UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON D.C. 20555

January 7, 1994

NRC INFORMATION NOTICE 94-01: TURBINE BLADE FAILURES CAUSED BY TORSIONAL EXCITATION FROM ELECTRICAL SYSTEM DISTURBANCE

Addressees

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees to potential blade failures in low-pressure turbines reportedly caused by torsional vibration resulting from disturbance in the electrical power system. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

On July 12, 1993, at Susquehanna Unit 1, automatically shut down as a result of high turbine vibration, which was felt in the control room (Reference 1). The maximum amplitude recorded was about 0.038 cm [15 mils] at bearing No. 8. Two blades from the L-1 row on the governor end of the low-pressure C turbine separated from the rotor. The failed blades gouged diaphragms (stationary rotors) and damaged other blades in the L-0 and L-1 rows. Cracks were found at the roots of several blades in the L-1 row. The fragments of the blades damaged 50 to 100 condenser tubes.

The plant was operating at 100 percent power at the time of the event. Control room operators responded to the event by entering the appropriate procedures. The emergency core cooling and engineered safety feature systems were not initiated. The licensee concluded that primary containment integrity was maintained.

Susquehanna Unit 1 uses General Electric low-pressure turbines, model number TB 170X592. Each turbine operates at 1800 revolutions per minute. The L-1 blades are about 96 cm [38 inches] long. The root (finger dovetails) of a blade consists of six plates, each plate being about 6 cm [2 1/2 inches] wide, 10 cm [4 inches] long, and 1 cm [3/8 inch] thick. Each plate has six pin holes arranged in three rows of two holes each. The blade is attached to the

rotor by pins staked in the holes. The failed blades were severed at the top rows of holes, as indicated in Figure 1.

Previous Events

Between 1973 and 1976, at Prairie Island Units 1 and 2, the licensee, Northern States Power Company, had sustained a total of five blade failures or cracking events in its Westinghouse low-pressure turbines. All failed blades were from the L-2 or L-1 row of the low pressure rotor. The licensee attributed these failures to torsional vibration resulting from electrical system excitation. To resolve the problem, the licensee (1) modified the L-2 blades and the L-1 disc to be unresponsive to 120-Hz excitation, (2) performed a torsional test before returning the system to service.

In 1985, eight blades from the last stage of a General Electric low-pressure turbine failed and separated from the rotor at one of the units of a foreign nuclear plant. The blade failures were attributed to high cycle fatigue as a result of the electrical disturbance which excited the 19th torsional mode of rotor vibration at or near the resonant frequency of 120.5 Hz. The failed blades caused unbalanced mass and produced a large vibration on the turbine-generator unit, which in turn failed the alternator shaft. The failed alternator shaft caused leakage of hydrogen and lubrication oil from the seal system and led to a fire in the generator-alternator area. A subsequent torsional test at the other unit of that plant showed that a 0.05 Hz change in the electrical frequency contributed to a three fold increase in stress response in the L-0 row blades.

Discussion

Since the 1970's, some blade failures of low-pressure turbines at nuclear power plants have been attributed to torsional excitation of the turbine-generator shaft as a result of an electrical system disturbance. When the frequency of the excitation coincides with the natural torsional frequency of the turbine rotor, the rotor and blade responses are highly magnified. The blade eventually fails by fatigue.

The electrical system disturbances could be caused by (1) negative-phase sequence current resulting from unbalanced load among the three electric phases, caused by the load imbalance creating a current in the generator stator opposite to the main current; (2) electric faults resulting from high speed reclosing of field relay contacts; (3) load rejection; and (4) switching operations on the transmission line (Reference 2).

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Brian K. Grimes, Director
Division of Operating Reactor Support
Office of Nuclear Reactor Regulation

Technical contact: John Tsao, NRR
(301) 504-2702

References:

1. Letter from E. C. Wenzinger of the U.S. Nuclear Regulatory Commission to R.G. Byram of Pennsylvania Power & Light Company, Subject: NRC Region I Combined Inspection 50-387/93-11; 50-388/93-11, August 31, 1993.
2. Technical Information Letter (TIL-1012-2), "Effect of Electrical System Vibration on Turbine-Generator Torsional Response," General Electric Company, Schenectady, New York, September 8, 1987.

Attachments:
1. Figure 1. The Finger Dovetail of a Typical Blade
2. List of Recently Issued NRC Information Notices

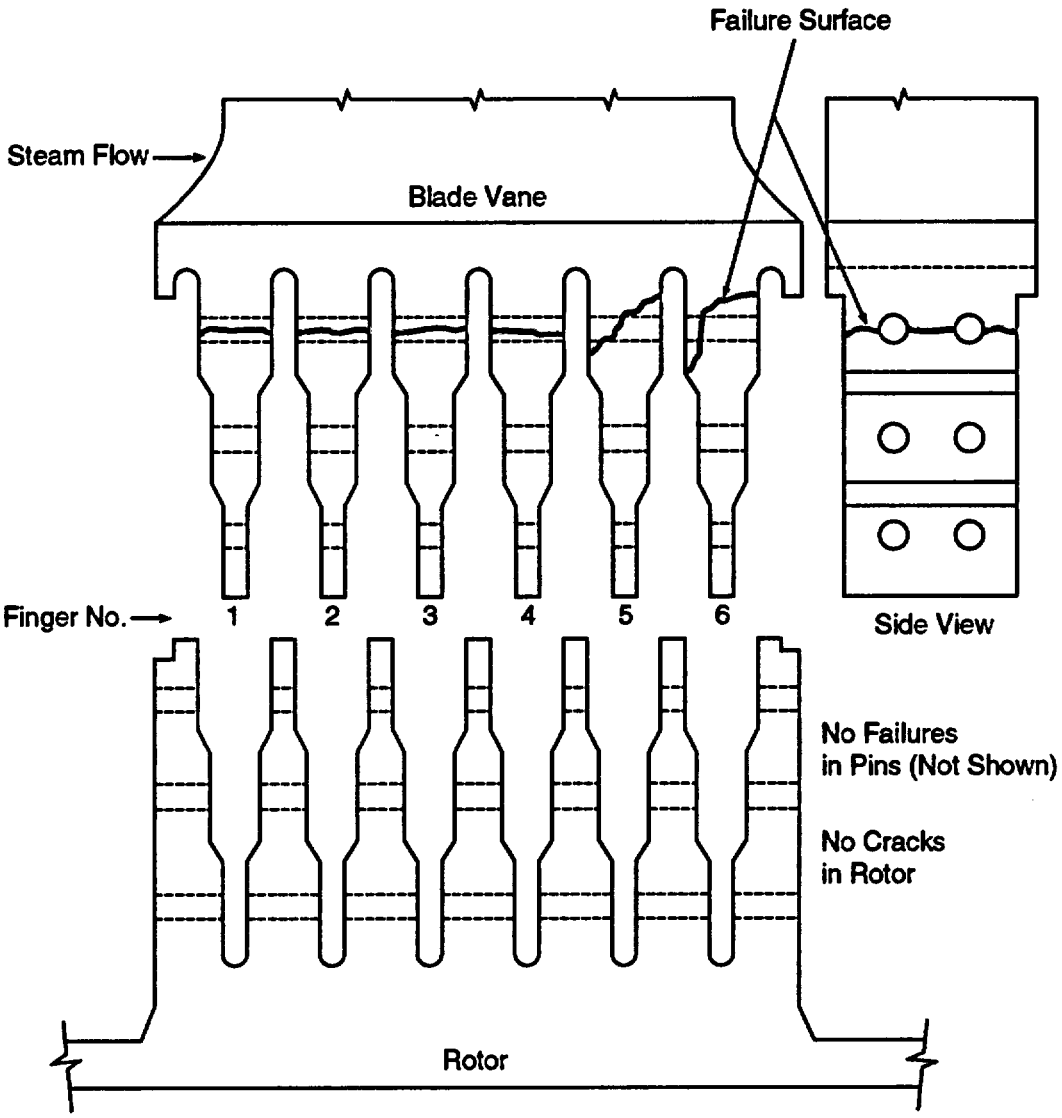

Figure 1 The Finger Dovetail of a Typical Blade

LIST OF RECENTLY ISSUED NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
93-101	Jet Pump Hold-Down Beam Failure	12/17/93	All holders of OLs or CPs for boiling-water reactors
93-100	Reporting Requirements for Bankruptcy	12/22/93	All U.S. Nuclear Regulatory Commission licensees.
91-29, Supp. 2	Potential Deficiencies Found During Electrical Distribution System Functional Inspections	12/22/93	All holders of OLs or CPs for nuclear power reactors.
93-99	Undervoltage Relay and Thermal Overload Setpoint Problems	12/21/93	All holders of OLs and CPs for nuclear power reactors.
93-98	Motor Brakes on Valve Actuator Motors	12/20/93	All holders of OLs and CPs for nuclear power reactors.
93-97	Failures of Yokes Installed on Walworth Gate and Globe Valves	12/17/93	All holders of OLs or CPs for nuclear power reactors.
93-96	Improper Reset Causes Emergency Diesel Generator Failures	12/14/93	All holders of OLs or CPs for nuclear power reactors.
93-95	Storm-Related Loss of Offsite Power Events due to Salt Buildup on Switchyard Insulators	12/13/93	All holders of OLs or CPs for nuclear power reactors located close to a large body of salt water.
93-94	Unauthorized Forced Entry into the Protected Area at Three Mile Island Unit 1 on February 7, 1993	12/09/93	All holders of OLs or CPs for nuclear power reactors.
93-93	Inadequate Control of Reactor Coolant System Conditions During Shutdown	12/08/93	All holders of OLs or CPs for nuclear power reactors.

OL = Operating License
CP = Construction Permit

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*SEE PREVIOUS CONCURRENCES

OFFICE	*OGCB/DOR	*TECH ED	*DE/EMCB	*DE/EMCB/NRR	*D:DE:EMCB
NAME	CVHodge	DGable	JTsao	JStrosnider	KWichman
DATE	11/18/93	10/20/93	10/20/93	10/25/93	10/22/93

*C:EELB/DE	*D:DE:NRR	*C:OGCB/DORS	D:DORS/NRR
CBerlinger	JWiggins	GHMarcus	BKGrimes
10/27/93	11/24/93	11/30 /93	01/4/94

DOCUMENT NAME: 94-01.IN

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This information notice was coordinated with OIP because it mentions a foreign plant.

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DOCUMENT NAME: TURBTORS.INF

electrical disturbance which excited the 19th torsional mode of rotor vibration at or near the resonant frequency of 120.5 Hz. The failed buckets caused unbalanced mass and produced a large vibration on the turbine-generator unit, which in turn failed the alternator shaft. The failed alternator shaft caused leak of hydrogen and lubrication oil from the seal system and led to a fire in the generator-alternator area. A subsequent torsional test of the turbine of the sister unit at the plant showed that a 0.05 Hz change in the electrical frequency contributed to a three fold increase in stress response in the L-0 row buckets.

References 7 through 12 in Attachment 1 are included to provide additional information.

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11/24

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