# RESEARCH AND EXPERIMENTATION OF AN ELECTRICAL FAULT DETECTION SYSTEM FOR INDUCTORS USED IN EV CHARGING STATIONS

## NGHIÊN CỨU VÀ THỰC NGHIỆM HỆ THỐNG PHÁT HIỆN HƯ HỎNG VỀ ĐIỆN CHO CÁC LOẠI CUỘN CẢM DÙNG TRONG CÁC TRẠM SẠC XE ĐIỆN

**Nguyen Dac Minh Triet, Le Hoai Nam***

*The University of Danang – University of Science and Technology, Vietnam*

*Corresponding author: lehoainam@dut.udn.vn

(Received: October 25, 2024; Revised: January 27, 2025; Accepted: Febuary 18, 2025)

DOI: 10.31130/ud-jst.2025.457E

**Abstract** - With the growing integration of electric vehicles (EVs) into daily life, the demand for reliable charging stations has significantly increased. Ensuring the electrical safety of these stations requires high-quality inductor components to maintain accuracy and efficiency during charging. This study presents the development of an automatic electrical fault detection system for inductors, aimed at enhancing cost-effectiveness and reducing risks for businesses. First, the paper provides the structure, standards, and technical parameters of different types of inductors. Then, the overview and working principle of the electrical fault detection system are presented in detail. Experimental results are analyzed to assess the system's accuracy and reliability, demonstrating its potential for improving the performance of inductor components in EV charging stations.

**Key words** - Electrical fault detection system; EV charging station; inductor

**Tóm tắt** - Với sự phổ biến của xe điện trong cuộc sống hàng ngày, nhu cầu về các trạm sạc đã tăng lên đáng kể. Việc đảm bảo an toàn điện cho các trạm này đòi hỏi các thành phần cuộn cảm phải có chất lượng cao để duy trì độ chính xác và hiệu quả trong quá trình sạc. Nghiên cứu này trình bày quá trình phát triển một hệ thống tự động phát hiện hư hỏng cho cuộn cảm cho các loại cuộn cảm dùng trong các trạm sạc xe điện, nhằm nâng cao hiệu quả về chi phí và giảm rủi ro cho doanh nghiệp. Đầu tiên, bài báo cung cấp cấu trúc, tiêu chuẩn và thông số kỹ thuật của các loại cuộn cảm khác nhau. Sau đó, tổng quan và nguyên lý hoạt động của hệ thống phát hiện lỗi hư hỏng về điện được trình bày chi tiết. Các kết quả thử nghiệm được phân tích để đánh giá độ chính xác và độ tin cậy của hệ thống, chứng minh tiềm năng của hệ thống trong việc cải thiện hiệu suất của các thành phần cuộn cảm trong các trạm sạc xe điện.

**Từ khóa** - Hệ thống phát hiện hư hỏng về điện; hệ thống sạc xe điện; cuộn cảm

## 1. Introduction

In recent years, the electric vehicle (EV) trend has become a long-term vision and goal in both developed and developing nations [1]. In May 2021, U.S. President Joe Biden declared a statement that aligns with the current global situation, as the number of EVs continues to rise in many world powers [2]. Vietnam is also part of this race, with VinFast pioneering the EV movement [3]. Overall, the development and application of technology in the EV sector are increasingly emphasized [4].

Initially, it is worth noting the superior features of EVs compared to current internal combustion engine vehicles, such as improving environmental cleanliness and reducing noise pollution. Furthermore, the operational and maintenance costs are significantly lower than those of traditional internal combustion engines [5-6]. However, a major challenge in making EVs widespread among the public lies in battery technology, charging time, and the coverage of the charging station network [7-8]. The charging station infrastructure, which ensures the smooth operation of EVs, is a key factor in the development of the EV industry [9-10]. Following this trend, VinFast has swiftly expanded its charging station network to all 63 provinces in Vietnam [11].

To rapidly expand the network of charging stations, the components that make up VinFast charging pillars must be ensured in terms of supply and output quality [12]. Inductors, often used in electrical circuits such as DC-DC converter, as shown in Figure 1 [13] are among the critical components situated within EV charging stations. The converters regulate the battery's voltage to ideal levels, distributing power to different EV components [14]. Within these converters are power inductors that allow DC power to pass through while resisting AC power. The inductors are combined with integrated circuits (ICs), which perform high-speed charging and allow DC-DC converters to adjust voltages to the necessary levels [15]. Inductors also serve to filter electrical noise during the charging process, reduce electromagnetic interference, and aid in thermal management, effectively minimizing heat generation during high-power charging. To ensure the inductors operate at optimal productivity, it is essential to rely on basic electrical parameters, including leakage inductance (LCR), resistance component of a conductor (copper wire) (DCR), and insulation capability (Hipot) [16].

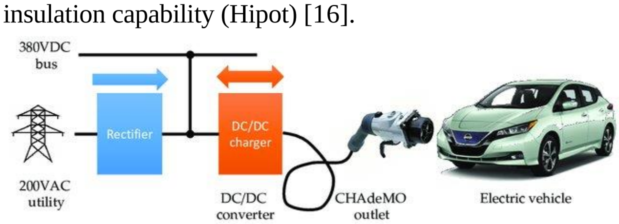



***Figure 1.*** *The role of the inductor in EV charging systems [6]*

However, the implementation of a manual inspection process for the output quality of inductors requires significant expense to achieve the desired quantity. Currently, manual electrical inspections require up to four workers, with a productivity rate of 400-500 components per day. This productivity is relatively low, consumes significant manpower, and yields low reliability. Additionally, the process is dependent on the skill of the workers, resulting in inconsistent quality. Product specifications exhibit significant inaccuracies, leading to high production costs and low output. Therefore, the development of an automatic electrical fault detection system for controlling the output quality of inductors is necessary to optimize time, costs, and labor in the inductive components manufacturing industry.

This article describes the design process and experimental setup of an electrical fault detection system for inductors. Initially, the characteristics, structure, and technical parameters of these inductors are described. This is followed by the design and assembly process of the system, which will also be introduced in the next section. Based on experimental results, the accuracy and reliability levels of the system used in inductor manufacturing plants are assessed.

## 2. Structure and characteristics of inductors

Within the scope of this article, it is necessary to perform electrical testing on two distinct types of inductors: 006 and 007, both components are located within a large kit inside each charging station (Figure 2). In detail, the construction of these inductors includes four basic components (Figure 3): two coils (1) wound around two ferromagnetic cores (2), the coils soldered to four copper terminals (3), and an insulating plastic header (4) fitted in place to ensure electrical insulation.

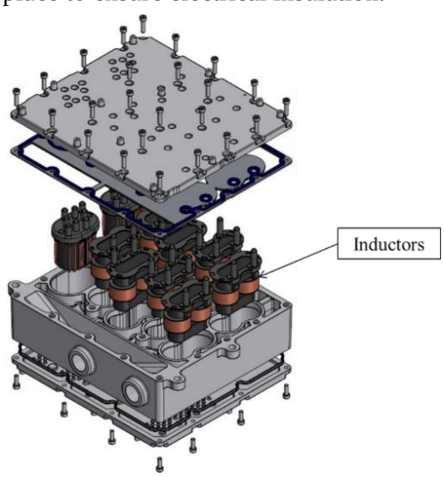
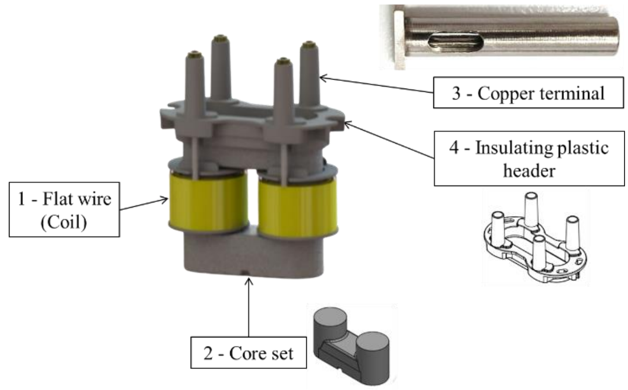



***Figure 2.*** *Components of the kit within the charging station*

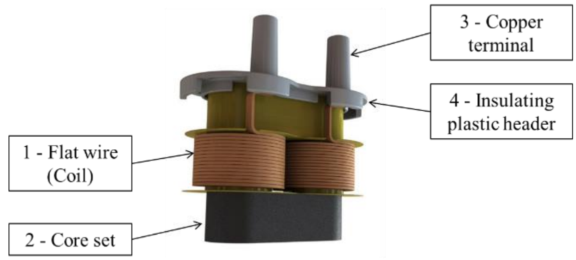
Similar to inductor 006, inductor 007 also includes the components shown in Figure 3(b) but has only two terminals: two coils (1) wound around two ferromagnetic cores (2), the coils soldered to two copper terminals (3), and an insulating plastic header (4) fitted in place to ensure electrical insulation.

For inductor 006 to meet the output standards for use in charging stations, the parameters of inductance (LCR, DCR, Hipot) must be guaranteed to avoid instability during operation. In contrast, inductor 007 only requires compliance with the output standard for inductance (LCR) and insulation capability (Hipot).

The specific parameters and threshold values for the electrical performance of these inductors, detailed in Table 1, are determined based on electromagnetic standards established by the manufacturer, with careful consideration of measurement errors. These thresholds ensure reliable operation and effective functionality of the inductors within the charging station.




*(a) Inductor 006*




*(b) Inductor 007*

***Figure 3.*** *Structure of inductors*

***Table 1.*** *Specific parameters of the inductors*

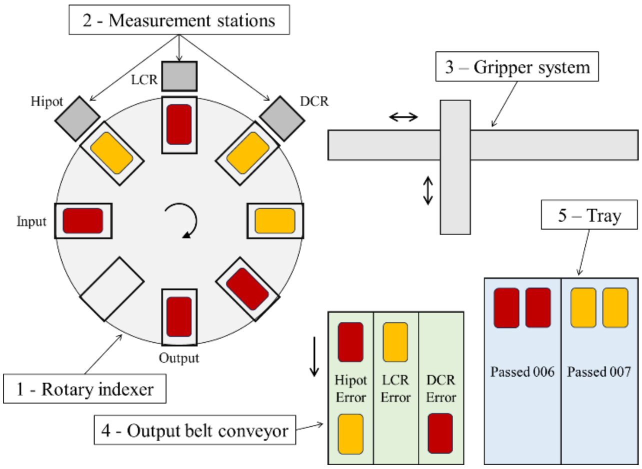
| ***Type*** | ***Parameters*** | ***Required value*** |
|---|---|---|
| 006 | Self-inductance (mH) | ≥1.5 |
| | Leakage inductance (µH) | 7.6 ÷ 11 |
| | DC resistance (mΩ) | ≤ 39.6 |
| | Dielectric strength test (mA) | ≤ 3 |
| 007 | Self-inductance (mH) | 156.4 ÷ 211.6 |
| | Leakage inductance (µH) | ≤ 27.5 |
| | Dielectric strength test (mA) | ≤ 3 |

## 3. Electrical fault detection system

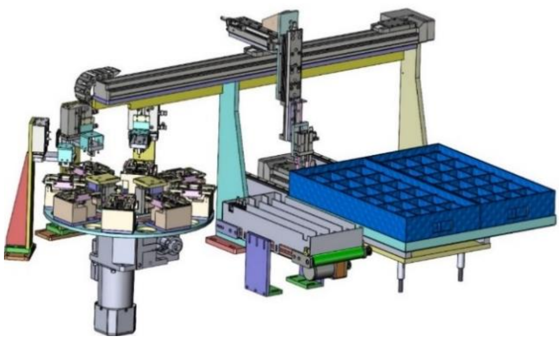
### *3.1. System structure*

The system structure, shown in Figure 4, includes a rotary indexer (1) for mounting inductors, three electrical measurement stations, a 3DoFs gripper system, an output belt conveyor for error inductors, and a tray for passed inductors, with the overall dimensions of the system being 1500 mm × 850 mm × 800 mm.

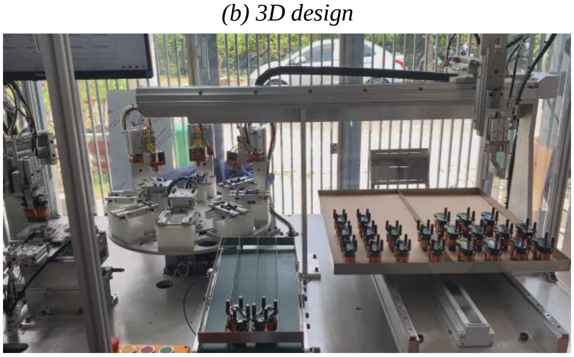
The process starts by placing the inductor at the Input position on the rotary indexer, with parameters detailed in Table 2. The rotary indexer then sequentially moves the inductor through the following measurement stations (Hipot, LCR, DCR). After measurements are complete, a gripper removes the inductor from the Output position and sorts them based on Passed or Failed results and inductor type. When the tray of Passed inductors is full, a signal alerts the operator to empty the tray, allowing the process to continue.




*(a) System structure*



*(b) 3D design*



*(c) Real system*

***Figure 4.*** *Fault detection system for evaluating the electrical performance of inductors*

***Table 2.*** *Specific parameters of rotary indexer*

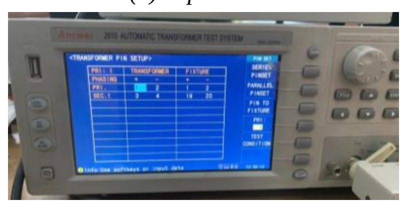
| ***Parameters*** | ***Value*** |
|---|---|
| Number of indices stop | 8 |
| Revolution of input shaft | 80rpm |
| Cam curve | Modified Sine curve |
| Size of sub-table | ø480 x t10 |
| Weight of jig | 0,5 kg/set |
| Weight of workpiece | 0,2 kg/piece |
| Rotation cycle | 8s |

Three electrical measurement stations are the core of the fault detection system:

- Hipot: Includes two signal ends. One end connects directly to the four copper terminals of inductor 006 or the two copper terminals of inductor 007, while the other end contacts the surface of the insulating plastic header to check electrical leakage on the insulating layer. The results are displayed on the Hipot tester (Figure 6). This measurement, also referred to as a dielectric strength test, evaluates whether the insulation of the non-conductive surface can effectively prevent electric shock risks at the operating voltage;

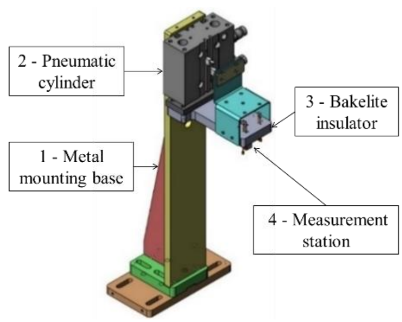
- LCR & DCR: Both of these stations feature one signal end that connects directly to the four copper terminals of inductor 006 or the two copper terminals of inductor 007. The LCR station measures the inductance and leakage inductance of the inductors, while the DCR station verifies whether the resistance of the conductors falls within the permissible threshold.


*(a) Hipot tester*

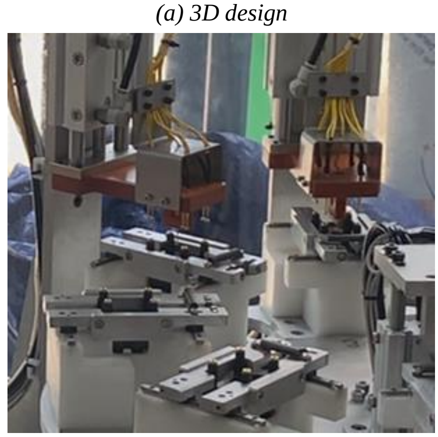


*(b) LCR&DCR tester*

***Figure 5.*** *Electrical tester devices*




*(a) 3D design*



*(b) Real mechanism*

***Figure 5.*** *Mounting mechanism of measurement stations*

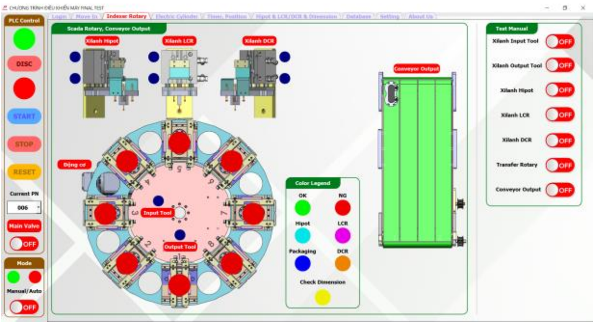
Each measurement station is mounted on a mechanism consisting of three main components (Figure 5):

- Metal mounting base (1): provides structural stability to the mechanism, preventing positional deviations during measurement;

- Pneumatic cylinder (2): enables the vertical movement of the measurement stations during the inductor transfer process;

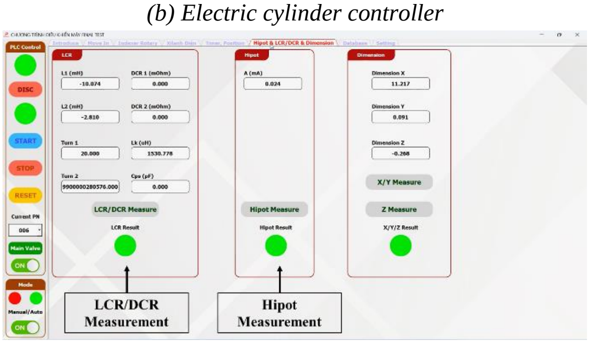
- Bakelite insulator (3): offers excellent electrical insulation and thermal resistance, minimizing interference with the measurement process.

### *3.2. Control system*

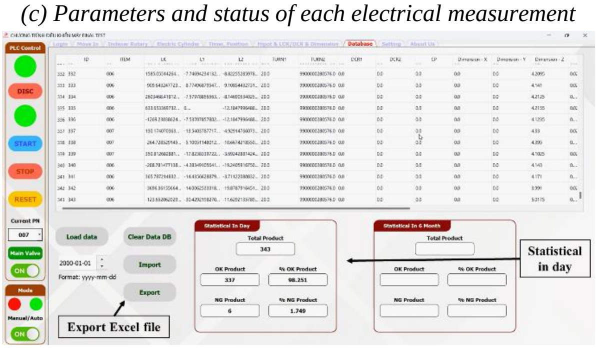


*(a) Inductor status on the rotary indexer*

*(b) Electric cylinder controller*




*(c) Parameters and status of each electrical measurement*




*(d) The database and statistical measurement*

***Figure 7.*** *The HMI application*

The fault detection system is controlled by a PLC system via an HMI (Human-Machine Interface). To develop the HMI, Python was utilized in combination with the PySide library for building the user interface (UI) and the Snap7 library for establishing communication with the S7-1200 PLC.

The system's functionalities include display screens for various mechanisms, such as the rotary indexer, gripper system, and display parameters obtained from Hipot, LCR, and DCR tests. These parameters are stored in a database, allowing operators to retrieve data and export it into Excel files as needed. Additionally, the software provides daily statistical analysis, including the number of inductors measured and the Failed/Passed percentage (Figure 7).

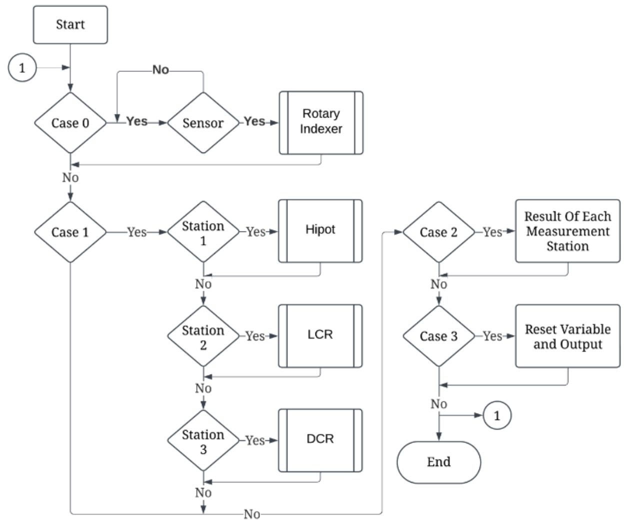



***Figure 8.*** *The PLC's flowchart*

The PLC's flowchart is programmed using SCL (Structure Control Language) instead of the Ladder logic. Unlike Ladder logic, SCL supports conditional statements and loops similar to high-level programming languages like C, enabling faster task processing and reduced programming time for complex control systems (Figure 8). This setup delivers an efficient and user-friendly interface for operating and monitoring the system.

***Figure 9.*** *The completed operating process of system*

The system operates in two modes: Manual and Auto. In Manual mode, devices such as cylinders and conveyors can be controlled directly via the UI control panel using switches and control buttons. In Auto mode, the operator simply presses the "START" button to initiate the process, and the entire workflow - from testing an inductor to its output - is completed automatically within 8 seconds. Once the tray is full, the operator empties it, and the process continues seamlessly. Figure 9 illustrates the complete process of inductor quality testing using the proposed fault detection system.

For safety, the system includes an emergency "STOP" button that allows operators to immediately halt operations in hazardous situations, such as sudden external impacts on the machine.

## 4. Results and discussion

### *4.1. Accuracy of mechanism*

To evaluate the accuracy of this system, a series of samples was tested, starting with trials exclusively using type 006, then type 007, and finally a mix of both types. Sample sizes ranged from 50 to 250, with each trial recording the number of inaccurate measurements to calculate the system's accuracy. Detailed accuracy rates for each sample size are presented in Figure 10.

The results show that as the sample size increases, the system's accuracy improves and stabilizes. When the sample size exceeds 250, the accuracy ratio remains consistent, indicating stable performance. Additionally, the system's accuracy is not significantly affected by whether it tests type 006, type 007, or a combination of both.

However, two common issues were identified during operation that can lead to system failure: the initialization phase of the transformer tester and misaligned movements of the gripper system. Therefore, the system should be thoroughly checked during startup to ensure smooth operation.

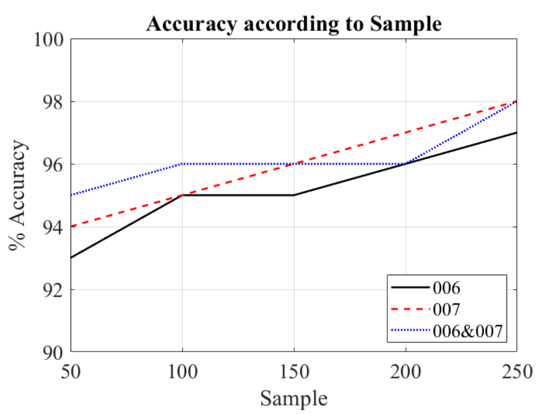



***Figure 10.*** *Accuracy results of testing of the inductors*

### *4.2. Operating time of fault detection process*

Another important factor to consider is the operating time of the mechanism, as a faster response time directly correlates with higher productivity in processing the number of inductors each day. The operating time is measured from when the component is placed on the rotary indexer until it is sorted into the output conveyor or tray. Figure 11 presents the results of the operating time for the fault detection system with inductors 006 and 007.

Fluctuations in operating time can occur during the quality-checking process due to the varying distances of samples from the input to the output of the system. Some samples may require less time if they are closer to the picking arm while on the rotary indexer. This variation is primarily caused by the travel distance of the pneumatic arm as it transfers the sample from the rotary indexer to the output tray.

Overall, the average processing time is 8.95 seconds for inductor type 006 and 8.74 seconds for type 007. For faulty samples, the processing time is typically under 8.5 seconds.

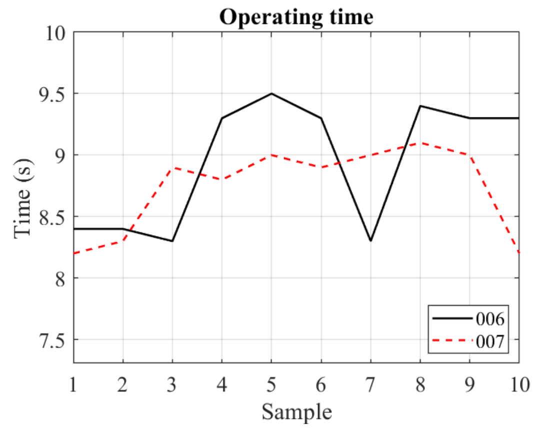



***Figure 11.*** *Operating time for checking the inductors*

## 5. Conclusions

This paper presents the design and fabrication of an automatic electrical fault detection system for inductors used in EV charging stations. The system's characteristics, essential parameters, and proposed solution have been thoroughly detailed. Through research and development, the following key results have been achieved:

- The system seamlessly integrates mechanical components such as conveyors, cylinders, and rotary elements with a PLC controller and a PC-based user interface;

- It automatically adjusts to measure both types of inductors (006 and 007) continuously;

- Labor costs are significantly optimized, requiring only one operator instead of four, while improving output and speed. Productivity has increased threefold, from 400–500 components per day to over 1,200 components per day, while also saving valuable factory workspace;

- The system can be easily adapted to detect various types of inductors by modifying the fixture design and adjusting test thresholds to accommodate specific shapes and specifications. This flexibility allows most existing mechanisms to remain unchanged, avoiding a complete structural redesign.

The system effectively meets the enterprise's needs, reducing costs and significantly increasing productivity. It ensures the uninterrupted manufacturing of inductor components for charging stations. However, some limitations remain, including mechanical folding errors, measurement inaccuracies, and high system costs. Future development will focus on addressing these issues by optimizing the mechanical mechanism for greater accuracy, reducing costs through production and equipment optimization, and further increasing processing speed to achieve even higher output productivity.

**Acknowledgment:** This work was supported by The University of Danang - University of Science and Technology under project number T2024-02-30.

## REFERENCES


[1] J. Saliba, "The Race to Electric Vehicles", *in SoAS - Theses and Dissertations*, pp. 482, 2022. https://doi.org/10.26756/th.2022.482.

[2] J. Murray, "Global Briefing: President Biden declares 'the future of the auto industry is electric'", *in BusinessGreen*, August 6, 2021. [Online]. Available: https://www.businessgreen.com/news-analysis/4035283/global-briefing-president-biden-declares-future-auto-industry-electric. [Accessed June 28, 2024].

[3] K. Vu, "Vietnam's VinFast to launch first electric car in 2021", *in Reuters*, May 28, 2020. [Online]. Available: https://www.reuters.com/article/vietnam-vinfast/update-1-vietnams-vinfast-to-launch-first-electric-car-in-2021-idUSL4N2DA2AZ/ [Accessed June 28, 2024].

[4] C. Zimm, "Improving the understanding of electric vehicle technology and policy diffusion across countries", *in Transport Policy, Elsevier*, vol. 105, pp. 54-66, 2021. https://doi.org/10.1016/j.tranpol.2020.12.012.

[5] P. Weldon, P. Morrissey, and M. O'Mahony, "Long-term cost of ownership comparative analysis between electric vehicles and internal combustion engine vehicles", *in Sustainable Cities and Society, Elsevier*, vol. 39, pp. 578-591, 2018. https://doi.org/10.1016/j.scs.2018.02.024.

[6] Z. Liu *et al.*, "Comparing total cost of ownership of battery electric vehicles and internal combustion engine vehicles", *in Energy Policy, Elsevier*, vol. 158, 2021. https://doi.org/10.1016/j.enpol.2021.112564.

[7] O. Egbue and S. Long, "Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions", in *Energy Policy, Elsevier*, vol. 48, pp. 717-729, 2012. https://doi.org/10.1016/j.enpol.2012.06.009.

[8] G. Krishna, "Understanding and identifying barriers to electric vehicle adoption through thematic analysis", *in Transportation Research Interdisciplinary Perspectives, Elsevier*, vol. 10, pp. 100364, 2021. https://doi.org/10.1016/j.trip.2021.100364.

[9] F. Alanazi, "Electric Vehicles: Benefits, Challenges, and Potential Solutions for Widespread Adaptation", in *Appl. Sci*., vol. 13, no. 10, 2023. https://doi.org/10.3390/app13106016

[10] M. S. Mastoi *et al.*, "An in-depth analysis of electric vehicle charging station infrastructure, policy implications, and future trends", in *Energy Reports, Elsevier*, vol. 8, pp. 11504-11529, 2022. https://doi.org/10.1016/j.egyr.2022.09.011.

[11] T. Thinh, "Tram sac VinFast dat mat do 3,5 km/tram tai 80 thanh pho tren ca nuoc", in *Dantri*, October 11, 2023. [Online]. Available: https://dantri.com.vn/o-to-xe-may/tram-sac-vinfast-dat-mat-do-35-kmtram-tai-80-thanh-pho-tren-ca-nuoc-20231011132657875.htm [Accessed June 28, 2024].

[12] Vinfast, "Tong quan tram sac VinFast", in *Vinfastauto*, October 21, 2022. [Online]. Available: https://vinfastauto.com/vn_vi/tong-quan-tram-sac-vinfast [Accessed June 28, 2024].

[13] N. D. Duy, B. N. Tam, and K. Yukita, "Design and Optimization of Three-Phase Dual-Active-Bridge Converters for Electric Vehicle Charging Stations", in *Energies*, vol. 13, no. 1, 2019. https://doi.org/10.3390/en13010150

[14] S. Chakraborty, H-N Vu, M. Hasan, D-D Tran, M. E. Baghdadi, and O. Hegazy, "DC-DC Converter Topologies for Electric Vehicles, Plug-in Hybrid Electric Vehicles and Fast Charging Stations: State of the Art and Future Trends", *in Energies*, vol. 12, no. 8, 2019. https://doi.org/10.3390/en12081569

[15] B. Dull, "Transformers and Inductors for Electric Vehicles and Charging", in *Triadmagnetics*, March 13, 2024. [Online]. Available: https://info.triadmagnetics.com/blog/transformers-and-inductors-for-electric-vehicles-and-charging [Accessed June 28, 2024].

[16] Panasonic In., "Basic Knowledge of Inductors", *in industrial.panasonic.com*, September 14, 2020. [Online]. Available: https://industrial.panasonic.com/ww/ss/technical/b6 [Accessed June 28, 2024].