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Study on Planning for 150 Kv Outdoor System Substation at Substation Paya Geli, North Sumatra

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Abstract: *The substation is an important part of the power system. In addition to substations for power generation, they must be able to distribute power reliably and safely. In this study, based on the SPLN standard, I analyzed and calculated the components of the Paya Geli substation so that the selected components could actually conduct electricity properly and safely. The selection of the substation components in Paya Geli was based on these calculations and criteria. From this it can be concluded that the design results of the Paya Geli substation are in accordance with the design.*
Keywords: *substation; 150 Kv .; outdoor system*

I. Introduction

Substations are a vital part of the electric power system, power cannot be distributed without substations. Therefore, the construction of substations requires accurate calculations as needed. In addition, the designed substation must be safe and reliable.

The power plant generates the electrical power on the system by converting raw energy sources to the electrical energy. The electrical energy generated in power plants is then distributed to the loads where the electrical energy converted again for consumer activities. The size of newly built power plants is getting bigger from time to time due to its capacity increase, and it is not feasible to build the power plants close the loads because of the human population density. The role of transmission system is to deliver the electricity from the power plant to the consumers. Electric power transmission is an important part of power system network. A long transmission line is necessary to connect electric power from power plants in remote areas to load centers in the city. A load centre may be fed from many power plants through transmission lines that also connect many power plants within a large interconnected power system. Regulations for generation and load arrangement are necessary in order to maintain the stable operation of interconnected power system. Power Plants Trans.

The voltage stability issue is one of the problems that might occur in the power system. It starts with a disturbance in the system that causes deficiencies of reactive power supplies in an area. The loads in deficit area then takes power from the neighboring areas and will increase the power flowing at transmission line. This condition makes the losses in the transmission line to increase and causes a voltage drop in deficit area. A progressive situation of reactive power supply deficiency in deficit area may lead to a voltage instability problem. Further effect can be avoided either by recovering the reactive power supply in the disturbed area or by reducing the loads in the disturbed area. Those tasks are accomplished by adhering to operator's manual actions or by using automatic computerized equipment. Voltages in the system are expected to be in the range of normal operating limit, which is between +5% and -10% according to the grid code. In the real operating system, the voltages might drop or rise out from the operating limit after the disturbances in the system. Stable voltage condition provides that the voltage after small disturbance is identical or near the value of pre-disturbance value. The voltage instability in the form of the voltage collapse occurs when the voltage at one or more buses drops bellow operating limit after the disturbance occurrence. The load that increases in a remote area from power generator should be followed by an increasing power transfer to that area. If the power transfer does not increase due to a load increase then the voltage in the remote area will drop significantly.

II. Review of Literature

2.1 Country Of Power Plant

Indonesia is a country with a lot of islands which are spread from the east to the west. Sumatera is one of the five biggest islands, and being the second most populated island after Java in Indonesia. To fulfill electricity needs across the Sumatera Island, an interconnected transmission line was built. The interconnection brings possibilities to build power plants away from the load center and closer to the fuel sources. Up to now, the Sumatera interconnection system is divided into two parts, north Sumatera system and south Sumatera system. South Sumatera interconnection system connects six provinces: Lampung, Sumatera Selatan, Bengkulu, Jambi, Riau and Sumatera Barat. The area of this study is at South Sumatera interconnection system, on Lampung province as the southern end of Sumatera Island.

The fuel resources in south Sumatera are diverse from hydro and gas to coal and oil resources, and they are concentrated in a few places. The majority of the power plants in south Sumatera system are coal and gas powered with little percentage of hydro power in the southern and the northern part of the south Sumatera system. Sumatera Selatan is a province within the South Sumatera interconnection system with the most abundant energy resources in the form of gas and coal. Many coal and gas power plants are built in this province to maximize the use of coal and gas in the province. The electrical interconnected system brings the possibilities to deliver the power by the transmission line from Sumatera Selatan to the other provinces that have lack of energy resources. The province with lack of energy resources depends on the power transported by the transmission line to fulfill some of its demands. The disturbance on the transmission line will interrupt the power flow from Sumatera Selatan. To reduce the dependence to the transmission line, many power plants are also built on the remote areas from the energy sources. The power plants that are built far from the coal sources are obtaining their fuel by transporting the coal from Sumatera Selatan or Sumatera Barat province to the other province by other means of transportations.

2.2 Substation

Substation as a component of the distribution system plays a very important role because it is a liaison between electric power services and consumers. The functions of the substation are:

1. Receive and distribute electrical power as needed at a certain voltage safely and reliably
2. Distribution of power to other substations and distribution substations through medium voltage feeders.

Substations according to the installation of equipment are divided into 2 types, namely:

- Conventional Substation)
- Gas Insulated Substation (GIS)

Load changes are routine disturbance in the power systems that influence the steady state condition of the power system. Generator outputs should increase or decrease to adapt the load change, and the power flow of the transmission line might change to adapt the new load composition. The new load composition may lead to an extreme condition where some limitations are exceeded. The limitations that might be exceeded are the power generated by power plants, the transmission line load limit, the voltage regulation limit, etc. the voltage stability phenomenon may occur as the effect of a disturbance that already passes the limitation in the system. Progressive voltage instability starts with the failure of the power supply in an area or a significant increase of power demands in the area.

The voltage in the power failure area will therefore fall below nominal voltage. In order to fulfill the power demands in it, the power should be drawn from the other sources in the neighboring areas over the transmission line or by starting additional power plants in the power failure area. In order to increase the medium voltage level during the voltage drop, the tap changer in the transformer will react by increasing its tap position. The increase of tap position will reduce the transformer high voltage side reactance and increase the current flow to the transformer. It causes more power needs to be drawn from neighboring areas. While the power demand is increasing, the power supplied by the generator and voltage compensation equipment might reach their limitation and they will be unable to fulfill the power demands. This situation will make the voltage drop condition last longer and even get worse when the power from the load area keeps increasing which means lower voltage is expected during the need of the power rises. A shunt capacitor will not help very much in voltage instability situations, because the reactive power supplied by shunt capacitor depends on its terminal voltage.

The supplied reactive power is significantly low when the voltage on its terminal is lower. It also means that in the heavily shunt capacitor compensated area the need for reactive power in the area during voltage instability situation also increases significantly.

2.3 Single Line Diagram

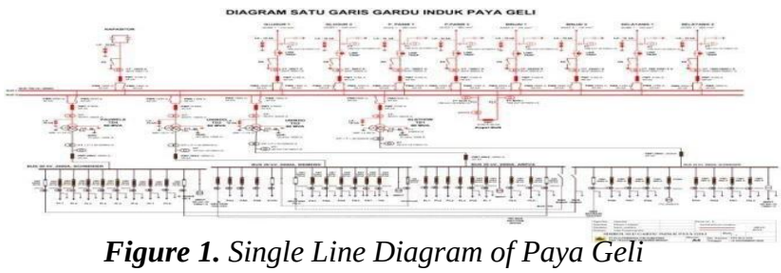

Figure 1. *Single Line Diagram of Paya Geli*

The Paya Geli Substation uses a double busbar system that functions as a backup, so it does not affect the system during maintenance of the substation. The Paya Geli Substation consists of equipment with the following details:

1. Power Transformer
2. *Current Transformers*
3. *Transformer Potential*
4. *Disconnecting Switch*
5. *Circuit Breakers*
6. *Lightning Arrester*
7. *Relay*Protection
8. KWH- Meter
9. *Grounding*

The function of the breaker (circuit breaker) isserves as a protection of the circuit electrical system, where this device works by turning off the power when the level is too high to prevent overcurrent surges and short circuits, which can cause damage to the electrical circuit itself as well as a hazard to people in the vicinity.

2.4 Arrester

Figure 2. *Lightning arrester Pasonni Villa*

Arrester is a key in an electric power system. When the surge comes to the substation, the arrester functions to release the electric charge (discharge), and reduce the abnormal voltage at the substation. The requirements that must be met by the arrester are as follows:

1. Parkover voltage and discharge voltage are voltages at the terminals at all times, so they can be low enough to disconnect equipment. The connection is also known as the voltage drop.
2. The arrester must be able to break the dynamic current and can continue to work as before the limit of the mains voltage that can turn off the current is called the arrester voltage rating.

Arrester Protection Range To protect against surge currents, a surge arrester must be installed between the transformer which is the main purpose of this protection and the load breaker. Another consideration is that the arrester will also be able to absorb electrical impulses from a power cut.

Another consideration is the installation of arresters on the medium voltage side to protect the transformer from surge currents on the medium voltage side.

2.5 Generator Voltage Regulator

Generator is the source of the electrical power in the system; it provides the voltage and current needed to operate the load. To provide the stable power system operation, the voltage at generator terminal output has to be maintains at nominal value during operation in normal or disturbance condition. The auxiliary for power plant operation also takes power from the generator output. The steady terminal voltage of generator is needed to maintain stable operation of the power plant auxiliary components and to reduce the effect from the voltage drop condition at the remote area from the generator. To maintain the generator output voltage, the generator terminal voltage is maintained by regulating the field current flowing in field winding.

In order to maintain the voltage output of generator, the output voltage of generator is continuously monitored by a voltage measurement sensor and fed back to the input of voltage regulator. The input voltage is compared with the reference voltage and the difference is used as an input to voltage regulator. The voltage regulator output is passed to exciter to generate a proper magnitude of generator's field winding current to compensate the difference between the reference and terminal voltage.

III. Discussion

Measuring transformers, or commonly known as measuring transformers, are specially designed for measurements in power systems. This transformer is widely used in electric power systems because it has several advantages, including:

- Provides electrical insulation for power systems
- Supports various qualities
- High reliability
- Simple physical form

Current transformers and voltage transformers convert current or voltage to lower levels for relay or metering operation.

1) Current transformer: Current transformer is used to measure the load current of a circuit. By using a current transformer, it is possible to measure large load currents with a measuring instrument (amperemeter).
2) Voltage Transformer: A voltage converter or voltage converter is a transformer that operates on:

- It converts the high voltage value on the primary side to the low voltage value on the secondary side and is used for measurement and protection.
- Separation of the secondary circuit from the primary circuit which separates the measuring and protective devices from high voltages.

Grounding or grounding is one of the key elements of an electrical system. If the grounding system can function properly, it must meet the following requirements:

a. Establish a low impedance ground path for the safety of personnel and equipment.
b. Use of corrosion-resistant materials against soil chemical conditions to maintain the system while the equipment is still functioning
c. Equipped with a strong mechanical system, but easy to maintain
d. Overcome repeated interruptions due to power surges

On the substation transmission line, the ground resistance does not exceed 5 Ohms. On high-voltage lines the maximum allowable resistance is 15 Ohms, while on medium-voltage lines, the maximum allowable resistance is 25 Ohms.

Soil resistance is related to water content and temperature, so it can be assumed that the ground resistance of a system will change according to climate change every year.

Table 1. Average Resistance of Soil by Type

No	Uraian Tanah	Tahanan rata – rata (Ohm)
1	Sawah, Rawa (Tanah Liat)	0 - 15
2	Tanah garapan (Tanah Liat)	1 - 20
3	Sawah, Tanah Garapan (kerikil)	10 - 100
4	Pegunungan (Biasa)	20 - 200
5	Pegunungan (Batu)	200 - 500
6	Pinggir Sungai (Berbatu)	100 - 500

When designing a substation, the safe distance between components is very important. If the components are too close together, a short circuit will occur. To overcome this, component routing must comply with existing standards.

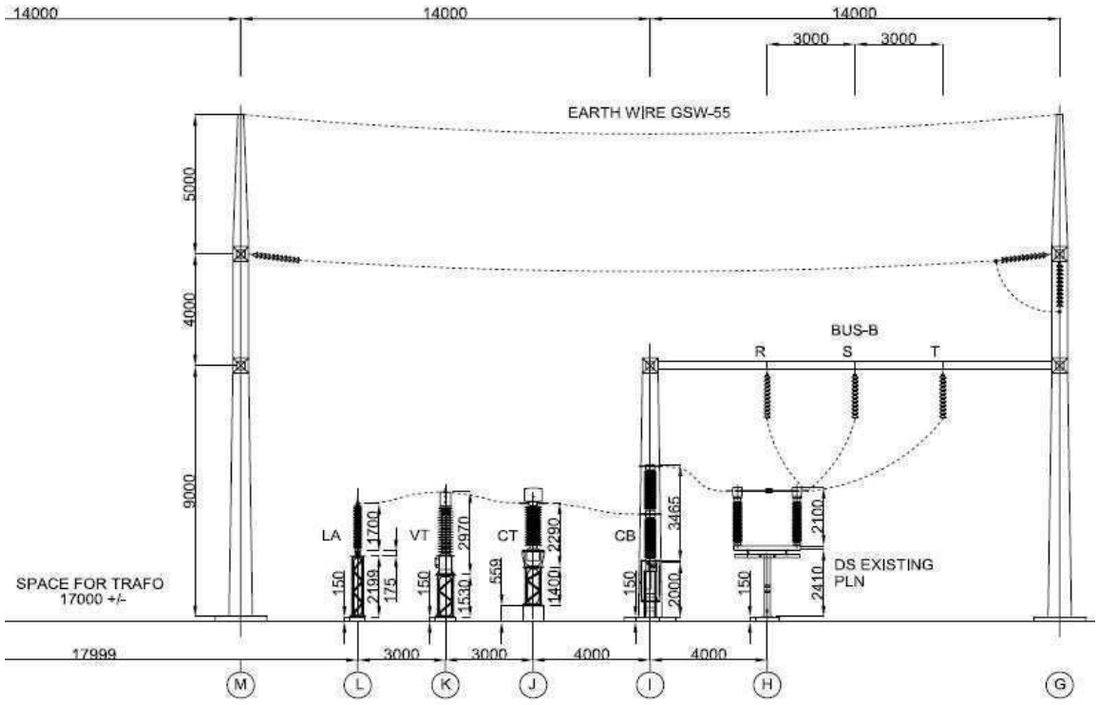

Figure 3. *Example of component distance in the field in Paya Geli*

Table 2. Distance between Component and Ground

	Distance between components with ground(mm) In the field	*Minimum Arching Distance(Phase* *to* *Earth)According to IEC 61466-2(mm)*
Lightning Arrester	2200	1300
Voltage Transformer	1530	1300
Current Transformers	1400	1300
Circuit Breakers	2000	1300
Disconnecting Switch	2140	1300

	Distance between components (mm) in the field	*Minimum arching distance (phase to phase) (mm)*
Lightning arrester – Voltage transformers	3000	1395
Voltage Transformer – Current Transformers	3000	1395
Current Transformer – Circuit Breakers	4000	1395
Circuit Breaker – Disconnecting Switch	4000	1395

From table 3, it can be seen that the component distance (phase – phase and phase – earth) at the Paya Geli Substation has exceeded the minimum standard specified by IEC 61466 - 2 and IEC 71 – 2.

*Relay*Protection is equipment used to detect disturbances that occur in a system. The protection relay will work automatically to disconnect the system by giving a signal to the CB to separate the equipment from the system before a disturbance occurs.

Figure 4. *Schneider Protection Relay*

Based on the size and type of work, the protection relays can be distinguished as follows:

- *Over Current Relay*is a safety relay circuit that responds to currents that exceed a predetermined value in a circuit to be secured
- Under Voltage Relay is a relay that uses voltage as its measurement variable. The relay operates when it detects a voltage drop that exceeds a predetermined limit. The voltage drop is less than the nominal voltage of 5° for a relatively long time. Efficiency drops when the voltage drops below 10%.
- *Ground Fault Relay*used to protect electrical equipment from short-circuit faults that occur. When the ground fault relay detects a short-circuit current, the ground fault relay outputs a trip signal.
- *Differential Relay*Is a relay that works according to Kirchhoff's Law. This law requires that the current flowing at a point is equal to the current flowing out at that point. Differential protection point means the safe area limited by two current transformers.
- *Thermal Overload*is a relay that works to disconnect the system by detecting from the thermal on the circuit breaker due to excessive current.

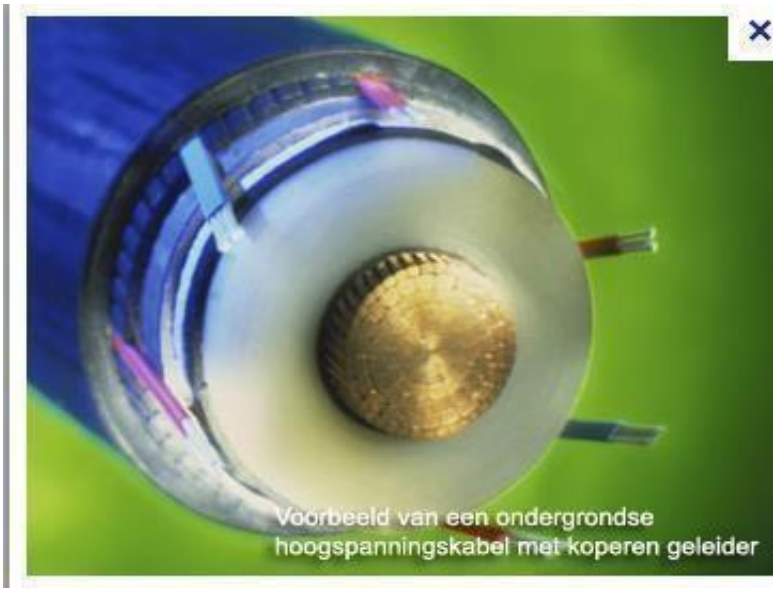

Figure 5. *ABB 150 150 kV cable*

Cables are PVC-wrapped aluminum or copper conductors. The insulating material used must be able to isolate the conductor from other conductors. It is the insulation that distinguishes low voltage cables from medium or high voltage cables. A busbar is a plate made of copper or aluminum that can conduct electricity to an electrical panel, distribution panel or substation. The size of the busbar greatly affects the maximum amount of current that can be delivered safely.

Dual busbar systems are used for 150kV busbars to meet load distribution and continuity requirements. This system has the advantage that if one busbar is damaged or repaired, another busbar can be used to distribute power.

The use of the busbar is based on the rated current of the circuit breaker to allow the busbar to properly power each component. The busbar measures 10 x 80 and is used up to 3 bars per phase. Complying with the PUIL 2000 standard, the maximum current through the 10 x 803 bar bus bar is 3450 amps.

In analyzing electric power, a single line diagram is a simplified notation for a three-phase electric power system. Instead of representing a separate three-phase line, a conductor is used. This makes it easier to read diagrams and circuit analysis.

Electrical elements such as circuit breakers, transformers, capacitors, bus bars, and other conductors can be represented using symbols that have been standardized for single line diagrams. The elements on the diagram do not represent the physical size or location of the electrical equipment, but it is a common convention to arrange the diagram in the same left-to-right, top-down, switch, or other order represented. Some of the elements used in a single line diagram are Transformers, Circuit Breakers, etc.

IV. Conclusion

From the results of the analysis and calculations, it can be concluded that the electrical system of PT. PLN (Persero) GI Paya Geli is still in good condition because the selection and installation of all equipment is in accordance with the calculation of functions and capabilities.

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