SYSTEM FOR TESTING OF LITHIUM-ION BATTERIES AND ELECTRIC MOTORS FOR ELECTRICAL VEHICLES

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Abstract: *Presented is a system for testing and certification of lithium-ion batteries and electric motors intended for hybrid drive vehicles (HEV) and electric vehicles (EV). The work presents studies of selected pair of modern lithium - ion batteries - electric motor for urban car with a view to obtain data for efficiency of of the overall system engine torque, capacity and lifetime of the the battery and other technological parameters under laboratory conditions . Conclusions are made and decisions taken for the future improvement of the setting to expand its capacity to develop software, hardware and devices for testing and certification of import and Bulgarian lithium-ion batteries and electric motors in the laboratory and real environment in accordance with directives and standards the EU.*

KEYWORDS: *electric vehicle*

1. Introduction

Increasing popularity of electric vehicles is caused by rising oil prices and environmental pollution. People are looking for alternative and environmentally safe fuel for their vehicles. The electric car is the ideal solution and has its advantages and disadvantages [1].

2. Purpose of work

The purpose of this work is to present a system for testing and certification of lithium - ion batteries for hybrid drive vehicles (HEV) and electric vehicles (EV). Based on initial research is proposed a simple dynamic model of the discharge and charge the battery, similar to [2], but it presents the dynamics of voltage when current is different. Conclusions are made for future improvement of the system in order to expand its capacity to develop software, hardware and devices for testing.

3. Preconditions and need for ecological urban transport

The massive use of fossil energy sources is an indication that humanity will soon be able to destroy its fossil energy resources. The biggest consumers of oil derivatives in the city are ordinary vehicles. Internal combustion engine pollute the environment and are among the biggest consumers of oil in the world. City electric car offers an alternative to the above disadvantages of the internal combustion engine - combines environmental protection, human independence by rising oil prices and energy crises, as well as individual travel comfortably in City congested with parking position vehicles. Difficulties with the mass realization of urban electric vehicles are caused by the limited choice and higher prices. Searching for electric vehicles in our days is caused primarily by the high ecological culture of the authorities and the population in highly developed countries, the intention to save environment and by reason of increased oil prices. The main problem that stops a massive deployment of the electric vehicles in the city is transport and storage of energy [1,2]. It is easy to transport gasoline or oil with reason to burn it, when it is necessary. This energy is given to humanity in the stored form completely ready for use. For example, a gallon (4.54 liters) is equivalent to the energy around 1,3.108 J, while two volts leaden accumulator with 100Ah capacity is equivalent to 6.105 J, the stored energy in the battery is several orders of magnitude less than that of fossil fuels [1]. Recently, by targeting research and development are made lighter lithium-ion batteries, but they are very expensive [3]. Another disadvantage is that electric cars have low mileage on one battery charge (up to 100-160 km) and speed is limited to 90 km / h, making it impossible for them to move long distances, especially on motorways. Therefore EV can travel very little distance without recharging its battery than hybrid, but is very suitable for a second family car in the city. We ask ourselves - why do we need electrical power for our vehicles and not biofuel ? In the opinion of many environmentalists and specialist biofuel doesn`t have future. Alarming reports come from around the world about damage by biofuels [1]. The future is electricity. It is a strategic object of global politics and will never lose their essential role in the world. Those countries that have developed technologies for production and storage of electricity will soon rule the world economy. Bulgaria as an EU member must not lose its strategic position in production and storage of electricity and the production of electric vehicles, where it has a long tradition.

4. Principle of work and main components of the system

Fig. 1 represents the principal block diagram of the system (the rig). It is composed of several blocks - Charger 1, accumulator 2, engine 5, differential 6, brake system 8 and control unit 3.

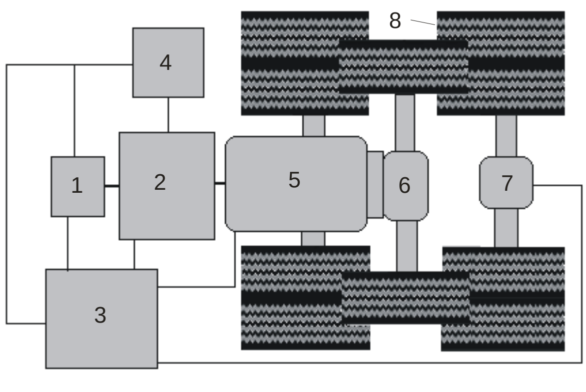

Figure 1. Schematic block diagram of the rig.

The principle of operation of system is as follows: accumulator 2 powered motor 5, which is connected mechanically through electromagnetic coupling with differential 6. Differential is equipped with wheels which run over roller of the brake rig 8. Brake rig 8 creates a brake effort on the wheels of the differential 6, which can be adjusted by the DC motor 7. Drives for hybrid vehicles can be tested (HEV), as to the system shall be included autonomous current source 4, which represents a hydrogen fuel cell where the pollutant emissions are zero or generator of electricity, running with a small gas internal combustion engine with minimum amounts of CO2 emitted into the atmosphere - 20 g / km, bearing in mind that the modern standard for new small city car with an internal combustion engine is 120 g / km. This autonomous power source can additionally charge lithium-ion battery 5 when is necessary. The whole system is controlled by the computer 3, which special software set programs for the operation of the selected pair of battery - electric motor, as simulate different modes of traction. To the rig is developed battery management system (BMS), connected to the computer 3. In BMS through appropriate sensors will record and analyze data on the efficiency of the entire system, engine torque, the efficiency of heat recovery and hybrid propulsion, power, capacity, battery life, and many other technology parameters . Accumulator and electric motor can be changed and tested with various combinations. Analysis of test data will be used to assess the suitability of the battery or electric motor for their work and their compliance with the standards for the operation of hybrid and electric vehicles in the EU .

4.1.Characteristics of the main components of the system

Batteries: The battery is main, the most important strategic element of hybrid and electric propulsion. Recently, rapid development got traction lithium-ion batteries (Li-ion) [5,15]. Unfortunately, these batteries are still expensive and difficult to access, although conventional Li-ion batteries are commonly used in portable devices. These Li-ion batteries provide up to 20% more power per unit weight compared to NiMH and three times more than lead-acid batteries.

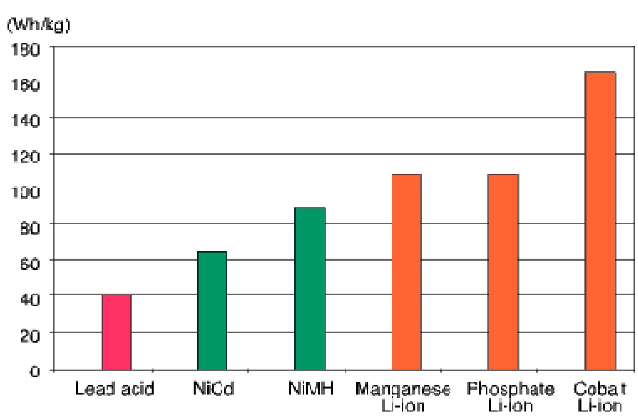

Figure 2. Energy density of different types of batteries

The diagram in Figure 2. illustrates the energy density of lead, nickel and lithium-ion batteries. It should be noted that Li-ion batteries have the potential for high energy density, but in contrast the lowering of the standards of safety (risk of explosion) and reduction of life cycle, making it necessary to seek for safety components and mandatory system for microprocessor control (BMS). Therefore, Li-ion batteries have great potential for development and are an important subject of research and applied activities. Very promising in terms of safety and weight are lithium polymer batteries (Li-Po), but they still have not shown these qualities in mass production [16.17]. The system can test lithium-ion batteries with a capacity of 10 kw to 25 kw.

Electric Motors: The most frequently in the production of electric vehicles are used synchronous three-phase induction electric motors with permanent magnets (PMSM) [13,14]. Some companies produce mainly for military purposes, brushless DC motors with permanent magnets (BLDC) with high torque [13.14]. Both engines are lightweight, powerful, have a system for regenerative braking - this is a process by which electric power is used as a generator to charge the battery when the car stops. The disadvantage is their high price. To transform a car with a combustion engine to electric, some companies offer amateur sets of components for the conversion (AC induction or DC brush motors, controllers, etc..), Which are lower cost, but can not achieve technological BLDC or PMSM parameters motors [13.14].

4.1.1. Selection of pair battery - motor for initial testing

With proposed system can be tested modern traction electric motors weighing 60 kg and power of 60 kW. For initial testing are chosen pair Li-ion battery and electric motor with lowest possible power able to drive a small city HEV or EV car. Elected BLDC motor with a rated output of 10 kW, which may be insufficient power to drive electric car, but motor ratio weight / power / price is suitable for hybrid drive systems [16]. Selected Li-ion battery has a power of 12 kW/100Ah.

4.1.2 Test cycle

Battery management system (BMS) provides comprehensive data on the elements of battery as the state of voltage modules, current, state of charging and discharging, temperature of battery and etc., 4 times per second . Data is recorded by computer and analyzed. Received information gives an indication of the battery in the hybrid cycle. Fig.3 shows the maximum and minimum amplitude of the voltage for each of the 8 modules, recorded during the preparation. From the chart can be seen that the voltages of the modules are superimposed well, indicating their equal operation during the test cycle and the effective state of charge (SOC) of the battery

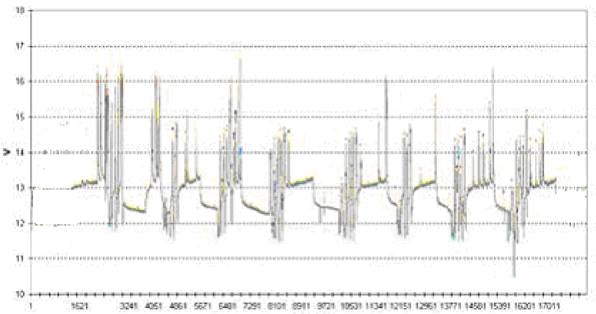

Fig. 3. Maximum and minimum amplitude of voltage of the battery module during testing

5. Dynamic model for battery use

Based on initial studies of charging and discharging of the battery was confirm the electrochemical behavior of Li-ion battery directly to the final voltage, open circuit voltage, internal resistance, the current discharge and charge [1, 2]. This model is applied for both discharge and charge. Based on test data in this work is offered a simple dynamic model of battery.

5.1 Model of discharge

A feature of this model is the use of filtered current (i*), passing through the polarization of resistance. Battery voltage is given by the formula:

$$V_{batt} = E_0 - K\frac{Q}{Q-it}\cdot it + R.i + A_{exp}(-B.\ it) - K\frac{Q}{Q-it}\cdot it^* \qquad (1)$$

where:

V_{batt} t = battery voltage (V)
E_0 = constant battery voltage (V)
K = constant polarization (V / (Ah))
Q = battery capacity (Ah)
$it = \int idt$ = actual battery charge (Ah)
A = area of the exponential amplitude (V)
B = exponential time constant area (Ah) -1
R = internal resistance (W)
i = battery current (A)
i^* = filtered current (A)

Exponential zone of equation (1) is valid for Li-Ion battery. For other batteries (lead acid, NiMH and NiCd),have a phenomenon of hysteresis between charge and discharge, regardless of the battery SOC [6], [7]. This phenomenon can be represented by nonlinear dynamic equation:

$$Exp(t) = B\ .|\ i(t)|\ .\ (-Exp(t) + A\ .\ u(t)) \qquad (2)$$

Where

$Exp(t)$ = area of exponential voltage (V)

i(t) = current of the battery (A)

u(t) = charging or discharge mode

Exponential voltage depends on its initial value $Exp\ (t_0)$ and load $(u(t)=1)$ mode, or discharge $(u(t)=0)$. Fig. 4 shows the complete model system for landing of battery:

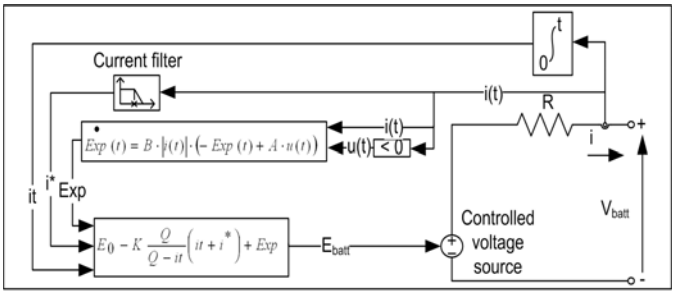

Fig. 4: Model of the discharge of the battery

5.2. Model of charge

The characteristic of charging, especially at the end of charging (EOS) is different and depends on the type of battery. Lead-acid and Li-Ion batteries have the same EOC characteristics, because voltage increases rapidly when the battery reaches full charge. This phenomenon is modeled by polarization resistance.

In charging mode, polarization resistance increases, while the battery is almost fully charged (it = 0). Above that point, the polarization resistance increases sharply. Instead polarization resistance of the discharge model (equation (1)), the polarization resistance is now given by:

$$\text{Polarization. Resistance} = K\frac{Q}{it} \qquad (3)$$

In theory, when it = 0 (fully charged), polarization resistance is infinite. This is not true in practice. In fact, experimental results show that the contribution of the polarization resistance is shifted by about 10% of battery capacity. Then equation (3) becomes:

$$\text{Polarization. Resistance} = K\frac{Q}{it-0{,}1Q} \qquad (4)$$

Like a model of dilution, where the exponential voltage for Li-Ion battery is Aexp (-B. It)), the voltage is given by equation (2).

5.3 Generalized model of Li-ion battery

Charge:

$$V_{batt} = E_0 - R.i - K\frac{Q}{Q-it}\ .\ (it + i^*) + A_{exp}(-B.\ it) \qquad (5)$$

Discharge:

$$V_{batt} = E_0 - R.i - K\frac{Q}{it - 0{,}1.Q}.i^* - K\frac{Q}{Q - it}.\ it + \quad (6)$$

$A_{exp}(-B.\ it)$

6. Results and discussion

To be able the hybrid car to be accessible and attractive to more people and companies operating in urban and suburban environment, needs to be affordable. After analysis of all existing schemes, prototypes and production cars and hybrid electric vehicles, it is concluded that for purposes of development, the optimal option would be to establish a prototype, manufactured by processing in the EU small car in serial hybrid with parallel split hybrid system, according to the scheme presented in Figure 2. replacing the standard rear axle with a serial mechanical differential that can be connected to the motor, using all available achievements and developments in the field of hybrid systems.

Under this scheme the first stage can be a prototype, equipped with a Li-ion battery-new Bulgarian construction. Prototype to be tested in urban and suburban environment, taking decision for further development. When shown good test results, you may seek European or other independent companies - manufacturers, to fund further development and serial production of hybrid car to be built in Bulgaria, will then be possible to replace mechanical differential prototype electric differential, traction motor to replace a pair of wheel motor and onboard computer to manage the elements of the hybrid system.

7. Conclusion

Can make the following conclusions:

- The development of this proposed system of a hybrid car with Bulgarian Li-ion battery will be minimal structural revisions and will hold all standard systems and components for the selected conventional vehicle, while maintaining Euro 4 certificate.

- Developed a hybrid car will be able to simultaneously drive four wheels - the front two of the standard unit - differential - internal combustion engine and an electric motor rear-wheel, while keeping all factory safety systems;

- In town, or driving in a resort environment, the driver of the car you may want to switch mode motor traffic only. For highway driving, the car will be made auto electric switch only at speeds below 60 km / h or switching to manual mode at the request of the driver.

- Will achieve savings of gasoline, friendly operation and environmentally acceptable means of transport in heavy city traffic, resorts and golf courses.

- Hybrid system will be developed on a modular basis. The driver will be able to stay at each refueling traction battery of standard electrical grid in urban areas or in the future of special flexible solar batteries in the suburban environment even in motion [18.19].

- Hybrid technology can be applied in urban public transport buses and trucks, which will further improve the ecological environment in cities.

8. Literature

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