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Mems-Concept Using Micro Turbines for Satellite Power Supply

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1. Introduction

Since the mid-nineties the power demand of GEO satellites has increased immensely (Nobbe, Tappert, 2004). This increased power demand is needed for applications like telecommunication, navigation and Earth observation. Conventional solar cells are producing the necessary electrical power through photovoltaic, whereas often large solar arrays are needed because of the relatively low cell efficiency and the temperature dependency of the Maximum Power Point (MPP). But solar cells are not the only possible concept to convert solar energy into electrical energy. The key concept of present paper is the use of a thermo-dynamic conversion principle, using the Organic Rankine Cycle (ORC).

Extensive research work has been conducted in the last fifty years related to ORC spacecraft applications. The new approach, which will be highlighted in this work, is the use of so called Power-MEMS (Power Micro Electro-Mechanical Systems) in order to convert solar into electrical energy. Here, a Micro-Turbine-Generator-Module (MTG-Module), consisting of a Cassegrain collector system, a vapor generator, a turbine-generator system and a condenser/ radiator, works by the use of the organic fluid Toluene. Final goal is the use of many MTG-Modules integrated on a spacecraft panel in order to supply a satellite with electrical power.

2. Background Power MEMS

Within the last five years many laboratories have put a lot of effort in research of different system concepts for Power-MEMS. Main focal point within this effort was set on the open Joule process, where a work gas (e.g. Butan, Methan or Hydrogen gas) is fired together with Oxygen in a micro combustion chamber. The hot combustion gases impel a micro turbine feeding a micro generator.

These Power-MEMS will be used as an alternative to batteries for laptops, camcorders or other power consuming mobile applications. The research group of Reynaerts (Department of Mechanical Engineering, University of Leuven, Belgium) (Peirs et al., 2003) has developed a Power-MEMS using a single-stage axial micro turbine with a rotor diameter of 10 mm (compare Figure 1). This turbine is a first step in the development of a micro generator. The expansion of the gas takes place in the stationary nozzles. The turbine is made of stainless steel using die-sinking electro-discharge machining (EDM).

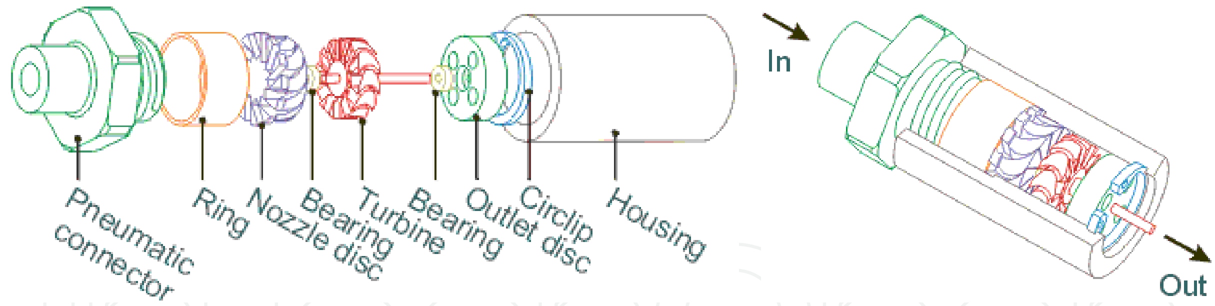

Fig. 1. Micro turbine design from Reynarts, University of Leuven, Belgium; (Peirs et al., 2003)

The Power-MEMS weighs 66 g, which is hold by a micro bearing system (compare Table 1). The turbine has been tested to speeds up to 160,000 rpm and generates a maximum mechanical power of 28 W with an efficiency of 18.4 %. When coupled to a small generator, it generates 16 W of electrical power, which has an efficiency for the total system of η=10.5 % (Peirs & Reynaerts, 2004).

Part	Mass (g)
Turbine	36
Pneumatic connector	15.8
Ring	0.77
Nozzle disc	1.78
Small bearing	0.03
Large bearing	0.07
Rotor	1.63
Outlet disc	0.35
Circlip	0.27
Housing	15
Generator	30
Total*	**66**

* including Turbine & Generator

Table 1. Masses of different parts of the Prof. Reynarts Power-MEMS turbine; (Peirs et al., 2003)

Another Power-MEMS is designed by the research group of Epstein at the MIT, USA (Jacobson et al., 2006). Here, the Power-MEMS is a 5-level wafer-bonded micro-machined turbine/bearing rig. The production process involves the use of 5 wafers, 16 masks, and 9 deep silicon etching steps, double-sided deep reactive ion etching (DRIE), and Laser-Assisted-Etching (LAE) (Lin et. al., 2006). Materials like ceramics such as silicon carbide (SiC) and silicon nitride (Si3N4) are used for this chip turbine engine. Figure 2 shows a cutaway of the engine as well as a Si-wafer of radial inflow turbine stages.

The micro engine also uses the open Joule process, where Hydrogen was chosen as a first fuel. Figure 3 shows a cross section of the H2 demo engine. The centrifugal compressor and radial turbine rotor diameters are 8 mm and 6 mm respectively (Epstein, 2004). The compressor discharge air wraps around the outside of the combustor to cool the combustor walls, capturing the waste heat and is so increasing the combustor efficiency while reducing the external package temperature.

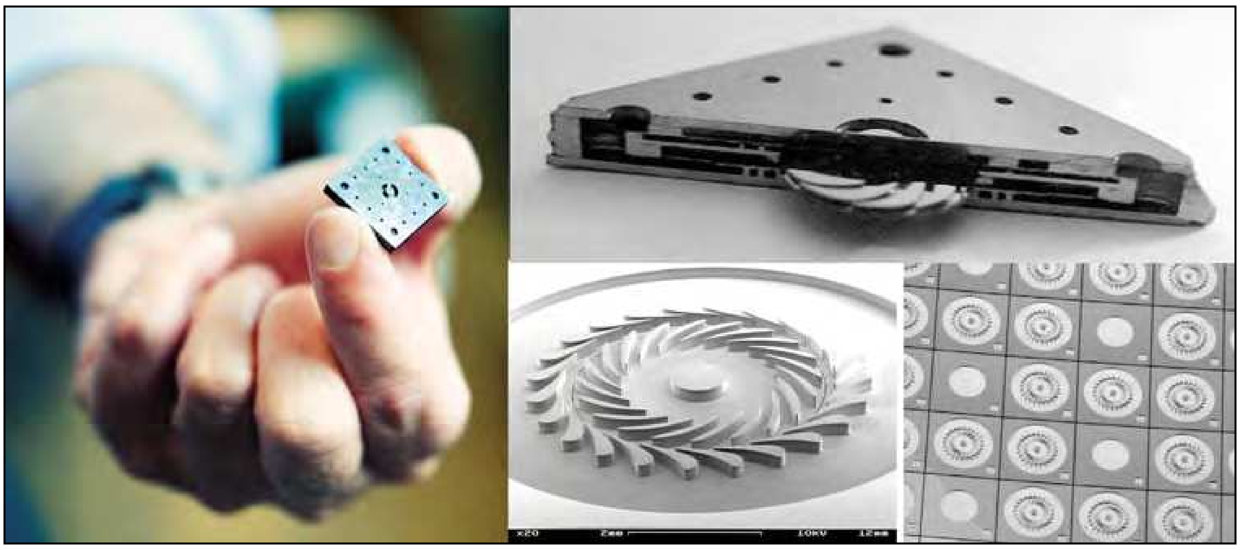

Fig. 2. Upper side: Cutaway H2 demo gas turbine chip; Lower left & right: A 4:1 pressure ratio, 4 mm rotor dia radial inflow turbine stage a swell as a Si wafer of radial inflow turbine stages; (Epstein, 2004)

Thrust bearings on the centreline and a thrust balance piston behind the compressor disk support the axial loads. The peripheral speed of the compressor is 500 m/s so that the rotation rate is 1.2 Mrpm. With 400 µm span airfoils, the unit is sized to pump about 0.36 g/sec of air, producing 0.1 Newton of thrust or 17 W of shaft power (Epstein, 2004).

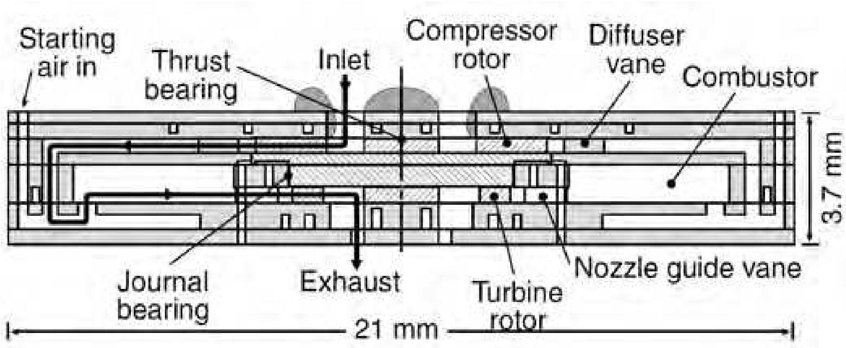

Fig. 3. H2 demo engine with conduction-cooled turbine constructed from six silicon wafers developed by the MIT research group of Prof. Epstein; (Epstein, 2004)

A Power-MEMS that is working with the closed Rankine cycle is under development at the Department of Mechanical Engineering - Columbia University, USA (Frechette, 2003a). Here, a system-level and component design study of a micro steam turbine power plant-on-a-chip was conducted. The Power-MEMS is similar build up as the H2 demo engine from Epstein, MIT (compare Figure 4). Possible application for this type of Power-MEMS is power generation from waste energy (e.g. PCU-cooling, illumination heat or car radiator heat). The work fluid for this Power-MEMS is water.

The micro fabricated device consists of a steam turbine that drives an integrated micro feed pump (3 mm thick by 1 cm², planar form). Two-phase flow heat exchangers are also integrated on-chip with the rotating components to form a complete micro heat engine unit, which is converting heat to electricity. Expected power levels range from 1-12 W per chip with energy conversion efficiency in the range of 1-11% (compare Figure 5) (Frechette, 2003b). The figure presents the predicted performance for three different configurations:

- Top bars are for a high superheated temperature (800°C) and high pressure (8 MPa) by 50°C ambient temperature,
- mid bars represent lower temperature (400°C) and lower pressure (0.6 MPa), and
- lower bars are the same device, but with 25°C ambient temperature. This last configuration requires active cooling with a fan that is driven by a fraction of the micro Rankine device output.

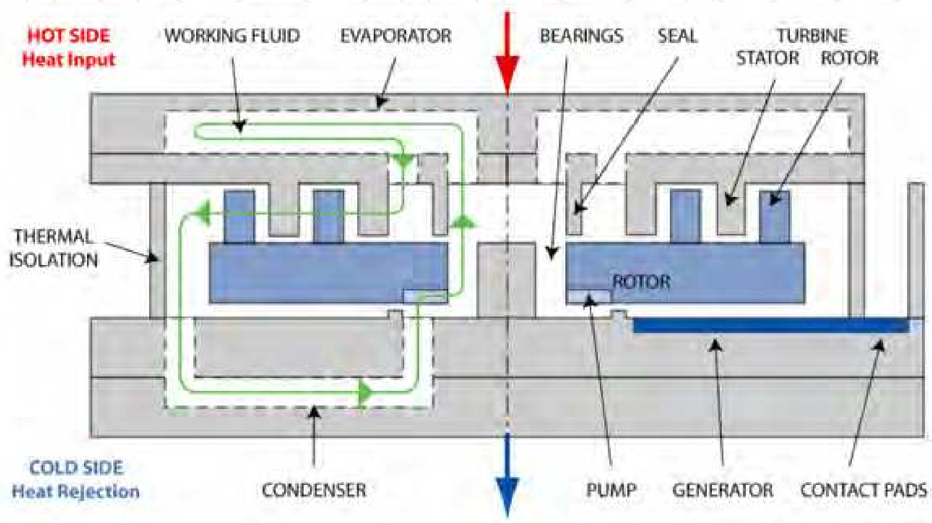

Fig. 4. Cross-section schematic of micro steam-turbine power plant-on-a-chip; (Frechette, 2003a)

Summarized, all shown Power-MEMS have an increasing Technology Readiness Level (TRL), although some concepts are still in its preliminary design phases. Nevertheless, an implementation for a spacecraft application seems conceivable.

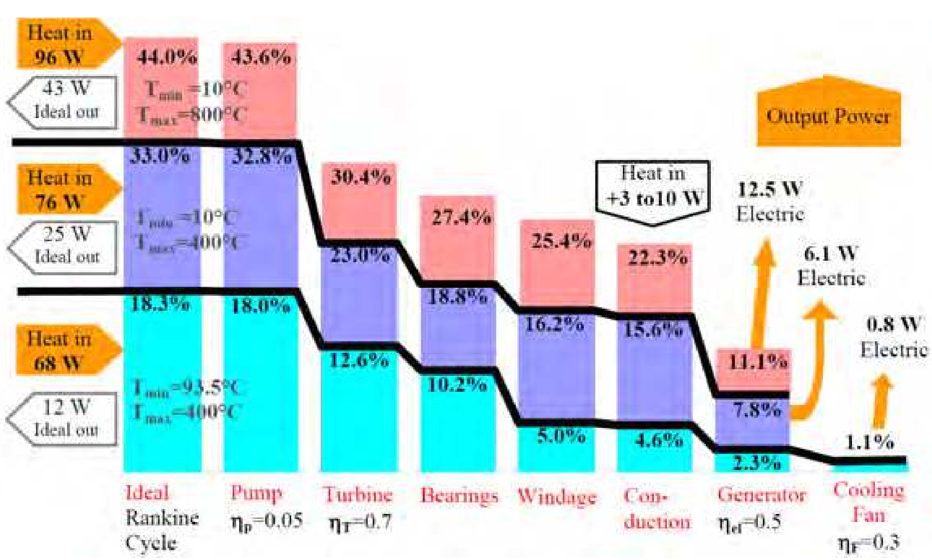

Fig. 5. Predicted performance of the micro steam turbine power Plant-on-a-chip for three configurations. (water 24 mg/s, Pmax=0.6 MPa); (Frechette, 2003b)

3. Requirements & assumptions

First step is the determination of the MTG's electrical power output. From here, the thermodynamic Rankine cycle can be calculated. The resulting thermodynamic values directly affect the geometric construction of the module. During this preliminary study several requirements and assumptions were made.

The key system requirements are:

- Electrical power output P > 10 Watt per MTG-Module
- Solar radiation concentrated by the use of a Cassegrain collector system
  Modular design shall be used for the MTG many modules on one solar panel
- Closed Rankine cycle principle used as conversion principle
- MTG concept shall offer high average temperature of condenser in order to keep radiator surface small
- System shall be robust
- Lifetime of system > 10 a

The key assumptions are:

- Only energy conversion system within the power subsystem is subject of evaluation here (no batteries or PCUs)
- Negligence of microgravity effects for Rankine cycle process
- Calculation of stationary mode only (no considerations concerning start or end working phases)
- Negligence of Albedo and IR-radiation due to GEO orbits
- Specific solar flux S=1350 W/m²
- Vertical incidence of sun's radiation towards collector system

4. Description of concept

As major work principle the Organic Rankine Cycle (ORC) was selected. The ORC works at lower temperatures than the normal Rankine cycle. Here, the working fluid is not water but an organic fluid with a lower evaporation temperature. To match the system requirements a fluid with a long stable life time and a low degradation factor had to be chosen. The decision was made for Toluene (C_7H_8), which has excellent characteristics for the MTG process (Prabhu, 2006). Toluene has the following characteristics:

- Molar mass: 92.14 g/mol
- Melting point -93°C (189 K)
- Boiling temperatue: 110.6 °C
- Boiling pressure: 1.01325 bar
- Critical temperature: 320.95
- Critical pressure: 42.365 bar
- Thermal conductivity: 0.134 W/mK
- Density: 0.87 g/cm³

Key principle for the Rankine cycle (organic or not organic) is the isobar evaporation of a liquid work fluid within a vapor generator. The hot vapor impels a turbine, which again drives a generator for the electrical power generation. After the steam passes through the turbine, the condenser detracts the thermal heat so that the steam condensates and returns again into its liquid form. A feed pump transports the fluid towards the vapor generator and compresses the fluid to boiler temperature (compare Figure 6).

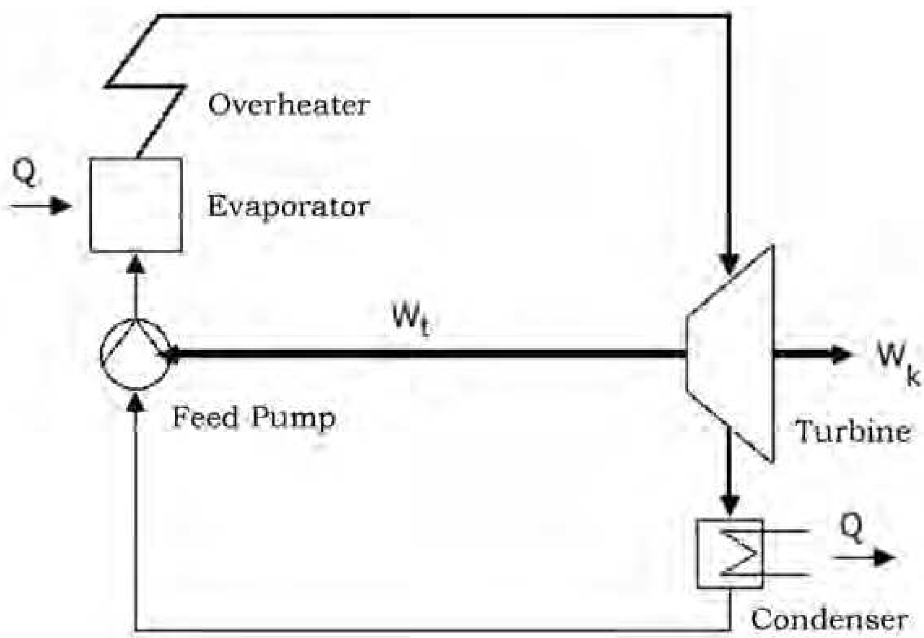

Fig. 6. Thermal dynamic flowchart of the closed Rankine cycle process.

The MTG Module concept is build up of five subsystems:

- Cassegrain mirror collector system
- Micro receiver system/ vapor generator
- Turbine-Generator system
- Condenser/ radiator system
- Micro feed pump

Figure 7 (left) depicts the schematic cross-section of a MTG-Module, where the collector system, the thermal engine section and the radiator system are assembled to a single module.

The Cassegrain mirror collector system has a parabolic primary mirror and a hyperbolic secondary mirror that reflects the light back down through a hole in the primary mirror (compare Figure 7, right). An advantage of this collector concept is the possibility to place the Power-MEMS behind the primary mirror. This way the radiator is always in the shadow of the primary mirror, which is important for a sufficient radiation.

The receiver system is an evaporator or heat exchanger that consists of single metal foils, which are connected by a diffusion bonding process to form a nearly monolithic body. The number of integrated micro channels is in the order of several hundreds to several thousands (comp. Figure 8).

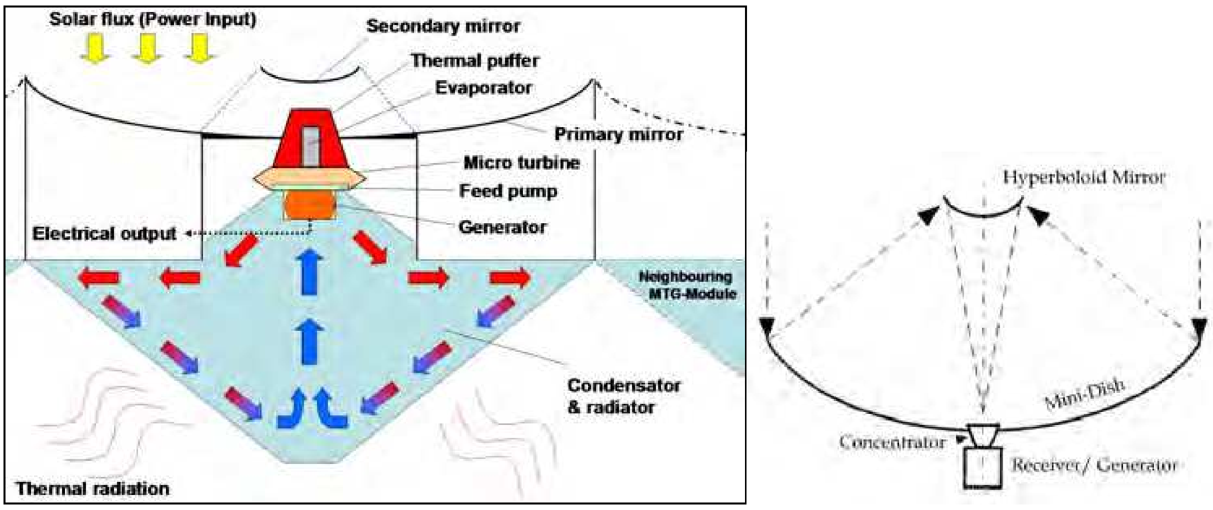

Fig. 7. Left: Schematic cross-section of a Micro-Turbine-Generator (MTG-Module); Right: Schematic drawing of a Cassegrain collector & concentration system

The devices have an extremely high heat transfer to volume ratio of about 30,000 m^2 per m^3, which makes it possible to transfer thermal power in the range of several kilowatts within a volume of some cubic centimeters only (Brandner & Schubert, 2005).

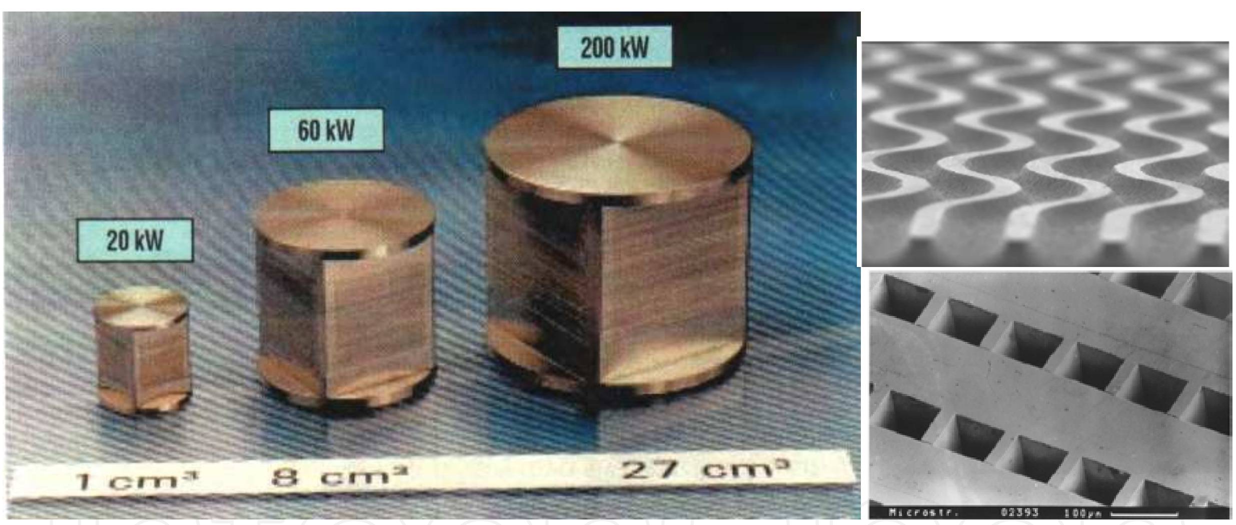

Fig. 8. Different microstructure heat exchanger made of stainless steel, each channel at 100µm edge length; (Brandner & Schubert, 2005)

The turbine-generator system consists of a micro turbine, as to some extent discussed in the previous chapter, and a micro generator. The study revealed that concerning the micro generator a great demand for research exists due to the fact that until now no applicable micro generator is available (concerning long-life expectance). Although, some research is performed on the field of micro generators, like the generator from the research group of Schmidt at Technical University of Berlin, Germany (compare Figure 9) (Walter, 2004).

The condenser/ radiator system, where the hot Toluene vapor has to condensate after leaving the turbine, consists of the same micro channel heat exchange system as the evaporator system. In addition to the condenser a radiator must radiate the heat.

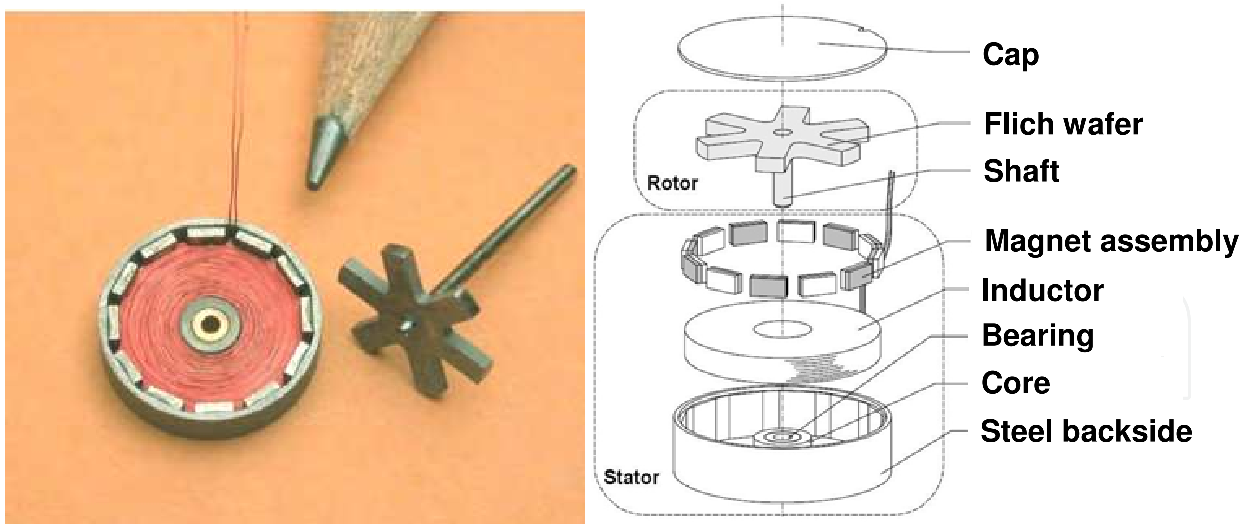

Fig. 9. Prototype for a micro fabricated generator, developed at the Technical University Berlin, Germany (Walter, 2004)

For the optimal geometric design several preliminary concepts were discussed during the study. A promising solution is a radiation dome at the back side of the MTG Module (compare Figure 10). The dome inhabits a secondary passive fluid cycle system (hot tube principle) transporting the heat from the condenser to the outer side of the MTG-Module (shadow side). The domes avoid mutual radiation effects between the different radiation systems, when many MTG modules are implemented on one solar panel.

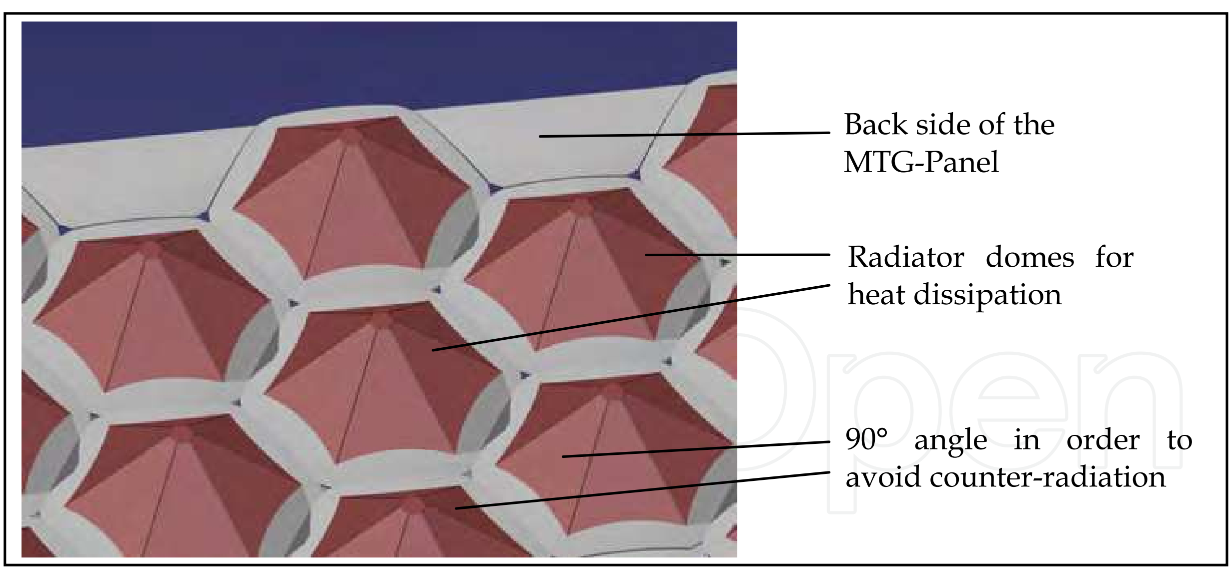

Fig. 10. Key principle for the condenser/ radiator, where radiation domes shall optimize the radiation area, the opposite radiator plates always stand with an angle of 90° to each other in order to avoid counter-radiation

After the Toluene vapor has condensated and returned into its liquid form, a micro feed pump transports the work fluid back to the evaporator system. An additional task of the feed pump is the compression of the fluid to the required boiler pressure. Many feed pumps within Rankine cycle machines are coupled directly (over the shaft) with the turbine. The

Rankine Power-MEMS designed by the Columbia State University already has an integrated micro feed pump (compare Figure 4). For the MTG-Module a similar micro pump system would be conceivable.

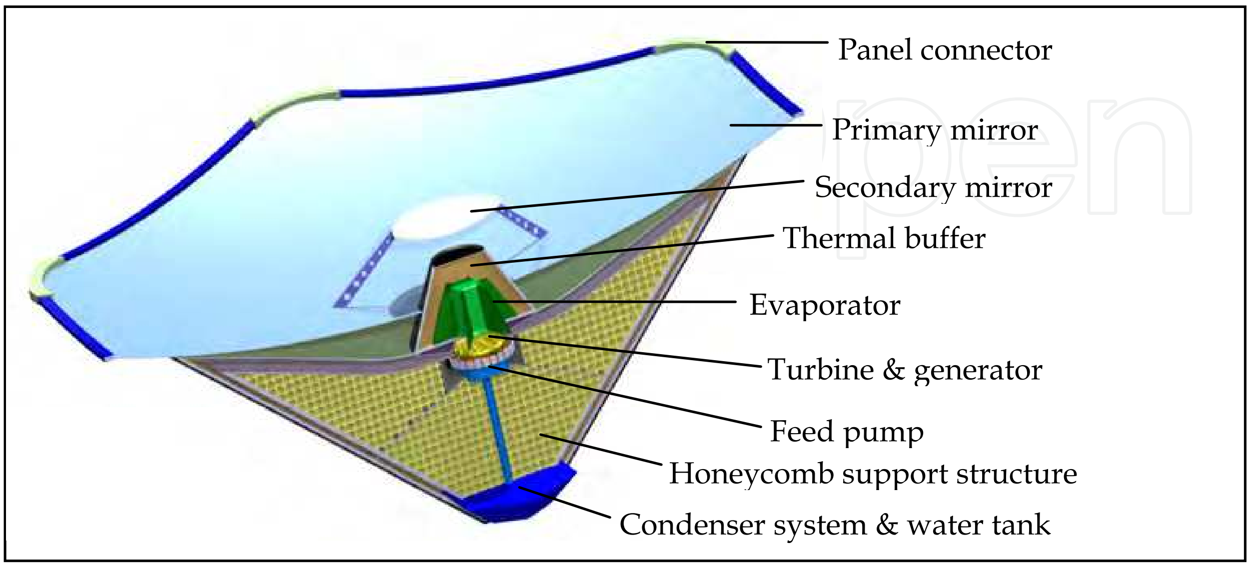

Fig. 11. Cross section of a Cassegrain collector mirror system with a MTG-Module attached

Figure 11 shows a first drawing on the actual design of a MTG-Module. The cross section shows all necessary subsystems and elements for one Module. A honey comb support structure fills the not needed volume between mirror system and radiator and adds additional stiffness to the module.

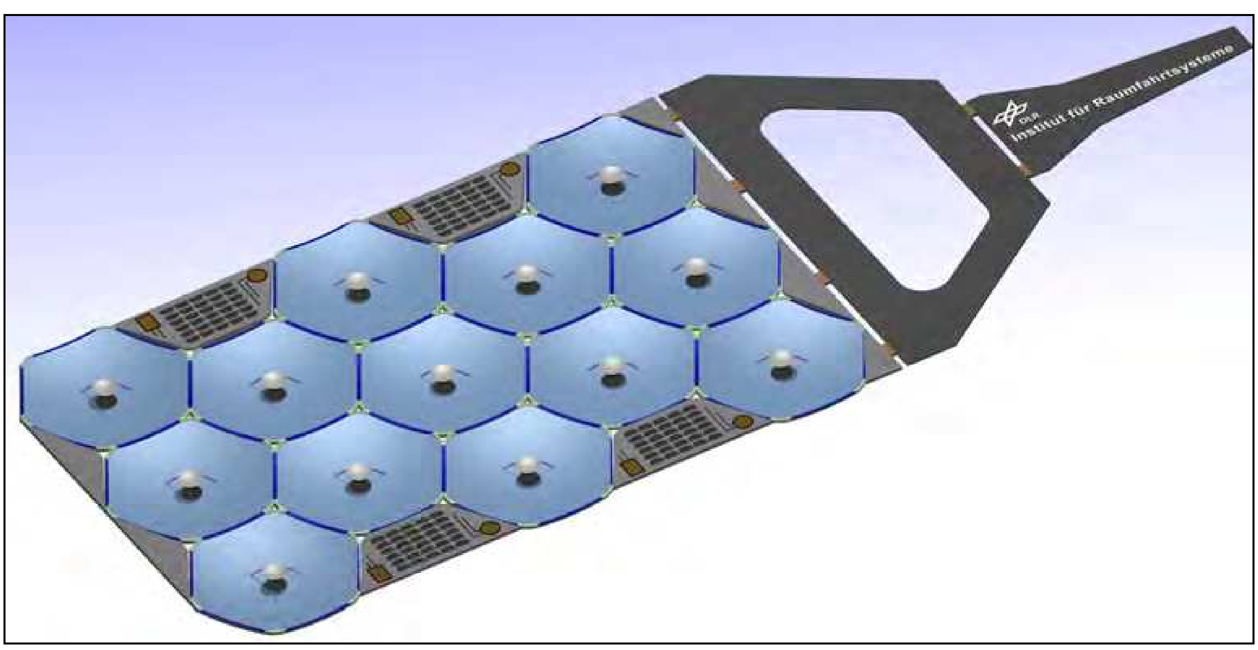

Fig. 12. Example of a perspective depiction of an assembled solar panel with many Cassegrain MTG-Modules

Figure 11 also depicts the micro thermal buffer system that is placed within the receiver system. This heat buffer system, which usually consists of a thermal salt compound, stores the thermal load during on daylight phase. During shadow phase the Rankine process is empowered by the heat dissipation of the thermal buffer. With such a buffer system several positive implications on the overall system could be established like for example the possible reduction of battery mass due to the fact of ongoing cycle power during shadow phases.

The final goal is to integrate many MTG-Modules on a solar panel. As seen in Figure 12 the primary mirrors have a hexagon-type form in order to optimize usable panel area. This way a maximum of solar flux can be captured and concentrated. Every single MTG-Module will convert the solar energy into electrical energy. The partial electrical power outputs from each of the small steam power plants will be interconnected and serve the power subsystem as primary energy conversion source.

5. Thermodynamic calculation

The ORC process can be divided into seven sub processes (compare Figure 13):

1-2 Isobar heat supply
2-3 Isobar heat supply (saturated vapor)
3-4 Isobar overheating
4-5 Isentropic relaxation
5-6 Isobar heat dissipation
5-7 Isobar heat dissipation (saturated vapor)
7-1 Isentropic pressure boosting

The Toluene cycle process was calculated for boiler pressure of 5 bar within the isobar heat supply. The starting fluid temperature (point 1) starts at 290 K and has an end temperature of 508 K before it enters the turbine.

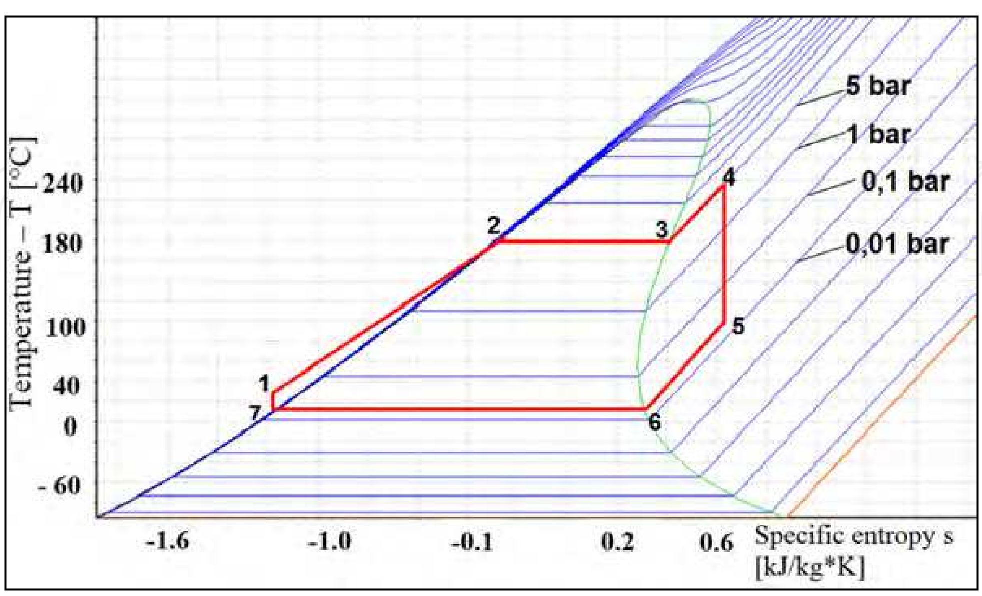

Fig. 13. Temperature-Entropy Diagram for the Toluene Rankine cycle within the MTG-Module.

Within the turbine the vapor relaxes from 5 bar to 0.03 bar and leaves the turbine at a temperature of 373 K (point 5). During the vapor/ fluid mixture flows through the condenser, heat dissipation decreases the temperature to 290 K. Table 2 shows the key thermodynamic working parameters of the chosen and calculated Toluene Rankine cycle (Goodwin, 1989).

Working point	Temp-erature [K]	Pressure [bar]	Specific Enthalpy [kJ/kg]	Entropy [kJ/kg*K]	Average specific heat capacity cp [kJ/kg*K]
1	290	5	-420	-1.15	1.8183
2	453	5	-163	-0.3	1.8183
3	453	5	163	0.4	1.4469
4	508	5	313	0.648	1.4469
5	373	0.03	100	0.648	0.9780
6	290	0.03	-13	0.312	0.9780
7	290	0.03	-430	-1.15	1.029 (cv)

Table 2. Different working points for Toluene Rankine cycle

Having determined the key parameters for the cycle process the specific enthalpies can be calculated for the heat supply and for the heat dissipation. Using the standard thermo dynamical calculation methods one receives the following specific enthalpies:

$$\left.\begin{aligned} dh_{1-2} &= 295\frac{kJ}{kg} \\ dh_{2-3} &= 326\frac{kJ}{kg} \\ dh_{3-4} &= 79\frac{kJ}{kg} \end{aligned}\right\} \dot{q}_{in} = dh_{1-2} + dh_{2-3} + dh_{3-4} = dh_{1-4} = 700\frac{kJ}{kg}$$

$$\left.\begin{aligned} dh_{5-6} &= -81\frac{kJ}{kg} \\ dh_{6-7} &= -417\frac{kJ}{kg} \end{aligned}\right\} \dot{q}_{out} = dh_{5-6} + dh_{6-7} = dh_{5-7} = -498\frac{kJ}{kg}$$

For the turbine an enthalpy gradient of 213 kJ/kg results and the pump needs an enthalpy effort of 571 J/kg or 0.571 kJ/kg. Within the requirements electrical power output for the MTG-Module was set to 10 Watt. To fulfil this goal the necessary mass flow of the work fluid Toluene needs to be calculated. Equation (1) represents the method to calculate the different power consumptions:

$$P = \Delta h \cdot \dot{m}$$

$$P = Power; \quad \Delta h = spec.\, Enthalpy\ difference; \quad \dot{m} = mass\ \ flow \tag{1}$$

The turbine and the generator efficiency factor was chosen each to η=0.7 so that a needed thermal gross power output of at least 20 Watt is required. Because the feed pump is going to be impelled by the turbine shaft the efficiency factor of the feed pump (η=0.2) has to be considered as well:

$$P_{T(net)} = P_{th(gross)} - \frac{P_{pump}}{\eta_p}$$

$$\Rightarrow P_{th(gross)} = P_{T(net)} + \frac{P_{pump}}{P_{pump}} \tag{2}$$

$$P_{T(net)} = Net\ power\ turbine\ ; \quad P_{th(gross)} = Gross\ power\ thermal;$$

$$P_{pump} = Power\ \ feed\ pump; \quad \eta_p = efficiency\ \ factor\ pump$$

Table 3 shows the different possible mass flows with the according calculated thermal input and output powers for the MTG-Module. The blue highlighted mass flow of 0.1 g/sec was chosen for the ongoing calculation process. This way for a net turbine power output of 21 Watt a thermal input power of 70 Watt is required. An average temperature of ØTrec=548 K on the surface of the receiver was calculated (by use of general heat transition equations) under the special consideration of Toluene mass flow and the resulting thermal transfer and absorption from the fluid.

Mass flow [kg/sec]	Total input power [Watt]	Total output power [Watt]	Power feed pump** [Watt]	Gross power turbine [Watt]	Net power turbine* [Watt]
0.00001	7.008	-4.983	0.029	2.130	2.101
0.00005	35.042	-24.914	0.143	10.650	10.507
0.0001	**70.084**	**-49.827**	**0.286**	**21.300**	**21.014**
0.0005	350.418	-249.136	1.428	106.500	105.072
0.001	700.836	-498.271	2.855	213.000	210.145

* Net turbine power under consideration of feed pump power

** Feed pump power under consideration of efficiency factor: η=0.2

Table 3. Different calculated net turbine power values as a function of the impelled mass flow

Having calculated the mass flow and the required thermal power input of the overall system, the geometric size of the primary mirror can be determined. Here, it has to be considered that the secondary mirror shadows the centre part of the primary mirror. Not the full primary mirror system can be used for the solar concentration process (compare Figure 14).

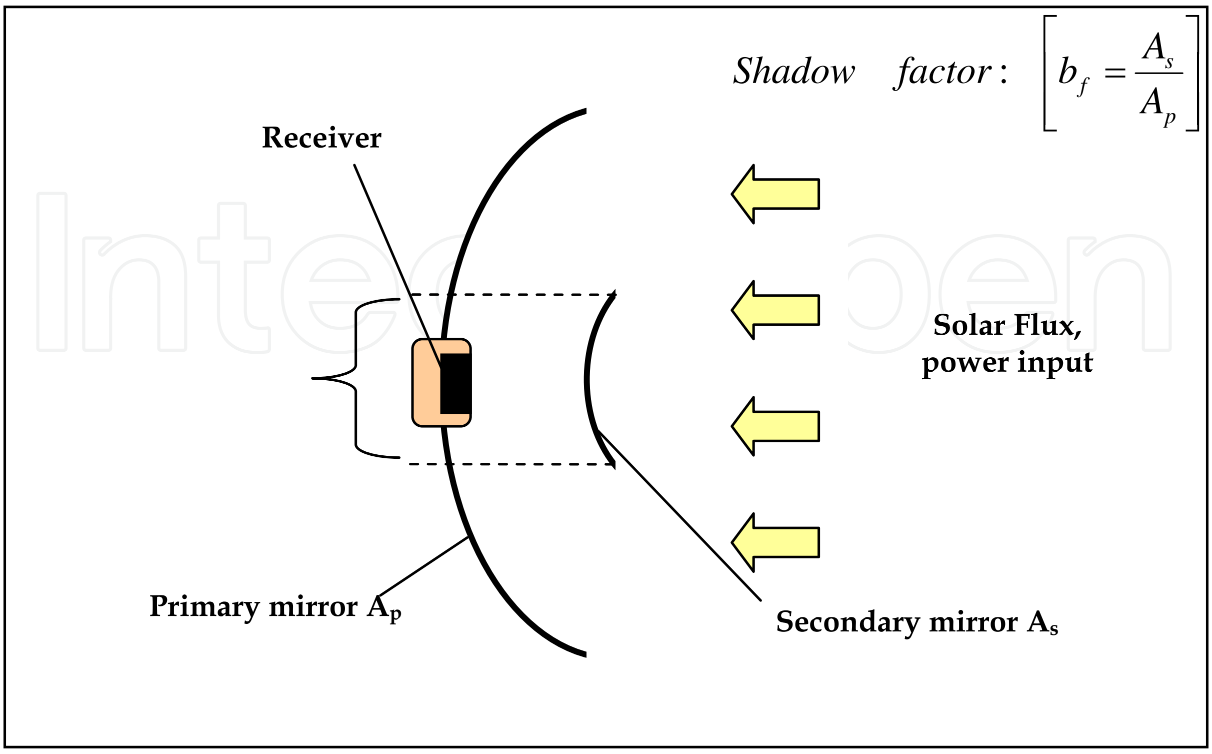

Fig. 14. Depiction of shadowing area of the secondary mirror towards the primary mirror

Since the solar flux is concentrated onto the receiver, the receiver surface itself emits radiation to some extent, which has to be considered as loss energy. The required thermal power for the Cassegrain collector system was calculated with a thermal power balance approach (equation 3):

$$\dot{Q}_{in} + \dot{Q}_{emi} = \dot{Q}_{coll}$$

$$\dot{Q}_{in} = required\ input\ power\ ; \quad \dot{Q}_{emi} = emitted\ loss\ power;$$
$$\dot{Q}_{coll} = Power\ collector\ system \tag{3}$$

Considering the shadowing effects of the secondary mirror and the emitted loss energy of the hot receiver, the needed mirror area can be calculated as follows (Zörner, 1991):

$$\dot{Q}_{in} + \dot{Q}_{emi} = A_p \cdot S \cdot (1 - b_f) \cdot \alpha_s$$
$$\Rightarrow A_p = \frac{\dot{Q}_{in} + \dot{Q}_{emi}}{S \cdot (1 - b_f) \cdot \alpha_s} \tag{4}$$

$$\dot{Q}_{in} = required\ input\ power\ ; \quad A_p = Area\ of\ primary\ mirror;$$
$$\dot{Q}_{emi} = emitted\ loss\ power; \quad S = Spec.\ solar\ const.;$$
$$b_f = shadow\ factor; \quad \alpha_s = Absorption\ factor$$

Outgoing from equation (4) and by considering a specific solar flux constant of S=1350 W/m² and a high absorption factor (α= 0.8), the needed primary mirror area results to 703 cm² with a theoretical radius of rp=15 cm.

The closed-loop configuration also introduces the need to remove high heat fluxes from the condenser side. To determine the geometric deviations of the condenser/ radiator system, 49.8 Watt has to be emitted by the radiator (compare Table 4). According to a hint estimate using the heat transition equation and the Boltzmann equation a total radiator area of 1508 cm² (theoretical radius of 21 cm) is needed. Table 4 summarizes all required and calculated values for the MTG Module.

Category	Calculated Value		Category	Calculated Value
Electrical Power (System output)	10.3 Watt		Area of primary mirrc	703 cm²
Generator power (η=0.7)	14.7 Watt		Absorptions factor rec	0.8
Turbine power (η=0.7)	21 Watt		Radius of primary mir	15 cm
Feed pump power (η=0.7)	0.286 Watt		Shadow factor	0.02
Thermal gross power (turbine)	21.3 Watt		Average temperature r	548 K
Primary mirror power	95 Watt		Area of receiver	10.4 cm²
Power receiver (from cycle proces	70 Watt		Radius of receiver	1.8 cm
Power loss receiver (from radiatic	4.3 Watt		Area of heat dissipatio	15 cm²
Power radiator (from cycle proces	-50 Watt		Average temperature r	306 K
Mass flow Toluene	100 mg/sec		Area of radiator	1508 cm²
Specific solar flux (concentraded)	67500 W/m²		Radius of radiator	21 cm
Concentration factor C	50			

Table 4. Summarized values of calculated values and technical facts of the Micro-Turbine-Generator (MTG-Module)

Efficiency factor for the MTG-Module, considering the previous assumptions and the geometrical design (703 cm² of primary mirror) and a power output of 10.3 Watt results to η=10.85 % (solar-to-electrical efficiency). The comparing solar cell alternative (same area of 703 cm², triple junction, EOL conditions, working temperature T=100°C) has a solar-to-electrical efficiency of η=18.7 % (Schubert, 2006).

6. Conclusions

The principle of MTG-Modules reveals a huge development potential not only for space application but also for terrestrial regenerative energy conversion. Nevertheless, several arguments have to be examined carefully in order to evaluate the potential of the MTG-Module. Until now, the module cannot compete with the solar-static principle (solar cell). The efficiency factor as calculated in the previous chapter is by a factor of 1.72 lower than the efficiency factor of the competing system (solar cell, triple junction, EOL conditions, T=100°C) (Schubert, 2006). But while the needed cell area for the solar cells increases linear with the required power output most of the MTG area is non-imaging-mirror. These mirrors are relatively easy to produce and therefore low-priced.

Management of two-phase flow in a closed micro system comes with its own set of challenges. Achieving complete evaporation (droplet-free) and superheating before the vapor enters the turbine are critical. The condenser has a similar technical challenge, with the requirement of preventing vapour from entering the pump. Also the heat transition between the condenser and the passive hot tube system of the radiation dome has to be evaluated in more detail. Especially, the difficulties to establish a constant heat sink only by radiation might be a source for future problems. In addition to it, the radiator has a bigger area than the primary mirror so that a modular design requirement is difficult to fulfil although the use of radiation domes was considered.

A successful development of highly integrated systems, such as the Micro-Turbine-Generator (MTG-Module), requires acceptable operation of all involved components. Manufacturing tolerances, simplified components models, and two-phase flow physics in micro gravity environment are examples of potential sources of variability that can affect a future development program.

For a dynamical system with rotating parts requires high translational speeds and therefore high frequencies. This in turn implies that such parts will be highly stressed. Therefore, the components have to be a high degree of robustness in mechanical design and manufacture. It also limits material choices to those capable of carrying the loads. Nevertheless, from a system level point of view the MTG-Module has several pros & cons that are summarized as follows:

Pros:

- No power loss due to temperature dependency and shifting Maximum Power Point (MPP) like for solar cells
- Thermal buffer system also provides necessary thermal energy during eclipse phases => battery mass reduction
- Most of MTG area is a "non-imaging-mirror", which can be produced at little cost
- No danger of hot-spots, as they typically occur at solar cells
- Theoretical efficiency factor is the Carnot efficiency factor
- Advantageous overall energy balance during production process compared to solar cells
- In general: MTG-Modules can also be used for terrestrial applications within the regenerative energy industry

Cons:

- By now the theoretical efficiency factor is lower than for solar cells
- Difficulties of two-phase flow systems in micro gravity environment
- Moving parts
- The potential mass will be higher than for solar cells
- Fluid consistency cannot be determined by now
- Radiator is bigger than the collector system => mutual radiation effects for panel use

7. Acknowledgement

Presently (by end of 2010) the subject is under review of the System Analysis Group (SARA) at the German Aerospace Centre (DLR) Bremen, Germany. Future research work will create general concept and design work

8. References

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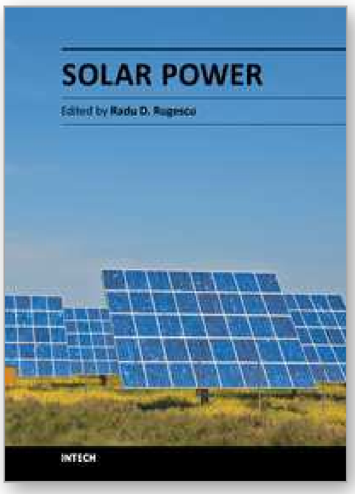

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A wide variety of detail regarding genuine and proprietary research from distinguished authors is presented, ranging from new means of evaluation of the local solar irradiance to the manufacturing technology of photovoltaic cells. Also included is the topic of biotechnology based on solar energy and electricity generation onboard space vehicles in an optimised manner with possible transfer to the Earth. The graphical material supports the presentation, transforming the reading into a pleasant and instructive labor for any interested specialist or student.