INTRODUCTION OF DIFFERENT TECHNIQUES USED FOR OPTIMIZATION OF TRANSIENT STATE STABILITY

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ABSTRACT

Power system stability is defined as an ability of the power system to remain in synchronism under any type of disturbances. Now a days , some research has been done in the area of transient stability improvement with different optimization techniques by power system engineers. In this, overview of different techniques used for assessment and improvement of the transient stability in power system. Optimization techniques play an important role for resolving various issues in Power Systems stability. This paper presents a review on introduction of different methods used for Power System Transient stability in resolving power system stability issues. Under fault condition, transient stability analysis is the most important concepts for a reliable, secure and stable operation of power system. The system to be unstable if there is any delay time to cleared the fault and remove the line. Intelligence technique like PSO, ACO etc has been used for this purpose. Modified Euler method is used to calculate the rotor angle. of the generators under various fault conditions. This reviewing and summarizing the vast verity of techniques to improve transient stability of power system.

Keywords: *Transient state stability, Optimization, AI techniques, Faults*

1. Introduction

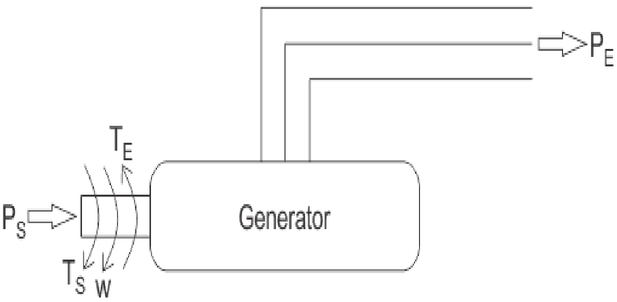
For the successful operation of power system and engineer's ability, it is necessary to provide reliable and uninterrupted service to loads. The reliability of power supply means more than being available. Generally, constant voltage and frequency must be fed in loads at all times. The first requirement of reliable service is to keep the synchronous generator running in parallel and with adequate capacity to meet the load demand. Under normal condition synchronous machine do not easily loss the synchronism. If a machine move to slow down or speed up, synchronizing forces tend to keep it in step. Conditions to arise, such as a fault on the network, sudden application of a major load such as a steel meal, failure in a piece of equipment, or loss of a line or generating unit. In which operation is such that the synchronizing force in more or one machines may not be adequate and small impact in the machine may cause to lose synchronization.

The transient stability studies involve the determination of whether or not synchronism is maintained after the machine has been subjected to large disturbance. This causes sudden application of load, loss of generation, fault on the system. In most disturbances, oscillations are of such magnitude that linearization is not permissible and the nonlinear swing equation must be solved.

1.1 Transient Stability Mechanism

It is defined as the ability of the power system to remain in synchronism or come back to its normal operating condition under large disturbances. The large disturbances occurs in the system due to the sudden removal of the load, line switching operations; fault occurs in the system, sudden outage of a line, etc.

Swing Equation for Determining Transient Stability



In order to determine the transient stability of a power system using **swing equation**, let us consider a synchronous generator supplied with input shaft power P_S producing mechanical torque equal to T_S as shown in the figure below. This makes the machine rotate at a speed of ω rad/sec and the output electromagnetic torque and power generated on the receiving end are expressed as T_E and P_E respectively.

When, the synchronous generator is fed with a supply from one end and a constant load is applied to the other, there is some relative angular displacement between the rotor axis and the stator magnetic field, known as the load angle δ which is directly proportional to the loading of the machine. The machine at this instance is considered to be running under a stable condition.

Now if we suddenly add or remove load from the machine the rotor decelerates or accelerates accordingly with respect to the stator magnetic field. The operating condition of the machine now becomes unstable and the rotor is now said to be swinging w.r.t the stator field and the equation we so obtain giving the relative motion of the load angle δ w.r.t the stator magnetic field is known as the **swing equation** for transient stability of a power system. Here for the sake of understanding, we consider the case where a synchronous generator is suddenly applied with an increased amount of electromagnetic load, which leads to instability by making P_E less than P_S as the rotor undergoes deceleration. Now the increased amount of the accelerating power required to bring the machine back to a stable condition is givenby,

$$Accelerating\ power\ ,\ P_{AG} = P_S - P_E$$

Similarly, the accelerating torque is given by,

$$T_{AG} = T_S - T_E$$

Now we know that

$$P_{AG} = T_{AG}\,\omega = I\alpha\,\omega$$

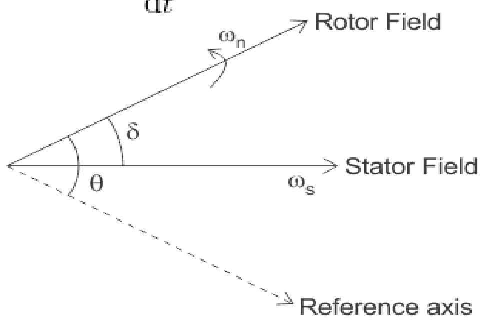
(since T = current × angular acceleration)

Furthermore, angular momentum, M = Iω

$$P_{AG} = M\alpha$$

But since on loading the angular displacement θ varies continuously with time, as shown in the figure below, we can write.

$$\theta = \omega_s + \frac{d\delta}{dt}$$



Angular position of rotor with respect to reference axis

Double differentiating the above equation w.r.t time, weget,

$$\frac{d^2\theta}{dt^2} = \frac{d^2\delta}{dt^2}$$

where angular acceleration

$$\alpha = \frac{d^2\theta}{dt^2} = \frac{d^2\delta}{dt^2}$$

Thus we can write,

$$P_{AG} = M\frac{d^2\delta}{dt^2}$$

$$or\ M\frac{d^2\delta}{dt^2} = P_S - P_E$$

Now the electromagnetic power transmitted is given by,

$$P_E = \frac{V_G.V_M}{X}\sin\delta = P_{max}\sin\delta$$

$$Since,\ when\ \delta = 0, maximum\ amplitude = \frac{V_G.V_M}{X}$$

Thus we can write,

$$M\frac{d^2\delta}{dt^2} = P_S - P_{max}\sin\delta$$

This is known as the swing equation for **transient stability in power system**.

In order to understand the different aspects of the improvement techniques, the basics of transient stability assessments are briey summarized by means of the well- known equal area criterion (EAC]. The EAC determines the transient stability limit according to the acceleration and deceleration area A1 and A2, respectively. Generators are accelerating or decelerating once there is a mismatch between mechanical power supplied to the turbine and electrical power delivered to the grid.

Pa = Pm - Pe

The stability limit is derived by calculating the maximum clearing angle and, based on that, the criticalclearing time (CCT) which describes the time that the generator takes to advance from the initial rotor angle to the critical rotor angle. Hence, the greater the CCT, the more severe disturbances the generator (system) can withstand.

1.2 Factors affecting transient stability

1. The post-disturbance system reactance as seen from the generator. The lower the Pmax will be , if weaker the post-disturbance system,

2. Fault clearing time duration . For the longer time fault is applied, the longer the rotor will

be accelerated and the more kinetic energy will be gained. The more energy that is gained during acceleration, the more difficult it is to dissipate it during deceleration.
3. Inertia of the generator affects the transient stability. For the higher inertia, the rate of change of angle is slower and the the kinetic energy gained during the fault is lesser.
4 The generator internal voltage which is determined by excitation system and infinite bus voltage which is a system voltage. The lower these voltages, the lower the Pmax will be.
5. Generator loading before the disturbance affects transient stabilty. The higher the loading, closer the unit will be to Pmax , which means that during acceleration , it is more likely to become unstable.

The two-machine system can be equivalently reduced to a single machine connected to infinite bus bar. The qualitative conclusions regarding system stability drawn from a two-machine or an equivalent one-machine infinite bus system can be easily extended to a multimachine system.

It has been seen that transient stability is greatly affected by the type and location of a fault, so that a power system analyst must at the very outset of a stability study decide on these two factors.

2. Solution Methods for Transient Stability

There are various factors which affects the transient stability causes the system to be unstable. So it necessary to make a system stable for reliable & secure operation , there are two methods for solving the transient stability problem

2.1 Numerical integration method

This is the most common technique**, particularly used for large systems; during the fault** and after the fault the power system differential equations are solved using numerical methods

2.2 Direct or energy method

This method is used for a two bus system known as the equal area criteria mostly used to provide an intuitive insight into the transient stability problem

3. Methods to improve the transient stability

Transient Stability is the ability of the power system to maintain/remain in synchronism after the sudden large disturbance. These disturbances may be because of the application of faults, clearing of faults, switching ON and OFF, surges in EHV system

1] By increasing the system voltage ,transient stability of the system can be improved. Increase in the voltage profile of the system implies increase in the power transfer ability. Due to this, it helps in increasing the difference between initial load angle and critical clearance angle. Hence increase in power allows the machine to allows to rotate through large angle before reaching critical clearance angle.

2] Increase in the X/R ratio in the power system increases the power limit of the line. Thus helps to improve the stability

3] High speed circuit breakers helps to clear the fault as quick as possible. The quicker the breaker operates, the faster the fault cleared and better the system restores to normal operating conditions

4] The main reason for the instability in the power system is because of the excess energy supplied by the turbine during the fault condition. Fast Valving is used in reducing the mechanical input power when the generator is under acceleration during the fault condition and hence it improves the stability of the system

5] The most of the faults occur in power system system will be momentary and it can be self cleared faults. Hence circuit breakers employed for fault clearance opens in sensing the fault with time delay of 2 cycles and re-closes after particular time to determine whether the fault is cleared or not cleared.

6] The other ways to improve the transient stability are by using lightning arresters, high neutral grounding impedance, single pole switching, quick Automatic Voltage Regulators (AVRs).

The transient stability of power systems is a nonlinear problem, from the past the power system was only confined to planning and design but now a days the transient stability studies are important both in operational planning as well as real-time operation. "Transient" means changing.

So for transient stability the system stage is changing where if the transition is considered from one equilibrium to the other then due the large disturbances occur. So improvement in transient stability is the main requirement. There are various another methods to improve transient stability.

3.1 By the Joint Usage of DC System

The stability problem generally occur in parallel ac-dc systems. There was a lots of study on same problems and according to that results are obtained by an experiments on the artificial ac and dc transmission facilities. Dc power of steady state is more as compared with the ac power, with improved transient stability. The transient stability is improved if the dc power is rapidly increasing in case of faults in the ac system. In 3-phase short circuit the sending ac system results in a serious decrease of the dc power which causes the generator to accelerate at the sending end. Two control methods are present for the countermeasure.

3.2 By using UPFC

In this , how unified power flow controller (UPFC) parameters and how it should be controlled in order to achieve the maximal desired effect for solving first swing stability problem has been explained. These types of problems mainly appear for bulky power systems with long transmission lines. There are various methods of reference identification of the series part, in order to improve the transient stability of the system based on: optimal parameters, state variables and also injection models were studied. Finally, a method based on state variables and using the local measurement was proposed.

3.3 By using multiple models and switching

Most common problem in adaptive control is the poor transient response which is observed when adaptation is initiated. Here a stable strategy is developed for improving the transient response by using multiple models of the plant for controlling and switching between them. These models are identical except for initial estimates of the unknown plant parameters and control is applied to determine at every instant by the model which best approximates the plant. Result which we get after simulation indicates the improvement in performance that can be achieved.

3.4 Transient Stability Simulation by the Waveform Relaxation Methods

In this a new methodology for power system dynamic response calculations is presented. This technique is known as the waveform relaxation which is extensively being used in transient analysis of VLSI circuits and it can take the advantage of new architectures in computer systems such as parallel processors and gives the computational results.

3.5 By the phase-shift insertion

The computational studies of transient stability of synchronous machines are connected to an infinite bus bar by a double-circuit transmission line and are used to illustrate the effect of relative phase-shift where the insertion between the machine and its associated power system takes place. This method of obtaining a change in the effective rotor-excitation angle and thus the power transfer is described together with an outline of possible methods of implementation by a phase-shifting transformer in a power system.

4. Conventional Techniques

There are various conventional techniques used for transient stability improvement are discussed. A technique is considered conventional when no RES are involved. conventional techniques make up the greatest part in the liter-
ature since they includes techniques with SGs, FACT and any other approaches that do not involve RES-based units.

4.1 Preventive Transient Stability Control

A] SG Re-Dispatch

One of the most effective preventive actions to increase the transient stability margin is to re-dispatch generators in order to reduce their active power set point. In this generators are operated further away from the stability limit. The acceleration area decreases and the deceleration area increases. Due to cost effciency, the dispatch of generators is usually determined by the use of optimal power flow calculations where either transient stability constraints are derived from a time-domain sensitivity analysis, or the whole set of power flow equations is directly included in the OPF formulation In 4th-order Taylor expansion is used to speed up solving of OPF calculations including transient stability constraints. The authors of propose to derive linearized transient stability constraints outside the OPF calculation to not further complicate the OPF formulation. In time- domain simulations are combined with pre-assessment contingency altering and a fast re-dispatch estimation to reduce the computational burden of the stability assessment.

B] Load Shedding

When referring to load shedding most commonly it will be associated with frequency regulation such as under frequency load shedding to prevent a power system from collapse due to generation. However, load shedding can also be used to improve transient stability of power systems, e.g. By reducing the demand., it reduces the loading of generators which can be again down to the power-angle relationship. i.e. the reduced active power set point of the generator implies a reduction of the rotor angle and thus an increased stability margin. To improve transient stability , it has been proposed a risk-based coordination of generation rescheduling and load shed- ding. If the generation rescheduling cannot resolve the issue, load shedding is added to ensure that the system is within the defined security boundaries.

C] Reduction of System Reactances

Transmission networks are mainly determined by their inductive series reactances which have distinct impact on the transient stability. The power transfer capacity is inversely proportional to the transmission reactance. The transfer capability in pre-fault conditions can be increased by reducing the series reactances of the network. By adding parallel transmission lines and use of transformers with low leakage reactances, reduction of the system reactances can be achieved Since this two techniques for reducing the system reactance's are rather expensive, other techniques as fixed or variable series compensation based on FACTS are used. system voltage is only applicable to a very limited extend.

D] Variable Series Compensation

Thyristor-controlled series capacitor (TCSC) and static synchronous series compensator (SSSC) are the series connected devices which are capable to act on the power system in a serial manner. Variable series devices can be used to preventive as well as in emergency control. TCSC consists of a fixed series capacitor C2 and a capacitor C1 in parallel with an inductor L. The thyristor controls the total reactance of the circuit .

5. Intelligent-Based Optimization Technique

Intelligent-based optimization techniques try to simulate human behavior. Intelligent-based optimization techniques present a better, faster and accurate solution to an optimization problem than the existing conventional optimization techniques. Intelligent based optimization technique includes: GA, PSO, ACO, TS, Simulated Annealing (SA), Artificial Bee Colony Algorithm (ABCA), Differential Evolution (DE) and Hybrid system using a combination of one or more of the later methods.

5.1 Genetic Algorithm (GA):

GA uses a method of 'natural selection and genetics' for obtaining an optimized solution. Unlike other optimization methods, GA work with a population of individuals represented by bit strings and modifies the population with random search and competition and it is widely applied in power system stability optimization.

5.2 Particle Swarm Optimization (PSO)

PSO is a population-based search algorithm, which solely depends on the behaviour of the flock of birds. In PSO, To form a population, a number of particles are randomly generated and are discarded. The search behavior of a particle is therefore influenced by that of other particles within the swarm. PSO can be said to be a kind of symbiotic cooperative algorithm.

5.3 Ant Colony Optimization (ACO)

ACO is based on foraging techniques of real ant colonies. ACO is also a population-based search algorithm, which searches for an optimized solution. ACO involves how ants find the shortest paths between their nest and food source, without any visible, central, active coordination mechanism.

5.4 Tabu Search (TS)

TS is basically a neighborhood search that starts its solution in a random manner and subsequently search for a neighborhood of current solution. In each iteration, as the current solution changes, the neighborhood also changes until the best solution is obtained. TS on its own is not an efficient optimization techniques, hence, it should be combined with other optimization techniques.

6. Software used to improve/Analyze transient stability

1] E-Tap Software
2] MATLAB/Simulink Software Package
3] Power world Simulator
4] SKM Software
5] PSCAD Software
6] Easy Power

7. Conclusion

In this , the review of studies on different techniques /methods to improve transient stability in power system has been presented. Use of intelligent-based optimization algorithms are getting very popular in power systems stability studies. This literature review was undertaken to explore and show the importance of intelligent based optimization techniques in damping out low frequency oscillation for the enhancement of stability studies. This literature review may serve as an eye opener to power system, researchers, engineers and practitioners in order to enhance system stability. From the discussion , it is cleared that, there are some drawback in conventional techniques, So it is better to used modern non conventional techniques based on artificial intelligence. This techniques having advantages such as simplicity, better oscillation than conventional to use in problem such as transient stability in power system. Also Some software tools has been introduced which are used to analyze/enhance transient state stability.

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