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

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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 sinchronous 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 power 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

Manuscripts 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

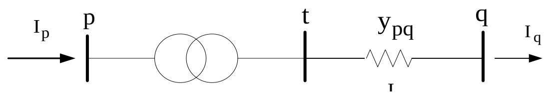

Figure 1: Representation Model of Tap - Changing Transformer

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 - 1) / a2)], or t, 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.

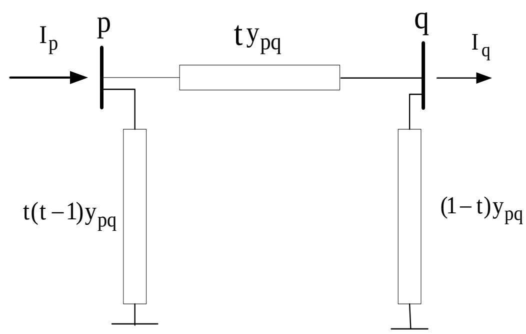

Figure 2: Equivalent to Transformer with Tap Changer

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

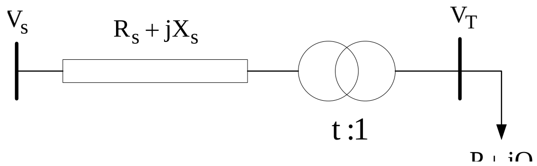

Figure 3: Model Thevenin Equivalent

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

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

$$V^2{}_T t^2 - V_T V_S t + R_s P + (X_S + X_t)Q = 0 \quad (2)$$

From this equation the value of t can be obtained:

$$t_1 = (V_S V_T + ((V_S V_T)^2 - 4V_T{}^2(R_s P + (X_S + X_t)Q))^2/2V_T{}^2$$
$$t_2 = (V_S V_T + ((V_S V_T)^2 - 4V_T{}^2(R_s P + (X_S + X_t)Q))^2/2V_T{}^2$$

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.

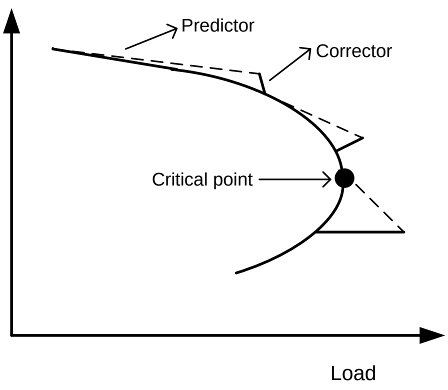

Figure 4: The Predictor and Corrector scheme

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 (λ) are expressed as:

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

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

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 step of this study is to conduct a study using the 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	-.0878	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

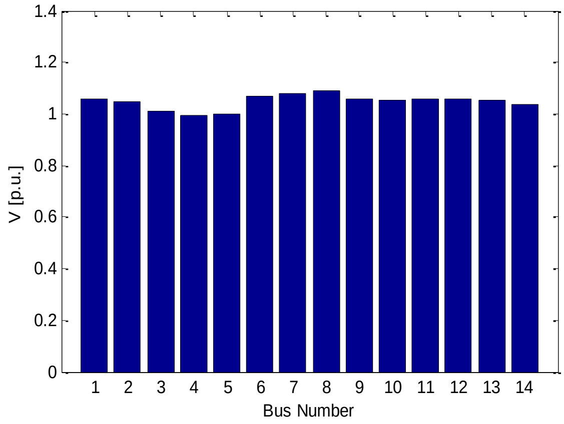

Figure 5: Tap Changer Model in PSAT Software

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

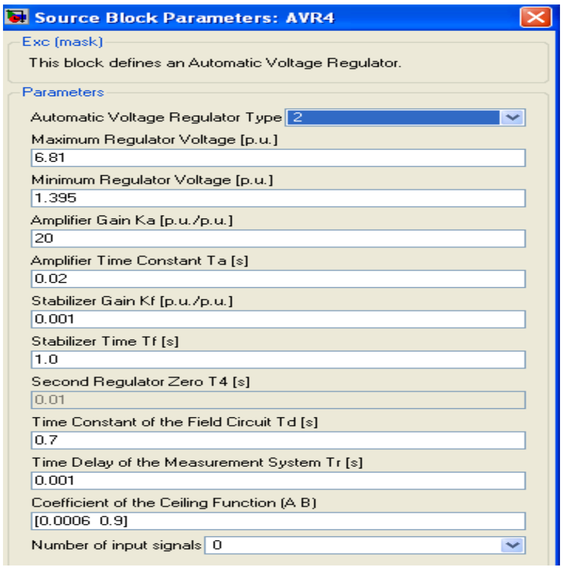

Figure 6: AVR Model in PSAT Software

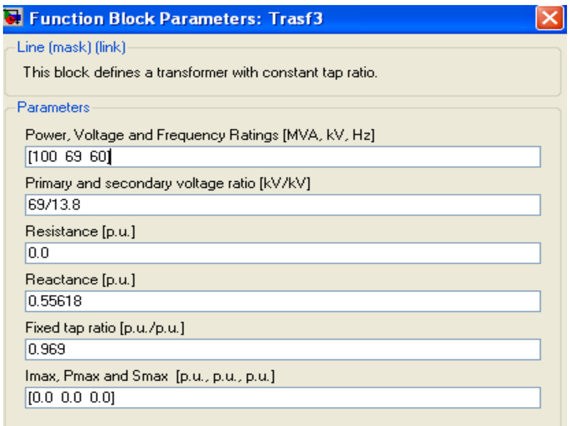

Figure 7: Tap Changer Model in PSAT Software

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.

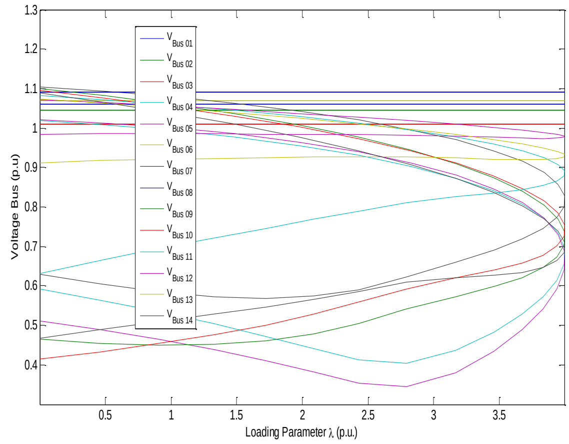

Figure 8: Relationship Between Loading Parameters and Bus Voltage

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

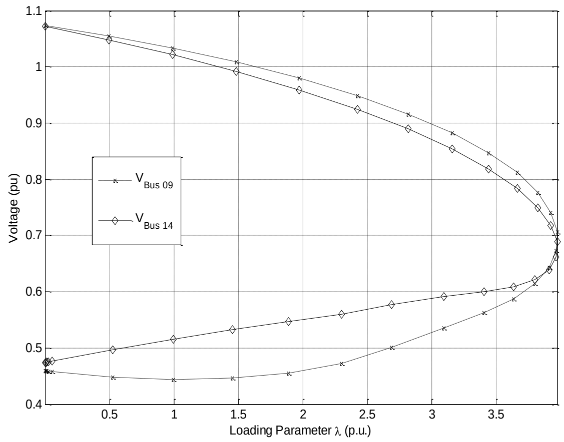

Figure 9: Relationship Between Loading Parameters and Voltage Bus 14 and Bus 9

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.

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