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Design of 3-Phase Load Dividing Automatic System with Naive Bayes Method

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Abstract: The electric power distribution system is a process for distributing electricity from a 150 kV electric power transmission system to consumers, both 20 kV consumers and 380/220 V consumers. The problem that often occurs in the electric power distribution system at PT.X is load imbalance due to consumption power on each phase is not the same so that a neutral current appears. The current flowing in the neutral phase will cause power losses. Based on these problems, a load balancing device was made for a three-phase network with the standard SPLN No. 17 of 2014, namely the magnitude of the value of the current imbalance between the phases may not exceed 25%. This tool is also equipped with an overcurrent protection system and a tapping phase limitation system to support the performance of the load balancing device on a three-phase network. The method used is the Naive Bayes method. The naïve Bayes method is used to calculate the current parameters in the R, S, T, and N phases. The classification results will be used as a reference for activating the tapping phase system and the protection system. This system uses Internet of Things technology as a media monitoring of neutral current, current and voltage values in phases R, S and T as well as power losses values. Based on the test results, when there is an imbalance of 30.20%, a neutral current of 1.20A appears, causing a power loss of 0.17W. After the tapping phase is carried out, the percentage of unbalance is reduced to 12.20%, the neutral current is 0.45A, and the power losses are 0.02W.

Keywords: Load Unbalance, Neutral Current, Tapping Phase

1. Introduction

The most important system in the electric power industry is the distribution system since it has a continuous connection with electricity consumers [1]. The process of sending ten-gauge electric energy from the 150-kV transmission system to consumers (whether 20-kV or 380/220-volt consumers) is known as the system distribution. The most often used distribution system is a three-phase with a four-wire system that consists of three-phase cables and one global cable [2], [3].

Unbalanced load on each phase (R, S, and T) is a non-technical problem often occurring in power distribution systems [4]. The low voltage distribution system network has extensive network coverage, which often causes the low voltage distribution system to become unbalanced. This is because household customers use single-phase power, causing load imbalance in the low-voltage distribution network [5]-[7].

An unbalanced low-voltage distribution system will have an impact on a number of things, including transformer operation, overheating of the overloaded phase, current flowing in the neutral wire, and a drop in end voltage on the overloaded phase network. So that the electric power at the consumer level becomes worse [8]. Transferring a large one-phase load to a lower one is one method of reducing engineering losses [9]. The solution to this load imbalance is to balance the load on the transformer [10].

According to Sinaga, loads affect the quality of the electric power system's electrical energy [11]. The quality of electrical energy changes when there is a load imbalance. Voltage unbalance is one such change. This occurs due to load imbalance, which occurs when one of the phases carries a greater load on the lines of a three-phase system [12].

In the paper entitled "Load Balancing Analysis of the Low Voltage Network of the AMH02 Distribution Substation Amahai Feeder at PT. PLN (Persero) Masohi," written by C. de Queljoe et al. in 2020, the procedure for loading on traffic is explained. The current procedure is being carried out to address issues that frequently arise in traffic, such as traffic jams, excess points at lanes that are closer together, currents flowing at highway intersections, and drops of voltage at lanes that are closer together. Balancing the load is carried out via the method of moving the house's tap [13].

In 2020, Hilmi Dzakwan conducted a study titled "Load Balancing Design on Secondary Distribution Channels by Monitoring Power Losses Due to Neutral Currents Based on IoT." It describes the design and load balancing devices on secondary distribution lines that can be constructed to reduce load balancing by as much as 20% [14]. If a load imbalance occurs, the load will automatically switch from the phase with the high current load to the phase with the lower current load [15].

A study entitled "Auto feeder Design and Water Quality Monitoring for Vaname Shrimp Ponds at Ibap Banjar Kemuning Using the Naive Bayes Method Based on Wireless Sensor Networks" explained how pond water conditions were classified using the naive Bayes method [16]. The naive Bayes method uses pH, temperature, ammonia, and salinity sensors to calculate water quality [17]. The android application receives classification results in real time and is used as a reference to activate water pumps and DC motors to monitor water conditions and regulate shrimp feeding according to pond conditions. The author wants adaptation of this technique to simplify the classification of transformer conditions and simplify the calculation of current parameters in the R, S, T, and N [18], [19]. The results of the classification will be used as a reference to start the phase tapping system and protection system.

The phase current parameters R, S, T, and N are calculated using the Naïve Bayes method to create a prototype Design of a Load Sharing Phase Tapping System in a Three-Phase Network Using the Naïve Bayes Method. The results of the classification will be used as a reference to activate the tapping phase and protection system. In accordance with the standard SPLN No. 17 of 2014, the limit for imbalance in this system is 25% [20]. This system categorizes imbalances based on three-time intervals. The first interval lasts from 1 second to 4 seconds and will turn on the indicator light. The second interval lasts from 5 seconds to 10 seconds, and the buzzer will sound [21].

If the second interval time is longer than the first interval time, the system will release the load. If the imbalance is more than 25%, the relay will convey load information on the phase with the largest load current and move the phase with the smallest load current. In addition, the system has an overcurrent protection system [22], [23]. If the current on one of the phases exceeds the tolerance limit, Arduino will order the SSR to trip. Using Internet of Things technology, this system tracks the R, S, and T phase current and voltage values as well as the neutral current and power loss values [24], [25]. It is expected that this load current balancing prototype can reduce the neutral phase current and power loss.

2. Materials and Methods

Figure 2.1 explains the workflow concept of the entire system implemented in the form of a flowchart. Starting from the initialization of the current and voltage sensors, the data can then be processed by the Arduino Mega 2560 microcontroller. Data from the Arduino Mega 2560 microcontroller will enter the data grouping stage using the Naïve Bayes method. The grouped data will be displayed on the 20x4 LCD and the Blynk application.

In this system there are two condition scenarios, if the two scenarios are not running then the system is indicated to be normal and will be displayed in the monitoring data. The first condition is a condition where there is an overload current, if the first condition occurs then the overcurrent protection system will work. The second condition is a condition where the imbalance of the R, S, and T phase currents is more than 25%. If the second condition occurs, the tapping phase system and the unbalanced time classification system will work.

The following is the hardware design that will be used in this Final Project, the design can be seen in Figure 2 is the overall design of the prototype. Table 1 show the remarks on hardware design based on Figure 2. The design of the wiring diagram is used to make it easier when assembling the required electrical components. Electrical equipment or components that have been prepared are arranged in such a way as to form a system that has a certain work function. All components are assembled or installed according to the working principle of the tool used. The design of the tool to be made refers to the block diagram shown in Figure 3.

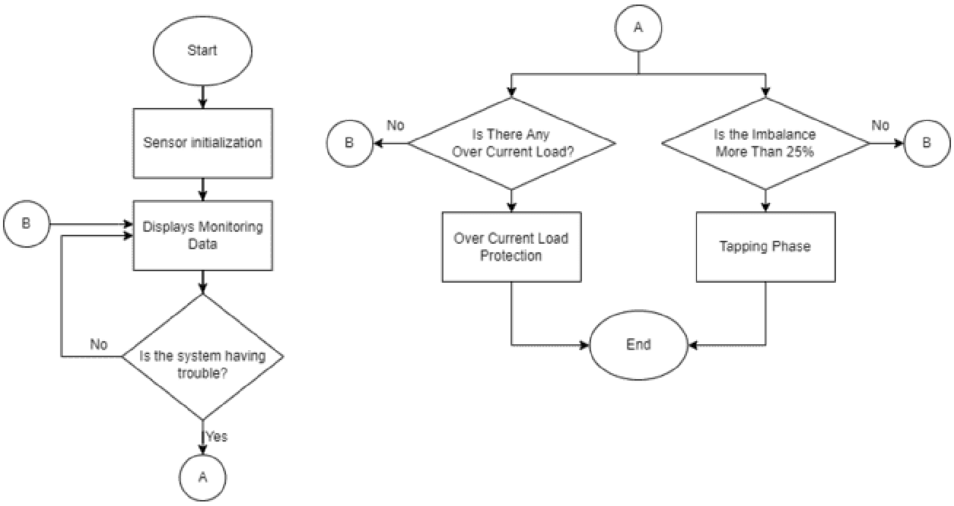
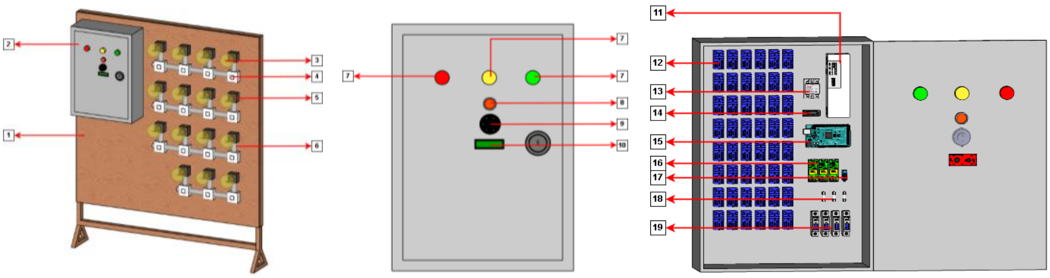


Figure 1. Entire Flowchart of Load Dividing Automatic System

Table 1. Remarks on Hardware Design

No	Component	No	Component
1	Plywood board	8	Buzzer
2	Panel box	9	LCD 16 x 2
3	Bulb	10	Power supply unit 5VDC
4	Switch	11	Relay 5VDC
5	Fitting lamp	12	ESP32
6	Indicator lamp of R, S, and T phase	13	Arduino Mega 2560
7	Plywood board	14	PZEM 004T



(a) (b) (c)

Figure 2. (a) Entire Hardware Design (b) Outside part of box panel (c) Inside part of box panel

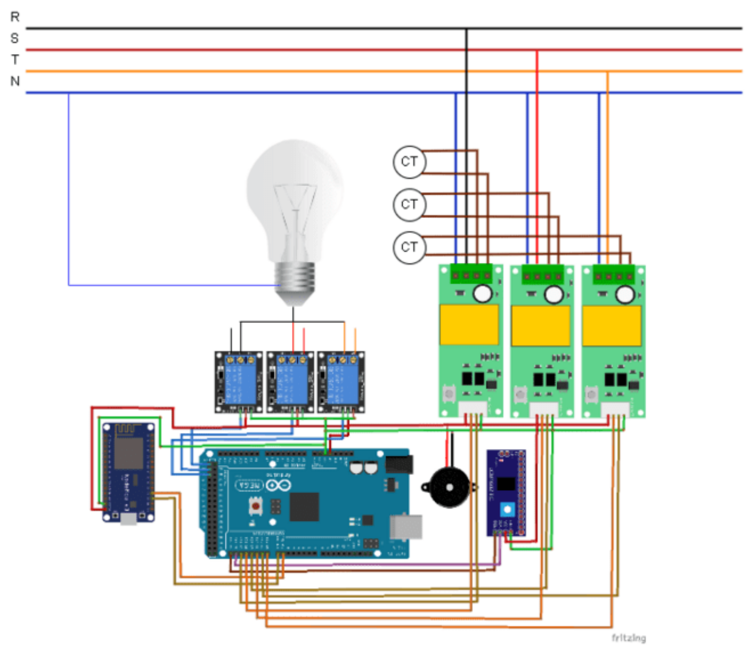


Figure 3. Entire Wiring of Arduino

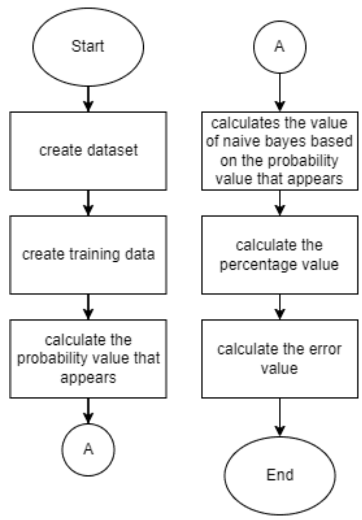


Figure 4 Method Flowchart

To carry out the functions in the design of this tool, in this final project there are several programs that need to be made, namely:

1. Programming PZEM-004T sensor readings on Arduino Mega.
2. Automatic relay performance programming and control on Arduino Mega.
3. Auto buzzer performance programming and control on Arduino Mega.
4. Auto indicator light performance programmer and control on Arduino Mega.
5. Programming to display PZEM-004T sensor readings from Arduino Mega to LCD.
6. Programming to display PZEM-004T sensor readings from Arduino Mega to the Blynk application on a smartphone.

This final project uses the naïve Bayes algorithm to help classify transformer conditions. In this final project, Naïve Bayes testing will be tested using manual calculations, using machine learning applications, and will be tested factually.

Based on Figure 4, the first thing to do is create a dataset. The dataset is divided into 2 variables, namely input variables and class variables. Then proceed with creating training data and calculating the probability value of each variable. After calculating the probability value, proceed with calculating the bayes value. After knowing the probability value that has been calculated, it is continued by calculating the percentage of the predicted value. After getting the percentage of the predicted value then proceed by comparing the predicted value with the training data that has been made so that the error value is obtained

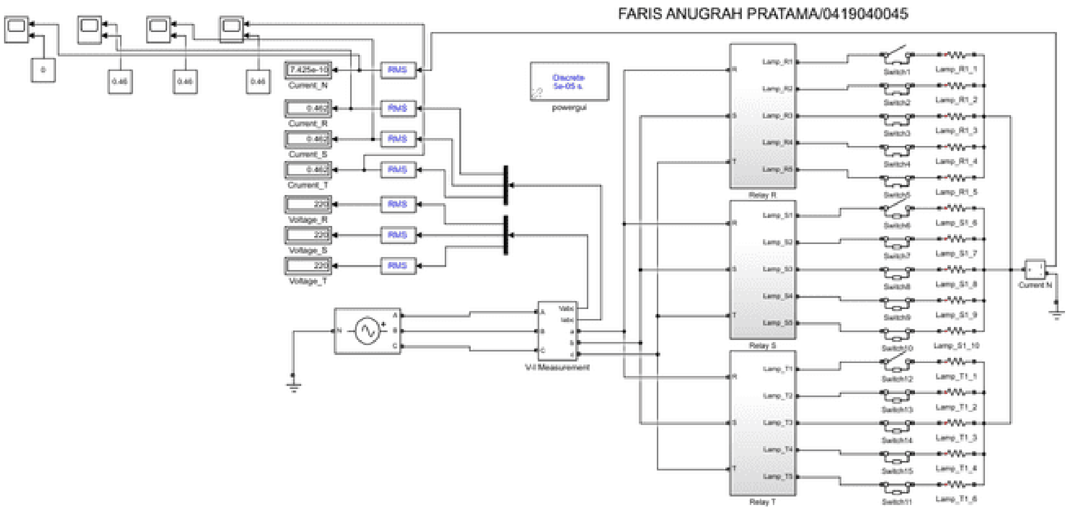
3. Results

3.1. Simulation

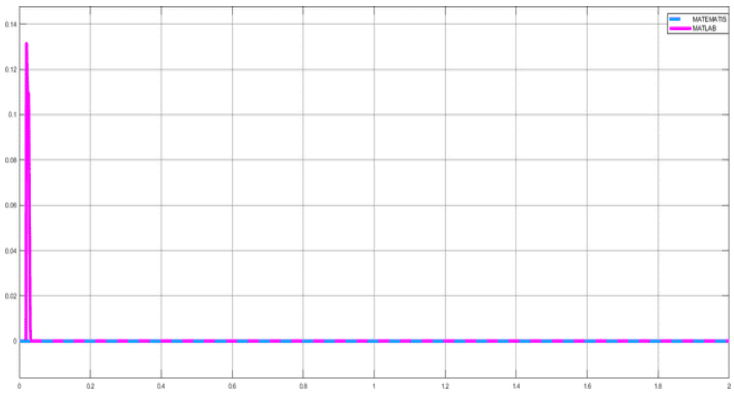
Integrated simulation testing consists of unbalanced load testing and neutral current testing. This circuit has 15 loads with a power of 100 watts where each load is connected to a switch and from each switch it is connected to 3 relays, namely relays R, S, and T. The workings of this system are to turn on the switches on each phase according to with the scenarios that have been created. If the current is read in a balanced state, the relay will not make a switch and if there is an imbalance in the current due to a difference in the amount of power on each phase, the relay will move from the phase with the large current to the phase with the small current.

For phase R, the switch on the load will be connected to 3 relays, namely relay R which is connected to NC to the load and 2 other relays namely relay S and T connected to NO. Vice versa, for loads on phase S, the relay S is connected to NC to the load and the other 2 relays namely relays R and T are connected to NO to the load.

3.1.1 Testing 1 Condition 1



(a)



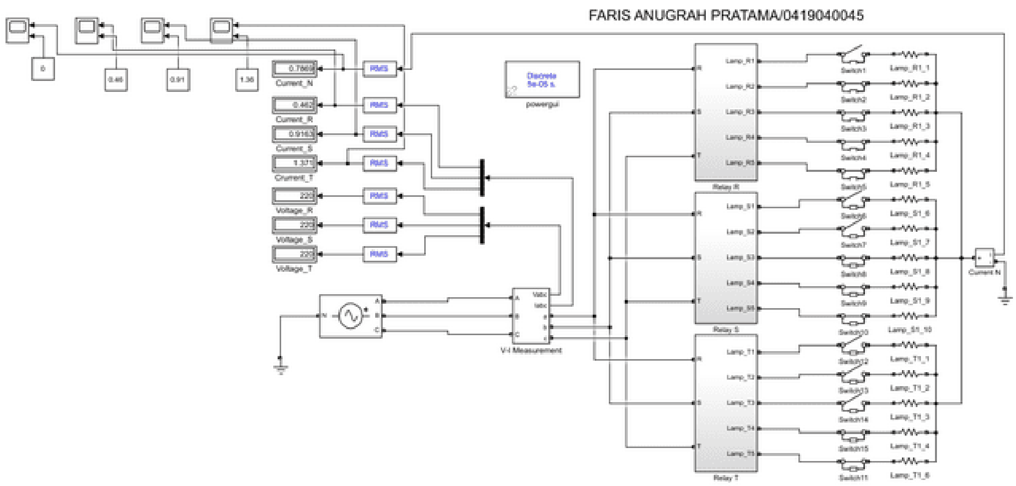
(b)

Figure 5. (a) Overall System Series (b) Circuit on R Phase Load

The first test is to simulate a balanced load using 3 loads of 100 watts each connected to the R, S, and T phases. The values from the simulation results are 220V for the voltages on the R, S, and T phases. 0.462A for the currents on the R, S, and T phases. R, S, and T. The value of the neutral current is very small due to balanced loads. Then it can be seen in the signal image that there is a spike resulting from switching on from the relay

3.1.2 Testing 1 Condition 2

The second test is to simulate an unbalanced load using 1 load connected to phase R, 2 loads connected to phase S, and 3 loads connected to phase T. The initial value of the simulation results is 220V for the voltage on phases R, S, and T. 0.462A for the current in phase R, 0.9163A for the current in phase S, and 1.371A for the current in phase T. The value of the neutral current is 0.7869A. In step 1, relay switching is carried out so that the load becomes balanced. The value after balancing is 220V for the voltage on phase R, S, and T. 0.9169A for the current on phase R, 0.9163A for the current on phase S, and 0.9158A for the current on phase T. The value of the neutral current is 0.0003809A. Then it can be seen in the signal image that there are signal spikes in the R, S, and T phases resulting from the switching on of the relay in step 0 and small spikes in the R and T phase signals as a result of switching the relay in step 1.



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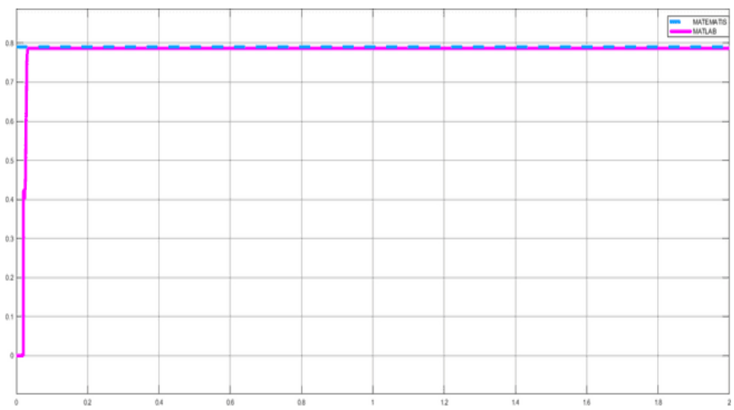
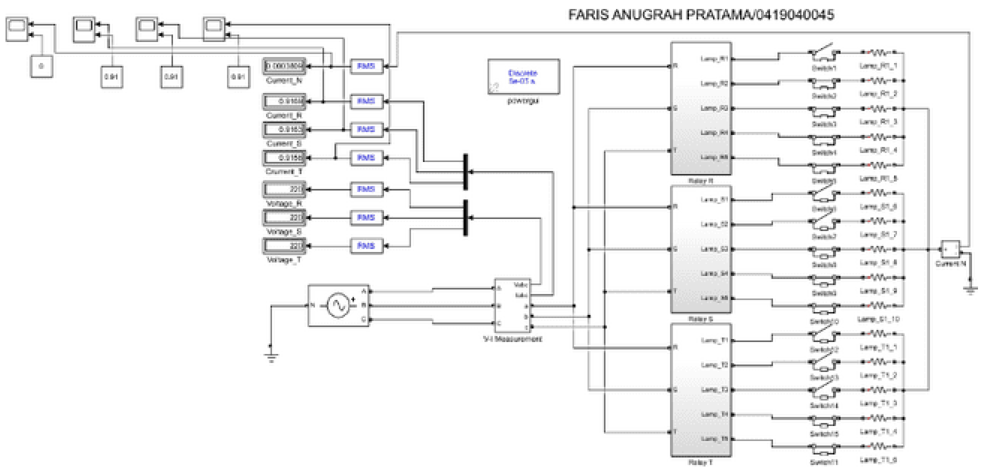


(b)

Figure 6. (a) Tapping Phase Simulation Series Test 1 Condition 1 (b) Signal on Neutral Phase



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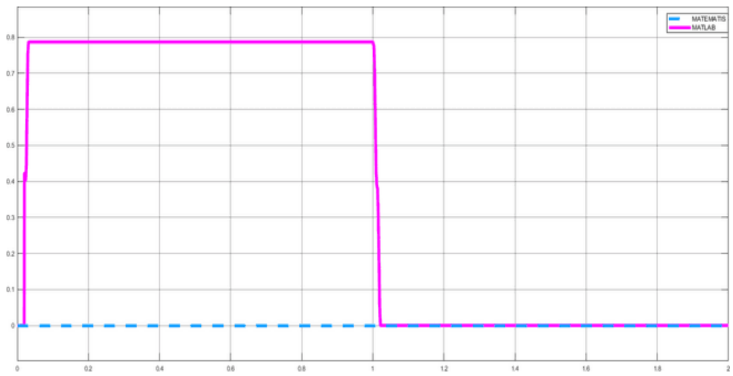
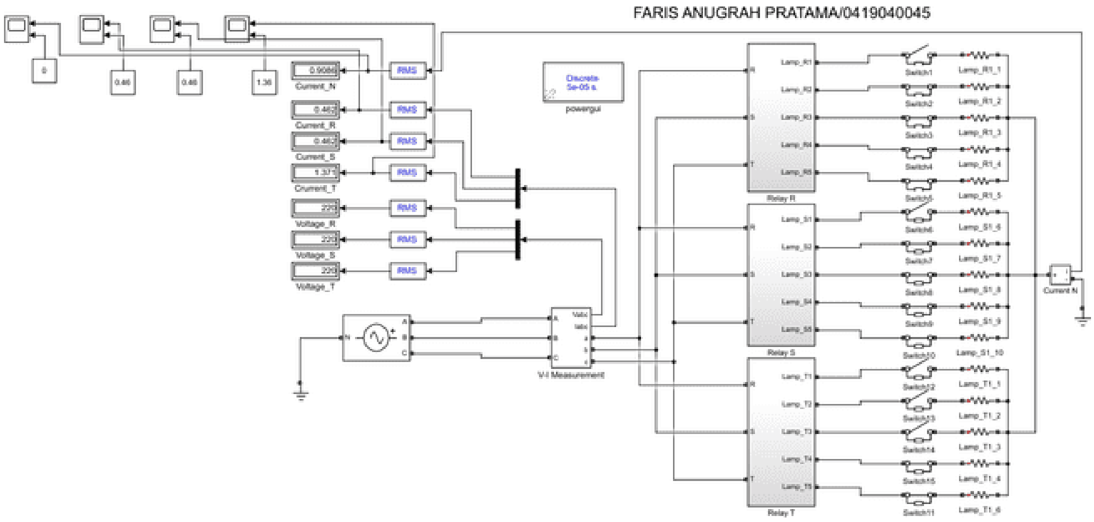


(b)

Figure 7. (a) Tapping Phase Simulation Series Test 1 Condition 2, before switching (b) Signal on Neutral Phase, before switching

3.1.3 Testing 1 Condition 3

The third test is to simulate an unbalanced load using 1 load connected to phase R, 1 load connected to phase S, and 3 loads connected to phase T. The initial value of the simulation results is 220V for the voltage on phases R, S, and T. 0.462A for current on phase R, 0.462A for current on phase S, and 1.371A for current on phase T. The value of the neutral current is 0.9086A. In step 1, relay switching is carried out with the aim of balancing the load. The value after balancing is 220V for the voltages on the R, S, and phases T. 0.9169A for the current in phase R, 0.462A for the current in phase S, and 0.9158A for the current in phase T. The value of the neutral current is 0.4543A. It can be seen even though switching has occurred in the relay, the current in the neutral phase remains high.



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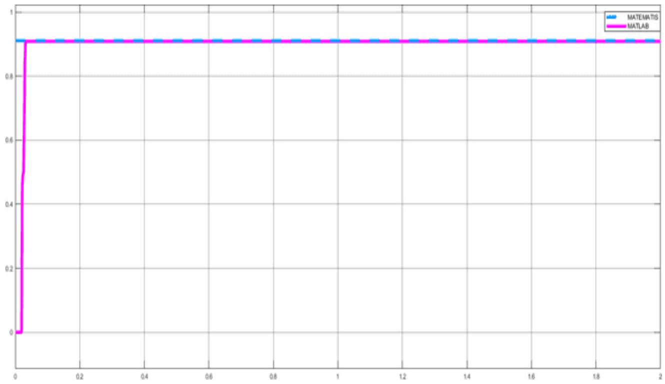


(b)

Figure 8. (a) Tapping Phase Simulation Series Test 1 Condition 3, before switching (b) Signal on Neutral Phase, before switching

3.2. Result of Calculation

3.2.1 Calculation Testing 1 Condition 1

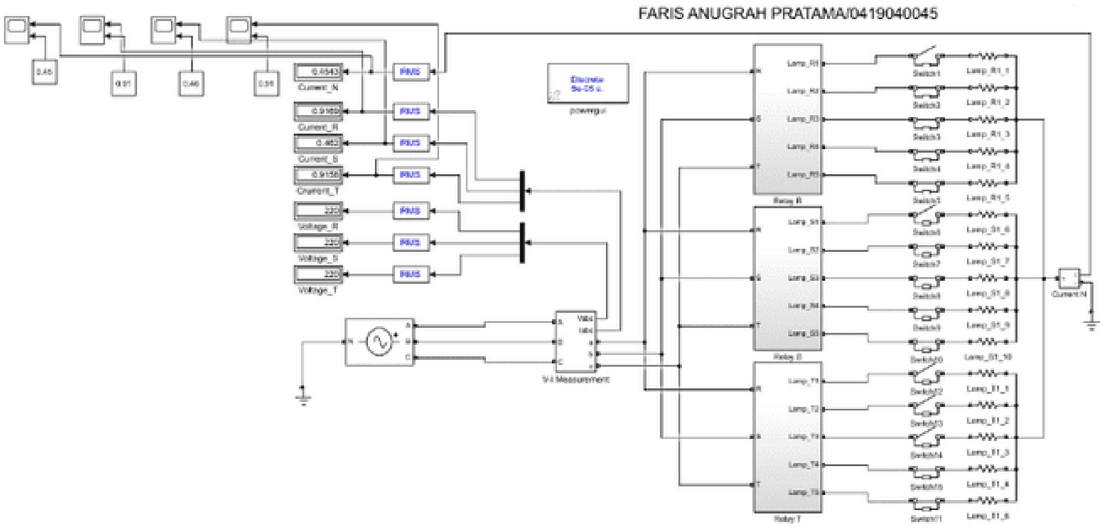
Neutral current calculation

Total Sin = 0,45 × Sin (0) + 0,45 × Sin (240) + 0,45Sin (120)

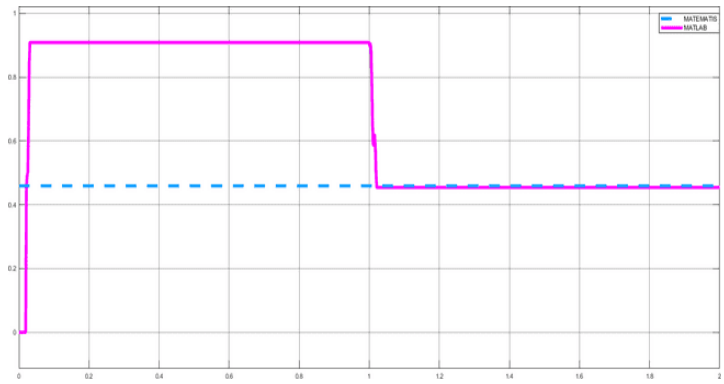
Total Cos = 0,45 × Cos (0) + 0,45 × Cos (240) + 0,45Cos (120)

IN = (02 + 02)0,5

IN = 0 A



(a)



(b)

Figure 9. (a) Tapping Phase Simulation Series Test 1 Condition 3, after switching (b) Signal on Neutral Phase, after switching

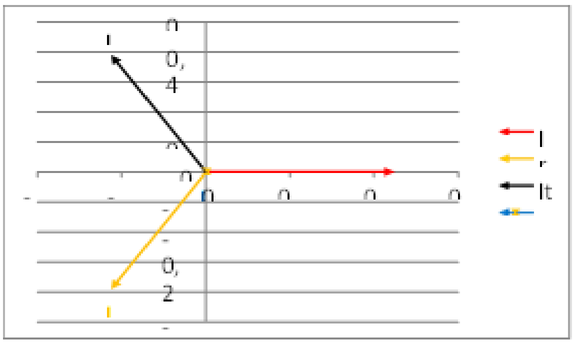


Figure 10 Interphase Current Graph

Based on the graph in Figure 9, there is no difference in the value of each phase and when added together it is zero. This situation does not generate a neutral current.

3.2.2 Calculation Testing 1 Condition 2

Neutral Current Calculation

Total Sin = 0,45Sin (0) + 0,91Sin (240) + 1,36Sin (120)

Total Cos = 0,45Cos (0) + 0,91Cos (240) + 1,36Cos (120)

IN = (−0,685)2 + (0,39)2)0,5

IN = 0,79 A

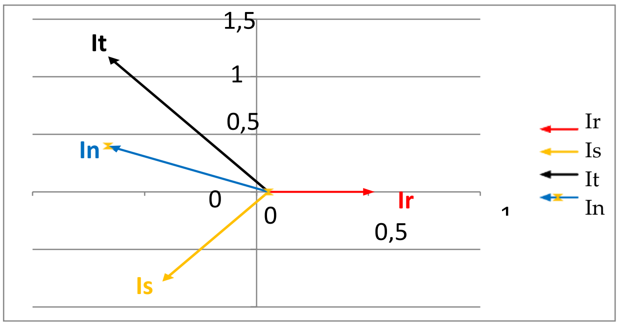


Figure 11 Interphase Current Graph

There is a difference in the value of the current in each phase which in theory will give rise to a neutral current. Based on calculations, the value of the neutral current is 0.79A. Head and shoulders shots of authors that appear at the end of our papers.

3.2.3 Calculation Testing 1 Condition 3

Neutral current calculation

Total Sin = 0,45Sin (0) + 0,45Sin (240) + 1,36Sin (120)

Total Cos = 0,45Cos (0) + 0,45Cos (240) + 1,36Cos (120)

IN = (−0,455)2 + (0,79)2)0,5

IN = 0,91 A

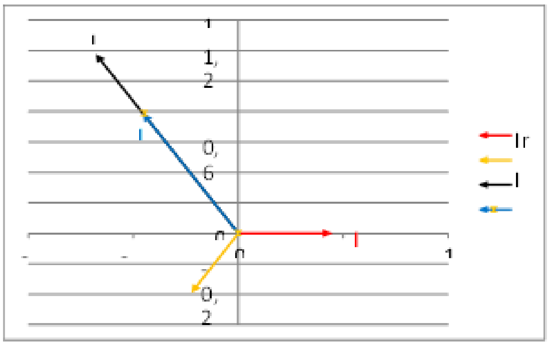


Figure 12 Interphase Current Graph

There is a difference in the value of the current in each phase which in theory will give rise to a neutral current. Based on calculations, the value of the neutral current is 0.91A.

4. Discussion

4.1. Tapping Phase Testing

Integrated testing is testing the entire system which consists of a combination of components that are bound to each other to form a single unit. In this final project, what is meant by integrated testing is a combination of testing between tapping phases. After testing the supporting components, the next step is to test the function of the system as a whole. The actual integrated test without a method is a test that is carried out regardless of the simulation results from the method that has been simulated. This test aims to determine the overall function of the system can work properly by analyzing the load imbalance protection system.

Based on table 2 there are 4 data showing the percentage of imbalance exceeding 25%. In a row data numbers 4, 5, 7, 8, and 9 have an Unbalanced Load Percentage (UL) of 33.30%, 32.60%, 30.20%, 26.50% and 32.80%. Test data that has an imbalance percentage above 25% will automatically experience a tapping phase.

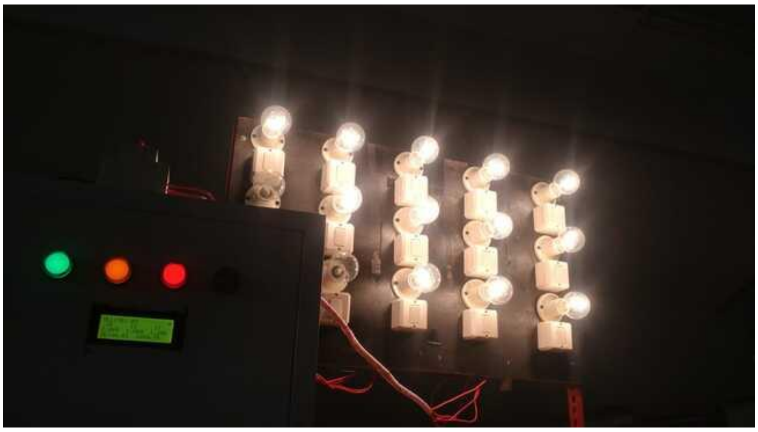


Figure 13. Integrated Tool Testing

Table 2 Tapping Phase Testing Table

No	Testing						
	Ir (A)	Is (A)	It (A)	UL (%)	In (A)	*Losses* (W)	Condition
1	1,67	0,85	1,26	21,90	0,80	0,08	Balanced
2	1,64	1,66	1,65	0,50	0,00	0,00	Balanced
3	1,24	2,07	1,65	16,80	0,80	0,08	Balanced
4	0,84	2,10	1,26	33,30	1,20	0,17	Unbalanced
5	0,86	0,44	0,44	32,60	0,40	0,02	Unbalanced
6	1,71	1,29	1,28	13,10	0,45	0,02	Balanced
7	0,86	1,72	2,14	30,20	1,20	0,17	Unbalanced
8	0,86	0,81	1,71	26,50	0,90	0,10	Unbalanced
9	0,44	0,87	1,29	32,80	0,79	0,07	Unbalanced
10	0,44	0,44	0,44	0,00	0,00	0,00	Balanced

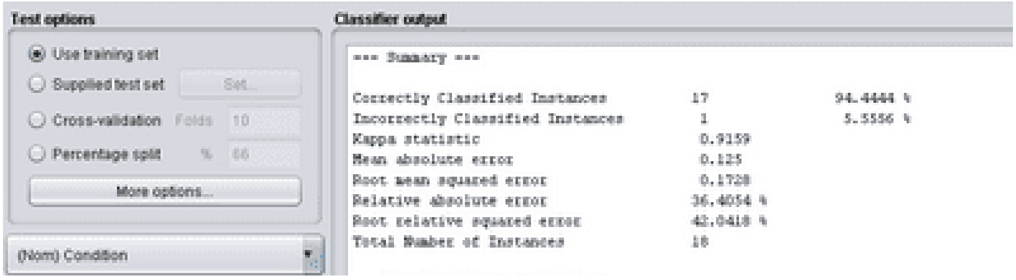


Figure 14. Result of Method Simulation

Table 3. Result of Method Simulation Table

No	Classifier Output		
1	Correctly Classified Instances	17	94.4444%
2	Incorrectly Classified Instances	1	5.5556%
3	Kappa Statistic	0.9159	
4	Mean Absolute Error	0.124	
5	Root Mean Squared Error	0.1728	
6	Relative Absolute Error	36.4054%	
7	Root Relative Squared Error	42.0418%	
8	Total Number of Instances	18	

4.2 Naïve Bayes Method Testing

As can be seen in Figure 4.50, it is known that the probability values for each class (pointed by arrows) successively from normal to trip are 0.41, 0.23, 0.27, 0.09. After looking at the probability value of each class, then in Figure 4.51 it is known that the accuracy of the predicted value of the reference data (assumptions). Overall accuracy is shown in the Correctly Classified Instances chart, the chart shows data that matches the reference values that have been made as many as 17 out of 18 data or 94.44%. Incorrectly Classified Instances (data that do not match) in this chart shows data that does not match the reference data as much as 1 out of 18 data or 5.56%. When the load is balanced ideally the neutral current will not appear. In calculations and simulations when the load is balanced, the neutral current is 0.00A. It can be seen that the average error value in the calculation of the simulation is the smallest, namely 1%, this is because each data is almost not influenced by other factors such as hardware and other factors, or in other words, both data are in ideal conditions

5. Conclusions

Based on the experiments that have been carried out in balanced conditions, the unbalance percentage value is 0.50% and the neutral current read is 0 A, when the unbalanced condition is unbalanced, the percentage value is 33.30% and the neutral current read is 1.20A. After tapping the phase, the percentage of imbalance becomes 13.40% and the neutral current that is read is 0.50A. The neutral current value arises due to an imbalance in the load. Based on testing, when the percentage unbalance value is 33.30%, a neutral current of 1.20A arises and when the percentage unbalance value is 0.00% (balanced), the neutral current value that is read is 0%.

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