Logic Determining Recovery Actions to be Applied at Bus 24-1

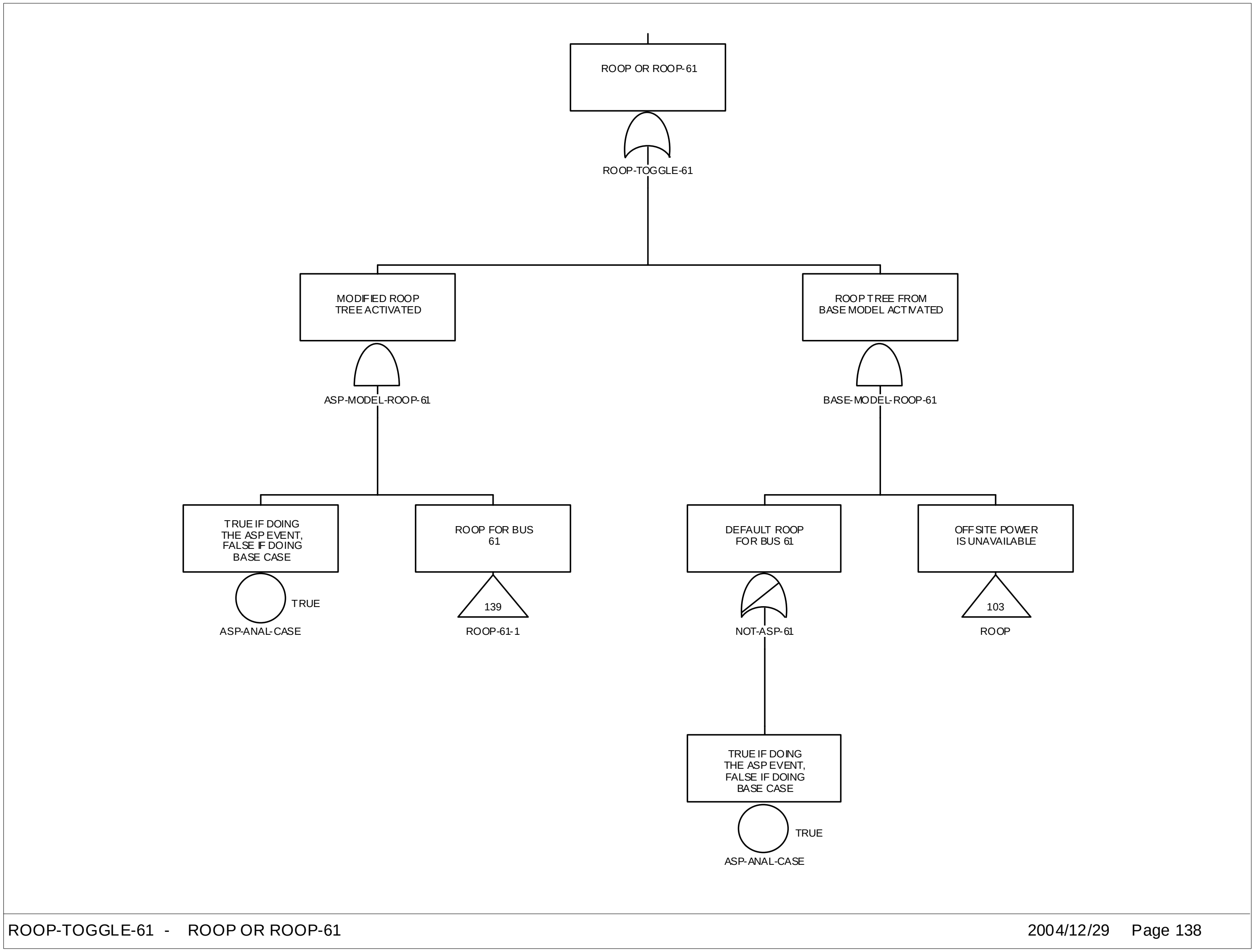


Figure 9. Portion of Fault Tree Logic Determining Recovery Actions to be Applied at SBO Bus

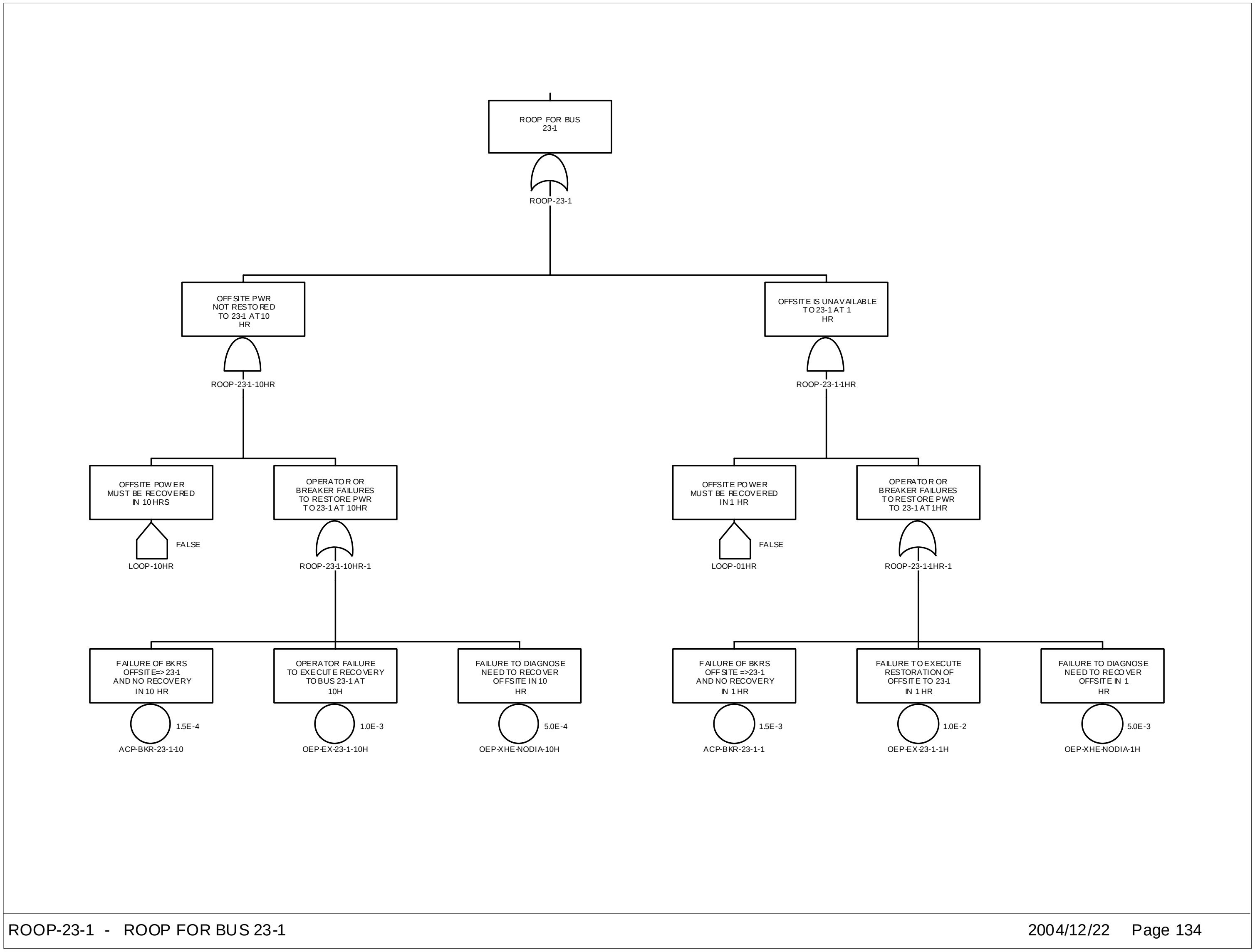


Figure 10. Recovery Actions at Bus 23-1

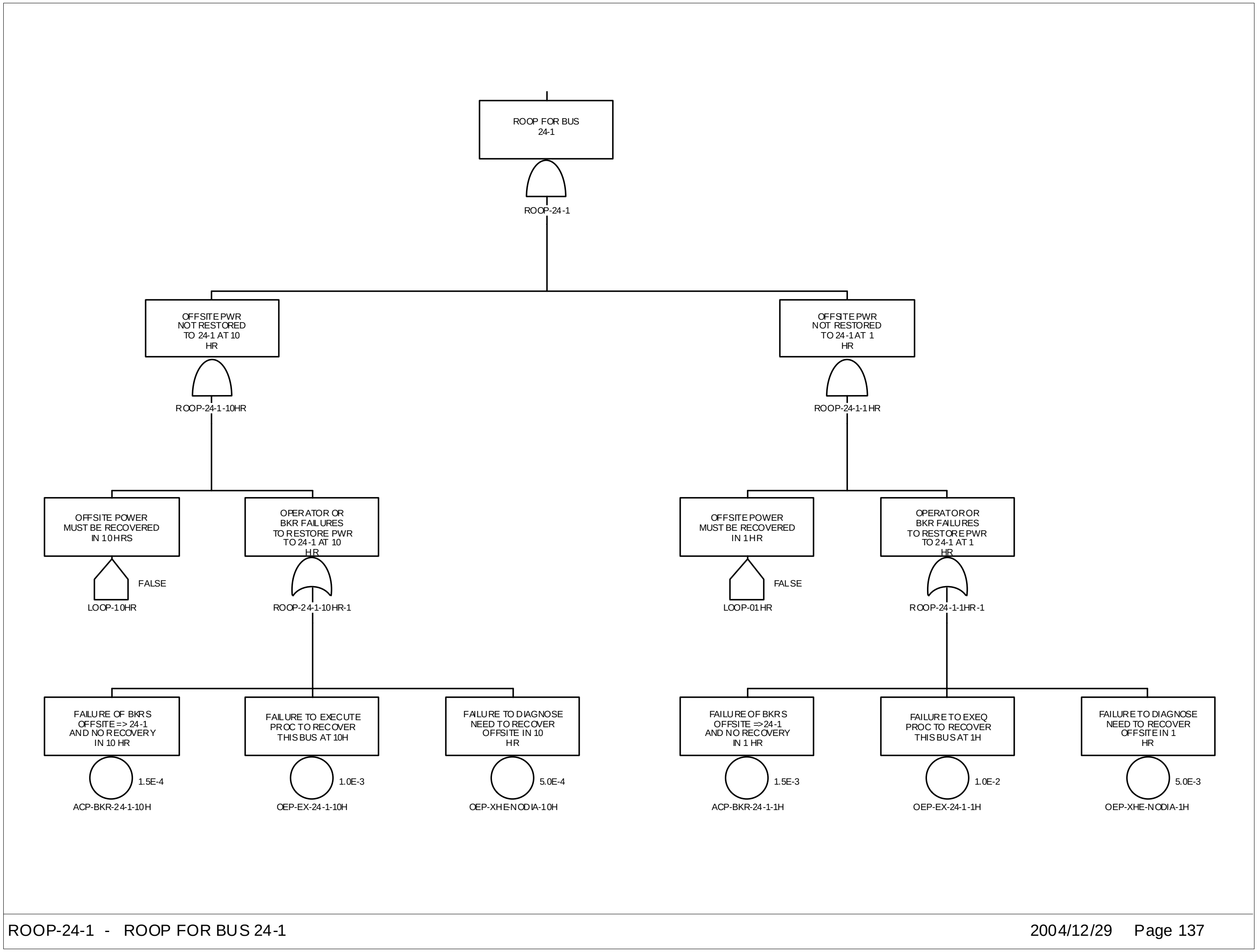


Figure 11. Recovery Actions at Bus 24-1

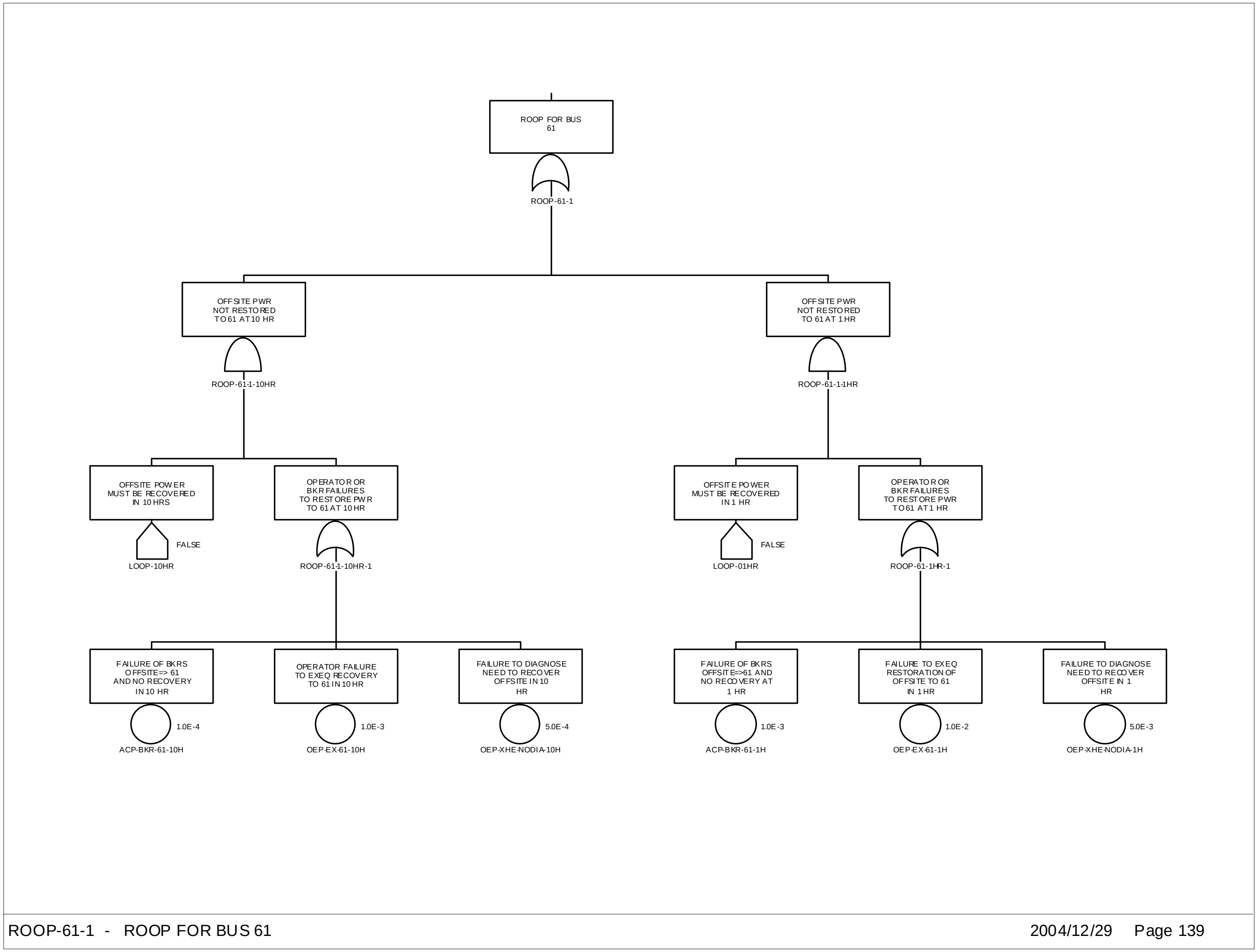
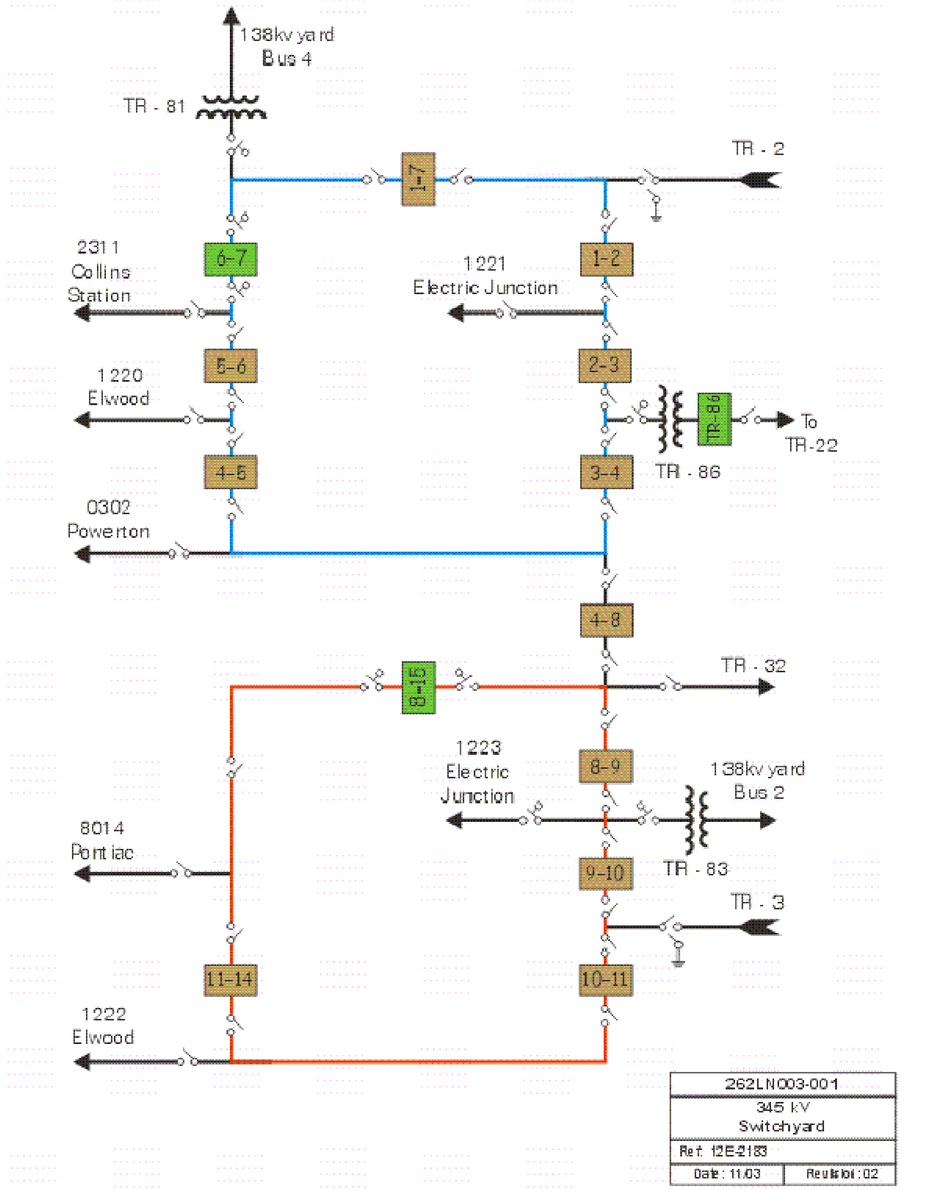


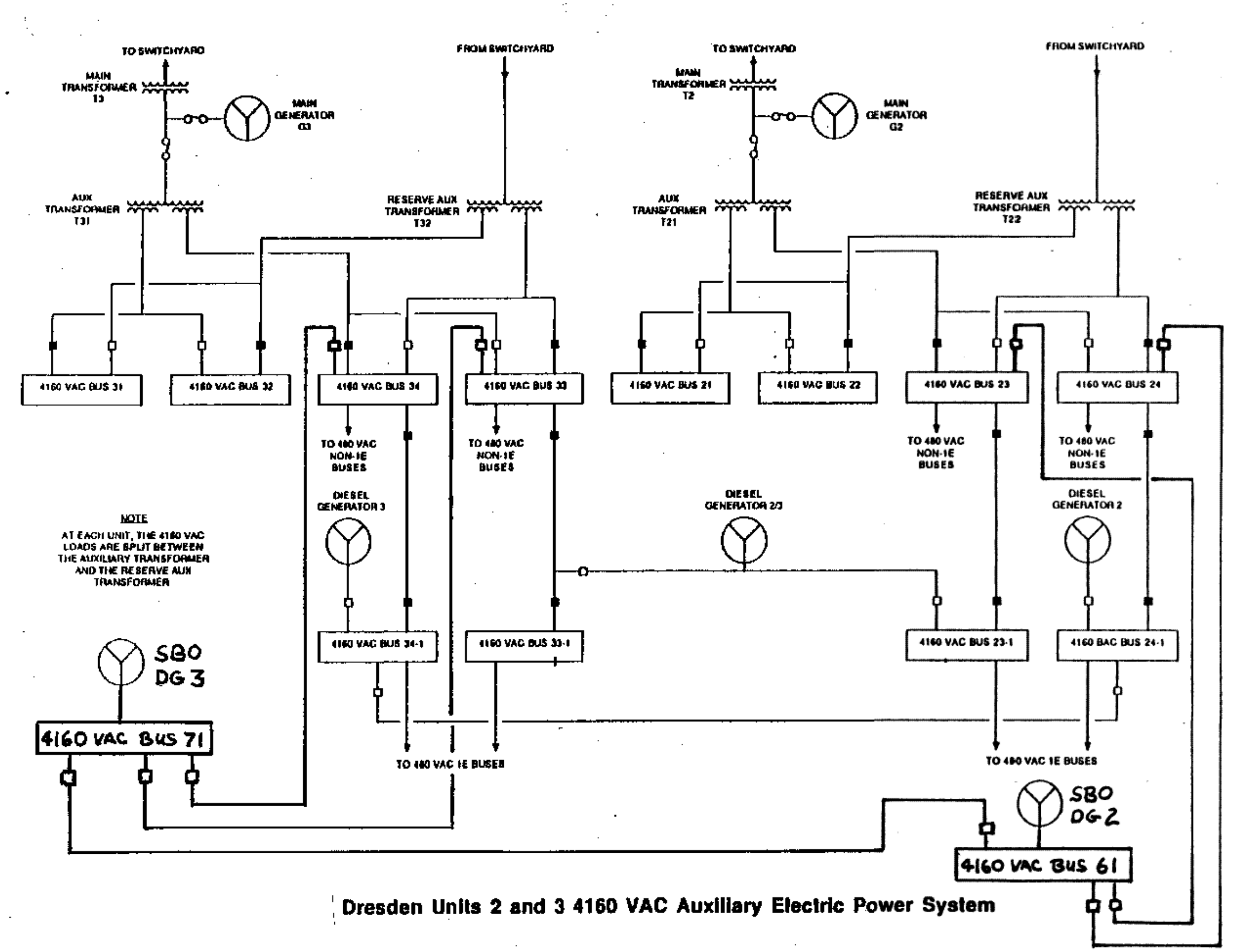
Figure 12. Recovery Actions at SBO Bus

Appendix D

Single Line Drawings



Drawing 1: Switchyard Single Line



Dresden Units 2 and 3 4160 VAC Auxiliary Electric Power System

Drawing 2: 4160 kV Electric Power System