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Loadbank Implementation Study with Resistive - Inductive Load for 1 Phase Generator Testing

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Abstract— *Loadbank as a generator test tool is an instrument that has the purpose of checking the performance of the generator when given a load so as to know the maximum limit or output of the generator according to the specifications listed on the engine. Digitalization of the loadbank is needed because the basis of this research is to simplify and speed up the generator testing process, the retrieval of test result data, and the accuracy of generator loading tests. This device uses resistive and inductive load types that are regulated by relays after undergoing processing on the microcontroller. The design stage consists of the electrical system design process and hardware design. The data analysis stage is to compare the results of digital loadbank measurements with theoretical calculations and simulations. The results displayed on the LCD display are the measurement values of voltage, current, power, frequency, and power factor. The results of this study show that a 1-phase generator that has 1100 watt specifications can only be loaded with 80% of the loadbank capacity. Based on sensor readings, the 10% condition produces 78.6 watts of power, the 20% condition produces 154.9 watts of power, the 30% condition produces 232.2 watts of power, the 40% condition produces 308.6 watts of power, the 50% condition produces 386.1 watts of power, the 60% condition produces 465.3 watts of power, the 70% condition produces 543.3 watts of power, and the 80% condition produces 621.9 watts of power.*

Keywords— *Digital loadbank, 1-phase generator set testing, resistive-inductive.*

I. Introduction

Loadbank is a device intended to check and evaluate the performance and performance of generating equipment when given a load (amperage) according to the machine label[7]. Loadbank is used to test the power capability of units or devices that produce electrical energy such as batteries, batteries, generators, or inverters and various other power plants. The loadbank used by PT INKA (Persero) is an analog type loadbank, where the measurement variables provided have values that are less in accordance with the capacity of the object to be tested.

Loadbank functions as a pseudo load used to overload the generator[9]. The loads used in the loadbank include resistive loads and inductive loads. Resistive loads are pure resistor loads where electrical energy is converted into heat or mechanical energy, while inductive loads are loads that contain wire coils wrapped around an iron core[4].

In research conducted by [6] on the effect of inductive and resistive loads on induction generators explains that the characteristics of the two loads are very influential on induction generators. The inductive load lowers the voltage to 170 V at a full load of 60 W while the resistive load lowers the voltage to 190 V.

Based on the above problems, research is needed on "Loadbank Implementation Study with Resistive - Inductive Load for 1 Phase Generator Test". This aims to facilitate the testing of generator sets so that the variables inputted will be more precise and the efficiency of the generator set tested can be calculated optimally.

II. Theoretical Overview

In this chapter, several things are explained that need to be used as references or references such as previous research and the theoretical basis used. These things are used by researchers as a basis for designing measuring instruments that can work as planned.

A. Electrical Energy

Energy is the ability to do effort (work) or make a change[10]. The definition of electrical energy is the ability to do or produce electrical effort (the ability needed to move a charge from one point to another). The electric power formula can use the notation as below:

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

Description :
P = Power (watt)
V = Voltage (volt)
I = Current (ampere)

B. Power Factor

The power factor (power factor) denoted cos φ is defined as the ratio between the current that can produce work in a circuit to the total current entering the circuit or can be said to be the ratio of active power (kW) and apparent power (kVA)[2].

C. Resisive Load

Resistive loads are pure resistor loads where electrical energy is converted into heat or mechanical energy. Resistive loads absorb apparent power and convert it completely into active power. Pure resistive loads include incandescent bulbs, electric irons, or heaters. Since current and voltage are in phase, either the current matches the voltage or the phase angle is zero and the power factor is one (φ = 0o and cos φ = 1)[4].

D. Inductive Loads

Inductive loads are loads that contain a coil of wire wrapped around an iron core. The absorbed electrical energy is converted

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into a magnetic field, this load absorbs apparent power which is converted entirely into inductive reactive power. One example of an inductive load is electrical equipment using electric motors and ballasts or transformers. In inductive loads, the current is lagging 90o against the voltage or the phase angle is 90o, so cos φ = 0[4].

E. *Ohm's Law*

Ohm's law describes a link between electric current, voltage and resistance[5]. In a circuit, a potential difference is needed to produce an electric current. Experiments conducted by George Simon Ohm (the inventor of Ohm's Law) state that the amount of electric current in a conductor is proportional to the potential difference given. So it can be written through a mathematical equation, namely::

$$V = I \, . \, R$$

Keterangan :
V = voltage (volt)
I = current (ampere)
R = resistance (ohm)

Rumus untuk hambatan total rangkaian listrik paralel adalah sebagai berikut.

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_n}$$

F. *Electrical Impedance*

Electrical impedance is generally defined as the total resistance in an electronic circuit when given an alternating current (AC). In the electric power system there are several parameters used to calculate or find the value of impedance (Z), namely the value of resistance (R) and reactance (X)[8].

In a circuit where the resistor and inductor are strung in series and connected to an alternating voltage or AC, the XL and Z equations are as follows.

$$X_L = 2 \, . \, \pi \, . \, f \, . \, L$$

$$Z = \sqrt{R^2 + X_L{}^2}$$

Information :
π = 22/7
f = frequency (Hz)
L = inductance (H)
Z = impedance (Ω)
R = resistance (Ω)
X_L = inductive reactance (Ω)

G. *Arduino Uno*

Arduino UNO is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. Arduino UNO contains everything needed to support a microcontroller, easily connect it to a computer with a USB cable or supply it with an AC to DC adapter or use a battery to start it[1].

H. *Sensor PZEM-004T*

PZEM-004T is a sensor module that can be used to measure rms voltage, rms current and active power that can be connected via Arduino or other opensource platforms [3]. This module also serves all the basic requirements of this PZEM-004T measurement as a separate board. The physical dimensions of the PZEM-004T board are 3.1 × 7.4 cm. The PZEM-004T module is bundled with a 33 mm diameter current transformer coil. The wiring of this module has 2 parts, namely voltage and current input terminal wiring, and serial communication wiring.

III. Research Methodology

This chapter will describe the method that will be a reference in carrying out the research "Loadbank Implementation Study with Resistive - Inductive Load for 1 Phase Generator Testing".

A. *System Diagram*

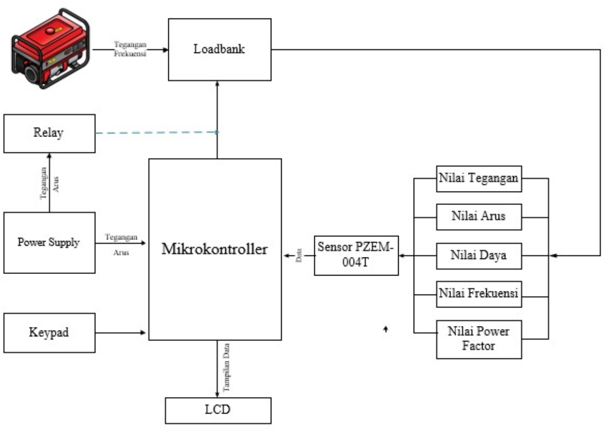

Fig. 1. Block Diagram

Figure 1. shows the working principle of the "Loadbank Implementation Study with Resistive - Inductive Load for 1 Phase Generator Testing" system, which is as follows:

1) The generator is an electrical generating device that will be measured the value of voltage, current, power, frequency, and power factor by a digital loadbank with resistive and inductive loading.
2) PZEM-004T sensor is used as a component that can read the value of current, voltage, power, and frequency and power factor processed through a microcontroller.
3) The Arduino Uno microcontroller will send information data that will be displayed on the LCD Display and control the relay.
4) Relay functions to regulate the flow of voltage from the generator to the load in the loadbank.
5) Power supply functions as a converter of 220V AC voltage into 5V DC voltage. The voltage comes from PLN electricity to be able to supply several components such as microcontrollers, fan coolers, and relays.

B. *Hardware Flowchart*

An explanation of the hardware flowchart design seen in the figure below is as follows:

1) The initial stage is to connect the loadbank voltage source with PLN electricity using a cable.
2) The next stage checks the condition of the DC Fan, Power Supply, and Arduino Uno after the voltage is applied, whether it can turn on perfectly or not.
3) The next stage is to turn on the generator first and then

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connect the generator to the load outlet on the right side of the hardware using a cable Relay functions to regulate the flow of voltage from the generator to the load in the loadbank.

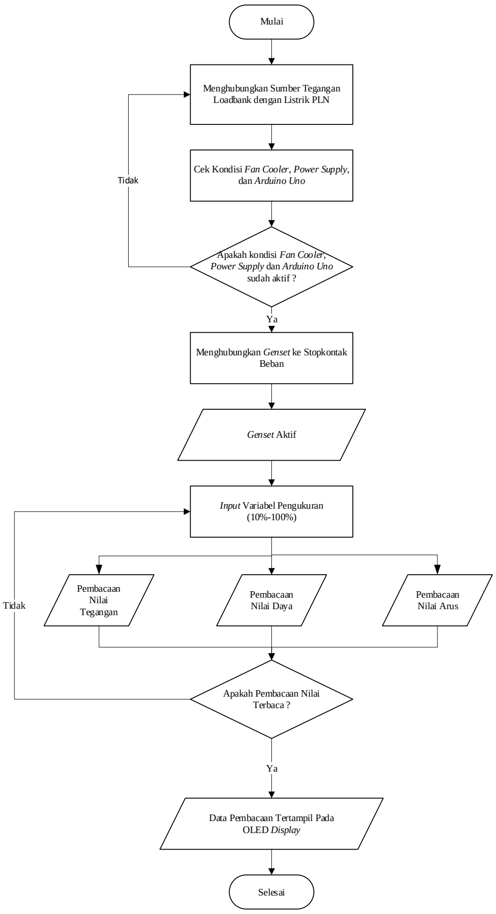

Fig. 2. Hardware Flowchart

4) After the generator is confirmed to be active, then input the measurement variables on the keypad matrix by giving inputs starting from 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, to 100%. The measurement variable has been determined in this study to obtain the data value to be achieved, namely 10% to 100% loading conditions with multiples of 10.
5) The last stage is to make sure whether the data value reading can work properly. After the microcontroller processes the data readings from the sensors, the data results will be displayed on the LCD Display which displays the results of the voltage value, power value, current value, frequency value, and power factor.

IV. RESULTS AND DISCUSSION

A. Hardware Design Results

This stage of the hardware fabrication process is based on the design that has been designed. Stages in the form of component assembly on the panel. In this step, a demonstration is done to show the installation of the components in the panel box.


Fig. 3. Loadbank Hardware

B. Component Testing Results

At this stage, component testing is carried out to validate the components so that they can function properly and in accordance with the specifications listed. Some of the components tested include microcontrollers, PZEM-004T sensors, resistive - inductive loads, LCD displays, and generators.

1. Microcontroller Testing

In this study using an Arduino Uno type microcontroller. Testing is done by testing the pin voltage on the Arduino using a digital multimeter.

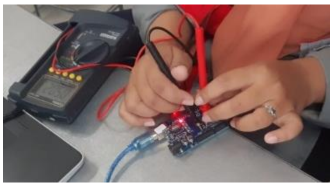
Fig. 4. Microcontroller Testing

2. Sensor Testing

In this study using the PZEM-004T Sensor. Testing is done to find out the sensor can read voltage values, current values, power values, frequency values and power factor and then send data to the microcontroller.

The test shows that the average error in voltage readings is 0.13%, the average error in current readings is 0.38%, the average error in power readings is 0.62%, the average error in frequency readings is 0.06% and the average error in power factor readings is 1.01%. The error data is in accordance with the information on the datasheet about the measurement accuracy of the PZEM-004T sensor. Measurement accuracy provides an error tolerance of ± 0.5% for voltage, current, power and frequency readings while the error tolerance is ± 1% for power factor readings on the PZEM-004T sensor. Therefore, it can be concluded that the PZEM-004T sensor readings are ideal because the resulting error is still within the tolerance threshold.

3. Resistor and Inductor Load Testing

Resistor and inductor load testing is carried out using a digital multimeter and LCR meter with the aim of knowing the value of resistance and inductance in accordance with its specifications.

From the testing of resistors and inductors in the picture above, it produces different values for each resistor component, namely block 1 is worth 636 Ω, block 2 is worth 631 Ω, block 3 is worth 630 Ω, block 4 is worth 627 Ω, block 5 is worth 628 Ω, block 6 is worth 631 Ω, block 7 is worth 628 Ω, block 8 is worth 627 Ω, block 9 is worth 629 Ω, and block 10 is worth 623

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Ω. While each inductor has the same value of 32 uH.

Fig. 5. Load Testing

4. LCD Display Testing

LCD Display testing is done with the aim of knowing whether the LCD Display can turn on and bring up the characters of numbers, letters, and images.

Fig. 6. LCD Display Testing

5. Generator Testing

Generator testing is done to determine that the generator can turn on and produce output in the form of voltage and frequency. Checking the generator output is done using a digital multimeter.

Fig. 7. Generator Testing

C. Loadbank Testing of Genset Read by Measuring Device

This test is carried out by connecting the loadbank with a 1-phase generator and then the measuring instrument in the form of a power quality analyzer clamps the phase and neutral parts of the loadbank. The power quality analyzer produces data values in the form of voltage, current, power, frequency, power factor and power triangle values.

Based on TABLE I. shows the results of data values obtained from loadbank test measurements connected to the generator with the use of loadbank conditions of 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80%.

Giving a load of 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80%. gives an influence on the frequency issued by the generator. Graphical evidence can be seen in the following figure.

TABLE I. Measuring Instrument Readings on Electric Genset

Loadbank Condition	Measurement Results by Measuring Instrument				
	Voltage (V)	Current (A)	Power (W)	Frequency (Hz)	Power Factor
10%	224,04	0,35	78	51,81	0,97
20%	222,33	0,69	154	52,80	0,98
30%	221,98	1,04	231	51,68	0,99
40%	221,83	1,38	307	52,54	0,99
50%	221,63	1,73	384	51,88	0,99
60%	221,84	2,08	462	52,49	0,99
70%	221,40	2,43	538	51,85	0,99
80%	223,09	2,76	617	51,45	0,99

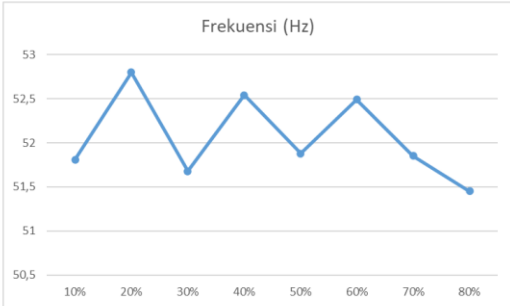

Fig. 8. Graph of Frequency against Loading Condition

Based on the figure above, it can be seen that the results of giving load to the generator set there is a frequency variation at each loading level. This indicates instability or variation in the performance of the generator set when tested with a loadbank. The greater the load given, the frequency released by the generator set fluctuates downward because the load from the loadbank causes changes in the overall operational conditions of the generator set, such as temperature, pressure, and fuel availability. These factors affect the stability of the frequency output by the generator set, and when a load is suddenly added or removed it can cause mechanical reactions in the generator set to increase, so the generator set engine must adjust to cope with the additional load.

TABLE II. Power Triangle Measurement

Loadbank Condition	Measurement Results by Measuring Instrument		
	Active Power (Watt)	Reactive Power (VAR)	Apparent Power (VA)
10%	78	19	80
20%	153	23	155
30%	231	20	232
40%	307	23	308
50%	384	23	385
60%	461	25	462
70%	538	19	538
80%	617	15	617

Based on TABLE II. power triangle, shows the results of additional data obtained from the power quality analyzer measuring instrument. The power triangle data can be used as proof of the reading of the power factor value when testing.

$kW = kVA \cdot \cos\varphi$

$78 = 80 \cdot \cos\varphi$

$\cos\varphi = 0{,}97$

The power triangle data can be used as proof of the results of the relationship between the three values. The equation used is equation (2.5) which is as follows.

$kVA^2 = kW^2 + kVAR^2$
$kVA^2 = 78^2 + 19^2$
$kVA^2 = 6445$
$kVA = 80{,}2\ VA$

D. Loadbank Testing of Generators Read by Measuring Instruments

This test is carried out by connecting the loadbank with a 1-phase generator and then the PZEM-004T sensor on the loadbank reads and outputs the results of data values in the form of voltage, current, power, frequency, and power factor values on the LCD Display.

TABLE III. Measuring Instrument Readings on Electric Genset

Loadbank Condition	Measurement Results by Sensor				
	Voltage (V)	Current (A)	Power (W)	Frequency (Hz)	Power Factor
10%	223,80	0,35	78,60	52,20	1,00
20%	222,20	0,70	154,90	51,90	1,00
30%	221,50	1,05	232,20	52,00	1,00
40%	221,50	1,39	308,60	52,00	1,00
50%	221,50	1,74	386,10	52,60	1,00
60%	221,90	2,10	465,30	52,40	1,00
70%	221,80	2,45	543,30	52,40	1,00
80%	222,6	2,79	621,9	51	1,00

E. Impedance and Power Calculation

The following is one example of calculation in 20% loadbank condition during testing.

Unknown :
Resistor Block 2 = 631 ohm
Frequency = 50 Hz
Inductance = 32 uH = 0,000032 H
then,
$X_L = 2 \cdot \pi \cdot f \cdot L$
$X_L = 2 \cdot 22/7 \cdot 50 \cdot 32 \times 10^{-6}$
$X_L = 0{,}01\ \Omega$

Then put it into the impedance equation:
$Z = \sqrt{R^2 + X_L^2}$
$Z = \sqrt{631^2 + 0{,}01^2}$
Z = 631 ohm

After knowing the impedance, the calculation of Rtotal is carried out

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_{total}} = \frac{1}{636} + \frac{1}{631}$$

$$R_{total} = 316{,}74\ \Omega$$

Then the current proof can be done with the following calculation.

Unknown :
Impedance = 316,74 ohm
Voltage = 222,2 V
V = I . R
I = V / R
I = 222,2 / 316,74
I = 0,70 A

So to prove the power value, it is done with the following equation.
$P = V \cdot I \cdot \cos\varphi$
$P = 222{,}2 \cdot 0{,}7 \cdot 1$
P = 153,31 watt

V. Conclusion

The loading process of the generator with a resistive - inductive load only reaches the condition of 80% of the loadbank, where the condition produces a power of 621.9 watts and a current of 2.79 amperes based on sensor readings. In this loading condition, the performance of the generator set, which has a specification of 1100 watts, has been reduced because it has caused abnormal vibrations. Therefore, it is known that this 1-phase generator has a power output of 56.53% of the specifications listed on the label. Resistive - inductive loading conditions of 10% to 80% also produce waves of the relationship between voltage and current, where in each phase wave condition the electric current is slightly lagging behind the source voltage. This is due to the presence of a load that is inductance or has an inductive reactance value so that a phase shift of φ.

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