FIRST RESULTS OF A TURBO GENERATOR TEST FOR POWERING THE HV-SOLENOIDS AT A RELATIVISTIC ELECTRON COOLER

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Abstract

One of the challenges in a relativistic electron cooler is the powering of high voltage exceeding 2 MV and the powering of HV-solenoids, which sit on different high potentials within a high voltage vessel and need a floating power supply.

In this report we present the turbo generator "Green Energy Turbine" (GET), an assembly of a turbine and a generator, as a possible candidate for powering e.g. the HV-solenoids and give an overview over the future road map.

INTRODUCTION

For the successful realisation of many experiments in the field of hadron physics, it is essential to keep the emittance constant by counteracting the emittance blow up e.g. due to scattering experiments. One possibility to prevent the emittance from increasing is the electron cooling technique [1], which will be used for example at the High Energy Storage Ring (HESR) at GSI/FAIR to permit high energy antiproton experiments [2]. The HESR has a circumference of 575 m and can operate in two modes, the "High Luminosity" (HL) and "High Resolution" (HR) mode. Some experimental demands are summarised in Table 1 [3].

Table 1: Experimental Demands of the HESR

	HL	HR
Momentum range	$1.5 - 15\ \frac{\text{GeV}}{\text{c}}$	$1.5 - 9\ \frac{\text{GeV}}{\text{c}}$
Peak luminositiy	$2 \cdot 10^{32}\ \frac{1}{\text{cm}^2\text{s}}$	$2 \cdot 10^{31}\ \frac{1}{\text{cm}^2\text{s}}$
Momentum resolution	$\frac{\Delta p}{p} = 10^{-4}$	$\frac{\Delta p}{p} = 10^{-5}$

To meet these requirements for the high resolution mode, magnetised electron cooling with a 4.5 MeV, 1 A electron beam is necessary.

An option for the HESR is an upgrade to the Electron Nucleon Collider (ENC), which allows experiments with polarised electrons and protons [4] and needs magnetised electron cooling as well. In that case, an 8 MeV, 3 A electron beam is needed.

In order to solve critical technical issues, the Helmholtz-Institut Mainz (HIM) promotes collaborations with other Institutes such as Forschungszentrum Juelich (FZJ), Budker Institute of Nuclear Research Novosibirsk (BINP SB RAS), Russia and Lehrstuhl fuer Technische Thermodynamik und Transportprozesse (LTTT), University Bayreuth. One of the challenges is the powering of HV-solenoids, which are located on different electrical potentials inside a high voltage vessel, which is why they need a floating power supply.

Because conventional solutions e.g. pelletron or cascade transformers, are limited [5, 6], an alternative concept to achieve a high voltage of 8 MV and a current of 3 A is necessary. Within a design study, BINP SB RAS has proposed two possibilities to build a power supply in a modular way. The first proposal is to use two cascade transformers per module. One cascade transformer powers 22 small HV-solenoids, the second one should generate the acceleration/deceleration voltage for the electron beam. The cascade transformers themselves are fed by a turbo generator, which is powered by nitrogen under high pressure that could be generated outside of the high voltage vessel. The second possibility is to use two large HV-solenoids per module, which are composed of four small coils. In this proposal, the HV-solenoids are powered directly by a turbo generator [7]. Both concepts have in common that they need a suitable turbo generator which delivers a power of 5 kW. A research for proper turbo generators has identified the Green Energy Turbine (GET) from the company DEPRAG as a potential candidate [8]. At HIM, two GET were bought and tested.

GREEN ENERGY TURBINE

The turbo generator Green Energy Turbine (Figure 1) is an assembly composed essentially of a turbine and a generator.

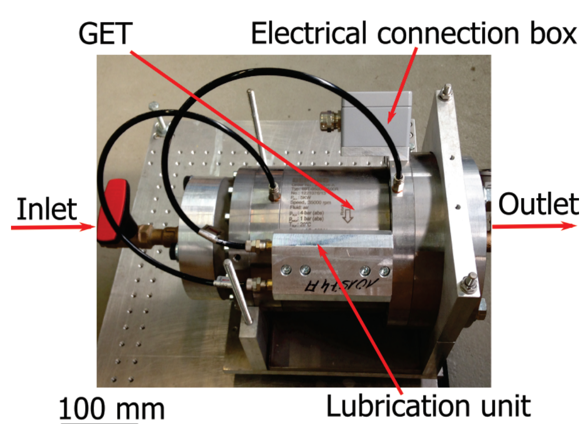

Figure 1: The turbo generator Green Energy Turbine (GET) with a pressure resistent lubrication unit.

The compressed working gas, in our case dry air, enters the GET on the inlet side and is expanded through a nozzle. The resulting accelerated air drives a turbine, which in turn drives

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a generator. After the expansion, the air is diverted around the generator and leaves the GET on the outlet side at normal pressure. The generator is connected in delta configuration, which generates three-phase current. The turbine and the generator are supported by ball bearings, which need a small amount of fresh lubricant in regular operation. Therefore a pressure resistant lubrication unit is mounted at the GET, which allows to inject small amounts of lubricant in regular intervals. Our long term tests indicate that is necessary to use 300 mm^3 of fresh lubricant every 1000 hours. The used lubricant is stored in special containers which are cleaned during maintenance, so that the contamination of the driving air is minimal. The GET itself should work for the typical time for one production run at the HESR which is of the order of nine month without maintenance. Further properties of the GET are listed in Table 2. .

Table 2: Properties of the GET

Property	Value
Power	5 kW
Revolution speed	35000 min^{-1}
Pressure (in)	4 bar
Pressure (out)	1 bar
Mass Flow	$4\ \frac{\mathrm{m}^3}{\mathrm{min}}$
Pressure condensation point	−20°C
Voltage phase to phase	263 V
Current	12 A
Norminal frequency	583 Hz

TEST MEASUREMENTS OF THE GET

In order to characterise the GET, different measurements with two turbo generators were done at HIM. A sketch of the test set-up is shown in Figure 2. A buffer tank is filled by a

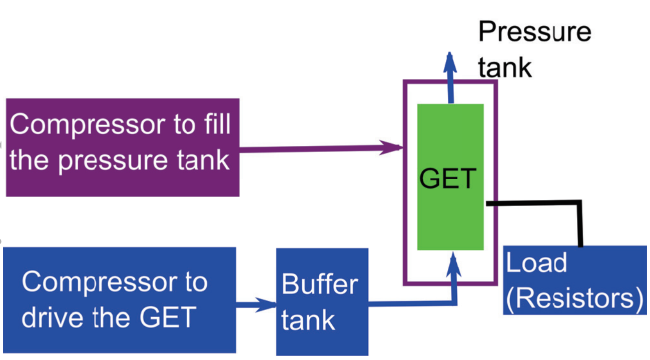

Figure 2: Test set-up at HIM for characterising the GET. Inside the buffer tanks heaters are installed for heating the pressurised air before it enters the turbo generator. The heaters are powered by the GET itself.

compressor, which consumes a power of 40 kW to generate compressed air at 4 bar (abs) and an airflow of 4 $\frac{\mathrm{m}^3}{\mathrm{min}}$. To reduce condensation (from the ambient air) after the expansion within the turbo generator, the air in the buffer tank is heated. In the regular operation, the turbo generator is located within a high voltage vessel at a pressure of 10 bar (abs). For tests, the GET is mounted in a pressure tank, which can be filled with air up to 11 bar (abs), as load resistors are used. Figure 3 shows the measurement of the DC power as function of the revolution speed for both tested GETs and two different loads.

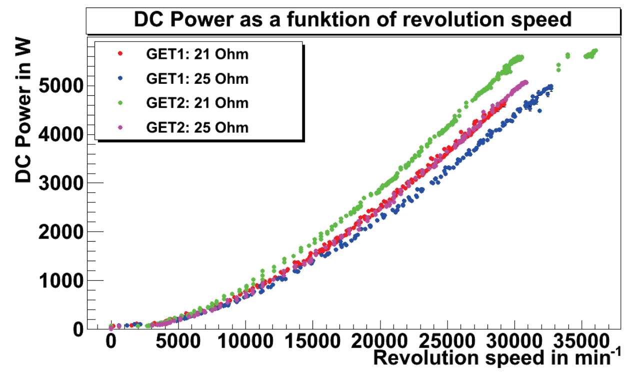

Figure 3: Measurement of the DC power as function of the revolution speed for both GET and different loads.

The measurements show that it is possible to generate the needed power of 5 kW within the limits of the GET, but the characteristics of both turbo generators differ a little. The outlet temperature of the air for a load of 25 Ω is presented in Figure 4.

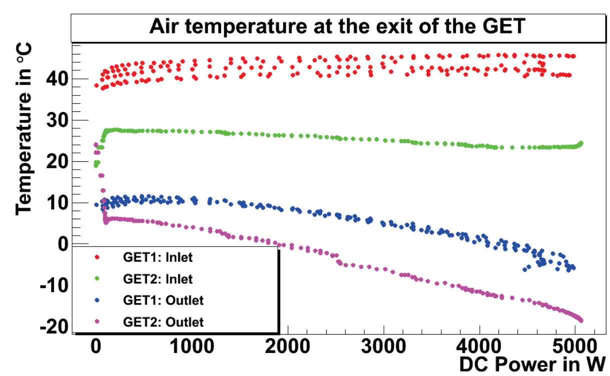

Figure 4: Air outlet temperature as function of the DC power for a load of 25 Ω. The temperature drop of the air after the expansion is in the order of 50 K.

For both turbo generators, the drop of the air temperature is in the range of (50 ± 5)°C, which means that the expanded gas could in principle be used for the cooling of the HV-solenoids.

Another important point is the pressure resistance of the turbo generator. It must be ensured that no sulphur hexafluoride may penetrate into the turbo generator. To test whether gas can penetrate into the GET, the pressure in the pressure tank was raised to 10 bar (abs). Because of leaking instrumentation feedthroughs in the pressure tank the air blew of slowly, which can be seen in Figure 5. A different way to

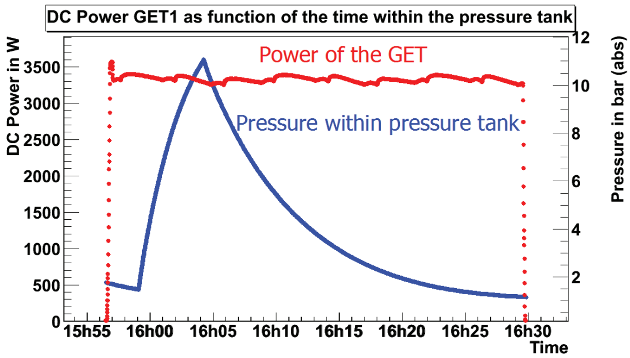

Figure 5: Power of GET1 as a function of the pressure within the pressure tank. Due to the fact that the pressure inside the GET (which is mounted in the set-up) cannot be measured directly, the power of the GET for different pressures was measured, because it decreases if air passes into the turbo generator. In several measurements, no drop in the performance was observed.

test the pressure resistance is to fill the turbo generator itself with air up to 11 bar (abs) and to measure the pressure inside the GET. It was done with the second turbo generator, which is not installed in the set-up currently. During a week, no pressure drop inside the GET was measured. As a result it can be stated that the Green Energy Turbine is pressure resistant and that leakage of SF_6 into the turbine driving gas will be minimal.

FURTHER ROAD MAP

Both turbo generators were successfully tested at HIM, so that both can be sent to BINP SB RAS this year, where they will be implemented in a test set-up for powering HV-solenoids. After completion of the set-up, which serves to demonstrate floating powering of components at very high static potentials, the device will be sent to HIM and installed later [7]. Furthermore, two more turbo generators are in development, one which works with pure nitrogen in a closed circuit and another which has gas bearings instead of ball bearings. A modification of the test set-up at HIM for the module from BINP SB RAS is in preparation. In this set-up, the GET will operate in a closed nitrogen circuit and a SF_6 environment.

The previous idea to drive the turbo generator with sulphur hexafluoride will not be pursued at the moment, because we have not been able to identify a commercial compressor system for Sulphur hexafluoride which would offer attractive operating conditions. After gaining experience with the 600kV nitrogen-turbine driven prototype at HIM we will define the necessary steps how to extend the capabilities into the multi MV range.

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