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Determination of Accurate Critical Clearing Time for Transient Stability Assessment

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Abstract **- Transient Stability Assessment (TSA) is essentially important since recent blackout in northern India turns most of the research people towards dynamic security. Transient stability is inherently a Differential-Algebraic equation which is needed to be tackled by an effective method. So, Time Domain Approach is implied in solving TSA.The main objective of this paper is to determine accurate Critical Clearing Time (CCT) for various line outages and to check whether system stability is preserved during contingency cases. The results are simulated for WSCC three generators, nine bus system through which the robustness and effectiveness of this approach has been proved.**

Index Terms **– Transient Stability Assessment, Time Domain Approach,Center of Inertia, Critical Clearing Time,Critical Angle.**

I. INTRODUCTION

Now a day'selectricity demand has been enormously increasing so it is hard to maintain operating point of the power system within the securable limits**.** Transient Stability as a constraint [1] becomes essentially important since it is necessary to run power system network within the reasonable stability margin. In general, transient stability will fall under the category of large signal stability where it can be defined as system potential to withstand large transient disturbances [2], [9]. This large disturbance will results in event such as huge deviation in rotor angles, power flows, and bus voltages of system. Thus a preventive action is needed to preserve the system stability. Transient stability assessment (TSA) is kind of a preventive method to detect whether the system stability is preserved after the occurrence of possible fault events. There are many methods to approach TSA. In this paper, time domain approach is taken to evaluate system stability under various contingency cases[3]. Time domain approachhas been used as a reference scale for TSA. It is accurate, robust and proven to be faster in real time process with the support of high speed Computers.

II. FORMULATION OF TRANSIENT STABILITYASSESSMENT

There are two ways to evaluate system stability under time domain approach.

1. Assigning a FaultClearing Time (t_{cl}) and checking whether the system is stable throughout the specified period.
2. Calculating CCT for various contingencies and checking the system stability by assigning the credible margin(<100 degrees) and observingthe machine angle whether it is within the acceptable limits [4].

In this paper, latter method is used for evaluation of transient stability due to its less computational time. The dynamic response of the multi machine system [5] is a set of differential equation which can be formulated as:

$$\frac{2H_i}{\omega_s}\frac{d^2\delta_i}{dt^2} = P_{mi} - P_{ei} , \qquad i = 1, \ldots . m \qquad (1)$$

$$\frac{d\delta_i}{dt} = \omega_i, \qquad i = 1, \ldots . m \qquad (2)$$

Where

δ_i: Rotor angle of machine i

ω_i:Angular speed of generator i

ω_s: Synchronous speed in rad per sec

H_i: Inertia constant of machine i

P_{mi}: Mechanical power input to the machine i

P_{ei} : Electrical power output to the machine i

m: No of machines in a system

This swing equation is solved using 4^{th}order Runge- kutta method [6], [8] since it doesn't require explicit evaluation which is higher than first order.

The fourth order Runge -Kutta method can be formulated as

$$x_{i+1} = x_i + \Delta x \quad (3)$$

$$\Delta x = \frac{1}{6}(k_1 + k_2 + k_3 + k_4) \quad (4)$$

$$k_1 = f(x_i, t_i)\Delta t \quad (5)$$

$$k_2 = f\left(x_i + \frac{k_1}{2}, t_i + \frac{\Delta t}{2}\right)\Delta t \quad (6)$$

$$k_3 = f\left(x_i + \frac{k_2}{2}, t_i + \frac{\Delta t}{2}\right)\Delta t \quad (7)$$

$$k_4 = f(x_i, t_i + \Delta t)\Delta t \quad (8)$$

Where

k_1:Slope at the beginning of time step

k_2 : First approximation to slope at mid step

k_3: Second approximation to slope at mid step

k_4: Slope at the end of the step

The δ_i can be measured with respect to synchronously rotating plane. Instability of machine (i) is defined as deviation of Rotor Angle (δ_i) from the remaining part of the system. For testing the machines instability, it is precise to compare the relativerotor angleswith respect to reference angle instead of monitoring absolute Rotor angles. The Centre of Inertia (COI) is used as reference angle because it represents mean motion of the system [7]. Usually synchronous stability of all machines is evaluated only through COI.

The COI (δ_0) for entire system is calculated using linear combination of all machine angles and it can be formulated as:

$$\delta_0 = \frac{1}{M_T}\sum_{i=1}^{N} M_i\delta_i \quad (9)$$

The center of speed (ω_0) can be formulated as:

$$\omega_0 = \frac{1}{M_T}\sum_{i=1}^{N} M_i\omega_i \quad (10)$$

$$M_T = \sum_{i=1}^{N} M_i \quad (11)$$

Where

M_i → Inertia of center

Transforming all system variables $\delta_i$and ω_i into COI variables and it can be represented as

$$\theta_i = \delta_i - \delta_0 \quad (12)$$

III. TEST PROCEDURE

The steps sequence which is used to be carried out during TSA is given below

Step 1: Load the data's such as$P_g, Q_g, P_{load}, Q_{load}, V_i$.

Step 2:Initially run power flow program for the system.

Step 3:Obtain voltage limits, real and reactive power injections from the power flow results.

Step 4:Select a contingency and identifyfault bus and the line to be removed during the contingency.

Step 5:Compute δ_i and construct the swing curve. Check whether machine angles are within the acceptable limit (< 100 degrees).

Step 6:Compute corresponding Critical Clearing Time for the contingency.

Step 7:Go to contingency list and check for another possible contingency.

IV. RESULTSAND DISCUSSION

The performance of the time domain approach has been tested using WSCC 3 generator 9 bus systems. To start with pre fault system is run for a small time. Then a three phase fault has been simulated in one of the lines of 9 bus system. In orderto find how for the transient stability is sustained during post fault condition Critical Clearing Time, Critical machine angle of the system are calculated. Further all 3 machine angleshave been computed for each line outages.

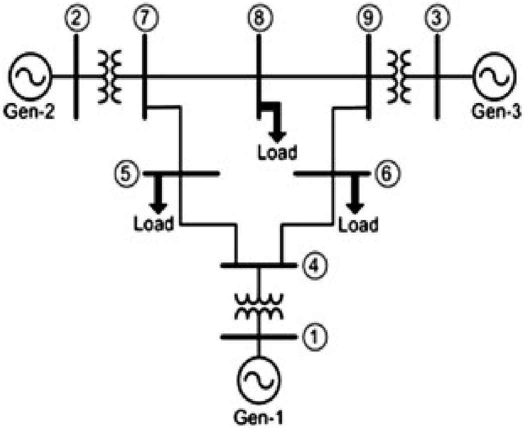

Fig.1 WSCC 3 generator, nine bus system.

Case 1:Fig.2. shows the response of the system for the fault occurred at the bus 4 and it was cleared by removing the line 4-6. From the swing curve, the rotor angle of machine 1 is assigned as critical angle since it occupies the largest value in the system.

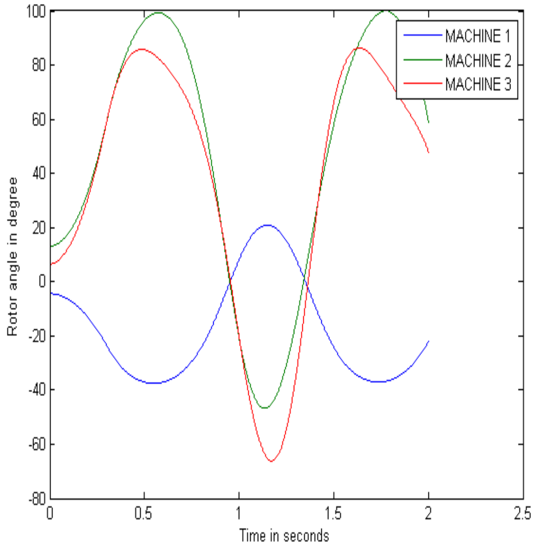

Fig.2stable trajectory of rotor angle for Case1.

Case 2:Fig.2. Shows the response of the system for the fault occurred at the bus 5 and was cleared by removing the line 5-7. From the swing curve, the rotor angle of machine 1 is assigned as critical angle since it occupies the largest value in the system.

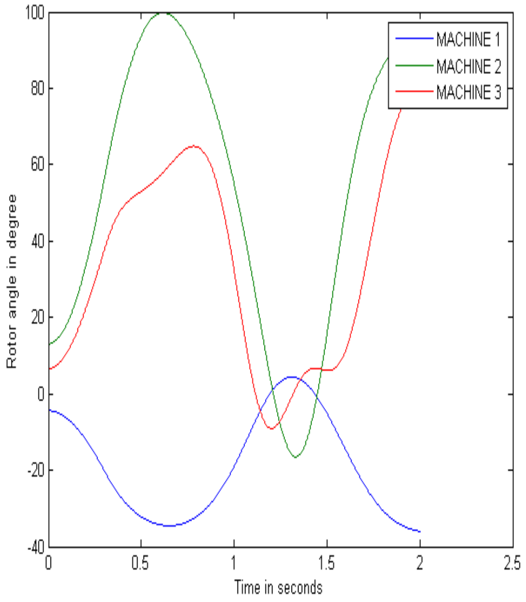

Fig.3stable trajectory of rotor angle for Case 2.

Case 3:Fig.4. shows the response of the system for the fault occurred at the bus 6 and was cleared by removing the line 6-9. From the swing curve, the rotor angle of machine 2 is assigned as critical angle since it occupies the largest value in the system.

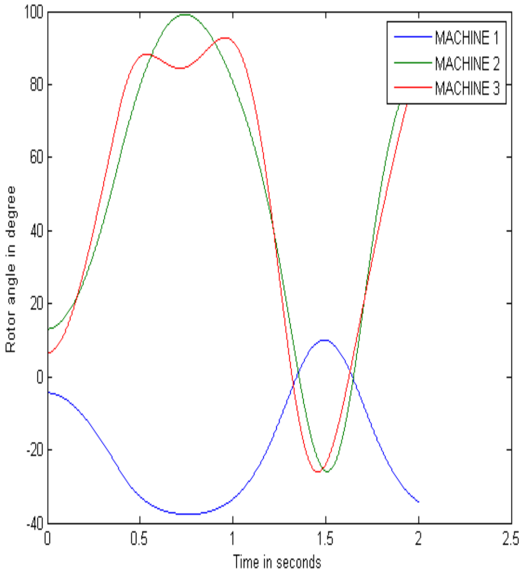

Fig.4stable trajectory of rotor angle for Case 3.

Table I shows the parameters such as critical clearing time and critical angle for various line outages of WSCC 3 generator 9 bus system.

TABLE I

SIMULATION RESULTS FOR WSCC 3 GENERATOR 9 BUS SYSTEM

Faulted Bus	Line to be Removed	CCT	M1	M2	M3	CCA
4	4-5	0.286	18.40	99.63	68.42	99.63
4	4-6	0.30	20.58	99.88	86.30	99.88
5	5-7	0.30	4.38	99.90	80.12	99.90
6	6-9	0.38	10.75	99.22	92.80	99.22
7	7-8	0.17	18.78	99.89	29.04	99.89
8	8-9	0.28	4.73	99.96	73.34	99.96

From the table it is observed that avery low critical clearing time and highest critical angle has occurredfor the fault atbus no 8 so it is assigned as a severe case.

V. CONCLUSION

In this paper,stability of the system was analyzed under transient conditions through Time Domain Approach. This approach was assessed for WSCC three generator nine bus systems. The Critical Clearing Time is determined and investigated to test how far the system stability can sustained for possible contingencies.Through the test results it is observed that time domain approach is proven to be an efficient androbust method.

REFERENCES

[1] K.W.Chan, R.W.Dun, A.R.Daniels: On-line stability constraint assessment for large complex

power systems. Electric Power Systems,Research. Na.46, pp169-176, 1998.

[2] PrabhaKundur , John Paserba, VenkatAjjarapu , GöranAnderson,Anjan Bose , Claudio Canizares, Nikos Hatziargyriou , David Hill, Alex Stankovic, Carson Taylo, Thierry Van Cutsem, and Vijay Vittal,“Definition and Classification of Power System Stability”, *IEEETrans. on Power Systems, Vol: 19, No.2, May 2004.*

[3] C.K. Tang, C.E. GrahPm, M.A. El-Kady, R.T.H.Alden, “Transient Stability Index from ConventionalTime Domain Simulation,” IEEE Paper No 93SM 487-9 PWRS.

[4] T.NguyenandM.A.Pai,“Dynamicsecurity-constrainedrescheduling ofpowersystemsusingtrajectorysensitivities,”*IEEETrans.PowerSyst.*, vol.18,no.2,pp.848–854,May2003.

[5] H. El-Adiad and K.Nagappan, “*Transient stability region of multi-machine power systems*,”IEEE Trans. Power Appar. Syst., vol. PAS-85, Feb. 1966, pp. 169-178.

[6] P. Kundur , “*Power System Stability &Control*,”McGraw-Hill, New York

[7] Peter W. Sauer, M. A. Pai“*Power systems dynamics and stability*”, Pearson education 2003.

[8] HadiSadaat, “*Power System Analysis*”, Tata McGraw Hill, 2002 Edition

[9] M.Pavella, PG. Murthy , “*Transient stability of power systems: theory and practice*” John Wiley and Sons; 1994.