TRANSIENT STABILITY AND ANALYSIS OF MULTI-MACHINE SYSTEM USING MAT-LAB

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Abstract - Transient stability has always been one of the major concerns of power system engineers. Due to its non-linear nature, transient stability poses challenging computational and analytical problems. Transient stability evaluation is required in both planning and operation levels. Even at the planning stage more stability runs are possible if transient stability evaluation is faster.

The work presented here deals with transient stability analysis of a power system. The multi-machine transient stability programme has been implemented on MATLAB-6.5.

The work involves doing off line time domain simulations for various contingencies and finding critical clearing times. The database so created of such contingencies through off line simulations can be utilized for taking corrective actions if the contingency is real. The technique is tested on 10 Machines, 39 bus systems.

INTRODUCTION

Present day trend is to transmit more & more power over long transmission lines for economical reasons. Interconnection of power system. Continuous transient disturbances.

Stability - The stability of interconnected dynamic components is its ability to return to normal or stable operation after has been subjected to some form of disturbance.

Instability has bad effect on service to consumer loads. If a group of m/c falls out of step, it should be disconnected & resynchronized. The resynchronization is quite lengthy & cause heavy economic loss to Generation Company [5]

Transient Stability - It is the ability of a system to return to normal or stable operation after sudden disturbances or faults. Transient stability of a system refers to the stability (generators remaining in synchronism) when subjected to large disturbances such as faults and switching of lines[5].

Literature Review - In recent years, energy, environment, right-of-way, and cost problems have delayed the construction of both generation facilities and new transmission lines, while the demand for electric power has continued to grow. This situation has necessitated a review of the traditional power system concepts and practices to achieve greater operating flexibility and better utilization of existing power systems.

Motivation of the Present Work - Transient stability of a transmission is a major area of research from several decades. Transient stability restores the system after fault clearance. Any unbalance between the generation and load initiates a transients that causes the rotors of the synchronous machines to “swing” because net accelerating torques are exerted on these rotors. If these net torques are sufficiently large to cause some of the rotors to swing far enough so that one or more machines “slip a pole” and synchronism is lost. So the calculation of transient stability should be needed. A system load flow analysis is required for it. The transient stability needs to be enhanced to optimize the load ability of a system, where the system can be loaded closer to its thermal limits.

Problem Statement - Occurrence of fault may lead to instability in a system or the machine fall out of synchronism. Load flow study should be done to analyze the transient stability of the power system. If the system can’t sustain till the fault is cleared then the fault instabilise the whole system. If the oscillation in rotor angle around the final position go on increasing and the change in angular speed during transient condition go on increasing then system never come to its final position. The unbalanced condition or transient condition may leads to instability where the machines in the power system fall out of synchronism. Calculation of load flow equation by Newton Raphson method, Runge Kutta method, and decoupled method gives the rotor angle and initial condition.

Time Domain Approach - The TD approach simulates the system dynamics in the during-fault and post-fault configurations.

The during-fault period is quite short (e.g., 100 ms or so). On the other hand, the post-fault period may be much longer: typically, a system, which does not lose synchronism after, say, some seconds, is considered to be stable.

The maximum simulation period of 3 s is enough for simplified modeling. The criteria detecting the loss of synchronism are also a matter of operational practices; they may differ from one power system to another and from one T-D program to another.

They generally depend on maximum deviation of machine rotor angles and rotor speeds; these are subjective rather than objective criteria, inspired from the system operator experience.
T-D methods assess the system robustness by assessing stability limits: power limit for a given clearing time or critical clearing time (CCT) [7].

**Merits and Demerits of Time Domain Method**

**Merits:**
T-D methods are able to provide essential information about relevant parameters of the system dynamic evolution with time (machine swing curves, i.e. rotor angles; speeds, accelerations, powers, etc.). Consider any power system modeling and stability scenario. Reach the required accuracy, provided that the modeling of a power system is correctly designed and its parameters accurately known.

**Demerits:**
T-D methods are unable to provide:
- Straightforward screening tools in order to discard "uninterestingly harmless" disturbances.
- Sound stability margins, which would inform one about "how far" from (in) stability the system is, and which would yield suitable sensitivity analysis tools [1].

**Power Flow Studies**
A power flow program finds the steady state voltage and angle at each bus for a given system. The power flow problem is therefore formulated as a set of non-linear algebraic equations suitable for computer solution. The algorithm used is the Newton-Raphson method for finding voltage magnitudes and their angles at all buses. [1]

**Power Flow Equations**
- The starting point for a power flow solution is a single-line diagram of the power system. Input data consists of –
  - Bus data
  - Transmission line data
  - Transformer data
  - Generator data and load data

**Buses**
- **Slack Bus** - Both the voltage magnitude and angle are known at the slack bus.
- **PQ Bus** - Real power and reactive power is known.
- **PV Bus** - Known voltage magnitude and real power generation. The voltage angle at a PV bus is not known. [5]

**Formation of Admittance Matrix**
Mechanical power input $P_m$ is constant.

Machine internal voltage $E$ (voltage behind the transient reactance) is constant.

The mechanical rotor angle of a machine coincides with the angle of the voltage behind the transient reactance. [6]

$X_d'$ is the direct axis transient reactance.

Loads are represented by passive impedance. Damping is neglected.

**Runge-Kutta Method**
- The non-linear sets of differential and algebraic equations are solved step-by-step by using numerical integration techniques.
- For numerical integration, fourth order Runge-Kutta method is chosen as final state is calculated after integrating four times, once at the initial state, twice at the midpoint and once at the final state during the interval.

- It has been established in the literature that the results are more accurate if the time step is between 0.001 and 0.005 and hence time step of 0.005 has been used in the differential equations solution in MATLAB programming. [6]

- **Swing Equation**
  - The relative position of the rotor axis and the resultant magnetic field axis is fixed. The angle between the two is known as the power angle or torque angle.
  - During any disturbance, rotor will decelerate or accelerate with respect to the synchronously rotating air gap mmf, a relative motion begins. The equation describing the relative motion is known as the swing equation. [7]

  The swing equation
  $$ M \frac{d^2 \theta}{dt^2} = P_m - P_e $$

**Equation for Multimechine System**

$$ P_e = \text{Re} \{ \sum_{i=1}^{n} P_{e,i} \} $$

$$ P_e = \text{Re} \{ \sum_{i=1}^{n} E_i Y_i^{*} E_i^{*} \} $$

$$ \frac{d\theta_i}{dt} = \frac{\pi f}{H_i} \{ P_{e,i} - P_{r,i} \} $$

$$ \frac{d\delta_i}{dt} = \omega_i $$

$$ P_{r,i} = \text{Re} \{ EI^{*} \} $$

- $H_i$ is the inertia constant in second, $f$ is the frequency in Hertz and is constant (not affected by changes in $\omega$), $P_{m,i}$ is the mechanical power input for machine $i$; $P_{e,i}$ is the electrical power output of machine $i$; and $\omega_i$ the relative angular velocity of the rotor of machine $i$. [7]

**39 Bus, 10 Generator System**

![Fig 4.6 Ten Machine System](image)
GENERATOR DATA

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<th>$R_e$</th>
<th>$X_{e'}$</th>
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Simulation Result
BEFORE FAULT (line14-34(at0.24sec))

AFTER FAULT(line14-4(at0.25sec))

CONCLUSION

In this dissertation, transient stability analysis is performed and critical clearing angles are found. The simulations are carried out on systems viz., 10 machine 39 bus systems. The transient stability is studied using swing equation and its solution using numerical methods implemented in MATLAB 6.5. The solution of swing equation is obtained using Runge-Kutta method for its accuracy. For analysis classical model of synchronous machine has been considered for the simplicity and fair accuracy it offers. Modern power systems have many interconnected generating stations, each with several generators and many loads. This multi-machine stability analysis takes into account first swing instability.

REFERENCE


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