LI-ION ACCUMULATORS SYSTEM FOR AIRPLANE DRIVE

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Abstract: This paper deals with the drive description of the accumulators system that will be used in the airplane VUT 051 RAY. This modular system consists of 3060 Li-ion accumulators Panasonic NCR18650A. Nominal voltage of each accumulator is 3.6V and nominal capacity is 3Ah. The Battery block monitoring board is introduced in this document. The next, some measured results of constant current discharging are presented.

Keywords: Li-ion accumulator, Battery monitoring

1. INTRODUCTION

Recently, Lithium-ion (Li-ion) accumulators has better capacity/weight ratio of all accumulators types. Due to this fact, they could be successfully used for some mobile applications, because these applications need high accumulated energy with maximally low weight – for example automotive industry or aerospace.

Following chapters present the Li-ion accumulators system (includes a monitoring system) that is designed as an energy source for the airplane VUT 051 RAY. DC-line (the *Battery*), composed of this kind of accumulators, will feed mainly a synchronous motor (about 50kW) through a power charger. Similar projects of electric airplanes are HK36 Super Dimona, Antares DLR H2, ENFICA-FC (see lit. [1]).

2. DESCRIPTION OF LI-ION ACCUMULATOR PANASONIC NCR18650A

The Li-ion rechargeable accumulators Panasonic NCR18650A consists of a spiral structure with 4 layers. A positive electrode is activated by cobalt acid lithium; a negative electrode is activated by special carbon. A separator is put together in a whirl pattern and stored in the case. It also incorporates the variety of safety protection systems such as a gas discharge valve which helps prevent the accumulator from exploding by releasing internal gas pressure [2].

The next safety system of these accumulators calls Heat Resistant Layer (HRL). This layer is connected between the cathode and the anode of accumulator by the Figure 1. HRL creates temperature-dependent resistor (posistor). When the accumulator is discharged by high current (for example thanks short-circuit), the HRL resistance is so high that the accumulator stops to give current to the circuit and due to this fact the accumulator temperature decreases spontaneously. This action happens when the layers temperature is about 80°C.

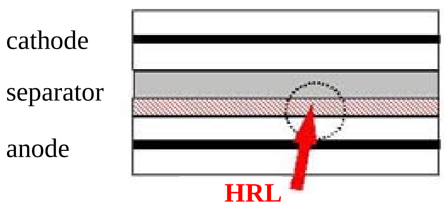

Figure 1: Position of Heat Resistant Layer (HRL) [2].

For this application, each accumulator is equipped by an external NTC thermistor for temperature measuring. The thermistor must be fixed on the positive pole side because this pole is hotter during discharging. This fact is shown on the next figure:

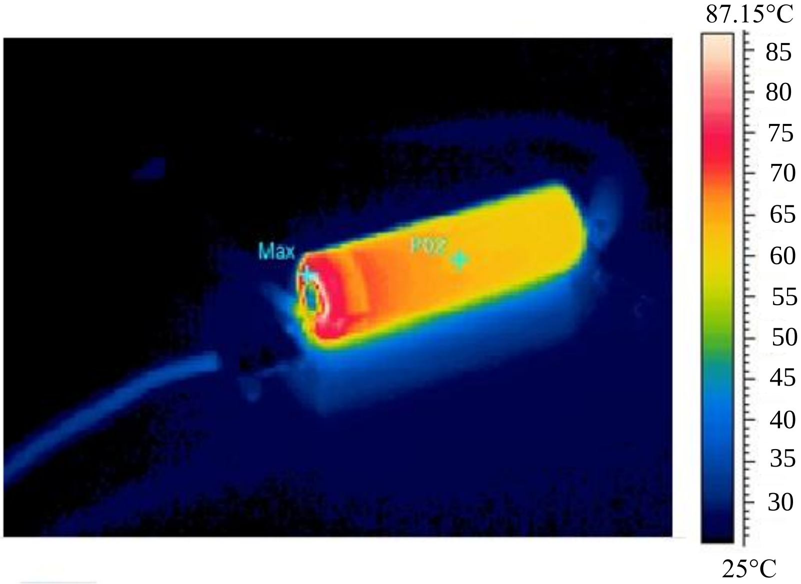

Figure 2: Thermo-figure of accumulator during discharging [3].

3. BATTERY DESCRIPTION

As it was written earlier, the feeding DC-line of drive for the airplane is designated the *Battery*. The following table presents some basic parameters of the *Battery* compared with the same parameters of particular Li-ion accumulator Panasonic:

Parameter	**Panasonic NCR18650A**	**Battery**
Nominal voltage [V]	3.6	324
Maximal voltage [V]	4.2	378
Nominal capacity [Ah]	3	102
Mass [kg]	0.0455	150 (only accumulators 140)
Maximal current [A]	6	204

Table 1: Table of some basic accumulator and *Battery* parameters.

The *Battery* is modular system of Li-ion accumulators and it is consisted of following subgroups:

Battery = 6 × *Battery pack* = 30 × *Battery block* = 3060 × accumulator Panasonic

a) BATTERY BLOCK

The *Battery block* is the group of 102 (3 × 34) pieces of the Li-ion accumulators Panasonic NCR18650A. These accumulators are connected in series-parallel by the Figure 2a). The voltage levels are measured at each parallel combination of the accumulators.

Every accumulators of the *Battery block* are fixed between two four-layer PCBs – Positive and Negative pole. Consequently, these PCBs have the connecting reason and the holding reason. Each

Battery block has own Battery block monitoring board that controls special parameters (more in 4th chapter).

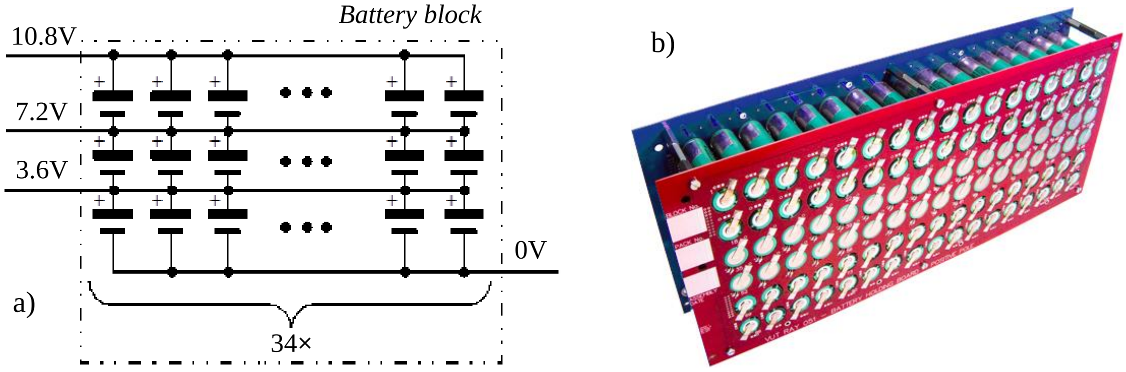

Figure 3: *Battery pack*. a) Connecting scheme of accumulators. b) Illustration photo.

b) BATTERY PACK

The *battery pack* is the five pieces group of *Battery blocks* connected in series. These units will be mounted behind a pilot's cockpit into two panels. Six pieces of the *Battery packs* create the *Battery* (complete DC-line of drive).

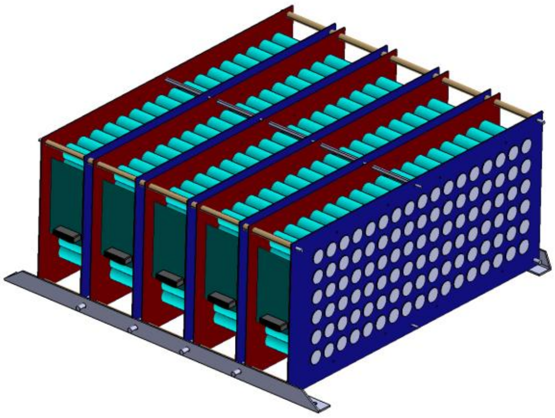

Figure 4: *Battery pack* model [3].

4. BATTERY BLOCK MONITORING

Battery block monitoring computer is included at each *Battery block*; hence the *Battery* contains 30 pieces of the computers. The monitoring system is controlled by the processor Freescale DSP MC56F8036. *Battery block* monitoring boards are four-layer PCBs. The figure 5a) shows the placement of the monitoring PCB.

The primary functions of the monitoring computers:

- Temperature measuring of each accumulator by NTC thermistors (tree multiplex structure)
- Voltage measuring of each parallel accumulator combinations (Figure 3a))
- Balancing circuits controlling during charging of the *Battery*
- Saving of maximal temperatures and measured voltage levels to an external FLASH memory
- Communication with a main computer through CAN bus by the CANaerospace protocol

Monitoring computers has in CAN protocol following emergency messages:

- Exceeding of allowed temperature for each accumulator
- Non-allowed over-voltage level for each parallel combination of accumulators
- Non-allowed under-voltage level for each parallel combination of accumulators

In the case of incorrect processor function, the monitoring PCB is equipped by an analog safety circuit that watches the voltage level of each *Battery block*. In the case of over-voltage or under-voltage level, the analog safety circuit sends an error message directly to the main computer.

An active balancing circuit works during the charging of the accumulators. The capacity difference of individual accumulator's series can be caused either by accumulator's parameters dispersion during their production or by their aging that it is caused by their working. Each parallel combination of the accumulators is equipped by the active balancing system (see [4]) that reduces the danger of weak accumulator overcharging. This system enables to equally distribute energy between each accumulators connected in series.

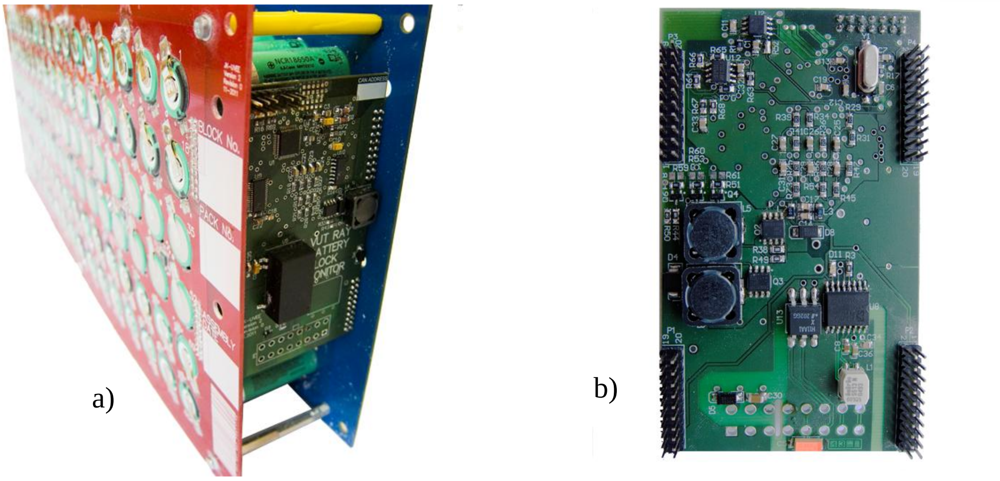

Figure 5: Battery block monitoring PCB. a) Top side – Location on *Battery block*. b) Bottom.

5. MEASUREMENT OF DISCHARGING

Discharging of the *Battery block* was performed by constant current 116A (3.4A per one accumulator). This current level is equivalent to current load during horizontal flight of the airplane. Capacity 102Ah were discharged from *Battery block*. Measurement finished when the voltage level of some parallel accumulator group was lower than 2.7V. Additional cooling was not used for temperature reducing. Ambient temperature before the measurement was 23°C.

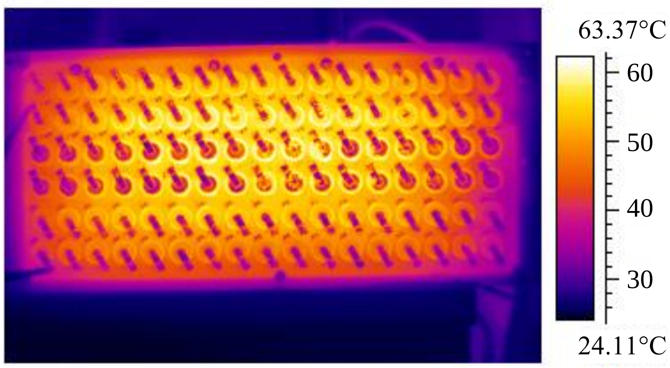

Figure 6: Thermo-figure of *Battery block* during discharging by constant current 106A.

Figure 6 describes *Battery block* temperature in the end of discharging. The warmest accumulators are at the second horizontal line from the top side because warm air moves up. Accumulators at the edge of the *Battery block* are cooled by ambient air. The point of maximal temperature has 62.37°C. It is clear, that *Battery* need to be equipped by flowing air.

Figure 7 shows typical discharging curves measured at each parallel accumulator group of *Battery block*. From the graph, it is apparent that some curve start to decrease critically when voltage is lower than approximately 3V (accumulator is discharged).

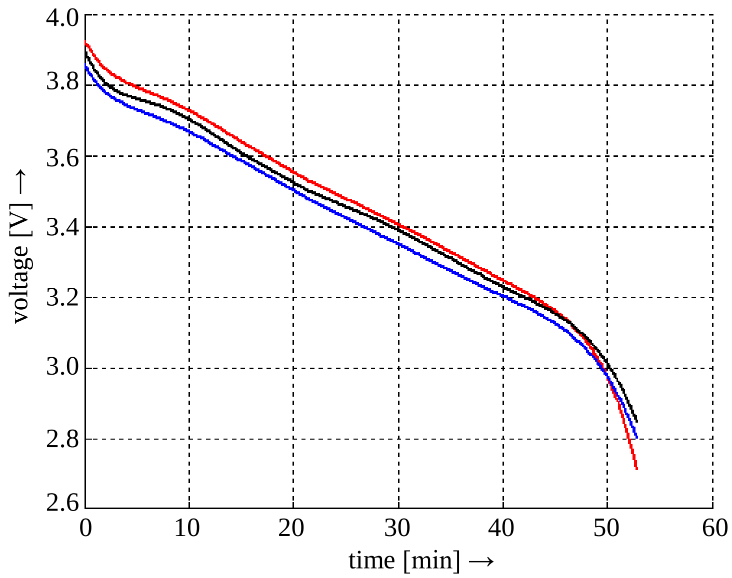

Figure 7: Discharging curves (constant current 106A).

6. CONCLUSION

The measuring results shows power dissipations at Li-ion accumulator Panasonic NCR18650A cause quite serious warming. Due to this fact the accumulators will have to be cooled by flowing air.

The next work will be focused for measuring of maximal current load (204A) and mechanical tests. All *Battery packs* could be mounted into the airplane after performing of all necessary tests.

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