Contemporary Journal of Applied Sciences (CJAS)
Vol. 3, No. 12, 2025: 793-806

Analysis of the Effect of High Temperature and Humidity on the Body, LCD, and Measurement Accuracy of Prepaid (Electronic) Single Phase Energy Meter

Ongky Ganesia[1]*, Musa Partahi Marbun[2]
Fakultas Teknik Elektro, Institut Teknologi PLN Jakarta
Corresponding Author: Ongky Ganesia ongky2310500@itpln.ac.id

A R T I C L E I N F O

Keywords: Energy Meter, Meter, Temperature, Humidity, Paired Sample T-Test

Received : 24, October
Revised : 26, November
Accepted: 28, December

A B S T R A C T

Energy meters have an important role in electricity transactions between providers and consumers. Therefore, the reliability of energy meters is essential to ensure fairness transactions and consumer trust in providers. The research titled "Analysis of the Influence of High Temperature and Humidity on the Performance of Prepaid (Electronic) Single-Phase Energy Meters" has the objective of determine the impact of high temperature and humidity (85°C and 95%) on the physical components, LCD display, and measurement accuracy of single-Phase prepaid energy meters. The research method is an experimental study, involving testing three brands of single-Phase prepaid energy meters (brands A, B, and C) with 50 samples for each brand and a testing duration of 60 days. The research location is at the Low Voltage Laboratory of PT PLN (Persero) Pusat Sertifikasi, South Jakarta. Data analysis was conducted by comparing samples before and after testing using a paired samples t-test.

DOI: https://doi.org/10.55927/cjas.v3i12.104
E-ISSN: 3031-3643
https://nblformosapublisher.org/index.php/cjas/index

INTRODUCTION

Electricity is a primary need for households and industries alike, and its supply in Indonesia is managed by PLN. Electricity is generated from fossil fuels and renewable energy sources, then transmitted through high-voltage transmission networks to substations before being distributed to consumers. On the customer side, energy meters are the primary tool for measuring electricity consumption and the basis for billing calculations, so their accuracy is important for transaction fairness and public trust. The reliability of the entire infrastructure, from generation to metering, is a critical factor in ensuring a sustainable electricity supply and supporting national development. Electricity consumption continues to increase in line with digitalization, automation, and the use of electric vehicles, which make daily activities dependent on electrical energy. Indonesia's electrification ratio also rose from 84.35% in 2014 to 99.83% in 2024. In these conditions, energy meters play an important role as a tool for measuring electricity usage and as the basis for transactions between providers and consumers.

Previous research has also discussed Study of the Effect of Temperature on Electronic Scales. This study aims to test electronic scales using the CSIRO method, determine the correction values in tests with varying temperatures, and determine the differences in the final results in terms of uncertainty values in tests with several variations in room temperature. The method used in this study was The Calibration of Weights and Balances (CSIRO), which included testing the repeatability of readings, indication deviation, the effect of off-center mass, and hysteresis. The scales used were electronic scales with a fine accuracy class, namely class II. The results showed that temperature affected the readings on electronic scales. The smallest correction value was at a temperature of 27 ^{0}C, and the largest correction value was at a room temperature variation of 25 ^{0}C. The higher the room temperature, the greater the uncertainty value. The component of electronic scales that is most affected by temperature variations is the strain gauge.

As an alternative approach, previous research discusses the effects of excessive heat on various types of electronic components. Through a literature review, particularly studies and technical reference materials, this research found that at the micro level, overheating causes material degradation on or within certain electronic components. This degradation is further caused by cracks, expansion, and other structural deformations. The degradation is also caused by changes in the physical and chemical properties of certain materials due to excessive heat exposure. At the macro level, the effects of overheating on system failure result from the degradation of different constituents and components, cause-effect loops, and neighboring effects. Both the micro and macro effects of overheating on electronic components increase the health and safety risks of entire electronic assemblies and electronic devices. Therefore, through a literature review, this paper also discusses techniques or processes to prevent overheating or reduce the negative effects of excessive heat levels.

Previous research "Analysis of the Effect of Environmental Temperature Changes on the Current Carrying Capacity of Medium Voltage Cables" The

objective is to obtain conductors with maximum current carrying capacity in order to optimize medium voltage air lines by accurately selecting conductors based on their current carrying capacity, taking into account the effects of changes in ambient temperature. The method used to determine the current carrying capacity of a conductor is the IEEE std. 738 heat balance method. The results of this study show that the conductor with the highest KHA is BCC-1/2H with a KHA value of 1609.64 A. The KHA value increases when the ambient temperature is low and decreases when the ambient temperature is high, but this is also influenced by wind speed, solar radiation intensity, and conductor resistance.

The purpose of this study is to determine and evaluate the durability of single-phase prepaid energy meters available on the Indonesian market when exposed to extreme environmental conditions, particularly high temperatures and high humidity, using experimental research methods with data analysis using paired samples t-tests.

LITERATURE REVIEW

Table 1. Literature Review

Num	Researcher Name	Research Title	Novelty	Year
1	Yustika Apyudea U, Siti Fatimah, M. Sc [1]	Studi Pengaruh Temperatur Terhadap Timbangan Elektronik	The sample of this study is an electronic scale and its effect is limited to a temperature of 22^0C to 27^0C	2018
2	Adel Ahmed Almubarak [2]	The Effects of Heat on Electronic Components	The research sample is electronic components (PCBs, transistors, diodes, resistors, and capacitors) and their effect is limited to high temperatures	2017
3	Furqan Baharsyah, Syahrizal, Mansur Gapy [3]	Analisis Pengaruh Perubahan Suhu Lingkungan Terhadap Kapasitas Pembawa Arus pada Kabel Tegangan Menengah	The study sample is medium voltage cables and their effect on ambient temperature (19 - 23^0C)	2018
4	Kiki Rosiana Dewi, Suyitno, Nur Hanifah Yuninda [4]	Pengaruh Peningkatan Suhu Dan Besaran Arus Terhadap Tahanan Penghantar Kabel Listrik Tegangan Rendah Jenis Nym	The research sample is the low-voltage cable of NYM and its effect on temperature (20 – 70 ^{0}C) and current magnitude	2019

Num	Researcher Name	Research Title	Novelty	Year
5	Prachi M. Kirad & Tanushka Sharma [5]	Degradation of Electronic Devices Overtime	The research sample is electronic components and their effect on temperature	2021
6	Adelia Janis Parahita [6]	Pengaruh Kelembaban Udara Terhadap Kelayakan Tahanan Isolasi Stator Pada Generator 60 MW PLTA Panglima Besar Soedirman MRICA Dengan Menggunakan Uji Polarization Index	The study sample is the stator on the generator and its effect on temperature up to 63 ^{0}C	2023
7	Rio Sandi [7]	Analisis Pengaruh Kelembaban Udara Terhadap Kuat Medan Listrik Di Sekitar Saluran Udara Tegangan Tinggi (Sutt) 150 Kv Quadruple	The study sample was the strong electric field around SUTT 150 kV and its effect on air humidity (52%, 59%, and 84%)	-

Definition of energy meter

An energy meter is a device used to measure electrical energy per hour (Wh). This unit describes the amount of energy used in one hour by an electronic device or load that consumes one kilowatt of power. This device is widely used in various sectors, ranging from households, commercial buildings, industries, to power generation facilities and substations, as a tool for recording energy consumption and as a basis for billing systems. In an energy meter, a transaction occurs between the electricity provider and the electricity consumer based on the recorded energy multiplied by the applicable electricity tariff.

In principle, energy meters measure by multiplying three main parameters, namely voltage (volts), electric current (amperes), and time (hours). Voltage and current represent the amount of instantaneous electrical power (in watts), while time indicates the duration for which the power is used. The combination of these three parameters produces the value of electrical energy in watt-hours (Wh) or, more commonly, in kilowatt-hours (energy). Single-phase energy meters for residential consumers are typically installed in front of the house for easy access by homeowners and for monitoring and reading by utility personnel.

Two-Sample Analysis

Two-sample analysis is one of the inferential statistical methods used to directly compare two groups of data, whether in the form of averages, proportions, or variances. The main purpose of this method is to determine whether there is a statistically significant difference between the two groups, which can be interpreted as meaning that the differences that arise are not merely

the result of random variation or mere coincidence. This method is commonly used in various fields of research, such as science, health, engineering, and social sciences, to test differences in treatment, conditions, or characteristics between two populations or samples.

Two-sample analysis can be performed using various approaches, depending on the type of data and the accompanying assumptions. If the data is normally distributed and has homogeneous variance, then the independent samples t-test or paired samples t-test can be used. Meanwhile, if the normality assumption is not met, non-parametric tests such as the Mann-Whitney U Test or Wilcoxon Signed-Rank Test can be used. The results of this analysis will help researchers make data-driven decisions, such as determining the effectiveness of treatment, the success of intervention, or performance differences between two groups.

METHODOLOGY

Research Design

This study focuses on analyzing the effect of high temperature and humidity on the performance of single-phase prepaid energy meters. The scope of the study is limited so that the analysis is more focused and in-depth, with the following details:

a) The study only covers 1-phase prepaid energy meters, so it does not discuss postpaid types or three-phase energy meters.
b) The environmental parameters used for testing are a temperature of 85°C and a relative humidity of 95%, with a continuous exposure time of 60 days, in order to simulate extreme conditions that can occur in tropical or closed industrial environments.
c) The performance aspects of the energy meters analyzed include changes in the device body, LCD display durability, and energy measurement accuracy compared to the reference standard (class 1).
d) This study only uses three brands of 1-phase prepaid energy meters that are commonly used by consumers and adopted by PLN, so the results do not represent the entire population of meters available on the market.

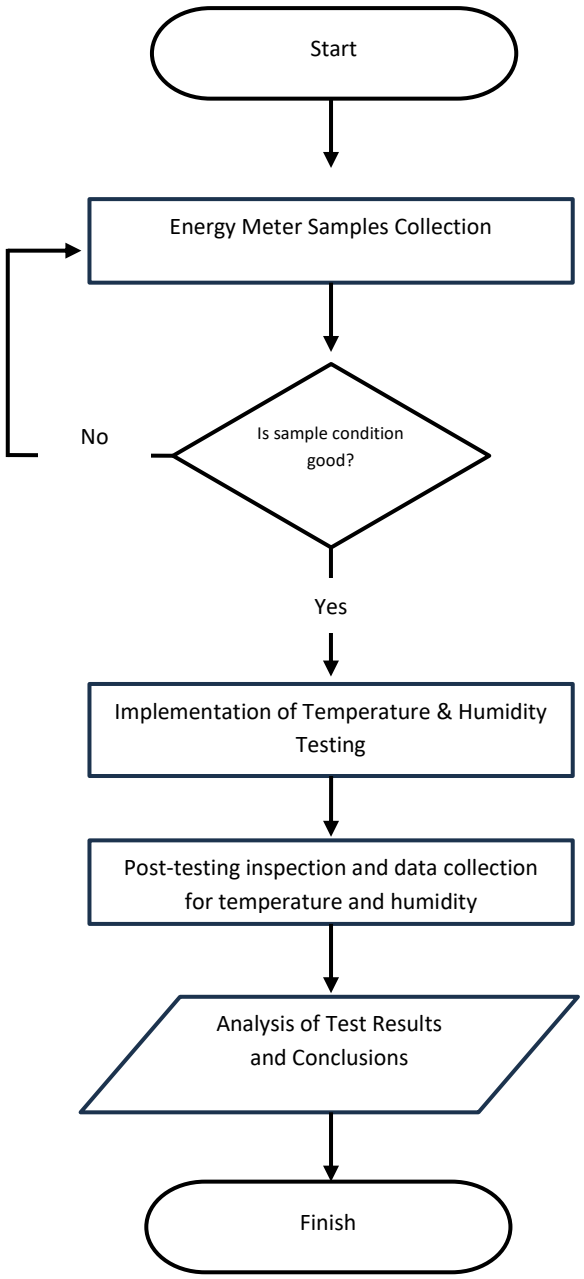

Figure 1. Research Flowchart

Samples Collection

Figure 1 shows a description of the process of research flowchart. The process starts from the energy meter samples collection, The samples collected were 3 different brands, with 50 pieces of each brand. All samples must undergo a pre-test, which includes inspection of the body, LCD, and energy measurement accuracy. After all inspections and tests on the samples have been confirmed to have passed, the next process can be carried out. However, if there are samples that do not pass, then the samples must be collected again.

Pre-Test

The pre-analysis stage aims to prepare samples for testing, including pre-inspection of the body, pre-inspection of the LCD, and testing of energy measurement accuracy. The results of these inspections and tests will become the

initial data that will later be compared with the data after temperature and humidity testing. Therefore, if there are samples that do not pass the pre-test, then the samples must be collected again.

Temperature & Humidity Test

This stage is the core of the research, which includes testing at a temperature of 85 degrees Celsius and humidity of 95%, with all samples energized at a voltage of 230 volts. The test is conducted for 60 days non-stop. After 60 days, the voltage on the meter is turned off and the chamber is also turned off. All samples can be removed from the chamber. After that, post-test checks can be carried out, including body checks, LCD checks, and energy measurement accuracy tests. This provides results before and after the temperature and humidity tests. Both sets of data can then be analyzed using the paired sample t-test method.

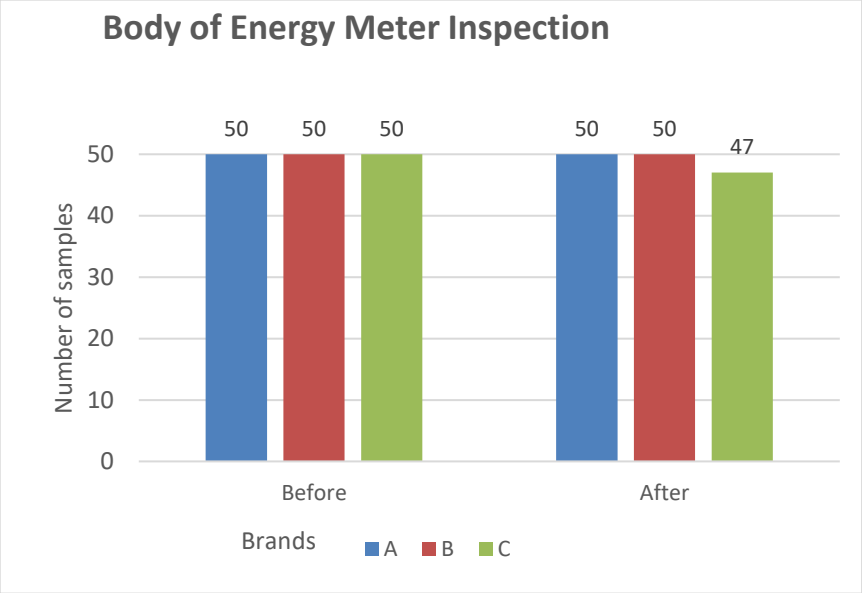

Figure 2. Before And After Body of Energy Meter Inspection

In Figure 2, it can be seen that after temperature and humidity testing, 3 out of 50 samples of brand C failed the body inspection. This means that there were changes after undergoing the 60-day testing process. This shows that a small portion of brand C units experienced degradation or changes in body condition in the form of discoloration (yellowing) as a result of the testing treatment. In contrast, for brand A and B, no body changes were found at all in all samples tested during the same period. In other words, all units of both products showed stable body resistance and were not affected by the testing conditions for 60 days.

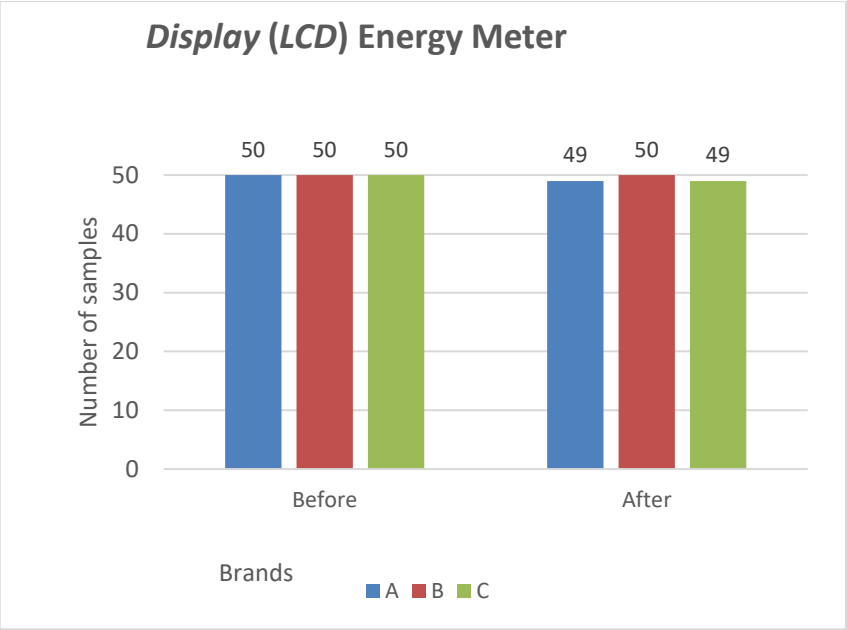

Figure 3. Before And After LCD Inspection

Referring to Fig 3, it can be seen that there were changes in the performance of the LCD display of the energy meter after testing at a temperature of 85^0C and humidity of 95% for 60 days, particularly for brands A and C. Each of these two products showed one sample that experienced changes in the LCD screen. The damage that occurred was that the LCD could not display any information (blank). This change may indicate the vulnerability of the LCD component of the energy meter to exposure to high temperatures and humidity for a certain period of time. Meanwhile, brand B showed different results, where all samples did not experience any changes in the LCD display after testing. This shows that the B brand display has better stability and durability under the test conditions compared to brands A and C.

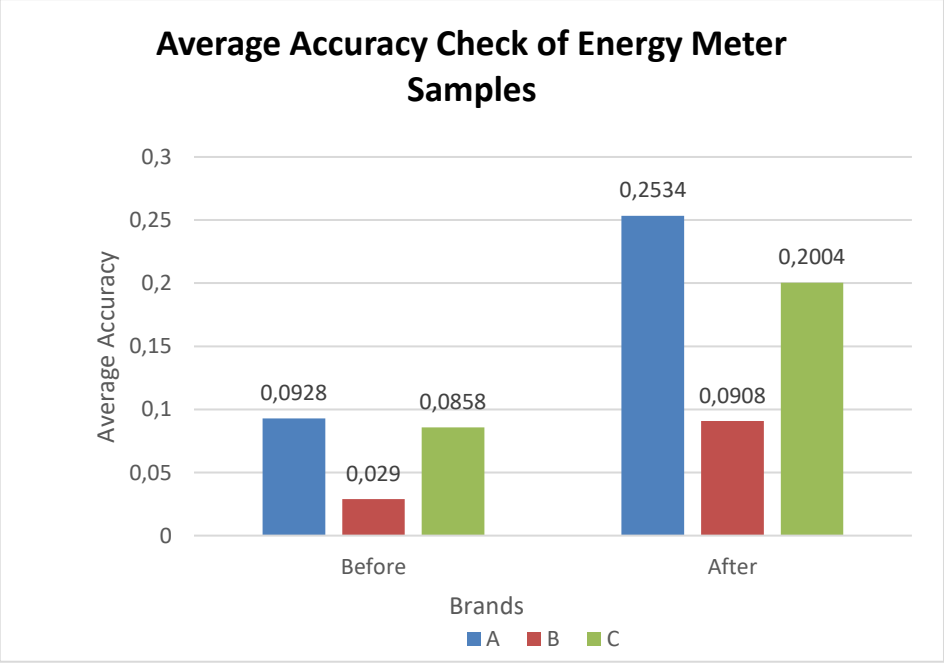

Figure 4. Before And After Energy Measurement Accuracy

Based on the data displayed in Figure 4.6, it can be seen that all brands A, B, and C, on average after experiencing changes in the accuracy aspect after passing the testing process with a temperature of 85^0C and humidity of 95% for 60 days. This change indicates that exposure to high temperature and high relative humidity for a certain period has an impact on the performance of measuring electrical energy in the three products. In addition, the test results also indicated that there were some samples that experienced significant changes in accuracy

Analysis

After obtaining the results of the physical inspection of the body, LCD, and energy measurement accuracy on the energy meter that has been carried out before and after testing with exposure to high temperatures and extreme humidity, the next step is to analyze the data using statistical methods with the paired sample t-test model. The method is used because it is considered the most suitable for comparing the same sample with two different conditions, in this case, before and after temperature and humidity testing. The data analysis will obtain the results of the significance of the effect of temperature and humidity on the sample.

RESEARCH RESULT

Based on the results of the body inspection of the energy meter body that has been carried out before and after testing with exposure to high temperatures and extreme humidity, it is known that there are no indications of deformation, cracks, or other structural damage to the tested unit. This finding shows that testing in environmental conditions with temperatures reaching 85^0C and a relative humidity level of 95% carried out continuously over a period of 60 days only provides changes to product C, so it can be said that it does not have a significant impact on the body integrity or material durability of the single Phase prepaid energy meter body. So, it can be concluded that the device has good resistance to conditions. The results of the 1 phase prepaid energy meter body inspection are in accordance with table 1 as follows:

Table 1. Mean difference test results of Body Inspection of Brands A, B, and C

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std.Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 3	PRE_C - POST_C	.06000	.23990	.03393	-.00818	.12818	1.769	49	.083

Based on the output results in the "Paired Samples Test" table, a significance value (Sig. 2-tailed) of 0.083> 0.05 is obtained. This shows that there is no statistically significant difference between the average value of the measurement results before (Pre Test) and after (Post Test) testing, which means that exposure to high temperature and extreme humidity has an insignificant and real effect on the performance of the energy meter on the body of brand C. As for brand A and brand B, the test results show that there is no difference at all between the Pre Test and Post Test results, so it can be concluded that high temperature and humidity conditions during the test period did not affect the stability and reliability of the energy meter body in these two products.

The three brands of energy meter samples tested used a 14-segment LCD of the HTN (High Twisted Nematic) type. Based on the datasheet, the HTN type LCD has the following temperature resistance characteristics:

a. Normal operating temperature: -30^{0}C to 85^{0}C
b. Maximum temperature: -40^{0}C to 90^{0}C

Based on the temperature characteristics above, the LCD should be able to withstand the specified test temperature. However, in addition to applying temperature, the experiment also applied humidity to the sample. The results of the LCD inspection of the 1-phase prepaid energy meter are in accordance with table 2 as follows:

Table 2. Mean Difference Test Results of Brand A, B, and C LCD Inspections

Paired Samples Test									
	Paired Differences					t	df	Sig. (2-tailed)	
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
				Lower	Upper				
Pair 1	PRE_A - POST_A	.02000	.14142	.02000	-.02019	.06019	1.000	49	.322
Pair 3	PRE_C - POST_C	.02000	.14142	.02000	-.02019	.06019	1.000	49	.322

Based on the output results in the "Paired Samples Test" table, the significance value of brand A (Sig. 2-tailed) is 0.322> 0.05. brand C (Sig. 2-tailed) is 0.322 > 0.05. This shows that there is no statistically significant difference between the average value of the measurement results before (Pre Test) and after (Post Test) testing, which means that exposure to high temperatures and extreme humidity has an insignificant and real effect on the performance of energy meters in the LCD section of brands A and C. As for brand B, the test results show that there is no difference at all between the Pre Test and Post Test results, so it can be concluded that high temperature and humidity conditions during the test period did not affect the stability and reliability of the LCD energy meter in both brands.

Table 3. Mean Difference Test Results of Accuracy Checks of Brands A, B, and C

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRE_A - POST_A	-.16060	.17036	.02409	-.20902	-.11218	-6.666	49	**.000**
Pair 2	PRE_B - POST_B	-.06180	.14143	.02000	-.10199	-.02161	-3.090	49	**.003**
Pair 3	PRE_C - POST_C	-.11460	.31024	.04387	-.20277	-.02643	-2.612	49	**.012**

Based on the "Paired Samples Test" output table above, it is known that the Sig value. (2-tailed) brand A is 0.000 <0.05, so it can be concluded that there is an average difference between the Pre Test and Post Test study results, which means that there is an effect of temperature and high humidity on the performance of the energy Meter on the accuracy of brand A measurements. Then for brand B is 0.003 <0.05, so it can be concluded that there is an average difference between the Pre Test and Post Test results, which means that there is an effect of temperature and high humidity on the performance of the energy Meter on the accuracy of brand B measurements. brand C is 0.012 <0.05, so it can be concluded that there is an average difference between the results of the Pre Test and the Post Test, which means that there is an effect of temperature and high humidity on the performance of the energy Meter on the measurement accuracy of brand C. So it can be explained that there is an effect of temperature and high humidity on the performance of the energy Meter on the measurement accuracy of the three products.

The no significant difference between the test results before and after high temperature and high humidity treatment indicates that the single Phase prepaid energy meter device has good resistance to extreme environmental conditions. This reflects that the device's performance remained stable despite exposure to 85°C temperature and 95% relative humidity for 60 days, which can be interpreted as a positive signal regarding the quality and durability of the product. Based on the above results, it can be shown that devices that are able to maintain their function and body shape under extreme conditions show consistent performance, making them suitable for use in various challenging operational conditions.

The no significant difference between the observation results of the LCD display before and after high temperature and extreme humidity treatment indicates that the LCD component on the single-Phase prepaid energy meter has good resistance to extreme environmental influences. This finding indicates that exposure to a temperature of 85°C and relative humidity of 95% over a period of

60 days caused a loss of information display on the LCD in a small portion of the entire sample, the very small difference value even close to zero indicates that the changes that occur are not statistically significant which indicates the stability and quality of the component.

The results of this energy measurement accuracy test show that there is a significant difference in energy measurement accuracy values between before and after the energy meter is exposed to extreme environmental conditions. Thus, it can be concluded that single-phase prepaid energy meters have a changing level of accuracy despite being tested in 85°C temperature and 95% relative humidity for 60 days continuously. This finding reflects that exposure to high temperature and humidity affects the device's ability to record energy consumption precisely.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of data analysis, the conclusions that can be drawn are:

1. There is no significant effect on the energy meter body between sebleum and after testing 85^0C temperature and 95% humidity. Body variable results on product C show a significance value of 0.083> from the significance level of 0.05.
2. There is no significant effect on the LCD energy meter between before and after testing 85^0C temperature and 95% humidity. LCD variable test results on products A and C show a significance value of 0.322> from the significance level of 0.05.
3. There is a significant influence on the measurement accuracy of energy meters between before and after testing 85^0C temperature and 95% humidity. The test results of the Measurement Accuracy Check variable on product A show a significant value of 0.000 < from the significance level of 0.05. Product B shows a significant value of 0.003 < the significance level of 0.05. Product C shows a significant value of 0.012 < the significance level of 0.05.

ADVANCED RESEARCH

1. For consumers and user agencies, the results of this study can be used as consideration in choosing a prepaid energy meter based on its durability and performance stability in extreme environmental conditions such as high temperatures and high humidity. Stable performance in various aspects, such as body condition, LCD display reliability, and measurement accuracy, can reflect the overall quality of the product and support efficient and minimally disruptive operations in the field.
2. For manufacturers or suppliers of energy meters, the results of this test can be used as a reference to be more transparent in explaining the technical durability of products in varying environmental conditions. Open explanations regarding product durability and specifications can reduce potential information gaps between manufacturers and users, as well as increase market confidence in the product. In addition, durability tests such as this are important to be carried out periodically to ensure that product

quality remains consistent under any conditions and is reliable in the long term.

3. Based on the accuracy test results after applying temperature and humidity, it may be considered to provide additional protection, such as adding a thicker seal or one of better quality, with the aim of maximally blocking exposure to external temperature and humidity.

ACKNOWLEDGMENT

This research was fully funded by the Institut Teknologi PLN Jakarta. I would like to express my gratitude for the support provided, which made this research possible.

REFERENCES

Advernesia. (2021). Cara Uji Paired Sample T Test dengan SPSS dan Contohnya. Advernesia.Com. Retrieved from https://www.advernesia.com/blog/spss/cara-uji-paired-sample-t-test-dengan-spss-dan-contohnya/

B. Zhang, F. Zhang, and W. Tang, 'Research on The Hidden Dangers and Countermeasures of Electricity Safety in College Students' Apartments', IOP Conf. Ser.: Earth Environ. Sci., vol. 769, no. 4, p. 042105, May 2021, doi: 10.1088/1755-1315/769/4/042105.

Chicco, D., Sichenze, A. & Jurman, G. A simple guide to the use of Student's t-test, Mann-Whitney U test, Chi-squared test, and Kruskal-Wallis test in biostatistics. BioData Mining 18, 56 (2025). https://doi.org/10.1186/s13040-025-00465-6

Cloud Software Group, Inc. Two-Independent-Samples Test Types. IBM Documentation.

D. Achiriloaiei, L. Kun, C. S. Nes, and I. Dumitru, 'Comparative Study of Mechanical Properties of Aluminium Wires from New and Used ACSR Conductors', SSP, vol. 254, pp. 159–163, Aug. 2016, doi: 10.4028/www.scientific.net/SSP.254.159.

F. Lequien et al., 'Characterization of an Aluminum Conductor Steel Reinforced (acsr) After 60 Years of Operation', Engineering Failure Analysis, vol. 120, p. 105039, Feb. 2021, doi: 10.1016/j.engfailanal.2020.105039.

Frey, B. B. (2023). Paired-Samples t Test. In There's a Stat for That!: What to Do & When to Do It (pp. 46–47). SAGE Publications, Inc. https://doi.org/10.4135/9781071909775.n18

Introduction to Statistics. Non-parametric Tests: Mann-Whitney U and Two-Sample t-Tests. University of Sheffield, 2025.

J. S. Forrest and J. M. Ward, 'Service Experience of the Effect of Corrosion on Steel-Cored-Aluminium Overhead-Line Conductors', Proceedings of the IEE - Part II: Power Engineering, vol. 101, no. 81, pp. 271–283, June 1954, doi: 10.1049/pi-2.1954.0064.

Methodological guide. Metode Analisis Uji Beda 2 Sampel: Independent T-Test dan Mann-Whitney. Universitas Pendidikan Indonesia, 2020.

Rodrigues, L. M. R., Macedo, J. R., Gondim, I. N., Rezende, P. H. O., & Xavier, G. L. (2022). Analysis of the sensitivity of electronic active energy meters to

voltage sags☆. Electric Power Systems Research, 206. https://doi.org/10.1016/j.epsr.2022.107787

S. Socarras and R. T. Magari, 'Modeling the Effects of Storage Temperature Excursions on Shelf Life', Journal of Pharmaceutical and Biomedical Analysis, vol. 49, no. 2, pp. 221–226, Feb. 2009, doi: 10.1016/j.jpba.2008.10.029.

Shivprasad, M., More, S., Korane, K. K., Khamkar, A. K., Jadhav, A. V., Keripale, N. C., & Shinde, A. B. (2020). Prepaid Energy Meter System. International Research Journal of Engineering and Technology. Retrieved from www.irjet.net [14] M. J. Abdulaal et al., "Real-Time Detection of False Readings in Smart Grid AMI Using Deep and Ensemble Learning," IEEE Access, vol. 10, pp. 47541–47556, 2022, doi: 10.1109/ACCESS.2022.3171262.

Statistical Consulting. (2018). SPSS Tutorials: Paired Samples t Test. Kent State University, 1–11. Retrieved from https://libguides.library.kent.edu/SPSS/PairedSamplestTest

Studies on the Effects of Environmental Pollution on Acsr Conductors', Rev.Chim., vol. 70, no. 11, pp. 3984–3986, Dec. 2019, doi: 10.37358/RC.70.19.11.7687.

V. T. Morgan, 'Effect of Elevated Temperature Operation on the Tensile Strength of Overhead Conductors', IEEE Trans. Power Delivery, vol. 11, no. 1, pp. 345–352, Jan. 1996, doi: 10.1109/61.484034.

Xu, M., Fralick, D., Zheng, J. Z., Wang, B., Tu, X. M., & Feng, C. (2017). The differences and similarities between two-sample t-test and paired t-test. Shanghai Archives of Psychiatry, 29(3), 184–188. https://doi.org/10.11919/j.issn.1002-0829.217070