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ACCESSION NBR:9511270217 DOC.DATE: 95/11/17 NOTARIZED: NO DOCKET #
FACIL:50-269 Oconee Nuclear Station, Unit 1, Duke Power Co. 05000269
50-270 Oconee Nuclear Station, Unit 2, Duke Power Co. 05000270
50-287 Oconee Nuclear Station, Unit 3, Duke Power Co. 05000287
AUTH.NAME AUTHOR AFFILIATION
HAMPTON,J.W. Duke Power Co.
RECIP.NAME RECIPIENT AFFILIATION
Document Control Branch (Document Control Desk)

See Rpt.

SUBJECT: Forwards response to NRC 951102 RAI on plant electrical sys issues.Rev 0 to Calculation OSC 5336, "ONS Units 1,2 & 3 Cyme-Keowee Program Verification" & Calculation OSC-4995, "Electrical Calculation for PIRs 0-92-0455 & 0-92-0490...."

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Duke Power Company
Oconee Nuclear Generation Department
P.O. Box 1439
Seneca, SC 29679

J. W. HAMPTON
Vice President
(803)885-3499 Office
(803)885-3564 Fax

DUKE POWER

November 17, 1995

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Subject: Oconee Nuclear Station
Docket Nos. 50-269, -270, -287
Response to Request for Additional Information on Oconee Electrical System Issues

In a letter dated November 2, 1995, the NRC Staff requested additional information from Duke Power by November 17, 1995. The Staff's request is in connection with its review of the Oconee electrical system.

On November 8, 1995, Duke Power met with the Staff at Oconee Nuclear Station to discuss the issues and to clarify our understanding of some of the questions. Duke Power has made every effort, given the short response time, to understand what information is being requested, and to provide a detailed response to the multiple parts of each of the twelve questions. Attachment 1 reiterates the Staff's requests, and contains our response to each request for additional information.

In some instances, the information that is provided in Attachment 1 has been newly developed based upon our understanding of the Staff's concerns. We request the opportunity to supplement and/or clarify the new information as appropriate. If additional information is needed by the NRC Staff, we suggest a meeting at your offices.

If you have any questions regarding this matter, please contact J. E. Burchfield at (803)885-3292.

Very Truly Yours,

J. W. Hampton, Site Vice President
Oconee Nuclear Station

MEB

A001

xc: L. A. Wiens, Project Manager
ONRR

P. E. Harmon, Senior Resident Inspector
Oconee Nuclear Station

S. D. Ebneter, Regional Administrator
Region II

Ed Jordan, Chairman
CRGR

ATTACHMENT 1

Duke Power's Response to the Additional Information Requested in the NRC's November 2, 1995 Letter

Request 1

Describe the periodic and one-time tests that have been or are being performed to demonstrate the ability of the emergency power sources (Keowee Hydro Units and Lee Gas Turbines) and the associated controls and switching logic to perform their required design-basis actions. Describe the design basis performance each test is meant to demonstrate and the degree to which it demonstrates that performance. Provide the basis for the acceptance criteria used in the test. If analytical work was done to further support the ability of the power sources to perform as intended (e.g. to verify design basis accident loading capability where actual design basis loading has not been performed), describe the analysis performed and how it supplemented the test results. Describe what tests or data was used to verify the accuracy of the analytical work and provide the degree of correlation between the analysis and verification tests/data.

Response to Request 1

As background, Keowee Hydro Station is the emergency onsite power source for Oconee Nuclear Station. It consists of two 87.5 MVA generating units which are capable of supplying power to Oconee via two independent paths. The overhead path consists of either Keowee unit's overhead generator breaker, the Keowee main step-up transformer, overhead transmission line, isolated 230kV switchyard Yellow Bus, startup transformer on each Oconee unit and associated breakers. A degraded grid with an engineered safeguards (ES) signal or complete loss of the system grid (LOOP) necessitate this alignment. When operating in this mode, this path is completely isolated from the offsite power system.

The underground emergency power path consists of the pre-selected Keowee unit's underground generator breaker, the underground cables, transformer CT-4, SK breakers and the standby busses. Due to the capacity limits of the underground cables, transformer CT-4 and associated standby bus switchgear, the non-essential loads of the unit are shed prior to connecting the Oconee unit to this path. A degraded grid with an ES actuation, complete loss of the

system grid or a failure of an Oconee unit's startup source necessitate this alignment.

Lee Steam Station provides an additional source of emergency power for Oconee Nuclear Station when neither Keowee Hydro unit is available or when a Keowee unit is in an extended outage. Lee Steam Station has three combustion turbine generators which can be aligned to supply power to Oconee. Only one combustion turbine is required to supply Oconee emergency loads. The dedicated path from Lee consists of an electrically isolated transmission line, transformer CT-5, the SL breakers and the standby busses. The connection of a Lee combustion turbine to Oconee is not an automatic function. When a Lee combustion turbine is required to support Oconee, the connection of a Lee combustion turbine to the standby busses is required within one hour or prior to the Keowee outage by the Technical Specifications.

Testing of the emergency power systems is performed with great thoroughness. During the development of the testing, all design basis criteria were considered. Integral testing on the system level is performed when practical and the functions and logic are verified to the component level. The testing and supporting analysis of the emergency power system comply with or exceed the requirements of the Technical Specifications. The Oconee emergency power system meets its design basis and the testing demonstrates the capability of the system to perform its intended design functions.

Both periodic and one-time tests have been or are being performed to demonstrate the ability of the emergency power sources to perform their required design basis functions. These tests include the following:

PERIODIC/ONE-TIME

1. PT/0/A/0620/16 - Keowee Emergency Start Test
2. PT/0/A/0610/22 - Degraded Grid and Switchyard Isolation Functional Test
3. PT/1,2,3/A/0610/01J - Emergency Power Switching Logic Functional Test
4. Keowee Load Rejection Test*
5. TT/0/A/0650/01 - Keowee Black Start Test
6. Keowee Overhead Path & RCP Motor Load Test
7. PT/0/A/0610/19 - 100kV Power Supply Prior To Extended Keowee Outages
8. PT/0/A/0610/06 - 100kV Power Supply From Lee Steam Station

9. PT/0/A/0610/23 - Lee Gas Turbine Operation To the Grid Verification
10. Lee Combustion Turbine & ASW Motor Test
11. Keowee Low Power Test (scheduled for 11/22/95)
12. PT/1,2,3/A/0610/01A - EPSL Normal Source Voltage Sensing Circuit
13. PT/1,2,3/A/0610/01B - EPSL Startup Source Voltage Sensing Circuit
14. PT/1,2,3/A/0610/01C - EPSL Standby Bus Voltage Sensing Circuit

* Post NSM ON-52966 implementation

The Keowee Emergency Start Test (Test 1) is a periodic test that demonstrates Keowee's ability to emergency start upon receipt of a Keowee emergency start signal. In addition, it verifies the ability of the Keowee units to accelerate to rated speed and voltage within the committed time of 23 seconds. Achieving rated speed and voltage within 23 seconds allows ECCS injection to occur within the time assumed in the large break LOCA analyses. Also, this test demonstrates Keowee's ability to supply the equivalent loads of an Oconee LOCA/LOOP unit and two Oconee LOOP units. In accordance with the Technical Specifications, the capacity of the Keowee units is verified by accepting load from the system grid at the maximum practical rate. Keowee routinely demonstrates its capability to supply power in excess of the emergency loads when it generates to the system grid. The loading of a Keowee unit which is isolated from the system grid is performed in other periodic tests discussed below. In addition, the overhead generator breaker re-closing timer setpoints are verified during this periodic surveillance.

The Degraded Grid and Switchyard Isolation Functional Test (Test 2) periodically demonstrates Keowee's ability to separate from the system grid (load reject) upon receipt of a Keowee emergency start signal. During the test, Keowee energizes the overhead path up to the startup breakers for each Oconee unit following completion of the 230 kV switchyard isolation. When a LOOP or degraded grid concurrent with an ES signal occurs, the 230 kV switchyard Yellow Bus isolates from the system grid and aligns to the overhead path. This test ensures that either channel of the dual channel switchyard isolation logic can isolate the Yellow Bus from the system grid and align each Oconee unit startup transformer to the overhead path. During the test, the Keowee units receive an emergency start as a result of the simulation of a degraded grid concurrent with an ES actuation. The overhead unit, which is connected to the grid, load rejects by tripping its overhead generator

breaker and automatically realigns itself to energize the overhead path. Also, the underground Keowee unit starts upon receipt of the emergency start signal and runs in standby. The acceptance criteria of this test include verification of proper breaker alignments in the switchyard, load rejection of the overhead Keowee unit, and verification of the alignment of the overhead power path. Since Oconee generation is not prohibited by the switchyard isolation, this test is performed with the Oconee units on line. Therefore, no Oconee auxiliary loads are available to be loaded onto the overhead Keowee unit. The capability of the overhead path equipment to carry loads equivalent to the emergency needs of the Oconee units is routinely demonstrated during shutdown, startup, and following reactor trip of an Oconee unit. The Degraded Grid and External Grid Protection System voltage relay setpoints and operation are verified in their specific relay maintenance/calibration procedure.

The Emergency Power Switching Logic Functional Test (Test 3) is a periodic test that demonstrates primarily the capability of the emergency power switching logic (EPSL) to adequately transfer the Oconee auxiliary loads to an available power source. This test is performed during the refueling outage on each Oconee unit. The Keowee underground unit, Lee combustion turbine (CT) and offsite power are used as sources of power during this switching logic test. Transfer of the Main Feeder Busses (MFBs) from the normal source to the startup source, startup source to the standby bus and re-transfer back to the startup source are demonstrated during this test. Since the non-essential loads are shed prior to transferring to the standby bus, both channels of the load shed logic are verified to actuate during this test. Upon loss of the startup source, the undervoltage logic for the reactor coolant pump motors is verified to trip. During the test, actual auxiliary loads of the shutdown Oconee unit are transferred to the different sources. Keowee's ability to emergency start as a result of a simulated LOOP and LOCA is demonstrated during this test. For the Unit 1 EPSL test, the Keowee underground unit black starts since its auxiliary loads are lost as a result of a simulated LOOP on Oconee Unit 1.

This test was configured differently prior to 1987. Upon loss of the startup source (simulated LOOP), the auxiliary loads were transferred to the standby busses and loaded onto an accelerating Keowee underground unit. Since 1987, the transfer to the standby busses occurs with the standby bus energized by a Lee combustion turbine. The simulated loss of the Lee CT then results in an automatic dead bus block

transfer of loads to an idling Keowee unit. This evolution verifies the EPSL logic between the SL and SK breakers. During these transfers, a Lee CT supplies power to the Oconee auxiliary loads for approximately 60 minutes and Keowee provides power to the Oconee loads for one to two hours. Instability of a Keowee unit or Lee CT would be identified by either the Oconee, Keowee or Lee control room operators. This test is performed two to three times a year and no stability concerns have been identified. In order to document the stability of the Keowee units, voltage and frequency monitoring of the Keowee unit supplying Oconee will be performed periodically beginning with the present Oconee Unit 1 outage. During the present Oconee Unit 1 outage, additional data will be collected while blocks of loads are added and rejected from the Keowee unit. Response to Request 3 provides more details on the monitoring associated with the upcoming test.

As a prerequisite to this EPSL test, the undervoltage logic for the normal, startup and standby sources is performed to ensure the 2 out-of 3 logic is functioning properly by Tests 12, 13 and 14, respectively. Each relay in the undervoltage logic and the associated auxiliary relays are verified to ensure that the logic functions properly. The transfer time delay relay setpoints and undervoltage relay setpoints for both the 4 kV and 7 kV systems are verified in their own respective calibration procedure.

Following the implementation of modification ON-52966, a Keowee Load Rejection Test (Test 4) will be performed periodically. This modification adds overfrequency protection, governor failure monitoring and governor failure protection to the Keowee units. This test verifies the ability of the Keowee units to load reject and return to normal speed within the required time. Appropriate instruments, such as the MW/VAR meter and frequency relays, are calibrated by their respective procedures prior to this surveillance test. Tripping of the Keowee generator breaker on emergency start and re-closing within the appropriate timeframe is demonstrated during this transient. Successful realignment to the appropriate power path within the defined time is the acceptance criterion for this test.

As part of the design of this modification, several Keowee load rejection tests were performed to collect data associated with the response of the Keowee units to a loss of load. These tests were performed at power levels ranging from 60 to 90 MW and consisted of both single and dual unit load rejections. Actual emergency start signals were used to initiate each load rejection.

A Keowee Black Start Test (Test 5) demonstrated Keowee's ability to emergency start with only DC power (black start) available to its auxiliaries. The black start feature was part of the original Keowee design and was tested as part of the pre-operational startup testing for Keowee. This feature was reverified during a one-time test in December of 1992. As mentioned in the description of Test 3, whichever Keowee unit is connected to the underground path is black started during each Oconee Unit 1 EPSL functional test. Although the black start test is considered a one-time test, this feature is demonstrated on a routine basis. As at Oconee, the DC system at Keowee is monitored and tested periodically. Along with other periodic battery preventative maintenance, service and performance tests are conducted to demonstrate that the DC system is performing as designed.

A one-time test of the Keowee Overhead Path with a Reactor Coolant Pump (RCP) Motor Load (Test 6) was performed on May 31, 1993 to collect data for the certification of a computer model. During the test, a 9000 hp RCP motor was block loaded onto an idling Keowee overhead path unit. The block loaded RCP motor resulted in an inrush MVA that was larger than the LOCA loads of an ONS unit. Since the purpose of this test was to obtain data, no test acceptance criteria were established. The Keowee unit accepted this load as expected. Calculation OSC-5336 documents the correlation between the test data and the computer model simulation. A copy of this correlation is contained in Attachment 2.

The 100 kV Power Supply Prior to Extended Keowee Outages Test (Test 7) demonstrates annually that a Lee combustion turbine can start, connect to an isolated 100 kV transmission line, and energize the Oconee main feeder busses. A recent revision to this test procedure moved the Technical Specification requirements of surveillance 4.6.6 to the EPSL Functional Test procedure which is described in Test 3. This revision allows the EPSL functional test to be a more integrated test of this system.

The 100kV Power Supply from Lee Steam Station Test (Test 8) demonstrates the requirements of Technical Specification Surveillance 4.6.7. The test starts a Lee CT and loads the CT to the approximate accident loads of an Oconee unit. Oconee non-essential loads are used to achieve this load capacity since the engineered safeguards loads are not available during a refueling outage. The one hour time requirement for starting and dedicating a Lee CT to Oconee is part of the test acceptance criteria. This test is

performed on an eighteen month frequency in accordance with Technical Specification 4.6.7.

The Lee Gas Turbine to the Grid Verification Test (Test 9) ensures the ability of a Lee CT to supply the equivalent of an Oconee LOCA/LOOP unit and two Oconee LOOP units. This test is performed with the Lee CT generating to the system grid which is consistent with the Technical Specification requirements.

A one-time test (Test 10) of a Lee CT with the Auxiliary Service Water (ASW) Pump motor was performed on February 10, 1995 to collect data for the certification of a computer model. During the test, the ASW Pump motor was block loaded onto the standby busses which were powered by an isolated Lee CT. In addition, other loads at Lee were added and rejected to obtain data for the response of the Lee CT during these transients. Since the purpose of this test was to obtain data, no test acceptance criteria were established. Calculation OSC-3290 documents the correlation between the test data and the computer model simulation. A copy of this correlation is contained in Attachment 3.

The Keowee Low Power Test (Test 11) is scheduled to be performed during the present Oconee Unit 1 refueling outage as part of the EPSL test. The Keowee underground unit is loaded as it accelerates to rated speed and voltage which is similar to the EPSL test prior to 1987. When the Keowee unit is at steady-state, blocks of load are added and rejected from the Keowee unit. This test will collect data on the Keowee unit during the load transients. Further details of this test are discussed in response to Request 3.

Keowee and Lee generate to the system grid for commercial peaking power. A majority of the circuits and functions that must operate for grid generation are the same circuits and functions that operate during an emergency. Grid generation reduces the amount of time that failures are left undetected in certain circuits. The ability to use these sources for commercial power generation is an asset to the emergency power system.

Oconee bridges the gap between testing and actual design requirements by using analysis. Since actual design basis loads are not available for functional testing, computer models are used to ensure the full loading capability of the emergency power sources. The computer modeling tool which is used at Oconee is the CYME program. The CYME program is capable of dynamically modeling the power source and the electrical loads. Certification testing and analysis for

the CYME program have been performed for Keowee and Lee. Further details on the test and model correlations are provided by the descriptions of Tests 6 and 10. The voltage adequacy analysis for the Oconee auxiliaries has been performed for the Keowee overhead path, Keowee underground path, and Lee CTs. This analysis includes the worst case design accident loads. In addition, failures are postulated which result in the loading of additional non-essential loads. The possibility of the generator terminal voltage operating below nominal has been considered by the analysis. Finally, the addition of loads for the non-accident units after the accident loads of the affected unit has been analyzed to cover the possible transfer scenarios. Other combinations of possible loadings between ONS units have been analyzed.

For the Keowee underground path analysis, the CYME model assumes that the Keowee units are at rated speed and voltage when the load is applied. This analysis methodology is acceptable for the following reasons:

1. During an emergency start, the Keowee wicket gates are initially opened to approximately 50% to allow for quick acceleration. A normal start of the Keowee unit would initially open the wicket gates to approximately 25%. Therefore, the wicket gates are in a position to accept load during an emergency start without requiring additional governor response. The voltage regulator in the emergency mode continues to operate as allowed by the volts/hertz limiter. From steady-state, the governor and voltage regulator must respond from their idling position to accept the load which is applied. Thus, steady-state loading is as demanding as when accelerating.

2. The starting MVA for a Keowee unit which is loaded during acceleration is less than the starting MVA calculated in the analysis for a Keowee unit which is loaded at steady-state. This is because the voltage of the accelerating Keowee unit is less than rated voltage.

3. Possible delays, if any, in reaching rated speed and voltage within 23 seconds for the Keowee unit loaded while accelerating do not impact operability. If the Keowee unit is loaded at approximately 11 seconds, minimum flow injection of the ECCS within the required 48 seconds is assured. The 23 second requirement is necessary in order to actuate the re-transfer to startup logic in a timely manner to ensure that the 48

second ECCS requirement is met assuming a loss of the underground path.

Request 2a

In a document prepared by Duke Power for the Oconee resident inspectors a comparison is made between typical plant diesel tests and the Keowee tests. It is indicated that the Keowee emergency start test and emergency power switching logic test (#1 and #2 in the document) is similar to the engineered safeguards test (#1 in the document) performed on diesel generators. The diesel tests typically required in technical specifications are intended to test the entire range of required diesel generator and switching logic performance, including LOOP, LOOP/LOCA, load reject, load capability, standby start and run, test mode override, hot start, automatic trip bypass, and transfer back to offsite power. The integrated LOOP and LOOP/LOCA load sequencing tests typically require that simulated or actual loss of offsite power and emergency safeguards actuation signals be applied and that all subsequent required automatic operations be demonstrated to occur as they normally would, up to and including loading of required loads to the diesel generators (utilizing final actuated equipment in its required operating mode where practicable). Identify the Keowee, Lee Gas Turbine, and related engineered safeguards tests that are performed periodically to demonstrate the full range of required capabilities comparable to diesel generator tests. For the Oconee emergency power sources these tests would include, but not necessarily be limited to: LOOP and LOOP/LOCA from standby and generating to the grid, swapover between overhead and underground paths given a failure of one or the other during an event, standby start and run, load capability, load reject, automatic trip bypass, and transfer back to offsite power. Are the LOOP and LOOP/LOCA tests done in an integrated fashion comparable to diesel tests?

Response to Request 2a

Requests 1 and 2a are associated with the testing that is performed on Keowee and Lee. Therefore, the response to this part of Request 2 is addressed in the response to Request 1. Attachment 4 contains a copy of the document that was prepared for the Oconee resident inspectors and is referenced in Request 2a.

Request 2b

In the document prepared for the Oconee resident inspectors, it is indicated that prior to 1987 an emergency power switching logic test was periodically performed that loaded a Keowee unit (at 11 seconds) while it was still accelerating. At present that test is performed by loading the Keowee unit after it has fully accelerated. Describe why the test changed. It appears that both tests should be performed since the Keowee units are required to perform in either manner depending on the event scenario. This would be consistent, for example, with the diesel generator load sequencing tests that are typically required to be performed periodically to demonstrate, to the extent practicable, the ability of machines to perform in a manner in which they would actually be called upon. Please comment.

Response to Request 2b

Initially, the various functions of the Emergency Power Switching Logic were tested separately during each Oconee unit's refueling outage. In order to reduce outage risk and to perform a more integrated test, the various EPSL tests were combined into four tests in 1987. The resulting four EPSL tests were the functional test, normal source voltage sensing test, startup source voltage sensing test, and standby bus voltage sensing test. The EPSL functional test is an integrated test which verifies all of the functions that the Emergency Power Switching Logic would perform in a Design Basis Event.

The ability of a Lee combustion turbine to supply an Oconee unit's main feeder bus on a transmission line separated from the Duke grid is included in the functional test. This inclusion allowed testing of the SL and SK breaker logic in a more integrated manner with Lee energizing the standby busses. This configuration, which allows for a more integrated test, does not allow block loading of Keowee while it is accelerating. We consider this change adequate because testing at steady-state provides reasonable assurance that all of the design basis conditions are met. A Keowee low power test, as described in our response to Request 3, will be performed during the present ONS Unit 1 refueling outage to gather data and further confirm the adequacy of the Keowee response. These test results will be evaluated and the need for future tests will be assessed. Additional justification supporting the steady-state loading is provided in the response to Request 1 under Test 11.

Request 3

We understand that an instrumented test similar to the pre-1987 test addressed above is intended to be performed during the next refueling outage. Please provide details of the intended tests such as how the test will be performed, what electrical loads will be picked up, what will be the total megawatt and MVA value of the loads energized, and what instrumented values will be recorded.

Response to Request 3

During the EPSL functional test that is scheduled for the present Oconee Unit 1 outage, the Keowee units will be emergency started from a shutdown condition. At approximately 11 seconds, the accelerating underground Keowee unit will be block loaded with the Oconee Unit 1 shutdown loads and Keowee underground unit auxiliary loads. Based on system operation, Keowee will obtain steady-state before additional loads can be added. Three blocks of load totaling approximately 6 MVA will be added to the Keowee unit by starting CCW pump motors. A total of three CCW pumps will be loaded on the Keowee unit in series. This will result in the loading of the Keowee unit to approximately 8 MVA. When the loading is complete, a block load rejection of approximately 4 MVA will be initiated by tripping two CCW pumps simultaneously. The following parameters will be monitored during this test:

At Keowee:

1. Generator Voltage
2. Generator Current
3. Generator Megawatts
4. Generator Frequency
5. Generator Field Voltage
6. Generator Field Current
7. Voltage Regulator Auto/Manual Status

At Oconee:

1. Main Feeder Bus Voltage
2. Main Feeder Bus Current
3. Main Feeder Bus Megawatts
4. Keowee Auxiliaries, 1TC-4, Current
5. Keowee Auxiliaries, 1TC-4, Megawatts
6. CCW Motor Current
7. CCW Motor Voltage
8. CCW Motor Kilowatts
9. CCW Motor Reactive Power

This information represents our current plan, but the details could be subject to change.

Request 4

With regard to the above test, calculation number KC-UNIT 1 & 2-2023 indicates on page 22 that the Keowee voltage regulator might be brought online very close to, or in excess of, (9 secs + 2.5 secs = 11.5 secs) the 11 second LOCA load application point of a Keowee standby unit. Will the intended test monitor the point at which the regulator is brought online during acceleration of the Keowee unit? Because of the tight timing tolerances involved we believe this point should be monitored.

Response to Request 4

The response to Request 3 indicates that the point when the voltage regulator will be brought online will be monitored. This is accomplished by monitoring the Keowee voltage regulator auto/manual status.

Request 5

An emergency start test from standby was performed on Keowee Unit 2 on May 22, 1993. The instrument chart from that test indicates that at 11 seconds (the point at which LOCA loads would be loaded onto the unit if it were connected to the underground path) the voltage output on the unit was at 8.181 Kv and the unit rpm was 84. This gives a per-unit voltage of 0.593 and a per-unit frequency of 0.653, which results in a volts/hertz ratio of 0.908. Based on this it appears that the Keowee Unit 2 voltage is running up at a slower rate than the frequency (at least during the first 11 seconds of the start) and the volts/hertz limiter in the regulator is not needed during this period (in fact it may not even be online at this time, see above question). The reduced voltage relative to frequency may also affect the starting capability of equipment energized at 11 seconds. This appears to support the need for further testing to establish the Keowee voltage and frequency response to design basis accident loading at 11 seconds from standby, and the capability of equipment to start under those conditions. Also, in Duke's analysis of the onsite power system to demonstrate the capability to start and accelerate emergency loads, was this apparent low-voltage starting

condition considered? If so, please describe how it was considered.

Response to Request 5

During startup of a Keowee unit, the volts/hertz limiter will not allow the voltage regulator to raise voltage such that the ratio of per unit voltage to per unit frequency exceeds 105%. The limiter is designed to protect the generator and connected transformers from damage. As noted in the question, this protection is not needed when in manual since no active controls are present to try to maintain output voltage.

Further testing of loading a Keowee unit while accelerating at reduced voltage and frequency will be performed in the present Oconee Unit 1 outage. See response to Request 3 for details. Refer to the response to Request 1 under Test 11 for justification that supports the adequacy of loading an accelerating Keowee unit.

Request 6

In response to EDSFI finding 5-1, a Duke Power Company letter dated July 6, 1993, states that calculation OSC-4995 documents that no credible single failure exists that would render the Keowee voltage regulators inoperable. Please provide this calculation. The Duke letter also states that the volts/hertz limiting feature of the regulator which the EDSFI team questioned is also included in the analysis. The concern with the Keowee voltage regulators is that they could fail in a manner that would result in out-of-tolerance voltages being applied to redundant Oconee electrical loads, potentially damaging or disabling the equipment. With regard to the volts/hertz limiter, Table C.1-1 in the Keowee PRA identifies an event on May 4, 1993, that resulted in "VARs going in the hole" while Keowee Unit 1 was generating to the grid. It indicated that the unit did not respond to the voltage adjust or the base adjust controls, and the problem was found to be in the volts/hertz limiter card. The result of the failure of the volts/hertz limiter card (VARS going in the hole) indicates that field excitation of the Keowee generator was reduced, which would have resulted in a voltage reduction on the output of the Keowee generator had it been supplying Oconee in the emergency mode. Please comment on this event relative to the analyzed single-failure potential of the volts/hertz limiter to create such a problem.

Response to Request 6

Calculation OSC-4995, see Attachment 5, documents an operability evaluation of past failures that were attributed to the Keowee voltage regulator. The manufacturer's technical representatives and Duke regulator experts evaluated if the units were operable during the past failures. In addition to the specific failures, this evaluation considered if there could be a credible failure which could adversely affect generator voltage. As explained below and in the response to Request 7, no credible failures have been identified which would cause this condition. This conclusion is based on the experience of the manufacturer and internal technical experts.

The failure of the regulator has the potential to affect the generator output voltage in three ways. When describing these failure modes, it is assumed that the LOCA unit loads are being powered by the Keowee unit aligned to the underground path. It is also assumed that this Keowee unit has a failed regulator. One assumed failure mode would be the failure of the regulator logic section to provide a control signal. This failure is equivalent to operation of the regulator in manual and has been analyzed using the CYME model with no problems identified.

Another assumed failure mode results in an increase in the generator voltage. For the Keowee units, an increase in generator voltage is not considered a problem because there are several protective features in the regulator equipment that protect against an increase in the generator voltage. In addition, some of the protective features operate independent of the regulator. The volts/hertz limiter will prevent voltage from increasing above 105% for most logic drawer failures. Additional features provide protection for failures in and down stream of the signal mixer. The overvoltage module will prevent the voltage from exceeding 120%. Upon completion of calculation OSC-2024, a recommendation was made to move the volts/hertz relay to the emergency lockout relay. This recommendation is scheduled to be implemented by minor modifications OE-7432 and OE-8226. Once the modifications are implemented, the volts/hertz relay will trip the Keowee unit when voltage exceeds 116% for 30 seconds. From an overvoltage perspective, the limiting component in a power system is the system transformer which is protected by the protective trip. Therefore, the emergency power system loads would be protected from overvoltage.

The last assumed failure mode results in a decrease in the generator voltage. It should be noted that this failure mode cannot occur as a result of a firing circuit or power amp drawer failure. These drawers have built in redundancy which prevents the postulated failure mode. However, automatic regulator logic drawer failures can be postulated to cause this type of failure. The single failure would not adversely impact the ability of the emergency power system to perform its intended function due to the existence of additional undervoltage protection on the underground path which detects any failure that causes generator voltage to decrease below approximately 6 kV. When a low voltage is sensed on the underground path, the LOCA loads are automatically transferred to the overhead power path, fed by the other Keowee unit. This response to a regulator failure is what has been considered credible. The potential for failures which cause voltage to decrease to some intermediate value above the undervoltage relay setpoints will be addressed in the following analysis of the volts/hertz limiter failure that occurred on May 4, 1993.

The May 4, 1993 failure caused the output of the volts/hertz limiter to drop from its normal +12VDC output to -4VDC. In addition, the output of the signal mixer changed to +2VDC. The following comments explain how the unit responds to this failure during emergency power operation.

When the regulator is operating in manual or automatic, the system is calibrated to provide rated voltage (13.8KV) with no load on the generator. The output of the automatic regulator adds to or subtracts from the base signal. The output of the signal mixer when the generator is at rated voltage is 0 VDC for this calibration method. The equipment manufacturer was contacted to determine the transfer function that describes the impact of a change in the signal mixer output voltage on field voltage. The manufacturer stated that a 1VDC change in the signal mixer output causes a 60VDC change on the field voltage. Also, he stated that the maximum voltage possible on the field would be 1.22*240V with the bridge loaded. The maximum voltage possible on the field would be 1.35*240V with the bridge unloaded.

The field voltage at 13.8KV with no load is 675A*.163Ω = 110VDC. Based on the information provided by the manufacturer, the +2VDC signal out of the signal mixer due to the failure would phase the SCR's back to minimum. Using the transfer function from the previous paragraph, this change in the signal mixer output corresponds to 0.02*1.22*240VAC = 5.9VDC which provides 35A to the field. The generator saturation curve verifies that the generator

voltage decreases well below the emergency power switching logic (EPSL) setpoints on the 4KV system. This will cause a transfer of LOCA unit loads to the overhead emergency power source.

Due to the minimum excitation limiter (MEL) and the design of the signal mixer module, the response of the excitation system to this failure is different depending on the operation of the unit. When connected to the grid, the window of control that is available for automatic control by the voltage regulator is defined on the high end by the volts/hertz and MEL. For the low end, the window of control is defined by the MEL. The signal mixer uses an auctioneered concept for the four inputs, which consist of the three limiters and the voltage error detector output. This design allows the generator to continue commercial operation during most logic drawer failures. When a failure of the volts/hertz limiter card causes excitation on the machine to drop, the MEL would respond to the leading VAR's (VARS going in the hole) and increase its output to prevent a decrease in excitation below the minimum excitation limit. This MEL protection is designed to prevent unit trips on loss of excitation due to failures such as the volts/hertz limiter failure. Therefore, the Keowee unit was not tripped by the loss of field relay as a consequence of the May 4, 1993 limiter failure.

Thus, the volts/hertz module failure in 1993 does not contradict the conclusions in OSC-4995, and would not have prevented the emergency power system from performing its intended safety function. The calculation concluded that no credible failures exist in the logic modules which could cause voltage to drop into an intermediate level that would not be detected by EPSL. Additional analysis of the voltage regulator has been provided in the response to Request 7.

Request 7

With regard to the single-failure potential of the Keowee voltage regulators, have internal power supply failures of the voltage regulators been analyzed? Such failures might include open-circuiting of rectifier bridge diodes or SCRs, and shorting or open-circuiting of coupling or filtering capacitors. Have failures of diodes or SCRs in other regulator circuits, such as in the field three phase bridge rectifier, been analyzed? Have failures of capacitors in other regulator circuits been analyzed? The effects of failures in power supply circuits, in particular, are often very difficult to predict because of the widespread affect on all circuits. Have the effects of high resistance in the

control pots of the base adjust and voltage adjust portions of the voltage regulators been analyzed? We know that statements have been made that if the voltage adjust portion of the regulators fail, the base adjust portion will maintain voltage at an adequate value; but if the voltage adjust pots develop high resistance as the result of oxidation, corrosion, or contamination, what will the affect on the voltage be?

Response to Request 7

In general, only those systems or components with a credible chance of failure are assumed to fail. Duke Power is not aware of a requirement that all possible failures must be assumed. Also, components are assumed to fail only in a credible failure mode.

The Westinghouse excitation system used at Keowee is equipped with many redundant features that are not normally provided on diesel generators. These features are designed to allow continued commercial unit operation with a regulator failure. In addition, they provide protection against excitation system failures during emergency operation. These features include:

- Eight power amp drawers, of which only five are required for unit emergency operation.

- Dual firing circuits, either of which will maintain proper unit control if the other firing circuit fails in the low direction.

- Several limiter modules that are designed to maintain voltage within safe limits if a failure occurs in the logic drawer.

- Two power supplies that are each equipped with a fuse to protect against internal short circuits. The power supplies have blocking diodes and a relay to isolate the output of a failed module from the other redundant module. Also, the relay provides an input to the excitation system blown fuse alarm (1,2SA2-38). This is an example of the way the Westinghouse design has evolved to make these units as fail-safe as possible.

The Westinghouse excitation system is designed with protective features to protect the unit from overvoltage in the event of a failure. These features include;

- The volts/hertz limiter which will limit voltage to 105% if a failure occurs in most logic drawer modules.

- A volts/hertz protective relay which will trip the unit at 116% voltage after a 30 second time delay.

- An overexcitation module which will limit high voltage failures to 120% on the generator output for all failures upstream of the pulse generator. The pulse generator is the module which provides the pulse train to the power amp drawers. This feature also provides protection for most potential failures in the pulse generator module.

Other failures that have been specifically considered:

- Excitation system breaker failures which included the failure of the breakers to close, the failure of the field flash breaker to trip, and the assumption of an electrical fault on the breaker contacts.

- Voltage adjuster control circuit failures. Analysis of the Oconee emergency power system assumes generator output voltage is greater than 13.5KV. The adjusters are set such that the generator voltage will be 13.8KV at the preset positions. Thus, a failure of the adjuster to move will not be of adverse consequence.

  The adjusters are controlled by manual switches. Also, there is an automatic control of the voltage adjuster from the synchronizer and from the DC overcurrent relay to the base adjuster. These controls are provided by single relays and/or contacts. Thus, a failure which causes the adjusters to move from the preset is considered credible.

  The base adjuster controls a 0-10VDC signal which is summed with the bias and regulator output signals. The resulting signal shifts a 10V peak to peak sinusoidal voltage in the pulse generator up or down. This voltage controls the delay angle for the generation of the firing pulse during the half cycle when the voltage across the appropriate SCR is positive. The regulator signal can compensate for the effects of a failed base adjuster in the maximum or minimum position (reference KM-312-0089-001, Tab 1, page 3). Thus, the generator provides adequate voltage for all potential failures in the base adjuster control circuit.

If the voltage adjuster fails and drives voltage high, the generator voltage increases until the volts/hertz limiter setpoint of 105% voltage is exceeded. A failure in the low direction drives the voltage to the lower limit. The voltage error detector has been calibrated to provide a ±15% range of voltage control which could decrease generator voltage to 11.7KV. Using the CYME model, an analysis of the emergency power system response to this minimum voltage was performed and no concerns were identified.

- Cooling fan failures - No concerns were identified due to multiple fans.

- Power amplifier failures - No concerns exist for these failures due to the redundancy of these drawers and the fact that all six legs of the bridge in all drawers are protected by a fuse. The fuse protects the field against shorts in the power amplifier drawer.

- Firing circuit failures - The system is equipped with two redundant firing circuits which have an independent power supply. The output from each of these drawers provides a firing pulse train at the appropriate delay angle to fire the SCR's in the power amp. If there is a difference in the two outputs, the SCR's will fire when the first pulse is received with positive AC voltage applied to the SCR. Thus, a failure in one firing circuit which makes the voltage decrease would not impact unit operation. A firing circuit failure that causes voltage to increase would be seen on the generator output. The regulator is equipped with an overvoltage module which will limit a voltage surge to 120%. The system is equipped with a volts/hertz protective relay which operates independent of the rest of the system. This protective relay will trip the unit if the voltage exceeds 116% for 30 seconds. As a result of a regulator failure, the ONS emergency system loads could be exposed to a maximum of 120% voltage for 30 seconds. This setpoint was chosen to protect the generator and main stepup (MSU) transformer which are typically the limiting components in a power system from an overvoltage perspective.

Logic drawer failures - Based on the knowledge and experience of the manufacturer, there are no credible single failures in the regulator logic drawer that could result in a voltage decrease to an intermediate level.

Regulator failures that could cause an adverse unit response will be promptly detected and corrected due to the use of these units on a regular basis for commercial power generation (as was the V/Hz limiter failure). This frequent operation adds a degree of reliability over a diesel powered unit which could sit with an undetected failure until the next unit operation.

Request 8

Calculation number KC-UNIT 1-2-0098 provides a single failure analysis that was performed on the Keowee Unit 1&2 speed control governors. It states that governor linkages, cables, and gearing are inherently rugged and simple in operation; and there are no creditable failures of these items. Table C.1-1 in the Keowee PRA, however, identifies a problem on July 5, 1985, in the Keowee Unit 1 governor that was determined to be due to the linkage on the 33XY switch binding. The result was that the unit failed to reach rated speed when started for an operability verification test. Although this would have had no effect on an emergency start since it is indicated that the circuitry is bypassed during an emergency start, it seems to refute the conclusion in the single failure analysis. Also, in report no. AO-269/75-4 dated May 14, 1975, an event is reported that resulted in Keowee Unit 2 no-load speed oscillations between 90 and 140 rpm. We were told that the reason for the speed oscillations was a failure of a linkage in the governor control. Please comment.

Response to Request 8

The basis for the single failure analysis is that there are no credible mechanical failures that could affect the governor without preventing a Keowee unit start or resulting in the removal of the unit from the emergency power system. It is our judgement the two examples cited do not contradict the conclusion of the single failure analysis. The linkage failure was due to poor maintenance. The failure met the basis of the single failure analysis in that the Keowee unit did not reach no load rated speed. It is our judgement that under loaded conditions, the output speed and voltage would exceed trip setpoints and initiate transfer to the other Keowee unit. Based on the operating experience of the governor and the experience of the manufacturer, the subcomponents of the governor are simple in operation and rugged. Any credible failure of one governor will not prevent the other governor from performing or Keowee from completing its mission.

Additional governor failure protection is added by NSM ON-52966 which installs a speed switch within the governor actuation cabinet of each Keowee unit. This switch senses governor flyball motor speed by utilizing a magnetic pickup device mounted above the flyball motor. A failure of the governor flyball motor to rotate during unit operation will result in machine overspeed.

After implementation of NSM ON-52966, the logic provided by the magnetic speed switch will automatically trip the closed generator breakers (overhead and underground paths) if the speed switch of the applicable Keowee unit has not indicated proper flyball motor rotation after about 8.5 seconds following an emergency start signal. Following breaker trip, overfrequency relays (also added under NSM ON-52966) will prevent automatic breaker closure as long as the affected Keowee unit is above 110% speed.

For all conditions of operation, if the governor fails in an underspeed mode, the Oconee undervoltage relays will protect the loads. For overspeed failures during emergency starts from a dead stop, and steady-state conditions, the speed switch protects the loads. For overspeed failures during emergency starts while generating to the grid, the Keowee overfrequency relays will protect the loads.

Request 9

Calculation KC-UNIT 1-2-0098 also addresses failure of pressure tank float valve OG-7. It concludes that the valve serves no safety function; the only function of the valve is to make regaining control of the unit easier. Report RO-269/82-11 dated August 20, 1982; however, reported that a leak in that valve resulted in the Keowee Unit 1 turbine not being able to attain sufficient speed to parallel to the grid. It appears that this may have also resulted in lower than required frequency to Oconee loads if the unit was called upon to power them. Please correlate the effects seen during this event to the conclusions reached in the governor single failure analysis.

Response to Request 9

Part of the corrective action for this event included the installation of a float valve failure circuit under NSM-2189. The modification installed a pressure switch on the piping which connects the pressure tank float valve to the governor actuator cabinet. This switch is set at 280 psig and starts a governor oil pump when actuated. Since the

modification precludes a float valve failure, the single failure analysis does not postulate a float valve failure. In addition, the float valve is currently tested for premature closure during the annual governor maintenance.

Request 10

With regard to the potential for a failure in the Keowee voltage regulators or governors to create an out-of-tolerance voltage or frequency, please identify any voltage or frequency monitoring instrumentation available that would: 1) alarm the out-of-tolerance condition, 2) shut the Keowee units down or otherwise drive the condition to a fail-safe zero state, or 3) separate the Oconee electrical loads from the out-of-tolerance condition. Provide the setpoints, location, and sensing point of the instrumentation. If the instrumentation provides an alarm, identify the location of the alarm, the manning of the space the alarm is located in, and the procedures available that instruct the operator on what action to take when the alarm comes in.

Response to Request 10

The emergency power system has various instruments and control logic which monitor and react to out of normal variations in voltage and frequency. For variation in Keowee voltage, the regulator provides many statalarms in the Keowee Control Room. These alarms provide indication of the following:

1. Generator Regulator Has Tripped To Manual (1,2SA2-31)
2. Generator Excitation Low (1,2SA2-33)
3. Generator Maximum Excitation Timing (1,2SA2-34)
4. Generator Maximum Excitation Limiting (1,2SA2-35)
5. Generator Field Limited By Volts/Hertz (1,2SA2-37)
6. Regulator Blown Fuse (Power Supply and Bridge) (1,2SA2-38)

Variations in frequency are also alarmed in the Keowee control room. A computer point on each generator provides an alarm on overfrequencies above 105%. Modification ON-52966 provides additional overfrequency statalarms and relay targets in the Keowee control room that indicate above normal frequencies (1,2SA2-49). Alarms indicating low governor oil pressure indicative of possible low frequencies are also provided in the Keowee control room.

All statalarms received at Keowee provide an alarm in the Oconee Unit 1 and 2 control room. If the alarms do not clear when acknowledged, then Keowee is contacted to ensure the appropriate and timely response.

Oconee control rooms are staffed around the clock and the Keowee station is staffed around the clock. The Keowee and Oconee control rooms have instrumentation providing direct indication of Keowee voltage and frequency. During an emergency start, Keowee procedure AP/0/A/2000/002 requires the operator to monitor each unit's voltage and frequency output through the control room gauges. Communication between Oconee and Keowee is maintained through telephone lines and two-way radio per the procedure.

The undervoltage relay logic, associated with the EPSL, monitors voltage at the startup and standby busses. These relays which are configured in two out of three logic provide alarms and controls necessary for EPSL transfer and breaker operations. The standby bus undervoltage relays have a pick up setpoint of approximately 47%, based on 13.2 kV. Failures of the underground unit or path would activate these relays and associated logic to allow EPSL to retransfer load back to startup. In a similar fashion, the startup source undervoltage relays alarm in the respective unit control room and function to trip or block closure of the startup breakers. These relays are set at approximately 87%, based on 13.2 kV. Activation of these relays allows EPSL to transfer auxiliary loads to the standby busses.

Other logic providing protection from abnormal frequencies is added with modification ON-52966. Governor flyball motor monitoring is being implemented to detect failures of the governor during startup. Upon actuation, events recorder alarms in the Keowee control room are provided during normal and emergency operation. Circuitry tripping the generator breakers from this new logic provides protection during emergency conditions. Also, overfrequency permissives are being installed in the generator breaker close circuits to prevent the breakers from closing if the unit is operating with above normal frequencies. Alarms from these relays also provide indication during normal and emergency operation.

Request 11

Calculation KC-UNIT 1 & 2-2023, "Analysis of Keowee Voltage Regulator Settings," indicates that a Keowee main stepup transformer tap change and reactive line drop compensator feature in the voltage regulator is intended to be

implemented in order to allow Keowee to provide additional MVARs to the grid and reduce the potential for over-excitation of the stepup transformer. The reactive line-drop compensator feature will replace the currently used reactive droop feature in the voltage regulator. The recommendation in the calculation is to set the line-drop compensator module to provide approximately 10 percent compensation. With this feature in place and both Keowee units providing rated MVARs to the grid at minimum grid voltage conditions, if one of the Oconee units developed a need for emergency power from Keowee, the voltage at the Keowee generator terminals through the underground path would be reduced up to 10 percent from its grid generating value due to the minimal MVARs required by the single Oconee unit relative to the pre-event rated MVARs provided to the grid. Would this voltage be sufficient to adequately start and operate Oconee electrical equipment? If not, what procedural controls will be put in place to preclude Keowee from operating in this region? If calculations have been done to establish the adequacy of operating the Keowee units with the new tap settings and line-drop compensator in place please provide them.

Response to Request 11

The implementation of changes to the MSU tap and the generator compensation were recommendations in KC-2023. These changes are considered in order to optimize the MVAR capability of the generator. Before implementation of the changes, an extensive evaluation and revision of the existing analyses is necessary to ensure that the design bases of the ONS emergency power system will not be violated. Since we have not decided to implement these changes, the necessary evaluations have not been performed.

Request 12

In Calculation OSC-5096, "Fault/Failure Analysis for Oconee Nuclear Station Emergency Power System When Two Keowee Hydro Units Are Generating to the Grid," dated January 20, 1993, there is no mention of the potential for a fault in the Oconee switchyard to actuate the 59GN relays connected to both Keowee units, and cause a simultaneous lockout of both units if they are generating to the grid. Item 22, "Ground Fault [Unit 1]," states "Due to the Delta configuration of the Main Stepup transformer primary, the ground fault will not be seen by protective devices for Unit 2 13.8 Kv bus." The potential for this type of relaying protection (59GN) to actuate due to ground faults on the high-side of a step-up transformer can arise as a result of zero-sequence

capacitive coupling between the windings of the transformer. Describe the coordination that exists between the 59GN relays and other protective relays to clear single-line-to-ground faults such that a single fault will not cause a relay lockout of both Keowee units while they are generating to the grid. Also address how this coordination would be affected by a fault which was not cleared by its primary protective device (i.e., the closest breaker fails to open and clear the fault).

Response to Request 12

The design of the Keowee neutral ground relay uses a dummy load resistor in parallel with the relay, which according to the Westinghouse Transmission and Distribution Reference book, eliminates the risk of a false generator trip due to a ground fault on the high side of the transformer. In addition, the design of the protective relays ensures that sufficient coordination exists in order to clear the ground fault before the generator neutral overvoltage relays actuate.

Considering a ground fault on the 230KV switchyard, the overhead transmission line, or on the high side of the Keowee MSU transformer, the longest time that any fault could remain connected would be for a fault on the Keowee overhead line. The differential protective relay will detect this fault and trip ACB 1 and 2 in 330 milliseconds (reference OSC-5096, Attachment 3, fault F7). The generator neutral overvoltage relays are CV-8 voltage relays which are set for 5.4V pick up and a time delay of 1.6 seconds at 500% of pick up (reference OSC-4300 Appendix J). Assuming that the 230KV system fault will cause the worst case ground current to flow in the generator, the fastest the CV-8 relay can pick up at this time setting is 0.8 seconds (reference IL 41-201M). Thus, ACB-1 and 2 will be tripped at least 0.47 seconds before the generator neutral overvoltage relay can time out to trip the emergency lockout relay.

Referencing the second part of the question, faults on the non-safety portions of the system, including the switchyard and the external grid, did assume a subsequent failure of a breaker to clear the fault. This is already included in calculation OSC-5096. Faults on the safety-related portions of the system would be the single failure. A subsequent failure of a safety-related breaker is not assumed. Thus, assumption of a failure of ACB-1 or 2 to trip is not required by the Oconee Emergency Power System design basis.