Design and Balancing Load Current in 3-Phase System Using Microcontroller ATMEGA 2560

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Abstract— **The design of balancing the load current on three-phase systems using a microcontroller ATMega 2560 is a tool that serves to reduce the power loss. Power loss due to the load current unbalance the current flows in the neutral phase on three-phase systems. Current flows in the neutral phase distribution transformer into a detriment to PT. PLN (Persero) for the power lost to the earth and can not be used by consumers. So that it will balanced the load current to reduce the value of neutral current. The tool is also equipped with a monitoring system that displays current magnitude of each phase including the neutral phase.**

The methods in making this tool is divided into two parts: first, the design of hardware consist of designing electronic components which are used by the current sensor circuits, relay, LCD (Liquid Crystal Display) etc. Second, the design of software is a tool listing program procedure including the monitoring program displays the current of each phase on LCD using the Arduino IDE. SCT013-030 current sensor used, the output of the current sensor is connected to the pin ADC (Analog to Digital Converter) microcontroller ATMega 2560. Then microcontroller process the data and generate a current value displayed on the LCD. The other result of processing current value is a command to enable or disable the relay that connects three-phase resource with single-phase loads.

The result of the test design of balancing load current on three-phase system using a microcontroller ATMega 2560 succeed balancing the load current by moving the channel load of sequence number load the smallest connected to the phase with the current biggest load toward a phase that has a load current smallest when neutral current exceeds the limit is permitted. In this situation, the neutral current will not be possible be zero. In fact, the maximum current value for the neutral phase for PT. PLN (Persero) 50 amperes calibrated to 1 ampere and is used as a limit on this prototype. If the neutral current on LCD monitor exceeds 1 ampere, then there will be balancing of the load current. The current sensor measurement results are displayed on a monitoring approach measurement result using pliers ampere.

Keywords: Balancing load current, monitoring system, SCT013-030, microcontroller ATMega 2560, channel load, neutral phase current.

I. INTRODUCTION

PT. PLN (Persero) is a state company that provides electricity to communities in Indonesia. The main requirement is needed when using electrical equipment is power electricity. Thermal and nonthermal energy or fossil and non-fossil can produce electrical energy supplied to the customers, industrial and commercial.

One of the problems of the PT. PLN (Persero) is losses when distributing electricity to customers due to the unbalance load current in distribution transformers. Unbalanced load flow effect there is the current flowing into the neutral phase and should be balancing the load current. Based on data from PT. PLN (Persero) Rayon Kuta, the problem of unbalance load current in distribution transformers on July 2015 listed 27 problems with the composition of the 15 issues successfully completed, 4 problems cancel to solved because neutral current drops under than the limit values and 8 problem unsolved. so there is 19 solved with average load current value 81,47 ampere.

PT. PLN (Persero) has a section in charge of Technical Services overcome the problem of load current imbalance on distribution transformers. One purpose of establishing the Pelayanan Teknik section to reduce losses due to unbalanced load currents. In fact officer needed more time to go to distribution transformers, measure load current and current in each feeder and then turn off an electricity to switching only one-phase load and non-essentials. Many time during current flowing on the neutral current gave more loss.

Based on these facts so the necessary solutions to reduce losses due to the unbalanced load current is using sensor current integrated with relay are conecting load feeder and feeder phase on distribution panel controled with microcontroller. In this study will be made prototype design of balancing the load current in 3 phase system using ATMega 2560 microcontroller.

This tool will work with the program that has been created based on the operational procedures Pelayanan Teknik section. if neutral current value more than limit and then relay detector will give information which load is connected to phase with biggest current value and switches that load to phase with lower current value. Moving load current line to one phase with lower load current using relay. LCD as interface to show load current value include neutral phase. When unbalanced load current are solved, current sensor detect load current on neutral phase to decide balancing load current for made balanced load current.

II. LITERATURE REVIEW

A. Jaringan Tegangan Rendah line

Jaringan Tegangan Rendah (JTR) is a feeder that connects the Saluran Udara Tegangan Menengah (SUTM) with Saluran Listrik Tegangan Rendah lines (SLTR) or Tegangan Rendah (TR). In JTR distribution substations that are made up of various components to distribute electric power depending on the type of construction. Components are generally composed of a fuse cut-out, step-down transformer, lightning arresters, main fuse, busbar / rail phase, fuse busbar channel / rail grounding.

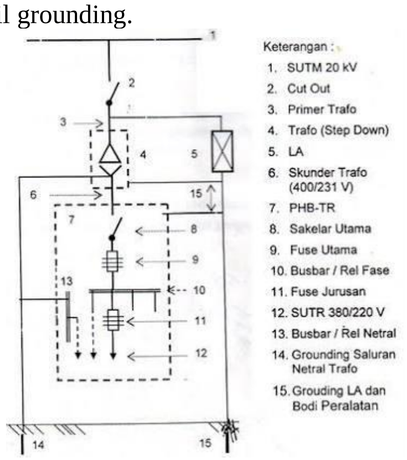

Figure 1: Line Diagram Distribution Stasion

In Figure 1 can be seen from SUTM 20 kV medium voltage distribution transformers before heading using step-down transformer are fuse cut-out that functions as a safety transformer. There is also a lightning arrester which serves to secure distribution substation transformers and other equipment in case of over-voltage including lightning surge. On the secondary side of distribution transformers are the main switch and main fuse as a safety. Then there is a busbar or rail main phase which will be divided into several channels according to the load imposed on the transformer. Fuse channel installed for securing lines of each channel when there is excessive current. Other safety equipment such as grounding transformer and grounding lightning arresters [1].

B. Balancing Load Current in 3-Phase System

Unbalanced load current due to dominant of customers with single-phase load than customers with three-phase load. So that it make single-phase load are connected to which one phase of phase on three phase system. The customers with single-phase load often have different operating hours, consequently the load current flowing in each phase on three phase system will not be the same. In this condition make many of load current is flowing in neutral phase. In other side angle phase are change from 120 degree and make unbalanced load current in transformer. the definition of balance load current is :

1. The large third vector of current or voltage are same.
2. The third vector of current or voltage make 120º angle of each other.
3. Nuetral current value is zero ampere.

While the definition of an unbalanced load current if two conditions are not met or the second condition is not fulfilled at all, so there are four possible causes for the unbalanced load situations such as:

1. The third vector are same and cannot have 120º angle of each other.
2. The third vector are not same and make 120º angle of each other.
3. The third vector are not same and cannot make 120º angle of each other.
4. There is load current flowing neutral phase.

As a effect of unbalanced load current flow only affects the secondary side of distribution transformers (phase-R, S-phase, T-phase and phase-N) and load current flowing neutral phase is losses in power electricity. This problem can be solved with switching load line. Balancing the load current is carried out in several stages, the initial measurement, mapping and switching load line and end with measurement. The initial measurement is intended to determine the condition of the current flowing in each phase and occurs unbalanced load current. And then, the switching of the load by moving the load line connected to the phase which has the largest load current to the phase with the smallest load current. The last stage by measuring the current in each phase to know if the load current is already balanced [2].

C. Microcontroller Arduino

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.. Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions [3]:

1. Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX). Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip .
2. External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2). These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a

change in value. See the attachInterrupt() function for details.
3. PWM: 0 to 13. Provide 8-bit PWM output with the analogWrite() function.
4. SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Duemilanove and Diecimila.
5. LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
6. I2C: 20 (SDA) and 21 (SCL). Support I2C (TWI) communication using the Wire library (documentation on the Wiring website). Note that these pins are not in the same location as the I2C pins on the Duemilanove.

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software on running on a computer [3].

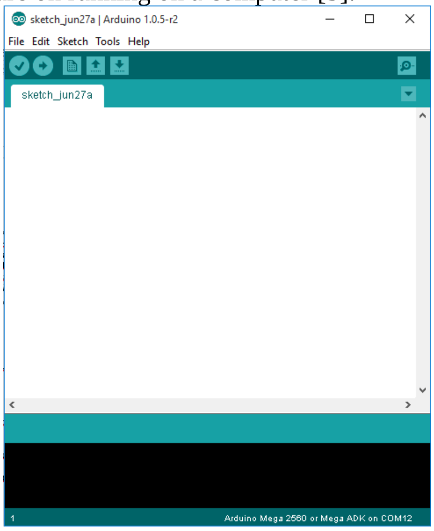

Figure 2: Worksheet Arduino IDE

The figure shown in figure 2 to make code program completed with toolbar to help connect code program to microcontroller arduino. Program created by arduino IDE called with sketches. File sketches created will then be save using the format .ino. Various features that can be used in making the program code such as copy, paste, cut, searching and replace text. Sketches that have been made will be examined and displays an error message during the process of exporting. The error message also provides information on the location of the error on sketches. Arduino IDE also comes with a selection of the microcontroller which is used later. Other features, such as verify, upload, new, open, save and serial monitors have their respective functions [3].

1) Verify: Verify function checks the program code so that there are no mistakes made both structural and commands used.

2) Upload: Upload function to compile and download the program code of the program code in microcontroller module used.

3) New : New functions to provide new worksheets to make sketches.

4) Open: The function of this feature to open the source code files that have been made in advance and stored in the format .ino.

5) Save: Save is used to store program code or sketches that have been made.

6) Serial monitor: Serial monitor is a feature used for monitoring the program code if it works as planned.

D. Current Sensor SCT013-030

Splilt-core Current Transformer is a current sensor that uses the concept of performance of the current transformer. Designed to produce a current transformer secondary current value is smaller than the primary side. Current transformer to change the current value on a transmission line to a smaller value so it is safer to do measurements. Figure 3 will explain the workings of a current transformer.

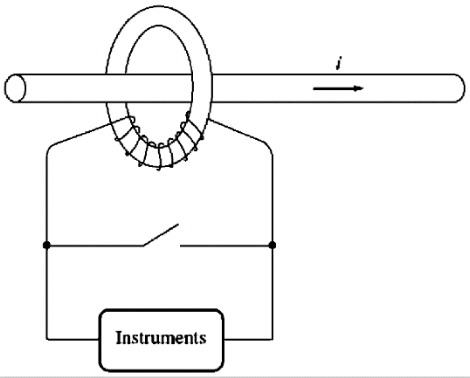

Figure 3: Current Transformer

Consists of the current transformer secondary winding contained in the ferromagnetic ring, with the primary winding through the center of the ring. Cicin- ferromagnetic withstand a flux of the primary winding. This flux induces a voltage and current to the secondary winding. The ratio between the current transformer primary winding and a secondary affect the resulting current. The ratio of the current transformer typically ranging from 600: 5, 800: 5 or 1000: 5 ampere with standard ratios at the secondary winding of 5 amperes [4]. Sensor current are current sensors SCT013-030 with a maximum current that can be measured at 30 amperes. The current transformer using permanent magnets as ferromagnetic ring [5].

E. Relay

In electronics, the relay is the component most often used to disconnect or connect a circuit controlled manner. Relay is an electronic switch that works by using magnetic fields. This component consists of a coil and slab that serves as a switch. When winding supply with electrical current magnetic field will arise and draw the slab. Relay is used Songle SPDT 12 volt is used on this tool. As for the various types of relays by poles such as [6]:

1. COMMON is a reference pole.
2. NC (Normally Close) pole position is initially connectes to COMMON.
3. NO (Normally Open) is a pole with initial position open and will be connected to COMMON if the relay coil by electrical currents.

Based on the number of poles in the relay, the relay can be divided into four types such as:

1. SPST = Single Pole Single Throw
2. SPDT = Single Pole Double Throw
3. DPST = Double Pole Single Throw
4. DPDT = Double Pole Double Throw

Pole is number of COMMON, while Throw number of terminal output (NO dan NC).

F. Liquid Crystal Display

Liquid Crystal Display (LCD) is one of the electronic components that serves to display numbers, letters or other symbols. LCD made with CMOS logic that works with do not produce light but reflects light in the vicinity of the front-lit or transmit light of a back-lit. The number of characters that can be displayed by an LCD depending on the specifications owned [7].

There are several important points to give orders to the LCD, such as:

1. Pin data is the data path the character you want displayed in the LCD, this pin can be connected to other circuits such as microcontrollers with 8 bit data width.
2. Pin RS (register select) is a pin that serves as an indicator to determine the incoming command is a command or data. When logic zero (low) indicates that the entry is a command, whereas if a logic one (high) indicates that the entry is the data.
3. Pin RW (read write) is a pin that serves to distinguish the orders given on the LCD to read data or write data.
4. Pin E (enable) pin is used to hold incoming and outgoing data.
5. VLCD pin is a pin that serves to adjust the brightness of the display on the LCD, this pin is usually connected to trimpot 10 kΩ and a voltage of 5 V is used as a source of LCD.

G. Transformer

A transformer is a device that changes ac electric power at one voltage level to ac electric power at another volt age level through the action of a magnetic fie ld. It consists of two or more coils of wire wrapped around a common ferromagneticcore. These coils are (usually) not directly connected. The onl y connection between the coils is the common magnetic flux present within the core. One of the transfonner windings is connected to a source of ac electric power, and the second (and perhaps third) transformer winding supplies electric power to loads. 1lle transfonner winding connected to the power source is called the primary winding or input winding, and the winding connected to the loads is called the secondnry winding or output winding. If there is a third winding on the transformer, it is called the tertiary winding [4].

In the prototype uses a current transformer with 5 ampere output, connected to the primary side voltage of 220 volt grid and the secondary side will produce an output of 6 volts, 9 volts and 12 volts in accordance with specifications owned.

III. RESEARCH METHODS

This research was conducted at the Laboratory of Basic Electrical Engineering Faculty of Engineering, University of Udayana start of the month January 2016 to June 2016. The study measures the flow can be seen in Figure 4.

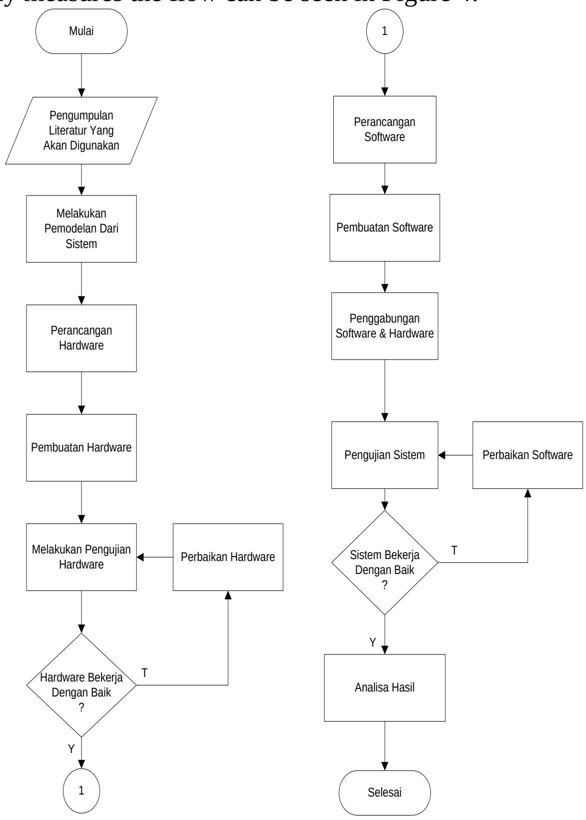

Figure 4: Procedure Research

Steps of design balancing the load current 3 phase system using a microcontroller ATMega 2560 is as follows.

1. Collecting literature used then perform modeling of the system.
2. From modeling followed by the design and manufacture of hardware with hardware testing and repair to work properly.
3. And then, the design and manufacture of such software program and the merger of hardware and software to test until the system is working properly.
4. When the entire system can work well done analysis to obtain results, finished.

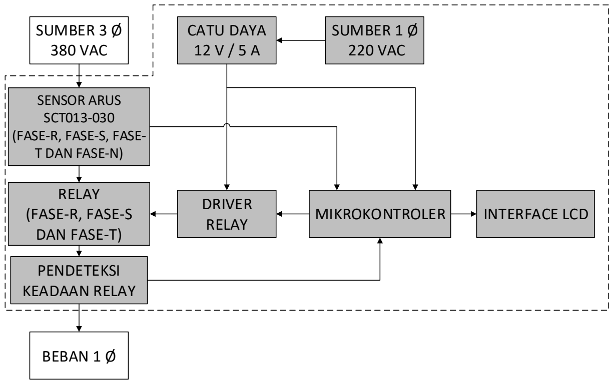

Figure 5: Block Diagram Circuit

Hardware design in manufacturing engineering balancing the load current 3 phase system using ATMEGA 2560 microcontroller according to Figure 5 is as follows:

1. The design of power supply circuit.
2. The design of driver relay circuit.
3. The design of current sensir circuit.
4. The design of LCD circuit.
5. The design of microcontroller circuit.

A. Software Design

When designing the necessary computer software installed software arduino IDE (Integrated Development Environment) to create a program listing as a command to be applied to the microcontroller ATMega 2560.

IV. RESULT AND DISCUSSION

Results and discussion for the current load balancer design on 3-phase systems using a microcontroller ATMega 2560 is as follows.

A. Realization of Design

Realization of the load balancer design on 3-phase systems using a microcontroller ATMega 2560 can be seen in Figure 6.

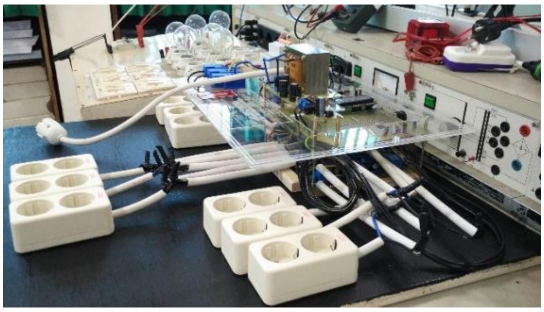

Figure 6: Realization Results Design

B. Testing the Power Supply Circuit

Testing the power supply circuit in the load balancer design in 3-phase systems using a microcontroller ATMega 2560 is needed to determine the magnitude of the output voltage produced and determine the magnitude of the voltage drop in case of load.

TABEL 1: TESTING VOLTAGE OUTPUT

No	Field Meassurement	Condition	Meassurement (volt)
1	IC LM 7809	Tanpa Beban	8,94
		Berbeban dengan Arus 186,1 mA	8,82
2	Diode Bridge	Tanpa Beban	14,45
		Berbeban dengan Arus 293,3 mA	13,17

From the results of testing of the power supply circuit obtain results as shown in Table 1 where there is a voltage drop resulting from the installation of the burden of microcontroller circuit and relay drivers. The amount of deviation of test results against the initial design can be seen in Table 2. The results of the output voltage irregularities in the power supply circuit is located between the working voltage of the circuit limit on the prototype so that the output voltage of the power supply circuit can be used.

TABEL 2: PERCENTAGE DEVIATION

No	Field Meassurement	Condition	Deviation
1	IC LM 7809	Tanpa Beban	0,67 %
		Berbeban dengan Arus 186,1 mA	2 %
2	Diode Bridge	Tanpa Beban	20,41 %
		Berbeban dengan Arus 293,3 mA	9,75 %

C. Testing Liquid Crystal Display Circuit

The test results for a series of LCD (Liquid Crystal Display) can be seen in Figure 7, where the LCD displays karate read 'arusR', 'arusS', 'Arust' and 'arusN'. LCDs use a specification writing dimensions 16 x 2 character.

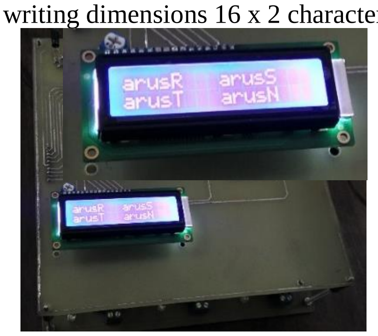

Figure 7: Testing of Liquid Crystal Display

D. Testing Driver Relay

Relay driver circuit testing is done by providing an active command for the relay is connected to phase R, S phase, T phase and each phase N 3 pieces. Microcontroller pin is enabled as output is connected to the relay driver. See test results on the relay active command can be seen in Figure 8.

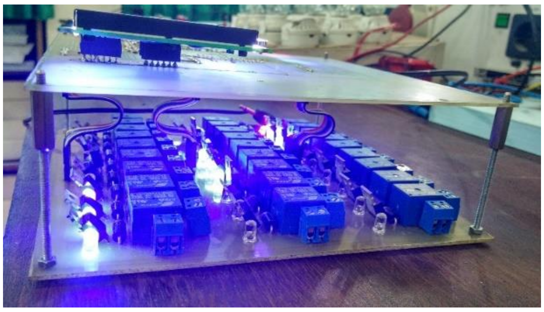

Figure 8: Testing Driver Relay Circuit

E. Testing Current Sensor

Tests carried out by the current sensor SCT013-030 draping the cables connected to the first load phase. as seen in Figure 9 where the RMS current measurement results yield a value of 0.55 amperes.

Figure 9: Testing Current Sensor Circuit

F. Testing Microcontroller

Microcontroller circuit testing is done by giving the command to display the characters that read 'Agus Putra Mardiana 1204405020' on the serial monitor. The test results can be seen in Figure 10 to see repeat orders continuously.

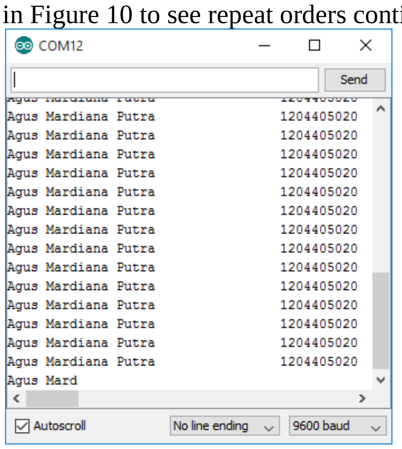

Figure 10: Testing Microcontroller

G. Testing all System

Testing of the entire system is done by six situations and conditions variety. Tests were first conditioned phase R has the biggest load current. Testing with this condition is done twice, first smallest load current is in phase S and the second smallest load current in phase T. In figure 11 a load current conditions on a 3 phase system with the smallest load current is in phase S.

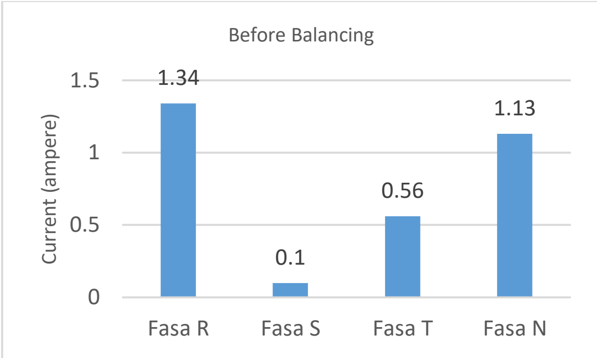

Figure 11: Graph Before Balancing Load Current from Phase R to Phase S

After the prototype to rebalance the load current for neutral current exceeds 1 ampere, the results can be seen in Figure 12 where the neutral current drops to 0.82 ampere.

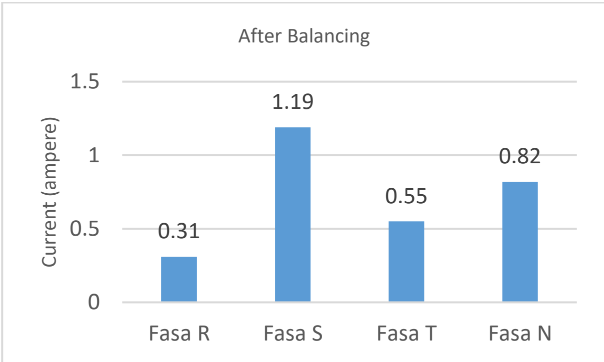

Figure 12: Graph After Balancing Load Current from Phase R to Phase S

In figure 13 a load current conditions on a 3 phase system with the smallest load current is in phase T.

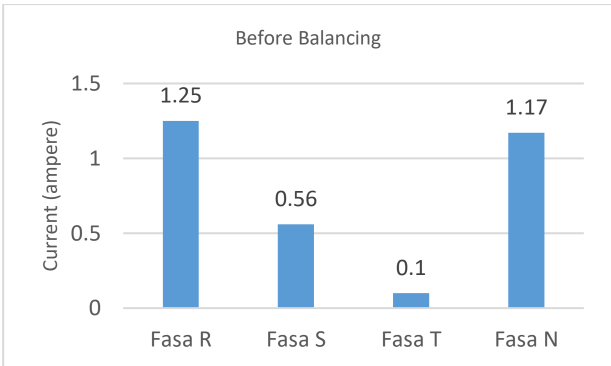

Figure 13: Graph Before Balancing Load Current from Phase R to Phase T

After the prototype to rebalance the load current for neutral current exceeds 1 ampere, the results can be seen in Figure 14 where the neutral current drops to 0.93 ampere.

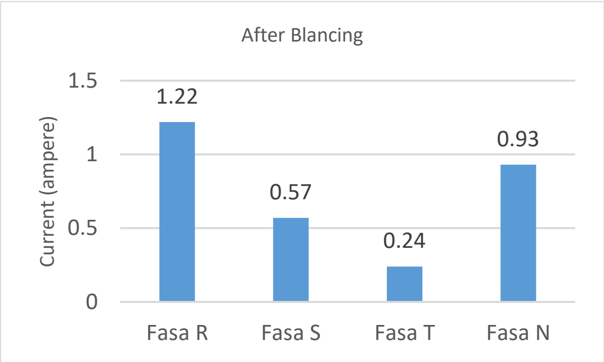

Figure 14: Graph After Balancing Load Current from Phase R to Phase T

The second testing phase condition S has the biggest load current. Testing with this condition is done twice, first smallest load current is in phase R and the second smallest load current in phase T. In figure 15 a load current conditions on a 3 phase system with the smallest load current is in phase R.

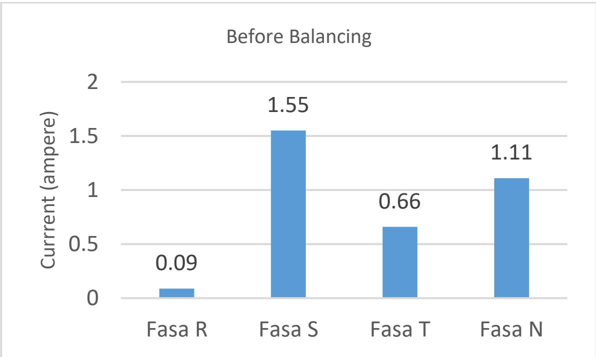

Figure 15: Graph Before Balancing Load Current from Phase S to Phase R

After the prototype to rebalance the load current for neutral current exceeds 1 ampere, the results can be seen in Figure 16 where the neutral current dropped to 0.84 ampere.

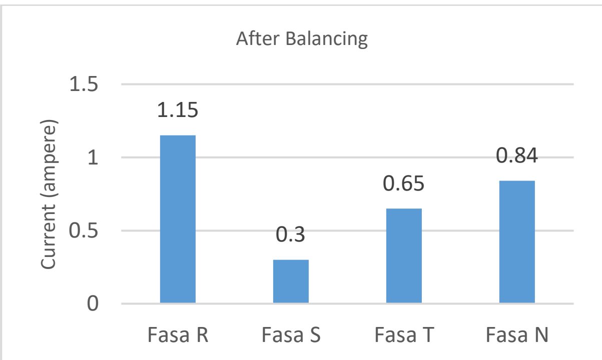

Figure 16: Graph After Balancing Load Current from Phase S to Phase R

In the figure 17 is a burden on the current condition of 3 phase system with the smallest load current is in phase T.

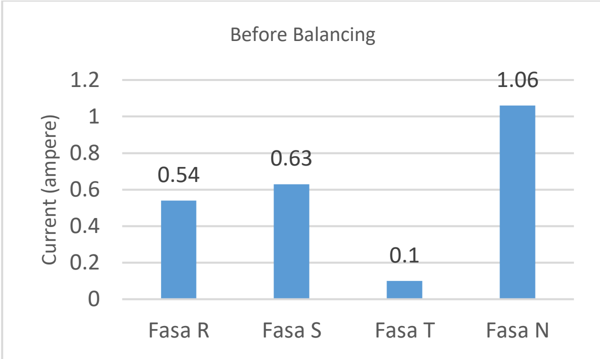

Figure 17: Graph Before Balancing Load Current from Phase S to Phase T

After the prototype to rebalance the load current for neutral current exceeds 1 ampere, the results can be seen in Figure 18 where the neutral current dropped to 0.64 ampere.

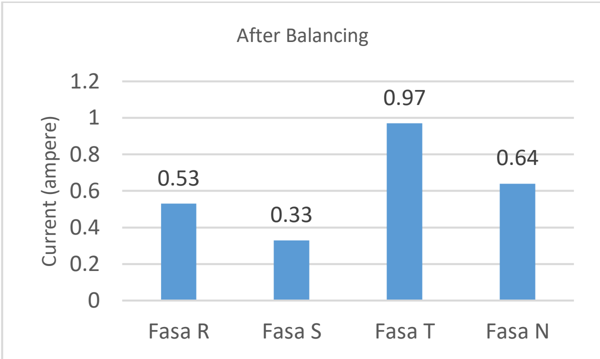

Figure 18: Graph After Balancing Load Current from Phase S to Phase T

The second condition testing phase T has the largest load current. Testing with this condition is done twice, first smallest load current is in phase R and the second smallest load current in phase S. In figure 19 a load current conditions on a 3 phase system with the smallest load current is in phase R.

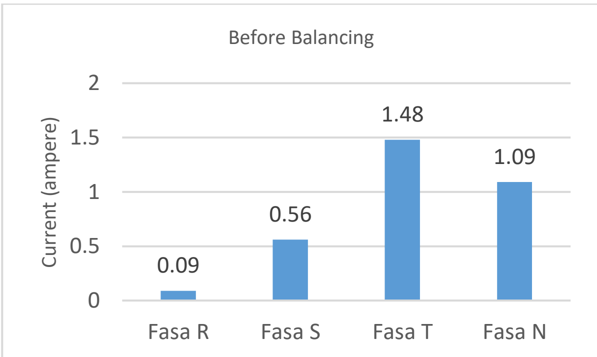

Figure 19: Graph Before Balancing Load Current from Phase T to Phase R

After the prototype to rebalance the load current for neutral current exceeds 1 ampere, the results can be seen in Figure 20 where the neutral current dropped to 0.83 ampere.

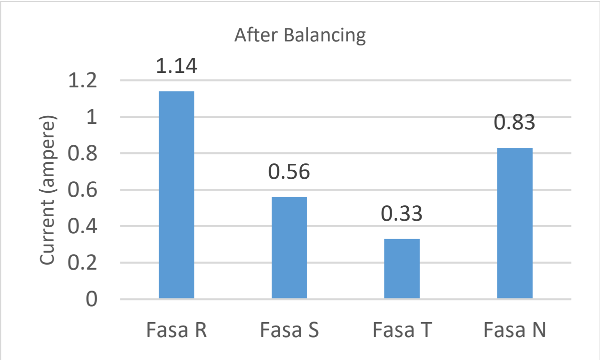

Figure 20: Graph After Balancing Load Current from Phase T to Phase R

In the figure 21 is a burden on the current condition of 3 phase system with the smallest load current is in phase S.

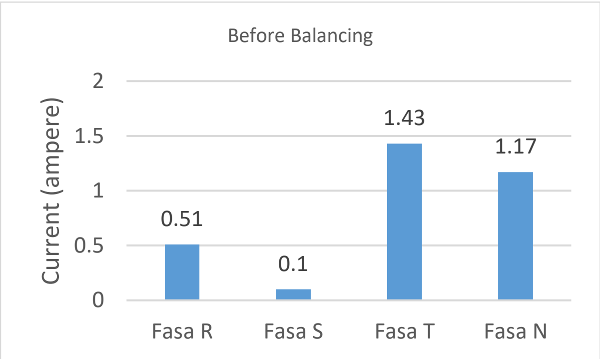

Figure 21: Graph Before Balancing Load Current from Phase T to Phase S

After the prototype to rebalance the load current for neutral current exceeds 1 ampere, the results can be seen in Figure 22 where the neutral current dropped to 0.85 ampere.

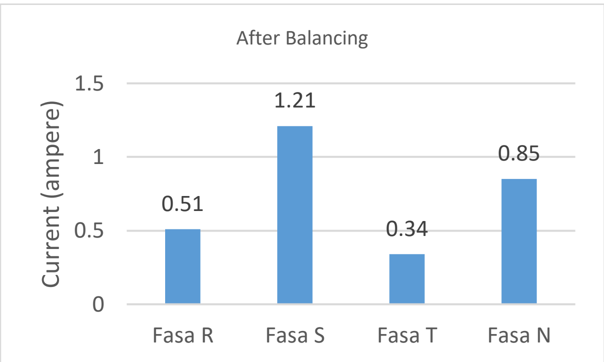

Figure 22: Graph After Balancing Load Current from Phase T to Phase S

Based on the results of testing the entire system at the current load balancing design in 3-phase system using the microcontroller ATMega 2560 with six conditions, the tool is able to rebalance the load so that the neutral current is reduced and the test was successful.

V. CONCLUSION

Based on the results of tests performed on the design of balancing the load on 3-phase systems using a microcontroller can be concluded in 2560 ATMega.

1) The design of balancing the load current at 3 phase system using ATMEGA 2560 microcontroller has been successfully carried out using current sensor SCT013-030 as input values and microcontroller ATMega 2560 as a data processor to generate a command output.

2) The test results show balancing the load current 3 phase system is done by detecting the amount of neutral current, neutral current time exceeds 1 ampere + 10%, the prototype will detect the phase that has the largest load current. The next prototype load detecting sequence numbers that are connected to that phase, the removal channels carried the burden of the phase which has the greatest value of the load current to the phase with the smallest load current value starting from the sequence number in which the smallest load channel numbering predetermined load.

3) Testing with the entire situation and the conditions used give results prototype capable of balancing the load current resulting in the value of neutral current is reduced so that the power loss due to imbalance in the load current 3 phase system to be reduced.

4) Balancing the load current by the prototype was able to reduce the handling time of load current situation of imbalance on 3-phase systems at distribution substations so that the power loss for PT PLN (Persero) is reduced by the length of time handling in the field.

REFERENCE

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