UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
611 RYAN PLAZA DRIVE, SUITE 400
ARLINGTON, TEXAS 76011-8064

February 15, 2000

Garry L. Randolph, Vice President and
Chief Nuclear Officer
Union Electric Company
P.O. Box 620
Fulton, Missouri 65251

SUBJECT: NRC SPECIAL INSPECTION REPORT NO. 50-483/99-15

Dear Mr. Randolph:

This refers to the inspection conducted on November 29, 1999, through February 3, 2000, at the Callaway Plant facility. The enclosed report presents the results of this inspection.

This special inspection was conducted to investigate the circumstances, causes, risk significance, and corrective actions associated with a degraded switchyard voltage condition, which occurred following a reactor trip on August 11, 1999. Our inspection revealed that you did not have adequate provisions in place to ensure the operability of the offsite power system following a trip of the reactor and main generator. The results of our inspection indicate that this condition was caused, in part, by a failure to properly consider all the potential impacts of power market deregulation on the reliability of the electrical grid relative to the design and licensing basis of your facility. We note that you reached a similar conclusion as documented in Licensee Event Report 50-483/99-005. The NRC believes that it is essential that licensed facilities ensure that the fundamental assumptions used in the design and licensing basis are maintained and that appropriate measures are taken to preserve these bases when conditions warrant.

The results of our inspection revealed that an inadequate procedure for verifying the operability of the offsite power sources contributed to this event. In addition, a number of other performance problems were identified by your staff or the NRC. These include: control room operator performance deficiencies, including failure to detect the degraded voltage condition and a lack of a comprehensive understanding of the importance of the computer contingency model; erroneous and nonconservative alarm setpoint; erroneous and nonconservative minimum voltage input to a computer model; a lack of knowledge of Callaway Plant voltage requirements on the part of Energy Supply Operations personnel; an inadequate load flow analysis; a high threshold for conducting root-cause analyses; and an inadequate review of a related NRC Information Notice. Notwithstanding, these problems, we acknowledge that the immediate and short-term actions to restore and maintain acceptable switchyard voltage were effective.

Given the importance of this issue, we would like to fully discuss its causes, implications, and corrective actions at a management meeting. This meeting has been scheduled to be conducted on March 13, 2000, at 1 p.m. in the Region IV office in Arlington, Texas. During this

meeting, we request that you discuss the causes of the event, including its significance, as well as your proposed corrective actions. With respect to corrective actions that have not yet been implemented, we request that you provide the implementation schedule for these actions. Additionally, we request that you address your perspectives regarding the adequacy of: the thresholds for conducting root-cause analyses; treatment of industry operating experience, including NRC generic communications; the process for verifying set point changes; the process for updating and revising electrical distribution system calculations, including load flow analyses; control room operator knowledge and awareness of conditions affecting the operability of offsite power sources; and administrative interfaces between control room operators and Energy Supply Operations personnel, as well as design interfaces. We would also like to discuss your insights regarding the failure to detect low switchyard voltage following the 1995 reactor trip.

Based on the results of this inspection, the NRC has determined that one Severity Level IV violation of NRC requirements occurred. The violation is being treated as a noncited violation, consistent with Section VII.B.1.a of the Enforcement Policy. The noncited violation is described in the subject inspection report. If you contest the violation or severity level of the noncited violation, you should provide a response within 30 days of the date of this inspection report, with the basis for your denial, to the Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington DC 20555-0001, with copies to the Regional Administrator, U.S. Nuclear Regulatory Commission, Region IV, 611 Ryan Plaza Drive, Suite 400, Arlington, Texas 76011, the Director, Office of Enforcement, United States Nuclear Regulatory Commission, Washington, DC 20555-0001; and the NRC Resident Inspector at the Callaway Plant facility.

In accordance with 10 CFR 2.790 of the NRC's "Rules of Practice," a copy of this letter, its enclosure, and your response, if requested, will be placed in the NRC Public Document Room.

Should you have any questions concerning this inspection, we will be pleased to discuss them with you.

Sincerely,

/s/

Arthur T. Howell III, Director
Division of Reactor Safety

Docket No.: 50-483
License No.: NPF-30

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NRC Inspection Report No.
50-483/99-15

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E-Mail report to D. Lange (DJL)
E-Mail report to NRR Event Tracking System (IPAS)
E-Mail report to Document Control Desk (DOCDESK)

E-Mail notification of report issuance to the CWY SRI and Site Secretary (VGG, DVY).

E-Mail notification of issuance of all documents to Nancy Holbrook (NBH).

bcc to DCD (IE01)

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ENCLOSURE

U.S. NUCLEAR REGULATORY COMMISSION
REGION IV

Docket No.:	50-483
License No.:	NPF-30
Report No.:	50-483/99-15
Licensee:	Union Electric Company
Facility:	Callaway Plant
Location:	Junction Highway CC and Highway O Fulton, Missouri
Dates:	November 29, 1999, through February 3, 2000
Inspectors:	J. Shackelford, Senior Reactor Analyst
	D. Acker, Resident Inspector, Project Branch E
Approved By:	Arthur T. Howell III, Director Division of Reactor Safety

ATTACHMENT: Supplemental Information

EXECUTIVE SUMMARY

Callaway Plant
NRC Inspection Report No. 50-483/99-15

On August 11, 1999, Callaway Plant operators initiated a manual reactor and turbine trip in response to a reheater drain tank rupture. The NRC conducted a special inspection to investigate the causes and corrective actions associated with the piping rupture. The details of that issue are documented in NRC Inspection Report 50-483/99-11 and in Licensee Event Report 99-003. The details of this inspection report are focused on the circumstances, causes, risk significance, and corrective actions associated with issues related to a degraded switchyard voltage condition which was observed following the trip.

Operations

- Prior to the trip, which occurred on August 11, 1999, the Ameren transmission system was experiencing near peak loading conditions and a significant amount of power was being transferred ("wheeled") across the system. These conditions were brought about by environmental and economic conditions, which created an opportunity for power in the North-Central United States to be sold in the South due to an imbalance in supply and demand. This created a condition, whereby, the Callaway Plant was supplying excessive voltage support to the grid, such that following the unit trip, switchyard voltages dropped to unacceptable levels (Section O2.1).

- A violation of Technical Specification 6.8.1 was identified because the licensee's methods and surveillance procedure associated with verifying the operability of offsite power were inadequate. The procedure did not incorporate considerations of post-trip switchyard voltage or instrument uncertainties and inaccuracies. This Severity Level IV violation is being treated as a noncited violation, consistent with Section VII.B.1.a of the NRC Enforcement Policy. This item was placed in the licensee's corrective action program as Suggestion-Occurrence-Solution Report 99-3604 (Section O3.1).

- The computer points, which had been established to alert operators to a low switchyard voltage condition, were erroneous and nonconservative and also failed to incorporate considerations of instrument uncertainty and inaccuracy (Section O3.1).

- Licensed operators failed to detect to the low voltage condition in the switchyard following the transient on August 11, 1999. The switchyard voltage dropped to a level below the operability limits for approximately 10 hours on August 11th and 12 hours on August 12th without being detected or mitigated by plant operators. Subsequently, plant and system operators were alerted to the condition and took appropriate corrective actions (Section O4.1).

- The system operators at Energy Supply Operations had an erroneous and nonconservative understanding of the voltage requirements at the Callaway Plant switchyard. This deficiency contributed to delays in the detection and restoration of low switchyard voltage at the site (Section O4.1).

- No formal operating agreements related to switchyard voltage requirements or personnel performance expectations exist between the Callaway Plant site and Energy Supply Operations personnel. The lack of such agreements contributed to: 1) a lack of understanding of voltage requirements on the part of Energy Supply Operations personnel, 2) an incomplete understanding on the part of licensed operators as to the operability requirements associated with offsite power, and 3) the amount of time necessary to restore switchyard voltage to acceptable levels following the August 11, 1999, event (Section O4.1).

Engineering

- The system load flow analyses, which were in effect at the time of the event, had not accurately incorporated considerations of load growth and power wheeling stemming from power market deregulation. This resulted in an underestimation of the system loading conditions which were observed at the time of the August 11, 1999, event. Additionally, prior to the August 11, 1999 reactor trip, the licensee did not have adequate provisions to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit (Section E2.2).

- The immediate and short-term corrective actions associated with correcting the degraded voltage condition were adequate. However, the effectiveness of these actions was limited by the lack of formal operating agreements between site personnel and Energy Supply Operations. Additionally, the licensee had missed an earlier opportunity to address this issue in that the NRC issued an information notice in early 1998 alerting licensees to the potential impacts of economic deregulation. The licensee had reviewed and closed this notice without further action. Additionally, while the licensee had conducted an extensive engineering review immediately following the event, the formal root-cause effort had been significantly delayed (Section E2.3).

Report Details

Summary of Plant Status

The Callaway Plant operated at 100 percent reactor power throughout the course of this inspection.

I. Operations

O1 Conduct of Operations

O1.1 Event Description and Chronology of Transient (93702)

On August 11, 1999, at 9:25 a.m., the plant operators manually tripped the main turbine and the reactor in response to a rupture in the reheater drain line. The NRC conducted a separate special inspection to investigate the circumstances, causes, and corrective actions associated with the piping rupture. The details of that issue are documented in NRC Inspection Report 50-483/99-11 and in Licensee Event Report 99-003. The details of this inspection report are focused on the circumstances, causes, and corrective actions associated with issues related to a degraded switchyard voltage condition, which was observed following the trip.

Prior to the transient, the unit was operating at 100 percent power. The Ameren transmission system was experiencing near peak electrical loading levels and a large amount of power was flowing from North to South through the system (i.e., “power wheeling” was in progress). Following the plant trip, switchyard voltage promptly dropped several thousand volts (kV) and began a slow decline thereafter. The switchyard voltage dropped below the procedural limit of the licensee's surveillance procedure used to verify the operability of the offsite power sources, (Procedure OSP-NB-00001, "Class 1E Electrical Source Verification") at approximately 10:17 a.m. Switchyard voltage continued to drop for several hours and eventually began slowly rising in response to decreasing system loading. The voltage increased above the procedurally specified minimum limit at approximately 10:05 p.m.. Switchyard voltage remained below the procedural limit (and inoperable) for approximately 10 hours without being detected and mitigated by plant or system operators.

At approximately 9:59 a.m. on August 12, 1999, switchyard voltage, in response to increasing system load once again dropped below the Procedure OSP-NB-00001 limit. At approximately 4:15 p.m., engineering personnel detected the low voltage condition and informed plant operators. The plant operators, in conjunction with the system operators, as well as, being aided by decreasing system load, took actions to restore the switchyard voltage. Switchyard voltage was restored above the procedural limit at approximately 9:49 p.m. Switchyard voltage remained below the procedural limit (and inoperable) for approximately 12 hours on August 12, 1999.

O2 Operational Status of Facilities and Equipment

O2.1 Grid and Plant Conditions Preceding the Degraded Switchyard Voltage Event

a. Inspection Scope (92700)

The inspectors reviewed the offsite and onsite conditions and resultant voltages associated with the Callaway Plant trip of August 11, 1999. The inspectors reviewed plant and system logs and interviewed plant and system operators and engineering personnel.

b. Observations and Findings

On August 11, 1999, the Callaway Plant was operating at 100 percent power and was in a normal electrical lineup. Offsite power was being supplied by the transmission system via the two engineered safeguards transformers. As noted in Section O1.1, the local transmission system was experiencing near peak loading levels and a large amount of power was being "wheeled" from North to South through the Ameren system. The combination of high local demand and high system bias was brought about by a combination of environmental conditions, economic factors and system hardware issues. At the time of the transient, cooler weather was prevailing in the Northern-Central United States while unseasonably hot temperatures were being experienced in the Ameren control area and further South. Additionally, there were several electrical power generator outages in the South. This coupled with essentially full generation capacity in the North created an economic opportunity for power purchases in the North to be "wheeled" through the Ameren system to satisfy the high southern demands. These conditions were of such a magnitude that on August 10, 1999, the licensee's Engineering Supply Operations personnel had requested transmission loading line relief, in accordance with Policy 9 of the North American Electric Reliability Council operating manual. The net effect of these conditions contributed to a scenario, whereby, the Callaway Plant was supplying excessive voltage support to the electric grid to the extent that system post-trip voltages were observed to be inadequate to support the operability of the offsite power system. From a risk perspective, offsite power is important in that it is the preferred source of electrical power for the plant safety equipment used to mitigate accidents. Additionally, offsite power is important in the event of a loss of the onsite emergency supplies.

Following the event, historical reviews were conducted to determine whether similar conditions had existed at the site and on the transmission system such that post-trip voltages would have dropped below acceptable limits. Using a number of different assumptions related to system loading levels, "wheeling" bias, and voltage support

levels supplied by the Callaway Plant generator, estimates were derived of previous periods of vulnerability. These estimates ranged from a high value of approximately 54 hours to a low of approximately 3 hours of additional vulnerability over the previous 12 months. It was determined that the most viable method employed assumptions related to the level of reactive output supplied by the Callaway Plant in conjunction with nearby fossil units. Using this method, a total of approximately 36 hours of vulnerability were identified.

c. Conclusions

The inspectors noted that prior to the trip, which occurred on August 11, 1999, the Ameren transmission system was experiencing near peak loading conditions and a significant amount of power was being transferred ("wheeled") across the system. These conditions were brought about by environmental and economic conditions, which created an opportunity for power in the North-Central United States to be sold in the South due to an imbalance in supply and demand. This created a condition, whereby, the Callaway Plant was supplying excessive voltage support to the grid, such that following the unit trip, switchyard voltages dropped to unacceptable levels.

O3 Operations Procedures and Documentation

O3.1 Plant Procedures for Monitoring Operability of Offsite Power

a. Inspection Scope (92700)

The inspectors reviewed the licensee's methods and procedures for monitoring the operability of offsite power at the Callaway Plant facility. A review of the applicable records and documentation was performed and interviews were conducted with the appropriate licensee personnel.

b. Observations and Findings

The operability requirements associated with the offsite power system are contained in the licensee's Technical Specification 3.8.1.1 and the associated surveillance requirements are in Technical Specification 4.8.1.1.1. The surveillance requirements specify that the operability of the offsite transmission network be verified at least once every 7 days. The licensee implemented the requirements of Technical Specification 4.8.1.1.1 by the performance of Operations Surveillance Procedure OSP-NB-00001, "Class 1E Electrical Source Verification," Revision 9, dated February 9, 1999. This procedure, among other activities intended to verify the operability of other aspects of the electrical distribution system, required the operators to monitor and record the switchyard voltage as read on the indications available on the main control board. Additionally, two plant computer points (one for each of the switchyard busses) had been established to alarm when switchyard voltage decreased below the minimum operability limits established by Procedure OSP-NB-00001.

The licensee, at its Energy Supply Operations facility, also maintained a computer model of the Ameren system which included modeling of the Callaway Plant switchyard. The Energy Supply Operations facility is located approximately 80 miles west of the site in St. Louis, Missouri. This facility serves as a central monitoring and dispatching station for the entire Ameren system. This model evaluated the real-time system conditions and predicted post-contingency voltages based on a number of transmission system element failures, including a trip of the Callaway Plant main generator. This computer simulation updated every 6 minutes. Thus, the computer post-contingency results would have provided the most accurate and timely prediction of post-trip switchyard voltages at Callaway Plant during periods of main generator operation.

The inspectors determined that the main control room indicators provided a meaningful indication of switchyard voltage only when the main generator was offline. During periods of power operation, especially when the Callaway Plant generator was providing significant voltage support to the transmission system, the control room indications would not provide an accurate or meaningful representation of switchyard voltage following a projected trip of the unit. Thus, the values, which were recorded in Procedure OSP-NB-00001, would not necessarily establish that offsite power was in an operable status when the unit was online. The licensee indicated that the plant control room operators would use this information, in conjunction with the post-contingency results provided by Energy Supply Operations personnel to determine the operability of offsite power. However, Procedure OSP-NB-00001 did not provide any information regarding the impact or importance of the Energy Supply Operations contingency results, nor did the procedure account for instrument uncertainty or inaccuracy when comparing the as-found switchyard voltage indications to the acceptance criteria specified in the procedure. As a result, the inspectors determined that the licensee's method, as specified in Procedure OSP-NB-00001, for ensuring the operability of offsite power was inadequate.

As mentioned previously, the licensee had established an annunciation capability associated with low switchyard voltage. This was via two balance-of-plant computer point low voltage alarms (one for each switchyard bus) and was implemented as a response to an earlier NRC finding and violation (50-483/9818-03). Following the trip, the balance-of-plant computer failed due to moisture intrusion in the power supply. This resulted in the loss-of-computer annunciation capability associated with the low switchyard voltage condition. It should be noted, however, that this annunciation capability was inadequate in that the low voltage set point had been incorrectly set in the plant computer. Plant personnel had made a transposition error when inputting the voltage parameters and had inadvertently reversed the final two digits in the set point. This error resulted in a nonconservative alarm set point. Additionally, even the "correct" set point did not incorporate considerations of the instrument uncertainty and inaccuracy to ensure that the alarm would be received prior to dropping below the minimum acceptable value. The plant computer was restored on August 11, 1999, at approximately 6:15 p.m.; however, no alarm was received for switchyard low voltage due to the erroneous (nonconservative) alarm set point. Voltage dropped below the

operability limit on August 12, 1999, and eventually dropped below the erroneous alarm set point. However, plant operators again failed to detect the low switchyard voltage condition. The information related to low switchyard voltage was available as a computer point which was in alarm, as well as, via an alarm printout.

Technical Specification 6.8.1 requires that written procedures shall be established, implemented and maintained covering the activities specified in Appendix A of Regulatory Guide1.33, "Quality Assurance Program Requirements (Operation)," dated February 1978. Appendix A, Section 8.b of Regulatory Guide 1.33, requires implementing procedures for each surveillance test, inspection, or calibration listed in the technical specifications. The failure to provide adequate instructions to assure reliable indication of switchyard voltages and the failure to establish adequate procedures for the evaluation of potentially inoperable offsite power supplies is a violation of Technical Specification 6.8.1. This Severity Level IV violation is being treated as a noncited violation, consistent with Section VII.B.1.a of the Enforcement Policy. This violation is in the licensee's corrective action program as Suggestion-Occurrence-Solution Report 99-3604 (50-483/9915-01).

c. Conclusions

The inspectors concluded that the licensee's surveillance procedure associated with verifying the operability of offsite power was inadequate. The procedure did not incorporate considerations of post-trip switchyard voltage or instrument uncertainties and inaccuracies. This was identified as a noncited violation of Technical Specification 6.8.1.

O4 Operator Knowledge and Performance

O4.1 Plant and System Operator Knowledge and Performance During the Degraded Switchyard Voltage Condition

a. Inspection Scope (92700)

The inspectors examined the knowledge and performance aspects of licensed operators, as well as, system operators. Records of logs were reviewed and interviews were conducted with cognizant personnel.

b. Observations and Findings

As described in Section O1.1, switchyard voltage dropped below operability limits following the reactor trip on August 11 and 12, 1999. Voltage was below operability limits for approximately 10 hours on August 11th and for about 12 hours on August 12th without being detected or mitigated by licensed plant operators. Plant engineering personnel detected the out-of-specification voltage condition on August 12, 1999, at approximately 4:15 p.m., at which point plant operators entered the appropriate technical specification action statement. (The limiting condition for operation associated with the inoperability of offsite power specifies a 24-hour allowable outage time.) Upon

being informed of the low voltage condition, plant operators, in conjunction with Engineering Supply Operations personnel took actions to restore switchyard voltage. These actions included realignment of major loads of the Callaway Plant electrical busses, as well as, certain system realignments on the Ameren transmission system. Additionally, the recovery from the low voltage condition was aided by a gradually decreasing system load in the late afternoon and early evening hours of August 12, 1999. Switchyard voltage was eventually restored to the acceptable band at approximately 9:49 p.m., approximately 4 ½ hours following detection of the low voltage condition.

The plant computer was deenergized following the reactor trip (see Section 03.1) and all available annunciation associated with switchyard voltage was lost until the computer was restored approximately 9 hours after the event. However, on August 12th switchyard voltage again dropped below the operability limits and also dropped below the computer alarm set points. (Section 03.1 describes how these set points had been established in a nonconservative manner.) Plant (and system) operators failed to acknowledge the low switchyard voltage alarms and take any compensatory actions. A review of the daily alarm printout from the plant computer on August 12th showed the computer points in alarm and below the operability limits. Additionally, the inspectors noted that a fiber optic channel, or supervisory control and data acquisition system, was used by the licensee to collect and transmit critical system information from the field to the Energy Supply Operations. This particular link had been inadvertently severed (in an unrelated incident) by maintenance personnel earlier in the day and had the effect of eliminating the data flow related to switchyard voltage from the site to Energy Supply Operations. The licensee indicated that system operators were reluctant to take immediate actions to restore the system voltage until the fiber optic channel could be restored.

The inspectors also reviewed the plant data from the most recent reactor trip prior to that of August 11, 1999. A plant trip had occurred on August 16, 1995, and switchyard voltage had also dropped to unacceptable (i.e., exceeded operability limits) levels following that event. As with the August 11, 1999, event, the low voltage condition went undetected by plant and system operators.

As described in Section O3.1, the Energy Supply Operations personnel maintained and monitored a computer simulation of the Ameren system, which included modeling related to the Callaway Plant switchyard. Certain alarms were established within the program, such that, an annunciation would be initiated whenever the projected Callaway Plant switchyard voltage (post-trip) was predicted to be below acceptable values. Upon receipt of this alarm, the intent was for Energy Supply Operations personnel to call the Callaway Plant control room and alert the operators to this condition. However, it was determined that system operators at Energy Supply Operations had an erroneous and nonconservative understanding of the Callaway Plant switchyard voltage requirements. As a result, the annunciator set points in the Energy Supply Operations model were established in a nonconservative manner and did not alert operators to the low voltage condition on August 11th or the morning and early afternoon of August 12th. Voltage eventually dropped to a level lower than even the nonconservative set points. However, at that time the supervisory control and data acquisition line had already been severed

and no indication of voltage was available to the Energy Supply Operations personnel. Upon further review, the inspectors determined that no formal operating agreements related to monitoring and maintaining switchyard voltage existed between the Callaway Plant site and the Energy Supply Operations organization. The Energy Supply Operations understanding of Callaway Plant switchyard voltage requirements consisted primarily of an informal, erroneous, and nonconservative, knowledge base on the part of the system operators.

Following the event, the licensee revised the Ameren system computer model to reflect the correct limitations associated with the Callaway Plant switchyard. Additionally, the annunciation scheme was changed so as to give a higher visibility and priority to potentially low voltage conditions at Callaway Plant. The Energy Supply Operations staff also developed a set of contingency procedures to be used in the event that a similar scenario occur in the future. The licensee indicated that the contingency procedures would shorten the recovery time from the 4 ½ hours seen during the event to approximately 15 minutes.

During the inspection, the inspectors interviewed various system operators and plant personnel with respect to their understanding of the requirements and indications associated with the Callaway Plant switchyard. The inspectors determined that the Energy Supply Operations personnel had been adequately briefed as to the actions to be taken upon receipt of the low voltage annunciation on the computer contingency model associated with the Callaway Plant switchyard (i.e. notify the Callaway Plant control room). The Energy Supply Operations contingency results appear to be the most reliable indication of projected switchyard voltage following a trip of the Callaway Plant. However, as of the start date of this inspection, Callaway Plant operators did not have a comprehensive understanding of the implications of the Energy Supply Operations contingency results information necessary to assure the operability of offsite power. In general, the operators were not familiar with the implications of the Energy Supply Operations post-contingency results. The operators that were interviewed indicated that they would not immediately declare offsite power inoperable based on the projections provided by the Energy Supply Operations contingency model provided that the current switchyard voltage levels were within acceptable limits. (The operators did indicate that they would pursue the matter with engineering.) However, discussions with licensee management indicated that it was their expectation that offsite power would be declared inoperable if the Energy Supply Operations model yielded unacceptably low post-contingency voltages. In response to these concerns, the licensee issued a night order on December 1, 1999, which provided definitive guidance regarding the implications associated with the Energy Supply Operations contingency analysis.

c. Conclusions

The licensed operators at the Callaway Plant failed to detect the low voltage condition in the switchyard following the plant trip on August 11, 1999. The switchyard voltage dropped to a level below the operability limits for approximately 10 hours on August 11th

and 12 hours on August 12th without being detected or mitigated by plant operators. Subsequently, plant and system operators were alerted to the condition and took appropriate corrective actions to restore switchyard voltage. Further reviews indicated that a similar period of inoperability had occurred at the time of the most recent trip prior to the August 11th event and also went undetected.

The Energy Supply Operations personnel had an erroneous and nonconservative understanding of the voltage requirements at the Callaway Plant switchyard. This deficiency contributed to delays in the detection and restoration of low switchyard voltage at the site.

No formal operating agreements related to switchyard voltage requirements or personnel performance expectations exist between the Callaway Plant and Energy Supply Operations personnel. The lack of such agreements contributed to: 1) a lack of understanding of voltage requirements on the part of Energy Supply Operations personnel, 2) an incomplete understanding on the part of licensed operators as to the operability requirements associated with offsite power, and 3) the prolonged period of time necessary to restore switchyard voltage to acceptable levels following the August 11, 1999 event.

O8 Miscellaneous Operations Issues (92700)

O8.1 Risk Assessment

a. Inspection Scope (92700)

The licensee performed a quantitative risk assessment of the issues related to the degraded switchyard voltage. The licensee used selected reliability data from their updated risk analysis and made certain assumptions regarding the reliability of the offsite power system during the periods of degraded voltage. The NRC senior reactor analysts in the Region IV office performed a review of the licensee's analysis and also performed limited independent calculations to validate the results.

b. Observations and Findings

The actual risk significance of the low voltage condition appears to be low on the basis of approximately 36 total hours of vulnerability over the past 12 months. From a risk perspective, offsite power is important in that it is the preferred source of power for the plant equipment used to mitigate accidents. Additionally, offsite power is necessary in the event that the onsite emergency sources are not available. The licensee's final estimate of the incremental conditional core damage probability was 2.24E-07 and is reported in Licensee Event Report 99-005-01. This is the increase in the annual probability of core damage as a result of this condition. However, the inspectors determined that this would most likely represent a lower bound in that the estimate does not include the potential impacts of emergency core cooling system failures due to "double-sequencing," which may have been introduced by this condition. (See Section E2.3 of this report for a description of the double-sequencing phenomenon.)

Additionally, the overall potential risk significance of the condition may have been somewhat higher, since the licensee had no methods in place which would have detected the condition absent the event, which occurred. Additionally, the environmental and economic conditions which caused the event remained in place to (had it not been for detection because of the event) create further periods of vulnerability.

c. Conclusions

The actual risk significance of the degraded switchyard voltage event was low based primarily on the fact that only 36 hours of suspected plant vulnerability were identified during the period from July 20, 1998, through August 12, 1999. However, the inspectors determined that the potential risk significance of the event may have been somewhat higher due to the potential impact of double-sequencing and the fact that no methods were in place, which would have detected the condition, and the fact that environmental and economic conditions remained in place to create further periods of vulnerability.

II. Engineering

E2 Engineering Support of Facilities and Equipment

E2.1 Description of Callaway Plant Offsite and Onsite Electrical System Design

The Callaway Plant switchyard is part of the Ameren system control area. This control area is included in the Mid-America Interconnected Network (MAIN) Reliability Council and is part of the Eastern Interconnection of the National Electric Transmission System. Three 345 kV transmission lines connect the Callaway Plant to the transmission area grid. One transmission line exits the local switchyard to the South and connects to the transmission system at a substation approximately 30 miles away. Two 345 kV transmission lines exit the local switchyard to the North and connect to the system at another substation approximately 20 miles away. Each of these two lines are run in a single right-of-way. Section 8.2.1.3.2 of the Callaway Site Final Safety Analysis Report indicated that any one of the three 345 kV transmission lines was capable of supplying the site loads.

The local switchyard was located adjacent to the site boundary and consisted of two independent 345 kV busses and associated breakers. The transmission system power could be connected to either bus. Additionally, there were two 345/13.8 kV safeguards transformers located in the switchyard. Either of these two transformers could supply 13.8 kV power to one of the emergency safeguards transformers located within the site boundary. A 345 kV line connected power to the other emergency safeguards transformer through transformers located within the site boundary.

The plant safety-related loads were connected to one of two 4.16 kV safety-related busses, each with power supplied either from an offsite source or an emergency diesel generator. The local switchyard supplied 13.8 kV power from either safeguards

transformer to an onsite 13.8/4.16 kV emergency safeguards transformer. The local switchyard supplied 345 kV power to the other safety-related bus via an onsite 345/13.8 kV startup transformer and an onsite 13.8/4.16 kV emergency safeguards transformer. Both of the 4.16 kV safety related busses could be aligned to either the startup transformer or one of the safeguards transformers.

E2.2 Design Basis and Engineering Issues Associated with the Operability of Offsite and Onsite Electrical Power Systems

a. Inspection Scope

The inspectors reviewed the offsite and onsite electrical distribution system design calculations and analyses to ensure adequate voltage for safety-related equipment during design basis events.

b. Observations and Findings

b.1 Design Basis and Engineering Issues Associated with Onsite Voltages

The licensee stated that the limiting condition for minimum voltage on the 345 kV system was the reset point for the degraded voltage relay. Under accident conditions, the degraded voltage relay was set to separate the safety-related loads from the offsite source when a degraded voltage condition existed for 8 seconds. Because motor starting currents would lower bus voltages, licensee calculations assumed that the degraded voltage relay would pick up, therefore, the licensee based the acceptability of offsite power on the higher reset voltage of the relay.

The inspectors reviewed calculations associated with the degraded voltage relay set point. The inspectors observed that the licensee had based the set point and reset point on meeting the technical specification value plus loop uncertainty. The inspectors noted that the uncertainty calculation was based on Bechtel Calculation J-U-GEN, "Methodology for Determination of Instrument Loop Uncertainty Estimates," dated June 27, 1984. The inspectors reviewed the licensee's degraded voltage relay uncertainty calculation and determined that it was consistent with Calculation J-U-GEN methodology.

The inspectors reviewed the licensee calculations for worst-case onsite loading. The inspectors observed that the licensee calculations correctly assumed the minimum acceptable offsite voltage. The inspectors observed that the calculations indicated that the minimum steady state onsite 4.16 kV system voltage was approximately 30 volts above the degraded voltage relay reset point. The inspectors discussed the program used to determine the steady state voltages with the licensee. The licensee stated that they had changed programs several times but had always compared the newest program to actual voltages taken during startup testing. The inspectors noted that the licensee was using a recognized industry modeling program.

The inspectors asked the licensee for their transient voltage analysis for ensuring the adequacy of starting safety-related equipment. The licensee stated that they did not

currently have a program to calculate transient voltages. The licensee based their transient voltage acceptability on individual motor starting curves, the time delays between starting of safety-related loads, tripping of most nonsafety equipment, and the transient analysis, which was performed to show acceptable voltages during starting of the same equipment using the onsite emergency diesel generators. The licensee stated that the above data showed adequate margin to ensure that there was adequate voltage during starting of safety-related equipment using offsite power. The inspectors reviewed the data and determined that there was adequate margin in the licensee's analysis to demonstrate that the degraded voltage relays would not trip offsite power during an event provided that offsite power was at or above its design basis voltage value. Additionally, the inspectors reviewed the licensee's Final Safety Analysis Report and associated voltage drop calculations. It was determined that if the licensee maintained the safety bus voltage above the degraded relay set point, that the licensee's calculations and analyses were adequate to demonstrate sufficient voltage to start and run safety-related equipment.

b.2 Design Basis and Engineering Issues Associated with Transmission System Voltages

The inspectors also reviewed the computer analysis program used by the Energy Supply Operations organization to project system response and voltage to yearly worst-case loads (i.e., This was the transmission system load flow study and should not be confused with the on-line contingency model described earlier.) Prior to the trip which occurred on August 11, 1999, the previous system load flow analyses had not anticipated the potential impact of economic deregulation and power wheeling. This resulted in an underestimation of the system loading conditions, which were observed at the time of the event. The licensee's revised (current) analysis included assumptions that only one 345 kV transmission line was in service to the Callaway Plant, that the largest local generator was offline, and that the system was experiencing maximum winter loads. The maximum winter load was defined as the best estimate of winter load based on historical and projected data plus an additional 5 percent for conservatism. Under these assumed conditions the licensee then modeled a trip of the Callaway Plant generator.

The results showed that the offsite voltage to Callaway Plant would be adequate to maintain safety-related 4.16 kV voltage above the degraded relay set point. However, the inspectors noted that there was no margin between the predicted voltage and the licensee low voltage limit. The inspectors also noted that actual summer 1999 and projected summer 2000 loads and transfers of power across the transmission system were higher than those modeled by the licensee. These higher loads would result in lower transmission system (and switchyard) voltages. The licensee stated that they planned to install capacitor banks to help maintain system voltages before high summer loading conditions occurred. The licensee also stated that they were considering the installation of automatic tap changing transformers which would automatically compensate for changing transmission system voltages and maintain site voltage at a constant level. Further, the licensee indicated that they would revise their summer loading analysis after hardware changes were made to ensure that adequate voltages would be maintained in the summer of 2000.

In addition to the system load flow analysis, the system operator used the online contingency modeling program (described previously in this report) for monitoring grid parameters. As discussed previously, this program had an added feature that combined actual system parameters along with postulated contingencies, such as loss-of-transmission lines and generation, including Callaway Plant. Therefore, this program provided continuous monitoring of the Callaway Plant offsite voltage, and predicted voltage if Callaway Plant generation was lost. The system operator added an audible alarm in the control area specifically for when the program predicted that there would be degraded Callaway Plant voltage following a unit trip. The inspectors observed the results of this program and the alarm response procedure. The inspectors determined that the system operator had a reasonable contingency plan in place to raise system voltage after an alarm was received. The inspectors concluded that the Callaway Plant voltage analysis for worst-case winter loads and the online program were adequate to demonstrate and maintain acceptable offsite voltages until summer 2000.

However, the inspectors observed that prior to the August 11, 1999, trip, conditions existed at the site and on the transmission system on several occasions during the previous twelve months such that offsite voltage would have been below the required minimum value, had Callaway Plant tripped. Prior to the August 11, 1999, reactor trip, no provisions were in place to monitor or detect these periods of potential vulnerability.

Had an emergency safeguards actuation occurred during August 11 and 12, design calculations indicated that the degraded voltage relay would likely have tripped the offsite power source to one or both safety-related busses. Under this condition some safety-related equipment would have started on the offsite power source, tripped when offsite power was separated from the bus, and then restarted after the emergency diesel generators had come up to speed and been connected to the bus. This condition is sometimes described as double sequencing. The licensee did not have an analysis that demonstrated that this phenomenon would not introduce unanalyzed failure modes with respect to the emergency core cooling systems or onsite power supplies. The licensee indicated that they would review the potential impact of this issue.

c. Conclusions

The inspectors concluded that the modeling and calculations associated with onsite voltages were acceptable to demonstrate that the minimum allowable offsite voltage would be adequate to support safety-related equipment during a worst-case design basis event. Further, the licensee's revised system load flow analysis demonstrated that acceptable system voltages (using the worst-case Callaway Plant design basis assumptions) could be maintained until the summer of 2000. The licensee had planned hardware modifications at the Callaway Plant prior to summer 2000 at which time the system load flow study would be revised.

The inspectors determined that the previous system load flow analyses had not adequately incorporated considerations of load growth and economic deregulation. This resulted in an underestimation of the system loading conditions, which were observed at

the time of the August 11, 1999, event. Additionally, prior to the August 11, 1999, reactor trip, the licensee did not have adequate provisions to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss-of-power generated by the nuclear power unit.

E2.3 Evaluation of the Licensee's Root Cause Analysis and Corrective Actions

a. Inspection Scope (92700)

The inspectors reviewed the activities and results associated with the licensee's root-cause analysis. Additionally, the inspectors reviewed the corrective actions, which had been either implemented or planned to prevent recurrence of the degraded voltage condition.

b. Observations and Findings

The inspectors determined that while the licensee's engineering organization had conducted extensive engineering reviews of the event, a formal root-cause analysis had not been initiated until approximately mid-November 1999. The licensee indicated that various factors related to outage activities and resource limitations had precluded an earlier start for the formal root-cause investigation. Accordingly, the inspectors were unable to assess the overall adequacy of the root-cause effort. The root-cause effort had not received a priority commensurate with its importance in that this issue affected the power supplies to important safety systems at the plant and yet the root-cause effort was significantly delayed. Notwithstanding the delays in conducting the formal root-cause effort, the licensee had implemented a number of immediate and short-term corrective actions. Additionally, the licensee had proposed a long-term engineering solution to prevent recurrence of the degraded voltage condition.

The inspectors noted that the NRC had alerted licensees to the potential impact of economic deregulation on the reliability of offsite transmission networks on February 27, 1998, in NRC Information Notice 98-07, "Offsite Power Reliability Challenges from Industry Deregulation". The licensee had reviewed this information notice in early 1998 and had closed the issue without the need for further action or review. During the inspection, the licensee indicated that the closure of this information Notice was not handled in accordance with its safety significance and entered this item into their corrective action program.

The immediate corrective actions following the detection of the low voltage condition consisted of a series of electric plant realignments both in the Callaway Plant, as well as, on the Ameren transmission system. The Callaway Plant operators shifted several large motor loads to alternate power supplies and the system operators at Energy Supply Operations performed realignments on certain elements of the transmission system. Additionally, during the recovery from the degraded voltage, the system loading

was slowly decreasing due to the reduced demand normally seen in the late afternoon and early evening hours. The immediate corrective actions to restore voltage were effective but may have been hampered or delayed by the lack of formal operating agreements and contingency plans between the site personnel and Energy Supply Operations.

The near-term and intermediate corrective actions taken by the licensee included electric plant restrictions, a revised Energy Supply Operations computer contingency alarm set point, development of Energy Supply Operations contingency procedures, and revision of the Callaway Plant computer alarm set points. The inspectors determined that these actions were adequate; however, the effectiveness of these measures was weakened by the lack of formal operating agreements and a lack of a comprehensive understanding by plant personnel as to the significance of the results of the Energy Supply Operations contingency analyses. Additionally, the licensee took actions to establish a level of redundancy in the supervisory control and data acquisition lines, which should minimize the possibility of future losses of critical data.

As of the end date of the inspection, the licensee indicated that long-term corrective actions to preclude the recurrence of the event were in the conceptual design phase. These changes included consideration of hardware modifications to add extra capacitance to the safety busses or perhaps replacement of the engineered safeguards feature transformers with new devices with automatic load tap changers. The inspectors determined that these proposed changes appeared adequate at a conceptual level. However, the overall effectiveness of the modifications was not assessed.

c. Conclusions

The inspectors concluded that the immediate and short-term corrective actions associated with correcting the degraded voltage condition were adequate. However, it was determined that effectiveness of these actions was limited by the lack of formal operating agreements between site personnel and Energy Supply Operations. It was also noted that the licensee had missed an earlier opportunity to address this issue in that the NRC has issued an information notice in early 1998 alerting licensees to the potential impacts of economic deregulation. The licensee had reviewed and closed this notice without further action. Additionally, the inspectors noted that while the licensee had conducted an extensive amount of engineering review immediately following the event, the formal root-cause effort had been significantly delayed.

V. Management Meetings

X1 Exit Meeting Summary

The inspectors presented the inspection results to members of licensee management at the conclusion of the inspection on February 3, 2000. The licensee acknowledged the findings which were presented.

The licensee indicated that certain materials, which were reviewed during the inspection, were of a proprietary nature. All materials which were identified as proprietary were returned to the licensee. This report contains no proprietary information.

ATTACHMENT

SUPPLEMENTAL INFORMATION

PARTIAL LIST OF PERSONS CONTACTED

Licensee

J. Blosser, Manager-Operations Support
D. Christian, NSRB Member, Vice President Nuclear Operations, Virginia Power
K. Connelly, Senior PRA Engineer
M. Haag, Senior Design Engineer, Callaway Plant
R. Harsey, Manager, Energy Supply Operations
G. Hughes, Supervising Engineer-Quality Assurance
M. Killgore, NSRB Member, TXU Electric
B. Little, NSRB Member, Contractor
R. Mecredy, NSRB Member, Vice President Nuclear Operations, Rochester Gas & Electric
W. Miller, NSRB Member, Professor, University of Missouri
P. Nauert, Supervising Engineer, Energy Supply Operations
A. Passwater, Manager-Corporate Nuclear Services
E. Pfeiffer, Staff Engineer, Transmission Planning
G. Randolph, Vice President and Chief Nuclear Officer
M. Reidmeyer, Senior Engineer, Callaway Plant
D. Shafer, Supervising Engineer-Regulatory Operations
K. Shah, Supervising Engineer, Transmission Planning
P. Shannon, Supervising Engineer-Operations
D. Waller, Supervising Engineer-Electrical Design
D. Whiteley, Manager-Electrical Engineering and Transmission Planning

INSPECTION PROCEDURES USED

IP 90700	Feedback of Operational Experience Information at Operating Power Reactors
IP 90712	In-Office Review of Written Reports of Nonroutine Events at Power Reactor Facilities
IP 92700	Onsite Follow-up of Written Reports of Nonroutine Events at Power Reactor Facilities
IP 93702	Prompt Onsite Response to Events at Operating Power Reactors

ITEM OPENED AND CLOSED

Opened and Closed

50-483/9915-01	NCV	Violation of Technical Specification 6.8.1 for inadequate procedure for verifying operability of offsite power (Section O3.1)

LIST OF DOCUMENTS REVIEWED

Bechtel Calculation J-U-GEN, "Instrument Loop Uncertainty Estimates," Revision 0

Calculation NB-05, "System NB Protective Relays," Revision 001

Colt Industries Calculation VTS-985-031480-03R, "Analysis of Load Table and Predictions of Voltage Dip and Frequency Excursions at the Various Load Step Conditions," Revision 0

Calculation ZZ-62, "Load Flow - Voltage Drop Calculation," Revision 5

Callaway Plant Administrative Procedure ETP-ZZ-02000, “Process Computer Operations and Configuration Management,” Revision 3

Callaway Plant Operations Procedure ODP-ZZ-00016, “Reactor Operator Watchstation Practices and Logs,” Revision 39

Callaway Plant Off Normal Operating Procedure OTO-RJ-00001, “Loss of Plant Computer,” Revision 4

Callaway Plant Operations Surveillance Procedure OSP-NB-00001, “Class 1E Electrical Source Verification,” Revision 9

Callaway Unit Technical Specifications

Final Safety Analysis Report, Section 8.0, “Electric Power,” Revision OL-0

I&C LOOP Calibration Procedure ISL-NF-NB01A, "LOOP-Misc; NB01A Degraded & UV to LSELS," Revision 012

Licensee Event Report 50-483/99-005

Night Order #0120.0015, “Switchyard Voltage Requirements,” dated December 01, 1999

NUREG-0830, “Safety Evaluation Report Related to the Operation of the Callaway Plant, Unit 1, Docket STN 50-483,” October 1981