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Thermal Overload Relay Trainer Design for Electric Motor Control Practice

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Abstract

The limited availability of adequate practical learning media often poses a significant challenge for students in understanding the applied principles of electrical components, particularly the Thermal Overload Relay (TOR). This study aims to design, develop, and evaluate the feasibility of a TOR trainer as an innovative learning medium for electric motor control practicum. The research methodology employed is Research and Development (R&D), adapting the 4D development model (Define, Design, Develop, Disseminate), which was limited to the development stage. Data were collected using Likert-scale validation instruments involving media and subject matter experts. The analytical results indicate that the TOR trainer obtained an average validation score of 4.2, categorized as "Highly Feasible." Specifically, the validity testing yielded a feasibility percentage of 93.5% for the media aspect and 91.35% for the material design aspect. These findings demonstrate that the developed TOR trainer possesses superior presentation quality and is highly representative for use as a supporting medium in practical activities. The implementation of this media is expected to enhance student comprehension effectiveness and the overall quality of the learning process in electric motor control systems within technical education environments.

Keywords: *Learning Media, Thermal Overload Relay, Electric Motor Control, 4D Model*

Abstrak

Keterbatasan ketersediaan media praktikum yang memadai sering kali menjadi kendala utama bagi mahasiswa dalam memahami prinsip kerja komponen kelistrikan secara aplikatif, khususnya pada unit *Thermal Overload Relay* (TOR). Penelitian ini bertujuan untuk merancang, mengembangkan, dan menguji tingkat kelayakan *trainer* TOR sebagai media pembelajaran inovatif pada praktikum pengendalian motor listrik. Metode penelitian yang diterapkan adalah *Research and Development* (R&D) dengan mengadaptasi model pengembangan 4D (*Define, Design, Develop, Disseminate*), yang dibatasi hingga tahap pengembangan (*Develop*). Data penelitian dikumpulkan melalui instrumen lembar validasi berbasis skala Likert yang melibatkan para ahli media dan ahli materi. Hasil analisis menunjukkan bahwa *trainer* TOR memperoleh skor rata-rata validasi sebesar 4,2, yang masuk dalam kategori "Sangat Layak". Secara spesifik, pengujian validitas memberikan persentase kelayakan sebesar 93,5% pada aspek media dan 91,35% pada aspek desain materi. Temuan ini mengindikasikan bahwa pengembangan *trainer* TOR memiliki kualitas penyajian yang unggul dan sangat representatif untuk digunakan sebagai media pendukung dalam kegiatan praktikum. Implementasi media ini diharapkan dapat meningkatkan efektivitas pemahaman mahasiswa serta kualitas proses pembelajaran pada mata kuliah sistem kendali motor listrik di lingkungan pendidikan teknik.

Kata kunci: Media Pembelajaran, *Thermal Overload Relay*, Pengendalian Motor Listrik, Model 4D

Introduction

Electric motors are a key component in modern power systems and industry. Nearly all industrial, household, and public equipment utilizes electric motors as the primary drive. Electric motors work by converting electrical energy into mechanical energy. However, a common problem is overheating due to excessive current, which can cause serious damage to the motor windings and the overall electrical system [1]. To overcome this problem, a thermal overload relay (TOR) is used as a protection device. Thermal overload relay functions to monitor the current flowing to the motor and disconnects the electric current if the current exceeds a predetermined limit. In this way, TOR can prevent damage to the motor due to overheating. Thermal Overload Relay (TOR) is designed to protect the motor by disconnecting the electric current if an overload occurs [2].

In the context of vocational education, understanding the working principles of TOR is crucial. Students are expected to not only understand the theory but also be able to apply these concepts in real-world practice. Unfortunately, limited learning resources in laboratories often limit students' ability to master electric motor protection skills. This results in students being underprepared for the world of work, which demands high technical skills [3].

Several previous studies have developed training media to assist in learning electrical engineering. One study developed an electromagnetic control trainer for electric motor installations in vocational schools, which was proven to improve student understanding. Designed a TOR monitoring system for a 3-phase induction motor. The focus of the study was on testing the TOR response to load variations, with the result that tripping did not always occur according to the initial settings, providing a direct picture of the TOR working characteristics in an induction motor [4]. Introduced a TOR design based on Arduino Uno with a PZEM-004T sensor. This study demonstrates microcontroller integration as an alternative TOR design that is accurate and capable of providing real-time data [5]. The difference with my research, my research does not only test the performance of TOR, but also focuses on the design and creation of a practical trainer used as a learning medium in the electric motor control course. The trainer is designed to be educational, allowing students to understand the working principle of TOR, the TOR current setting process, the effect of the load on the motor and TOR directly [6]. Thus, the main difference lies in the research objectives: the previous study was analytical and monitoring, while my research focuses on developing practical media (trainers). However, to date, there has been little research focused on trainers specifically for motor protection using Thermal Overload Relays [7].

The urgency of this research lies in the need for applicable and contextual learning media. The TOR trainer can be a practical solution to bridge the gap between theory and practice. With this trainer, students can learn directly how TOR works in protecting electric motors from damage due to overload. In addition, the trainer also functions as a practical tool that encourages students to think critically, conduct experiments, and understand the concept of protection as a whole [8].

The purpose of this research is to design a TOR trainer design that is suitable for electric motor control practicums and to test the trainer's suitability as a learning medium.

The benefits of this research are expected to provide a positive contribution in the world of vocational education, both as teaching materials, learning media, and references for further research. The design of this thermal overload relay trainer can be used as a means of education to the public regarding how to use it and increase public understanding regarding how to operate and utilize the components in the tool [9].

Method

This research uses the Research and Development (R&D) method with the 4D development model. R&D is a type of research aimed at developing a new and useful product or innovation. The main goal of R&D is to improve product quality and increase effectiveness and efficiency in a process. This model consists of four stages: Define, Design, Develop, and Disseminate. This research was only conducted up to the Develop stage [10].

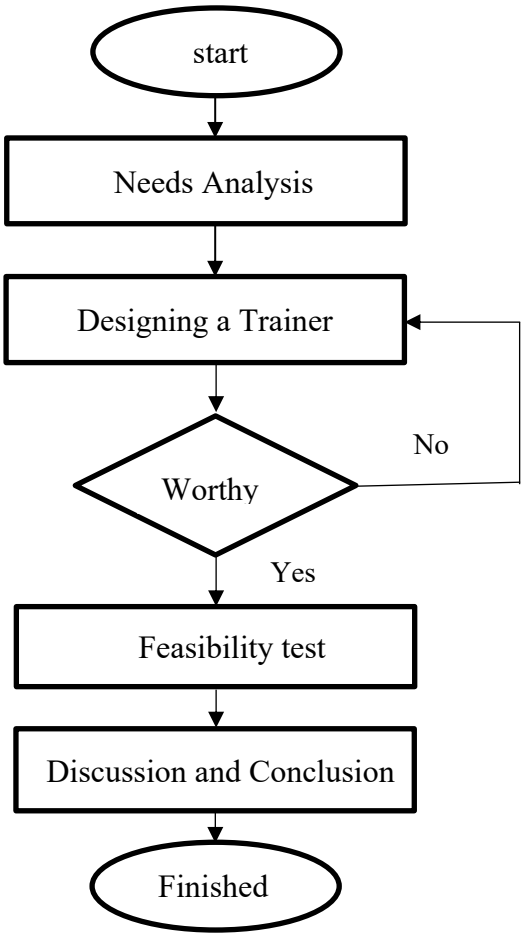


Figure 1. Thermal Overload Relay Trainer Research Flow

Define: At this stage, learning needs are identified through observations of practical activities and interviews with lecturers and students. This stage also includes a literature study to strengthen the theoretical basis for developing the TOR trainer. Design: This stage includes the physical design of the TOR trainer, including the selection of components such as electric motors, contactors, relays, control panels, and banana plug connectors. The design is carried out by paying attention to aspects of safety, practicality, and ease of use. Develop: This stage includes the creation of a TOR trainer prototype and validation tests. Validation is carried out by media experts to assess the technical aspects

and appearance of the trainer, as well as by material experts to assess the suitability of the learning content. Disseminate: This stage was not implemented because the research was still limited to development and initial trials. For this study, the development design used followed the research and development procedure by applying the 4D development model, which consists of the following stages: define, design, development, and disseminate. This has been adjusted and modified as can be seen in the following flowchart [11].

The research process for developing a Thermal Overload Relay (TOR) trainer begins with the initial stage or needs identification, where researchers observe problems in the learning process, particularly the limited practical media that can explain the working concept of TOR in a realistic manner. Next, a needs analysis is conducted to determine the specifications, components, and features required for the trainer to effectively support practical learning of electric motor control [12]. The next stage is trainer design, which includes designing the control and power circuits, selecting components, and designing the physical appearance of the device. Once the prototype is complete, A feasibility test was carried out by design experts and media experts to assess the function, security, and effectiveness of the trainer in supporting learning. The design expert validation indicators can be seen in Table 1 below.

Table 1. Design Validation Feasibility Indicators

No	Eligibility Indicators	Number of Questions
1.	Physical Design and Layout	6
2.	Functions and Operations	3
3.	Benefit	5

Validation indicators in the aspects of Physical Design and Layout, Function and Operation, and Benefits include assessments of the neatness of component layout, label clarity, safety, and ease of use of the tool, suitability of the function of each part of the tool with the designed working principle, ease of operation, and reliability of the system in displaying the concept of thermal overload in real terms, and the extent to which the media provides benefits in supporting the learning process, helping students understand the concept of electric motor control, and improving practical skills in the laboratory. These three aspects are interrelated to ensure that the learning media is not only technically feasible, but also educationally effective and safe to use in practical activities [13]. Next, the media validation feasibility indicators can be seen in Table 2 below.

Table 2. Media Validation Feasibility Indicators

No	Eligibility Indicators	Number of Questions
1.	Media Forms	5
2.	General View	4
3.	Practical	5
4.	Technical	3
5.	Media quality	2

Media suitability indicators in the aspects of Media Form, General Appearance, Practicality, Technicality, and Media Quality include an assessment of the suitability of the media form to the learning objectives and characteristics of the material, an attractive, neat, and proportional general appearance so that it is easy for users to understand, the

level of practicality of the media in the process of use and maintenance in the laboratory, technical aspects that assess the accuracy of the function of each component according to the design, as well as the overall quality of the media that reflects the durability, safety, and reliability of the tool when used in practical activities. These aspects ensure that the media not only meets functional standards, but also has aesthetic value, efficiency, and effectiveness as a learning aid that is suitable for use [14].

The test results were then analyzed in the discussion stage, to identify strengths, weaknesses, and potential for further development. Finally, the study concluded with a conclusion summarizing the success of the TOR trainer design as an innovative learning medium in electric motor control practice. The TOR trainer schematic can be seen in Figure 2 below.

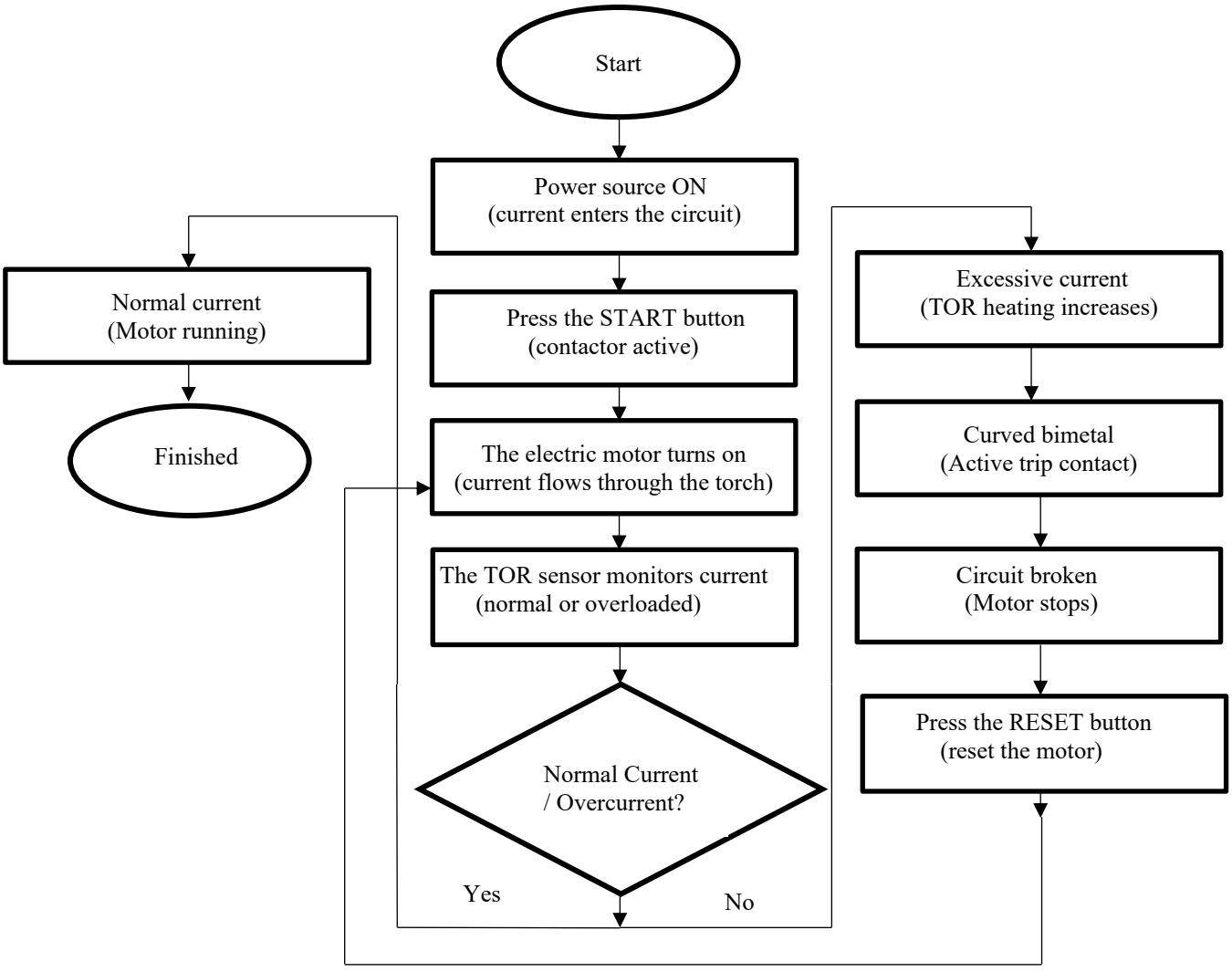


Figure 2. TOR trainer schematic

The research instrument was a validation sheet with a Likert scale (1-5). Data were analyzed descriptively and quantitatively to determine the product's feasibility category. The following equation shows the formula for calculating the trainer's feasibility percentage in Formula 1:

$$\textbf{Eligibilty Percentage} = \frac{\textbf{Total Value}}{\textbf{Maximum Value Amount}} \textbf{X100\%} \quad \text{.....(1)}$$

The expert validation result categories are determined based on the response levels shown in Table 3.

Table 3. Categories of Expert Validation Results

Category	Percentage Rate (%)
Very Worthy	80 – 100
Worthy	61 – 80
Quite Decent	41 – 60
Not feasible	21 – 40
Totally Unworthy	0 - 20

The analysis was carried out by calculating the average score and interpreting the results based on the assessment criteria. In this study, the researcher collected expert validation data by presenting the thermal overload relay training aid or trainer to media experts and design experts. This process was accompanied by the distribution of media validation sheets and design validation sheets.

Result and Discussion

The resulting research product is a Thermal Overload Relay (TOR) trainer. This trainer is equipped with an electric motor, TOR, switch, fuse, and simulation panel. The trainer design is made in the form of a medium-sized panel box so that it is easy to move and use in practicums. The following is a picture of the Thermal Overload Relay wiring diagram in Figure 3 below.

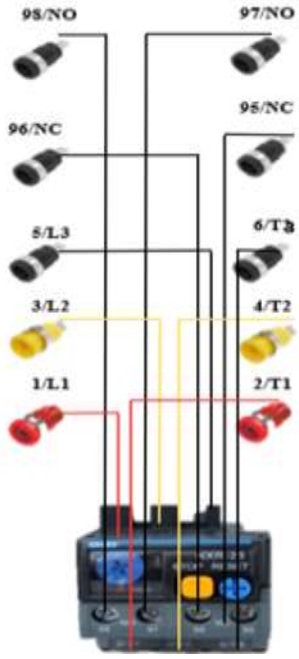


Figure 3. Thermal Overload Relay Trainer Wiring Diagram

The wiring diagram shows a Tor circuit trainer for a three-phase motor consisting of a thermal overload relay and auxiliary contacts as a learning medium for the electric motor control system. Tor functions to connect and disconnect the power flow from the source to the motor through terminals L1–L3 and T1–T3, while the overload relay

functions as a motor safety from overcurrent by disconnecting the control circuit when an overload occurs. NO (Normally Open) and NC (Normally Closed) auxiliary contacts are used for control circuits, such as interlock and holding circuit functions. The following is the design result of the Thermal Overload Relay Trainer in Figure 4.

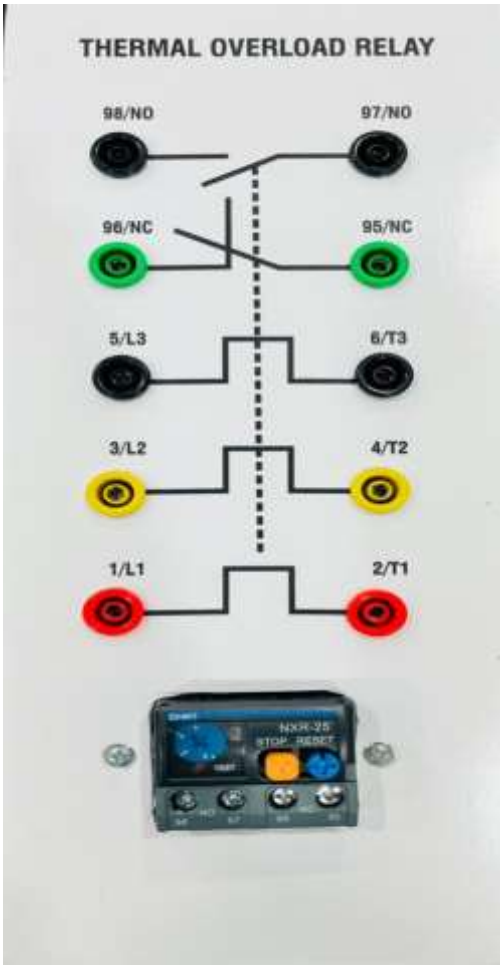


Figure 4. Thermal Overload Relay Design Results

Testing of the Thermal Overload Relay (TOR) teaching aid was conducted through two validation aspects, namely media validation and design validation. This validation process involved four expert lecturers on campus, where two lecturers acted as media expert validators and two other lecturers as design expert validators. The purpose of the media validation test was to determine whether the TOR teaching aid was suitable for use in the learning process, especially for students taking electric motor control courses, seen from the aspects of appearance, component clarity, safety of use, and ease of operation. Meanwhile, design validation aims to assess the design and layout, function and operation, and the benefits of the teaching aid in helping students understand the working principles of the Thermal Overload Relay in an electric motor control system. The results of this assessment serve as the basis for determining whether the Thermal Overload Relay teaching aid meets the eligibility standards for use as a learning medium. The results of the media validation can be seen in Table 4 below.

Table 4. Media Validation Results

No	Indicator	Question aspects	Criteria	
			Val 1	Val 2
1.	Media forms	The components of the teaching aids are clearly shown.	5	5
2.		Easy to understand teaching aids	4	4
3.		Teaching aids have main components	5	5
4.		Teaching aids become practical media tools	5	5
5.		The teaching aids displayed present the concept of the tor material.	5	5
6.	General View	The design of this prop can attract attention	5	5
7.		The layout of the components on this teaching aid is precise, making it an attraction.	4	5
8.		The appearance of this tool is simple so it is easy to understand.	5	4
9.		The trainer's general appearance already reflects the learning media.	4	4
10.	Practical	Tools and materials are easy to get	5	5
11.		TOR trainer is easy to use by lecturers and students during practical	5	4
12.		The tools and materials used are easy to understand their function	5	5
13.		This teaching aid has long-term durability.	4	4
14.	Technical	The tools and materials used in the teaching aids are suitable for use.	5	5
15.		This prop has a relatively affordable initial cost.	5	5
16.		The trainer for three-phase induction motors can function properly.	5	5
17		The operation of this trainer tool has a working method that is easy to understand.	5	4
18		The operation of this trainer tool is done manually	4	5
19	Media quality	This teaching aid has high selling power	4	5
20		Lower maintenance costs	4	5
		Amount	93	94
		Percentage	93	94
		Overall percentage	93,5	

The results of media validation conducted by two expert validators indicate that the Thermal Overload Relay (TOR) teaching aid has met the eligibility criteria as a learning medium. The experts' assessment includes several aspects, such as physical appearance, neatness of construction, safety of use, clarity of component layout. In

general, the value given indicates that the media design is good enough and is able to facilitate the learning process of electric motor control practices. With these results, it can be concluded that the TOR teaching aid media is declared suitable for use and effective as a supporting tool for learning media. And then a design validation test is carried out to determine whether the thermal overload relay trainer teaching aid is suitable or not for use for electric motor control practices, as can be seen in table 5 below.

Table 5. Media Validation Results

No	Indicator	Question aspects	Criteria	
			Validator 1	Validator 2
1.	Physical design & layout	The component layout is neat and easy to understand.	5	5
2.		The quality of the trainer's physical neatness	5	4
3.		Safety of Use of Electrical Components	5	4
4.		Safe cable arrangement, no mess	5	4
5.		Standardization of wiring diagram symbols and electrical symbols that are standard and recognized internationally or nationally	5	5
6.		Material and physical quality	5	4
7.	Function & Operation	Electrical wiring complies with safety standards	5	4
8.		Implementing K3 Safety on Thermal Overload Relay Trainers	5	4
9.		Input-output wiring labels on the thermal overload relay trainer	5	5
10.	Benefit	With the thermal overload relay trainer, students can clearly understand the use of tor for three-phase electric motors.	5	4
11.		Can expand understanding of Tor for three-phase induction electric motors	4	4
12.		Students can improve their practical electrical skills in Tor and three-phase induction motor materials.	5	4
13.		Can motivate students in carrying out the Electric Motor Control Practicum learning	5	4
14.		Can support learning in the Practical course Electric Motor Control	5	4
		Amount	69	59
		Percentage	98,5	84,2
		Overall percentage	91,35	

Based on the validation results carried out by two validators, the feasibility percentages were 98.2% and 84.2% respectively, with an average overall percentage of 91.2%. These results indicate that the Thermal Overload Relay (TOR) teaching aid is in the Very Feasible category for use as a learning medium. This high percentage indicates that both from the aspect of physical appearance, media construction, as well as from the aspect of material suitability and its usefulness for the learning process, the TOR teaching aid has met the established feasibility standards. Thus, this media is considered capable of helping students to practice electric motor control. The following is a graph of the results of the Media and Design validation can be seen in Figure 5 below.

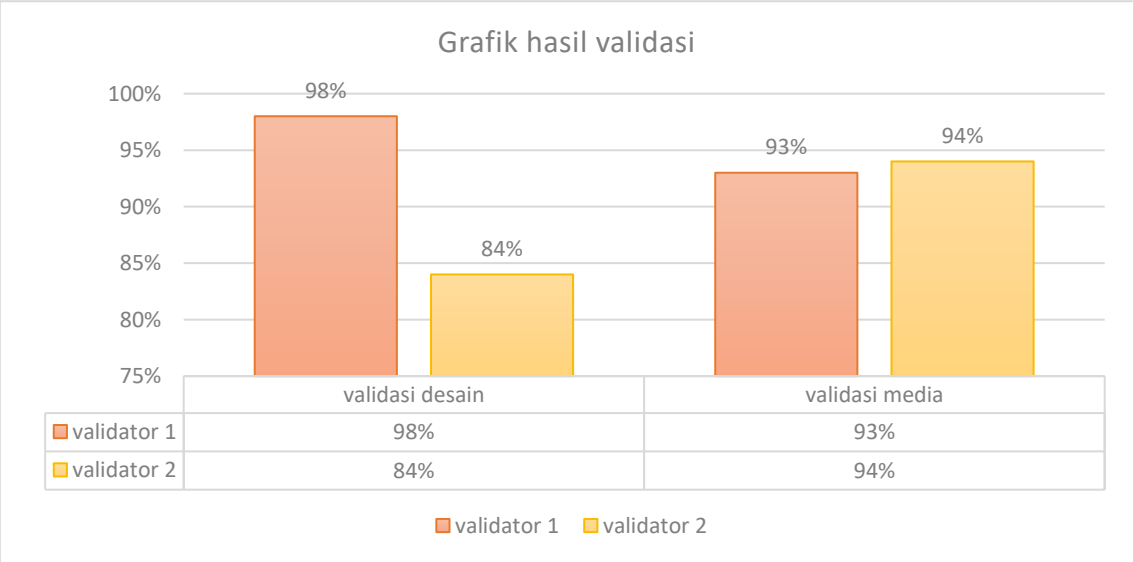


Figure 5 Media and Design Expert Validation Graph

The graph shows a comparison of the assessment results between two validators for design and media aspects. In the design validation section, validator 1 gave a score of 98%, indicating that the design was deemed very feasible and in accordance with the established criteria. Meanwhile, validator 2 gave a score of 84%, indicating that although the design was good, there were still several aspects that were deemed to need improvement or refinement. For media validation, both validators gave relatively high and consistent results. Validator 1 gave a score of 93%, while validator 2 gave a score of 94%. These scores indicate that the developed learning media has met the eligibility standards, both in terms of appearance, functionality, and ease of use. Overall, the graph shows that both the design and media have obtained a very feasible category, with a reasonable difference in assessments between validators. These findings indicate that the developed product has met the eligibility criteria and is ready to be used in the learning process.

The results of this study indicate that the development of the Thermal Overload Relay (TOR) trainer successfully met the research objective, namely producing a suitable and effective practical media to support learning about electric motor control. This finding was obtained through a validation process by four validators consisting of two media experts and two design experts. The validation process was conducted using a Likert scale assessment sheet (1–5), allowing researchers to obtain a quantitative picture of the feasibility level of the TOR trainer. The media validation results showed a feasibility percentage of 93.5%, while the design validation obtained a percentage of 91.35%, so

both were in the Very Feasible category. The data were obtained from the sum of the scores given by the validators based on indicators of media form, general appearance, practicality, technicality, media quality, as well as indicators of physical design and layout, function and operation, and benefits of the TOR trainer. Theoretically, these findings support the view that practice-based learning media can improve understanding of the concept of electric motor protection and students' technical skills. The developed TOR trainer not only clarifies the working concept of TOR through direct simulation, but also strengthens the theory of experiential learning which emphasizes the importance of active student involvement in laboratory practice. In addition to confirming the existing theory, this research resulted in a modification of the learning media that is more practical and portable so that it can be used as a model for the development of electrical engineering media in the future. Thus, the TOR trainer is proven to be effective, safe, and relevant as a learning aid in electric motor control practice.

Conclusion

Based on the research findings and discussion, it can be concluded that the development of the Thermal Overload Relay (TOR) trainer successfully achieved the research objectives, namely designing and testing the feasibility of a learning medium for electric motor control laboratory exercises. The resulting trainer has undergone a validation process by two media experts and two design experts, yielding a feasibility percentage of 93.5% for the media aspect and 91.35% for the design aspect, thereby being categorized as Highly Feasible. These findings indicate that the TOR trainer has a good presentation.

The thermal overload relay trainer developed in this study is recommended for use as a supporting medium for electric motor control practicums to enhance the effectiveness and quality of the learning process. For future development, the trainer could be refined by incorporating more comprehensive features, such as integration with Programmable Logic Controller (PLC)-based control systems, the implementation of digital sensors, and the design of more systematic and diverse practicum modules. These enhancements aim to ensure alignment with educational requirements and technological advancements in the field of industrial electricity.

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