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Detailed Study of Transient Stability of a General Power System

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Abstract : The objective of this thesis paper is to investigate and understand the stability of power system, with the main focus on stability theories. The thesis first explained the definition of power system stability and the need for power system stability studies. It then proceeded to discuss on the various stability problems after which the thesis provided a brief introduction on basic control theory and study. Next the thesis examined the concept of system stability and some stability theories.

1. Introduction and Basic Stability Theory

An interconnected power system basically consists of several essential components. They are namely the generating units, the transmission lines, the loads, the transformer, static VAR compensators and lastly the HVDC lines [1]. During the operation of the generators, there may be some disturbances such as sustained oscillations in the speed or periodic variations in the torque that is applied to the generator. These disturbances may result in voltage or frequency fluctuation that may affect the other parts of the interconnected power system. External factors, such as lightning, can also cause disturbances to the power system. All these disturbances are termed as faults. When a fault occurs, it causes the motor to lose synchronism if the natural frequency of oscillation coincides with the frequency of oscillation of the generators. With these factors in mind, the basic condition for a power system with stability is synchronism. Besides this condition, there are other important condition such as steady-state stability, transient stability, harmonics and disturbance, collapse of voltage and the loss of reactive power.

2. Definition of stability of a system

The stability of a system is defined as the tendency and ability of the power system to develop restoring forces equal to or greater than the disturbing forces to maintain the state of equilibrium [2].
Let a system be in some equilibrium state. If upon an occurrence of a disturbance and the system is still able to achieve the equilibrium position, it is considered to be stable. The system is also considered to be stable if it converges to another equilibrium position in the proximity of initial equilibrium point. If the physical state of the system differs such that certain physical variable increases with respect to time, the system is considered to be unstable. Therefore, the system is said to remain stable when the forces tending to hold the machines in synchronism with one another are enough to overcome the disturbances. The system stability that is of most concern is the characteristic and the behaviour of the power system after a disturbance.

3. Need for Power System Stability

The power system industry is a field where there are constant changes. Power industries are restructured to cater to more users at lower prices and better power efficiency. Power systems are becoming more complex as they become inter-connected. Load demand also increases linearly with the increase in users. Since stability phenomena limits the transfer capability of the system, there is a need to ensure to stability and reliability of power system due to economic reasons.

Stability studies

The performance of a power system is affected when a fault occurs. This will result in insufficient or loss of power. In order to compensate for the fault and resume normal operation, corrective measures must be taken to bring the system back to its stable operating conditions. Controllers are used for this function. Some of the control methods used to prevent loss of synchronism in power systems are [3] [4]:
(1) Excitation control: During a fault the excitation level of the generator drops considerably. The excitation level is increased to counter the fault.
(2) An addition of a variable resistor at the terminals of the generator. This is to make sure that the power generated is balanced as compared to the power transmitted.
(3) An addition of a variable series capacitor to the transmission lines. This is to reduce the overall reactance of the line. It will also increase the maximum power transfer capacity of the transmission line.
(4) Turbine valve control: During a fault the electrical power output (Pe) of the generator decreases considerably. The turbine mechanical input power (Pm) is decreased to counter the decrease of Pe.

Stability studies are generally categorized into two major areas: steady-state stability and transient stability [2]. Steady-state stability is the ability of the power system to regain synchronism after encountering slow and small disturbances. Example of slow and small disturbances is gradual power changes. The ability of the power system to regain synchronism after encountering small disturbance within a long time frame is known as dynamic stability. Transient stability studies refer to the effects of large and sudden disturbances. Examples of such faults are the sudden outrage of a transmission line or the sudden addition of removal of the loads. Transient stability occurs when the power system is able to withstand the transient conditions following a major disturbance. When a major disturbance occurs, an imbalance is created between the generator and the load. The power balance at each generating unit (mechanical input power – electrical input power) differs from generator to generator. As a result, the rotor angles of the machines accelerate or decelerate beyond the synchronous speed of for time greater than zero ($t > 0$). This phenomenon is called the "swinging" of the machines.

There are two possible scenarios when the rotor angles are plotted as a function of time:
The rotor angle increases together and swings in unison and eventually settles at new angles. As the relative rotor angles do not increases, the system is stable and in synchronism. One or more of the machine angles accelerates faster than the rest of the others. The relative rotor angle diverges as time increase. This condition is considered unstable or losing synchronism.
These studies are important in the sense that they are helpful in determining critical information such as critical clearing time of the circuit breakers and the voltage level of the power system.The main aim of this thesis project is to investigate the various power system stability problems, after which one important problem will be singled out for discussion and research. To maintain synchronism within the distribution system can proved to be difficult as most modern power system are very large.

4. Definition of stability

An undisturbed motion is considered to be stable when the disturbed motion remains close to the undisturbed motion after encountering small disturbance. To elaborate on the above statement:
If small disturbances were encountered and the effect on the motion is small, the undisturbed motion is considered to be stable
If small disturbances were encountered and the effect on the motion is considerable, the undisturbed motion is termed "unstable".
If small disturbances were encountered and the effect tends to disappear, the disturbed motion is considered "asymptotically stable".
If regardless of the magnitude of the disturbances and the effect tends to disappear, the disturbed is considered "asymptotically stable in the large".

5. SYSTEM STABILITY

In this section, a systematic basis for classification of power system stability. The classification of power system stability proposed here is based on the following considerations [4]:
The physical nature of the resulting mode of instability as indicated by the main system variable in which instability can be observed. The size of the disturbance considered which influences the method of calculation and prediction of stability. The devices, processes, and the time span that must be taken into consideration in order to assess stability.
Fig. 1 gives the overall picture of the power system stability problem, identifying its categories and subcategories. The following are descriptions of the corresponding forms of stability phenomena.

Rotor Angle Stability

Rotor angle stability refers to the ability of synchronous machines of an interconnected power system to remain in synchronism after being subjected to a disturbance. It depends on the ability to maintain/restore equilibrium between electromagnetic torque and mechanical torque of each synchronous machine in the system. Instability that may result occurs in the form of increasing angular swings of some generators leading to their loss of synchronism with other generators.
For convenience in analysis and for gaining useful insight into the nature of stability problems, it is useful to characterize rotor angle stability in terms of the following two subcategories:

Small-disturbance (or small-signal) rotor angle stabilityis concerned with the ability of the power system to maintain synchronism under small disturbances. The disturbances are considered to be sufficiently small that linearization of system equations is permissible for purposes of analysis [3] [4].
Small-disturbance stability depends on the initial operating state of the system. Instability that may result can be of two forms: i) increase in rotor angle through a non oscillatory or a periodic mode due to lack of synchronizing torque, or ii) rotor oscillations of increasing amplitude due to lack of sufficient damping torque.
In today's power systems, small-disturbance rotor angle stability problem is usually associated with insufficient damping of oscillations. The periodic instability problem has been largely eliminated by use of continuously acting generator voltage regulators; however, this problem can still occur when generators operate with constant excitation when subjected to the actions of excitation limiters (field current limiters).[5]

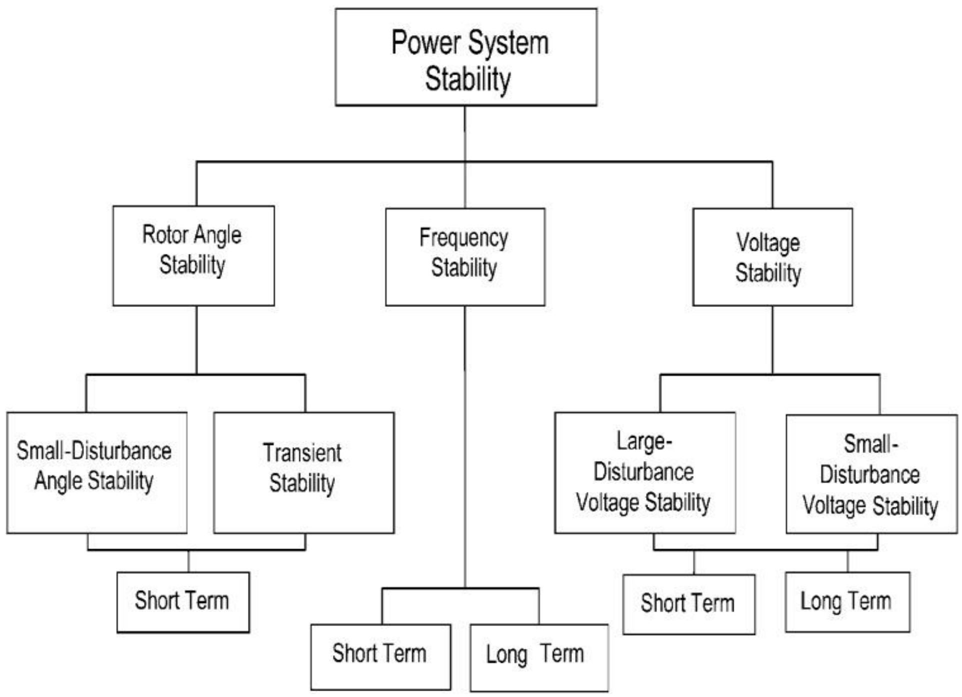

Fig. 1.Classification of power system stability.

Large-disturbance rotor angle stability or transient stability, as it is commonly referred to, is concerned with theability of the power system to maintain synchronism when subjected to a severe disturbance, such as a short circuit on a transmission line. The resulting system response involves large excursions of generator rotor angles and is influenced by the nonlinear power-angle relationship.
Transient stability depends on both the initial operating state of the system and the severity of the disturbance. Instability is usually in the form of a periodic angular separation due to insufficient synchronizing torque, manifesting as first swing instability. However, in large power systems, transient instability may not always occur as first swing instability associated with a single mode; it could be a result of superposition of a slow inters area swing mode and a local-plant swing mode causing a large excursion of rotor angle beyond the first swing [4]. It could also be a result of nonlinear effects affecting a single mode causing instability beyond the first swing.
The time frame of interest in transient stability studies is usually 3 to 5 seconds following the disturbance. It may extend to 10–20 seconds for very large systems with dominant inter-area swings.
As identified in Fig.1, small-disturbance rotor angle stability as well as transient stability is categorized as short term phenomena.

Voltage Stability
Voltage stabilityrefers to the ability of a power system to maintain steady voltages at all buses in the system after being subjected to a disturbance from a given initial operating condition. It depends on the ability to maintain/restore equilibrium between load demand and load supply from the power system. In-stability that may result occurs in the form of a progressive fall or rise of voltages of some buses. A possible outcome of voltage instability is loss of load in an area, or tripping of transmission lines and other elements by their protective systems leading to cascading

outages. Loss of synchronism of some generators may result from these outages or from operating conditions that violate field current limit [3].

A major factor contributing to voltage instability is the voltage drop that occurs when active and reactive power flow through inductive reactance's of the transmission network; this limits the capability of the transmission network for power transfer and voltage support. The power transfer and voltage support are further limited when some of the generators hit their field or armature current time-overload capability limits. Voltage stability is threatened when a disturbance increases the reactive power demand beyond the sustainable capacity of the available reactive power resources. As in the case of rotor angle stability, it is useful to classify voltage stability into the following subcategories:

Large-disturbance voltage stability

It refers to the system'sability to maintain steady voltages following large disturbances such as system faults, loss of generation, or circuit contingencies. This ability is determined by the system and load characteristics, and the interactions of both continuous and discrete controls and protections. De-termination of large-disturbance voltage stability requires the examination of the nonlinear response of the power system over a period of time sufficient to capture the performance and interactions of such devices as motors, under load transformer tap changers, and generator field current limiters. The study period of interest may extend from a few seconds to tens of minutes.

Small-disturbance voltage stability

It refers to the system'sability to maintain steady voltages when subjected to small perturbations such as incremental changes in system load. This form of stability is influenced by the characteristics of loads, continuous controls, and discrete controls at a given instant of time. This concept is useful in determining, at any instant, how the system voltages will respond to small system changes. With appropriate assumptions, system equations can be linearized for analysis thereby allowing Computation of valuable sensitivity information useful in identifying factors influencing stability. This linearization, however, cannot account for nonlinear effects such as tap changer controls (dead bands, discrete tap steps, and time delays). Therefore, a combination of linear and nonlinear analyzes is used in a complementary manner [3].

As noted above, the time frame of interest for voltage stability problems may vary from a few seconds to tens of minutes. Therefore, voltage stability may be either a short-term or a long-term phenomenon as identified in Figure 1.

Short-term voltage stability

It involves dynamics of fast acting load components such as induction motors, electronically controlled loads, and HVDC converters. It is recommended that the term transient voltage stabilitynot be used.

Long-term voltage stability

It involves slower acting equipment such as tap-changing transformers, thermo-statically controlled loads, and generator current limiters. The study period of interest may extend to several or many minutes, and long-term simulations are required for analysis of system dynamic performance [3].

REFERENCES

[1] M .A Pai, Power System Stability New York: North-Holland, 1981

[2] H. Saadat, Power System Analysis McGraw-Hill International Editions, 1999

[3] Shireesha R Methuku; Anurag K Srivastava; Noel N Schulz;, "Comprehensive Modeling and Stability Analysis of Biomass Generation", North American Power Symposium (NAPS), 2009, 4-6 Oct. 2009

[4] PrabhaKundur;John Paserba; VenkatAjjarapu;GöranAndersson ;Anjan Bose ;Claudio Canizares;Nikos Hatziargyriou;David Hill; Alex Stankovic; Carson Taylor; Thierry Van Cutsem; Vijay Vittal; "Definition and Classification of Power System Stability", IEEE transactions on power systems, vol. 19, no. 2, may 2004

[5] Dg Tliienq; Van Ciitsem arid CoslasVortriius Voltage Stability of Electric Power System (National Technical University, Athens,. (University of Liege, Belgiiiiii) Published by Kluwer Academic Publishers I01 Assiiiippi Park, Nonvell