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Assessment of Transient Stability of Power System by Using Equal Area Criteria

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ABSTRACT

The electric market liberalization increases its importance, as economical pressure and intensified transactions tend to operate electric power systems much closer to their security limits than ever before. The trend to merge existing systems into much larger entities and to monitor them in shorter and shorter time horizons creates more difficulties. This holds true for analysis aspects and even more for control, in as much as, today; control actions must cope with considerably more stringent market requirements than in the past. The difficulties increase further when it comes to transient stability phenomena. In this paper possible methods of transient stability have been discussed. Some MATLAB programs have been developed to study the transient stability cases by using these methods.. These programs are helpful in determining critical power angle, critical clearing times for circuit breaker, voltage level of systems and transfer capability between systems. Thus, a better relay setting can be proposed.

Keywords:—*swing equation, transfer reactance, power angle curve and equal area criterion.*

I. INTRODUCTION

Stability of a power system is its ability to return to normal or stable operating conditions after having been subjected to some form of disturbance. Conversely, instability means a condition denoting loss of synchronism or falling out of step. Furthermore, stability is the tendency of a power system to develop restoring forces equal to or greater than the disturbing forces in order to maintain the state of equilibrium. The system is said to remain stable (to stay in synchronism), if the forces tending to hold machines in synchronism with one another are sufficient to overcome the disturbing forces. Stability is conducted at planning level when new generating and transmitting facilities are developed. The studies are needed in determining the relaying system needed, critical fault clearing time of circuit breaker, critical clearing angle, auto reclosing time TCR, voltage level and transfer capability between system. When the power system loss stability, the machines will lose synchronization and it will no longer working at synchronous speed. This will lead to power, voltage and current to oscillate drastically. It can cause damage to the loads which receive electric supply from the instable system[2]. The stability of a system refers to the ability of a system to return back to its steady state when subjected to a disturbance. Power is generated by synchronous generators that operate in synchronism with the rest of the system. A generator is synchronized with a bus when both of them have same frequency, voltage and phase sequence. Power system stability can be defined as the ability of the power system to return to steady state without losing synchronism. Usually power system stability is categorized into Steady State, Transient and Dynamic Stability [3].

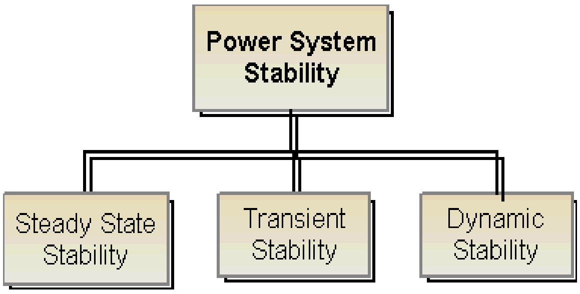


Figure 1: Power System Stability

Compare to the steady state, the transient stability have to be given more attention since its influence greatly on the power system. Transient studies are needed to ensure that the system can withstand the transient condition following a major disturbance.

Short circuit is a severe type of disturbance. During a fault, electrical powers from the nearby generators are reduced drastically, while powers from remote generators are scarily affected. In some cases, the system may be stable even with sustained fault; whereas in other cases system will be stable only if the fault is cleared with sufficient rapidity. Whether the system is stable on the occurrence of a fault depends not only on the system itself, but also on the type of fault, location of fault, clearing time and the method of clearing.

Transient stability limit is almost always lower than the steady state limit and hence it is much important. Transient stability limit depends on the type of disturbance, location and magnitude of disturbance.

1.1.1 Steady State Stability Studies

Steady state stability is the ability of the system to develop restoring forces equal to or greater than the disturbing force and remain in equilibrium or synchronism after small and slow disturbances. Increase in load is a kind of disturbance. If increase in loading takes place gradually and in small steps and the system withstands this change and performs satisfactorily, then the system is said to be in steady state stability. Thus the study of steady state stability is basically concerned with the determination of upper limit of machine's loading before losing synchronism, provided the loading is increased gradually at a slow rate. In practice, load change may not be gradual. Further, there may be sudden disturbances due to

(i) Sudden change of load
(ii) Switching operation
(iii) Loss of generation
(iv) Fault

1.1.2 Dynamic Stability Studies

Dynamic stability is the ability of the power system to maintain stability under continuous small disturbances also known as small-signal stability. These small disturbances occur due random fluctuations in loads and generation levels. Furthermore this stability is able to regain synchronism with inclusion of automatic control devices such as automatic voltage regulator (AVR) and frequency controls. This is the extension of the steady state stability which takes a longer time to clear the disturbances [5].

1.1.3 Transient Stability Studies

Transient stability is the ability of the power system to maintain synchronism when subjected to a severe transient disturbance such as the occurrence of a fault, the sudden outage of a line or the sudden application or removal of loads [2][4]. The resulting system response involves large excursions of generator rotor angles and is influenced by the nonlinear power-angle relationship. Following such sudden disturbances in the power system, rotor angular differences, rotor speeds, and power transfer undergo fast changes whose magnitudes are dependent upon the severity of disturbances. For a large disturbance, changes in angular differences may be so large as to cause the machine to fall out of step. This type of instability is known as Transient Instability. Transient stability is a fast phenomenon, usually occurring within one second for a generator close to the cause of disturbance. The objective of the transient stability study is to ascertain whether the load angle returns to a steady value following the clearance of the disturbance [3].

Transient stability studies are related to the effect of the transmission line faults on generator synchronism. The transient instability phenomenon is a very fast one and occurs within one second or a fraction of it for generator close to location of disturbance.

During the fault, the electrical power from nearby generators is reduced and the power from remote generators remains relatively unchanged. The resultant differences in acceleration produce speed differences over the time interval of the fault and it is important to clear the fault as quick as possible. The fault clearing removes one or more transmission elements and weakens the system. The changes in the transmission system produce change in the generator rotor angles. If the changes are such that the accelerated machines pick up additional load, they slow down and a new equilibrium position is reached. The loss of synchronism will be evident within one second of the initial disturbance.

Faults on heavily loaded lines are more likely to cause instability than the fault on lightly loaded lines because they tend to produce more acceleration during the fault. Three phase faults produce greater accelerations than those involving one or two phase conductors. Faults which are not cleared by primary fault produce more angle deviations in the nearby generators. Also, the backup fault clearing is performed after a time delay and hence produces severe oscillations. The loss of a major load or a major generating station produces significant disturbance in the system.

Factors influencing transient stability:

(i) Generator inertia
(ii) Generator loading
(iii) Generator output (power transfer) during fault-depends on fault location and fault type
(iv) Fault clearing time
(v) Post-fault transmission system reactance
(vi) Generator reactance
(vii) Generator internal voltage magnitude- this depends on field excitation, i.e. the power factor of the power sent at the generator terminals
(viii) Infinite bus voltage magnitude.

Causes of Transient:

Transients are disturbances that occur for a very short duration and the electrical circuit is quickly restored to original operation provided no damage has occurred due to the transient. An electrical transient is a cause-and-effect phenomenon. For transients to occur there must be a cause, some of the more common causes of transients:

(i) Atmospheric phenomena (lightning, solar flares, geomagnetic disturbances)
(ii) Switching loads on or off
(iii) Interruption of fault currents
(iv) Switching of power lines
(v) Switching of capacitor banks

1.2 Problem Statement

Power industries worldwide move toward deregulation and competition. At the same time, electrical power systems are becoming more complicated. Even short interruptions in electrical supply can lead to serious consequences. The stability problem is concerned with the behavior of the synchronous machine after disturbances. Transient signals are one of the causes of instability. Transients occur when there is a sudden change in the voltage or the current in a power system. Controlling the power many problems can be solved with enhancing the quality of the performance. The stability of an interconnected power system is its ability to return to normal or stable operation after having been subjected to some form of disturbance. Power system stability is a term applied to alternating-current electric power systems, denoting a condition in which the various synchronous machines of the system remain in synchronism, with each other. Fault occurrence in a power system is due to transients. In this research, an approach has been done to stabilize the system. The transients have been analyzed and have obtained a 7 better result in a simple approach. This research is developed to find the critical time clearing and power angle of a system for a given fault conditions by using MATLAB software. Transient stability studies are conducted when new generating and transmitting facilities are planned. This is helpful in analyzing the step by step solution of the swing curve and equal area criterion method for a given application where there are sudden increases in input power and three-phase fault on transmission line.

1.3 Objectives

In order to overcome of the stability problem, this project proposes the analysis of the transient stability of the power system using MATLAB. The objectives of the work are:

(i) To determine critical power angle, critical clearing times for circuit breaker, voltage level of systems and transfer capability between systems for indicate whether system is stable or not.

(ii) To analyze the step by step solution of the swing curve and equal area criterion method using software programming, MATLAB for stabilize the system.

(iii) To analyze the situation of sudden increases in input power and three-phase fault on transmission line via the equal area criterion method whether the system may cause the system instability.

1.4 Project Scope

The scopes to development this project includes of:

(i) Focuses only three cases study of transient stability of power system using method;

- Case 1: step by step solution of the swing curve
- Case 2: equal area criterion on sudden increase in power input
- Case 3: equal area criterion for a three phase fault

(ii) Using programming MATLAB as software for the simulation.

2.1.1 Transient Stability

Transient State Stability is the ability of the power system to maintain in stability after large, major and sudden disturbances. For example are, occurrence of faults, sudden load changes, loss of generating unit, line switching. Large disturbance do occur on the system. These include severe lightning strikes, loss of transmission line carrying bulk power due to overloading. The transient stability studies involve the determination of 10 whether or not synchronism is maintained after the machine has been subjected to severe disturbance[2]. Types of disturbances [3].

(i) Sudden application of load/sudden load changing
(ii) Loss of generation
(iii) Fault on the system

Each generator operates at the same synchronous speed and frequency of 50 hertz while a delicate balance between the input mechanical power and output electrical power is maintained. Whenever generation is less than the actual consumer load, the system frequency falls. On the other hand, whenever the generation is more than the actual load, the system frequency rise. The generators are also interconnected with each other and with the loads they supply via high voltage transmission line [7].

Any disturbance in the system will cause the imbalance between the mechanical power input to the generator and electrical power output of the generator to be affected. As a result, some of the generators will tend to speed up and some will tend to slow down. If, for a particular generator, this tendency is too great, it will no longer remain in synchronism with the rest of the system and will be automatically disconnected from the system. This phenomenon is referred to as a generator going out of step [7].

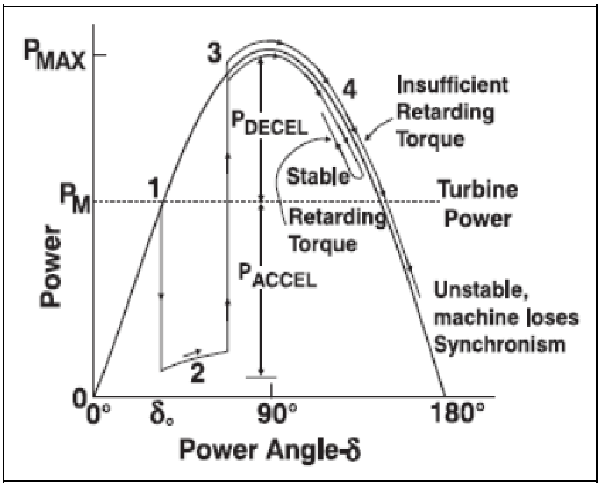
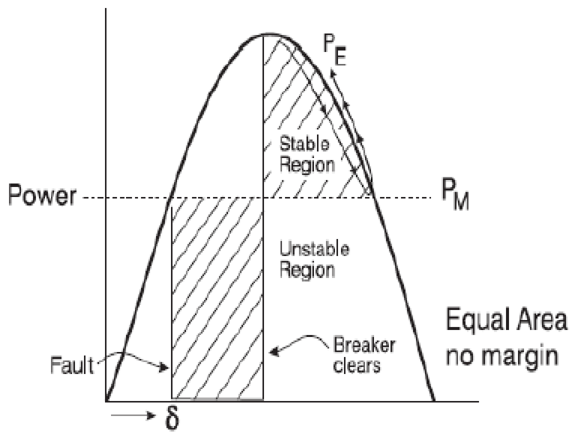
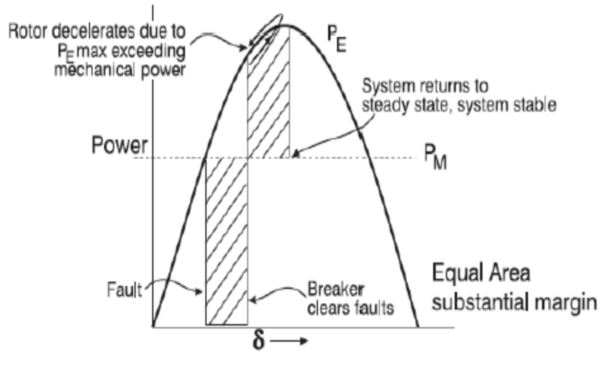


Figure 2.1: Transient stability illustration

Transient stability is primarily concerned with the immediate effects of a transmission line disturbance on generator synchronism. Figure 2.1 illustrates the typical behavior of a generator in response to a fault condition. Starting from the initial operating condition (point 1), a close-in transmission fault causes the generator electrical output power ***Pe*** to be drastically reduced. The resultant difference between electrical power and the mechanical turbine power causes the generator rotor to accelerate with respect to the system, increasing the power angle (point 2). When the fault is cleared, the electrical power is restored to a level corresponding to the appropriate point on the power angle curve (point 3). Clearing the fault necessarily removes one or more transmission elements from service and at least temporarily weakens the transmission system. After clearing the fault, the electrical power out of the generator becomes greater than the turbine power. This causes the unit to decelerate (point 4), reducing the momentum the rotor gained during the fault. If there is enough retarding torque after fault clearing to make up for the acceleration during the fault, the generator will be transiently stable on the first swing and will move back toward its operating point. If the retarding torque is insufficient, the power angle will continue to increase until synchronism with the power system is lost [6].



(a)



(b)

Figure 2.2: Effect of fault clearing time

Power system stability depends on the clearing time for a fault on the transmission system. Comparing the two examples in figure 2.2 illustrates this point. In the example of slower fault clearing in figure 2.2 (a), the time duration of the fault allows the rotor to accelerate so far along the curve of PE that the decelerating torque comes right to the limit of maintaining the rotor in synchronism. The shorter fault clearing time in figure 2.2 (b) stops the acceleration of the rotor much sooner, assuring that sufficient synchronizing torque is available to recover with a large safety margin. This effect is the demand placed on protection engineers to install the fastest available relaying equipment to protect the transmission system [6].

III. RESULT

The SLD is shown in fig for case study.

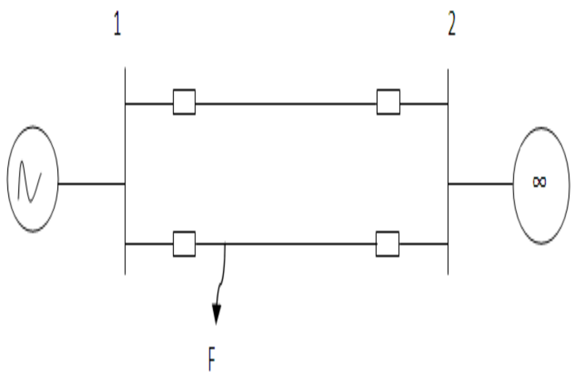


Figure 2.3 : Two Bus System

(a) Atemporary three phase fault occurs at the sending end of the line at point F. When the fault is cleared, both line are intact.

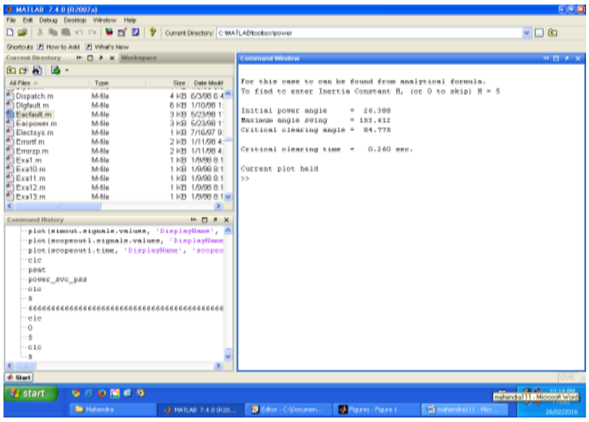


Figure 2.4: Output Screen

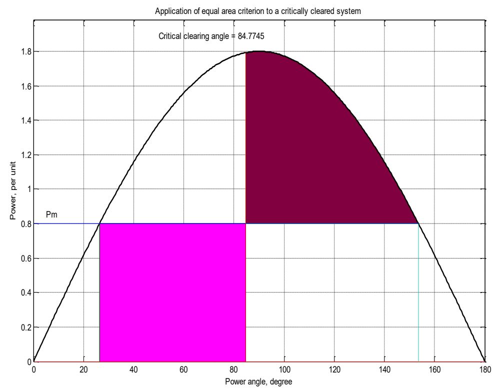


Figure 2.5: Equal Area Criteria

(b) A three phase fault occure at middle of one lines, The fault is cleared and the faulted line is isolated.

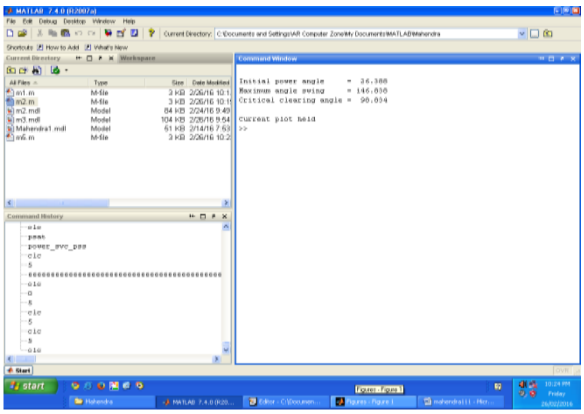


Figure 2.6: Output Screen

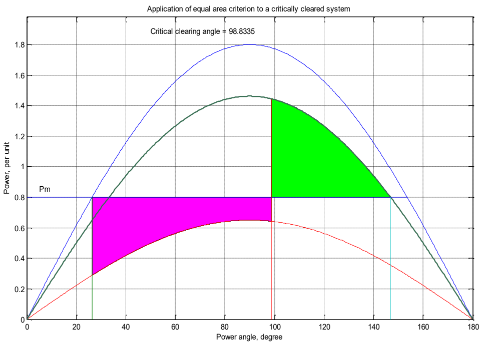


Figure 2.6: Application of equal area citation to critically cleaned system

IV. CONCLUSION

Each generator operates at the same synchronous speed and frequency of 50 hertz while a delicate balance between the input mechanical power and output electrical power is maintained. Whenever generation is less than the actual consumer load, the system frequency falls. On the other hand, whenever the generation is more than the actual load, the system frequency rise. The generators are also interconnected with each other and with the loads they supply via high voltage transmission line [7].

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