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Optimizing Renewable Energy System Performance with Real-Time Monitoring Techniques

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ABSTRACT
Research Background: In the face of climate change challenges and the need for sustainable energy, renewable energy systems are becoming increasingly important. However, to maximize the efficiency and performance of renewable energy systems, monitoring techniques are needed that can provide real-time information about the operational conditions of the system. Research Objectives: This research aims to optimize the performance of renewable energy systems through the application of real-time monitoring techniques. This is done by utilizing data obtained directly from sensors connected to the energy system. Research Methods: The research methods used include literature study, system requirements analysis, real-time monitoring infrastructure design, prototype implementation, and functionality testing. The collected data was analyzed to evaluate the system performance and effectiveness of real-time monitoring techniques. Research Results: The implementation of real-time monitoring techniques successfully improves the performance of renewable energy systems by providing accurate and timely information about operational conditions. This allows for more efficient management and responsiveness to changes in environmental conditions or energy demand. Research Conclusion: The application of real-time monitoring techniques can significantly improve the efficiency and performance of renewable energy systems. With real-time information, better decision-making can be made, enabling more effective management and responsiveness to system and environmental dynamics.

Keywords: *Renewable Energy, System Performance, Monitoring Techniques*

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INTRODUCTION

Inverted pyramid, as a metaphor to illustrate the challenges in renewable energy systems (Cai et al., 2020), reveals complexity and the need for the right solution (Rudolph et al., 2019). A crucial issue in the management of renewable energy systems is the lack of real-time understanding of system performance (Ibrar et al., 2019). This results in an

inability to respond quickly to changing conditions and energy demand (Dhahak et al., 2020), resulting in suboptimal use of renewable resources.

In the context of climate change and the need for sustainable energy (Jafari et al., 2021), efficiency and maximum performance of renewable energy systems is becoming increasingly important (Kazemian & Khoshnevis, 2021). The main challenge faced is the ability to monitor and optimize system performance in real-time (Majumder et al., 2019). Without a proper understanding of operational conditions, effective and responsive decision-making is difficult (Chen et al., 2023), leading to an increased risk of system instability and failure.

This research aims to address these challenges by applying real-time monitoring techniques to renewable energy systems (Park et al., 2020). The focus is on developing a monitoring infrastructure that can provide accurate and timely information on system performance (Betlem et al., 2019), enabling more efficient and responsive management.

The importance of addressing this issue lies in the need for solutions that can improve the efficiency and performance of renewable energy systems (Nie et al., 2020). By understanding real-time operational conditions (Khel et al., 2021), decision making can be optimized (Moayedi et al., 2020), resources can be utilized efficiently (Arce & Macabebe, 2019), and system stability can be maintained.

The application of real-time monitoring techniques is expected to address such issues by providing a better understanding of the performance of renewable energy systems (Zhang et al., 2019). Through integration of sensors connected to the system and live data analysis (Kundu et al., 2024), information obtained can be used to respond quickly and effectively to changing conditions (Kar et al., 2022), optimizing overall system performance.

This research was conducted in response to the urgent need to improve the efficiency and performance of renewable energy systems (Dattoma et al., 2019). In the face of climate change challenges and increasing energy demand, the implementation of real-time monitoring techniques is crucial to ensure optimal use of renewable resources (Cannas et al., 2021). Therefore (Sayyad et al., 2020), This research aims to explore the potential of real-time monitoring techniques in optimizing the performance of renewable energy systems.

This research is expected to fill the gap in understanding and managing the performance of renewable energy systems by applying real-time monitoring techniques (El-Shafeiy et al., 2023). Through accurate and timely data collection, as well as careful analysis of the system's operational conditions (Weidner et al., 2023), This research will identify ways to improve the overall efficiency and responsiveness of the system.

Currently, monitoring and control of renewable energy systems is often done conventionally (Wu et al., 2018), with limitations in real-time understanding of system performance (Farzana et al., 2020). The innovation proposed in this research is the development of a more integrated and responsive real-time monitoring technique (Nagarathna et al., 2022). This involves implementing sensors that are directly connected

to the system (Islam & Volakis, 2021), careful data analysis, and the use of information technology to respond quickly and effectively to changing conditions.

The novelty of this article lies in the more holistic and real-time approach to monitoring and controlling renewable energy systems (Yang et al., 2021). Compared to previous research which may have focused more on certain aspects of monitoring or controlling (Clarkson & Williams, 2021), This research proposes a more comprehensive approach that utilizes real-time monitoring technology to improve overall system performance.

Furthermore, this research will involve prototype development and field testing to evaluate the performance of real-time monitoring techniques under real operational conditions. It is expected that the results of this research will provide valuable insights for future researchers in the development of more advanced and applicable solutions in optimizing the performance of renewable energy systems.

RESEARCH METHODOLOGY

Research Design

This research uses a quantitative research design, which is inputted into google form as many as 20 questions (Payal et al., 2024). Which includes what influences will be caused when students use technology-enabled language learning (Favale et al., 2020). This method is used in order to formulate a new thought that is useful for every level of students (Spernjak, 2021). Then developed into a research that can be held accountable for its accuracy (Dong & Liu, 2023), which is tailored to each event experienced by the student (Selwyn, 2019). This collection method is useful to test the feasibility of language-based learning itself to improve student learning achievement (Shadiev & Yang, 2020). The quantitative method can also be interpreted as a research stage that begins with making a questionnaire containing 20 items (Gosal et al., 2019), then every answer given by students is processed using the spss application (Pardo et al., 2019). The data obtained can be proven accurate through a google form created by the researcher. And researchers also input the highest gain and also the lowest gain from the questionnaire distributed to each student. Then conclude these statements.

Research Procedure

The steps taken in this study began by asking permission from the campus and working with English teachers. Then every student filled in, from the beginning of the questionnaire made by the researcher until it reached the acquisition of filling which the researcher considered to have met the expected acquisition by the researcher. Then the researcher is also very concerned about ethics in making questionnaires that use good language and are also polite. So that students can fill out this questionnaire in a fast period of time, which makes it easier for researchers to examine various Exploring the Potential of Renewable Energy in Contemporary Engineering Development.

Research Subject

The subjects of this research are students of UIN Mahmud Yunus Batusangkar, the role of the researcher is to collect every answer given by students (Dube, 2020).

Researchers are also assisted by English lecturers who teach at UIN Mahmud Yunus Batusangkar, especially educators who teach in the field of technology (Dubey, 2021). This study is to measure the ability of students using questions in the form of tests and then counted from the highest series of acquisition numbers to the lowest series of numbers (Hao & Ho, 2019). The researcher then inputted the score obtained through the research subject which became a reference to determine the category of Optimizing Renewable Energy System Performance with Real-Time Monitoring Techniques (Alma Çallı & Ediz, 2023). The type of research conducted is research that strongly considers every answer given by students, which aims to determine the effect of Exploring the Potential of Renewable Energy in Contemporary Engineering Development.

Research Ethics

Of the approximately 1000 students enrolled at Mahmud Yunus State Islamic University Batusangkar, only 50 students contributed to this study. Of these. 50 students participated in this study, of which 25 were male and 25 were female with a maximum age of 19 years and 18 years. The data collection of these participants came from various villages or jorongs adjacent to UIN Mahmud Yunus Batusangkar. This research has obtained permission from the lecturer who teaches language courses. This study used several principles of research ethics. First, there was no coercion in filling out the questionnaire. This research only expects the volunteerism of students and female students who study here. Then every question must be answered completely without leaving any part of the questionnaire. This formular is very supportive and upholds rights and there is no coercion at all. This is done to ensure that the participants understand the essence of this study, out of 50 participants 80% expressed their willingness to fill out this questionnaire.

Data Collection Technique

The technique used by researchers in collecting data is to obtain various information that can be measured, compared, and calculated carefully. Through a google form format made by researchers, which was filled in by 50 students of UIN Mahmud Yunus Batusangkar. Data collection was carried out on first semester students in the 2023/2024 academic year. After obtaining permission to conduct research from language lecturers, and also IT links, online questionnaires were distributed to students of various majors. The distribution of this questionnaire was carried out on March 1, 2024 to March 30, 2024. The process of processing data that has been collected from respondents in the research field. The questionnaire data was then downloaded into an Excel file and then transferred to SPSS. 20 questions to review, the final score data is recorded in the SPSS application which can be verified. Then recapitulated as interesting as possible so that readers are interested in reading articles made by researchers.

Data Collection and Analysis

Then the data that has been collected is inputted and processed using the SPSS application. Distributed in the form of tables and diagrams that can calculate the scores obtained from students. The way the data is analyzed is by comparing each answer given by each student with previous studies. Data is presented in the form of average scores and

percentages. Then the data is tested using the oneway anova test. Which compares the acquisition score of each group that fills in each statement related to the questionnaire made by the researcher. Researchers also really take into account the scores obtained by each student who fills out the questionnaire previously made by the researcher. And will never leave the slightest answer given by students from the beginning of filling out the questionnaire until the last student fills out this questionnaire. Furthermore, researchers will also summarize in an accurate conclusion.

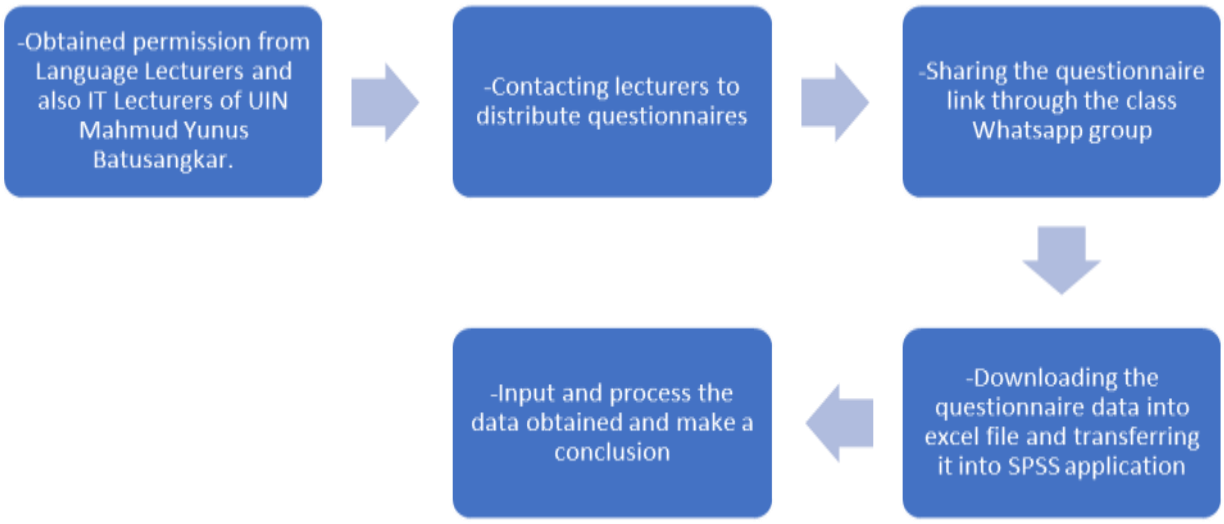
Table 1. 1
Categories of Acquisition of Exploring the Potential of Renewable Energy in Today's Engineering Development

No.	Gain category	Value interval
1	Strongly agree	>90%
2	Agree	70-80%
3	Disagree less	50-60%
4	Do not agree at all	0-40%
Total		100%

Table 1. 2
Research Sample Details

No	Student Batch	Gender		Total
		Male	Female	
1	T.A 2022	10	10	20
2	T.A 2023	15	15	20
	Total	**25**	**25**	**50**

Flowchart of quantitative research



RESULT AND DISCUSSION

Table 1.3
Acquisition on Optimizing Renewable Energy System Performance with Real-Time Monitoring Techniques

No	Statement	SS	S	KS	SKS
1	The application of real-time monitoring techniques to renewable energy systems enables the collection of accurate and timely data on the operational conditions of equipment and infrastructure.	70%	30%	10%	0%
2	By utilizing sensor technology directly connected to the system, real-time monitoring enables early detection of potential problems or failures in renewable energy systems.	65%	35%	0%	0%
3	One of the key benefits of real-time monitoring is its ability to enable quick and precise decision-making in response to changing conditions or energy demand.	70%	30%	0%	0%
4	The use of real-time monitoring techniques in renewable energy systems can improve operational efficiency by optimizing resource usage and reducing unexpected downtime.	65%	30%	5%	0%
5	The integration of smart sensors and	60%	40%	0%	0%

	information technology in real-time monitoring techniques enables early identification of opportunities to optimize system performance.				
6	With real-time monitoring, renewable energy systems can be automatically regulated and controlled based on the data obtained, increasing the responsiveness and adaptability of the system.	85%	15%	0%	0%
7	Real-time monitoring techniques also enable remote monitoring of renewable energy systems, allowing management of the system from a remote location via the internet.	60%	40%	0%	0%
8	One of the other advantages of real-time monitoring is its ability to support preventive maintenance, by providing early warning of potential problems or failures in the system.	50%	50%	0%	0%
9	The implementation of real-time monitoring can help improve the reliability and operational safety of renewable energy systems by identifying and addressing problems more quickly and efficiently.	65%	30%	5%	0%
10	With the continued development of sensor technology and data analysis, it is expected that real-time monitoring will continue to be a more advanced and effective solution in optimizing the performance of renewable energy systems in the future.	70%	30%	0%	0%

Table 1.4
Acquisition of Optimizing Renewable Energy System Performance with Real-Time Monitoring Techniques Tested for Feasibility with the One Way Anova Test

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.

X.01	T. A 2022	1,400	4	,600	.	.
	T. A 2022	,000	5	,000		
	Total	1,400	9			
X.02	T. A 2022	1,100	4	,275	2,750	,148
	T. A 2022	,500	5	,100		
	Total	1,600	9			
X.03	T. A 2022	2,100	4	,525	.	.
	T. A 2022	,000	5	,000		
	Total	2,100	9			
X.04	T. A 2022	,900	4	,225	.	.
	T. A 2022	,000	5	,000		
	Total	,900	9			
X.05	T. A 2022	1,600	4	,400	3,000	,080
	T. A 2022	,500	5	,100		
	Total	2,100	9			
X.06	T. A 2022	2,100	4	,525	.	.
	T. A 2022	,000	5	,000		
	Total	2,100	9			
X.07	T. A 2022	1,600	4	,400	4,000	,080
	T. A 2022	,400	5	,300		
	Total	2,100	9			
X.08	T. A 2022	2,100	4	,525	.	.
	T. A 2022	,000	5	,000		
	Total	2,100	9			
X.09	T. A 2022	1,600	4	,400	.	.
	T. A 2022	,000	5	,000		
	Total	1,600	9			
X.10	T. A 2022	1,900	4	,475	4,750	,059
	T. A 2022	,500	5	,100		
	Total	2,400	9			

Optimizing the performance of renewable energy systems with real-time monitoring techniques is a crucial step in responding to demands for energy sustainability and improving operational efficiency. These techniques become a kind of eye that continuously and accurately monitors the performance of renewable energy systems, enabling early detection of problems and potential failures. With real-time monitoring capabilities, managers can respond quickly to changing conditions or energy demand, minimizing the risk of downtime and maximizing overall system performance.

The application of real-time monitoring techniques makes a significant contribution in filling the existing gaps in the understanding and management of renewable energy systems. Previously, limitations in monitoring led to the inability to respond quickly to

problems or changes in conditions. However, with the use of sensor technology and real-time monitoring systems, this gap can be addressed by providing more complete and timely information on system performance.

Real-time monitoring also opens up opportunities for innovation in optimizing the performance of renewable energy systems. With careful data analysis, managers can identify inefficient patterns of energy consumption and design more optimized management strategies. This can include automatic regulation of equipment, centralized energy use, or even integration of energy storage systems to maximize efficiency.

As technology develops and the demand for renewable energy increases, real-time monitoring is becoming increasingly important. It paves the way for the development of more sophisticated and adaptive solutions in managing energy resources. By taking into account real-time operational conditions, renewable energy systems can adapt quickly to changes in the environment or energy demand, thus maintaining system stability and sustainability.

However, real-time monitoring also brings a number of challenges that need to be overcome. One of these is the management of the large and complex data generated by monitoring systems. Adequate infrastructure and data analysis expertise are required to ensure the data is used effectively in decision-making. In addition, data security is also a major concern in the implementation of real-time monitoring. The real-time availability of data also means that it can be subjected to cyber-attacks, making data protection and network infrastructure crucial.

Furthermore, continuous research and development is needed to improve the effectiveness and efficiency of real-time monitoring. This involves the development of more sophisticated sensors, smarter data analysis algorithms, and the integration of new technologies such as artificial intelligence or machine learning to improve monitoring and decision-making capabilities.

It is expected that with continued innovation and in-depth research, real-time monitoring techniques will become more effective and efficient in optimizing the performance of renewable energy systems in the future. This will make a significant contribution to maintaining energy sustainability and meeting the increasing energy demand globally.

CONCLUSION

The conclusion of the effort to optimize renewable energy system performance with real-time monitoring techniques is that this approach enables more effective and responsive management of fluctuations in energy production and consumption. By utilizing real-time monitoring systems, users can actively monitor the performance of renewable energy systems, identify potential problems or improvement opportunities, and take corrective actions quickly and appropriately. This enables better operational optimization, increased energy efficiency, and more seamless integration with existing energy grids, thus supporting the transition to a more sustainable and reliable energy system.

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