LIMA Programme

Power Plant Risk Management

20th September 2023

Romeo Ouattara & Philani Mbatha

Munich RE

NOT IF, BUT HOW

Image: Munich Re

Agenda

Munich RE

01

Equipment characteristics & exposures

02

Failure examples

03

Maintenance

04

Safety protection measures

05

Risk assessment

06

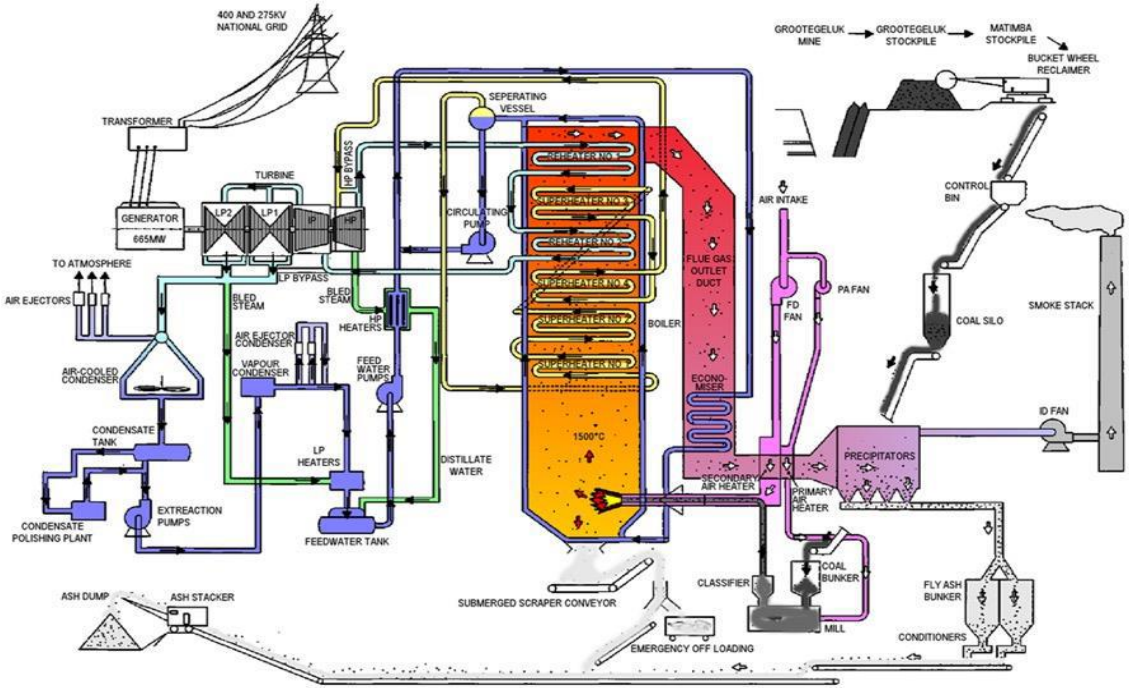
Conclusion

Introduction

01

Image: Munich Re

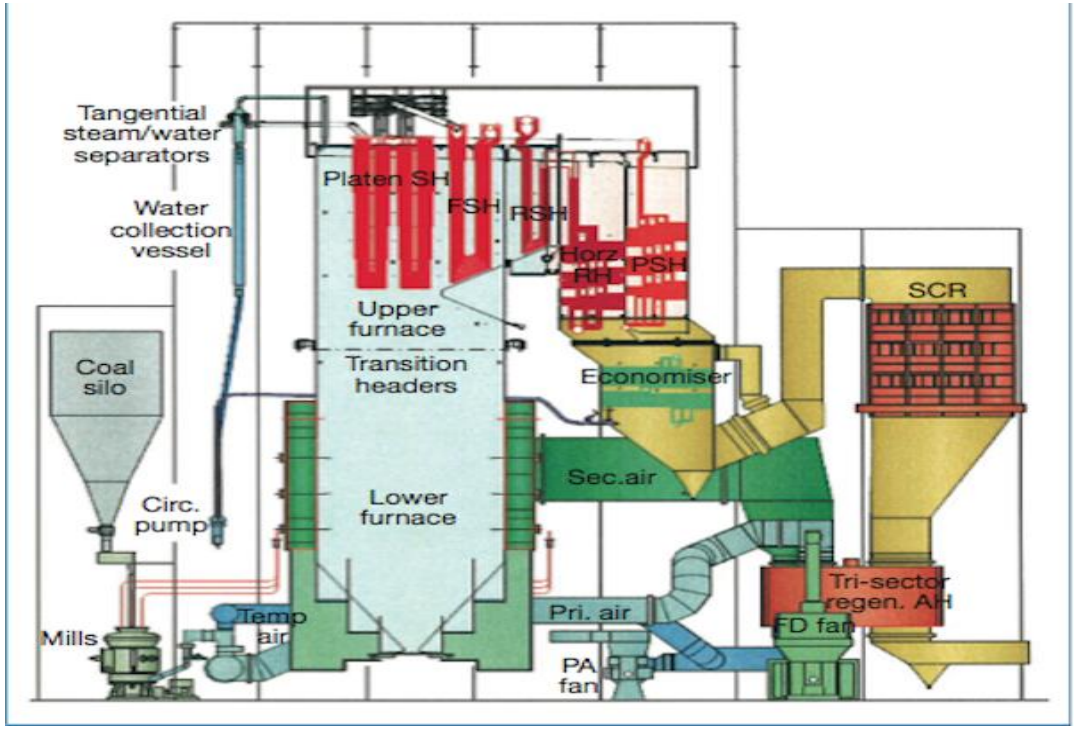
Equipment characteristics & exposures
Typical 600MW coal fired power plant



Exposures:

- Fire, explosion, high speed rotating equipment, high temp/pressure steam, electrical shock, chemical spillage, emissions. Other environmental impacts.
- Mechanical failure, civil structure collapse.
- Physical harm, human error, sabotage.
- Natural perils.
- Terrorism.

Equipment characteristics & exposures
Typical 600MW coal fired plant boiler



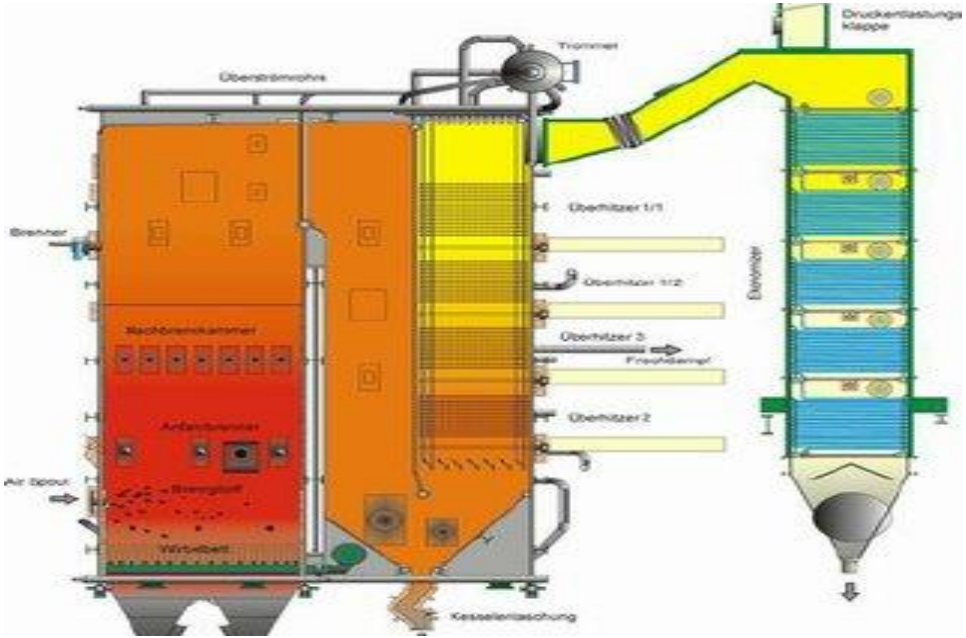
Exposures:

- High temperature, erosion & corrosion
- Combustion Control
- Control Systems – OEM support
- High energy piping (creep, vibration, flow accelerated corrosion
- Precipitators, Fabric Filters
- Emissions
- Fire, explosion, chemical, environment

Processes:

- Fuel preparation – coal movement and sampling
- Combustion - Burner systems
- High pressure/temp steam - production.
- Waste removal – ash
- Emissions control

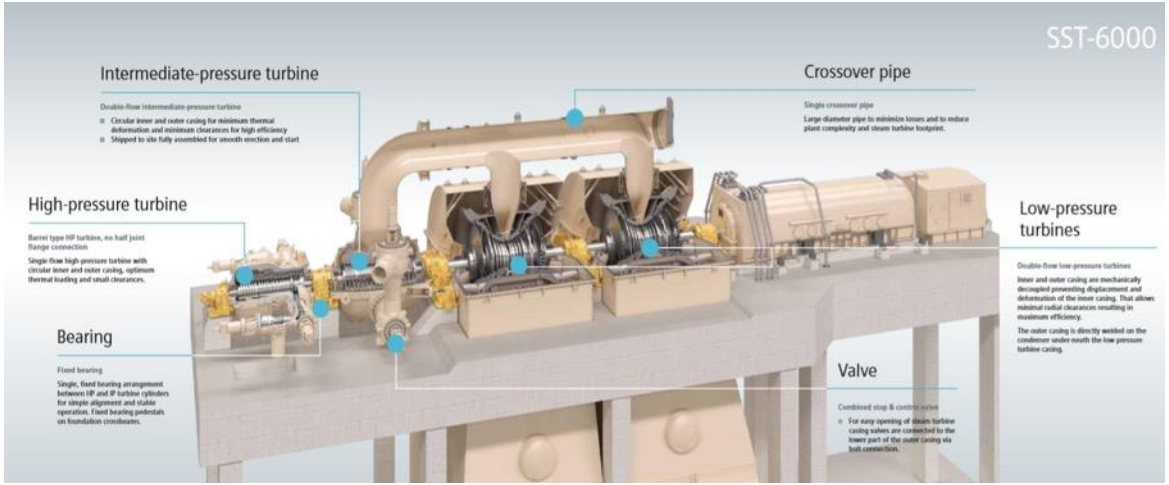
Equipment characteristics & exposures
Typical 600MW coal fired plant boiler



Management:

- Boiler pressure parts – Economisers, Superheaters etc. – management.
- Maintenance inspection/planning.
- Water treatment - Water and Steam Quality.
- Life assessment of equipment.
- Pressure testing.
- TPL overview.

Equipment characteristics & exposures
600MW Steam Turbine Generator



Picture of an opened 600MW ST showing HP, IP Dual flow LP's (2 off).

Exposures:

- High pressure, temperature steam
- Rotating speed.
- Vacuum
- Water Ingress
- Creep/SCC

Processes:

- Conversion of steam to electrical power

Management:

- Overspeed – 110% of rated speed
- Vibration
- Steam quality
- Inspection

Equipment characteristics & exposures
Generators

Exposures:

- High pressure, temperature steam
- Rotating speed.
- Electrical failure
- Hydrogen leak
- SCC

Processes:

- Uses the rotational speed from the turbine to produce electrical power.

Management:

- Speed control
- Hydrogen purity monitoring, moisture,

Typical section through a generator

Equipment characteristics & exposures
Generators

Munich RE

Management: continued

- Routine testing
- Hydrogen purity monitoring, moisture,
- Rotor/stator insulation, grounding, motoring, wedge tightness, cooling systems
- Protection – e.g. under/over voltage, earth fault, interturn fault etc.
- Monitoring/protective devices

Equipment characteristics & exposures
Transformers

Exposure:

- Fire and or explosion
- Oil leakage/contamination

Processes:

- Voltage step up or down.

Management:

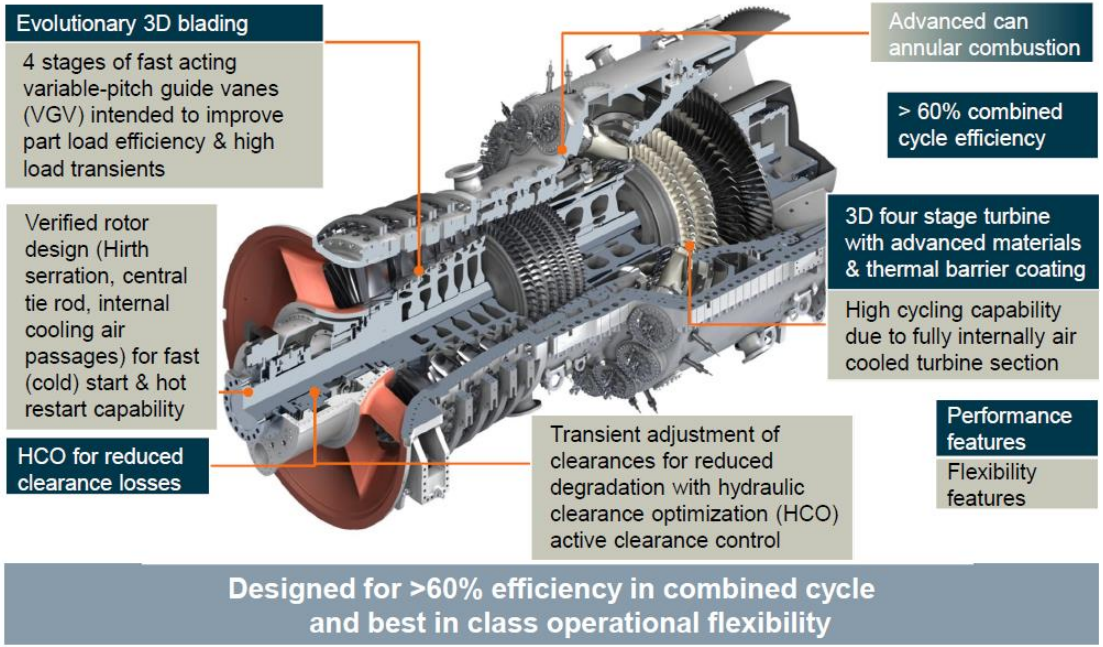
- Temperature – fully functioning oil and air cooling
- Oil condition, tap changers
- Lightning/surge protection
- Gas condition monitoring and trips

Equipment characteristics & exposures
Transformers

Management: continued

- Bushings, winding insulation, ELCID, Power Factor/Tan Delta testing
- Tap changers
- GSUT replacement time – up to 2 years

Equipment characteristics
Gas turbines in SC/CCPP



Siemens SGT8000H

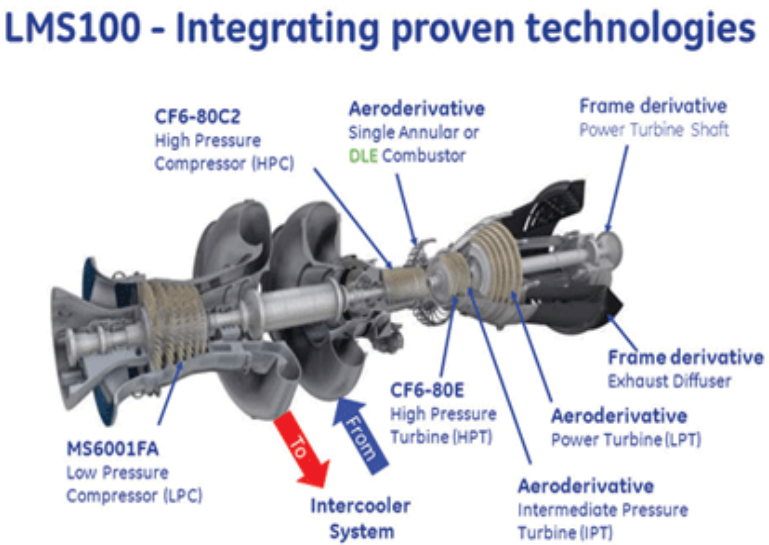
Exposure:

- New and High technology (design & materials) – prototype, unproven or proven.
- High temperatures
- High stress/speed
- Creep.
- Expensive to repair or replacement
- Long lead times for replacement
- Emissions

Processes:

- Combustion of fuel to rotational energy/electrical generation

Equipment characteristics
Gas turbines in SC/CCPP



GE LMS 100 - Aeroderivative

Management:

- Gas/air quality
- Maintenance – hours driven
- Adherence to OEM TIL's
- Expensive to repair (replacement)
- Long lead times for replacement
- Designed life
- Environment
- Significant impact on safety & critical to business

Failure examples

02

Image: Munich Re

Failure examples : Boiler explosion

Munich RE

- **Circumstances** – shift change over, problematic combustion, inadequate combustion monitoring
- **Cause** – sub-stoichiometric combustion, furnace tube leak, other distractions
- **Damage** circa US$400M
- **Lesson learnt** – Combustion monitoring, management of furnace steam leaks.

Failure examples : Steam turbine overspeed

Munich RE

- **Circumstances** – testing, loss of load.
- **Cause** – testing or loss of load.
- **Damage** – dependent upon size but a 600MW unit circa US$150M
- **Lesson learnt** – proper procedures, understanding the risk, ensuring safety devices operate prior to test.

Failure examples
Lower Pressure Steam Turbine Failure

- **Circumstances** – loss of 4 final stage LP turbine blades, one at the root the others at the airfoil.
- **Cause** – metal fatigue – HCF
- **Damage** – extensive damage to LP blades on inner stages circa US$32M – Open claim
- **Lesson learnt** – Vibration monitoring – step change, improved inspections

Failure examples
Gas turbine compressor failure

Munich RE

- **Circumstances** – Unit operating with Power Augmentation.
- **Cause –** rapid temperature transients when switch on and off of the High Fogging system
- **Damage** – Reserve of US$10M, later OEM dropped their claim – BI Claim remains Open (circa 73 days including 18 days of recommissioning)
- **Lesson learnt** – phased start up and shutdown of the HF system to minimise temperature transients.

Failure examples
Transformer fire or explosion

- **Circumstances** – unit tripped on differential protection – fire - history of phase sheath failures,
- **Cause** – installation error and incompatibility of material along with aging
- **Damage:** PD US$5M, BI US$300k/day.
- **Lesson learnt** – purchase or spare repair kits, QA/QC

Time base maintenance philosophy

03

Image: Munich Re

Time base maintenance philosophy
600MW coal fired power plant

Munich RE

Activity	Cycle time (years)	Duration (days)	Scope
General Overhaul	6	84	Full inspection with major replacements/repairs to boiler, steam turbine cylinders opened
Inspection (IN)	1 – 1,5	14	Generally inspection only with minor repairs - monitoring
Interim Repair (IR)	3	49	Mid – cycle replacement/repairs
Inspection (IN)	4,5	14	Prior to a major or a mini
Mini Overhaul	3	63	Similar to an IR but more extensive

Time base maintenance philosophy 110MW gas turbine

Munich RE

Activity	Equivalent Operating Hours (Equivalent Starts)	Duration (Typical)	Scope
A inspection	8,000/16,000 (400/800)	3/5	Boroscope Inspection
B Inspection	24,000 (1,200)	14	Hot Gas Path Inspection
A Inspection	32,000/40,000 (1,600/2,000)	3/5	Boroscope Inspection
C Inspection	48,000 (2,400)	35	Major Overhaul (rotor removal),

The above timings can be moderated by the number of starts – more starts less operational hours. The use of Extended Life HGP components will change the above to reduce maintenance timing and typically removes the CI's but may replace with a boroscope inspection.

Time base maintenance philosophy 739MVA generators & transformers

Munich RE

Activity	Cycle time (years)	Duration	Scope
Interim Resistance (IR)/Polarization Index (PI) testing	2		Generally done during main plant outage
Power Factor Testing, ELCID	6 – general/major overhauls	7 to 10 days	Will require disconnection of HV cabling at bushings
Dissolved Gas Analysis	Min annually,		Manual sampling, continuous monitoring. DP estimate
Winding ratio etc	2		

Safety protection measures

04

Image: Munich Re

Safety protection measures
Station and Equipment protections

Munich RE

- Human Element - Staff Training – new staff and refresher training
- Up to date work procedures – operations and maintenance
- PTW – comprehensive permit to work system – to include Hot Work/Confined space, etc.
- Management of Change – formal process.
- Housekeeping
- Emergency/Evacuation Plan.
- Business Recovery Plan

Routine testing:-

- Overpressure and vacuum devices – safety valves/vacuum breakers
- Electrical protection – protection monitoring and testing
- Vibration monitoring – fixed and manual – alarm and trip functions.
- Combustion controls – dark check, air/fuel ratio, flame monitoring/furnace temperature etc.
- ST overspeed protection.

Safety protection measures
Station and Equipment protections

Munich RE

Routine testing:- continued

- Fire Detection and Protection Systems – including annual performance testing of fire pumps.
- Emergency/Evacuation Plan exercises

Condition monitoring of equipment:-

- Dissolved gas analysis – continuous and manual – transformers
- Lube Oil analysis – turbines, gearboxes
- Vibration analysis
- Thermographic surveys
- Sound survey
- Boiler Hanger survey – hot, cold hot.

Long term:-

- Life Assessment of components
- Life of Plant Plan

Safety protection measures
Fire water system

Munich RE

	Building & area	Hydrant	Water spray system	Sprinkler system	Foam system	Gas extinguishing system	Note
1	Fuel oil storage tanks	O	V		V		
2	Fuel oil pump station	O					
3	Fuel oil treatment plant	O					
4	Compressed air station	I					
5	Diesel generator room	I					
6	Natural gas receiving station	O					
7	GT area	O					
8	GT noise enclosures and control cubicles					V (by GT supplier)	
9	GT lube oil skid / Hydraulic oil skid / Fuel oil skid					V (by GT supplier)	
10	Waste water treatment plant	O					
11	Demin. water treatment plant	O					
12	Generator step-up transformers / unit transformers / LV transformers	O	V				
13	Control / electrical building						
13.1	LV / MV switchgear room	I				V	
13.2	Electronic and relay room	I				V	

Fire Pumps

The plant is provided with a dedicated fire water reservoir. In case of fire the system will operate with the two hours storage available in the fire water reservoir. The fresh water is applied for the fire fighting system.

The fire water shall be supplied to fire water network by a fire water pumping system housed in a fire pump station. The pumping system shall comprise of:

- One electric driven fire pump
- One electric jockey pump
- One diesel engine driven fire pump

Risk assessment

05

Image: Munich Re

Risk assessment

Munich RE

Risk Control Engineering is critical part of underwriting decision process

- Understand occupancy hazards and production flow
- Know the damage mechanism and industrial trend
- Identify the key exposures and objects
  - Key and major equipment /bottleneck
  - Special risk exposures
    - ✓ Prototype
    - ✓ Spoilage and contamination & controlled environment or clean room
    - ✓ Hazard substances (PCB-polychlorinated biphenyl, CFCs)
    - ✓ Obsolescence and depletion by law
    - ✓ Aging
    - ✓ Country of origin

Conclusion

06

Image: Munich Re

Conclusion

- Large investments are ahead of us in the energy sector in Africa
- Power plant is highly specialised class of business which requires specialists and multiple disciplines
- Nature of claims and type of covers result in complex claims settlement
- Risk management is crucial

Thank you for your attention!

Romeo Ouattara & Philani Mbatha

Munich RE

NOT IF, BUT HOW

Image: Munich Re