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Features of Hyundai Kona electric diagnostics using the LAUNCH X-431 PRO 3S multi-brand scanner

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Abstract. Problem. *The rapid growth of the electric vehicle fleet in Ukraine has created a practical need for reliable diagnostic methods that are compatible with locally available service equipment. In particular, service stations must be able to assess the technical condition of popular models such as the Hyundai Kona Electric using universal, multi-brand diagnostic tools.* ***Goal***. *The aim of this paper is to investigate the capabilities and limitations of the LAUNCH X-431 PRO 3S multi-brand diagnostic scanner for technical diagnosis of the Hyundai Kona Electric, with a focus on battery condition, key electronic control units (ECUs) and the detection of hidden faults and data manipulations.* ***Methodology***. *The study combines a literature review on EV diagnostics, OBD-II–based approaches and battery health assessment with practical experiments on a Hyundai Kona Electric using the LAUNCH X-431 PRO 3S. A step-by-step diagnostic algorithm is proposed, and real-time data streams are analyzed for a range of ECUs, including Airbag, IC (cluster module), IBU-BCM, Smart Key Unit, EV Battery System and OBC.* ***Results***. *The experiments show that the LAUNCH X-431 PRO 3S provides full access to the main EV subsystems, enabling rapid fault code reading, detailed analysis of live parameters and execution of special functions. The paper demonstrates how the combined analysis of battery voltages, accumulated energy, operating time and AC charging counters can be used to infer realistic mileage, identify odometer tampering and evaluate high-voltage battery state of health.* ***Originality***. *The work offers one of the first structured diagnostic procedures for Hyundai Kona Electric using a broadly available multi-brand scanner, linking specific X-431 data parameters with EV-specific diagnostic tasks such as verifying real mileage, assessing battery degradation and detecting intentional masking of warning indicators.* ***Practical value***. *The proposed algorithm and parameter interpretations provide service engineers and used-EV evaluators with a practical, reproducible approach to comprehensive diagnostics of Hyundai Kona Electric using LAUNCH X-431 PRO 3S, reducing diagnostic time, improving fault detection accuracy and lowering the risks associated with purchasing and servicing used EVs.*

Keywords: *electric vehicle diagnostics, OBD-II, battery condition, real-time monitoring, LAUNCH X-431, error codes, energy consumption.*

Introduction

Development of electric vehicles has created the need to improve methods of technical diagnostics and maintenance of vehicles equipped with high-voltage systems. The Hyundai Kona Electric is one of the most widespread representatives of modern electric cars; it is characterized by a complex electronic architecture, integration of numerous electrical and electronic systems, and advanced charging and safety systems. Therefore, effective diagnostics of such systems requires the use of specialized equipment capable of providing access to the electronic control units (ECUs) of various subsystems [1–4].

The multi-brand diagnostic scanner LAUNCH X-431 PRO 3S is a universal tool for reading fault codes, performing actuator tests, monitoring real-time parameters and carrying out service procedures for a wide range of vehicles, including elec-

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tric cars. Its use during maintenance of the Hyundai Kona Electric makes it possible to promptly detect and eliminate faults that occur in the high-voltage system, the regenerative braking system, the on-board charging system and auxiliary electronic modules.

Analysis of publications

Diagnostics of electric vehicles is a key element in ensuring their reliable operation and high-quality maintenance. Primary attention is paid to checking the condition of the high-voltage traction battery, the electric drive, the inverter and the control systems, which differ fundamentally from the units of conventional vehicles. Consequently, modern diagnostic approaches must take into account the specific operating features of electric transport and ensure high accuracy of the results obtained [5–10].

In the article "Diagnostics of Electric Vehicles Using OBD-II: Principles, Capabilities and Prospects", the authors investigate the use of the OBD-II interface for electric vehicle diagnostics. They have established that via OBD-II it is possible to read important data from the high-voltage battery, inverter and electric motor; however, there are limitations, in particular regarding monitoring of the cell-balancing state of the battery [6]. The possibilities of using OBD-II for EV diagnostics are examined through analysis of its functional potential, the specifics of data acquisition and interpretation. The article also assesses the limitations of this diagnostic method in comparison with other diagnostic approaches. Another study, "On determining productive capacity of EV traction battery repair area", analyses the technical and economic aspects of diagnostics and repair of EV traction batteries in Ukraine [7]. The paper shows that traditional repair approaches do not fully take into account the specifics of EV systems, which creates a need to adapt diagnostic equipment. In the article "Rational organization of the work of an electric vehicle maintenance station", practical aspects of EV diagnostic processes are considered: service preparation and the use of high-tech equipment, including multi-brand tools [8]. An analysis of the technological processes of EV diagnostics is carried out. Information on the main services provided by maintenance stations when performing EV diagnostics is collected and systematized.

In the work "Diagnostics of electric drive Electric vehicle with Valve Motor" [9], faulty states of the EV electric drive are considered. These are associated with failure of a functional element, circuit faults (open or short circuit), or deviation of element parameters from their nominal values. In the first case, the problem of structural identification of the system state is addressed, and in the second, that of parametric identification. The article "Using the method of the spectral analysis in diagnostics of electrical process of propulsion systems power supply in electric car" [10] presents a simulation model of the electric drive system for EV diagnostics. The developed model adequately reproduces the electrical processes occurring in the power circuits of the EV electric drive system. This model can be used for virtual studies of EV electric drive dynamic modes and for their diagnostics.

These Ukrainian studies indicate growing attention to the issues of maintenance and diagnostics of electric vehicles, as well as the need to adapt universal diagnostic equipment to local service conditions.

Regarding the international literature, work [11] analyses EV diagnostics using methods for determining the State of Health (SoH) of batteries, which can also be implemented in diagnostic scanners. LAUNCH, in its technical documentation, describes the X-431 series as follows: "X-431 Series offers comprehensive diagnostic capabilities for a wide range of vehicle makes and models" [12]. It is noted there that for new-energy EVs an additional "EV Diagnosis Add-On Kit" is required, which enables battery pack analysis and supports DoIP and CAN-FD. In the article on the use of the LAUNCH X431 EV Diagnostic Upgrade Kit for Tesla, "How to Connect and Diagnose Tesla with LAUNCH X431 EV Diagnostic Kit" [13], step-by-step instructions are given: connecting adapters, activating the software and checking the state of the battery pack. This demonstrates that multi-brand scanners are expanding their functionality for EV diagnostics. These sources [11–13] confirm that universal diagnostic devices such as the X-431 PRO 3S are already adapted for EV systems and support functions for battery state assessment, special adapters and dedicated software.

In [14], the authors present diagnostics of traction batteries in a small-sized urban electric vehicle. Based on a literature review and observation of current market trends, a methodology for assessing the technical condition of EV batteries is proposed. The proposed method was tested on an electric vehicle after 4.5 years of operation and a mileage of 30.000 km.

Article [15] investigates how the SoH of a high-voltage EV battery can be assessed under real operating conditions, taking into account the driver's style. A data-driven approach is proposed for tracking SoH using current and voltage measurements during operation of the high-voltage battery. The authors developed a neural-network-based model for processing sequential battery data, which is capable of determining SoH with an error of 2.46%. In [1], the current state of key indicators of high-voltage EV batteries is examined, with emphasis on diagnostic and prognostic approaches to their evaluation. These include battery SoH, state of safety (SoS), service life, remaining useful life (RUL) and cell-level indicators. The researchers predict how this information will be generated in the future for millions of electric vehicles. It is forecast that future trends and key challenges for battery performance prediction and management in EV applications will be presented from four perspectives: interaction with cloud boundaries; full-scale diagnostics; artificial intelligence; and electronic state-of-health reports for high-voltage batteries.

In [16], failures of high-voltage batteries are studied and classified into mechanical, electrical, thermal, inconsistency-related and ageing-related categories. General fault-diagnosis methods are presented from both mechanistic and symptom-based perspectives, with particular attention to data-driven methods. These methods are applied to electric vehicles, offering guidance on early warning of battery risks. Unlike traditional methods, data-driven approaches provide excellent real-time fault detection and long-term prognostic capabilities. In addition, an improved strategy for coordinated management of multiple faults is proposed through cooperation between the electric vehicle and cloud technologies for high-voltage battery systems.

Researchers from universities in Texas and Norman, in their study [17], developed an architecture for a fault-diagnosis model using feature-extraction techniques. An LSTM-based approach for fault diagnosis is proposed. This approach was tested in practice on an electric vehicle prototype and, according to the authors, is more accurate than other machine-learning-based fault-diagnosis methods. The EV and the fault-diagnosis model are implemented in MATLAB software. The study shows how deep learning contributes to fault diagnosis in electric vehicles. The simulation and experimental results confirm that higher fault-diagnosis accuracy is achieved through the application of LSTM.

Summarising this review, it can be noted that Ukrainian studies clearly emphasise the need to adapt diagnostic equipment to EV transport, particularly to models popular in Ukraine. Foreign sources demonstrate practical solutions and technological approaches implemented in the LAUNCH X-431 multi-brand scanner and its EV add-ons. Together, these materials form a basis for investigating the diagnostics of the Hyundai Kona Electric using the LAUNCH X-431 PRO 3S: Ukrainian works in the context of the local market and service environment, and international works in the context of the scanner's functional capabilities.

Purpose and Tasks

The goal of this work is to investigate the specific features of using the multi-brand diagnostic scanner LAUNCH X-431 PRO 3S for technical diagnostics of the Hyundai Kona Electric, in particular to analyse the available functions, the effectiveness of data reading, and the limitations of the device in the context of EVs.

To achieve this goal, the following tasks are set:

- to analyse the technical characteristics of the LAUNCH X-431 PRO 3S scanner, its compatibility with electric vehicles, and its support for EV-specific functions;
- to propose an algorithm for diagnostics using the multi-brand scanner LAUNCH X-431 PRO 3S;
- to study the structure of the electronic control units of the Hyundai Kona Electric and identify the key systems subject to diagnostics;

to investigate the Special Function capabilities in the LAUNCH X-431 PRO 3S multi-brand automotive scanner.

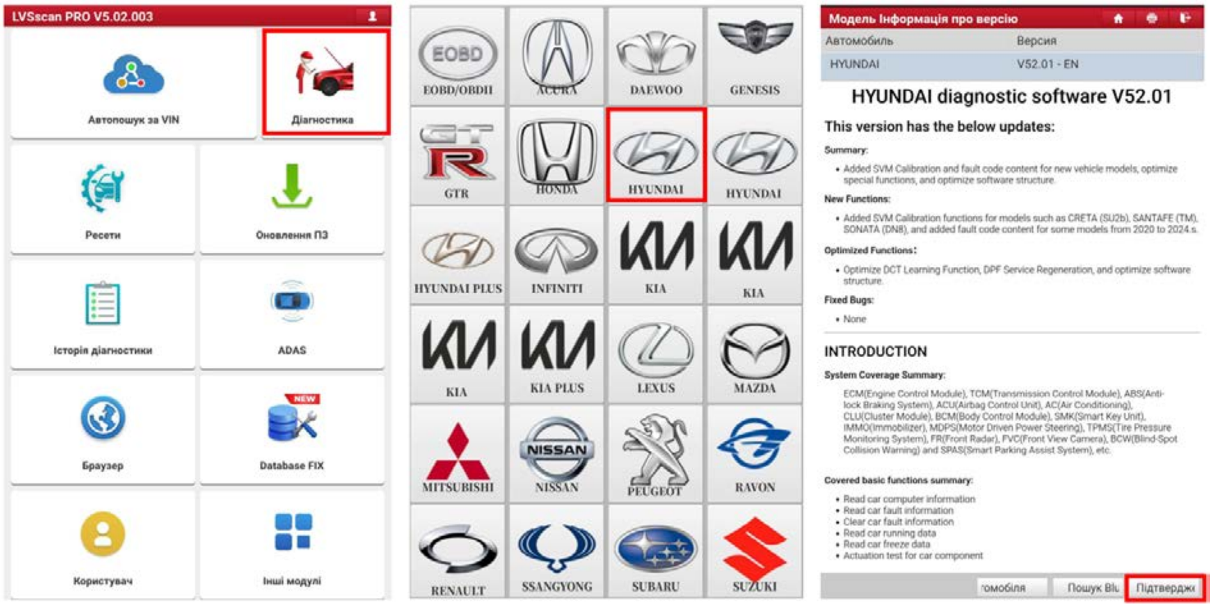
The automotive multi-brand scanner LAUNCH X-431 PRO 3S

The automotive multi-brand scanner LAUNCH X-431 PRO 3S (Fig. 1), with the full PRO software version, supports more than 300 vehicle makes and over 40 special functions, which help to carry out in-depth and detailed diagnostics of the vehicle's electrical and electronic systems.

Fig. 1. The automotive multi-brand scanner LAUNCH X-431 PRO3S

When connecting the LAUNCH X431 PRO3S, it must be paired with the tablet/smartphone on which the corresponding software is installed. After that, the "LVSscan PRO" application is launched, see Fig. 2a. By pressing the "Diagnostics" tab, we select the vehicle brand and model, Fig. 2b, and then press the "Confirm" button (bottom left), Fig. 2c.

– After the connection is established, the program starts. The Launch device does not always read the VIN code automatically, in which case it must be entered manually.



a b c

Fig. 2. Launching the software of the multi-brand scanner LAUNCH X-431 PRO3S: a – "LVSscan PRO" application screen; b – selection of the vehicle brand and model; c – confirmation screen of the selected option

Diagnostic algorithm using the multi-brand scanner LAUNCH X-431 PRO 3S

The first step in diagnosing an electric vehicle is to check whether it is able to charge in different ways:

- from DC chargers (ports: CCS1, CCS2, CHAdeMO, NACS, GB/T);

- from AC chargers (ports: Type 1 (SAE J1772), Type 2 (Mennekes), NACS, GB/T);

- from a 220 V outlet.

The next step in the electric vehicle diagnostic algorithm is to start a quick scan for faults in the vehicle, see Fig. 3a. The detected faults will indicate whether there is anything critical and will form an initial impression of the vehicle's condition. Once the program has completed the quick diagnostic procedure, a screen with the electronic control units is generated, where the presence or absence of faults in each unit is indicated, Fig. 3b.

A specific feature of Kia and Hyundai electric vehicles is that when there are faults or stored fault histories related to the airbag control unit, these records are usually duplicated in two locations, as Case 1 and Case 2. Depending on the software version, this may be displayed as: Airbag (Primary Crash), Airbag (Secondary Crash) or Airbag (Event #1), Airbag (Event #2). Therefore, for analysis it is sufficient to enter any one of these menu items. Also, on Kia and Hyundai electric vehicles, if there has been a voltage drop of the auxiliary 12-V battery, this drop is stored as a fault code.

The third step in the electric vehicle diagnostic algorithm is the analysis of each electronic control unit (ECU). Below, we present the analysis of several ECUs that allow us to form an overall picture of the EV's condition.

Airbag ECU

Next, we go to the Airbag control unit, Fig. 4a, and select Read Data Stream (real-time data), Fig. 4b, select all available parameters, Fig. 5c, and analyse them.

When analyzing the Airbag ECU data, we pay attention to whether all airbags are enabled and to the voltage of the 12-V battery. This value should be in the range from 14 V to 15 V.

We then analyse the resistance values from the airbag sensors. If the resistance is 25.5 Ω (or 35 Ω or 65 Ω), this means that a factory shunt is installed on the sensor, see Fig. 5 (first screen – without translation).

Below is an explanation of the main designations in Fig. 6:

- CAB resistance – resistance of the side curtain airbag;

- SAB resistance – resistance of the seat airbag;

- KAB resistance – resistance of the knee airbag;
- Driver Buckle Switch: Unbuckled – not latched; Blocked – latched. This indicates whether the seat belt is fastened. If it is not fastened but the status shows BLOCKED, then a dummy (artificial) buckle or bypass is installed. The same parameter is checked for the passenger seating positions;
- DAB resistance – resistance of the driver airbag in the steering wheel;

PAB resistance – resistance of the passenger airbag in the front dashboard area.

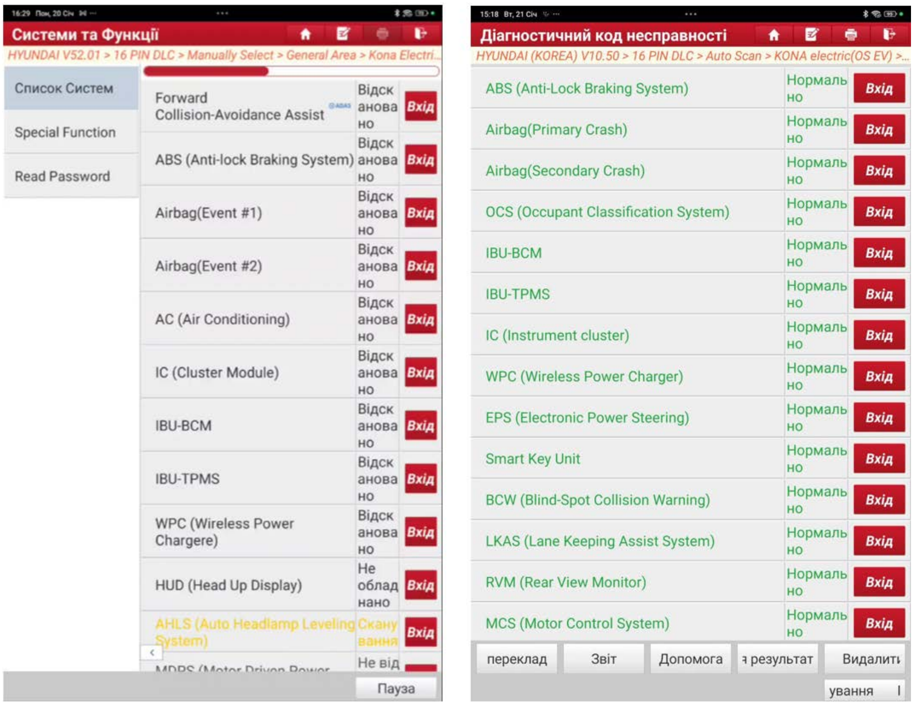


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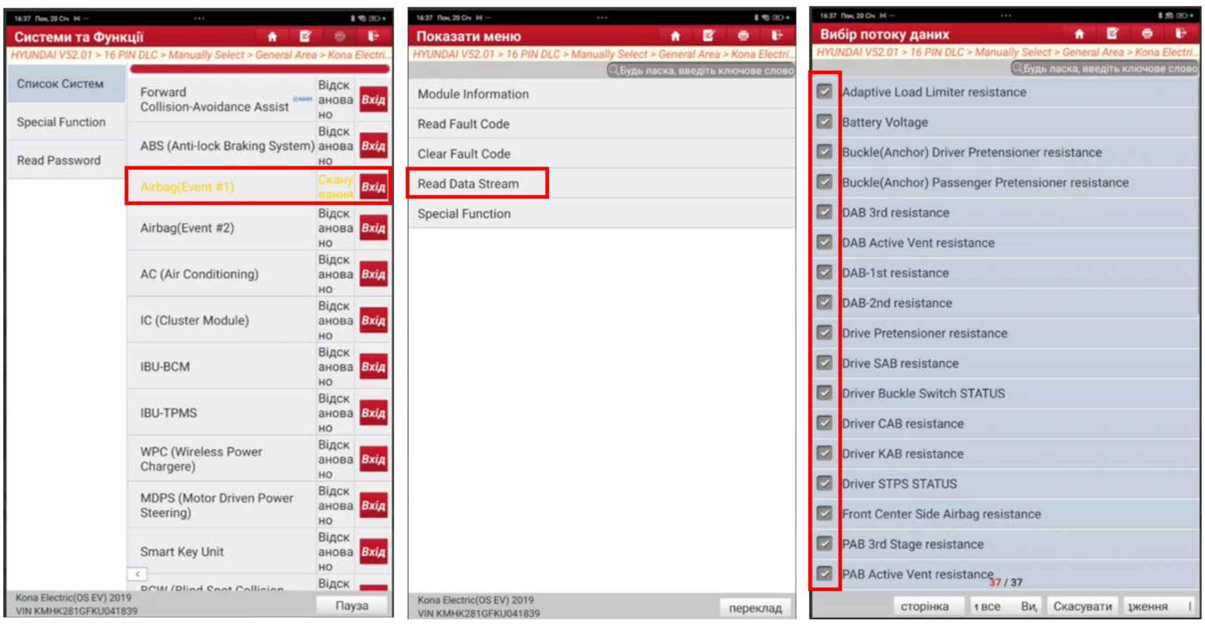
Fig. 3. Screens of the LAUNCH X-431 PRO3S scanner software: a – screen during quick scanning; b – screen after quick scanning



a b c

Fig. 4. Airbag ECU: a – screen for selecting the Airbag unit; b – selection of “Read Data Stream”; c – data stream screen of the Airbag unit

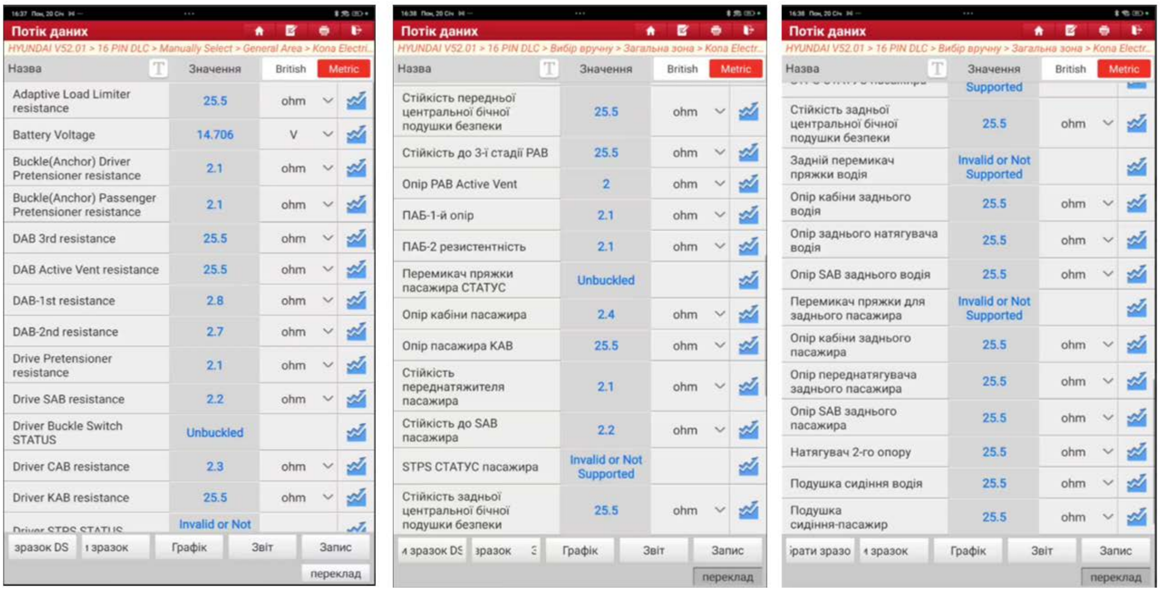


Fig. 5. Data stream screens of the Airbag control unit

IC (Cluster Module) ECU

Next, we enter the IC (Cluster Module) unit (instrument cluster), Fig. 6a, select Read Data Stream, Fig. 6b, select all available parameters and analyze them, Fig. 6c.

When analyzing the data of the IC (Cluster Module) ECU, we focus on the following indicators:

- Odometer;
- Battery Voltage on CLU (voltage of the 12-V battery);

Battery Warning Lamp (12-V battery warning lamp) – whether it has not been shunted so that it does not light up at low voltage.

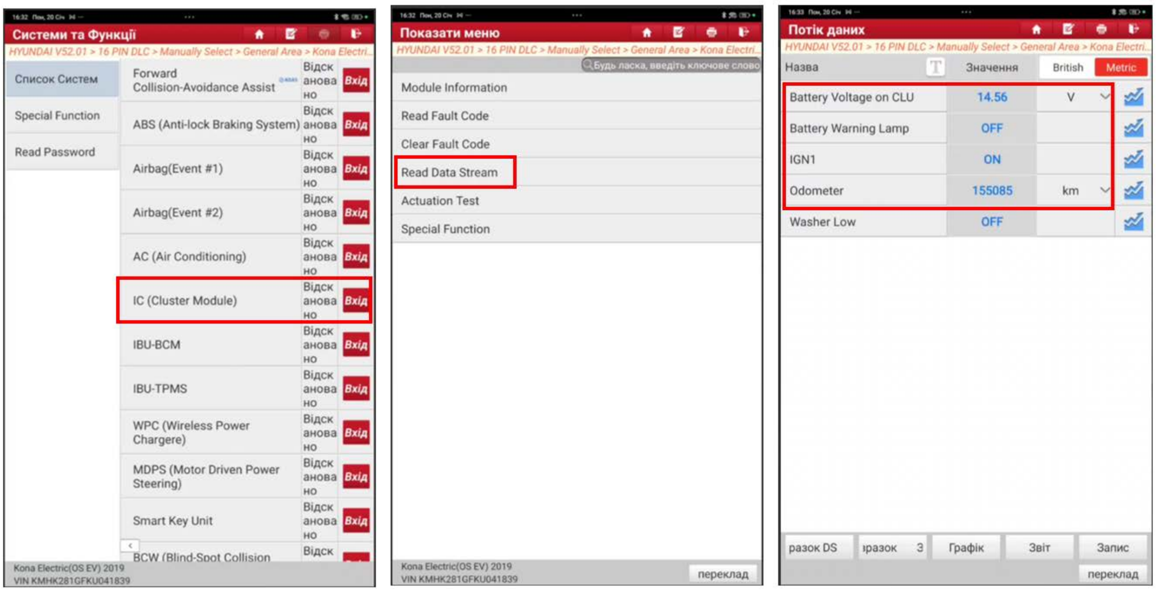


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Fig. 6. IC (Cluster Module) ECU: a – starting the IC (Cluster Module) unit; b – selecting “Read Data Stream”; c – data stream screen of the IC (Cluster Module) unit

IBU-BCM ECU

Next, we analyze the IBU-BCM ECU (Integrated Body Control Module, BCM). As with the previous units, we select “Read Data Stream”, choose all available parameters, and analyze them.

The parameters of this unit make it possible to check whether any shunts have been installed on the warning indicators in the instrument cluster. Particular attention should be paid to whether a shunt is installed on the “Check” indicator on the dashboard, as this indicator is sometimes bypassed so that the fault is not visible on the panel.

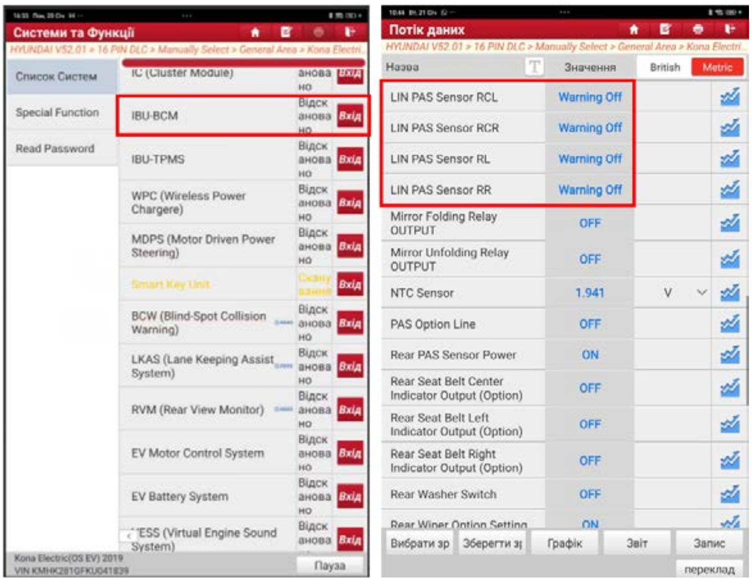

Fig. 7. Launching and analyzing the IBU-BCM control unit

Smart Key Unit ECU

Next, we open the “Smart Key Unit” control unit, Fig. 8a, select Read Data Stream, Fig. 8b, choose all available parameters and analyze them, Fig. 8c.

We check how many keys are programmed to the vehicle, Fig. 8c. This is useful information, especially before purchasing the car.

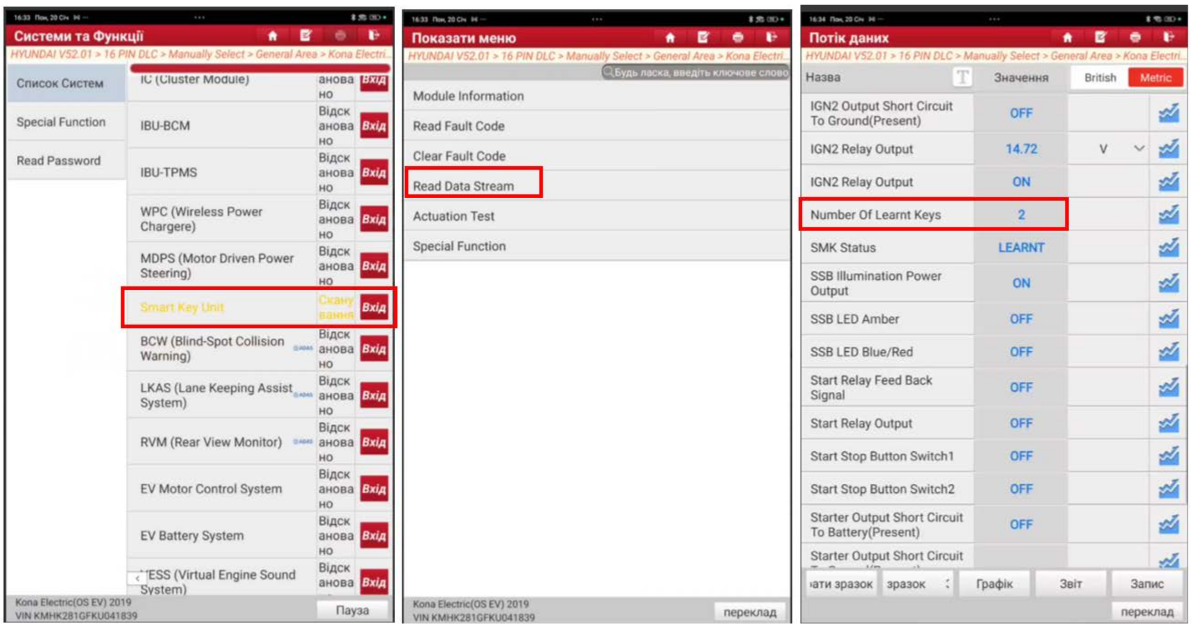

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Fig. 8. Smart Key Unit ECU: a – starting the “Smart Key Unit” block; b – selecting “Read Data Stream”; c – data stream screen of the Smart Key Unit block

EV Battery System block

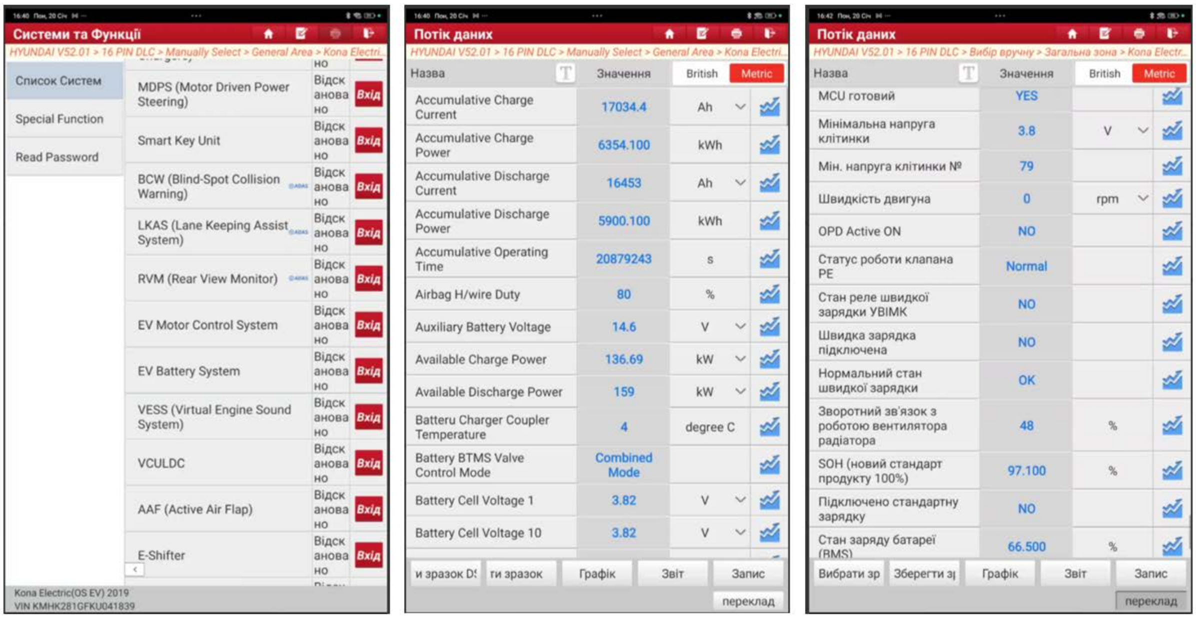
Next, we open the EV Battery System block (electric vehicle battery system), Fig. 9a, select “Read Data Stream”, choose all available parameters and analyse them, Fig. 9 b, c.

When analyzing the data of the EV Battery System ECU, we focus on the following parameters:

- “Battery LTR Rear Temperature” – this value should correspond to the ambient (outside) temperature;
- “Available Charge Power”;
- “Available Discharge Power” – these two parameters show the nominal capabilities of the EV during charging and discharging;
- “Display SoC” – state of charge of the vehicle (this must be cross-checked with the

indication on the instrument cluster to verify they match. The cluster display may show SoC inaccurately; this is often observed on the Nissan Leaf);

- "Maximum Cell Voltage";
- "Minimum Cell Voltage" – these two values should be within the range 2.7÷4.2 V and should be equal.



a b c

Fig. 9 EV Battery System ECU: a – starting the "EV Battery System" unit; b – selecting "Read Data Stream"; c – data stream screen of the "EV Battery System" unit

Ideally, at 0% SoC the cell voltage is about 3.0 V, and at 100% SoC about 4.1 V.

If at 100% SoC the voltage is 3.9 V or lower, this indicates poor condition of the high-voltage battery. Likewise, if at 0% SoC the voltage is below 3.0 V, this also indicates poor battery condition.

- "Battery Cell Voltage" – the cell voltages should be equal; if one value differs from the others, the corresponding cell is problematic. A difference of 0.1 V already indicates a faulty cell;
- "BMS Warning" – if the value is "Yes", there are faults in the operation of the high-voltage battery;
- "Battery State of Charge (BMS)" – this always differs from the displayed SoC, because the system reserves about 3 kWh of the battery capacity;
- "Total Charged Energy" (E_{total});
- "Total Discharged Energy";
- "Total Operating Time";
- "Cumulative Charge Current";
- "Cumulative Discharge Current";
- "Winter Mode Status";
- "SoH – State of Health of the Battery".

To determine whether the obtained parameters correspond to the real mileage of the vehicle, the value of "Total Charged Energy" (E_{total}) should be divided by the "*Odometer*" reading.

For Kia and Hyundai electric vehicles with a 64 kWh high-voltage battery, the average energy consumption ($E_{avg,calc}$) is typically 18÷21 kWh per 100 km.

If a significantly different value is obtained, it suggests that the odometer reading has been artificially altered (mileage rolled back) or that the high-voltage battery has been replaced.

$$E_{avg.calc} = E_{total} / Odometer \cdot 100, \quad (1)$$

where E_{total} is the "cumulative charge energy" or the total amount of received energy, kWh, and $E_{avg,calc}$ is the average energy consumption.

We also analyze the "Total operating time" parameter. On average, 1 km of mileage corresponds to an operating time of 160±30 s. Usually, when the mileage is artificially adjusted, the "Total operating time" parameter is not changed. Therefore, it can be used to roughly estimate the actual mileage of the vehicle. However, we should keep in mind that this time includes both driving and charging.

The "Total AC charging time" can also be checked; it is shown in the next block. Accordingly, if we subtract the "Total AC charging time" (T_{ch}) from the "Total operating time" (T_w), we obtain the motor hours (M_t).

$$M_t = T_w - T_{ch}. \quad (2)$$

We multiply the “cumulative charge current” by the nominal voltage of the high-voltage battery and check whether it corresponds to the cumulative charge power (E_{calc}) (the values should be approximately the same). If it does not correspond, this indicates that the recorded values have been artificially modified (“rolled back”).

$$E_{calc} = Q_{dis} \times U_{avg}, \quad (3)$$

where Q_{dis} is the accumulated discharge capacity, Ah, and U_{avg} is the average battery voltage, V.

We also pay attention to the SoH (state of health) indicator of the battery. To roll this value back, the high-voltage battery must be disconnected, and then you have to connect to the BMS and adjust this parameter. Not everyone does this (due to lack of capability, equipment, time, etc.).

If the “Winter mode status” is enabled, the electric vehicle will heat/cool the high-voltage battery while driving to the charging station, using the onboard navigation system, thereby reducing the range per charge and increasing electricity consumption.

“OBC” block (On-Board Charger)

Next, we go to the “OBC” (On-Board Charger) block (on-board charging unit), Fig. 10a, select Read Data Stream, select all available parameters, and analyse them, Fig. 10 b, c.

We analyse the following indicators:

- “Total AC charging time” – this is the time value which, taking into account its units, must be subtracted from the “Total operating time” to obtain the motor hours;
- “AC Charging Counter” (AC_{ch}) – the counter of charging from the AC mains. We multiply this value by 200 ± 20 km to obtain the approximate mileage of the electric vehicle (an error of ±10.000 km is within acceptable limits).

$$Odometr = AC_{ch} \times 200. \quad (4)$$

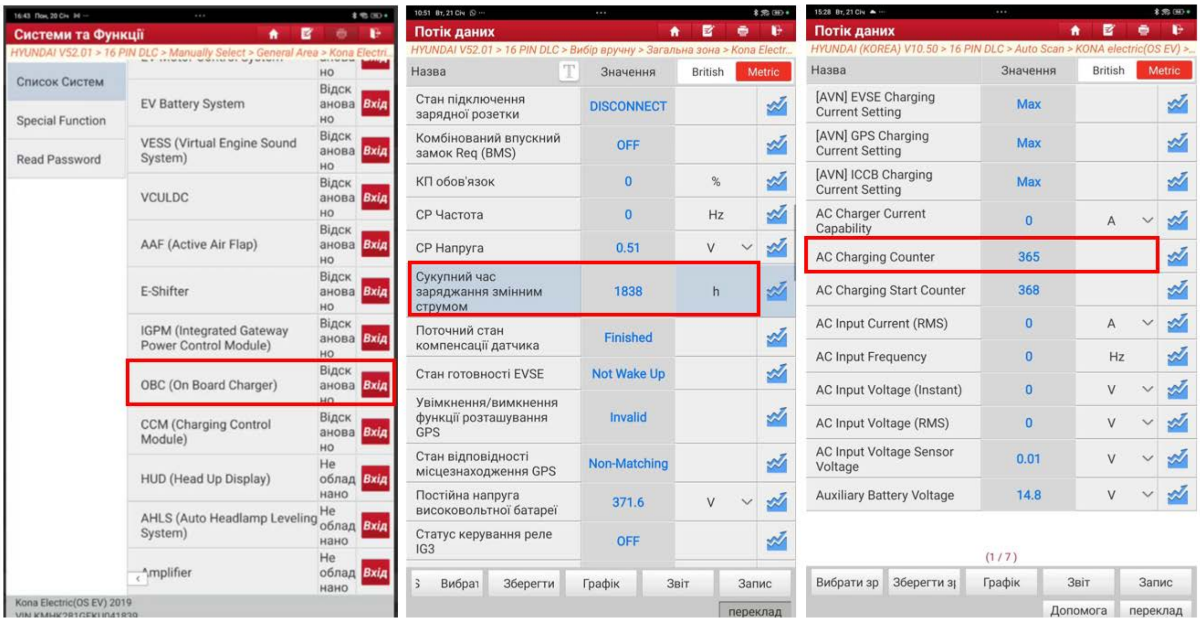


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Fig. 10 ECU “OBC (On Board Charger)”: a – starting the “OBC (On Board Charger)” block; b – selecting “Read Data Stream”; c – data stream screen of the “OBC (On Board Charger)” block

Special Functions (Special Function) in the multibrand automotive scanner LAUNCH X431 PRO3S

Main functions of LAUNCH X431 PRO3S. “Quick Test” – a full, non-reduced scan that detects all existing faults in all systems in the minimum possible time. During the scan, information about each control unit being polled and the detected faults is sequentially displayed on the screen, together with the progress in percent, and after the procedure is completed, a final report is shown.

“Coding” – changing the control unit settings, in particular the configuration data of the control system.

“Actuator Test / Actuator Operation” – in this mode, the diagnostician can directly control, from the scanner via the ECU, those actuators that are normally controlled by the ECU itself: various valves, fans, injectors, indicators, etc., thereby checking their mechanical and electrical serviceability.

In fact, this opens up a fairly wide range of possibilities for vehicle diagnostics and adjustment. Depending on the available software for a specific vehicle make, the list of special functions can differ significantly. Below we provide only some of them that were available at the time of diagnosing the 2019 Hyundai Kona Electric.

To open the "Special Function" menu, select "Special Function" from the side menu on the screen, Fig. 11a.

Oil Maintenance Reset, Fig. 11,b.

1. If the indicator lights up on the instrument cluster, the vehicle must be serviced. To turn off the indicator, it is necessary to reset the mileage or driving time, after which the system will start a new maintenance cycle.

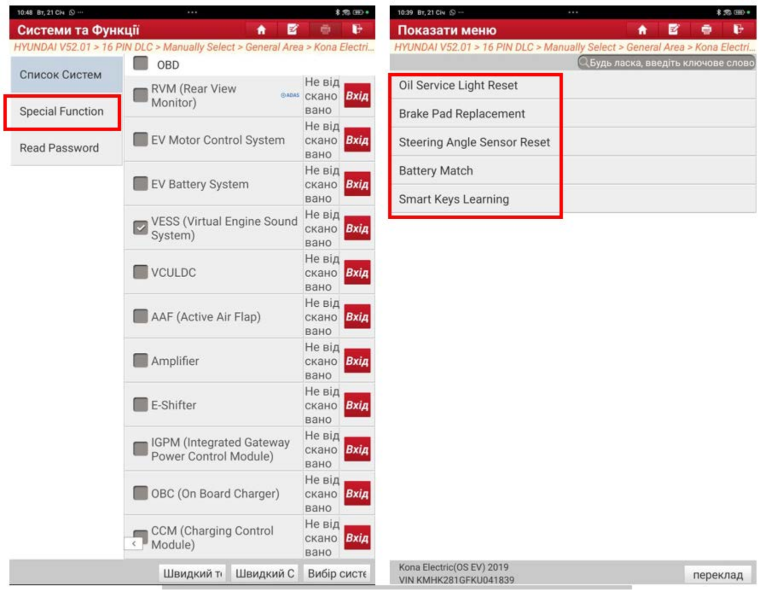
2. After changing the oil or the equipment that monitors its service life, the indicator must be "reset".

Brake Pad Replacement, Fig. 11,b.

1. If the brake pads wear down to the sensor line intended for wear monitoring, the wear sensor sends a brake pad replacement signal to the on-board computer. After replacing the pads, the error signal must be "reset". Otherwise, the warning light on the instrument cluster will remain on.

2. A reset must be performed in the following cases:

- the brake pad and the brake pad wear sensor have been replaced;
- the brake pad warning indicator is illuminated;
- it is necessary to clear a short circuit in the brake pad sensor electrical circuit;
- the servomotor has been replaced.



a b

Fig. 11 Launch and analysis of Special Function using the Launch x431 Pro3S scanner: a – selection of "Special Function"; b – selection of "Read Data Stream"

Steering Angle Sensor Reset, Fig. 11,b.

The purpose of this special function is to record, in the ESP control unit or in the separate steering angle sensor (SAS) control unit, the values corresponding to the zero angle, i.e. the steering wheel position when the vehicle is moving in a straight line.

1. First, set the steering wheel to the neutral position at which the vehicle should travel straight ahead. Taking this position as a reference, the electronic control unit can calculate the exact steering angle to the left and right.

2. This procedure is performed after replacement of the steering angle sensor, replacement of mechanical steering components (steering gear, steering column, tie rod, steering knuckle), wheel alignment, or restoration of the body geometry.

Battery Match (Reset)

Battery system service, Fig. 11b. This function is intended to calibrate the BMS SOC value to the SOC value of the replaced main battery when the high-voltage main battery is replaced.

Smart Keys Learning, Fig. 11,b

This function allows the configuration (programming) of smart keys to the vehicle.

Conclusion

The Hyundai Kona Electric is one of the most popular mid-price electric vehicles actively operated on Ukrainian roads; therefore, the development of effective approaches to its diagnostics is undoubtedly relevant.

The study has shown that the multibrand scanner LAUNCH X-431 PRO 3S provides full access to the main electronic systems of the Hyundai Kona Electric, in particular: the high-voltage battery, the charge control system, the inverter, the electric motor, the recuperation system, and various electronic control units.

Practical diagnostics have confirmed that the LAUNCH X-431 PRO 3S enables both reading of current parameters and in-depth fault diagnostics, including hidden ones. For example, by analyzing the parameters obtained during diagnostics, it is possible to determine whether the odometer readings have been artificially altered (corrected). Thus, a fairly wide range of possibilities for vehicle diagnostics and adjustment is opened up. Depending on the available software for a specific vehicle make, the list of special functions available in the multibrand scanner LAUNCH X-431 PRO 3S may differ significantly. The paper presents the set of special functions available when diagnosing a Hyundai Kona Electric vehicle.

The multibrand scanner LAUNCH X-431 PRO 3S provides a complete cycle of EV service diagnostics: from quick scanning and data stream reading to special procedures and detection of manipulations with mileage/battery parameters. Following the proposed algorithm increases the accuracy of diagnostic conclusions, reduces the time required to locate faults, and minimizes the risk of incorrect decisions during servicing and diagnosing electric vehicles.

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Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Особливості діагностики Hyundai Kona electric з використання мультимарочного сканеру LAUNCH X-431 PRO 3S

Анотація. Проблема. *Швидке зростання парку електромобілів в Україні створило практичну потребу в надійних методах діагностики, сумісних з місцевим сервісним обладнанням. Зокрема, станції технічного обслуговування повинні мати можливість оцінювати технічний стан популярних моделей, таких як Hyundai Kona Electric, використовуючи універсальні мультимарочні діагностичні сканери.* ***Мета.*** *Метою цієї роботи є дослідження можливостей та обмежень мультимарочного діагностичного сканера LAUNCH X-431 PRO 3S для технічної діагностики Hyundai Kona Electric, з акцентом на стан акумулятора, ключові електронні блоки керування (ЕБУ) та виявлення прихованих несправностей і маніпуляцій з даними.* ***Методологія.*** *Дослідження поєднує огляд літератури з діагностики електромобілів, підходи на основі OBD-II та оцінку стану акумулятора з практичними експериментами на Hyundai Kona Electric за допомогою LAUNCH X-431 PRO 3S. Запропоновано покроковий алгоритм діагностики, а також проаналізовано потоки даних у режимі реального часу для ряду ЕБУ, включаючи подушку безпеки, модуль кластера IC, IBU-BCM, блок смарт-ключа, систему акумуляторів електромобілів та бортовий комп'ютер.* ***Результати.*** *Експерименти показують, що LAUNCH X-431 PRO 3S забезпечує повний доступ до основних підсистем електромобілів, що дозволяє швидко зчитувати коди несправностей, детально аналізувати параметри в реальному часі та виконувати спеціальні функції. У статті демонструється, як комбінований аналіз напруги акумулятора, накопиченої енергії, часу роботи та лічильників зарядки змінного струму може бути використаний для визначення реального пробігу, виявлення втручання в одометр та оцінки стану високовольтного акумулятора.* ***Оригінальність.*** *Робота пропонує одну з перших структурованих діагностичних процедур для Hyundai Kona Electric з використанням широкодоступного мультимарочного сканера, пов'язуючи конкретні параметри даних X-431 з діагностичними завданнями, специфічними для електромобілів, такими як перевірка реального пробігу, оцінка деградації акумулятора та виявлення навмисного маскування попереджувальних індикаторів.* ***Практична цінність.*** *Запропонований алгоритм та інтерпретації параметрів надають сервісним інженерам та оцінювачам вживаних електромобілів практичний, відтворюваний підхід до комплексної діагностики Hyundai Kona Electric за допомогою LAUNCH X-431 PRO 3S, скорочуючи час діагностики, підвищуючи точність виявлення несправностей та знижуючи ризики, пов'язані з купівлею та обслуговуванням вживаних електромобілів.*

Ключові слова: *діагностика електромобілів, OBD-II, стан акумулятора, моніторинг у режимі реального часу, LAUNCH X-431, коди помилок, споживання енергії.*

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