The Effect Assessment Method of Control and Protection Systems on Transient Stability of Power Systems

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Abstract: In order to overcome the problems of simulation methods, the power system transient stability assessment method using critical fault clearing time functions has been developed. Using the above method, this paper has developed the new method which can assess accurately and efficiently the effects of control and protection systems on transient stability which is the most important characteristic to assess in power systems. At first, critical fault clearing time functions CCT(W:load) are defined by taking notice of the fact that transient stability is mainly controlled by fault clearing time and load. Next, the method to be enable to assess accurately and efficiently the effects of control and protection systems on transient stability has been newly developed by using the above functions. Finally, it has been applied to the effect assessment in the occurrence of a three-phase fault in a model power system. Results of application have been clarified its effectiveness.

Keywords: Control system, Protection system, Power system, Transient stability, Critical fault clearing time

1. INTRODUCTION

Transient phenomena caused by faults of power systems are very complex and greatly affected by control and protection systems. In order to assess accurately transient phenomena, analysis are not appropriate, so simulation methods must be used. But, they have the following problems.

1) The simulation of complex transient phenomena demands a great deal of calculation time and costs.
2) It is difficult to gain the whole prospects of effect assessment based on results of individual simulation cases.
3) When simulation condition change, simulation must be carried out from the beginning.

In order to overcome the above problems, the power system transient stability assessment method using critical fault clearing time functions has been developed.[1],[2] Using the above method, this paper has developed the new method which can assess accurately and efficiently the effects of control and protection systems on transient stability which is the most important characteristic to assess in power systems. At first, critical fault clearing time functions CCT(W:load) are defined by taking notice of the fact that transient stability is mainly controlled by fault clearing time and load. Next, the method to be enable to assess accurately and efficiently the effect of control and protection systems on transient stability has been developed by using the above functions. Finally, it has been applied to the effect assessment in the occurrence of a three-phase fault in a model power system. Results of application have been clarified its effectiveness.

2. EFFECT ASSESSMENT METHOD

The flowchart for the effect assessment method is shown in Fig.1. The developed method is composed of the following nine parts.

1) Selecting all control and protection (c.&p.) systems for detail assessment
2) Setting up control and protection system for detail assessment
3) Setting up assessment fault
4) Generating critical fault clearing time functions
5) Generating average energy loss functions
6) Check of assessment faults
7) Generating total average power loss function
8) Check of assessment control and protection systems
9) Assessing effect of control and protection systems

The steps of the above flowchart are shown as follows.

1) Selecting all control and protection systems for detail assessment

When there are many control and protection systems for assessment, preliminary assessment is carried out in order to assess efficiently the effects of control and protection systems on transient stability.

a) Setting up control and protection system for preliminary assessment
b) Calculating critical fault clearing time CCT only when severe faults have been occurred in loads with high occurrence frequency (neighborhoods of the rated load in general)
c) Selecting control and protection system for detail assessment by repeating from a) to b) without exception, considering that control and protection systems which make values of CCT lager can improve more effectively transient stability

2) Setting up control and protection system for detail assessment

3) Setting up assessment fault

Severe faults are preferentially set up. In case of line faults, faults of representative location are discretely set up and functions of line fault are generated by interpolating them.

4) Generating critical fault clearing time functions

The flowchart for generating critical fault clearing time functions is shown in Fig.2. The critical fault clearing time CCT is calculated using the bisection algorithm. [3] The steps of this flowchart are shown as follows.

a) Setting up load

The load W is set up.

b) Setting up initial fault clearing time CT1,CT2

The lower stability limit CT1 and upper stability limit CT2 is set up, considering that the finally calculated critical fault clearing time CCT will be between CT1 and CT2.

c) Calculating fault clearing time CT

The mid-point value CT which is fault clearing time in the

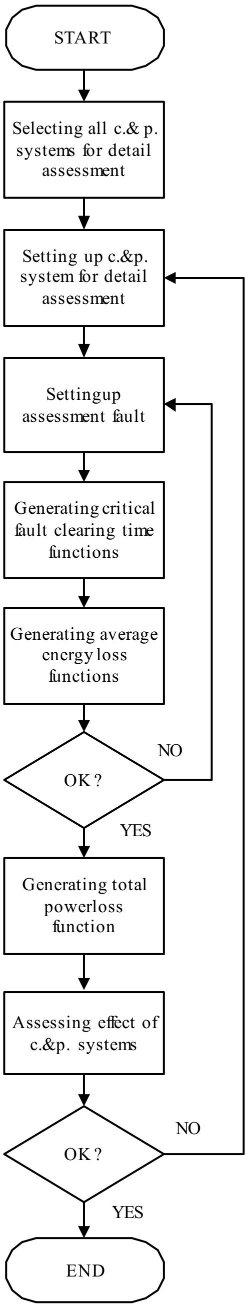

Fig. 1 Flowchart of effect assessment method.

next simulation is calculated by averaging stability limit CT1 and CT2.

d) Simulating transient phenomena caused by faults of power systems

At first, the load flows before the occurrence of fault are calculated based on the data about load and power system. Next, the transient phenomena after the occurrence of fault are calculated based on the data about fault, initial load flow and power system.

e) Check of system stability

The system stability is checked based on results of simulation. If it is found that the system is stable, then the lower stability limit CT1 of interval is replaced by the mid-point value CT. Otherwise the upper value CT2 is replaced by the mid-point value CT. Because the critical fault clearing times of generators are generally different, they have different CCT functions classified into some modes. Therefore, the system stability must be checked in all modes.

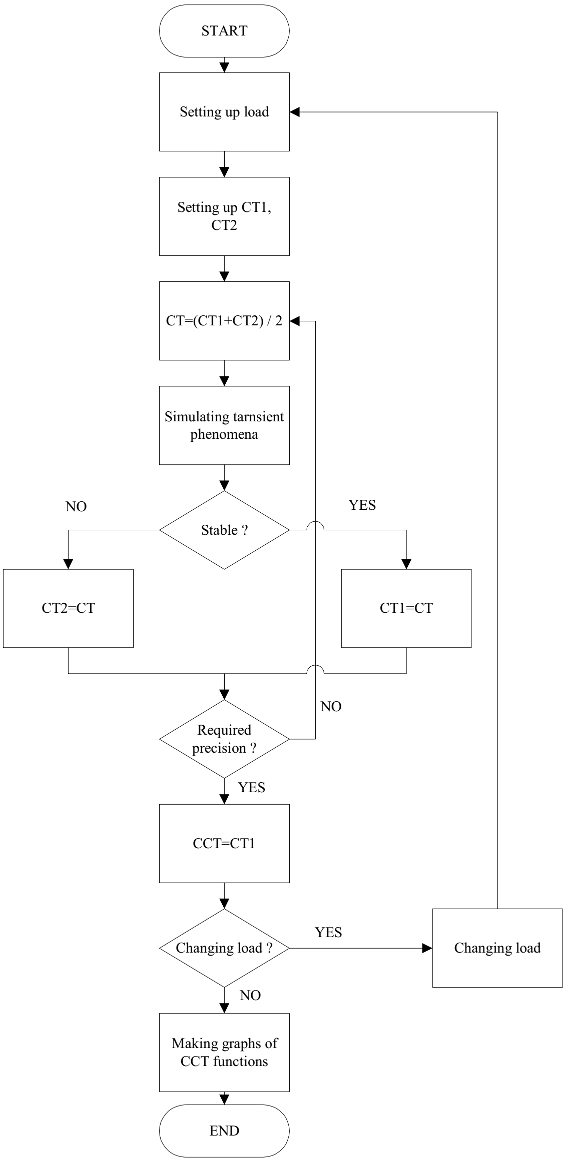

Fig. 2 Flowchart of generation of critical fault clearing time functions.

f) Check of calculation precision

The calculation precision is checked by comparing the difference between CT1 and CT2 with the required precision e. If the difference is smaller than e, then CCT equals CT1. Otherwise, step c) is processed next.

g) Check of request of changing load

It is checked if changing load is required in order to make graphs of CCT functions. If it is found that changing load is required, then load is changed according to the algorithms previously developed in order to generate efficiently CCT functions [4] and step a) is processed next. Otherwise, graphs of CCT functions expressed discretely are made based on CCT data in various loads.

5) Generating average energy loss functions

a) Setting up CT

b) Calculating average energy loss of fault i

At first, WTAim (average energy loss due to the out of step in mode m of fault i) is calculated by integrating the product of PL(W), Cim(W), Rim(W), Tim(W), and W from Wb to Wt about independent variable W.

Where
W : load
Wb : bottom (minimum) value of load
Wt : top (maximum) value of load
PL(W) : probability density function of load
Cim(W) : function for discriminating occurrence of out of step defined as follows
0 (stable) : CT is smaller than CCTim(W)
1 (unsatable) : CT is not smaller than CCTim(W)
Where
CCTim(W) : critical fault clearing time function in mode m of fault i
CT : fault clearing time
Rim(W) : ratio of average energy loss in mode m of fault i to total average energy in normal state
Tim(W) : average fault duration time in mode m of fault i

Next, WTAi (average energy loss of assessment fault i) is calculated by adding WTAim from 1 to mt about independent variable m.

Where
mt : total mode number of out of step

c) Making WTAi(CT) (average energy loss function of assessment fault i) by repeating from a) to b) without exception

6) Check of assessment faults

It is checked if all assessment faults are assessed. If it is found that all faults are assessed, step7) is processed next. Otherwise, step3) is processed next.

7) Generating total average power loss function

WA(CT) (total average power loss function of assessment faults) is calculated by adding the product of WTAi(CT) and Fi from 1 to it about independent variable i.

8) Assessing effects of control and protection systems

The effects of control and protection systems on transient stability is assessed, using all generation functions.

9) Check of assessment control and protection systems

It is checked if all control and protection systems are assessed. If it is found that all control and protection systems are assessed, the effect assessment ends. Otherwise, step2) is processed next.

3. APPLICATION TO MODEL SYSTEMS

3.1 Conditions of assessment

In order to confirm the effectiveness of this method, it was applied to a model power system on the following conditions.

1) A model power system is composed of 5 generators, 11 duplicate lines and 19 nodes. Its constitution is shown in Fig.3. The capacity of generators 1 is much bigger than those of other generators. The total capacity of other generators is 487MVA.

2) Generators are expressed by the d-q axes model.

3) Generators are controlled by AVR (automatic voltage regulators), PSS (power system stabilizers), and governors.

4) Only the three-phase-to-ground-fault at node 14 of one line of duplicate lines is simulated among faults. It is one of the most severe type faults.

5) Only the out of step due to the decrease of transient stability is simulated among fault cascading phenomena. Generators in out of step are isolated from the power system and cause energy loss. The average fault duration time is 1 hour.

6) The probability density function is discretely expressed by 5 sections.

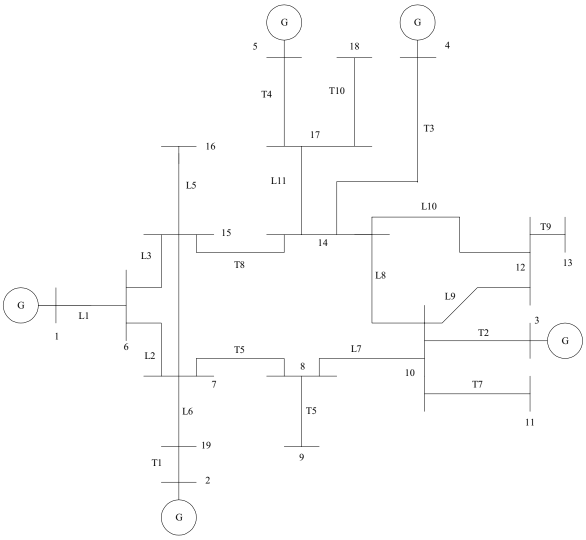

Fig. 3 Constitution of model power system.

3.2 Results of assessment

The results of application have been clarified the following facts.

1) In case of that THEX (thyristor excitation system) are adopted as AVR, graphs of the critical fault clearing time functions of generators are shown in Fig.4. These graphs make it clear that generators have different CCT functions and these functions increase monotonously with the increase of load till 120 % of the rated load and they decrease rapidly in more load than it.

2) In case of that AC1A (alternating current excitation system), DC1A (direct current excitation system), ST1A (static excitation system), and THEX are adopted as AVR, graphs of the critical fault clearing time functions of the generators 3 are shown in Fig.5. Considering that excitation systems which make values of CCT larger can improve more effectively transient stability, these graphs make it clear that these functions are different and can be classified into one group of ST1A & THEX and the other group of AC1A & DC1A. Because the critical fault clearing time functions of the latter group are almost zero from 40% to 80% of the rated load, power systems of the latter group are more unstable. The above results make it clear that the former group is more suitable than the latter group for preventing the transient instability of power systems in this case. But, it is required to calculate CCT in the neighborhoods of the rated load (for example, 80% of the rated load) in selecting all excitation systems for detail assessment, for the latter group has higher values of CCT in the rated load than them of the former group.

3) In case of that DPSS (system by deviation between input and output for generator), PPSS (system1 by output for generator), TPSS (system2 by output for generator), and YPSP (system by improved Y method) are adopted as PSS, graphs of the critical fault clearing time functions of the generator 2 are shown in Fig.6. These graphs make it clear that these functions are very similar and types of power stabilizers have little effects on transient stability.

4) In case of that GVTH (system for thermal turbine), Y1GV (system for simple tandem thermal turbine), and Y4GV (system for waterpower) are adopted as governors, graphs of the critical fault clearing time functions of the generator 2 are shown in Fig.7. These graphs make it clear that these functions are very similar and types of governors have little

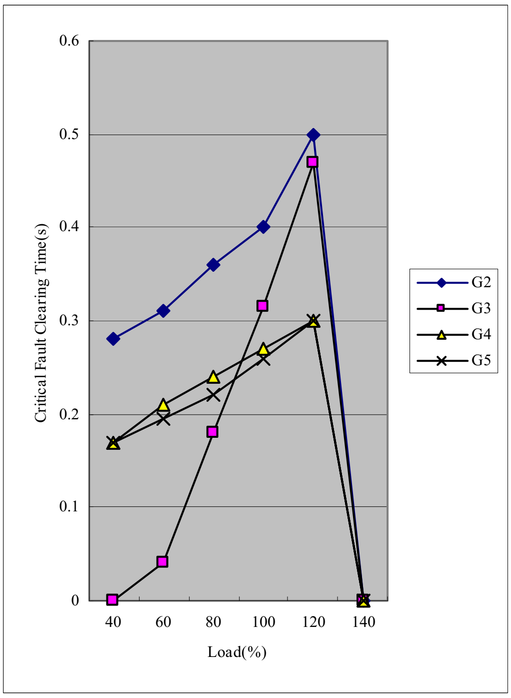

Fig. 4 Critical fault clearing time functions of generators with THEX.

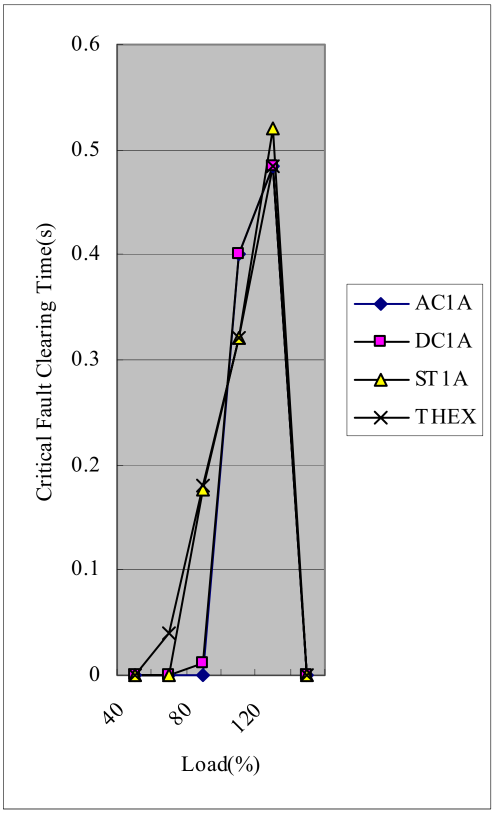

Fig. 5 Critical fault clearing time functions of generators 3 with AC1A, DC1A, ST1A, and THEX.

effects on transient stability.

5) The change of the average energy loss by fault clearing time is shown in Fig.8. This graph makes it clear that the

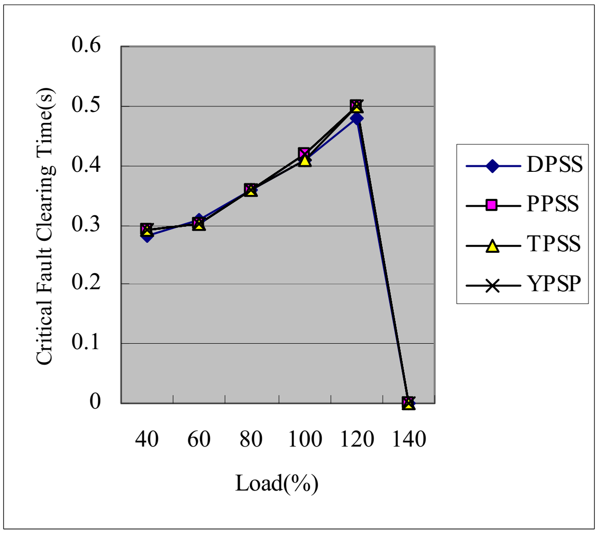

Fig. 6 Critical fault clearing time functions of generators 2 with DPSS, PPSS, TPSS, and YPSP.

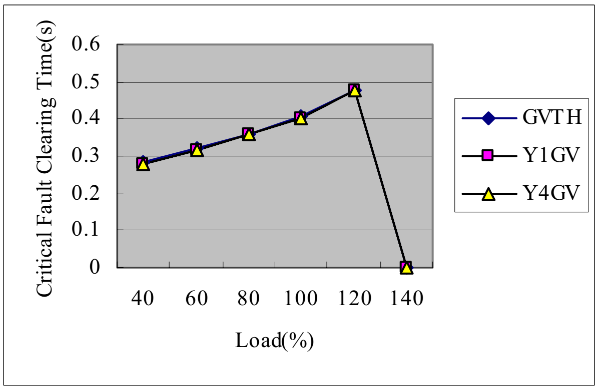

Fig. 7 Critical fault clearing time functions of generators 2 with GVTH, Y1GV, and T4GV.

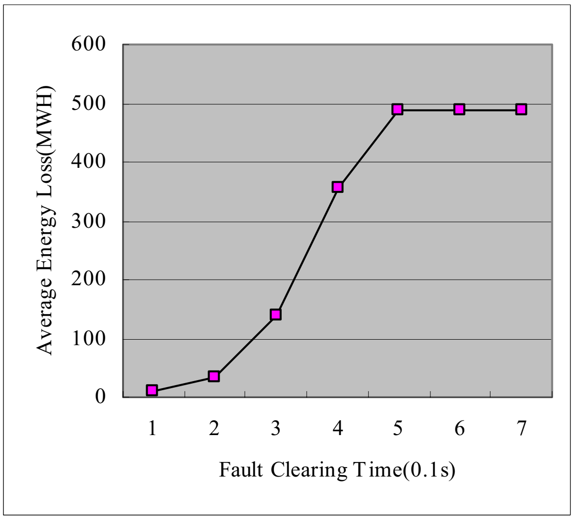

Fig. 8 Change of average energy loss by fault clearing time.

average energy loss increases monotonously with the increase of fault clearing time. The degree of increase is large from 0.2 to 0.5 second, but it is small in more load than it. The above results make it clear that the fault clearing time of the control and protection systems must be smaller than 0.2 second.

6) Because the fault clearing time is calculated by adding detection time of protection system relays and action time of circuit breakers, the above value can be used as the target ones of fault clearing time in designing protection systems.

4. CONCLUSION

We have developed the method to be enable to assess accurately and efficiently the effects of control and protection systems on transient stability. It has been applied to a model power system with 5 generators. Results of application have been clarified the following facts.

1) This method can accurately and efficiently assess the effects of control and protection systems on transient stability.
2) The effects of control and protection systems on transient stability can be visually grasped by graphs of critical fault clearing time functions.
3) The control and protection system to be suitable for preventing the transient instability of power systems can be accurately decided among assessment ones.
4) This method can greatly improve the design and selection method of control and protection systems for preventing the transient instability of power systems.

The future works are summarized as follows.

1) The developed method will be applied to various control and protection systems in various power systems and the results of application will be assessed.
2) The gained data will clarify the effect characteristics of control and protection systems on transient stability.
3) The accuracy and efficiency of the developed method will be improved based on the above assessment results.

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