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Risk/Safety Management Technical Memo
"Loss of Offsite Power at U.S. Nuclear Power Plants – 2004 Update"

This technical memo is a supplement to EPRI Technical Report 1009889, "Losses of Offsite Power at U.S. Nuclear Power Plants Through 2003." That report provides a database and overview analysis of losses of offsite power at U.S. nuclear generating units for the 10 year period 1994 through 2003. This supplement provides loss of offsite power data for the year 2004 and limited overview data and analysis for the 10 year period 1995 through 2004. Those wishing a more extensive overview can integrate the data in this supplement with the event database and broader range of information provided in Report 1009889.

It is worth reiterating that for each loss of offsite power event, EPRI determines how long all offsite power is truly unavailable. This is in contrast to having an alternate source available but not used. For example, at many plants emergency diesel generators (EDGs) automatically repower safety buses when offsite power is lost. It is often possible–when necessary–to reenergize safety buses from offsite power in a short time. However, it is usually more prudent to remain on the EDGs, deal with plant situations that need more immediate and urgent attention, and defer switching back to offsite power until a less critical, more convenient moment.

During the year 2004 there were 7 losses of all offsite power at U.S. nuclear power plants. This is considerably higher than the 10 year average of about 3 losses per year at the 103 nuclear power plants that are operating in the U.S. The reasons for the increased losses in year 2004 are easily identified. Three of the losses were a result of the high level of hurricane activity during 2004. Brunswick 1, while at power, experienced a LOOP during Hurricane Charley and Saint Lucie 1 & 2, while shutdown, during Hurricane Jeanne. For all 3 of these LOOPs, the conditions and plant responses were such that the safety significance was considered minimal.

Another 3 of the LOOPs occurred at one site during one event. The 3 Palo Verde units became isolated from the grid when a fault occurred on a 230 kV transmission line about 47 miles from the plant. The fault should have been cleared within a few cycles, however a defective relay failed to operate and the fault persisted which resulted in the local grid becoming deenergized. One of the 7 LOOPs during year 2004 was more typical of the random events that occasionally occur. At Dresden 3, one phase of a 345 kV switchyard breaker failed to open during testing of an offsite transmission line.

A description of the loss of all offsite power events is presented in Table 1. During the year (2004), there were 5 events that involved a partial loss of offsite power. These events are also briefly described in this supplement. Four of these events resulted in the main unit tripping off-line. The descriptions of these events are presented in Table 2.

The definitions of the categories that are used in Tables 1 and 2 to describe the events are as follows:

Category Definitions

- No offsite power available for 30 minutes or longer to the safety buses.

Ib. No offsite power available for less than 30 minutes to the safety buses.

IIa. With the unit on-line, the startup/shutdown sources of offsite power for the safety buses become deenergized.

The main generator remains on-line (connected to the offsite grid) and power for the safety buses is available from a unit auxiliary transformer.

IIb. With the unit on-line, the startup/shutdown sources of offsite power for the safety buses remain energized but in question. There is low or unstable grid voltage, or there might be if the unit trips, or trips along with a LOCA and emergency safety feature actuation.

The main generator remains on-line (connected to the offsite grid) and power for the safety buses is available from a unit auxiliary transformer.

III. The unit auxiliary source of power for the safety buses becomes deenergized or unavailable, but offsite power for the safety buses remains available, or can be made available, from a startup/shutdown source.

Utilization of this source may require a fast or slow automatic transfer, or manual switching from the control room. A loss of unit auxiliary power that is the result of a unit trip is not a category III event. To be a category III event the loss of power from the unit auxiliary source must be the initiating event and precede the unit trip. Most problems that trip the unit off-line are not category III events. A category III event is more properly associated with a failure of main electrical power hardware that makes near term availability of the unit auxiliary source of power for the safety buses unlikely.

IV. No offsite power available during cold shutdown because of special maintenance conditions that do not occur during or immediately following operations.

Table 1 that follows briefly describes the 7 events during year 2004 where <u>all</u> offsite power was lost. As previously indicated, it is a somewhat unusual group of events. Three of the events were hurricane related and another 3 of the events involved the loss of 3 units at one site from one event. The order of the listings is by the duration of the loss.

Table 1
Losses of All Offsite Power at U.S. Nuclear Plants During Year 2004

Duration hrs:mins	Plant	Date	COMMENTS
11:07	Saint Lucie 1 Category Ia	09/25/04	St. Lucie Units 1 & 2 were shut down at noon on September 25, 2004 in preparation for the arrival of Hurricane Jeanne. At 23:56 on that same day, with the Hurricane in full force, both Units lost all offsite power to both of each unit's two startup transformers (two per unit, a total of four). All four emergency diesel generators successfully started and loaded. The St. Lucie 230 kV switchyard has a conventional breaker and one half arrangement with 4 crossties (bays) between the main buses. Each crosstie has 3 circuit breakers and can terminate 2 sources, loads, or lines, for a switchyard total of eight. The 230 kV switchyard provides switching capability for the two main generator outputs, four startup transformers, (two terminations with two transformers per termination), three outgoing transmission lines and one distribution substation. When this LOOP occurred, two of the switchyard crossties had previously been opened in order to take the two main Units out of service. The LOOP occurred when faults occurred both in the feed to the distribution substation and the connection to one of the three transmission lines. The locations of these faults were such that clearing required that the other two crossties be opened. While two transmission lines and the West 230 kV main bus remained energized, the configuration that resulted from the particular location of these faults removed all paths for getting power to the startup transformers. The cause of the faults was salt spray that accompanied the hurricane. The deenergized transmission line was reenergized about 8 minutes after the initiation of the LOOP. Had the need existed it is probable that offsite power could have been made available at this time via the startup transformers. However the need was not urgent and the decision was made to not restore power to the startup transformers until switchyard inspections were made. Because of the conditions that existed, the indicated LOOP times are for the period until offsite power was actually restored.
10:13	Saint Lucie 2 Category Ia	9/25/04	

Table 1
Loses of All Offsite Power at U.S. Nuclear Plants During Year 2004 (Continued)

Duration hrs:mins	Plant	Date	COMMENTS
2:47	Brunswick 1 Category Ia	08/14/04	At the time of this event Brunswick 1 was at 67% power output and Brunswick 2 at 100%. The Brunswick 1 switchyard is connected to the grid via four 230kV transmission lines and the Brunswick 2 switchyard via another (different) four 230kV lines. Brunswick 2 was not involved in this event and remained at 100% output. This event began when, while experiencing severe weather associated with Hurricane Charley, a fault occurred on the Weatherspoon 230kV transmission line, one of the four lines that connect Unit 1 to the grid. The Unit 1 230kV switchyard has two main buses, 1A and 1B. Each transmission line terminates in two circuit breakers, one to bus 1A and one to bus 1B. To clear the Weatherspoon line fault, both breakers must open. In this instance, the circuit breaker that connects the Weatherspoon line to bus 1B developed an internal fault itself when called on to isolate the Weatherspoon fault. This required that the backup differential relays isolate all of 230kV bus 1B by opening all bus 1B circuit breakers. (Bus 1A remained energized.) The startup auxiliary transformer was aligned to bus 1B as a source and was supplying the Unit 1 emergency buses and the Unit 1 reactor coolant recirculation pumps. Hence, when bus 1B deenergized, these loads also lost power. The loss of the reactor coolant recirculation pumps caused Brunswick 1 to trip off-line. The emergency diesel generators started and reenergized the emergency buses. The startup auxiliary transformer was reenergized by connecting it to bus 1A 2:47 after the event began. It could have been repowered sooner had the need existed. However, the diesel generators started and loaded successfully and it was judged prudent to deal with other important plant parameters and to further evaluate the plant's status.

Table 1
Loses of All Offsite Power at U.S. Nuclear Plants During Year 2004 (Continued)

Duration hrs:mins	Plant	Date	COMMENTS
1:04	Palo Verde 1	06/14/04	At 07:41 MST a fault to ground occurred on the Westwing to Liberty 230 kV transmission line about 47 miles northeast of the Palo Verde Nuclear Power Station. The fault is believed to have been initiated by a waste streamer from a large bird falling on a 230 KV line insulator. The fault and line should have been cleared within a few cycles. However a defective relay at Westwing failed to open one of the 230 KV line breakers and the fault persisted for approximately 38 seconds and eventually became a three phase fault. During this period the fault was fed by the 230 kV system and by three 525 / 230 kV transformers in the Westwing switchyard. Eventually, all local transmission lines became denergized and disconnected from the Palo Verde Switchyard. All three Palo Verde Units were tripped by their generator protection relays. Six additional nearby generation units shut down representing a total loss of nearly 5,500 MWe. All of the EDGs (for all three units) started and loaded. However the Unit 2 “A” EDG failed after about 26 seconds (because of a failed diode in its excitation control circuit. All three Palo Verde 525 to 13.8 kV startup transformers were energized and offsite power was available within 1 hour and 4 minutes after the inception of the event. The emergency safety feature buses were transferred back to offsite power at convenient times after offsite power was available. It should be noted that in addition to its emergency diesel generators, the Palo Verde station has two redundant 3400 kW station blackout gas turbine generator sets. Arizona Public Service is using what has been learned from this experience to examine and, where appropriate, upgrade its transmission system relaying. This event has been reported extensively. The listed references are recommended for further information.
1:04	Palo Verde 2	06/14/04	
1:04	Palo Verde 3	06/14/04	
	Category Ia		

Table 1
Loses of All Offsite Power at U.S. Nuclear Plants During Year 2004 (Continued)

Duration hrs:mins	Plant	Date	COMMENTS
0:30	Dresden 3 Category Ia	05/05/04	Dresden Unit 3 tripped off and a LOOP occurred when 345 kV switchyard breaker CB 8-15 was opened to support the testing of a 345 kV offsite transmission line. "C" phase of CB 8-15 failed to open which caused multiple protective relays and local breaker backup relays to operate. Their operations caused the 345 kV Unit 3 ring bus to isolate and opened the crosstie to the Unit 2 ring bus. This disconnected Unit 3's generator from the switchyard and deenergized the Unit 3 Reserve Auxiliary Transformer, resulting in a LOOP. The two emergency diesel generators started and repowered their respective safeguard buses. The Unit 2 Reserve Auxiliary Transformer remained energized from offsite power throughout the event and could have been utilized to repower the Unit 3 safeguard buses within 30 minutes if needed (only switching is required). However the diesel generators were operating as designed and this transfer could be delayed until more urgent tasks were completed. Offsite power was restored to Unit 3 at a convenient moment about two hours after the event began.

The partial losses of offsite power are described in Table 2. There were 5 such events. While these events generally had low safety significance and safety bus capability always existed, it is interesting to note that 4 of these 5 events resulted in main unit trips. Table 2 follows. The order of the listing is chronological.

Table 2
Selected Partial Losses of Offsite Power at U.S. Nuclear Plants During Year 2004

DATE	PLANT	COMMENTS
06/12/04	Summer Category: None	This was a several second long partial loss of all offsite power during a severe thunderstorm. The unit remained at 100% power throughout the event. Summer Nuclear Station has two sources of offsite power for the two emergency safeguard buses. One source comes from the plant's 230 KV switchyard and the other from a 115 kV transmission line that originates at the Parr Substation. Power from the 230 kV source was unaffected. A lightning strike upstream of the Parr Substation caused multiple breakers at Parr to cycle and resulted in a several second loss of power on the 115 kV transmission line to Summer. The "A" EDG started and loaded. Although the 115 kV source was reenergized in seconds, operators felt it prudent to stay on the "A" EDG, for several hours to further assure of the offsite source's reliability. Subsequent to the event, personnel found a faulty breaker at the Parr Substation. This was the underlying cause of the brief loss of 115 kV power to Summer.
06/22/04	Limerick 2 Category: None	Limerick Unit 2 tripped from 100% power when a fault occurred in a breaker in the 500 kV switchyard. The fault occurred on the B-phase of breaker CB-135 when it was opened in preparation for breaker maintenance. Four 500 kV circuit breakers correctly opened (including the main generator output breakers) to isolate the fault. A concurrent failure of the secondary wiring of a current transformer in the 500 kV switchyard, in combination with the ground fault current from the initial fault, caused an additional four 500 kV circuit breakers to open. Unit 2 did not lose offsite power during this event. Its reserve auxiliary (startup) transformer remained energized from the 220 kV switchyard.

Table 2
Selected Partial Losses of Offsite Power at U.S. Nuclear Plants During Year 2004 (Continued)

DATE	PLANT	COMMENTS
08/15/04	River Bend Category: None	This event resulted in a partial loss of offsite power. Two of the unit's safety buses remained energized from offsite power throughout the event. The main unit did trip off-line. While the event had low safety significance, it did reveal a subtle breaker maintenance problem. While River Bend was at 100% power, a tower failed on one of the four 230kV transmission lines that connect River Bend to the 230kV grid and resulted in an electrical fault. The line's circuit breaker at the River Bend switchyard received a trip signal but the breaker's mechanical operation was somewhat slow. This resulted in activation of the backup protection system which signaled for all the circuit breakers on the switchyard's north bus to open, but two of these circuit breakers also experienced slow operation. The fault eventually isolated, but not before the main generator output transformer ground fault relay also activated because of the extended fault duration. This resulted in a main unit trip. The initial line fault also resulted in a fault on an adjacent transmission line, and this line's breaker at River Bend also experienced problems and resulted in the loss of offsite power to one of the 3 River Bend safety buses. Two of the 3 safety buses remained energized from offsite power throughout this event.

Table 2
Selected Partial Losses of Offsite Power at U.S. Nuclear Plants During Year 2004 (Continued)

DATE	PLANT	COMMENTS
09/06/04	Crystal River 3 Category: None	This event resulted in a partial loss of offsite power. One of the unit's two safety buses remained energized from offsite power throughout the event. The main unit did trip off-line. During strong winds associated with Tropical Storm Francis, a fault occurred on a 230kV transmission line that terminates in the Crystal River switchyard. The fault occurred about two miles from the switchyard and was caused by the mechanical failure of a vertical string of insulators. The two appropriate circuit breakers opened and cleared the line and fault. The switchyard arrangement is such that the opening of these breakers also deenergized one of the two sources that supply the Startup Transformer and the Backup Engineered Safeguards Transformer. Forty nine minutes later a separate fault occurred at a breaker that is located on the 230kV switchyard south bus. The cause of this fault was contamination from wind and salt spray that accompanied Tropical Storm Francis. Primary and backup bus differential relays activated to deenergize the 230kV switchyard south bus and clear the fault. This caused seven additional circuit breakers to open which removed the remaining source of power to the Startup Transformer and the Backup Engineered Safeguards Transformer. This also deenergized the Train B Engineered Safeguards 4.16kV bus. The Train B emergency diesel generator started and loaded. The Train A Engineered Safeguards Bus remained energized from offsite power throughout this event. This bus was being fed from the 230/4.16kV "Offsite Power Transformer" which remained energized.
10/01/04	River Bend Category: None	While at 100% power, a flashover across a post insulator in the 230 kV station transformer yard caused the loss of Reserve Station Transformer No.1 which interrupted power to the Division 1 standby bus. The Division 1 diesel generator started automatically and restored power to the bus. Thirteen minutes later, a second flashover occurred across a 230 kV post insulator on the main generator output line, causing a main unit trip. The other two standby buses remained energized from offsite power throughout the event. The flashover of the insulators was caused by contaminants in conjunction with heavy fog. The contaminants were a buildup over time of solids carried by cooling tower drift. This buildup was worsened by months of abnormally low rainfall that resulted in little or no natural cleaning.

Table 3 summarizes the loss of offsite power experience for the year 2004. The 7 losses of all offsite power during year 2004 is roughly double the recent long term experience of something close to 3 LOOPs per year at U.S. nuclear power plants. As has been pointed out in the writeup for years when there have been no losses, or only one or 2 losses, these are very small numbers and there will be considerable year to year variability. We can expect that the long term experience will still be something close to 3 losses of all offsite power per year. Years with an unusual bunch-up of events such as occurred in 2004 do occur, but they have not occurred frequently.

Table 3
Losses of Offsite Power at U.S. Nuclear Plants (By Generating Unit)
–For Year 2004–

		Number of Events in 103.0 Total Unit Calendar Years	Losses Per Gen. Unit Year
Ia.	Longer than 30 minutes	7	0.068
Ib.	Less than 30 minutes	0	–
	Total	0	0.068
IIa.		0	–
IIb.		0	–
III.		0	–
IV.		0	–

Table 4 shows the overall losses of offsite power per generating unit year for the 10 year period 1995 through 2004. For all durations there were 28 losses of all offsite power in a total of 1043.0 generating unit years. This is equivalent to 0.027 losses per generating unit year. Even though there were 7 loss of all offsite power events in 2004, the net long term experience remains essentially unchanged. This is because the multiyear experience has leveled out and remains similar today to what it was a decade ago.

Table 4
Losses of Offsite Power at U.S. Nuclear Plants (By Generating Unit)
–Ten years (1995 through 2004)–

	Number of Events in 1043.0 Total Unit Calendar Years	Losses Per Gen. Unit Year
Ia. Longer than 30 minutes	27	0.026
Ib. Less than 30 minutes	1	0.001
Total	28	0.027
IIa.	13	0.012
IIb.	3	0.003
III.	8	0.008
IV.	6	0.006

Analysts who monitor offsite power performance and reliability at nuclear power plants are interested in the role that weather plays and in the median duration of offsite power losses. This supplement will conclude with brief remarks that are pertinent to these two areas.

In the 10 year period, 1995 through 2004, 10 of the total of 28 loss of all offsite power events were the result of weather conditions. Three of these 10 weather related events occurred in year 2004 and were initiated by hurricanes. As is frequently the case, these LOOPs had a longer duration (11:07, 10:13 and 2:47). The median duration of the 10

weather related LOOPs that occurred during the past 10 years was approximately 7 hours.

The median duration of all 28 loss of all offsite power events that occurred during the last 10 years was about three hours. The median duration for the 18 non-weather related events (out of the total of 28 weather and non-weather LOOP events during the last 10 years, was about 1.5 hours. The median duration for weather related LOOP events approximates four times the duration for non-weather events (7 hours vs. 1.5 hours).

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