**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

OLD MGT Chapter

The development of Micro Gas Turbines (MGT) started in the late 1980s, mainly driven by the automotive industry for mechanical drive as an alternative to reciprocating diesel and gasoline engines (internal combustion engines – ICE) mainly driven by the advantages of the MGT regarding low emissions, fuel flexibility and a potential to compete on cost with ICE due to less maintenance requirements. With the use of a high-speed generator instead of mechanical drive the technology became suitable for use in hybrid vehicles in the 1990s. How- ever, at that time the hybrid electrical drive train was not a sufficiently mature technology and did not raise further interest. Instead other non-automotive companies picked up the technology and introduced it on the decentralised power generation market where its long life and low maintenance cost could compensate for the higher initial cost. Recent years witness a drive for effective distributed power generation systems with fuel flexibility, particularly utilising various types of biofuel stock and coupling to concentrated solar power. This, in addition to recent developments in automotive hybrid electrical drive train and requirements for range extenders, led to renewed interest in re-considering MGT technology. MGTs are generally developed and produced in Europe by SMEs with limited research and development resources to move the technology to the same level as larger gas turbines (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 re- search and innovations in this field.

**Cycle innovations**

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The simple gas turbine cycle typically used in industrial and aero-engine gas turbines shown in Figure (a) relies on high pressure ratio and turbine inlet temperatures (TIT) to achieve the high cycle efficiency. This is facilitated by the ability to have multistage axial compressors and turbines in addition to turbine cooling technology. These are not feasible in the small scale and thus MGTs are typically constructed from single stage compression and expansion with limited pressure ratio and scope for turbine cooling. They rely on the recuperated cycle configuration to achieve higher efficiency than the simple cycle configuration (Figure (b)). Almost all commercial MGTs use this cycle, which in practice cannot achieve more than about 30% efficiency. To be competitive on efficiency with similar power output ICE’s, new cycle configurations are required that are practical and commercially viable. Some of the research areas may include increasing the pressure ratio via multi-stage compression while increasing the TIT through the use of ceramic components or innovative turbine cooling technologies that may be facilitated by the advancements in additive manufacturing technology.

New cycle configurations may also arise from the nature of the application. For example, the MGT may be used for combined heat and power with the primary operational cost factor being the provision of heat and power over an operating period, for example a year of operation. In order to adapt to seasonal changes in heat demand, it may be possible to utilize part of the heat output for generating steam which can be injected into the turbine to augment electric power output when the demand for heat is low. Other options which have been considered in the past, but still require significant R&D are MGTs coupled to fuel cells.

**Component performance**

* 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.
* 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.
* 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.

**Integrated 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.

