HSE

Health and Safety Executive

HSE information sheet

Fire and explosion hazards in offshore gas turbines

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Contents

Introduction

This information sheet provides guidance for duty holders of offshore installations on identifying fire and explosion hazards in offshore gas turbines. In recent years there has been a marked increase in fires associated with these machines. The aim of this sheet is to identify good practice and provide guidance on minimising risks from fire and explosion hazards associated with turbines operating in an offshore environment.

Background of gas turbine incidents in the UK offshore sector

A detailed review of offshore gas turbine incidents completed in 2005[1,2] indicated that there were 307 hazardous events over a 13 year period, 1991 to 2004, involving 554 machines. Analysis of the incidents indicates that about 40% arise during normal operation, about 20% at start-up, 20% during or following maintenance and a further 10% arise at fuel changeover.

Liquid Leak Detection Performance

Based on the analysis[1,2] and indicated in table 1 below, of the 134 gas leaks 30 were undetected. But 50 of the 61 liquid fuel leaks were undetected, and of the 42 oil leaks 41 were not detected. The proportion of undetected leaks that subsequently ignited is self-evident.

Offshore gas turbine enclosures are fitted with gas detection, but it is known that there are significant numbers without flammable liquid detection. Flammable liquid detection in the form of oil mist detectors are fitted to some turbine enclosures usually in the enclosure exhaust duct. Oil mist detection would help improve the detection efficiency of flammable liquid leaks, both diesel and lube oil. Specifically it would provide an early warning of flammable liquid leaks.

Table 1 – Some gas and flammable liquid leak and ignition data

Fluid	No of Leaks	Detected	Ignited	Undetected	Ignited
Gas	134	104	1	30	18
Liquid Fuel	61	11	2	50	31
Oil	42	1	1	41	40
Unidentified Fluid	35	Unknown	31	Unknown	Unknown

The very high proportion of undetected and subsequently ignited liquid leaks indicates that the standard of liquid leak detection in turbine enclosures is very poor[3]. The much higher proportion of ignition of undetected leaks is a clear indication that liquid leak detection needs to be significantly improved. To date the integrity of the turbine enclosures has contained the fire or explosion events but as platforms and their equipment degrade the probability of an enclosure failure increases.

Explosions in Enclosures
It is foreseeable that delay in detection of oil mists may result in an explosion. To date an explosion event has not been recorded, only fires. An explosion within a turbine enclosure will almost certainly lead to loss of its integrity and hence its fire barrier capability. Platform threatening escalation may occur on loss of enclosure integrity. Oil mist detection in the exhaust ducts of the turbine enclosures will provide an early warning of any oil leaks. Additionally, early warning allows for the rapid shutdown of a turbine thereby minimising the leakage of flammable liquids into the enclosure and hence minimising its fire load.

Underlying causes of fires and explosions in enclosures

Gas turbines are housed in enclosures and there are large areas of hot surfaces. Most turbines are dual fuel and run on diesel at least part of the time. Unfortunately oils (diesel and lubricating oil) have auto ignition temperatures (AIT) significantly lower than gas, and combined with the large hot areas in the turbine enclosures form a high risk scenario. The AIT of diesel and lube oils are ~240^{o}C whereas methane is 530^{o}C, and the external surface of a combustion chamber can reach ~200-400^{o}C. If diesel or lube oil contacts surfaces at these temperatures, ignition will almost certainly occur. This is confirmed by the record of fires and explosions in gas turbines in the UKCS[1,2]

Good practice is seen as fitting oil mist or vapour detection instruments into turbine enclosures exhaust ducts to provide early warning of oil leaks.

Prevention, mitigation and good practice

It should be noted that the turbines offshore are enclosed in fire proof housings with gas, heat and smoke detection, and fire suppression systems[4]. Within the housings the environment in relation to the fire and explosion hazards is significantly different from the main process plant. The frequency of ignition is significantly higher than on process plant and is dominated by liquid leaks and fires.

1 Enclosure integrity and fire resistance
None of the recorded events (fires) quoted above have breached the fire proof enclosures. The high incidence of combustion events within turbine housings is characterised by the integrity of these enclosures preventing the fire from escalating into platform threatening events. However platforms are ageing and the integrity of turbine housing is also degrading. It is essential therefore that turbine enclosures are maintained such that they retain their original fire resistance. The turbines themselves continue to operate at the same fuel pressures and flow rates and hence pose the same fire or explosion hazard. Hence it is essential that the enclosures maintain their original design integrity. Regular 3rd party inspection is essential.

2 Minimisation of fire loading
Two flammable fluids are fed into turbines; fuel and lubricating oil. To minimise the extent and duration of fires, and the severity of an explosion, both flammable fluid inflows need to be stopped as soon as possible following detection of heat, smoke or fire. Isolation and venting of both fuel gas and diesel is generally a standard

arrangement of two or more isolation valves with a vent line between them. If running on gas a venting system removes excess fuel gas and routes to the platforms flare system; diesel is routed to a dump tank or the hazardous drains. Clearly fuel isolation valves and the venting systems are critical components in minimising fire and explosion hazards within turbine enclosure.

The turbines lubricating oil is not generally isolated on shutdown, although there are turbines which, in an emergency stop, do shutoff main oil flows and have a low pressure backup system. Lube oil is generally pumped to the critical turbine bearings via a mechanically geared impeller. On emergency shutdown the gearing usually continues to pump oil around the bearings to prevent seizure and to remove residual heat from various components. Any loss of containment hence continues to be fed by the geared impeller.

Main oil lubrication is provided at about 50-100psi and a backup system at about 30psi. Back-up lube systems have independent pipework to the main lubricating oil flowlines so that a leak in the main lines is not fed by the back-up system. Lubricating oil sumps contain between 200 – 800 gallons, and prevention of these volumes of oil spraying into an enclosure will reduce significantly the fire loading on an enclosure.

Isolation valves on fuel and oil lines may have lost their integrity due to their age and/or the harsh conditions within the enclosure. If these isolation valves are not fully functioning it is strongly recommended that they are replaced by new valves as soon as practicable.

3 Flammable vapour detection

Turbine enclosures have forced ventilation and both gas and oil mist detection should be installed in the enclosures exhaust ducting. It appears that most offshore turbine enclosures are fitted with gas and heat detection but only a few have oil mist detection. If an oil spray or gas leak ignites immediately, a fire results. If there is a delay in ignition it is probable that there will be an explosion event. Gas turbine enclosures do not have any measurable blast resistance, particularly from internal explosions. Therefore, should an explosion occur, even a ‘low overpressure event’, it is foreseeable that the turbine enclosure will be damaged such that it will lose its fire protection integrity. Hence any fire following the explosion will have the potential to escalate to a platform threatening event.

Oil mist detection fitted within the enclosures exhaust duct would detect gas and oil mist leaks from all sources. It would complement the gas detectors and provide early indication of any flammable fluid thus reducing the risk of an explosion and hence loss of enclosure integrity. This is viewed as the best practical way of providing an early warning of oil leaks.

4 Fire suppression

A fire suppression / protection system consists of components for automatic detection actuation, suppression material supply and delivery into (usually) an enclosed area. Fire suppression agents commonly used are: CO_2, Argon, ‘Argonite’, ‘Inergen’, FM200 or water mist[5,6].

For turbine enclosures a water mist system appears to be the preferred choice offshore, as these systems have been demonstrated to be suitable and effective for the protection of spaces on board ships for some time. The advantage of water mist is its ability to quench flames and lower temperatures due to its high evaporative heat capacity.

All fire suppression systems will require supporting rules and procedures to ensure the discharge target spaces are not occupied, or have warning systems in place to ensure evacuation before mist/gases are discharged.

5 Competency and housekeeping issues

Based on the relatively high incidence of fires within the turbine enclosures the following points are offered as guidance and examples of good practice.

i. Identify foreseeable fire scenarios and evaluate the locations of both fuel and lubricating feed lines and isolation valves, for rapid isolation. Best practice is seen as incorporating automatic isolation valves.

ii. Isolation valves classed as safety critical elements (SCE), exercised regularly according to a performance standard and status included in the planned maintenance (PM) record.

iii. Performance standards for opening /closing times for remote isolation valves included in PM routines.

iv. Fuel gas pipework and oil lines clearly marked up to minimise errors in intervention activities that may lead to hydrocarbon leaks.

v. Regular inspection of drip trays and mats to minimise the enclosure fire loading with immediate removal of flammable materials.

Relevant legal requirements

Health and Safety at Work etc Act 1974 (HSWA), Sections 2 & 3

Offshore Installations (Safety Case) Regulations 2005 (SCR05), Regulation 14

Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995 (PFEER) Regulations 5, 9, 12 and 13

Offshore Installations and Wells (Design and Construction, etc) Regulations 1996 (DCR) Regulation 5

References

1 Gas turbine hazardous incidents; A review of the of UK Onshore and Offshore installations. Roger C. Santon c/o Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire, SK17 9JN

2 Accident statistics for fixed offshore installations units on the UK Continental Shelf 1980-2005 Research Report 566 HSE Books 2007 http://www.hse.gov.uk/research/rrpdf/rr566.pdf

3 Control of safety risks at gas turbines used for power generation HSE guidance note PM84 Second edition HSE Books 2003 ISBN 0717621936

4 Functional safety of electrical/electronic/programmable safety-related systems IEC 61508-1 1998

5 NFPA 750 Standard on water mist fire protection systems 2003

6 Carbon dioxide as a fire suppressant: Examining the risks United States Environmental Protection Agency EPA430-R-00-002 February 2000

Further information

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This information sheet contains notes on good practice which are not compulsory but which you may find helpful in considering what you need to do