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STABILITY OF POWER SYSTEM

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Abstract

The purpose of this paper is to know the stability of power supply systems. Power system stability means the ability of the system to remain in equilibrium condition for normal working hour's conditions and after the occurrence of certain disorders. So the main problem of stability in power systems is synchronous machines during the presentation of disorders to maintain synchronization.

INTRODUCTION

The stability of the power system is the term that represents a condition in which different synchronous machines remain in synchronization system, or "in step" with each other. Conversely, instability marks a condition that involves the loss of synchronization, or exit "out of step". In normal work of the power system of all synchronous machines rotors rotate with same speed synchronous and say that the machines are in synchronism.

But in case of disruption in SEE rotor synchronous machines begin to change the speed, some rotating faster and some slowly and some remain brought to synchronous speed. For machines of the first and second case we say that are losing synchronicity. If the machine is not able to confront disorders it would change so much the number of rotations that prevented to work in parallel with other machines, so it should be disconnected from the system (this regularly is done by the frequency protection) and we say that the machine has dropped from synchronization. The problem of stability of the electric system is divided into two main categories: static and transient stability. SEE stability is conditioned by the stability of each synchronous machine in the system. If even only one synchronous machine loses stability, then the whole power system loses stability.

SEE analysis provides enough information dealing with the ability of the system to remain in synchronism against disorders that are a result of the collapse of any line, generator or load change. Analysis can determine the changes to voltages, currents, power, number of machine adjustment etc., in SEE during the time of the break and after it.

Transient system stability analysis includes bus bars, transmission lines, transformers, electrical machines and impedance or static admittance of consumers, synchronous or asynchronous machine features. This analysis is described with differential equations. The number of differential equations that describe the machines performance depends on the accuracy of SEE stability analysis in order to obtain data necessary for the recognition of the work that SEE performed during system diverse failures today are predominantly used digital calculating machines.

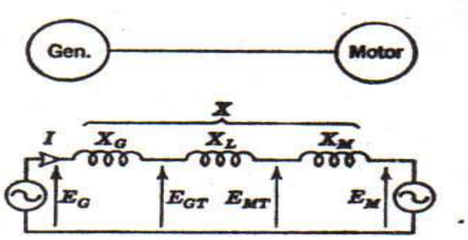


Figure 1.Simple power system with two machines.

If considered a very simple power system as in Figure1, which consists of a synchronous generator which supplies a synchronous motor through a power supply circuit comprising an inductive series of resistances X_L, then each of the synchronous machines may appear , at least approximately, by means of a constant voltage source in series with a constant resistance. Consequently, the generator is presented with E_G and X_G, dhe motor with E_M and X_M. Combining the machine resistance and line resistance in a single resistence, we will gain an electrical circuit consisting of two constant voltage sources, E_G and E_M,, connected via resistance $X = X_G+X_L+X_M$. Will be shown that the electricity transmitted by the generator to the motor depends on the difference in phase for angle δ of two voltages E_G and E_M. Once these voltages are generated by the flux produced by the energization of machine bays, their phase difference is the same as the electrical angle between the machines rotors.

The voltage vector diagram shown in Figure 2.

$$E_G=E_M+jXI \quad (1)$$

Consequently the current is

$$I=\frac{E_G-E_M}{jX} \quad (2)$$

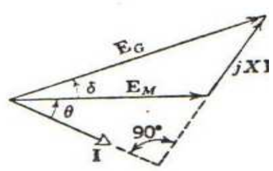


Figure 2.Vector diagram of simple power system with two machines.

Power output of the generator as the input power of the motor, as there is no the presentation of the machine.

resistance in the line is given by:

$$P = \mathrm{Re}(\overline{E}_G I) \qquad (3)$$

$$= \mathrm{Re}\left(\overline{E}_G \frac{E_G - E_M}{jX}\right) \qquad (4)$$

Were, Re means "the real part" and $\overline{E}_G$ will mean conjuction of E_G. Now let be

$$E_M = E_M \angle 0 \qquad (5) \text{ and}$$

$$E_G = E_G \angle \delta \ , \qquad (6) \text{ then}$$

$$\overline{E}_G = E_G \angle -\delta \qquad (7)$$

Replacement of equations 5, 6, and 7 into equation 4 will produce:

$$\begin{aligned} P &= \mathrm{Re}\left(\overline{E}_G \angle -\delta \frac{E_G \angle \delta - E_M \angle 0}{X \angle 90^0}\right) \\ &= \mathrm{Re}\left(\frac{E_{G^2}}{X} \angle 90^0 - \frac{E_G - E_M}{X} \angle -90^0 - \delta\right) \\ &= -\frac{E_G E_M}{X} \cos(-90^0 - \delta) \\ &= \frac{E_G E_M}{X} \sin\delta \end{aligned} \qquad (8)$$

This equation shows that the power P transmitted from the generator to the motor varies with the sinus of the angle of displacement δ between two rotors, as plotted in Figure3. Curve is known as the power-angle curve. The maximum current which can be transmitted in relaxed condition with a given resistance X and internal voltages E_G and E_M is:

$$P_m = \frac{E_G E_M}{X} \qquad (9)$$

and is appeared in the angle of displacement δ =90^0. The maximum current value can be increased either by increasing internal voltages or by lowering the resistance of the circuit.

The system is stable only if the angle of displacement δ is in the range of 90^0 until +90^0, where dP / d δ is positive, that is, the range in which the increase of the angle of displacement results in the increase in the transmitted current. Suppose that the system operates in a stable condition at point A, Figure 3. Mechanical entry and of the generator and the motor mechanical exit if corrected for rotating losses will be equal to the power P. Now assume that we have an increase in displaced load of the motor. Currently the motor angular position with respect to the generator, and thus enter to the motor, will be nonreplaced, but the output of the motor will be increased. So, consequently, the net rotation instant of the motor will try to slow it down, and his speed gradually decreases. As a result of motor speed drop, δ will increase, and as a result the input currents will increase, until eventually the input and output are still in the balance, and the new situation of relaxation appears to point B, higher than A on curve force-angle (it is assumed that the generator speed will remain constant. Currently generator can be slowed down so that the head of the first movement to operate and to increase input to the generator sufficiently to balance the growing output).

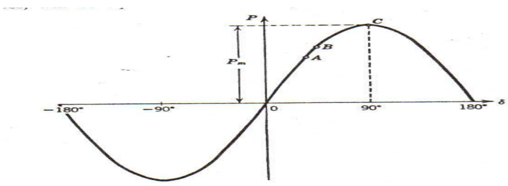


Figure 3 power curves - simple power system angle

(Figure 1) Assume that the input power of the motor increases gradually until reaching its maximum point - the point C. If you now have an additional increase in motor load, displacement angle δ will grow as before, but its growth will not increase input. Instead of that the output will be decreased, thus increasing further the difference between input and output, and thus slowing down the motor faster. The motor will lose momentum and probably will stop (if not kept in motion by the action of the Inducible motor resulting from buffering circuits which may be present). Pm is the stable limit of the system state tranquility. Is the maximum power that can be transmitted, and synchronization may be lost if it is tried transmitting more power than this limit.

If you instantly have an extra large load on the motor, instead of increasing the load slowly, the motor will lose its step even though the load does not exceed the stable limit of state of tranquility. The reason is as follows: When a large increase of load is added to the motor axis, mechanical power output of the motor exceeds excessively the electrical input power, and the input deficiency is supplied from the kinetic energy reduction.

The motor slows down, the angle of displacement δ is increased and we have a consequent increase of the result of the input. In accordance with the assumption that the new load does not exceed the limit stable state of tranquility, δ grow up to the appropriate values for operation in calm condition, a value such that the motor input is equal to the and output where the slowing moment disappears. When such a value of δ is reached, the motor will work very slowly. Its angular moment hampers its speed to be increased to normal values at once. Consequently, it will work very slowly, and the angle of displacement increases above the appropriate value. Once the angle passes this value input of the motor will outbalance the output, and the slowing down net moment is now an accelerating moment. Motor speed increases and approaching normal to speed. However, before regaining the normal speed, the angle of displacement can be grown in such a level that the operating point on curve-power angle (Figure 3) will not only pass setting (point C) but will go so much on that input of the motor will be reduced to a value lower than the output. If such thing happens, the rotating net moment will change from accelerated rotation moment unot rotation moment. Speed, which is still below normal, now reduced again, and continues to decrease but still a little during each slipping cycle. Synchronization is definitely lost. In other words, the system is unstable.

However, if demand growth is not immediate, the motor will regain normal speed before displacement angle becomes too great. Then the net rotating moment is still an accelerating moment and causing increased motor speed which is now larger than normal. Displacement angle then decreases and approaches again to adequate value, exceeding this value on account of inertia. Motor Rotor oscillates about the position of new angular of tranquility. Oscillations eventually are lost due to the depreciation of the moment, which is neglected in this analysis.

Amortized oscillator movement characterizes stable system. With a sudden increase of the load, there is an upper limit that the motor load can withstand without losing step. This is the limit of transient stability of the system for the given condition. Transient stability limit is always on the limit of stability of the state of tranquility, but, unlike the past, may have different values, depending on the value of the disorder. The disorder may come from the sudden increase in load, as discussed earlier, or by the sudden increase in resistance caused, for example, from the disconnection of one or more parallel lines as occur during normal disconnection process. More severe forms of disorders which energy system is subjected to are short circuits. Therefore, the effect of short circuits (or "breakings" as are often called) should be determined in almost all stability studies.

A three phase short circuit on the line which connects the generator and the motor completely stopped the flow of electricity between the machines. Output of the generator becomes zero in a pure circuit resistant; input of the motor also becomes zero. Due to the slowness of operation of the first movement runner who pushes the generator, the generator mechanical input power remains constant for probably 3/4 of a second. Also, since the power and the rotating momentum of the motor load are speed functions and since the speed cannot change all at once, no more than a few percent and until the synchronization is lost, the mechanical output power of the motor can be considered constant. Since the electrical currents of the two machines is reduced by short circuit, while the mechanical strength of the two remains constant, there is a rotating accelerated momentum on the generator and a rotating slowing down momentum in the motor. Consequently, the generator speed increases, and the motor slows down, and it is clear that the synchronization will be lost if the short circuit is not eliminated fast in order to return before they differentiate machine synchronization angle and speed. If the short circuit is located on one of two parallel lines and if it is not in any of the ends of the lines, and if the short circuit is of any kind other than three-phase, so a grounded line, line by line, or two lines in earthing, then a part of Synchronization power can further be transmitted beyond the breaking, but the amplitude of power-angle curve will be reduced compared to that before the break. In some cases, the system will be stable even with a sustainable short circuit, while in other cases the system will be stable only if the short circuit is eliminated with a considerable speed. Will the system be stable during the break will depend not only on the system itself, but also on the type of break, the speed of elimination, and therefore elimination methods, so is eliminated by the sequence opening of two or more breakings, or Simultaneous opening and a broken line is reclosed or not. For any constant set of these conditions, the question of whether it is a stable system depends on how much electricity the system machineries before the breaking in question occurs. Consequently, for any disorder there is a value of the transmitted currents, called the passing limit of the stability, under which the system is stable and above which the system is unstable.

Stability limit is a form of current limit, but the system's current limit is not always determined by the issue of stability. Even in a system which consists of synchronous generator which supplies power to a load resistance, there is a maximum power received by the load until the load resistance changes. Clearly here is a limit of currents that has nothing to do with the issue of stability.

Systems with many machines

Rarely happens to exist a simple power system consisting of a synchronous motor and a generator. Most energy systems have many generating stations, generators, and many loads, most of which are combinations of synchronous motors, synchronous condensers, inductive motors, lamps, and other heating equipment. The problem of stability in such energy system usually has to do with the current which is machineried by a group of synchronous machines in another. As a rule, the two groups consist mainly of generators. During the disturbance, machines in each group fluctuate more or less together, i.e., they preserve the approximate angular position, although these vary a lot compared to the machines in other group. For purposes of analysis, each group of machines may be replaced with equivalent schemes. If this is done, there is an equivalent generator and an equivalent synchronous motor, although the latter usually represented by the machines that are currently generator.

Due to the uncertainty of what machine will fluctuate along, or to improve the accuracy of forecasting, it is often desirable to represent synchronous machines power system with more than two equivalent machines. However, qualitatively the behavior of the machine in an actual system is usually similar to that of systems with two machines. If synchronization is lost, machines in each group remain united, even though they lose the step along with another group.

Once the behavior of the system with two machines represents the behavior of the system with a lot of machines, at least qualitatively, and after two-machine system is very simple compared to the many machines which represents, two-machine system is extremely useful for describing general concepts of stability of the energy systems and the influence of other factors in stability.

Occurennce of any disturbance in the power balance in the system causes a fault on the momentum on the angular equilibrium of frequency and voltage in SEE. Depending on the level of changes caused disturbances may qualify as small or large disorders.

Stability calculations at small disorder called static stability analysis, and stability calculations during large disturbances exploiting nonlinear differential equations.

SEE stability usually isdescribed depending on the state of the variable which examined so the following concepts are exploited:

•Angular stability (static and transient).

• frequency stability.

• voltage stability.

Dynamic system as in (Figure4),

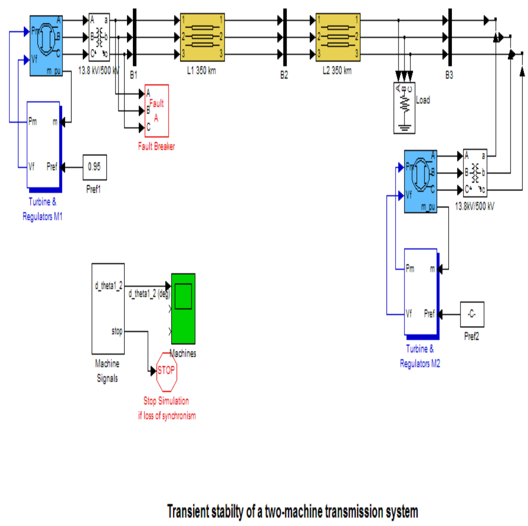


Figure 4

Analize how the critical angle δ_{12} varies depending on:

1. From the place the short circuit occurred, The system stability condition here is that

the angle δ_{12} after disorder return in a constant final value, which ensure the synchronization of the generator and motor.

2. Connection time

3. What is the type of short circuit: single phase or threephase.

In this example of a dynamic system analogously use stability analysis methodology of one mechanical system.

Second order differential equations rotary measures are:

$$\frac{2H_1}{\omega_s}\frac{d^2\delta_1}{dt^2}+\frac{k_{D1}}{\omega_s}\cdot\frac{d\delta_1}{dt}+P_{G1}(\delta_{12})=P_{m1} \text{ dhe}$$

$$\frac{2H_2}{\omega_s}\frac{d^2\delta_2}{dt^2}+\frac{k_{D2}}{\omega_s}\cdot\frac{d\delta_2}{dt}+P_{M2}(\delta_{21})=P_{m2}$$

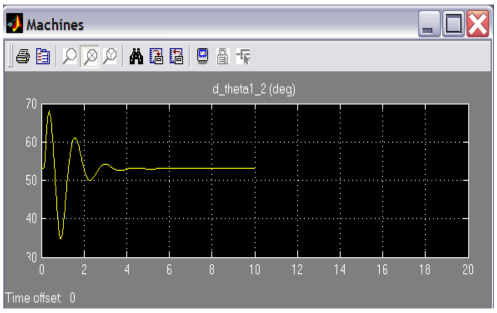
Two movement differential equations can be replaced in stability analysis by the common equation, in which instead of the rotor angles of the two machines δ_1 dhe δ_2, the angle occurs between them between their electromotive forces behind transient reactance: $\delta_{12}=\delta_1-\delta_2$ differential equation is obtained:

$$\frac{2H_0}{\omega_s}\frac{d^2\delta_{12}}{dt^2}+\frac{k_D}{\omega_s}+\frac{d\delta_{12}}{dt}-P_{G1}(\delta_{12})=P^0_{m1}$$

To solve the above differential equations iterative methods can be used, but can also by means of the methods with the help of simulation programs such as the program "MATLAB".

1) Taking the dynamic system as in the figure below we present angle change δ_{12} depending on the place the failure occurred.

a. When short connection occurs immediately after the transformer fluctuation of the angle δ_{12} will be as follows



b. When short circuit occurs on the online as in Figure 5 fluctuation of the angle δ_{12} will be extinguished quickly and the system will stabilize as follows:

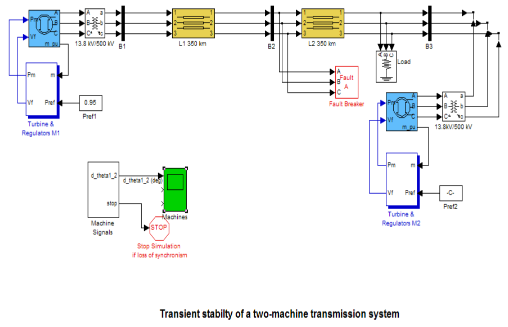
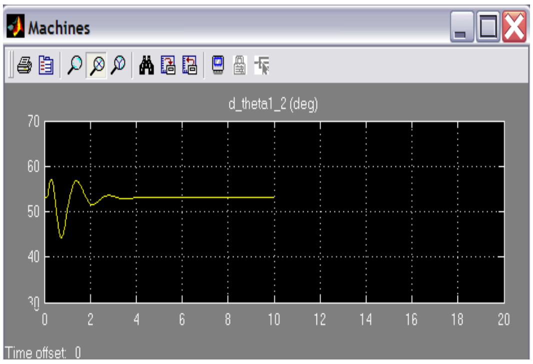


Figure 5



2) Examine critical angle change δ_{12} depending on the time of failure diconnection. Taking the dynamic system as in Figure 6, we will have:

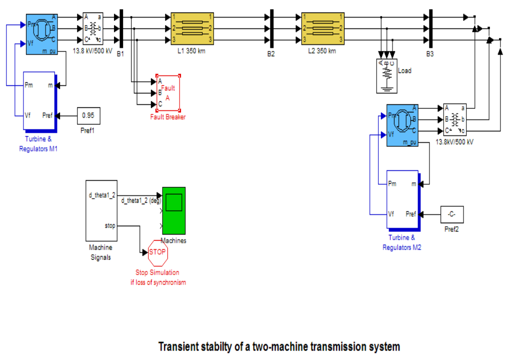
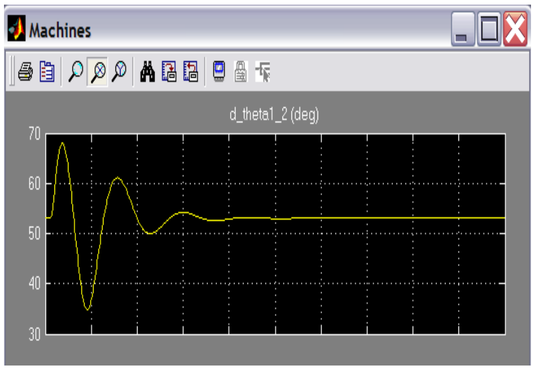
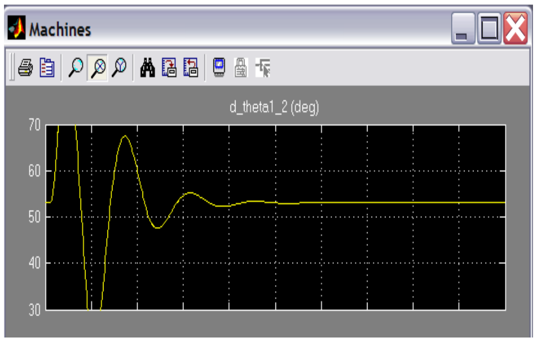


Figure 6

Angle change δ_{12} when the diconnection time is 0.2 s.

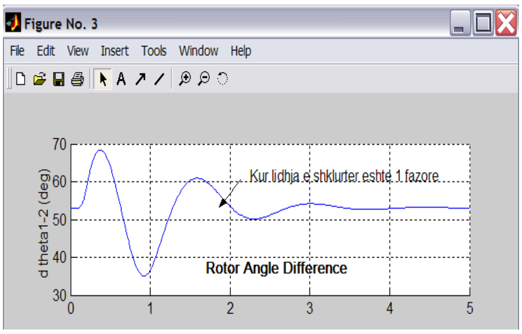


Angle change δ_{12} when the diconnection time is 0.3 s.

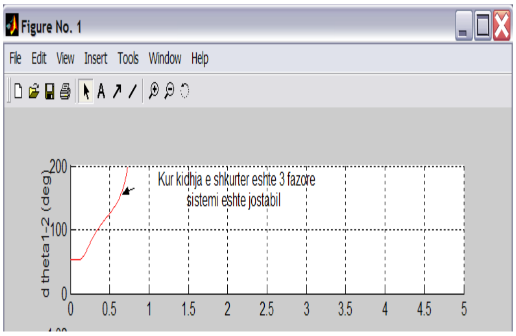


3) We prezent the changes of angle δ_{12} in the case of short circuit single-phase and three phase:

When the short circuit is single phase we have this change of angle δ_{12} .



When short circuit is three phase, we gain the change in the angle from which is seen that the system is unstable.



Bad effects of instability

When a machine loses the step with other machines in the system, it no longer serves its function. If it comes to the generator, it is not a reliable source of electricity. If it comes to the motor, it does not transmit mechanical power at required speed. If it comes to the capacitor, it no longer holds adequate volate on its connector blocks, instability means failure of the system as a power-transmission connection.

Moreover, large synchronous machines out of the step are not only useless, it is worse than useless; it is harmful, as causes voltage disorders. Voltages will fluctuate down and up within a broad range. Therefore instability has a harmful effect as service for customers just like the breakings, with difference that here the effect of instability lasts more. If the instability flows as a result of the break, the elimination of break itself cannot restore stability. Downgraded voltage fluctuations continue after eliminating the breaking. Machines or groups of machines, which are out of step with the rest of the system must either return to the step or must be disconnected from the system. Each of these operations, if done manually will last much longer compare to the same function performed automatically. As a rule, the best way to restore in step the machines is disconnection and risinkronizimi. Protective relays are made to open the brake at a particular location when output from the step conditions is notified to take place. Such relays, however, are not yet in wide use. It is preferable that the power system to be divided so that each part have adequate generating capacity connected to supply the load connected to it. Some overload may be covered temporarily until system risinkronizohet.

Common protective relays in all probability will not operate properly during states out of step, so confuse the disconnectors of line circuits intacted. Such confusion may terminate without the need to service against load and may divide the system into parts so that the generation capacity of some parts to be inadequate.

Trend in the design of energy systems is to increase the reliability of electricity services. Once instability has harmful effect on the quality of service, energy systems must be designed and operate so that instability be unreliable and occurs only rarely.

CONCLUSIONS

In this paper the results obtained in a concrete example (Figure 4) and simulations from software program "MATLAB" can draw up the following conclusions:

When short circuit takes place immediately after the transformer is seen that the angle δ_{12} will change as is the case in (a) where the oscillations are larger than in case (b) when the short circuit occures on the line after emitting busbar. This fluctuation of the angle δ_{12} will be extinguished rapidly and the system will be stabilized. System stability condition is therefore the angle δ_{12} after disorders should return back to a final value, constant, which ensure the synchronization of the generator and motor.

From disconnection times reviewed 0.2 s and 0.3 s we examine the critical angle change. From the results obtained for the critical angle and critical disconnection time of failure and elimination we see that as much as the time is higher the greater is the amplitude of oscillations. Short circuits with single-phase the system will oscillate and gradually stabilize, while with three phase short circuits the angle δ_{12} will grow without limits and the system will be unstable (review time is 0.2 sec).

Power system stability means the ability of the system to remain in equilibrium condition for normal operating conditions and after the presentation of various transition processes henec the synchronous machines during the presentation of disorders should maintain synchronization.

The problem of stability of the electric system is divided into:

Static stability: the ability of the electric system to maintain synchronization over small and slow disturbances (such as gradual changes to load).

Transient stability: the ability of the electric system to maintain synchronization over large and fast disturbances.

As factors to affect transient stability are:

Place-fault location,

Transmission system reactance during the occurrence of the fault and after fault elimination and Time of faull disconnection.

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