HSE procedures for HyPowerGT (Initial)

D4.1 –Public

HyPowerGT – Demonstrating a hydrogen-powered gas-turbine engine fuelled with up to 100% H2

Version 01 – Date 30/11/2024

Abstract

In this this report are reported the initial assessment on the HSE guidelines considering the retrofitting of existing gas turbine with the Dry Low NOx combustion system able to burn variable mixture of H2-CH4 (up to 100% H2).

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Executive Summary

The HyPowerGT project aims at moving technological frontiers to enable gas turbines to operate on hydrogen without dilution. The core technology is a novel dry-low emission combustion technology (DLE H_2) capable of handling mixtures of natural gas and hydrogen with concentrations up to 100% H_2.

The new technology will be fully retrofittable to existing gas turbines, thereby providing opportunities for refurbishing existing assets in industry (CHP) and offering new capacities in the power sector for load levelling the grid system (unregulated power) and for mechanical drives.

While on the one hand the technology adheres to the strictest specifications for fuel flexibility, NO_x emissions, and ramp-up rate stated in the Strategic Research and Innovation Agenda 2021-2027, on the other hand it becomes of primary importance to evaluate the risks introduced by mixtures of natural gas and hydrogen with concentrations up to 100% H_2 in existing gas turbines currently operating with natural gas only.

For this reason, a Failure Modes, Effects, and Criticality Analysis (FMECA) has been carried out on November, 5th and 6th at the Baker Hughes (hereinafter BH) Florence site. The analysis, chaired by SINTEF and attended by representatives from BH (owner of the DLE H2 technology) and Lucart S.p.A. (operator of a CHP plant integrated in a paper production facility operating at the tail-end of a 13 MW NovaLT12 gas-turbine engine), was aimed at:

- Identifying possible single failure modes within the systems/equipment under analysis;
- Identifying the likely effects of these failures and any potential consequences in terms of “severity” and “criticality”;
- Verifying the existence of adequate design measures to mitigate the identified risks to a tolerable level; and
- Investigating the possibility to introduce additional engineering barriers to further reduce the probability of occurrence of hazardous events or the severity of the consequences.

Where residual risks are still present, administrative barriers must be defined.

Purpose of this deliverable is to provide safety guidelines defining the actions to take the residual risks under control and to further reduce the risks.

These guidelines have been prepared starting from the results of the FMECA and leveraging on the know-how and experience accumulated by BH in the framework of the validation process of a non DLE combustion system, able to manage mixtures of natural gas and hydrogen with concentrations up to 100% H_2, successfully validated at TRL7 (early 2024).

The guidelines set forth in this deliverable (initial) are based on the knowledge and information available in the current stage of the project (M12) and shall be kept updated throughout the

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project period as appropriate, leveraging on the knowledge matured throughout it, up to the issue of deliverable D.4.2 (M44), where the final version of the guidelines will be reported.

It is worth to remark that these guidelines are focused on the risks specifically introduced by the retrofitting the DLE H_2 technology on existing gas turbine to enable them to handle mixtures of natural gas and hydrogen with concentrations up to 100% H_2, while guarantying low NO_x emissions; indeed, the risks that are not modified by the HyPowerGT project will still be managed referring to the information and procedures (including the procedures to be applied in the event of an anomaly or emergency situation) reported in the site operating procedures and instructions and in the Operation and Maintenance Manual.

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1. Introduction

The retrofitting on gas turbines operating with natural gas of the novel dry-low emission combustion technology (DLE H_2), capable of handling mixtures of natural gas and hydrogen with concentrations up to 100% H_2, introduces risks that, if not properly addressed, could result in potentially severe consequences.

A correct design, properly supported by risk assessment studies, contributes to eliminate the risks (through inherently safe design) or to reduce them to a tolerable level, by identifying the engineering barriers to prevent the occurrence of hazardous events and/or mitigate the potential consequences.

However, where residual risks still exist, additional administrative barriers (procedures, training etc.) must be defined.

Purpose of this deliverable is to provide safety guidelines defining the actions to take the residual risks under control and to further reduce the risks.

2. Scope and Objective

These guidelines, developed in the framework of HyPowerGT Project, have the objective to define measures aimed at further reducing the residual risk associated with the retrofitting on gas turbines operating with natural gas of a novel dry-low emission combustion technology (DLE H_2), capable of handling mixtures of natural gas and hydrogen with concentrations up to 100% H_2.

3. Reference Documents

Deliverable D.9.1 “Safety Manual”.

HOLD

4. Terms, definitions and acronyms

BH	Baker Hughes
CHP	Combined Heat and Power
DLE	Dry Low Emissions

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FMECA Failure Modes, Effects, and Criticality Analysis

5. Deliverable Update Schedule

An initial draft of this deliverable (D4.1) is prepared in the early stage of the project and delivered at M12. The document is updated regularly throughout the duration of HyPowerGT to reflect the knowledge matured throughout the project, up to the issue of deliverable D.4.2 (M44), where the final version of the guidelines will be reported.

6. Hazard Identification

A Failure Modes, Effects, and Criticality Analysis (FMECA) has been carried out on November, 5th and 6th at the Baker Hughes (hereinafter BH) Florence site. The analysis, chaired by SINTEF and attended by representatives from BH (owner of the DLE H_2 technology) and Lucart S.p.A. (operator of a CHP plant integrated in a paper production facility operating at the tail-end of a 13 MW NovaLT12 gas-turbine engine), was aimed at:

- Identifying possible single failure modes within the systems/equipment under analysis;
- Identifying the likely effects of these failures and any potential consequences in terms of “severity” and “criticality”;
- Verifying the existence of adequate design measures to mitigate the identified risks to a tolerable level; and
- Investigating the possibility to introduce additional engineering barriers to further reduce the probability of occurrence of hazardous events or the severity of the consequences.

According to the outcomes of the FMECA, that will be documented in the deliverable D.4.9 “Safety Manual” (to which reference shall be made for further details), the main identified hazards requiring additional administrative controls are the following:

- Multiple back-to-back failed start-up, potentially leading to hydrogen ignition in the exhaust due to ignition source (hot surfaces). This scenario is prevented by the automatic start-up sequence, with automatic trip (stop of start-up sequence) and purging if flame is not detected;
- Leakage of hydrogen inside the gas turbine enclosure from piping, valves, connections, flexible hoses etc., leading to hydrogen concentration in flammability range and

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potential fire and/or explosion if ignited. The frequency of this scenario is reduced through material choice and the potential consequences are mitigate by the presence of fire & gas detection system and mechanical ventilation system inside the enclosure;

- Leakage of hydrogen outside the gas turbine enclosure from piping, valves, connections etc., leading to hydrogen concentration in flammability range and potential fire and/or explosion if ignited. The frequency of this scenario is reduced through material choice and flanged connections minimization (priority is given to welded connections);
- Maintenance activities on system sections still containing hydrogen (pressure hazard, flammability hazard);

The FMECA will be reviewed as appropriate to consider the knowledge matured throughout the project. The updated outcomes shall constitute the base for the revision of the safety guidelines provided in the next paragraph.

7. Safety Guidelines

The following safety prescription shall be applied to further mitigate the residual risks connected to the retrofitting on gas turbines operating with natural gas of a novel dry-low emission combustion technology (DLE H_2), capable of handling mixtures of natural gas and hydrogen with concentrations up to 100% H_2:

- The personnel working on the plant must be informed and trained on the risks associated with the use, maintenance and cleaning of the lines and equipment handling CH_4/H_2 mixtures, as well as on the related prevention and protection measures to be adopted. Part of the training shall cover emergency situations, with specific focus on the actions to restore safety conditions and how to activate Emergency Response Team if the situation is out of control;
- Always refer to the system Operation and Maintenance Manuals provided by the Manufacturer, which contain the information and procedures for correctly operating the system, including the procedures to be applied in the event of an anomaly or emergency situation;
- If something is not clear enough, stop work and report to the facility manager
- Personnel accessing plant areas shall wear portable multi-gas detector suitable for methane/hydrogen mixtures at different concentrations, in order to detect potential presence of flammable gases or oxygen-depleted atmospheres, even localized;
- Access inside the enclosure shall be forbidden if the machine is running and shall be regulated by specific procedures, to account for potential flammable or oxygen-depleted atmospheres;

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- The Hazardous Areas Classification shall be carried out taking into account the worst condition related to the entire methane/hydrogen concentration range. In the classified areas, it shall be forbidden to use equipment/tools or perform activities that could generate an ignition source; e.g. the following shall be forbidden:
    - Using open flames;
    - Using non-ATEX equipment/tools;
    - Smoking;
    - Performing hot works or other activities with the potential for spark projection (e.g. grinding);
    - Using of equipment/tool producing heat or that could overheat;
- Flanged connection shall be subjected to a specific connection protocol;
- Ordinary and extraordinary maintenance procedures shall be based on the Operation and Maintenance Manual and good maintenance practices and shall include the need for purging with nitrogen and checking potential residual pressure presence inside the system prior to intervention.
- Periodic substitution of flexible hoses connecting fixed piping to the gas turbine shall be foreseen, the relevant frequency shall be defined according to the Manufacturer instructions;
- Proper Operating instructions shall be defined to withstand multiple back-to-back failed start-up (e.g. investigation of potential causes before trying another start-up);
- Lifting protocol shall be defined in order to reduce the probability of line/equipment rupture due to collision or dropped objects;
- Leak Test shall be carried out shall be carried out with proper frequency, using a gas with a molecular weight similar to the hydrogen, such as helium;
- Risks related to the interactions with other existing installations shall be assessed and proper risk mitigation measure defined;
- An Emergency Response Plan shall be prepared (or checked and updated as necessary, if existing), to include the potential emergencies related to the use of CH_4/H_2 mixtures;
- A pre-start up checklist shall be prepared to define the minimum safety checks to be carried out before any start-up (first start-up, start-up after shutdown, start-up after maintenance).

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