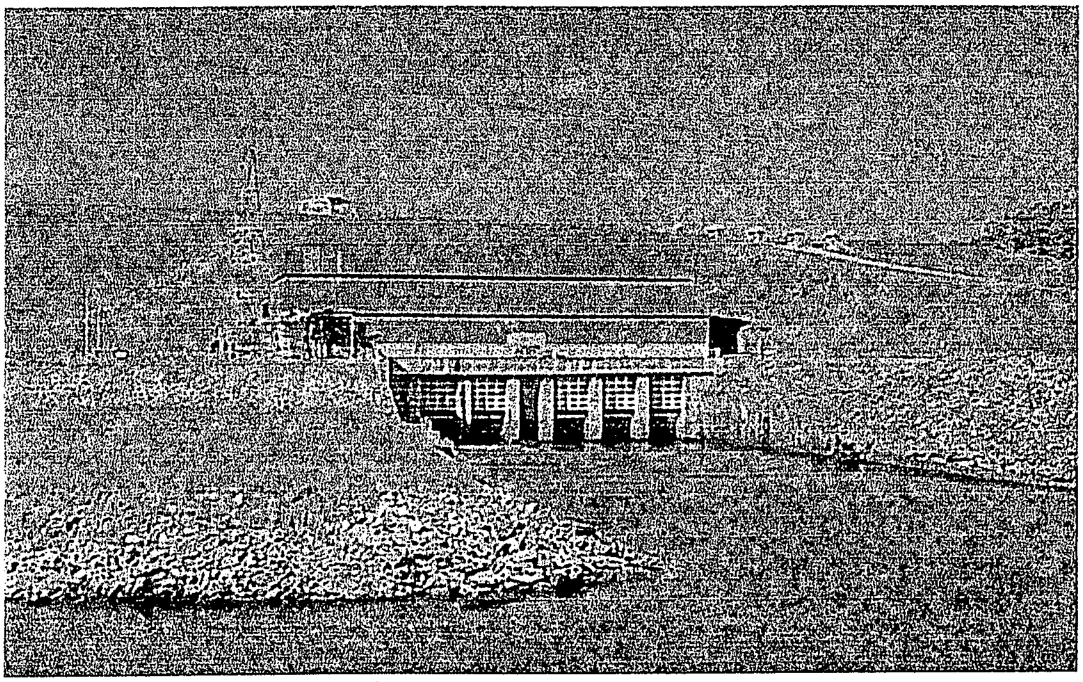
DUKE POWER COMPANY

Oconee Nuclear Station



Emergency Power and Engineered Safeguards Functional Test Report

Volume I

DUKE POWER COMPANY

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Executive Summary

Purpose:

This report documents the Oconee Emergency Power and Engineered Safeguards Functional Test performed on January 2-5, 1997. The purpose of this report is to document, as much as practical, every facet of the test including planning, development, execution and results.

Scope:

The scope of this report can be subdivided into three parts: (1) Test Scenario Selection, (2) Test Planning and Execution, and (3) Recorded Test Results. The intent of the Test Scenario Selection section is to document the reasoning for the scenarios selected for this test. A deterministic and probabilistic review was used in the scenario selection process.

The intent of the Test Planning and Execution portions is to capture the many different aspects that went into performing this test. This test was a once in a plant lifetime evolution, thus much planning and preparation went into its development. Substantial resources including management oversight and just in-time training were dedicated to performing this test.

The intent of the Recorded Test Results section is to document the response of the emergency AC power system during the test scenarios. Much data was recorded during each test evolution. The response from the power source (Keowee Hydro or Lee Combustion Turbine (CT)) through the auxiliary power system down to the safety related 208V buses was monitored during this test. Various selected pieces of equipment including 4160 and 600V motors, a battery charger input, and motor operated valves (MOVs) were monitored.

This report will be kept in the Oconee document control system along with the temporary test procedure for future reviews and engineering evaluations.

Background:

The design of the Oconee emergency AC power system is unique among nuclear power plants. The design, maintenance and testing of this system has been under scrutiny over the past several years. During 1995-96, the U.S. Nuclear Regulatory Commission (NRC) offices of Nuclear Reactor Regulation (NRR) and Analysis and Evaluation of Operational Data (AEOD) performed reviews of the design and operational characteristics of the Oconee emergency power system. Draft reports of these reviews dated July 8, 1996 were provided to Oconee. An issue noted in these reports was the lack of a fully integrated functional test involving actual mitigating equipment equivalent in magnitude to the design basis required levels. Pre-operational testing of the Oconee emergency power system included functional, integrated tests of each individual Oconee unit with the onsite power sources. However, no

record of an integrated functional test simultaneously involving all three units emergency power systems could be found.

Because of the Oconee emergency power system's design, "integrated testing" of one shut down Oconee unit which connects to the onsite emergency power source, cannot be done without some impact on the reliability of emergency power to the other two operating Oconee units at the time these tests are being performed. In late 1996, a rare opportunity occurred with all three nuclear reactors shut down at Oconee. Duke Power, after consultation with the NRC, decided to perform a one-time integrated test of the Oconee emergency power system.

Planning and Execution:

The Emergency Power and Engineered Safeguards Functional Test exercised and challenged the emergency power and engineered safeguards systems. The scenarios selected for this test were worst case or bounding loading scenarios. The scenarios included both three Unit Loss of Offsite Power (LOOP) and Loss of Coolant Accident (LOCA) /LOOP scenarios. Both of the Keowee emergency power paths (i.e. overhead and underground paths), from the Keowee unit through the respective path to each unit's main feeder buses, were included in the test scope. Likewise, both modes of Keowee operation (standby and grid generation), were included. Similarly a worst case loading scenario for the Lee CT was included in the test scope. The scenarios tested were:

- Test 1 - Three Unit LOOP with a failure of the overhead path.
- Test 2 - Three Unit LOOP with Keowee initially generating to the grid.
- Test 3 - LOCA/LOOP with a failure resulting in starting a large unscheduled load with the LOCA unit.
- Test 4 - LOCA/LOOP with a failure resulting in starting a large unscheduled load with the LOCA unit and Keowee initially generating to the grid.
- Test 5 - LOCA/LOOP with a failure of the overhead path and Keowee initially generating to the grid.
- Test 6 - LOCA/LOOP with neither Keowee unit available (i.e. Lee CT as the source).
- Test 7 - Post-accident Keowee partial loss of load.

Significant planning and effort went into the development and execution of this test. Dedicated resources were used to develop and manage the test procedure and data acquisition test procedure. Oconee management, Plant Operations Review Committee (PORC), and Duke's Nuclear Safety Review Board (NSRB) participated in the review of the test procedure. Just In-Time training was developed for the Oconee operators and Keowee and Lee personnel participating in this test. During the test dedicated resources were organized

and staffed for both day and night shifts to support test execution, problem solving, and troubleshooting.

Results & Conclusions:

Overall, the Oconee Emergency Power and Engineered Safeguards Functional Test was a success.

The efforts of thorough planning and development of the test procedure, combined with the training of those involved enabled successful completion of the test. There were many positive comments from both Duke and non-Duke witnesses of the test on the control and/or execution of the test including: control of test activities, thorough test and control room briefing, and communication/coordination of test evolutions.

The emergency power system, engineered safeguards system and all other systems tested performed satisfactorily for this test. The test acceptance criteria (TAC) for each of the test scenarios were all satisfied. The ultimate function of the emergency power system, to deliver power to the required load such that cooling water can be delivered to the core to mitigate an accident, was demonstrated for the simulated design basis accidents. In Tests 1 through 5, Keowee successfully emergency started on LOOP or ES actuation, aligned itself to the appropriate power path, energized, accelerated and carried the applied accident loads. The loads used in these test scenarios were the actual Oconee mitigating accident loads of the magnitude expected for a design basis accident. All safety related 4KV pumps challenged in an accident [i.e. high pressure injection (HPI), low pressure injection (LPI), low pressure service water (LPSW), motor driven emergency feed water (MDEFW), and reactor building spray (RBS)] were started during these tests. For the LOOP units, additional non-LOOP loads (one LPI pump for Units 1 & 2) were also added to the other hot shutdown loads for each case. Likewise, for Test 6, the Lee CT successfully energized, started, accelerated and carried the applied accident loads. In each test, all of the Oconee non-load shed load centers energized as expected supplying power to its connected loads during the tests. In each test the safety 4KV motors started and accelerated as expected. Each safety related motor started and accelerated well before the motor over current relay actuation setpoints. For the tests where the engineered safeguards (ES) MOVs were challenged (Test 3-6), all MOVs stroked to their proper ES position with no problems.

An enormous amount of data was collected during these tests. The response of the system from the source down to the 208V buses was monitored for voltage, current, and power for each test. The data collected supports the conclusion that the emergency power system is able ability to perform its intended design functions.

Table ES- 1, on the following page, summarizes the maximum inrush and steady state load automatically applied to the Keowee unit and Lee CT during these test.

Table ES- 1: Maximum Inrush and Steady State KVA on Keowee and Lee CT		
Test & Source	**Max. Inrush Load KVA**	**Max. Steady State Load KVA**
Test 1, Keowee	42,000	8,910
Test 2, Keowee	69,000	9,918
Test 3, Keowee	30,000	7,852
Test 4, Keowee	40,200	8,474
Test 5, Keowee	36,000	11,432
Test 6, Lee CT	30,720	10,485

1. Emergency Power System Overview

Each Oconee unit is provided with several sources of electrical power. The Normal, Start-up and Standby Sources are part of the Emergency Power System as described below. (Refer to Attachment 4: Oconee Emergency Power System Single Line diagram)

The Normal source of power for an operating Oconee Unit is from the unit's generator via the Auxiliary transformer (1T, 2T, or 3T). The Auxiliary transformer provides 6900V power for the Reactor Coolant Pumps (RCPs), and 4160V power to two Main Feeder Buses (MFBs) for the remaining loads. For an Oconee Unit that is shut down, normal power can be supplied from the 230KV Switchyard back charged through the unit's Main Step-up transformer to the Auxiliary transformer.

The Start-up source of power is from the 230 KV Switchyard (SWYD) via the unit's Start-up transformer (CT1, CT2, or CT3), and provides both 6900V power for RCPs and 4160V power to the MFBs.

The Standby bus can receive power from transformer CT4 supplied from Keowee Hydro (KH) through the underground feeder or from transformer CT5 supplied from either the Central Switchyard or a Lee Steam Station combustion turbine (CT). The underground feeder and associated transformer (CT4) as well as CT5 and its associated path are sized to carry full Engineered Safeguards loads of one Oconee unit plus the auxiliary loads required for safe shutdown of the other two Oconee units. However, the Standby source only provides 4160V power to the MFBs and cannot provide 6900V power for RCPs.

Each Oconee unit's auxiliary power sources are monitored by the Emergency Power Switching Logic (EPSL) and the Main Feeder Bus Monitor Panels (MFBMP). EPSL will monitor the voltage available to the Normal Source, and will initiate a breaker trip to isolate the Normal Source if an undervoltage condition exists. It will then attempt to transfer to the Start-up Source by closing the Start-up breakers if voltage is available there. For events, such as a unit trip, this transfer provides power to station loads.

In the event that power is not available via the Start-up Source, the MFBMP will initiate automatic actions to provide power. The Standby Bus is not normally energized, but after a 20 second time delay, the MFBMP will automatically emergency start KH, actuate EPSL to loadshed unnecessary loads after a 1 second time delay, and connect one KH unit to the Standby Buses. After an additional 10 seconds time delay, EPSL will initiate Standby Breaker closure to energize the MFBs from the Standby Buses.

In the event of an Engineered Safeguards (ES) actuation and power is not available via the Start-up Source, the EPSL actuates to load shed unnecessary loads after a 1 second time delay, and connects one KH unit to the Standby Buses. After an additional 10 seconds time delay, EPSL will initiate Standby Breaker closure to energize the MFBs from the Standby Buses.

In the event of a Loss of Offsite Power (LOOP), the External Grid Trouble Protection system (EGTPS) will initiate an automatic emergency start of KH and isolate the 230KV Yellow bus

from the Duke transmission system to align the Keowee overhead path. Each Oconee unit's MFBs are then energized from the KH overhead unit after the Start-up source breakers (E1 and E2) for each Oconee unit close.

The 230KV SWYD has two electrical buses and a number of circuit breakers that connect the generators with the transmission system. The SWYD is arranged in a breaker-and-a-half scheme, with the two buses designated as the RED bus and the YELLOW bus. The buses provide junction points for the power exchange between generators and the system. The SWYD can receive power from the generator output transformers for Oconee Units 1 and 2, and Keowee Hydro Station. In addition, the SWYD can supply power to the Start-up transformers for Oconee Units 1, 2, and 3. The SWYD also connects to four pairs of 230KV transmission lines (Jocassee, Dacus, Oconee, and Calhoun) and via the auto-bank transformer to the 525KV SWYD that connects the Oconee Unit 3 generator to the 525KV distribution system.

Keowee Hydro Station consists of two 87.5MVA hydroelectric generators, Air Circuit Breakers (ACBs) 1 through 4, the Main Step-up transformer, auxiliary power load centers 1X and 2X, and associated support equipment and auxiliaries. Each KH unit is provided with its own automatic start equipment. Both units undergo a simultaneous automatic start and run in standby on EGTPS actuation, an ES actuation on any of the three Oconee Units, or an extended loss of voltage on any unit's MFBs. On an emergency start, the unit connected to the underground feeder supplies that feeder while the other unit, remaining in standby, is available to supply the overhead path.

The "overhead" emergency power path is from one KH unit, through the unit overhead generator breaker (ACB-1 or 2), the main step-up transformer through PCB-9, the switchyard yellow bus, the applicable Oconee unit startup transformer (CT1, 2, or 3), and the associated startup breakers (E1 and E2) to the main feeder buses.

The "underground" emergency power path is from one KH unit, through the unit underground generator breaker (ACB-3 or 4), an underground feeder, transformer CT4, the CT4 feeder breakers (SK-1 and SK-2), the standby buses (SBB), and unit standby breakers (S1 and S2) to the MFBs. This underground feeder is selected, at all times, to one KH generator on a predetermined basis and is energized along with CT4 whenever the associated KH unit is in service.

Lee Steam Station combustion turbines (CT) are used as backup onsite emergency power sources for Oconee when the Keowee units are not available. Three CTs, each rated at 44MVA, are available for Oconee's use. A dedicated transmission line from the Lee Steam Station to Oconee is energized when a Lee CT is used. A Lee CT is manually started and connected to the Oconee Standby bus through transformer CT5.

The 100KV Central Switchyard is another source of power to Oconee. This source is connected to Oconee through transformer CT5.

2. Test Scenario Selection

2.1 Scenarios Considered in Test Scope Development

Integrated tests, as opposed to individual component or equipment tests, test the integrated function of the various individual components that make up the complete system. Integrated tests are intended to identify any undesirable interactions between the individual components when they function together in the fashion they may be called upon during an actual design basis or operating event. Integrated tests are therefore, typically designed to test the operability of the system as a whole under conditions as close to its design basis as practical, and to test the full sequence that brings the system into operation.

In developing the scope of the integrated test, a review of the design basis requirements for the emergency power system was performed. An integrated design basis accident (DBA) test for each possible combination and permutation, including single failures, of the emergency power system is not practical. However, the scenarios considered for this test are the worst case or bounding Loss of Coolant Accident (LOCA) and Loss of Offsite Power (LOOP) scenarios, for which the onsite emergency power sources (Keowee Hydro or Lee Combustion Turbine) are required to mitigate. Failures, consistent with the design requirements of the emergency power system, resulting in more demand of the system or accident unit were also considered. Both modes of operation for the Keowee units (i.e. standby or grid generation) were considered for each applicable scenario. Table 2- 1 below lists the scenarios considered for inclusion into the scope of these tests and documents the expected Oconee loading sequence and condition for each case.

For the three Unit LOOP cases, a complete loss of the external transmission system is postulated resulting in each Oconee unit tripping. As a result of the LOOP, the Oconee External Grid Trouble Protection System actuates giving a Keowee emergency start actuation and subsequent switchyard isolation. For the scenario of a LOCA without a LOOP, the LOCA unit would receive power to its auxiliaries from the offsite source. A failure of the startup source or path would also have to be postulated for the accident unit to receive its power from the onsite emergency power source. For the LOCA/LOOP cases, one Oconee Unit experiences a LOCA plus a LOOP and the other two Oconee Units experience a LOOP only.

Table 2- 1 Scenarios Considered in Test Scope Development

	Design Basis Accident Scenario	Keowee Initial State	Oconee Loading Sequence
1	Three Unit LOOP	Standby	LOOP units load on the overhead (o/h) path at ≈90% voltage and frequency increasing
2	Three Unit LOOP	Generating to grid	LOOP units load on the o/h path at rated voltage and 110% frequency decreasing
3	Three Unit LOOP with a failure of the o/h path	Standby	LOOP units load on the underground (u/g) path at rated voltage and frequency
4	Three Unit LOOP with a failure of the o/h path	Generating to grid	LOOP units load on the u/g path at rated voltage and frequency
5	LOCA with a failure of the startup path	Standby	LOCA unit loads on the u/g path at reduced voltage and frequency
6	LOCA with a failure of the startup path	Generating to grid	LOCA unit loads on the u/g path at rated voltage and 110% frequency decreasing
7	LOCA/LOOP	Standby	LOCA/LOOP unit loads on the u/g path at reduced voltage and frequency LOOP only units load on the o/h path.
8	LOCA/LOOP	Generating to grid	LOCA/LOOP unit loads on the u/g path at rated voltage and 110% frequency decreasing LOOP only units load on the o/h path.
9	LOCA/LOOP with a failure of the overhead path	Standby	LOCA/LOOP unit loads on the u/g path at reduced voltage and frequency. LOOP only units load on the u/g path ≈20 sec. later at rated voltage and frequency

Table 2- 1 Scenarios Considered in Test Scope Development

	Design Basis Accident Scenario	Keowee Initial State	Oconee Loading Sequence
10	LOCA/LOOP with a failure of the overhead path	Generating to grid	LOCA/LOOP unit loads on the u/g path at rated voltage and 110% frequency decreasing. LOOP only units load on the u/g path ≈15 sec. later at rated voltage and frequency
11	LOCA/LOOP with a failure of the underground path	Standby	LOOP only units load on the o/h path at ≈90% voltage and frequency increasing LOCA/LOOP unit loads on the o/h path ≈5 sec. Later at rated voltage and frequency.
12	LOCA/LOOP with a failure of the underground path	Generating to grid	LOOP only units load on the o/h path at rated voltage and 110% frequency decreasing LOCA/LOOP unit loads on the o/h path ≈5 sec. later at rated voltage and frequency.
13	LOCA/LOOP with a failure resulting in starting a large unscheduled load with the LOCA unit	Standby	LOCA/LOOP unit plus a LOOP only unit loads on the u/g path simultaneously at reduced voltage and frequency. Remaining LOOP only unit loads on the o/h path.
14	LOCA/LOOP with a failure resulting in starting a large unscheduled load with the LOCA unit	Generating to grid	LOCA/LOOP unit plus a LOOP only unit loads on the u/g path simultaneously at rated voltage and 110% frequency decreasing. Remaining LOOP only unit loads on the o/h path.

Table 2- 1 Scenarios Considered in Test Scope Development

	Design Basis Accident Scenario	Keowee Initial State	Oconee Loading Sequence
15	Three Unit LOOP with neither Keowee unit available	N/A (Lee CT on the standby bus)	LOOP units simultaneously load on Lee CT at rated voltage and frequency
16	LOCA/LOOP with neither Keowee unit available	N/A (Lee CT on the standby bus)	LOCA/LOOP unit loads on Lee CT at rated voltage and frequency. LOOP only units load on Lee CT ≈20 seconds later at rated voltage and frequency. Time delayed non-safety related loadcenters automatically load ≈30 seconds after the second block load at rated voltage and frequency.
17	Post-accident Keowee partial loss of load	N/A	Remaining connected Oconee loads continue to operate through the loss of load transient.

2.2 Selected Test Scenarios

The test scenarios listed above in Table 2- 1 were reviewed from a deterministic and probabilistic perspective. From this list, seven scenarios were chosen for inclusion into the scope of the test. The scenarios selected are numbers 2, 3, 10, 13, 14, 16 and 17. To be consistent with the order of the test as discussed and performed in the actual testing procedure (PT/0/A/0610/025), the selected test cases will be referred to hereinafter as noted in Table 2- 2 below.

Table 2- 2 Emergency Power and Engineered Safeguards Functional Test Scenarios

TEST #	Table 2.1-1 ref.	Design Basis Accident Scenario
Test 1	(#3)	Three Unit LOOP with a failure of the overhead path.
Test 2	(#2)	Three Unit LOOP with Keowee initially generating to the grid.
Test 3	(#13)	LOCA/LOOP with a failure resulting in starting a large unscheduled load with the LOCA unit.
Test 4	(#14)	LOCA/LOOP with a failure resulting in starting a large unscheduled load with the LOCA unit and Keowee initially generating to the grid.
Test 5	(#10)	LOCA/LOOP with a failure of the o/h path and Keowee initially generating to the grid
Test 6	(#16)	LOCA/LOOP with neither Keowee unit available (i.e. Lee CT as the source).
Test 7	(#17)	Post-accident Keowee partial loss of load

The scenarios selected for the integrated tests included both three Unit LOOP and LOCA/LOOP scenarios. Both of the Keowee emergency power paths (i.e. overhead and underground paths), from the Keowee unit through the respective path to each units main feeder buses were included in the scope. Likewise, both modes of Keowee operation (i.e. stand by and grid generation), were included in the scope of these tests. Test 6 was included to demonstrate Lee's ability to perform under simulated LOCA/LOOP loading.

These tests were selected because they are considered to be bounding scenarios. The three Unit LOOP load is the largest individual or single block load applied to a Keowee unit. The

LOCA/LOOP cases represent the largest total load to be automatically connected to the emergency power source. The LOCA/LOOP cases do not represent the largest single block load applied to the Keowee emergency power source due to the offset in the loading time for a LOCA and LOOP unit.

The following paragraphs provide additional detail for each of the specific scenarios selected for the scope of these tests.

2.2.1 Test 1 - Three Unit LOOP With a Failure of the Overhead Path

Test 1 represents the single largest block load applied to the Keowee underground path. This test loads the three Oconee units at $t \approx 31$ seconds at rated Keowee voltage and frequency. Since the Keowee units will be at rated voltage and frequency at 31 seconds regardless of the initial state of the Keowee units, the initial state of Keowee does not impact the test.

2.2.2 Test 2 - Three Unit LOOP with Keowee Initially Generating to the Grid.

Test 2 represents the single largest block load applied to the Keowee overhead path. This case tests the entire overhead path from Keowee through the isolated switchyard to each Oconee unit and their applicable LOOP loads. This scenario loads the three Oconee units following load rejection at rated voltage and 110% frequency decreasing.

A Keowee initial condition of generating to the grid was chosen over the standby initial condition because it is a more challenging scenario to the Keowee unit and the connected Oconee auxiliary loads. The Keowee unit is challenged more because it has to respond and recover from a loss of full load generation. Additional circuitry in the Keowee air circuit breakers (ACBs) are challenged to separate the unit from the offsite grid on emergency start actuation that are not challenged from an initial start from standby. Also, the connected Oconee loads would be challenged more due to their energization at frequencies of 110% of rated decreasing rather than ≈90% of rated increasing if Keowee was initially in standby.

2.2.3 Test 3 - LOCA/LOOP with a Failure Resulting in Starting a Large Unscheduled Load with the LOCA Unit

This test addresses one of the unique facets of the emergency power system design, Keowee loading accident loads at reduced voltage and frequency. This test represents the largest block load involving an accident (LOCA) unit with Keowee initially at standby. This test loads the LOCA unit plus the additional unscheduled load on the Keowee underground path at approximately 60% of rated voltage and frequency increasing. This scenario is also performed, as Test 4 below, with Keowee generating to the grid.

A "large unscheduled load" is typically considered to be a 4KV transformer feeder or large 4KV motor failing to shed from the LOCA unit. For this test, Oconee Unit 3 was the simulated LOCA unit. The majority of the secondary systems on Oconee Unit 3 were not in service at the time of the test therefore, no additional large 4KV motor load was available for the test. So, another Oconee unit's entire LOOP loads were used to simulate the large unscheduled load to simultaneously load with the LOCA unit. This additional load bounds

any other possible single load that could be chosen to simultaneously start with the LOCA unit.

2.2.4 Test 4 - LOCA/LOOP with a Failure Resulting in Starting a Large Unscheduled Load with the LOCA Unit and Keowee Initially Generating to the Grid

This test represents the largest block load involving an accident (LOCA) unit with Keowee initially generating to the grid. This test loads the LOCA unit plus the additional unscheduled load on the Keowee underground path following load rejection at rated voltage and 110% of rated frequency decreasing. This scenario is thought to be the more challenging test of the scenarios involving a LOCA unit. This is because the connected LOCA loads would be challenged more as a result of being energized with the unscheduled load at rated voltage and frequencies of 110% of rated rather than at reduced voltage and frequency as seen in Test 3.

As in Test 3, the large unscheduled loads used to simultaneously load with the LOCA unit are LOOP loads of another unit. This additional load bounds any other possible single load that could be chosen to simultaneously start with the LOCA unit.

2.2.5 Test 5 - LOCA/LOOP with a Failure of the Overhead Path and Keowee Initially Generating to the Grid

This test represents the largest cumulative load automatically applied to the Keowee underground path. The load applied to the Keowee unit in this test is sequenced on in two blocks. First, the LOCA/LOOP unit will be loaded following load rejection at rated voltage and 110% of rated frequency decreasing. The second transient is block loading the other two LOOP only units.

The primary objective of this test was to demonstrate Keowee's and the LOCA unit's ability to successfully perform during and following the second loading transient, not to demonstrate Keowee's ability to successfully start and accelerate a LOCA unit's loads. The ability to start and accelerate a LOCA units' loads was previously tested by bounding cases in Test 3 and Test 4.

Regardless of whether Keowee was initially generating to the grid or in standby, the second loading transient would occur with Keowee at rated voltage and frequency. The results of Test 3 (LOCA/LOOP with a failure resulting in starting a large unscheduled load with the LOCA unit) provided the justification necessary to determine that an additional test of this scenario with Keowee initially at standby was not necessary. In Test 3, the Keowee unit accelerated the connected LOCA plus LOOP load and obtained rated voltage and frequency well before the time a LOOP unit would load if the overhead path was postulated to fail (i.e. t= 31 seconds).

An initial condition of Keowee generating to the grid was chosen over Keowee at standby because it provided a more challenging scenario. With Keowee initially in standby there are approximately 20 seconds between the first (LOCA at $t \approx 11$) and second (two LOOP at $t \approx 31$) loading transients. With Keowee initially generating to the grid the time between the two

loading transients is shorter. Therefore, more equipment, particularly MOVs, could still be operating and thus susceptible to this second loading transient.

2.2.6 Test 6 - LOCA/LOOP with Neither Keowee Unit Available (i.e. Lee CT as the Source)

A Lee CT serves as the emergency onsite power source when the Keowee unit(s) are not available. This test represents the largest cumulative load applied to a Lee CT. The LOCA/LOOP loads applied to the Lee CT are sequenced on in three blocks. First the LOCA/LOOP unit will be loaded at rated voltage and frequency. A second transient of block loading the other two LOOP only units occurs ≈20 seconds later. Finally, a third transient of block loading the LOOP only unit's non-safety non-loadshed load centers occurs ≈30 seconds after the second load transient.

This test is considered the more challenging test of the two Lee CT cases considered. The reasoning is that the magnitude of load for a three Unit LOOP is approximately equivalent to that of a single LOCA unit when Lee CT is the source. This is due to the administrative restrictions on the LOOP unit's HPI pumps when Lee is the source energizing the standby buses and also, the physical circuitry restrictions which delay loading some of the non-safety load centers when Lee is the source. Since the initial load would be approximately the same for the three Unit LOOP case and the LOCA/LOOP case, the latter case was chosen since it resulted in a second loading transient of the two LOOP units followed by a third loading transient of the LOOP units' delayed non-safety related load center. The LOCA/LOOP case was also chosen because this scenario would exercise engineered safeguards equipment to demonstrate its capabilities.

2.2.7 Test 7 - Post-Accident Keowee Partial Loss of Load

This test, unlike the others, is not a DBA scenario. It is more of a post accident recovery evolution. The intent of this test was to demonstrate Keowee's ability to reject part of its load, such as when the Oconee Control Room Operator secures a device being powered by Keowee, while continuing to provide power within acceptable limits to the remaining connected loads. This test addresses stability questions of Keowee at low load when generating separated from the grid and during partial loss of load scenarios.

2.3 Independent Scope Review

The selected scenarios for the Emergency Power and Engineered Safeguards Functional test were presented to ONS management and the Oconee Plant Operations Review Committee (PORC). The PORC requested an independent review of the scope of the test. An independent review was performed on December 2-3, 1996. The reviewer concluded that the scenarios selected for the scope of the emergency power and integrated safeguards functional test would bound the design basis loading sequence scenarios and that these tests would demonstrate the capability of the emergency power system. In addition, the Duke Nuclear Safety Review Board (NSRB) reviewed the test scenarios and found them acceptable.

3. Test Planning and Execution

At the onset of the Oconee three unit outage, Oconee dedicated resources to determine if performing the Emergency Power and Engineered Safeguards Functional Test during the three unit Oconee outage, was feasible to be performed. Duke Power concluded, as noted in a letter to the NRC dated November 21, 1996, that it was feasible to perform the test during the Oconee three unit outage.

To perform a test of this large scale, substantial procedure development, training and other parallel efforts leading to test execution were started. One of the first efforts started was the development of the execution test procedure, TT/0/A/0610/025. A second effort was the development of the data acquisition procedure, TT/0/A/0610/025A. Each of these are described in more detail below in Sections 3.2 and 3.3 respectively.

The seven test parts were performed over 4 days beginning January 2, 1997 and ending on January 5, 1997. Actual testing was performed during the day shift hours with test recovery and realignment activities for the next test segment being performed during the night shift. As expected, many persons, including representatives from the NRC, witnessed the execution of this test. Positive comments about the execution and performance of the test were made by the NRC inspection team during their exit meeting. Additional information pertaining to the NRC Inspection Team's observations during these tests are documented in NRC Inspection Report 96-20 dated March 10, 1997.

Overall, the test execution was a success. The emergency power system, engineered safeguards system, and all others tested performed satisfactorily.

3.1 Infrequently Performed Test or Evolutions

3.1.1 Management Oversight

Nuclear System Directive (NSD) 213 implements recommendations from INPO SOER 91-01 by requiring management oversight of certain infrequent tests and evolutions. The Emergency Power and Engineered Safeguards Functional Test met the criteria contained in NSD 213 for management oversight. A "Management Oversight Briefing" package for this test was prepared by the Oconee Superintendent of Operations, and approved by the Oconee PORC on December 31, 1996. A copy of this package is contained in Attachment 1 of this report.

3.1.2 Training

Due to the complexity and magnitude of the Emergency Power and Engineered Safeguards Functional Test, additional training was developed and conducted for the Oconee operations and Keowee and Lee personnel involved. A "Just In-Time Training Plan" was developed by the Oconee Training Center with input from knowledgeable test experts. The training

consisted of classroom and simulator sessions for the licensed operators, an in plant review for the non-licensed operators, and a review of the expected test response for the Keowee Hydro and Lee Steam Station personnel. The classroom training included a review of the procedure including contingency actions. The simulator portion enabled the operators to have hands on experience for performance of the test procedure under simulated operating conditions. A copy of the "Just In-Time Training Plan" was provided to the NRC in a letter dated December 26, 1996.

3.1.3 Personnel Support/Organization

Significant resources were involved in the planning, development, training, and execution of this test. An organization chart of personnel to support the execution of this test, including the data acquisition, was created. The organization chart included the Operations Shift Manager, Management Designee, Test Coordinator, Electrical & Mechanical Systems Representative, Data Collection Manager, and Plant Support functions. With the plan to execute tests during the day shift hours and recover/re-align during the night shift, the plant support functions were staffed for both day and night shifts. This allowed for any problems discovered one day to be resolved before the next day's testing. A copy of these organization charts are included in Attachment 2 of this report.

3.2 TT/0/A/0610/025 - Emergency Power and Engineered Safeguards Functional Test

Test procedure TT/0/A/0610/25 is the procedure that was used to control and execute these tests. Due to the size of this procedure, a copy is not included as a part of this report. A typed copy of the Test Log Record Sheets kept during the execution of the test is contained in this report as Attachment 3.

3.2.1 NRC Issuance of Amendment

In developing a safety evaluation for the test procedure in accordance with 10 CFR 50.59, Duke Power concluded the one time Emergency Power and Engineered Safeguards Functional Test may involve an unreviewed safety question (USQ) which requires prior NRC approval of the test in accordance with 10 CFR 50.90. This conclusion was based on the fact that there may be a marginal increase in the possibility of a loss of power as compared to the other emergency power tests currently performed within the licensing basis. The current licensing basis indicates that pre-operational and periodic tests are performed on the emergency power system utilizing a single Oconee unit's loads. However, the proposed one time test involves safety equipment on all three Oconee units. Also, the proposed one time test is comprised of six parts whose scope has not been previously described in the licensing basis.

By letter dated January 2, 1997, the NRC issued an Amendment to the Facility Operating License for the Oconee Nuclear Station, Units 1, 2, and 3 to allow the conducting of these test.

3.2.2 Test Purpose

The purpose of this test was to demonstrate the ability of the Oconee emergency power system and engineered safeguard equipment to satisfactorily perform during the simulated LOOP and LOCA/LOOP scenarios. This test was also performed to accumulate emergency power system performance data and ECCS hydraulic data during these simulated LOCA and LOOP scenarios. In performing this test, the capability of the onsite sources and Oconee's unique design could be demonstrated resulting in more confidence in the design and present testing program at Oconee.

3.2.3 Test Method

The following sub-sections discuss the test method and sequence followed during the performance of these tests.

3.2.3.1 Simulated Accident Loads:

Actual Oconee Unit 1, 2 and 3 loads were used to simulate the actual LOCA and LOOP loads. Oconee Units 1 and 2 are the units simulating LOOP only for their respective units and Unit 3 is the unit simulating LOCA/LOOP. The loads actuated on each Oconee unit for these tests were selected to achieve as close as possible the design basis profile for the particular accident scenario. However, there are practical and physical limitations to simulation of an actual accident or operating event scenario. As a result, some pump alignments, such as reactor building spray, were operated in recirculation or bypass flow loops. In addition, some valves may not be cycled against the same differential pressures they might see during an actual event. To help offset the loss in steady state load as a result of certain pumps operating in the recirculation or bypass mode, additional loads were added to each of the units. In the LOOP scenarios an LPI pump on both Units 1 and 2 was included with the hot shutdown loads on Units 1 & 2. On the simulated LOCA scenarios, two spent fuel pool (SFP) cooling pumps on Unit 3 were configured to automatically load with the LOCA loads. Regardless of whether a pump is operating in bypass or full flow, the starting or inrush requirements of the motor are the same. Therefore, the presence of these additional loads increased the starting duty requirements of the emergency power source for these simulated accident scenarios because these additional loads are not designed LOOP and LOCA loads.

Calculation OSC-6803, Integrated Test (ES / LOOP) Load Calculation, was prepared prior to the test to estimate the difference in test steady state load verses design basis load in brake horse power (BHP) for the different accident scenarios. The calculation estimated the steady state BHP for the three Unit LOOP test cases to be within approximately 1.6% (140 BHP lower) of the design basis calculated amount. For the LOCA/LOOP test cases the estimated steady state BHP was within approximately 4.4% (465 BHP lower) of the design basis calculated amount. However, the inrush or starting duty for the test cases exceeded the design basis load due to the additional LPI and SFP pumps.

3.2.3.2 ***Initial Lineup:***

Operations aligned the Units 1 and 2 primary and secondary systems per procedure enclosures to allow the running of non-load shed loads to simulate hot shut down (LOOP) loads plus an LPI pump on Units 1 & 2. Of these loads, the Motor Driven Emergency Feedwater (MDEFW) and High Pressure Injection (HPI) pumps were operating in recirculation. Unit 3 also simulated hot shutdown loads during Tests 1 and 2.

Operations aligned Unit 3 primary and secondary systems to perform an Engineered Safeguards (ES) channel 1 through 8 actuation during tests 3, 4, 5, and 6. This includes aligning the HPI and Low Pressure Injection (LPI) Systems so that full Emergency Core Cooling System (ECCS) injection would occur when ES was actuated and the Main Feeder Busses (MFB's) energized. Other ES components [Reactor Building Cooling Units (RBCU's), Penetration Room Ventilation (PRV) fans, Low Pressure Service Water (LPSW) pumps, Reactor Building Spray (RBS) pumps] were also aligned to run in the ES mode. Electric containment isolation valves were initially aligned so that they must travel to their safety position when ES was actuated and the MFB's were re-energized. The Unit 3 secondary system was aligned to allow running both Motor Driven Emergency Feedwater (MDEFW) pumps in recirculation.

Keowee Hydro Unit 2 was used as the source of emergency power for Tests 1 - 5 and 7. The same Keowee unit was used to maintain consistency from a data acquisition standpoint. Only one set of data collecting equipment had to be connected at Keowee for these tests.

3.2.3.3 Test 1 - Block Loading Three Unit Loss Of Offsite Power (LOOP) Loads onto the Keowee Underground:

All three Oconee Units were aligned to their respective startup transformers. Loads were started on all three units (HPI pumps, MDEFW pumps, LPSW pumps, etc.) to simulate hot shutdown loads plus an LPI pump on Units 1 & 2. Simultaneously, all three Unit's startup transformers were de-energized and Keowee Emergency started from shutdown a condition. After ≈ 21 seconds all three Oconee Units Load Shed. At ≈ 31 seconds all three Oconee Units Block Load onto the Keowee underground unit.

3.2.3.4 Recovery from Test 1 - Dead Bus Transfer to Startup Source (System Grid):

After loading onto the Keowee underground, dead bus transfers (one Oconee Unit at a time) were performed to transfer back to the startup transformer. Enclosures were provided to recover essential loads after each units dead bus transfer.

3.2.3.5 Test 2 - Block Loading Three Unit LOOP Loads onto the Keowee Overhead after Keowee Load Rejection and Switchyard (S.Y.) Isolation:

All Three Oconee Units were aligned to their respective startup transformers. Simulated hot shutdown loads were started on each Oconee Unit. The Keowee overhead unit was started and placed on the system grid at 60MW. A Switchyard Isolation was initiated which resulted in: (1) a loss of power to each Oconee Unit, (2) emergency start of both

Keowee Unit's, and (3) a load rejection of the Keowee Overhead Unit. All three Oconee Units received power from the Keowee Overhead unit through their respective startup transformer in ≈ 20 seconds.

3.2.3.6 Recovery from Test 2 - Synchronization of the Keowee Overhead Unit to the System Grid:

While supplying all three Oconee Unit loads, the Keowee overhead Unit was synchronized back to the System Grid across PCB-8. This connected all three Oconee Units to the system grid. The switchyard configuration was then restored to normal.

3.2.3.7 Test 3 - Block Loading One Unit LOCA and One Unit LOOP loads (large unscheduled load) onto the Keowee Underground simultaneously while accelerating (≈ 60% voltage and frequency):

All three Oconee Units were aligned to their respective startup transformers. Unit 1 had an ES channel placed in test to initiate LOCA-timing in Emergency Power Switching Logic (EPSL). Simultaneously, Unit 1 and Unit 3 had their startup transformers de-energized and ES channels 1 through 8 actuated on Unit 3. The Keowee underground unit did not start its AC oil lift pump prior to ES actuation. Unit 1, with simulated hot shutdown loads, and Unit 3, with simulated ES loads, (including MDEFDW pumps), were block loaded onto the Keowee Underground Unit in ≈ 11 seconds. ECCS flow was terminated prior to reconnecting back to the offsite source.

3.2.3.8 Recovery from Test 3 - Dead Bus Transfer to Startup Source (System Grid):

Dead Bus Transfers (one Oconee Unit at a time) were performed to transfer back to the startup transformers. Enclosures were provided to recover essential loads after each Dead bus transfer.

3.2.3.9 Test 4 - Block Loading one unit LOCA and one unit LOOP loads (large unscheduled load) onto the Keowee Underground simultaneously after Load Rejection:

The same test sequence described in Test 3 above was performed with the exception that the Keowee Underground unit was placed on the System Grid at ≈60MW prior to de-energizing the Unit 1 and Unit 3 startup transformers and actuating ES channels 1 through 8 on Unit 3.

3.2.3.10 Recovery from Test 4 - Dead Bus Transfer to Startup Source (System Grid):

After loading onto the Keowee Underground, dead bus transfers (one Oconee Unit at a time) were performed to transfer back to the startup transformers. Enclosures were provided to recover essential loads after each Dead bus transfer.

3.2.3.11 Test 5 - Block Loading Single Unit LOCA followed by Two Unit LOOP loads to the Keowee Underground after Keowee Load Rejection:

All three Oconee Units were aligned to their respective startup transformers. The Keowee Underground Unit was started and placed on the System Grid at ≈ 60MW of load. Simultaneously all three startup transformers were de-energized and ES channels 1 through 8 were actuated on Unit 3. Unit 3 loaded onto the Keowee underground (after load rejection) in ≈ 20 seconds with simulated ES loads (including MDEFW pumps). Units 1 and 2 block loaded on the Keowee underground in ≈ 31 seconds with simulated hot shut down loads plus an LPI pump on each unit. Enclosures were provided for each Oconee Unit to restart essential loads (spent fuel cooling, switchyard Battery Feeders, CCW pumps, etc.) and terminate ECCS flow (Unit 3) at the appropriate time. The Keowee underground path was loaded near ≈ 20MVA by manually adding these loads.

3.2.3.12 Test 7 - Keowee Partial Loss of Load & Recovery from Test 5 - Dead Bus Transfer to the Startup Source (System Grid):

After manually increasing the load on the Keowee Underground by adding 4KV load shed pump motors (to ≈20MVA), dead bus transfers (one Oconee Unit at a time) were performed to transfer each Oconee unit back to its startup transformer. Keowee response to this partial load rejection was monitored and recorded during this evolution. Enclosures were provided to recover essential loads after each dead bus transfer.

3.2.3.13 Test 6 - Block Loading Single Unit LOCA followed by Two Unit LOOP Loads onto the Lee Combustion Turbine (CT):

A Lee CT was placed on the standby busses. All three Oconee Units were aligned to their respective startup transformers. Simultaneously, all three startup transformers were de-energized and ES channels 1 through 8 were activated on Unit 3. Unit 3 block loaded onto the Lee CT with LOCA loads (including MDEFDW pumps) in ≈ 11 seconds. Unit 1 and Unit 2 block loaded onto the Lee CT with hot shut down loads in ≈ 31 seconds. The Unit 1 & 2 non-safety time delayed load centers block loaded onto Lee CT in ≈ 41 seconds. An enclosure was provided to terminate ECCS flow on Unit 3 at the appropriate time.

3.2.3.14 Recovery from Test 6 - Dead Bus Transfer to the Startup Source (System Grid):

After loading onto the Lee CT, dead bus transfers (one Oconee Unit at a time) were performed to transfer back to the startup transformer. Enclosures were provided to recover essential loads after each dead bus transfer.

3.2.3.15 System Realignment:

Procedural guidance was provided to align the plant systems and components back to a normal configuration.

3.2.4 Test Acceptance Criteria

Overall the test was a success. This section details the specific test acceptance criteria (TAC) for the individual tests. Since this test was a functional test, the acceptance criteria were based on the system functional requirements. Ultimately, the emergency power system must deliver power to the required loads such that cooling water can be delivered to the core. The ability of the emergency power source to start, connect to the Oconee units, and energize and accelerate the applicable accident loads is the theme seen throughout the acceptance criteria. For the simulated LOCA scenarios, delivering appropriate LPI flow to the core is also included in the acceptance criteria. Recorded electrical data of the system's response to these tests can be found in Section 4 of this report.

3.2.4.1 Test 1: Keowee starts and accelerates the connected loads simulating a 3 unit LOOP loading on the underground path.

Acceptance Criteria:

- Both Keowee Units emergency start on simulated LOOP actuation.
- The Keowee underground unit obtains rated speed 128.6 RPM (122.2 - 135 RPM) and voltage 13.8kv (13.5 - 14.49KV) ≤ 23 seconds after emergency start actuation.
- Each Oconee unit automatically transfers to receive power from the standby bus.
- The connected 4KV motors (HPI, LPSW, MDEFW, LPI) and 600V CC Pump LOOP loads start, accelerate, and continue to operate until secured.

The acceptance criteria for the first three items were successfully met. The Keowee units emergency started on the simulated LOOP actuation. The underground unit, initially in standby, obtained rated speed and voltage in ≈16.4 seconds, well before each Oconee unit successfully transferred to receive power from the standby buses. The fourth acceptance criterion was met with the exception of the 600V 3A-Component Cooling (CC) pump failing to start and operate until secured. Each of the other specified loads started and operated as intended. Failure of the 3A-CC pump literally results in the TAC not being met. However, the results of this test are satisfactory, even with this deficiency, because of the following:

1. The cause of the 3A-CC pump failure was the control power fuse blew. The fuse blew because the one installed was an incorrect size (too low amperage). The fuse was replaced with the correct size and the CC pump operated as expected during the remaining tests. This problem was documented in PIP 97-0040.
2. The 3A-CC pump is a relatively small load (50 HP) compared to the Oconee units hot shutdown loads. This test included running two LPI pumps (≈660 HP) which are not hot shutdown loads. These two LPI pumps provided additional load (both steady state and inrush), when the main feeder buses are reenergized, which compensates for the loss of the 3A-CC pump.

*3.2.4.2 Test 2: **Keowee separates from the system grid and starts and accelerates the connected loads simulating a 3 unit LOOP loading on the overhead path.***

Acceptance Criteria:

- The overhead Keowee unit separates from the system grid on emergency start actuation.
- The switchyard isolation logic properly isolates the Yellow Bus from the system grid.
- The connected 4KV motor (HPI, LPSW, MDEFW, LPI) and 600V CC Pump LOOP loads start, accelerate, and continue to operate until secured.

The acceptance criteria for this test were all successfully met. The Keowee unit successfully load rejected from grid generation on emergency start actuation and energized the overhead path following switchyard/Yellow bus isolation. The connected LOOP loads started and operated as intended until secured.

*3.2.4.3 Test 3: **Keowee, loaded while accelerating at less than rated voltage and frequency, starts and accelerates the connected LOCA and LOOP loads on the underground path.***

Acceptance Criteria:

- Both Keowee Units emergency start on engineered safeguards actuation.
- Oconee Units 1 & 3 automatically load shed and transfer to receive power from the standby bus.
- The Keowee underground unit accepts load at reduced voltage and frequency.
- The connected Unit 3 4KV motors (HPI, LPI, LPSW, RBS, MDEFW) and 600V RBCU LOCA loads start, accelerate, and continue to operate until secured.
- The connected non-load shed loads are energized following the transfer to the standby bus.
- All ES actuated MOVs operate to their ES position.
- LPI flow $\geq$ 2800 gpm per pump $\leq$ 48 seconds.

The acceptance criteria for this test were all successfully met. The Keowee units successfully emergency started from standby and the underground unit accepted Oconee Units 1 & 3 loads at reduced voltage and frequency. The Keowee unit, while starting the connected LOCA and LOOP loads, accelerated to rated speed and voltage in $\approx$16.6 seconds. The connected LOCA motors started and operated until secured and the connected non-load shed load centers were also energized. Each engineered safeguards actuated MOV stroked to its proper ES position. Also, LPI flow $\geq$ 2800 gpm per header to the core was established in $\approx$ 22.9 seconds following ES actuation.

3.2.4.4 Test 4: Keowee separates from the system grid and starts and accelerates the connected LOCA and LOOP loads on the underground path following load rejection.

Acceptance Criteria:

- Both Keowee Units emergency start on engineered safeguards actuation.
- Oconee Units 1 & 3 automatically transfer to receive power from the standby bus.
- The Keowee underground units ACBs (e.g. ACB-2 & 4 for Unit 2) open on emergency start actuation.
- The connected Unit 3 4KV motors (HPI, LPI, LPSW, RBS, MDEFW) and 600V RBCU LOCA loads start, accelerate, and continue to operate until secured.
- The connected non-load shed loads are energized following the transfer to the standby bus.
- All ES actuated MOVs operate to their ES position.
- LPI flow ≥ 2800 gpm per pump ≤ 48 seconds.

The acceptance criteria for this test were all successfully met. The Keowee units successfully emergency started and the underground unit successfully separated itself from the grid and underground path during the load rejection. The underground unit accepted Oconee Unit 1 & 3 loads and the connected LOCA motors started and operated until secured. The connected non-load shed load centers also were energized. Each engineered safeguards actuated MOV stroked to its proper ES position. LPI flow ≥ 2800 gpm per header to the core was established in ≈ 27.4 seconds following ES actuation.

3.2.4.5 Test 5: Keowee separates from the system grid and starts and accelerates the connected LOCA loads followed by 2 unit LOOP loads on the underground path following load rejection.

Acceptance Criteria:

- Both Keowee Units emergency start on engineered safeguards actuation.
- The Keowee underground unit's ACBs (e.g. ACB-2 & 4 for Unit 2) open on emergency start actuation.
- Each Oconee unit automatically transfers to receive power from the standby bus.
- The connected Unit 3 4KV motors (HPI, LPI, LPSW, RBS, MDEFW) and 600V RBCU LOCA loads start, accelerate, and continue to operate until secured.
- The connected non-load shed loads are energized following the transfer to the standby bus.
- All ES actuated MOVs operate to their ES position.
- LPI flow ≥ 2800 gpm per pump ≤ 48 seconds.

The acceptance criteria for this test were all successfully met. The Keowee units successfully emergency started and the underground unit successfully separated itself from the grid and

underground path during the load rejection. The underground unit accepted Oconee Units 1, 2, & 3 loads and the connected LOCA motors started and operated until secured. The connected non-load shed load centers were energized. Each engineered safeguards actuated MOV stroked to its proper ES position. LPI flow ≥ 2800 gpm per header to the core was established in ≈ 27.7 seconds following ES actuation.

3.2.4.6 Test 6:The Lee CT starts and accelerates the connected LOCA loads followed by 2 unit LOOP loads.

Acceptance Criteria:

- Each Oconee unit automatically transfers to receive power from the standby bus energized by a Lee CT.
- The connected Unit 3, 4KV motors (HPI, LPI, LPSW, RBS, MDEFW) and 600V RBCU LOCA loads start, accelerate, and continue to operate until secured.
- The connected non-load shed loads are energized following the transfer to the standby bus.
- All ES actuated MOVs operate to their post ES position.
- LPI flow ≥ 2800 gpm per pump ≤ 48 seconds.

The acceptance criteria for this test were all successfully met. Oconee Units 1, 2, & 3 transferred and received power from the standby buses which were energized by a Lee CT. The connected LOCA motors started and operated until secured and the connected non-load shed load centers were energized. Each engineered safeguards actuated MOV stroked to its proper ES position. LPI flow ≥ 2800 gpm per header to the core was established in ≈ 22.0 seconds following ES actuation.

3.2.4.7 Test 7 - Keowee Partial Loss of Load

Acceptance Criteria:

- none

Test 7 did not have any acceptance criteria. This partial loss of load evolution (test) was performed when recovering from Test 5, during the dead bus transfer of loads from Keowee back to the Startup source (system grid). Data was collected during this evolution to demonstrate Keowee's response to this transient.

3.3 TT/0/A/0610/25A, Test Equipment Setup Procedure For The Emergency Power And Engineered Safeguards Functional Test

3.3.1 Overview

TT/0/A/0610/25A was used to control and document the connection of data collection equipment to various components in the ONS emergency electrical power system, various valve operators, and to various fluid system pressure instruments. The intent of the data collection was to obtain information to document the results of the response of the systems tested during the simulated LOCA and LOOP scenarios.

3.3.2 Electrical Parameters

3.3.2.1 Electrical Power System

Given this was a one time test involving all three Oconee Units, data acquisition equipment was installed to record as much power system data as possible. To monitor the whole system response to these loading scenarios, many monitoring points from the source down to the 208V bus were selected. Because of limitations regarding the number of power recording data acquisition equipment available, selected points were chosen to be monitored. The points monitored are listed in Table 3-1 below. The digital instrumentation equipment used to collect the data is compiled in Enclosure 13.1 of procedure TT/0/A/0610/25A. Pre- and post-test calibration checks were performed on all monitoring equipment. No calibration problems were identified.

Table 3- 1: Summary of Power System Test Data Locations

Points Monitored	Monitor Location	Parameters Monitored
Keowee Generator Output	Keowee Generator Bus	V, I, MW, MVA, MVAR, Field V & I
Lee Generator Output	Lee Generator Bus	V, I, MW, MVA, MVAR, Field V & I
Units 1, 2, & 3 Main Feeder Buses (MFB)	At the MFB (Standby Bus for Unit 3 Voltage on underground tests)	V, I, MW, MVA, MVAR
Transformers CX and 3X4 primary	At the applicable 4KV Switchgear feeder breakers	V, I, MW, MVA, MVAR

Table 3- 1: Summary of Power System Test Data Locations		
Points Monitored	**Monitor Location**	**Parameters Monitored**
600VAC Load Centers: 1X5, 1X6, 3X5, 3X6, 3X8, 3X9	At the applicable Load Center	V, I, MW, MVA, MVAR
Safety 600 and 208VAC MCCs: 3XS1, 3XS2, & 3XS3	At the applicable MCC bus.	V, I, MW, MVA, MVAR
RBCU Fan-3B	At the applicable MCC feeder breaker	V, I, MW, MVA, MVAR
Battery Charger 3CA	At the applicable MCC feeder breaker	V, I, MW, MVA, MVAR
4160V Pump Motors: LPI-3B, RBS-3B, LPSW-3B, MDEFW-3B, HPI-3B, & MDEFW-1A	At the applicable 4160V Switchgear bus	V, I, MW, MVA, MVAR

NOTE: Load Centers 1X5, 1X6, 3X4, 3X5, and 3X6 are non-safety related load centers that automatically re-energize (some with a time delay) after power is restored.

The electrical power system data was collected as follows;

- Keowee Generator Data - Voltage and Current was monitored on the secondary of high accuracy relay/metering potential transformers (PTs) with a ratio of 120/1 & current transformers (CTs) with a ratio of 1000/1. A test loop with a ratio of 1/20 was also used for improved recorder resolution.

- Lee Generator Data - Voltage and current was monitored on the secondary of high accuracy relay/metering PTs with a ratio of 120/1 & CTs with a ratio of 400/1. A test loop with a ratio of 1/20 was also used for improved recorder resolution.

- MFB Data - Voltage and current was monitored on the secondary of high accuracy relay/metering PTs with a ratio of 20/1 & CTs with a ratio of 600/1 (1200/1 for Test 2 only). A test loop with a ratio of 1/20 was also used for improved recorder resolution.

- 4160V Motor/Load Center Transformer Feeder Data - Voltages were monitored on the secondary of high accuracy relay/metering PTs with a ratio of 35/1 connected to the applicable 4160V Switchgear bus. Current data was collected by probes clamped on the individual load cables.

- 600V Load Center, 600/208V MCC, RBCU Motor, & Battery Charger Data - Voltage was monitored by direct connection to 600/208VAC buses. Current data was collected by probes clamped directly on the 600V Load Center busses, the individual MCC bus feeder, and load cables.

3.3.2.2 Motor Operated Valves

Eleven Unit 3 engineered safeguards MOVs were monitored using Liberty Technologies, INC. Motor Power Monitor (MPM). The MOVs monitored were: 3HP-24, 3HP-26, 3LP-17, 3BS-2, 3HP-27, 3LPSW-24, 3PR-19, 3LPSW-6, 3LPSW-565, 3HP-4, and 3HP-20. These MOVs were selected as a representative sample of the installed motor operator/valve population. The MOVs were chosen considering worst case MOV undervoltage, and those expected to have the highest differential pressure requirements. These factors, along with valve and operator specific information, were used to select a representative sample of all ES MOVs, ensuring that MOVs with and without hammer-blow, with and without compensators, various types of valves (i.e. gate, globe, ball, butterfly), and various type operators (Limitorque and Rotork) were included.

The instruments were previously calibrated on a scheduled periodic basis. Pre and post test checks were performed on the equipment, with no problems identified.

3.3.3 Mechanical Parameters

Pressure instruments were installed to monitor suction pressure, discharge pressure, and flow rate on the LPI-3B, RBS-3B, LPSW-3B, MDEFW-3B, HPI-3B, RBCU-3B, MDEFW-1A pumps. This data will be used to examine the hydraulic characteristics of these pumps.

3.4 Post-Test Equipment Verification

Second only to nuclear and personnel safety, equipment damage during or as a result of this extensive testing was a concern. The equipment exercised during these tests was designed to operate under these conditions. However, an integrated test involving all three Oconee unit's equipment had never been performed in the past. As a result of this concern, pre-test, intermediate-test, and post-test checks on the various plant equipment were performed.

For the motor operated valves (MOVs), pre- and post-static tests of the eleven valves monitored with the MPM equipment were performed. The static tests were performed to ensure the MPM equipment was connected and operating properly and to identify any MOV anomalies and define valve operation prior to the emergency tests. The pre- and post-static tests were compared by overlaying the valve traces of recorded data. No changes in the MOV as a result of these tests were identified and no apparent degradation/damage was noticed. Also, for each safety related MOV actuated in Tests 3 through 6, computer point alarms wired for thermal overload annunciation were checked after each individual test. No overload actuations were identified for any of the test scenarios.

Prior to the tests, surveys of various plant equipment, including the unit block houses and 4KV switchgear locations, were made. Surveys were performed to note any protective relay

actuations or other abnormal conditions. These same surveys were performed after each test. No indication of protective device actuation on connected equipment was observed.

A post-test functional check was performed for each of the 4KV motors exercised during these test scenarios,. The preventive maintenance (PM2) group at Oconee performed these inspections which included functionally operating the motors, and an electrical motor preventive maintenance check which included motor winding and insulation measurements. These inspections were completed with no indication of damage or degradation observed.

4. Test Results

This section documents the test results for each of the seven tests. Recorded data for each test, from the source down to the 208V MCCs and MOVs, is included in the applicable sections. Various parameters for each test are plotted in the figures as referenced in the sections below. The time scale used in the figures for all data (except MOVs) is cycles. The major scale is 300 cycles (5 seconds). The minor scale is 60 cycles (1 second).

4.1 Test 1, Three Unit LOOP With A Failure Of The O/H Path.

This test simulated a three unit LOOP with the Keowee Units initially shutdown, and a failure of the overhead circuit. Keowee Unit 2 emergency started and the three Oconee LOOP units loaded onto the underground path. The expected scenario for this test is as follows:

- A three unit LOOP occurs at time t=0
- Units 1, 2 and 3 MFBs transfer to the underground and are energized at t ≈ 31 seconds
- Units 1, 2, and 3 RBCUs transfer to high speed at t ≈ 50 seconds
- Loadcenter X7 is re-energized on Unit 1 and loadcenters X4 are re-energized on Units 2 and 3 at t ≈ 81 seconds.

4.1.1 Test 1, Keowee Profile (V, I, KVA, KW, f)

Figures 4.1.1-1 through 5 plot the Keowee response to Test 1. In these plots, the time t = 0 is assigned to when Emergency Start actuation occurs (the generator field was flashed).

Figure 4.1.1-1 is a plot of the Keowee voltage and current response. The Keowee unit was at rated voltage when load was applied. All units loaded within a 1 second interval. As illustrated by the current plot, the first LOOP unit (Unit 2) closes onto Keowee at around 1874 cycles(31.2 seconds). The second unit (Unit 3) closes at 1899 cycles (31.7 seconds) and the third unit (Unit 1) closes onto Keowee around 1935 cycles (32.3 seconds). Maximum current inrush is 1933 amperes rms. Current drops to approximately 375 amperes within 6 seconds following inrush. Starting at around 2826 cycles (47.1 seconds) and again at around 3638 cycles (60.6 seconds) additional inrush currents occur as the Reactor Building Cooling Fans transfer to high speed. Starting at around 4959 cycles (82.7 seconds) three other inrush currents occur due to energizing the Unit 1 X7 loadcenter and the Unit 2 and 3 X4 loadcenters. Note that the inrush as the RBCU fans shift to high speed and when the load centers are energized has no noticeable impact on the Keowee Unit 2 terminal voltage. Final steady state current is around 392 amperes.

Figure 4.1.1-2 is a plot of the Keowee voltage during the inrush period. The slight time separation between Oconee unit auxiliary loads is illustrated by the three successive voltage dips. The worst case dip is to approximately 12,526 volts at 1940 cycles volts or 90.8% of 13.8KV. Voltage recovers to near steady state value from the initial dip in about 3 seconds.

Figure 4.1.1-3 is a plot of the KVA output from Keowee. The maximum inrush is around 42,000 KVA at 1935 cycles. Steady state KVA loading is around 9036 KVA.

Figure 4.1.1-4 is a plot of the KW output from Keowee. The maximum inrush is approximate 12,000 KW. The steady state load is 7,426 KW.

Figure 4.1.1-5 is a plot of the frequency response of the Keowee unit. A plot of the Keowee current is also included to indicate when load was applied to Keowee. Frequency was approximately 59.2 hertz when load was applied. Minimum frequency after loading was around 57.77 hertz at 2069 cycles (34.5 seconds). Frequency recovers to around 59.23 hertz, which is consistent with the current governor speed-no-load setting.

Selected values are listed in the table below for quick reference:

Table 4- 1: Test 1, Summary of Keowee Response

Description	Time	Value
Keowee Unit 2 Emergency Start	0	
Volts and Frequency just prior to loading		Frequency = 59.2 Hz Volts = 13.856 KV
Unit 2 loads	31.2 seconds	Frequency = 59.1 Hz Min. Volts = 12.872 KV
Unit 3 loads	31.7 seconds	Frequency = 59.0 Hz Min. Volts = 12.658 KV
Unit 1 loads	32.3 seconds	Frequency = 58.7 Hz Max. Current = 1933 Amps Min. Volts = 12.526 KV Max. KVA = 42,000 KVA Max. KW = 11,400 KW
Min. freq. After loading	34.5 seconds	57.77 Hz
1X7, 2X4, 3X4 Loading	82.7+ seconds	
Steady state values		Current = 392 Amps Volts = 13.869 KV KVA = 9,036 KVA KW = 7,426 KW Frequency = 59.23 Hz

The Keowee power data reflects recorder tolerance bands which are magnified by bigger multiplication factors due to higher ratio PT's & CT's than the MFB load data. Thus, the sum total of Unit 1, 2, and 3 MFB load in Section 4.1.2 will provide a more reliable indication of actual Keowee load.

4.1.2 Test 1, MFB Profiles (V, I, KVA, KW)

Figures 4.1.2-1 and 2 are the plots of the Unit 1 MFB profiles. Figures 4.1.2-3 and 4 are plots of the Unit 2 MFB profiles. Figure 4.1.2-5 is a plot of the Standby Bus voltage and Unit 3 MFB current. Figure 4.1.2-6 is a plot of the Unit 3 loading. Time t = 0 starts with loss of voltage on Unit 1 for all of these plots. A close examination of these plots shows that Unit 2 loaded first, then Unit 3 and then Unit 1. Since the standby bus voltage was monitored for the Unit 3 data, the Figure 4.1.2-5 correctly shows the standby bus being energized from Keowee prior to the MFBs being energized on any of the units.

Table 4- 2: Test 1, Summary of MFB Response

Description	Time	Value
Unit 1 and 3 MFB lose Voltage	0	
Unit 2 MFB loses voltage	.03 seconds	
Unit 2 MFB loads	31.75 seconds	Min. Volts = 2.805 KV
Unit 3 MFB loads	32.16 seconds	Stdby Bus Min= 2.804 KV
Unit 1 MFB loads	32.66 seconds	Min. Volts = 2.809 KV
Unit 1 MFB Steady state		Current = 449 Amps Volts = 4.213 KV KVA = 3,265 KVA KW = 2,734 KW
Unit 2 MFB Steady state		Current = 401 Amps Volts = 4.213 KV KVA = 2,909 KVA KW = 2,470 KW
Unit 3 MFB Steady state		Current = 379 Amps Stdby Bus KV = 4.198 KV KVA = 2,737 KVA KW = 2,325 KW

4.1.3 Test 1, 4KV Motor Profiles (V, I, KVA, KW)

Figures 4.1.3-1 and 2 are the plots of the MDEFW 3B profile. Figures 4.1.3-3 and 4 are the plots of the HPI 3B profile. Voltages are monitored at the 4.16KV switchgear level. Points from the motor feeder overcurrent relays for each motor are also plotted on Figures 4.1.3-1 and 3 and indicate a significant margin between motor starting and overcurrent relay tripping.

4.1.4 Test 1, RBCU FAN 3B Motor Starting Profiles (V, I, KVA, KW)

RBCU FAN 3B was not started in Test 1.

4.1.5 Test 1, 600V Loadcenter Profiles (V, I, KVA, KW)

Figures 4.1.5-1 and 2 are the profiles for 1X5. After about a 1 second delay there is a significant increase in load, which is consistent with motors starting after the voltage reaches contactor pickup voltage. Note that as the contactors pickup the voltage continues to rise.

Figures 4.1.5-3 and 4 are the profiles for 1X6. After about a 1.5 second delay there is a significant increase in load, which is consistent with motor starting after the voltage reaches contactor pickup voltage. About 6 seconds after energization, a battery charger loads.

Figures 4.1.5-5 and 6 are the profiles for 3X5. After about a 3 second delay there is a significant increase in load, which is consistent with motor starting after the voltage reaches contactor pickup voltage. About 9 seconds after energization, a battery charger loads.

Figures 4.1.5-7 and 8 are the profiles for 3X6. The characteristics for 3X6 are very similar to profiles for 3X5.

Figures 4.1.5-9 and 10 are the profiles for 3X8. There is about a 2 second delay after energization before a significant load increase occurs. The loading at around 2 seconds after energization is a RBCU FAN starting on low speed. At approximately 5 seconds after energization, the battery charger loads. At around 32 seconds the RBCU FAN transfers to high speed.

Figures 4.1.5-11 and 12 are the profiles for 3X9. There is an immediate increase in loading when the loadcenter is energized as a RBCU fan starts on low speed. Approximately 7 seconds after energization, a battery charger loads. The RBCU fan transfers to high speed approximately 18 seconds after energization.

Figures 4.1.5-13 and 14 are profiles for 3X4. After an initial inrush, the load stabilizes at a low value (approximately 100KW).

The load increases as described above on some buses approximately 6 to 10 seconds after the bus is re-energized due to the power battery charger restarting is expected. The chargers are designed with an automatic time delay in the startup of the charger. Likewise, the RBCU fan transfer to high speed was expected. No loading anomalies were evident.

4.1.6 Test 1, 600V Safety MCC Profiles (V, I, KVA, KW)

Figures 4.1.6-1 through 4.1.6-6 chart the voltage, current, KVA and KW profiles for the 600V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increase at energization is small. A significant increase in loading occurs on 3XS1 and 3XS2 when the battery chargers load. Note that the charger loading has negligible impact on MCC voltage. Minimum voltage after MCC energization is 385 volts (64.2 %) and occurs on 600V MCC 3XS2. The minimum steady state voltage MCC voltage is 592V (98.7% of 600V) on 3XS1. MCC voltage recovers to near steady state value in approximately 4 seconds.

4.1.7 Test 1, 208V Safety MCC Profiles (V, I, KVA, KW)

Figures 4.1.7-1 through 4.1.7-6 chart the voltage, current, KVA and KW profiles for the 208V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increase at

energization is small. The 208V MCCs primarily serve MOVs which do not operate during a LOOP. Minimum voltage after MCC energization is 131.3 volts (63.1 %) and occurs on 208V MCC 3XS2. The minimum steady state voltage occurs on 3XS1 and is 208V. Figure 4.1.7-5 indicates a constant load on 208V MCC 3XS3 of one ampere even during the loss-of-voltage. The expected load on this MCC is approximately 0 amperes and lack of current change during the loss and restoration of power confirms this.

4.1.8 Test 1, Battery Charger 3CA (V, I)

Figure 4.1.8-1 charts the voltage and current for Battery Charger 3CA. Note that the charger current characteristic mirrors that seen at the MCC and loadcenter levels. Charger supply voltage is monitored at the MCC.

4.1.9 Test 1, Motor Operated Valves (V, I, KW)

This test scenario involved LOOP units only, therefore no ES valves were stroked.

4.2 Test 2, Three Unit LOOP With Keowee Initially Generating To The Grid.

This test simulated a three unit LOOP with the load applied to the overhead circuit. Keowee Unit 2 was initially loaded to approximately 60 MW to the grid. The Keowee Unit load rejected and the three Oconee units' LOOP loads were supplied by the overhead Circuit. The expected scenario for this test is as follows:

- A three unit LOOP occurs and Keowee Unit 2 load rejects at time t=0
- The overhead path is energized when Keowee decreases to 66 Hertz following load rejection.
- Units 1, 2 and 3 MFBs are energized including Unit 1 X7 and Units 2 and 3 X4 loadcenters at t ≈ 20 seconds.

4.2.1 Test 2, Keowee Profile (V, I, KVA, KW, f)

Figures 4.2.1-1 through 4.2.1-6 plot the Keowee response to Test 2. In these plots, the time t = 0 is assigned to when the Keowee unit load rejected on Emergency Start actuation.

Figure 4.2.1-1 is a plot of the Keowee voltage and current response. Maximum current inrush is slightly below 3300 amperes rms. There are two distinct high inrush currents. The first inrush occurs around 884 cycles (14.7 seconds) and has a maximum current of 3293 amperes. This inrush is when the Keowee Main Step-up and Startup Transformers CT1, CT2 and CT3 are energized. The second inrush occurs around 1058 cycles (around 17.6 seconds) and has a maximum current of around 2570 amperes when all three units MFBs are energized. Connection to the three LOOP units appears to have occurred essentially simultaneously. At around 1974 cycles(32.9 seconds) and again at around 2723 cycles(45.4 seconds) additional inrush currents occur as the Reactor Building Cooling Fans transfer to high speed. Test 2 inrush current magnitude is higher than for Test 1 because the overhead path results in a higher voltage at the terminals of the starting loads. Final steady state current is around 534 amperes.

Figure 4.2.1-2 is a plot of the Keowee voltage during the inrush periods. The voltage dip during the first inrush to 12.512KV at 885 cycles (14.8 seconds) is not as great as the voltage dip during the second inrush to 11.757KV at 1066 cycles (17.8 seconds) or 85.2 % of 13.8KV) even though the current is higher for the first inrush. The first inrush was due to charging the large transformers, which contains a large DC offset component. This DC current will not significantly impact the flux in the generator air gap, and thus the voltage dip was smaller for this inrush even though the magnitude of the current was larger. Recovery to near rated voltage occurs in approximately 2.5 seconds.

Figure 4.2.1-3 is a plot of the KVA output from Keowee. During the first inrush, the maximum load is around 69,000 KVA. During the second inrush, the maximum load is around 54,600 KVA. Steady state KVA loading is 12,647 KVA.

Figure 4.2.1-4 is a plot of the KW output from Keowee. The first KW inrush occurs during transformer energization. The maximum inrush occurs when the MFBs are energized and is around 16,200 KW. The steady state load is 8,918 KW.

Figure 4.2.1-5 and 4.2.1-6 are plots of the frequency response. A plot of the Keowee current is also included on Figure 4.2.1-5 to indicate when load was applied to Keowee. Frequency was approximately 65.4 hertz when the Keowee Main Step-up (MSU), CT1, CT2 and CT3 transformers were energized. Distortion caused by the transformer inrush currents resulted in an inaccurate measurement of frequency as can be seen by the discontinuities in the frequency plot. When the MFBs were energized the Keowee frequency was 59.6 hertz. Minimum frequency after loading was approximately 57.56 hertz. Frequency recovers to above 60Hz (60.92 Hz) due to the governor speed droop characteristic.

Table 4-3: Test 2, Summary of Keowee Response

Description	Time	Value
Initial Keowee 2 Load		59,400 KW
Keowee 2 load rejects (Emergency Start)	0	
Volts and frequency just prior to loading		Volts = 14.030 KV Frequency = 65.4 Hz
MSU, CT1, CT2, CT3 energized	14.7 seconds	Max. Current = 3293 Amps Min. Volts = 12.512 KV Max. KVA = 69,000 KVA Frequency = ~65.4 Hz
MFBs energized	17.6 seconds	Max. Current = 2542 Amps Min. Volts = 11.757 KV Max. KVA = 54,600 KVA Max. KW = 16,200 KW Frequency = ~ 59.6 Hz
Min. Frequency After Loading		57.56 Hz
Steady state values		Current = 534 Amps Volts = 14.069 KV KVA = 12,647 KVA KW = 8,918 KW Frequency = 60.92 Hz

The Keowee power data reflects recorder tolerance bands which are magnified by bigger multiplication factors due to higher ratio PT's & CT's than the MFB load data. Thus, the

sum total of MFB loads in Section 4.2.2 will provide a more reliable indication of actual Keowee load.

4.2.2 Test 2, MFB Profiles (V, I, KVA, KW)

Figures 4.2.2-1 and 2 are the plots of the Unit 1 MFB profiles. Figures 4.2.2-3 and 4 are plots of the Unit 2 MFB profiles. Figure 4.2.2-5 is a plot of the MFB voltage and the Unit 3 MFB current, and Figure 4.2.2-6 is a plot of the Unit 3 loading. Time, t = 0, starts with loss of voltage on Unit 1 for all of these plots. A close examination of these plots show the units loaded almost simultaneously with Unit 2 loading first, then Unit 1 and then Unit 3.

Table 4- 4: Test 2, Summary of MFB Response

Description	Time	Value
Unit 1, 2 and 3 MFB lose Voltage	0 seconds	
Unit 2 MFB loads	17.62 seconds	Min. Volts = 3.122 KV
Unit 1 MFB loads	17.63seconds	Min. Volts = 3.157 KV
Unit 3 MFB loads	17.73 seconds	Min. Volts = 3.162 KV
Unit 1 MFB Steady state		Current = 460 Amps Volts = 4.466 KV KVA = 3,527 KVA KW = 2,904 KW
Unit 2 MFB Steady state		Current = 445 Amps Volts = 4.467 KV KVA = 3,396 KVA KW = 2,811 KW
Unit 3 MFB Steady state		Current = 392 Amps Volts = 4.472 KV KVA = 2,995 KVA KW = 2,508 KW

4.2.3 Test 2, 4KV Motor Profiles (V, I, KVA, KW)

Figures 4.2.3-1 and 2 are the plots of the MDEFW 3B profile. Figures 4.2.3-3 and 4 are the plots of the HPI 3B profile. Figures 4.2.3-5 and 6 are the plots of the MDEFW 1A profile. Figures 4.2.3-7 and 8 are the plots of the LPSW 3B profile. Voltages are monitored at the 4.16KV switchgear level. Points from the motor feeder overcurrent relays are also plotted for each motor on Figures 4.2.3-1, 3, 5 and 7. The data indicates a significant margin between motor starting and overcurrent relay tripping for each motor.

4.2.4 Test 2, RBCU Fan 3B Motor Starting Profiles (V, I, KVA, KW)

RBCU fan 3B was not started in Test 2

4.2.5 Test 2, 600V Loadcenter Profiles (V, I, KVA, KW)

Figures 4.2.5-1 and 2 are the profiles for 1X5. After about a 0.5 second delay there is a significant increase in load, which is consistent with motors starting after the voltage reaches the contactor pickup voltage.

Figures 4.2.5-3 and 4 are the profiles for 1X6. There is a significant increase in load after about 0.5 seconds, which is consistent with motors starting when the voltage reaches contactor pickup voltage. About 6 seconds after energization, a battery charger loads.

Figures 4.2.5-5 and 6 are the profiles for 3X5. There is a significant increase in load after about 1.5 seconds, which is consistent with motors starting when the voltage reaches contactor pickup voltage. About 9 seconds after energization, a battery charger loads.

Figures 4.2.5-7 and 8 are the profiles for 3X6. The characteristics for 3X6 are very similar to the profiles for 3X5.

Figures 4.2.5-9 and 10 are the profiles for 3X8. The loading right after energization includes a RBCU fan starting on low speed. At approximately 3 seconds after energization, the battery charger loads. At around 31 seconds the RBCU fan transfers to high speed.

Figures 4.2.5-11 and 12 are the profiles for 3X9. There is an immediate increase in loading when the loadcenter is energized as a RBCU fan starts on low speed. Approximately 5 seconds after energization, a battery charger loads. The RBCU fan transfers to high speed approximately 17 seconds after energization.

The load increases on some buses approximately 3 to 10 seconds after the bus is re-energized due to the power battery charger restarting as expected. The chargers are designed with an automatic time delay in their startup circuit. Likewise, the RBCU fan transfer to high speed was expected. No loading anomalies were evident.

4.2.6 Test 2, 600V Safety MCC Profiles (V, I, KVA, KW)

Figures 4.2.6-1 through 4.2.6-6 chart the voltage, current, KVA and KW profiles for the 600V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increase at energization is small. A significant increase in loading occurs on 3XS1 and 3XS2 when the battery chargers load. Note that the charger loading has negligible impact on MCC voltage. Minimum voltage after MCC energization is 439.3 volts (73.2 %) and occurs on 600V MCC 3XS2. The minimum MCC steady state voltage is 627V (104.5% of 600V) on 3XS1. Voltage recovers to near the steady state value in around 2 seconds for 3XS1 and 2, and 3 seconds for 3XS3.

4.2.7 Test 2, 208V Safety MCC Profiles (V, I, KVA, KW)

Figures 4.2.7-1 through 4.2.7-6 chart the voltage, current, KVA and KW profiles for the 208V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increase at

energization is small. The 208V MCCs primarily serves MOVs which do not operate during a LOOP. Minimum voltage after MCC energization is 149.8 volts (72 %) and occurs on 208V MCC 3XS2. The minimum steady state voltage occurs on 3XS2 and is 219.9V. Figure 4.2.7-5 indicates a constant load on 208V MCC 3XS3 of about one ampere, even during the loss-of-voltage. The expected load on this MCC is near zero (motor controller power), and the lack of current change during the loss and restoration of power confirms this.

4.2.8 Test 2, Battery Charger 3CA (V, I)

Figure 4.2.8-1 charts the voltage and current for Battery Charger 3CA. Note that the charger current characteristic mirrors that seen at the MCC and loadcenter levels. Charger supply voltage is monitored at the MCC.

4.2.9 Test 2, Motor Operated Valves (V, I, KW)

This test scenario involved LOOP units only, therefore no ES valves were stroked.

4.3 Test 3, LOCA/LOOP With A Failure Resulting In Starting A Large Unscheduled Load With A LOCA Unit.

This test simulated a LOCA/LOOP on Oconee Unit 3 and a LOOP on Unit 1. This test simulates a failure which simultaneously loads the LOCA unit and the unscheduled load (the LOOP unit) on the Keowee underground path at less than rated voltage and frequency increasing. In this test, the Keowee units were initially shutdown. When the LOCA/LOOP occurs, Keowee emergency starts. The expected scenario for this test is as follows:

- A LOCA/LOOP occurs on Oconee Unit 3 and a LOOP occurs on Oconee Unit 1 at $t = 0$
- Unit 1 and 3 MFBs are energized with Unit 3 LOCA loads and Unit 1 LOOP loads at $t \approx$ 11 seconds.
- Unit 3, 3X4 loads at $t \approx 61$ seconds.

4.3.1 Test 3, Keowee Profile (V, I, KVA, KW, f)

Figures 4.3.1-1 through 6 plot the Keowee response to Test 3. In these plots, the time $t = 0$ is assigned to when the generator field flash voltage was detected (Emergency Start).

Figure 4.3.1-1 is a plot of the Keowee voltage and current response. Maximum current inrush is 1543 amperes rms. The inrush occurs at around 736 cycles (12.2 seconds) when the Unit 1 and Unit 3 MFBs are energized and lasts around 5 seconds. After the first large inrush, the current increases slightly again at around 1,052 cycles. A comparison of the Keowee frequency and current plot (Figure 4.3.1-5) with the various motor current curves shows this current increase is due to increased motor current during the transient above 60 Hz. The increased speed with a constant applied voltage causes reduced motor torque, which increases motor slip causing an increase in motor current. Additional inrushes occur at around 1696 cycles (28.3 seconds) and again at around 2,444 cycles (40.7 seconds) as the Unit 1 Reactor Building Cooling Fans transfer to high speed, and at around 3820 cycles (63.7 seconds) due to energizing the Unit 3X4 load center. These transients have no noticeable impact on the Keowee Unit 2 terminal voltage. Final steady state voltage was 13.833KV and current was approximately 341 amperes.

Figure 4.3.1-2 is a plot of the Keowee voltage during the inrush period. The voltage dips from 8.161KV (59.1%) to 7.621KV (55.2%) at 736 cycles (12.26 seconds) due to the inrush when the LOCA and LOOP units load. Voltage reaches its rated value 3.2 seconds after load was applied.

Figure 4.3.1-3 is a plot of the KVA output from Keowee. The maximum inrush is approximately 30,000 KVA. Steady state KVA loading is around 7,801 KVA.

Figure 4.3.1-4 is a plot of the KW output from Keowee. The maximum inrush is approximately 10,800 KW. The steady state load is 6,600 KW.

Plots are provided of the Keowee frequency response with unit current (Figure 4.3.1-5) and V/Hz Ratio (Figure 4.3.1-6). The frequency/current plot indicates load was applied to Keowee when frequency was around 43.67 Hz. Frequency increases to a steady state value of 59.37 hertz, which is approximately the speed-no-load setpoint.

The frequency and volts/hertz ratio (V/Hz) plot shows that the V/Hz ratio is about 0.7pu until 540 cycles (9 seconds), and increases at approximately a constant rate from 540 to 736 (12.3 seconds) cycles. At 12.3 seconds, the V/Hz ratio dips as the unit is loaded, and then recovers and increases with a steeper slope due to voltage regulator action. During the load start transient, the V/Hz ratio increases from 0.76 to 1.016. This has been identified as a test anomaly and is discussed in section 5.2.1 of this report.

Selected values are listed in the table below for quick reference:

Table 4- 5: Test 3, Summary of Keowee Response

Description	Time	Value
Keowee Unit 2 Field Flashed	0	
Unit Regulator In Automatic	12.0 seconds	
Voltage and Frequency just prior to loading		Frequency = 43.55 Hz Voltage = 6.161 KV
Unit 1 & 3 MFBs energized	12.3 seconds	Max. Current = 1543 Amps Min. Volts = 7.621 KV Max. KVA = 30,000 KVA Max. KW = 10,800 KW Frequency ≈ 43.67 Hz
Loadcenter 3X4 loads	63.8 seconds	
Steady state values		Current = 341 Amps Volts = 13.833 KV KVA = 7,801 KVA KW = 6,600 KW Frequency = 59.37 Hz

The Keowee power data reflects recorder tolerance bands which are magnified by bigger multiplication factors due to higher ratio PT's & CT's than the MFB load data. Thus, the sum total of MFB load in section 4.3.2 will provide a more reliable indication of actual Keowee load.

4.3.2 Test 3, MFB Profiles (V, I, KVA, KW)

Figures 4.3.2-1 and 2 are the plots of the Unit 1 MFB profiles. Figures 4.3.2-3 is a plot of the Standby Bus voltage and Unit 3 MFB current. Figure 4.3.2-4 is a plot of the Unit 3 loading. These plots were aligned so that t = 0 is the loss of voltage on Unit 1. A close examination of these plots shows that the units loaded essentially simultaneously. Since the standby bus voltage was monitored for the Unit 3 data, Figure 4.3.2-3 shows the standby bus being energized from Keowee prior to the MFBs being energized on any of the units.

Table 4- 6: Test 3, Summary of MFB Response

Description	Time	Value
Unit 1 MFB loses Voltage	0	
Unit 3 MFB loses voltage	.2 seconds	
Standby Bus Energized	12.8 seconds	
Unit 1 and 3 MFB load	13 seconds	Stdby Bus Min= 1.829 KV
Unit 1 MFB Steady state		Current = 404 Amps Volts = 4.233 KV KVA = 2,945 KVA KW = 2,449 KW
Unit 3 MFB Steady state		Current = 674 Amps Stdby Bus KV = 4.217 KV KVA = 4,907 KVA KW = 4,145 KW

4.3.3 Test 3, 4KV Motor Profiles (V, I, KVA, KW)

Figures 4.3.3-1 and 2 are the plots of the MDEFW 3B profile. Figures 4.3.3-3 and 4 are the plots of the HPI 3B profile. Figures 4.3.3-5 and 6 are the plots of the MDEFW 1A profile. Figures 4.3.3-7 and 8 are the plots of the LPSW 3B profile. Figures 4.3.3-9 and 10 are the plots of the LPI 3B profile. Figures 4.3.3-11 and 12 are the plots of the RBS 3B profile. Voltages are monitored at the 4.16KV switchgear level. Points from the motor feeder overcurrent relays for each motor are also plotted on figures showing current and voltage, and indicate a significant margin between motor starting and overcurrent relay tripping. On the motor plots an increase in current and load is seen after the motor has started which then declines to the steady state value. The increased current and load result from the Keowee overspeed transient above 60 hertz during startup.

4.3.4 Test 3, RBCU Fan 3B Motor Starting Profiles (V, I, KVA, KW)

Figures 4.3.4-1 and 2 plot the response of RBCU fan 3B when starting on low speed. During a LOCA, the fan will start and remain on low speed. Unit 3 was the LOCA unit during the test, so as expected the fan remained on low speed. There is a 1.7 second delay between when voltage was applied on the MCC until the fan started, which is consistent with motor starting after the voltage reaches the contactor pickup voltage.

4.3.5 Test 3, 600V Loadcenter Profiles (V, I, KVA, KW)

Figures 4.3.5-1 and 2 are the profiles for 1X5. After about a 2 second delay there is a significant increase in load, which is consistent with motor starting after the voltage reaches the contactor pickup voltage.

Figures 4.3.5-3 and 4 are the profiles for 1X6. After about a 2.5 second delay there is a significant increase in load, which is consistent with motor starting after the voltage reaches the contactor pickup voltage. About 9 seconds after energization, a battery charger loads.

Figures 4.3.5-5 and 6 are the profiles for 3X5. After about a 3 second delay there is a significant increase in load, which is consistent with motor starting after the voltage reaches the contactor pickup voltage. About 12 seconds after energization, a battery charger loads.

Figures 4.3.5-7 and 8 are the profiles for 3X6. The characteristics for 3X6 are very similar to profiles for 3X5.

Figures 4.3.5-9 and 10 are the profiles for 3X8. There is about a 2 second delay after energization before a significant load increase occurs. The loading at around 2 seconds after energization is a RBCU fan starting on low speed and other motor loads starting. At approximately 6 seconds after energization, the battery charger loads.

Figures 4.3.5-11 and 12 are the profiles for 3X9. There is an increase in loading 1 to 1.5 seconds after the loadcenter is energized as a RBCU fan starts on low speed and other motors start. Approximately 9 seconds after energization, a battery charger loads.

Figures 4.3.5-13 and 14 are profiles for 3X4. After an initial inrush, the load stabilizes at a low value (approximately 100KVA). Note these plots primarily represent the characteristics of the transformer and show the inrush during transformer energization which quickly decays off exponentially.

Figures 4.3.5-15 and 16 are profiles for the feeder to transformer CX. After about a 3 second delay there is an increase in load, which is consistent with motor starting after the voltage reaches the contactor pickup voltage. After about a 12 second delay, the loading characteristics of the battery chargers can be seen in Figure 4.3.5-15. Note that these plots primarily reflect the characteristics of the transformer.

6.7 Test 7, Conclusions

Test 7 successfully demonstrated the capability of the robust Keowee Unit to reject the loads on one Oconee unit and to successfully carry the remaining Oconee and Keowee loads. The voltage and frequency of Keowee and the connected load remained well within acceptable limits during this transient.

recovered to near rated value on the Keowee Unit in less than 3 seconds after load was applied. In this test, the 4KV motors started and reached steady state conditions well before the overcurrent relay actuate time as demonstrated by Figures 4.4.3-1 through 12. Voltage on the 600V MCCs 3XS1 and 3XS2 reached near steady state values in about 4 seconds and 3XS3 in around 7 seconds as illustrated in Figures 4.4.6-1 through 6. MOVs successfully started and completed stroke within the normal stroke time. Performance clearly demonstrates the capability of the system to start and supply the loads on a LOCA unit while handling the largest unscheduled load.

6.5 Test 5, Conclusions

Test 5 successfully demonstrated the capability of the Keowee Unit following a load rejection, Keowee underground path, and emergency power system to start the LOCA loads on an Oconee Unit and continued to supply these LOCA loads during the subsequent two LOOP unit loading. Voltage recovered to near rated value on the Keowee Unit in less than 2.5 seconds after the first load transient of the LOCA loads. This test also demonstrated the capability to simultaneously start and supply the loads of two LOOP units following the LOCA. Following this second load transient, voltage recovered to approximately rated value on the Keowee Unit in less than 2.5 seconds after the two unit LOOP loads were applied. In this test, the 4KV motors started and reached steady state conditions well before the overcurrent relay actuate time as demonstrated by Figures 4.5.3-1 through 12. Voltage on the 600V MCCs 3XS1 and 3XS2 reached near steady state values in around 2.5 seconds, and 3XS3 in around 6 seconds as illustrated in Figures 4.5.6-1 through 6. MOVs successfully started and completed stroke within the normal stroke time. It should be noted that loading of the LOOP units following the LOCA loading did not cause loads on the LOCA unit to dropout. The LOCA loads continued to perform their function during the second loading transient. Performance clearly demonstrates the capability of the system to start and supply the loads on a LOCA unit, and then simultaneously start and supply the loads of two LOOP units.

6.6 Test 6, Conclusions

Test 6 successfully demonstrated the capability of a Lee CT, transmission circuit from Lee to Oconee, and emergency power system to start and supply the LOCA loads on an Oconee Unit. The test also demonstrates the capability to simultaneously start and supply the load of two LOOP units following the LOCA loading. Voltage recovered to near rated value on the Lee Unit in less than 1 second after the LOCA load was applied. In this test, the 4KV motors started and reached steady state conditions well before the overcurrent relay actuate time as demonstrated by Figures 4.6.3-1 through 12. Voltage on the 600V MCCs 3XS1 and 3XS2 reached near steady state values in around 2.5 seconds and MCC 3XS3 in around 6.5 seconds as illustrated in Figures 4.6.6-1 through 6. MOVs successfully started and completed stroke within the normal stroke time. Loading of the LOOP units did not cause loads on the LOCA unit to drop out and then restart. Performance clearly demonstrates the capability of the system to start and supply the loads on a LOCA unit and then simultaneously start and supply the loads of two LOOP units. Performance when supplied from Lee was very similar to that obtained in Test 5 when supplied from Keowee.

6. Conclusion

6.1 Test 1, Conclusions

Test 1 successfully demonstrated the capability of the Keowee Unit, the Keowee underground path and the emergency power system to start and supply the LOOP loads on three Oconee units simultaneously. Voltage recovered to near rated value on the Keowee Unit in less than 3 seconds after the LOOP loads were applied. In this test, the 4 KV motors started and reached steady state well before the overcurrent relay actuate time as demonstrated by Figures 4.1.3-1 through 4. Voltage on the 600V MCCs reached near steady state values in around 4 seconds as illustrated in Figures 4.1.6-1 through 6. System performance was clearly satisfactory.

6.2 Test 2, Conclusions

Test 2 successfully demonstrated the capability of a Keowee Unit on load rejection, the Keowee overhead path and the emergency power system to start and supply the LOOP loads on three Oconee units simultaneously. Voltage recovered to near rated value on the Keowee Unit in less than 2.5 seconds after the LOOP loads were applied. In this test, the 4 KV motors started and reached steady state well before the overcurrent relay actuate time as demonstrated by Figures 4.2.3-1 through 8. Voltage on the 600V MCCs reached near steady state values in less than 2 to 3 seconds as illustrated in Figures 4.2.6-1 through 6. Comparing Test 1, the underground circuit, and Test 2, the overhead circuit; it can be seen that the overhead circuit results in less voltage drop between the Keowee source and the load terminals. This results in some better performance in load starting times and voltage recovery.

6.3 Test 3, Conclusions

Test 3 successfully demonstrated the capability of an accelerating Keowee Unit while, Keowee underground path, and emergency power system to start and simultaneously supply the LOCA loads on one Oconee Unit and the LOOP loads on another Oconee unit. Voltage reached rated value on the Keowee Unit in about 3.2 seconds after the loads were applied. In this test, the 4KV motors started and reached steady state conditions well before the overcurrent relay actuate time as demonstrated by Figures 4.3.3-1 through 12. Voltage on the 600V MCCs 3XS1 and 3XS2 reached near steady state values in around 5 seconds and MCC 3XS3 in around 10 seconds as illustrated in Figures 4.3.6-1 through 6. MOVs successfully started and completed their strokes within the normal stroke time. Performance clearly demonstrates the capability of the system to start and supply the loads on a LOCA unit while handling the worst case unscheduled load.

6.4 Test 4, Conclusions

Test 4 successfully demonstrated the capability of the Keowee Unit following load rejection, Keowee underground path, and emergency power system to start and simultaneously supply the LOCA loads on one Oconee Unit and the LOOP loads on another Oconee unit. Voltage

signal and simulating the LOOP did not cause any problems with the test execution. Two plots of MCC voltage and MOV current detailing this sequence the MOV starting as the voltage decays away are included in Appendix 3 as Figure 4.3.9-1 and 4.3.9-2. These two plots are included as representative plots for each of the HPI valves during each of the ES tests.

The Keowee auxiliary control scheme will trip ACB-8 if voltage is lost for 4 seconds. The logic uses ACB-4 being closed as an input to determine if Unit 2 is the "underground" or "overhead" unit. With the implementation of nuclear station modification (NSM) ON-52966, the Keowee Unit 2 underground feeder breaker, ACB-4, is tripped on an emergency start actuation if the unit was generating to the grid. With ACB-4 tripped, the auxiliary breaker control system now thinks Unit 2 is the pre-selected overhead unit. Thus, ACB-6 closed as designed since power was available from transformer 2X (backup source) on the Keowee 13.8KV bus during this test scenario. If this were are real LOCA/LOOP DBA with the Keowee units generating to the grid, ACB-8 would have reclosed to supply the Unit 2 Keowee auxiliaries. This anomaly occurred as a result of the test's simulation of a LOOP. If auxiliary power had not been available from the backup source, ACB-8 would have reclosed after ACB-4 re-energized the underground path and transformer CX.

5.2.3 600VAC MCC 3XS3 Voltage Inconsistencies

Test monitoring equipment checks prior to Test 5 revealed a bad voltage connection probe on the MCC 3XS3 recorder. From the Test 4 data, it was determined that this connection failed in the middle of Test 4. This failure only affected one of the two voltage probes connected to MCC 3XS3, and the Test 4 data for this MCC is from the good probe only.

5.2.4 MOV 3LP-17

Motor Operated Valve 3LP-17, which is a gate valve, briefly stalled while starting following contactor pickup during Tests 4, 5 and 6. The stall times were approximately 1.0, 1.0,and 0.4 seconds respectively for the three tests. The valve recovered in each case and completed its stroke to its proper ES position. Following inrush the valve stroke was normal. Normal valve hammerblow and unwedging were observed following inrush. The short stall duration did not affect the valve's performance and no degradation was noticed during the valve post static and functional testing.

5.2.5 HPI MOVs Receive Start Signal Prior to Loss of Power

During the execution of this test the engineered safeguards (ES) actuation and simulated LOOP actuation was performed manually via a countdown method. At the count down mark, Control Room Operators actuated ES channels 1 & 2 along with tripping the switchyard PCBs feeding the unit startup transformers. The remaining ES channels were actuated within the next few seconds while the emergency power source were starting or aligning to the Oconee units. One of the systems actuated by ES channels 1 & 2 is the HPI system.

From review of the MOV data, it was noticed that the HPI valves monitored actually received a start signal before offsite power was removed. Thus the ES signal to the valves was slightly quicker than the simulated LOOP. This occurrence, although not planned, had no impact (positive or negative) on the operation of these valves. Normal starting, including hammerblow and unwedging where applicable, were evident in the valve strokes following reenergization from the emergency onsite power source.

It is worth mentioning that this testing resulted in a sequence of events for these HPI valves which is similar to a LOCA followed by LOOP scenario. This sequence of actuating the ES

5.1.4 Load Center 1X7 Failed To Reenergize During Test 3

During Test 3, load center 1X7 failed to reenergize as expected. This was determined to be a test procedure problem, because only 1 channel of load shed for Unit 1 was initiated per the procedure. The control logic for transformer 1X7 is such that "one" channel of load shed will cause a trip of the load center, but "both" channels of load shed are required to satisfy the automatic re-close logic. The logic functioned exactly as designed for this situation. The procedure was revised to include both channels of load shed initiation, and the load center operated as expected in later tests.

5.2 Test Data Review

5.2.1 Keowee V/Hz During Test 3

In Test 3, during the emergency start acceleration of Keowee to rated voltage and frequency, the V/Hz ratio increased from 0.76 to 1.02, but never reached 1.05. The reason for this is two fold:

First, to provide for the black start capability, the source of power for the Keowee exciter bridge in the voltage regulator is from the Keowee generator output voltage instead of from an auxiliary constant voltage source. Since generator voltage is building up as the machine accelerates, and dips when the unit is loaded, potential energy available to the exciter varies with the generator output voltage.

Second, the Westinghouse type WTA voltage regulator system at Keowee uses a "Base" manual control system instead of a "DC Error Detector" system. The Base system provides a constant firing angle determined by the base adjuster preset position, where the DC Error detector system will adjust the firing angle based on field voltage or current. Thus, with the Base system, less excitation energy is available during unit startup than would be available from a DC Error Detector system.

These two factors limit the energy available to drive the unit into an over-voltage condition where the V/Hz limiter would take control to maintain a constant (1.05) V/Hz ratio during startup. It is important to note that even with a volts/hertz ratio initially lower than 1.0 pu, the robust system successfully started and accelerated the loads.

5.2.2 Keowee Auxiliaries Did Not Load Back Onto CX During Test 4.

The Keowee auxiliary breaker control scheme allows the auxiliaries to be supplied from their normal source unless power is lost from the normal source for longer than 34 seconds. If the normal source is not available after 34 seconds, the auxiliaries then transfer to the backup source. In Test 4, the underground Keowee unit's auxiliaries (Unit 2) were supplied through ACB-8. ACB-8 opened as expected on loss of voltage as a result of the Oconee Unit 1 LOOP. During Test 4, power was lost at the ACB-8 feeder (CX transformer primary) for 18 seconds. Thus, ACB-8 should have reclosed, however the CX transformer data (feeder to ACB-8) shows no load on the transformer after voltage recovers. The Unit 2 Keowee auxiliary loads transferred to receive power from their backup source, Transformer 2X.

5. Anomalies or Notable Points

The following is a summary of items noticed during the performance of the test and review of data collected from this test .

5.1 Test Execution

5.1.1 3A CC Pump Failure During Test 1

Investigation of the failure identified a blown motor control power transformer (CPT) secondary fuse. The fuse was undersized for the application and was replaced. The 3A CC pump performed satisfactorily for the remaining tests. Refer to section 3.2.4.1 of this report for additional information.

5.1.2 LOOP Unit (1C and 2A) RBCU Fans Trip on Restart and Transfer to High Speed

Units 1 & 2 experienced trips of Reactor Building Cooling Unit (RBCU) fan motors as follows;

- Test 1 - 2A RBCU Tripped
- Test 2 - 2A RBCU Tripped
- Test 3 - 1C RBCU Tripped
- Test 4 - 1C RBCU Tripped
- Test 5- 1B & 2A RBCU Tripped
- Test 6 - 1C & 2A RBCU Tripped

The potential for the RBCU fans to not restart following a LOOP was noted in advance in the test procedure and previously documented in problem investigation process (PIP) # 3-O96-0528. This problem only occurs when the RBCU is restarted, and then transferred to high speed with insufficient time for the starter thermal overload unit to cool down. This problem does not occur during normal or emergency (LOCA) operation. Since the RBCUs did start and run for a period of time, their load was present during the critical times from an electrical systems performance perspective. PIP # 2-O97-0044 was initiated to document the occurrences of these motor trips during these tests.

5.1.3 1C LPI 50G Relay Tripped Indicating Light

A tripped indicating light was received in Tests 2 through 6 on the non-safety LPI 1C motor feeder 50G relay. LPI 1C was not in service during any of the tests. The investigations determined this indication was actuating when the load shed signal was reset during post test plant recovery. It was determined that the problem was caused by the lack of a transient suppressor for several relays in the DC control circuit. This problem did not impact the operation of the LPI 1C pump. The pump would have been available if needed. Other breaker circuits were reviewed and no other similar problems were noted. PIP 1-O97-0050 was written to track resolution of this problem.

4.7.2 Test 7, MFB Profiles (V, I, KVA, KW)

Figures 4.7.2-1 and 2 are the plots of the Unit 1 MFB profiles for Test 7. Test values are summarized below

Table 4- 13: Test 7, Summary of Keowee and Unit 1 MFB Response

Description	Time	Value
Keowee Steady State before load was dropped		Current = 820 Amps Volts = 14.000 KV KVA = 19,800 KVA KW = 13,800 KW Frequency = 60.85 Hertz
Keowee Steady State after load was dropped		Current = 420 Amps Volts = 14.060 KV KVA = 10,200 KVA KW = 7,200 KW Frequency = 60.85 Hertz
Unit 1 MFB before load was dropped		Current = 1331 Amps Volts = 4.010 KV KVA = 9,240 KVA KW = 6,900 KW
Unit 1 MFB Steady state after load was dropped		Current = 1330 Amps Volts = 4.220 KV KVA = 9,720 KVA KW = 7,020 KW

The load increases slightly on the Unit 1 MFB after dropping the other MFB because the increased bus voltage will result in reduced motor slip.

4.7 Test 7, Post-Accident Keowee Partial Loss of Load

This test drops a large block of load from Keowee while Keowee is at relatively low load (≈ 20MVA) and disconnected from the system grid. The test demonstrate Keowee's ability to reject part of its load while continuing to provide power within acceptable limits to the remaining connected loads. This test was performed during recovery from Test 5 and data from this test was recorded from Keowee and the Oconee Unit 1 MFB.

4.7.1 Test 7, Keowee Profile (V, I, KVA, KW, f)

Figures 4.7.1-1 through 4 plot the Keowee response to Test 7. In these plots, t = 0, is 300 cycles (5 seconds) before the partial load is dropped from Keowee.

Figure 4.7.1-1 plots the voltage and current response at Keowee. The average initial voltage was 14,000 volts. When the load was dropped, (from around 820 to 420 amperes), the voltage increased momentarily to around 14,173 volts then stabilized to around 14,060 volts

Figure 4.7.1-2 plots the Keowee output KVA. The initial KVA was 19,800. At 300 cycles, 9,600 KVA of load (48.5% decrease) was dropped off resulting in a final running load of 10,200 KVA.

Figure 4.7.1-3 plots the Keowee output KW. The initial KW was 13,800. 6,600 KW load was dropped instantaneously resulting in a final running load of 7200 KW.

Figure 4.7.1-4 plots the Keowee Unit 2 frequency. The initial frequency was around 60.85 Hz before the load was dropped. When the load was dropped, the frequency increased and peaked at 62.3 Hz (2.4% increase) at 595 cycles. The frequency transient lasted about 10 seconds and the steady state frequency returned to a value of 60.85 Hz.

interrupted by this loading transient and the stroke time was compatible with the calculated and previous diagnostics test values. Hammerblow effect is not applicable to the design and unwedging is not applicable to this test.

4.6.9.9 Test 6, 3LPSW-565

Figures 4.6.9.9 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-565 during Test 6. The valve started and moved to its ES position properly during this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading transient and the stroke time was compatible with the calculated and previous diagnostics test values. Hammerblow effect is not applicable to the design and unwedging is not applicable to this test.

4.6.9.10 Test 6, 3HP-4

Figures 4.6.9.10 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-4 during Test 6. The valve started and moved to its ES position properly during this test. Hammerblow effect is not applicable to the design and unwedging is not applicable to this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading and the stroke time was compatible with the calculated and previous VOTES test values.

4.6.9.11 Test 6, 3HP-20

Figures 4.6.9.11 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-20 during Test 6. The valve started and moved to its ES position properly during this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading and the stroke time was compatible with the calculated and previous VOTES test values. Hammerblow effect is not applicable to the design and unwedging is not applicable to this test.

was observed following inrush. Unwedging is not applicable to this double disc gate valve design. The stroke time was compatible with the calculated and previous VOTES test values.

4.6.9.4 Test 6, 3BS-2

Figures 4.6.9.4 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3BS-2 during Test 6. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. After the bus is reenergized at the contactor pickup point, a contactor transient is observed as the voltage increases. This is evident from the voltage and current plots. Normal hammerblow and valve unwedging was observed for this stroke.

4.6.9.5 Test 6, 3HP-27

Figures 4.6.9.5 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-27 during Test 6. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unwedging are not applicable to this valve design.

4.6.9.6 Test 6, 3LPSW-24

Figures 4.6.9.6 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-24 during Test 6. The valve started from an intermediate (throttled) position and moved to its ES position properly during this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading transient. Hammerblow is not applicable to this no lost motion actuator design.

4.6.9.7 Test 6, 3PR-19

Figures 4.6.9.7 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3PR-19 during Test 6. The valve started and moved to its ES position properly during this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading transient and the stroke time was compatible with the calculated and previous diagnostics test values. Normal unseating was observed for this valve stroke and hammerblow is not applicable to this actuator design.

4.6.9.8 Test 6, 3LPSW-6

Figures 4.6.9.8 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-6 during Test 6. The valve started and moved to its ES position properly during this test. After the bus is reenergized at the contactor pickup point, a contactor transient is observed. This is evident from the voltage and current plots. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not

Table 4.6.9 - Test 6, Summary of MOV Results						
Unit 3 MOVs	MCC Source	MCC Voltage at Contactor Pickup (% rated MCC V)	MCC Voltage at MOV peak Inrush (% rated MCC V)	MOV Inrush Duration (sec.)	Time for Voltage to reach 100% (sec.)	MOV Stroke Time (sec.)
HP-024	208-3XS1	71.5%	70.4%	0.238	2.36	12.91
HP-026	208-3XS1	65.0%	66.2%	0.446	2.39	12.76
LP-017	600-3XS1	78.5%	78.6%	0.391	2.59	8.82
BS-002	208-3XS2	65.5%	64.6%	0.12	2.62	12.32
HP-027	208-3XS2	64.3%	63.1%	0.303	2.58	12.33
LPSW-024	208-3XS2	71.7%	71.3%	0.178	2.58	26.98
PR-019	208-3XS2	73.9%	73.4%	0.093	2.61	59.2
LPSW-006	208-3XS3	67.5%	66.8%	0.207	6.58	57.07
LPSW-565	600-3XS3	66.8%	66.3%	0.162	6.58	52.36
HP-004	208-3XSF	73.0%	71.9%	0.111	2.41	28.45
HP-020	208-3XSF-A	70.8%	69.9%	0.138	2.41	28.96

4.6.9.1 Test 6, 3HP-24

Figures 4.6.9.1 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-24 during Test 6. The valve started and moved to its ES position properly during this test. Normal unwedging was observed. Hammerblow is not applicable to this no lost motion actuator design. The stroke time was compatible with the calculated and previous VOTES test values. From the voltage and current plots, note this valve completed its stroke just prior to the loading transient of the Units 1 and 2 LOOP loads.

4.6.9.2 Test 6, 3HP-26

Figures 4.6.9.2 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-26 during Test 6. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unwedging are not applicable to this valve design. After the bus is reenergized at the contactor pickup point, a contactor transient is observed as the voltage increases. This is evident from the voltage and current plots. From the voltage and current plots, note this valve completed its stroke just prior to the loading transient of the Units 1 and 2 LOOP loads.

4.6.9.3 Test 6, 3LP-17

Figures 4.6.9.3 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LP-17. The valve started and moved to its ES position during this test. After the bus is reenergized at the contactor pickup point, a contactor transient is observed. This MOV stalls for approximately 0.40 seconds following contactor pickup, however normal hammerblow

4.6.7 Test 6, 208V Safety MCC Profiles (V, I, KVA, KW)

Figures 4.6.7-1 through 4.6.7-6 chart the voltage, current, KVA and KW profiles for the 208V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increase at energization due to MOVs starting is almost immediate and of short duration. The LOOP units loading causes a momentary dip in the MCC load. Minimum voltage after MCC energization is 133 volts (63.9 %) and occurs on 208V MCCs 3XS2. The minimum steady state voltage occurs on 3XS2 and is 207V. The momentary current spike seen on 208V MCCs 3XS1 and 3XS2 at loss on voltage is due to the channel 1 and 2 (HPI) MOVs receiving a start signal prior to the actual loss of power to the MCC's.

4.6.8 Test 6, Battery Charger 3CA (V, I)

Figure 4.6.8-1 charts the voltage and current for Battery Charger 3CA. Note that the charger current characteristic mirrors that seen at the MCC and loadcenter levels. Charger supply voltage is monitored at the MCC.

4.6.9 Test 6, Motor Operated Valves (V, I, KW)

Table 4.6.9 below summarizes the MOV data for Test 6. During this test each engineered safeguards MOV started and stroked to its proper ES position. For each MOV there is a time delay (≈ 0.040 - 2.75 seconds) following reenergization of the MCC buses prior to the individual MOV contactor pickup. This detail can be seen in the voltage and current plots for each valve. The sections following the summary table provide specific details for each of the monitored MOVs for this test.

After the bus is reenergized at the contactor pickup point, a contactor transient for four MOVs (3HP-26, 3LP-17, 3BS-2, and 3LPSW-6)is observed as the voltage increases. The current transient usually occurs so quickly (≈ 1-3 cycles) that the contactor does not drop out. For this test 3HP-26 is an exception. Its contactor pickup transient is ≈ 30 cycles which is longer that the others. This transient, although it has negligible impact on the valve's performance, is worth mentioning to help explain the current decreases and increases during the applicable MOVs inrush period.

4.6.5 Test 6, 600V Loadcenter Profiles (V, I, KVA, KW)

Figures 4.6.5-1 and 2 are the profiles for 1X5. Loads started simultaneous with loadcenter energization.

Figures 4.6.5-3 and 4 are the profiles for 1X6. Load pickup was almost simultaneous with loadcenter energization. About 6 seconds after energization, a battery charger loads.

Data was not collected for 3X5 in Test 6 due to a recorder programming error. The loss of this data would not have adversely impacted any test acceptance criteria, and thus this problem is not significant.

Figures 4.6.5-5 and 6 are the profiles for 3X6. After about a 1 second delay, there is a significant increase in load, which is consistent with motors starting after the voltage reaches contactor pickup voltage. A battery charger loads after about a 9 second delay.

Figures 4.6.5-7 and 8 are the profiles for 3X8. The loading at around 1 seconds after energization is a RBCU fan starting on low speed and other motor loads starting. Approximately 4 seconds after energization, the battery charger loads. Loading of the LOOP units causes a short dip in the loadcenter amperes. A similar dip in load amperes was seen in the charger profile (See section 4.6.8).

Figures 4.6.5-9 and 10 are the profiles for 3X9. There is an increase in loading about 1 second after the loadcenter is energized as a RBCU fan starts on low speed and other motors start. Approximately 6 seconds after energization, a battery charger loads. Loading of the LOOP units causes a momentary dip in the loadcenter ampere load.

The time delay in load increases on some buses due to the power battery charger restarting is expected. The chargers are designed with an automatic time delay in the startup of the charger.

4.6.6 Test 6, 600V Safety MCC Profiles (V, I, KVA, KW)

Figures 4.6.6-1 through 4.6.6-6 chart the voltage, current, KVA and KW profiles for the 600V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increases immediately at energization on 3XS1 and 3XS2. The load on 3XS3 increases approximately .9 seconds after energization as RBCU fan 3B starts. A significant increase in loading occurs after about 4 to 6 seconds on 3XS1 and 3XS2 when the battery chargers load. Note that the charger loading has negligible impact on MCC voltage. Loading of the LOOP units causes a short decrease in MCC load amperes. Minimum voltage after MCC energization is 396 volts (66.0 %) and occurs on 600V MCC 3XS1. The minimum steady state voltage MCC voltage is 590V (98.3% of 600V) and occurs on 3XS1. Voltage recovers to near the steady state value in 2.5 seconds on 3XS1 and 3XS2. Voltage recovery on 3XS3 takes 6 seconds since the RBCU fan is starting.

Figures 4.6.2-1 and 2 are the plots of the Unit 1 MFB profiles. Figures 4.6.2-3 and 4 are the plots of the Unit 2 MFB profiles. Figures 4.6.2-5 is a plot of the Standby Bus voltage and Unit 3 MFB current. Figure 4.6.2-6 is a plot of the Unit 3 loading. A close examination of the plots show that Unit 3 loaded first. Unit 2 loaded second and Unit 1 loaded approximately 1 second later.

Table 4- 12: Test 6, Summary of MFB Response

Description	Time	Value
Unit 1, 2 and 3 MFBs lose Voltage	-.1 seconds	
Unit 3 MFB loads	12.6 seconds	
Unit 2 MFB loads	31.5 seconds	
Unit 1 MFB loads	32.5 seconds	
Unit 1 MFB Steady state		Current = 407 Amps Volts = 4.227 KV KVA = 2,966 KVA KW = 2,443 KW
Unit 2 MFB Steady state		Current = 364 Amps Volts = 4.227 KV KVA = 2,644 KVA KW = 2,236 KW
Unit 3 MFB Steady state		Current = 672 Amps Stdby Bus KV = 4.211 KV KVA = 4,875 KVA KW = 4,130 KW

4.6.3 Test 6, 4KV Motor Profiles (V, I, KVA, KW)

Figures 4.6.3-1 and 2 are the plots of the MDEFW 3B profile. Figures 4.6.3-3 and 4 are the plots of the HPI 3B profile. Figures 4.6.3-5 and 6 are the plots of the MDEFW 1A profile. Figures 4.6.3-7 and 8 are the plots of the LPSW 3B profile. Figures 4.6.3-9 and 10 are the plots of the LPI 3B profile. Figures 4.6.3-11 and 12 are the plots of the RBS 3B profile. Voltages are monitored at the 4.16KV switchgear level. Points from the motor feeder overcurrent relays for each motor are also plotted on figures showing current and voltage and indicate a significant margin between motor starting and overcurrent relay tripping.

4.6.4 Test 6, RBCU Fan 3B Motor Starting Profiles (V, I, KVA, KW)

Figures 4.6.4-1 and 2 plot the response of RBCU fan 3B starting on the LOCA unit. During a LOCA, the RBC fans should start and run on low speed, and the RBCU fan 3B functioned as expected.

Figure 4.6.1-4 is a plot of the KW output from Lee. Just before Oconee Unit 3 loads , the Lee CT auxiliary load was approximately 3120 KW. The maximum inrush when the Unit 3 LOCA loads are connected is 11,040 KW with a steady state LOCA load of around 7,200 KW. The maximum inrush of 14,400 KW occurs after the Unit 1 and Unit 2 LOOP loads. Once all loads are operating, steady state load is around 11,400 KW

Figure 4.6.1-5 and 6 are plots of the frequency response of the Lee unit. A plot of the Lee current is also included on Figure 4.6.1-5 to indicate when load was applied to Lee. The initial Lee speed before loading was 60.4 hertz. Minimum frequency during loading was around 59.3 hertz at 4147 cycles (69.1 seconds). Due to governor speed droop, frequency recovers to ~59.4 hertz.

The results of the Lee response to Test 6 is summarized below:

Table 4- 11: Test 6, Summary of Lee Profiles

Description	Time	Value
Unit 3 MFB loss of Voltage	-0.1 seconds	
Initial Lee Load		3,120 KW
Initial Lee Frequency	0	60.4 Hz
Unit 3 MFB energized	12.6 seconds	Max. Current = 1243 Amps Min. Volts = 12.474 KV Max. KVA = 30,713 KVA Max. KW = 11,040 KW
First LOOP unit loads	31.5 seconds	Max. Current = 925 Amps Min. Volts = 13.278 KV Max. KVA = 22,320 KVA Max. KW = 12,000 KW
Second LOOP unit loads	32.5 seconds	Max. Current = 1244 Amps Min. Volts = 13.986 KV Max. KVA = 30,720 KVA Max. KW = 14,400 KW
Min. freq. After loading	69.1 seconds	59.3 Hz
Steady state values		Current = 552 Amps Volts = 14.324 KV KVA = 13,673 KVA KW = 11,954 KW Frequency = 59.4 Hz

4.6.2 Test 6, MFB Profiles (V, I, KVA, KW)

4.6 Test 6, LOCA/LOOP with Neither Keowee Unit Available (i.e., Lee CT as Source)

This test represents the largest cumulative load automatically applied to the Lee Combustion Turbine (CT). The LOCA (Unit 3) unit was loaded at rated voltage and frequency. The two LOOP units (Units 1 and 2) loaded approximately 20 seconds later. Finally the non-safety, non-loadshed loadcenters on the LOOP only units load about 30 seconds after the second load transient. The expected scenario for this test is listed below:

- Oconee Unit 3 LOCA and Unit 1 and 2 LOOP at t=0 seconds
- Oconee 3 MFB loads onto Lee at t ≈ 11 seconds
- Units 1 and 2 load onto Lee at t ≈ 31 seconds
- Unit 3 loadcenter 3X4 loads at t ≈ 61 seconds
- Units 1, 2 and 3 loadcenters 1X5, 1X6, 2X5, and 2X6 load at t ≈ 61 seconds
- Unit 1 Loadcenter 1X7 and Unit 2 Loadcenter 2X4 load at t ≈ 81seconds

In all plots for this test, Time t = 0, is assigned to 6 cycles after the power source was lost from the Unit 3 MFB on LOOP and ES actuation.

4.6.1 Test 6, Lee Profile (V, I, KVA, KW, f)

Figures 4.6.1-1 through 6 plot the Lee response to Test 6. Figure 4.6.1-1 is a plot of the Lee voltage and current response. Unit 3 LOCA loads connect to Lee at around 757 cycles (12.6 seconds). Maximum inrush current was 1243 amperes. The first LOOP loads at around 1889 cycles (31.5 seconds) followed by the other LOOP unit at 1952 cycles (32.5 seconds) Maximum current inrush is 1244 amperes rms. At around 2400 cycles (49.7 seconds) a RBCU fan transfers to high speed. Starting at around 2600 cycles through 4200 cycles additional loads are connected which includes RBCU fan transfers to high speed and loading of the X5 and X6 load centers on Units 1 and 2. Loadcenters 1X7 and 2X4 load about 1 second apart starting at 4950 cycles. Steady state current is around 552 amperes.

Figure 4.6.1-2 is a plot of the Lee voltage during the main inrush periods. Generator voltage dips to 12.474KV (90.4 % of rated) during the Unit 3 load inrush at 766 cycles (12.8 seconds), and recovers back to nominal in less than 1 second. When Units 1 and 2 load, the voltage dips to 13.278KV (96.2%) at 1899 cycles (31.65 seconds). Generator voltage overshoots during recovery, and stabilizes near the initial steady state value.

Figure 4.6.1-3 is a plot of the KVA output from Lee. Just before Oconee Unit 3 loads, the Lee CT was supplying it's own auxiliary loads equal to around 3,120 KVA. During Unit 3 LOCA loading, the maximum load is around 30, 713 KVA. Steady state LOCA loading was around 8,000 KVA. During LOOP unit loading, the maximum load was 30,720 KVA. The total steady state load is around 13,000 KVA

4.5.9.8 Test 5, 3LPSW-6

Figures 4.5.9.8 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-6 during test 5. The valve started and moved to its ES position properly during this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading transient and the stroke time was compatible with the calculated and previous diagnostics test values.

4.5.9.9 Test 5, 3LPSW-565

Figures 4.5.9.9 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-565. The valve started and moved to its ES position properly during this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading transient and the stroke time was compatible with the calculated and previous diagnostics test values. Hammerblow effect and unwedging are not applicable to this valve design.

4.5.9.10 Test 5, 3HP-4

Figures 4.5.9.10 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-4 during test 5. The valve started and moved to its ES position properly during this test. Hammerblow effect is not applicable to the design and unwedging is not applicable to this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading and the stroke time was compatible with the calculated and previous VOTES test values.

4.5.9.11 Test 5, 3HP-20

Figures 4.5.9.11 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-20 during test 5. The valve started and moved to its ES position properly during this test. Hammerblow effect is not applicable to the design and unwedging is not applicable to this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading and the stroke time was compatible with the calculated and previous VOTES test values.

current plots, note this valve completed its stroke just prior to the loading transient of the Units 1 and 2 LOOP loads.

4.5.9.3 Test 5, 3LP-17

Figures 4.5.9.3 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LP-17. The valve started and moved to its ES position properly during this test. After the bus is reenergized at the contactor pickup point, a contactor transient is observed. This MOV stalls for approximately 1 second following contactor pickup, however normal hammerblow was observed following inrush. Unwedging is not applicable to this double disc gate valve design. The stroke time was compatible with the calculated and previous VOTES test values.

4.5.9.4 Test 5, 3BS-2

Figures 4.5.9.4 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3BS-2 during test 5. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Normal hammerblow and valve unwedging was observed during this valve stroke. This valve completed its stroke just prior to the loading transient of the Units 1 and 2 LOOP loads.

4.5.9.5 Test 5, 3HP-27

Figures 4.5.9.5 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-27 during test 5. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unwedging are not applicable to this valve design (i.e. no lost motion glove valve).

4.5.9.6 Test 5, 3LPSW-24

Figures 4.5.9.6 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-24 during test 5. The valve started from an intermediate (throttled) position and moved to its ES position properly during this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading transient. Hammerblow is not applicable to this no lost motion actuator design.

4.5.9.7 Test 5, 3PR-19

Figures 4.5.9.7 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3PR-19during test 5. The valve started and moved to its ES position properly during this test. During mid-stroke of this valve a voltage transient, as a result of the Units 1 & 2 LOOP loading, was observed. The voltage dipped approximately 25% prior to recovering back to normal. The valve stroke was not interrupted by this loading transient. The stroke time was compatible with the calculated and previous diagnostics test values. Normal unseating was observed for this valve stroke and hammerblow is not applicable to this design.

each valve. The sections following the summary table, provide specific details for each of the monitored MOVs for this test.

After the bus is reenergized at the contactor pickup point, a contactor transient for 3LP-17 is observed as the voltage increases. The current transient occurs so quickly (≈ 3 cycles) that the contactor does not drop out. This transient, although it has negligible impact on the valve's performance, is worth mentioning to help explain the current decreases and increases during the applicable MOVs inrush.

Table 4.5.9 - Test 5, Summary of MOV Results

Unit 3 MOVs	MCC Source	MCC Voltage at Contactor Pickup (% rated MCC V)	MCC Voltage at MOV peak Inrush (% rated MCC V)	MOV Inrush Duration (sec.)	Time for Voltage to reach 100% (sec.)	MOV Stroke Time (sec.)
HP-024	208-3XS1	77.3%	76.6%	0.219	2.66	13.01
HP-026	208-3XS1	74.2%	74.2%	0.235	2.5	12.73
LP-017	600-3XS1	77.6%	77.5%	1.112	2.6	9.58
BS-002	208-3XS2	73.4%	72.0%	0.091	2.66	12.38
HP-027	208-3XS2	73.5%	75.9%	0.391	2.61	12.37
LPSW-024	208-3XS2	77.1%	77.5%	0.166	2.56	29.51
PR-019	208-3XS2	76.6%	78.7%	0.096	2.63	59.19
LPSW-006	208-3XS3	77.8%	78.7%	0.13	5.97	57.04
LPSW-565	600-3XS3	77.3%	77.6%	0.118	6.08	52.37
HP-004	208-3XSF	74.5%	73.9%	0.099	2.55	28.56
HP-020	208-3XSF-A	75.2%	75.0%	0.161	2.49	29.17

4.5.9.1 Test 5, 3HP-24

Figures 4.5.9.1 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-24 during test 5. The valve started and moved to its ES position properly during this test. Normal unwedging was observed during this stroke. Hammerblow is not applicable to this no lost motion actuator design. The stroke time was compatible with the calculated and previous VOTES test values. From the voltage and current plots, note this valve completed its stroke just prior to the loading transient of the Units 1 and 2 LOOP loads.

4.5.9.2 Test 5, 3HP-26

Figures 4.5.9.2 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-26 during test 5. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unwedging are not applicable to this valve design. From the voltage and

Figures 4.5.6-1 through 4.5.6-6 chart the voltage, current, KVA and KW profiles for the 600V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increases immediately at energization. A significant increase in loading occurs after about 5 seconds on 3XS1 and 3XS2 when the battery chargers load. Note that the charger loading has negligible impact on MCC voltage. Starting of RBCU fan 3B on low speed can be clearly seen in the figures for 3XS3. Loading of the LOOP units causes a short decrease in MCC load amperes. Minimum voltage after MCC energization is 431 volts (71.8 %) and occurs on 600V MCC 3XS3. The minimum steady state voltage MCC voltage is 592V (98.7% of 600V) and occurs on 3XS1. Voltage recovers to near the steady state value in 2.5 seconds on 3XS1 and 3XS2. Voltage recovery on 3XS3 takes 6 seconds since the RBCU fan is starting.

4.5.7 Test 5, 208V Safety MCC Profiles (V, I, KVA, KW)

Figures 4.5.7-1 through 4.5.7-6 chart the voltage, current, KVA and KW profiles for the 208V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increase at energization due to MOVs starting is immediate and of short duration. The LOOP units loading causes a momentary dip in the MCC amperes. Minimum voltage after MCC energization is 146 volts (70.2 %) and occurs on 208V MCCs 3XS2. The minimum steady state voltage occurs on 3XS1 and 3XS2 and is 208V. The momentary current spike seen on 208V MCCs 3XS1 and 3XS2 at loss of voltage is due to the ES channels 1 and 2 (HPI) MOVs receiving a start signal prior to the actual loss of power to the MCC's.

4.5.8 Test 5, Battery Charger 3CA (V, I)

Figure 4.5.8-1 charts the voltage and current for Battery Charger 3CA. Charger supply voltage is monitored at the MCC.

Note that the charger current characteristic mirrors that seen at the MCC and loadcenter levels. The charger input current oscillates due to the two rapid voltage drops during the LOOP loading transients. Until the charger controls respond, the charger will appear to be a resistive load on the system. Thus, input current followed the change in input voltage when the first LOOP unit is loaded. The dip in input voltage and current causes a corresponding drop in charger output voltage. Recovery of AC system voltage, along with the charger controls responding to bring DC voltage back up to the float voltage, causes input current to increase. This cycle is repeated when voltage dips again with the loading of the second LOOP unit.

4.5.9 Test 5, Motor Operated Valves (V, I, KW)

Table 4.5.9 below summarizes the MOV data for Test 5. During this test each engineered safeguards MOV started and stroked to its proper ES position. For each MOV there is a time delay (≈ 0.040 - 2.75 seconds) following reenergization of the MCC buses prior to the individual MOV contactor pickup. This detail can be seen in the voltage and current plot for

4.5.4 Test 5, RBCU Fan 3B Motor Starting Profiles (V, I, KVA, KW)

Figures 4.5.4-1 and 2 plot the response of RBCU fan 3B starting on the LOCA unit. During a LOCA, the RBC fans should start and run on low speed, and RBCU fan 3B functioned as expected.

4.5.5 Test 5, 600V Loadcenter Profiles (V, I, KVA, KW)

Figures 4.5.5-1 and 2 are the profiles for 1X5. Since voltage was ~75% when the load center was energized, loads started simultaneous with loadcenter energization.

Figures 4.5.5-3 and 4 are the profiles for 1X6. After less than a 1 second delay there is a significant increase in load, which is consistent with motor starting after the voltage reaches the contactor pickup voltage. About 6 seconds after energization, a battery charger loads.

Figures 4.5.5-5 and 6 are the profiles for 3X5. After about a 1 second delay there is a significant increase in load, which is consistent with motor starting after the voltage reaches the contactor pickup voltage. About 9 seconds after energization, a battery charger loads. Loading of the LOOP units result in a voltage dip, during which the load center current decreased momentarily.

Figures 4.5.5-7 and 8 are the profiles for 3X6. The characteristics for 3X6 are very similar to profiles for 3X5.

Figures 4.5.5-9 and 10 are the profiles for 3X8. There is less than a 1 second delay after energization before a significant load increase occurs. The loading at around 1 second after energization is a RBCU fan starting on low speed and other motor loads starting. Approximately 3 seconds after energization, the battery charger loads. Loading of the LOOP units causes a short dip in the loadcenter amperes. The current on 3X8 (which is the source for the 3CA battery charger) during this transient correlates well with the 3CA current for the same time period.

Figures 4.5.5-11 and 12 are the profiles for 3X9. There is an increase in load about 1.5 seconds after the loadcenter is energized as a RBCU fan starts on low speed and other motors start. Approximately 5 seconds after energization, a battery charger loads. Loading of the LOOP units causes a momentary dip in the loadcenter ampere load.

The time delay in load increases on some buses due to the power battery charger restarting is expected. The chargers are designed with an automatic time delay in the startup of the charger. No loading anomalies were evident.

4.5.6 Test 5, 600V Safety MCC Profiles (V, I, KVA, KW)

the loss of voltage on Unit 1 for all of these plots. An examination of the plots show that Unit 3 (LOCA unit) loaded first. Unit 2 loaded second and Unit 1 loaded approximately 0.8 seconds later. Since the standby bus voltage was monitored for Unit 3, Figure 4.5.2-5 shows the standby bus being energized from Keowee prior to the MFBs being energized on any of the units.

Table 4- 10: Test 5, Summary of MFB Response

Description	Time	Value
Unit 1 loses Voltage	0	
Unit 2 MFB loses Voltage	.63 seconds	
Unit 3 MFB loses Voltage	.65 seconds	
Standby Bus Energized	15.5 seconds	
Unit 3 MFB loads	15.6 seconds	Stdby Min. Volt = 3.250 KV
Unit 2 MFB loads	32.7 seconds	Min. Volts = 3.529 KV
Unit 1 MFB loads	33.5 seconds	Min. Volts = 3.157 KV
Unit 1 MFB Steady state		Current = 452 Amps Volts = 4.233 KV KVA = 3,292 KVA KW = 2,801 KW
Unit 2 MFB Steady state		Current = 416 Amps Volts = 4.232 KV KVA = 3,030 KVA KW = 2,618 KW
Unit 3 MFB Steady state		Current = 703 Amps Stdby Bus KV = 4.217 KV KVA = 5,111 KVA KW = 4,403 KW

4.5.3 Test 5, 4KV Motor Profiles (V, I, KVA, KW)

Figures 4.5.3-1 and 2 are the plots of the MDEFW 3B profile. Figures 4.5.3-3 and 4 are the plots of the HPI 3B profile. Figures 4.5.3-5 and 6 are the plots of the MDEFW 1A profile. Figures 4.5.3-7 and 8 are the plots of the LPSW 3B profile. Figures 4.5.3-9 and 10 are the plots of the LPI 3B profile. Figures 4.5.3-11 and 12 are the plots of the RBS 3B profile. Voltages are monitored at the 4.16KV switchgear level. Points from the motor feeder overcurrent relays for each motor are also plotted on figures showing current and voltage and indicate a significant margin between motor starting and overcurrent relay tripping.

The results of the Keowee Unit response for Test 5 are summarized in the table below:

Table 4- 9: Test 5, Summary of Keowee Response

Description	Time	Value
Initial Keowee 2 Load		58,200 KW
Keowee 2 load rejects	0	
Frequency and voltage just prior to loading		Frequency = 65.73 Hz Voltage = 14.010 KV
CT4 energized	14.7 seconds	Max. Current = 513 Amps Frequency = 65.3 Hz
MFB energized, Unit 3 LOCA loads energized.	14.9 seconds	Max. Current = 1303 Amps Min. Volts = 12,990 KV Max. KVA = 30,600 KVA Max. KW = 8,400 KW Frequency = 64.7 Hz
First LOOP unit loads	32.0 seconds	
Second LOOP unit loads	32.7 seconds	Max. Current = 1583 Amps Min. Volts = 13,004 KV Max. KVA = 36,000 KVA Max. KW = 13,200 KW
Min. freq. After loading		57.6 Hz
Steady state values		Current = 500 Amps Volts = 14.072 KV KVA = 12,000 KVA KW = 9,637 KW Frequency = 60.9 Hz

The Keowee power data reflects recorder tolerance bands which are magnified by bigger multiplication factors due to higher ratio PT's & CT's than the MFB load data. Thus, the sum total of MFB load in section 4.5.2 will provide a more reliable indication of actual Keowee load.

4.5.2 Test 5, MFB Profiles (V, I, KVA, KW)

Figures 4.5.2-1 and 2 are the plots of the Unit 1 MFB profiles. Figures 4.5.2-3 and 4 are the plots of the Unit 2 MFB profiles. Figures 4.5.2-5 is a plot of the Standby Bus voltage and Unit 3 MFB current. Figure 4.5.2-6 is a plot of the Unit 3 loading. Time, t=0, is defined as

near steady state value occurs in less than 3 seconds. The small 0.73 second time difference in the loading of the LOOP units can be seen in the voltage dips.

Figure 4.5.1-3 is a plot of the KVA output from Keowee. Just before load rejection, the load was 58,800 KVA. During the Unit 3 LOCA loading, the maximum load is around 30,600 KVA. During LOOP unit loading, the maximum load was 36,000 KVA. The steady state load is around 12,000 KVA

Figure 4.5.1-4 is a plot of the KW output from Keowee. Just before load rejection, the load was 58,200KW. The maximum inrush when the Unit 3 LOCA loads are connected is 8,400 KW with a steady state LOCA load of 4,200KW. The maximum inrush KW occurs after the Unit 1 and Unit 2 LOOP units load and is 13,200 KW. Once all loads are operating, steady state load is 9,637 KW

Figure 4.5.1-5 is a plot of the frequency response. A plot of the Keowee current is also included on the figure to indicate when load was applied to Keowee. Frequency is ≈ 65Hz when CT4 is energized and 64.7Hz when Unit 3 loads. Minimum frequency after loading was around 57.6 hertz at 1169 cycles. Frequency recovers to above 60Hz (60.9Hz) due to the governor speed droop characteristic.

4.5 Test 5, LOCA/LOOP With Failure Of The Overhead Path And Keowee Initially Generating To The Grid

This test simulated a LOCA/LOOP on Oconee Unit 3 and a LOOP on Units 1 and 2. The LOCA unit loads first followed later by the two LOOP units. This test represents the largest cumulative load automatically applied to the Keowee Underground Circuit. In this test, Keowee Unit 2 was initially loaded to approximately 60 MW. The load applied to Keowee is sequenced in two blocks. The LOCA unit will be loaded following load rejection at rated voltage and 110% frequency decreasing. The two LOOP units load later. The expected scenario for this test is as follows:

- Oconee Unit 3 LOCA/LOOP, Unit 1 and 2 LOOP at t=0 seconds
- CT4 energized from Keowee Unit 2
- Oconee 3 MFB loads onto the Underground Circuit at t ≈ 20 seconds
- Units 1 and 2 load onto the underground at t ≈ 31 seconds
- Unit 3 loadcenter 3X4 loads at t ≈ 61 seconds
- Unit 1 Loadcenter X7 and Unit 4 Loadcenter X4 load at t ≈ 81seconds

4.5.1 Test 5, Keowee Profile (V, I, KVA, KW, f)

Figures 4.5.1-1 through 5 plot the Keowee response to Test 5. In these plots, t = 0, is assigned to the time when the Keowee Unit 2 load rejects on Emergency Start actuation.

Figure 4.5.1-1 is a plot of the Keowee voltage and current response. Transformer CT4 is energized around 879 cycles (14.7 seconds). Maximum CT4 inrush current is 513 amperes. The MFB bus on Unit 3 loads at around 892 cycles (14.9 seconds). Maximum current inrush is 1303 amperes rms, and lasts approximately 3 seconds. At around 1919 cycles (32 seconds) the first LOOP unit loads and the second LOOP unit loads around 1963 cycles (32.7 seconds). Maximum inrush current due to the LOOP units loading was 1583 amperes. Between 2340 and 3800 cycles, additional inrush currents occur as the Reactor Building Cooling Fans on the LOOP units transfer to high speed. At around 3868 cycles (64.5 seconds) an additional small inrush occurs a loadcenters 3X4 loads on Unit 3. Loadcenters 1X7 and 2X4 load simultaneous at 4990 cycles (83.4) seconds. Final steady state current is around 500 amps.

Figure 4.5.1-2 is a plot of the Keowee voltage during the main inrush periods. The generator voltage dips to a minimum of 12.990 KV (94.1%) during the Unit 3 load inrush at 892 cycles (14.9 seconds). The voltage recovers to near steady state value in slightly over 2 seconds. The voltage sags slightly (to around 13.95KV) at around 1200 cycles when the Keowee frequency undershoots due to action of the V/Hz limiter. The voltage dips to 13.004KV (94.2%) at 1969 cycles (32.8 seconds) when the two LOOP Units load. Voltage recovery to

observed as the voltage increases. This is evident from the current plots. Hammerblow and unseating are not applicable to this valve design.

4.4.9.10 Test 4, 3HP-4

Figures 4.4.9.10 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-4 during test 4. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unseating are not applicable to this valve design.

4.4.9.11 Test 4, 3HP-20

Figures 4.4.9.11 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-20 during test 4. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unseating are not applicable to this valve design.

4.4.9.4 Test 4, 3BS-2

Figures 4.4.9.4 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3BS-2 during test 4. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. After the bus is reenergized at the contactor pickup point, a contactor transient is observed as the voltage increases. This is evident from the voltage and current plots. Normal hammerblow was observed and normal valve unwedging was observed during this test.

4.4.9.5 Test 4, 3HP-27

Figures 4.4.9.5 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-27 during test 4. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unwedging are not applicable to this valve design (no lost motion globe valve).

4.4.9.6 Test 4, 3LPSW-24

Figures 4.4.9.6 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-24 during test 4. The valve started from an intermediate (throttled) position and moved to its ES position properly during this test. Hammerblow is not applicable to this no lost motion actuator design. The valve stroke appeared to be normal.

4.4.9.7 Test 4, 3PR-19

Figures 4.4.9.7 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3PR-19 during test 4. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous diagnostics test values. Normal unseating was observed for this valve stroke and hammerblow is not applicable to the no lost motion actuator design.

4.4.9.8 Test 4, 3LPSW-6

Figures 4.4.9.8 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-6. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous diagnostics test values. After the bus is reenergized at the contactor pickup point, a contactor transient is observed as the voltage increases. This is evident from the voltage and current plots. Hammerblow for this valve and unseating are not applicable.

4.4.9.9 Test 4, 3LPSW-565

Figures 4.4.9.9 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-565 during test 4. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous diagnostics test values. After the bus is reenergized at the contactor pickup point, a contactor transient is

Table 4.4.9 - Test 4, Summary of MOV Results						
Unit 3 MOVs	MCC Source	MCC Voltage at Contactor Pickup (% rated MCC V)	MCC Voltage at MOV peak Inrush (% rated MCC V)	MOV Inrush Duration (sec.)	Time for Voltage to reach 100% (sec.)	MOV Stroke Time (sec.)
HP-024	208-3XS1	73.1%	70.8%	0.243	3.67	13.3
HP-026	208-3XS1	68.8%	67.7%	0.485	3.57	13.13
LP-017	600-3XS1	76.1%	76.9%	1.033	3.03	9.74
BS-002	208-3XS2	67.5%	67.6%	0.126	3.72	12.55
HP-027	208-3XS2	67.0%	66.6%	0.316	3.22	12.66
LPSW-024	208-3XS2	71.2%	71.9%	0.217	3.64	29.45
PR-019	208-3XS2	75.0%	75.0%	0.097	3.72	59
LPSW-006	208-3XS3	70.4%	70.1%	0.241	6.79	56.86
LPSW-565	600-3XS3	71.0%	79.2%	0.618	6.95	52.47
HP-004	208-3XSF	74.1%	73.4%	0.109	3.69	28.81
HP-020	208-3XSF-A	72.9%	70.7%	0.159	3.62	29.35

4.4.9.1 Test 4, 3HP-24

Figures 4.4.9.1 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-24 during test 4. The valve started and moved to its ES position properly during this test. Normal unwedging was observed. Hammerblow is not applicable to this no lost motion actuator design. The stroke time was compatible with the calculated and previous VOTES test values.

4.4.9.2 Test 4, 3HP-26

Figures 4.4.9.2 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-26 during test 4. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unwedging are not applicable to this valve design (no lost motion globe valve). After the bus is reenergized at the contactor pickup point, a contactor transient is observed as the voltage increases. This is evident from the voltage and current plots.

4.4.9.3 Test 4, 3LP-17

Figures 4.4.9.3 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LP-17 during test 4. The valve started and moved to its ES position during this test. After the bus is reenergized at the contactor pickup point, a contactor transient is observed. This MOV stalls for approximately 1 second following contactor pickup, however normal hammerblow and unwedging was observed following inrush. Unwedging is not applicable to this double disc gate valve design. The stroke time was compatible with the calculated and previous VOTES test values.

Minimum voltage after MCC energization is 396 volts (66 %) and occurs on 600V MCC 3XS3. The minimum steady state voltage MCC voltage is 604V (100.7% of 600V) and occurs on 3XS1 and 3XS3. Voltage recovers to near the steady state value in around 4 seconds on 3XS1 and 3XS2. Recovery on 3XS3 takes around 7 seconds due to the RBCU fan starting.

4.4.7 Test 4, 208V Safety MCC Profiles (V, I, KVA, KW)

Figures 4.4.7-1 through 4.4.7-6 chart the voltage, current, KVA and KW profiles for the 208V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increases immediately on MCC energization. Minimum voltage after MCC energization is 138 volts (66.3 %) and occurs on 208V MCCs 3XS1. The minimum steady state voltage occurs on 3XS2 and is 211V. The momentary current spike seen on 208V MCCs 3XS1 and 3XS2 at loss of voltage is due to the ES channel 1 and 2 (HPI) MOVs receiving a start signal prior to the actual loss of power to the MCC's.

4.4.8 Test 4, Battery Charger 3CA (V, I)

Figure 4.4.8-1 charts the voltage and current for Battery Charger 3CA. Note that the charger current characteristic mirrors that seen at the MCC and loadcenter levels. Charger supply voltage is monitored at the MCC.

4.4.9 Test 4, Motor Operated Valves (V, I, KW)

Table 4.4.9 below summarizes the MOV data for Test 4. During this test each engineered safeguards MOV started and stroked to its proper ES position. For each MOV there is a time delay (≈ 0.040 - 2.75 seconds) following reenergization of the MCC buses prior to the individual MOV contactor pickup. This detail can be seen in the voltage and current plots for each valve. The sections following the summary table provide specific details for each of the monitored MOVs for this test.

After the bus is reenergized at the contactor pickup point, a contactor transient for five MOVs (3HP-26, 3LP-17, 3BS-2, 3LPSW-6 and 3LPSW-565) is observed as the voltage increases. The current transient usually occurs so quickly (≈ 1-7 cycles) that the contactor does not drop out. For this test 3LPSW-565 is an exception. Its contactor pickup transient is ≈ 30 cycles which is longer that the others. This transient, although it has negligible impact on the valve's performance, is worth mentioning to help explain the current decreases and increases during the applicable MOVs inrush period.

4.4.5 Test 4, 600V Loadcenter Profiles (V, I, KVA, KW)

Figures 4.4.5-1 and 2 are the profiles for 1X5. After about a 2 second delay there is a significant increase in load, which is consistent with motor starting after the voltage reaches contactor pickup voltage.

Figures 4.4.5-3 and 4 are the profiles for 1X6. After about a 2 second delay there is a significant increase in load, which is consistent with motor starting after the voltage reaches the contactor pickup voltage. About 9 seconds after energization, a battery charger loads.

Figures 4.4.5-5 and 6 are the profiles for 3X5. After about a 2.5 second delay there is a significant increase in load, which is consistent with motor starting after the voltage reaches the contactor pickup voltage. About 9 seconds after energization, a battery charger loads.

Figures 4.4.5-7 and 8 are the profiles for 3X6. The characteristics for 3X6 are very similar to profiles for 3X5.

Figures 4.4.5-9 and 10 are the profiles for 3X8. There is about a 2 second delay after energization before a significant load increase occurs. The loading at around 2 seconds after energization is a RBCU fan starting on low speed and other motor loads starting. Approximately 4 seconds after energization, the battery charger loads.

Figures 4.4.5-11 and 12 are the profiles for 3X9. There is increase in loading about 1.5 seconds after the loadcenter is energized as a RBCU fan starts on low speed and other motors start. Approximately 7 seconds after energization, a battery charger loads

Figures 4.4.5-13 and 14 are profiles for the feeder to transformer CX. The transformer is unloaded. This is considered a test anomaly (see section 5.2.2 for details). Note these plots are the primary characteristics of the transformer, and show the inrush characteristic which rapidly decays away.

The time delay in load increases on some buses due to the power battery charger restarting is expected. The chargers are designed with an automatic time delay in the startup of the charger. No loading anomalies were evident.

4.4.6 Test 4, 600V Safety MCC Profiles (V, I, KVA, KW)

Figures 4.4.6-1 through 4.4.6-6 chart the voltage, current, KVA and KW profiles for the 600V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increase at energization is small. After about a 1 to 2 second delay there is an increase in load on MCCs 3XS1 and 3XS3, which is consistent with motor starting after the voltage reaches the contactor pickup voltage. A significant increase in loading occurs on 3XS1 and 3XS2 when the battery chargers load. Note that the charger loading has negligible impact on MCC voltage. Starting of RBCU fan 3B on low speed can be clearly seen in the plots for 3XS3.

4.4.2 Test 4, MFB Profiles (V, I, KVA, KW)

Figures 4.4.2-1 and 2 are the plots of the Unit 1 MFB profiles. Figures 4.4.2-3 is a plot of the Standby Bus voltage and Unit 3 MFB current. Figure 4.4.2-4 is a plot of the Unit 3 loading. Time t = 0 is defined as the loss of voltage on Unit 1 for all of these plots. A close examination of these plots shows that the units loaded essentially simultaneously. Since the standby bus voltage was monitored for Unit 3, Figure 4.4.2-3 shows the standby bus being energized from Keowee prior to the MFBs being energized on any of the units.

Table 4- 8: Test 4, Summary of MFB Response

Description	Time	Value
Unit 1 and 3 MFB loses Voltage	0	
Standby Bus Energized	15.1 seconds	
Unit 1 and 3 MFB loaded	15.2 seconds	Stdby Bus Min= 2.854 KV
Unit 1 MFB Steady state		Current = 439 Amps Volts = 4.324 KV KVA = 3,269 KVA KW = 2,740 KW
Unit 3 MFB Steady state		Current = 702 Amps Stdby Bus KV = 4.304 KV KVA = 5,205 KVA KW = 4,431 KW

4.4.3 Test 4, 4KV Motor Profiles (V, I, KVA, KW)

Figures 4.4.3-1 and 2 are the plots of the MDEFW 3B profile. Figures 4.4.3-3 and 4 are the plots of the HPI 3B profile. Figures 4.4.3-5 and 6 are the plots of the MDEFW 1A profile. Figures 4.4.3-7 and 8 are the plots of the LPSW 3B profile. Figures 4.4.3-9 and 10 are the plots of the LPI 3B profile. Figures 4.4.3-11 and 12 are the plots of the RBS 3B profile. Voltages are monitored at the 4.16KV switchgear level. Points from the motor feeder overcurrent relays for each motor are also plotted on the figures showing current and voltage and indicate a significant margin between motor starting and overcurrent relay tripping.

4.4.4 Test 4, RBCU Fan 3B Motor Starting Profiles (V, I, KVA, KW)

Figures 4.4.4-1 and 2 plot the response of RBCU fan 3B motor when starting on low speed. During a LOCA, the fan will start and remain on low speed. Unit 3 was the LOCA unit during the test, so as expected the fan remained on low speed. There is an approximately 2 second delay between when voltage was applied on the MCC until the fan started, which is consistent with motor starting after the voltage reaches the contactor pickup voltage.

Figure 4.4.1-4 is a plot of the KW output from Keowee. Just before the load rejection, the load was 58,200KW. The maximum inrush KW occurs when the MFB is energized and is 12,000 KW. The steady state load is 7,199 KW.

Figure 4.4.1-5 is a plot of the frequency response. A plot of the Keowee current is also included on the figure to indicate when the load was applied to Keowee. Frequency when the MFB loads was 65.32 hertz (108.8%). Minimum frequency after loading was around 56.96 hertz at 1,214 cycles. Frequency recovers to above 60Hz (60.81 hertz) due to the governor speed droop characteristic.

Figure 4.4.1-6 is a plot of frequency over a much longer period of time (13,500 cycles). This plot shows the frequency stabilizing at around 60.81 hertz.

A summary of the Keowee Unit 2 results for Test 4 is listed in the following table:

Table 4- 7: Test 4, Summary of Keowee Response

Description	Time	Value
Initial Keowee 2 Load		Initial KW = 58,200 KW
Keowee 2 load rejects	0	
Frequency and Voltage just prior to loading		Frequency = 65.76 Hz Voltage = 14.251 KV
CT4 energized	15 seconds	Max. Current = 757 Amps Max. KVA = 16,800 KVA Frequency = 65.73 Hz
MFB energized	15.2 seconds	Max. Current = 1735 Amps Min. Volts = 12.741 KV Max. KVA = 40,200 KVA Frequency = 65.32 Hz
Min. freq. After loading	20.2 seconds	56.96 Hz
Steady state values		Current = 362 Amps Volts = 14.186 KV KVA = 8,545 KVA KW = 7,199 KW Frequency = 60.85 Hz

The Keowee power data reflects recorder tolerance bands which are magnified by bigger multiplication factors due to higher ratio PT's & CT's than the MFB load data. Thus, the sum total of MFB load in section 4.4.2 will provide a more reliable indication of actual Keowee load.

4.4 Test 4, LOCA/LOOP with a Failure Resulting in Starting a Large Unscheduled Load with a LOCA Unit and Keowee Initially Generating to the Grid

For this test, a LOCA/LOOP was simulated on Oconee Unit 3 and a LOOP on Unit 1. This test places Unit 3 LOCA loads plus the unscheduled Unit 1 LOOP loads simultaneously on the Keowee Underground Path following a load rejection. The unit should be loaded with rated voltage, and frequency at 110% decreasing. The expected scenario for this test is as follows:

- Oconee Unit 3 LOCA/LOOP and Unit 1 LOOP at t=0 seconds
- CT4 energized from Keowee Unit 2
- Oconee Unit 1 and 3 load onto the Underground Circuit at t ≈ 20 seconds
- Unit 1 Loadcenter X7 and Unit 3 Loadcenter X4 load at t ≈ 61 seconds

4.4.1 Test 4, Keowee Profile (V, I, KVA, KW, f)

Figures 4.4.1-1 through 6 plot the Keowee response to Test 4. In these plots, the time, t = 0, is assigned to when the Keowee Unit 2 load rejects on Emergency Start actuation.

Figure 4.4.1-1 is a plot of the Keowee voltage and current response. Transformer CT4 is energized around 900 cycles (15 seconds). Maximum CT4 inrush current is 757 amperes. The Unit 1 and Unit 3 MFB buses load at around 914 cycles (15.2 seconds) Maximum current inrush is 1,735 amps. The inrush lasts approximately 4 seconds. At around 1,860 cycles (31 seconds) and again at around 2,592 cycles (43.2 seconds) additional inrush currents occur as the Unit 1 Reactor Building Cooling Fans transfer to high speed. At around 3,834 cycles (63.9 seconds) an additional small inrush occurs as loadcenters 1X7 and 3X4 load. Loading 1X7 and 3X4 was almost simultaneous. Steady state current is around 362 amperes.

Figure 4.4.1-2 is a plot of the Keowee voltage during the inrush periods. The voltage dips during the load inrush to 12.741 KV or 92.3 % of rated when the LOCA and LOOP units load at 914 cycles. Voltage recovers to near rated in approximately 3 seconds. The voltage sags slightly (to around 13.9KV) between 1,140 and 1,300 cycles due to action of the V/Hz limiter when Keowee frequency undershoots recovering from the load rejection.

Figure 4.4.1-3 is a plot of the KVA output from Keowee. Just before the load rejection, the load was 59,400 KVA. During loading of Oconee loads, the maximum load is around 40,200 KVA. The steady state load is approximately 8,545 KVA.

4.3.9.10 Test 3, 3HP-4

Figures 4.3.9.10 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-4. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unseating are not applicable to this valve design.

4.3.9.11 Test 3, 3HP-20

Figures 4.3.9.11 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-20. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unseating are not applicable to this valve design.

hammerblow was observed. Unwedging is not applicable to this double disc gate valve design. The stroke time was compatible with the calculated and previous VOTES test values.

4.3.9.4 Test 3, 3BS-2

Figures 4.3.9.4 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3BS-2. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. After the bus is reenergized at the contactor pickup point, a contactor transient is observed as the voltage increases. This is evident from the voltage and current plots. Normal hammerblow was observed. Valve unwedging was observed but not very distinct.

4.3.9.5 Test 3, 3HP-27

Figures 4.3.9.5 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-27. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unwedging are not applicable to this valve design.

4.3.9.6 Test 3, 3LPSW-24

Figures 4.3.9.6 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-24. The valve started from an intermediate (throttled) position and moved to its ES position properly during this test. Hammerblow is not applicable to this no lost motion actuator design. The valve stroke appeared to be normal.

4.3.9.7 Test 3, 3PR-19

Figures 4.3.9.7 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3PR-19. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous diagnostics test values. Normal unseating was observed for this valve stroke. Hammerblow is not applicable to this no lost motion actuator design.

4.3.9.8 Test 3, 3LPSW-6

Figures 4.3.9.8 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-6. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous diagnostics test values. After the bus is reenergized at the contactor pickup point, a contactor transient is observed as the voltage is increases. This is evident from the voltage and current plots.

4.3.9.9 Test 3, 3LPSW-565

Figures 4.3.9.9 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LPSW-565. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous diagnostics test values. Hammerblow effect and unseating are not applicable to this valve design.

After the bus is reenergized at the contactor pickup point, a contactor transient is observed for three MOVs (3HP-26, 3BS-2, and 3LPSW-6) as the voltage increases. The transient usually occurs so quickly (≈ 1-7 cycles) that the contactor does not drop out. This transient, although it has negligible impact on the valve's performance, explains the current decreases and increases during the applicable MOVs inrush period.

Table 4.3.9 - Test 3, Summary of MOV Results

Unit 3 MOVs	MCC Source	MCC Voltage at Contactor Pickup (% rated MCC V)	MCC Voltage at MOV peak Inrush (% rated MCC V)	MOV Inrush Duration (sec.)	Time for Voltage to reach 100% (sec.)	MOV Stroke Time (sec.)
HP-024	208-3XS1	67.7%	66.9%	0.223	4.83	12.24
HP-026	208-3XS1	55.5%	57.4%	0.446	5.51	12.27
LP-017	600-3XS1	80.3%	79.6%	0.086	3.57	7.98
BS-002	208-3XS2	58.1%	56.6%	0.12	4.86	11.65
HP-027	208-3XS2	55.8%	55.4%	0.317	3.56	11.77
LPSW-024	208-3XS2	65.6%	65.5%	0.181	4.97	30.64
PR-019	208-3XS2	68.4%	68.8%	0.085	5.04	58.35
LPSW-006	208-3XS3	61.4%	60.9%	0.178	10.15	56.23
LPSW-565	600-3XS3	64.2%	64.4%	0.113	10.18	51.49
HP-004	208-3XSF	68.1%	66.5%	0.098	4.85	27.57
HP-020	208-3XSF-A	66.8%	65.4%	0.134	4.87	28.2

4.3.9.1 Test 3, 3HP-24

Figures 4.3.9.1 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-24. The valve started and moved to its ES position properly during this test. Normal unwedging was observed. Hammerblow is not applicable to this no lost motion actuator design. The stroke time was compatible with the calculated and previous VOTES test values.

4.3.9.2 Test 3, 3HP-26

Figures 4.3.9.2 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3HP-26. The valve started and moved to its ES position properly during this test. The stroke time was compatible with the calculated and previous VOTES test values. Hammerblow and unwedging are not applicable to this valve design. After the bus is reenergized at the contactor pickup point, a contactor transient is observed as the voltage increases. This is evident from the voltage and current plots.

4.3.9.3 Test 3, 3LP-17

Figures 4.3.9.3 - 1 through 3 chart the voltage, current, and total real power (TRP) for 3LP-17. The valve started and moved to its ES position properly during this test. Normal

The time delay in load increases on some buses due to the power battery chargers restarting is expected. The chargers are designed with an automatic time delay in their startup circuit. No loading anomalies were evident.

4.3.6 Test 3, 600V Safety MCC Profiles (V, I, KVA, KW)

Figures 4.3.6-1 through 4.3.6-6 chart the voltage, current, KVA and KW profiles for the 600V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increase at energization is small. After about a 1 to 1.5 second delay there is an increase in load, which is consistent with motor starting after the voltage reaches the contactor pickup voltage. A significant increase in loading occurs on 3XS1 and 3XS2 when the battery chargers load. Note that the charger loading has negligible impact on MCC voltage. Starting of RBCU fan 3B on low speed can be clearly seen in the figures for 3XS3. Minimum voltage after MCC energization is 244 volts (40.7 %) and occurs on 600V MCC 3XS1. The minimum steady state MCC voltage is 591V (98.5% of 600V) and occurs on 3XS1. Voltage recovers to near steady state in 4 to 5 seconds on 3XS1 and 3XS2. Voltage recovers to near the steady state value on 3XS3 in approximately 10 seconds due to the RBCU fan starting.

4.3.7 Test 3, 208V Safety MCC Profiles (V, I, KVA, KW)

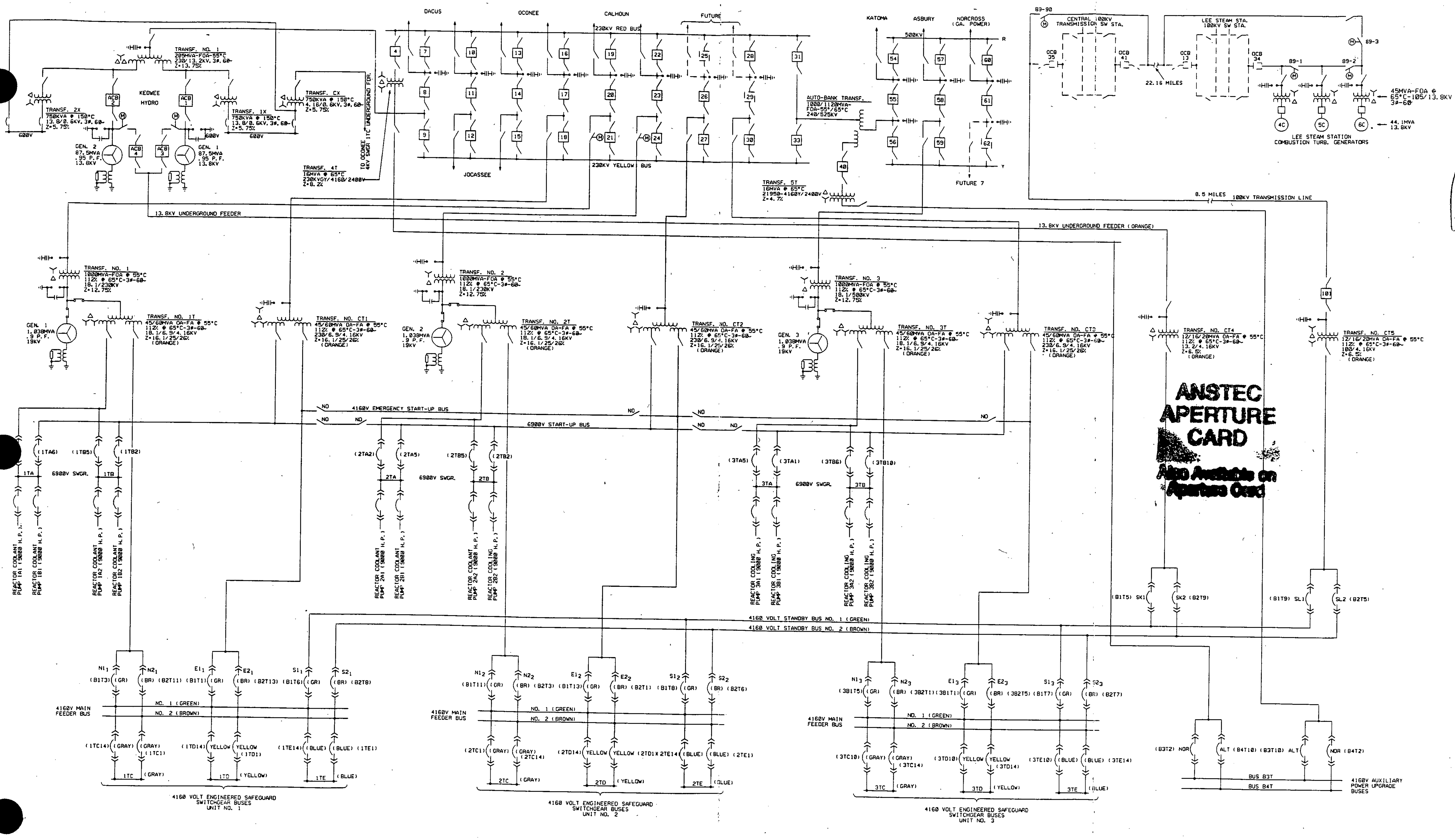
Figures 4.3.7-1 through 4.3.7-6 chart the voltage, current, KVA and KW profiles for the 208V Safety MCCs (3XS1, 3XS2, 3XS3) monitored during the test. The load increase at energization is small. After about a 1 second delay there is an increase in load, which is consistent with MOVs starting after the voltage reaches the contactor pickup values. Minimum voltage after MCC energization is 84 volts (40.3 %) and occurs on 208V MCCs 3XS1 and 3XS2. The minimum steady state voltage occurs on 3XS2 and is 207V. The momentary current spike seen on 208V MCCs 3XS1 and 3XS2 upon loss of voltage is due to the channel 1 and 2 (HPI) MOVs receiving a start signal prior to the actual loss of power to the MCC's.

4.3.8 Test 3, Battery Charger 3CA (V, I)

Figure 4.3.8-1 charts the voltage and current for Battery Charger 3CA. Note that the charger current characteristic mirrors that seen at the MCC and loadcenter levels. Charger supply voltage is monitored at the MCC.

4.3.9 Test 3, Motor Operated Valves (V, I, KW)

Table 4.3.9 below, summarizes the MOV data for Test 3. During this test each engineered safeguard MOV started and stroked to its proper ES position. For each MOV there is a time delay (≈ 0.040 - 2.75 seconds) following reenergization of the MCC buses prior to the individual MOV contactor pickup. This detail can be seen in the voltage and current plots for each valve. The sections following the summary table provide specific details for each of the monitored MOVs for this test.



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