ISBN: 978-602-5649-417

ANALYSIS OF ELECTRICAL DISTRIBUTION SYSTEMS JAVA-BALI 500 KV BASED ON STEADY STATE STABILITY LIMIT USING RADIAL EQUIVALENT INDEPENDENT (REI) DIMO

Firman Yudianto[1] and Rizqi Putri Nourma Budiarti[2]

[1] Information System, Faculty of Engineering, Universitas Nahdlatul Ulama Surabaya
Surabaya, Indonesia
firman_yudianto@unusa.ac.id

[2] Information System, Faculty of Engineering, Universitas Nahdlatul Ulama Surabaya
Surabaya, Indonesia
rizqi.putri.nb@unusa.ac.id

Abstract

The need for power is increasing. Plant construction also increased. Electrical power distribution system needs to be improved to obtain maximum service. Steady state stability is a major concern in the operation of the power system, especially at peak load conditions. This paper analyzes on the stability of the steady state in power distribution. Radial Equivalent Independent Approach method (REI) Dimo used in this paper to reduce transmission nets into a bus load of equivalence. From the bus load can be calculated indices equivalent steady state stability for each loading condition. Through this method, can facilitate determining the stability limit is still safe for the stability of the steady state in the Java-Bali electricity system of 500 kV.

Keywords: Steady State Stability, Power Distribution, REI Dimo.

Introduction

The stability of the electric power system has become an important problem for securing the operation of the electric power systems (Hamada et al.). Many occurrences of total power failure are caused by the instability of the power system. This event has shown that the stability of the power system becomes an important phenomenon.

One method to solve the stability problems of electric power system is the approach Radial Equivalent Independent (REI) Dimo (Dimo, “Etude de La Stabilité Statique et Du Réglage de Tension”)(Dimo, “L’Analyse Des Réseaux d’Energie Par La Méthode Nodale Des Courants de Court-Circuit. L’Image Des Nœuds”)(Dimo, *Nodal Analysis of Power Systems*)(Eleschova and Beláň)(Dimo, “Etude de La Stabilité Statique et Du Réglage de Tension”)(Molina et al.)(Savulescu), . REI can reduce buses that have a load to an equivalent load bus.

This paper shows the use of the Dimo method to analyze the steady state stability of the 500 kV in Java-Bali electrical system. System 500 kV in Java-Bali interconnection consists of 23 buses with 28 channels and 8 power plants. By using the Dimo method, the 500 kV in Java-Bali interconnection system can be reduced to 9 buses consisting of eight power plants and a load bus. To see steady state stability, the formula and P-V curve are found in REI-DIMO (Eleschova and Beláň)(Molina et al.).

Research methods

a. Steady State Stability Based on DIMO Approach

The power system consists of linear sub-system, such as the transmission lines, transformers, reactors, capacitors and admintansi buses to ground (line charging and tap transformer) and non-linear sub-systems such as generators, load and synchronous codens. Buses can be divided into non-essential buses, which should be eliminated and essential buses, which should be maintained unchanged.

The transmission net can not be reduced by applying the star-delta transformation due to the nonlinearity of the injected power bus MW and Mvar power. In general, the equivalent model must fulfill some of the following [7]:

1. Judging from its boundaries, the equivalence must be accurate and reliable to represent the behavior of the power system
2. The reduction model should produce as close as possible to the physical properties of the power system
3. Equivalents must correspond to the computational procedures used to solve subsequent problems.

4. The equivalent must ensure that the mathematical solutions are feasible.

Among the various techniques solutions proposed in the literature, the REI-Dimo methodology stands out as a very unique concept of the same type of linearizing injection by replacing the transmission net with admintansi constant, then classify the transmission net into a single injection of the non-linear applied to bus fictitious called REI bus. This process is possible to introduce a fictitious net, the bus will be eliminated and bus REI fictitious, which is linear, has no losses and can be eliminated by Gaussian reduction. This net is called zero power balance network and represent the main concept in the REI-Dimo (Molina et al.).

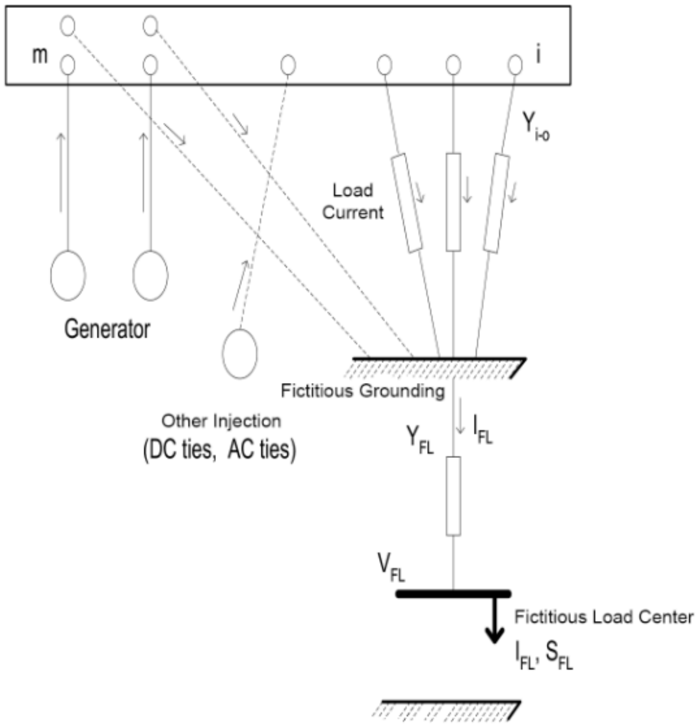

Figure 1. Zero power balance network [6]

The radial properties of REI meet one of the rules for the application of steady state stability (voltage stability). For systems that consist of G generators, synchronous codens and active injections such as DC ties or AC ties, which connect it to one of the bus radial load of fictitious or actual load through admintansi Y1, ..., Yi, ..., YG, Dimo developed the following formula, as follows:

$$\frac{d\Delta Q}{\mathrm{dV}} = \sum_m \frac{Y_m E_m}{\cos\delta_m} - 2\left(\sum_m Y_m + Y_{load}\right)V \qquad (2.1)$$

with:

Em = internal voltage of the machine (assumed to be constant, not affected by small changes are made in conditions of steady state stability)

δ_m = Internal angle of the engine with reference to the voltage V on the load bus (both fictional or actual)

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

$$Y_{load} = \frac{Q_{load}}{V^2} \qquad (2.2)$$

With Qload value taken from the base case or recalculated at each step taking into account the structure of the constant load, cos ϕ fixed, as shown in Figure 2. The general formulation of these criteria has been developed in [6] and given in equation 2.3.

$$\frac{d\Delta Q}{\mathrm{dV}} = \sum_m \frac{Y_m E_m}{\cos(\delta_m + \gamma_m)} - 2\left(\sum_m Y_m \cos\gamma_m + Y_{load} + Y^{\gamma}\right)V \quad (2.3)$$

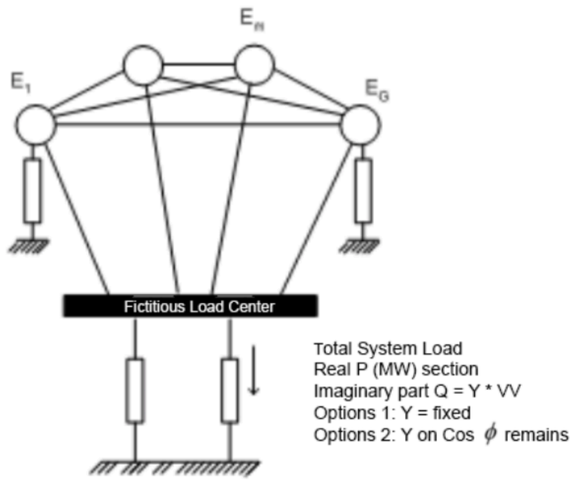

Figure 2. REI for a fictitious load centers [6]

b. Methodology systems

The reduction procedure of 500kV Java-Bali system is as follows:

1. Ready for electric power system data
2. Run load flow to get the voltage and voltage angle.
3. Determine the load bus
4. Determine the fictitious neutral bus
5. Connect the load bus to the fictitious neutral bus with constant Y bus admintansi. The constant Y bus equation is $Y_{bus} = \frac{P + jQ}{V^2}$
   with:
   P = Active power
   Q = Reactive power
   V = Bus Voltage

6. Determine the current I from the load bus to the fictitious neutral bus with the equation $I = \left(\dfrac{S^*_{in}}{E_i - jF_i} \right)$

   with:

   S^*_{in} = Conjunctive Real power from bus I to the fictitious neutral bus

   E_i = Active bus voltage i (E_i = V cos α)

   F_i = Reactive bus voltage i (F_i = V sin α)
7. Determine the load center bus
8. Use Kirchhoff law to determine the current flowing to the load center bus
9. Calculate the power to the fictitious neutral bus
10. Determine the value of the impedance Z_{lc} from fictitious neutral bus to to the load center bus using the equation, $R_{lc} + jX_{lc} = \left(\dfrac{P + jQ}{I \times I^*} \right)$

    with:

    Z_{lc} = impedance *load center*

    R_{lc} = resistance *load center*

    X_{lc} = reactance *load center*

    I_{lc} = current *load center*
11. Change impedance Z_{lc} into Y_{lc} admintansi
12. Determine the voltage at the load center to the equation $V_{lc} = \dfrac{S_{lc}}{I^*_{lc}}$

    with:

    V_{lc} = Voltage *load center*

    S_{lc} = Real power *load center*

    I_{lc} = Current *load center*
13. Run load flow to generate new Y bus admintansi.
14. Reduce the Y matrix with Gaussian
15. Analysis of the limit of steady state stability due to the increase of the load using equation 2.1.

c. Interconnection System 500 kV Java-Bali

The Interconnection System 500 kV Java-Bali consists of 23 buses with 28 channels and 8 power plants. The Interconnection System 500 kV Java-Bali can be described as a single line diagram in Figure 3. Data on those channels in the 500 kV interconnection system Jawa-Bali is given in Table 4.2. Data generation of the interconnection system 500 kV Java Bali is shown in Table 3.1.

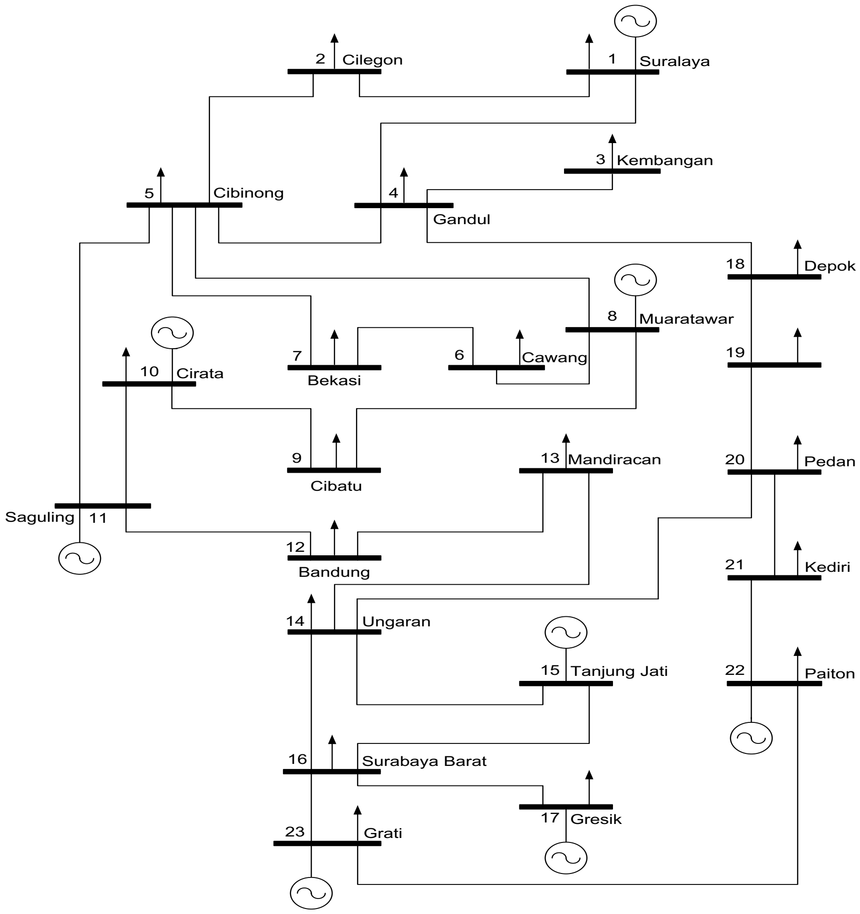

Figure 3. Interconnection System 500 kV Java-Bali

Research Results and Discussion

Table 1 is the Y bus matrix of 500 kV Java- Bali system after Gaussian elimination. Figure 4 is the REI result from 23 buses to 8 bus generators and an equivalent load bus. Admittance, bus voltage, power generators, and total system load in the REI are shown in Table 2.

Table 1. Results of the Y matrix after gaussian

No Bus	9
1	-0.2296 - 2.7875i
8	-0.2282 - 2.5303i
10	-0.1732 - 1.8221i
11	0.0657 - 3.0665i
15	0.1065 - 0.6660i
17	0.0144 - 1.6252i
22	-0.0420 - 2.1648i
23	0.1672 - 0.6704i
9	0.3178 + 15.2987i

ISBN: 978-602-5649-417

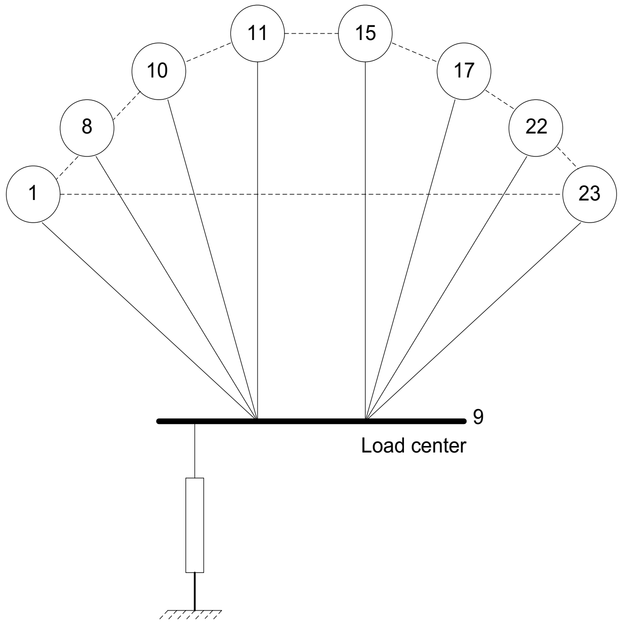

Figure 4. The REI Results on the Java-Bali System

Table 2. REI Parameter Results from 23 buses

No Bus	Y re G (pu)	Y im B (pu)	REI MW	REI MVAr	V (pu)	V ang (0)
1	-.2296	-.7875	3314.18	988 564	1:02	0
8	-.2282	-.5303	1470	679 361	1	-6241
10	-.1732	-.8221	400	484 322	1	-7029
11	0.0657	-.0665	535	1043.09	1	-6663
15	0.1065	-0666	830	361.87	1	9938
17	0.0144	-.6252	810	608 616	1	9,735
22	-0042	-.1648	2820	895 043	1	14 303
23	0.1672	-.6704	198	395.97	1	11 751
9	-0637	-.0341	10264	4032	0.94	-4267

Table 3 shows changes in voltage, voltage angle and stability index. System voltage, voltage angle and stability index are influenced by changes in load on the system.

Table 3. Changes in voltage, voltage angle and stability index on load center

Step	P	Q	V	Stability index
1	10282	4032	0862	-35 465
2	10 582	4149.642	0851	-34.6615
3	10882	4267.285	0.84	-33.7503
4	11182	4384.927	0829	-32.7083
5	11 482	4502.57	0816	-31.5035
6	11782	4620.212	0801	-30 092
7	12082	4737.855	0785	-28.4108
8	12 382	4855.497	0766	-26.3504

9	12682	4973.14	0744	-23.7298
10	12 982	5090.782	0717	-20.1893
11	13282	5208.425	0.68	-14.7933
12	13500	5293.912	0637	-7638
13	13582	5326.067	0602	-1.6842
14	13590	5329.204	0593	-0.2847
14	13592	5329.989	0591	0099

Figure 5 shows the relationship between voltage and load. The voltage is inversely proportional to changes in load. Voltage decreases due to the additional load.

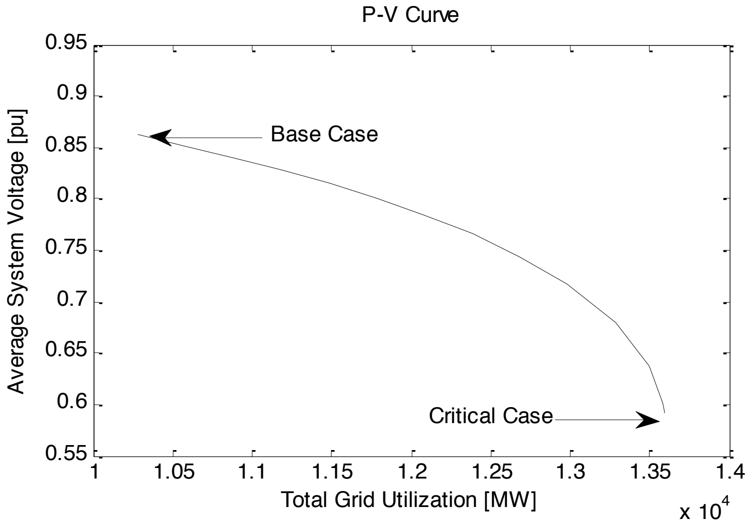

Figure 5. 500kV Java-Bali system P-V curve

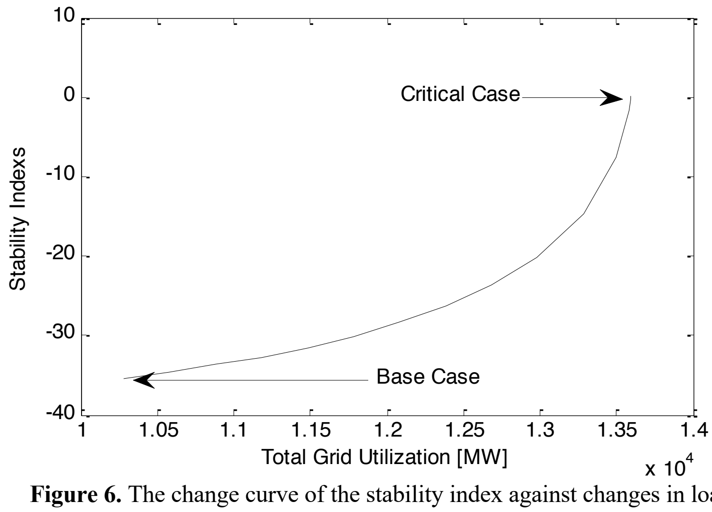

Figure 6. The change curve of the stability index against changes in load

Figure 6 shows the relationship of stability index to load. The system stability index under normal circumstances the load 10282 MW (-35.465) And critical load of 13592 MW (0.099).

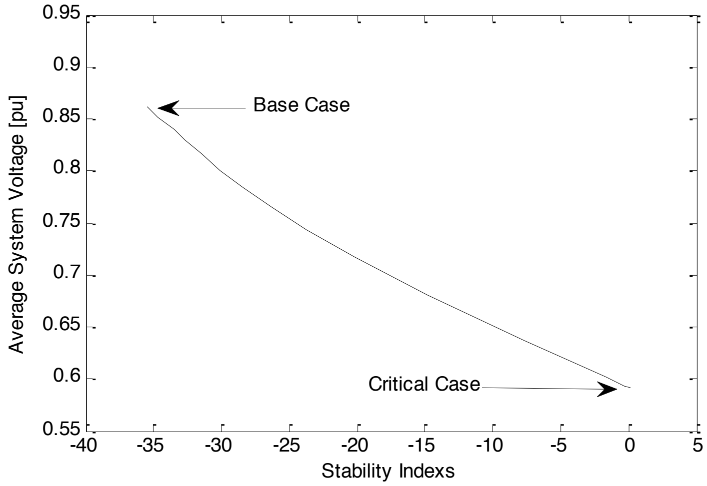

Figure 7. The curve changes in the stability index against voltage

Figure 7 shows the relationship between the stability index and the average voltage of the system. The average system voltage drop causes the stability index approaching to close to a value 0 or the lower of the stability index.

Conclusions and recommendations

Steady state stability can be analyzed by looking at the system stability index. The system is not stable at a load of 13582 MW of total generation amounted to 13659 MW.

References

Dimo, Paul. "Etude de La Stabilité Statique et Du Réglage de Tension." *RGE, Paris*, vol. 70, no. 11, 1961, pp. 552–56.

---. "L'Analyse Des Réseaux d'Energie Par La Méthode Nodale Des Courants de Court-Circuit. L'Image Des Nœuds." *RGE, Paris*, vol. 7, 1962, pp. 151–75.

---. *Nodal Analysis of Power Systems*. International Scholarly Book Services, Inc., Forest Grove, OR, 1975.

Eleschova, Zaneta, and Anton Beláň. "The Power System Steady-State Stability Snalysis." *Image (Rochester, N.Y.)*, no. 3, 2008, pp. 54–57.

Hamada, MM, et al. "Simple and Efficient Method for Steady-State Voltage Stability Assessment of Radial Distribution Systems." *Elsevier*, https://www.sciencedirect.com/science/article/pii/S0378779609002016. Accessed 1 Apr. 2019.

Molina, R. D. M., et al. "Dimo's Approach to Steady-State Stability Assessment: Methodology Overview, Numerical Example, and Algorithm Validation." *Real-Time Stability Assessment in Modern Power System Control Centers. IEEE Press and Wiley, Hoboken*, 2009.

Savulescu, Savu C. *SOLVING OPEN ACCESS TRANSMISSION AND SECURITY ANALYSIS PROBLEMS WITH THE SHORT-CIRCUIT CURRENTS METHOD* 十. Citeseer, 2002.