Fermi Unit 2

Newport, MI

Owner: Detroit Edison Company

Reactor type: Boiling water reactor

Commercial operations began: January 18, 1988

Outage dates (duration): December 25, 1993 to January 18, 1995 (1.1 years)

Reactor age when outage began: 5.9 years

Fleet status: Only reactor owned by the company

Synopsis

The catastrophic failure of the main turbine began the outage and determined its length. The plant had a history of high main turbine vibrations and had undertaken a series of refurbishments to upgrade the quality of the low pressure turbine blades. Rather than incur the cost of the refurbishments all at one time, management elected to do a little during each refueling outage. The main turbine catastrophically failed before the string of refurbishments could be completed. It took slightly over one year to repair the main turbine as well as repair the systems damaged by water, fires, and pieces flung from the turbine when it failed.

Process Changes

No discernible changes relating to this event were identified.

Commentary

Setting aside the important point that more aggressive management response to longstanding turbine problems likely would have prevented this extended outage, once the event happened Detroit Edison and the NRC undertook thorough and effective measures to deal with the damage it caused. The company's efforts were largely focused on restoring the physical plant. The NRC's efforts were largely focused on restoring the processes (e.g., work management and work control). Collectively, the efforts allowed Fermi Unit 2 to restart in significantly better condition.

NRC Systematic Assessment of Licensee Performance (SALP) History

Date	Operations	Maintenance	Engineering	Plant Support
05/1989	2	3	3	2/1/1
04/1990	2	3	2	1/1/1
05/1991	2	2	2	1/2/1
10/1992	2	2	2	1/1/1
05/1994	3	2	2	1
05/1996	3	2	2	1

NOTE: A rating of 1 designated a superior level of performance where NRC attention may be reduced. A 2 rating designated a good level of performance with NRC attention at normal levels. A rating of 3 designated an acceptable level of performance where increased NRC attention may be appropriate.

Details

August 1988: The main turbine automatically tripped on high vibration of the #8 and #9 bearings. The company attributed the high vibration levels to the failure of an air line that caused excessive cooling of the turbine lubricating oil.[1]

March 1989: The reactor was manually shut down due to main turbine high vibrations.[2] Workers disconnected the circuit that would automatically trip the main turbine when vibrations rose too high.[3]

September 1989: During the first refueling outage, workers discovered broken blades in the 5th stage of low pressure turbine 2 and damaged blades in the 5th stage of low pressure turbines 1 and 3. Some of the pieces from the broken blades were not found, but the company attributed their absence to the high vibration experienced since startup in 1988. The 5th stage blades in all three low pressure turbines were removed. The 8th stage blades on all three low pressure turbines showed signs of excessive wear. Due to the unavailability of spare parts, only the 8th stage blades on low pressure turbine 1 were replaced. The plan was to refurbish the old 8th stage blades in low pressure turbine 1 and install them on low pressure turbine 2 during the second refueling outage. The old 8th stage blades from low pressure turbine 2 would be refurbished and installed in low pressure turbine 3 during the third refueling outage.[4]

December 1989: The reactor automatically scrammed from 15 percent power when the main turbine tripped on high thrust wear on the turbine bearings. Workers disconnected the trip on thrust wear.[5]

November 25, 1990: The reactor was shut down because of main turbine high vibrations. The NRC stated to the media, Detroit Edison "had more problems with turbine vibration at Fermi 2 than at the average plant. They've had vibration problems from the very beginning."[6] Workers discovered broken blades in the 4th stage of low pressure turbine 3 and found that some of the broken pieces had damaged the adjacent shroud. The failures were attributed to stress from high loading on the 4th stage blades after the broken and damaged 5th stage blades were removed in September 1989. The 4th stage blades were removed.[7]

April 1991: During the second refueling outage, workers installed redesigned blades in the 4th and 5th stages of all three low pressure turbines.[8]

September 1992: The 8th stage blades from low pressure turbine 2, which were removed during the second refueling outage and refurbished, had been planned to replace the original 8th stage blades in low pressure turbine 3 during the third refueling outage. But Detroit Edison deferred that work to the fourth refueling outage.[9] The fourth refueling outage was scheduled to start in March 1994.[10]

August 13, 1993: The reactor automatically scrammed from 93 percent power due to a false signal of high water level in the reactor vessel initiated as an operator was removing tape from a level instrument equalizing valve handle. Following the reactor scram, the reactor coolant system experienced an excessive cooldown rate (greater than 100°F per hour) attributed to inadequate procedures and simulator training, operator distractions caused by nearly 100 burned-out light bulbs on control room panels, and stress from high operator work load. All of the control rods fully inserted during the scram, but six control rods failed to show full insertion due to burned-out light bulbs. After the false high water level tripped all of the feedwater pumps, an operator started the standby feedwater pump, but its injection valve did not show that it had opened due to a burned-out light bulb. Several containment isolation valves also did not show they had closed on the control room panel display due to burned-out light bulbs. The operators were hindered in their attempts to monitor drywell pressure because its chart recorder in the control room had failed. The main steam isolation valves automatically closed due to the false high water level signal and the operators relied on the safety relief valves to control reactor pressure—but the safety relief valve tailpipes did not indicate high temperature due to burned-out light bulbs. When the main steam isolation valves were re-opened, seven of the eight indicator lights failed to show "open" because they were burned out.[11]

May 1993: Workers modified the steam control valves to the main turbine to increase power output to 105 percent of the original power rating. The control valve modifications had the unintended consequence of producing steam oscillations. Power was administratively limited to 93 percent of rated.[12]

December 25, 1993: The main turbine automatically tripped due to an erroneous mechanical overspeed signal caused by high vibrations. The reactor, which was operating at 93 percent power, received an automatic scram signal triggered by the turbine trip. The high vibration was caused by catastrophic failure of the turbine blades. Ejected blade parts ripped through the turbine casing and severed condenser tubes and other piping. The rupture of piping supplying hydrogen gas to the generator for cooling caused a large fire. The plant's fire brigade took 37 minutes to muster, dress, and enter the turbine building to fight the fire. Their efforts were hindered by numerous communication problems, including malfunctions of personnel motion detectors (e.g., "man down" alarms).

About 500,000 gallons of water from broken general service water piping and turbine building closed cooling water piping flooded the radwaste building basement to a depth of approximately six feet. Workers were slow to isolate the systems with broken piping to terminate the flooding, due to the total lack of procedures for a turbine building internal flood. The severed condenser tubes permitted water from Lake Michigan to flow into the condenser hotwell, from where it was pumped to the condensate storage tank. The standby feedwater system pumped water from the condensate storage tank to the reactor vessel. The lake water caused conductivity and chloride levels of the reactor vessel water to significantly exceed specifications.[13]

December 28, 1993: The NRC issued a Confirmatory Action Letter to Detroit Edison detailing steps to be taken prior to restarting the reactor.[14]

January 14, 1994: The plant manager issued the Fermi 2 Recovery Plan, a 226-page document detailing 16 major efforts to support restarting the reactor:[15]

1. Water management: The event caused significant amounts of water to be in places it shouldn't be (e.g., the radwaste building basement) and poorer quality water to be in places designed to hold water. This task sought to rectify both problems.
2. Turbine generator: The event severely damaged the turbine and generator, as well as their support systems. This task was to repair or replace components as necessary to restore system functions.
3. Fire protection system: The event disabled or impaired the fire detection and suppression system in the turbine building. This task sought to maximize protection from the degraded system until it could be restored to full capability and also to assess the adequacy of fire barriers and address any findings.
4. B3105F031B response: During the event, the discharge valve for recirculation pump B malfunctioned. This task sought to identify the root cause of the failure and implement measures to prevent recurrence.
5. Plant area cleanup: This task sought to restore the plant to its original condition while minimizing the amount of contaminated trash generated during the cleanup.
6. Nuclear fuels concerns: The event resulted in the reactor vessel water chemistry exceeding specifications on parameters such as conductivity and chloride concentrations. This task sought to evaluate the impact of the chemistry excursion on fuel reliability.
7. System layup: This task sought to minimize the impact of poor water chemistry on plant systems by controlling system operations until water could be treated and returned to specifications.
8. System walkdowns: Systems affected or potentially affected by the event needed to be visually inspected to verify they were capable of supporting reactor restart.
9. Structural support: During the event, seismic alarms were received in the control room. This task sought to inspect structures, supports, and components for signs of damage caused by the high vibration levels.
10. Scram team: This task sought to review plant response to the event and determine any equipment and/or procedural improvements needed.
11. Financial controls: This task sought to ensure sufficient resources remained available to conduct all the necessary recovery evolutions.
12. Outage transition: Due to the expected length of the outage needed to restore the turbine/generator, it was decided to combine it with the next refueling outage.
13. Radwaste systems recovery: The event generated a large volume of contaminated water that must be processed, including some containing 17,000 gallons of lubricating oil. This task covered treatment of the event's water and restoring the radwaste system to its design capability.
14. Vessel internals inspection: Related to Items 6 and 7, this task sought to evaluate the impact of poor water chemistry on the reactor vessel and its internal components.
15. Sequence of events recorder: During the event, the sequence of events recorder experienced several apparent anomalies in the items it reported and when it reported them. This task sought to evaluate this system and correct any identified deficiencies.
16. Condenser repair: The event severed condenser tubes and caused oil-laden water to fill the condenser hotwell. This task sought to repair the tubes and clean the condenser.

May 18, 1994: The NRC issued its SALP report for Fermi 2 and lowered the rating in operations from 2 to 3. The NRC regional administrator explained the reduction as follows:

> *"The ratings represent a decline in performance from the previous assessment period particularly for the area of Operations. This can be attributed to failure to effectively correct adverse conditions resulting in repetitive performance deficiencies. Causes for these deficiencies that were common to multiple SALP functional areas included inadequate work controls, failure to adequately communicate management expectations to workers, perceived scheduler pressure, and inadequate corrective actions."*[16]

August 24, 1994: Detroit Edison submitted its response to the NRC's Confirmatory Action Letter indicating that all but three items had been completed and that information on the remaining items would be provided at a later date.[17]

October 13, 1994: Detroit Edison supplemented its response to the items on the NRC's Confirmatory Action Letter with information about turbine testing during restart.[18]

January 18, 1995: Unit 2 was connected to the electrical grid to end its extended outage.[19]

February 11, 1995: Workers connected two data acquisition system (DAS) units to the reactor vessel water level instrumentation channels in an attempt to diagnose spurious alarms appearing on the sequence of events alarm system. When the DAS units were turned off, operators noticed that the indicated water level in the reactor vessel dropped about 10 inches. Subsequent investigation revealed that the DAS units added impedance in excess of 100,000 ohm to the instrumentation circuits. The bias introduced by this impedance would have caused the reactor core isolation cooling and high pressure coolant injection systems to automatically initiate at a level about five inches higher than analyzed and to automatically trip at a level about 17 inches higher than analyzed. The workers had connected the DAS units without any safety evaluation under Title 10 of the Code of Federal Regulations (CFR), Part 50.59, or any other formal assessment of the potential impact.[20]

March 7, 1995: Operators restarted the reactor following a three-week outage to repair cracks in piping that provide lubricating oil to the main turbine. These cracks were revealed during testing following restart from the year-plus turbine outage, necessitating the reactor to be shutdown while the piping was replaced.[21]

March 16, 1995: The reactor was shut down due to high turbine vibration levels. As a result of the catastrophic turbine failure on December 25, 1993, and the ensuing long outage, the turbine shaft developed bows. Workers attempted to counteract the effect of these bows by attaching "balance shots" to the turbine shaft similar to how mechanics attach weights to rims to balance wheels. But the balancing was complicated by the fact that the bows changed their shape as the metal shaft heated up, causing a balance shot properly positioned for a cold shaft to be in the wrong place for a heated shaft. Detroit Edison brought in Hopper & Associates, General Electric, and GEC Alshtom to diagnose the problem, but several weeks had passed without success in reducing the high turbine vibration levels.[22]

April 9, 1995: Operators manually scrammed the reactor from 80 percent power for a test to monitor the turbine vibration levels during its coastdown after the turbine trip. When the water level inside the reactor vessel dropped farther than anticipated causing the automatic initiation of emergency makeup systems, the company was forced to declare an Unusual Event, the least serious of the four emergency levels.[23]

Notes

[1] Greenman, E.G. 1994. NRC Region III augmented inspection team (AIT) review of the December 25, 1993, Fermi 2 turbine-generator failure. Letter to Douglas R. Gipson, senior vice president, nuclear operations, Detroit Edison Company, February 7. Edward G. Greenman was director, reactor projects at the Nuclear Regulatory Commission (NRC).

[2] Slat, C. 1990. Fermi generator: troubled history. *Monroe Evening News*, November 27.

[3] Greenman, 1994.

[4] Ibid.

[5] Ibid.

[6] Slat, 1990.

[7] Greenman, 1994.

[8] Ibid.

[9] Ibid.

[10] Airozo, D. 1994. AIT: Not fixing blades in ’92 may have contributed to Fermi turbine failure. *Inside NRC*, February 21.

[11] NRC. 1993. Operating reactors events briefing 93-34, September 8.

[12] Greenman, 1994.

[13] Ibid.

[14] Martin, J.B. 1993. Confirmatory action letter. Letter to Douglas R. Gipson, senior vice president, nuclear generation, Detroit Edison Company, December 28. John B. Martin was regional administrator at the NRC.

[15] McKeon, R. 1994. *Fermi 2 recovery plan*. Newport, MI: Detroit Edison Company.

[16] Martin, J.B. 1994. Letter to Douglas R. Gipson, senior vice president, nuclear generation, Detroit Edison Company, May 18. John B. Martin was regional administrator at the NRC.

[17] Colburn, T.G. 1994. Fermi 2 – Restart action plan issues closeout – Safety evaluation. Letter to Douglas R. Gipson, senior vice president, nuclear generation, Detroit Edison Company, November 15. Timothy G. Colburn was senior project manager at the NRC.

[18] Colburn, 1994.

[19] McKeon, R. 1995. Monthly operating status report for January 1995. Letter to NRC, February 15. Robert McKeon was plant manager at the Detroit Edison Company.

[20] NRC. 1995. Potential for data collection equipment to affect protection system performance. Information Notice No. 95-13, February 24.

[21] Detroit Edison Company. 1995. Fermi 2 power plant restarted. Press Release, March 7.

[22] Dizard III, W. 1995. Fermi’s restart date indefinite as turbine vibrations continue. *Nucleonics Week*, March 16.

[23] NRC. 1995. Daily Event Report No. 28654, April 9.