**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 decentralized power production infrastructure, the intermittent generation characteristics of wind and solar energy sources creates a need for fast, reliable, and dispatchable power generation to maintain grid stability. Besides large centralized combine cycle power plants, decentralized power production with smaller gas turbines is an increasingly attractive option, as they can stabilize the power grid on the low and mid voltage level while providing relief to 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 can help to further reduce the energy consumption from the power production infrastructure 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 small gas turbines in the range from 1 MW to 20 MW are well established in industrial applications, for smaller consumers, micro gas turbine (MGT) technology has the potential to provide effective distributed power generation systems with both fuel flexibility (e.g., biofuel stock) and compatibility with solar power generation. While small gas turbines are part of the portfolio of the large gas turbine manufactures, 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, with the major MGT production occurring in the USA (e.g., Capstone Turbine Corporation). Designs used by SMEs 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. Designs that are optimized for performance are used by some manufactures such as Capstone, however the relatively low production volumes translate into expensive component 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 cost, 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, the 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 overall performance. Such systems have been investigated by researchers and show high potential to significantly improve performance. Unfortunately, these systems are far from commercialization with further R&D needed to solve technological and cost issues. Examples of such systems include the following:

* Hybrid Cycles: A unique cycle is integrated into the traditional MGT cycle, such as
  + High temperature fuel cells
  + An external high temperature heat source, such as concentrated solar power (CSP)
* Integrated Cycles: The MGT cycle is connected to another cycle or technology, such as
  + Energy storage technologies
  + Bottoming cycles
* Non-Conventional Cycles: A new, non-MGT cycle that takes advantage of MGT technology. Examples include
  + Wet cycles (e.g., micro humid air cycle (mHAT))
  + Inverted Brayton cycle
* Higher efficiency Brayton cycles
  + High pressure ratio cycles
  + Intercooled and recuperated cycles

In order to integrate MGT technology into 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 larger counterparts that benefited from investments for 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 are worth considering.
* Combustion: Combustion technology research typically aims to either improve combustion efficiency and stability while reducing NOx emissions, or develop effective technologies for alternative fuel use. Alternative fuels of particular focus include biofuels and stranded/associated gas, both of which are of variable composition and quality (i.e., calorific value, impurities and potentially corrosive). MILD combustion is also emerging as important development area 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, challenges for heat exchangers still remain. In order to maintain high cycle efficiency, heat exchangers for MGT systems must achieve a reasonable service life with high effectiveness and low pressure losses while also keeping the weight and cost down. The main barrier to reducing the capital costs of MGTs is the difficulty in reducing the manufacturing cost of recuperators, even when mass production is possible. To overcome this barrier, 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 five options for MGT bearings: rolling angular contact ball bearings, oil film bearings, floating ring bearings, magnetic bearings and air/foil bearings. Rolling angular contact ball bearings are the most common bearing used in smaller MGTs. The technology is well known, but requires an oil system. The second type, oil film bearings, are most common in automotive turbochargers. This bearing type is robust, but has high friction losses making it unattractive for MGT applications. Magnetic bearing development has benefited significantly from research for larger engines; however, their development and implementation cost for MGTs has 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 not typically used in MGTs due to the high development costs, and thus, more research and development are required to capitalise on their advantages.
* Power electronics and control systems: A key enabling technology for MGTs is the integrated high-speed electrical generators typically installed on the same shaft as the compressor and turbine, eliminating the need for mechanical gear-boxes. The result is a very compact, high efficiency system. High-speed permanent magnet (PM) generators are typically used due to their high power density and high efficiency characteristics. These generators operate as a motor during start up, but yield positive power production once combustion is stabilized and rotating speeds increase. The power flow to and from the generators is processed via power electronics with control systems regulating the overall process. Although power electronics and control technology are well-developed fields, the challenge is to provide a robust and cost effective design that also reliably incorporates non-traditional power sources outside of the MGT. One such area of research is in MGTs driven by concentrated solar power, where the fuel supply cannot be used as a control parameter as is typically the case. The challenge is to produce, control and optimize an inverter suitable for grid interconnection with the capability to support synchronous motor drives and variable solar radiation input.