



**D'APPOLONIA**



RINA  
GROUP

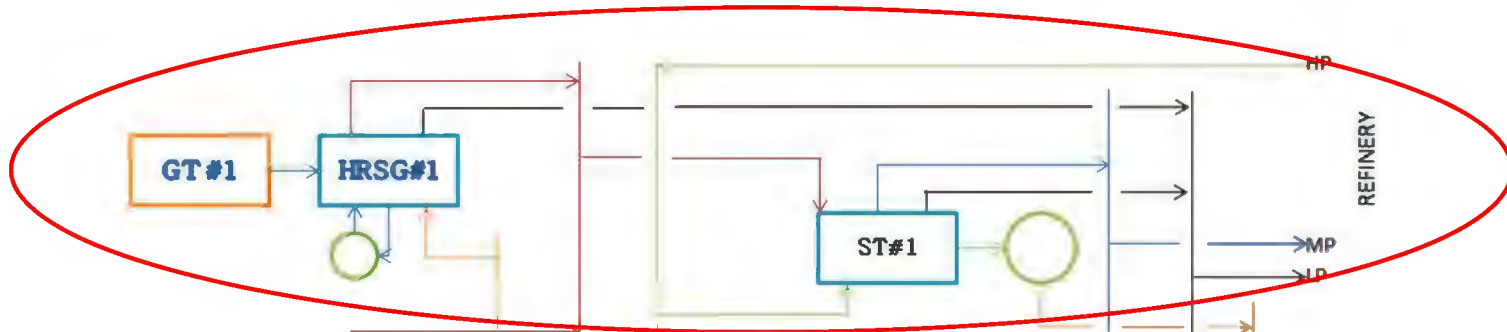
# RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM)

# Case Study - Feasibility Study for Power Generation Unit

The Study scope of work is addressed at analyzing the availability associated to a Power Generation and MP/LP Steam production, individuating the elements whose failure leads either to partial/total loss of production or to spurious Plant Shut-Down.

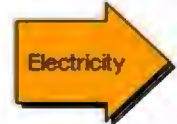
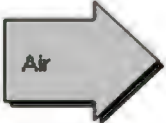
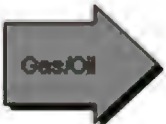
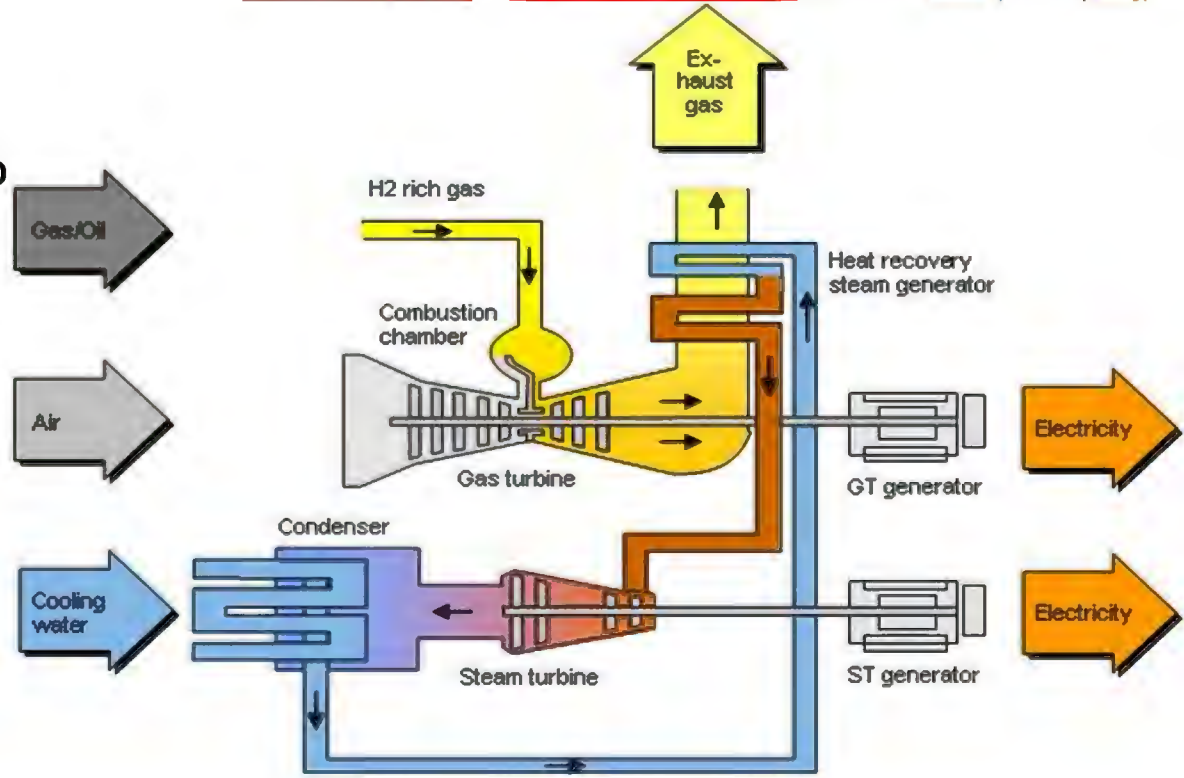


# Power Generation Unit – Functional Block Diagram



GT: 4x33%  
(3+1)

ST: 3x33%



## Power Generation Unit – RAM Analysis

<p><b>Reliability</b></p> <p><math>R(t)</math></p>	<p>The probability that a component or system performs its function properly without interruption for an allocated period of time</p>
<p><b>Availability</b></p> <p><math>A(t)</math></p>	<p>The probability that a component or a plant performs its function properly in a given instant</p> <p>Expected production of a plant</p>
<p><b>Maintainability</b></p>	<p>The probability that a component (or system) is repaired within a fixed time</p>

# Power Generation Unit – RAM Analysis

*Master Equipment List (MEL)*

*Failure Mode and Effects Analysis (FMEA)*

*Availability Analysis (AA)*

# Power Generation Unit – RAM Analysis

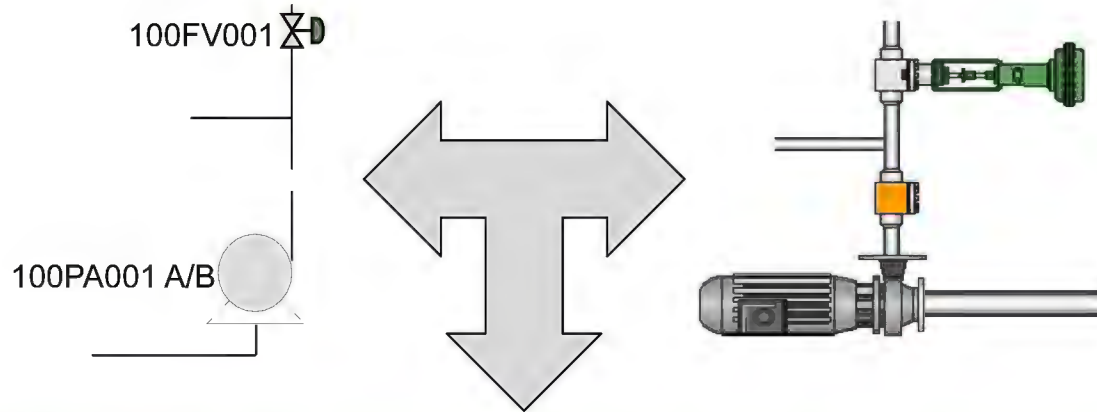
*Master Equipment List (MEL)*

*It consists in filling the FMEA electronic worksheets with all the Reference Items subject to analysis and identifying the applicable Failure Modes*

*Failure Mode and Effects Analysis (FMEA)*

*Availability Analysis (AA)*

# RAM Analysis – Master Equipment List



FMEA/FMECA/FMECTA - D'Appolonia SpA P-HSE

row	Unit	#	hold	Item tag	Item description	Ref. doc.	Ref. item	Status	Remarks
1	Unit 100	1	<input type="checkbox"/>	100PA001A	Pump A	100-00-XX-01		Duty	
2	Unit 100	2	<input type="checkbox"/>	100PA001B	Pump B	100-00-XX-01		Stand By	
3	Unit 100	3	<input type="checkbox"/>	100FV001	Control Valve	100-00-XX-01			
*			<input type="checkbox"/>						

Record: 1 of 3 | Unfiltered | Search



# Power Generation Unit – RAM Analysis

*Master Equipment List (MEL)*

*Failure Mode and Effects Analysis (FMEA)*

*This activity consists in identifying the reference items Failure Modes and determining their effects on the system*

*Availability Analysis (AA)*



# RAM Analysis – Failure Mode and Effects Analysis (FMEA)

DappRAM Main Menu

Project Name

Doc. No. 000-30

Fig.

## Failure Mode and Effects Analysis

DATE: 10/01/2011  
 SECTION UNIT/LOOP: Vacuum Distillation Unit (U180)  
 REFERENCES: 160-GD-B-04011 160-GD-B-04012 160-GD-B-04013 160-GD-B-04014

COMPILED BY: \_\_\_\_\_  
 (D'Appolonia)  
 ATTENDED BY: \_\_\_\_\_  
 (Company)

ITEM TAG NR.	ITEM FUNCTIONAL IDENTIFICATION	FAILURE MODES and CAUSES	LOCAL EFFECTS	EFFECTS on PLANT PRODUCTION	PROD. LOSS - GASOLINE (%)	PROD. LOSS - DIESEL (%)	PROD. LOSS - FUEL OIL (%)	PROD. LOSS - SULPHURIC ACID (%)	DETECTION METHOD	COMPENSATING PROVISION	REMARKS	PPD
E-1601	VGO / Crude Exchanger	Insufficient heat transfer	No crude oil preheating	U160 SD that leads to turn down of Plant production to 60%. Fuel Oil: U200 or U260 SD and 72hrs-delayed loss of production; Diesel: 20hrs-delayed U300 SD and consequent loss of production; Sulphuric Acid: 20hrs-delayed U300 SD and consequent loss of production; Gasoline: 20hrs-delayed U300 SD and consequent 100hrs-delayed U500-U530 SD that leads to loss of production.	100	100	100	100	Continuous condition monitoring	Gasoline: LVGO/HVGO Tank T-761C, Full Range Naphtha Tank T-7508 Diesel: LVGO/HVGO Tank T-761C Fuel Oil: Vibreaker Feed Tank T-714		160-GD-B-04011
E-1601	VGO / Crude Exchanger	Internal/External Leakage	Crude oil into VGO to T-761C/U300	U160 SD that leads to turn down of Plant production to 60%. Fuel Oil: U200 or U260 SD and 72hrs-delayed loss of production; Diesel: 20hrs-delayed U300 SD and consequent loss of production; Sulphuric Acid: 20hrs-delayed U300 SD and consequent loss of production; Gasoline: 20hrs-delayed U300 SD and consequent 100hrs-delayed U500-U530 SD that leads to loss of production.	100	100	100	100	Continuous condition monitoring	Gasoline: LVGO/HVGO Tank T-761C, Full Range Naphtha Tank T-7508 Diesel: LVGO/HVGO Tank T-761C Fuel Oil: Vibreaker Feed Tank T-714		160-GD-B-04011
E-1602	VR / Crude Exchanger	Insufficient heat transfer	No crude oil preheating	U160 SD that leads to turn down of Plant production to 60%. Fuel Oil: U200 or U260 SD and 72hrs-delayed loss of production; Diesel: 20hrs-delayed U300 SD and consequent loss of production; Sulphuric Acid: 20hrs-delayed U300 SD and consequent loss of production; Gasoline: 20hrs-delayed U300 SD and consequent 100hrs-delayed U500-U530 SD that leads to loss of production.	100	100	100	100	Continuous condition monitoring	Gasoline: LVGO/HVGO Tank T-761C, Full Range Naphtha Tank T-7508 Diesel: LVGO/HVGO Tank T-761C Fuel Oil: Vibreaker Feed Tank T-714		160-GD-B-04011
E-1602	VR / Crude Exchanger	Internal/External Leakage	Crude oil into Vacuum Residue to U260	U160 SD that leads to turn down of Plant production to 60%. Fuel Oil: U200 or U260 SD and 72hrs-delayed loss of production; Diesel: 20hrs-delayed U300 SD and consequent loss of production; Sulphuric Acid: 20hrs-delayed U300 SD and consequent loss of production; Gasoline: 20hrs-delayed U300 SD and consequent 100hrs-delayed U500-U530 SD that leads to loss of production.	100	100	100	100	Continuous condition monitoring	Gasoline: LVGO/HVGO Tank T-761C, Full Range Naphtha Tank T-7508 Diesel: LVGO/HVGO Tank T-761C Fuel Oil: Vibreaker Feed Tank T-714		160-GD-B-04011
V-1601	Crude Desalter	Critical	No desalted crude to V-1602 and consequent low corrosion effects	No Effects	0	0	0	0	Continuous condition monitoring	None		160-GD-B-04011
P-1611A	Recycle Water Pump A	Critical (escl. FTS and STP)	No recycle water to V-1601	No Effects	0	0	0	0	Continuous condition monitoring	Spare Pump P-1611B		160-GD-B-04011
P-1611B	Recycle Water Pump B	Critical (escl. FTS and STP)	No recycle water to V-1601	No Effects	0	0	0	0	Continuous condition monitoring	None		160-GD-B-04011
P-1611B	Recycle Water Pump B	Fail to start on demand	No recycle water to V-1601	No Effects	0	0	0	0	On demand	None		160-GD-B-04011
E-1603	VR / Crude Exchanger	Insufficient heat transfer	No crude oil preheating	U160 SD that leads to turn down of Plant production to 60%. Fuel Oil: U200 or U260 SD and 72hrs-delayed loss of production; Diesel: 20hrs-delayed U300 SD and consequent loss of production; Sulphuric Acid: 20hrs-delayed U300 SD and consequent loss of production; Gasoline: 20hrs-delayed U300 SD and consequent 100hrs-delayed U500-U530 SD that leads to loss of production.	100	100	100	100	Continuous condition monitoring	Gasoline: LVGO/HVGO Tank T-761C, Full Range Naphtha Tank T-7508 Diesel: LVGO/HVGO Tank T-761C Fuel Oil: Vibreaker Feed Tank T-714		160-GD-B-04011

## Power Generation Unit – RAM Analysis

*Master Equipment List (MEL)*

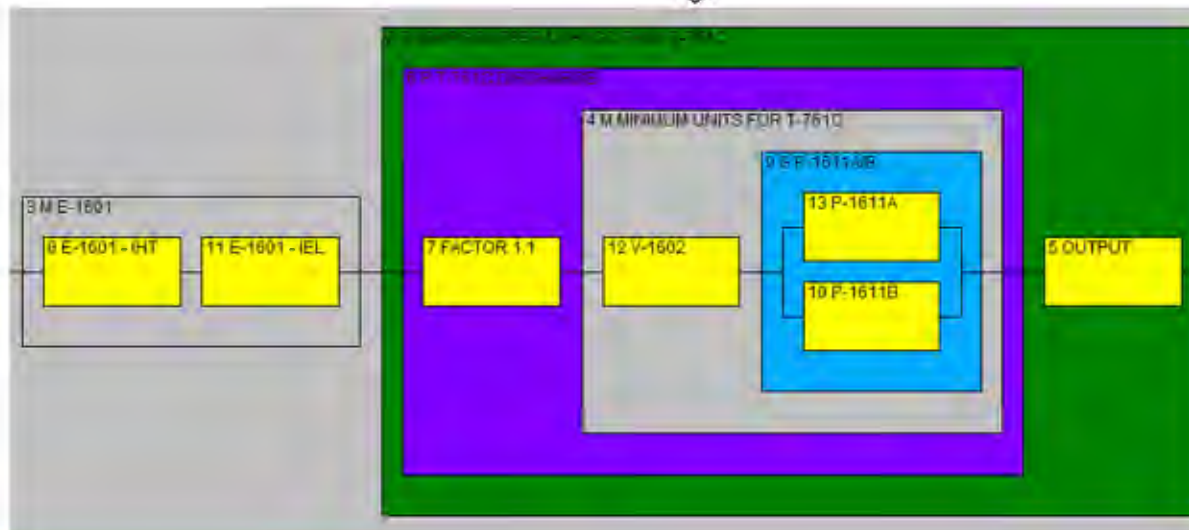
*Failure Mode and Effects Analysis (FMEA)*

*Availability Analysis (AA)*

*This activity consists in predicting the performance of the system in terms of production availability, taking into account items reliability and sparing, operating and preventive maintenance philosophy*

# Power Generation Unit – FMEA <-> RBD

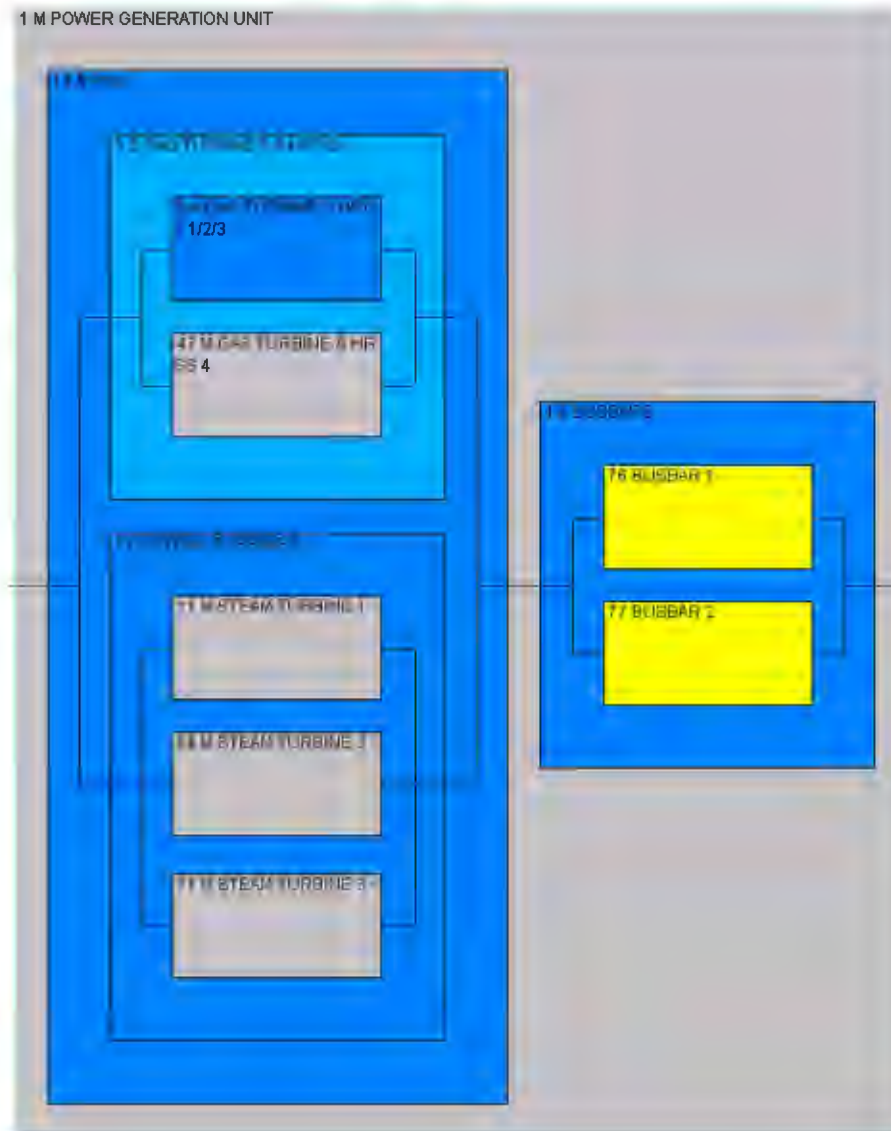
ITEM TAG	ITEM FUNCTIONAL IDENTIFICATION	FAILURE MODES and CAUSES	LOCAL EFFECTS	EFFECTS on PLANT PRODUCTION	PROD. LOSS [%]	DETECTION METHOD	COMPENSATING PROVISION	REMARKS	PFD
E-1601	VGO / Crude Exchanger	Insufficient heat transfer	No crude oil preheating	U160 SD that leads to loss of production	100	Continuous condition monitoring	None	-	160-4011
E-1601	VGO / Crude Exchanger	Internal/External Leakage	Crude oil into VGO to T-761C/U300	U160 SD that leads to loss of production	100	Continuous condition monitoring	None	-	160-4011
V-1601	1st Crude Desalter	Critical	No desalted crude to V-1602 and consequent low corrosion effects	No Effects	0	Continuous condition monitoring	None	-	160-4011
V-1602	2nd Crude Desalter	Critical	No desalted crude to V-1603 and consequent high corrosion effects	U160 SD that leads to 20hrs-delayed loss of production	100	Continuous condition monitoring	LVGO/HVGO Tank T-761C	-	160-4011
P-1611A	Recycle Water Pump A	Critical (escl. FTS and STP)	No recycle water to V-1601	No Effects	0	Continuous condition monitoring	Spare Pump P-1611B	-	160-4011
P-1611B	Recycle Water Pump B	Critical (escl. FTS and STP)	No recycle water to V-1601	U160 SD that leads to 20hrs-delayed loss of production	100	Continuous condition monitoring	LVGO/HVGO Tank T-761C	-	160-4011
P-1611B	Recycle Water Pump B	Fail to start on demand	No recycle water to V-1601	U160 SD that leads to 20hrs-delayed loss of production	100	On demand	LVGO/HVGO Tank T-761C	-	160-4011



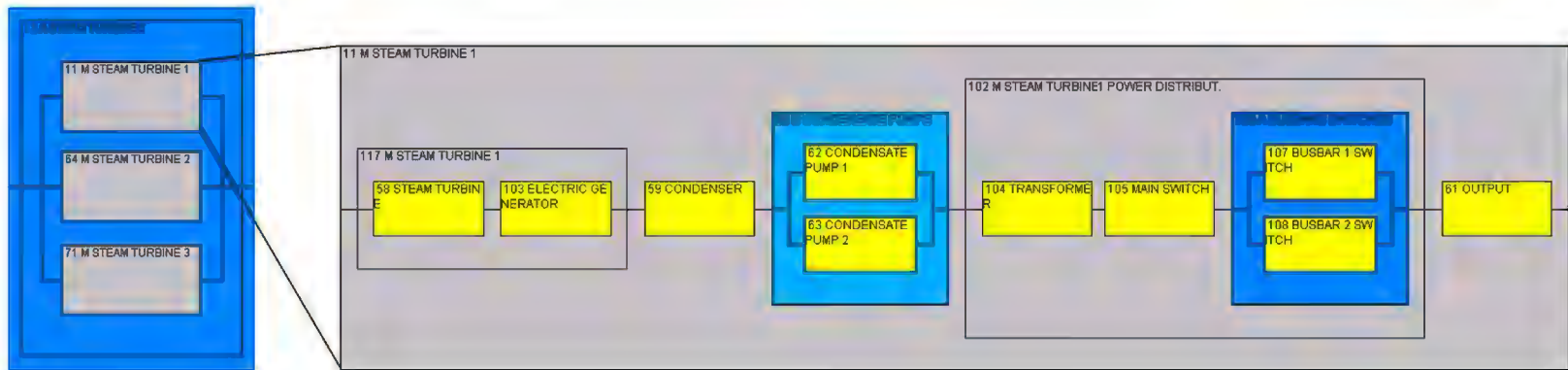
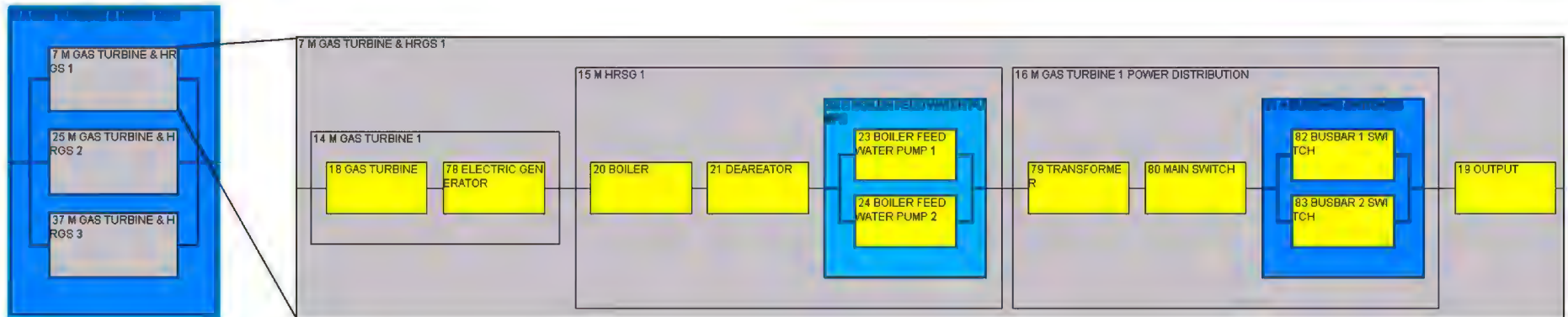
# Power Generation Unit – Reliability Block Diagram (RBD)

GT: 4x33%  
(3+1)

ST: 3x33%



# Power Generation Unit - Reliability Block Diagram (RBD)





# Power Generation Unit – Reliability Data

ITEM	FM	$\lambda$ [h <sup>-1</sup> ]	MTTF [h]	PFD	MTTR <sup>1</sup> [h]	Source
Electric Generator Turbine Driven - Main Power	Critical	3.71E-05	26,925	-	36.0	Oreda 2009, page 259
Transformer	Fails to provide Pwr	1.70E-06	588,235	-	40.0	Red book, page 6.57
Breakers	Spurious Op.	1.20E-06	833,333	-	24.0	Red book, page 6.56
Gas Turbine	Critical - FtSoD	2.35E-04	4,248	-	74.0	Oreda 2009, page 103
	Fail to Start on Demand	1.06E-04	-	2.25E-01		
Boiler (Heat exchangers)	Critical	8.91E-06	112,233	-	20.2	Oreda 2009, page 303
Deareator (Flash Drum)	Critical	1.27E-05	78,802	-	23.2	Oreda 2009, page 351

ITEM	FM	$\lambda$ [h <sup>-1</sup> ]	MTTF [h]	PFD	MTTR <sup>1</sup> [h]	Source
Pump – Centrifugal	-	-	23,015	3.81E-02	33.2	Sum of Centrifugal Pump and Electric Motor
Pump - Centrifugal	Critical - FtSoD	3.51E-05	28,490	-	18.0	Oreda 2009, page 146
	Fail to Start on Demand	4.53E-06	-	-	-	
Electric Motor	Critical - FtSoD	8.35E-06	119,760	-	14.0	Oreda 2009, page 281
	Fail to Start on Demand	4.17E-06	-	-	-	
Steam Turbine	Critical	2.71E-04	3,684	-	56.4	EPRI-1004241 (pag. 9-6)
	Fail to Start on Demand	1.22E-04	-	2.25E-01		
Condenser (Separator)	Critical	2.89E-05	34,650	-	21.1	Oreda 2009, page 377
Busbar (<20kV)	Fails to provide Pwr	1.70E-07	5,882,353	-	40.0	Red book, page 6.57
PCV+Control System	Critical	2.94E-06	340,136	-	19.4	Oreda 2009, pages 467, 574

## Power Generation Unit – Planned Maintenance

ITEM	Inspection Type	Frequency [y]	Duration [h]
Gas Turbine	Combustion	1	240
	<i>Hot Gas Path</i>	3	432
	<i>Major</i>	6	720
HRSBG	Major	2	96
Steam Turbine	Minor Overhaul (1 <sup>st</sup> year)	1	336
	<i>Minor Overhaul</i>	3	336
	<i>Major Overhaul</i>	6	672



# Power Generation Unit – Results (Availability)

	Plant	GTs + HRSGs	Single GT Train	STs	Single ST Train
<b>Output Data from RAMP</b>					
<b>Availability [%]</b>	99.45	99.18	95.43	94.44	94.45
<b>Time q=0 [h]</b>	145	3	1,202	1	1,461
<b>Time on PM [h]</b>	0	0	720	0	1,008
<b>Mission Time [h]</b>	26,280	26,280	26,280	26,280	26,280
<b>Capacity [MW]</b>	120.0	82.5	27.5	37.5	12.5