**Micro Gas Turbine**

**Technology**

Research and

Development

for European

Collaboration

**System Integration**



# Acknowledgments

This document was produced by the European Turbine Network (ETN) in order to identify a number of key areas that require substantial R&D efforts for micro turbines from the European community to become competitive in the energy sector worldwide.

The manuscript was produced by Peter Breuhaus from the International Research Institute of Stavanger (IRIS) and co-authored by Mario Ferrari from University of Genoa (UNIGE).

The European industry involved or interested in the development of micro turbine technology has identified a number of key areas that require substantial R&D efforts for micro turbines to become competitive in the energy industry. These include recuperator technology, turbomachinery, system integration, multi-fuel combustion technology and material technology. These areas correspond to the working groups defined in the minutes of the ETN meeting on MGT technology held in Brussels 8 October 2015. This document presents potential work areas and proposed project outlines for European collaboration to improve MGT technology, based on the input of the member of the MGT System Integration working group.

Contributions to this document were provided by the organisations listed below:

|  |  |
| --- | --- |
| International Research Institute of Stavanger | http://www.iris.no/s/forside/logo-topp.png?x1=0&x2=137&y1=0&y2=42 |
| University of Genoa | http://www.lingue.unige.it/eventi/metaphor2016/images/Logo_unige_08_intestato.jpg |
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Contents

[Acknowledgments 1](#_Toc438461009)

[1 Introduction 3](#_Toc438461010)

[2 State of the Art 4](#_Toc438461011)

[3 Necessary Technology Developments 4](#_Toc438461012)

[4 Working Group Member Contributions 7](#_Toc438461013)

[5 References 8](#_Toc438461014)

# Introduction

Microturbines are small gas turbines used for small-scale power generation at one point in a distributed network or at a remote location. These power sources typically have rated power outputs between 25 kW and 500 kW. Relative to other technologies for small-scale power generation, microturbines offer a number of advantages, including: a small number of moving parts, compact size, light weight, low emissions, low electricity costs, potential for low cost mass production, and opportunities to utilize waste fuels. They have been commonly used in many engineering fields.

The current challenging performance targets for microturbines include fuel-to-electricity efficiencies of 40% or higher, capital costs less than $500/kW, NOx emissions reduced to single parts per million, several years of operation between overhauls, lives of 40,000 hours and fuel flexibility [1-2].

A schematic diagram of the TURBEC T100 Micro turbine is shown in following figure 1 [3], where the different components are:

1. Electric Generator
2. Air inlet
3. Combustion chamber
4. Recuperator air by-pass
5. Compressor
6. Turbine
7. Regenerator
8. Heat exchanger



Figure 1 – Schematic draw of the TURBEC T100 Micro turbine system [3]

Typical operating conditions are:

* Combustion chamber pressure = 4.5 bar
* Turbine Inlet Temperature = 950°C
* Turbine exit gas temperature = 620-650°C
* Exhaust gases temperature = 80°C
* Rotation speed = 70000 rpm

# State of the Art

# Necessary Technology Developments

Current development for power generation is following two main trends: towards smaller distributed units and plant integration into wider energy systems. Wider energy systems consist of an integration of various energy sources or plants with a clear trend towards high efficiency, renewable energy and utilization of low exergy flows, such as coupling electrical and thermal systems (e.g. district heating). In this context, MGTs are positively competing against internal combustion engines in terms of low maintenance, noise and emissions. Furthermore, they are interesting devices for development of advanced plants, such as for example hybrid systems based on fuel cell technology.

As a consequence MGTs and the MTG cycles need further development towards:

• Higher electrical efficiency;

• Increased flexibility for integration with other systems;

• Increased flexibility towards the utilization of various sources of energy.

Therefore future development activities should consider the following three aspects:

1. Improvement of current cycles and new advanced cycles;

2. Development of the necessary technologies to allow the design of advanced and new cycles;

3. Design of MGTs according the needs of the new processes and their integration into other cycles.

## New advanced cycles

The evaluation and R&D activities connected to advanced cycles is usually closely connected to specifically chosen type of cycle and, thus, they cannot be subject to generate some ideas for general R&D activities and possible projects. However, an interdisciplinary approach is essential as already mentioned above.

Possible advanced cycles might be:

• Wet cycles, as one type of advanced cycles, are processes with extraordinary high water content in the work fluid (e.g. humid air turbine, TopCycle etc.). There are some general aspects related to these cycles which might be topic of R&D activities, as reported in the following points:

o The combustion process and design in case of water injection and the operation and stability aspects (e.g. surge margin) have to be improved.

o The challenges when connecting the GT to bigger volumes and the resulting change in transient behaviour as well as during start-up and shutdown operations need to be considered in close connection with the development of wet cycles.

o Topics related to water recovering at MGT discharge duct have to be highlighted especially for applications with low water source.

o Effect of water on the components, especially on the recuperator: lifetime, performance, etc.

• Important issues have to be analysed on the MGTs for hybrid systems, such as cycle layout (including MGT and component optimization), system dynamic aspects affecting the machine (especially surge problems due to the connection with a large volume), MGT control system issues to manage all the additional constraint problems and other interaction aspects with the fuel cell.

• Integration with bottoming cycles (e.g. ORC or others) to increase electrical efficiency towards MGT/CC cycles.

• Inverted Brayton cycle (IBC) for very small units (electric power of less than 2 kW  no turbochargers available) or for small units (up to 30/50 kWe) using very low caloric fuels containing hydrogen (e.g. wood gas); this eliminates the high power needed for the fuel compressor and the technical and economic problem of compressing hydrogen fuels.

• Combination of the MGT with energy storage technologies and systems to be better suited for different time pattern of demand for e.g. electricity and/or heat. This also supports the integration of fluctuating renewable sources, such as equipping SCP plants with high temperature energy storage systems. Extensive application of MGTs in co-generation and smart grids including generation of cooling power towards absorption chillers. Even if this point is mainly related to integration of existing technologies, optimization will be essential for efficient management.

• Eventually considering Exhaust Gas Recirculation (EGR) as a method and tool for enhance CO2 capture and sequestration by increasing the content of CO2 in the exhaust gas of the MGT. However, this might be questionable for smaller size units.

• Exhaust gas recirculation for CHP units (e.g. 1 kWe IBC MGT) to increase the water content in the exhaust gas to increase the thermal efficiency of the system (condensing heating technology).

• Integration of innovative components for CO2 sequestration.

• Combination of MGT with gasifiers (e.g. wood, sewage sludge) (e.g. in combination with IBC: no need for fuel compression; reuse of hot gases produced by the gasifier).

The use of other working fluids than air is an issue, which might require additional R&D efforts. Use of other working fluids require closed loop cycles. Some of the topics connected to it might be already covered in other WPs. In this context, topics of interest might be:

• External combustion or heat input (e.g. waste heat recovery), allowing the use of various fuels and heat sources might in case of combustion result in avoiding or reducing extra efforts in fuel preparation / treatment. => most likely covered in “MGT Fuel Flexibility”

• Humidification of mGT in order to increase the electrical efficiency in moments of low heat demand.

## Design of MGTs for new processes

Most current MGT designs target a compact MGT with closely integrated and connected components (compressor, combustor, turbine, recuperator) which makes it challenging to integrate them into other processes. The design differs from systems designed for integration (e.g. turbochargers) and therefore:

* need to able to match different compressor and turbine specification (e.g. for various mass flow differences);
* need to design recuperators resilient to changes in flow composition and load. Current recuperators are optimised for ‘normal’ operation of mGTs. This makes it difficult to ensure optimised operation when for example injecting water in the system. More resilient recuperators may introduce a small efficiency penalty when working in ‘normal’ conditions but could better adapt to changes in mGT load and flow composition to ensure a higher overall efficiency;
* need to connect to other components (flange dimensions, positions and forms);
* cover different main operating profiles via versions for peak load efficiency (i.e. base-load operation) and those optimised for more or less continuously changing operating conditions (compromise in peak load efficiency for the benefit of a flat efficiency characteristic).

As consequence a new MGT design has to be linked with systems integration aspects considering the following main issues:

* Modular and open design to allow to:
	+ integrate other heat sources (e.g. CSP, high temperature waste heat) while still keeping the combustor;
	+ easily exchange combustor part to comply with different fuels as well as the above-mentioned complementary firing;
	+ design aspects to use exhaust heat for various other purposes;
	+ easily integrate components based on high flexibility (e.g. flanges or tee joints to connect additional components);
	+ obtain the specific MGT performance requested by advanced cycles, such as hybrid systems based on fuel cells.
* More open control system to:
	+ allow connecting additional signals;
	+ operate the integration with controllers related to additional components (e.g. fuel cells, water injection unit, EGR);
	+ allow including other safety relevant signals to protect other connected components;
	+ eventually allow for controlling additional functions (e.g. second combustor, additional valves etc.);
	+ be interconnected to other controllers in the energy systems either as master or as slave, which might also require the exchange and transfer of additional/more signals;
	+ implement innovative control approaches, such as Model Predictive Control based solutions;
	+ allow an easy integration with diagnostic tools.

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# Working Group Member Contributions

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| Task | IRIS | UNIGE (TPG) |  |  |  |  |  |  |
| Literature Review | X | X |  |  |  |  |  |  |
| Hybrid Power Plants |  |  |  |  |  |  |  |  |
| Fuel Cell hybrid | X | X |  |  |  |  |  |  |
| Solar Hybrid | X |  |  |  |  |  |  |  |
| Humidification of MGT | X | X |  |  |  |  |  |  |
| Inverted Brayton Cycle |  | X |  |  |  |  |  |  |
| Combination of MGT with gasifiers | X |  |  |  |  |  |  |  |
| External combustion or heat input (WHRU) | X | X |  |  |  |  |  |  |
| Exhaust Gas recirculation | X | X |  |  |  |  |  |  |
| Integration with CO2 sequestration components | X | X |  |  |  |  |  |  |
| Combination with energy storage technology | X | X |  |  |  |  |  |  |
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2. D.J. Zhang, M. Zeng, J.W. Wang, Q.W. Wang, *Creep analisys of cross wavy primary surface recuperator for microturbine system*. Proceeding of ASME Turbo Expo 2008 – GT 2008-51505
3. E. Bianchi, *Microturbina TURBEC*.