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A Voltage Analysis of The Transmission Network in The Aceh Subsystem During the Energization of the 275 Kv Nagan–Sigli Sutet using Digsilent

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ABSTRACT

Voltage In Accordance With A Steady State. In 2023, The Aceh Subsystem Received An Additional 440 Mw Of Power Plants And In 2025 Will Be Energized Sutet Nagan - Sigli 275 Kv #1 Then With The Addition Of This Network There Will Be Changes In The Transmission Network. Based On The Problems Above, The Author Will Analyze The Impact That Occurs When The Conductor Enters. In This Final Project, A Simulation Is Carried Out With The Entry Of The Conductor And The Voltage Response In The Aceh Subsystem Using The Digsilent Power Factory 15.1 Application. So That The Location That Experiences High Voltage At The Main Substation Is Obtained, Both At Gi 150 Kv Or Gitet 275 Kv. The Simulation Results Show That When Energizing The Conductor Sutet Nagan - Sigli 275 Kv #1 Will Have An Impact On Overvoltage Voltage In Almost All Main Substations. In Overcoming This, It Is Highly Recommended To Install A Reactor At Gitet Sigli As A Node Substation To Improve The Voltage To Be Stable According To Pln Recommendations.

Keywords: Voltage stability,High voltage, and Energizing Substation.

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1. INTRODUCTION

Voltage stability is an important part of the operation of an electric power system. Voltage instability is the inability of the system to maintain the voltage profile within the permissible limits after a disturbance or change in system configuration. Every electric power system is expected to maintain its voltage stability (Anisah, S. 2017).

A system can be said to be stable if the voltage is within the tolerance limit of the nominal voltage set by PLN (Kassakian, J. et al 2023). In addition to being caused by disturbances, the system can be categorized as experiencing voltage instability if there is an increase in load, the release of transmission lines, changes in system configuration or generators that are suddenly removed from the system which causes the voltage to be outside the specified stability limits of the electric power system Anisah, (Siti, et al, 2018). The highest voltage ever achieved in SS Aceh is 300 kV at GITET Nagan and 300 kV at GITET Sigli in June 2024 and with an average power supply capacity (DMP) of 720 MW so that there is an energy surplus of 80 MW that will be transferred to SS Sumut. This surplus is due to the operation of the Nagan Raya PLTU units 3 and 4 at the end of 2023.

Strengthening of the Aceh Subsystem's electrical energy is increasingly being improved, one of which is by building the Nagan - Sigli 275 kV SUTETdelivery person#1 which will operate in 2025. By energizing the Nagan - Sigli 275 kV SUTET line #1, it will affect the voltage profile of the Main Substations (GI) spread across the Aceh Subsystem. As regulated in the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 20 of 2020 concerning the Electric Power System Network Regulations (Grid Code) for system voltage with a nominal voltage of 150 kV must be maintained within the limits of -10% and +5% of 150 kV; so it must be in the range of values 135 to 157.5 kV and for system voltage with a nominal voltage of 275 kV must be maintained within the limits of -5% and +5%, namely in the range of values 261.25 kV to 288.75 kV (Tharo, Z., et al 2024).

To determine the effect of the operation of the Nagan - Sigli 275 kV line #1 SUTET on the Sumatra electricity system, especially the Aceh Subsystem, a power flow study is needed (Ali, O., et al 2024). The study will obtain the active power flow and reactive power on each channel and also the voltage and voltage angle of each GI bus in the Aceh Subsystem. The power flow study can be done using the Newton-Raphson method, but for ease of calculation, a simulation will be carried out using the Digital SImuLation Electrical NeTwork calculation program (DigSILENT) computer program Rahmaniar, (R., et al 2021).

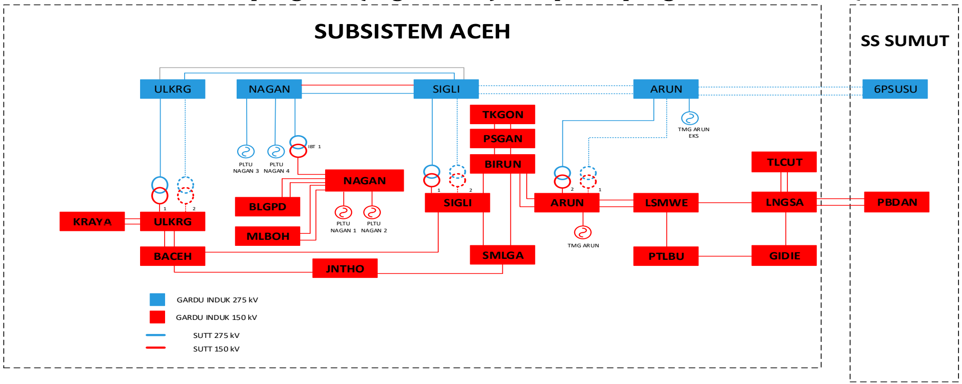


Figure 1. Single Line Diagram Subsystem Aceh

2. RESEARCH STAGES

2.1 . Data Load Flow

Aceh subsystem load flow data is entered after the single line diagram is represented into the DIgSILENT program. The data needed is primary data from the Generator (generator), Transmission and Transformer. This time the study used to determine the impact of the voltage profile on the operation of the Nagan - Sigli 275 kV # 1 SUTET uses a power flow study (Load Flow Analysis) (Marsudi Djiteng, 2015.).

2.2. Data Generator (Generator)

The generator data required is the generator rating on the generator, which DIgSILENT can then automatically calculate into other data required for filling in basic data in the form of capacity, voltage and power factor (Aryza, S., et al ,2024). as in Table 1 below:

Table 1. Simulation Generator Parameter Data according to realization

PEMBANGKIT	DMN (MW)	Active Power	Reactive Power	u, Magnitude	Power Factor
		MW	Mvar	p.u.	
PLTMG ARUN 1	8,5	0	0	0	1
PLTMG ARUN 10	8,5	0	0	0	1
PLTMG ARUN 11	8,5	8,500006	2,000002	1,047329	0,9734172
PLTMG ARUN 12	8,5	8,800006	2,000002	1,047329	0,9751328
PLTMG ARUN 13	8,5	8,500006	4,000003	1,047329	0,9048187
PLTMG ARUN 14	8,5	8,000006	2,000002	1,047329	0,9701425
PLTMG ARUN 15	8,5				
PLTMG ARUN 16	8,5				
PLTMG ARUN 17	8,5	0	0	0	1
PLTMG ARUN 18	8,5	0	0	0	1
PLTMG ARUN 19	8,5	0	0	0	1
PLTMG ARUN 2	8,5	0	0	0	1
PLTMG ARUN 3	8,5	0	0	0	1
PLTMG ARUN 4	8,5	0	0	0	1
PLTMG ARUN 5	8,5	0	0	0	1
PLTMG ARUN 6	8,5	0	0	0	1
PLTMG ARUN 7	8,5	0	0	0	1
PLTMG ARUN 8	8,5	0	0	0	1
PLTMG ARUN 9	8,5	0	0	0	1
PLTMG ARUN PEAKER 1	18	12,50001	1,000001	1,048511	0,9968153
PLTMG ARUN PEAKER 10	18				
PLTMG ARUN PEAKER 11	18	0	0	0	1
PLTMG ARUN PEAKER 12	18	0	0	0	1
PLTMG ARUN PEAKER 13	18	0	0	0	1
PLTMG ARUN PEAKER 2	18	11,00001	2,000002	1,048511	0,9838699
PLTMG ARUN PEAKER 3	18	11,00001	1,000001	1,048511	0,9958932
PLTMG ARUN PEAKER 4	18				
PLTMG ARUN PEAKER 5	18				
PLTMG ARUN PEAKER 6	18				
PLTMG ARUN PEAKER 7	18				
PLTMG ARUN PEAKER 8	18				
PLTMG ARUN PEAKER 9	18				
PLTU NAGAN RAYA 1	80	65	-23,1612	1	0,9419854
PLTU NAGAN RAYA 2	80	65	-23,1612	1	0,9419854
PLTU NAGAN RAYA 3	200	140,0001	15	1,903921	0,9943092
PLTU NAGAN RAYA 4	200	140,0001	-10	1,89155	0,9974587

2.3. Transmission Data

The required transmission data is the transmission rating of the conductor wire used to transmit power, which DIgSILENT can then automatically calculate the rating data into other data required for filling in basic data such as positive sequence impedance Z1, positive sequence angle, positive/zero sequence reactance X0/X1 (Solin, Y. S., et al. 2024).

Table 2. Simulation Transmission Parameter Data

Penghantar	Nominal Current	Length	Irated	R1	X1	R0	X0	B1
	kA	km	kA	Ohm	Ohm	Ohm	Ohm	uS
ACEH - ULEE KARENG 1	0,638	14,5	0,638	1,732897	5,917744	4,945517	18,14879	41,0613
ACEH - ULEE KARENG 2	0,638	14,5	0,638	1,732897	5,917744	4,945517	18,14879	41,0613
ARUN - SIGLI 1		166	1,822	6,22127	50,26167	41,11557	181,0969	633,5023
ARUN - SIGLI 2		166	1,822	6,22127	50,26167	41,11557	181,0969	633,5023
BIREUN - ARUN 1	1,25	48,93	1,25	4,498881	20,50118	15,33981	61,77464	138,4986
BIREUN - ARUN 2	1,25	48,93	1,25	4,498881	20,50118	15,33981	61,77464	138,4986
BIREUN - SAMALANGA 1	0,638	38,46	0,638	4,596361	15,6963	13,11756	48,1381	108,9116
BIREUN - SIGLI 2	0,638	99,43	0,638	11,8829	40,5794	33,91261	124,4506	281,5673
BIREUN - TAKENGON 1	1,276	73,51	1,276	4,411534	21,10826	20,69841	83,11545	294,7957
BIREUN - TAKENGON 2	1,276	73,51	1,276	4,411534	21,10826	20,69841	83,11545	294,7957
BLANG PIDIE - TAPAK TUAN 1		65	0	0	0	0	0	0
BLANG PIDIE - TAPAK TUAN 2		65	0	0	0	0	0	0
IDIE - PANTON LABU	1,25	55,95	1,25	5,144337	23,4425	17,54062	70,63747	158,369
JANTHO - ACEH	0,638	32,92	0,638	3,934274	13,43532	11,22803	41,20401	93,22331
KRUENG RAYA - ULEE KARENG 1	0,638	17,5	0,638	2,091428	7,142104	5,968727	21,90371	49,55674
KRUENG RAYA - ULEE KARENG 2	0,638	17,5	0,638	2,091428	7,142104	5,968727	21,90371	49,55674
LANGSA - IDIE	1,25	46,13	1,25	4,241435	19,32801	14,462	58,23961	130,5731
LANGSA - LHOKSEUMAWE	1,25	128,57	1,25	11,8214	53,86956	40,30737	162,321	363,9233
LANGSA - TUALANG CUT 1	0,638	24,07	0,638	2,87661	9,823454	8,209558	30,12699	68,16176
LANGSA - TUALANG CUT 2	0,638	24,07	0,638	2,87661	9,823454	8,209558	30,12699	68,16176
LHOKSEUMAWE - ARUN 1	1,25	17,4	1,25	1,599847	7,290427	5,454991	21,96768	49,25149
LHOKSEUMAWE - ARUN 2	1,25	17,4	1,25	1,599847	7,290427	5,454991	21,96768	49,25149
LHOKSEUMAWE - PANTON LABU	1,25	30,62	1,25	2,815364	12,82948	9,59953	38,65807	86,67131
MEULABOH - CALANG 1		90	0	0	0	0	0	0
MEULABOH - CALANG 2		90	0	0	0	0	0	0
NAGAN RAYA - BLANG PIDIE 1	0,638	105,08	0,638	12,55813	42,88528	35,83965	131,5224	297,567
NAGAN RAYA - BLANG PIDIE 2	0,638	105,08	0,638	12,55813	42,88528	35,83965	131,5224	297,567
NAGAN RAYA - MEULABOH 1	1,276	18,3	1,276	1,098233	5,25481	5,15278	20,69123	73,38811
NAGAN RAYA - MEULABOH 2	1,276	18,3	1,276	1,098233	5,25481	5,15278	20,69123	73,38811
NAGAN- SIGLI 1	1,822	166,5	1,822	6,240009	50,41306	41,23941	181,6423	635,4105
NAGAN- SIGLI 2		166,5	1,822	6,240009	50,41306	41,23941	181,6423	635,4105
PANGKALAN BRANDAN - LANGSA 1	1,25	78	1,25	7,17173	32,68122	24,45341	98,47582	220,7826
PANGKALAN BRANDAN - LANGSA 2	1,25	78	1,25	7,17173	32,68122	24,45341	98,47582	220,7826
PANGKALAN SUSU - ARUN 1		224	3644	4,272447	53,87779	51,35873	230,4265	1072,221
PANGKALAN SUSU - ARUN 2		224	3644	4,272447	53,87779	51,35873	230,4265	1072,221
SAMALANGA - SIGLI 1	0,638	65,69	0,638	7,850623	26,80942	22,4049	82,22028	186,0219
SIGLI - ACEH	0,638	90,21	0,638	10,78101	36,81653	30,76794	112,9105	255,4579
SIGLI - JANTHO	0,638	58,9	0,638	7,039149	24,03828	20,08903	73,72164	166,7939
SIGLI - NAGAN RAYA 1		173	1,836	5,873232	52,15023	42,23898	188,5026	660,368
SIGLI - NAGAN RAYA 2	1,836	173	1,836	5,873232	52,15023	42,23898	188,5026	660,368
SIGLI - ULEE KARENG 1	1,822	65	1,822	2,436039	19,68077	16,09947	70,91142	248,0581
SIGLI - ULEE KARENG 2	1,822	65	1,822	2,436039	19,68077	16,09947	70,91142	248,0581

2.4. Transformer Data

The required transformer data is the transformer capacity at the substation or in the generating system, then entered into the DIgSILENT application and automatically calculates the rating data into other data required for filling in basic data such as positive sequence, capacity or zero sequence on the transformer.

Table 3. Simulation Transformer Parameter Data

Lokasi Trafo	Trafo	Kapasitas (MVA)	Act.Pow.	React.Pow.	App.Pow.	Pow.Fact.
L1ACEH 1	TD 1	60	23,3	5,310114	23,89743	0,975
L1ACEH 2	TD 2	60	31,3	7,133339	32,10256	0,975
L1ACEH 3	TD 3	60	23,6	5,378493	24,20513	0,975
L1ARUN 2	TD 1	60	20,2	4,603618	20,71795	0,975
L1ARUN MOB	TD Mobile	60	16,7	3,805972	17,12821	0,975
L1BIREUN 1	TD 1	60	14,4	3,281793	14,76923	0,975
L1BIREUN 2	TD 2	60	14,2	3,236209	14,5641	0,975
L1BLANG PIDIE	TD 1	60	24,6	5,606393	25,23077	0,975
L1IDIE 1	TD 1	20	14,3	3,259001	14,66667	0,975
L1IDIE 2	TD 2	30	11,9	2,712034	12,20513	0,975
L1JANTHO	TD 1	30	8,8	2,005534	9,02564	0,975
L1KRUENG RAYA	TD 1	60	19,7	4,489681	20,20513	0,975
L1LANGSA 1	TD 1	60	19,1	4,352931	19,58974	0,975
L1LANGSA 2	TD 2	30	9,4	2,142284	9,641026	0,975
L1LHOKSEUMAWE 1	TD 1	60	28,4	6,472427	29,1282	0,975
L1LHOKSEUMAWE 2	TD 2	60	11,3	2,575297	11,58974	0,975
L1MEULABOH 1	TD 1	30	12,7	2,894359	13,02564	0,975
L1MEULABOH 2	TD 2	60	16,5	3,760389	16,92308	0,975
L1NAGAN RAYA	TD 1	30	19	4,330143	19,48718	0,975
L1PANTON LABU 1	TD 1	30	16,2	3,692018	16,61539	0,975
L1PANTON LABU 2	TD 2	30	9,3	2,119488	9,538461	0,975
L1SAMALANGA	TD 1	60	13,7	3,122263	14,05128	0,975
L1SIGLI 1	TD 1	60	19,6	4,466876	20,10256	0,975
L1SIGLI 2	TD 2	60	28,4	6,472427	29,1282	0,975
L1TAKENGON	TD 1	60	12,2	2,780409	12,51282	0,975
L1TAKENGON 2	TD 2	60	11,4	2,598088	11,69231	0,975
L1TUALANG CUT 1	TD 1	60	20,8	4,740368	21,33333	0,975
L1TUALANG CUT 2	TD 2	30	7,8	1,777636	8	0,975
L1ULEE KRUENG	TD 1	60	16,3	3,714805	16,71795	0,975

Fig 2. Alur Research

3. RESULTS AND DISCUSSION (10 PT)

3.1 Results of Aceh System Power Flow Before the Entry of the 275 kV Nagan – Sigli SUTET #1

From the results of the power flow simulation using DIgSILENT software during daytime conditions, the voltage value on each busbar has an operating value limit that is still in accordance with the Grid Code or the value recommended by PLN.

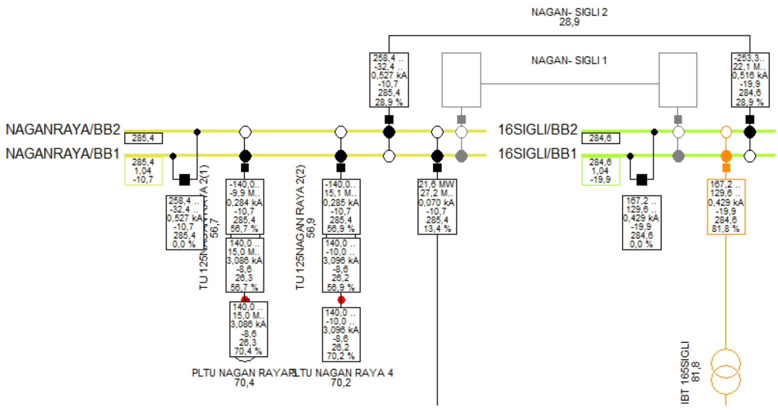


Fig 3.Digsilent PowerFactoryNagan – Sigli 275 kV High Voltage Transmission Line #1before operating

Table 4. Voltage Data Before Operation of SUTET Nagan – Sigli 275 kV #1

NO	KOMPONEN	GARDU INDUK	TEGANGAN (kV)	TEGANGAN SEBELUM ENERGIZE (kV)
1	BB 1	SIGLI	275	282
2	BB 2	SIGLI	275	282
3	BB 1	ULEKARENG	275	279
4	BB 2	ULEKARENG	275	279
5	BB 1	NAGAN	275	286
6	BB 2	NAGAN	275	286
7	BB 1	ARUN	275	286
8	BB 2	ARUN	275	286
9	BB 1	TUALANG CUT	150	151
10	BB 2	TUALANG CUT	150	151
11	BB 1	LANGSA	150	152
12	BB 2	LANGSA	150	152
13	BB 1	IDIE	150	150
14	BB 2	IDIE	150	150
15	BB 1	PANTON LABU	150	152
16	BB 1	LHOKSEUMAWE	150	153
17	BB 2	LHOKSEUMAWE	150	153
18	BB 1	BANDA ACEH	150	152
19	BB 2	BANDA ACEH	150	152
20	BB 1	BLANG PIDIE	150	153
21	BB 2	BLANG PIDIE	150	153
22	BB 1	JANTHO	150	154
23	BB 1	KRUENG RAYA	150	153
24	BB 2	KRUENG RAYA	150	153
25	BB 1	ULEE KARENG	150	152
26	BB 2	ULEE KARENG	150	152
27	BB 1	MEULABOH	150	154
28	BB 2	MEULABOH	150	154
29	BB 1	NAGAN RAYA	150	154
30	BB 2	NAGAN RAYA	150	154
31	BB 1	ARUN	150	156
32	BB 2	ARUN	150	156
33	BB 1	SAMALANGA	150	155
34	BB 2	SAMALANGA	150	155
35	BB 1	BIREUN	150	155
36	BB 2	BIREUN	150	155
37	BB 1	TAKENGON	150	156
38	BB 2	TAKENGON	150	156
39	BB 1	SIGLI	150	159
40	BB 2	SIGLI	150	159
41	BB 1	PEUSANGAN	150	155
42	BB 2	PEUSANGAN	150	155

From the simulation results shown in the table above, the voltage at the Sigli Main Substation is only approaching the maximum limit of the permitted operating voltage value.

3.2 Results of Aceh System Power Flow After the Entry of the 275 kV Nagan – Sigli SUTET #1

After the 275 kV Nagan – Sigli #1 SUTET was entered into the system with Digsilent simulation, the voltage results on each busbar can be seen as follows:

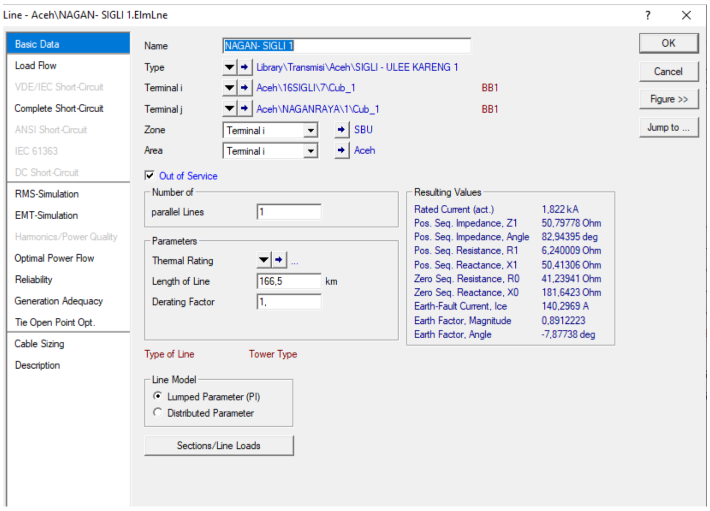


Fig 4.Digsilent PowerFactory (Parameter Settings)Nagan – Sigli 275 kV SUTET #1)

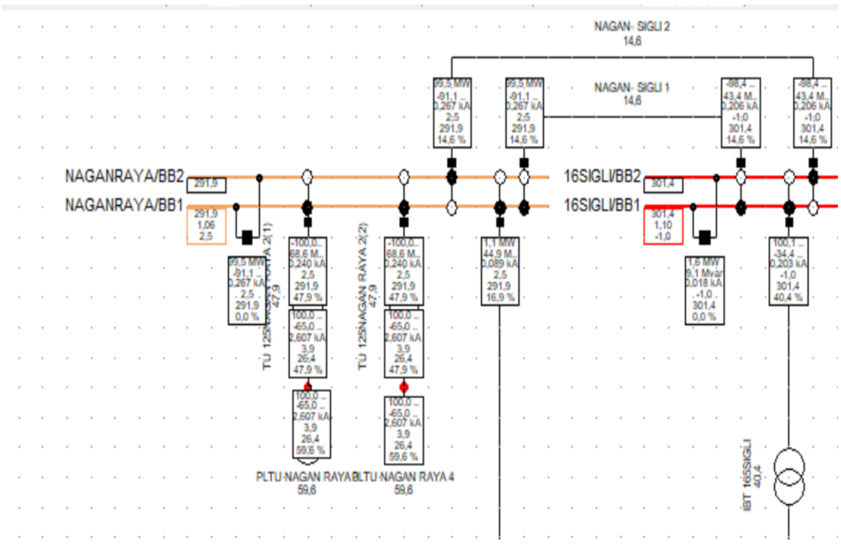
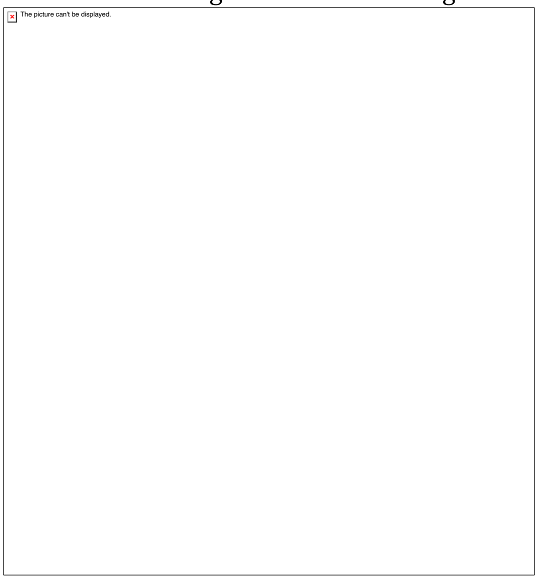


Fig 5. Digsilent PowerFactory Nagan – Sigli 275 kV High Voltage Transmission Line #1*Energize*

Table 5. Voltage Data at SUTET Nagan



– Sigli 275 kV line #1 Energize
= Values that have exceeded the maximum limit permitted by PLN.

The way to calculate voltage loss is using the following formula:
ΔVd(LN) = $VS - VR\ /VS \times 100\%$
VS = Voltage after SUTT*eenergize*
VR = Voltage before SUTT*energize*
ΔVd = Voltage Loss

From the table above, it can be seen that the results of the simulation show that the voltage at several buses or substations exceeds the maximum limit specified, which will result in major disruptions to the Nagan power plant units 1 to 4, where the entire Aceh subsystem load is supplied from this power plant, disruptions to the conductors, damage to the MTU at the substation, all of which will have an impact on widespread consumer outages.

The potential loss arising from power plant disruptions can be calculated as follows by assuming the electricity sales tariff to consumers is 1,444 per / kWh, then the loss can be calculated when the condition of the Nagan PLTU is 400 MW, the number of kWh outages in 1 hour

=400 x 1,000 x 1 = 400,000 kWh

Amount of rupiah in 1 hour

=400,000 x 1,444.7 x 1 = Rp. 577,880,000.

3.2 Results of Aceh System Power Flow After the Entry of the 275 kV Nagan – Sigli #1 SUTET with the Installation of Reactors at the Sigli GITET

The high voltage generated when the 275 kV Nagan – Sigli #1 SUTET enters the Aceh subsystem can be overcome by installing a reactor, one of the functions of which is to compensate for Var. through the application*Digsilent*we can do simulation related to the need for reactors that help reduce voltage by absorbing MVAR.

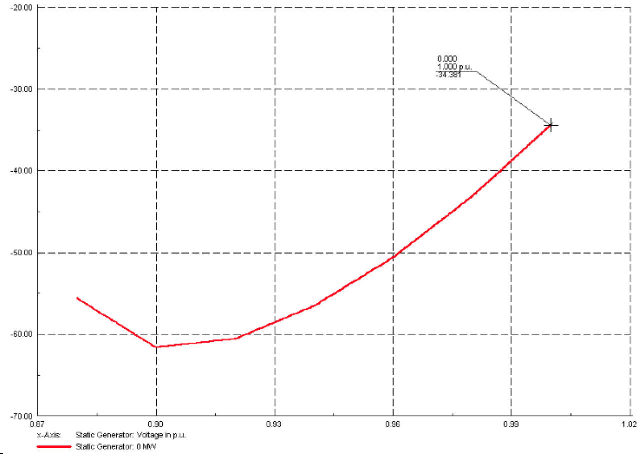


Fig 6. The need for a 25 Mvar reactor in the Aceh subsystem

The following are the data results that have been calculated by the Digsilent application for the reactor installation at GITET Sigli which has the highest voltage:

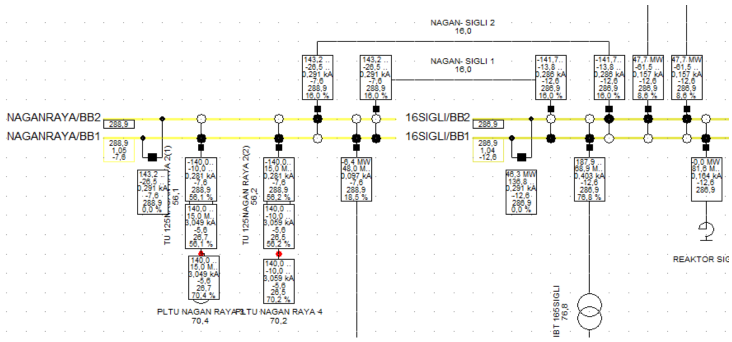


Fig 6. Digsilent PowerFactorySUTET Nagan – Sigli 275 kV #1 and reactorafter operation

4. CONCLUSION

After conducting an analysis using Digsilent PowerFactory in this final assignment, it was found:

1. Voltage instability caused by the addition or operation of the 275 kV Nagan – Sigli #1 SUTET on the 275 kV and 150 kV transmission in the Aceh Subsystem.
2. At the time of the entry of the 275 kV Nagan - Sigli #1 SUTET in the Aceh subsystem, the voltage in all substations exceeded the operating voltage limit permitted by PLN, namely -10% and +5% of 150 kV; which should be in the range of 135 to 157.5 kV and for the system voltage with a nominal voltage of 275 kV must be maintained within the limits of -5% and +5%, namely in the range of 261.25 kV to 288.75 kV.
3. InTo overcome the case of overvoltage at the main substation, the author recommends installing a reactor at GITET Sigli so that the voltage pattern in the Aceh Subsystem is within the safe limits desired by PLN.

For the development of this final assignment, further calculation development can be carried out with reactor settings.

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