**Decentralisation**

**P. Kutne, G. Terzer**

Comments from the PB meeting

P. Kutne presented a general structure of the new chapter.

G. Terzer:

* Can provide inputs on micro grids.
* What is our definition of decentralization? General PB agreement on *Consumed where it is produced*

A. Sayma:

* Must mention the integration within a system
* Aggreement on industrial applications power range from 1 to 20 MW

While the increasing share of renewable energy has transformed the energy market from a centralized to a more and more decentralized power production, the intermittent generation characteristic of wind and solar energy sources creates a need for fast, reliable, and dispatchable power generation to guarantee for grid stability. Besides large centralized combine cycle power plants decentralized power production with smaller gas turbines are an attractive option, as it can stabilize the power grid on the low and mid voltage level and helps to relieve the high voltage network. Decentral biomass and other renewable energy sources can be used at their origin without the need of transportation. Moreover the high overall efficiency of such gas turbines helps to reduce the energy consumption if used in combined heat and power applications. And finally if such decentralized units are connected to a “virtual power plant”, the reliability of the power supply can further increased.

While in industrial applications small gas turbines in the range from 1 MW to 20 MW are already established, for smaller consumers micro gas turbine (MGT) technology has the potential to provide effective distributed power generation systems with fuel flexibility, particularly utilising various types of biofuel stock and coupling to concentrated solar power. While small gas turbines are part of the portfolio of the large gas turbine manufactures and the R&D needs are similar to that of the larger gas turbines, MGTs are generally developed and produced in Europe by SMEs with limited research and development resources (Market leader is Capstone, USA). Designs typically rely on off-the shelf components such as those designed for automotive turbochargers, which are relatively cheap but are not optimised for MGT operation due to the different trade-off between high design point efficiency and system size and cost. Thus their performance characteristics are limited to what is achievable to balance research and development and production costs. With the growing demand for more efficient and cost effective energy systems to meet emission reduction targets, it is timely that research and development is conducted to take MGTs to a level that realises their theoretical potential in terms of performance and reliability.

There is sufficient evidence that MGTs have the potential to become a fast growing industry in multiple applications with significant contributions to the energy efficient low carbon economy if a concerted research and development effort is accelerated to overcome the technological challenges that still hinder their progress.

**Challenges**

The research challenges are related to two categories. The first is mainly related to the general cycle efficiency resulting from the system configuration for given component characteristic which affect both design point and off design performance in addition to fuel flexibility. The second is related to system components performance which also affects cycle efficiency and fuel-flexibility, but also system operation, cost, reliability, operability and life. Consequently following are the recommended areas for research and innovations in this field.

**System Integration**

While the typical layout for commercial micro gas turbines is based on the classical recuperated Brayton cycle, the integration of the micro gas turbine components in other systems can offer innovative solutions to improve the overall performance of the system. Such systems are investigated by research activities and show high potential for strong performance increase. But they are far away form a commercial level and further R&D is needed to solve technological and cost issues. For example these are:

* Hybrid Cycles: In these cycles is different technology is integrated in-between the traditional MGT components like
  + Integration of high temperature fuel cells
  + Integration of an external high temperature heat source like concentrated solar power (CSP)
* Integrated Cycles: In these cycles the MGT is still a single system, but connected to other cycles or technologies
  + Integration with energy storage technologies
  + Integration with bottoming cycles
* Non-Conventional Cycles: These cycles are different from the recuperated Brayton cycle bust using MGT technology
  + Wet cycles (especially micro humid air cycle (mHAT))
  + Inverted Brayton cycle

In order to use the ability of the MGT technology to be integrated in such systems, there is a need to adapt the design of the MGT towards:

* Higher electrical efficiency
* Higher flexibility for integration in or with other systems
* Increased flexibility towards the utilization of various sources of energy

**Component performance**

* Turbomachinery: The efficiency of small-scale compressors has been limited by the lack of detailed fundamental research into aerodynamics in comparison with their large counterparts that benefited largely from huge investments from the aviation applications. The effects of secondary and leakage flows, shock boundary layer interactions, surface finish, and relatively large geometric tolerances on aerodynamic performance require further research to determine when the payback from improved efficiency can counter the additional cost of design and manufacturing improvements. Newly emerging research into surface features that can provide passive control of secondary and leakage flows seem to be worth considering.
* Commercially available micro gas turbines have already proven high fuel flexibility in terms of the combustion system. But the overall performance of the system doesn't show the same flexibility, as the turbo machinery
* Combustion: Areas of improved combustion technology aim either to improve combustion efficiency and stability while reducing NOx emissions or develop effective combustion technologies for alternative fuel, in particular biofuels of variable composition and quality in terms of calorific value and impurities. Lean premixed combustion and flameless combustion are emerging as important development areas for MGTs.
* Heat Exchangers: Used as recuperators or as the main heating unit in externally fired MGTs, heat exchangers are in principle a well-established technology with a large number of design options. However, the main challenges are to achieve the high effectiveness and low pressure losses required to maintain high cycle efficiency while keeping the weight and cost down. The main barrier to reducing the capital costs of MGTs is the difficulty in reducing the cost of manufacture of recuperators even when mass production is possible. Thus technological advances are required in materials and manufacturing processes to improve performance and increase reliability while reducing production costs. Additive manufacturing has recently been used to produce compact heat exchangers, but typically at the expense of low effectiveness and high pressure losses. Thus further research and development is still required in this area. Another area of research and development is in the use of metallic foam materials for producing compact heat exchangers.
* Rotordynamics and bearings: Most of the current micro gas turbine designs rely on centrifugal compressor and radial turbine designs. An alternative approach is to use two-stage compressors and two-stage turbines in order to reduce the rotational speed and improve the dynamic behaviour. There are four options for MGT bearings: rolling angular contact ball bearings, oil film bearings, floating ring bearings, magnetic bearings and air/foil bearings. The first is the most common type particularly in smaller MGTs. The technology is well known, however, it requires an oil system. The second type is most common in automotive turbochargers. It is robust, but has high friction losses making it unattractive for MGT applications. Much work in larger engines was done on magnetic bearings; however, their development and implementation cost for MGTs prevented them from being used despite their advantages of oil free operation and the inherent ability to control vibrations. Foil air bearings have made significant progress during the last 25 years in many applications due to their reliability and oil free operation. However, despite their potentially superior performance, they are still not used in MGTs due to the high development costs and thus more research and development are required to capitalise on their advantages.
* Power electronic and control system: A key enabling technology for MGTs is the integrated high-speed electrical machines typically installed on the same shaft as the compressor and turbine eliminating the need for mechanical gear-boxes that can be problematic, if even possible at the high rotational speeds. The result is a very com- pact high efficiency system. High-speed permanent magnet (PM) machines are typically used due to their high power density and high efficiency characteristics. These machines operate as a motor during start up and switch to generation via power electronics. Although power electronics and control technology are well-developed fields, the challenge is to provide a robust and cost effective design for the application at hand. An additional area of research is in MGTs driven by concentrated solar power, where the fuel supply cannot be used as a control parameter as in the case of combustion powered MGTs; the challenge is to produce a grid tie inverter with the synchronous motor drive capability incorporated to provide a suitable optimal control for the system to optimise the overall performance over a wide range of solar input radiation. Such challenges are still un-resolved.