US-APWR
NRC Questions

April 18, 2008
Mitsubishi Heavy Industries, Ltd.

NRC QUESTION – Starting Air Capacity (1/3)

- The MHI documents state the starting air system is good for 3 start attempts. The current Standard Review Plan has a recommendation of enough air for 5 attempted starts. How is MHI addressing that delta?

NRC QUESTION – Starting Air Capacity (2/3)

- The US-APWR is provided with four (4) 50% GTG. If one GTG is in the test mode (or after testing is completed), the remaining three (3) GTG can ensure that the plant safety system can be powered, even if a single failure is considered. Therefore, each GTG has sufficient air to allow for three (3) start capability.

NRC QUESTION – Starting Air Capacity (3/3)

- It is assumed that the reasons and basis for sufficient air for five (5) start requirement are:

  - The requirement has been provided for a conventional (typical) NPP equipped with two (2) safety trains.

  - Each EDG should be able to be tested. If one EDG is in test, only the other EDG is available to perform its safety function.

  - It is preferable that each EDG has air storage for two times start capability in consideration of test.

  - It is not necessary to assume that a LOOP occurs while one EDG is tested, but it is necessary to assume that a LOOP occurs after the completion of EDG testing.

  - The air receiver should have enough capacity. That is minimum 3 times in addition to above two times. Therefore, EDG should have total about 5 times capability.

NRC QUESTION – Safety vs. Non-safety GTG (1/2)

- Discuss the difference between safety GTGs versus non-safety GTGs

NRC QUESTION – Safety vs. Non-safety GTG (2/2)

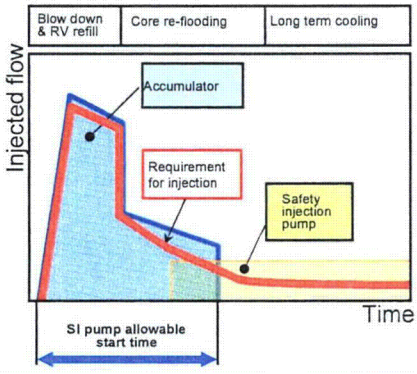
	EPS – GTG	AAC – GTG
Rating	4500kW, 6.9kV	4000kW, 6.9kV
Starting	Air	DC Power
Location	Independent	
Fuel Supply & Storage	Independent	
Qualification	Class 1E	Non Class 1E
Auxiliaries	Independent	

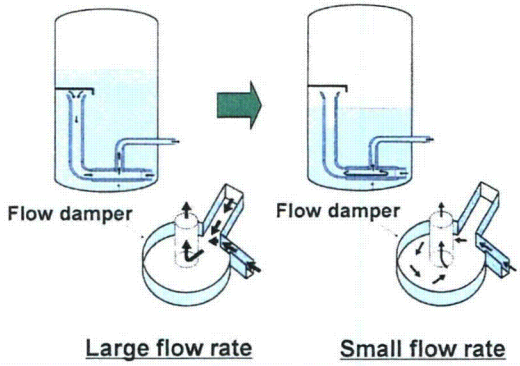
NRC Question GTG – STARTING TIME (1/3)

- EPS starting time: 40 sec starting time for GTGs versus 10 sec staring time for Diesels
- Why acceptable for LBLOCA and SBLOCA?

NRC Question GTG – STARTING TIME (2/3)

- System Design (Cont'd)
  - ✓Advanced Accumulator
    - •Automatic switching of injection flow rate by flow damper
    - •Integrates function of low head injection system
    - •Long accumulator injection time allows longer time for safety injection pump to start





Topical Report of Advanced Accumulator was submitted to the NRC

NRC Question GTG – STARTING TIME (3/3)

- CS pumps/Heat Exchangers used for RHR functions during shutdown
  - ✓In current PWR plants, RHRS functions as the low head safety injection system (Common use of RHR and LHSI)
  - ✓In US-APWR, the function of the low head safety injection (LHSI) is integrated into the Advanced Accumulator and safety injection pumps (SIP)

Comparison of Systems

System	US-APWR	Current PWR
Containment Spray System	CS/RHRS	CSS
Residual Heat Removal System	CS/RHRS	RHRS/LHSI
Low Head Safety Injection System	Advanced Accumulator and SIP	RHRS/LHSI
Accumulator Injection System	Advanced Accumulator	Accumulator
High Head Safety Injection System	SIP	SIP

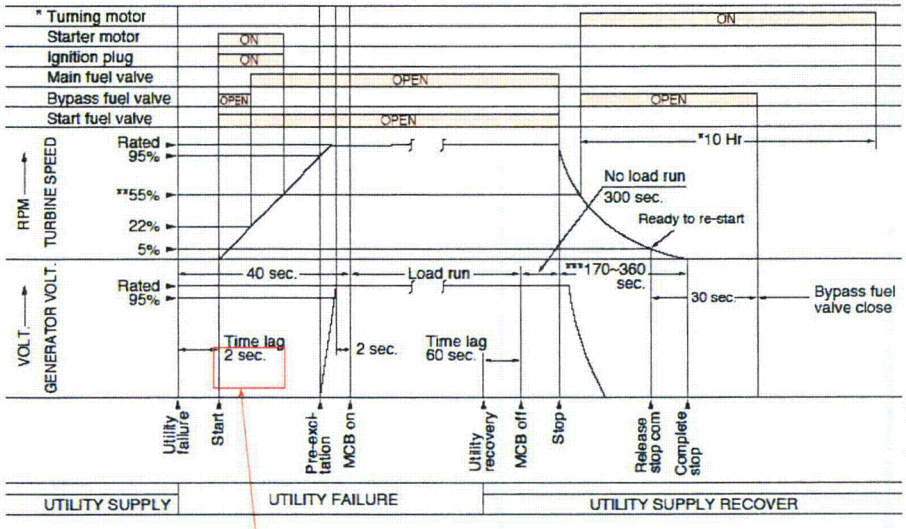
NRC Question – Governor and Excitation of GTG (1/6)

- Discuss the excitation and governor systems of the gas turbine

Governor(2/6)

TYPICAL OPERATION , TIMING CHART

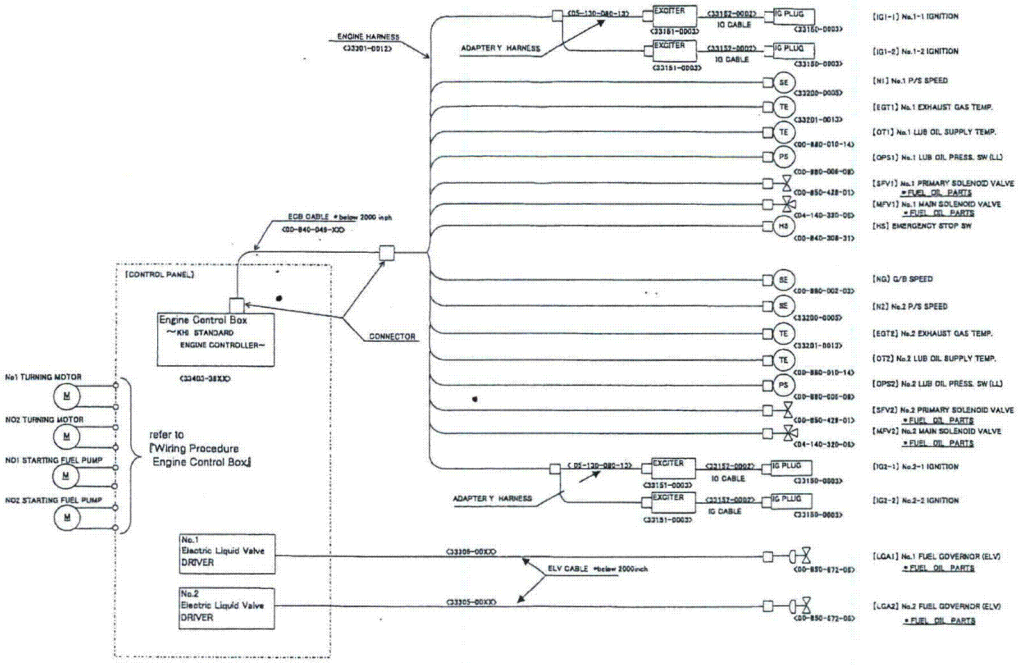
● Typical Timing Chart Of Operation



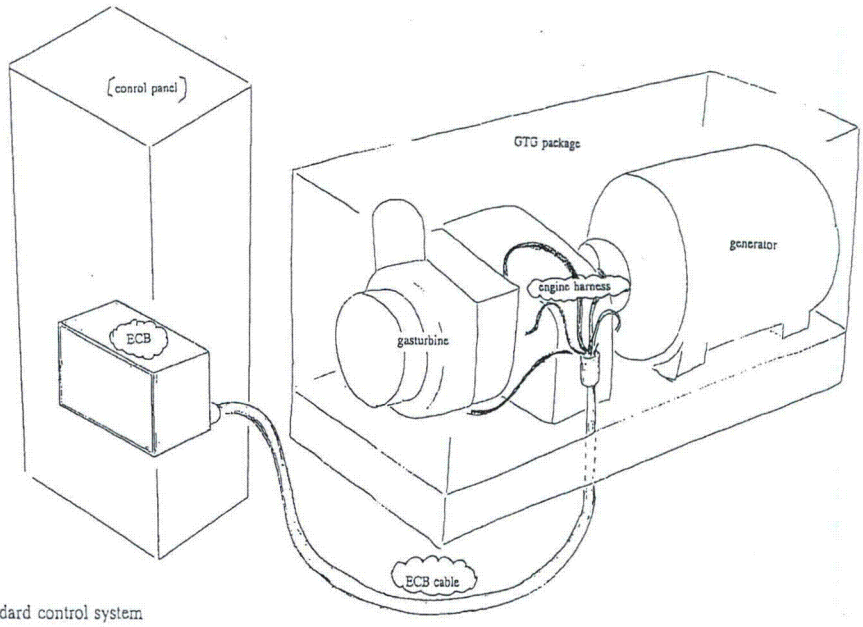
Note:
* Supplied with GPS1250 or larger model.
** 70% rpm for GPS250 and GPS500
*** 70 sec. for GPS250 and GPS500

The required time to confirm the black out.

Governor(3/6)

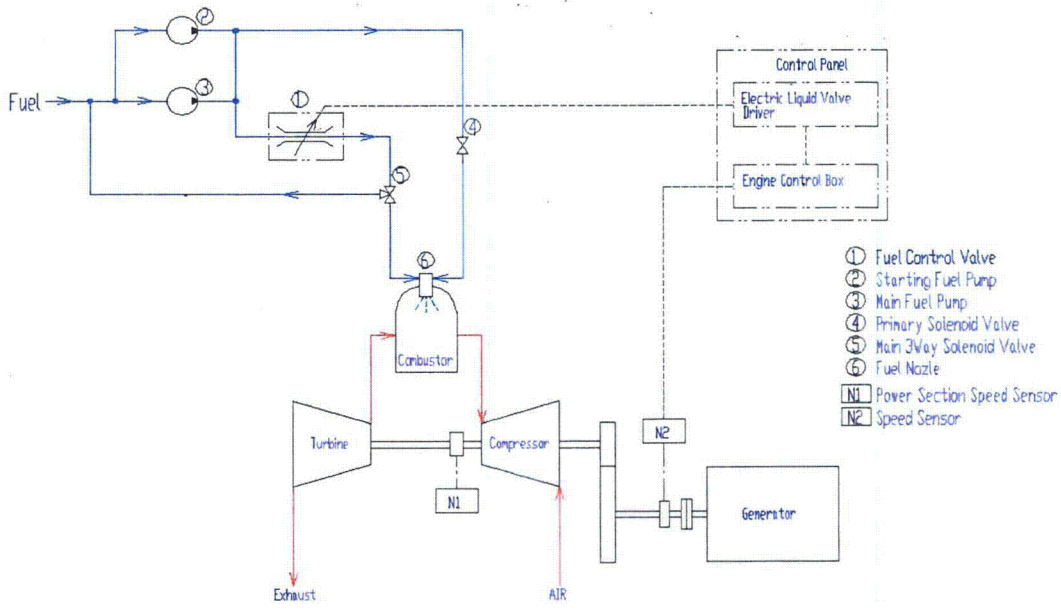


Governor(4/6)



standard control system

Governor(5/6)



Governor System

Voltage Regulator (6 of 6)

- **Brushless Exciter**
  - ✓ Eliminates maintenance associated with brush type generator field
- **Permanent Magnet Alternator**
  - ✓ Supplies continuous power to Voltage Regulator
  - ✓ Superior motor starting capabilities
- **Static Voltage Regulator**
  - ✓ Two AVRs supplied, manual and automatic
  - ✓ Voltage regulator motor operated potentiometers
  - ✓ Overexcitation protection
  - ✓ Underfrequency/Overvoltage Protection

NRC Question – Droop & Isochronous modes for GTG (1/3)

- **Droop Operation – GTG operating parallel to the grid. Speed control is a governor function which reduces the governor reference speed as engine fuel position (kW load) increases and vice versa, increases the governor reference speed as engine fuel position (kW load) decreases.**
- **Isochronous Operation – GTG operating on its Safety Related Bus. Isochronous speed control is the ability to return to the original engine speed after a change in kW load.**

NRC Question – Droop & Isochronous modes for GTG (2/3)

IEEE 387- 2001

- **4.5.1.4 Governor operation**

  If the diesel engine is equipped to operate in both the isochronous and the droop mode, provisions shall be included to automatically place the engine governor in the proper mode of operation when the diesel generator unit is required to operate automatically (see 4.5.2.2).

NRC Question – Droop & Isochronous modes for GTG (3/3)

IEEE 387- 2001

- **4.5.2.2 Automatic control**

  Upon receipt of an emergency start-diesel signal, the automatic control system shall provide automatic startup and automatic adjustment of speed and voltage to a ready-to-load condition.

  a) A start-diesel signal shall override all other operating modes and return control of the diesel generator unit to the automatic control system.

  b) An emergency start-diesel signal shall not override any manual non-operating modes such as those for repair and maintenance.

NRC Question – Reliability Analysis (1/4)

- A discussion on the Reliability Analyses

NRC Question – Reliability Analysis (2/4)

- More than 6000 units of GPS Gas Turbine series have been supplied in worldwide facilities. The GPS Gas Turbine series had been developed aiming at Emergency or Backup generator usage. They are designed so that not only performance for power operation may be ensured but also reliability required of emergency start be achieved.

NRC Question – Reliability Analysis (3/4)

- GPS GTG Packages have industrial based field data available for estimating the starting reliability collected from starting events confirmed, as shown in table 7.2-1.
  - ✓ Number of Units 375
  - ✓ Start Attempts 7394
  - ✓ Failed Starts 2
- Based on the field data, starting reliability is estimated as below;

  $(1 - 2/7394) \times 100 = 99.97\%$

  3.0×10^{-4} per demand

NRC Question – Reliability Analysis (4/4)

- The probability of failure to start of the EPS GTG is lower than that of any DGs (3.5×10^{-3} per demand) as reported in NUREG/CR-6928 "Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power plant, February 2007".

NRC Question – GTG Fuel

- Fuel specifications for the gas turbine and how they might differ from the fuel used in diesel generators.

- The KHI GTG can use:
  a. #2 Diesel Fuel (low sulfur fuel)
  b. Kerosene

A decision was made to use typical #2 Diesel Fuel. Therefore there is no difference between GTG and DG in the type of fuel used.

NRC Question- Site Testing (1 of 3)

- On-site testing requirements of RG 1.9, Positions 2.2 and 2.3; RG 1.41, Position 1 and 2; and requirements of Section 7, "Site Testing" of IEEE-387.

NRC Question Site Testing (2 of 3)

- Site Testing
  - ✓ IEEE 387 Section 7.2, RG 1.9 Section 2.2
    - Site Acceptance Testing
    - Pre-Operational Testing
    - Periodic Testing (ongoing)
  - ✓ Tests occur at site after final assembly
  - ✓ ESI simulates many of the tests at factory
  - ✓ Final performance of site testing by utility with MHI/KHI/ESI oversight as required

NRC Question Site Testing (3 of 3)

Table 1

Reference: IEEE 387 Clause:	Tests	Site acceptance tests (7.2)*	Pre-operational tests (7.3)*	Availability tests (7.4.2.1)* (Surveillance)		System operation tests: shutdown/ refueling (7.4.2.2)*	Independence tests 10 years (7.4.2.3)*
				Monthly	6 Month		
7.2.1.1	Starting	X		X			
7.2.1.2	Load acceptance	X		X			
7.2.1.3	Rated Load	X		X			
7.2.1.4	Load Rejection	X					
7.2.1.5	Electrical	X					
7.2.1.6	Subsystem	X					
7.3.3	Reliability		X				
7.5.1	Start		X	X			
7.5.2	Load Run		X	X			
7.5.3	Fast Start		X		X	X	
7.5.4	LOOP		X			X	
7.5.5	SIAS		X				
7.5.6	Combined SIAS and LOOP		X			X	
7.5.7	Largest load rejection		X			X	
7.5.8	Design load rejection		X			X	
7.5.9	Endurance and load margin		X*			X	
7.5.10	Hot restart		X			X	
7.5.11	Synchronizing		X			X	
7.5.12	Protective trip bypass		X			X	
7.5.13	Test mode override		X			X	
7.5.14	Independence		X				X

* Use 2 h and 22 h
* IEEE Std 387-1995

Table 1 taken from RG 1.9 Rev. 3, & IEEE-387