AiMT Advances in Military Technology
Vol. 7, No. 1, June 2012

Workplace for Performance Testing of Energy Accumulators for Electric Devices

J. Sadil[*] and M. Leso

Department of Control and Telematics, Faculty of Transportation Sciences, CTU in Prague, Czech Republic

The manuscript was received on 21 September 2011 and was accepted and was accepted after revision for publication on 23 February 2012.

Abstract:

For electric devices with critical requirements on energy, performance parameters and characteristics of their accumulators are very important and desirable to know. Automated workplace within the Department of Control and Telematics, Faculty of Transportation Sciences at Czech Technical University in Prague (CTU FTS) established in 2010 is able to perform both short-term and long-term testing of electric accumulators performance. The workplace is introduced in Chapter 2, Chapter 3 presents HW and SW solution of the workplace and an example of results for $LiFeYPO_4$ *accumulator is finally shown in chapter 4.*

Keywords:

Energy accumulators, electrical measurement, automation, automated measurement, education, long-term testing.

1. Introduction

Devices with power supply independent on power grid are experiencing dynamic development recently. Significant component of these devices is their energy accumulator. Although parameters of accumulators improve over the time, they still constitute a restriction of device performance.

Based on identified performance parameters of accumulators, it is possible to know the most important properties of the whole device concerning operation. In case of electric and hybrid electric vehicles, the accumulator is crucial component concerning traction, operation and cost aspects.

Therefore it is meaningful to test the performance of accumulators alone. For that purpose, automated workplace for performance testing of electric accumulators has been established at Czech Technical University in Prague, Faculty of Transportation Sciences.

---

[*] *Corresponding author: Department of Control and Telematics, Faculty of Transportation Sciences, Czech Technical University in Prague, Konviktská 20, 110 00 Praha 1, Czech Republic, phone: +420 224 359 568, fax: +420 224 359 545, E-mail: sadil@fd.cvut.cz*

The reason for establishing such a workplace is in supporting both contemporary faculty projects, such as “Faculty Railway”, and newly established master study program “Electromobility”. But application of such is wider and can be certainly found in military area as well.

2. Scope of Testing of Accumulators

The workplace is able to test automatically both short-term and long-term performance of electric accumulators. Every type of electrochemical accumulators and supercapacitors can be tested here. Both measured and computed data are saved to internal data files with defined sample period, which allows consecutive processing.

Special emphasis is placed on the safety of measured accumulator. Every accumulator is supposed to be performed in the voltage interval defined by producer of the accumulator. When some of measured parameters (upper/lower voltage, temperature, current) exceeds the defined interval, the testing process is stopped.

Furthermore, temperature of accumulator surface is monitored and it is possible to define the maximum temperature of testing. When exceeding that temperature, the measurement can be interrupted.

Finally, there is an independent electrical circuit, which monitors the activity of a control PC. If the control PC stops generating verification signal, then all devices are disconnected from the power supply, so that the accumulator will remain in the open-circuit mode.

2.1. Description of Testing Workplace

Principle scheme of testing workplace can be seen in Fig. 1.

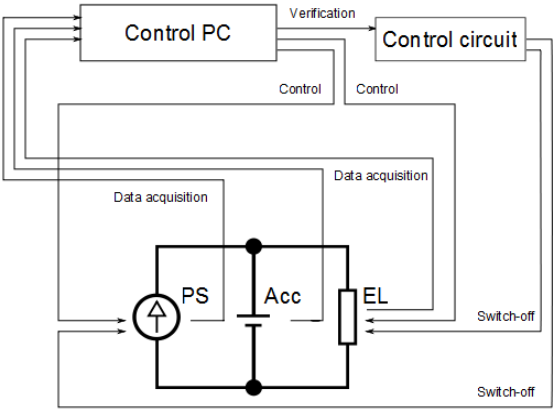


Fig. 1 Scheme of testing workplace [authors]

Thick lines represent the measured circuit, thin lines represent the control and data processes. Devices in the circuit have the following meaning:

- PS ..... power supply,
- Acc ... measured accumulator,
- EL ..... electronic load.

The workplace can be seen in the photograph in Fig. 2.

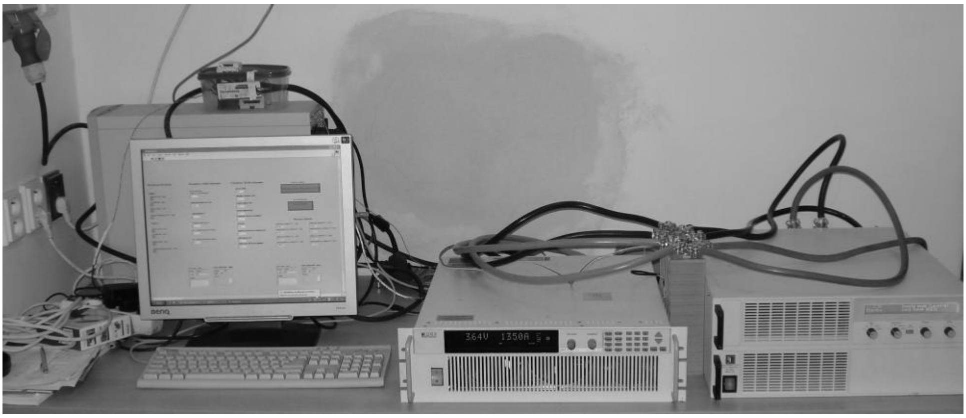


Fig. 2 Workplace for testing accumulators in Prague, Konviktská 20

2.2. Parameters of One Partial Cycle

Several parameters of testing are stated in this chapter. At first, we mention general ones:

- Sample period T_S (s) for data acquisition.
- System for assigning names to data files.

When discharging the accumulator, following parameters can be changed due to application:

- Nominal discharge current I_{DisN} (A).
- Minimum voltage of accumulator U_{Min} (V).
- Depth of discharge DOD (%).
- Maximum acceptable temperature ϑ_{Max} (°C).
- Time delay after discharging TD_{Dis} (s).

When charging the accumulator, following parameters can be changed due to application:

- Nominal charge current I_{ChN} (A).
- Maximum voltage of accumulator U_{Max} (V).
- Minimum charge current I_{ChMin} (A).
- Maximum acceptable temperature ϑ_{Max} (°C).
- Time delay after charging TD_{Ch} (s).

2.3. Procedure of One Partial Cycle

Let us assume, that the accumulator is fully charged when the testing begins. Both power supply and electronic load are connected in parallel to the accumulator, but both of them are switched off. One partial cycle is then thought as one discharging followed by one charging of the accumulator.

Discharging then runs as follows. Accumulator starts to discharge immediately by the defined current I_{DisN} by switching the electronic load on (power supply stays switched off). Data is stored in a data file with the defined sample period T_S. We find actual values of the following quantities in the data files:

- Temperature on accumulator surface ϑ_S (°C).

- Voltage of accumulator U_{Acc} (V).
- Voltage of electronic load U_{EL} (V). The voltage difference U_{Acc} - U_{EL} (V) represents voltage drop in wires.
- Discharge current of accumulator I_{Dis} (A).
- Discharge power of accumulator P_{Dis} (W).
- Discharge power of electronic load P_{EL} (W).
- Energy discharged from accumulator during one time sample W_{Dis1S} (Ws).
- Total energy discharged from accumulator during discharging $W_{\mathrm{Dis\Sigma}}$ (Ws).

Defined discharging runs then until one of the following conditions is fulfilled:

- Total energy discharged from accumulator during discharging $W_{\mathrm{Dis\Sigma}}$ is greater than the energy corresponding to the defined depth of discharge *DOD*.
- Measured voltage of accumulator U_{Acc} is less than minimum voltage of accumulator U_{Min}.
- Measured temperature on accumulator surface ϑ_{S} is greater than maximum acceptable temperature ϑ_{Max}.

Depending on the desired depth of discharge, discharge current, state of the accumulator etc., either the first or the second of the above-mentioned condition is applied. The third condition is used rather in a case of emergency.

When the discharging is finished, electronic load is switched off and after the elapse of a time delay after discharging TD_{Dis}, the charging process starts.

Charging then runs as follows. Accumulator starts to be charged by the defined current I_{ChN} by switching the power supply on (electronic load stays switched off). Data is stored in a data file with the defined sample period T_{S}. We find actual values of the following quantities in the data files:

- Temperature on accumulator surface ϑ_{S} (°C).
- Voltage of accumulator U_{Acc} (V).
- Voltage of power supply U_{PS} (V). The voltage difference $U_{\mathrm{PS}} - U_{\mathrm{Acc}}$ (V) represents voltage drop in wires.
- Charge current of accumulator I_{Ch} (A).
- Charge power of power supply P_{PS} (W).
- Charge power of accumulator P_{Ch} (W).
- Energy charged to accumulator during one time sample W_{Ch1S} (Ws).
- Total energy charged to accumulator during charging $W_{\mathrm{Ch\Sigma}}$ (Ws).

The defined charging runs in CC (constant current) mode, as long as the voltage of accumulator U_{Acc} is less than the maximum voltage of accumulator U_{Max}. When the voltage of accumulator U_{Acc} reaches the value of U_{Max}, then charging mode is changed to the CV (constant voltage) mode with the set voltage U_{Max}. In that mode, the charge current of accumulator I_{Ch} decreases in time.

Charging is then finished, if one of the following conditions is fulfilled:

- The charge current of accumulator I_{Ch} is less than defined value of minimum charge current I_{ChMin}.
- Measured voltage of accumulator U_{Acc} is greater than the maximum voltage of accumulator U_{Max}.
- Measured temperature on accumulator surface ϑ_{S} (°C) is greater than maximum acceptable temperature ϑ_{Max}.

The first of the above-mentioned condition is usually applied. The second and the third ones are applied rather in a case of emergency.

When the discharging is finished, then after the elapse of a time delay after charging TD_{Ch}, the next discharging process starts.

2.4. Procedure of Capacity Test

The procedure of accumulator capacity test is in general the same as the procedure of any other cycle. The difference is that the value of *DOD* is not used. In that case, the accumulator will be fully discharged and the discharging is finished by the condition of minimum voltage of the accumulator. Next charging procedure charges the accumulator fully again.

It is possible to set the value of discharge and charge current for capacity test different from the values of discharge and charge current of common cycles.

2.5. Procedure of Long-term Testing

Long-term testing is considered as a defined number of series of the following processes:

- Defined number of partial cycles described in chapter 2.3.
- Defined time delay before the test of capacity to equilibrate to ambient temperature.
- One test of capacity described in Chapter 2.4.

Depending on the desired parameters of long-term testing, it is clear, that in range of today parameters of accumulator, some long-term testing can take quite a long time. Some lifetime test can take months or even year of time.

3. HW and SW Solution

The Above-mentioned performance testing described in Chapter 2 is covered by the following HW and SW solution.

3.1. HW Solution

In this chapter, the most important devices used for testing are stated.

A6KW device is used as power supply. It is a programmable power supply with maximally 20 V, 300 A, 6000 W. Internal sensor of this device is also used for the measurement of current during charging and for the measurement of voltage of power supply.

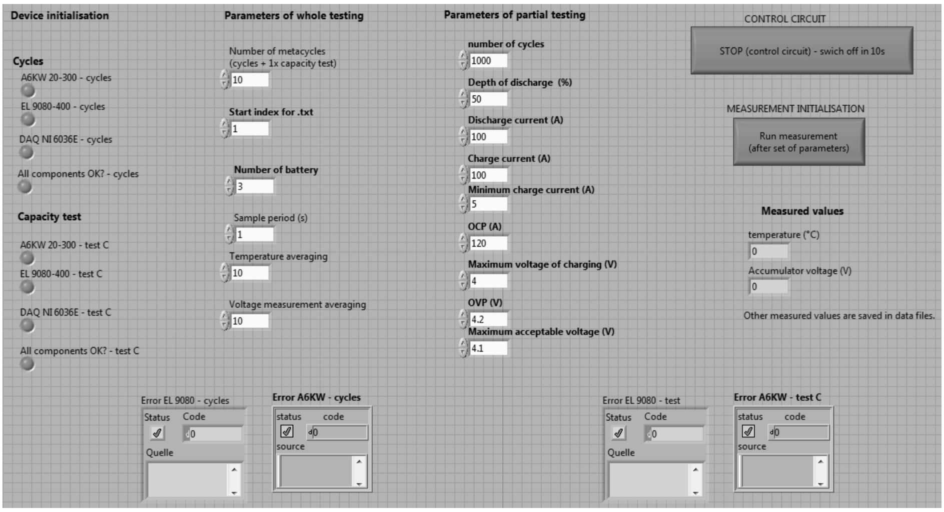
EL-9080-400 device is used as electronic load. It is a programmable electronic load with maximally 80 V, 400 A, 4800 W. Internal sensor of this device is also used for the measurement of current during discharging and for the measurement of voltage of electronic load.

NI 6036E is a 16-bit PCMCIA DAQCard used for the measurement of voltage of accumulator, for the measurement of temperature (in cooperation with temperature sensor SMT 160) and for the generation of verification signal for control circuit.

3.2. SW Solution

Labview is used as SW for the complex process of testing, which involves entering of parameters, devices control, data acquisition, managing data files, etc. Times sequenced structure of discharging, waiting and charging is combined with while-cycle loops to reach required amount of cycles.

Front panel of application for long-time testing can be seen in Fig. 3.



Number of metacycles (cycles + 1x capacity test): 10
Start index for .txt: 1
Number of battery: 3
Sample period (s): 1
Temperature averaging: 10
Voltage measurement averaging: 10

number of cycles: 1000
Depth of discharge (%): 50
Discharge current (A): 100
Charge current (A): 100
Minimum charge current (A): 5
OCP (A): 120
Maximum voltage of charging (V): 4
OVP (V): 4.2
Maximum acceptable voltage (V): 4.1

temperature (°C): 0
Accumulator voltage (V): 0

Other measured values are saved in data files.

Status ☑ Code 0
status ☑ code 0
Status ☑ Code 0
status ☑ code 0

Fig. 3 Front panel of SW used for testing [authors

4. Results of Testing

In this chapter, some results of testing carried out in the above-described testing workplace are shown. Fig. 4 shows discharging characteristics. Accumulator is discharged with a constant current of 135 A and the voltage is decreasing. Fig. 5 shows computed electric power and discharged energy of the accumulator during the discharging shown in Fig. 4.

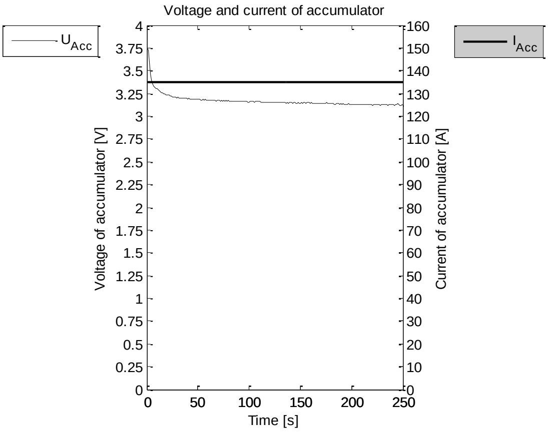


Fig. 4 Voltage and current during discharging of accumulator 90 Ah LiFeYPO4 after 13000 cycles of 10% depth under 35 °C

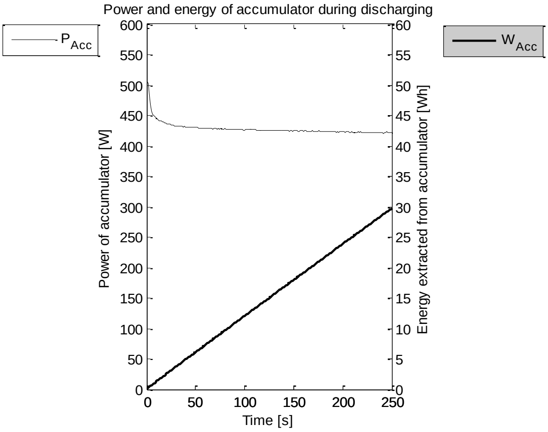


Fig. 5 Power and energy during discharging of accumulator 90 Ah LiFeYPO4 after 13000 cycles of 10% depth under 35 °C

Fig. 6 shows charging characteristics. Accumulator is charged with a constant current of 135 A, the voltage is increasing. When the voltage reaches the maximal value of 4.0 V, the current has to be lowered appropriately. Fig. 7 shows computed electric power and charged energy of the accumulator during the charging shown in Fig. 6.

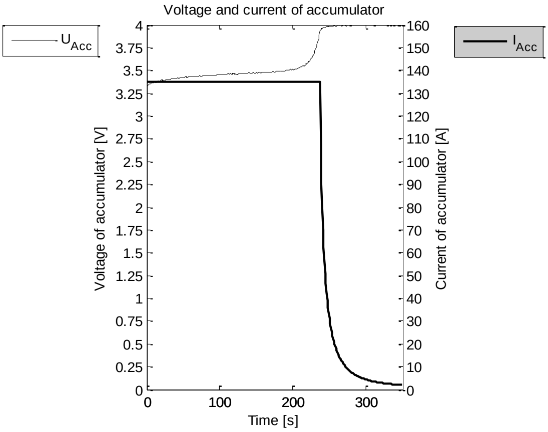


Fig. 6 Voltage and current during charging of accumulator 90 Ah LiFeYPO4 after 13000 cycles of 10% depth under 35 °C

An Example of results is summarized in the following table.

Tab. 1 Summary of example results - accumulator 90 Ah LiFeYPO4 after 13000 cycles of 10% depth under 35 °C

I [xC]	ϑ [°C]	W_{Out} [Wh]	W_{In} [Wh]	η [%]
1.5	35.0	29.6	32.4	91.4

Symbol η represents the efficiency of the process of discharging and charging back. The efficiency of partial cycle is very high in comparison with previous common technologies (Pb, NiCd).

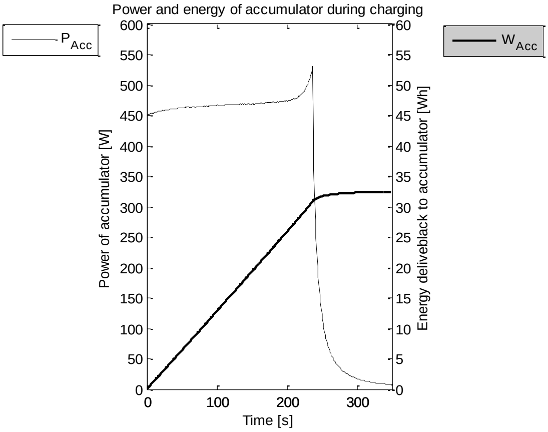


Fig. 7 Power and energy during charging of accumulator 90 Ah LiFeYPO4 after 13000 cycles of 10% depth under 35 °C

When concerning new application of accumulator with unknown parameters, we recommend long-term testing of one or a couple of cells to know the life cycle of future accumulator battery (pack) in advance.

5. Conclusion and Further Plans

The workplace for the complex performance testing of electric accumulators within Czech Technical University in Prague, Faculty of Transportation Sciences, has been introduced in this paper. Because accumulators are still the weakest component of present electric devices with independent power source, especially electric and hybrid electric vehicles, such workplace is very useful to learn about the operation and life of proposed electric vehicle or device in advance. It is possible to test not only electrochemical accumulator, but for example supercapacitors as well.

With present equipment, it is possible to perform any thought operation (cycling) of electric accumulators including long-term testing at our workplace. We are also able to measure temperature during testing. Possibility of temperature control is desirable for future. Then we would be able to test accumulators in different climatic environment. So we consider purchase of oil bath to extend the workplace to reach this aim.

References

[1] VOTRUBA, Z. et al. *Předpokládané trendy rozvoje elektrických a jiných alternativních pohonů v osobních automobilech* (*Presumed trends of development of electrical and another alternative drives of passenger cars*) [Research report CTU FTS LSS 374b/2009]. Prague: CTU FTS, 2009.

[2] CETL T. *Aplikace elektrochemických zdrojů* (*Application of electrochemical power sources*), Prague: CTU FEE, 2004.

[3] *PCE Power Control* (manufacturer of A6KW device) [on line] [cited 2011-02-15]. Available from: <http://www.pce-powercontrol.de>.

[4] *Elektro-Automatik* (manufacturer of EL-9080-400 device) [on line] [cited 2011-02-15]. Available from: <http://www.elektroautomatik.de>.

[5] *National Instruments* (information about used DAQ card) [on line] [cited 2011-02-15]. Available from: <http://sine.ni.com/psp/app/doc/p/id/psp-138/lang/en>.

Acknowledgement

This research has been realized using the support of Technological Agency, Czech Republic, programme Centres of Competence, project No. TE01020020 of the Josef Božek Competence Centre for Automotive Industry. This support is gratefully acknowledged.