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Effects of 500 kV EHV Transmission Lines on Location Determination and Capacity of Shunt Reactor in South Sulawesi Systems

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Abstract. Electricity in South Sulawesi system is so extensive that it is necessary to construct a 500 kV Extra High Voltage (EHV) to avoid instability and waste of electricity during the distribution of electricity. need. Therefore, this paper describes the implementation of research on optimizing the electrical energy network system from renewable energy power plants in the form of the application of extra high voltage transmission. This research was carried out as an effort to implement a 500 kV extra high voltage transmission in South Sulawesi. The length of the 500 kV EHV to be installed includes an extra-long transmission, which is 365 kms which will produce more voltage on the network during light loads. So, it is necessary to make efforts to improve the electrical system to meet applicable standards, including the addition of the shunt reactor. The purpose of this study is to obtain conclusions about the effect of the shunt reactor on the South Sulawesi transmission system after the 500 kV EHV is applied. The research that has been carried out aims to obtain the optimal location and capacity of a shunt reactor. The results of this study will be very useful for electricity stakeholders, especially transmission companies in South Sulawesi.

1. Introduction

Current conditions in the South Sulawesi system, the distribution of electric power is done through a 150 kV high voltage (HV) transmission lines and 275 kV extra high voltage (EHV) transmission lines [1]. The power transmission system needs to be provided with a backbone so that the system is still sufficient to meet the development needs of South Sulawesi's load for the next 40 years. The system that is very suitable as a backbone is a 500 KV transmission system. Another factor driving the need for a 500 kV system in the South Sulawesi System is the presence of Wind Turbine Power Plant in Sidrap with a capacity of 70 MW and Jenepono with a capacity of 60 MW (South Sulawesi) which has an impact on system operation due to its intermittent energy source characteristics. In addition to intermittent generating factors, another factor influencing the operation of the South Sulawesi system is load characteristics. The government encourages the smelter industry to grow in the South Sulawesi region and this will have an impact on the operation of the electricity system because of the load characteristics of the smelter in the form of an electric arc furnace so it must be able to be anticipated.

For future development, it is necessary to study the application of 500 kV EHV on the South Sulawesi system. From several studies conducted by researchers that the South Sulawesi system is currently unable to anticipate the development of such a burden. In 2019 the Electric Power Supply Business Plan was issued as a master plan document for the development of Indonesia's electricity system, including



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the plan to construct a 500 kV on South Sulawesi transmission system for the 2019-2028 planning period of 365 kmc [2].

The plan for the development of the 500 kV EHV by the Government of Indonesia is very encouraging. However, before the 500 kV system is implemented in South Sulawesi, a study needs to be done on the need for a 500 kV voltage level transmission system to get the condition of the system if 500 kV has been applied. One thing that needs to be studied is the use of shunt reactors that function to control the voltage increase in the 500 kV transmission system [3]. In an EHV transmission line system especially 500 kV, changing the voltage level becomes the most important problem. So the purpose of this paper is to determine the location and size of the shunt reactor capacity to increase the voltage level in the South Sulawesi transmission system.

2. Research Method

2.1. Test System Description

The South Sulawesi electricity interconnection system is supplied by large-scale power plants located at Jeneponto 400 MW and Sengkang 192 MW. The large-scale power output voltage after going through a step-up transformer is a 150 kV system. While the 190 MW Poso voltage of 275 kV. In Palopo substation there is an interconnection between the 150 kV system and the 275 kV system. South Sulawesi's electricity load is mostly in the southern area, namely in Makassar City. The total installed capacity of the plant in South Sulawesi is 1367 MW. The peak load is 950 MW. The number of existing substations (SS) in South Sulawesi is 33 units with a total capacity of 1888 MVA [4]. The length of the 500 kV transmission line to be built is 365 kmc, using a 4 x Zebra ACSR conductor [5]. Single line diagram of South Sulawesi's system is shown in Figure 1.

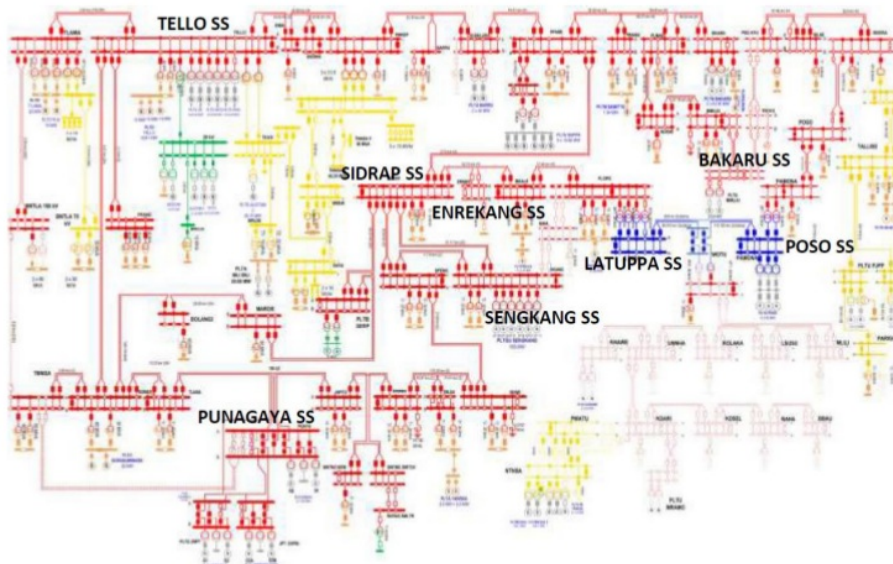


Figure 1. Single line diagram of South Sulawesi system [5]

2.2. Shunt Reactor

The shunt reactor is a coil that is installed in parallel with the system so that it can absorb capacitive reactive power from the electric power system by the installed capacity of the shunt reactor. Shunt reactors are used in systems that have large charging currents during light / low loads. Shunt reactors can be installed directly on the EHV bus which functions for secondary voltage absorption during light/low loads.

2.3. Simulation Procedure

The work steps undertaken to carry out this research are: 1) Survey of technical data from government offices dealing with electricity, namely: PLN South Sulawesi (Indonesian Republic Electricity Company), as well as supporting data on writing from relevant agencies and reference books in libraries related to the subject matter. 2) Forming a model based on the case that might exist based on references and available data. 3) Calculation of parameters from existing data for 500 kV transmission line system of South Sulawesi. Existing data entered into the calculation model to complete the calculation of: shunt reactor inductance to increase the electric length, and determine the compensation of the shunt reactor to increase the voltage level. And 4) Getting results in the form of conclusions from calculations that have been done. In shunt reactor compensation in the South Sulawesi transmission system is done only in the substations associated with a 500 kV transmission system. As a result, the installation of shunt reactor compensation for shunt reactor use simulation was installed at 150 kV Punagaya substation, 150 kV Sidrap substation, 150 kV Bakaru substation, 275 kV Latuppa substation, and 500 kV Sidrap substation. To do the simulation, the system is connected to the shunt reactor, where the shunt reactor is installed in one of the substations, then the other substations are not given a shunt reactor. Each simulation is performed shunt record installations ranging from 400 MVar to 600 MVar with the addition of MVar, which is 50 MVar. The voltage will be observed on all five buses. The increase and decrease in voltage on each bus are observed to exceed the operating voltage limit. The voltage that occurs must be within the limit of the voltage that is still permissible, that is, it cannot be more than 105% of the working voltage and must not be less than 95% of the nominal voltage by following applicable standards.

Analysis of the effect of the shunt reactor will use power flow calculations using the Newton Raphson method [6]. This method is used to get the power flow in each network as well as the voltage of each voltage at each busbar / substation. The voltage profile of the power system operation by the reactive power balance in the South Sulawesi system can be expressed by the following Equation (1):

$$\sum Q_{gi} - \sum Q_{cl} = \sum Q_{ok} + \sum Q_L \quad (1)$$

where, $\sum Q_L$ = reactive power loss of the system, $\sum Q_{ok}$ = reactive power load on the load bus k, $\sum Q_{cl}$ = injection of reactive power from other sources, and $\sum Q_{gi}$ = reactive power generated by the generator.

3. Result and Discussion

3.1. Calculation Result

Table 1 shows the magnitude of the voltage at 5 (five) substations. The value of this voltage arises due to the installation of a shunt reactor on the 275 kV Latuppa substation. Table 2 is a result table of the installation of the shunt reactor in 150 kV Punagaya substation. Table 3 also shows the operational voltages of several substations in South Sulawesi, where these results are the effects of installing a reactor shunt on a 150 kV Sidrap substation. Table 4 shows the simulation results of placing the shunt adhesive on the 500 kV Sidrap substation.

Table 1. Placement of the shunt reactor on the 275 kV Latuppa substation

Shunt Reactor (MVar)	Bus Voltage (kV)				
	Latuppa	Punagaya	Sidrap	Bakaru	Sidrap
	275	150	150	150	500
400	Not convergent				
450	Not convergent				
500	272	154	160	154	512
550	267	153	159	153	508
600	262	153	159	152	504
650	255	151	157	151	500

Table 2. Placement of shunt reactor on the 150kV Punagaya substation

Shunt Reactor (MVar)	Bus Voltage (kV)				
	Latuppa 275	Punagaya 150	Sidrap 150	Bakaru 150	Sidrap 500
400	Not convergent				
450	320	148	161	156	519
500	314	144	158	153	508
550	311	142	156	151	502

Table 3. Placement of the shunt reactor on the 150kV Sidrap substation

Shunt Reactor (MVar)	Bus Voltage (kV)				
	Latuppa 275	Punagaya 150	Sidrap 150	Bakaru 150	Sidrap 500
400	Not convergent				
450	314	154	149	154	496
500	311	152	148	153	489
550	308	151	146	148	483
600	305	150	144	151	476

Table 4. Placement of a shunt reactor on a 500kV Sidrap substation

Shunt Reactor (MVar)	Bus Voltage (kV)				
	Latuppa 275	Punagaya 150	Sidrap 150	Bakaru 150	Sidrap 500
400	313	152	159	152	504
450	309	151	157	150	496
500	304	149	155	149	489
550	301	148	154	147	483
600	297	146	153	145	476
650	295	145	152	144	471
700	293	144	151	143	467
750	291	143	150	142	462

3.2. Discussion

Table 1 above shows the application or use of a shunt reactor at 275 kV Latuppa substation located in Palopo. If the operating limit of the substation is based on a voltage limit of $\pm 5\%$, then at a capacity position between 600 - 650 MVar, the voltage at each substation is within the operating limit. The voltage on the Latuppa substation is 255 kV, Punagaya substation is 155 kV, Sidrap150 substation is 157 kV, Bakaru substation is 151 kV, and Sidrap500 substation is 500 kV. Another case with another scenario, where the placement of the shunt reactor at 150 kV Punagaya substation, 150 kV Sidrap substation, 150 kV Enrekang substation, and 500 kV Sidrap substation produces operating stresses on all substations outside the standard operating voltage limits.

The results of this study show the effect of the reactor shunt on the South Sulawesi electricity system, where the reactor shunt decreases the stress on all substations / busbars. The effect of the reactor shunt on the distribution of electrical energy from power plants in the South Sulawesi system through a long transmission line by using AC EHV at low loads causes a large load on the line at each node. The charge

flow is an electric current, a current caused by charging. Discharging a channel due to alternating voltage is called a charging current, the charging current always flows in the transmission line even though the network is open. The charging current due to the influence of network capacitance will cause reactive power. The reactive power generated by the 500 kV transmission line is approximately 1 kmc = 1 MVAR. If the 3 (three) phase network in South Sulawesi's 500 kV system has a length of 365 kms, the reactive power generated = 365 MVAR. To compensate for such a large reactive power, it is necessary to install an inductor in the form of a Shunt Reactor greater than 365 MVAR generated by the 500 kV transmission line.

South Sulawesi's 500 kV EHV transmission lines is a long network so it requires compensation equipment to control the working voltage at each node along the network which serves to reduce the dielectric length of the 500 kV transmission to increase the capacity of the power line. At present, the 500 kV long network compensation tool is using a Shunt Reactor which is connected to the 500 kV busbar side, 275 kV side, and the 150 kV side. When the load is full due to the device effect which causes the capacitive reactive power of the network is relatively large, it can be absorbed by the load so that there is no over-voltage, but at low load conditions ie on holidays / large MVAR the network cannot be absorbed by the load causing a voltage the substation exceeds the operational allowable working voltage from the nominal voltage (+5% to -10%).

4. Conclusion

The conclusions of this study are:

- Shunt reactors are needed when light loads occur, while the excess power system must be absorbed beforehand.
- The most ideal shunt reactor position is at 275 kV Latuppa substation, and the shunt reactor capacity is 600 - 650 MVAR.

Acknowledgments

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