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A Modeling of Voltage Protection Variation System Number of KWH Meter Rotation

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ABSTRACT
The main difference between prepaid and postpaid electricity lies in the payment method. As the name implies, 'postpaid' means paid after use. While 'prepaid', paid or purchased before use. This study is a comparison between Postpaid kwh meters and Prepaid kwh meters with the use of varying loads with voltage reduction treatment with a voltage of 230 volts, 220 volts, 198 volts and 165 volts. In the varying loads in the kwh meter rotation test, the prepaid rotation speed is longer than the postpaid rotation speed with a difference of 0.53 hours or 32 minutes. While in the Energy-saving lamp (LHE) load, the study found a very significant difference from the kwh meter rotation with a voltage of 198 Volts and the LHE load for 3.53 hours or 212 minutes between prepaid and postpaid, so prepaid is better than postpaid.

Keywords :* *Modelling, Voltage Protection, and KWH Meter Rotation.

INTRODUCTION

Electricity plays a very important role in life. Electricity is the main source of energy in every activity both in households and industries. PT. PLN (Persero) is the largest electricity service provider in Indonesia. Previously, PT. PLN (Persero) customers received a Postpaid electricity program service, namely using electricity first and then paying in the following month. PLN carries out billing to customers, sometimes there are customers who are late or do not pay, so PLN will cut off the electricity supply to customers if they are in arrears or late for a certain period of time (PLN 2013). To develop services to the community and reduce disconnections, the company tried innovation by issuing a prepaid electricity program or also called Smart Electricity. The prepaid electricity program is that the community pays in advance to buy the electricity they will consume in the form of a deposit (TOKEN), then the community can measure and calculate their own electricity usage every day.

The accuracy and stability of electrical energy measurement play a crucial role in power distribution systems. One of the key components in this process is the kWh meter, which records the amount of electrical energy consumed by customers. However, variations in supply voltage can significantly impact the rotation speed of electromechanical kWh meters or the digital readings of modern energy meters. These variations may lead to errors in energy measurement, resulting in over-registration or under-registration of electricity consumption. To address this issue, a voltage protection variation system is essential. This system regulates voltage fluctuations to ensure that kWh meters function within acceptable accuracy limits, reducing billing errors and improving overall power system reliability. By modeling such a system, we can analyze how different levels of voltage variation affect kWh meter performance and develop strategies to minimize measurement deviations.

Voltage fluctuations in power distribution networks arise due to several factors, including:

- Load imbalances and peak demand variations
- Power system faults and transient disturbances
- Harmonics and poor power quality
- Voltage drops in long-distance transmission

These fluctuations can cause inaccurate energy measurements, leading to financial losses for both electricity providers and consumers. Understanding the relationship between voltage variations and kWh meter rotation is essential for developing protection systems that enhance measurement precision.

LITERATURE REVIEW

KWH Meters and Energy Measurement.

A kilowatt-hour (kWh) meter is an essential device in electrical power distribution systems, used to measure the energy consumption of residential, commercial, and industrial users. The accuracy of kWh meters is crucial for fair billing, efficient energy management, and regulatory compliance **(**Singh & Gupta, 2020). There are two main types of kWh meters:

1. Electromechanical kWh Meters – These meters use a rotating aluminum disk whose speed is proportional to the power consumed. Variations in voltage and current can affect disk rotation, leading to measurement inaccuracies (Bollen, 2016).
2. Digital (Electronic) kWh Meters – These meters use microprocessors and sensors to record energy consumption. They are less susceptible to mechanical errors but may still be affected by voltage fluctuations if not properly calibrated (Mekhilef et al., 2018).

Previous Research on Voltage Protection and Meter Accuracy

Several studies have explored the relationship between voltage fluctuations and kWh meter performance:

- Hossain et al. (2020) analyzed the impact of overvoltage and undervoltage conditions on electromechanical meters, highlighting **a** ±7% deviation in recorded energy due to voltage instability.
- Patel et al. (2019) investigated the effectiveness of automatic voltage regulation in maintaining meter accuracy, concluding that AVRs reduce energy measurement errors by 90%**.**
- Zhao et al. (2021) explored the role of smart meters and AI-based error correction, finding that digital meters with real-time compensation algorithms achieve an accuracy improvement of 98%**.**

Types of KWH Meters

Kwh meters are classified into two main categories:

- Electromechanical Meters: These meters operate using **a** rotating aluminum disk, which moves at a speed proportional to the power consumed. Voltage fluctuations can significantly impact the disk’s speed, affecting measurement accuracy (Gupta & Choudhary, 2019).

International Journal of Economic, Technology and Social Sciences
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Volume 5 Number 2 page 88-95

- Electronic (Digital) Meters: These meters use solid-state components and microcontrollers to measure energy consumption. Although more resistant to mechanical wear, they still require stable voltage levels to ensure accurate readings (Mekhilef et al., 2018).

METHODS

Prepaid electricity services are considered to be able to help save people's expenses. This service is carried out with a credit system. Customers are welcome to buy credit according to their respective abilities, to then be able to use electricity. Credit will usually be in the form of a token number that is entered into the electricity meter. If successful, the credit increases and electricity can be used. In postpaid electricity services, customers are allowed to use electricity as much as they want for one month. Customers then have to pay the total electricity bill calculated based on usage for a month. Because there are no limits, the postpaid system sometimes causes electricity usage to swell. As a result, suddenly the bill at the end of the month jumps due to uncontrolled usage. Electricity from PLN that will be distributed to households (loads), is first distributed through the MCB which functions as a current limiter and safety device in the event of a short circuit. Then it is also distributed into the KWH meter. This aims to further utilize the existing KWH meter equipment.

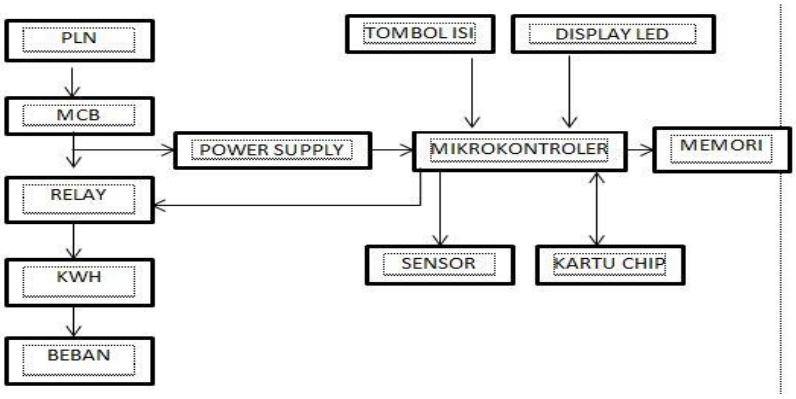

Figure 1. Block Diagram of Prepaid KWH Meter System

Table 1. Prepaid kWh meter specifications

Merek	Smart Meter
Tegangan (V)	230 volt
Kapasitas	5(60) A
Type	Smi-810
Putaran	1600 putaran 1 kWh

Below are the specifications of the Postpaid Kwh Meter used in the test, as follows:

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url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 5 Number 2 page 88-95

Table 2. Postpaid kWh meter specifications

Merek	Melcoinda
Tegangan (V)	230 volt
Kapasitas	5(25) A
Type	M2XS4V2
Putaran	1250 putaran 1 kWh

The test circuit from source to load is sequenced as in the picture below:

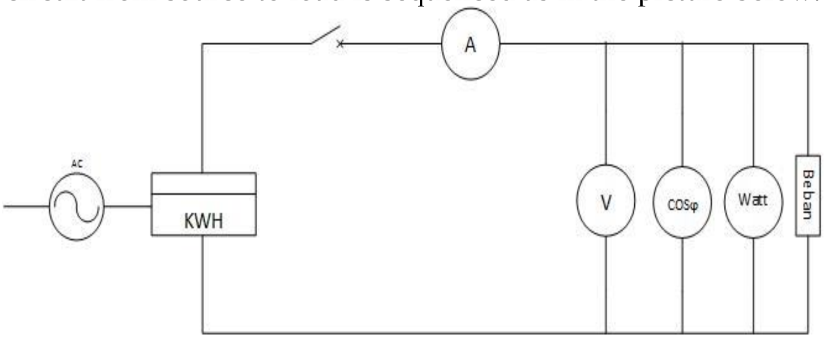

Figure 2. kWh meter load circuit

The source provides input voltage through a voltage regulator then connected to the kwh meter, and the kwh meter output is connected to the MCB (Miniature Circuit Breaker). Then from the MCB it is connected in series with an ampere meter (I), then paralleled with voltage, cos φ, watt meter, and load.

RESULTS AND DISCUSSION

Results

After conducting tests using an unloaded induction motor load, energy-saving lamps and a combination of energy-saving lamps and incandescent lamps with a normal source voltage of 220 volts, the following test data were obtained.

Table 3. Measurement results at 220 volts

NO	Beban	Arus (A)	Tegangan (V)	Cos φ	Daya (Watt)	Kwh Prabayar Detik/putaran	Kwh Pascabayar Detik/putaran
1	Motor induksi	1.6	220	0.4 lag	198	11.22 detik	13.45 detik
2	LHE	0.25	220	0.98 lead	56	38.41 detik	41.43 detik
3	LHE dan Pijar	0.5	220	0.98lead	132	16.79 detik	20.13 detik

Here is the calculation using manual:

$$tp = \frac{n.k}{3600}$$

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url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 5 Number 2 page 88-95

Where:

tp = Total time for 1 (one) cycle kwh
N= Number of one constant rotation in seconds
t = total time in hours 3600
K = constant meter rotation /kwh. for Prepaid kwh meter 1600 input /kwh and for Postpaid kwh meter 1250 input /kwh

To find the time difference value, the following formula is obtained:

$$ts = t_{max} - t_{min}$$

Where:

t_s = Total time difference
t_{max} = The largest time value
t_{min} = Smallest time value sum

The following is to calculate the amount of time required for 1 (one) Kwh Meter rotation using a 220 Volt source voltage on the load:

a. Measuring based on induction motor load
Prepaid kWh meter
11.22 seconds x 1600 = 17.952 seconds
=299.8 minutes =4.98 hours
Postpaid kWh meter
13.45 seconds x 1250 = 16.812 seconds
=280.2 minutes =4.67 hours
t maximum – t minimum = 299.8 – 280.2 = 19.6 minutes or 0.32 hours, hours, after doing the calculation, the total difference in rotation time of the Postpaid kWh meter and the Prepaid kWh meter is 19 minutes or 0.32 hours.
b. Measuring based on energy saving lamp (ELP) load
Prepaid kWh meter
38.41 Seconds X 1600 = 61.456 seconds
=1024.2 minutes =17.07 hours
Postpaid kWh meter
41.43 seconds x 1250 = 51.787 seconds = 863.125 minutes = 14.38 hours
t maximum – t minimum = 1024.2 – 863.125 = 161 minutes or 2.68 hours, after doing the calculation, the total difference in rotation time of the Postpaid kWh meter and the Prepaid kWh meter is 161 minutes or 2.68 hours
c. Measuring based on the load of energy-saving lamps (ELS) and incandescent lamps with a source voltage of 220 volts
Prepaid kWh meter 16.79 seconds x 1600 = 26.864 seconds = 447.7 minutes = 7.46 hours
Postpaid kWh meter 20.13 seconds x 1250 = 25.162 seconds = 419.3 minutes = 6.98 hours
tmaximum – tminimum = 447.7 – 419.3 = 29 minutes or 0.48 hours, after doing the calculation, the total difference in rotation time of the Postpaid kWh meter and the Prepaid kWh meter is 29 minutes or 0.478 hours.

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International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 5 Number 2 page 88-95

To calculate the current and electric power based on the analysis, it can be calculated based on the load as follows;

a. Induction motor load

$I = \frac{P}{V}$

$I = \frac{195}{220}$

$I = 0{,}9A$

and the amount of electrical power is:

$P = I.V.cos\varphi$

$P = 0.8x220x\ 0.4$

$P = 78\ watt$

b. Energy saving lamp load

$I = \frac{P}{V}$

$I = \frac{59}{220} = 0.26\ A$

the amount of electrical power is:

$P = I.V$.cos φ

$P = 0.26\ x220$x 0.98 leads

$P = 57.82\ watt$

c. Variation in load of energy saving lamps (ELS) and incandescent lamps

$I = \frac{P}{V}$

$I = \frac{139}{220} = 0{,}63\ A$

the amount of electrical power is:

$P = I.V$.cos φ

$P = 0.63\ x220x0.98\ lead$

$P = 136.2\ watt$

Using 230 volt voltage

Below are the results of testing and measuring prepaid kWh meters and postpaid kWh meters using a 230 volt source voltage on induction motor loads, energy-saving lamps (EWS), and incandescent lamps. The EWS are as follows;

Table 4. Measurement results at 230 volts

NO	Beban	Arus (A)	Tegangan (V)	Cos φ	Daya (Watt)	Kwh Prabayar Detik/putaran	Kwh Pascabayar Detik/putaran
1	Motor induksi	1.7	230	0.4 lag	232	09.22 detik	11.40 detik
2	LHE	0.25	230	0.99 lead	58	37.94 detik	40.39 detik
3	LHE dan Pijar	0.5	230	0.98lead	138	16.02 detik	19.41 detik

a. Measuring based on induction motor load
Prepaid kWh meter

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Volume 5 Number 2 page 88-95

09.43 seconds x 1600 = 15.088 seconds = 251.4 minutes = 4.19 hours
Postpaid kWh meter
11.40 seconds x 1250 = 14,250 seconds = 237.5 minutes = 3.95 hours
tmaximum – tminimum = 251.4 – 237.5 = 14 minutes or = 0.23 hours, after doing the calculation, the total difference in rotation time of the Postpaid kWh meter and the Prepaid kWh meter is 14 minutes or 0.23 hours.

b. Measuring based on the load of energy-saving lamps (ELS)
Prepaid kWh meter
37.94 seconds x 1600 = 60.704 seconds = 1.011 minutes = 16.86 hours
Postpaid kWh meter
40.39 seconds x 1250 = 50.487 seconds = 841 minutes = 14.02 hours
tmaximum – tminimum = 1,011 – 841 = 170 minutes or = 2.83 hours, after doing the calculation, the total difference in rotation time of the Postpaid kWh meter and the Prepaid kWh meter is 170 minutes or = 2.83 hours

c. Measuring based on the load of Energy Saving Lamps (ELP) and Incandescent Lamps
Prepaid kWh meter
16.02 seconds x 1600 = 25.632 seconds = 427.2 minutes = 7.12 hours
Postpaid kWh meter
19.41 seconds x 1250 = 24.262 seconds = 404.3 minutes = 6.73 hours
tmaximum – tminimum = 427.2 – 404.3 = 24 minutes or = 0.4 hours, after doing the calculation, the total difference in rotation time of the Postpaid kWh meter and the Prepaid kWh meter is 24 minutes or 0.4 hours.

a. Induction motor load

$I = \frac{P}{V}$

$I = \frac{232}{230}$

$I = 1\,A$

And the amount of electrical power is:

$P = I.V.\cos\varphi$

$P = 1x230x\ 0.4 lag$

$P = 92{,}8\ watt$

b. Energy saving lamp load

$I = \frac{P}{V}$

$I = \frac{59}{220}$

$I = 0{,}25\ A$

the amount of electrical power is:

$P = I.V.\cos\varphi$

$P = 0{,}25\ x230$ x 0.99 leads

$P = 58.41\ watt$

c. Variation in load of energy saving lamps (ELS) and incandescent lamps

$I = \frac{P}{V}$

International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976
International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 5 Number 2 page 88-95

$$I = \frac{139}{230}$$
$$I = 0{,}60\ A$$

the amount of electrical power is:

$P = I.V \cos\varphi$

$P = 0{,}60\ x230$ x 0.98 leads

$P = 136{,}22\ watt$

CONCLUSION

Based on the test results on the comparison of the performance of prepaid and postpaid KWh meters at various voltage conditions and types of loads, several important findings were obtained. Prepaid KWh meters are proven to have more stable and efficient performance than postpaid KWh meters, especially at low voltages. This is shown through the difference in more consistent rotation times on prepaid KWh meters, both for induction motor loads, energy-saving lamps (ELP), and a combination of incandescent lamps and ELP. For the induction motor load, the postpaid KWh meter also recorded a faster rotation time of up to 2.03 hours compared to prepaid. Even in the combination of LHE and incandescent lamp loads, the difference in rotation time was recorded at 0.53 hours. With these results, the prepaid KWh meter is not only more accurate in measuring electrical energy consumption but also more efficient in maintaining rotation stability at various load and voltage variations. This makes it a better choice to support efficient power consumption, especially in systems that require high accuracy in energy management. This research also confirms the superiority of prepaid technology in providing more modern and measurable electricity services, so that it can help users to monitor and control electricity consumption independently.

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