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T junction configuration performance in a transmission subsystem

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Abstract

A cement factory, namely PT Semen Imasco Asiatic, requires a large supply of power for production. However, in the area where the cement factory was established, namely Puger District, there was no electricity capable of supplying it, so PLN built the Puger substation. In the original plan, the transmission line will be built directly from GI Tanggul to GI Puger. However, because the plant must operate immediately, the electricity supply is taken from the existing Tanggul substation-Jember substation transmission line using the T-Junction configuration. In this paper, an analysis of the power flow of the Paiton-Grati subsystem will be carried out when the power supply from Tanggul Substation to Puger Substation is passed through the T-Junction configuration or when the transmission line is connected from the Tanggul Substation to the Puger Substation directly. The result of this research is that there is no significant difference between the two conditions in power losses, voltage drop, current, and power factor parameter so that the T-Junction configuration is quite feasible to use even though it is temporary.

Keywords : power flow, power losses, Puger substation, T Junction configuration, Tanggul Substation, voltage drop

1 Introduction

Electrical energy has an important role in human life. Electricity consumption has been rising quickly recently due to the rapid increase of the human population, buildings, and technological applications [1]. The use of electricity is on the rise because it is a more efficient replacement for traditional fuels like coal, natural gas, and human muscles. Electrical energy is used in several sectors, namely household, business, social, government office buildings, public street lighting, industrial, etc. [2]. PT. Semen Imasco Asiatic, which operates in the industrial sector, requires a large supply of electricity. Cement production is a very energy-intensive and polluting industry. A modern cement plant's normal electrical energy use is around 110–120kWh per ton of cement [3]. In Jember Regency area, precisely in Puger District, there is not enough electricity to supply cement production, therefore PT. Semen Imasco Asiatic ordered PT. PLN (Perusahaan Listrik Negara) to build a transmission line that can supply sufficient electricity for the cement production process. Due to the short deadline of the transmission line construction process, PT. PLN made a breakthrough in the construction of a transmission line, temporarily built a T junction configuration transmission line (see Figure 1).

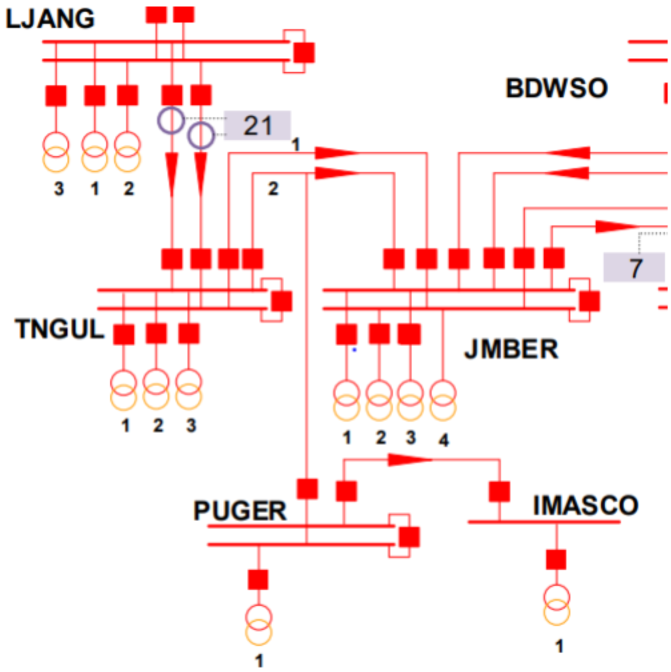

Figure 1: T junction configuration between Tanggul Substation and Puger Substation

The performance of this T connection needs to be analyzed using power flow analysis. There are already a variety of grid operating and planning analysis tools available. These can be grouped into those following categories: 1. frequency domain steady-state analysis (power flow, three-phase power flow, and harmonic studies), 2. time domain transient and steady-state analysis, 3. resource optimal dispatch analysis, and 4. various market dispatch-based analyses [3]. The most important analysis for power system planning, operation, and control is load flow (or power flow), which provides the initial conditions for power system studies such as stability and security evaluations [4]. The magnitudes and phase angles of load bus voltage, reactive powers as well as voltage phase angles at generator buses, real and reactive power flow on transmission lines, and power at the reference bus are among the primary findings of the load flow research. Other variables are also mentioned [5]. There are three methods can be used in load flow analysis. They are Gauss-Seidel method, Newton-Raphson method and Fast-Decoupled method [6]. The Gauss-Seidel method is simple and straightforward to use, although it takes longer (more iterations) as the number of buses grows. The Newton Raphson approach is more accurate than all others and yields better results in fewer iterations. The Fast Decoupled approach is the quickest of all, but it is also the least accurate because assumptions are made to speed up the calculation [7]. The Gauss-Seidel method can be used to adjust the magnitude and angle of voltages. As a result, it can be used to boost the power transfer capability of existing transmission lines while lowering operational and investment expenses [8].

Many researchers have conducted research on power flow in a transmission system, but there has been no research founded that has analyzed the power flow in a transmission system with a T junction. A power flow analysis was performed to select electrical equipment settings based on output data, with the power flow analysis corresponding to planning and design fundamentals. The required input for electrical system modeling is discussed in line with the standards and can withstand worst-case scenarios [9]. A classification of the load flow equation, the different bus types, and the most widely used methods for solving power flow equation problems and a comparison of their performance are provided in [10]. The results of the Newton-Raphson method perform all components of the grid including generators, transmission lines and load equivalent profiles. This paper presents the results of the analysis of the Paiton-Grati subsystem power flow with T Juntion amongs Tanggul-Puger-Jember Substation using ETAP software. The Paiton-Grati subsystem is part of the East Java Province Electricity System (see Figure 2). There are also five other subsystems, namely the Ngimbang subsystem, the Krian-Gresik subsystem, the Kediri subsystem, the Krian subsystem, and the Paiton-Grati subsystem.

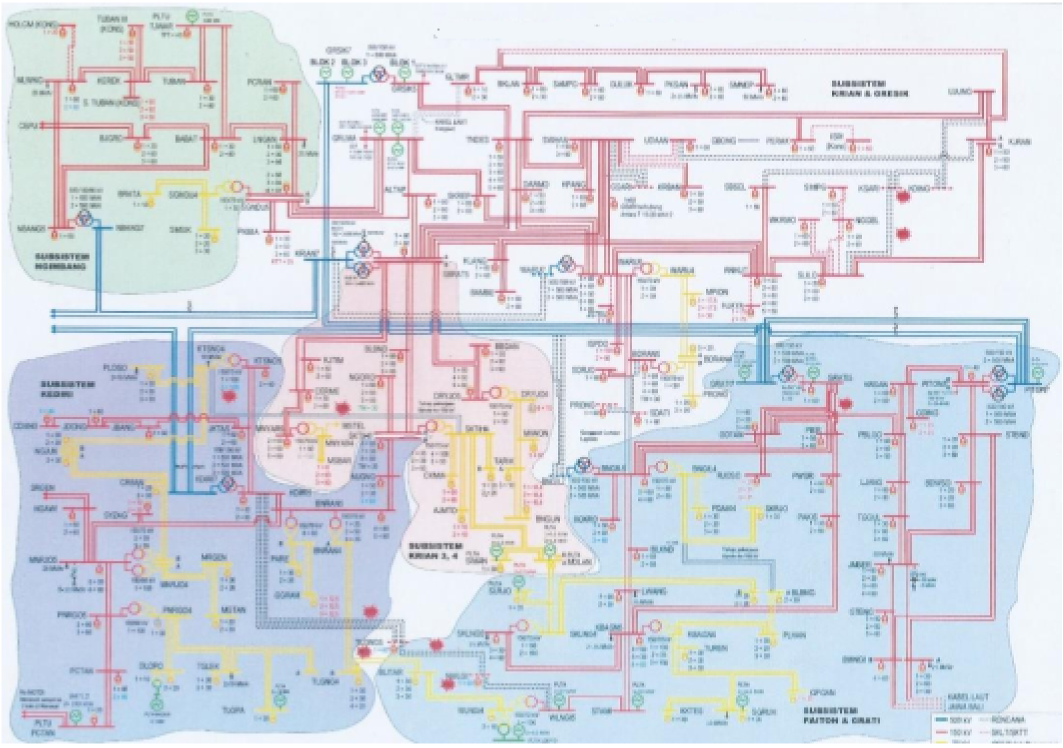

Figure 2: Electrical System Configuration of East Java Province

Due to the fact that in the future a transmission line will be built that directly connects the Tanggul Substation and the Puger Substation so that the T junction is no longer used, a power flow analysis will also be carried out in that condition (see Figure 3).

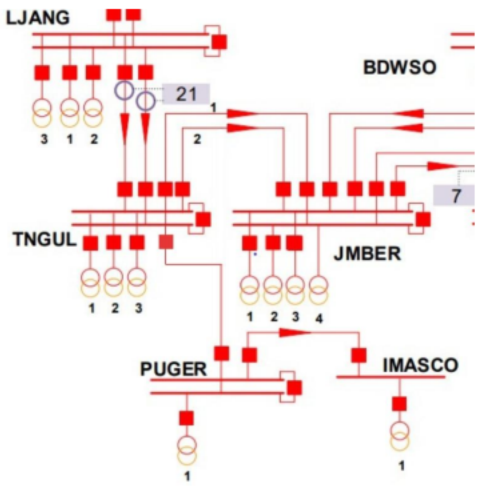

Figure 3: Transmission line between Tanggul Substation and Puger Substation Without T Junction Configuration

2 Method

This research was conducted in several stages which will be described as follows.

2.1 Data Collecting

The first step of this research is to obtain research data in the form of a single line diagram of the Paiton-Grati sub-system and transmission line parameter data. The transmission line parameters obtained consist of system voltage, transmission line distance between buses, type of transmission line conductor between buses, cross-sectional area of the conductor, and current-carrying ability of the conductor. The place of data collection is from PT. PLN (Persero) Operational Service Unit (UP2B) East Java and APP Malang.

2.2 Modelling Paiton-Grati Subsystem

Based on the single line diagram that has been obtained, the Paiton-Grati subsystem is redrawn in ETAP and parameter data is entered to resemble the actual conditions. ETAP (Electrical Transient Analyzer Program) is an analysis platform for generation, transmission, distribution, and industrial power systems design, simulation, operation, control, optimization, and automation. Arc flash, load flow, short circuit, relay coordination, cable capacity, transient stability, optimal power flow, and more are among the software solutions offered by ETAP [11]. There are two models of the Paiton-Grati subsystem, they are subsystem with a T junction amongs Tanggul-Puger-Jember substation and without junction.

2.3 Simulating Paiton-Grati Subsystem

The simulation was carried out using ETAP software to analyze the performance of the Paiton-Grati subsystem with T-Junction. The simulation results are in the form of power flow analysis. A power flow analysis focuses on different types of AC power and typically uses simplified notation such as a single line diagram and per-unit system (i.e.: voltages, voltage angles, real power and reactive power) [12]. The power flow analysis method used is the Newton-Raphson method.

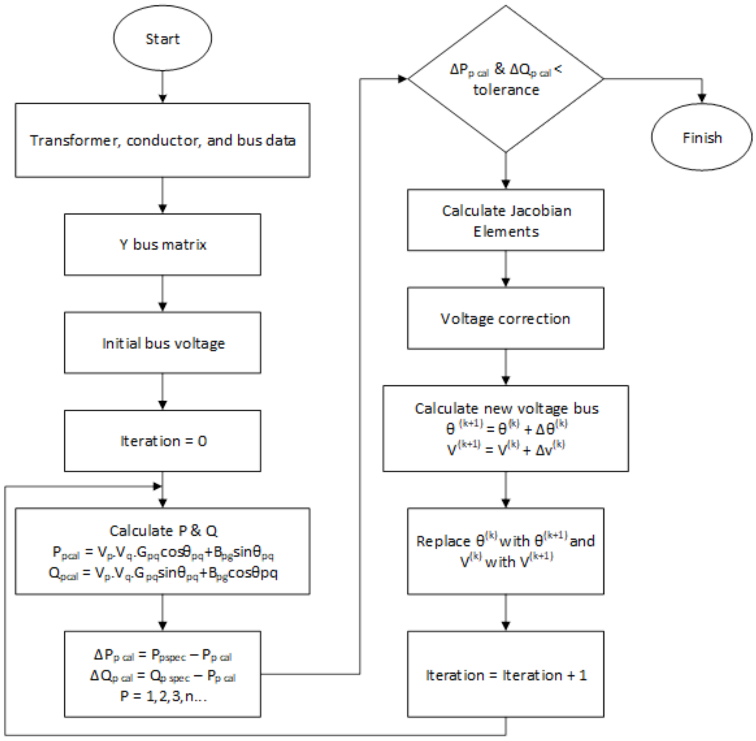

Figure 4: Flowchart of Newton Rhapson Method

The parameters that are the focus of this simulation are voltage drop and power losses. The energy given by a voltage source is diminished as electric current passes through the passive components of an electrical circuit, which is referred to as voltage drop [13]. Voltage drop is often expressed as a percentage after being compared with the voltage at the receiving end (V_r) [14].

$$\Delta U\% = \frac{V_s - V_r}{V_r} x100\% \tag{1}$$

Electrical energy generated at power plants is transported to load centers, where it is delivered to consumers via transmission lines that connect one location to another. Some of the transmitted power is lost to the environment due to the physical qualities of the transmission medium. Because transmission lines typically span vast distances, sometimes hundreds of kilometers, power losses could eat up a significant amount of the transferred electricity. The overall consequence of power losses on the system is that the amount of power accessible to users is reduced [15]. Transmission line losses cause the received power on a bus to be reduced with the power delivered or sent. The number of losses affects the amount of power that must be sent. So that the power delivered must exceed the required power to match the demand from the customer.

2.4 Comparing Paiton-Grati Subsystem With T-Junction and Without T-Junction

At this stage, the simulation results of power flow from both configurations, subsystems with T Junction and without T junction, are compared. The main compared parameters are voltage drop and power losses. The results of this comparison will be used as material for discussion and drawing conclusions. The flow chart of this research can be seen in Figure 5.

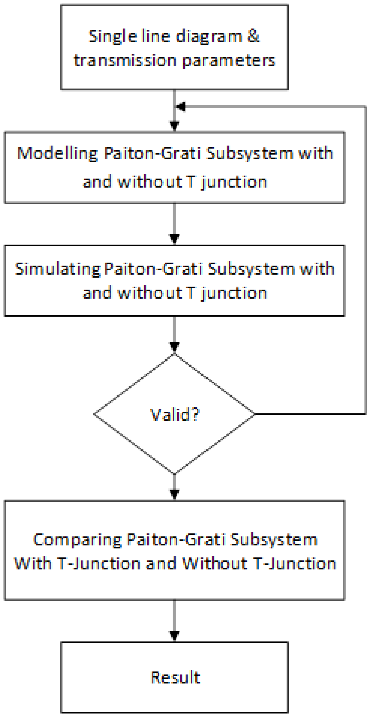

Figure 5: Flowchart of evaluating two different configurations in same subsystem

3 Results and Discussion

3.1 Modelling of Paiton-Grati Subsystem

3.1.1 With T-Junction

The paiton-grati subsystem is redrawn in the ETAP software based on the image... After that, the transmission parameter data is inputted into the available program. The image of the embankment-puger subsystem modeling without T-Junction can be seen in Fig..

3.1.2 Without T-Junction

While the modeling drawing of the paiton-grati subsystem without T-Junction, where GI Tangul and GI Puger are directly related, can be seen in Figure...

3.2 Simulation of Paiton-Grati Subsystem

3.2.1 With T-Junction

By studying the power flow, we can find out the voltage on each bus in the system, both magnitude and phase angle of the voltage, active power and reactive power flowing in each line in the system, the condition of all equipment, whether it meets the limits specified for distributing desired power. Power flow analysis is carried out to evaluate several parameters, including voltage drop and transmission line losses. In the Table 1 you can see the load flow simulation results of Paiton-Grati Subsystem with T-Junction.

Table 1: Load flow simulation results of Paiton-Grati Subsystem with T-Junction

No.	Transmission Channel	Simulation		Current (A)	% PF
		P (MW)	Q (MVAR)		
1	BCKRO1-NPDAN1 150	21.4	6.9	88.7	95.2
2	BCKRO2-NPDAN2 150	21.4	6.9	88.7	95.2
3	BNGIL1-BCKRO2 150	41.9	15.1	175.5	94
4	BNGIL2-BCKRO2 150	41.9	15.1	175.6	94
5	BNGIL1-LWANG2 150	127.7	25.3	513.4	98.1
6	LWANG1-KBAGN1 150	44.1	12.1	185.8	96.4
7	LWANG2-KBAGN1 150	44.1	12.1	185.8	96.4
8	KBAGN1-SKLNG2-A 150	63.1	39.7	306.6	84.6
9	KBAGN1-SKLNG2-B 150	63.1	39.7	306.6	84.6
10	STAMI-KBAGN2-A 150	1.5	17.6	72.7	8.5
11	STAMI-KBAGN2-B 150	1.5	17.6	72.7	8.5
12	STAMI-WLNGI 150	62.8	44.7	320.2	81.5
13	PAKIS1-KBAGN2 150	96	22.6	403.5	97.3
14	PAKIS2-KBAGN2 150	96	22.6	403.5	97.3
15	PWSARI1-PAKIS2 150	116.7	35.1	488.4	95.8
16	PWSARI2-PAKIS1 150	116.7	35.1	488.4	95.8
17	PIER1-PWSAR1 150	137	47.4	570.1	94.5
18	PIER2-PWSARI2 150	137	47.4	570.1	94.5
19	PIER1-BNGIL1 150	63.1	27.8	271	91.5
20	PIER2-BNGIL2 150	63.1	27.8	271	91.5
21	GDTAN1-PIER1 150	115.7	33.5	470	96.1
22	GDTAN2-PIER2 150	115.7	33.5	470	96.1
23	GRATI2-PIER1 150	106.7	59.2	459	87.4
24	GRATI2-PIER2 150	106.7	59.2	459	87.4
25	GRATI2-GDTAN1 150	183.3	126.3	837.2	82.4
26	GRATI2-GDTAN2 150	183.3	126.3	837.2	82.4
27	GDTAN1-RJOSO 150	25.2	11.6	108.4	90.8
28	GDTAN2-RJOSO 150	25.2	11.6	108.4	90.8

No.	Transmission Channel	Simulation		Current (A)	% PF
		P (MW)	Q (MVAR)		
29	GDTAN1-PBLGO1 150	30.3	21.9	146.2	81.1
30	GDTAN2-PBLGO2 150	126.7	-62.8	563.8	-89.6
31	PBLGO1-LJANG1 150	14.5	15.6	84.7	68.1
32	PBLGO2-LJANG2 150	102.8	0.4	409.9	-100
33	LJANG1-TNGUL1 150	26.4	-8.1	111.8	-95.7
34	LJANG2-TNGUL2 150	26.4	-8.1	111.8	-95.7
35	TNGUL2-JMBER2 150	11.1	-6.8	92.9	-40.7
36	TNGUL1-JMBER1 150	9.3	-21	52.8	85.1
37	TNGUL1-PUGER2 150	12.9	7.2	59.8	87.4
38	PUGER1-IMASCO 150	7.8	5.7	38.8	80.7
39	KRSAN1-PBLGO2 150	276.4	48.2	1093	-98.5
40	KRSAN2-PBLGO1 150	open	open	open	open
41	GDING-KRSAN1 150	5.1	2.3	22	91.3
42	GDING-KRSAN2 150	5.1	2.3	22	91.3
43	PITON2-KRSAN1 150	36.2	37.1	198.9	69.8
44	PITON2-KRSAN2 150	283.9	-69.9	1122	-97.1
45	PITON2-STBDO1 150	145.9	17.1	563.9	99.3
46	PITON2-STBDO2 150	145.9	17.1	563.9	99.3
47	STBDO1-BDWSO1 150	53.7	8.1	212.7	98.9
48	STBDO2-BDWSO2 150	53.7	8.1	212.7	98.9
49	BDWSO1-JMBER1 150	41.4	3	164.6	99.7
50	BDWSO2-JMBER1 150	41.4	3	164.6	99.7
51	JMBER1-GTENG1 150	26.4	1	105.6	99.9
52	JMBER2-BWNGI1 150	0.6	9.9	38.9	5.7
53	GTENG1-BWNGI2 150	52.3	26.1	230.5	89.4
54	STBDO1-BWNGI1 150	81	-8.4	319.2	-99.5
55	STBDO2-BWNGI2 150	81	-8.4	319.2	-99.5
56	SKLNG2-BLBNG1 A 70	36.3	35.9	437.5	71.1
57	SKLNG2-BLBNG1 B 70	36.3	35.9	437.5	71.1
58	SKLNG2-SLRJ1 A 70	0.9	0.2	7.5	98
59	SKLNG2-SLRJ1 B 70	0.9	0.2	7.5	98
60	WLNGI1-LDOYO1 70	4.5	1.2	40.8	96.6
61	KBAGN3-TUREN1 70	35.2	4.3	293.1	99.3
62	KBAGN3-PLHAN2 70	6.7	1.6	57.3	97.2
63	KBAGN4-PLHAN2 70	6.7	1.6	57.3	97.2
64	KBAGN4-SGRUH1 70	33.7	-6.3	283	-98.3
65	BLBNG2-PLHAN1 A 70	12	28.8	271.1	38.5
66	BLBNG2-PLHAN1 B 70	12	28.8	271.1	38.5
67	TUREN1-GPGAN1 70	4.1	-9	84.4	-41.3
68	SGRUH1-GPGAN1 70	7.1	5.6	76.4	78.6
69	SGRUH1-KKTES1 70	5.8	2.1	51.7	93.9
70	SGRUH1-KKTES2 70	5.8	2.1	51.7	93.9

Row with yellow color from the Table 1 is the T-Junction transmission line that is linking Tanggul and Puger Substation. Based on the simulation results, it is known that $V_{Tanggul} = 142.7$ kV and $V_{Puger} = 143.1$ kV, then the amount of % V_{drop} based on the formula is 0.279%. From the calculation results using the formula, it shows that the % V_{drop} value is below zero. This indicates that the voltage profile of the sending bus, namely the TANGGUL-1 bus, is smaller than the PUGER-2 bus, which is 143.1 kV. So that's what causes % V_{drop} to be negative.

Based on the calculation results, it is known that the TANGGUL-1 to PUGER-2 line has $P_{losses} = 0.000032$ MW and $P_{tanggul-puger} = 12.9$ MW. Then the value of % Losses from the line based on the formula is 0.000248%.

3.2.2 Without T-Junction

The simulation results of the power flow of Paiton-Grati Subsystem without T-Junction (directly Tanggul to Puger Substation) can be seen in Table 2 below. Row with red color from the Table 1 is the T-Junction transmission line that is linking Tanggul and Puger Substation.

Table 2: Load flow simulation results of Paiton-Grati Subsystem without T-Junction

No.	Transmission Channel	Simulation		Current (A)	% PF
		P (MW)	Q (MVAR)		
1	BCKRO1-NPDAN1 150	21.4	6.9	88.7	95.2
2	BCKRO2-NPDAN2 150	21.4	6.9	88.7	95.2
3	BNGIL1-BCKRO2 150	41.9	15.1	175.6	94
4	BNGIL2-BCKRO2 150	41.9	15.1	175.6	94
5	BNGIL1-LWANG2 150	127.7	25.3	513.3	98.1
6	LWANG1-KBAGN1 150	44.1	12.1	185.8	96.4
7	LWANG2-KBAGN1 150	44.1	12.1	185.8	96.4
8	KBAGN1-SKLNG2-A 150	63.1	39.7	306.6	84.6
9	KBAGN1-SKLNG2-B 150	63.1	39.7	306.6	84.6
10	STAMI-KBAGN2-A 150	1.5	17.6	72.7	8.5
11	STAMI-KBAGN2-B 150	1.5	17.6	72.7	8.5
12	STAMI-WLNGI 150	62.8	44.7	320.2	81.5
13	PAKIS1-KBAGN2 150	95	22.6	403.5	97.3
14	PAKIS2-KBAGN2 150	96	22.6	403.5	97.3
15	PWSARI1-PAKIS2 150	116.7	35.1	488.4	95.8
16	PWSARI2-PAKIS1 150	116.7	35.1	488.4	95.8
17	PIER1-PWSAR1 150	137	47.4	570.1	94.5
18	PIER2-PWSARI2 150	137	47.4	570.1	94.5
19	PIER1-BNGIL1 150	63.1	27.8	271.1	91.5
20	PIER2-BNGIL2 150	63.1	27.8	271.1	91.5
21	GDTAN1-PIER1 150	115.7	33.5	470.4	96.1
22	GDTAN2-PIER2 150	115.7	33.5	470.4	96.1
23	GRATI2-PIER1 150	106.8	59.2	459.2	87.5
24	GRATI2-PIER2 150	106.8	59.2	459.2	87.5
25	GRATI2-GDTAN1 150	183.5	126.2	837.7	82.4
26	GRATI2-GDTAN2 150	183.5	126.2	837.7	82.4
27	GDTAN1-RJOSO 150	25.2	11.6	108.4	90.8
28	GDTAN2-RJOSO 150	25.2	11.6	108.4	90.8
29	GDTAN1-PBLGO1 150	30.9	21.6	147.3	82.1
30	GDTAN2-PBLGO2 150	126.7	-62.9	564.3	-89.6
31	PBLGO1-LJANG1 150	15.1	15.2	85.3	70.4
32	PBLGO2-LJANG2 150	103.7	-0.9	413.7	-100
33	LJANG1-TNGUL1 150	27.2	-8.6	115.3	-95.4
34	LJANG2-TNGUL2 150	27.2	-8.6	115.3	-95.4
35	TNGUL2-JMBER2 150	4.5	-18.1	75.3	-24.1
36	TNGUL1-JMBER1 150	4.5	-18.1	75.3	-24.1
37	TNGUL1-PUGER2 150	12.9	7.2	59.9	87.3
38	PUGER1-IMASCO 150	7.8	5.7	38.9	80.7
39	KRSAN1-PBLGO2 150	277.4	-48.9	1097.5	-98.5
40	KRSAN2-PBLGO1 150	open	open	open	open
41	GDING-KRSAN1 150	5.1	2.3	22	91.3
42	GDING-KRSAN2 150	5.1	2.3	22	91.3
43	PITON2-KRSAN1 150	36.3	37.2	199.6	69.9
44	PITON2-KRSAN2 150	284.8	-70.6	1126	-97.1
45	PITON2-STBDO1 150	145.1	17.4	561	99.3
46	PITON2-STBDO2 150	145.1	17.4	561	99.3
47	STBDO1-BDWSO1 150	53.2	8.4	211	98.8
48	STBDO2-BDWSO2 150	53.2	8.4	211	98.8
49	BDWSO1-JMBER1 150	40.9	3.3	162.8	99.7
50	BDWSO2-JMBER1 150	40.9	3.3	162.8	99.7
51	JMBER1-GTENG1 15	26.6	0.8	106.6	100
52	JMBER2-BWNGI1 15	0.3	10.1	39.7	2.7
53	GTENG1-BWNGI2 150	52.1	26.3	230	89.3
54	STBDO1-BWNGI1 150	80.8	-8.2	318.1	-99.5
55	STBDO2-BWNGI2 150	80.8	-8.2	318.1	-99.5
56	SKLNG2-BLBNG1 A 70	36.3	35.9	437.5	71.1
57	SKLNG2-BLBNG1 B 70	36.3	35.9	437.5	71.1

No.	Transmission Channel	Simulation		Current (A)	% PF
		P (MW)	Q (MVAR)		
58	SKLNG2-SLRJ1 A 70	0.9	0.2	7.5	98
59	SKLNG2-SLRJ1 B 70	0.9	0.2	7.5	98
60	WLNGI1-LDOYO1 70	4.5	1.2	40.8	96.6
61	KBAGN3-TUREN1 70	35.2	4.3	293.1	99.3
62	KBAGN3-PLHAN2 70	6.7	1.6	57.3	97.2
63	KBAGN4-PLHAN2 70	6.7	1.6	57.3	97.2
64	KBAGN4-SGRUH1 70	33.7	-6.3	283	98.3
65	BLBNG2-PLHAN1 A 70	12	28.8	271.1	38.5
66	BLBNG2-PLHAN1 B 70	12	28.8	271.1	38.5
67	TUREN1-GPGAN1 70	4.1	-9	84.4	-41.3
68	SGRUH1-GPGAN1 70	7.1	5.6	76.4	78.6
69	SGRUH1-KKTES1 70	5.8	2.1	51.7	93.9
70	SGRUH1-KKTES2 70	5.8	2.1	51.7	93.9

Based on the simulation results, it is known that $V_{Tanggul}$ = 143.2 kV and V_{Puger} = 142.1 kV, then the amount of $\%V_{drop}$ based on the formula is 0.007%. Based on the calculation results, it is known that the TANGGUL-1 to PUGER-2 line has P_{losses} = 0.000032 MW and $P_{tanggul-puger}$ = 12.9 MW. Then the value of %Losses from the line based on the formula is 0.000248%.

3.3 Discussion

The simulation results from the two models that have been carried out, when compared directly, the results can be seen in the Table 3.

Table 3: Load flow simulation results of Paiton-Grati Subsystem without T-Junction

No	Transmission Line	with T-junction				
		Voltage (V)	P(MW)	Q(MVAR)	Current (A)	% PF
1	TNGUL1-PUGER2 150	142.7	12.9	7.2	59.8	87.4
		without T-Junction				
		Voltage (V)	P(MW)	Q(MVAR)	Current (A)	% PF
		143.2	12.9	7.2	59.9	87.3

From Table 3, it can be seen that the reconfiguration of the transmission line, that is installing the transmission line from the Tanggul Substation to the Puger Substation directly, did not produce significant changes. This is evident from the simulation results above, which is only a slight change in the voltage value, when with T-Junction the bus voltage value is 142.7 kV and when without T-Junction (directly connected) the bus voltage value is 143.2 kV. While the value of active power and reactive power is known to remain the same when there is a T-Junction and when connected directly (without a T-Junction), namely P of 12.9 MW and Q of 7.2 MVAR. For the current value there is a slight change from 59.8 A when there is a T-Junction and to 59.9 A when without a T-Junction (directly connected). When there is a T-Junction the current value is smaller because there is more load flowing in the line.

4 Conclusion

Based on the simulation results and the above discussion, the following conclusions can be drawn:

1. Active Power and Reactive Power in the line when there is a T-Junction and without a T-Junction remains the same value, namely the P value of 12.9 MW and the Q value of 7.2 MVAR.
2. The difference in voltage from the two conditions increases by 0.5 kV and the difference in current increases by 0.1 A.
3. There is also a difference in voltage drop, namely when there is a T-Junction of 0.279% and when without a T-Junction of 0.007%
4. From the several differences that occur, there is no significant difference when power flows from GI Tanggul to GI Puger via T-Junction or when power flows from GI Tanggul to GI Puger directly.

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