Nuclear Operating Company

South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

July 1, 2003
NOC-AE-03001556
10CFR50.73
G25

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852

South Texas Project
Unit 2
Docket No. STN 50-499
Licensee Event Report 02-004 Supplement
Turbine Blade Failure

Pursuant to 10CFR50.73, South Texas Project submits the attached Supplement to Unit 2 Licensee Event Report 02-004 regarding a turbine blade failure that occurred on December 15, 2002. The original Licensee Event Report was submitted on February 13, 2003 when cracked blades were identified in Low Pressure Turbines 22 and 23. Since then, data was evaluated and the final root cause was determined. In addition, a study was performed by Siemens-Westinghouse to verify the effectiveness of the corrective actions. The study showed that the corrective actions achieved the desired results. This event did not have an adverse effect on the health and safety of the public.

No additional corrective actions were assigned as a result of this supplement and this report contains no commitments.

If there are any questions on this submittal, please contact S. M. Head at (361) 972-7136 or me at (361) 972-7849.

E. D. Halpin
Plant General Manager

kaw

Attachment: LER 02-004 Supplement (South Texas, Unit 2)

IE22

cc:

(paper copy)

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NRC FORM 366 (7-2001)	U.S. NUCLEAR REGULATORY COMMISSION	APPROVED BY OMB NO. 3150-0104	EXPIRES 7-31-2004

LICENSEE EVENT REPORT (LER)

(See reverse for required number of digits/characters for each block)

1. FACILITY NAME	2. DOCKET NUMBER	3. PAGE
South Texas Unit 2	05000 499	1 OF 4

4. TITLE
Turbine Blade Failure

5. EVENT DATE			6. LER NUMBER			7. REPORT DATE			8. OTHER FACILITIES INVOLVED	
MO	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REV NO	MO	DAY	YEAR	FACILITY NAME	DOCKET NUMBER 05000
12	15	2002	2002 -	04 -	01	07	01	2003	FACILITY NAME	DOCKET NUMBER 05000

9. OPERATING MODE	1
10. POWER LEVEL	100

11. THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR ': (Check all that apply)

	20.2201(b)		20.2203(a)(3)(ii)		50.73(a)(2)(ii)(B)		50.73(a)(2)(ix)(A)
	20.2201(d)		20.2203(a)(4)		50.73(a)(2)(iii)		50.73(a)(2)(x)
	20.2203(a)(1)		50.36(c)(1)(i)(A)	X	50.73(a)(2)(iv)(A)		73.71(a)(4)
	20.2203(a)(2)(i)		50.36(c)(1)(ii)(A)		50.73(a)(2)(v)(A)		73.71(a)(5)
	20.2203(a)(2)(ii)		50.36(c)(2)		50.73(a)(2)(v)(B)		OTHER Specify in Abstract below or in NRC Form 366A
	20.2203(a)(2)(iii)		50.46(a)(3)(ii)		50.73(a)(2)(v)(C)		
	20.2203(a)(2)(iv)		50.73(a)(2)(i)(A)		50.73(a)(2)(v)(D)		
	20.2203(a)(2)(v)		50.73(a)(2)(i)(B)		50.73(a)(2)(vii)		
	20.2203(a)(2)(vi)		50.73(a)(2)(i)(C)		50.73(a)(2)(viii)(A)		
	20.2203(a)(3)(i)		50.73(a)(2)(ii)(A)		50.73(a)(2)(viii)(B)		

12. LICENSEE CONTACT FOR THIS LER

NAME	TELEPHONE NUMBER (Include Area Code)
Kathleen A. Work	361-972-7936

13. COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT

CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX

14. SUPPLEMENTAL REPORT EXPECTED				15. EXPECTED SUBMISSION DATE	MONTH	DAY	YEAR
	YES (If yes, complete EXPECTED SUBMISSION DATE)	X	NO				

16. ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines)

At 1808 hours on December 15, 2002, Unit 2 was at 100% power when it was manually tripped due to excessive vibration in Low Pressure Turbine 22. Subsequent investigation identified that a blade had cracked and broken off and was ejected from the low pressure turbine into the condenser. Additional cracked blades were found in Low Pressure Turbines 22 and 23.

The cause of the blade cracking was a design flaw with the rotor train (natural frequency modes near 120 Hz) and a faulty new generator rotor (differences between old and new rotor cause increased rotor train response). These flaws were not recognized by the vendor, Siemens-Westinghouse, due to errors in their modeling of the Turbine-Generator rotor system. Corrective actions include repairing the Unit 2 rotor system and damaged blades, installing vibration monitoring equipment, and evaluating the data taken during and after the Unit 2 restart. Subsequent studies confirmed that the corrective actions were effective in reducing torsional vibrations and the plant has operated continuously since March 2003.

This event resulted in no personnel injuries, offsite radiological releases or damage to safety related equipment. There were no challenges to plant safety and the plant responded as expected.

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NARRATIVE *(If more space is required, use additional copies of NRC Form 366A)* (17)

DESCRIPTION OF EVENT

On December 15, 2002, at 1808 hours, Unit 2 was manually tripped due to excessive vibration in the low pressure turbine. A visual inspection revealed that a blade had been ejected from low pressure turbine 22 and was found in the condenser. The ejected blade came from the last row of blades (L-0 blade row) prior to the condenser. Unit 2 had just completed an outage (2RE09) and the unit had been returned to 100% power on December 10, 2002. The outage encompassed steam generator replacement, power uprate from 3800 MWT to 3853 MWT, and replacement of the main generator rotor.

Based on the initial visual inspection after the blade was ejected, further inspections were performed which revealed additional cracking in the low pressure turbines 22 and 23. Low pressure turbines 22 and 23 had been inspected during the previous outage (2RE08) per our inspection plan. Two cracks were found on low pressure turbine 23 and were repaired at that time. All other blades on these two rotors were inspected with no problems identified.

Repairs were made on all of the cracked blades found on the low pressure turbines as a result of this event. In addition, a Blade Vibration Monitoring System (BVMS) and Torsional Vibration Monitoring System (TVMS) were installed on Unit 2. Thirty seven days after the initial event, Unit 2 was safely restarted and reached 100% power on January 23, 2003 at 1502 hours. At 1617 on January 23 power was reduced due to unacceptable torsional vibration readings and on January 24, 2003, Unit 2 was taken off-line again. The turbine was inspected and additional cracked blades were found.

EVENT SIGNIFICANCE

This event resulted in no personnel injuries, radiation exposure, offsite radiological releases or damage to important safety related equipment. The event is reportable pursuant to 10CFR50.73(a)(2)(iv)(A) because it resulted in a condition that resulted in manual or automatic actuation of the reactor protection system.

This event was not risk significant for nuclear safety. The PRA group has determined that the Conditional Core Damage Probability (CCDP) for a turbine trip event is calculated by dividing the core damage frequency by the initiating event frequency, or CCDP = 2.91E-07/1.09 and CCDP = 2.68E-07. This result is typical for general transient initiating events and is not risk significant. It is less than the 1E-06 limit in Regulatory Guide 1.174, An Approach for Using Probabilistic Risk Assessment in Risk Informed Decisions on Plant Specific Changes to the Licensing Basis, judged acceptable for risk-informed decisions. The Conditional Large Early Release Probability (CLERP) is: LERF contribution divided by IE frequency, or 1.3065E-08/1.0875. CLERP = 1.20E-08 which is also well below the NRC limits identified in RG 1.174.

CAUSE OF EVENT

The Unit 2 low pressure turbine blades have experienced blade cracking due to a design flaw with the rotor train (natural frequency modes near 120 Hz) and a faulty new generator rotor (differences between old and new rotor cause increased rotor train response). These flaws were not recognized by the vendor, Siemens-Westinghouse, due to errors in their modeling of the Turbine-Generator rotor system.

The degradation influence that caused the high cycle fatigue cracks of the L-0 blade roots is high torsional vibration at 120 Hz. High cycle fatigue is driven by high alternating stresses at the L-0 blade root area. Based on Unit 2 startup testing and investigation into the Unit 2 failures, high torsional vibrations are the cause of the alternating stresses at the L-0 blade roots. The root cause of the torsional vibration is a combination of the following:

NARRATIVE *(If more space is required, use additional copies of NRC Form 366A)* (17)

1. The entire rotor train has several vibration modes that reside near 120 Hz (modes 19-24). These modes were considered by the vendor to be non-excitable modes. The design of the rotor system is such that the frequencies near 120 Hz were known, but not considered to be sensitive to excitations in the rotor train. During normal turbine generator operation there are steady state excitation forces that occur at twice the electrical frequency (120 Hz). These forces result from unbalanced transmission system voltages. These forces are known as negative phase sequence currents and act upon the generator rotor via the generator stator through the air gap. The forces create torque in the opposite direction of normal generator rotation. Discussions with the vendor show that a site specific torsional vibration analysis was not performed for the South Texas Project until 1997, and prior to 1997 the vendor relied on comparisons with a different plant of similar, but not the same design.

   The current Turbine Generator Rotor system design (with the modified Generator Rotor and original Generator Rotor) is such that there are numerous torsional vibration mode natural frequencies near 120 Hz that were determined to be non-excitable by the vendor. The frequencies are now subject to significant excitation due to negative phase sequence currents.

2. A new main generator rotor was installed in Unit 2 during 2RE09. The new rotor slots were machined incorrectly during fabrication and, therefore, the rotor is not identical to the original generator rotor. Also, the new generator rotor has additional slots that have been filled with filler material and the slots are slightly offset from original design.

   The vendor used their torsional analysis model to calculate the torsional frequency changes due to the new rotor. The calculations determined that the significant excitable vibration mode (Generator-Turning Gear-Jackshaft mode) moved further away from 120 Hz (118.9 Hz to 116.7 Hz) and therefore created more margin. The other modes near 120 Hz were again calculated to be non-excitable and deemed acceptable for use. The final vendor analysis concluded there were no significant changes and the new rotor design would perform as the old rotor.

   Based on the liberated blade's fracture surface, startup testing and investigation, the alternating stresses imposed on the L-0 blades before and after 2RE09 have changed significantly. The test data clearly shows the alternating stresses are significant and cracks are initiating and propagating very quickly at the blade roots such that plant operation is not possible for more than a few days. With the new generator rotor installed and the same or similar electrical forcing function (negative phase sequence currents), the torsional vibration response of the rotor train is up to 10 times greater than the Siemens-Westinghouse models predicted. The torsional vibration response was seen immediately after the main generator breaker closure.

   Siemens-Westinghouse believes that their torsional model is inaccurate with respect to modeling the modified (new) generator rotor and significantly under-predicts the torsional vibration response of the LP rotor train due to normal negative sequence currents. A group of several world experts met with Siemens-Westinghouse in Orlando on February 18 and 19, 2003. This group concluded that the replacement Generator rotor has directly caused the natural frequencies near 120 Hz to be excited and that the Siemens-Westinghouse model is incorrect in its ability to both accurately model the rotor system and predict natural frequencies.

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NARRATIVE *(If more space is required, use additional copies of NRC Form 366A)* (17)

CORRECTIVE ACTIONS

1. A torsional vibration monitoring system was installed in Unit 2. This action was completed on January 19, 2003.
2. Repairs are being made to the cracked blades found in the Unit 2 low pressure turbines. These repairs were completed on March 12, 2003.
3. Modifications and repairs were made to the Unit 2 rotor system to make it less sensitive to excitations in the rotor train. These repairs were completed March 12, 2003.

Corrective action number 1 from the original LER referred to blade vibration monitoring equipment that was installed on January 19, 2003. This equipment was later shutdown because the data was not reliable. The blade vibration monitoring system software was not able to distinguish accurate blade tip movement. The torsional vibration monitoring equipment was used to verify the effectiveness of the modifications. The results of the verification tests showed that the corrective actions appear to be effective. The plant has operated continuously since March 2003.

ADDITIONAL INFORMATION

A search of industry operating experience found the following six events involving turbine blade failures that appear that they could be similar to our event (i.e., a blade was ejected and the cause was probably due to torsional vibration or off-normal operating conditions):

Plant	Month of Blade Failure
Maanshan (Taiwan)	July 1985
Indian Point 3	July 1986
North Anna 1	August 1986
Susquehanna 1	July 1993
Palisades	July 1997
Diablo Canyon 1	November 2000

Operating experience information also shows that, since July of 1998, Comanche Peak 2 has needed to downpower each summer because the BVMS blade vibration amplitude goes above the alert level. Comanche Peak 1 is not affected by these high vibrations.