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SUSTAINABLE DEVELOPMENT INTEGRATED ANALYSIS AND ATTRIBUTES FOR POWER ASSOCIATED STABILITY

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ABSTRACT

It is very important for electric utilities to provide continuous power supply with minimal interruption. In order to do that, it is essential to install protecting equipments such as, circuit breakers and protective relays which protect the synchronous generators and transmission lines. In this work, an effective analysis on the power related aspects is accomplished with mathematical models. The proposed work can be implemented and carried forward using simulation of the mathematical models and approaches for energy optimization.

Keywords - Energy Curve, Energy Management, Power Stability

INTRODUCTION

Ever since the 20th century, till the recent times all major power generating stations over the globe has mainly relied on A.C. distribution system as the most effective and economical option for the transmission of electrical power. Even the most effective way to produce bulk amount of power has been with the evolution of A.C. machine (i.e. alternator or synchronous generator). In the power plants, several synchronous generators with different voltage ratings are connected to the bus terminals having the same frequency and phase sequence as the generators, while the consumer ends are feeded directly from those bus terminals. And therefore for stable operation it is important for the bus to be well synchronized with the generators over the entire duration of transmission, and for this reason the power system stability is also referred to as synchronous stability and is defined as the ability of the system to return to synchronism after having undergone some disturbance due to switching on and off of load or due to line transience.

To understand stability well another factor that is to be taken into consideration is the stability limit of the system. The stability limit defines the maximum power permissible to flow through a particular point or a part of the system during which it is subjected to line disturbances or faulty flow of power. Having understood these terminologies related to power system stability let us now look into the different types of stability. The synchronous stability of a power system can be of several types depending upon the nature of disturbance, and for the purpose of successful analysis it can be classified into the following 3 types as shown below:

1) Steady state stability.
2) Transient stability.
3) Dynamic stability.

STEADY STATE STABILITY

The steady state stability of a power system is defined as the ability of the system to bring itself back to its stable configuration following a small disturbance in the network (like normal load fluctuation or action of automatic voltage regulator). It can only be considered only during a very gradual and infinitesimally small power change. In case the power flow through the circuit exceeds the maximum power permissible, then there are chances that a particular machine or a group of machines will cease to operate in synchronism, and result in yet more disturbances. In such a situation, the steady state limit of the system is said to have reached. Or in other words the steady state stability limit of a system refers to the maximum amount of power that is permissible through the system without loss of its steady state stability.

TRANSIENT STABILITY

Transient stability of a power systemrefers to the ability of the system to reach a stable condition following a large disturbance in the network condition. In all cases related to large changes in the system like sudden application or removal of load, switching operations, line faults or loss due to excitation the transient stability of the system comes into play. It infact deals in the ability of the system to retain synchronism following a disturbance sustaining for a reasonably long period of time.

And the maximum power that is permissible to flow through the network without loss of stability following a sustained period of disturbance is referred to as the transient stability of the system. Going beyond that maximum permissible value for power flow, the system would temporarily be rendered as unstable.

DYNAMIC STABILITY

Dynamic stability of a system denotes the artificial stability given to an inherently unstable system by automatic controlled means. It is generally concerned to small disturbances lasting for about 10 to 30 seconds.

REVIEW OF LITERATRE

Dahal (2009) - Analysis of stability is essential for power system planning and stable operation. The results of transient and steady-state stability studies depend on the appropriate choice of load models. This study investigates modeling issues of the induction motors that are used as a dynamic part of load models. Due to its superiority, we propose the application of the rotor speed frame based model of induction motors instead of a system frequency frame based model in power system stability simulations. A comparative study of steady-state stability of a power system is performed with different induction motor models. The implementation of lower-order models gives more optimistic results. A larger proportion of induction motor load degrades the stability of power systems. It is shown that a third-order model implemented in a rotor speed frame based system is most suitable for stability studies.

Pans (2005) - With the deregulation of power industry in many countries, the traditionally vertically integrated power systems have been experiencing dramatic changes leading to competitive electricity markets. Power system planning in such an environment are now facing increasing requirements and challenges because of the deregulation. The traditional deterministic power system analyses techniques have been found in many cases have limited capability to reveal the increasing uncertainties in today's power systems. The power system operation and planning are demonstrating probabilistic characteristics which requires emphasizes on probabilistic techniques. A key probabilistic power system analysis technique is the probabilistic power system small signal stability assessment technique. With the many factors such as demand uncertainty, market price elasticity and unexpected system congestions, it is more appropriate to have probabilistic power system stability assessment results rather than a deterministic one especially for the sake of risk management in a competitive electricity market. We present a framework of probabilistic power system small signal stability assessment technique in this paper supported with detailed probabilistic analysis and case studies. The results of this paper can be used as a valuable reference for utility power system small signal stability assessment probabilistically and reliably.

Fishov (2007) - Russian and foreign conceptions of power system stability standardization are considered. A necessity to revise the actual power system stability regulations fundamentals under current economic and network conditions of the Unified Power System of Russia (the UPS of Russia) is founded. Special attention is given to evaluation of required steady-state stability margins under normal and post-fault conditions of power system operation. The results of computer simulations intended for comparison of required transient and steady-state stability margins in the Russian Far East Interconnected Power System model are presented. Conclusions regarding the possible ways of power system stability regulations improvement based on the typological transmission systems structures are made.

Liu (2012) - Recently, the security and stability of power system with large amount of wind power are the concerned issues, especially the transient stability. In Denmark, the onshore and offshore wind farms are connected to distribution system and transmission system respectively. The control and protection methodologies of onshore and offshore wind farms definitely affect the transient stability of power system. In this paper, the onshore and offshore wind farms are modeled in detail in order to assess the transient stability of western Danish power system. Further, the computation of critical clearing time (CCT) in different scenarios is proposed to evaluate the vulnerable areas in western Danish power system. The result of CCTs in different scenarios can evaluate the impact of wind power on power system transient stability. Besides, some other influencing factors such as the load level of generators in central power plants, load consumption level and high voltage direct current (HVDC) transmission links are taken into account. The results presented in this paper are able to provide an early awareness of power system security condition of the western Danish power system.

Zhiyong (2008) - Low frequency oscillation is one of the most important dynamic stability problems in power system, which has great effects on the security and stability of power system. In recent years, low frequency oscillation phenomenon occurred for many times in China. A new fact is introduced which may lead to low frequency power oscillation of power system. In a power plant experiment, it was found that the quick operation of governing system would cause the pressure oscillation in turbine steam inlet pipeline. The frequency of pressure oscillation depends heavily on the structure and size of steam inlet pipeline. It is found that the frequency of the steam pressure continuous fluctuation is in the range of 0.1~10 Hz, which cover the frequency of power system low frequency oscillation. The interaction between the steam pressure and the power system may be occurred. On the basis of single machine infinite bus model, the process of quick operation of steam turbine governing valve and the effect of steam pressure fluctuation in turbine steam pipe on power system dynamic stability was researched through the simulation. The simulation results indicate that the quick operation of steam turbine governing valve may lead to power system low frequency oscillation, if the natural frequency of pressure fluctuation caused by governing valve quick operation is equal or close to the power system natural oscillation frequency. The conclusion can provide reference to research into the causes of power system low frequency oscillations.

Du, W., H. (2009) - This paper investigates the impact of a large photovoltaic (PV) penetration on power system small signal oscillation stability. A comprehensive model of a single-machine infinite-bus power system integrated with a PV power generation power plant is established. Numerical computation of damping torque contribution from the PV power plant is carried out, which is confirmed by the results of calculation of system oscillation model and non-linear simulation. Those results indicate that power system oscillation stability can be affected either positively or negatively. There exists an operational limit of the PV power plant as far as system oscillation stability is concerned. Beyond the operational limit, the PV generation supplies negative damping torque, thus damaging system oscillation stability. Hence for the safe penetration of PV generation into power systems, the operational limit of oscillation stability of the PV power plant must be considered.

Soman (2004) - Postfault rotor angle oscillations lead to power swings. Both unstable and stable swings can induce distance relay tripping. For unstable swings, a new computational procedure to locate all of the electrical centers is developed. It simplifies the work associated with visual screening of all the R-X plots. For stable swings, a generic three-tier hierarchy of stability-related norms defined by branch norm, fault norm, and system norm is proposed. Ranking by branch norm leads to ranking of power swings. Ranking by fault norm leads to ranking of faults or contingencies. Magnitude and rate of change of system norm can be used to detect an out-of-step condition. Results on a ten-machine system and a utility system with detailed models are also presented.

Iyambo,(2007) - It is widely accepted that transient stability is an important aspect in designing and upgrading electric power system. This paper covers the modeling and the transient stability analysis of the IEEE 14 test bus system using Matlab Power System Toolbox (PST) package. A three-phase fault is located at two different locations, to analyze the effect of fault location and critical clearing time on the system stability. In order to protect overhead transmission line, conductors and insulators, it is suggested that the faulted part to be isolated rapidly from the rest of the system so as to increase stability margin and hence decrease damage.

Yorino,(2010) - This paper proposes a new formulation for transient stability analysis for electric power systems. Different from existing methods, a minimization problem is formulated for obtaining critical clearing time (CCT) for transient stability. The method is based on the computation of a trajectory on the stability boundary, which is referred to as critical trajectory in this paper. The critical trajectory is defined as the trajectory that starts from a point on a fault-on trajectory at CCT and reaches a critical point of losing synchronism. The new proposal includes a modified trapezoidal formulation for numerical integration, the critical conditions for synchronism, and the unified minimization formulation. It will be demonstrated that the solution of the minimization problem successfully provides the exact CCT that agrees with the conventional numerical simulation method.

Guowei (2011) - A new method for small signal stability analysis of large-scale power system is presented in this paper. The task of the eigenvalue analysis method which is the most common method used in the small signal stability analysis is to obtain the eigenvalue of the state matrix. However，it is very difficulty for the exiting mathematic method to solve the eigenvalue of the studied system when the orders of system reach thousands or more. In this paper, the numerical solution of matrix exponential by employing the precise time-step integration and the numerical curve of the trace of matrix exponential are used to solve the linearization and high-order state matrix of system. For the numerical curve of the trace, the impact of the positive real part of eigenvalues will be extended of the corresponding period while the impact of the negative real part of eigenvalues will be diluted. The mode parameters, such as frequency, damp, can be obtained by using the HHT method to analyze the sections divided according to time-domain characteristics the numerical curve. Then the small signal stability is analyzed by employing the mode parameters. The results carried out on the 16 machine-68 buses test system show that the proposed method is effective for the small signal stability analysis for the large power system. The analysis process is shown in Figure 1.

Chongtao (2013) - This paper proposes a new method to compute the varying value of a controller parameter that causes the eigenvalue to cross the small-signal stability boundaries. In the method, the crossing point of the eigenvalue locus and the boundary can be determined, without having to calculate the eigenvalues or eigenvectors of the state matrix of power system. The models are established and the unreduced Jacobian matrix is used to improve the computing efficiency.

Naoto Yorino (2009) - This paper proposes a new method for transient stability analysis for electric power systems. Different from existing methods, a minimization problem with boundary values is formulated for obtaining critical conditions for transient stability, where a new numerical integration method is developed by modifying the trapezoidal formula to solve effectively the boundary value problem. The proposed method is to compute directly a trajectory on the stability boundary, which is referred to as critical trajectory in this paper. The critical trajectory to be obtained is the trajectory that starts from a point on a fault-on trajectory and reaches a critical point such as an unstable equilibrium point (UEP), or more exactly, controlling UEP (CUEP). The solution of the minimization problem provides critical clearing time (CCT) and exit point simultaneously.

Huynh Chau Duy - Transient stability analysis has recently become a major issue in the operation of power systems due to the increasing stress on power system networks. This problem requires evaluation of a power system's ability to withstand disturbances while maintaining the quality of service. Many different techniques have been proposed for transient stability analysis in power systems, specially for a multimachine system. These methods include the time domain solutions, the extended equal area criteria, and the direct stability methods such as the transient energy function. However, the most methods must transform from a multi-machine system to an equivalent machine and infinite bus system -, -. This paper introduces a method as an accurate algorithm to analyse transient stability for power system with an individual machine. It is as a tool to identify stable and unstable conditions of a power system after fault clearing with solving differential equations. This method is performed for an Northern VietNam power system

D. E. Echeverría - This paper presents a new approach to predict the time evolution of rotor angles of synchronous machines based on a modification of the Taylor series expansion in order to assess the transient stability of power systems in real time. To demonstrate the benefits of the proposed approach, a comparative analysis is made with other approaches which have been used for predicting the rotor angles, namely regression and interpolation algorithms and an approach based on original Taylor series expansion. The different prediction approaches are applied to the New England benchmark power system to predict the time evolution of the rotor angles in terms of stability and instability of first and second swing. The obtained results highlight the prediction accuracy of the proposed approach and the fulfilment of computational time requirements concerning real time applications.

S.Sankara Prasad (2012) - Power system is subjected to sudden changes in load levels. Stability is an important concept which determines the stable operation of power system. In general rotor angle stability is taken as index, but the concept of transient stability, which is the function of operating condition and disturbances deals with the ability of the system to remain intact after being subjected to abnormal deviations. For the improvement of transient stability the general methods adopted are fast acting exciters, circuit breakers and reduction in system transfer reactance. The modern trend is to employ FACTS devices in the existing system for effective utilization of existing transmission resources. These FACTS devices contribute to power flow improvement besides they extend their services in transient stability improvement as well. In this paper, the studies had been carried out in order to improve the Transient Stability of WSCC 9 Bus System with Fixed Compensation on Various Lines and Optimal Location has been investigated using trajectory sensitivity analysis for better results. In order to improve the Transient Stability margin further series FACTS device has been implemented. A fuzzy controlled Thyristor Controlled Series Compensation (TCSC) device has been used here and the results highlight the effectiveness of the application of a TCSC in improving the transient stability of a power system.

Yuri (1998) - This paper presents a new general method for computing the different specific power system small signal stability conditions. The conditions include the points of minimum and maximum damping of oscillations, saddle node and Hopf bifurcations, and load flow feasibility boundaries. All these characteristic points are located by optimizing an eigenvalue objective function along the rays specified in the space of system parameters. The set of constraints consists of the load flow (equations, and requirements applied to the dynamic state matrix eigenvalues and eigenvectors. Solutions of the optimization problem correspond to specific points of interest mentioned above. So, the proposed general method gives a Comprehensive characterization of the power system small signal stability properties. The specific point obtained depends upon the initial guess of variables and numerical methods used to solve the constrained optimization problem. The technique is tested by analyzing the small signal stability properties for well-known example systems.

Kanika (2013) - Transient stability analysis is today's one of the major issues for proper operation of the power systems as the stress on power systems is increasing day by day. In order to improve the power system, it requires an evaluation of system's ability to withstand the disturbances simultaneously maintaining the service quality. For transient stability analysis of power system, various techniques have already been proposed such as extended equal area criteria, the time domain solution and a few direct stability methods such as transient energy function. In most of these methods, a transformation is done from multi-machine system to an equivalent machine as well as an infinite bus system. An analysis of transient stability for the power system using an individual machine is done with the help of an accurate algorithm is done in this paper. This paper describes the fault conditions in the infinite bus bar with the multi-machine system. This paper discusses modelling and theoretical issues associated with voltage and angle stability of power systems. A time-scale decomposition is performed to illustrate how the critical modes can be identified with reduced-order models and the bifurcation phenomena can be explained with these low order models. Examples are given for single and muhimachine systems.

Mohamed (2014) - One of the worst types of fault that a power system should be designed to withstand is a short circuit. Within the various types of fault current limiters, the superconducting fault current limiter (SFCL) has an extremely fast current limitation. The rapid switching action and the self-sensing nature of the superconductor make SFCLs particularly attractive in fault protection. This very fast time response is potentially shorter than those of the classical current limiters. There are two common types of SFCLs resistive-SFCL which is inserted directly in series with the circuit to be protected and inductive-SFCL which is a transformer shorted by superconducting tube. Yttrium barium copper oxide (YBCO) and Bismuth strontium calcium copper oxide (Bi- 2212) superconducting materials were used with both types. This paper presents a comparison study between the impacts of installing resistive-SFCL and inductive- SFCL with YBCO and Bi-2212 materials on the transient stability of multi-machine power system during large disturbances. Because SFCLs have extremely fast current limitations, they have better ability to maintain the synchronization of the generators in the power systems. The resistance of SFCLs during fault conditions helps in increasing the output electrical power and hence decreases the accelerated power of the rotor that enhances the stability of the generators. Simulation studies are performed using 9-bus 3-machine system. All analyses were performed using MATLAB package.

POWER SYSTEM STABILITY

Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact.

The definition applies to an interconnected power system as a whole. Often, however, the stability of a particular generator or group of generators is also of interest. A remote generator may lose stability (synchronism) without cascading instability of the main system. Similarly, stability of particular loads or load areas may be of interest; motors may lose stability (run down and stall) without cascading instability of the main system.

The power system is a highly nonlinear system that operates in a constantly changing environment; loads, generator outputs and key operating parameters change continually. When subjected to a disturbance, the stability of the system depends on the initial operating condition as well as the nature of the disturbance.

Stability of an electric power system is thus a property of the system motion around an equilibrium set, i.e., the initial operating condition. In an equilibrium set, the various opposing forces that exist in the system are equal instantaneously (as in the case of equilibrium points) or over a cycle (as in the case of slow cyclical variations due to continuous small fluctuations in loads or a periodic attractors).

Power systems are subjected to a wide range of disturbances, small and large. Small disturbances in the form of load changes occur continually; the system must be able to adjust to the changing conditions and operate satisfactorily. It must also be able to survive numerous disturbances of a severe nature, such as a short circuit on a transmission line or loss of a large generator. A large disturbance may lead to structural changes due to the isolation of the faulted elements.

At an equilibrium set, a power system may be stable for a given (large) physical disturbance, and unstable for another. It is impractical and uneconomical to design power systems to be stable for every possible disturbance. The design contingencies are selected on the basis they have a reasonably high probability of occurrence. Hence, large-disturbance stability always refers to a specified disturbance scenario. A stable equilibrium set thus has a finite region of attraction; the larger the region, the more robust the system with respect to large disturbances. The region of attraction changes with the operating condition of the power system.

The response of the power system to a disturbance may involve much of the equipment. For instance, a fault on a critical element followed by its isolation by protective relays will cause variations in power flows, network bus voltages, and machine rotor speeds; the voltage variations will actuate both generator and transmission network voltage regulators; the generator speed variations will actuate prime mover governors; and the voltage and frequency variations will affect the system loads to varying degrees depending on their individual characteristics. Further, devices used to protect individual equipment may respond to variations in system variables and cause tripping of the equipment, thereby weakening the system and possibly leading to system instability. If following a disturbance the power system is stable, it will reach a new equilibrium state with the system integrity preserved i.e., with practically all generators and loads connected through a single contiguous transmission system. Some generators and loads may be disconnected by the isolation of faulted elements or intentional tripping to preserve the continuity of operation of bulk of the system. Interconnected systems, for certain severe disturbances, may also be intentionally split into two or more “islands” to preserve as much of the generation and load as possible. The actions of automatic controls and possibly human operators will eventually restore the system to normal state. On the other hand, if the system is unstable, it will result in a run-away or run-down situation; for example, a progressive increase in angular separation of generator rotors, or a progressive decrease in bus voltages. An unstable system condition could lead to cascading outages and a shutdown of a major portion of the power system.

Power systems are continually experiencing fluctuations of small magnitudes. However, for assessing stability when subjected to a specified disturbance, it is usually valid to assume that the system is initially in a true steady-state operating condition.

A typical modern power system is a high-order multivariable process whose dynamic response is influenced by a wide array of devices with different characteristics and response rates. Stability is a condition of equilibrium between opposing forces. Depending on the network topology, system operating condition and the form of disturbance, different sets of opposing forces may experience sustained imbalance leading to different forms of instability.

Large-disturbance voltage stability refers to the system's ability 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. Determination 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, underload 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 refers to the system's ability 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 (deadbands, discrete tap steps, and time delays). Therefore, a combination of linear and nonlinear analyzes is used in a complementary manner.

Short-term voltage stability involves dynamics of fast acting load components such as induction motors, electronically controlled loads, and HVDC converters. The study period of interest is in the order of several seconds, and analysis requires solution of appropriate system differential equations; this is similar to analysis of rotor angle stability. Dynamic modeling of loads is often essential. In contrast to angle stability, short circuits near loads are important. It is recommended that the term transient voltage stability not be used.

Long-term voltage stability involves slower acting equipment such as tap-changing transformers, thermostatically 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. Stability is usually determined by the resulting outage of equipment, rather than the severity of the initial disturbance. Instability is due to the loss of long-term equilibrium (e.g., when loads try to restore their power beyond the capability of the transmission network and connected generation), post-disturbance steady-state operating point being small-disturbance unstable, or a lack of attraction toward the stable post-disturbance equilibrium (e.g., when a remedial action is applied too late). The disturbance could also be a sustained load buildup (e.g., morning load increase). In many cases, static analysis can be used to estimate stability margins, identify factors influencing stability, and screen a wide range of system conditions and a large number of scenarios. Where timing of control actions is important, this should be complemented by quasi-steady-state time-domain simulations.

Frequency stability refers to the ability of a power system to maintain steady frequency following a severe system upset resulting in a significant imbalance between generation and load. It depends on the ability to maintain/restore equilibrium between system generation and load, with minimum unintentional loss of load. Instability that may result occurs in the form of sustained frequency swings leading to tripping of generating units and/or loads.

ROTOR ANGLE STABILITY

Rotor angle stability is the ability of interconnected synchronous machines of a power system to remain in synchronism. The stability problem involves the study of the electromechanical oscillations inherent in power systems.

A fundamental factor in this problem is the manner in which the power outputs of synchronous machines vary as their rotors oscillate. Rotor angle stability is the ability of the interconnected synchronous machines running in the power system to remain in the state of synchronism. Two synchronous generators running parallel and delivering active power to the load depends on the rotor angle of the generator (load sharing between alternators depends on the rotor angle).

During normal operation of the generator, rotor magnetic field and stator magnetic field rotates with the same speed, however there will be an angular separation between the rotor magnetic field and stator magnetic field which depends on the electrical torque (power) output of the generator. An increase in the prime mover speed (turbine speed) will result in the advancement of the rotor angle to a new position relative to the rotating magnetic field of the stator. On the other hand reduction in the mechanical torque will result in the fall back of the rotor angle relative to the stator field. In equilibrium condition there will be equilibrium between the input mechanical torque and output electrical torque of each machine (generator) in the power system and speed of the machines will remain same. If the equilibrium is upset which results in the acceleration or deceleration of rotors of the machines. If one of the inter connected generator moves faster temporarily with respect to the other machine. rotor angle of the machine will advance with respect to slow machine. This results in the load deliver by faster generator increases and load delivered by slow machine decreases. This tends to reduce the speed difference between the two generators and also the angular separation between the slow generator and fast generator. Beyond certain point the increase in the angular separation will result in decrease of power transfer by the fast machine. This increases the angular separation further and also may lead to instability and synchronous generators fall out of synchronism.

SMALL SIGNAL STABILITY

Small-signal stability analysis is about power system stability when subject to small disturbances. If power system oscillations caused by small disturbances can be suppressed, such that the deviations of system state variables remain small for a long time, the power system is stable. On the contrary, if the magnitude of oscillations continues to increase or sustain indefinitely, the power system is unstable. Power system small-signal stability is affected by many factors, including initial operation conditions, strength of electrical connections among components in the power system, characteristics of various control devices, etc. Since it is inevitable that power system operation is subject to small disturbances, any power system that is unstable in terms of small-signal stability cannot operate in practice. In other words, a power system that is able to operate normally must first be stable in terms of small-signal stability. Hence, one of the principal tasks in power system analysis is to carry out small-signal stability analysis to assess the power system under the specified operating conditions.

TRANSIENT STABILITY

The ability of a synchronous power system to return to stable condition and maintain its synchronism following a relatively large disturbance arising from very general situations like switching ‘on’ and ‘off’ of circuit elements, or clearing of faults etc. is referred to as the transient stability in power system of the system. More often than not, the power generation systems are subjected to faults of this kind, and hence its extremely important for power engineers to be well-versed with the stability conditions of the system.

In general practice studies related to transient stability in power system are done over a very small period of time equal to the time required for one swing, which approximates to around 1 sec or even less. If the system is found to be stable during this first swing, its assumed that the disturbance will reduce in the subsequent swings, and the system will be stable thereafter as is generally the case. Now in order to mathematically determine whether a system is stable or not we need to derive the swing equation of power system.

TRANSIENT STABILITY BY DIRECT METHODS

Power system stability is the property of alternating current power systems which insures that the system will remain in operating equilibrium through both normal and abnormal operating conditions. When used in reference to interconnected synchronous machines, operating equilibrium refers to the synchronous, or common-frequency, operation of all machines in the system. Loss of this synchronous behavior will be caused by a disturbance. The disturbance may be slight and considered normal in terms of frequency of occurrence during operation or it may be severe and unusual.

The traditional approach is to divide power system stability analyses into two classes based upon the type of disturbance; these are steady-state stability analysis and transient stability analysis. Steady-state analysis is concerned with slow and gradual changes that occur during operation such as governor response to slight changes in speed, system response to small changes in load, and the action of voltage regulation equipment to normal fluctuations. Transient analysis is concerned with severe disturbances such as sudden, large load changes and short circuits. Since short circuits, or faults as they are called, constitute the most severe disturbance to a 1 #power system, their effects must be determined in nearly all stability studies.

In transient stability, the critical clearing time of circuit breakers to clear a fault is the of vital importance when the system is subjected to large disturbances. In real-world application, the critical clearing time can be interpreted in terms of meaningful quantities such as maximum power transfer in the prefault state. The energy-based methods are a special case of the more general Lyapunov's second method or the direct method. The direct methods determine stability without explicitly solving the system differential equations. Energy function methods have proven to be good ways to determine transient stability in a more reliable way than numerical methods. Energy function methods are considered the future of dynamic security assessment.

MATHEMATICAL FORMULATION

From basic mechanics, the sum of potential energy (PE) and kinetic energy (KE) for a conservative system is constant. Thus using well known formulas for KE and PE, we have an expression for the total energy for the system in terms of the state

$$\delta = (\delta, \delta') :$$

$$V(\delta) = \tfrac{1}{2} M \delta^2 + \int_{\delta 0}^{\delta} . P(u) .\ du$$

It can be noted that at equilibrium point (i.e. with $\delta = \delta 0$ and $\delta=0$) both the KE and PE are zero. Now for the power system after time t >= T. that is after the fault is cleared, the system energy is described by Equation

$$V(\delta(t)) = ½ M \, \delta^2{}_T + \int_{\delta 0}^{\delta} .P(u).\, du$$

The potential energy curve is the key factor in determining the transient stability.

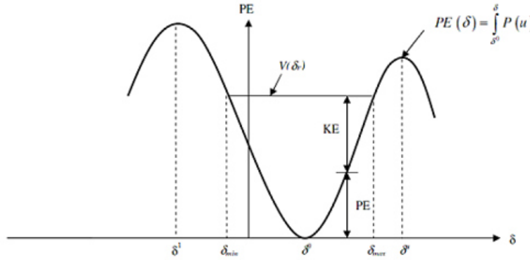

Figure 1 – Potential Energy Plot

It becomes unstable, that is, if the fault is not cleared before rotor angle becomes δmax, the trajectory will diverge towards the UEP δ^M. for any $T > T_{critical}$, $\delta(t)$ is always positive and $\delta(t)$ increases monotonically with t.

CONCLUSION

Power system stability has been recognized as an important problem for secure system operation since the 1920s. Many major blackouts caused by power system instability have illustrated the importance of this phenomenon. Historically, transient instability has been the dominant stability problem on most systems, and has been the focus of much of the industry's attention concerning system stability. As power systems have evolved through continuing growth in interconnections, use of new technologies and controls, and the increased operation in highly stressed conditions, different forms of system instability have emerged. For example, energy stability, frequency stability and interarea oscillations have become greater concerns than in the past. This has created a need to review the definition and classification of power system stability. A clear understanding of different types of instability and how they are interrelated is essential for the satisfactory design and operation of power systems. As well, consistent use of terminology is required for developing system design and operating criteria, standard analytical tools, and study procedures.

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