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Measurement of SK-Ecat performance in a series of sessions from October 20 to November 19 2021.

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Abstract

As part of the contract between the Department of Physics and Leonardo Corporation have been carried out some measurements of the performance of an SK-Ecat prototype (henceforth called prototype A) during a three hours period. A second and different prototype (henceforth called prototype B) was also tested, during a subsequent measurement session. This technical report contains the results of the measures done on those prototypes and should be used in the internal R&D process of Leonardo Corporation and does not constitute an industrial certification.

1 Introduction

The prototype A under review (See figure 1) was looking like a cube of 150 mm side containing a light source and connected to a reflective pyramid, 600 mm high, which conveys light to a solar panel, measuring 500x330 mm, and some control sensors located at the base. A careful inspection of the apparatus verified that the entire structure was practically empty and weighed no more than 2kg. During operation a very intense blue light was emitted from the top and illuminated the solar panel and sensors at the bottom. According to the contractor, the solar cells are high-efficiency multi-layer cells with an energy yield of 40% and are particularly suitable for the light spectrum of the light source.

Prototype B had a completely different look and seemed to be a technological development of the first one.A small white box with a square base with side 7 cm and 9 cm in height was superimposed on another silver parallelepiped, with base 9 x 7 cm and height 2. Some wires entered in the upper part and two groups of cables, red and black came out of the lower one. The weight of the whole prototype B was about 250g. In the case of prototype B, it was not possible to inspect the inside, but it was observed that during operation, cold white light came out of the base.

Both prototypes were connected to several control electronics boards that were powered by a grid-connected power supply.

Wires from the solar panel (in case of prototype A) or otherwise outgoing from the system (in case of prototype B) were connected directly to a load resistor cooled in an insulating oil bath. The load resistor was a commercial type model "Arcol 21.10 GB HS 150 1 R J".[8]

2 Measures

The measurements that were made involved the power input and output from the system. Input power was measured directly from the 220V 50Hz outlet using an industrial power meter. Output power measurements were made using a high-precision FLUKE 189 multimeter. [4] A second multimeter, with a lower accuracy was used occasionally for checking and gave results perfectly compatible with the first one. The first measurement that was made was the actual value of the load resistance.

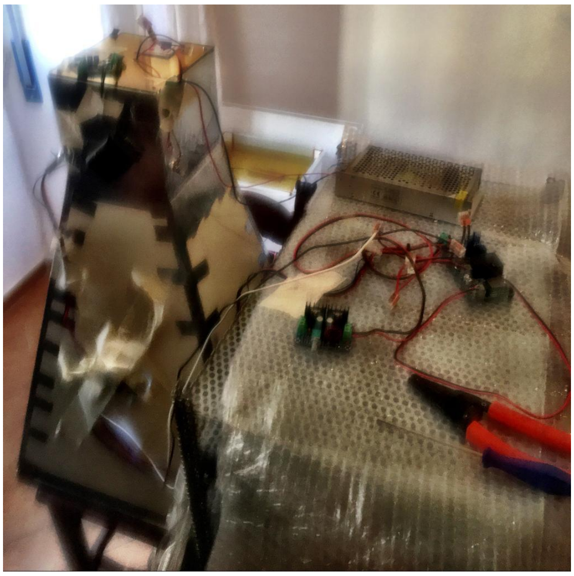

Figure 1: Image of the SkEcat prototype A.

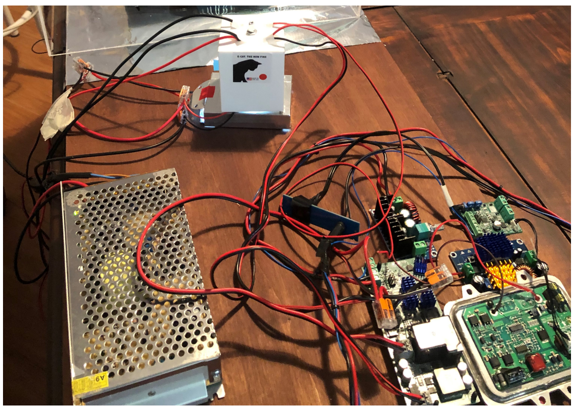

Figure 2: Image of the SkEcat prototype B with the control electronics and the power supply.

Measure	Value	Unit
Cables resistance	0.4	Ω
Total resistance	1.4	Ω
Load resistance	1.0 +/- 0.2	Ω

Table 1: Measure of the load resistance a value of 1Ω that matches the nominal value of the resistor. The same resistance was used in in both tests.

Given the low value of the load resistance it was decided not to introduce an ammeter in series to the circuit in order not to affect the experimental conditions. From the measurement of the voltage drop at the resistor terminals the current and power dissipation can be easily obtained.

The input power, measured using an industrial wattmeter[5], was measured first by disconnecting the apparatus from the power supply and then with the apparatus on so that losses due to the power supply could be subtracted. In the case of prototype A this measurement led to evaluate the absorption of the system at the value of $1.1W$ while in the case of prototype B the net absorption was too low to be measured.

During the functioning of the apparatus the wattmeter has always been in operation reporting a constant power absorption. The potential drop at the ends of the resistor was measured

Measure	Value	Unit	Cos Φ
No-load power	0.2	W	0.06
Power in operation	1.3	W	0.08
Net power	1.1 +/- 0.2	W	

Table 2: Measurement of the power absorbed by the Prototype A.

Measure	Value	Unit	Cos Φ
No-load power	0.8	W	0.05
Power in operation	0.6	W	0.06

Table 3: Measurement of the power absorbed by the Prototype B. The power was too low to be measured by the industrial wattmeter used. Considering the precision of the wattmeter used the two values are compatible.

continuously throughout the measurements for a period of three hours in case of prototype A and for about six hours in case of prototype B.

A small potential drop at the ends of the resistor was measured even with the apparatus turned off. This phenomenon was caused by ambient light filtering through the reflective cone. The observation of this signal was further confirmation that the measured voltage was originating from the solar panel in case of prototype A and from a photosensitive component.

3 Radiation Measurements

In addition to the measurements of power produced, in a subsequent session (19-11-2021), measurements of possible emission of ionizing radiation were also carried out.

A LUDLUM 2241-3[6] counter coupled to a model 44-9[7] detector was used for the measurement. In addition to this, a GQ portable personal counter model GCM500+ was also used which has the ability to log data as a function of time.

The GQ counter was turned on about 50 minutes before arriving to the laboratory and remained on until you moved away from the lab. The LUDLUM meter was turned on in the lab before turning on the reactor so as to measure the background radiation at the site.

Before turning on the reactor the first thing done with both instruments was a background radiation count. The measurement was done several times obtaining values (with the LUDLUM rate meter) from 118 to 160 counts per minute with the reactor off. Placing the detector next to the reactor (see 3) and turning it on did not show any statistically significant increase in counts with values reading from a minimum of 117 up to a maximum of 168. The values obtained by the GQ counter were smaller because of the smaller area of the sensor but even in that case no significant difference was seen with the reactor on or off.

In conclusion in this data taking session there was no significant evidence of ionizing radiation emitted by the SK-Ecat.

Measure	Value	Unit
Voltage drop (11.50)	9.96	V
Voltage drop (13.20)	9.99	V
Voltage drop (14.50)	9.97	V
Off Voltage	≈ 0.18	V

Table 4: Voltage drop at the resistor leads for Prototype A. The value was almost constant during the measure period. Three data points are reported. The instrument precision was 1mV. The small potential difference with the apparatus powered off was originated by the ambient light.

Measure	Value	Unit
Voltage drop (11.10)	11.4	V
Voltage drop (11.50)	11.6	V
Voltage drop (12.15)	11.7	V
Voltage drop (14.32)	11.7	V
Voltage drop (16.02)	11.7	V
Voltage drop (17.12)	11.7	V
Off Voltage	≈ 0.12	V

Table 5: Voltage drop at the resistor leads for Prototype B. The value was almost constant during the measure period. Six data points are reported. The instrument precision was 1mV. Also in this case a small dependence of the measure on the ambient light was noted.

4 Final considerations

This report collects the results of measurements conducted over multiple sessions from October 20 to November 19, 2021.

The prototypes under examination seem to generate a power of about 100W while absorbing only 1W or less. The origin of the emitted power is unknown to the author of this report.

The current density originated from the solar panel appears to be $\approx 6.1mA\ cm^2$ that is a well below the reported maximum current density for commercial ($\approx 35mA\ cm^2$) and laboratory ($\approx 42mA\ cm^2$) solar cells. In case of prototype B by doing the ratio of areas the current density rating ($\approx 158mA\ cm^2$) far exceeds that of any known solar panel. As it appears from the measurements made a total of $\approx 624Wh$ of energy was produced by prototype B. Noting then that the total volume is $567cm^3 = 0.563L$ and the total weight is about 250g it can be found that the energy density of the prototype seem to exceed the gravimetric and volumentric energy densities of known batteries[9].

No significant emission of ionizing radiation from Prototype B was detected during measurements performed on November 19, 2021.

5 Possible program of research and development

In this section we define a sketch of a possible research and development program for the examined technology, highlighting its potential. The considerations we will make are to be considered preliminary and conservative with respect to possible real developments and are based on the measurements that have been made.

Assuming, very conservatively, that there are no further developments in the underlying technology, we can calculate the possible energy produced by a set of devices mounted in standard IEC-60297 racks. The typical dimensions of such a rack are a minimum usable width of 17.75 inches a depth of 36 inches and a height of 42 or 45 "Rack Units" (U) where 1U is equal to 1.75 inches. Each rack plane have a usable horizontal area of $\approx 45x88cm$.

Assuming to arrange the SK-ECAT units, with the same basic dimensions of the prototype B, one next to the other, each plane could contain 54, with a vertical occupation of 3U (13 cm).

So based on the current measurements every 3U we would have the production of 5.4kW; 15 such units can fit in a 45U rack with a total power per rack of about 81kW. Already from these figures we see that a single 3U unit could provide enough power to power an entire rack of servers that on average draw around 4kW. Other units could be dedicated to power the cooling systems.

For larger applications we can imagine installing generator racks in containers, which would then become easily transportable and installable modules. A standard container has internal dimensions of 12 x 2.35 and 2.39 h meters and therefore can accommodate up to 38 racks with a possible total

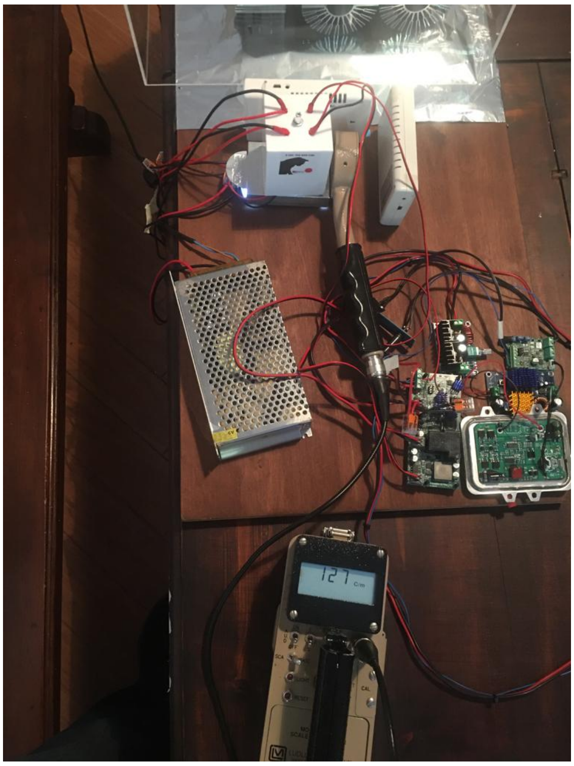

Figure 3: The setup with the Ludlum detector next to the reactor. Behind it the withe GQ logger. No correlation with the switching on or off of the SK-Ecat is visible in the data.

power of about 3MW. This figure can be compared to the power of nuclear reactors for marine applications ranging from about 90MW (27 containers) up to 345MW (115 containers).In both cases, the volume occupied, the lower weight and a substantial simplification of the system would perfectly justify this type of application.

We also note that since the power of a railway locomotive ranges from 3 to 9MW these applications also appear possible.

It is not necessary that the sizing of the reactors is always calculated on the maximum power that can be delivered by the system. The simultaneous use of modules for continuous energy production and accumulators could make the system more compact.
The study of future applications should include these starting points:

- A complete I V characterization of the single module in order to identify the conditions of maximum transferred power and fill factor (see e.g. [1]);
- A study of the uniformity of the characteristics of the individual cells constructed;
- A study of the constancy of individual module characteristics as a function of time and environmental conditions;
- A an experimentation of the interconnection of different modules (see e.g. [2]);

From the engineering point of view, the mechanics will have to be optimized to make it robust,compact,light and able to dispose of any excess heat.

The interconnection between the various elements could be guaranteed by carbon fiber printed circuits that can also perform the function of mechanical support and have a good thermal conductivity.

Improved performance and a lightweight structure could also lead to aviation applications. [3]

A more detailed research program, with implementation goals, Gantt chart, quality control and budget can only be realized with the agreement of the Inventor Andrea Rossi.

Declaration of no Conflict of Interest

The author declares that there is no potential conflict of interest or any relationship of a financial or personal nature with any person, firm, or organization that would inappropriately influence the conduct and results of this work.

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