INTEK Jurnal Penelitian
Vol. 10, No. 1, pp. 78-83, April 2023

Portable Load Monitoring System of Substation Transformer Based on IoT Included GPS

Putu Agus Mahadi Putra [1,*,a] , Renny Rakhmawati [2,b], and Aura Aulia [3,c]
[123] Department of Electrical Engineering, Politeknik Elektronika Negeri Surabaya, Jl. Raya ITS, Surabaya, 60111, Indonesia
[*,a] Corresponding Author: mahadi@pens.ac.id

***Abstract* — Transformer is a very important thing for distributing electricity. One of the troubles that happen to transformer is overload which can shorten their life or worse case it can cause an explosion. Up until now, PLN Corporation still doesn't have mitigation alerts for overload. Load monitoring is still carried out manually, involving data input on the web, a process prone to errors caused by human intervention. Therefore, this research project was undertaken to enable web-based monitoring and real-time parameter visualization in the historical context. Additionally, the research was designed to be portable, allowing it to be easily relocated. This study employed a current sensor, voltage sensor, and GPS, all of which were processed by a microcontroller. The outcomes were displayed on an LCD and monitored on the web through the use of ESP8266. The primary goal of this research was to assist PLN in mitigating overload issues and reducing human errors, particularly in light of the high costs associated with substation transformers. The test results from the past revealed that this system could accurately measure voltage and current values, with an average sensitivity of 0.1803% and 1.15%, respectively. Furthermore, it incorporated GPS for location tracking during relocation and exhibited a high level of accuracy in the past.**

Keywords—component; Substation transformer, monitoring, portable, overload

I. Introduction

The substation is a very important subsystem to maintain the continuity of electricity distribution. One of the main pieces of equipment in a substation is a power transformer. Power transformers can experience various kinds of disturbances, one of which is overload or overload. Power transformers at substations should not be loaded more than 80% of their capacity[2, 5-8]. However, the load conditions in the field are constantly changing. At peak load, the transformer can experience an increase in the percentage of loading that exceeds a predetermined standard. The excess load that can be borne by the transformer is about 5-10% of its capacity[5,7-8]. On the other hand, overload can affect the transformer which can cause the transformer to become very hot. If done continuously, it will be able to shorten the working life of a transformer. This can be detrimental to PLN because there is wasted power due to the heat. Customers can also be harmed if the transformer explodes due to the overload because there will be a power outage and the affected area is quite large[1].

To prevent the occurrence of such overload disturbances, it is necessary to carry out daily inspections of the transformer by measuring the current and voltage on the transformer. From these two parameters, the transformer loading value can then be known. If an overload fault is found on the transformer, further action will be taken to regulate the load. This is considered less effective because it checks the measuring meter manually and then inputs data on the web monitoring manually as well. So the officers did the work twice[4]. On the other hand, these checks are also carried out simultaneously with other checks in the field so that errors are very prone to occur by humans, such as errors in writing data on the logsheet, reading errors on measuring instruments, and errors when entering data on the web manually[3].

This study involved the development of a monitoring system aimed at providing early warnings in case of transformer overload disturbances. Additionally, it

DOI : http://dx.doi.org/10.31963/intek.v10i1.3740

enabled the tracking of the transformer's location and offered the flexibility of being easily relocated to different sites as required. The device was intended to minimize human labor, allowing individuals to be reassigned to more essential tasks, while also serving as a preventive measure against human errors.

II. Research Methodology

A. System General Design

The design of this research can be seen in the system block diagram in Figure 1 and the IoT block diagram in Figure 2 as follows:

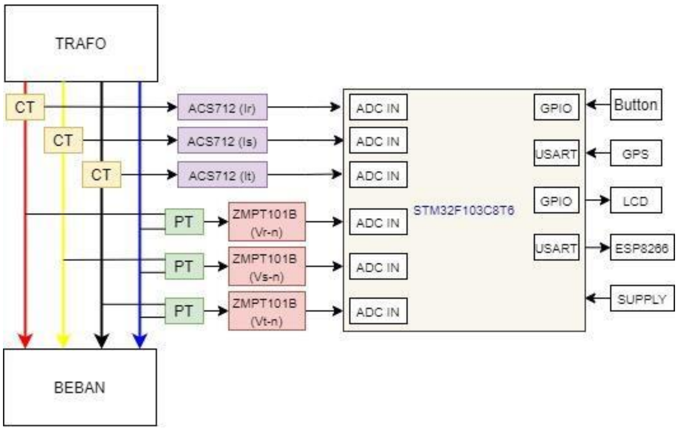

Figure 1. System Block Diagram

Figure 2. IoT Block Diagram

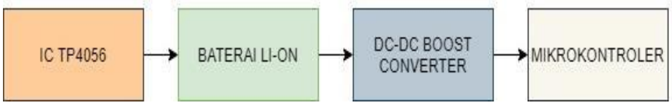

Figure 3. Block Supply System Diagram

In Figure 1 it is known that the Substation Transformer supplies the load and then the energy sent will be measured by CT and PT measuring device on the outgoing side of the Substation Transformer. From the secondary side, CT and PT were monitored using the ACS712 current sensor and the ZMPT101B voltage sensor where each sensor was connected to each phase. The data obtained by the current and voltage sensors were then processed by the microcontroller and displayed on the LCD and sent to web monitoring with the help of ESP8266. The location where the device works were detected by GPS which sent to web monitoring with the help of ESP8266[2].

Figure 2 is an IoT block diagram where after the system is processed by the microcontroller it was sent to the database and then displayed on the monitoring web in the form of a graph of the loading of the transformer capacity and a location map display.

Figure 3 is a block supply system diagram which was very important for this research because the system concept was a portable device.

B. Test Planning

This research is a prototype because the data collection cannot be done directly in the field. The use of this prototype used ratio so that the value represented the actual value in the field. The primary side voltage of the transformer in the field was 150kV and the secondary side was 20kV. Tests were conducted using a 220V power source on the primary side of the transformer, resulting in the ratio being determined based on the primary side of the transformer as follows.:

$$\frac{\text{Test } Vp}{\text{Real } Vp} = \frac{1}{x}$$

$$\frac{220\ V}{150\ kV} = \frac{1}{x}$$

$$x = 681$$

Information :

Test Vp = Workable primary side voltage (V)
Real Vp = Primary side voltage in real conditions (V)

By comparing the primary side voltage that was tested with the voltage on the actual primary side conditions, a ratio of 1/681 or 1:681 was determined. Consequently, for subsequent readings, 1 represents the test comparison while 681 represents the real field value, meaning that each measurement of 1 on the instrument corresponded to a value of 681 in the actual conditions.

With a predetermined ratio, it was determined the value of the secondary side voltage used to carry out the

DOI : http://dx.doi.org/10.31963/intek.v10i1.3740

test. The calculation of the secondary side voltage that can represent the value in the field as follows:

$$\frac{\text{Test } Vs}{\text{Real } Vs} = \frac{1}{x}$$

$$\frac{x}{20\ kV} = \frac{1}{681}$$

$$x = 29{,}36$$

Information :

Test Vs = workable secondary side voltage (V)
Real Vs = secondary side voltage in real condition (V)

With a ratio of 1:681, the secondary side voltage value used for testing was 29.36V. However, none of the transformers on the market have a secondary side with a value of 29.36V. Therefore, in testing this research device, a transformer that has the closest secondary side voltage value was used, which was 30V. So that the transformer used was 3 pieces 220/30V single-phase transformer which was connected in parallel to become a 3-phase transformer.

The selection of transformer capacity is adjusted to the load to be supplied, namely on the secondary side. With a real condition transformer of 150/20 kV 50MVA, it can receive a maximum load of 1443.37 A or 1.44 kA. So that the full load on the test transformer that can be used was as follows:

$$\frac{I_{full\ load}\ \text{test}}{I_{full\ load}\ \text{real}} = \frac{1}{681}$$

$$\frac{x}{144{,}37\ A} = \frac{1}{681}$$

$$x = 2{,}11\ A$$

Information :

$I_{\text{full load}}$ test= Maximum current that can be tested (A)
$I_{\text{full load}}$ real = Maximum current under real conditions (A)

With a ratio of 1:681, the maximum current that can be tested was 2.11A. However, in a 220/30 V transformer on the market, the maximum current is at least 3A. So, in testing this research device, a 220/30 V transformer was used which has a value of being able to supply a maximum current of 3A.

III. Results and Discussion

After performing partial testing on each component used in this study, the next step was to perform integration testing. This test combined all existing components to determine whether the device was working as planned or not. The following figure shows the hardware of the research that has been planned and made.

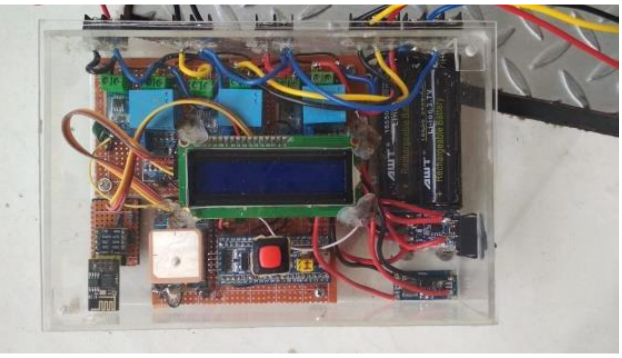

Figure 4. Top view of hardware

In this integration test, all components must be able to work according to their respective duties and work simultaneously in accordance with the purpose of making this research. The way this device works was that the current sensor and voltage sensor will read the current and voltage parameters then the data will be processed by the microcontroller with the transformer loading formula. Of the three phases, the current used to calculate the loading was the maximum current.

Calculations that have been processed and sent to the LCD and the database. From these calculations, it measured the condition of the transformer. This test was also carried out with a screen record of the PC screen using a zoom meeting so that the web monitoring display looks clearer.

This integration test used a 3-phase transformer composed of 3 single-phase 220V/30V step-down transformers with a capacity of 90VA. The data used in this research was data that scaled with 1:681, meaning that for each parameter that has a value of 1, the original

DOI : http://dx.doi.org/10.31963/intek.v10i1.3740

value in the field is 681. Some of the transformer conditions tested are as follows:

1. Normal Condition

Normal conditions were the conditions where the transformer loading was 60% to 80% where the transformer was loaded ideally.

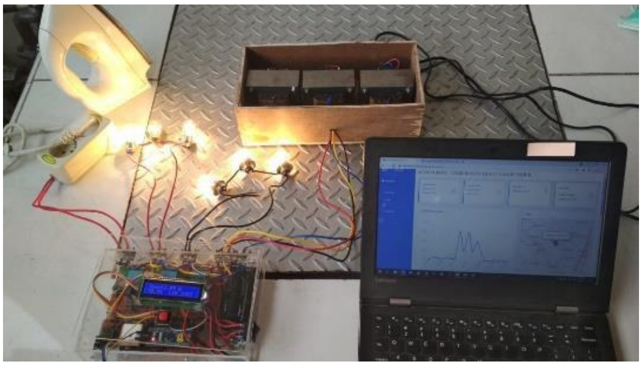

Figure 5. Loading under normal conditions

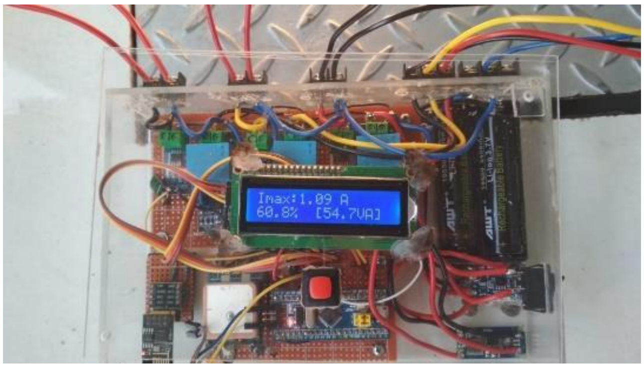

Figure 6. Display results under normal conditions

2. Underload Condition

Underload condition is a condition where the transformer loaded less than 60% and is not good for transformer work.

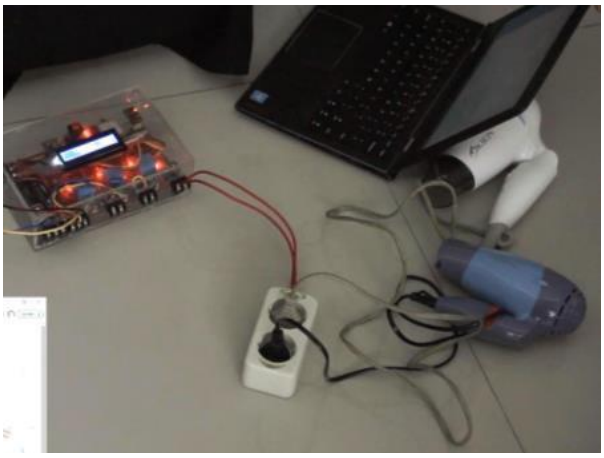

Figure 7. Loading underload conditions

Figure 8. Underload conditions display

3. Overload Condition

The overload condition is a condition where the transformer is loaded more than 80%. This condition is quite dangerous because it can reduce the working life of the transformer and the most fatal can cause the transformer to explode.

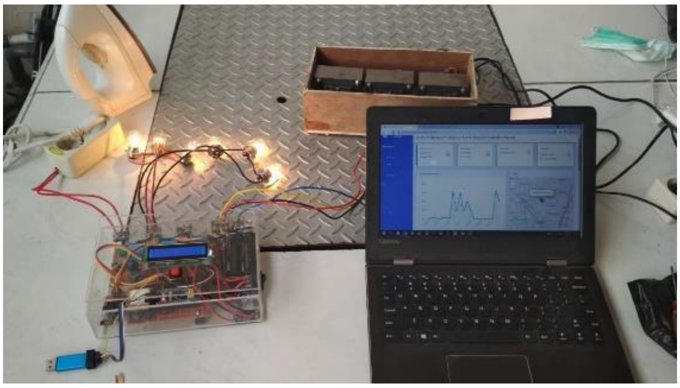

Figure 9. Loading of overload conditions

DOI : http://dx.doi.org/10.31963/intek.v10i1.3740

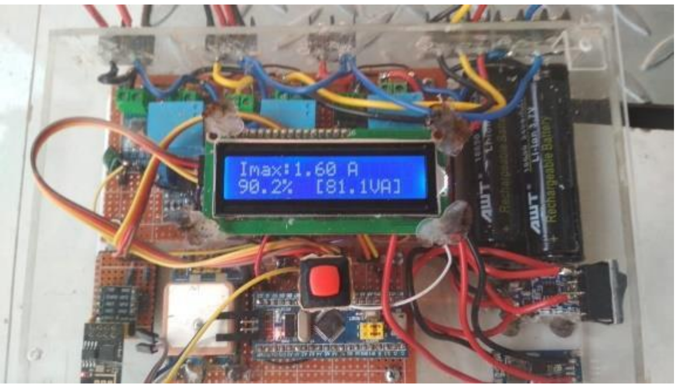

Figure 10. Overload condition display

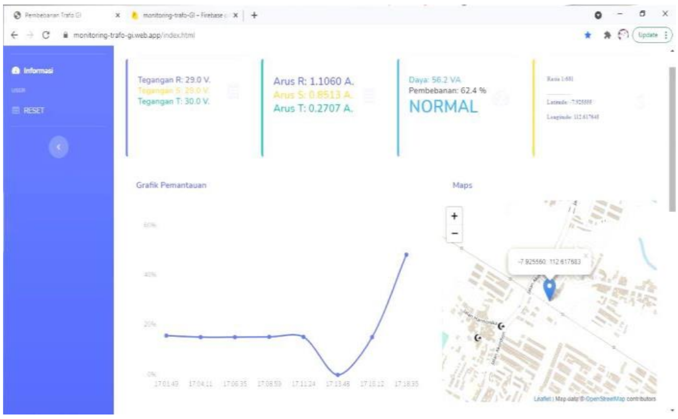

Figure 11. Display of normal condition monitoring web

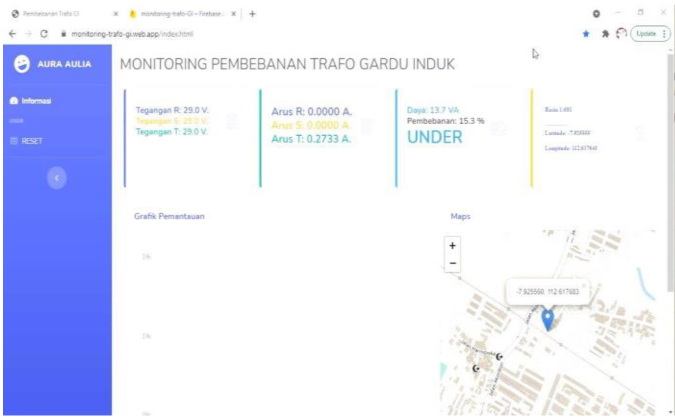

Figure 12. Display of underload condition monitoring web

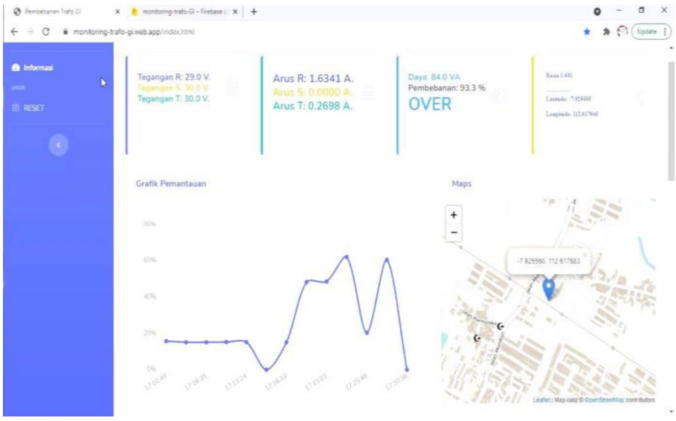

Figure 13. Display of Overload condition monitoring web

From partial testing and integration testing, it can be seen that the sensors work quite well where the error is less than 5%. The ESP8266 WiFi module sent data every 5 seconds. GPS can detect a fairly accurate location when operated in an open or semi-open space.

With the concept of a device that was a portable device that can be carried anywhere, the role of supply here was very important. This research used a rechargeable lithium battery as a supply. Charging the battery was assisted by IC TP4056 with USB type C. Energy from the battery can be consumed by components with the help of the step-up module DC-DC Boost Converter.

The data obtained from the results of this test was then compared with the original data or real data in the field. The real data used as a comparison here was the monitoring log sheet for the 150/20 kV 50MVA transformer at the Sukolilo Substation in March 2020 where the data is shown in table 1 as follows:

Table 1. Data on monitoring transformers 150/20 kV 50MVA Sukolilo Substation March 2020

Date	Im (A)	Vm (kV)		P (MW)	Q (MVAR)	S (MVA)
		Prim	Sek			
10	175		20,7	5,9	1,8	6.16
11	461		20,4	15,48	4,6	16.15
12	455		20,5	15,3	4,8	16.04
13	469,9		20,62	15,9	4,9	16.63
16	374,4		20.38	12,6	3,8	13.16
17	348,6		20,34	11,3	3,62	11.86
18	590,4		20,59	24,7	6,15	25.45
19	586,78		20,58	19,88	6	20.76
20	500		21,4	17,29	5	17.99
23	508		20,69	17,2	5,22	17.97
24	466,6		20,44	15,8	4,62	16.46

DOI : http://dx.doi.org/10.31963/intek.v10i1.3740

From Table 1. This data is from the 150/20 kV 50MVA transformer monitoring log sheet Sukolilo Substation in March 2020 with the apparent power value (S) calculated manually.

The results of data collection for each condition are presented in table 2. Within this table, you can find the reading values and those that have been assigned a ratio of 1:681. These values are specifically listed in the "Real Condition" column, representing the actual conditions in the field.

Table 2. Comparison table of device readings and the real conditions

Conditions	Device Readings				Real Conditions			
	Im (A)	V (V)	S (VA)	% Load	Im (A)	V (V)	S (VA)	% Load
Underload	1.05	29.0	53.0	58.9	715.05	19.75	22.130	44.26
Normal	1.09	29.0	54.7	60.8	742.29	19.75	25.392	60.78
Overload	1.60	29.0	81.1	90.2	1089.6	19.75	47.273	90.54

The equipment used in this research functions effectively as per the intended design, with all components operating in accordance with their designated roles. For optimal location detection, it is essential that the GPS antenna is not obstructed by dense materials like concrete.

IV. Conclusion

From the research, several conclusions can be drawn including the following: The ZMPT101B voltage sensor reading has an average error of 0.1803%. ACS712 current sensor readings have an average error of 1.15%. The microcontroller can process data in the form of voltage, current, power, and loading and display it on the LCD and web monitoring. The process of sending data to the database takes 5 seconds. GPS can display the location in the form of a digital map on the web monitoring within 2 to 5 minutes.

From the research, it cannot be separated from errors in both planning and manufacture. To improve these shortcomings and as input for a better future, the following suggestions are given: to make it easier for users to record and send data, it can be developed with an Android/IOS-based application. In the future, it will not only monitor but also control transformer protection. Can customize dynamic SSID and passwords that are changed by the user.

Acknowledgement

The authors would like to thank the Politeknik Elektronika Negeri Surabaya (PENS) for supporting this research.

References

[1] Adhuna, N.K., Perancangan Prototype Monitoring Parameter- Parameter Transformator Daya Secara Online, Jurnal, *Institut Teknologi Sepuluh Nopember*

[2] Awaliah, Sistem Monitoring Pembebanan Transformator Pada Gardu Distribusi Berbasis IoT Dilengkapi dengan GIS (Geographic information System), Tugas Akhir, *D3K PLN PENS 2017*

[3] Frisila, L., Irianto C.G., Perancangan Prototype Realtime Monitoring Beban Transformator Distribusi 20kV Berbasis Mikrokontroler, Jurnal, *Universitas Trisakti*

[4] Gunadhi, A., Pranjoto, H., Susilo, Y.S., Sistem Pelacakan dan Pengamanan Kendaraan Berbasis GPS dengan Menggunakan Komunikasi GPRS, Jurnal, Widya Teknik, 2014

[5] Karditama, Y.A., Sistem Monitoring Pembebanan Transformator Pada Gardu Distribusi Berbasis IoT, Tugas Akhir, *D3K PLN PENS 2016*

[6] PT. PLN (Persero), Buku Pedoman Trafo Arus, Jakarta, 2014.

[7] PT. PLN (Persero), Buku Pedoman Trafo Tegangan Final, Jakarta, Oktober 2014.

[8] PT. PLN (Persero), Buku Pedoman Trafo Tenaga Final, Jakarta, 2014.

DOI : http://dx.doi.org/10.31963/intek.v10i1.3740