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HIGH VOLTAGE BATTERIES DIAGNOSTIC

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Abstract

Hybrid vehicles history begins between XIX and XX century because then has been constructed first hybrid vehicle project. The first men who produced electric propulsion mounted in front hubs connected with generator powered by spark ignition engine was Ferdynand Porsche. Vehicle was called Lohner – Porsche Electromobile. The first en masse produced hybrid vehicle was the first generation Toyota Prius. These model premiere was in 1996, and production started one year later. Vehicle was equipped in 1,5 dcm 58 hp spark ignition engine with added electric propulsion generated 40 mechanical hp. There has been mounting 72 hp spark ignition engine and 44 hp electric generator since 2000. Fuel consumption of these model was 5 liter on 100 km. Beginning XXI century 95% hybrid vehicles were Toyota Prius. The biggest competitor of Toyota Prius was Honda Insight. Lexus and Mercedes started producing hybrid vehicles few years later. The most popular brands selling hybrid vehicles are Toyota and Lexus – Toyota Motor Corporation.

Article describes high voltage battery example diagnostic possibilities in a hybrid or electric vehicle. Constructing vehicle models using two propulsion systems (spark ignition engine and electric generator) cause development and increase control system devices. The measurements has been made by using various diagnostic devices for example: diagnostic scanner mega macs 66, high voltage battery tester. Reading faults code is not enough so it is necessary to use data list what describes this article.

Keywords: *hybrid vehicles diagnostics, high voltage battery, HV battery test*

1. Introduction

A modern hybrid car is a technical system that is constructed using the latest achievements in many field of science, primarily in mechanical engineering, electrical engineering, electronics, information technology, and chemistry [5, 8].

An increase in exhaust emission requirements for internal combustion engines and a dynamic development of electrical engineering and electronics favour the introduction of vehicles with two-propulsion or electric drive on a broad scale. The availability of ever more powerful electronic circuits resulted in the use of these circuits in the systems that control different operating parameters of the hybrid systems consisting of an internal combustion engine and an electric motor. The system efficiency that can be achieved with a given hybrid power train solution depends primarily on the control system [8].

The higher-level hybrid power train control system coordinates the operation of the entire drive, while the individual components have their own control functions. In addition to controlling the components, hybrid power train control includes operational strategy, which optimises the mode of system operation. This strategy affects the functions that determine reduction of the fuel consumption and the emission of toxic exhaust components by a vehicle [1, 2, 5, 8].

2. Test object

A 2009 Toyota Prius 1.8 HSD car was selected as a test object; it is a hybrid vehicle with Hybrid Synergy Drive technology. It combines an internal combustion engine 2ZR-FXE with an electric generator (MG1) and an electric motor (MG2) and a high voltage battery as shown in Fig. 1. This system uses a high-voltage battery with a DC voltage of 201.6 V and a converter that boosts the voltage to the working voltage, which is approximately 650 V. The maximum total power is 100 kW, which, after conversion, is about 136 horsepower [8].

In order to achieve the adopted scope of the study, the diagnostic devices were used, such as a diagnostic tester – Mega Macs 66.

The objective of the study was to present the methods and problems in diagnosing electric and electronic equipment in two-propulsion vehicles using different devices and, based on the results, examine the correct or incorrect operation of a given element, and evaluate the possibilities of diagnostic equipment [8].

Fig. 1. Test object – a Toyota Prius 1.8 HSD car and battery HV

Internal combustion engine 2ZR-FXE – 1800CC 16-VALVE DOHC EFI[8]:
- capacity – 1798 cm^3,
- maximum power – 73 kW / 5200 rpm,
- maximum torque – 142 Nm / 3500 rpm.

Electric generator (MG1):
- AC motor-generator with a permanent magnet rotor,
- generates electric voltage and serves as the starter of internal combustion engine.

Electric motor (MG2):
- AC motor-generator with a permanent magnet rotor,
- serves as the main electric motor with high torque,
- maximum power – 60 kW / 13500 rpm,
- maximum torque – 207 Nm.

3. Toyota Prius 1.8 HSD power train

In the 3rd generation Prius, the series-parallel system with a power split was used. The propulsion system consists of an internal combustion engine, transaxle, electric drive, and batteries.

The internal combustion engine used in this system, coded 2ZRFXE, works in the Atkinson cycle. The Atkinson cycle is characterised by different piston stroke during the fuel-air mixture compression and expansion. In terms of construction, it is difficult to achieve because it would be necessary to change the entire engine design but Toyota has applied a simple and well-known method to bypass this problem by changing the valve timing. Consequently, the system can control the opening time of intake and exhaust valves. This cycle, compared to the Otto cycle, uses the expansion process and thus the efficiency of the engine cycle increases. In addition, in the internal combustion engine with the Atkinson cycle, the maximum engine speed has been reduced and solutions associated with the drive timing have been changed by reducing the friction force resistance. Among others, in the 3rd generation Toyota Prius, the air conditioning compressor and the water pump are driven by electric motors. This allowed a significant reduction in fuel consumption [5, 6, 8].

Electronic Continuous Variable Transmission (eCVT) is a step-less gearbox having a planetary gear connected to the internal combustion engine and electric engines MG1 and MG2, as well as to the differential gear. The electric motor MG1 has two functions. The first one is the role of a generator that charges the battery during energy recovery when the vehicle brakes or at a standstill when the internal combustion engine drives the rotor. Its second function is the role of a starter to start the internal combustion engine. The electric motor MG2 acts as a drive. It is worth noting that both devices are three-phase electric motors. The voltage on which MG2 operates is 650V AC. The satellite yoke is connected directly to a friction clutch, which is permanently disengaged, i.e. is connected to the shaft of the internal combustion engine. It is not possible to disconnect the drive shaft from the eCTV gearbox through the clutch. The solar wheel is connected to the rotor of electric motor MG1. The ring wheel is connected to the rotor of electric motor MG2 [8].

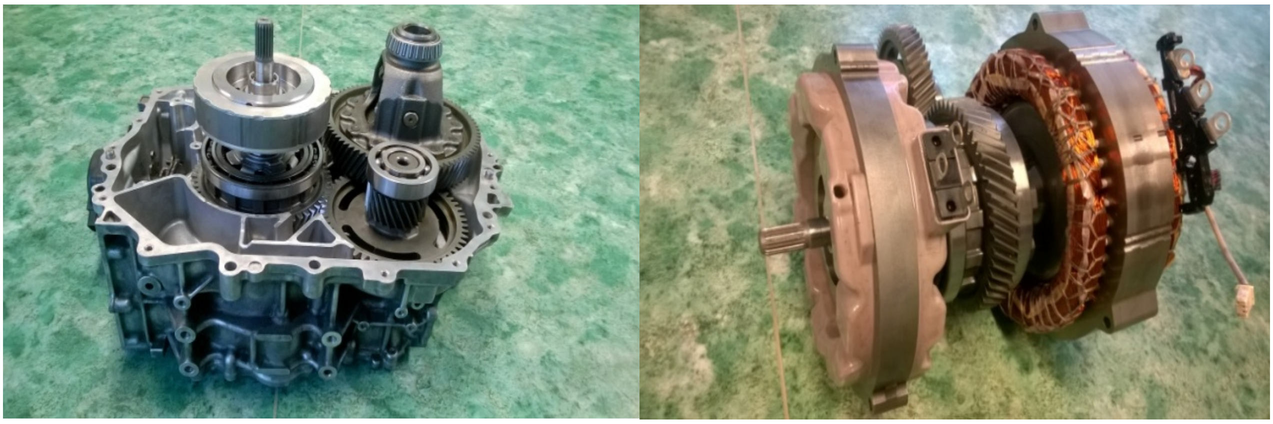

Fig. 2. Electronically controlled continuously variable transmission (eCVT)[8]

The electrical system consists of electric motors MG1 and MG2 and a frequency inverter and high voltage cables. The frequency inverter is intended to change 201.6 V DC to 650 V AC and vice versa, as well as to control the speed of electric motors. The fact that the current flow is controlled by a computer is means of power transistors shows that this system must be cooled due to large current flow. However, these transistors cannot exceed the temperature of 65 degrees centigrade and therefore the petrol engine cooling system cannot be used. An additional cooling system has been used in the form of a plate on which power transistors are mounted. The cables through which high voltage flows from the battery to the frequency inverter are bright orange in colour. This way one can immediately identify whether given component, such as a compressor or water pump, are supplied with high voltage [8].

A high voltage (HV) nickel-metal hydride (NiMH) battery with the rated voltage of 201.6 V is composed of 28 cells with a total capacity of 6.5 Ah and a maximum power of 27 kW and is characterised by a high density of the stored energy. The alkaline electrolyte contained in it does not participate in the reaction with electrodes as it happens in the most commonly used lead-acid batteries. In addition, the battery can work even when it is partially charged, which does not affect its overall service life. It has a high charging and discharging efficiency, which is crucial in the vehicles of that type. This battery has a temperature sensor and its own cooling system in order to maintain optimum working temperature, especially during the high load. Another important element of the battery is the channels that drain out the hydrogen escaping from the cells in the case of critical battery status [2, 8].

Each individual component of the power train has its own controller that is independent of the other ones; whereas all controllers are monitored by the hybrid power train controller (Fig. 3) to which, for example, the accelerator pedal is directly connected.

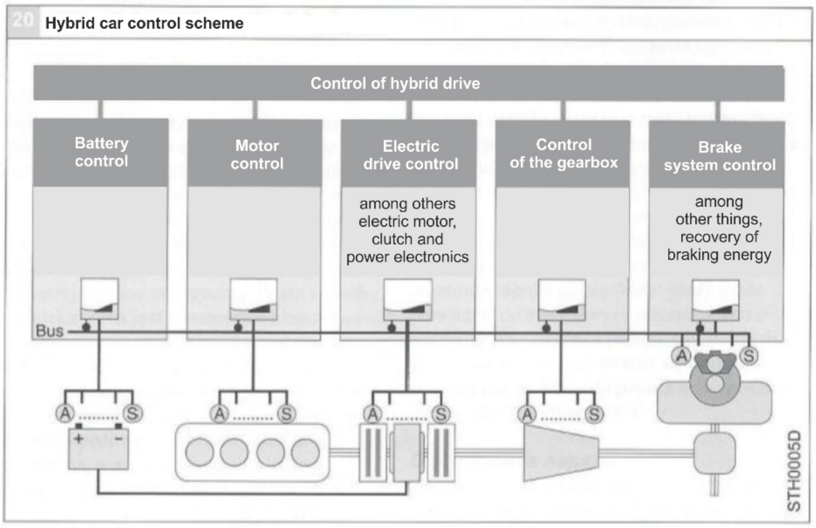

Fig. 3. Hybrid power train control system [2]

4. Diagnostics of HV batteries

The Toyota Group guarantees a five-year or one hundred-thousand-kilometre guarantee on the hybrid system battery. The guarantee for a hybrid battery can be extended for a specific amount provided by the manufacturer for a period of one year (for cars whose age is less than ten years). The condition imposed by the manufacturer, so that the guarantee is not broken or that it is possible to extend it, is to check the state of the hybrid system at an authorized service station [10]. This is done during the periodic technical inspection of the vehicle performed by the mechanic (i.e. every fifteen thousand kilometres or every year).

To perform the control a laptop with a cable that allows connecting it to the vehicle via a DLC connector, with access to the Internet and an account that allows the mechanic to log on to the manufacturer's website are needed. After connecting the cable, the chassis number should be entered on My Tech Doc website that will enable to connect to the vehicle. At the moment of positive connection, the vehicle data appears (in this case the Toyota III Prius of the third generation described in the previous chapter) and the control of the hybrid system state must be started, which consists of seven stages. In order to have the control at a given level, each of the requirements for the diagnosis during the test should be met. The test result is printed for the vehicle owner and it is also recorded in the electronic history of the vehicle. Fig. 4 shows the result of such a control.

Fig. 4. Certificate of high-voltage battery test

Checking the status of each cell of the traction battery can be easily done using the Mega Macs 66 diagnostic tester. It is a universal tester for the diagnostics of vehicles of a wide range of vehicle brands with installed software with HGS Data service data, which connects to the vehicle via a DLC interface. After connecting with the car, we can choose the parameter we want to control, read the value from the sensors in real time. In the analysed case, these are the voltages of the individual cells of the HV battery in the Toyota ZRW3 2ZRFXE Toyota Prius III. Fig. 5 shows a screenshot of the program at the time of the test.

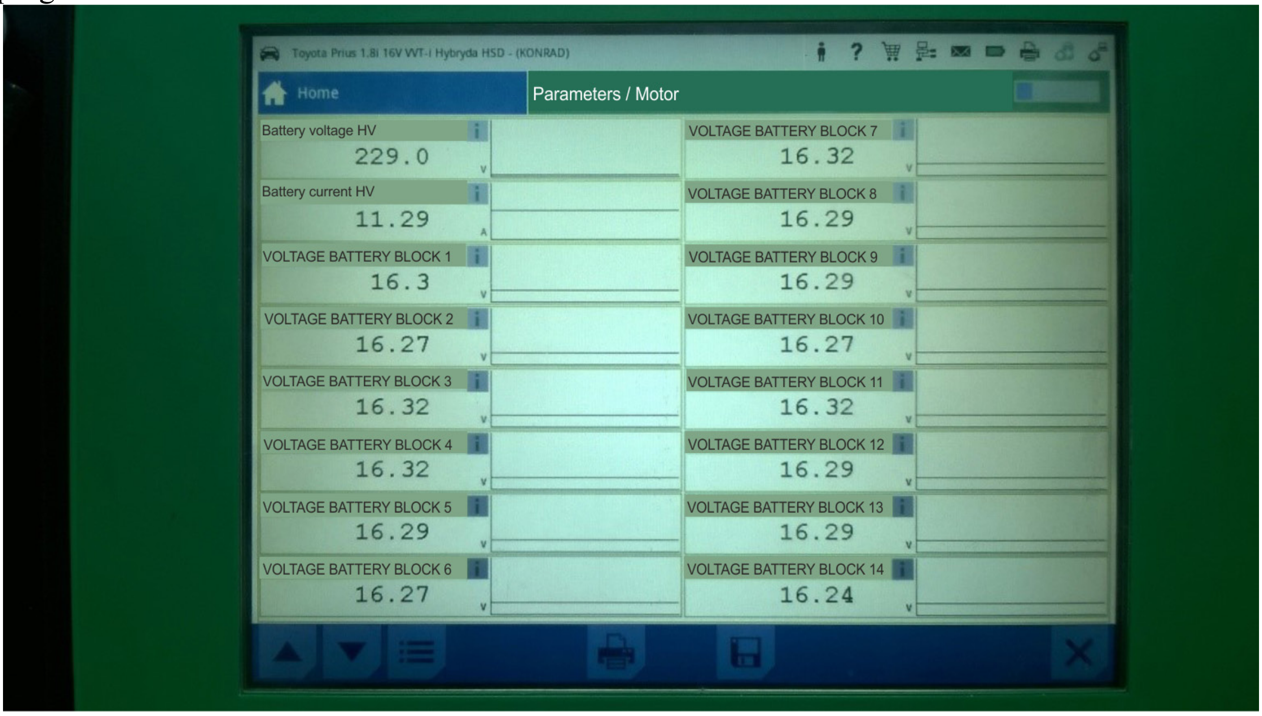

Fig. 5. Current parameters of the HV battery [8]

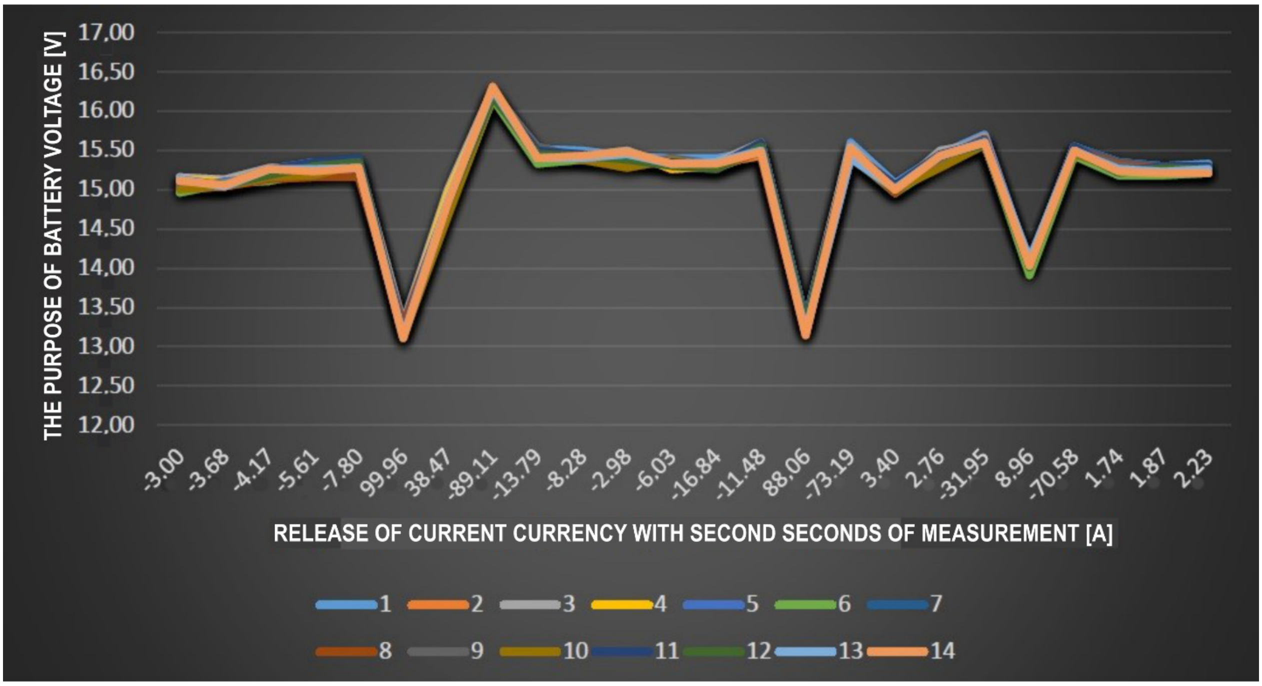

Fig. 6. Voltage values of individual HV battery cells

Based on the data obtained during the measurement in the normal controller-setting mode, it can be noticed that the voltage value on each link is very similar. It means that each of them works correctly; it is not damaged. Positive values on the horizontal axis indicate the moments in which the current is drawn from the battery. This means that it supported the internal combustion engine in the vehicle's drive, while the positive current values indicate the moment when the battery is recharged probably as a result of energy recovery during braking of the vehicle.

5. Conclusions

The main purpose of the research described in the article is to present the diagnostic methods and measurements of the high-voltage battery of a hybrid vehicle drive system to search its faults.

The Toyota Prius, which has been tested by an authorized service station using a hybrid battery test included in the service, is fully functional. This is evidenced by the printout of the certificate together with all positive results. It can be seen that in this vehicle there are no fault codes in the vehicle's on-board computer. The internal resistance, voltage of each of the fourteen modules and the temperature of the entire battery have the appropriate values, there is no damage to the insulation between the battery's cells and the hybrid system coolant pump and fan are operational. The fact that all of the controlled items ended with a positive result cause that the whole test of the system went well as shown in Fig. 4.

With the help of the Mega Macs 66 diagnostic tester, it was checked whether the error codes were saved in the controller's memory. Then the current parameters were observed. This function allowed checking the internal resistance and voltage of individual battery cells depending on the current shown in Fig. 6.

The article presents two ways to check the condition of a high-voltage battery, where at authorized service stations the control consisted of performing tests of individual elements of the hybrid system, and at the Department of Motor Vehicle Operation tests, were made using Mega Macs 66 universal tester. The result of the HV battery condition is positive in both cases, with the difference that in the case of Mega Macs 66 tester, there are accurate measurements of the individual cells of the HV battery and the status of each cell can be determined, not just the state of the HV battery. This data determines which cell, not the entire HV battery, should be replaced in the event of damage.

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