ICITACEE 2016

by Ardiaty Arief

Submission date: 27-Sep-2022 09:18AM (UTC-0400)
Submission ID: 1910354965
File name: arief2016.pdf (253.62K)
Word count: 3067
Character count: 17030

Proc. of 2016 3rd Int. Conf. on Information Tech., Computer, and Electrical Engineering (ICITACEE), Oct 19-21st, 2016, Semarang, Indonesia

Voltage Drop Simulation at Southern Sulawesi Power System Considering Composite Load Model

Ardiaty Arief and Muhammad Bachtiar Nappu
Department of Electrical Engineering
Faculty of Engineering, Hasanuddin University
Makassar 90245, Indonesia
E-mail: ardiaty@eng.unhas.ac.id, ardiaty@engineer.com

***Abstract*—Voltage instability has becoming one of the major concern for power systems utilities nowadays. It is believed as one of the major drives of the blackouts. Moreover, nowadays, many loads are single-phase small air conditioning motors which are prone to stall when the voltage falls because of short circuits in transmission lines. Excessive motor stalling may cause the system to experience voltage collapse or cascaded generator tripping, especially with inadequate reactive power compensation. This paper assesses and compares dynamic voltage stability of Southern Sulawesi power system considering static and dynamic load modelling.**

Keywords- dynamic load modelling, voltage collapse, voltage stability

I. INTRODUCTION

In the late 20th century, voltage instability has become one of the major drives of the blackouts and it is believed as the root cause of the blackout in Northeast U.S. and Canada at 14 August 2003 [1]. A mainstream scenario for occasion of voltage instability is excessive system loading because of intense power transfers across the network, followed by incidents (such as a fault, line overloaded, congested lines or generator reaching its excitation limit) where these events may activate relay actions [2-7]. As results, progressive voltage drop or rise may evolve in some buses as result of shortfall of load, or loss of transmission lines and other elements by their protective systems that may instigate cascading failures.

When a sequence of voltage instability events result in a blackout (total or partial), or significant low voltage which are below acceptable limit in most parts of the system, it is said to be voltage collapse. Voltage collapse is instability of heavily loaded electric power systems which can result in declining voltages, cascading failure and blackouts [8]. It may occur quickly or even slowly depending on the dynamics of the system and is caused by single or multiple contingencies (these can be the sudden removal of generation, transformer or transmission line, increase of load without sufficient increase of reactive power, or the slow clearing of the system fault) [9-12].

Voltage instability can cause the entire grid to experience significant voltage drop, therefore mitigation action is demanded. During planning and operation of power systems, voltage problems have become a main concern, because of significant amount of failures caused by voltage instability. Several methods to mitigate voltage instability are application of reactive power-compensating devices; control of network voltage and generator reactive output; coordination of protections/controls; control of transformer tap changers and under voltage load shedding [18, 19]. Under voltage load shedding (UVLS) plays a vital part in power system control when the system is subjected to large disturbances. Research has validated that UVLS is an effectual counter-measure deed against voltage collapse. In the literature, various techniques have been developed to formulate efficient UVLS schemes [13-26].

Voltage collapse is more likely on deficit of reactive power [27, 28]. Voltage stability depends heavily upon the amount, location and type of reactive power sources available. Large voltage may decline if the reactive power supply is too far away, of inadequate amount, or too dependent on shunt capacitors, such as the usual contingency. Another major factor that causes a rapid voltage collapse is the characteristic of loads being served by the utilities [29]. Nowadays, many loads are single-phase small air conditioning motors which are prone to stall when the voltage falls because of short circuits in transmission lines, especially during hot weather, since these motors comprise a high percentage of loads. Excessive motor stalling may cause the system to experience voltage collapse or cascaded generator tripping, especially with inadequate reactive power compensation. Therefore, it is essential to consider static and dynamic load modelling especially induction motor driven loads for voltage stability analysis.

This paper assesses and compares dynamic voltage stability of Southern Sulawesi power system considering static and dynamic load modelling. This paper is organized as follow. Section II provides a brief overview on power systems modelling, including static and dynamic load modelling. Section III describes the test system, Section IV elaborates case study and analysis whereas Section V concludes the main findings of the research.

II. POWER SYSTEM MODELING

A. Synchronous Generator Modeling

In this study, the detailed 6th order synchronous machine model is employed. The detailed explanations of the 6th order synchronous machine modeling and the differential equations can be found in [30].

978-1-5090-0890-2/16/$31.00 ©2016 IEEE

B. *Load Modeling*

Load modeling is one of the most significant components in dynamic voltage stability simulation including under voltage load shedding. In this work, the load at each bus is represented as composite load which is a combination of static load and dynamic load. Further detail of the load configuration is explained in Section V.

Generally, load are reliant of the bus voltage [31]. The static load's voltage dependence can be expressed through a polynomial or exponential formulation. Static ZIP load modeling is usually stated as a function of voltage magnitude at a specific bus to which the load is connected as [32, 33],

$$P_{Li}(V_i) = P_{Li}^{0}\left[\alpha_P\left(\frac{V_i}{V_0}\right)^2 + \beta_P\left(\frac{V_i}{V_0}\right) + \gamma_P\right] \qquad (1)$$

$$Q_{Li}(V_i) = Q_{Li}^{0}\left[\alpha_Q\left(\frac{V_i}{V_0}\right)^2 + \beta_Q\left(\frac{V_i}{V_0}\right) + \gamma_Q\right] \qquad (2)$$

Dynamic load model is important for dynamic voltage stability analysis [34], because induction motors will decelerate substantially if their terminal voltage falls as a result of short circuits [35]. The generic load dynamic models are [36-39],

$$T_p\frac{dP_d}{dt} + V^{\alpha_t}P_d = V^{\alpha_t}P_s(V) + \alpha_t T_p\frac{P_d}{V}\frac{dV}{dt} \qquad (3)$$

$$T_q\frac{dQ_d}{dt} + V^{\beta_t}Q_d = V^{\beta_t}Q_s(V) + \beta_t T_q\frac{Q_d}{V}\frac{dV}{dt} \qquad (4)$$

III. THE TEST SYSTEM: THE SOUTHERN SULAWESI SYSTEM

A. *Description of the Study System [40]*

The Southern Sulawesi interconnected system in Indonesia consists of many different power generations which are connected by some transmission lines of 150 kV, 70 kV and 30 kV. The Southern Sulawesi system has a distinctive characteristic where the main economic power generation centers are located in the northern part of the system, whilst the main load center is located in the southern part.

Loads in Southern Sulawesi system are dominated by household load. However in Makassar city, as the capital of the South Sulawesi province (represented by buses Tello, Panakukang, Tallo Lama and Tanjung Bunga substations), the dynamic loads are mostly air conditioning and water pump loads. Makassar is the center of business for eastern part of Indonesia.

B. *Load Composition*

In this works, the load is assumed to be peak load. In the main city, Makassar, the load is exemplified as 50% static and 50% dynamic motor, since Makassar is the center of province governance, offices, business and the residents are mainly in the middle and upper economic levels. Fig. 3 shows the load representation in Makassar zone. In the other small towns, the load is represented as 80% static and 20% dynamic. Detail of the load composition is presented in Table 1 whereas detailed parameters of induction motors can be found in [41].

TABLE I LOAD COMPOSITION

Substation (Bus No)	Load type (%)				
	Static	Dynamic motor			
		I	II	III	IV
Bakaru (1), Polmas (2), Majene (3), Pinrang (4), Pare-Pare (5), Barru (7), Pangkep (8), Bosowa (9), Sungguminasa (14), Talasalapang (15), Jeneponto (16), Bulukumba (17), Sinjai (18), Bone (19), Soppeng (20), Sidrap (21), Makale (22), Palopo (23), Sengkang (24)	80	20	-	-	-
Tello (10), Panakukang (11), Tallo Lama (12) Tanjung Bunga (13)	50	20	25	5	-

IV. CASE STUDY AND ANALYSIS

In this study, the system is assumed under a stressed condition at the peak load. Voltage drop analysis is performing by comparing the voltage drop with static load modelling only and static – dynamic load modelling.

A. *Static load modelling only*

Fig. 1 shows the voltage collapse after fault occurs causing the loss of transmission line between buses Pangkep and Tello when loads are modelled with static load modelling only. For this simulation, buses Tello, Panakukang, Tanjung Bunga, Tallo Lama, Pangkep and Bosowa become unstable. The lowest voltage is 0.83 pu.

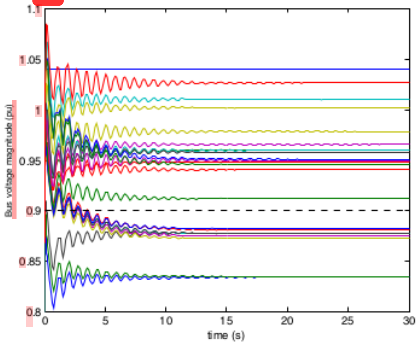

Fig. 1 Voltage drop after outage with static load modeling only

B. *Static and dynamic load modelling*

Fig. 2 shows the voltage collapse after fault occurs causing the loss of transmission line between buses Pangkep and Tello. From this outage, there are 3 critical zones identified: zone Makassar City, Pangkep and Palopo. Fig. 3 shows voltage decline drop at Makassar City zone and it clearly show significant voltages decline at substations in Makassar zone that drop to 0.66 – 0.69 pu at *t*=30 s. This is because Makassar as the load center in the system has substantial large amount of induction motor loads. Since motors have difficulties to reaccelerate after large disturbances then they stall and distressing the voltage at Makassar zone.

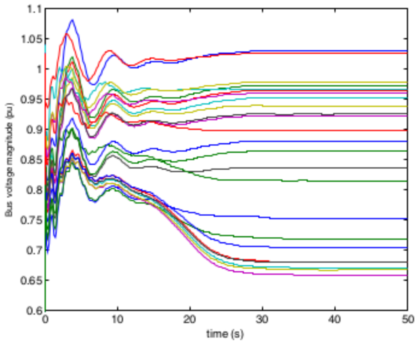

Fig. 2 Voltage drop after outage between bus Pangkep and Tello

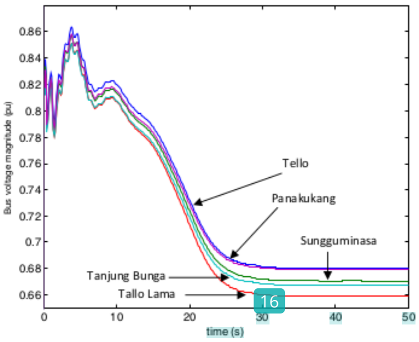

Fig. 3 Voltage drop after fault in the critical affected zone: Makassar City

Table 2 presents the comparison of the voltage drop with static load modelling only and static-dynamic load modelling. By using static load modelling, the lowest voltage is 0.83 pu with 6 buses with voltage below stability limit. However, when consider the dynamic load modelling, bus Tallo Lama has the lowest voltage of 0.66 pu with 8 unstable buses.

TABLE 2 COMPARISON OF VOLTAGE DROP BETWEEN STATIC AND STATIC-DYNAMIC LOAD MODELLING

	Load modelling	
	Static	Static and dynamic
Lowest voltage	0.83 pu	0.65 pu
Unstable buses	Tello Panakukang Tanjung Bunga Tallo Lama Pangkep Bosowa	Tello Panakukang Tanjung Bunga Tallo Lama Pangkep Bosowa Makale Palopo

V. CONCLUSIONS

This paper presents dynamic voltage stability of Southern Sulawesi power system considering static and dynamic load modelling. This paper compares the voltage drop with the same amount of total load and same fault location. The results are significantly different, where with static load modelling only, the lowest voltage is 0.83 pu with 6 buses with voltage below stability limit. However, when consider the dynamic load modelling, bus Tallo Lama has the lowest voltage of 0.66 pu with 8 unstable buses.

Dynamic load modelling is important for dynamic voltage stability assessment, since excessive motor stalling may bring the system to experience voltage collapse. Furthermore, it can provide better assessment for under voltage load shedding design.

REFERENCES

[1] D. Novosel, M. M. Begovic, and V. Madani, "Shedding Light on Blackouts," *IEEE Power and Energy Magazine,* vol. 2, pp. 32-43, 2004.

[2] S. A. A. Dessi, A. H. Osman, and A. I. Ibrahim, "Voltage stability assessment of a real power system using a detailed dynamic load model," in *2013 3rd International Conference on Electric Power and Energy Conversion Systems (EPECS)*, Istanbul, Turkey, 2-4 October 2013, pp. 1-6.

[3] M. B. Nappu, "Locational Marginal Prices Scheme Considering Transmission Congestion and Network Losses," *Universal Journal of Electrical and Electronic Engineering,* vol. 2, pp. 132-136, DOI: 10.13189/ujeee.2014.020307, 2014.

[4] M. B. Nappu, "LMP-lossless for congested power system based on DC-OPF," in *2014 Makassar International Conference on Electrical Engineering and Informatics (MICEEI)*, Makassar, Indonesia, 26-30 November, 2014, pp. 194-199.

[5] M. B. Nappu, A. Arief, T. K. Saha, and R. C. Bansal, "Investigation of LMP forecasting for congested power systems," in *2012 22nd Australasian Universities Power Engineering Conference (AUPEC)*, Bali, Indonesia, 26-29 September, 2012, pp. 1-6.

[6] M. B. Nappu and T. K. Saha, "A comprehensive tool for congestion-based nodal price modelling," in *2009 IEEE Power & Energy Society General Meeting (PES GM)*, Calgary, Alberta, Canada, 26-30 July, 2009, pp. 1-8.

[7] M. B. Nappu and A. Arief, "Network Losses-Based Economic Redispatch for Optimal Energy Pricing in a Congested Power System," *Energy Procedia, September,* 2016.

[8] I. Dobson and L. Lu, "Computing an Optimum Direction in Control Space to Avoid Stable Node Bifurcation and Voltage Collapse in Electric Power Systems," *IEEE Transactions on Automatic Control,* vol. 37, pp. 1616-1620, 1992.

[9] M. Begovic, D. Fulton, M. R. Gonzalez, J. Goossens, E. A. Guro, R. W. Haas*, et al.*, "Summary of "System Protection and Voltage Stability"," *IEEE Transactions on Power Delivery,* vol. 10, pp. 631-638, 1995.

[10] M. Bachtiar Nappu, A. Arief, and R. C. Bansal, "Transmission management for congested power system: A review of concepts, technical challenges and development of a new methodology," *Renewable and Sustainable Energy Reviews,* vol. 38, pp. 572-580, 2014.

[11] M. B. Nappu and A. Arief, "Economic redispatch considering transmission congestion for optimal energy price in a deregulated power system," in *2015 International Conference on Electrical Engineering and Informatics (ICEEI)*, 2015, pp. 573-578.

[12] M. B. Nappu, R. C. Bansal, and T. K. Saha, "Market power implication on congested power system: A case study of financial withheld strategy," *International Journal of Electrical*

Power & Energy Systems, vol. 47, pp. 408-415, DOI:10.1016/j.ijepes.2012.09.016, 2013.

[13] T. S. P. Fernandes, J. R. Lenzi, and M. A. Mikilita, "Load Shedding Strategies Using Optimal Load Flow With Relaxation of Restrictions," *IEEE Transactions on Power Systems,* vol. 23, pp. 712-718, 2008.

[14] C. M. Affonso, L. C. P. da Silva, F. G. M. Lima, and S. Soares, "MW and MVar Management on Supply and Demand Side for Meeting Voltage Stability Margin Criteria," *IEEE Transactions on Power System,* vol. 19, pp. 1538-1545, 2004.

[15] Y. Wang, I. R. Pordanjani, W. Li, W. Xu, and E. Vaahedi, "Strategy to minimise the load shedding amount for voltage collapse prevention," *IET Generation, Transmission & Distribution,* vol. 5, pp. 307-313, 2011.

[16] T. Q. Tuan, J. Fandino, N. Hadjsaid, J. C. Sabonnadiere, and H. Vu, "Emergency Load Shedding to Avoid Risks of Voltage Instability Using Indicators," *IEEE Transactions on Power Systems,* vol. 9, pp. 341-351, 1994.

[17] T. Amraee, A. M. Ranjbar, B. Mozafari, and N. Sadati, "An Enhanced Under-Voltage Load-Shedding Scheme to Provide Voltage Stability," *Electric Power Systems Research,* vol. 77, pp. 1038-1046, 2007.

[18] A. Wiszniewski, "New Criteria of Voltage Stability Margin for the Purpose of Load Shedding," *IEEE Transactions on Power Delivery,* vol. 22, pp. 1367-1371, 2007.

[19] B. Otomega and T. Van Cutsem, "Undervoltage Load Shedding Using Distributed Controllers," *IEEE Transactions on Power Systems,* vol. 22, pp. 1898-1907, 2007.

[20] S. K. Tso, T. X. Zhu, Q. Y. Zeng, and K. L. Lo, "Evaluation of Load Shedding to prevent Dynamic Voltage Instability Based on Extended Fuzzy Reasoning," *IEE Proceedings Generation, Transmission and Distribution,* vol. 144, pp. 81-86, 1997.

[21] C. J. Parker, I. F. Morrison, and D. Sutanto, "Simulation of Load Shedding as a Corrective Action Against Voltage Collapse," *Electric Power Systems Research,* vol. 46, pp. 235-241, 1998.

[22] A. Arief, Z. Dong, M. B. Nappu, and M. Gallagher, "Under voltage load shedding in power systems with wind turbine-driven doubly fed induction generators," *Electric Power Systems Research,* vol. 96, pp. 91-100, DOI:10.1016/j.epsr.2012.10.013, 2013.

[23] A. Arief, M. B. Nappu, M. Gallagher, and D. Zhao-Yang, "Under voltage load shedding utilizing trajectory sensitivity to enhance voltage stability," in *2011 21st Australasian Universities Power Engineering Conference (AUPEC)*, Brisbane, QLD Australia, 25-28 September, 2011, pp. 1-6.

[24] A. Arief, "Under Voltage Load Shedding Using Trajectory Sensitivity Analysis Considering Dynamic Loads," *Universal Journal of Electrical and Electronic Engineering,* vol. 2, pp. 118-123, DOI: 10.13189/ujeee.2014.020304, 2014.

[25] A. Arief, M. B. Nappu, Z. Y. Dong, and M. Arief, "Under voltage load shedding incorporating bus participation factor," in *The 9th International Power and Energy Conference (IPEC)*, Singapore, 27-29 October, 2010, pp. 561-566.

[26] A. Arief, M. B. Nappu, X. Yin, X. Zhou, and Z. Y. Dong, "Under Voltage Load Shedding Design with Modal Analysis Approach," in *The 8th IET International Conference on Advances in Power System Control, Operation and Management (APSCOM)* Hong Kong, 8th-11th November, 2009.

[27] M. Biglari, "Dynamics of Voltage Stability in a Multi Node System," in *42nd International Universities Power Engineering Conference*, Brighton, UK, 4-6 September, 2007, pp. 641-644.

[28] A. Arief, Antamil, and M. B. Nappu, "An Analytical Method for Optimal Capacitors Placement from the Inversed Reduced Jacobian Matrix," *Energy Procedia, September,* 2016.

[29] C. J. Mozina, "Undervoltage Load Shedding," in *60th Annual Conference for Protective Relay Engineers* Texas, USA, 27-29 March, 2007, pp. 16-34.

[30] P. W. Sauer and M. A. Pai, *Power System Dynamics and Stability*. Champaign, Illinois, USA: Stipes Publising L.L.C, 2006.

[31] B. H. Lee and K. Y. Lee, "Dynamic and static voltage stability enhancement of power systems," *IEEE Transactions on Power Systems,* vol. 8, pp. 231-238, 1993.

[32] W. W. Price, "Power System Dynamic Modeling," in *Power System Stability and Control*, L. L. Grigsby, Ed., ed Boca Raton: CRC Press, Taylor and Francis Group, 2007.

[33] J. R. Shin, B. S. Kim, M. S. Chae, and S. A. Sebo, "Improvement of Precise P/V Curve Considering Effects of Voltage-Dependent Load Models and Transmission Losses for Voltage Stability Analysis," *IEE Proceedings- Generation, Transmission and Distribution,* vol. 149, pp. 384-388, 2002.

[34] A. Borghetti, R. Caldon, A. Mari, and C. A. Nucci, "On dynamic load models for voltage stability studies," *IEEE Transactions on Power Systems,* vol. 12, pp. 293-303, 1997.

[35] B. Sapkota and V. Vittal, "Dynamic VAr Planning in a Large Power System Using Trajectory Sensitivities," *IEEE Transactions on Power Systems,* vol. 25, pp. 461-469, 2010.

[36] R. M. Rifaat, "On Composite Load Modeling for Voltage Stability and Under Voltage Load Shedding," in *IEEE Power Engineering Society General Meeting*, Denver, Colorado, USA, June 7 - 10, 2004, pp. 1603-1610 Vol.2.

[37] B. Hua and V. Ajjarapu, "A Novel Online Load Shedding Strategy for Mitigating Fault-Induced Delayed Voltage Recovery," *IEEE Transactions on Power Systems,* vol. 26, pp. 294-304, 2011.

[38] W. Xu and Y. Mansour, "Voltage Stability Analysis Using Generic Dynamic Load Models," *IEEE Transactions on Power Systems,* vol. 9, pp. 479-493, 1994.

[39] R. Balanathan, N. C. Pahalawaththa, and U. D. Annakkage, "Undervoltage Load Shedding for Induction Motor Dominant Loads Considering P, Q Coupling," *IEE Proceedings-Generation, Transmission and Distribution,* vol. 146, pp. 337-342, 1999.

[40] PT. PLN (Persero) AP2B Sistem Sulawesi Selatan, *Kondisi Kelistrikan Sistem Sulawesi Selatan dan Barat*. Makassar, Indonesia: PT. PLN (Persero) 2010.

[41] IEEE Task Force on Load Representation for Dynamic Performance, "Standard Load Models for Power Flow and Dynamic Performance Simulation," *IEEE Transactions on Power Systems,* vol. 10, pp. 1302-1313, 1995.

ICITACEE 2016

ORIGINALITY REPORT

SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS
16%	11%	10%	4%

PRIMARY SOURCES

1	S. A. Al Dessi, A. H. Osman, A. I. Ibrahim. "Voltage stability assessment of a real power system using a detailed dynamic load model", 2013 3rd International Conference on Electric Power and Energy Conversion Systems, 2013 Publication	2%
2	scholarworks.uno.edu Internet Source	1%
3	espace.library.uq.edu.au Internet Source	1%
4	eprints.undip.ac.id Internet Source	1%
5	Dingguo Chen, R.R. Mohler. "Neural-network-based load modeling and its use in voltage stability analysis", IEEE Transactions on Control Systems Technology, 2003 Publication	1%
6	oaktrust.library.tamu.edu Internet Source	1%

7	Hasan Hedayati. "A Method for Placement of DG Unitsin Distribution Networks", IEEE Transactions on Power Delivery, 07/2008 Publication	1 %
8	Submitted to King Fahd University for Petroleum and Minerals Student Paper	1 %
9	Muhammad Bachtiar Nappu. "LMP-lossless for congested power system based on DC-OPF", 2014 Makassar International Conference on Electrical Engineering and Informatics (MICEEI), 2014 Publication	1 %
10	discovery.ucl.ac.uk Internet Source	1 %
11	K. Mollah, M. Bahadornejad, N.-K C. Nair, G. Ancell. "Automatic under-voltage load shedding: A systematic review", 2012 IEEE Power and Energy Society General Meeting, 2012 Publication	1 %
12	collections.mun.ca Internet Source	1 %
13	H. Bevrani, A. G. Tikdari. "Chapter 9 An ANN-Based Power System Emergency Control Scheme in the Presence of High Wind Power	<1 %

	Penetration", Springer Science and Business Media LLC, 2010 Publication	
14	Philip, A. "Eastern Long Island dynamic voltage stability", IEEE PES General Meeting, 2010. Publication	<1 %
15	cyberleninka.org Internet Source	<1 %
16	etheses.whiterose.ac.uk Internet Source	<1 %
17	mafiadoc.com Internet Source	<1 %
18	orbi.uliege.be Internet Source	<1 %
19	transgridsolutions.com Internet Source	<1 %
20	txspace.tamu.edu Internet Source	<1 %
21	www.mdpi.com Internet Source	<1 %
22	K. Morison, H. Hamadani, Lei Wang. "Practical issues in load modeling for voltage stability studies", 2003 IEEE Power Engineering Society General Meeting (IEEE Cat. No.03CH37491), 2003	<1 %

Publication

Exclude quotes	On	Exclude matches	< 5 words
Exclude bibliography	On		