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Control System Of Current Flow 3-Phase Unbalanced Based On Arduino Uno

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Abstract— **This unbalanced current 3 phase load is a disturbance that can cause damage to the power transformer. The load on each phase difference may result in a decrease in the power quality of the power system (e.g., IEEE and NEMA). Load unbalance on the power traformator causes losses, excess heat on one phase, reduced lifetime and efficiency on the power traformator. This research aims to design and make a prototype monitoring unbalanced 3 phase currents. Arduino microcontroller as the main controller function to read the current value will be displayed on the LCD (Liquid Crystal Display), activates the buzzer and LEDs as an indicator when there is an unbalanced in the current flow of a predefined value. The experimental results show that the prototype tool when compared to the ampere meter measuring devices can respond to the 3 phase unbalanced with an average error or accuracy of current per phase R = 3.92%, S = 3.44%, and T = the remaining 3.11%.**

Index Terms— **Load Unbalanced 3 Phase, Flow Sensors, Monitoring Systems, Microcontroller Arduino Uno.**

I. INTRODUCTION

Electrical energy is a source of energy that is needed in human life at this time. Almost all equipment with emerging technology requires electrical energy, so that electrical energy is the primary requirement or principal. Electrical energy is a very important requirement, both for everyday life as well as for the needs of the industry. This is because the electrical energy is converted into other forms of energy as well as energy. Therefore, the stability of the electrical energy distribution system should be maintained so that it can be used by consumers [1][2][11].

In maintaining the stability of the electrical distribution system required power quality and load on the distribution transformer. However, in the distribution of power to consumers must be considered also unbalanced load used by the consumer in order to avoid failures and problems in power transformers. To meet the needs of the electric power, dividends burdens initially evenly but because unbalanced ignition timing are the burdens that cause load unbalance in the supply of electricity. A load balance between each phase (R phase, S phase, and T phase) was the cause Circuits in neutral transformer [1][3][4][12].

Differences load on each phase can result decrease system power quality in power, one way to improve power system reliability by maintaining continuity of electrical power.

Due to load imbalance in power transformers, among others, could cause *losses* or losses in the transformer power, excessive heat in one phase on power transformers, reduced lifetime, efficiency transformer power and cause damage to equipment such as fuse on the capacitor bank, reduced torque at induction motors and heating over the induction motor [3][5][9]. Then there is need for flow monitoring system used to communicate information to the operator for analysis and preventing their occurrence when the operator information looking unbalanced load.

Power transformers in substations function to distribute electrical energy to consumers with a lower voltage level. Power transformer serves to lower voltage of 150 kV said primary voltage to a secondary voltage of 20 kV, 20 kV for distribution feeders lowered into 6 kV, 380 V. In general, the voltage received by the community an average of 380V (3-phase) for a medium scale and 220 V (1-phase) for a low scale. In this final project is done research for monitoring current is not balanced 3-phase by using arduino uno. Monitoring will provide information through the LCD *(*Light Emitting Diode*),* LED as Indicator and sign Buzzer when dis found unbalanced condition on one phase (R, S, T) exceeds the value you set programmable arduino uno, as well as on interference given that make use of Rheostat.

A. The lack of load-balanced 3 Phase

Understanding of load balanced is:

- Third current vector / voltage is equal.
- The third vector of each form an angle of 120^0 with one another Figure 1.

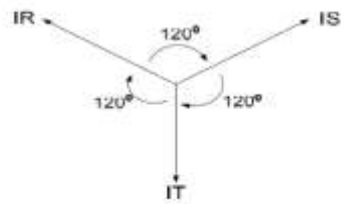

Figure 1. Vector diagram of the current state of balance

It can be seen that the vector sum of the three current *(Ir + Is + It)* is equal to zero, so as not to cause neutral Current.

While the definition of an unbalanced state is a state in which one or both circumstances unbalanced condition is not met.

Possibility of an unbalanced state, there are three, namely:

- Three vectors as great but do not form an angle of 120^0 with one another.
- The third vector is not as great but forms an angle of 120^0 with one another.
- The third vector is not as large and not form 120^0 to each other.

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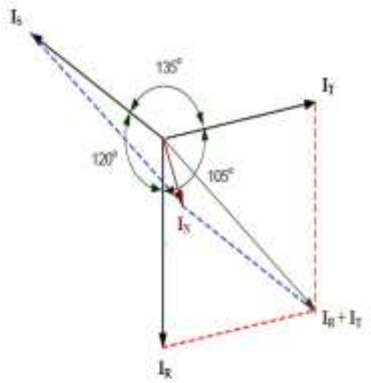

Figure (2) Vector diagram of the current state of Unbalanced

From Figure 2 shows a vector diagram of currents in the unbalanced state is seen that the sum of the three vectors current *(Ir + Is + It)* is not equal to zero so there is a quantity that flows on neutral side *(iN),* the amount depends on how much unbalanced factor.

B. Netral

Neutral flow in the power distribution system is known as the current flowing in the neutral wire in low voltage distribution systems three phase four wire. The neutral current appears if:

- Condition unbalanced load.
- Because of the harmonic currents due to non-linear loads. The current flowing in the neutral wire which is an alternating current.

For the distribution system of three phase four wire is the vector sum of the three phase currents in symmetrical components. If *I* is the amount of phase currents in the distribution of power equal to P in a balanced state, then the distribution of the same power but unbalanced magnitude of the phase currents can be expressed by the coefficients a, b, and c are:

$$[He] = a[I] \quad (1)$$
$$[Ib] = b[I] \quad (2)$$
$$[Ic] = c[I] \quad (3)$$

By Ia, Ib, and Ic respectively are phase currents R, S and T. When the three-phase power factor of the magnitude of the current being equal though different, magnitute power distributed can be expressed in show formula :

$$P = (a + b + c)\,.[V]\,.[I]\,.\cos\varphi \quad (4)$$

$$P = 3.\,[V].[I].\,\cos\varphi \quad (5)$$

If the equation (4) and (5) expressed power of the same amount, then of two equations that can be obtained requirements for coefficient a, b, c, namely:

$$a + b + c = 3 \quad (6)$$

Where in the steady state value of $a = b = c = 1$.

C. Imposition Analysis Unbalanced

Determine Amount of unbalance the load on each phase (load analysis) In the steady state level of coefficient a, b, c is 1. Therefore, the average load imbalance (in%) can formulated on:

$$I_{mean} = \frac{I_R + I_S + I_T}{3} \quad (7)$$

$$I_R = a.I_{average}\ then: a = \frac{I_R}{I_{Average}} \quad (8)$$

$$I_s = b.I_{average}\ then: b = \frac{I_s}{I_{Average}} \quad (9)$$

$$I_T = c.I_{average}\ then: c = \frac{I_T}{I_{Average}} \quad (10)$$

$$[\text{imbalanced}] = \frac{\{|a-1|+|b-1|+|c-1|\}}{3} x100\% \quad (11)$$

If the system is more than 25% then the otherwise unbalanced system [3][7][10].

D. Microcontroller Arduino Uno

Arduino is a microcontroller single-board is an open-source as in Figure 3. hardware microcontroller Arduino programmed using programming language wiring-based based syntax and library. Programmed wiring-based This is no different with the C / C ++, but with some simplifications and modification. To facilitate the application development, Arduino microcontroller also Use the Integrated Development Environment (IDE) based processing. Arduino microcontroller can paired with an assortment of sensors and other actuators. As for the sensors and actuators that can be attached to the Arduino such as motion sensors, ultrasonic, heat, sound, Ethernet Shield, LED Display and more.

E. Current Sensors

Known current sensor or current transformer, known as Current Transformer (CT) and using effect hall technology. These sensors are classified as components that have a good level of stability. Type flow sensor that is widely used is the current transformer known YHDC as CT sensor is at the core of an alternating electric current measurement, non-invasive sensors that can detect the flow current through a conductive wire. In the process of induction, the electric current through the wire the primary side will generate a magnetic field in the ferrite core sensors CT. Wire on the secondary side the core surrounds generates a small electrical current that is proportional. Furthermore, CT sensor with the addition of a small resistor (Burden resistor) will produce the output of the voltage can be measured by Arduino.

II. METHODE

Implementation of a prototype Generally current monitoring system is unbalanced 3 phase begins by taking the output from current sensor SCT-013-20A and processed by the arduino and shown to a 16x2 LCD (Liquid Crystal Display) as the output of RMS current (A), as well as in the form of a command issued arduino microcontroller output Buzzer and LED in case of 3-phase current imbalance in the program, whose value has setpoint. The system architecture will be made in this study as a whole can be seen in Figure 3.

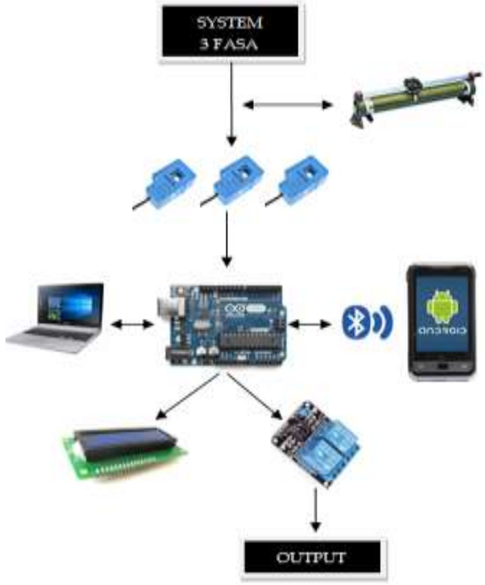

Figure 3. Blok Prototype

Current Sensor SCT-13-20A YHDC will read the current conditions at the observation point. Values have not issued the sensor can read well by the Arduino Uno to it required a series of preconditions which is a limit sensor output voltage is around 1 volt, so as not to damage the pin Analog arduino (A0, A2, and A3). Furthermore Arduino Uno will process and calculate the value of the current readings to be displayed on the LCD. While the output is in the form Buzzer and LED indicators as arduino output commands when there load unbalanced 3-*phase* and the output is also wearing a HC-05 Bluetooth module as an additional medium flow monitoring that will be displayed on your smartphone (Android).

III. DESIGN HARDWARE

A. The power supply or adapter

Is a device electronic components that function is used as a modifier of the AC voltage generated enumerated by the transformer into DC voltage 9 VDC and 5Vdc to be used for supply voltage at the microcontroller arduino and equipment other where there is a 16x2 LCD, Relay Module and Bluetooth Module HC-05, show in Figure 4.

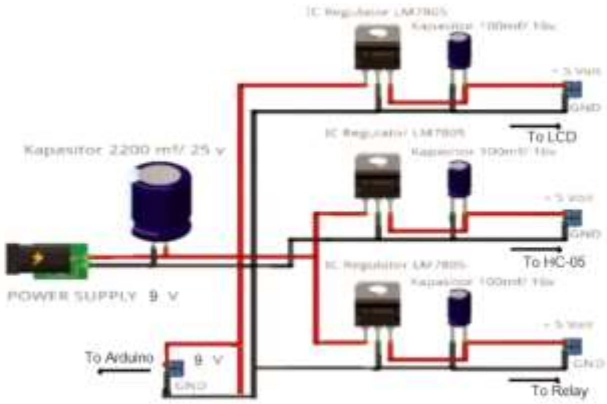

Figure 4. Circuit power supply

B. SCT013-20A Current Sensor

Current Sensor to the design of this tool serves as a place to input current sensor, so that when the current sensor is mounted on the cable system 3 *phase* then the current sensor will work and through the microcontroller arduino. The circuit is made as much as 3 pieces, due to input itself requires 3 circuits as reading the current value of R, S, and T. In 3feeder system *phase* in the execution of the circuit using Proteus 7.9 software.

C. Design of the overall circuit

Design of the circuit as a whole covers a series of power supply or adapter, current sensor circuit SCT-013, a series of LCD, LED and alarm circuits and Bluetooth circuit HC-05. Stage to the whole starts with a flow chart on the show in Figure 5.

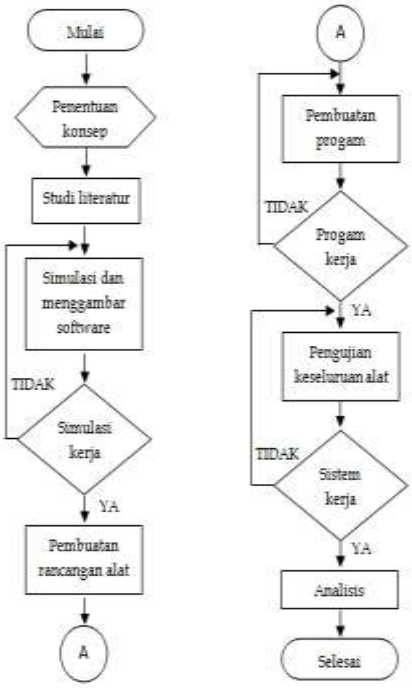

Figure 5. Flowchart

IV. RESULTS AND DISCUSSION

Results and discussion of that this is done as follows.

A. Testing the power supply or adapter

Testing and measurements performed on the input and output of the power supply. It aims to determine the magnitude of the voltage of work that went before to IC ATMega 328, because the board arduino can only operate with an input voltage 5-12 VDC so that the voltage on arduino and modules other stable for this tool using voltage 9 VDC to board arduino and regulator 5 Vdc for relay module and module *a Bluetooth* HC-05. Here are the results of measurements Table 1:

Table 1. Measurement of power supply

No.	Measurement	Vin (Vdc)	Vout (Vdc)	Volt Input
1	I	9.17	9.17	Arduino
2	II	9.17	5.07	Module Relay
3	III	9.17	5.07	Module HC-05
4	IV	9.17	5.07	LCD 16x2

B. Testing SCT-013-20A Current Sensor

In this current sensor testing tool used is 3 *phase* in each *phase* R, S, and T. Testing Flow Sensor SCT-13-20A tested by providing rheostrat 11 Ω load on the voltage of 20 Vac and Flow Max 5 Amperes. The output current of the SCT-13-20A directly observed with an LCD display. of testing the current sensor output data obtained as table 2 below:

Table 2. Test results SCT current sensor -013-20A

No.	Load (Ω)	Vout Sensor R (Volt)	Vout Sensor S (Volt)	Vout Sensor T (Volt)
1	11 Ω	0.07	0.06	0.07
2	10.5 Ω	0.07	0.07	0.08
3	10 Ω	0.08	0.08	0.09
4	9.5 Ω	0.09	0.08	0.09
5	9 Ω	0.09	0.09	0.10
6	8.5 Ω	0.10	0.09	0.10
7	8 Ω	0.11	0.10	0.11
8	7.5 Ω	0.12	0.10	0.12
9	7 Ω	0.13	0.11	0.13
10	6.5 Ω	0.14	0.12	0.13
11	6.1 Ω	0.15	0.13	0.14

C. Overall test and analysis tool

Of all test blocks already implemented this system can be seen in Figure 6.

Figure 6. All Tool Prototype

The prototype aims to find out the tool's ability to do the reading flow system 3 *Phase* currents balanced or unbalanced, and can display the current value to the LCD, and there is a value indicative of the form of output *buzzer* and LED lights in case of an unbalanced state of the current already at *setting point* in the program IDE arduino, and the results of testing of the tool shown in Table 3.

Table 3. The results of testing of the overall system

Load (Ω)	Volt (Vac)	Measurement Prototype (A)			Measurement Tool (A)		
		R	S	T	R	S	T
10.5 Ω	20 V	1.88	1.80	1.85	1.9	1.8	1.8
10 Ω	20 V	2.00	1.85	2.06	2.0	1.8	2.0
9.5 Ω	20 V	2.17	2.01	2.10	2.1	1.9	2.1
9 Ω	20 V	2.26	2.04	2.15	2.1	1.9	2.0
8.5 Ω	20 V	2.35	2.22	2.22	2.2	2.1	2.1
8 Ω	20 V	2.40	2.32	2.29	2.3	2.3	2.2
7.5 Ω	20 V	2.53	2.42	2.39	2.4	2.5	2.4
7 Ω	20 V	2.59	2.45	2.55	2.5	2.5	2.7
6.5 Ω	20 V	2.73	2.47	2.73	2.6	2.6	2.8
6 Ω	20 V	2.80	2.73	2.69	2.9	2.8	2.7

Table 4. Results of current measurement accuracy R *phase*

Load (Ω)	Measurement Prototype (A)	Measurement Tool (A)	Error (%)
	R	R	
10.5 Ω	1.88	1.9	1.06%
10 Ω	2.00	2.0	0 %
9.5 Ω	2.17	2.1	3.22 %
9 Ω	2.26	2.1	7.07 %
8.5 Ω	2.35	2.2	6.81 %
8 Ω	2.40	2.3	4.16 %
7.5 Ω	2.53	2.4	5.13 %
7 Ω	2.59	2.5	3.47 %
6.5 Ω	2.73	2.6	4.76 %
6 Ω	2.80	2.9	3.57 %
Avarage			3.92 %

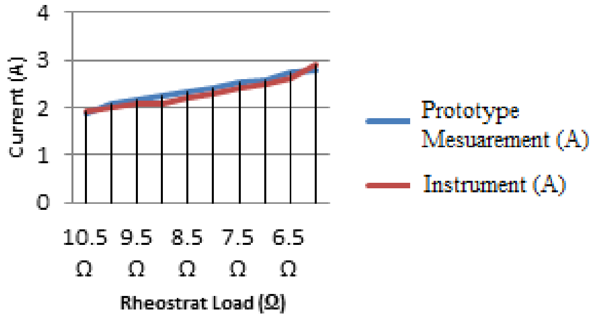

Figure 7. Graph Measurement Results R Phase

Table 5. Results of current measurement accuracy S *phase*

Load (Ω)	Measurement Prototype (A)	Measurement Tool (A)	Error (%)
	S	S	
10.5 Ω	1.80	1.8	0 %
10 Ω	1.85	1.8	2.77 %
9.5 Ω	2.01	1.9	5.47 %
9 Ω	2.04	1.9	6.86 %
8.5 Ω	2.22	2.1	5.40 %
8 Ω	2.32	2.3	0.86 %
7.5 Ω	2.42	2.5	3.30 %
7 Ω	2.45	2.5	2.00 %
6.5 Ω	2.47	2.6	5.26 %
6 Ω	2.73	2.8	2.56 %
Avarage			3.44 %

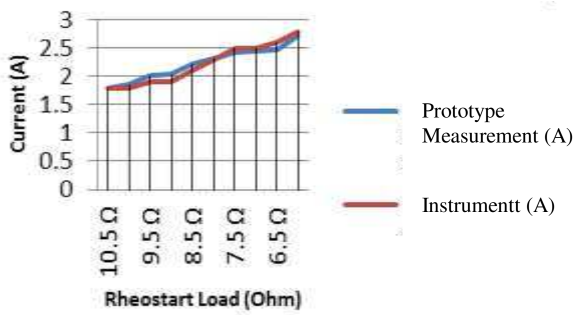

Figure 8. Graph Measurement Results S *phase*

Table 6. Results of current measurement accuracy T *phase*

Load (Ω)	Measurement Prototype (A) T	Measurement Tool (A) T	Error (%)
10.5 Ω	1.85	1.8	2.70%
10 Ω	2.06	2.0	2.91 %
9.5 Ω	2.10	2.1	0 %
9 Ω	2.15	2.0	6.97 %
8.5 Ω	2.22	2.1	5.40 %
8 Ω	2.29	2.2	3.93 %
7.5 Ω	2.39	2.4	0.41 %
7 Ω	2.55	2.7	5.88 %
6.5 Ω	2.73	2.8	2.56 %
6 Ω	2.69	2.7	0.37 %
Avarage			3.11 %

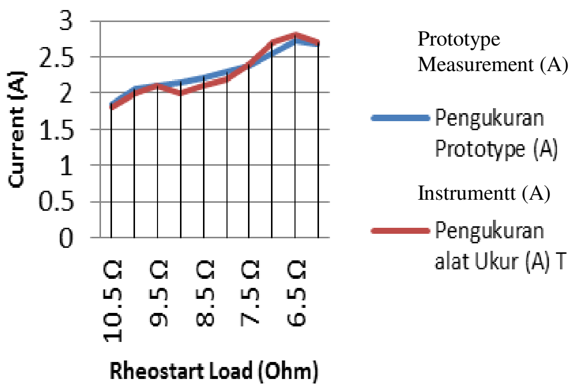

Figure 9. Graph Measurement results T *Phase*

From measurement results in table 3, 4, 5, and 6 , this current sensor is working properly. This can be proved by using pliers attached load amperes. For example at a load of 10 Ω in *phase* R-013-20A SCT current sensor measured currents are Ampere 2:07 while the results of measurements on the tang amperage is 2.0 Ampere. The slight differences in measurement results between the current sensor SCT-13-20A with pliers ampere influenced by the level of accuracy of the flow sensor. However, differences in the measurement results can already be used as a monitoring tool flows not balanced. *error* Measurement current sensor SCT-013-20A compared to the ampere pliers can be calculated with the following formula:

$$\%Error = \frac{(\,Reading\ Value - Real\ Value\,)}{Reading\ Value}\, x\ 100\%$$

From the calculations contained above average error on each *phase* R = 3.92%, S = 3.44% Phase and Phase T = 3:11 %. Measurement of flow sensors SCT-13-20A compared with pliers amperes. While the analysis of working prototypes analyzed that system happens balanced and happened not balanced on the set of tools, the system can detect the current in each *phase* R, S, and T and displayed on the LCD when rheostart shifted from 6 Ω to 10 Ω happened which flows on the system will change following the predetermined value formula. Here's an experiment testing the monitoring system of currents balanced and unbalanced:

➢ The test load balanced

Table 7. Results of testing load 11 Ohm balanced

Phase	Load (Ω)	Mensurement Prototype (A)	Mensurement Tool (A)	Buzzer	Info
R	11.3 Ω	1.70	1.7	OFF	Balanced
S	11.0 Ω	1.75	1.8		
T	11.1 Ω	1.79	1.8		

Table 8. Results of the testing load 8 Ohm balanced

Phase	Beban (Ω)	Measurement Prototype (A)	Measurement Tool (A)	Buzzer	Info
R	8.1 Ω	2.22	2.1	OFF	Balanced
S	8.3 Ω	2.39	2.3		
T	8.8 Ω	2.00	2.0		

9. Results of the testing load 6 Ohm balanced

Phase	Load (Ω)	Mensurement Prototype (A)	Mensurement Tool (A)	Buzzer	Info
R	6.2 Ω	2.69	2.6	OFF	Balanced
S	6.7 Ω	2.73	2.6		
T	6.6 Ω	2.45	2.4		

In table 7, 8, and 9 namely test show that the system is in balance.

➢ The test load unbalanced

Table 10. Results of testing the unbalanced load 1

Phase	Load (Ω)	Measurement Prototype (A)	Measurement Tool (A)	Buzzer	Info
R	10.1 Ω	1.88	1.7	ON	Unbalanced
S	9.7 Ω	1.85	1.7		
T	6.6 Ω	2.59	2.4		

Table 11. Test results unbalanced load 2

Phase	Load (Ω)	Measurement Prototype (A)	Measurement Tool (A)	Buzzer	Info
R	8.3 Ω	2.16	2.0	ON	Unbalanced
S	6.0 Ω	3.11	3.0		
T	8.2 Ω	2.17	2.0		

Table 12. test results unbalanced load 3

Phase	Load (Ω)	Measurement Prototype (A)	Measurement Tool (A)	Buzzer	Info
R	9.6 Ω	1.87	1.7	ON	Unbalanced
S	6.9 Ω	3.06	3.0		
T	6.1 Ω	2.80	2.7		

In the tables 10, 11, and 12 namely test show that the system is not balanced. Here's one example graph *serial plotter* of program IDE:

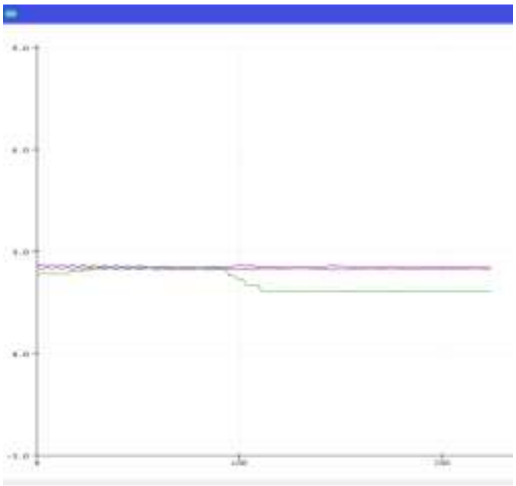

Figure 10. Graph unbalanced state.

Figure 10. Addressing one of the results graph that is not balanced on the load of each *phase* R = 8 Ω, S = 8 Ω, T = 10 Ω and flow R = 2.57 A, S = 2.49, and T = 1.83. In analyzes not balanced then the *buzzer* will sound and the LED indicator light red color "ON" is in a state *Fault* .Namely their description in the Value amperes will happen unbalanced value *setting point* be set to 25% in the program IDE from the current value of each of R, S, and T. *(PUIL and Journal Julios Santosa, 2009).*

V. CONCLUSION

After testing tools that have been created and are the result of data analysis, we can conclude couple of things as follows:

- The system is not balanced gave the response on the system arduino with a current value entered in the load rheostart, if there is a decrease in current or current rise in each phase (R, S, T) are different then, output *Buzzer (Alarm)*and the output LED will illuminate On systems that happens is not balanced.
- Accuracy monitoring of unbalanced 3 phase currents have an average mistake small relative measurement results with maximum rhesotart load 5 (A), the average current per phase R = 3.92%, phase S = 3.44%, and Phase T = the remaining 3.11%.

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