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Detailed Analysis of Li-ion Batteries for Use in Unmanned Aerial Vehicles

Merve Nur KAYA[1], Zehra URAL BAYRAK[2*]
[1] Department of Avionics, School of Aviation, Firat University, Elazig, Turkey
[1] mervee.nur.kayaa@gmail.com, *[2] zural@firat.edu.tr

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Abstract: With the developing technologies in the aviation, the transition to more electrical systems is increasing day by day. For this reason, research on the development of batteries has accelerated. Nowadays, Lithium ion (Li-ion) batteries are more widely preferred due to their energy-to-weight ratio and advantages such as having a lower self-discharge rate when not working compared to other battery technologies. Batteries convert the stored chemical energy into electrical energy and heat is released as a result of the chemical reactions. The heat released negatively affects the battery's lifespan, charging/discharging time and battery output voltage. The battery must be modeled correctly to see these negative effects and intervene in time. In this way, negative situations that may occur in the battery can be intervened at the right time without any incident.
In this study, the unmanned aerial vehicle (UAV) is powered by Li-ion batteries. It is simulated in Matlab/Simulink environment using the electrical equivalent circuit. A detailed model is created, taking into account temperature, state of charge (SoC), cell dynamics and operating functions. To estimate state of health (SoH) of the battery, resistance values must be known. Resistance and capacity values in the equivalent circuit of the Li-ion battery are obtained with the help of the simulation model. So, the SoH of the Li-ion batteries can be accurately predicted with the results obtained.

Key words: Li-ion, UAV, battery model, simulation.

Li-iyon Bataryaların İnsansız Hava Araçlarında Kullanımı için Detaylı Analizi

Öz: Havacılık alanında gelişen teknolojilerle birlikte daha fazla elektrikli sistemlere geçiş günden güne artmaktadır. Bu sebeple pillerin geliştirilmesine yönelik araştırmalar hız kazanmıştır. Günümüzde, enerji-ağırlık oranına ve diğer pil teknolojilerine kıyasla, çalışmadığı zamanlarda kendi kendine daha düşük deşarj oranına sahip olması gibi avantajları bulunmasından ve diğer pil türlerine göre çevreye daha az zarar vermesinden dolayı Lityum iyon (Li-iyon) bataryalar daha yaygın olarak tercih edilmektedir. Bataryalar, depoladığı kimyasal enerjiyi elektrik enerjisine dönüştürürler ve reaksiyon sonucunda ısı açığa çıkar. Açığa çıkan ısı bataryanın kullanım ömrünü, şarj/deşarj süresini ve batarya çıkış gerilimini olumsuz olarak etkilemektedir. Bu olumsuz etkileri görebilmek ve zamanında müdahale etmek amacıyla, bataryanın müdahale edilebilecek düzeyde modellenmesi gerekmektedir. Böylece bataryada oluşabilecek arıza durumlarında, doğru zamanda ve herhangi bir olay yaşanmadan müdahale edilebilecektir.
Bu çalışmada insansız hava aracının (İHA) gücü Li-iyon piller ile sağlanmaktadır. Li-iyon pilin elektriksel eşdeğer devresi kullanılarak Matlab/Simulink ortamında benzetimi yapılmıştır. Sıcaklık, şarj durumu, hücre dinamiği ve çalışma fonksiyonları dikkate alınarak pilin ayrıntılı bir modeli oluşturulmuştur. Pilin sağlık değerini tahmin etmek için direnç değerlerinin bilinmesi gerekir. Li-iyon pilin eşdeğer devresindeki direnç ve kapasite değerleri gerçekleştirilen model yardımıyla elde edilmiştir. Elde edilen sonuçlar sayesinde Li-iyon pillerin sağlık durumu doğru bir şekilde tahmin edilebilecektir.

Anahtar kelimeler: Li-iyon, İHA, batarya modeli, benzetim.

1. Introduction

The energy needs of modern life are rapidly diversifying and expanding with constantly developing technology and increasing mobility. Many applications, from electric vehicles to portable devices, are increasing the demand for a reliable and efficient energy storage solution. In this context, battery technologies have become an indispensable element of modern life by forming the basis of energy storage systems [1].

Mathematical modeling of batteries plays a critical role in the design and optimization of energy storage systems. These models are used to understand the battery's electrochemical behavior, charge/discharge processes, and performance under various operating conditions. In particular, Li-ion batteries stand out with their advantages such as high energy density, lightness, low self-discharge rate and long life. Therefore, effective modeling of Li-ion batteries is a critical step in the advancement of energy storage technologies [2].

Some of the studies in the literature on modeling Li-ion batteries are given below.

Hlinka et al. [4] carried out a study and modeling of the charging process of Li-ion batteries. The charging process was examined to compare long-term stored Li-ion batteries with new Li-ion batteries. Charging data has been obtained experimentally through long-term tests.

* Corresponding author: zural@firat.edu.tr. ORCID Number of authors: [1] 0009-0009-1707-5360, [2] 0000-0001-8249-0063

Afraz et al. [5] investigated a compact thermal management model in Li-ion battery packs, especially for Tesla Model S vehicles. It is a study to increase the efficiency and safety of Li-ion batteries for electric vehicles. It is found that major factors such as the decharge rate (C) value of the battery and the initial liquid temperature have a significant impact on the battery temperature and maximum temperature difference. This study provides valuable results for the design and analysis of battery thermal management systems.

Ozdemir et al. [6] extensively investigated the electrical and thermal behavior of Li-ion batteries under normal and abuse conditions. A detailed sensitivity analysis was performed by developing an electrochemical-thermodynamically coupled model. Thermal and electrical properties of the Li-ion battery were predicted for varying discharge rates at temperatures of 20 and 50 °C.

In the study by Hou et al. [7], health factors that may characterize battery degradation were extracted from charging data in order to accurately predict the health status of Li-ion batteries in real time and ensure the safe operation of the relevant equipment. Correlations between health factors and battery capacity were analyzed using Spearman and Pearson coefficients.

In a study by Cheng [8], the equivalent electrical circuit of a Li-ion battery cell was examined. Extended hybrid pulse power characterization was designed and implemented to observe the dynamic response of the battery cell in the time domain. The most suitable meta-heuristic-based method to quickly and systematically determine the equivalent electrical circuit parameters of the battery cell was examined.

Mastrogiorgio et al. [9] used machine learning/deep learning to predict the probability of thermal runaway in Li-ion batteries. Three different stages, namely safe operation, critical state of thermal escape and formation of real thermal escape, were determined with the classification approach. Novel convolutional neural networks were used to predict the evolution of heat sources.

Rezk et al. [10] conducted a study stating that the optimal parameter definition of the Li-ion battery model was important to accurately capture battery behavior and performance in electric vehicle applications. They proposed optimal parameter identification with Self-adaptive Bonobo Optimizer, a meta-heuristic optimization algorithm used in electric vehicle applications.

Mavi and Arslan [11] examined the thermal management of an electric vehicle's battery module for waste heat recovery. They used a two-phase flow system to provide a more effective heat transfer in the evaluation of waste heat. In the thermal analysis of the battery module, a parametric study was carried out using computer-aided fluid dynamics for different C values and discharge depths.

Kumar et al. [12] conducted a study to accurately predict the temperature-varying orthotropic thermal properties and volumetric heat production of Li-ion batteries. Temperature-dependent orthotropic thermal conductivities, specific heat and volumetric heat production of a Panasonic NCR18650BD cylindrical battery were estimated using an inverse approach. Experimental measurements were carried out with surface temperatures taken from suitable places on the battery.

Lee et al. [13] proposed a convolutional neural network model to predict the SoH of Li-ion batteries in the early stages of qualification tests. Five different types of convolutional neural network models were developed and these models were used to predict the SoH values of Li-ion batteries. The performance and reliability of the developed models were evaluated under various experimental conditions.

Navas et al. [14] emphasized that batteries that allow storing excess energy from renewable energy sources such as solar and wind are an important component, and a dynamic Li-ion battery model was created. This model is based on an electrical equivalent circuit model.

It is very important to create a correct battery model in systems that need to store electrical energy. For this reason, in this study, a detailed model of the Li-ion battery, which is frequently used in UAVs, is created. It is simulated in Matlab/Simulink environment using the electrical equivalent circuit of the battery. Simulation results are used to examine the effect of battery parameters on the efficiency of the system. This article will especially contribute to researchers working on the modeling, development and future use potential of the Li-ion batteries.

2. Batteries

Cells are storage units that allow us to store energy chemically and then use this stored chemical energy as electrical energy with the help of electrochemical cells. Battery is a cell group formed by combining multiple cells [15].

The properties of the cells, serial or parallel connection status, number of cells and external hardware structure are used to obtain the desired characteristics [15]. Some characteristic features of the batteries, which enable us to store energy and use it at desired times, are needed in order to see their current status, to increase the battery life by ensuring that it operates under operating conditions, and to ensure safe operation against possible adverse events.

The battery is the structure that contains electrolyte, electrode and other components. More than one battery comes together to form a module, and modules come together to form a package [16, 17]. Higher voltage can be obtained by connecting battery packs in series. This means high power with lower current. The high power generated will ensure better performance of the vehicle in which the battery group is used [17].

When current flows through a battery, the potential difference between the ends of the battery as a result of the kinetics of electrode reactions, the free enthalpy of the cell reaction and the change in cell resistance is called voltage [17, 18]. Open circuit voltage is the potential difference between the electrodes of the no loaded battery resulting from its internal resistance [16, 17].

There is a process in which the battery can be used as a result of the chemical and physical deformations it experiences during charging and discharging. The number of complete discharge-charge cycles during this process constitutes the cycle life of the battery [17, 18]. Higher C ratio, extreme temperature and high voltage range affect the cycle life as they affect the battery life [17]. The battery's lifespan is defined as its capacity value, which varies between approximately 500-1000 cycles, without falling below 80% of the initial capacity value. Problems occurring during electrochemical reactions shorten the life of the battery and cause it not to complete the required cycle life [19].

When using batteries, there is a need to determine the remaining energy in order to protect the battery, prevent over-discharge and extend battery life. This uses the SoC to determine the remaining energy and is expressed as 0%, 10%, 100%, etc. 0% corresponds to an empty battery and 100% corresponds to a fully charged battery [17, 20]. Accurate estimation of SoC information required for battery management systems and charging control is difficult and complex due to limited models and parametric uncertainties between models. That's why different methods are used to determine the SoC.

The coulomb counting method and ampere-hour methods use the standard measurement-based estimation approach. Open circuit protection and impedance measurement methods provide a more reliable estimation result. In addition, machine-based methods such as artificial neural networks and prediction logic provide a better estimate of the state of charge by taking non-consumption use into account. However, the prediction processes of these models are offline since the learning processes are very computational [20]. Equation (1) can be used to calculate SoC, which expresses the ratio of remaining capacity to rated capacity [16].

$$SoC = \frac{Remaining\ capacity}{Rated\ capacity} \tag{1}$$

Due to some irreversible chemical reactions occurring within the battery, internal resistance increases and capacity decreases. This causes the performance of the battery to decrease. Therefore, SoH is used to express the remaining useful life of batteries and the extent of aging. It is obtained by comparing the current conditions of the batteries with their initial conditions [17, 21]. It is seen from SoH information that operating the battery outside the recommended operating conditions, experiencing events such as extreme temperatures, overcharging, and overdischarging causes early aging of the battery [17, 22]. Equation (2) can be used to calculate SoH, which expresses the ratio of usable capacity to rated capacity [16].

$$SoH = \frac{Usable\ capacity}{Rated\ capacity} \tag{2}$$

Some types of batteries, which vary according to the chemical structure of the electrode and electrolyte inside, are Lead Acid (Pb-Acid), Nickel Cadmium (Ni-Cd), Nickel Metal Hydride (NiMH), Zebra, Lithium Polymer (LiPo), Lithium Air (Li-Air), Lithium Sulfur (Li-S), Zinc Air (Zn-Air), Zinc Bromide (Zn-Br), Lithium Ion (Li-ion). LiPo, Li-Air and Li-ion are commonly used batteries in the UAVs.

3. Modelling of Li-ion Batteries

The cells in Li-ion batteries, which were commercialized by Sony in 1991, consist of an anode, cathode, electrolyte and separator. These parts help in the production and storage of electricity [23-25]. The anode part, that is, the negative electrode, consists of carbon-based composites (usually graphite) as material and also a copper current collector. The cathode part consists of Lithium Cobalt Oxide ($LiCoO_2$), Lithium Iron Phosphate ($LiFePO_4$) and Lithium Manganese Oxide ($LiMn_2O_4$), which are transition metal oxides that have a lower discharge potential as the electrical capacity density increases. It consists of nickel-based cobalt oxide and also aluminum copper collector. $LiMn_2O_4$ is used in high security applications. But $LiCoO_2$ is widely used as cathode material [26]. The electrolyte consists of Li salt in a non-aqueous solvent [18, 25].

It is of great importance to create an appropriate battery model for the control and optimization of negative situations that may occur in the system [27]. Battery performance and health status can be determined through the created models. While electrical circuit models of batteries provide analytical predictions, chemical circuit models are very complex. There are also mathematical models in which battery parameters are expressed as variables of a mathematical equation [28]. In this study, the electrical circuit model is preferred because it is easier to control and not complicated. While creating the battery model, many subsystems are used to eliminate complexity and is simulated in the MATLAB/Simulink environment. Electrical and thermal structure are taken into account in the battery equivalent circuit model [29, 30].

The second order randles electrical equivalent circuit seen in Figure 1 is used while modeling. It gives better results in the literature [29]. Here, v_{ocv} is the ideal voltage source that varies depending on the current SoC of the battery, R_0 is the internal resistance, $v_0(t)$ is the voltage on the internal resistance, R_iC_i $(i = 1, 2)$ pair is the resistors that will represent the charge transfer, $v_1(t), v_2(t)$ refers to the voltage on these pairs, and $i(t)$ refers to the current passing through the circuit. R_0, R_1, R_2 values change depending on temperature and current.

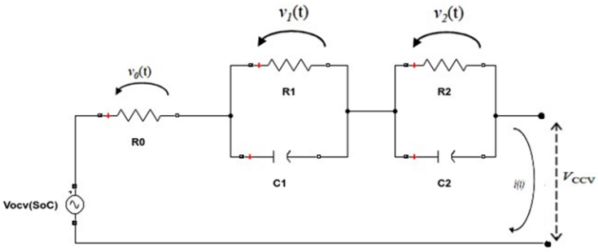

Figure 1. Second order randles electrical equivalent circuit

The battery is simulated in MATLAB/Simulink, taking into account the randles equivalent circuit in Figure 1 and the mathematical equations of this circuit [29]. The considered mathematical equations are obtained according to Ohm's and Kirchhoff's laws. $v_{ccv}(t)$ which represents the battery closed-circuit voltage, is obtained by Equation (3).

$$v_{ccv}(t) = v_{OCV}(t) - v_0(t) - v_1(t) - v_2(t) \quad (3)$$

The voltage on the internal resistance, the current passing through the R_1 resistor, the current passing through the C_1 and the total current passing through the circuit are given in Equations (4), (5), (6) and (7), respectively capacity.

$$v_0(t) = R_0 . i(t) \quad (4)$$

$$i_1(t) = \frac{v_1(t)}{R_1} \quad (5)$$

$$i_2(t) = C_1 . \frac{dv_1(t)}{dt} \quad (6)$$

$$i(t) = i_1(t) + i_2(t) \quad (7)$$

The total current value is found by adding the obtained $i_1(t)$ and $i_2(t)$. When these currents are written into Equation (7), the differential Equation (8) is obtained.

$$\frac{dv_1(t)}{dt} = \frac{1}{C_1} . i(t) - \frac{1}{R_1 . C_1} . v_1(t) \quad (8)$$

Data tables found in the literature and obtained as a result of experiments are used for non-constant R_1, C_1, R_2, C_2 values [29, 31].

In the cell dynamics subsystem shown in Figure 2, there are impedances consisting of R_0, R_1, C_1, R_2, C_2 values, $v_{OCVcell}$, I_{cell} are inputs of the system. At the outputs, there are $Vccv$ and V_0, V_1, V_2 terms to be used in thermal calculations.

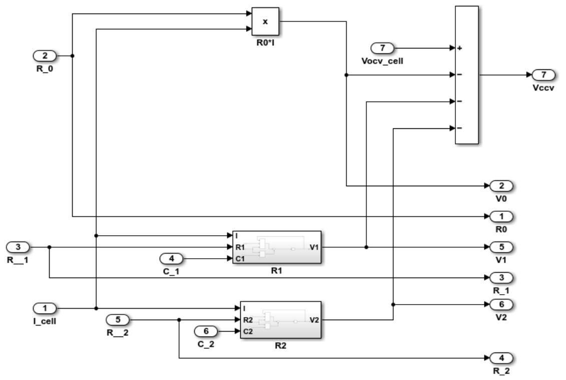

Figure 2. Model of cell dynamics subsystem

The thermal calculations subsystem is simulated with the help of the equations assuming the thermal energy balance. It is known that the heat energy stored in the system (Q_3) can be calculated by taking the difference between the heat energy given to the system (Q_1) and the heat energy removed from the system (Q_2) from the basic law of conservation of energy. This situation is shown in Equation (9). Q_1, whose formulation is given in Equation (10), represents the heat generated due to the internal resistances of the battery and the energy loss in the resistors. The power loss on the resistors is formulated in Equation (11) by taking the energy on the resistors into account. Q_2, which is the heat removed from the system, is transmitted in three ways: conduction, convection and heating. Q_2, calculated by neglecting conduction and radiation, is formulated with Equation (12) [29].

$$Q_1 - Q_2 = Q_3 \tag{9}$$

$$Q_1 = \sum_{i=1}^{n} I^2 R_i(t) \tag{10}$$

$$\frac{Q_1}{t} = \frac{v_0(t)^2}{R_0} + \frac{v_1(t)^2}{R_1} + \frac{v_2(t)^2}{R_2} \tag{11}$$

$$Q_2 = h_c.A(T(t) - T_a(t)) \tag{12}$$

where h_c is heat transfer coefficient (W/m^2 °K), A is battery outer surface area, $T(t)$ is battery internal temperature (°K), $T_a(t)$ represents the environmental temperature (°K). The equation by which the heat stored in the system can also be calculated is given in Equation (13).

$$Q_3 = m.C_p.\frac{dT(t)}{dt} \tag{13}$$

where m is battery mass (kg). C_p represents the specific heat of the battery (J/kg°K) and when multiplied, the total capacity coefficient C_i is obtained. If all these mentioned equations are replaced and arranged in Equation (13), the differential Equation (14) is obtained [29].

$$\frac{dT(t)}{dt} = \frac{1}{C_i}\left\{\left[\frac{v_0^2(t)}{R_0} + \frac{v_1^2(t)}{R_1} + \frac{v_2^2(t)}{R_2}\right] - \left[h_c.A(T(t) - T_a(t))\right]\right\} \tag{14}$$

The thermal calculations subsystem in Figure 3 is created by simulating Equation (14) in the Matlab/Simulink environment. As seen in Figure 3, the cell temperature $T(t)$ is obtained by using $T_a(t)$, which represents the initial value and entered by the user, and V_0, V_1, V_2, values calculated as output in the cell dynamics subsystem, as input.

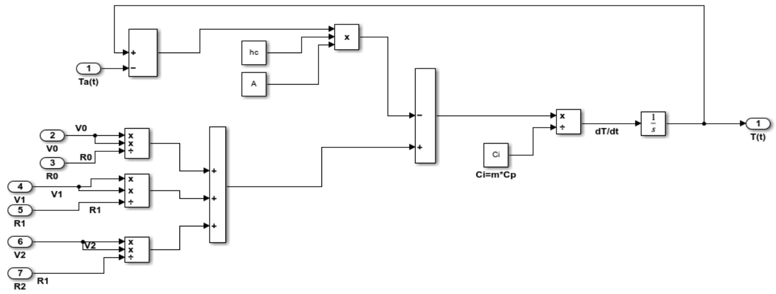

Figure 3. Model of thermal calculations subsystem

In order to determine the resistance and capacity values of R_0, R_1, C_1, R_2, C_2 which vary according to temperature and current charge state, the operating functions subsystem is created using the data tables found in the literature [20, 29, 31] and obtained from the tests carried out by the companies. Using the literature, the data table given in Table 1 is created for resistance and capacity values. These values are entered into look up tables and R and C values are obtained by interpolation method and used in subsystems. This subsystem can be seen in Figure 4. SoC and temperature input, open circuit voltage (v_{OCV_cell}) and R_0, R_1, C_1, R_2, C_2 impedance values are created as output.

Tablo 1. Data tables for resistances and capacities [20, 29, 31]

SoC	R_0 (Ω)			R_1 (Ω)			R_2 (Ω)		
	0 ^{0}C	25 ^{0}C	0 ^{0}C	0 ^{0}C	0 ^{0}C	40 ^{0}C	0 ^{0}C	25 ^{0}C	40 ^{0}C
0,1	0,00161	0,00205	0,00468	0,00468	0,00468	0,0008	0,00468	0,0008	0,0007
0,2	0,00149	0,00183	0,00084	0,00084	0,00084	0,00056	0,00084	0,00056	0,00054
0,3	0,00139	0,00173	0,00061	0,00061	0,00061	0,00051	0,00061	0,00051	0,0005
0,4	0,00135	0,00166	0,00056	0,00056	0,00056	0,00047	0,00056	0,00047	0,00047
0,5	0,00132	0,00163	0,00058	0,00058	0,00058	0,00049	0,00058	0,00049	0,00048
0,6	0,00136	0,00168	0,00061	0,00061	0,00061	0,00061	0,00061	0,00061	0,0006
0,7	0,00134	0,00164	0,00071	0,00071	0,00071	0,00066	0,00071	0,00066	0,00067
0,8	0,00133	0,00165	0,00076	0,00076	0,00076	0,00071	0,00076	0,00071	0,00071
0,9	0,00135	0,00168	0,00079	0,00079	0,00079	0,00069	0,00079	0,00069	0,00065
1	0,00142	0,00179	0,0007	0,0007	0,0007	0,00054	0,0007	0,00054	0,00048

SoC	C_1 (mF)			C_2 (mF)		
	0 ^{0}C	25 ^{0}C	40 ^{0}C	0 ^{0}C	25 ^{0}C	40 ^{0}C
0,1	1932,18	19211,03	20259,19	1932,18	19211,03	20259,19
0,2	17789,3	28931,85	28069,01	17789,3	28931,85	28069,01
0,3	28714,76	32396,9	29206,52	28714,76	32396,9	29206,52
0,4	29501,58	31501,14	30337,55	29501,58	31501,14	30337,55
0,5	28762,95	31579,66	29661,89	28762,95	31579,66	29661,89
0,6	26838,07	29368,02	26832,82	26838,07	29368,02	26832,82
0,7	23782,12	24301,35	23832	23782,12	24301,35	23832
0,8	22040,82	22281,47	20809,55	22040,82	22281,47	20809,55
0,9	20772,07	20610,91	20282,04	20772,07	2610,91	20282,04
1	22405,03	29856,73	28507,86	22405,03	29856,73	28507,86

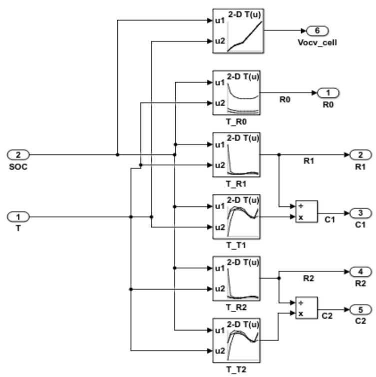

Figure 4. Model of operation functions subsystem

The calculation of SoC, which is specified by measuring the current flowing through the battery based on the coulomb counting method, is given in Equation (15) [29].

$$SoC(t) = SoC_{initial} + \frac{\int_0^t i(t).dt}{Q_{nom}} \quad (15)$$

where Q_{nom} represents the nominal capacity (Ah) of the battery. Modeling of this equation in Matlab/Simulink environment is shown in Figure 5. $SoC_{initial}$ and $Capacity\_nom$ (Q_{nom}) values, which are defined and changed in the Matlab environment, and I_cell are taken as the input, and so the SoC_cell is obtained as output.

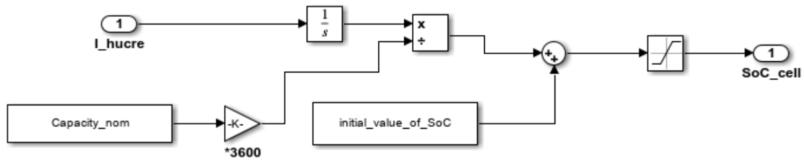

Figure 5. Model of SoC subsystem

Figure 6 shows the Li-ion battery model formed by combining all the subsystems given above.

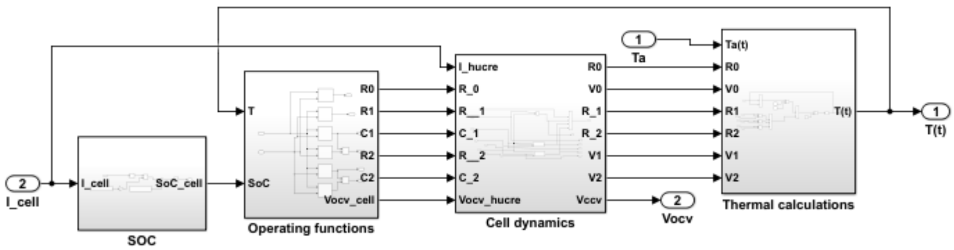

Figure 6. Li-ion battery model

4. Results and Discussions

In this study, the system containing the Li-ion battery used as the power source for UAVs is analyzed in the MATLAB/Simulink environment. The block diagram of the all system is given in Figure 7. In order to change the battery temperature, the ambient temperature change from outside is determined with the help of a signal generator. Battery block contains the battery cell created in detail in Chapter 3. An inverter is used to convert the direct voltage obtained from the battery cell into three-phase alternating voltage. In order to represent the UAV load, BLDC motor is preferred due to its features such as not requiring frequent maintenance, long life and high power.

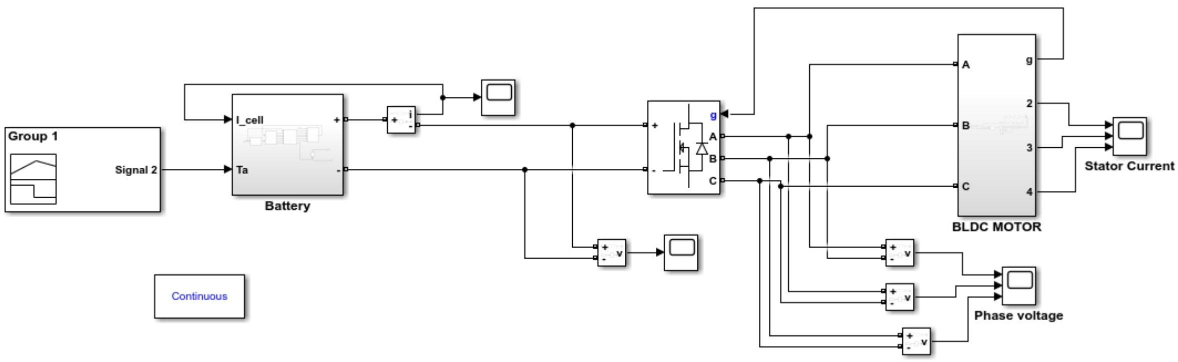

Figure 7. UAV system with Li-ion battery

Figure 8 shows the SoC change of the battery. It is obtained as a result of the load connected to the battery and the calculations made in the Charge Level Determination Subsystem. An exponential change is obtained as a result of the integrator block within the subsystem. Figure 9 shows the change graph of battery cell temperature. The T_a ambient temperature entered from outside is taken as input in the thermal calculations subsystem and is obtained as a result of the calculations made.

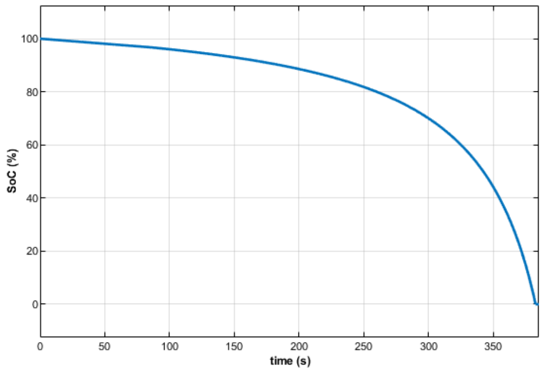

Figure 8. SoC of the battery

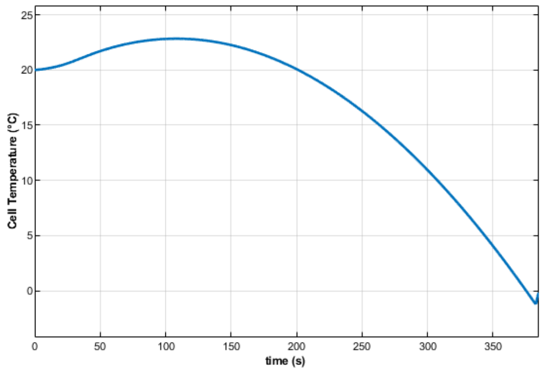

Figure 9. Battery cell temperature

The output voltage of the battery cell is seen in Figure 10. This voltage change is calculated by taking into account the voltage on the R_0, R_1, C_1, R_2, C_2 elements in the battery equivalent circuit according to the charge type, temperature and SoC state calculated with the help of look up tables in the operating functions subsystem, and the battery open circuit voltage according to the current SoC state. As can be seen from the graph, the voltage value changes depending on the usage time of the battery and the change of SoC. Voltage fluctuations between approximately 7.7 and 7.5 V can be prevented with the help of a DC/DC converter. Figure 11 shows the current drawn from the battery after the UAV load is connected to the battery. There are also fluctuations in current due to voltage fluctuation.

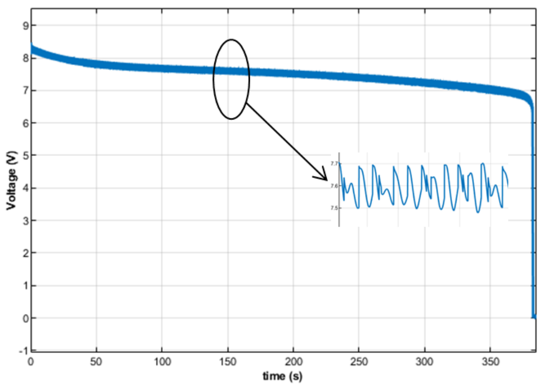

Figure 10. Battery output voltage

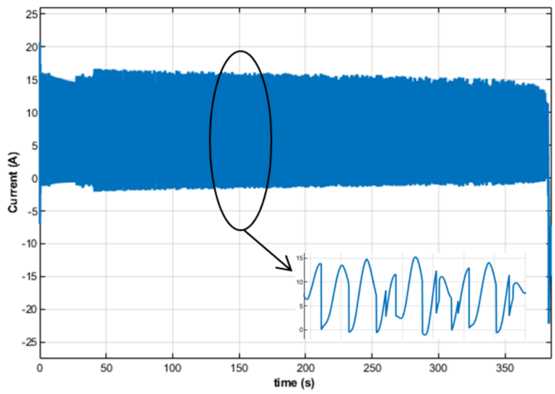

Figure 11. Current change of the battery

When the current drawn from the battery is different from zero, a change is observed in the output voltage and SoC values of the battery cell. The SoC value changes depending on the current drawn from the battery cell. The changing SoC value affects the output voltage of the battery cell. It has been observed that the battery output voltage reaches its maximum value when the SoC value is 100%. Additionally, it can be followed from Figure 8, Figure 10 and Figure 11 that when the SoC value is 0%, the battery output voltage is zero and no current is drawn from the battery.

The stator currents of the BLDC motor are given in Figure 12. The change of three-phase currents with a 120-degree phase difference between them can be observed from the figure. Figure 13 shows the output phase voltage changes of the inverter. The output voltage of one battery cell used in the system is 7.2 V. However, the output voltages are obtained by calculating the values entered in the look up tables in the operating functions using the interpolation method.

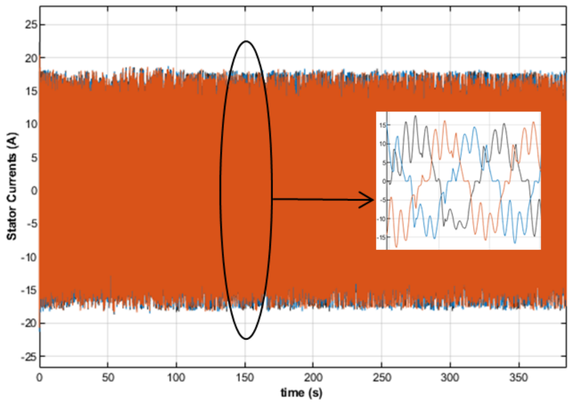

Figure 12. Stator Current Change

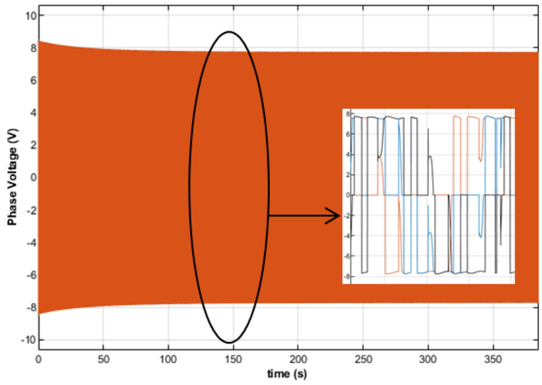

Figure 13. Phase Voltage Change

With the results obtained, changes in SoC and battery output voltage are observed depending on the usage time of the battery. It is known that if the SoC value drops below 20% while the battery is being discharged or goes above 80% while charging, it affects SoH of the battery. If these situations occur, they can be taken under control by intervening in the SoC subsystem. Depending on the battery usage rate, the output voltage value of the battery decreases in proportion to the SoC. In this study, the battery has been modeled in detail so that it can be taken under control in case of sudden voltage drops that may occur at the battery output.

5. Conclusions

With the increase in air traffic, harmful gas emissions released into the environment from gas turbine engines used in aircraft create serious problems. For this reason, studies on the increased use of electrical systems in aviation are gaining importance. However, the spread and use of electrical systems is not progressing at the desired rate. It is thought that these problems will disappear with the performance and development of batteries. For this reason, the importance of improving the performance of the battery by making an accurate simulation has become a necessity.

In this study, a Li-ion battery model is created by examining the battery models available in the literature for use in UAVs. The system, including the BLDC engine used to represent the UAV load, is modeled in the Matlab/Simulink environment. With the modeling carried out in this study, the health and charge status of the battery can be accurately determined and used in the desired system.

As a result of chemical reactions taking place inside the battery, the battery temperature increases. Increasing temperature will prevent battery reactions from occurring sequentially and completely. This will cause the internal resistance of the battery to increase. Increasing internal resistance will ensure that the battery spends its energy on its own internal resistance rather than on the system used. Thanks to these subsystems, battery temperature, voltage and internal resistances will be predicted. In this way, the battery can be intervened without any negative situation.

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