ETN

European Turbine Network

Position Paper

Gas Turbine Fuel Flexibility

for

Zero Emission Power Plants

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GAS TURBINE FUEL FLEXIBILITY FOR ZERO EMISSION POWER PLANTS

European Turbine Network - ETN *is a European association that brings together stakeholders with an interest in gas turbine technology. ETN, with its broad representation from across the whole value chain, creates a knowledgeable network that identifies and collaborates on challenges of the future. The intent is to optimise gas turbine research and technology development (RTD) in order to advance environmentally sound gas turbine technology with efficient, reliable and low cost operation.*

The aim of this paper is to highlight the necessary research and demonstration needs that emerge from the overall technology needs to reduce CO_2 emissions. If CO_2 pre-combustion capture is applied to reduce CO_2 emissions, the development of a gas turbine technology that is able to burn undiluted syngas with a high proportion[1] of hydrogen (derived from the gasification of coal or biomass) whilst achieving low NO_x emissions is required.

Emphasis:
RTD Needs for Burning Syngas in Gas Turbines for Zero Emission Power Plants

1. Today's Situation

Current gas turbine technology for power and heat generation is generally optimized for natural gas. This is a well developed and efficient conversion technology, producing low NO_x emission levels.

The challenge of global climate change has become incontestable, which calls for a drastic reduction of CO_2 emissions in the coming decades. Carbon Capture and Storage (CCS) has evolved as a promising technology to significantly reduce CO_2 emissions. However, pre-combustion CO_2 capture requires the combustion of hydrogen-rich fuels in gas turbines. In addition, energy security considerations in Europe urge stakeholders to increase the use of indigenous fuel sources like coal, biomass and various blends of alternative fuels with natural gas. This requires an increased fuel flexibility of gas turbines. Some technologies developed by gas turbine manufacturers currently allow for a small percentage of syngas to be mixed with natural gas or rely on special purpose designed gas turbine products capable of operating on (highly) **diluted** syngas. However, ***there are no generally available low-emission technologies to enable operation with undiluted hydrogen-rich syngas*[2] .** In order to contribute viable solutions to energy supply and green-house-gas (GHG) emission reduction, further gas turbine research and demonstration is essential for these kinds of fuel gases.

In this paper, fundamental aspects that need to be addressed are highlighted in order to operate gas turbines in an efficient, safe, reliable and environmental friendly manner utilising hydrogen-rich syngas from coal or biomass.

[1] High hydrogen content is generally referred to as greater than 40%.

[2] The syngas produced for zero emission power plants (by gasification and CO2 capture) will typically contain 80-90 % hydrogen (by volume) according to studies in FP6 projects.

2. Research Fields

With today's available technologies the most efficient and environmentally sound utilisation of coal and/ or biomass in gas turbines is to convert coal/biomass to syngas through gasification.

The combustion of syngas derived from biomass is CO_2 neutral and with an additional CO_2 capture process a negative CO_2 production can be obtained.

In order to provide zero CO_2 emission from coal gasification the syngas needs to be processed to capture the carbon, resulting in a hydrogen-rich fuel gas. However, the increased amount of hydrogen in the fuel gas will result in a higher reactivity (higher risk of flashback) and more difficulties to achieve near perfect premixing of fuel & air (an indispensable prerequisite for low NOx emissions). Consequently, higher NO_x emissions do result if no compensative modifications (dilutions with inert gases, leaner fuel/air mixtures, exhaust gas recirculation) are included. For an emission free power plant, it is therefore also necessary to solve this challenge. ***Today, the technology readiness level (TRL) of gas turbines to burn undiluted syngas from coal or biomass and to achieve ultra low or even zero emissions needs to be increased significantly.***

Compressor & Turbine (Imbalance)

Whether syngas from coal or from biomass is used, the compressors and/or turbines will have to be redesigned to meet the modified mass flow and operating pressure requirements. Especially for syngas from biomass, in order to maintain the turbine inlet temperature (TIT) and thereby the gas turbine efficiency at comparable levels of today, a larger volume flow of the syngas will be needed. However, larger fuel flow to the combustion chamber can either result in a higher back pressure, which increases the risk of unstable compressor operation and compressor surge or will need a turbine section which can cope with higher flow rates. To handle these problems, the compressor and/or turbine components of a gas turbine running on syngas need to be redesigned and/or adapted to the new operational conditions including altered hot gas properties.

Combustion

In order to safely burn syngas that have distinctly different combustion characteristics as compared to hydrocarbon fuels, further combustion related research and demonstration is needed in order to:

- solve the flashback and flame oscillation problems for lean and hydrogen fuelled combustors to increase turbine safety and operability;
- solve the problem related to auto-ignition of hydrogen-rich fuels at high temperature and pressure;
- modify the combustor in order to cope with the problem of high volumetric fuel flow rates.

Cooling concepts and materials /coatings

As a consequence of using syngas in gas turbines, the exhaust gas composition and temperature changes. Higher concentration of H_2O in the exhaust gas can change the heat transfer conditions, which could lead to increased metal temperature and thus to reduced component lifetime.

Fuel gas produced from biomass can contain several highly acid components, even though it has been cleaned in a separate cleaning step after gasification, which will cause increased corrosion on hot gas path parts having serious impact on turbine reliability and availability. Therefore, development of new, or more advanced cooling concepts and technologies as well as corrosion resistant new materials and coatings is required. Basic material properties such as creep strength, oxidation and corrosion resistance have to be improved to allow for the changes in hot gas composition and temperature. New cooling concepts based on air or steam-cooling have an impact on the compressor and turbine design. Hence, significant research work has to be carried out to cope with these new conditions.

3. Importance of Efficiency Increase

Even if properly redesigned gas turbines would be able to more or less maintain their high efficiency levels for these modified conditions, the additional auxiliary components required for fuel treatment/processing with current technology, will increase the internal energy consumption and thus reduce the overall electric efficiency by almost 10 percentage points. ***It is therefore vital that the conversion efficiency of the gas turbine is further improved to compensate for the efficiency loss due to CO_2 capture.***

4. Our Position

In summary, the use of undiluted syngas in gas turbines is related to issues of fundamental combustion physics & chemistry, which are not yet fully explored and certainly require modifications and adaptations to the compressor, combustion chamber and turbine design as well as cooling, materials and coating technologies. However, ***all these research topics are interconnected and each new strategy will affect the integral design and performance.*** Therefore, it is only by advancing the whole system that the fuel flexibility and overall performance of the gas turbine can improve. This requires a mix of fundamental research, industrial research and small scale demonstrations in the topics described above ***before*** progressing to medium and large scale demonstrations.

It is recognised that combustion technology to burn a limited amount of diluted syngas utilising conventional combustion systems is already available at an early commercial stage. However, a significant amount of further work is required to develop the technology burning undiluted syngas from coal or biomass, whilst achieving high-efficient, low CO_2 & NO_x emission power generation, hence enabling carbon capture and storage in a commercially viable way.

5. Conclusion

The European industry recognises the need for reducing greenhouse gas emissions to prevent or minimise the impact of global climate change. Carbon Capture and Storage is considered as a major strategy in achieving the goal of significantly reducing GHG-emissions. However, in order for power plants to operate with ultra low or even zero emissions, the whole gas turbine system needs to be advanced.

Currently gas turbines do not enable ***operation with undiluted hydrogen-rich syngas.*** Therefore, in order to improve the technology readiness level of the gas turbine, major research effort is needed.

Within the work of the European Turbine Network, necessary research areas and topics, which need to be addressed to achieve high efficiency, low emissions and low cost electricity and heat production, have been identified.

Realisation of the ambitious EU goals on CO_2 reduction, security of supply and energy conservation will, among other things, depend on the capability and speed to advance the readiness of various novel technologies. In order to successfully optimise gas turbine technologies, a common strategy and research effort among stakeholders along with a supportive European Energy research policy is of decisive importance to be able to meet the EU goals, which are crucial for our environment and society.

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