Safe and Secure Shaft to Support Robotic Hand on Live Line Operation

Ni Putu Susri Aprilian Iriani, I Wayan Jondra and I Nengah Sunaya
Electrical Department, Politeknik Negeri Bali, Jalan Kampus Bukit Jimbaran, Kabupaten Badung, Indonesia

Keywords: Safe, Live Line, Secure.

Abstract: The biggest problem that can affect the stability and reliability of the power system is a disturbance. Disruption of the electric power system can be caused by two factors, namely internal (ex: Pin Insulator rupture) and external factors (ex: animals). In particular moments outages may occur and cause by animals such as birds, squirrels, and snakes. Reducing the outage requires periodic maintenance in order to overcome such interference by installing Tekep Isolator. When first introduced Tekep Isolator was very effective to overcome the momentary interruption / permanent caused by animals, but the job requires considerable time and shut off the electric power. To cope with blackout feeders for the installation of the Tekep Isolator, then made the tool post Tekep Isolator. The results of a comparative analysis of the installation work insulator caps with and without blackout obtained significant savings. So, this tool is very useful if it is implemented in PT PLN (Persero) Region Bali and other areas that use the same type of Tekep Isolator. The shaft's insulation value is more than 100 Giga Ohm, the leakage current is lower than 1 milliampere, the dielectric strength is more than 11.6 kV, and the worker distance to live parts is more than 60 cm to make the system a safe state.

1 INTRODUCTION

Electrical energy is one of the important factors in the development of every nation, including Indonesia. Electrical energy has an important role for development in both economic and social aspects. Currently in Indonesia the only distribution of electrical energy is PT PLN (Persero). In the distribution of electrical energy, it is expected that the maximum power is channeled, so that consumers and producers feel comfortable. The electrical energy distribution system must have high reliability which aims to maintain the quality and continuity of electrical energy distribution (Fatmawati, 2021).

Reliability is a key word as a guarantee of the continuity of electricity supply to customers. The reliability performance in question is determined by the low number of SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index) and ENS (Energy Not Sale) (Sumper et al., 2004). Based on SPLN 59 of 1985, the permitted SAIFI is 1,199 times/year and the permitted SAIDI is 1.75 hours/year.

The Tekep Isolator is the brand of many insulator cover, gives chance to PLN to overcome natural disturbances in the all aluminum alloy conductor shield (A3CS) network caused by trees, animals, weather and so on. Tekep Isolator is a safety component of the medium voltage air distribution line (SUTM) network. The insulator tack is a component that functions to protect the tensile insulator, prevent fouling of the supported insulator, as well as to tie the A3CS conductor to the supported insulator. Tekep Isolator for substations can overcome phase-to-ground faults (Fan et al., 2021). If a single phase to ground fault occurs, it will interfere with the other two healthy phases in a three phase system (Fan et al., 2021)

In the installation of the insulator using a robotic arm with on the live line work method it is chance to reduce the value of SAIDI and SAIFI on the performing distribution network maintenance and providing the best service for customers. This paper discusses the test result the shaft of the insulator clamp installation tool with robotic hands for live line work safety on A3CS cables in medium voltage distribution.

Iriani, N., Jondra, I. and Sunaya, I.
Safe and Secure Shaft to Support Robotic Hand on Live Line Operation.
DOI: 10.5220/0011880400003575
In *Proceedings of the 5th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2022)*, pages 781-786
ISBN: 978-989-758-619-4; ISSN: 2975-8246

2 RESEARCH METHODE

2.1 Research Approach and Concept

To analyze these problems, this study was designed as a research with a qualitative approach. These problems will be discussed from measurement and test data, equipment calculations to obtain good insulation for medium voltage work safety shaft, and all connected components. This research was piloted at PT. Adi Putra, and the test results were analyzed statistically and mathematically to obtain the feasibility of a 20kV shaft tool for electrical safety, compare the role of electrical work safety, and then draw conclusions and recommendations.

2.2 Total Sample

This research was conducted by tested one sample on a shaft, tasted 6 data for each indicator. Data collection was carried out by testing the wet and dry conditions and measuring the value of the voltage and leakage current flowing into the water rheostat

2.3 Variable Operational Definition

In testing the feasibility of this robot hand tool, leakage current, insulation test, dielectric strength and clearance were also observed. This test is carried out by applying a voltage of 5,000 Volts and 10,000 Volts to the head and handle terminals. The test voltage is the amount of voltage applied to the sample through a high voltage tester. Leakage current is the amount of current flowing into the test sample, due to the given test voltage. Dielectric distance and clearance are measured with a ruler meter.

2.4 Data Analysis

Data obtained from the test results are processed quantitatively. The data is processed mathematically by the process of multiplication and division. The data is also processed statistically by finding the smallest value of all data if the limits are minimum such as insulation resistance, dielectric strength, space clearance, and finding the largest value of all data if the maximum limit is such as in leakage. current condition.

3 RESULT AND DISCUSSION

The results of this study are illustrated by pictures and tables. The analysis of the feasibility of the shaft as a robot hand operation tool was carried out to ensure work safety. Robotic hand tools must have good insulating resistance and insulated shafts to ensure work safety in construction, maintenance, repair and upgrading of medium-voltage distribution. However, no material is perfect, therefore research on this feasibility test is very important. This 20kV shaft is made of polypropylene pipe, which has good electrical characteristics because its volume resistivity coefficient is 8.5×10^{14} Ohm-cm.

Figure 1: 20kV Shaft as robot hand operation tools.

The perfect insulating material has an infinite resistance, which is currently not obtainable. There is a small leakage current flowing in the insulating material and it can be shown as below equation (Amin & Amin, 2011).

$$V = I \times R \quad (1)$$

$$R = V / I \quad (2)$$

where:
R = Insulating Resistance (Giga Ohm)
V = Voltage charge due the sample (Kilo Volt)
I = Leakage Current (microampere)

The normal air dielectric strength coefficient is 30 kV/cm, the total dielectric strength is total distance multiple with dielectric strength coefficient, as shown in the formula below (Kharal et al., 2018).

$$\mathcal{E} = \mathcal{E}_0 \times d \quad (3)$$

where:
$\mathcal{E}$ = Dielectric strength (KV)
$\mathcal{E}_0$ = Dielectric strength coefficient (KV/cm)
d = distance (cm)

3.1 Result

The minimum insulation for medium voltage is 100 Mega Ohms (Post et al., 2020). The maximum leakage current flow does not affect a shock to the human body is 1 milli amperes (Saba et al., 2014). Total the dielectric strength must exceed than the active voltage to avoid the electric discharge (Saba et al., 2014). The minimum safe distance between workers and 15,000 Volt active equipment is 90 cm (Ghosh et al., 2015). This Insulation Resistance Test is carried out to detect the quality of the 20kV shaft insulation resistance. This test is carried out by applying a voltage of 5,000 Volts and 10,000 Volts to the head and handle terminals. The insulation resistance test was carried out in dry and wet conditions ten times, the wet condition test as shown in figure 3.

Figure 2: Dry insulation resistance test with Megger 10,000 Volt.

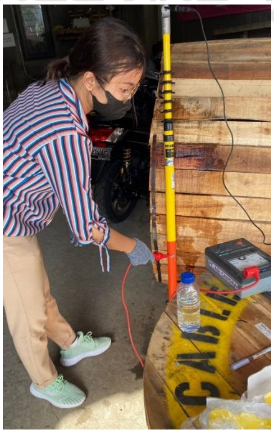

Figure 3: Wet insulation resistance test with Megger 10,000 Volt.

Tests were carried out using 5000 Volt and 10,000 Volt meggers. The results of the insulation resistance test using a megger are analyzed to get the leakage current, as calculated below.

1. Analysis of leakage current at voltage of 5000 Volt

   Voltage tested: 5.000 Volt DC
   Insulation resistance: 250.000 Mega Ohm
   The leakage current calculation:
   I = V/R
   = 5,000/250,000,000,000
   = 0,02x10-6 amperes
   = 0,02 micro amperes

2. Analysis of leakage current at voltage of 10.000 Volt

   Voltage tested: 10.000 Volt DC
   Insulation resistance: 500.000 Mega Ohm
   The leakage current calculation:
   I = V/R
   = 10000/500,000,000,000
   = 0,02x10-6 amperes
   = 0,02 micro amperes

   Through the same calculation, the leakage current as displayed in table 1 at below.

Table 1: Analysis of leakage current of 20kV shaft with megger 10kV.

Step of testing and condition	R Iso. at 5 KV (Giga Ohm)	R Iso. at 10 KV (Giga Ohm)	Leakage current at 5 KV (mA)	Leakage current at 10 KV (mA)
1 dry	250	500	0.0200	0.0200
2 dry	275	550	0.0182	0.0182
3 dry	290	580	0.0172	0.0172
4 dry	300	600	0.0167	0.0167
5 dry	310	620	0.0161	0.0161
6 dry	330	660	0.0151	0.0151
7 dry	370	740	0.0135	0.0135
8 dry	390	780	0.0128	0.0128
9 dry	430	820	0.0116	0.0116
10 dry	440	880	0.0113	0.0113
1 wet	62	124	0.0807	0.0807
2 wet	75	150	0.0667	0.0667
3 wet	80	160	0.0625	0.0625
4 wet	82	164	0.0609	0.0609
5 wet	67	134	0.0746	0.0746
6 wet	73	146	0.0684	0.0684
7 wet	78	156	0.0641	0.0641
8 wet	80	160	0.0625	0.0625
9 wet	65	130	0.0769	0.0769
10 wet	78	156	0.0641	0.0641
Maximum leakage current			0.0807	0.0807
Lower insulation	62	124		

Based on the data in table 1, the variation of the data can be illustrated by the graph in figure 4 below. Variations in insulation resistance are affected by the weather at the time of operation.

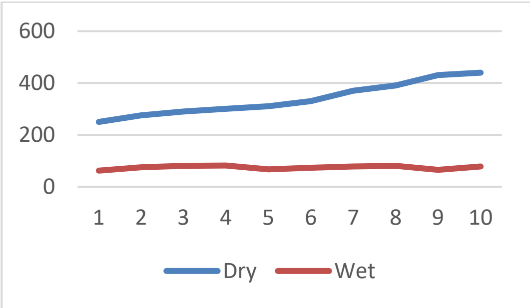

Figure 4: Graph of insulation resistance 5000 volt wet and dry conditions.

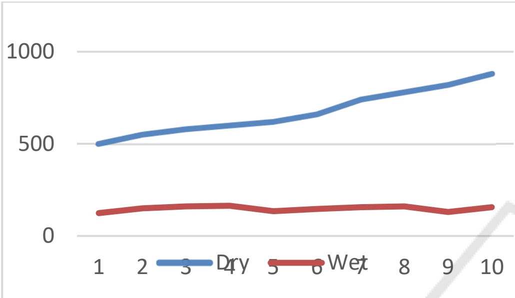

Figure 5: Graph of insulation resistance 10000 volt wet and dry conditions.

The insulation resistance value of the 20kV shaft in dry conditions by applying a test voltage of 5000 Volts and 10,000 Volts, one of which is 250 Giga Ohms and 500 Giga Ohms. The value of the insulation resistance of the 20kV shaft in wet conditions by applying a test voltage of 5000 Volts and 10,000 Volts, one of which is 62 Giga and 124 Giga. This insulation resistance value is obtained from an average of 10 times the leakage current of the 20kV shaft test. The minimum insulation resistance of the shaft is more than 100 Mega Ohms. The minimum insulation benchmark for medium voltage is 100 Mega Ohm (Post et al., 2020).

The value of the 20kV shaft leakage current in dry conditions by applying a test voltage of 5000 Volts and 10,000 Volts of 0.0200 microampere. The value of the 20kV shaft leakage current in wet conditions by applying a test voltage of 5000 Volts and 10,000 Volts of 0.0200 micro amperes. So it can be said that the leakage current is lower than 1 milli Ampere (Saba et al., 2014). The standard maximum leakage current that has no effect on shock to the human body is 1 milli ampere.

To determine a safe electrical working distance, there are two conditions that must be discussed for a 20kV shaft, namely dielectric strength, total distance and distance between potential live voltage equipment and workers when operating a robotic hand that attaches insulators to medium voltage equipment.

The rain angle is estimated to be a maximum of 30 degrees. Wet conditions decrease the dielectric strength. There are 6 rubber rings like an umbrella to protect the shaft from getting wet. Part of the dry shaft is protected by a rubber ring to maintain dielectric strength. Thus, the dielectric strength distance of the insulator fixing robot hand tool in the tension insulator clamp can be calculated as described below.

Figure 6: Rubber rings on 20kV shaft as safety.

If the shaded triangle in figure 6 is copied and pasted, it will be obtained as shown in figure 7 below.

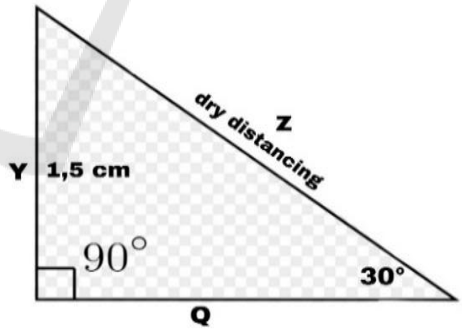

Figure 7: Angle distance.

Dry distancing calculation
Sin Q = Y/Z
Dry Distancing = 1,5/sin 30
= 1,5/0,5 = 3 cm
Total Dry Distancing = 6 x 3 cm = 18 cm

The normal air dielectric strength is 30 kV/cm (Saba et al., 2014). The total dielectric strength of grounding shaft with 6 pieces rubber ring is:

$\mathcal{E} = \mathcal{E}_0$ xd
$\mathcal{E}$ = 30 x 18 = 540 KV

The minimum creepage distance on the 20 kv shaft is 81%, it can be seen through the following calculation. Total length of shaft= Length of shaft + total dry distancing

= 300cm + 18cm

= 318cm

Minimum creepage distance of shaft =

Total shaft length - worker grip distance

= 318-60

= 258

Minimum creepage distance= 258/318 x100% = 81%

The total dielectric strength of the 20kV shaft as a robot hand operation aid with mathematical calculations is 540 kV. As shown in Figure 4 a 20kV shaft has a length of 3 meters. Thus the 20kV shaft is qualified to maintain the distance between the worker and the active part of the 15 kV phase to the ground with a minimum distance of 60 cm (Ghosh et al., 2015). The medium voltage distribution system in Indonesia is only 11.6 KV lower from phase to ground.

3.2 Discussion

Based on table 1, it can be seen that the maximum leakage current value is not more than 1 Ampere and the minimum insulation resistance of the grounding shaft is not less than 100 Mega Ohms (Jondra et al., 2020). The higher the voltage applied to the insulator, the leakage current value is increased (Negara et al., 2021). The standard maximum leakage current that has no effect on shock to the human body is 1 milli ampere. Based on the results of the safety distance analysis, two values were obtained for assessing the feasibility of a 20 kV shaft, namely: the value of dielectric strength and the distance between workers and active parts with potential for voltage release.

The analysis found that the 20kV shaft has a dielectric strength of 540 kV, and provides a safe distance between workers and live parts of 300 cm. The total dielectric strength benchmark must exceed the active voltage to avoid electric discharge (Saba et al., 2014). The benchmark for the minimum safe distance between workers and 15 kV active equipment is a minimum of 60 cm (Ghosh et al., 2015).

4 CONCLUSIONS

The requirements that must be met by the Robot Hand Installing Insulators in Medium Voltage Air Line Pull Insulators (SUTM) are that they can be remotely controlled and are able to close all insulator clamps perfectly, have a high level of security such as not delivering electric current to the linesman or work executors on during operation, the weight of the robot hand is according to the plan, which is appropriate and can be easily lifted up and the 20kV shaft tool on the robot hand is safe for medium voltage distribution systems with A3CS cables. This feasibility is determined based on good connection ability, leakage current, insulation resistance, dielectric strength, and safety distance. The results show that the shaft exceeds the specified requirements. The insulation value is more than 100 Giga Ohm, the leakage current is lower than 1 milliampere, the dielectric strength is more than 11.6 kV, and the worker distance to live parts is more than 60 cm to make the system in a safe state.

ACKNOWLEDGEMENTS

This research was funded by Lembaga Pengelola Dana Pendidikan and Direktorat Jenderal Pendidikan Vokasi Kementrian Pendidikan, Kebudayaan, Riset dan Teknologi 2021. We thank Director of Politeknik Negeri Bali for his support to this research and we thank *Project Management Office* of Domestic Vocational Higher Education Program Implementation of the Applied Scientific Research in 2021 for his support to this research.

REFERENCES

Amin, S., & Amin, M. (2011). Thermoplastic elastomeric (TPE) materials and their use in outdoor electrical insulation. *Reviews on Advanced Materials Science*, *29*(1), 15–30.

Fan, B., Yao, G., Wang, W., Yang, X., Ma, H., Yu, K., Zhuo, C., & Zeng, X. (2021). Faulty phase recognition method based on phase-to-ground voltages variation for neutral ungrounded distribution networks. *Electric Power Systems Research*, *190*(February 2020), 106848. https://doi.org/10.1016/j.epsr.2020.106848

Fatmawati, A. (2021). *Analysis of Eastern Indonesia's Electricity Demand 2014-2019*. *10*(5), 192–198.

Ghosh, M. C., Basak, R., Ghosh, A., Balow, W., & Dey, A. (2015). An Article on Electrical Safety. *IJSRD-International Journal for Scientific Research & Development*|, *3*(10), 2321–0613.

Jondra, I. W., Widharma, I. G. S., & Sunaya, I. N. (2020). Insulation resistance and breakdown voltage analysis for insulator cover type YSL-70AP. *Journal of Physics: Conference Series*, *1450*(1), 0–5. https://doi.org/10.1088/1742-6596/1450/1/012040

Kharal, K. H., Kim, C. H., Park, C., Lee, J. H., Park, C. G., Lee, S. H., & Rhee, S. B. (2018). A study for the measurement of the minimum clearance distance between the 500 kV DC transmission line and vegetation. *Energies*, *11*(10), 1–10. https://doi.org/10.3390/en11102606

Negara, I. M. Y., Asfani, D. A., & Fahmi, D. (2021). The Electrical Characteristics of Medium Voltage Insulators Against Contaminants at Coastal Area. *International Journal of Integrated Engineering*, *13*(6), 265–273. https://doi.org/10.30880/ijie.2021.13.06.023

Post, A. P., Break, V., & Test, D. (2020). *PERFORMANCE INSULATOR COVER TYPE: YSL-70-*. *20*(2), 95–98.

Sumper, A., Sudrià, A., & Ferrer, F. (2004). International reliability analysis in distribution networks. *Renewable Energy and Power Quality Journal*, *1*(2), 414–418. https://doi.org/10.24084/repqj02.299

T. M, S., J., T., E, R., & M. J., A. (2014). The Level of Awareness on Electrical Hazards and Safety Measures among Residential Electricity User's in Minna Metropolis of Niger State, Nigeria. *IOSR Journal of Electrical and Electronics Engineering*, *9*(5), 01–06. https://doi.org/10.9790/1676-09510106

Saba, N., Md Tahir, P., & Jawaid, M. (2014). A review on potentiality of nano filler/natural fiber filled polymer hybrid composites. *Polymers*, *6*(8), 2247-2273.