ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An ISO 3297: 2007 Certified Organization)*

Vol. 4, Issue 10, October 2015

# Comparative Study of Depending Factors of CCT in IEEE 14 Bus System

Rahul R Nair[1], R Visakhan[1], Sebin Joseph[1], Ancy Sara Varghese[2]

PG Student [Power System], Dept. of EEE, Saintgits College of Engineering, Kottayam, Kerala, India[1]

Assistant Professor, Dept. of EEE, Saintgits College of Engineering, Kottayam, Kerala, India[2]

**ABSTRACT**: A deregulated power system is expected to serve the needs of the customers with improved reliability and security parameters of the utility. A power system which offers uninterrupted service to its customers is said to be highly reliable. Hence to serve the cause unwanted tripping of CBs are minimized to a large extent. This is done by controlling the CCT of the relay. Efficient smart grid topologies can be developed by implementing novel control strategies for relays, especially with critical clearing time. The study presented in this paper describes to what extend CCT is vulnerable to change with each of the factors determining it. Loadability of the test system is also derived out of the study. A standalone IEEE 14 bus is used as the test system. Variation of CCT is observed using time domain simulation and eigen value analysis method in MTLAB\PSAT platform.

.**KEYWORDS:**CCT, Transient Stability Limit

## I. INTRODUCTION

Stability of the power system is an important problem faced by engineers in establishing secure system operation. Growing economies of the world has widely increased their load demand. As a result, the power system structure has become large in size as well as complex in nature.The transient contingency analysis of such a system becomes tedious. This pushes the system transient stability limit to a drastic condition and route for major reliability problems in power system.

Transient stability of the system is its ability to reach an equilibrium state after a transient fault has occurred[1]. Different methods are available for transient stability evaluation such as time domain simulation, artificial intelligence techniques and direct techniques based on the energy function[2],[3],[4]. Even though the causes for the distraction of transient stability are identified , less research is carried out in improving the stability limits. Most of the existing methods include providing multiple feeders in the system and by increasing the system capacity.All these methods are highly uneconomical.

Reliability of a power system can be improved by optimum control of the critical clearing time (CCT) of the relay system[5]. Change in CCT depends on the system pre-fault conditions. Reaction of the relay to a fault is determined by the current CCT value and by analysing this variation the reliability of the system can be improved[6]. This methodology turned out to be more efficient on the grounds that no extra designs are needed for the current framework.CCT has large scope in improving the reliability of smartgrid systems[7],[8]. When FACTS devices were incorporated to the system, the change in the value of CCT was drastic [9]&[10].

This paper is organized as follows. Section II describes the CCT of the system. Section III illustrates the relation between CCT and transient stability limit of the system. Section IV describes the simulation results and CCT values of IEEE 14 bus system tabulated at different conditions. Conclusion of the work is presented in section V. Here, the simulation platform used is MATLAB/PSAT[11].

DOI: 10.15662/IJAREEIE.2015.0410069

## II. CRITICAL CLEARING TIME

The critical clearing time is the maximum time within which a disturbance must be cleared else the system loses its stability. The aim of this calculation is to determine the characteristics of protection system required by the power system .Fault clearing time is total of the time taken by the relay to identify the problem and to close the electrical switch to excursion circuit and the time needed for the electrical switch to intrude on the shortcoming current.If the fault clearing time is less than the CCT then the system remains stable, otherwise the system goes to unstable condition and hence system has to be isolated from the grid. So CCT is the principal criterion for transient stability assessment and the system should have CCT higher than the fault clearing time even while CCT is not sufficient to evaluate transient stability when considering various scenarios of severe faults occurrence in power system.

Mathematically, CCT is a function of pre-fault conditions, calculated from the critical angle of a system from the equal area criteria in the P- $\delta$ characteristics of a power system.

Swing equation is, $\frac{2H}{\omega_s}\frac{d^2\delta}{dt^2} = p_m - p_e$ ……………………………………………….(1)

Integrating (1) w.r.t time $\delta = \frac{\omega_s}{2H} P_m t^2 + \delta_0$ ……………………………….…………….(2)

When $\delta = \delta_{cr}$ then 't' become '$t_{cr}$' and the equation can be rearranged into

$$t_{cr} = \sqrt{\frac{4H}{\omega_s P_m}(\delta_{cr} - \delta_0)} \quad \text{……………………………………………….(3)}$$

CCT can alsobe determined by analysing $'\delta'$ of the system from swing equation. One of the easiest method is to analyse the change in $\delta$ of the system that means $'\omega'$ $(\frac{d\delta}{dt})$ .If the value of $\omega$ is greater than $\omega_{critical}$, system goes to unstable condition. Hence, CCT is the timeduration between fault incipient time and the time instant when $\omega$ reaches $\omega_{critical}$.

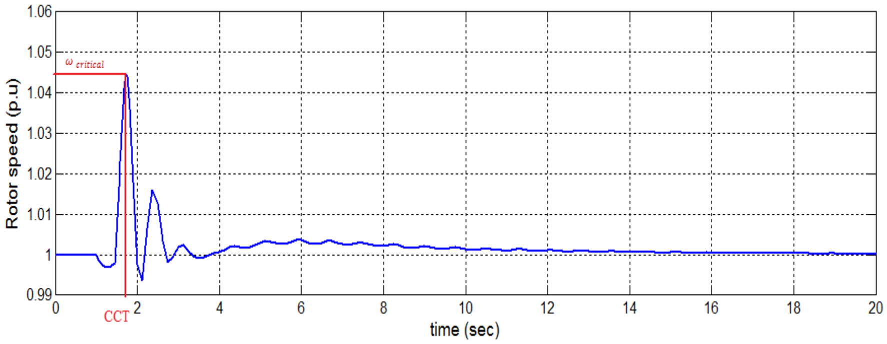

Fig.1 Relation between CCT and $\omega_{critical}$

## III.TRANSIENT STABILITY

Transient stability is the ability of the system to remain stable underlarge disturbances like short circuits, line outages, generation or load loss etc. Theevaluation of the transient stability is required offline for planning, design etc. and onlinefor load management, emergency control and security assessment. Transient stabilityanalysis deals with actual solution of the nonlinear differential equations describing thedynamics of the machines and their controls and interfacing it with the algebraicequations describing the interconnections through the transmission network.Since the disturbance is large, linearized analysis of the swing equation is not possible. Further, the fault may cause structural changes in the network, because of which the power angle curve pre-fault, during thefault and post fault may be different. Due to these reasons, a general stability criteria fortransient stability cannot be established, as was done in the case of steady state stability. Stability can be established, for a given fault, by actual solution of theswing equation.

Transient stability analysis is mainly performed through numerical simulations such as phase trajectory method and voltage stability method etc, all are time consuming and not necessarily suited for real time stabilityassessment[12],[13]. Transient stability limit depends on type of fault and the duration of fault. The power limit can be determined as a function of clearing angle and clearing time can be found by solving the swing equation up to the time of fault clearing. So transient stability is interrelated with critical clearing time (CCT). Through analysing CCT transient stability limit of the system can be analysed. This method also describes the maximum loadability of the system[14].

## IV.SIMULATION AND RESULTS

The simulation model is the IEEE 14 bus system, Which has two generator buses 1 and 2, For reactive power support to the system ,Synchronous compensators are connected to the bus 3, 6 and 8. The total generation capacity in IEEE 14 bus system is 272.6 MW + 108.83MVAr and the load demand is 259MW +81.4MVAr [15]. Maximum load demanded on the bus 5 in the system, for better study results three phase fault implanted at bus 5 and the fault incipient time was taken as 1 sec. Different case studies are done based on the depending factor of CCT

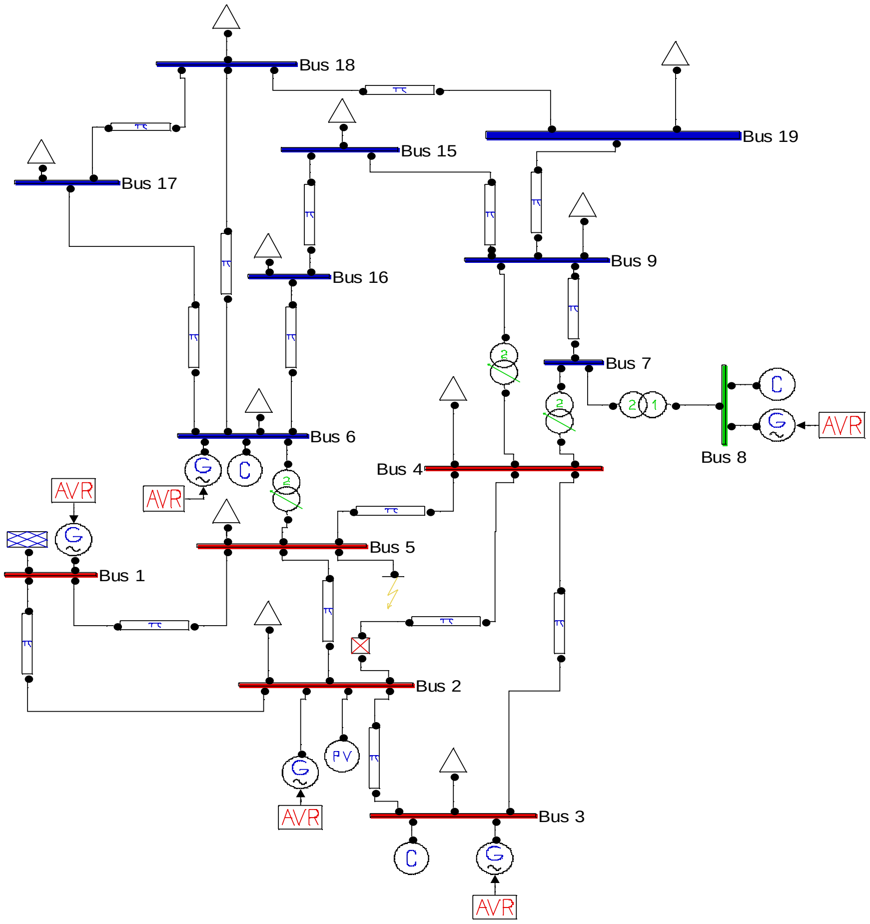

Fig.2 IEEE 14 bus test system

### a) Different Fault Location

CCT is interrelated with fault location in the line. In practical case fault can occur anywhere in the system. In this case study fault is implanted in 10 different locations in the line 5-4 and CCT is noted in each case by analyzing rotor speed $\omega$ of the system.

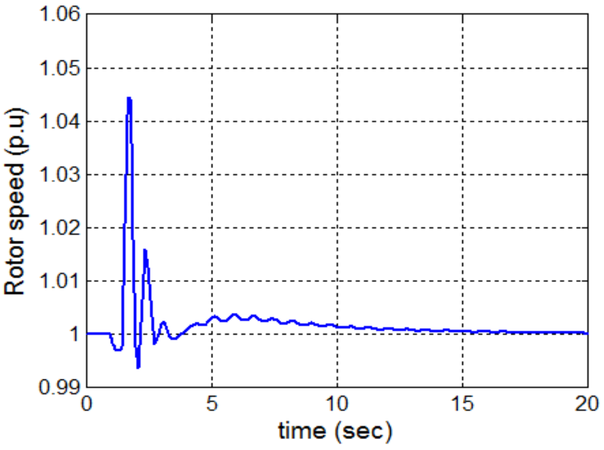

Fig.3 When Fault clearing time is 1.538 sec, the system remains in stable condition

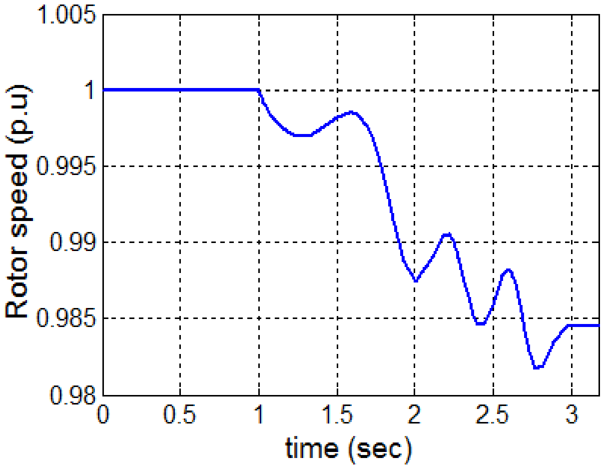

Fig.4 Fault clearing time is 1.539 sec, the system goes to unstable condition

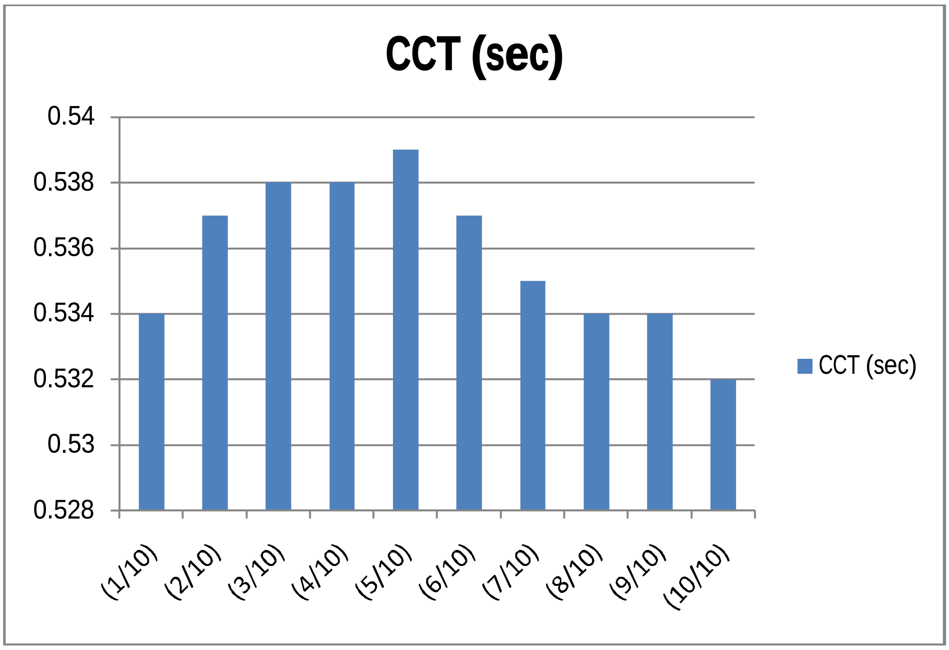

Fig.5 shows graph of CCT at different 10 locations in line 5-4

In Fig:3 clearing time of fault was 1.538 sec, rotor speed of the system settle down to a constant value so the system remains stable condition. In Fig: 4 fault clearing time was 1.539sec , rotor speed of the system dropout and the system goes to unstable. So the CCT of the system at this condition is 0.538 sec Table.1 and Fig:5 shows the CCT of the line 5-4 at 10differentlocations.From the table it is clear that, CCT is maximum when fault is on the middle of lineand CCT decreases when fault incident near to the bus.

| **Fault Location in Line (5-4)** | **CCT (sec)** |
|---|---|
| (1/10) | 0.534 |
| (2/10) | 0.537 |
| (3/10) | 0.538 |
| (4/10) | 0.538 |
| (5/10) | 0.539 |
| (6/10) | 0.537 |
| (7/10) | 0.535 |
| (8/10) | 0.534 |
| (9/10) | 0.534 |
| (10/10) | 0.532 |

Table.1 Variation of CCT at different 10 locations in line 5-4

### b)Different Load Conditions

.

In this case study three phase fault is implanted on the bus 5 and uniform loading is given to the system, load is increased up to 160% of the total load and CCT of the system obtained by analyzing $\omega$, rotor speed of the bus 5. Both uniform and non-uniform given to the system for contextual investigation yet the impact of non-uniform burden in the variation of CCT is lesser and it neglected.

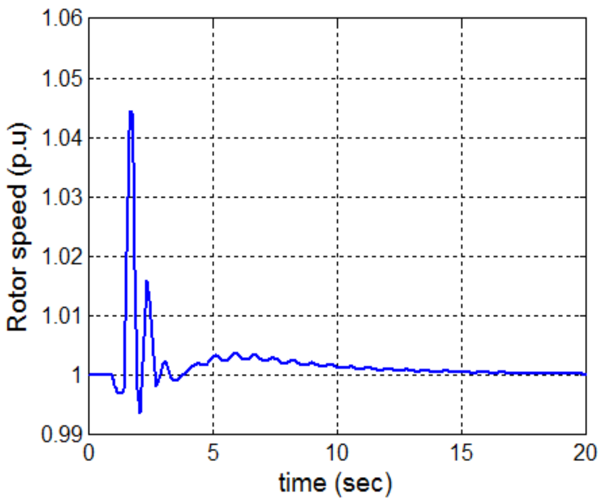

Fig.6 Fault clearing time is 1.531sec, the system remains in stable condition

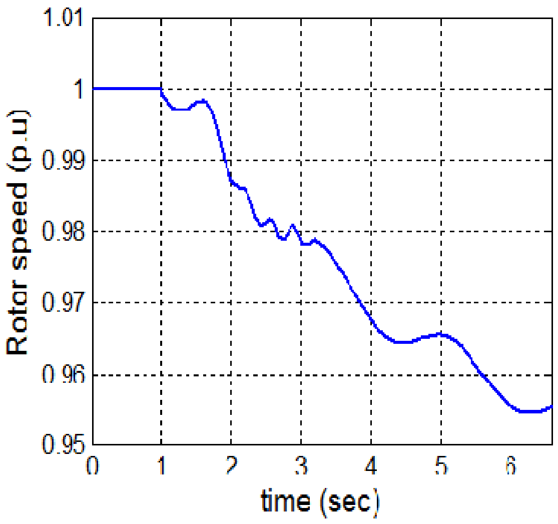

Fig.7 Fault clearing time is 1.532sec, the system goes to unstable condition

In Fig:6 clearing time of fault was 1.531 sec andin Fig: 4 fault clearing time was 1.532 sec, in the first case rotor speed of the system settle down to a constant value but in second case it dropout and the system goes to unstable. So the CCT of the system at this condition is 0.531 sec

`

| Multiplication Factor of load (Uniform loading) | CCT (sec) |
|---|---|
| 1 | 0.563 |
| 1.15 | 0.531 |
| 1.3 | 0.5 |
| 1.45 | 0.461 |
| 1.6 | 0.428 |
| 1.7 | system unstable |

Table.2 Variations of CCT at different load conditions

Table.2 shows different load condition and the corresponding CCT of the system. Load multiplication factor of the systemwas changed and CCT was observed.ofAs the load increases the CCT of the system decreases. Hence load and CCT are inversely proportional. When the load is increased beyond 160% , then system becomes fully unstable. The maximum load ability of the system is upto 160% of full load.

### c) Fault Resistance

Fault resistance isanother major depending factor of CCT. The fault resistance of three phase system is varied and CCT was noted and listed in the table.3 as shown. When the fault resistance decreases from a minimum value,variation in CCT is very less when the fault resistance is reduced. If the fault resistance increasedbeyond a particular value, system detects as a load and the system will not goes to the unstable condition.

| Fault Resistance | **CCT** |
|---|---|
| R=1e^-3 | 1.563 |
| R=1e^-4 | 1.514 |
| R=1e^-5 | 1.513 |
| R=1e^-6 | 1.514 |
| R=1e^-2 | 1.615 |
| R=1e^-1 | greater than 5 |

Table.3 Variation of CCT at different fault resistance

## VI.CONCLUSION

In this paper a comparative study of the dependent factors of CCT was done in IEEE 14 bus system by using eigenvalue analysis and time domain simulation. This dynamic model of the system studied in MATLAB/PSAT toolbox Most of the dependent factors were taken into account for this study. Case study for each parameter was done and tabulated the CCT for each dependent factors. This simply shoes how much was the dependency of each factor to the CCT

From the case studies it is clear that load condition of the system is the most dependent factor of CCT , that is load variation can change the CCT of the system up to 20-30 power cycles, but fault location and fault resistance influences only to 3-5 cycles. So Load condition is the main dependent factor of CCT. The maximum loadability of the IEEE 14 bus system was found to be 160% of the total load. The variation of CCT can be utilized to improve the reliability of the system by continuously changing the CCT setting of the protective equipment according to the load variation.

## REFERENCES

[1] P. Kundur, J. Paserba, V. Ajjarapu, G. Andersson, A. Bose, C. Canizares, N. Hatziargyriou, D. Hill, A. Stankovic, C. Taylor et al., “Definition and classification of power system stability ieee/cigre joint task force on stability terms and definitions,” Power Systems, IEEE Transactions on, vol. 19, no. 3, pp. 1387–1401, 2004.

[2] AdepojuGafariAbiola and TijaniMuhammedAdekilekun. Critical clearing time evaluation of nigerian 330kv transmission system. American Journal of Electrical Power and Energy Systems, 2(6):123–128, 2013.

[3] Luis FC Alberto, Flavio HJR Silva, and NG Bretas.” Direct methods for transient stability analysis in power systems”: state of art and future perspectives. In Power Tech Proceedings, 2001 IEEE Porto, volume 2, pages 6–pp. IEEE, 2001

[4] B Boussahoua and M Boudour. Critical clearing time evaluation of power system with upfc by energetic method. electric power, 5:11, 2009

[5] L Ren, Fang Tian, J Yan, Z Yu, Feng Su, and Tao Wu. Online application and fast solving method for critical clearing time of three-phase short circuit in power system. Int J Smart Grid Clean Energy, 2(1):93–99, 2013.

[6] Hung Nguyen Dinh, Minh Y Nguyen, and Yong Tae Yoon. Novel techniques for real time computing critical clearing time sime-b and ccs-b. Journal of Electrical Engineering & Technology, 8(2):197–205, 2013.

[7] SJ Mirazimi, B Salehi, M Tadayon, and HR Karshenas. Optimal relay placement in microgrids considering critical clearing time. In Power Engineering and Optimization Conference (PEOCO), 2013 IEEE 7th International, pages 691–696. IEEE, 2013

[8] P Sravanthi, K Radha Rani, J Amarnath, and S Kamakshaiah. Critical clearing time and transient stability analysis of scig based wind farm with statcom. In Smart Electric Grid (ISEG), 2014 International Conference on, pages 1–8. IEEE, 2014.

[9] “Critical Clearing Time and Transient Stability Analysis of SCIG based Wind Farm with STATCOM “Oleg Lenga, The National Academy of Sciences of Ukraine Institute of Electrodynamics Kiev, Ukraine

[10] E. Gholipour and S. Saadate, “Improving of transient stability of power systems using upfc,” Power Delivery, IEEE Transactions on, vol. 20, no. 2, pp. 1677–1682, 2005.

[11] F. Milano, “An open source power system analysis toolbox,” Power Systems, IEEE Transactions on, vol. 20, no. 3, pp. 1199–1206, 2005.

[12] 2014 IEEE International Conference on Intelligent Energy and Power Systems (IEPS) 21 5 “Application of Critical Clearing Time as a Transient Stability Criterion for Power System Expansion Planning”

[13] Naoto Yorino, ArdyonoPriyadi, Hironori Kakui, and Mitsuhiro Takeshita. A new method for obtaining critical clearing time for transient stability. Power Systems, IEEE transactions on, 25(3):1620–1626, 2010.

[14] J. Vishnu, R. Menon, T. Joseph, S. SREEDHARAN, V. Chittesh, V. DAS, and S. Joseph, “Ga based optimal facts controller for maximizing loadability with stability constraints,” International Journal of Electrical Engineering & Technology (IJEET), vol. 5, no. 12, pp. 111– 122, 2014.

[15] S. M. Kodsi and C. A. Canizares, “Modeling and simulation of IEEE 14 bus system with facts controllers,” University of Waterloo, Canada, Tech. Rep, 2003.