

# 7\_IJAER\_-\_INDAR.pdf

*by*

---

FILE	7_IJAER_-_INDAR.PDF (394.1K)	WORD COUNT	2386
TIME SUBMITTED	14-MAR-2020 08:23PM (UTC+0700)	CHARACTER COUNT	11071
SUBMISSION ID	1275475307		

## Steady State Stability Assessment using Continuation Power Flow based on Load Tap Changer

<sup>1</sup>Indar Caherah Gunadin, <sup>2</sup>Zaenab Muslimin and <sup>3</sup>Yusran

<sup>1,2,3</sup>Electrical Department, Hasanuddin University, Indonesia.

<sup>1</sup>Orcid: 0000-0001-9516-0282

### Abstract

Steady State Stability issues become topic of the problems that continue to attract the attention of researchers in the world, this is caused by the phenomenon of stability increases with the increase of electrical load. There are several causes of steady state stability issues include: lack of reactive power. In the operation of power systems, often performed actions on the change in value of the transformer tap changer. This study aimed to examine the effects of changes in the transformer load tap changer to change the steady state stability limit of the electric power system. By using the method of Continuation Power Flow (CPF), will see changes in the maximum loading limits and the value of critical voltage on each. From the simulations it appears that the addition of tap changer setting will lower the value of the maximum load. The test case in this study the IEEE 14 bus system.

**Keywords:** Steady State Stability, Continuation Power Flow, Tap Changer, Transformer, Load

### INTRODUCTION

Steady-state stability limit of the power system is the steady-state operating conditions where the power system is still in a stable condition but for small changes of operating parameters will bring the system loses its stability [1]. The initial definition refers to the concept that "the stability of the system to the condition of load changes gradually and slowly change" [2].

Voltage Collapse, causing the system to lose synchronous and instability caused by the strengthening of small oscillations of all forms of steady state instability. Based on the reality on the ground, steady state stability is associated with low availability of active and reactive power, low voltage level, and the amount of change in voltage for changes in load or over plants [3,4,6,7]. The conventional method of calculation which is based on the convergence of the Newton-Raphson power flow raised by Venikov [2,5,8]. This method requires a long computation time. Then the researchers gave some improvements to this method by adding a new algorithm to perform multiple load flow solution [7,8]. Chebbo [8] uses the concept of the theory of two buses to estimate the maximum load limit of the electric power system. In this method, the power system will be transformed into two buses connected by impedance thevenin. The impedance Thevenin determination

system requires power flow calculation, so that the method for determining the loading limit a bus load flow calculation required repeated, as a result of this method is practically difficult to apply [8]. This study aimed to examine the effect of the changes on the transformer load tap changer to change the steady state stability limit of the system. Case used is the IEEE-14 bus system using PSAT software.

### OLTC MODEL

A transformer with a turn ratio can be represented as an impedance or admittance connected in series with an ideal autotransformer, as shown in Figure 1

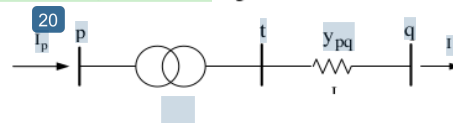


Figure 1: Representation Model of Tap - Changing Transformer

Tap ( $t=1/a$ ) is the deviation from the condition of excess or less than face value. Value range is usually between 0.8 and 1.2. In the model of equivalent three composing elements, namely:  $[(1-a)/a]$ ,  $[(a-t)/a^2]$ , or  $t$ ,  $[(t-1)]$  and  $(1-t)$ .

On tap changing normal conditions, the ratio of 'a' is equal to 1 and so the model is converted into a series transformer with the value being the value of emergency two shunt element is zero.

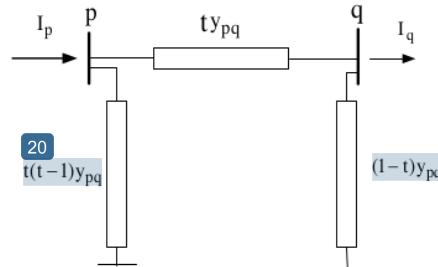


Figure 2: Equivalent to Transformer with Tap Changer

To determine the relationship between power on and load tap-changing ratio at different load voltages can be described in Figure 3

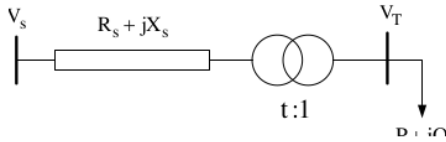


Figure 3: Model Thevenin Equivalent

By using a simple voltage drop relationships, the equation system is:

$$\Delta V = \left| \frac{V_s}{t} \right| - |V_T| = \frac{((X_s + X_t)/t^2)Q + (R_s/t^2)P}{V_T} \quad (1)$$

$$V_T^2 t^2 - V_T V_s t + R_s P + (X_s + X_t)Q = 0 \quad (2)$$

From this equation the value of  $t$  can be obtained:

$$t_1 = (V_s V_T + ((V_s V_T)^2 - 4V_T^2(R_s P + (X_s + X_t)Q))^2 / 2V_T^2)^{1/2}$$

$$t_2 = (V_s V_T + ((V_s V_T)^2 - 4V_T^2(R_s P + (X_s + X_t)Q))^2 / 2V_T^2)^{-1/2}$$

#### CONTINUATION POWER FLOW (CPF)

There are several methods that used to determine the stability limits of the system. One of them is Continuation Power Flow (CPF). There are convergence problems of Newton Raphson nearly load ability limits so the Continuation method can be effective solution.

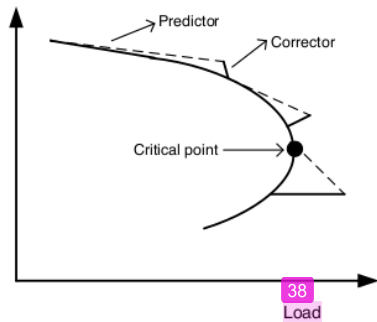


Figure 4: The Predictor and Corrector scheme

Fig.2.shows the predictor-corrector scheme used in the continuation power flow. From the Newton-Raphson, load flow equations can be written as:

$$P_i - \sum_{j=1}^N Y_{ij} V_i V_j \cos(\delta_i - \delta_j - \theta_{ij}) = 0 \quad (3)$$

$$Q_i - \sum_{j=1}^N Y_{ij} V_i V_j \sin(\delta_i - \delta_j - \theta_{ij}) = 0 \quad (4)$$

The new load flow equations consist of load factor ( $\lambda$ ) are expressed as:

$$P_{Li} = P_{L0} + \lambda(K_{Li} S_{\Delta base} \cos \theta_i) \quad (5)$$

$$Q_{Li} = Q_{L0} + \lambda(K_{Li} S_{\Delta base} \sin \theta_i) \quad (6)$$

Then, the power flow equation can be written as:

$$F(\delta, V, \lambda) = 0$$

Active power generation can be modified to:

$$P_{Gi} = P_{G0}(1 + \lambda K_{Gi})$$

To solve the , the continuation algorithm starts from a known solution and uses a predictor-corrector scheme to find subsequent solutions at different load levels [15]

#### RESULT

The system used as a test case is the IEEE 14 bus system. The study was conducted aiming to see the effect of Tap Changer, Load Characteristic and Current Limiter on Steady State Stability Limit use PSAT software version 1.3.4.

The initial of this study is to conduct a study using power flow Newton Raphson method. Results of Load Flow for IEEE 14 bus system are shown in Table 1 and fig. 5.

Table 1: Results of Load Flow

Bus No.	V [p.u.]	Phase [rad]	P gen [p.u.]	Q gen [p.u.]	P load [p.u.]	Q load [p.u.]
Bus 01	1.06	0	2.329	0.0801	0	0
Bus 02	1.045	-0.878	0.4	0.6910	0.217	0.127
Bus 03	1.01	-0.2257	0	0.3846	0.942	0.19
Bus 04	0.9934	-0.1754	0	0	0.478	0.04
Bus 05	1.0005	-0.1492	0	0	0.076	0.016
Bus 06	1.07	-0.2411	0	0.0390	0.112	0.075
Bus 07	1.0789	-0.2256	0	0	0	0
Bus 08	1.09	-0.2256	0	0.0687	0	0
Bus 09	1.06	-0.2531	0	0	0.295	0.166
Bus 10	1.0543	-0.2560	0	0	0.09	0.058
Bus 11	1.0586	-0.2509	0	0	0.035	0.018
Bus 12	1.0555	-0.2560	0	0	0.061	0.016
Bus 13	1.051	-0.2574	0	0	0.135	0.058
Bus 14	1.0381	-0.2724	0	0	0.149	0.05

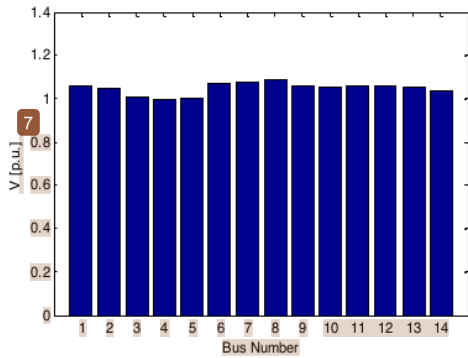


Figure 5: Tap Changer Model in PSAT Software

Then conducted studies Continuation Power Flow (CPF), which aims to see the bus that has a low level of stability which can be called as a bus or a weak (5) peak bus). The AVR and Tap Changer models used can be seen in Figure 6 and Figure 7.

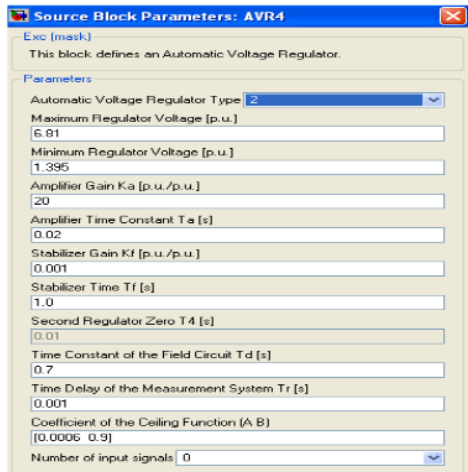


Figure 6: AVR Model in PSAT Software

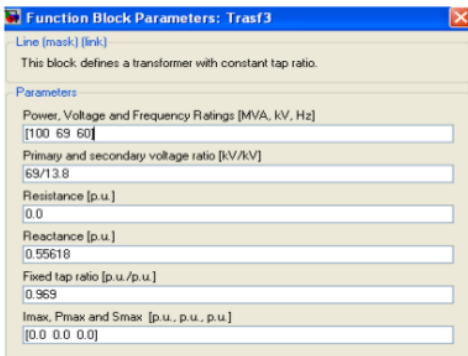


Figure 7: Tap Changer Model in PSAT Software

**Case I: For Normal Conditions**

Sections Under normal operating conditions setting state tap changer in the position as follows:

Line Tap Changer ratio of 5-6: 0932

Line Tap Changer ratio of 4-9: 0969

Line Tap Changer ratio of 4-9: 0978

Furthermore, with this data, analysis Continuation Power Flow (CPF) and the obtained results as in Figure 8.

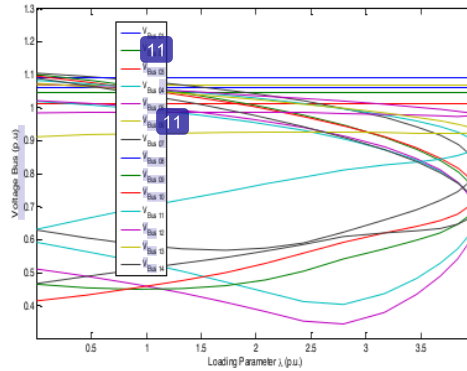


Figure 8: Relationship Between Loading Parameters and Bus Voltage

From Figure 8, it appears that the weakest bus (bus weak) is the bus 14, followed by a bus 9. This is due to the steepness of the graph for both bus is the most precipitous. This condition indicates that in the event of load changes, it will cause a voltage change is relatively larger than the other bus

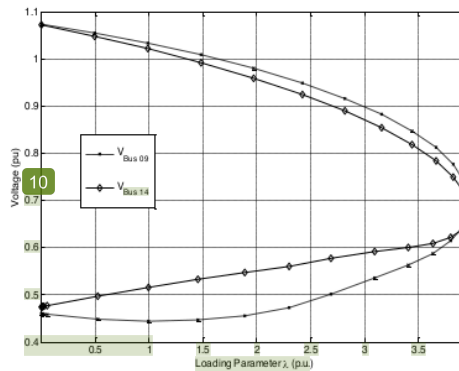


Figure 9: Relationship Between Loading Parameters and Voltage Bus 14 and Bus 9

From Figure 9 it appears that when the tap changer position in normal operation, the bus voltage on bus 14 will have a critical

voltage value of 0.45952 (pu) with a maximum load of 3.97295 (pu).

**Case II: Tap Changer change in position 0.9**

In this case that the tap changer has decreased with the changes as follows:

Line Tap Changer ratio of 5-6: 0.9

Line Tap Changer ratio of 4-9: 0.9

Line Tap Changer ratio of 4-9: 0.9

With the same simulation step then obtained the weakest buses remain on the bus 14 with the value of the critical stress of 0.46816 (pu) and the maximum loading of 3.9949 (pu).

**Case III: Tap Changer change in position 1.0**

Conditioned that the tap changer has decreased with the changes as follows:

Line Tap Changer ratio of 5-6: 1.0

Line Tap Changer ratio of 4-9: 1.0

Line Tap Changer ratio of 4-9: 1.0

Provided that the weakest buses remain on the bus 14 with the value of the critical stress of 0.46836 (pu) and the maximum loading of 3.95606 (pu)

**Case IV: Tap Changer change in position 1.1**

Conditioned that the tap changer has decreased with the changes as follows:

Line Tap Changer ratio of 5-6: 1.1

Line Tap Changer ratio of 4-9: 1.1

Line Tap Changer ratio of 4-9: 1.1

Provided that the weakest buses remain on the bus 14 with the value of the critical stress of 0.47238 (pu) and the maximum loading of 3.89324 (pu).

**Table 2:** Comparison of Change Tap Changer Relationship with the Imposition of Maximum and Critical Voltage

Value	Position of Tap Changer			
	Normal	tap = 0.9	tap = 1	tap = 1.1
V Critical of Load (p.u)	0.45952	0.46816	0.46836	0.47238
P Max (p.u)	3.97295	3.9949	3.95606	3.89324

**CONCLUSION**

The ratio of the transformer tap changer position greatly affects the maximum load limit. From the simulations we concluded that if the value of the ratio of the transformer tap changer increased the value of maximum power on the load side will decline, while the value of critical stress will rise.

**REFERENCES:**

- [1] P.M. Anderson and A.A. Fouad, *Power System Control And Stability*, Iowa State University Press, Ames, Iowa, 1982
- [2] Prabha Kundur, *Power System Stability and Control*, McGraw-Hill Inc, USA, 1994
- [3] T.J.E Miller, *Reactive Power Control in Electric System*, Jhon Wiley & Sons, USA, 1982
- [4] Hadi Saadat, *Power System*, McGraw-Hill Inc, USA, 1999
- [5] Thierry Van Cutsem and Vournas Costas, *Voltage Stability of Electric Power System*, Kluwer Academic Publisher, Massachusetts USA, 1998
- [6] Edward Wilson Kimbark, *Power System Stability*, Jhon Wiley & Sons, USA, 1948
- [7] Savu C.Savulescu, *Real-Time Stability Assessment in Modern Power System Control Center*, IEEE Press, Wiley, 2009
- [8] M.H. Haque, *A Fast Method for Determining The Voltage Stability Limit of A Power System*, Electric Power System Research 32, 1999, pp.35-43
- [9] Prabha Kundur, Jhon Paserba, Venkat jarapu, Goran Andersson, Claudio Canizares, *Definition And Classification of Power System Stability*, IEEE Transactions on Power System, Vol.19, No.2, May, 2004, pp.1387-1401
- [10] Federico Milano and Kailash Srivastava, *Dynamic REI Equivalent for Short Circuit and Transient Stability Analyses*, Electric Power System Research 79, 2009, pp.878-887
- [11] Indar Chaerah Gunadin, Adi Soeprijanto, Ontoseno Penangsang, *Steady State Stability Assessment Using Extreme Learning Machine Based on Modal Analysis*, International Review of Electrical Engineering (I.R.E.E.), Vol. 7. n. 3, pp. 4532-4537
- [12] S.Kamalasadan, D.Thukaram, A.K.Srivastava, *A New Intelligent Algorithm for Online Voltage Stability Assessment and Monitoring*, Electric Power System Research 31, 2009, pp.100-110
- [13] M.A.Tomim, J.R. Marti and L.Wang, *Parallel Solution of Large System Network Using The Multi Area Thevenin*

*Equivalent (MATE) Algorithm*, Electric Power System  
Research 31, 2009, pp.497-503

- 28
- [14] Joko Pitono, Adi Soepri<sup>16</sup>o, Mauridhi Hery Purnomo, Indar Chaerah Gunadin, *Power Generation Optimization Based on Steady State Stability Limit Using Particle Swarm Optimization (PSO)*, International Review on Modelling and Simulation (IREMOS), Vol 6, No 4 (2013), pp.1227-1232
- 22
- [15] Gunadin, I.C., Abdillah, M., Soeprijanto, A., Penangsang, "Determination of steady state stability margin using extreme learning machine ", WSEAS Transactions on Power Systems, 2012
- 6
- [16] Haniyeh Marefatjou and Iman soltani, *Continuation Power Flow Method with Improved Voltage Stability Analysis in Two Area Power System*, International Journal of Electrical Energy, Vol.1, No.1, March 2013

ORIGINALITY REPORT

---

**%33**  
SIMILARITY INDEX

**%26**  
INTERNET SOURCES

**%22**  
PUBLICATIONS

**%25**  
STUDENT PAPERS

---

PRIMARY SOURCES

---

**1** Submitted to Guru Nanak Dev Engineering College  
Student Paper **%4**

---

**2** Rusilawati, Irrine Budi Sulistiawati, Adi Soeprijanto, Rony Seto Wibowo. "Determination of Generator Steady State Stability Limit for Multimachine System based on Network Losses Concept", MATEC Web of Conferences, 2018  
Publication **%3**

---

**3** baadalsg.inflibnet.ac.in  
Internet Source **%2**

---

**4** www.arpnjournals.org  
Internet Source **%1**

---

**5** www.ijmer.com  
Internet Source **%1**

---

**6** www.ijoe.org  
Internet Source **%1**

---

**7** researchrepository.wvu.edu  
Internet Source **%1**

---

8

Submitted to Brunel University

Student Paper

% 1

9

Georg Lauss, Kai Strunz. "Multirate Partitioning Interface for Enhanced Stability of Power Hardware-in-the-Loop Real-Time Simulation", IEEE Transactions on Industrial Electronics, 2019

Publication

% 1

10

[tru.uni-sz.bg](http://tru.uni-sz.bg)

Internet Source

% 1

11

Fredy A. Sanz, Juan M. Ramirez, Rosa E. Correa. "Statistical estimation of power system vulnerability", 2013 North American Power Symposium (NAPS), 2013

Publication

% 1

12

Rusilawati Rusilawati, Adi Soeprijanto, Rony Seto Wibowo. "Reactualization of a Modified Single Machine to Infinite Bus Model to Multimachine System Steady State Stability Analysis Studies Using Losses Network Concepts and Radial Basis Function Neural Network (RBFNN)", International Review on Modelling and Simulations (IREMOS), 2017

Publication

% 1

13

N. Boonpirom, K. Paitoonwattanakij. "Static voltage stability enhancement using FACTS",

% 1

# 2005 International Power Engineering Conference, 2005

Publication

14

[www.wseas.us](http://www.wseas.us)

Internet Source

% 1

15

[shodhganga.inflibnet.ac.in](http://shodhganga.inflibnet.ac.in)

Internet Source

% 1

16

[eng.unhas.ac.id](http://eng.unhas.ac.id)

Internet Source

% 1

17

[www.srmuniv.ac.in](http://www.srmuniv.ac.in)

Internet Source

% 1

18

Chi-Jui Wu, Yuang-Shung Lee. "Application of superconducting magnetic energy storage unit to improve the damping of synchronous generator", IEEE Transactions on Energy Conversion, 1991

Publication

% 1

19

[ijres.org](http://ijres.org)

Internet Source

% 1

20

Submitted to Ege Üniversitesi

Student Paper

% 1

21

Xi-Fan Wang, Yonghua Song, Malcolm Irving. "Modern Power Systems Analysis", Springer Science and Business Media LLC, 2008

Publication

% 1

22	<p>Indar Chaerah Gunadin, Zaenab Muslimin, Agus Siswanto. "Transient stability improvement using allocation power generation methods based on moment inertia", 2017 International Conference on Electrical Engineering and Informatics (ICELTICs), 2017</p> <p>Publication</p>	% 1
23	<p><a href="http://fedetd.mis.nsysu.edu.tw">fedetd.mis.nsysu.edu.tw</a></p> <p>Internet Source</p>	% 1
24	<p><a href="http://mafiadoc.com">mafiadoc.com</a></p> <p>Internet Source</p>	<% 1
25	<p><a href="http://www.ritchennai.org">www.ritchennai.org</a></p> <p>Internet Source</p>	<% 1
26	<p>Submitted to Malaviya National Institute of Technology</p> <p>Student Paper</p>	<% 1
27	<p>V. Golov, D. Kormilicyn. "Oscillatory Stability Regions of Electrical Power System with Controlled Extra-High Voltage Transmission Line", 2018 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM), 2018</p> <p>Publication</p>	<% 1
28	<p><a href="http://repository.unhas.ac.id">repository.unhas.ac.id</a></p> <p>Internet Source</p>	<% 1

29 Submitted to National Institute of Technology, Patna  
Student Paper <% 1

---

30 ideatech.stts.edu  
Internet Source <% 1

---

31 www.readbag.com  
Internet Source <% 1

---

32 www.europment.org  
Internet Source <% 1

---

33 Submitted to University of Liverpool  
Student Paper <% 1

---

34 conference.nber.org  
Internet Source <% 1

---

35 Submitted to Higher Education Commission Pakistan  
Student Paper <% 1

---

36 Matin Meskin, Ilya Grinberg. "The Effect of Network Reduction on Overcurrent Relay Coordination in Interconnected Power Networks", 2019 IEEE Canadian Conference of Electrical and Computer Engineering (CCECE), 2019  
Publication <% 1

---

37 "Swarm, Evolutionary, and Memetic Computing", Springer Science and Business <% 1

# Media LLC, 2013

Publication

---

38

Submitted to CVC Nigeria Consortium

Student Paper

<% 1

---

39

Submitted to University of Northumbria at  
Newcastle

Student Paper

<% 1

---

EXCLUDE QUOTES ON

EXCLUDE  
BIBLIOGRAPHY ON

EXCLUDE MATCHES < 5  
WORDS