11.2 TURBINE-GENERATOR

11.2.1 Power Generation Objective

The power generation objective of the turbine-generator is to utilize steam produced in the reactor core to produce electric power. The turbine-generator controls work in conjunction with the Nuclear Steam Supply System controls to maintain essentially constant reactor pressure and to limit transients during load variations.

11.2.2 Power Generation Design Basis

The turbine-generator shall be capable of accepting the steam flow from the reactor vessel and producing a nominal electrical output of 1155 Mw(e).

The favorable orientation of the low pressure turbines provides assurance that safety related systems, structures, and components would not be damaged in the unlikely event a turbine missile is generated. The probability of a turbine generator failure leading to the ejection of external missiles will be controlled to be less than 1E-4/year (for favorably oriented turbines) in accordance with the methodology described in GE report dated January 1984 entitled “Probability of Missile Generation in General Electric Nuclear Turbines.” This report describes GE’s method for evaluating the probability of wheel missile generation for nuclear turbines manufactured by GE. Since approval of the method by the NRC in 1985 (reference NUREG-1048, Appendix U), it has been routinely applied to establish reinspection intervals for low-pressure (LP) rotors with shrunk on wheels and to furnish unit specific wheel probabilities.

Testing intervals of the tests listed below may impact the turbine missile generation evaluation:

1. Main stop valve testing
2. Control valve testing
3. Combined intermediate valve testing
4. Extraction system check valve testing
5. EHC hydraulic fluid sampling
6. Master trip solenoid valve testing
7. Over speed trip testing

The Unit 1 upgrade of the low pressure turbines to a monoblock rotor design further decreases the probability of a turbine generated missile from that previously evaluated for original plant shrunk-on rotors (Reference: Letter from H. A. Morgan (GE) to R. Smith (TVA), LP Turbine Missile Probability Concerns, Rev 1, dated Dec 5, 2003).”

11.2.3 Description

The turbine is an 1,800-rpm tandem-compound, six-flow, nonreheat unit with 43-inch last stage buckets. It has a double-flow, high-pressure cylinder and three double-flow low-pressure cylinders. Steam from the high-pressure cylinder passes through moisture separators before entering the low-pressure units. The turbine has five extraction stages for reactor feedwater system heating. Turbine controls include an electric-hydraulic speed governor, overspeed protection, steam admission control valves, emergency stop valves, combined intermediate stop-intercept valves, bypass valves, and pressure regulators (see Subsection 7.11 for turbine instrumentation and control).

Design conditions for the turbine are:

a. 965 psia (pre-uprated), 980 psia (uprated) steam pressure at the stop valves (essentially saturated), maximum moisture 0.28 percent (pre-uprated), 0.50 percent (uprated),

b. 2.00-in. Hg absolute backpressure,

c. Zero-percent system makeup, and

d. Extraction of steam and moisture from turbine to provide five stages of feedwater heating with feedwater return temperature to the reactor at 376.1°F (pre-uprated), 380.6°F (uprated).

The rated design flow is 13,369,581 (pre-uprated), 14,102,020 (uprated) pounds of steam per hour. The turbine is designed to accept, however, a maximum expected flow of 14,038,061 (pre-uprated), 14,557,900 (uprated) pounds of steam per hour under the above conditions with the control valves wide open.

For Unit 2 only, the generator is rated at 1,280,000 kVA at a 0.9 power factor (pre-uprated), 0.93 power factor (uprated) and a 75-psig hydrogen pressure, and has a short circuit ratio of 0.60. For Unit 3 only, the generator is rated at 1,332,000 kVA at a 0.93 power factor and a 75-psig hydrogen pressure and has a short circuit ratio of 0.58. The generator exciter system is of the Alterrex type rated at 2,635 kW and 500-V. The generator is a direct-coupled, 60-Hz, 22,000-V synchronous unit, with a water-cooled armature winding and a hydrogen-cooled rotor and stator core. When the turbine is operating at design backpressure, with valves wide open and all feedwater heaters in service, the generator will not be overloaded at a 0.9 power factor (pre-uprated), 0.93 power factor (uprated).

For Unit 1 Only: The generator is rated at 1,330,000 kVA at 0.95 power factor and a 75-psig hydrogen pressure and has a short circuit ratio of 0.58. The generator exciter system is of the Alterrex type rated at 2,635 kW and 500-V. The generator is a direct-coupled, 60-Hz, 22,000-V synchronous unit, with a water-cooled armature winding and a hydrogen-cooled rotor and stator core. When the turbine is operating at design back pressure with valves wide open and all feedwater heaters in service, the generator will not be over loaded at 0.95 power factor.

The turbine-generator produces 1,098,420 kW (pre-uprated), 1,155,240 kW (uprated) at the generator terminals and passes 13,369,581 (pre-uprated), 14,102,020 (uprated) pounds of steam per hour at rated operating conditions.

During normal operations, the steam admitted to the turbine is controlled by the pressure regulator which maintains essentially constant pressure at the turbine inlet, thus controlling reactor vessel pressure. The EHC system pressure regulator can control reactor pressure directly. The ability of the station to follow system load depends on adjustment of reactor power level. This is accomplished by changing Reactor Coolant Recirculation System flow or repositioning of control rods.

The steam admission valves close if an increase in system frequency or loss of generator load causes an increase in turbine speed. The loss of generator load is detected with power/load unbalance circuitry that results in a turbine control valve fast closure. This circuitry includes both an imbalance and a rate of change logic, which must be satisfied to generate the TCV fast closure signal. Reactor steam in excess of that which the admission valve will pass is bypassed directly to the main condenser through pressure-controlled bypass valves.

All other interlocks and features necessary to maintain system integrity, such as those for lube-oil pressure, seal oil pressure, and backpressure, are similar to those used in conventional turbine-generator systems.

The turbine-generator system is illustrated in Figures 1.6-29, sheets 1, 2, and 3 Subsection 1.6.

11.2.4 Tests and Inspections

The standard turbine tests at the factory consist of tests of such components as governor and control mechanisms, regulators, auxiliary oil pumps system, mechanical balance, and overspeed of rotors. The turbine was assembled at the factory to establish and verify the fits and operating clearances.

The generator was given standard factory tests which include the following:

Mechanical inspection,
Rotor balance,
Rotor overspeed run,
Measurement of cold resistance of stator and rotor windings,

Winding-insulation resistance measurement,
Dielectric tests,
Air leakage test on hydrogen cooled stator frame,
Resistance-temperature detector test, and
Flow continuity for armature winding.

Tests and inspection are conducted prior to and during operation to ensure functional performance as required for continued safe operation, and to provide maximum protection for operating personnel. Among these tests which are periodically performed are the following:

Testing of main stop valves and protective valves,
Testing of bypass valves and power-operated extraction system check valves,
Oil-level gauge testing,
Emergency overspeed protection
Thrust-bearing wear-detector testing,
Automatic pump starting,
Control valve tightness test, and
Main stop valve tightness test.

During normal operating periods duplicate equipment is rotated on a regular basis to assure backup equipment is in operational readiness at all times.