Voltage Analysis Improvement of 150 kV Transmission Subsystem Using Static Synchronous Compensator (STATCOM)

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Abstract. In this research, testing improvements to the distribution voltage electricity at 150 kV transmission subsystem Bandung Selatan and New Ujungberung using Flexible AC Transmission System (FACTS) technology. One of them is by doing the control of active and reactive power through the power electronics equipment Static Synchronous Compensator (STATCOM). The subsystem is tested because it has a voltage profile are relatively less well when based on the IEEE / ANSI C.84.1 (142.5 - 157.5 kV). This study was conducted by analyzing the Newton-Raphson power flow on the simulator DigSilent Power Factory 15 to determine the profile of the voltage (V) on the system. Bus which has the lowest voltage to be a reference in the installation of STATCOM. From this research is known that the voltage on the conditions of the existing bus 28, as many as 21-23 still below standard buses (142.5 kV), after the installation is done using STATCOM, voltage on the buses improved by increasing the number of tracks that follow the standard / is in the range 142.5 kV -157.5 kV as many as 23-27 buses or 78.6% - 96%, with the optimum mounting on a bus Rancaekek STATCOM II with a capacity of 300 MVA.

1. Introduction

An electric power transmission system has a very important role for electrical energy distribution. With the extremely high requirements will require good quality electricity for distribution. As is the case in this study is based on data in the field in 2016 are sourced from PT. PLN (Persero) *Area Pengontrol Beban* (APB) *Jawa Bagian Tengah*, the sub-system 150 kV transmission area Bandung Selatan on February 3 at 19:00 and February 15 at 19:00 if used PLN Standard [1], the value of the voltage buses has the appropriate value, because the value is in the range 135 kV - 157.5 kV (-10%, + 5%). However, in the present study used comparisons with the IEEE / ANSI C84.1 with rated voltage ± 5% of nominal voltage from 28 the existing buses, 21-23 are below the limit of 142.5 kV (0.95 p.u).

Solutions that can be used to improve the quality of the installation of electric power systems by using control technology are qualified. FACTS technologies allow to improve the operation of the transmission system to the minimum of infrastructure investment costs, environmental impact and execution time compared with the construction of new transmission lines [2]. One of the FACTS which are connected in parallel, has an efficiency of reactive power and voltage is STATCOM. Installation STATCOM needed to reduce losses and the minimum amount of reactive to generated [3].

The ability to overcome the problems STATCOM reactive power to make such equipment as an option for use. Moreover, with the development of power electronics today, STATCOM is also experiencing growth in reliability in operation. So based on reliability in the operation of the discussion of the STATCOM be an interesting thing to be examined

2. Flexible Alternating Current Transmission System (FACTS)

Flexible AC Transmission System (FACTS) is a power electronics-based equipment systems that provide control of one or more AC transmission lines to improve the control and improvement of power distribution. Where there are 3 types of FACTS ie, parallel, series and series-parallel [4].

The using of reactive power compensators in the electric transmission system has been proven to improve the quality and reliability of the electrical system. This is because in addition to be able to regulate the amount of reactive power in the system, reactive power compensators also has a function for setting and balancing of voltage levels. [5]

2.1. Static Synchronous Compensator (STATCOM)

Static Synchronous Compensator (STATCOM) is a plant Volt Amp Reactive (VAR) static, which output is varied to maintain or set the type of reactive impedance, using thyristor arrangement, reactors and capacitor switch, or the type of source synchronous voltage using pen-switch power converter[1]. In Figure 1 shows the topology of the STATCOM, which consists of a capacitor DC power converters are alternated by itself and step up transformer or transformer circuit.

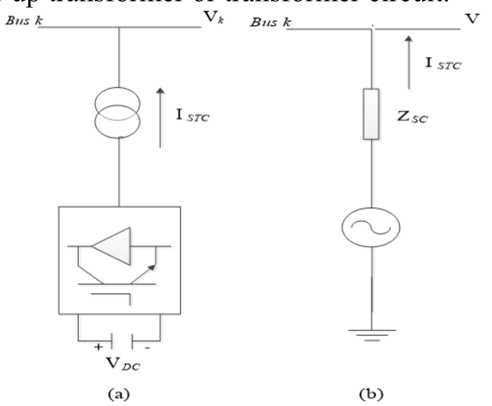

Figure 1. STATCOM equivalent circuit diagram of the circuit: (a) Schematic diagram of STATCOM; (b) equivalent circuit STATCOM. [6]

2.2. Working principle and control of STATCOM

STATCOM is a Voltage-Source Converter (VSC), which converts the DC input voltage into AC output voltage to compensate for active and reactive power needed by the system [7]. By using VSC controller and coupling transformer, STATCOM performance depicted in the figure below[8]

Basic operating principle of generator reactive power by using VSI is similar to a conventional synchronous machines. Reactive currents drawn by the synchronous compensator voltage depending on the magnitude of system voltage (V), the converter Vo and the overall circuit reactance (reactance leaking transformer with transformer coupling reactance) X : [7]

$$I = \frac{V - Vo}{X} \qquad (1)$$

And reactive power exchange found in expression in:

$$Q = \frac{1 - \frac{Vo}{V}}{X} V^2 \qquad (2)$$

STATCOM is FACTS controller that based on voltage source converter (VSC). Where VSC generates synchronous voltage at the fundamental frequency, large control voltage and phase angle. If a VSC is connected in parallel to the system by combining transformers, STATCOM can generate and absorb reactive power at bus paired and adjust the voltage [9].

3. Research Methods
In completing the necessary research framework / research stages of processing from start to start to finish in order to facilitate the writer and the reader in understanding the stages of execution of this study. Here is a flow diagram of the stages in performing research.

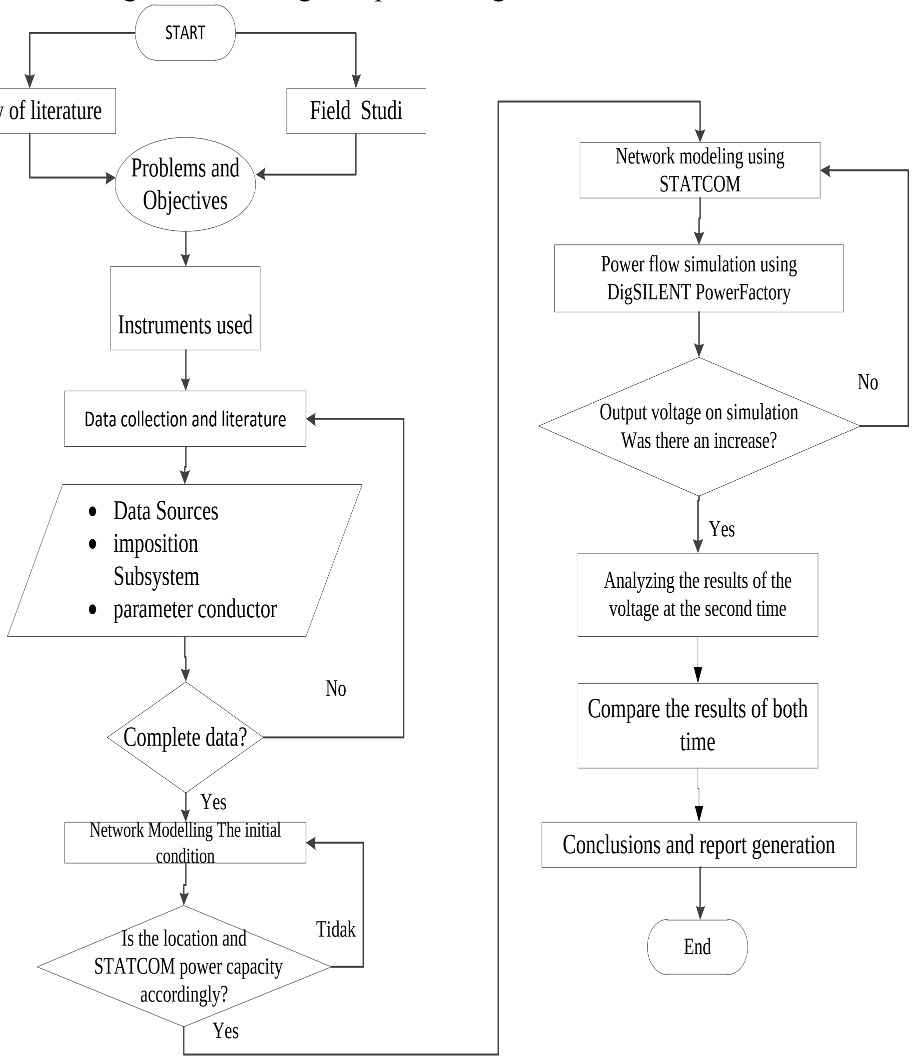

Figure 2. Research flowchart diagram

Based on the flow chart, technical data which includes such as data source of electricity, charging sub-systems and conductor parameters which can be described as follows:

Data loading is on subsystem consists of a static load of the sub-system of 150 / 70kV and dynamic load on the transformer, but the system was changed to a static load (lump load). The data consists of the capacity of the power, active power and reactive power. The data retrieved is the data loading that occurs in South Bandung subsystem 150 kV, contained on a single line diagram susbsitem South Bandung 150 kV and New Ujung Berung The loading of data to be tested was taken on February 3, February 15th at 19:00 and 19:00.

4. Results and discussion

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4.1. Profile voltage 150 kV transmission subsystem Bandung Selatan and new Ujungberung after installation STATCOM

Results obtained from the process of calculation and experimental approaches in determining the capacity and the injection of the STATCOM reactive power to maintain voltage value most prevalent in the overall bus placement STATCOM obtained by using STATCOM capacity of 300 MVA (+250 MVAr; -250 MVAr) on February 3, 2016, with the results shown in table 1 and table 2 as follows:

Table 1. Voltage profile simulation results after the installation of STATCOM in Rancaekek II bus dated February 3, 2016 at 19:00

No	Substation	V operating(kV) simulation without STATCOM	V with STATCOM
1	Bandung Selatan I	144,93	146,11
2	Bandung Selatan II	144,93	146,11
3	Bandung Utara II	**137,23**	144,09
4	Braga I	**141,47**	142,69
5	Braga II	**141,47**	142,69
6	Cibereum I	**141,32**	142,54
7	Cibereum II	**141,32**	142,54
8	Cigereleng I	**141,61**	142,83
9	Cikasungka I	**140,11**	148,51
10	Cikasungka II	**140,11**	148,51
11	Cianjur I	**134,30**	**135,59**
12	Dago Pakar I	**138,04**	144,85
13	Dago Pakar II	**138,04**	144,85
14	Darajat I	143,61	150,79
15	Darajat II	143,61	150,79
16	Kamojang I	**141,91**	149,17
17	Kamojang I	**141,91**	149,17
18	Kiaracondong I	**140,96**	145,53
19	Kiaracondong II	**140,96**	145,53
20	Panasia	144,36	145,54
21	Panasia II	144,36	145,54
22	Rancakasumba I	**139,75**	148,18
23	Rancakasumba II	**139,75**	148,18
24	Rancaekek II	**139,53**	148,63
25	Ujung Berung I	**139,13**	145,89
26	Ujung Berung II	**139,13**	145,89
27	Wayang Windu I	143,83	147,89
28	Wayang Windu II	143,83	147,89

According to the table 1 above, there are 27 standardized buses and one bus is not appropriate based on IEEE / ANSI C84.1 standard. In addition to the improved results by using STATCOM 3 =

300 MVA (+284.27 MVAr; -284.27 MVAr) on the buss on February 15, 2016 at 19.00, shown in the table 2 below:

Table 2. Voltage profile simulation results after the installation of STATCOM In bus Rancaekek II dated February 15, 2016 at 19:00

No	Substation	V operating(kV) simulation without STATCOM	V with STATCOM
1	Bandung Selatan I	143,40	144,75
2	Bandung Selatan II	143,40	144,75
3	Bandung Utara II	**135,39**	143,21
4	Braga I	**140,87**	**142,24**
5	Braga II	**140,87**	**142,24**
6	Cibereum I	**140,66**	**142,04**
7	Cibereum II	**140,66**	**142,04**
8	Cigereleng I	**141,00**	**142,37**
9	Cikasungka I	**138,61**	148,16
10	Cikasungka II	**138,61**	148,16
11	Cianjur I	**132,82**	**134,29**
12	Dago Pakar I	**136,15**	143,94
13	Dago Pakar II	**136,15**	143,94
14	Darajat I	**142,25**	150,37
15	Darajat II	**142,25**	150,37
16	Kamojang I	**140,66**	148,87
17	Kamojang I	**140,66**	148,87
18	Kiaracondong I	**138,94**	144,17
19	Kiaracondong II	**138,94**	144,17
20	Panasia	143,00	144,35
21	Panasia II	143,00	144,35
22	Rancakasumba I	**138,26**	147,83
23	Rancakasumba II	**138,26**	147,83
24	Rancaekek II	**137,85**	148,23
25	Ujung Berung I	**137,23**	144,94
26	Ujung Berung II	**137,23**	144,94
27	Wayang Windu I	142,90	147,49
28	Wayang Windu II	142,90	147,49

Results obtained voltage improvement as much as 22 pieces and buses are still under the standard IEEE / ANSI C84.1 as much as 6 pieces. So with the comparison between the two time ranges the number of bus improvements bus voltage range between 23-25 and the mean number of improvements of 82.14% - 96.4% of the total number of 28 buses.

4.2. Analysis effect of STATCOM most optimized placement

After the trial the effect of the installation of STATCOM, it is necessary to analyze the most optimal placement STATCOM, in order to produce the best voltage value improvement, which can be determined based on the table.

Based on the table 1, the result of improved value of the voltage buses on February 3, 2016 at 19:00 based on the value of the average voltage bus generated the overall order of placement on the bus STATCOM consist of Rancakasumba, Cikasungka, Rancaekek, Bandung Utara, Dago Pakar and Ujungberung. Whereas based on the result in table 2 of improved buses voltage value at the date of February 15, 2016 at 19.00, has a placement optimization results are quite different, which has four

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locations namely placement STATCOM there is in Rancaekek, Bandung Utara, Dago Pakar and Ujung Berung.

With the consideration of a STATCOM called optimal position when the voltage profile improvement occurs evenly and have an average value of a relatively large after a comparison between two different times, then the installation position STATCOM on buses that are considered the most optimal located on the Rancaekek II bus.

Based on the simulation results are show that STATCOM provide an effective additional voltage on the bus is connected directly. STATCOM placed as close to the bus closest to the loads.

5. Conclusion

Voltage profile in Bandung Selatan subsystems and New Ujungberung, which is dated February 3, 2016 and February 15, 2016 at 19:00 before using STATCOM overall when using SPLN have a value according to standards but if based on standard IEEE / ANSI C84.1 have conditions voltage relatively poorly characterized by the bus below the standard range between 21-23 buses below 0.95 p.u or 142.5 kV.

After installation of Static Synchronous Compensator (STATCOM) voltage profile in the subsystem Bandung Selatan and New Ujungberung, which is dated February 3, 2016 and February 15, 2016 19:00 have improved voltage of 28 buses that have so increasing the number of tracks that follow the standard IEEE / ANSI C84.1 as many as 27 buses on 3 February and 22 buss on February 15, with the installation of the bus Rancaekek II with a capacity of 300 MVA. Positioning and capacity STATCOM most optimal in maintaining the voltage profile of the most effective currently on Rancaekek II bus with a capacity of 300 MVA STATCOM.

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