ETN OUTLINE HYDROGEN

Application and advantages of hydrogen gas turbines

Hydrogen is seen as one of the most promising energy carriers in most of the future energy scenarios. Large scale future production of hydrogen is envisioned by water electrolysis making use of (surplus) electricity from renewable energy sources, like solar, wind and hydro power. Besides power generation applications with gas turbines to compensate for fluctuations in power generation by renewables, hydrogen can be used as a fuel in the transport sector, and is applicable for heating applications in households and industrial applications. Furthermore hydrogen can be stored in various physical conditions like compressed hydrogen, liquid hydrogen, physically adsorbed or chemically bound (e.g. in methane or ammonia, or various liquid organic hydrogen carriers) as energy storage medium. While in mobile applications fuel cells have the highest electrical efficiency to retransform hydrogen to electricity, in power generation it is expected that large scale combined cycle power (CCGT) plants are the most efficient, economically feasible way to compensate for power supply fluctuations caused by renewables. CCGT power plants have a higher efficiency, are less costly and need fewer rare materials than fuel cell based power plants. As it seems that the advantages of hydrogen fired gas turbines in a future energy scenario are not sufficiently honored, it is necessary to bring the hydrogen combustion topic (back) on the agenda. In a transition period from NG/methane based systems to fully decarbonised hydrogen based economies, methane/hydrogen mixtures can play a vital role in supporting the introduction of increasing amounts of hydrogen being produced by renewable energy sources.

State of the art

Besides a few gas turbines (GT) explicitly designed for hydrogen applications, today's GT fleet is optimised for natural gas but in most cases can handle up to 3-5vol-% hydrogen without any modification (as documented by respective fuel specifications of GT OEMs). To use fuels with higher hydrogen contents or even pure hydrogen, hardware modifications are mainly necessary regarding the combustion system and with respect to safety issues. From former GT developments for IGCC power plants technologies are available to burn gas mixtures with high amounts of hydrogen. However, these technologies typically use dilution agents as water or nitrogen, which reduces the overall efficiency and increases the complexity and the costs of the system. Some first industrial scale gas turbines are being developed at the moment, which are capable to burn gas mixtures with high hydrogen content (up to 100%) without dilution, but these solutions do not necessarily cover the required fuel flexibility needed for the transition phase of our energy systems.

Research needs

To reach the ambitious goals delivering gas turbines for combustion of 100% hydrogen in 2030 and providing retrofit solutions for existing gas turbines, significant research, development and testing is necessary:

Hydrogen combustion in gas turbines

- The combustion of hydrogen without dilution and with low emissions is still on an early development stage.
  - High burner inlet temperatures increase the risk for flash back in the premixing zone compared to natural gas.
  - The high reactivity of hydrogen inherently increases the auto ignition risk in the premixing section which needs to be addressed in future combustor development.
  - The targeted high TITs do not allow for higher air to fuel ratios which would help to reduce the reactivity of H2 flames.
  - Hydrogen flames exhibit a different thermoacoustic behaviour and therefore require different measures to avoid high pressure pulsations
  - Flame stabilization.
- In the transition to a hydrogen based energy system fuel flexible gas turbines are needed to utilise blends of hydrogen and other gaseous fuels e.g. natural gas

Retrofit of existing gas turbines

- While new gas turbines will be developed to be operated with higher hydrogen concentrations, the hydrogen capability of existing combustion systems has to be evaluated. As small changes to the combustion system can increase the risk of flash back and flame anchoring inside the burner, each gas turbine has to be rated separately.
  - Strategies to test and evaluate the maximum possible hydrogen content in the fuel for existing gas turbines have to be developed.
- The higher reactivity of hydrogen rich mixtures can lead to an increase in emissions. Mitigation concepts has to be developed to comply with legal limits.
- Cost effective retrofit solutions have to be developed to allow for a fast transit to a technology capable of higher hydrogen fuel contents and to fulfil customer's needs.
- Safety related topics of the overall system have to be investigated.
- Gas turbine efficiency.
  - Down rating effects of H2 properties (on turbines, compressor).

H2 GT Power Plant

- Topics which are relevant for the realization of a hydrogen power plant should be evaluated
  - Stability of fuel supply.

- Plant installation and commissioning.
- Plant standards and norms
- H2 Supply chain
  - H2 production
  - H2 storage
  - H2 transport

Objectives of the ETN Hydrogen Working Group

Enable and optimise the use of hydrogen in gas turbines by:

- Highlighting potential use, applications and benefits.
- Pave the way for funding opportunities by highlighting the research needs on gas turbines to burn hydrogen, in order to contribute to the deployment of those gases in future energy systems.
- Address operational issues/effects on gas turbines components related to the use of hydrogen.
- Explore market opportunities and retrofit solutions for existing and future gas turbines fleets operating with renewable gases (containing hydrogen).
- Assess and address operational safety aspects of hydrogen in gas turbines plants (and pipelines).
- To foster the use of hydrogen and hydrogen carriers (such as ammonia) as complementary energy vectors to decarbonise the energy systems.