US-APWR

GAS TURBINE GENERATOR (GTG)

used as Emergency Power Supply

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Mitsubishi Heavy Industries, Ltd.

Presentation Summary

Class 1E GTG

- Introduction
- Background
- GTG Advantages & Disadvantages
- Requirement, Design concept and Specification
- Onsite AC Power System
- Applicability for US mainly codes, standards
- Load Sequence
- Starting Capability
- Reliability
- Supporting System of GTG
- Control and Protection of GTG
- GTG System
- Class 1E Qualification

Presentation Summary

AAC-GTG

- Introduction AAC-GTG
- Onsite AC Power System
- Design Basis of AAC-GTG
- Requirement, Design concept and Specification
- Power Supply to Onsite Buses
- Operation under the SBO
- Diversity

Introduction(1) *Class 1E GTG*

- The US-APWR uses Gas Turbine Generators (GTGs), as Emergency Power Supply (EPS) in lieu of the commonly used Diesel Generators (DG).
- The reasons for the selection of the GTG are as follows:

  a. The Gas Turbine is a very simple rotating engine with few components

  b. The GTG System consists only of the gas turbine, generator, fuel transport, starting and control/instrumentation systems

  c. Water cooling system is not required

  d. The GTG presents a high level of reliability.

Introduction(2) *Class 1E GTG*

- In the case of the application on gas turbine generator system for nuclear power generation, should be considered high reliability and capability. To meet this requirement, the combination of an extremely reliable aircraft component with equally reliable industrial components such as reduction gears, electrical generator, governor, voltage regulator, relays and similar components is selected. The advance accumulator design of the US-APWR allows a starting time for the GTG of under 100 seconds.

GTG Advantages & Disadvantages(1) *Class 1E GTG*

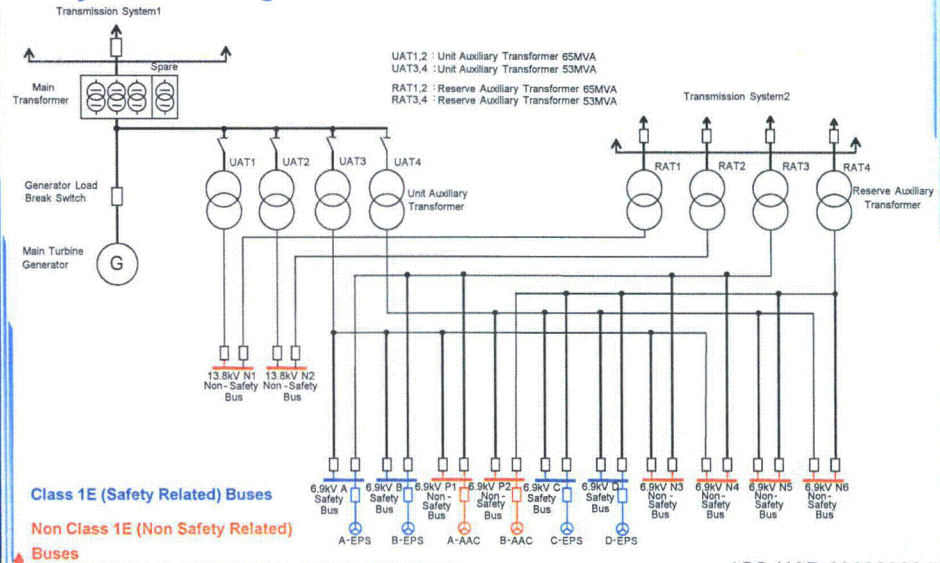
	Gas Turbine Generator	*Diesel Generator*
Space	*Compact*	*Large*
Cooling Water	*Not Required*	*Required*
Periodic Maintenance	*Required less than DG*	*Required*
Reliability	*Expected to be Better than DG*	*10^{-2} (/d)*
Starting Time	*40 sec*	*10 sec*

GTG Advantages & Disadvantages(2) *Class 1E GTG*

	Gas Turbine Generator	Diesel Generator
Noise level	*High Freq levels are ease to silence*	*Noisy*
Vibration	*Very small levels, because the engine is not reciprocating*	
Power Supply	*Frequency variation is small*	*+/- 2% Frequency variation*
Exhaust Gases	*Low levels, since the combustion efficient is high*	

Onsite AC Power System *Class 1E GTG*

➢System Configuration

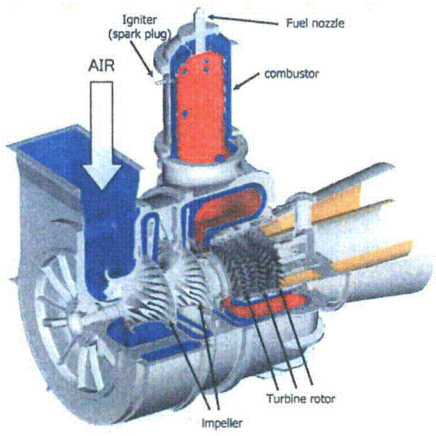


Requirement, Design concept and Specification
Class 1E GTG

- **Design requirement, Specification of EPS**
  - ✓ Class 1E, Seismic category 1
  - ✓ Four 50% units
  - ✓ 4500 kW Continuous @ 1,000 hrs Engine Overhaul Interval, 115° F Air Intake Temperature
  - ✓ 4950 kW Short Time @ 300 hrs Engine Overhaul Interval, 115° F Air Intake Temperature
  - ✓ 6900 V, 3-phase, 60 Hz
  - ✓ Air starting type, air receivers of each train have capability to start the GTG for three time.
  - ✓ Fuel: Diesel oil, fuel storage tank of each train has capability to operate the GTG during seven days under continuous rated capacity. Fuel day tank of each train has capability to operate the GTG during 1.5 hours under continuous rated capacity.
  - ✓ Class 1E GTG should satisfy with requirements of voltage/frequency variation required in R.G 1.9.

GTG System(1) *Class 1E GTG*

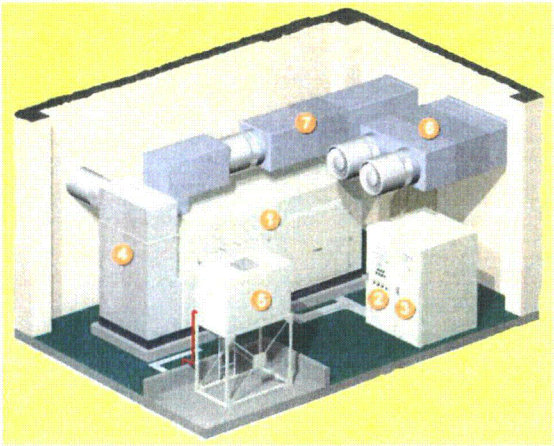
Engine



M1A-33Gas Turbine

GTG System(3) *Class 1E GTG*

TYPICAL SYSTEM LAYOUT



① ***Gas Turbine Package***
Includes gas turbine and generator with an acoustic enclosure.

② ***Control Panel***
Includes gas turbine and generator control panels.

③ ***Battery Panel***
Includes battery and charger.

④ ***Exhaust Silencer***

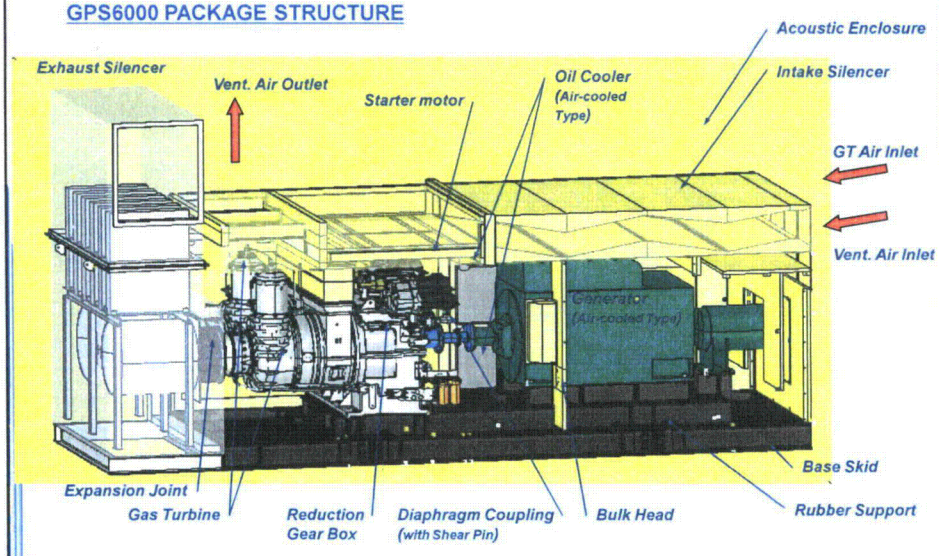
⑤ ***Liquid Fuel Service Tank***

⑥ ***Ventilation Intake System***
Includes fan and silencer.

⑦ ***Ventilation Exhaust System***
Includes fan and silencer.

GTG System(2) *Class 1E GTG*

GPS6000 PACKAGE STRUCTURE



Supporting System of GTG *Class 1E GTG*

Supporting system of GTG (1)

System	Diesel Generator System	Gas-Turbine Generator System
Fuel System		Fuel system of GTG is almost similar to DG's. Fuel system is designed based on requirement for safety-related EDG system.
Lubricant System		Amount of consumption of lubricant oil is less than DG's. System is simpler than DG's and system components are fewer than DG's. Lubricant system is used for both engine and generator. Also pre-heat of lubricant oil is not needed.
Starting System	Compressed air rotates the engine directly.	Stating air system of GTG is almost similar to DG's. Air-motors rotate the GTG. Starting system is designed based on requirement for safety-related EDG system.
Cooling System	Water cooling, pre-heat is needed for quick start.	Water cooling is not needed. Self ventilation fan can cool engine and generator package.

Supporting System of GTG *Class 1E GTG*

Supporting system of GTG (2)

System	Diesel Generator System	Gas-Turbine Generator System
Inlet/Exhaust air system		Inlet/Exhaust air system consists of ducts, fan and exhauster. Inlet air is used for both combustion and ventilation. Vented air is discharged, and exhaust is discharged via the exhauster/silencer.
I&C		✓Governor and AVR control is similar to DG's. Monitoring parameters, protection signals are differ from DG's. ✓Control logic of GTG is designed special to GTG, and logic is installed in Class 1E control cabinet.
Auxiliary Power		Auxiliary power is designed almost similar to DG's. ✓Pumps, fans are supplied power from Class 1E ac 480V plant power system. ✓Starting air valves, excitation of generator, control circuits are supplied power from Class 1E dc 125V plant power system.

Control and Protection of GTG(1) *Class 1E GTG*

Start up(1) *Start Signal*

Starting logic is designed to satisfy with requirements for safety-related EDG system. The Class 1E GTGs are started by following Methods.

- ✓ **Automatic starting by the ECCS signal**
- ✓ **Automatic starting by an undervoltage signal and degraded voltage signal on the Class 1E MV bus to which Class 1E GTG is connected**
- ✓ **Manual starting from MCR**
- ✓ **Manual starting from the GTG room**
- ✓ **Manual starting from the remote shutdown room**

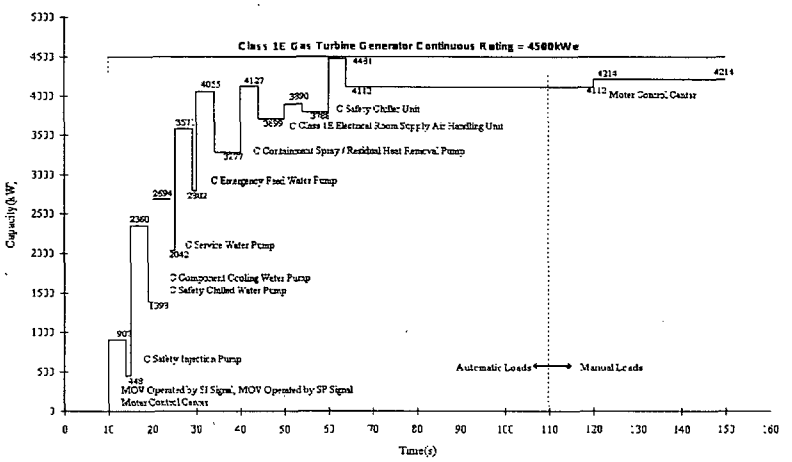
Control and Protection of GTG(2) *Class 1E GTG*

Start up(2) *Starting Time*

- ➢ **Starting Time**
  - ✓ (1) Starting time of GTG is required within 100 seconds by safety design and analysis of US-APWR. For GTG to reach set voltage and frequency, and GTG breaker should be closed within 100 seconds after starting signal is initiated.
  - ✓ (2) GPS 6000 can reach set voltage and frequency within 40 seconds as its standard specification.

Control and Protection of GTG(3) *Class 1E GTG*

Start up(3) *Load Sequence*



Control and Protection of GTG(4) *Class 1E GTG*

The following trip protective functions are provided during operation of the Class 1E GTG.

- ✓ Overspeed
- ✓ Generator differential current
- ✓ High exhaust gas temperature
- ✓ Failed to start
- ✓ Overcurrent
- ✓ Low pressure lube oil
- ✓ High pressure lube oil
- ✓ Anti motoring

During operation of the Class 1E GTG under a LOCA condition, all protective functions are bypassed except for "Overspeed", "Generator differential current" and "High exhaust gas temperature".

GTG System(1) *Class 1E GTG*

THE FEATURE OF GPS GAS TURBINE

1. No cooling water is required.
2. Easy to reduce the noise level (sound power level)
3. Less vibration
4. High seismic resistance
5. High reliability of starting
6. Less maintenance
7. High stability of the voltage frequency
8. Compact installation
9. Clean emission

GTG System(2) *Class 1E GTG*

GPS6000 Standard Specification

Item	Unit	Specification
Electrical Output (at 104 ° F)	kW	*4,800*
Allowable Ambient Temperature	° F	*41 – 104*
Starting Time	Sec	*Within 40.0*
Load Application Capacity	%	*100.0*
Frequency Deviation (Transient / Steady State)	%	*Within ±6.0 / ±0.3*
Fuel Type		*Kerosene / Diesel Oil / Heavy Oil*
Fuel Consumption (Kerosene / Diesel Oil / Heavy Oil)	Gal / Hour	*570.6 / 541.6 / 533.6*
Noise Level at 1m from Package	dB(A)	*85*
Noise Level at 1m from Exhaust Silencer Outlet	dB(A)	*90*
Gas Turbine Intake Air Flow Rate	CFM	*49,440*
Gas Turbine Exhaust Gas Flow Rate (at EGT 1103° F)	CFM	*135,255*
Ventilation Intake Air Flow Rate	CFM	*31,783*

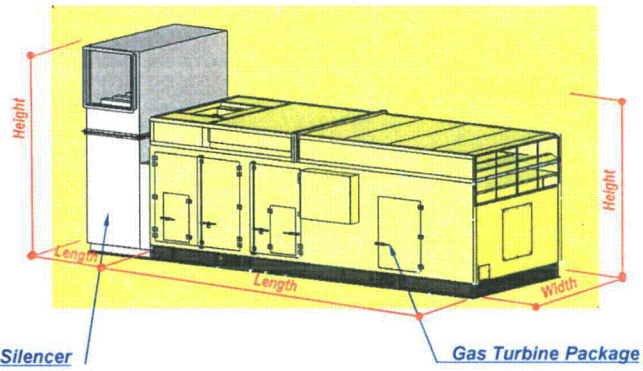
GTG System(3) Class 1E GTG

M1T—33 Gas Turbine Standard Specification

Item	Unit	Specification
Turbine Model		Kawasaki M1T-33
Engine Type		Heavy-duty, Single-shaft Simple Open Cycle
Compressor Type		2-Stage Centrifugal
Combustor Type		Single Can
Turbine Type		3-Stage Axial
Reduction Gear Box		Planetary + Parallel
Turbine Speed	rpm	18,000
Output Speed	rpm	1,500 / 1,800
Rated Power Output (at 40 ℃)	kW	5,200
Dry Weight	Lb (kg)	29,762 (13,500)
Recommended Lubricating Oil Type / Brand		Synthetic Oil Shell ASTO500 / Mobil Jet2 / Castrol AERO5000 / BP BPTO2380
Lubricating Oil Tank Capacity	Gal	95.1
Lubricating Oil Consumption	Gal / Hour	0.053

GTG System(4) Class 1E GTG

Size



Exhaust Silencer

Length	ft (m)	4.92 (1,500)
Width	ft (m)	9.84 (3,000)
Height	ft (m)	15.75 (4,800)
Weight	lb (kg)	11,244 (5,100)

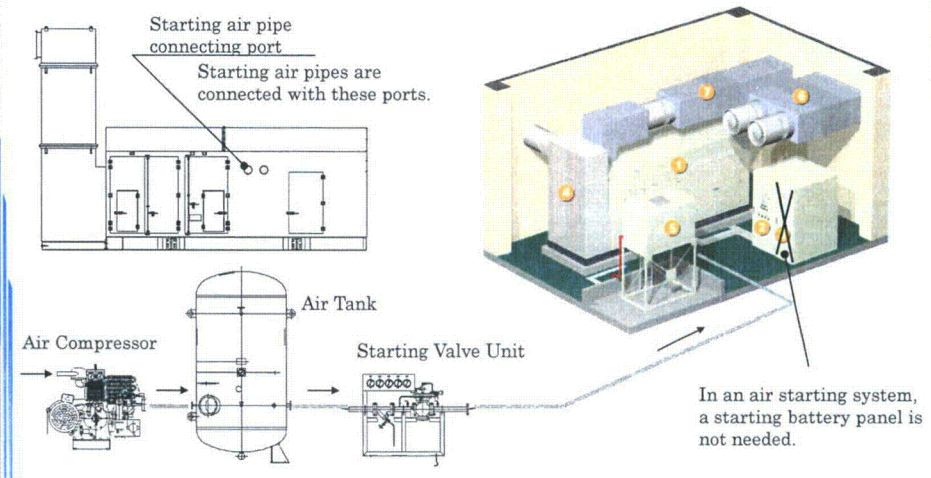
Gas Turbine Package

Length	ft (m)	25.26 (7,700)
Width	ft (m)	9.84 (3,000)
Height	ft (m)	11.81 (3,600)
Weight	lb (kg)	85,980 (39,000)

GPS6000 PACKAGE OUTLINE DIMENSIONS

GTG System(5) *Class 1E GTG*

Detail Design: Example, Air System



Important Input Parameter and Data to Safety analysis and PRA *Class 1E GTG*

Important input parameter and data to safety analysis and PRA are followings.

(1) Starting time: within 100 seconds

(2) Fuel storage tank: 7 days capacity per one train

(3) Reliability target are same as US nuclear EDGs.

Fail to Start

- Mean : 5.0×10^{-3} / demand
- 95%-tile : 1.5×10^{-2} / demand

Fail to Run

- mean : 8.0×10^{-4} / hr
- 95%-tile : 2.0×10^{-3} / hr

Above (1),(2) have already explained before. MHI shows the evaluation for "(3) Reliability" from next slide.

Reliability (1) *Class 1E GTG*

MHI's Reliability Verification Plan(1)

The reliability target of US-APWR Class 1E GTG is shown below. It is based on US EDG's data of NUREG-CR/6928. And this value is used to PRA analysis.

Fail to Start

- Mean : 5.0×10^{-3} / demand
- 95%-tile : 1.5×10^{-2} / demand

Fail to Run

- mean : 8.0×10^{-4} / hr
- 95%-tile : 2.0×10^{-3} / hr

Reliability (2) *Class 1E GTG*

MHI's Reliability Verification Plan(2)

MHI shows GPS6000 satisfies with reliability target of US-APWR using Bayesian approach.

First estimate of GPS6000 reliability performed by updating the non-informative prior (Jeffers's prior) with GPS's operational data.

(note)

Bayesian approach is one of general method of statistics, and is widely used to evaluate component reliability and its uncertainty.

NUREG-CR/6928 also uses this approach. Recognized in ASME PRA standard as preferred method for component data uncertainty analysis

Reliability (3) *Class 1E GTG*

MHI's Reliability Verification Plan(3)

In order to estimate GPS6000's reliability accurately, collection of data based on appropriate categorization is necessary.

MHI has analyzed available and relevant GPS's operational data.

Operational data has been collected from manufacture's records as shown in Table-1.

Reliability (4) *Class 1E GTG*

MHI's Reliability Verification Plan(4)

Table-1(1/2)

Product	Output(kVA)	Single engine or Twin engine	Fuel Type	Starting system	Failure/Number of starts	Failure/Operation hours
1	2000	Twin	Heavy Oil	Air	0 /251 d	0 /98 hr
2	2000	Twin	Heavy Oil	DC	0 /265 d	0 /75.4 hr
3	2000	Twin	Diesel Oil	DC	0 /100 d	0 /71.3 hr
4	2000	Twin	Kerosene	DC	0 /1053 d	0 /205 hr
5	2500	Twin	Heavy Oil	Air	0 /383 d	0 /1129.8 hr
6	2500	Twin	Heavy Oil	DC	0 /95 d	0 /16.4 hr
7	4000	Twin	Heavy Oil	Air	0 /540 d	0 /982 hr
8	4000	Twin	Heavy Oil	DC	0 /149 d	0 /96.8 hr
9	4000	Twin	Diesel Oil	Air	0 /225 d	0 /156.4 hr
10	4000	Twin	Diesel Oil	DC	0 /105 d	0 /50.8 hr
11	4000	Twin	Kerosene	DC	0 /263 d	0 /109.6 hr

Reliability (5) *Class 1E GTG*

MHI's Reliability Verification Plan(5)

Table-1(2/2)

Product	Output(kVA)	Single engine or Twin engine	Fuel Type	Starting system	Failure/Number of starts	Failure/Operation hours
12	4500	Twin	Heavy Oil	Air	0 /327 d	0 /125.1 hr
13	4500	Twin	Heavy Oil	DC	0 /130 d	0 /63.2 hr
14	4500	Twin	Diesel Oil	DC	0 /69 d	0 /80.3 hr
15	4500	Twin	Diesel Oil	DC	0 /147 d	0 /32.1 hr
16	4500	Twin	Kerosene	Air	0 /341 d	0 /455.1 hr
17	4500	Twin	Kerosene	DC	0 /251 d	0 /68.0 hr
18	5000	Twin	Unidentified	DC	0 /48 d	Operation period of those products are short. These are not used for evaluation as conservative.
19	5000	Twin	Unidentified	DC	0 /48 d	
20	6000	Twin	Unidentified	DC	0 /24 d	
21	6000	Twin	Unidentified	DC	0 /24 d	
22	6000	Twin	Unidentified	DC	0 /13 d	
23	6000	Twin	Unidentified	DC	0 /13 d	
24	6000	Twin	Unidentified	DC	0 /12 d	
25	6000	Twin	Unidentified	DC	0 /12 d	
26	6000	Twin	Unidentified	DC	0 /6 d	
27	6000	Twin	Unidentified	DC	0 /1 d	

Reliability (6) *Class 1E GTG*

MHI's Reliability Verification Plan(6)

➢ **Data collection of GTG fail to start**

1. GPS series have been produced with common design concept such as structure, dynamic characteristics and materials. Increasing of output is achieved to size up the design of small product analogously. Near output products have more similar design. MHI apply GPS6000 as EPS. GPS5000 is similar design as GPS6000. Also, GPS4000/4500 are almost similar design as GPS6000, and these are no significant difference of starting capability based on operation experiences. Another mean of increasing of output is using two engines with one generator. Over GPS 2000 products are twin type all.

2. Starting type is also considered whether air or DC motor.

Reliability (7) *Class 1E GTG*

MHI's Reliability Verification Plan(7)

➢ **Data collection of GTG fail to start (continued)**

3. MHI has selected the data of Table-1 as follow;
   - Data of GPS4000 to 6000 with air starting type
     ⇒ 1433 demands with 0 failure

This data is used to Bayesian approach of GTG reliability.

Reliability (8) *Class 1E GTG*

MHI's Reliability Verification Plan(8)

➢ **Data collection of GTG fail to run**

From view point of running reliability, type of starting system is not needed to consider. Also, there are no significant difference from operation experiences of large output twin engine products of over GPS2000. MHI has classified data into running time of over GPS2000 and running time over GPS4000.

1) Data of over GPS2000 ⇒ 3820 hours with 0 failure
2) Data of over GPS4000 ⇒ 2224 hours with 0 failure

Result of this, MHI evaluates both above 1) and 2) are considered proper to use to Bayesian approach. However, MHI evaluates using only data of 2) conservatively.

Reliability (9) *Class 1E GTG*

MHI's Reliability Verification Plan(9)

- **Reliability estimation of GTGs based on industry operational experience**
  - ✓ **Applicable data**
    - 1433 demands with 0 failure
    - 2224 run hours with 0 failure
  - ✓ **Uncertainty of failure rate/probability**
    - Estimated by posterior distribution of Bayesian approach

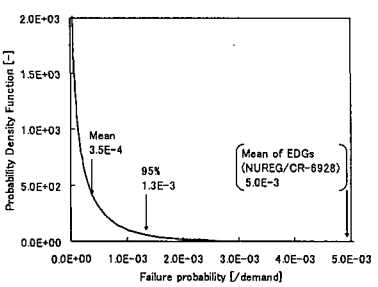
Table-2

	5%	Mean	95%	Distribution		
				Type	α	β
Fail to start	1.4E-6	3.5E-4	1.3E-3	Beta	0.5	1433
Fail to run	8.9E-7	2.2E-4	8.3E-4	Gamma	0.5	2224

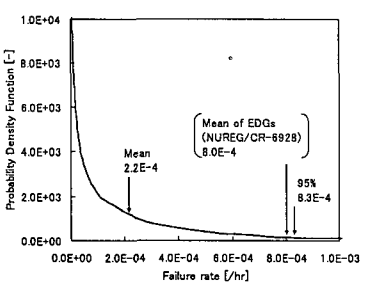
Reliability (10) *Class 1E GTG*

MHI's Reliability Verification Plan(10)

Posterior distribution of GTGs reliability



Fail to start



Fail to run

Reliability (11) *Class 1E GTG*

MHI's Reliability Verification Plan(11)

➢ US-APWR GTG test plan

✓ **Start test**

- Operational experience show that failure rate is lower than the mean failure rate of DGs (5.0E-3 /d), with 95% confidence.
- Start tests will be performed as a typical "qualification starting test". Total starting times is 100.
- Reliability will be updated by the starting test and surveillance test results obtained during plant operation

✓ **Run test**

- Operational experience show that failure rate is lower than the mean failure rate of DGs (8.0E-4 /hr), with approximately 95% confidence.
- Run test is not needed.
- Reliability will be confirmed and updated by surveillance test results obtained during plant operation

Table-3 GTG unreliability given start test results

Start Test results		Estimated US-APWR GTG reliability		
Trials	failures	5%	Mean	95%
100	0	1.3E-6	3.3E-4	1.3E-3

Reliability (12) *Class 1E GTG*

MHI's Reliability Verification Plan(12)

➢ Based on limited test data, GTG reliability appears to be capable of exceeding reliability assumed in PRA.

➢ In addition to MHI's PRA reliability target, MHI should satisfy with reliability requirement of R.G 1.155. R.G 1.155 requires over 0.95 or 0.975 reliability with 95% confidence.

Target case of 0.95: 100 start up test

Target case of 0.975: 150 start up test

➢ Future operating experience will be needed to demonstrate that reliability targets can be achieved and maintained over the life of the plant. MHI will update the GTG reliability during operation through surveillance tests.

Class 1E Qualification (1) *Class 1E GTG*

- *Plan of Class 1E Qualification*

  The GTG shall meet the same requirements for the Emergency Diesel Generator, complying with Regulatory Guide 1.9 Rev. 4 and IEEE-387.The qualification process will be completed by the end of 2010.

  - ✓ The Commercial Grade Item (CGI) dedication process will be used for the Qualification procedure, per EPRI NP 5652 endorsed by NRC GL 91-05. These guidelines will be applied to the procurement, acceptance, testing and Class 1E dedication of the GTG.
  - ✓ Procedure
    Testing will be performed per IEEE 387 and Regulatory Guide 1.9 Rev. 4
  - ✓ Seismic Qualification
    Seismic Analysis per IEEE 344

Class 1E Qualification (2) *Class 1E GTG*

Develop Dedication Report

- **Identify Form, Fit, and Function**
- **Failure Mode Analysis**
  - ✓ Effect of part failure on System
  - ✓ Credible Failure Modes of Part
- **Design Information**
  - ✓ Catalog Information
  - ✓ Manufacturer's Drawings, etc.
- **Critical Characteristics**
  - ✓ Dimensions
  - ✓ Operability
  - ✓ Material

Class 1E Qualification (3) *Class 1E GTG*

Develop Dedication Report (continued)

- **Environmental Qualification**
  - ✓ Manufacturer's specs
  - ✓ Environmental chamber
- **Seismic Qualification**
  - ✓ Perform an analysis
  - ✓ Write seismic (shake) test procedure
- **Shelf Life**
  - ✓ Identify materials
  - ✓ Utilize published standards
- **Maintenance / Surveillance / Replacement Interval**
  - ✓ Activity required by customer to maintain qualification
- **Verify operability**
  - ✓ Write functional test procedure

Class 1E Qualification (4) *Class 1E GTG*

- **Qualification Testing - IEEE-387 (1995) and US NRC RG1.9**
- **Factory Acceptance Testing**
  - ✓ **Engine Test**
    - Load Test at Factory
  - ✓ **Generator Test**
    - NEMA MG-1 at Factory
  - ✓ **Combined Unit Test (at Factory)**
    - Initial Operation and Load Test
    - Excitation & Controls Test
    - Alarm Verification
    - Start Time & Receiver Capacity
    - Protective Trip Bypass
    - Test Mode Override

Class 1E Qualification (5) *Class 1E GTG*

- **Type Test**
  - ✓ **Load capability tests**
    - 24-Hour Load Test
    - 110% Load Rejection Test
  - ✓ **Start and load acceptance tests**
    - 100 Start and Load Reliability Test
  - ✓ **Margin tests**
    - 110% of most severe load step

Class 1E Qualification (6) *Class 1E GTG*

- **Class 1E Qualification Schedule**

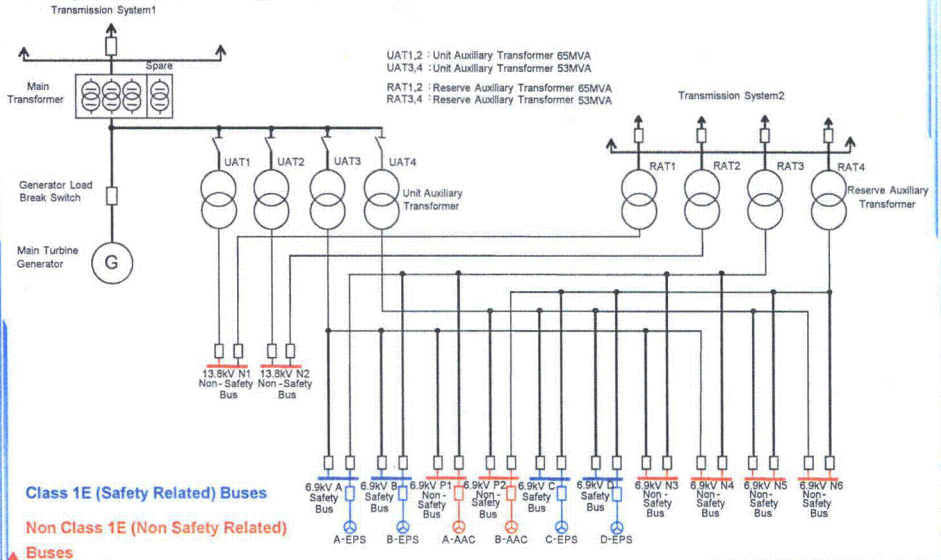
	2009								2010												2011		Remarks
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	
Manufacturing																							
Seismic Analysis / Testing																							
Type Test																							IEEE 387 Section6.2
Start and load acceptance tests																							
Margin tests																							
Load capability tests																							
Miscellaneous test																							

Introduction *AAC-GTG*

- The alternate AC power sources (AAC) are available in the event of a station blackout (SBO), when all offsite power sources and Class 1E GTGs are not available to bring the unit to a safe shutdown condition and maintain that status.
- US-APWR has two AAC power sources which apply non safety-related Gas Turbine Generators.

Onsite AC Power System *AAC-GTG*

System Configuration



Design Basis of AAC-GTG *AAC-GTG*

- *Design Basis*
  - ✓ AAC-GTG of a different type (Starting System, Capacity etc,) is provided to minimize the potential for common mode failure with either the offsite power or the Class 1E GTG system
  - ✓ The AAC-GTG is a non-class 1E engine-generator package connected to a 6.9kV AC "permanent" bus.
  - ✓ The AAC-GTG supplies power to loads of a class 1E bus through the tie line circuit during SBO.
  - ✓ The AAC-GTG supplies power to loads for 8 hours during SBO.
  - ✓ The AAC-GTG system to be designed having diversity from Class 1E GTG system.

Requirement, Design concept and Specification *AAC-GTG*

- **Design requirement, Specification of AAC-GTG**
  - ✓ Non safety-related, non Class 1E
  - ✓ Two units
  - ✓ 4000 kW Continuous
  - ✓ 6900 V, 3-phase, 60 Hz
  - ✓ DC motor starting type
  - ✓ Fuel: Diesel oil, fuel storage tank of each train has capability to operate the GTG during seven days under continuous rated capacity. Fuel day tank of each train has capability to operate the GTG during 1.5 hours under continuous rated capacity.

Power Supply to Onsite Buses *AAC-GTG*

- *Permanent Buses*
  - ✓ There are two buses for exclusive use for each AAC.
  - ✓ In LOOP condition, non-safety loads required are supplied via the "permanent" bus from AAC.

	Normal Operation	*LOOP*	*SBO*
Class 1E Buses	*RAT*	*EPS*	*AAC*
Non safety-related "Permanent" Buses	*UAT*	*AAC*	*AAC (Only Required Loads)*

Operation under the SBO(1) *AAC-GTG*

- *Definition of SBO*
  - ✓ SBO refers to the complete loss of alternate current electric power to the essential and nonessential switchgear buses.
  - ✓ SBO therefore involves the loss of offsite power concurrent with turbine trip and failure of onsite emergency ac power system (4 trains, 4 Class 1E emergency generators), but not the loss of available ac power to buses fed by station batteries through inverters or the loss of power from "alternate ac sources".

Operation under the SBO(2) *AAC-GTG*

➢ *Basic Concept against for SBO*

SBO occurs

The all offsite power and four EPSs will be lost. But two alternate AC power sources (AACs) and batteries will be still available.

Switching of buses and starting loads

Tie-line between permanent MV bus and safety MV bus will be connected. And needed loads (safety loads and non-safety loads) are re-operated. All operations can be achieved within one hour.

Plant Target and Safety

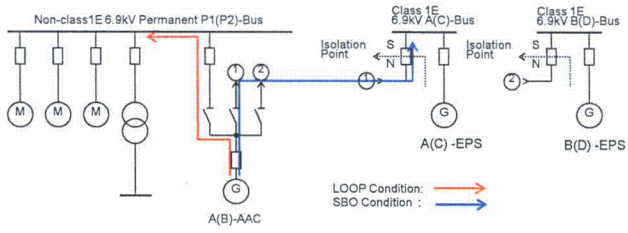
Plant can keep the integrity of components and safety condition (e.g. integrity of RCP seal) until completion of switching buses and re-starting loads. And after this, Plant can keep the Hot-Standby condition for 7 days without AAC fuel supply from offsite.

Operation under the SBO(3) *AAC-GTG*

➢ **AAC-GTG backup Power Supply to Class 1E buses**

When a SBO occurs, the AAC power source supplies power to any of the selected safety division in accordance with the following procedure:

1) Switching will be done manually to prevent starting loads on any other division.
2) Loads that need to be stopped on the "permanent" bus will be tripped manually.
3) The required breaker to the back-up division will be closed manually.
4) Back-up bus will be energized and loaded as necessary for coping with SBO. The loads will be started manually.



Operation under the SBO(4) *AAC-GTG*

➢ *Operation of Plant under the SBO Condition*

Function	*Main Features*
Reactivity Control	*Boric Acid Pump* ***(1 pump)***
Supply of RCS water	*Charging Pump* ***(1 pump)***
Control of RCS pressure	*Pressurizer Backup Heater* ***(1 train)***
Remove of decay heat	*Main Steam Relief Valve,* *Turbine Driven EFWP* ***(1 pump)***
Cooling of RCP seal	*Charging Pump* ***(1 pump)***
Supporting System	*ESWP* ***(1 pump)****, CCWP* ***(1 pump)*** *Containment Service Water Cooling Tower Fans* ***(1 train)*** *Chiller Unit, HVAC, Battery Charger, AAC supporting components, UPS unit, Instrument and Control Cabinets etc.*

( );**Required Minimum Quantity**

Operation under the SBO(5) *AAC-GTG*

➢ Evaluation

- ✓ Starting time of AAC is within 100 seconds after SBO occurs. Reenergize of bus by AAC and restarting of loads will be completed within one hour after SBO occurs.
- ✓ Plant can keep safety condition until completion of reenergize by AAC and restarting loads. RCP seal can be kept the integrity for 8 hours without cooling.
- ✓ Plant can keep safety and Hot Standby condition with only one AAC, one permanent division (and loads) and one Class 1E division (and loads) for 7 days.

Diversity(1) *AAC-GTG*

Diversity between EPS and AAC

- AAC-GTG should be designed to minimize the potential of common cause failure with safety-related EPS system. Diversity between design of Class 1E GTG system and AAC-GTG system is preferable.
- MHI is now under proceeding following two approach.
  1. Different Manufactures/Products
     : Design issue on diversity on between Class 1E GTG and AAC-GTG is clearly resolved by itself.
  2. Same Manufacture
     : Design issue on diversity is resolved by using analysis such as evaluation for eliminating CCF.
- MHI shows one approach of evaluation CCF from next slide.

Diversity(2) *AAC-GTG*

Detail of diversity between EPS and AAC(1)

- US-APWR applies GPS6000 as EPS, GPS5000 as AAC. Design and specification of these engine portion are almost similar. Table-5 shows detail differences between whole GTG system component and design between both systems.
- Each item of engine portion of both are almost similar. However, difference of output means difference of combustion rate, also dynamic characteristics of both are different. This deference effects to decrease the CCF potential.
- Also, there are many differences of spec., design and manufacture for supporting system component.

Diversity(3) *AAC-GTG*

Detail of diversity between EPS and AAC(2)

- As explained, design and specification of both engine portions are almost similar. However, NRC's report (discussed on "Reliability"), evaluates the cause and portion of failures.
- According to NRC report, cause and portion of failures of FY1998 to FY2007 has been researched as Table-4.

Table-4

Fail to start Total:116 failures		Fail to Run Total:65 failures	
Lank	Portion	Lank	Portion
1	I&C : 34 failures	1	Cooling : 15 failures
2	Generator : 23 failures	2	Engine : 12 failures
3	Starting air : 13 failures	3	Fuel oil : 11 failures
4	Governor: 12 failures	4	I&C : 9 failures
5	Fuel oil: 10 failures	5	Lube oil : 8 failures
6	cooling: 10 failures	6	Generator : 6 failures
8	Engine: 4 failures		

Diversity(4) *AAC-GTG*

Detail of diversity between EPS and AAC(3)

- According to Table-4, failure caused by engine are considered low probability. GPS6000 and GPS5000 planed to US-APWR are designed different supporting system including starting system.
  Based on this fact, Fail to Start caused by engine are considered low probability.
- In addition, GPS6000 and GPS5000 are designed different output, combustion rate. This different is expected to prevent the Fail to Run.
- MHI considers although GPS6000 and GPS5000 are similar engine design, it is expected to minimize the CCF potential view point both of start and run availability.

Diversity(5) *AAC-GTG*

Detail of diversity between EPS and AAC(4)

Table-5(1/3)

Group	No	Item	EPS	AAC
Engine	1	Type	M1T-33	M1T-33A
	2	Rated output (engine edge)	5200kW	4362kW
	3	Combustor spec/material/size	Single CAN Type/heat-resistant alloy	Same as follows
	4	Number of turbine blades /rows	1st row = 44 2nd row = 40 3rd row = 36	Same as follows
	5	Turbine engine spec/material/size	3-Stage Axial / nickel-based heat-resisting alloys	Same as follows
	6	Compressor spec/material/size	2-Stage Centrifugal / titanium alloy	Same as follows
	7	Number of compressor blade rows	Total 54	Same as follows
	8	Compressor compression ratio	10.23	10.08
	9	Exhaust gas temperature	595 degree C	540 degree C
	10	Exhaust gas flow	3830 m^3/min	3650 m^3/min
	11	Gear spec/material/size	Planetary + Parallel	Same as follows
	12	Change gear ratio	10:1	Same as follows

Diversity(6) *AAC-GTG*

Detail of diversity between EPS and AAC(5)

Table-5(2/3)

Group	No	Item	EPS	AAC
Supporting system Equipment installed on Engine	13	Starting Motor type	Air	DC motor
	14	Starting Motor quantity	4	8
	15	Starting Motor spec	Air Turbines x 4	40kW DC60V Motors x 8
	16	Main fuel pump (shaft driven) spec/quantity	screw type 23L/min @3.3MPa x 2	Potentially change manufacture
	17	Starting fuel pump (shaft driven) spec/quantity	Gear type x 2	Potentially change manufacture
	18	Starting fuel pump (DC motor driven)	DC24V gear type x 2	Potentially change manufacture
	19	Fuel control valve spec/quantity	Electric type x 2	Potentially change manufacture
	20	Main lube oil pump spec/quantity	Gear type x 2	Potentially change manufacture
	21	Pressure control valve spec/quantity	Plunger type x 2	Potentially change manufacture
	22	Ignition plug spec/quantity	surface gap type x 4	Potentially change manufacture
	23	Governor spec/quantity	Electric type x 2	Potentially change manufacture
Design control, Engineering, manufacturing	24	Designing/ manufacturing manual	Specified for MIT-33	Specified for MIT-33A
	25	Quality control department	Base with ESI	Base (without ESI)
	26	Manufacturing line	Base	Same with Base

Diversity(7) *AAC-GTG*

Detail of diversity between EPS and AAC(6)

Table-5(3/3)

Group	No	Item	EPS	AAC
GTG system supporting component	27	Fuel oil transfer pump	Safety-related	Non safety-related, different manufacture, different spec.
	28	Starting air valve	Safety-related	N/A
	29	Fuel day tank	Safety-related	Non safety-related, different manufacture, different spec.
	30	Fuel storage tank	Safety-related	Non safety-related, different manufacture, different spec.
	31	Fuel system piping	Safety-related	Non safety-related, different manufacture, different spec.
	32	Exhaust duct	Safety-related	Non safety-related, different manufacture, different spec.
	33	Inlet duct	Safety-related	Non safety-related, different manufacture, different spec.
	34	Ventilation fan	Safety-related	Non safety-related, different manufacture, different spec.
	35	Generator	Class 1E	Non Class 1E, different manufacture, different spec.
	36	Generator excitation circuit	Class 1E	Non Class 1E, different manufacture, different spec.
	37	AVR	Class 1E	Non Class 1E
	38	GTG control panel (hardwired)	Class 1E	Non Class 1E, different manufacture
	39	GTG control panel (DDC)	Class 1E	Non Class 1E, different manufacture
	40	AC power supply	Class 1E bus	Non Class 1E bus
	41	DC power supply	Class 1E bus	Non Class 1E bus