FIRE LOSS PREVENTION FORUM OF INDIA

LOSS PREVENTION IN THERMAL POWER PLANTS

NOVEMBER 2018

CONTENTS

Disclaimer: The technical recommendations for loss prevention in specific areas are a result of the discussion during the Fire Loss Prevention Forum of India (FLPFI) meeting held in November 2017. The recommendations shall not be taken as replacement to detailed recommendations provided in the standards (FM Global Property Loss Prevention Data Sheets).

1. EXECUTIVE SUMMARY

India is establishing a diversified energy supply portfolio which includes renewables, nuclear and fossil fuels. By their very nature, power plants have a high degree of potential risk factors and hazards. However, these factors can be mitigated against through the application of research based risk management techniques.

Risk management techniques help companies improve resilience: the ability to prepare for and recover from a business disruption.

The main purpose of this white paper is to raise both the awareness of the potential risks in the operation of power plants, and the preparation and the risk management needed to ensure the plants are more resilient and essential power supply is uninterrupted.

The operators in India's power generation industry, all of whom provide an essential public service, must evaluate and ensure whether their risk strategies minimise uncertainties, which in turn will maximise opportunities and production capability. Whether a company might be embarking on a risk strategy after a series of accidents or not, the key to reducing the probability of a power plant fire, explosion and equipment breakdown is preparation and safety precautions. By reducing the risk of fire, explosion and equipment breakdown hazards to a power plant, the safety of people, plant and production is greatly increased.

2. INTRODUCTION

For an industry that is evolving more rapidly than ever, the power generation industry and the companies that operate in this sector must develop new expertise to identify, evaluate and mitigate potential risks if they wish to remain in business. Whether adopting new technologies, investing in new plants or equipment, or managing ageing plants, these scenarios all involve a degree of risk.

Failure to do so can expose these companies to potential loss of lives or operational capacity and/or efficiency and would ultimately affect their profit, balance sheet and reputation. Amidst these changes, the fact remains that the majority of losses, whether caused by equipment failures, natural catastrophes or human errors, are preventable.

This paper provides unique insight into the causes and value of large losses in the global power industry, an overview of the risk factors and aims to help organisations across India improve their risk management controls and ensure continuity of power supply.

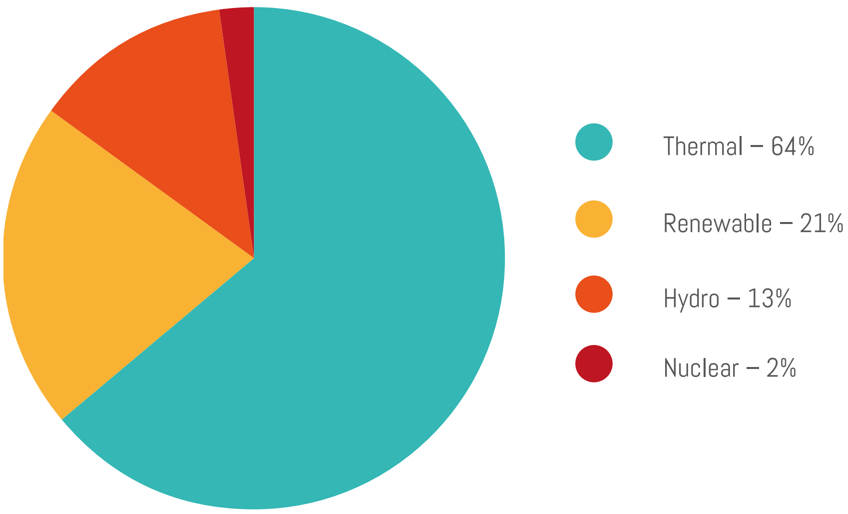
3. POWER SECTOR SITUATION IN INDIA

Despite a rapid growth in renewable energy and a projection that India will get 57% of its installed power capacity from clean energy sources by the end of 2026-27[1], coal fired power plants continue to dominate and are the mainstay of the power sector due to the abundance of coal, the cheapest and most affordable source of power in India. Coal fired plants operate predominately as baseload plants to offer stability to the national grid.

The total installed capacity of Power Generation in India as of 31st August 2018 is 344,668.1 MW (Source: Central Electricity Authority).

Thermal power	64%	221,802	MW
Renewable	21%	70,649	MW
Hydro	13%	45,457	MW
Nuclear	2%	6,780	MW

POWER SCENARIO: CONTRIBUTION



Total thermal installed capacity 221,803 MW

Coal	196,097.50 MW
Gas	24,867.38 MW
Diesel	837.63 MW

Total renewable energy capacity 66,649 MW

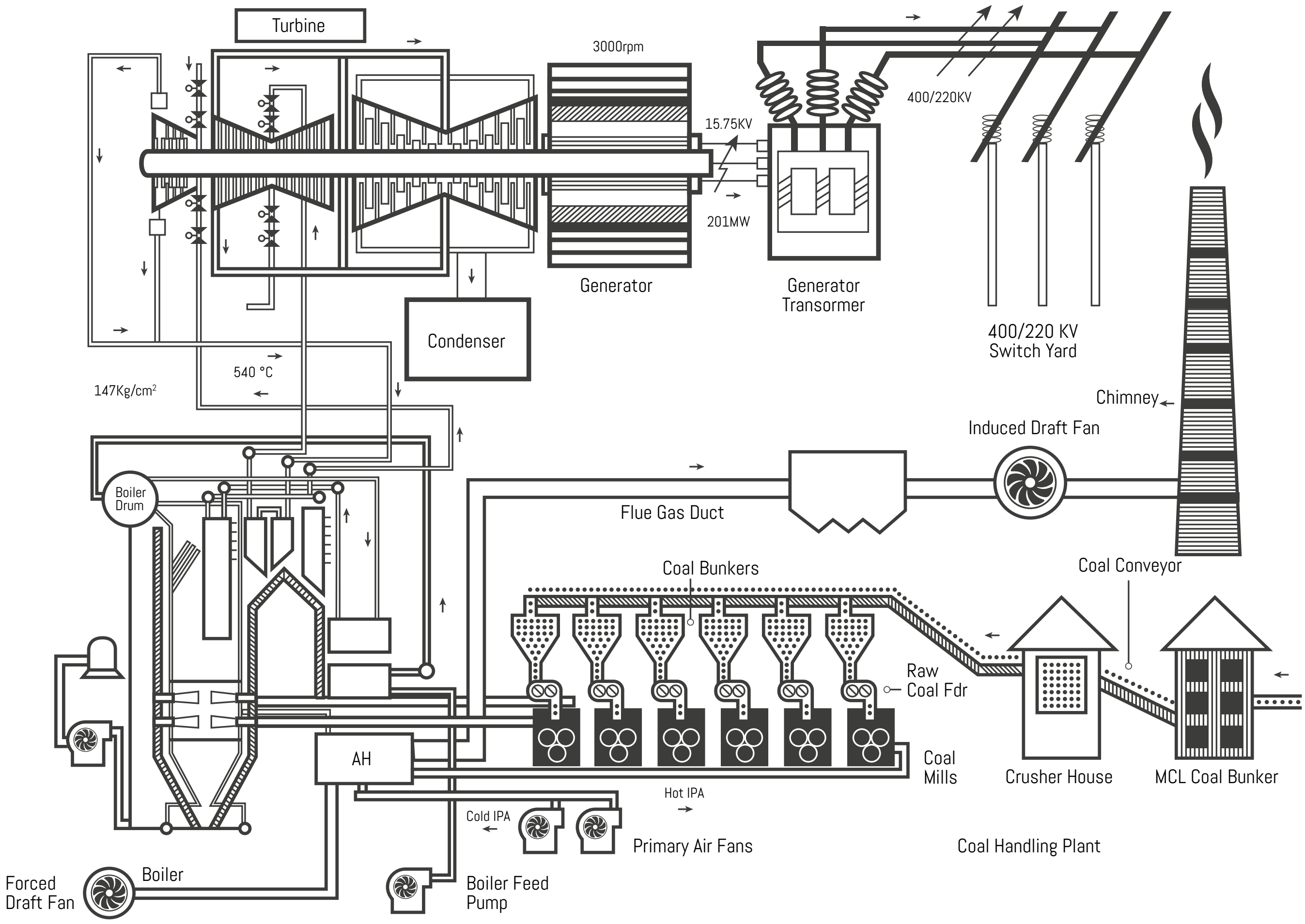
Wind power	34,29347 MW
Solar power	23,022.83 MW
Bio power	8,839.10 MW
Small hydro	4493.20 MW

The loading factor for thermal power had remained nearly the same between August 2017 and August 2018 even though there had been an increment in industrial growth. From the above data, it is evident that the power sector is dominated by the thermal energy source with coal based power plants catering to the major share of capacity.

[1]Central Electricity Authority, National Electricity Plan, 2018

4. FUNDAMENTALS OF A THERMAL POWER PLANT

Thermal power plants generate electricity by burning off fossil fuel in a large industrial furnace typically called a boiler. For coal fired plants, pulverised coal is blown into the furnace where it burns and gives away its heat to water and generates steam, which in turn moves the turbine at high speed. The turbine spins and drives a rotor attached to a current carrying conductor rotor magnet in a generator. These rotating magnetic fields moving across coils in the generator produce electric currents.



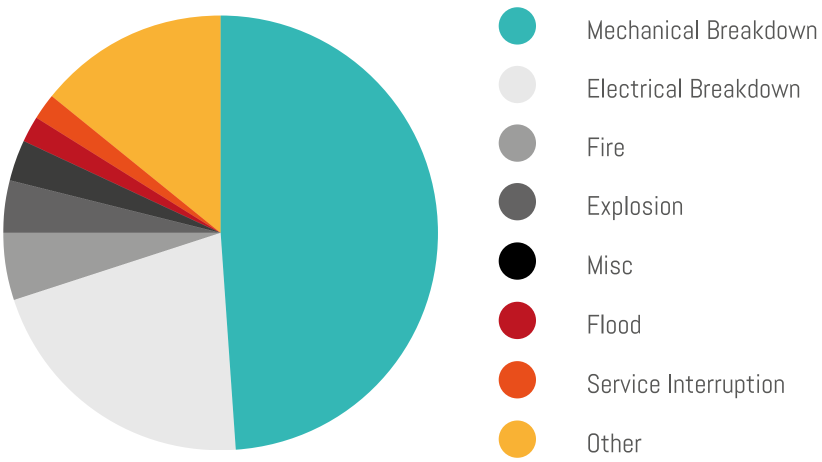
5. LOSS EXPERIENCES IN THE THERMAL POWER SECTOR

Power plants by their very nature are exposed to difficult and hazardous operating conditions due to the combination of large pieces of equipment operating at high speeds, fuel fired equipment, large quantities of lubrication oil and ignition sources which can lead to equipment breakdown and fire incidents. Equipment breakdown is a major hazard in their operation due to bulk quantities of coal, fuel oils and lubricating oils, making them more prone to accidents.

The majority of these incidents are the result of mechanical or electrical breakdown, or human error. Consequent fires or explosions can aggravate the severity of the incident. The reality is that modern utility-class machines handle vast amounts of kinetic energy and it takes careful engineering, operation, maintenance and adherence to procedures to convert the energy into electricity. Failing to adhere to any of these measures could result in a disaster.

POWER GENERATION LOSSES: BY PERIL

Historically, equipment breakdown is the key loss driver in the power generation industry, with turbine breakdown the most common as shown in the figure (below). A study found that over a 15-year period, the average loss was US $24 million and the average outage was more than 24 weeks. The study also found that 52% of these incidents were caused by mechanical failure, 19% were due to the failure of oil system fitting, 19% were electrical or loss of oil, and the remaining 10% was operator error. In two thirds of losses in the power generation industry, operator error is a contributing factor. This means that mechanical breakdown and other incidents may have an operator error component too. Pressurised fluids such as turbine lubricating, control or seal oil present a considerable fire hazard. The study concluded there was a high likelihood of fire whenever there was mineral oil under pressure, hot surfaces to ignite it and deficiencies in fire protection.



Another study carried out by an earlier wing of the Insurance Industry, Tariff Advisory Committee (TAC), for a 15-year period beginning in early 2000, looked at fire losses and fire behaviour in the electric generation industries. In that period there were 40 incidents of major fires resulting in a loss of Rs. 1,710 million, with the average loss per incident of Rs. 42.8 million. The most frequent causes were seen to be electrical and mechanical sparking and electrical short-circuit. The losses were most frequent in non-working hours between 18:00-06.00. *Note: Tariff Advisory Committee (TAC) no longer exists.*

6. CASE STUDIES

Unchahar Power Plant, 1st November 2017

A massive explosion at a newly commissioned unit of a coal fired power plant in the Uttar Pradesh state killed 34 people and injured over 80. One of the deadliest power plant accidents in recent years, an investigation by the Government owned plant operator, National Thermal Power Corporation (NTPC), will look at possible hot ash accumulation below a newly installed boiler which led to pressure build-up and the blast. The 1,550 MW plant supplies electricity to nine states and employs some 870 people.

Yakutsk Thermal Power Plant – 2nd October 2017

A fire at a thermal power plant in eastern Russia left 300,000 residents without light and heat for six hours. In one of the coldest habited areas of the world, a state of emergency was declared due to the freezing temperatures. While the cause of the fire is under investigation, this plant features old and outdated equipment and is soon to be retired.

Vallur Thermal Power Plant – 4th June 2017

A fire broke out at the NTECL Vallur Thermal Power Plant near Chennai, after a turbine in the third unit burst. While there were no casualties, it took firefighters three hours to extinguish the fire which completely gutted the unit. The thermal power plant, which has a 1,500 MW coal fired capacity, faced a shutdown causing power outages. The forced outage lasted 3 months.

Wanakbori Thermal Power Station – 6th June 2017

A coal conveyor belt at the Wanakbori Power Station in Gujarat caught fire and spread to other areas of the power unit, one of seven within the plant which produces 1,460 MW. The unit was shut down following the fire.

Chhattisgarh Power Station – 28th May 2017

An explosion in the turbine at the Chhattisgarh power plant led to injuries to seven employees and a shutdown of the plant. Extreme summer temperatures contributed to the explosion in the turbine and the fire was intensified by the spread of oil.

Talwandi Sabo Thermal Plant – 19th April 2017

A thermal power plant was shut down in Mansa for two months following a fire in the coal handling unit, completely destroying the conveyor belt system carrying coal from the handling unit to the thermal power unit. To meet the power demand in the summer peak period, units at other thermal power plants were started to meet demand.

Madian Gangue Power Generation – 10th August 2016

A massive explosion at a thermal power plant in Dangyang, Hubei, China killed 21 people and injured another five. The cause of the explosion was the result of a high pressure steam pipe that burst during testing.

Martin Drake Coal Fired Plant – 5th May 2014

A fire broke out at a 254 MW coal fired power plant in Colorado Springs, USA, causing significant damage to one of three coal burning units. The flash fire was a result of free-flowing lubricating oil coming into contact with high temperature steam pipes. The additional cost for replacement power was estimated at US $3 million per month for operator Colorado Springs Utilities.

JT Deely Station – 10th September 2013

An explosion at a coal fired plant in San Antonio, Texas, resulted in the closure of one of two coal burning units. The fire in the 420 MW Deely 1 was caused by coal dust in one of the coal silos catching fire and damaging the cascade building above.

Panipat Thermal Power Station – 22nd January 2018

An explosion in a boiler of an oil refinery left at least two people dead while over six others suffered critical injuries.

7. RISKS AND RISK MITIGATION MEASURES IN DIFFERENT AREAS OF A THERMAL POWER PLANT

Thermal plants must employ the proper measures to prepare, prevent and protect their facilities. However, year after year there are major fires or explosions in coal based thermal power plants. These major incidents can be traced back to a manageable list of oversights which are preventable when utilising the operational safety devices, proper maintenance and proficient operators, technicians and other plant personnel that are prepared to respond to upset conditions, proper fire prevention, detection and suppression procedures. Sadly, some facilities do not have adequate procedures in place or in extreme cases, they have no procedures at all. Emergency Operating Procedures (EOP), and knowledgeable operators prevent losses. EOP starts with properly equipment upset conditions. Fire related EOP come into play when critical EOP fail. Furthermore, if these procedures are not reviewed, revised and practiced annually, these plants are bound to make mistakes.

Fire protection systems, which includes containment, drainage, detection and suppression is a third line of defence, designed to mitigate losses, but not prevent them (i.e. first line of defence – equipment and safety systems that are in good maintenance and operational condition, second, operators & technicians to properly react to upset conditions not allowing it to escalate, and third, fire protection and emergency fire procedures).

In an environment where everyone is trying to minimise costs, maintenance often gets short shrift. Ultimately though, a lack of, or inadequate maintenance, is directly correlated with increased spending in the long-term in terms of equipment problems and failure. Such facilities will jeopardise the health and safety of plant personnel and will fail to meet their goals.

THE MAIN RISK AREAS IN A POWER STATION ARE AS FOLLOWS:

EQUIPMENT BREAKDOWN RISK
7.1 Steam Turbine
7.2 Boiler
7.3 Generator
FIRE & EXPLOSION RISK
7.4 Lubrication Oil Systems
7.5 Coal Conveyor Systems
7.6 Coal Stock Pile Yard
7.7 Coal Bunker
7.8 Cable Gallery
7.9 Fuel Oil Handling
7.10 Power Transformers
7.11 Other Equipment Hazards

RISK AREAS AND RISK MITIGATION MEASURES

Equipment Breakdown Risk

Equipment breakdown is the leading cause of property losses in the power generation industry. Equipment breakdown, upset operating conditions and human error have also resulted in large fire events and explosions; though less frequent, the results can be devastating from a property loss and human life perspective. Predominant factors when large property losses and loss of life incidents occur are:

- lack of adherence to safety norms. This seems to be a recurring cause when catastrophic incidents occur
- deficient inspection, testing and maintenance of equipment, auxiliary systems and safety systems
- operators and plant technicians:
  – not being familiar with normal operating procedures (this incidentally also results in a fire event not preceded by equipment breakdown)
  – being unprepared to react to upset conditions due to deficient emergency operating procedures and/or training

Property losses may be aggravated by a fire event following an equipment breakdown event or human error, if:

- fire protection systems are lacking or inadequate
- emergency operating procedures are inadequate and/or not followed

Other root causes of large catastrophic losses include:

- deficient human element programs
- maintenance induced – e.g. deficient outage management procedures (human element)
- operating the equipment beyond its design parameters or design life – ageing equipment
- deficient workmanship (i.e. QA/QC – e.g. at new installations and inadequate commissioning)

What is the solution?

- Implementing elements of process safety per FM Global Property Loss Prevention Data Sheet 7-43 "Process Safety"
  – Management commitment
  – Process/systems knowledge
  – Process hazard analysis/Scenario based risk assessments
  – Asset integrity (Inspection/Testing/Maintenance)
  – Management of change
  – Incident investigation
  – Contractor management (Contractor selection and oversight)
  – Operators (Training/SOP/EOP/Jumper management)
- Outage Management FM Global Property Loss Prevention Data Sheet 7-43 "Process Safety"
- OEM bulletin management
- Quality Assurance/Quality Control – internal and external
- Foreign Material Exclusion programs (FME)
- Hoisting equipment
- Log Out/Tag Out
- Layup procedures

- Fire Protection
  – Containment
  – Drainage
  – Active fire protection systems
  – Emergency Operating Procedures

7.1 Steam Turbine

A steam turbine is a rotary heat engine that converts energy of high pressure and high temperature steam into electrical energy by acting as the prime mover for the rotation of the generator.

RISKS ASSOCIATED INCLUDE:

- Loss of lubrication causing internal rubbing and the destruction or ceasing of the bearings
- Turbine over speed causing severe damage due to imbalance, higher vibration etc.
- Water induction can cause any of the following: rub damage, thrust bearing destruction, blade damage, thermal cracking, warping distortion and possible casing damage
- Motoring due to generator circuit breaker failure to operate following a shutdown or trip
- Higher vibrations may lead to damage to journal bearing and other internal components
- Fire hazard at lube/hydraulic/seal oil system
- Poor water and steam quality can lead to internal corrosion and erosion leading to successive damages
- Foreign objects causing impact damage to blades and internal components

RISK MITIGATION MEASURES INCLUDE:

- Loss of lubrication
  a. Regular checks of DC lube oil pump testing:
  – testing of Auxiliary and Emergency Lube Oil Systems, at least monthly
  – start and stop pressures of auxiliary and emergency lube oil pumps
  – test the tank low-level alarm. For normal lube oil system, the tank level should be checked per shift and for gravity (rundown tanks) it is recommended to test the low level alarm quarterly
  – conduct flow test during commissioning and after major upgrade or modification
  b. Inspection and testing on emergency system power supply system:
    1. Batteries
    2. Charger
  c. Lube oil analysis
- Overspeed
  a. Check electronic overspeed device. The electronic overspeed device trips the turbine at speed before the mechanical overspeed device acts. The mechanical device is the last reserve for operation and a safety aspect for the turbine.
  b. Check mechanical overspeed trip system
  c. Exercise steam admissions valves. A partial stroke test should be conducted weekly
  d. Exercise extraction non-return valves
- Water ingression
  Water ingression into a steam turbine can have catastrophic consequences and it is essential that protection is in place to prevent this happening. The main sources of water induction are turbine extraction/admission systems, feed water heaters, turbine drain systems, turbine steam seal systems and start up systems
- Check generator circuit breaker failure to operate protection
- Check water and steam purity and quality
- Routinely check and calibrate following control, protection and monitoring systems

Table 1. Recommended Steam Turbine Protective Devices, Alarms and Trips

The following table is taken from FM Global Property Loss Prevention Data Sheet 13-3 – Steam Turbines.

Protective Device	Actuated Device	Alarm	Trip[1]
1. Emergency overspeed trip	Turbine steam admission emergency stop valve(s) (all admission sources)		X
2. Thrust – and journal-bearings axial and radial position monitoring by means of proximity probes, micrometer measurement	Emergency stop valve	X	X
3a. Low oil-pressure sensor, main lube-oil pump	Annunciator, start auxiliary oil pump	X	
3b. Low oil-pressure sensor, auxiliary lube-oil pump	Annunciator, start emergency oil pump	X	X
3c. Low oil-pressure sensor, emergency lube-oil pump	Annunciator, shut emergency stop valve, turbine trip	X	X
4. Low oil-level sensor in tank	Annunciator, shut emergency stop valve, turbine trip	X	X
5. Low level (gravity-rundown tank system)	Annunciator	X	
6. High oil-level sensor in tank	Annunciator	X	
7. Condenser law vacuum	Emergency shutoff valve	X	X
8a. High-level switches on steam line drain pots	Annunciator, open drain valves	X	
8b. High high-level switches on all steam line drain pots	Annunciator, open drain valves	X	
9a. High-level switches on all feedwater heaters (closed and deaerating heaters)	High-level drain valve to the condenser or other receiver	X	
9b. High high-level switches on all feedwater heaters (closed and deaerating heaters)	Power-operated block valve in extraction line, power-operated drain valve on the turbine side of the NRV, or automatic shutoff valves on all sources of water to feedwater heater	X	
10. High and High high water level switches on boiler drums	Annunciator (audible alarm)	X	Operational procedure
11. High oil-temperature sensor, lube-oil header, supply of bearing drains	Annunciator	X	
12a. Turbine thrust bearing thermocouple, high temperature	Bearing metal temperature, and/or drain lube oil temperature	X	Operational procedure
12b. Turbine journal bearings thermocouples, high temperature	Have embedded RTDs in all Babbitt bearings and/or thermocouple in the bearing oil drain lines	X	Operational procedure
13. Vibration monitoring by hand-held or fixed instrumentation ($\leq$ 25 MW)	Senior operations notification procedure	X	
14. High vibration instrumentation on bearings, including the generator unit, exceeds set point	Annunciator and senior operations notification procedure	X	
15. Lubricating oil pumps	Pump drive motors	X	X
16. Lube-oil filters	Pressure switches, differential pressure (ΔP)	X	

[1] Sequential trip (turbine, followed by generator breaker when stop valve limit switches show valve is closed)

7.2 Boiler

The boiler is used to convert water into high pressure steam by the burning of fuel in the closed chamber which is surrounded by steam and water tubes.

The main failures of steam boilers include dry firing or overheating (44%), operator error (34%), explosion or overpressure, furnace explosion, corrosion and scale, and cracking. Boiler tube failures continue to be the leading cause of downtime for steam power plants.

RISKS ASSOCIATED INCLUDE:

- Normal boiler operation requires continuous circulation and replenishment of water. Overheating results when the boiler operation continues after the water level has fallen below the minimum safe operating level set by the boiler manufacturer
- There is a fire hazard at the fuel firing area (i.e. Coal/High Speed Diesel Fuel/Light Diesel Oil/Heavy Fuel Oil fuels) which can be due to leakage or spillage. The firing of high Volatile Matter coal, especially imported coal, may lead to coal combustion due to leakage in coal pipes
- Key process parameters must be adhered to avoid the risk of explosion in the mills when firing high Volatile Matter coal.
- Verify soot blowers and wall blowers are operating properly and blowing pressure is correct. There is a risk of explosion due to abnormal pressure and temperatures
- Overheating and exposure of coal to hot surfaces

RISK MITIGATION MEASURES INCLUDE:

- A steam inserting system at the mill inlet will wet the coal during startup and stopping of mill, thereby removing CO gas and preventing explosions
- By checking the soot and wall blower alignment and verifying that soot blowers index correctly, this will minimise any direct steam impingement on tubes
- Perform a non-destructive examination on areas subject to erosion in order to verify and trend remaining thickness and document results
- Check that vibration bars and baffles are securely attached
- A water spray system is recommended for coal transfer pipes and at coal burners – from the milling system to the firing zone This is in the event of any spontaneous combustion occurring due to coal deposits on pipes caused by coal leakages
- Proper safety valve design, installation and maintenance should be followed
- Install Low water fuel cut-off (LWFCO) protection systems on boiler not protected currently. Test all boiler operating controls and protection interlocks
- Adequately designed, installed and maintained combustion control is recommended
- For a Light Diesel Oil/Heavy Fuel Oil firing system, the provision of a Medium Velocity Water System (MVWS) is recommended due to the potential for leakage

RECOMMENDED BOILER MAINTENANCE PROGRAMME

- Annual fireside and waterside inspection – not to exceed two years between inspections
- Program for Ultrasonic testing (UT) of pressure parts subject to rapid thinning
- Remove slag from boiler passes by proper de-slagging arrangements
- Soot blower maintenance
- Inspect and test combustion controls
- NDE attachment welds and areas prone to cracking
- Inspect and test combustion controls
- Monitor waterside deposits on tubes in high heat release areas
- Inspect and repair furnace refractory and walls
- Conduct hydrostatic test after inspection

Whenever coal mills are stopped from operation, the residual coal left in the mill and the hot gases inside leads to the formation of Carbon Monoxide (CO). This gas is very explosive in nature and will spontaneously combust when it absorbs oxygen and higher temperatures. The VM in the coal also has a tendency to catch fire in a high temperature air environment, which is termed as spontaneous combustion. To avoid these eventualities, inerting steam is utilised to quench and evacuate such gases out of the mill.

7.3 Generator

The generator converts mechanical energy from the turbine into electrical energy.

RISKS ASSOCIATED INCLUDE:

- Foreign objects damaging rotor and stator
- Partial discharge can damage windings and result in a ground fault
- Overheating will cause insulation deterioration, resulting in ground fault, shorted turns
- Failure of retaining ring at high speed
- Vibration and mechanical looseness of stator components result in ground faults, phase-to-phase short circuit, or winding damage
- Localised overheating can cause vibration and winding ground faults
- Rotor winding fatigue causes cracking
- Core overheating will result in stator winding
- Stator core lamination short
- For hydrogen cooled generators, failure in oil retaining ring may lead to leakage of hydrogen
- Leakage in stator water cooling system may lead to ingress of hydrogen into water thus leakages leading to further damages

RISK MITIGATION MEASURES INCLUDE:

- An internal inspection of blades and balance weights is recommended
- Monitoring of partial discharge activity will identify potential defects before failure occurs while a regular visual inspection will ensure the rings are in a dry condition
- Visual Inspection – it is important to look for cleanliness and gross defects
- Check for internal water contamination and thermal deterioration
- Regular NDE is needed to ensure quality control
- Regular maintenance and inspection of all stator components should be carried out to check for any serious surface defects, including broken rotor bars, corona damage to insulation
- Assess the insulation status during overhauls

A base loaded generator can typically be expected to provide a useful life of 30 to 40 years when properly maintained andoperated.

FIRE & EXPLOSION RISK

7.4 Lubrication Oil Systems

A lube oil system provides lube oil for the bearings of the turbine generator unit. A hydraulic control oil system provides hydraulic oil to the electro-hydraulic control system. A seal oil system provides sealing oil to the hydrogen cooled generator.

Lube oil, seal oil and hydraulic oil are normally typical mineral oil. The oil systems and their piping are present above the turbine generator bearings, under the turbine generator and oil tank skid area. Oil releases are most often caused by electrical failure, fitting failure, operator error or vibration.

Inadequate fire protection systems and a lack of proper emergency protocols can lead to serious damage and extended outages in the event of a lubrication oil fire. An automatic sprinkler system is proven effective to extinguish the oil fires, with a properly designed containment and emergency drainage system to remove leaking oil and the discharged fire water outside the turbine hall.

RISK ASSOCIATED INCLUDE:

- Fire scenarios include below mentioned types of fire.
  – Pool fire: a localized free flow oil fire.
  – Spray oil fire: a pressurised oil fire.
  – Three-dimensional spill fire: a localized oil fire at the higher elevation flowing down to lower floor.

RISK MITIGATION MEASURES:

- The most effective means of limiting damage from an oil fire is to shut down quickly, however, lubricating oil cannot be shut down until the turbine has reached a point where significant additional equipment damage will not occur
- A comprehensive emergency response plan including a turbine oil fire scenario should be developed and incorporated with the plant emergency shut down procedure
- The key goal of the fire protection scheme should be to shut down the fuel supply, control where the released oil flows, and use automatic sprinklers protection to provide cooling and possible extinguishment of burning pools of oil
- Fire protection efforts must include the following:
  1. A comprehensive program to prevent accidental oil release
  2. An effective emergency procedure to bring the turbine to a safe shutdown condition
  3. A combination of active and passive protection features that include construction, curbing, emergency drainage and automatic fire protection
- Automatic sprinkler systems are recommended above turbine generator bearings, under the turbine generators and the oil tank skid area
- Containment and emergency drainage system should be designed to cater for the leaking oil and proposed fire water discharge
- FM Approved industrial fluid is recommended to use which has a high flash point and wouldn't sustain combustion when it is ignited
- Install FM Approved spray fire shields over oil piping flanges to reduce the potential spray fire hazard to a localised pool fire
- For control rooms inside turbine buildings, provide one hour fire rated construction, provide an independent air supply for ventilation and seal penetrations into the room
- Run AC and DC power and control cable for lubricating oil pumps in separate fire areas or enclose one set of cable in conduit and wrap it with one hour's fire rated material

7.5 Coal Conveyor System

The coal conveying system is used for the transportation of coal from the unloading point to the stockyard or to coal bunkers.

RISKS ASSOCIATED INCLUDE:

- Fire hazard on coal conveyors due to spontaneous combustion
- Friction caused by hot metal idler rollers which have been heated due to belt misalignment or slippage or damaged bearings
- Fire hazard in galleries due to coal accumulation on cables or cable trays
- Maintenance activities involving hot works can lead to weld splatter on coal conveyor
- Ignition of coal accumulation by light fittings and high temperature filaments
- Fluid coupling failures, oil spillage and leakage from gearbox
- Smouldering coal from stockyard travelling over conveyor belt

RISK MITIGATION MEASURES INCLUDE:

- Linear Heat Sensing (LHS) cables are installed above and below conveyors for detection of heat from a fire over the entire length. On the triggering of fire conditions the sprays over and below the conveyors get initiated for quenching
- Trip the conveyors once the fire detection system detects a fire
- The alignment and cleaning of cable trays in conveyor galleries is a critical maintenance factor as continual deposits of fine coal dust can lead to fire due to spontaneous combustion
- Adequate lighting provision is required in the coal handling plant area
- Chute block switches should be kept in service to provide early warning of chute blocking
- Pulleys, Idlers, Gear boxes, Fluid couplings should not be over-greased or over-filled
- A Hot Work Permit system must be followed
- The accumulation of coal dust on ILMS magnets and its belt should be avoided
- Fire Retardant (FR) grade belt to be used including bunker sealing belt, ILMS belt
- Medium Velocity Water System Fire protection system with Quart Bulb Detector (QBD) should be available in all conveyors
- Fire Retardant paint coating on cables shall be applied at the cable entry and exit Points
- Flame proof lamp fittings to be used in sensitive areas
- Underground tunnel areas must be well ventilated
- Spilled coal should not be stored on idle conveyors.
- Conveyor should be emptied before stopping
- Any belt sway is to be avoided by maintaining rollers at adequate distance
- Static Electricity hazards should be minimized by the permanent grounding of all equipment
- Better housekeeping should always be maintained for a dust free environment

Regardless of whether the conveyor system is in operation or under shutdown/maintenance, there should be regular vigilance of the conveyors with a minimum of once per shift. In addition, a CCTV camera should be provided at strategic locations within a Coal Handling Plant.

7.6 Coal Stock Pile Yard

The coal stock pile yard is used for the stacking, compacting and churning of coal.

RISKS ASSOCIATED INCLUDE:

- Fire hazard in yard due to spontaneous combustion by coal stocking.

RISK MITIGATION MEASURES INCLUDE:

- Coal to be stacked layer-by-layer at a height of 1-1.5 metre followed by a compaction and churning operation to minimise the air voids in the coal, reducing the possibility of smouldering which would lead to fire
- Stacking shall to be done in a trapezoidal stockpile (Not in a conical shape). A bulldozer shall be made available over the stock pile for the ramming operation
- A fire hydrant in the coal stock yard area should be regularly monitored
- A regular spray of water over coal stock yard will keep the upper surface of the coal wet and keep the stock yard area dust free. It has to be ensured that the spray system on both sides of stock piles should cross each other
- A proper sequence of stacking and reclaiming should be maintained with the principle of "First In, First Out" (FIFO) to ensure sequential usage of coal thus helping to minimise fire and smouldering coal
- Smouldering coal should be doused immediately to avoid further spreading of fire

7.7 Coal Bunker

Coal is transported from stockyard via conveyors into coal bunkers.

RISKS ASSOCIATED INCLUDE:

- Feeding of smouldering coal from stockyard may cause a fire in the residual coal sticking to bunker walls for long periods resulting in self-ignition
- Stocking of high Volatile Matter coal in bunkers for long period due to outage or shutdown
- Low bunker level coupled with unsatisfactory isolation from feeder/mill with subsequent pressurisation of furnace causing hot gases to pass through the bunker
- Fire spreading from bunker conveyor fires
- Dust explosion in enclosed area such as bunker or tripper galleries

RISK MITIGATION MEASURES:

- Bunker floor must be well ventilated
- Adequate lighting is required in the bunker floor
- High Volatile Matter coal should not be stored in the bunker for long periods and be emptied before stopping the unit via the chutes
- Leftover coal should be avoided in bunkers
- Bunkers should be emptied and cleaned thoroughly during overhaul of unit
- In idle bunkers containing coal, Carbon Monoxide content must be monitored regularly to detect any tendency of fire in advance
- Bunker gates must be maintained to ensure they close properly when bunker is not in use
- Hot coal should not be fed into the bunkers from the stockyard
- A Hot Work Permit system must be followed
- Fire hydrants located on the bunker floor should be checked regularly for adequate water pressure
- Fire hoses with matching couplings should be made available in the hose reel box located near the hydrant points at both ends as well as intermediate locations in the bunker floor
- Deluge systems triggered with linear heat detection should be installed along the conveyors. Trip the conveyors once the fire detection system detects a fire
- Dust extraction system must be in place and in a properly working condition. The bag filters of Dust Extraction system should be cleaned periodically in order to avoid any fire due to accumulation of coal
- Explosion-proof type electrical equipment in enclosed area

7.8 Cable Gallery

Cables in power plants transmit signals, control signals and electrical power.

RISKS ASSOCIATED INCLUDE:

- Plastic used as the cable jacket or as insulation for conductors may ignite, and many types of cable insulation will continue to burn beyond the area of ignition
- The type of insulation, quantity, and cable arrangement (horizontal or vertical) will determine how rapidly the fire will spread and how much smoke will be generated

RISK MITIGATION MEASURES INCLUDE:

- Control ignition sources
- Provide effective maintenance
- Improve housekeeping
- Seal cable penetrations
- Evaluate importance of cable
- Relocate or protect cable serving critical equipment
- Provide fire detection
- Provide fixed protection if cable is exposed by other combustibles
- Provide fixed protection or cable coating where cable is in a light hazard area or is the only combustible in the area

Cable galleries are the corridors which carry cables from one location to another.

RISKS ASSOCIATED INCLUDE:

- Electrical breakdown
- Fire hazard due to higher temperatures and short circuit
- Coal dust and flammable debris accumulation inside the cable tray can result in fire incidents
- Cables and cable joints can overheat
- Hot works such as welding or cutting in the cable gallery

RISK MITIGATION MEASURES INCLUDE:

- Cable trays should be placed in a vertical position and covered with a tray cover
- Cable trays should be regularly inspected and cleaned with particular care taken in the coal stack yard
- Cables are to be properly laid in the cable tray with loosely laid wires avoided
- Care should to be taken during gas cutting or welding near and above cable trays
- All cable entry points to cable gallery shall be fire sealed
- There should be a regular inspection of cable galleries, lighting fittings and wires
- Regular cleaning must be carried out to prevent fine coal dust accumulating on the lamps and fittings
- Automatic sprinkler system or cable coating is recommended

7.9 Fuel Oil Handling

The fuel oil handling system is used for the storage of liquid fuel oil such as High Speed Diesel Fuel/Light Diesel Oil/Heavy Fuel Oil and Low Sulphur Heavy Stock used as secondary fuel.

RISKS ASSOCIATED INCLUDE:

- Fire hazard due to oil spillage

RISK MITIGATION MEASURES INCLUDE:

- A fuel oil system has two arrangements, one for extinguishing the fire (Foam Pourer) and a second for cooling of the tank by Medium Velocity Water System spray as a ring header in case of fire

7.10 Power Transformers

Power transformers are required for transformation of electrical power from lower to higher voltage. Conventional power and distribution transformers are reliable devices when properly installed protected and maintained. Fortunately, their failure is relatively rare, considering the hundreds of thousands of transformers currently in service. Occasionally, however, an oil-insulated transformer will fail, resulting in expulsion of burning oil through the pressure relief device or rupture of the tank. Depending on the size of the transformer, large quantities of oil may be involved.

RISKS ASSOCIATED:

- The internal fault could be transformer winding arc, winding over-temperature, mechanical parts collapse etc. due to:
  – Reduction in dielectric strength
  – Reduction in mechanical strength
  – Reduction in thermal integrity of the current carrying circuit
  – Reduction in electromagnetic integrity
  – Fire hazard due to oil spillage, formation of gases and higher winding temperatures
  – Fire in high voltage transformer can be due to multiple causes like formation of gases, degradation of oil, spark generation. and higher winding temperature
  – Explode bushing could also result in rupture of oil tank and consequently the pool fire

RISK MITIGATION MEASURES INCLUDE:

- Establish a dissolved-gas-in-oil analysis plan for critical oil filled transformers
- Power & Distribution type Transformers – Annually
- Industrial Rectifier Duty Transformer – 3-6 months
- Arc furnace duty transformer – 3 months
- For extinguishing, Medium Velocity Water System or High Velocity Water System systems are in place which envelope the entire transformer. In order to control the spread of fire, transformers are separated by a fire wall or adequate safe separation distance
- Spill containment and emergency drainage to be provided
- FM Approved transformers or transformer oil is recommended

7.11 Other equipment hazards

DC SYSTEM BATTERIES

DC system batteries serve as an uninterruptable power source for critical processes or systems within a power plant.

RISKS ASSOCIATED INCLUDE:

- Water loss and dry out of a Valve Regulated Lead-Acid battery can occur due to corrosion of the battery plate, periodic venting of gases by battery overcharging and through the evaporation of water vapour through the seals, pressure-relief valve and battery case
- If the electrolyte uses too much water, battery capacity is reduced. Excessive loss of water can also create large voids in the electrolyte, leading to thermal runaway and generation of sufficient heat to rupture the battery case, and in some cases resulting in an explosion

Valve Regulated Lead-Acid batteries are sensitive to float voltage variations which if too high can increase the rate of internal gas generation, exceeding the cell's recombination ability.

Dryout can occur when these excess gases are vented through the pressure relief valve.

- Operating Valve Regulated Lead-Acid batteries at high temperatures require more current, increased heat generation which in turn results in higher currents and the potential for rupture

RISK MITIGATION MEASURES INCLUDE:

- Establish a battery maintenance programme including: checking maximum ambient temperature does not exceed recommended manufacturer's operating temperature, inspect all cells for cracks or leaks, check for corrosion and contamination on battery connections and corrosion, check the battery charger is the right type and check the float voltage is within the manufacturer's recommended operating range
- A battery monitoring system will warn of thermal runaway by measuring two of the following: battery temperature, battery voltage, float current, battery conductance

COOLING TOWERS

Cooling towers are a critical element of electrical power generation and efficiency, acting to reduce the temperature of the steam used to spin turbines before it is returned to the boiler.

RISKS ASSOCIATED INCLUDE:

- Cooling towers contain a number of fire hazards including fill material used for heat transfer and evaporation, fan stacks, fan decks, fan blades, louvers, partitions and catch basins
- Cooling towers are susceptible to fire whether they are online or offline, and because they are designed for good airflow, this adds to fire development, acceleration and severity
- Pipe corrosion and scale can form as part of the lifecycle of pipes with a cooling tower. This can cause the deterioration of fire protection pipes
- A cooling tower fire tends to be severe because towers are shielded from hose streams and the arrangement of fill allows for a fast-developing fire
- Hot work is the leading cause of cooling tower fire, primarily due to the repair or modification of the tower while idled and without water flow
- The main contributing factor to cooling tower loss is the lack of automatic sprinkler protection

RISK MITIGATION MEASURES INCLUDE:

- General practice – maintenance and inspections, in particular of electrical and mechanical systems that could present any ignition source
- Using non-combustible construction and fill material will limit damage from fire. If not possible, then less combustible fill material, louvers and drift eliminators are recommended
- Interior fire resistant barriers will limit the spread of fire from cell to cell
- Fixed automatic sprinklers offer the best protection for combustible cooling towers and can significantly reduce the extent of fire and associated downtime. For towers with a combustible fill and fan deck, deluge sprinkler protection is recommended
- Other fire safety measures include hoses for manual firefighting on the fan deck, spot sprinkler protection over fan motors and developing a pre-fire plant with local authorities to ensure hose streams and water supplies are adequate for the location, arrangement and position on the tower

8. LEGISLATION AND CODE OF PRACTICE

Recent losses across thermal power sector have highlighted the need to review existing standards on a regular basis. Most of the Indian standards mentioned below are not current except the National Building Code. IS-3034: Fire Safety of Industrial Buildings: Electrical Generating and Distributing Stations – Code of Practice is outdated and requires revision to reflect the latest trends in power station design and international practice. For example, passive systems are not touched upon in the existing IS-3034 standard and clauses need to be added for gas fired and oil-fired generating stations. Many of the other protection standards are already under revision.

IS-3034 covers the following topics:

- Building related requirements including construction, compartmentation etc.
- Power station facilities including coal handling, crushing, boiler, turbo generators etc.
- Electrical equipment including cable galleries, power transformers, outdoor equipment, battery room etc.
- Fire protection requirements for turbo generators, boiler house, coal handlers and conveyors, transformers, cable galleries, turbine cooling, outdoor tankage etc. along with the type of protection required for each including hydrant system, Sprinkler system, water spray system, foam system, fire alarm system etc.
- Workforce requirement, upkeep of the installations, emergency power requirements etc.

Fire prevention and protection
Fire safety requirements for power stations in India are governed by the following codes and standards:

- IS-3034 – Fire safety of industrial buildings: electrical generating and distributing stations – code of practice
- IS-13039 – External hydrant systems – provision and maintenance – code of practice
- IS-15105 – Design and installation of fixed automatic sprinkler fire extinguishing systems – code of practice
- IS-15325 – Design and installation of fixed automatic 1 high and medium velocity water spray system – code of practice
- IS-12385 – Design and installation of fixed foam fire extinguishing system – code of practice
- IS-3595 – Code of practice for fire safety of industrial buildings: Coal pulverizers and associated equipment
- IS-12459 – Code of practice for fire protection of cable runs
- IS-2189 – Code of practice for selection, installation and maintenance of automatic fire detection and alarm system
- IS-1646 – Code of practice for fire safety of buildings (general): Electrical installations
- National Building Code – 2016 for fire and life safety requirements
- TAC handbook for hydrant system, sprinkler system and water spray system
- NFPA-850 – Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

The following FM Global Property Loss Prevention Data Sheets can also help reduce the risk of fire and the failure of electrical and mechanical equipment at existing thermal power plant facilities. (Link to download – fmglobaldatasheets.com)

- 5-19 – Switchgear And Circuit Breakers
- 5-23 – Emergency And Standby Power Systems
- 5-31 – Cables And Bus Bars
- 5-4 – Transformers
- 6-2 – Pulverized Coal-Fired Boilers
- 6-23 – Watertube Boilers
- 6-4 – Oil- And Gas-Fired Single-Burner Boilers
- 6-5 – Oil- And Gas-Fired Multiple-Burner Boilers
- 7-101 – Fire Protection For Steam Turbines And Electric Generators
- 7-109 – Fuel Fired Thermal Electric Power Generation Facilities
- 7-11 – Conveyors
- 7-73 – Dust Collectors And Collection Systems
- 7-76 – Prevention And Mitigation Of Combustible Dust Explosion And Fire
- 7-79 – Fire Protection For Gas Turbines And Electric Generators
- 7-88 – Ignitable Liquid Storage Tanks
- 7-91 – Hydrogen
- 8-10 – Coal And Charcoal Storage
- 10-3 – Hot Work Management
- 13-3 – Steam Turbines

9. WAY FORWARD

Although power plants are much safer than they once were, there remain many hazards and it is up to the facility owners and managers to implement programmes and policies aimed at eliminating the accidents and make their properties more resilient.

The group discussion during the annual Fire Loss Prevention Forum of India meeting in November 2017 resulted in the following outcomes:

1. The white paper shall reach the regulators of thermal power plants in India. The information and knowledge will be spread to all the thermal power plants through the regulators.

2. Indian standard (IS 3034) shall be taken up for revision as it is very old standard and it needs to be revised. The discussion on revision will be taken up at the next meeting of the Firefighting Sectional Committee, CED 22 of Bureau of Indian Standards.

3. Some of the Indian standards for thermal power plants are also very old and need to be taken up for revision. A focused group and experts from the thermal power sector shall be consulted for revision.

10. NOTES