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Research Paper

Analysis of Stability Improvements by Using Capacitors

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Abstract

The demand for electricity has increased substantially while the expansion of electricity generation, power transmission is very limited, due to environmental restrictions, consequently some transmission lines, limiting power factor. Power flow in the generation system, covering the area of North Sumatra and Aceh which is managed by PT. PLN (Persero), ETAP 4.0 (Electrical Transient Analizer Program) is a program that can display GUI (Graphical User Interface) with unlimited bus number, ETAP 4.0 is useful for Power flow study. The data required by ETAP 4.0 on a generation system is a one-line diagram, nominal kV, and generator, bus, transformer, transmission, and safety rating. The power flow approach method used is the Newton-Raphson method with maximum iteration of 99 and the accuracy of 0.000001. The problem of power flows under consideration is the normal state system, one transmission is disconnected, one of the plants is not operating. The results of the power flow study for each problem obtained the lowest bus voltage, the highest losses in the transmis. The largest power distributed in power plants, new in high voltage transmission, increases the power of power from power to load, changes in voltage problems and improves system stability. This paper aims to verify the capacitor's ability to improve voltage regulation (voltage stability) in electric power transmission systems, from this capacitor simulated using ETAP 4.0 included in Newton-Raphson model.

Keywords: *Capacitors, Stability of voltage, Newton -Rapson, ETAP 4.0*

1. Introduction

Electricity system continues to develop, ranging from using one machine to multiple machines (multi-machine). This development is due to the demand for electrical energy needs is increasing so that the need for electric power plants that have large power capacity. The power generated by this electrical energy generating system is channeled through the interconnection system[1]–[3].

One analysis that can be performed on interconnection systems when steady state is a power flow study. Power flow completion methods are Gauss-seidel, Newton-raphson, and Fast Decoupled. The resulting from the power flow study is the direction of power flow, bus voltage, active power and reactive power. The results of the power flow study can be used to determine transmission losses, reactive power allocation, system capability to meet load growth and increase power supply[4], [5].

The North Sumatra Power Generation System (Sumbagut) is a power generation system that serves the Nangroe Aceh Darussalam (NAD) and North Sumatra areas through an interconnection system. The peak load experienced by the North of Sumatra system was 1,070 MW on December 28, 2005. The North of Sumatra system has about 37 main relay stations spread over NAD and North Sumatra areas.

Manual power flow calculations for the North of Sumatra system are so complex that it should be done using a computer program. ETAP 4.0 (Electrical Transient Analizer Program) is one of the computer programs used for calculation of power flow studies on power systems. The ETAP 4.0 program can be used for large power systems and requires very complex calculations. Therefore, ETAP 4.0 is used for calculation of power flow studies on the North of Sumatra system[6]–[10].

Electricity provides a very important role in people's lives as well as in the development of various economic sectors. In reality modern economy is very dependent on electricity as the basic input. This causes an increase in the number of power plants and the resulting capacity in the transmission line connecting the power station to the load centers will increase.

Power systems are widely interconnected, need an interconnection system because in addition to transmission from the transmission line there is a power plant where energy composition by type of power plant: (PLTGU, PLTU, PLTG, PLTD and PLTP) and load centers to minimize total power capacity and cost[11], [12].

The interconnection transmission allows taking advantage of the diversity of loads, the availability of sources and prices for power supplies to the load at minimum cost with the required reliability.

Utilization of electric power system, current power flow is provided by PT. PLN (Persero) UPB North of Sumatra, for the burden of the North Sumatra system, the load of the NAD system, with the total power generating MW, MVAR load, which has the substation and the number of buses, the flow of power in each transmission line, is determined by the characteristics of the channel itself. In addition, constant steady channel operation is always required so that the power flow can be continuously performed even though some parts of the channel may be interrupted. For this condition more than one power flow or multiple connected lines of transmission are required. Therefore, a control tool is needed to maintain the stability of the system in order to always operate maximum.[13]–[15]

Complex electrical system will always change the voltage, current, active power, reactive power and frequency on the power system. The amount of reactive power in the electric power systemis one indicator of the voltage stability. In this paper will be studied Analysis of Stability Improvement Using Voltage capacitor bank, Application[16], [17].

PT. PLN (Persero) UPB Sumbagut-NAD for optimizing the existing reactive power reserves in the electrical power system, the sensitivity method will be used, the sensitivity method will give the right generator information will minimize reactive power losses in the channel. Where the equipment is installed in a strategic location. Equipment used for the control of a power system by using a capasitor is a phase angle arrangement.[18]

Newton-Raphson method to explain the calculation of power flow in the system of several buses that will be analyzed by using Newton-Raphson simulation method is done by ETAP 4.0. Use of capacitor conditions before compensation in channels with multiple Buses, calculations of power and voltage flow using Newton-Raphson method. The use of capasitor after compensation, capacitor connected to bus to fix voltage, for the purposes of this improvement, generated reactive power (MVAR) of the capsitor.

2. Research Purposes

The purpose of this research is to improve the voltage stability by applying from PT.PLN power system (Persero) UPB North of Sumatra in the know load of North Sumatra system, NAD and generating power MW, MVAR, MVA and power factor that has substation and unlimited bus number and know, understand the use of ETAP 4.0 for power flows and capacitors placed on electrical power systems for the purpose of analyzing the improvement of voltage stability using ETAP 4.0.

a. To analyze the power flow on the transmission line
b. To analyze the placement and use of capacitors on the channel

Benefits of research

Referring to the purpose of this study, the research will be expected to provide various aspects of voltage stability and the importance to maintain the voltage profile that will be done[19], [20].

a. The theoretical benefits of knowing the use of tools or apps of equipment to be installed in a strategic location. Equipment used for control of electric power system, special in channel known as capacitor aims to improve the quality of power distribution from power plant to load one of the equipment capacitor serves to change the voltage changes

Practical benefits can provide meaningful input to PT. PLN (Persero) UPB North of Sumatra in using capacitors to regulate power flow and improve the stability of the power system. The capacitor regulates terminal voltage regulation by generating or absorbing the reactive power of the system. If lower system voltage capacitor generates reactive power (capacitor is capacitive) If higher system voltage capacitor absorbs reactive power (inductive capasitor).

3. Literature Review

Power System

Electric Power System is a series of electric power installations of generation, transmission and distribution operatedsimultaneously in order to supply electric power. The basic components that make up the power system are generators, transformers, transmission lines and loads. In analyzing the power system required diagrams that can represent every component of the power system. The always used diagrams are one-line diagrams and impedance diagrams or reactance diagrams, Figure 1. is a diagram of a single line of electrical power systems[21].

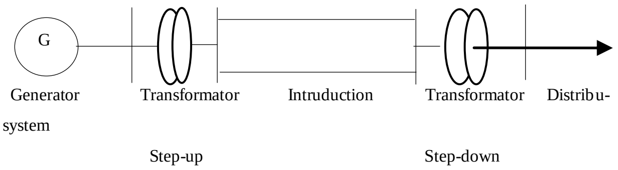

Fig 1: Diagram of a single line of electrical power system

The voltage stability is the ability of a power system to maintain sufficient voltage so that when the nominal load system increases, the actual power transferred to the load increases.

Bus Classification

Table 1: Classification Bus on power system

Bus type	Known quantities	Unknown quantities
Slack	IVI = 1,0 ; θ = 0	P, Q
Generator (PV Bus)	P, IVI	Q, θ
Load (PQ Bus)	P,Q	IVI, θ

Power Flow Similarity

The power flow equation is simple, for a system that has 2 buses. On each bus has a generator and load, although in reality not all buses have generators. The conductor connects between bus 1 and bus 2. On each bus has 6 electrical quantities consisting of: PD, PG, QD, QG, V, and δ. Figure 2. can be generated power flow equation by using impedance diagram[22], [23].

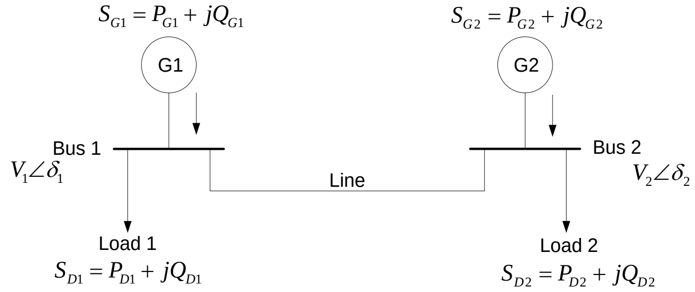

Fig 2: Diagram One Line System 2 Bus

Capacitors to Improve the Power Factor

The capacitor acts as a reactive power generator and thereby reduces the amount of reactive power as well as the total power generated by the utility part.

4. Research Methodology

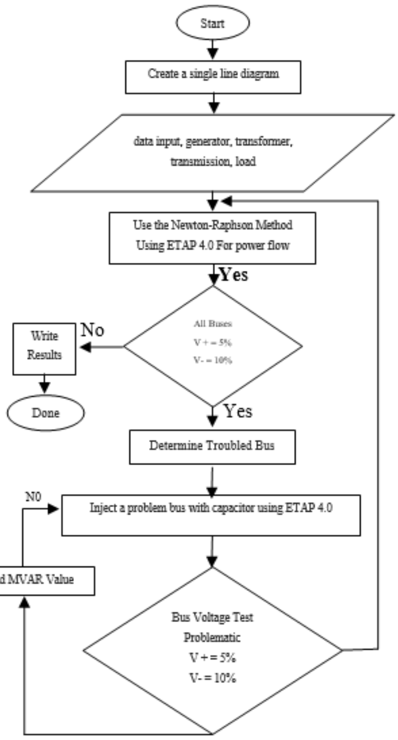

Fig 3: Research Diagram

Modeling Capacitors on Troubled Buses

Figure 4. model ETAP 4.0 shows a transmission system model for improving reactive power using a capacitor. Improved buses are buses that have decreased voltage, according to SPLN voltage V = + 5% up to V = -10% of nominal voltage 150 KV.

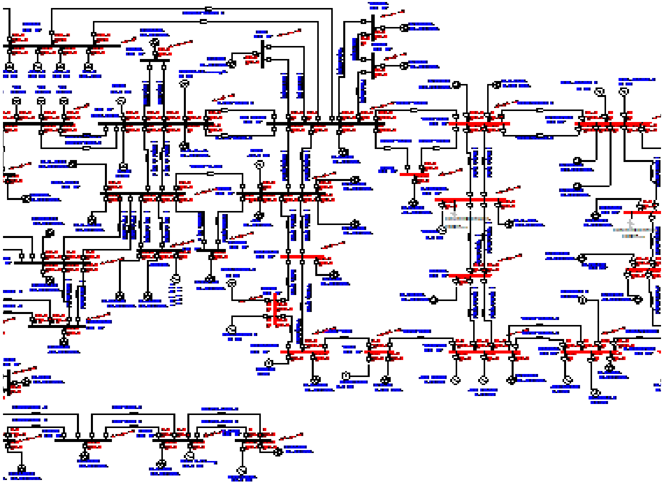

Fig 4: Series of ETAP 4.0 models operation of capacitor

5. Analysis and Results

Table 2: Results of power flow analysis during night load

No	Bus		Voltage		Volt	
	From		P	jQ	KV	%
1	BLWCC	SROTAN 1	138,7	17,.0	150	100
		SROTAN 2	138,7	17,.0		
		BNJAI 1	72,8	48,8		
		BNJAI 2	72,8	48,8		
	BLWTU	PPSAR 1	99,6	95,3	150	100
		PPSAR 2	99,6	99,6		
		LBHAN	16,1	9,8		
2	LBHAN	BLWTU	16,1	9,8	149,860	99,91
		LHTMA	7,5	4,6		
3	LHTMA	LBHAN	7.5	4,6		
4	PPASR	BLWTU 1	99,6	95,3	148,660	99,11
		BLWTU 2	99,6	95,3		
		SROTAN 1	66,7	68,6		
		SROTAN 2	66,7	68,6		
		MABAR 1	16,3	10,3		
		MABAR 2	19,5	11,2		
		PGELI 1	71,0	45,6		
		PGELI 2	71,0	45,6		
5	MABAR	PPSAR 1	16,3	10,3	148,427	98,95
6	PGELI	PPSAR 2	19,5	11,2		
		PPSAR 1	71,0	45,6	145,006	9,67
		PPSAR 2	71,0	45,6		
		GLUGUR 1	12,9	10,2		
		GLUGUR 2	12,9	10,2		
		TTKNG	17,2	39,3		
		NRMBE	30,0	46,9		
		BNJAI 1	1,3	29,9		
		BNJAI 2	1,3	29,9		
7	BLUGUR	PGELI 2	12,9	10,2	144,552	96,37
		PGELI 1	12,9	10,2		
8	BNJAI	PGELI 1	1,3	29,9	145,839	97,23
		PGELI 2	1,3	29,9		
		PBDAN 1	43,5	1,2		
		PBDAN 2	43,5	1,2		
		BLWCC 1	72,8	48,8		
		BLWCC 2	72,8	48,8		
9	PBDAN	BNJAI 1	43,5	1,2	143,321	95,55
		BNJAI 2	43,5	1,2		

Figure 5. Load curve is known that at some Buses System North of Sumatra-Nanggro Aceh Darussalam experience of change of stress where the condition of night load that is peak load time (WBP) without using capacitor.

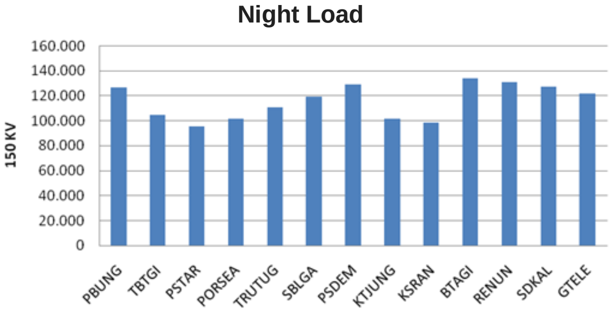

Figure 5: Night Load Curve

Load Flow Analysis Results on Morning Load

From the results of Load Flow analysis can be known, nahwa voltage in the percent limit of voltage see Table 3.

Table 3: Load Flow analysis results, voltage, and percent voltage during the morning load system

NO	BUS	Voltage		NO	BUS	Voltage	
		KV	%			KV	%
1	BLWTU	150	100	18	POR-SEA	130,152	86,77
	BLWTU	150	100	19	TRUTG	137,025	91,35
2	LBHN	149,467	99,64	20	SBLGA	143,140	95,43
3	PPSAR	148,587	99,06	21	PSDEM	147,179	98,12
4	MABAR	148,084	98,72	22	KTJUNG	118,417	78,94
5	PGELI	144,821	96,55	23	KSRAN	114,238	76,16
6	GLU-GUR	144,648	96,43	24	RTPAT	162,000	108
7	BNJAI	144,855	96,57	25	BTAGI	137,091	91,39
8	PBDAN	144,11	96,0	26	RENUN	138,89	92,5

		2	7			2	9
9	TIKNG	141,593	94,40	27	SDKAL	137,666	91,78
10	PBUNG	130.538	87,03	28	GTELE	135,981	90.65
11	NRMBE	142,416	94,78	29	LNGSA	144,043	96,03
12	TMORA	143,506	95,67	30	TLCUT	143,448	95,63
13	GKIM	141,690	95,89	31	IDIE	144,289	96,19
14	MDNA	143,281	95,52	32	LSMWE	145,437	96,96
15	SRO-TAN	143,838	95	33	BIRUN	145,888	97,26
16	TBTGI	121,363	80.91	34	SIGLI	147,353	98,24
17	PSTAR	124,593	83,04	35	BACEH	147,601	98,40

From Figure 6. it is known that in some buses of the North of Sumatra-Nanggro Aceh Darussalam (NAD) system outside the peak load time (LWBP) without using capacitors there are several buses undergoing voltage changes.

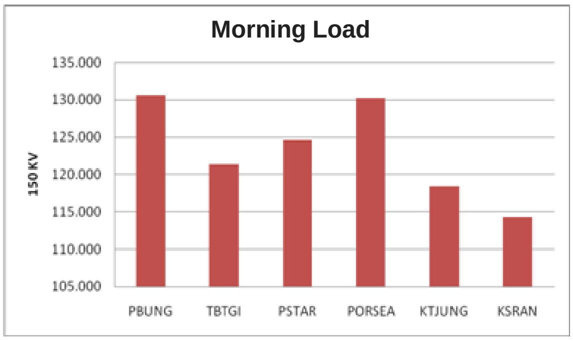

Figure 6: Morning Load Curve

Table 4. Problem bus taken sample 2 Bus as a benchmark for the pairs of capacitors, so that from Bus can be injected ΔQ

Table 4: Buses with night and morning load problems

Analysis results					
Night Load			Morning Expenses		
NO	Name Bus	Voltage KV	Voltage %	Voltage KV	Voltage %
1	PSTAR	94,978	63,32	124,583	83,04
2	KSRAN	98,251	63,50	114,238	76,16
3	TTINGGI	104,624	69,75	121,263	80,91

Load Flow Analysis Results Placement of capacitors at NightLoad

Table 5: before installed capacitor

Capasitor			Voltage on the bus	
No	City/Bus	ΔQ	KV	%
1	PSTAR			
2	KSRAN			
3	PBUNG		126,511	84,34
4	TBTGI		104,424	69,75
5	PORSEA		101,102	67,40
6	TRUTG		110,320	73,55
7	SBLGA		119,111	79,41
8	PSDEM		128,924	85,95
9	KTJUNG		101,368	67,58
10	BTAGI		133,708	89,14
11	RENUN		130,957	87,30
12	SDKAL		127,325	84,88
13	GTELE		121,606	81,07

Table 6: Already in pairs of capacitors in Pstar & Ksran Bus

ΔQ		Voltage on the Bus							
pstar	ksran	p.bung	tbtgi	porsea	trutg	sblga	psdem	ktjung	btagi
		126,50	104,60	101,10	110,30	119,10	128,9	101,3	133,7
-150	-150	129,86	112,19	109,97	116,99	124,98	133,0	110,3	135,4
-225	-225	131,63	116,34	114,86	120,57	128,10	135,11	115,3	136,2
-300	-300	133,42	120,73	120,04	124,30	131,31	137,22	120,6	137,1
-375	-375	135,21	125,31	125,49	128,13	134,58	139,30	126,3	138,0
-450	-450	136,91	130,02	131,14	131,99	137,83	141,27	132,2	138,8
-525	-525	138,43	134,74	136,89	135,76	136,89	143,06	138,31	139,5
-540	-540	138,61	135,32	137,88	136,42	137,88	143,36	138,7	139,6

Information
The red red colour parameter has not been fixed
The black colour parameter has been fixed (MVAR inject)

Load Flow Analysis Results Capacitor Placement on Morning Load

Table 7: Before installing Capacitors in Tbtgi&Ksran Buses

No	Bus	Capasitor	Voltage on the bus	
		ΔQ	KV	%
1	TBTGI			
2	KSRAN			
3	PBUNG		130,538	87,03
4	PSTAR		124,593	83,06
5	PORSEA		130.152	86,77
6	KYJUNG		118,417	78,94

Table 8: Already in Pairs of Capacitors in Tbtgi&Ksran Bus

No	ΔQ		Voltage on the Bus			
	tbtgi	ksran	pbung	pstar	porsea	ktjung
-			130,538	124,593	130,152	118,417
1	-90	-90	133,816	130,904	135,059	126,687
2	-135	-135	135,076	133,354	136,959	129,361
3	-180	-165	136,763	136,658	139,501	133,643
4	-210	-180	137,699	138,467	140,828	135,803

6. Conclusion

After the simulation, the results of the research can be concluded from the analysis of power flow system of North of Sumatra-Nanggro Aceh Darussalam (NAD) power plant using ETAP 4.0 program simulation is:

1. The voltage on each bus depends on the amount of reactive power on the bus
2. Lowest voltage for every problem review on bus 150 KV, ie in bus PSTAR and bus KSRAN
3. Voltage for the RTPAT 150 KV Bus peaked at 162 KV an average 108% Over voltage condition, where its MW is known while MVAR is unknown.
4. The highest power flow is in the transmission line between the BLWCC bus and S. Rotan.
5. Losses transmissi highest for each problem review is the transmission channel RTPAT-KSRAN
6. Losses the greater if the distance of the transmission line increases the greater the losses on the channel the greater.
7. The transmission channel of 13 buses is fixed by placement and using Capacitors
8. The capacitor connected to the PSTAR bus and the KSRAN bus to fix the voltage becomes problematic
9. From the analysis, for troubled fixes generated or injected reactive power -540 MVAR, -525 MVAR, -210 MVAR and -180 MVAR of Capacitors
10. Reactive forces exported by PSTAR bus and KSRAN buses may be reduced by 34.47% and 35.16% and 10.8% and 14.34%

Suggestions

For the perfection of this research it is necessary suggestion that can from analysis of power flow of system of generation of North Sumatra using simulation program ETAP 4.0 is

1. Matters to be considered for power flow analysis using ETAP 4.0 is the allocation of active power, reactive power and the desired voltage no bus

2. To produce an optimal power flow analysis then before doing the power flow analysis should be optimized for power distributed power plant
3. To produce an optimal power flow analysis then before doing the power flow analysis should be optimized for power distributed power plant
4. The result of power flow analysis in North of Sumatra-Nanggro Aceh Darussalam (NAD) generation system can be developed:
    a. Transient analysis of stability of North of Sumatra - NAD generation system
    b. Optimization of reactive power allocation

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