Redesign Gas Insulated Switchgear to Semi Air Insulated Switchgear 500 kV side and 150 kV side in EHVS Kembangan

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Abstract. The main role of 500 kV extra high voltage Gas Insulated Substation in transmission system is serves connection between the electrical generation and transmission system. To improve equipment performance and the quality and reliability of electricity distribution need time to maintain gas insulated line compartment but preparation to maintenance requires a long time, limited maintenance duration and long implementation of gas evacuation. This paper is object to redesign Gas Insulated Switchgear (GIS) to Semi Air Insulated Switchgear (AIS) on 500 kV side and 150 kV side with new design of Gas Insulated Line compartment in order to accelerate maintenance and gas evacuation job. with surveys, observations, analyses and Root Cause Problem Solving (RCPS), it can be seen the initiation of improvement to accelerate the maintenance of IBT and accelerate the repair of anomalies in the gas insulated line. After redesign Gas Insulated Switchgear to Semi Air Insulated Switchgear, this results show maintenance IBT after redesign is 25 hours faster and duration anomaly on GIL after redesign 24 hours faster.

1. Introduction
Along with the development and advancement of technology, the growth of industrial technology is closely related to electricity which is one of the important factors that strongly supports the development of construction, especially in the industrial sector, in modern life electricity is an absolute element to improve the welfare of society, therefore electrical energy is a benchmark community progress.

As one of the national vital objects, Extra High Voltage Substation (EHVS) Kembangan is a substation that has an important role in the distribution of electricity, especially the 500 kV system in the West of Java region. To improve equipment performance, quality and reliability of electricity distribution, one of them is by maintaining IBT 500 MVA. However, when performing maintenance and assessment of IBT is not optimal due to the limited duration of maintenance, the implementation of the long SF6 gas evacuation and testing on IBT cannot be carried out comprehensively because the GIL compartment on the 500 kV side and the 150 kV side use closed type so that only a part of the test can be done. The Gas-insulated Line (GIL) is a transmission system for the transmission of electricity at a high voltage level, with SF6 or SF6-N2 gas mixture as the insulating medium and the conductor kept in the centre of the metallic enclosure [1], Particularly due to its high reliability, insulation-aging resistance, and little environmental impact, the GIL suitably serves as the connections between power plants and substations, and deals with complicated landscapes [2,3].
to improve equipment performance and accelerate recovery during disruptions, it is necessary to redesign GIS (gas insulated switchgear) to semi AIS (air insulated switchgear) 500 kV side and 150 kV side in EHVS Kembangan.

2. Methods
This method will explain the research steps that will be carried out to speed up the maintenance process and accelerate anomaly repair of Gas Insulated Line (GIL) at EHVS Kembangan.

2.1. Survey
Site survey was conducted to find out the measurement of the distance between the Blast Wall, the height measurement of the 500 kV GISTET Building, the distance between the 500 kV Building and the 150 kV Building, the plan to place the gantry column, 150 kV cable placement plan and the work implementation method plan, site survey is the initial stage make it easier to plan basic designs from Gas Insulated Switchgear to Semi Air Insulated Switchgear.

2.2. Observation and analysis
Observation and analysis were carried out on the existing design on the 500 kV side of the Gas Insulated Line (GIL) compartment using only 1 gas section (closed type), with the existing design when conducting IBT maintenance the first to do is test SF6 gas in the 500 kV compartment, This test is carried out for 4 hours (12 points, where the test time 1 point = 20 minutes), after testing the SF6 gas it can be seen which SF6 gas conditions are still good and needs to be filter or SF6 gas that can no longer be used (gas SF6 which can no longer be used must be separated with a good tube packaging). After that, the SF6 gas evacuation from Disconnecting Switch (DS) bus compartment to the end of the 500 kV GIL compartment and LA compartments up to 0 (zero) bar, SF6 gas evacuation is carried out for 8 hours, after that remove the Man hole Bushing cover and the connection bar connection to IBT is carried out during 5 hours, then IBT testing for 8 hours, after testing the link bar reassembling for 5 hours, then refilling and vacuum gas SF6 for 12 hour, with the existing design, the duration of IBT maintenance takes 42 hours. It same with existing design if an anomaly of SF6 gas leak in the 500 kV GIL compartment, if you want to repair the leak, you must first evacuate the gas in the GIL compartment then repair it, after finishing repairing, then re-filling the compartment until it becomes normal pressure, repair work for anomaly gas leakage SF6 carried out for 36 hours.

2.3. Root Cause Problem Solving (RCPS)
To find the cause of IBT maintenance is not optimal, a method is needed to find the root problems that happen and to resolved these problem by using the RCPS (Root Cause Problem Solving) method as an analytical method to find the root problems that happen by breaking down the problem into simple components in a structured and systematic way. Schematic diagram of the root cause problem solving as shown Figure 1. below.
From the Root Cause Problem Solving (RCPS) above, causes of IBT maintenance is not optimal because:

- IBT assessment is not optimal due to the limited duration of maintenance and the long implementation of gas evacuation, testing on IBT cannot all be done because the GIL compartment uses closed type, only partial testing can be done.
- The difficulty in finding a replacement for IBT because the type and design must be in accordance with the existing IBT, so it must be measured in more detail from the height of the IBT and the position of the IBT bushing for connections from IBT to Gas Insulated Line (GIL).
- IBT loading not fulfil N-1, because if IBT is loaded to the maximum in a long time it can accelerate the life time of the equipment.

From Root Cause Problem Solving (RCPS) above there are two initiation improvements to optimize IBT maintenance, using 500 kV cable and redesign Gas Insulated Switchgear become Semi Air Insulated Switchgear.

- Initiation improvement using 500 kV cables are carried out with "difficult" implementation because bending of the 500 kV cable requires wide distances using narrow existing dimensions and cannot be changed anymore, it is difficult to implement the design but has a "high" impact.
- Initiation improvement using Redesign Gas Insulated Switchgear to Semi Air Insulated Switchgear using 3 gas sections are carried out with "medium" implementation and has a "high" impact.

3. Result and discussion

3.1. Comparison between Gas Insulated Substation and Air Insulated Switchgear

Substation is a sub-system of distribution from the power plant to consumers by passing the transmission line. Substation based on placement is installed outside the Building (Outdoor) or inside the Building (Indoor), the type of Substation based on insulation material is divided into two namely Gas Insulated Substation (GIS) [4] and Air Insulated Switchgear (AIS), bellow is a comparison between GIS and AIS:
Table 1. Comparison of GIS and AIS.

| Description      | AIS          | GIS                      |
|------------------|--------------|--------------------------|
| Area requirement | Large Area   | Less Area                |
| Insulation       | Air          | SF6 Gas                  |
| Maintenance      | Every 2 year | Every 25 year (major Overhaul) |

From Table 1. above, it can be seen comparison between GIS and AIS in terms of land for GIS requires only a small amount of land due to the compact GIS design [5], Gas insulated substation are more advantageous as it requires a compact size for installation [6], space required for GIS is less than 20% of AIS [6,7] whereas with AIS it requires large areas, The design of an air insulated substation starts with a basic work of selection of site which includes a large area of land and environmental conditions for the installation of substation [8], Gas insulated substation is based on the principle of operation of completely enclosure of all the live parts in metallic encapsulation which is loaded with compressed sulphur hexafluoride gas (SF6) [9], Gas insulated substation are preferred for 72.2 kV, 145 kV, 245 kV, 420 kV and above with all its equipment’s encapsulated in a metal enclosure compressed with SF6 in it [10]. when the major overhaul for GIS every 25 years, Operating life of GIS is more than 50 years and no major inspection is required before 25 years [6] while for AIS every 2 years.

3.2. Existing design EHVS 500 kV Kembangan

Existing design in the EHVS 500 kV Kembangan on the both side, 500 kV side and the 150 kV side use the closed type, the terminal connection between IBT bushing 500 kV side and 150 kV side with the Gas Insulated Line (GIL) enclosed in the compartment using materials Isolation SF6 Gas.

![Figure 2. Side view of the existing design.](image)

From Figure 2. at above, the connection between IBT (Inter Bus Transformer) and GIL compartments, both the 500 kV side and the 150 kV side using tubular (GIS) to Oil (IBT) with closed type, so that when maintenance IBT, first must evacuate the SF6 gas in the GIL compartment and remove the link bar that goes to IBT then doing maintenance activities. Similarly, if there are anomalies in the 500 kV GIL and 150 kV GIL must evacuate the SF6 gas first starting from the connection between IBT and GIL until the Gas Barrier (spacer) with closed type requires a relatively long time.

3.3. Semi AIS design

after collecting the required data, then make engineering design in accordance with the requirements of the maintenance team so that it can be quickly and easily when carrying out maintenance and handling anomaly work on GIL by also looking at operational aspects and equipment reliability, and conducting discussions with several manufacturer or manufacture to determine the workability of the
application of engineering design to be made, designing GIS to become semi AIS as shown in Figure 3.

![Figure 3](image)

**Figure 3.** Side view of semi AIS design.

From Figure 3 above we can see the difference in connection between the IBT and GIL (Gas Insulated Line) compartments on the 500 kV side and the 150 kV side with the existing design. Initially the connection using the closed type changed to open type. From the 500 kV side the connection uses Outdoor bushings and the 150 kV side uses a sealing end (SE) with IBT type is AIS.

3.4. **GIL compartment design from 1 gas section to 3 gas sections**

GIL (Gas Insulated Line) compartment design where the existing design uses 1 (one) gas section with closed type, if we find anomaly or SF6 gas leak (leakage) in the GIL compartment, when repairing the SF6 gas leak must first evacuate all gases from the connection between IBT and GIL until spacer with closed type, after that repairs are done, re-filling GIL compartments up to nominal pressure (repair work) anomalies or SF6 gas leak repair with the existing design requires a relatively long time. Display 1 gas section in the 500 kV side compartment as shown in Figure 4 below.

![Figure 4](image)

**Figure 4.** GIL Compartment 500 kV with 1 gas section.

Engineering design GIL compartment using 3 gas section, where the three sections are equipped with a gas connection that function for operation and maintenance, the gas connection operating conditions
are in the normally open position, when maintenance condition the gas connection in position close to speed up the gas evacuation process, as in Figure 5 below.

![Diagram showing GIL Compartment 500 kV with 3 gas section.](image)

**Figure 5.** GIL Compartment 500 kV with 3 gas section.

From Figure 5 above the design with 3 gas sections, each section is equipped with adsorbents and gas testing facilities. 3 (three) gas sections are sufficient to installed 1 gas monitoring (gas pressure) and rupture disk.

3.5. *Comparison Between Existing Design with SEMI AIS Design*

The difference duration between before and after the redesign of Semi AIS when preparing IBT maintenance is 25 hours faster, can be seen in Table 2, below

| Work Item                  |Duration (Hour) |
|---------------------------|----------------|
| SF6 Gas Testing           | 4              |
| SF6 Gas Evacuation        | 8              |
| Link Bar Release          | 5              |
| Link Bar Installation     | 5              |
| Refilling and Vacuuming Gas SF6 | 12              |
| Clamp Release             | -              |
| IBT Testing               | 8              |
| Total Duration (Hour)     | 42             |

If there is an anomaly or SF6 gas leakage in the GIL compartment using 3 gas section design that is by changing the position of the gas connection from normally open to normally close, then evacuation SF6 gas can only be done on the section that have a leak, Semi AIS Design is 24 hours faster compared with existing design. The difference in the duration of GIL recovery time before and after redesign Semi AIS like Table 3.
**Table 3. Comparison Duration Anomaly on GIL Before and after Redesign Semi AIS**

| Work Item                        | Before Design | After Design |
|----------------------------------|---------------|--------------|
| SF6 Gas Evacuation               | 8             | 2            |
| Link Bar Release                 | 5             | -            |
| Link Bar Installation            | 5             | -            |
| Refilling and Vacuuming Gas SF6  | 12            | 4            |
| Clamp Release                    | -             | -            |
| Recovery GIL                     | 6             | 6            |
| **Total Duration (Hour)**        | **36**        | **12**       |

4. Conclusion

Using the existing design (closed type) the time required for maintenance of IBT for 42 hours and repairing anomalies on the Gas Insulated Line takes 36 hours, while using redesign Gas Insulated Switchgear become Semi Air Insulated Switchgear design (open type) the time required for maintenance of IBT for 17 hours and repairs Anomaly in the gas insulated line for 12 hours because the GIL compartment design uses 3 gas sections so redesigning the Gas Insulated Switchgear into a Semi Air Insulated Switchgear can speed up duration IBT maintenance 25 hours faster and accelerate the repair of anomalies in the gas insulated line 24 hours faster.

References

[1] Qi B, Zhang G X, Li C R, Gao C J, Zhang B Y and Chen Z Z 2015 Research status and prospect of gas-insulated metal enclosed transmission line *High Volt. Eng* **41** 1466–73

[2] Koch H and Hillers T 2002 Second generation gas-insulated line *Power Eng. J.* **16** 111–6

[3] Koch H and Hopkins M 2005 Overview of gas insulated lines (GIL) *IEEE Power Engineering Society General Meeting, 2005* (IEEE) pp 940–4

[4] Strasser T, Andrén F, Kathan J, Cecati C, Buccella C, Siano P, Leitao P, Zhabelova G, Vyatkin V and Vrba P 2014 A review of architectures and concepts for intelligence in future electric energy systems *IEEE Trans. Ind. Electron.* **62** 2424–38

[5] Meier S, Werner T and Popescu-Cirstucescu C 2016 Performance considerations in digital substations *IET*

[6] Kamthe D and Bhasme N R 2018 COMPARATIVE ANALYSIS BETWEEN AIR INSULATED AND GAS INSULATED SUBSTATION—A REVIEW *J. Electr. Eng. Technol.* **9** 24–32

[7] Pinches D S and Al-Tai M A 2008 Very fast transient overvoltages generated by gas insulated substations *2008 43rd International Universities Power Engineering Conference* (IEEE) pp 1–5

[8] Sen S, Chatterjee A and Sarkar D 2013 Design of 132/33KV Substation *Int. J. Comput. Eng. Res.* **3**

[9] Kondalu M and Subramanyam P S 2013 Measurement of very Fast Transient over Voltages by using MATLAB in a 2-phase various Gas Insulated Substations *Int. J. Comput. Appl.* **72**

[10] Samikkannu R and Annadurai S K 2014 Estimation and analysis of VFTO in 420kV Gas Insulated substation *2014 International Conference on Circuits, Power and Computing Technologies [ICCPCT-2014]* (IEEE) pp 165–72