



# Evaluation Study of 150 kV Current Transformer at Bayline 1 Kota Bangun Bukit Biru Substation

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**Abstract.** The electrical power system comprises a generator, transmission, and distribution components. The substation is part of the electrical transmission system and contains a variety of equipment, including a 150 kV current transformer, which function is to measure electric current and to support protection needs. To maintain the operational feasibility of the current transformer, inspections must be conducted. This research aim is to determine the condition of the current transformers that are operating properly, whether they are still suitable for use, or if replacement is necessary to maintain the reliability of the electric power system assessed using PT.PLN (Persero) standards SK-DIR No 0520-2.K/DIR/2014. For the research method, there are three levels of inspection: In-Service Inspection, In-Service Measurement, and Shutdown Measurement. The results from the visual inspection indicate that the current transformer is in good condition. During the second level, using the thermovision method, on clamp and conductor  $\Delta T$  finale, the highest temperature was 4.672°C, while the highest temperature for the interphase isolator and housing was 0.7 °C. In the third level of inspection, the results were as follows: the highest ratio error from the ratio testing was -0.066% on the first core; the lowest resistance from the insulation testing was 1.33 G $\Omega$  at the secondary 2-ground phase T measuring point; the grounding resistance testing showed a resistance of 0.02  $\Omega$ ; the highest  $\tan \delta$  value recorded was 0.2037%; and the burden testing indicated the highest burden of the current transformer was 19.25 VA. Based on 3 levels of inspection, and by the established PT.PLN (Persero) standards, SK-DIR No 0520-2.K/DIR/2014, the condition of the current transformer is deemed normal.

**Keywords:** Current Transformer, Inspection, Operational Feasibility

## 1 Introduction

Electricity is one of the essential needs for humans. It is crucial for supporting daily life and productivity. The electric power system consists of three main components: generation or power plants, transmission, and distribution. Current transformers are one of

the essential components in a substation. Current transformers are connected to measurement and protection equipment.

A Current Transformer (CT) is a device used to measure the current flowing in an electrical power installation on the primary side (high voltage of 150 kV and medium voltage of 20 kV). It transforms high current values into lower current values with high accuracy and precision, which is useful for protection and metering [1].

As equipment ages, there will be a decline in the quality of the electrical equipment itself. If a fault occurs in the current transformer, it will affect the reliability of the electric power system. By conducting a three-level inspection of current transformer equipment, the operational suitability of the current transformer can be assessed. The method used to determine the condition of the current transformer is by carrying out 3 levels of inspection which are divided into In-services Inspection that is a visual inspection of physical condition, In-services measurement, read of the temperature of the current transformer parts using thermovision method, and Shutdown Measurement, ratio testing, insulation testing, grounding resistance testing,  $\tan \delta$ , and burden testing.

Therefore, the aim of this research is to determine the condition of the current transformers that are operating properly, whether they are still suitable for use, or if replacement is necessary to maintain the reliability of the electric power system assessed using PT.PLN (Persero) standards SK-DIR No 0520-2.K/DIR/2014.

## 2 Methods

### 2.1 Research Procedures

The method used to determine the condition of the current transformer is by carrying out 3 levels of inspection which are divided into In-services Inspection that is a visual inspection of physical condition, In-services measurement, read of the temperature of the current transformer parts using thermovision method, and Shutdown Measurement, ratio testing, insulation testing, grounding resistance testing,  $\tan \delta$ , and burden testing. The analysis used to determine the condition of the current transformer is by comparing the inspection results with PT. PLN (Persero) Standard SK-DIR No 0520-2.K/DIR/2014. The research procedures is shown in Fig. 1.

**In-Service Inspection.** Level 1 inspection involves visually observing the current transformer equipment to identify anomalies that may potentially impair its function or damage part or all the current transformers. The parts that are inspected include grounding, the terminal box, bolt tightness, and foundations [1].

**In-Service Measurement.** Level 2 inspection is a maintenance activity conducted by measuring/testing the equipment while it is energized or operating. During in-service measurement, the temperature of the current transformer will be measured using thermovision methods [1].

Thermovision is an activity that measures to determine the temperature of a device based on temperature imaging results. The temperature values are observed from the

colors in the images captured by the thermal imager [1]. Thermal imager detecting infrared energy from the surface of an object and using this data to calculate and estimate the temperature [2].

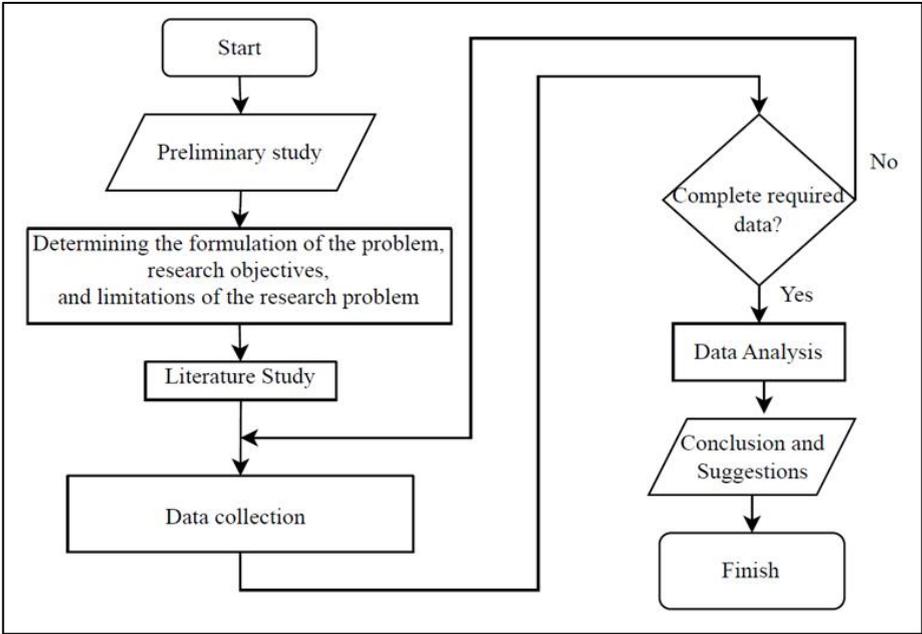


Fig. 1. Research Procedures

Thermovision measurements are divided into two parts:

- Conductors and clamp, aimed at determining the temperature differences between the conductors and the current transformer terminals. The data to be collected for thermovision measurement analysis includes the load current during measurement and the maximum load current (in amperes). The difference ( $\Delta T_{Finale}$ ) between the temperature of the conductors and the terminals will then be calculated using the formula.

$$\Delta T_{Finale} = \left(\frac{I_{max}}{I_{load}}\right)^2 \times \Delta T_{start} \tag{1}$$

Where  $I_{max}$  is the highest current value (Ampere),  $I_{load}$  is the current value during thermovision measurement (Ampere), and  $\Delta T_{Start}$  is the temperature difference between the conductor and the current transformer clamp (°C) [1].

The evaluation standards and thermovision recommendations for terminals and conductors can be found in Table 1.

**Table 1.** Recommendations and Evaluation of Thermovision for Terminals and Conductor [1]

No.	$\Delta T_{\text{Finale}}$	Recommendations
1.	<10°C	Normal, measurements will be conducted according to the schedule
2.	10°C-25°C	Measurements will be conducted in one month
3.	25°C-40°C	Repair is scheduled
4.	40°C-70°C	It will be repaired soon
5.	>70°C	Emergency condition

- The isolator and housing of the current transformer aim to detect any anomalies or hot spots in the current transformer. This thermographic inspection is conducted by measuring and comparing the temperatures obtained from the thermographic measurements of the R, S, and T phase CT. The evaluation standards and thermovision recommendations for isolator and housing is shown in the Table 2

**Table 2.** Recommendations and Evaluation of Thermovision for isolator and housing [1]

No.	$\Delta T$	Recommendations
1.	1°C-3°C	Abnormal condition, investigation is needed
2.	4°C-15°C	Indications of deficiencies have been detected, and scheduling for repairs is necessary
3.	>16°C	Major abnormal condition, troubleshooting is needed, or immediate replacement should be carried out.

**Shutdown Measurement.** Shutdown testing/measurement refers to activities conducted to measure or test equipment when it is not in operation. Tests performed while the transformer is offline including ratio testing, insulation resistance testing, ground resistance testing, (Tan  $\delta$ ) testing, and secondary burden testing of current transformers [1]. The tests conducted include:

- Ratio testing

The purpose of current transformer ratio testing is to determine the comparison between the test results and the manufacturer's specified ratio for the current transformer using CT-Analyzer. The current transformer tester, or CT Analyzer, is designed to perform automatic testing and calibration of low leakage currents in current transformers [3]. The standard for the ratio error of current transformers is based on the accuracy class of the metering or protection current transformers.

**Table 3.** Accuracy class of current transformers for metering purposes [1]

Class	The $\pm$ % ratio error of the current transformer is expressed as a percentage of the rated current.				The $\pm$ phase shift is expressed as a percentage of the rated current minute (1/60 degrees).			
	5	20	100	120	5	20	100	120
0.1	0.4	0.2	0.1	0.1	15	8	5	5
0.2	0.75	0.35	0.2	0.2	30	15	10	10
0.5	1.5	0.75	0.5	0.5	90	45	30	30
1	3.0	1.5	1.0	1.0	180	90	60	60

Class	The ± % ratio error of the current transformer is expressed as a percentage of the rated current.				The ± phase shift is expressed as a percentage of the rated current minute (1/60 degrees).			
	5	20	100	120	5	20	100	120
0.2S	0.75	0.35	0.2	0.2	30	15	10	10
0.5S	1.5	0.75	0.5	0.5	90	45	30	30

**Table 4.** Accuracy class of current transformers for protection purposes [1]

Class	Rated Current		Combined error at the accuracy limits of the primary rated current identifier. (%)
	Rasio Error (%)	Phase angle error (minute)	
5P	+1	+60	5
10P	+3	-	10
15P	+5	-	15

- Insulation testing

Insulation testing on current transformers measures the insulation resistance values between the prime to core, core, and core, or between the core and ground using an insulation tester. An insulation tester is a device used to determine the insulation resistance of an electrical installation [4]. The larger the insulation resistance, the smaller the leakage current. The standard of insulation is 1kV = 1MΩ [1].

- Grounding resistance testing

The grounding resistance testing of current transformers is conducted to ensure that the grounding conductors of the current transformers are properly installed, not loose, and free of damage [1], using an earth tester. Earth tester is used to measure and assess the resistance of equipment grounding. If the grounding resistance values are good, it can be ensured that the connection between the grounding conductor and the substation grounding system is also in good condition. The Grounding resistance standard is <1Ω.

- Tan δ testing

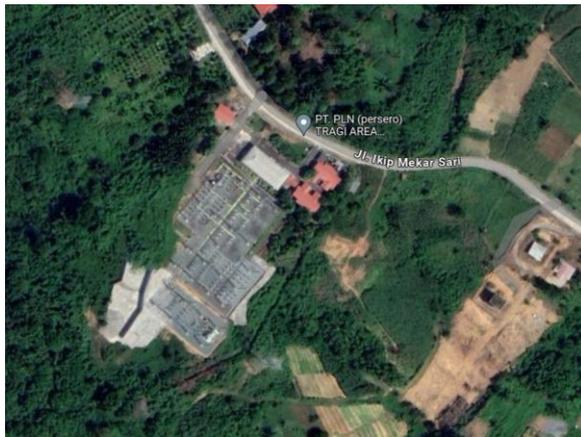
The tan δ test, or dissipation factor test/loss angle test, is conducted to determine the dissipation factor of the insulation material resistance in current transformers [1]. Generally, good insulation will behave as a perfect capacitive element; in this case, the current transformer will act as a pure capacitor. In a pure capacitor, the voltage and phase current are shifted by 90°, When there is contamination on the insulation, the insulation resistance decreases, leading to an increase in resistive current. The angle of shift between voltage and current will be less than 90°. This deviation from 90° can indicate the extent of contamination in the current transformer's insulation, also referred to as tan δ. CPC 100 and CP-TD 1 are used to tan δ test. CPC-100 is a versatile device designed for various primary tests for commissioning and maintaining substation equipment [5], CP TD 1 is used as an accessory for the primary test system CPC-100 [6]. The standard tan δ value is <1%.

- Burden testing

The secondary burden testing on current transformers aims to assess the magnitude of the secondary burden present on the secondary side of the current transformer, which will then be matched with the transformer's capability to handle that burden [7]. SMC-PTE-100-C, clamp amperemeter, and multimeter were used in the test. The standard of burden testing is by burden each current transformer core. SMC-PTE-100-C is a device designed to test protection relays based on measurements of current and/or single-phase voltage. It is compact in size, with accurate and reliable output power

## 2.2 Location

The Bukit Biru substation is located at Jalan Ikip Mekarsari RT. 24, Kelurahan Timbau, Kecamatan Tenggarong, Kabupaten Kutai Kartanegara, East Kalimantan, postal code 75511, with coordinates -0.45583300937165283, 116.97849166658438



**Fig. 2.** Bukit Biru Substations Location

Bayline 1 Kota Bangun- Bukit Biru is shown in Fig 3.



**Fig. 3.** Bayline 1 Kota Bangun-Bukit Biru

### 2.3 Research Tools

- The Required equipment for each testing is:
- Thermovision: Thermal Imager
- Ratio testing: CT Analyzer
- Insulation testing: Insulation Tester
- Grounding resistance testing: Earth Tester
- Tan  $\delta$  testing: CPC-100, and CP-TD1
- Burden testing: SMC-PTE-100C, Clamp Amperemeter, Multimeter

## 3 Results

Current Transformer nameplate is shown in Fig. 4.

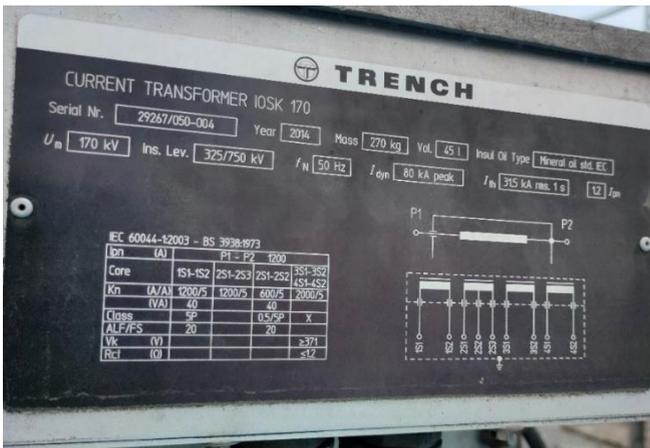


Fig. 4. Nameplate Current Transformer

The results of the three levels of inspection are as follows:

### 3.1 In-Service Inspection

The result of visual inspection is shown in Table 5.

Table 5. In-Service Inspection Result

No.	Inspection Parts	Condition		Condition
<b>Grounding</b>				
1	Grounding wire	Good	✓	Not Good
	Grounding terminals	Good	✓	Not Good
<b>Terminal Box</b>				
2	Cleanness	Dirty	Clean	✓

No.	Inspection Parts	Condition		
	Water Ingress	No	✓	Yes
<b>Body and Bushing</b>				
3	Cleanness	Dirty		Clean ✓
	Scratched and rusted body parts	Yes		No ✓
	Seek Glass	Dirty		Clean ✓
<b>Bolt Tightness</b>				
4	Main Terminal	Loose		Tight ✓
	Grounding	Losse		Tight ✓
	Secondary Wire Marking	Matching	✓	Not Match
<b>Foundation</b>				
5	Rift	Yes		No ✓
	Slope	Yes		No ✓

### 3.2 In-Service Measurement

The Inspection Result is shown in Table 6.

**Table 6.** In-Service Measurement Result

No	Inspection Parts	Condition Parts			
<b>1</b>	<b>R Phase</b>				
1.1	Temperature				
1.1.1	Conductor wire	CB Direc- tion	38.6 °C	DS Direc- tion	38.8 °C
1.1.2	Bushing clamp	CB Direc- tion	40.9 °C	DS Direc- tion	40 °C
1.1.3	Housing	41.5 °C			
1.1.4	Insulator	40.1 °C			
1.2	Load current				
1.2.1	Maximum load	30 A			
1.2.2	Load during measurement	21.6 A			
<b>2</b>	<b>S Phase</b>				
2.1	Temperature				
2.1.1	Conductor wire	CB Direc- tion	38.5 °C	DS Direc- tion	38.6 °C
2.1.2	Bushing clamp	CB Direc- tion	40.9 °C	DS Direc- tion	40.7 °C
2.1.3	Housing	41.8 °C			
2.1.4	Insulator	40.7 °C			
2.2	Load Current				
2.2.1	Maximum load	30 A			
2.2.2	Load during measurement	21.5 A			
<b>3</b>	<b>T Phase</b>				
3.1	Temperature				
3.1.1	Conductor wire	CB Direc- tion	38.4 °C	DS Direc- tion	38.5 °C

No	Inspection Parts	Condition Parts
3.1.2	Bushing clamp	CB Direction 40.8 °C DS Direction 40.1 °C
3.1.3	Housing	41.4 °C
3.1.4	Insulator	40.8 °C
3.2	Load Current	
3.2.1	Maximum load	30 A
3.2.2	Load during measurement	21.6 A

From the data obtained from in-service measurements, clamp and conductor wire, it is processed into secondary data that will be analyzed according to the following calculations, which uses the Phase R as an example:

$$\Delta T_{Final} = \left( \frac{I_{max}}{I_{load}} \right)^2 \times \Delta T_{Start} \tag{2}$$

$$\Delta T_{Final} = \left( \frac{30 A}{21.6 A} \right)^2 \times |40.9^{\circ}C - 38.6^{\circ}C|$$

$$\Delta T_{Final} = 1.3888^2 \times 2,3$$

$$\Delta T_{Final} = 1.9287 \times 2,3$$

$$\Delta T_{Final} = 4.4360^{\circ}C$$

From the calculation above, the same procedure was applied for calculating the other phases. As for the result of the thermovision clamp and conductor, it can be seen in the Table 7 as follow

**Table 7.** Thermovision Clamp and Conductor Finale Result

Phase	Direction	$\Delta T_{Final}$	Standard	Condition
R	Circuit Breaker	4.436°C	<10°C	Normal
	Disconnecting Switch	2.314°C	<10°C	Normal
S	Circuit Breaker	4.672°C	<10°C	Normal
	Disconnecting Switch	4.088°C	<10°C	Normal
T	Circuit Breaker	4.629°C	<10°C	Normal
	Disconnecting Switch	3.086°C	<10°C	Normal

By looking at the table of results above, it can be concluded that the condition of the current transformer is good condition.

From the data obtained from in-service measurements, insulator and housing, it is processed into secondary data that will be analyzed according to the following calculations, again using the Phase R as an example:

$$\Delta T_1 = |Insulator Temperature R - Insulator Temperature S| \tag{3}$$

$$\Delta T_1 = |40.1^{\circ}C - 40.7^{\circ}C|$$

$$\Delta T_1 = 0.6^{\circ}C$$

Basen on the calculation above, the same procedure was applied for calculating the other phases. As for the result of the thermovision insulator and housing, it can be seen in the Table 8 as follow

**Table 8.** Thermovision Insulator and Housing Final Result

Measuring Point	Stand-ard	R & S	Condi-tion	$\Delta T_1$		S & T	Condi-tion
				R & T	Condi-tion		
Insulator	<1°C	0.6°C	Normal	0.7°C	Normal	0.1°C	Normal
Housing	<1°C	0.3°C	Normal	0.1°C	Normal	0.4°C	Normal

By looking at the table of result, it can be concluded that the condition of the current transformer is good condition.

### 3.3 Shutdown Measurement

**Ratio Testing.** The result of rasio testing, the Table 9 as follow

**Table 9.** Ratio Testing Result

Phase	Ratio Error %			
	1s1-1s2	2s1-2s2	3s1-3s2	4s1-4s2
R	-0.058	-0.040	-0.048	-0.042
S	-0.062	-0.040	-0.050	-0.048
T	-0.066	-0.046	-0.042	-0.046
Class	5P	0.5/5P	X	X
Standard	±1%	±0.5%	±1%	±1%
Condition	Normal	Normal	Normal	Normal

By looking at the table of ratio testing results,it can be concluded that the condition of the current transformer is good condition.

**Insulation Testing.** The result of Insulation testing, the Table 10 as follow

**Table 10.** Insulation Testing Result

Measuring Point	Standard	Phase R	Condition	Phase S	Condition	Phase T	Condition
Primary-Ground	>150 MΩ	258 GΩ	Normal	266 GΩ	Normal	316 GΩ	Normal
Secondary 1-Ground		>2 GΩ	Normal	1,98 GΩ	Normal	1.86 GΩ	Normal

Measuring Point	Standard	Phase R	Condition	Phase S	Condition	Phase T	Condition
Secondary 1-Ground		>2 GΩ	Normal	1.64 GΩ	Normal	1.33 GΩ	Normal
Secondary 3-Ground		>2 GΩ	Normal	1.88 GΩ	Normal	1.83 GΩ	Normal
Secondary 4-Ground		>2 GΩ	Normal	1.73 GΩ	Normal	1.88 GΩ	Normal
Primary - Secondary 1		381 GΩ	Normal	330 GΩ	Normal	376 GΩ	Normal
Primary - Secondary 2		293 GΩ	Normal	318 GΩ	Normal	332 GΩ	Normal
Primary - Secondary 3		412 GΩ	Normal	384 GΩ	Normal	414 GΩ	Normal
Primary - Secondary 4		431 GΩ	Normal	407 GΩ	Normal	443 GΩ	Normal
Secondary 1- Secondary 2		>2 GΩ	Normal	>2 GΩ	Normal	>2 GΩ	Normal
Secondary 1- Secondary 3		>2 GΩ	Normal	>2 GΩ	Normal	>2 GΩ	Normal
Secondary 1- Secondary 4		>2 GΩ	Normal	>2 GΩ	Normal	>2 GΩ	Normal
Secondary 2- Secondary 3		>2 GΩ	Normal	>2 GΩ	Normal	>2 GΩ	Normal
Secondary 2- Secondary 4		>2 GΩ	Normal	>2 GΩ	Normal	>2 GΩ	Normal
Secondary 3- Secondary 4		>2 GΩ	Normal	>2 GΩ	Normal	>2 GΩ	Normal

By looking at the table of insulation testing results, it can be concluded that the condition of the current transformer is good condition.

**Grounding Resistance Testing.** The result of Grounding Resistance testing, the Table 11 as follow

**Table 11.** Grounding Testing Result

Current Transformer	Standard	Grounding Resistance (Ω)	Condition
Phase R		0.02	Normal
Phase S	<1 Ω	0.02	Normal
Phase T		0.02	Normal

By looking at the table of grounding resistance testing results, it can be concluded that the condition of the current transformer is good condition.

**Tan δ Testing.** The result of Tan δ testing, the Table 12 as follow

**Table 12.** Tan  $\delta$  Testing Result

Current Transformer	Standard	Tan $\delta$ (%)	Condition
Phase R		0.2037	Normal
Phase S	<1 %	0.1853	Normal
Phase T		0.1716	Normal

By looking at the table of Tan  $\delta$  testing results, it can be concluded that the condition of the current transformer is good condition.

## Burden Testing

**Table 13.** Burden Testing Result

Current Transformer	Standard	Burden (VA)							
		Core		Core		Core		Core	
		1s1-1s2	Condition	2s1-2s3	Condition	2s1-2s3	Condition	2s1-2s3	Condition
Phase R		16.4	Normal	18.75	Normal	18.65	Normal	14.1	Normal
Phase S	40 VA	16.35	Normal	19.25	Normal	19.05	Normal	13.55	Normal
Phase T		16.25	Normal	18.95	Normal	18.55	Normal	14.15	Normal

By looking at the table of burden testing results, it can be concluded that the condition of the current transformer is good condition.

## 4 Conclusions

According to In-service inspection, the physique current transformer parts (grounding, terminal box, body & bushing, bolt tightness) in good condition. According to In-service measurement, (thermovision clamp and conductor & Isolator and housing) current transformer in good condition. According to shutdown measurement, (ratio, insulation, grounding resistance, tan  $\delta$ , burden testing), current transformer in good condition.

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