DETERMINATION OF STABILITY INDEX OF ELECTRICAL POWER SYSTEM USING REI-DIMO METHODS

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DETERMINATION OF STABILITY INDEX OF ELECTRICAL POWER SYSTEM USING REI-DIMO METHODS

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ABSTRACT

Determination of electrical power system stability index by the REI-Dimo's method. This method is used to determine the Z equivalent of a system that has a lot of bus load becomes 1 bus load center. The method that has been developed by Paul Dimo could show how the effect of adding the load on the system whether it is still well worth or not by observing the output of stability index.

Calculation results for load conditions with the active power (P) 785.41 MW and reactive power (Q) 136.35 MVAr have a stability index of -21.452. Under these conditions, adding to the load with active power (P) 1818.22 MW and reactive power (Q) 315.65 MVAr has reached a critical point with a stability index of -0.1175.

Keywords: *REI-Dimo's Methods, Bus Load Center, Stability Index*

1. INTRODUCTION

The electrical power system is a system that consists of several elements, namely: power plant, transmission, distribution and load. Electrical power system operating in steady state at normal operating conditions. In the operation of the electrical power system load fluctuations can occur which can result changes in certain variables on systems such as frequency, voltage and so on. Changes in these variables could affect the stability of a system that operates in the solid state [1,2,3].

The stability of the electrical power system associated with the transmission system's ability to distribute the energy which is the output of a generation to get to the distribution system and load [4].

As for the formulation of the problem in this research: how to determine the z equivalent which is then used to determine the stability index of a transmission system. The effect of adding load to the stability index.

Some studies using REI-Dimo's method has been done before, such as: REI-Dimo's Method used to analyze changes that occur at the moment of a system [5,6].

REI-Dimo's method is also used to analyze contingency of power system. How exactly is the stability of electrical power systems [7].

REI-Dimo is also be combined with artificial intelligence techniques and used for contingency analysis of power systems [8,9].

This research it self is done by using the REI-Dimo's method to analyze the stability index of an electrical power transmission system. The system has many bus loads then be simplified by REI-Dimo's method to produce a bus load center. The ability of the transmission system to changes in load additions so that the percentage of actual load can be obtained by adding load to achieve stability index 0.

2. REVIEW OF LITERATURE

2.1 Stability of Electrical Power System

An electrical power system is good if they meet several conditions, such as:

1. Reliability is the ability of a system to distribute power or energy continuously.
2. Quality is the ability of electrical power system to produce magnitudes specified standard.
3. Stability is the ability of the system to return to normal operation after an interruption.

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For a complex network where there are few power plants interconnected with each other then the output power in the form of electrical quantities such as voltage and frecuency should be taken to ensure that no overload or underload at the power plant.

Electrical power systems have a dynamic the load or a load can change every second. This change with fixed power supply and must be supplied with the appropriate amount of power. If at some point there was a surge or decrease the load unexpected then this change has been categorized as a disruptions, in which the state of imbalance between electricity supply and demand for the electrical energy.

The stability of the electrical power system is defined as the ability of the system to maintain a balanced operating conditions and the ability of the system to return to normal conditions in the event of disruptions.

The stability of the system must be maintained in the operation of the power system. The stability of the system can be classified into three types, depending on the nature and magnitude of disruptions are: steady state stability, dynamic stability and transient stability [10].

2.1.1. Steady state stability

Steady state stability is the ability of electrical power system to accept a minor distraction that are gradual, occurring around the point of equilibrium at fixed conditions.

This stability depends on the characteristics of the components contained in the electrical power system include: generation, load, transmission network and the control system itself.

2.1.2. Dinamic stability

Dynamic stability is the ability of electrical power system to return to its equilibrium point after relatively small disruption suddenly in a long time.

Dynamic stability analysis is more complex because it also includes an automatic control components in the calculation.

2.1.3. Transient stability

Transient stability is the ability of the system to reach the point of equilibrium after a large disruption so that the system loses stability due to the disruption occurred on the ability of the system.

Analysis of transient stability is the main analysis to study the behavior of the power system, for example in the form of disturbance :

1. Sudden load changes due to the release of one of the generation units.
2. Changes in the transmission network, for example short circuit or disconnection the switch.

2.2 REI-Dimo's Equation

REI-Dimo method is used to simplify the complex transmission network with a constant admittance, then connected to a bus load of fictive load. The network is called zero power balance network which is the main concept REI-Dimo [11].

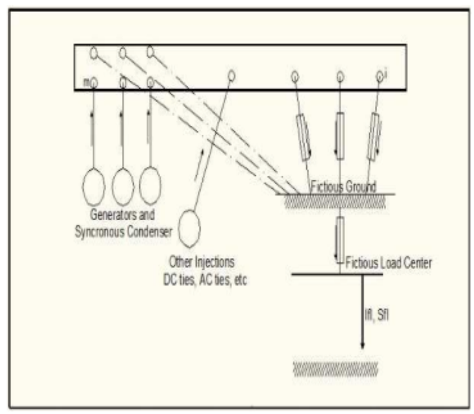

Figure 1 : Zero Power Balance Network

Paul Dimo introduced the concept of zero power balance network which aims to combine the system load to fictive load center while maintaining characters and basic power balance [9]. Radial nature of REI itself has fulfilled one of the rules of implementation reactive power steady state stability. For multi-generation system ranging from 1,..., I, ..., G generations, synchronous condensers and active injection like AC DC ties or ties, is connected to one bus radial fictive. Paul Dimo developed the following formula:

$$\frac{d\Delta Q}{dV} = \sum_m \frac{Y_m E_m}{\cos\delta_m} - 2\left(\sum_m Y_m + Y_{load}\right)V \text{ ...... (1)}$$

Where:

Em = The terminal voltage of the machine

δm = The voltage angle of the machine

V = The voltage at the load center

Yload = The admittance at the load center

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In this approach, the real part is represented by the value MW while the reactive part varies with the square of the voltage in accordance with

$$Y_{load} = \frac{Q_{load}}{V^2} \quad (2)$$

Load value of reactive power which is recalculated at each step by considering structure of the constant load, cos θ fixed. The formulation of these criteria has been developed with the equation.

$$\frac{d\Delta Q}{dV} = \sum_m \frac{Y_m E_m}{\cos(\delta_m + \gamma_m} - 2(\sum_m Y_m + Y_{load})V \quad (3)$$

3. RESEARCH METHODS

3.1 REI-Dimo's Procedures

Network reduction procedures of electrical power system which applied can be described as follows:

1. Preparing the data of electrical power system (in this case is data of the SULSELBAR system)
2. Run load flow to get the voltage and the voltage angle
3. Determine the fictive neutral bus (bus 45)
4. Connecting bus load to the fictive neutral bus with Y bus constant. The Formula of constant Y bus is

   $$Y_{bus} = \frac{P+jQ}{V^2} \quad (4)$$

   Where:
   P = active power
   Q = reactive power
   V = bus voltage
5. Calculating the current I on the bus load to a fictive neutral bus by the equation:

   $$I = \left(\frac{S_{in}^*}{E_i - jF_i}\right) \quad (5)$$

   where:
   S^*_{in} = real power conjunctive
   E_i = V cos α
   F_i = V sin α
6. Calculating the power that leads to the fictive neutral bus
7. Determining bus load center (bus 46)
8. Calculating the current flowing to the bus load center using Kirchoff's laws
9. Calculating the value of the impedance Z_{lc} from fictive bus load to the bus load center
10. Changing the impedance Z_{lc} into the form of constant admittance Y_{lc}
11. Determine the voltage at bus load center [10] by the equation

    $$V_{lc} = \frac{S_{lc}}{I_{lc}^*} \quad (6)$$

    Where:
    V_{lc} = voltage load center
    S_{lc} = real power of the load center
    I_{lc} = current load center
12. Running load flow to generate new Y bus admittances
13. Reducing bus matrix Y using Gaussian
14. Analyzing the stability index

3.2. Research Data

This research is done by conducting a case study on the SULSELBAR system:

Table 1 Operational Actual Condition

No Bus	Load		Generation	
	MW	MVAR	MW	MVAR
1	4.3	0.2	126	0.4
2	14.9	3.8	0	0
3	11.1	2.2	0	0
4	16.7	3	0	0
5	23.5	7	0.43	0
6	17.2	4.6	0	0
7	0	0	60	19
8	25.3	9	0	0
9	0	0	22.93	9.41
10	9.4	2.4	0	0
11	22.1	8	0	0
12	0	-20	0	0
13	31.1	8.5	0	0
14	40.78	13.35	0	0
15	14.1	4.5	0	0
16	48.5	15.5	8	5
17	69.2	18.4	0	0
18	0	-20	0	0
19	0.7	0	19.3	-0.1
20	17	2.1	0	0
21	25.5	3.9	0	0
22	0	0	0	0
23	0	0	0	0
24	37.7	9.7	0	0
25	0	-20	0	0
26	44.3	0	0	0
27	35.7	8.4	0	0
28	41.5	12.8	0	0
29	23.2	5.3	8	3.3
30	16.4	4	0	0
31	0	0	221.1	71.2

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32	20	4.3	0	0
33	28.8	7.3	0	0
34	14.9	6.9	9.7	-1.51
35	28.8	8.2	0	0
36	13.1	4.2	0	0
37	25	9.2	216.5	2.3
38	8.8	2.1	13.1	2.89
39	44.6	7.3	8.7	2.5
40	0	0	0	0
41	0	0	183.8	19.4
42	0	0	0	0
43	4.55	0.2	0	0
44	6.68	0	0	0

Table 2 Data Line of SULSELBAR System

from	**to**	**R**	**X**
bus	**bus**	**pu**	**pu**
1	2	0.02627	0.09440
2	3	0.05261	0.18902
3	4	0.03076	0.11023
1	5	0.03076	0.11023
2	6	0.03663	0.13159
5	6	0.01388	0.04974
6	7	0.00787	0.02826
6	8	0.02003	0.07198
6	8	0.01000	0.07946
8	10	0.01173	0.03973
10	11	0.02419	0.08667
11	12	0.00000	0.39492
12	13	0.03275	0.06013
12	20	0.36318	0.66671
11	14	0.01090	0.03919
11	15	0.00845	0.03024
15	16	0.00845	0.03024
14	16	0.04764	0.17071
16	24	0.00726	0.02600
16	17	0.04334	0.07958
16	18	0.00000	0.41587
16	22	0.00000	0.55350
16	27	0.00385	0.02635
22	23	0.12292	0.17508
18	19	0.06069	0.11141
18	20	0.05828	0.10699
20	21	0.03420	0.06278
18	21	0.02408	0.04421
24	25	0.00000	0.41587
25	26	0.04046	0.07428
27	28	0.00707	0.04256
27	29	0.00970	0.06649
27	30	0.05433	0.37234
29	31	0.01756	0.04609
29	32	0.03241	0.13837
31	32	0.00970	0.06649
32	33	0.04861	0.17466
33	34	0.03120	0.11211
34	35	0.01149	0.14603
33	35	0.03120	0.11211
35	36	0.04578	0.16306
8	36	0.02106	0.20275
36	37	0.02106	0.12670
8	37	0.01058	0.07259
8	38	0.06274	0.37753
8	30	0.01235	0.08464
38	39	0.03917	0.14076
39	40	0.00000	0.17234
40	42	0.05100	0.38000
41	42	0.00000	0.01300
42	43	0.01914	0.06356
43	44	0.01604	0.13353

Table 3. Data Impedance of Generation

from bus	to bus	R	X'
		pu	pu
1	47	0	0.1915
5	48	0	2.6867
7	49	0	0.4478
9	50	0	0.1452
16	51	0	1.9877
19	52	0	1.1425
29	53	0	0.2903
31	54	0	0.1452
34	55	0	1.9877
37	56	0	0.0581
38	57	0	0.8016
39	58	0	0.8956
41	59	0	0.1276

4. RESULTS AND ANALYSIS

Figure 4.1 showing the single load REI equivalent of SULSELBAR system with 13 bus generation and 1 bus load center.

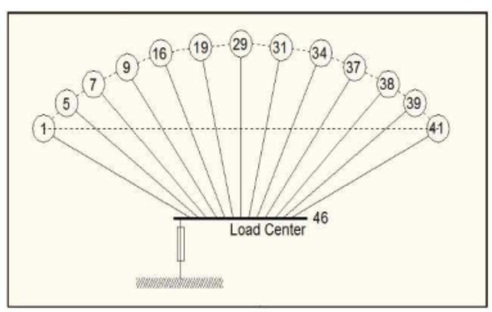

Figure 4.1: Single Load Equivalent of SULSELBAR System

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For admittance Y Bus value that obtained from the calculation using MATLAB software, can be seen in Table 3.

Table 3 Reduction matrix of Y after elimination gauss

Columns 1 through 3		
-5.1050+18.2318i	2.7361-9.8318i	0.0000+0.0000i
2.7361-9.8318i	-6.1563+21.8236i	1.3666-4.9101i
0.0000+0.0000i	1.3666-4.9101i	-3.7153+13.3128i
0.0000+0.0000i	0.0000+0.0000i	2.3487-8.4165i
2.3488-8.4165i	0.0005-0.0001i	0.0000+0.0000i
0.0000+0.0000i	1.9633-7.0529i	0.0000+0.0000i
0.0000+0.0000i	0.0003+0.0001i	0.0000+0.0000i
0.0016+0.0001i	0.0074-0.0039i	0.0000+0.0000i
0.0000+0.0000i	0.0002+0.0000i	0.0000+0.0000i
0.0000+0.0000i	0.0003+0.0001i	0.0000+0.0000i
0.0149-0.0026i	0.0618-0.0514i	0.0000+0.0000i
0.0004+0.0001i	0.0020-0.0007i	0.0000+0.0000i
0.0000+0.0000i	0.0000+0.0000i	0.0000+0.0000i
0.0032+0.0013i	0.0180-0.0025i	0.0000+0.0000i
Columns 4 through 6		
0.0000+0.0000i	2.3488-8.4165i	0.0000+0.0000i
0.0000+0.0000i	0.0005-0.0001i	1.9633-7.0529i
2.3487-8.4165i	0.0000+0.0000i	0.0000+0.0000i
-2.3487+8.4064i	0.0000+0.0000i	0.0000+0.0000i
0.0000+0.0000i	-7.7119+27.1985i	5.2049-18.6521i
0.0000+0.0000i	5.2049-18.6521i	-21.4640+83.8021i
0.0000+0.0000i	0.0006+0.0001i	9.1452-32.8389i
0.0000+0.0000i	0.0132-0.0098i	3.5884-12.8943i
0.0000+0.0000i	0.0004-0.0000i	1.5591-12.3887i
0.0000+0.0000i	0.0006+0.0001i	0.0000+0.0000i
0.0000+0.0000i	0.1052-0.1191i	0.0026-0.0003i
0.0000+0.0000i	0.0036-0.0020i	0.0001+0.0000i
0.0000+0.0000i	0.0000+0.0000i	0.0000+0.0000i
0.0000+0.0000i	0.0344-0.0104i	0.0005+0.0002i
Columns 7 through 9		
0.0000+0.0000i	0.0016+0.0001i	0.0000+0.0000i
0.0003+0.0001i	0.0074-0.0039i	0.0002+0.0000i
0.0000+0.0000i	0.0000+0.0000i	0.0000+0.0000i
0.0000+0.0000i	0.0000+0.0000i	0.0000+0.0000i
0.0006+0.0001i	0.0132-0.0098i	0.0004-0.0000i
9.1452-32.8389i	3.5884-12.8943i	1.5591-12.3887i
-9.2590+32.8687i	0.0090-0.0016i	0.0002+0.0001i
0.0090-0.0016i	-5.0445+15.9569i	0.0052-0.0027i
0.0002+0.0001i	0.0052-0.0027i	-8.4584+35.5757i
0.0003+0.0002i	0.0095-0.0027i	6.8356-23.1517i
0.0818-0.0328i	0.8676-2.3057i	0.0437-0.0364i
0.0023-0.0001i	0.0462-0.1111i	0.0014-0.0005i
0.0000+0.0000i	0.0000+0.0000i	0.0000+0.0000i
0.0196+0.0034i	0.4838-0.7844i	0.0127-0.0018i
Columns 10 through 12		
0.0000+0.0000i	0.0149-0.0026i	0.0004+0.0001i
0.0003+0.0001i	0.0618-0.0514i	0.0020-0.0007i
0.0000+0.0000i	0.0000+0.0000i	0.0000+0.0000i
0.0000+0.0000i	0.0000+0.0000i	0.0000+0.0000i
0.0006+0.0001i	0.1052-0.1191i	0.0036-0.0020i
0.0000+0.0000i	0.0026-0.0003i	0.0001+0.0000i
0.0003+0.0002i	0.0818-0.0328i	0.0023-0.0001i
0.0095-0.0027i	0.8676-2.3057i	0.0462-0.1111i
6.8356-23.1517i	0.0437-0.0364i	0.0014-0.0005i
-9.9422+33.8874i	3.0720-10.7484i	0.0025-0.0003i
3.0720-10.7484i	-14.6224+44.0558i	0.2988-3.0748i
0.0025-0.0003i	0.2988-3.0748i	-7.4876+16.1819i
0.0000+0.0000i	0.0000+0.0000i	6.9857-12.8259i
0.0215+0.0015i	10.0753-27.7834i	0.1455-0.1722i
Columns 13 through 14		
0.0000+0.0000i	0.0032+0.0013i	
0.0000+0.0000i	0.0180-0.0025i	
0.0000+0.0000i	0.0000+0.0000i	
0.0000+0.0000i	0.0000+0.0000i	
0.0000+0.0000i	0.0344-0.0104i	
0.0000+0.0000i	0.0005+0.0002i	
0.0000+0.0000i	0.0196+0.0034i	
0.0000+0.0000i	0.4838-0.7844i	
0.0000+0.0000i	0.0127-0.0018i	
0.0000+0.0000i	0.0215+0.0015i	
0.0000+0.0000i	10.0753-27.7834i	
6.9857-12.8259i	0.1455-0.1722i	
-6.9857+12.8258i	0.0000+0.0000i	
0.0000+0.0000i	-10.8060+28.7072i	

Using the parameters that have been obtained, then do the simulation by adding loading, and observe its influence to the voltage, thus forming PV curve (Figure 4.2).

To analyze the stability index, used the equations that developed by Paul Dimo, With the results of data reduction then obtained SULSELBAR system stability index amounted -21.4523. For the results can be seen in Figure 4.3.

Calculation results of Data testing with the addition of loading by the same percentage between the active power (P) and reactive power (Q) can be seen in Table 4.

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Table 4 Data testing of REI-Dimo

Load		SSL Index	Vlc (pu)
P (MW)	Q (MVAr)		
785.41	136.35	-21.4523	0.915
942.49	163.62	-20.0920	0.894
1099.57	190.89	-18.5476	0.871
1256.66	218.16	-16.7584	0.844
1413.74	245.43	-14.6213	0.813
1570.82	272.70	-11.9220	0.776
1727.90	299.97	-8.0085	0.726
1818.22	315.65	-0.1775	0.679

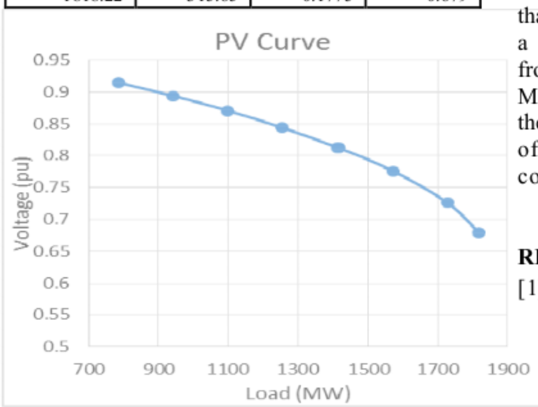

Figure 4.2 PV Curve

Figure 4.2 PV curves show the initial condition of loading with active power (P) 785.41 MW and reactive power (Q) 136.35 MVAr generates a voltage on the bus load center amounted 0.915 pu. Continuous loading cause the voltage at the bus load center down.

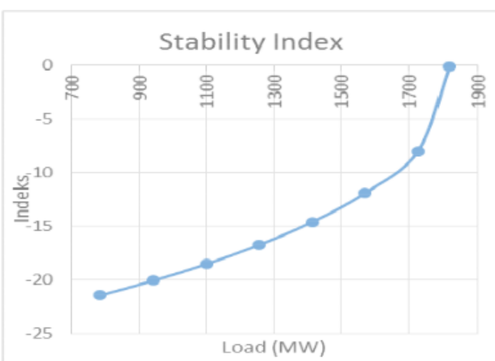

Figure 4.3 SSL Index Curve

With the same loading conditions seen in Figure 4.3 SSL Index Curve shows that the addition of loading produces stability index increasingly close to zero. The critical point of system is at value of loading with active power (P) 1818.22 MW and reactive power (Q) 315.65 MVAr.

5. CONCLUSIONS

The conclusion that can be drawn from the results of this research are :

The addition of loading can affect the stability index as seen in Figure 4.3. Increased load will led to stability index values closer to 0.

The critical point of system in the load position P = 1818.22MW and Q = 315.65 MVAr, means that transmission system of SULSELBAR still has a range of additional load approximately 131.5% from its initial position that now are P = 785.41 MW and Q = 136.35 MVAr. Additional loading on the system SULSELBAR could not over the value of steady state stability limit, so the system did not collapse.

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