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Intelligent System for Temperature Control of Li-Pol Battery

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Abstract

The article presents the most used types of rechargeable stand-alone power supplies, trends in the control of the state of the most common of them - Lithium-Polymer Rechargeable Batteries (LPRBs) during their work, especially when using the latter for powering unmanned aerial vehicles (UAV). The necessity of such control for the qualitative result is showed. In this work, for the first time studied is the possibility of two-parameter diagnostic and controlling the lithium-polymer accumulators used in unmanned aerial vehicles. The aim of study was developing of a new method for non-destructive testing and diagnosing the Li-Pol accumulators that took to account fact that electrochemical processes are accompanied by heat phenomena. We were using thermal imaging method for study heating and cooling of battery in process of its work for establishing connection between temperature and degree of discharging of battery. Being based on experimental investigations, the authors found the one-valued dependence between the chosen LPAB parameters (output voltage and internal temperature) and residual time for battery operation. With account of this relation, to diagnose the state of the battery during the drone flight one can perform the first diagnostic test of new LPAB before the flight, and the obtained individual characteristics that will be recorded to the drone memory and further used to come to the necessary decisions of ceasing or prolonging the drone operation. Investigations on the temperature phenomena of Li-Pol batteries are a new scientific and practical direction, which may allow not only to create control systems, but also to improve the batteries themselves.

Keywords

Thermal Imager, Non-Destructive Control, Lithium-Polymeric Rechargeable Battery, Unmanned Aerial Vehicle

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1. Introduction

All modern facilities that belong to the sphere of high technologies - computer equipment, telecommunication systems, medical portable diagnostic as well as remedial-and-prophylactic devices, up-to-date transportation systems use rechargeable stand-alone power supplies (RSPS) accumulators. Especial topicality to control and diagnose the state of accumulators arises in the case of small-size drones that are widely used for monitoring the ambient medium as well as for many purposes of modern life. If the accumulator is used in the body of some portable facility, there can arise a serious problem to lose all acquired information after discharging the accumulator, or the drone can fall down and be destructed by reason of this discharge. Therefore, it is very important to make a special diagnosis of the accumulator state in advance and to determine its residual charge after preceding

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operation to conclude about fall-safe return of the drone (command “go home”).

Today, the majority of drone producers practice the so-called “fixed-time flights”, when the user beforehand knows the time, during which the accumulator is capable to provide qualitative fulfilling the work, and these data are taken into account when planning the flight [1, 2]. But for wide application and implementation of drones, it is not suitable to test the battery for determining the flight period. Besides, in the cases when meteorological conditions are sharply changed, there arises the problem with fast discharging the accumulator, and the drone will not be able to perform the set task and even meet with an accident. It means not only ecological and economical waste but loss of important information, especially in conditions of war actions. Another side of this problem is that the accumulator loses its capabilities and considerably shortens its life span under excess discharge or permanent incomplete discharge [3].

With account of the mentioned above, the methods for fast estimation of the RSPS state are based on the characteristics obtained indirectly from the analysis of parameters that can be rather promptly measured. The values of measured parameters enable to estimate the technical state and predict the value of backup and nominal capacities inherent to this accumulator battery.

It is natural that the methods aimed at control and estimation of the RSPS state should be non-destructive, energy saving or with small energy expenses. It is desirable to possess smart diagnostics within the shortest period. All the considered diagnostic parameters of RSPS can be measured in a unified form during such a procedure [4-9].

Idea to develop a new method for non-destructive testing and diagnosing the Li-Pol accumulators was in that electrochemical processes are accompanied by heat phenomena. Therefore, using the up-to-date highly sensitive thermal imager or contact matrix temperature sensors can serve as a base for achieving the set purpose.

The accumulators based on lithium are the most often used in drones as power supplies. The decisive factors for these supply elements are not only their portability (i.e., small dimensions and mass) but high reliability and long operation life, too. Nowadays, the most perfect constructions of accumulator power sources are based on lithium-polymer accumulators that are widely used and called-for today. They possess very low velocity of self-discharge (approximately 3 to 5% during the first month, then this velocity decreases down to L..3°% per month. In addition, near 3% is consumed by the control circuit). Besides, having the same dimensions, the lithium power sources have the triply increased life span as compared with Ni Cd accumulators, and the memory effect is not absolutely observed in them. Due to the absence of liquid electrolyte, they are more safety in use. Li-Pol accumulators are compact and can be used in any configuration [10].

It was the main reason that just Li-Pol accumulator batteries (LPAB) used in drones became the object for investigations. Up-to-date LPABs have good specific characteristics. The amount of their charge/discharge operation cycles reaches 500 and more. The absence of liquid electrolyte makes these accumulator power sources more safety than those of previous generations.

However, when using LPAB the following situations must be excluded:

a) excess currents of charge or discharge;

b) short circuit;

c) recharge of accumulators at the levels higher or lower than the standard one;

d) exceeding the maximum accessible value of the accumulator temperature.

Ignoring these requirements can cause emergency. And for drones, it is extremely dangerous, because failure in the supply system immediately involves the crash of drone, which leads to losses of not only economic ones (i.e., the very drone) but all gathered information as well. It can be absolutely undesirable in conditions of war or anti-terroristic operations.

It is this reason that causes the necessity to provide permanent monitoring the state of LPAB during its operation and to control the level of residual energy (i.e., the residual charge) with the following estimation of the possibility to prolong the flight [11].

In the process of charging the accumulator, electric energy is transformed to the chemical one, and the system is in equilibrium up to the moment when even very low current flow takes place between electrodes [12-14]. When a consumer of choosing the temperature as a controlled parameter in LPAB. Its changes tightly bound with the processes occurring in the accumulator. As the second controlled parameter, the potential difference on the accumulator contacts was chosen, the value of which directly indicates changes in the residual capacity of LPAB.

2. Main Body

2.1. Research Significance

Search and development of smart non-destructive methods to control and diagnose lithium-polymer accumulators for drones will considerably expand possibilities of applying the drones in diversity of life spheres, namely: agriculture, aerial monitoring the Earth surface, providing the help in extraordinary situations, fulfilling the military tasks, and so on. Application of these methods will enable to make a great step to provide drones with the so-called “artificial intelligence”, that is will deliver drones from the necessity of a land operator that co-ordinates their operation. Consequently, it will enable to realize full automation of this system. This approach will provide considerable advantages in using the drones under conditions of the absence of controlling signals from the land. It means that the drone will get a definite task and during its fulfillment will make a decision of the following actions: to prolong or stop performing the task. It will allow to considerably shorten the economic expenses and to minimize cases of drone losses as a result of LPAB discharge.

2.2. Experimental Investigation

In this work, offered the idea of two-parameter controlling the state of LPAB during its operation in the body of drone.

As the first tested parameter, the voltage at the LPAB output was chosen. Its value allows estimating the current state of the battery in the following manner: the obtained voltage value is compared with the dot on the accumulator discharge characteristic (obtained at the initial testing or from the certificate data). In accord with its position, the system itself draws the conclusion of possibility to prolong or stop the task fulfillment.

As the second tested parameter, the temperature of the very battery was chosen. This choice was based on rather high sensitivity of accumulator to the temperature mode of operation. It is well known that lithium accumulators operate due to red-ox reactions that are inevitably accompanied by heat releasing. Besides, polymers in LPAB are influenced by a sharp temperature drop (which is typical for winter flights of drones). Both these facts allow stating that the temperature of the battery can indicate the period of its following operation.

2.3. Experimental Investigation

As the test-object, took the lithium-polymer accumulator battery produced by the firm Zippy Compact with the capacity 1500 mAh.

To provide the necessary real load on LPAB to correctly study its behavior in the process of testing it within the circuit of a prototype (Figure 1) used also the following facilities:

a) collector free motor KINGKONG 2204-2300KV;

b) regulator for these motors HobbyKing 12A BlueSeries Speed Controller;

c) servo-tester TL2638 CCPM;

d) multi-tester for measuring the voltage UNi-T UT50D (20v±0.01v);

e) thermal imager EasIR-4 with the accuracy of temperature measurements ±0.1°C.

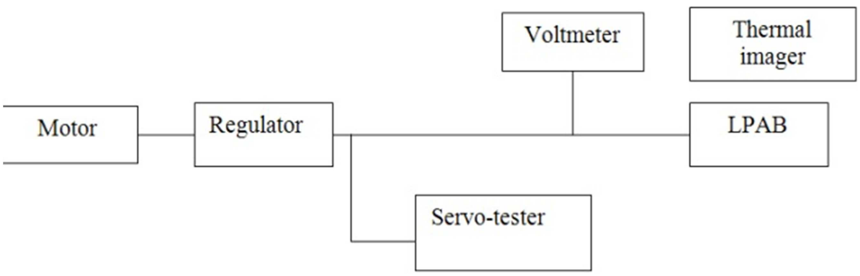

Figure 1. Block scheme for controlling the LPAB discharge during operation of the battery in the body of a drone.

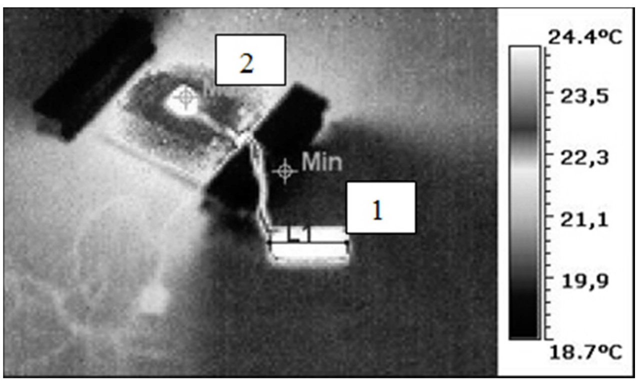

Figure 2. Results of temperature analysis for the studied prototype by using the thermal imager. 1 - accumulator battery that supplies the motor 2.

To control the temperature, used the thermal imager, since it enables to observe the distribution of temperature over the surface of the investigated object (Figures 2 and 3), which is very important for preliminary studying the temperature changes during LPAB operation.

This investigation was realized in the following manner. The servo-tester was adjusted to its extreme position, and the stand began to work with the maximum load on the motor at room temperature. Every minute, multi-tester voltage values were fixed in a table. Simultaneously, the LPAB temperature was fixed using the thermal imager. The experiment was carried out up to the full stop of the motor, i.e., when LPAB was fully discharged. These analyses were performed ten fold for each value of the external temperature that, as known, influences most of all on the character of discharge processes and can sharply change during the battery operation cycle.

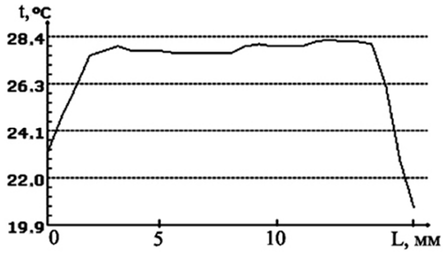

Figure 3. Plot for temperature distribution along the line L1 (see Figure 2) on the surface of LPAB.

2.4. Analytical Investigation

As a result of investigations, obtained the plots for dependences of the LPAB temperature on duration of stand operation (Figure 4) and LPAB discharge characteristics (Figure 5). One can see that at the initial stage LPAB shows self-heating, then the temperature decreases due to lowering the power of battery.

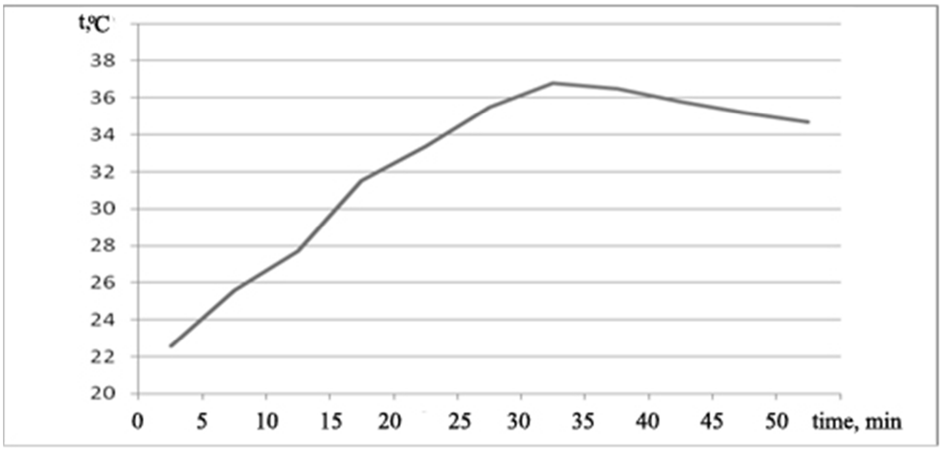

Figure 4. Plot for the LPAB temperature dependence on duration of stand operation.

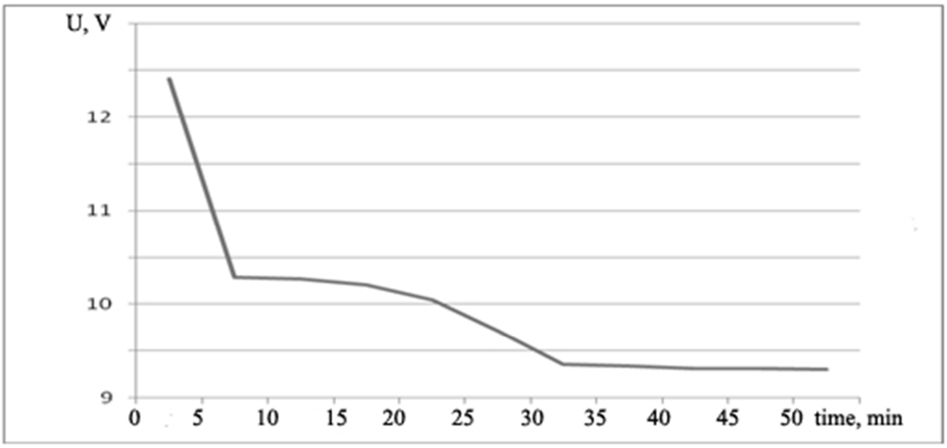

Figure 5. Plot for the LPAB discharge characteristic.

2.5. Comparison of Predictions and Experimental Results

As seen from the above plots, both chosen parameters are rather informative. They show that LPAB actively discharges for the first 6...7 min (when work duration of the studied battery is 10 min) and further it simply keeps the minimum necessary voltage level. And it is in this moment the temperature of accumulator begins to fall (as compared with the previous stage of heating).

3. Discussion of Results

Using the offered technique, one can perform the first diagnostic test of a new LPAB before the drone flight, and the obtained individual performances of accumulator will be recorded to the memory of drone for further decisions during this flight.

In what follows, under drone flight conditions the accumulator temperature can be controlled using remote contact temperature micro-sensors (or their matrix) with the accuracy ±0.2°C [15], and the obtained data should be compared with those of preliminary test-diagnostic. Within the framework of contact measuring the map of temperature distribution over the object surface, they use the thermal transducers of the kind “temperature/electric signal”, which are in direct contact with the chosen part of object.

By its potentialities, this method has some advantages as compared with remote thermography. First of all, it is an essentially lower cost, compactness and availability of a direct contact between the sensor and object. For the great amount of sensors, this contact enables to fix small temperature gradients. Since no intermediate substance is present between the object and thermal detector, the influence of any thermal barriers is eliminated.

When heating the accumulator stops, the system itself (or under participation of a land operator) will be able to draw a conclusion of further actions, taking into account the drone distance from the base point (point of departure) as well as ambient meteorological conditions.

4. Conclusion

In this work, for the first time studied is the possibility of two-parameter diagnostic and controlling the lithium-polymer accumulators used in unmanned aerial vehicles.

Being based on experimental investigations, the authors found the one-valued dependence between the chosen LPAB parameters (output voltage and internal temperature) and residual time for battery operation. With account of this relation, to diagnose the state of the battery during the drone flight one can perform the first diagnostic test of new LPAB before the flight, and the

obtained individual characteristics that will be recorded to the drone memory and further used to come to the necessary decisions of ceasing or prolonging the drone operation.

Investigations on the temperature phenomena of Li-Pol batteries are a new scientific and practical direction, which may allow not only to create control systems, but also to improve the batteries themselves.

References

[1] Kimchi, G., Buchmueller, D., Green, S. A., Beckman, B. C., Isaacs, Sc., Navot, A., Hensel, F., Bar-Zeev, A., Rault, S. S., (2013). Unmanned Aerial Vehicle Delivery System. US Patent 20150120094.

[2] Brar, S., Rabbat, R., Raithatha, V., Runcie, G., Yu, A., (2015). Drones for Deliveries. Pantas and Ting. Sutardja Center for Enterpreneurship&Technology. Berkeley Engineering. 21 p.

[3] Yefimov, O. N., Belov, D. G., Belov, G. P. et al, (1995). New materials for lithium accumulators. Mashinostroitel'. No 3. pp. 24 - 28 (in Russian).

[4] Skundin, A. M., Yefimov, O. N., Yarmolenko O. V., (2002). State-of-the-art as well as prospect for development and investigations of lithium accumulators. Uspekhi khimii. vol. 71, No 4, pp. 378 - 398 (in Russian).

[5] Zou, C., Manzie, C., Nesic, D., (2016) A framework for simplification of pde-based lithium-ion battery models. *IEEE Trans. Control Syst. Technol*. vol. 24, 1594–1609.

[6] Kim, T.; Wang, Y.; Fang, H.; Sahinoglu, Z.; Wada, T.; Hara, S.; Qiao, W., (2015) Model-based condition monitoring for lithium-ion batteries. *J. Power Sources*, vol. 295, 16–27.

[7] Iraola, U., Aizpuru, I., Gorrotxategi, L., Segade, J. M. C., Larrazabal, A. E., Gil, I., (2015) Influence of voltage balancing on the temperature distribution of a Li-ion battery module. *IEEE Trans. Energy Convers*., vol. 30, 507–514.

[8] Hannan, M. A., Lipu, M. S. H., Hussain, A., Mohamed, A., (2017) A review of lithium-ion battery state of charge estimation and management system in electric vehicle applications: Challenges and recommendations. *Renew. Sustain. Energy Rev.* vol. 78, 834–854.

[9] Gao, Z., Chin, Ch. S., Chiew, J. H. K., Jia, J., Zhang, C. (2017) Design and Implementation of a Smart Lithium-Ion Battery System with Real-Time Fault Diagnosis Capability for Electric Vehicles. *Energies*. vol. 10, 1503.

[10] Shcherban, A. P., Larin, V. Yu., (2015) Principles of operation and peculiarities of using the lithium-polymer accumulators. *International scientific journal "Technological audit and reserves of production"*. No 3, pp. 83 - 88 (in Ukrainian).

[11] Svens, P., (2014). Methods for Testing and Analyzing Lithium-Ion Battery Cells intended for Heavy-Duty Hybrid Electric Vehicles. Doctoral Thesis, KTH Royal Institute of Technology, Applied Electrochemistry Department of Chemical Engineering and Technology, SE -100 44 Stockholm, Sweden, 87 p.

[12] Chen, J.-J., Yang, F.-C., Lai, C.-C., Hwang, Y.-S., Lee, R.-G. (2009). A high efficiency multimode Li-ion battery charger with variable current source and controlling previous-stage supply voltage. IEEE Trans. Ind. Electron. vol. 56, N° 7. pp. 2469-2478.(6).

[13] Traub, L. W., (2016). Calculation of Constant Power Lithium Battery Discharge Curves. Batteries, vol. 2, N° 17, pp. 1-7.

[14] Lin, C.-H., Hsieh, C.-Y., Chen, K.-H., (2010) A Li-ion battery charger with smooth control circuit and built-in resistance compensator for achieving stable and fast charging. IEEE Trans. Circuits Syst. I Reg. Papers. vol. 57, N° 2, pp. 506-517.(7).

[15] Venger, Ie. F., Mitin, V. F., Maslov, V. P., Ushenin, Yu. V., Dvornichenko, M. M., Kachur, N. V., Turu, T. A. (2016) Digital contact thermograph. Patent of Ukraine on useful model No 105665 from 25.03.2016, Bulletin No 6/2016.