Proceedings of the Korean Nuclear Society Autumn Meeting
Seoul, Korea, October 1995

LOSS OF OFFSITE POWER TEST EXPERIENCE FOR YGN 4

Sung-Goo Chi, Kang-Sik Sung, Se-Chang Kim
Korea Atomic Energy Research Institute

Eul-Ki Kim, Young-Meen Eom, Young-Boo Choi
Korea Electric Power Corporation

Abstract

The loss of offsite power test was successfully performed on YGN 4 to demonstrate that the reactor can be shutdown and the RCS can be maintained in a hot standby condition following a loss of all offsite Alternating Current (AC) power. Following the loss of main generator and all offsite AC power, the onsite emergency diesel generators were automatically started and the plant was stabilized via natural circulation. Plant conditions were maintained in hot standby for at least 30 minutes before offsite power was restored. Thus, the capability of equipment, controls and instrumentation necessary to remove decay heat from the core using only onsite emergency power was demonstrated, thereby satisfying all objectives and acceptance criteria of the test.

I. Introduction

The Loss of Offsite Power test from 20% power was successfully performed on September 23, 1995. as required in Regulatory Guide 1.68 and FSAR Chapter 14[(1),(2)]. The major objectives of this test are 1) to test the ability of the operator and system to achieve stabilized hot standby condition following a loss of main generator and offsite power (loss of all offsite AC power) and 2) to demonstrate the satisfactory performance of the Auxiliary Feedwater System (AFWS) following a loss of main generator and offsite power.

A loss of the main generator and offsite power was simulated by simultaneously tripping the reactor (resulting in a loss of main generator) and opening appropriate breakers (resulting in a loss of offsite power). The loss of offsite power signal started the diesel generators and the Engineered Safety Features (ESF) sequencer loaded the Class 1-E load groups.

During the YGN 4 loss of offsite power test, the Test Data Acquisition System (TDAS) was used to evaluate the test results. The TDAS is a high speed computer based data acquisition and recording system. The TDAS consists of a real-time UNIX Operating System based on the 7250 mini-computer supplied by Concurrent Computer Corporation and a signal conditioning front-end system supplied by Analog Devices. The TDAS provides capabilities of real-time data acquisition, data recording, and data reduction up to 128 input channels. The TDAS can achieve a sampling rate up to 200,000 samples per second. During the YGN 4 startup testing, 112 input channels were used for data recording at 10 scans per second to properly evaluate the NSSS responses.

II. Test Experience of Loss of Offsite Power

Test Objectives and Acceptance Criteria

The major objectives of this test are 1) to test the ability of the operator and system to achieve stabilized hot standby condition following a loss of main generator and offsite power (loss of all offsite AC power) and 2) to demonstrate the satisfactory performance of the AFWS following loss of main generator and offsite power. The acceptance criteria of this test are that 1) NSSS is maintained in hot standby condition for at least 30 minutes on emergency power following a loss of all offsite AC power and 2) The AFWS automatically initiates auxiliary feedwater flow to both steam generators (S/Gs) and automatically maintains the S/G levels between 23.5% and 37.5% wide range(3).

Test Description

A loss of the main generator and offsite power is simulated by simultaneously tripping the reactor and manually opening a alternate breakers for the 4.16 KV Class 1E safety busses. During the loss of all offsite AC power, the fast bus transfer of 13.8 KV alternate power breakers and 4.16 KV Non-Class 1E alternate supply breakers will be disabled, resulting in an automatic loss of power to the Non-Class 1E busses when the turbine trips. A low voltage on 4.16 KV Class 1E safety busses due to loss of offsite power generates an undervoltage signal which starts the Class 1E emergency diesel generators which are designed to reach rated speed, voltage, and frequency within 10 seconds. The Engineered Safety Feature (ESF) sequencer will then load the Class 1-E load groups (e.g., essential loads, auxiliary feedwater pump, essential lighting, etc.). The simplified on-site electrical distribution system is presented in Figure 1.

The loss of offsite power and reactor trip results in a rapid decrease in core flow due to all RCPs tripping, a decrease in S/G level due to loss of Feedwater Control System (FWCS) and an increase in the S/G pressure. The AFWS is allowed to automatically initiate to provide feedwater flow to both S/Gs and maintain adequate level to remove decay heat.

The Steam Bypass Control System (SBCS) initially responds but Turbine Bypass Valves (TBVs) 1001 through 1006 (Condenser Dump) are quickly lost due to the loss of condenser vacuum. The S/G pressure is initially controlled by the TBVs 1007 and 1008 (Atmospheric Dump). The safety grade Atmospheric Dump Valves (ADVs) are also available to maintain the plant in hot standby condition. The required ADV opening to remove core decay heat is less than 10% of one ADV per S/G. Once the accumulator which provides ADV motive force discharges, the ADV are hydraulically locked in the "As Is" position. If the ADVs lock in open position, operator can close the ADV because the ADV hydraulic pump motor is powered from Class 1E emergency diesel. The increase in secondary pressure is not expected to open Main Steam Safety Valves (MSSVs) once the operator controls the ADVs properly according to the test procedure.

Auto operation of Pressurizer Level Control System (PLCS) does not occur because the charging pumps have to be manually restarted after the diesel generators sequence. The ESF sequencer provides a charging pump permissive to allow manual starting of charging pumps. The Chemical and Volume Control System (CVCS) letdown line is isolated due to high temperature on loss of charging. The Pressurizer Pressure Control System (PPCS) can respond to a low Reactor Coolant System (RCS) pressure with only 2 banks of backup heaters. The PPCS can not respond to a high pressure condition due to the loss of pressurizer main spray caused by the loss of all RCPs, requiring manual use of auxiliary spray.

Test Results and Key Parameter Trends

The responses of key NSSS parameters recorded by TDAS following the loss of offsite power are depicted in Figure 2. Following the loss of main generator and offsite power at 20% power level, all Control Element Assemblies (CEAs) were dropped into the core and the ESF busses were sequentially re-energized by the emergency diesel generators. The first charging pump was manually started within one minute of the trip followed by the charging suction being transferred to the emergency boration path, then back to the Volume Control Tank (VCT) to preclude unnecessary boration of the RCS.

Immediately following the trip, the critical safety parameters were monitored using the Critical Function Monitoring System (CFMS) by the control room operators. All RCPs were automatically tripped due to the loss of offsite power. As RCPs started coastdown, the RCS flowrate decreased rapidly. This reduction in RCS flowrate resulted in an increase in the hot leg temperature, causing the RCS loop temperature difference to increase. This increased loop temperature difference developed a natural circulation flow in the RCS loop and a fully developed natural circulation flow was reached about 10 minutes after the RCP trip. The natural circulation was verified by observing the following parameters ; (1) Hot leg temperatures were stable or decreasing, (2) Cold leg temperatures were close to and trending the S/G saturation temperatures, (3) Core delta T was less than full power delta T (31.7°C) (i.e., power to flow ratio is less than 1), and (4) Hot leg and Core Exit Thermocouples (CETs) temperatures were trending consistently. Reactor vessel head and plenum subcooling were maintained at greater than 15°C to preclude any loop void formation that could degrade the natural circulation.

Although one of the major concerns for this test was the capability of the AFWS for restoring and maintaining the S/G level, the AFWS was not actuated during the test because the S/G level did not decrease to the AFWS actuation setpoint of 23,5% wide range. As shown in Figure 2, the S/G level decreased slowly from about 70% to only 65% wide range for 30 minutes mainly due to the low core decay heat level at the time of this test. The ADVs were not utilized to release the primary heat to the atmosphere because the steam header pressure was not high enough to open ADVs.

Pressurizer level was maintained between 29.0% and 35.0%, thus remaining above the heater cutoff level (25%) throughout the test. The combination of the loss of primary heat sink (turbine stop valve close) with the reduction of RCS flow resulted in an increase in RCS pressure. The RCS pressure peaked at 160.0 kg/cm^2a and reached a low of 154.0 kg/cm^2a while natural circulation was in progress. Auxiliary spray was not required because the pressurizer pressure was not high enough for primary pressure control. The test results showed that both RCS overcooling and initiation of Safety Injection Actuation Signal (SIAS) was precluded, and primary system integrity was maintained as per design throughout the test.

III. Conclusions

Following the loss of main generator and all offsite power, the plant was stabilized and natural circulation was verified. Plant conditions were maintained in hot standby for at least 30 minutes before offsite power was restored. Thus, the as-built capability of equipment, controls and instrumentation necessary to remove decay heat from the core using only emergency power was demonstrated, thereby satisfying all objectives and acceptance criteria of the test.

References

(1) "Initial Test Program for Water-Cooled Nuclear Power Plant", Regulatory Guide 1.68, Rev.2, 1978.

(2) KEPCO, "YGN 3&4 FSAR, Chapter 14".

(3) KEPCO, "Test Procedure for PAT Loss of Offsite Power", 4S-I-000-30.

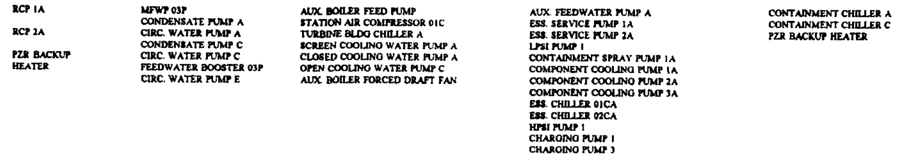

Figure 1. On-Site Electrical Distribution System

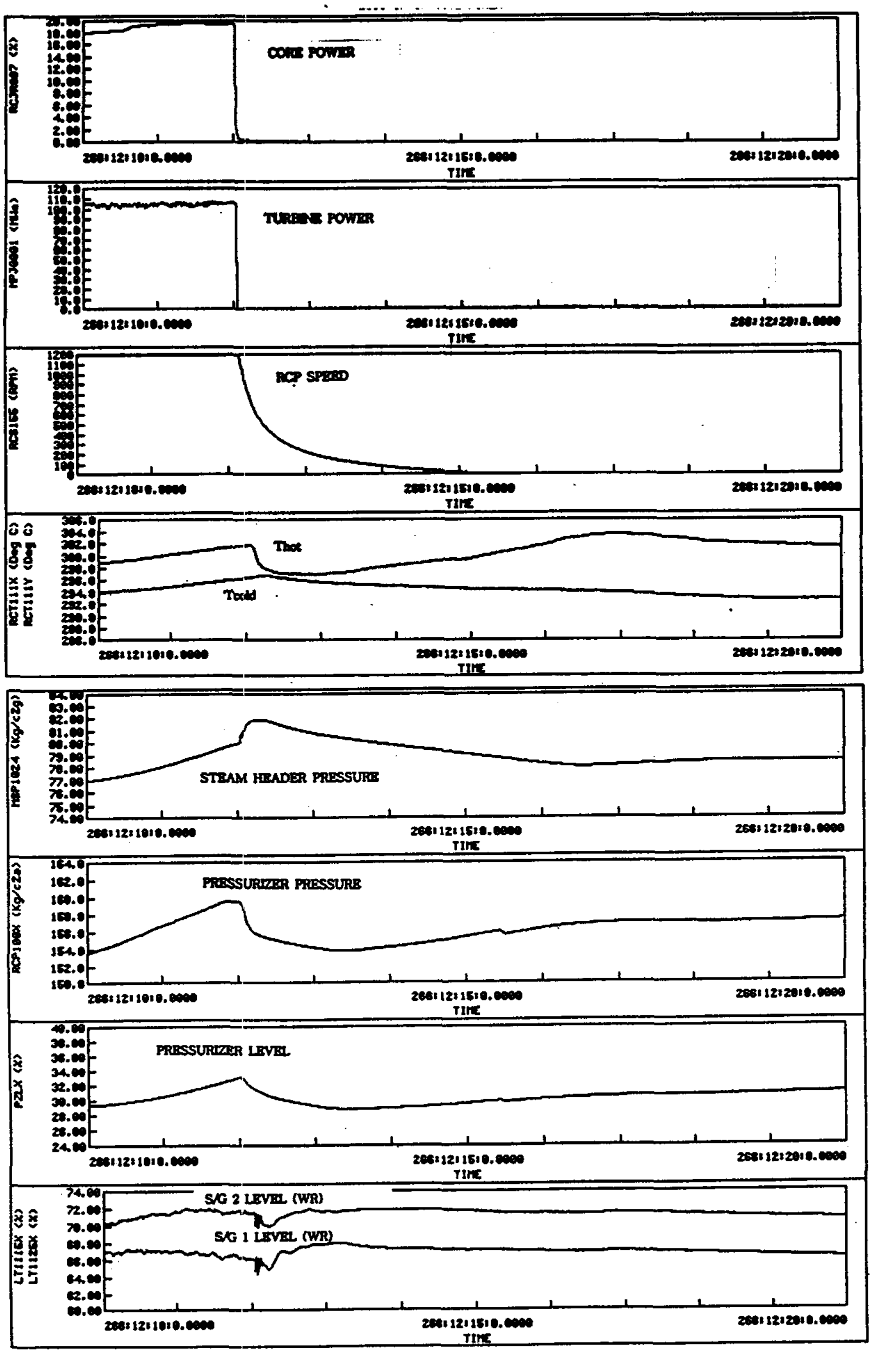

Figure 2. Results of Loss of Offsite Power Test