ECE4321 TERM PROJECT A
Spring 2009

Transient Stability Simulation
Due Last Day of Classes

Objective

The objective of this assignment is to gain experience in transient stability analysis of multi-machine power systems.

Problem Statement

For this purpose a three generator power system is considered as it is shown in Figure 1. System parameters are indicated in the Figure. The per unit values for the transmission lines, which appear in the Figure, are on a 100 MVA base. The parameters for the transformers and the generators are on their respective bases. A three phase fault occurs on the line 3-4 at time t=0. The impedance of the line on the left and right side of the fault are indicated in the Figure. The protection system clears the fault in 18 cycles after the fault initiation by opening the line breakers. Prior to the fault the system operates in such a way that:

$$P_{g1} = 75\,MW, \quad P_{g2} = 30\,MW, \quad V_1 = 1.0\ pu, \quad V_2 = 1.0\ pu$$

Assume that during transients the voltages behind the transient reactance of the three generators remains constant and the electric loads are constant impedance loads (classical model). For consistency use the following notation:

$$\tilde{E}_1 = E_1 e^{j\delta_1}, \quad \tilde{E}_2 = E_2 e^{j\delta_2}, \quad \tilde{E}_3 = E_3 e^{j0}$$

- Compute the generated real power of unit G3 and the reactive power generated by units G1, G2, and G3, i.e. solve the power flow problem. For this purpose use the program **WinIGS-F**.
- Compute the transient voltages $E_1, E_2\ and\ E_3$ and the position of the rotors $\delta_1\ and\ \delta_2$ prior to the fault.
- Compute the transient power versus $\delta_1\ and\ \delta_2$ for the three generators, i.e. $P_{ei}(t) = f_{i,f}\,(\delta_1(t), \delta_2(t)), \quad i = 1, 2, 3$, during the fault conditions, i.e. for time 0<t<18 cycles.
- Is the equal area criterion applicable for this system?

- Compute the transient response of the system during the fault, for a period of 18 cycles following the fault initiation. Use any method of your choice.
- Generate a plot of the rotor positions δ_1 *and* δ_2 and rotor speed ω_1 *and* ω_2 versus time for a period of 18 cycles following the fault initiation.
- Compute the transient power versus δ_1 *and* δ_2 for the three generators, i.e. $P_{ei}(t) = f_{i,post}(\delta_1(t), \delta_2(t)), \quad i = 1, 2, 3$, during the post-fault conditions, i.e. for time t> 18 cycles.
- Compute the transient response of the system during the post-fault conditions, for a period of 1.5 seconds following the tripping of the faulted line. Use any method of your choice.
- Generate a plot of the rotor positions δ_1 *and* δ_2 and rotor speed ω_1 *and* ω_2 versus time for a period of 1.5 seconds after the tripping of the faulted line.
- Write a report to summarize your work. State your observations and conclusions.

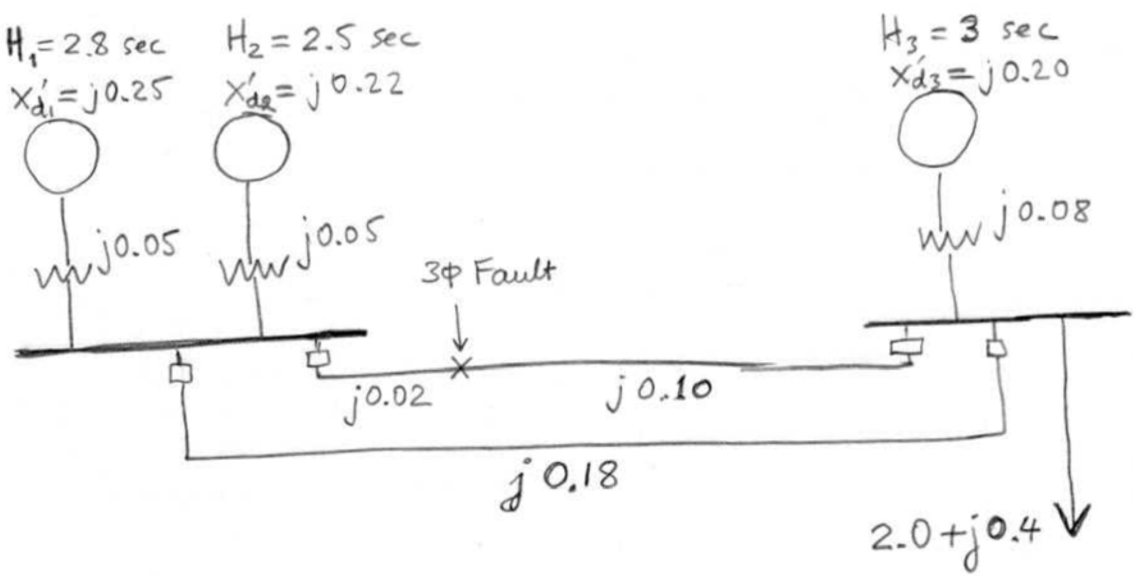

Figure 1. A Simplified Three Generator System

Additional data: Units G1 and G2 are rated 100 MVA, 15 kV. Unit G3 is rated 100 MVA, 18 kV. The transformers on the left are rated 100 MVA each, 15kV/115 kV, delta/wye connected. The transformer on the right is rated 100 MVA, 18kV/115 kV, delta/wye connected.

ECE4321 TERM PROJECT B
Spring 2009

Comparison of Transient Stability Simulation Algorithms

Due Last Day of Classes

Objective

The objective of this assignment is to compare three numerical methods for transient stability simulation, specifically, the Euler method, the trapezoidal integration method and the quadratic integration method.

Problem Statement

For this purpose a single generator power system connected to an infinite bus is considered as it is shown in Figure 1. The synchronous generator is a three-phase 200 MVA, 60 Hz, 18 kV. It delivers 200 MW to the infinite bus through the two three phase transmission lines. At the terminals of the generator the voltage is 1.0 pu and the power factor is 0.97 current lagging. At time t=0 a three phase fault occurs at the location A of the transmission line #1. Point A is located at a distance of 10% of the line length. Following the fault the breakers 1 and 2 operate to clear the fault within 15 cycles. In this case the line #1 is permanently disconnected from the system.

Compute the operating conditions of the system prior to the fault. Then:

Consider the fault conditions:

- For the fault period ($0<t<0.25$ seconds) define the differential equations and initial conditions that govern the system.
- Write a computer program for the numerical integration of above differential equations using Eulers's method. Compute the system response (rotor position, $\delta(t)$, and rotor speed, $\omega(t)$) for this system using the following time steps: (a) 1.0 millisecond, (b) 0.1 millisecond, and (c) 0.01 millisecond. Graph the results.
- Write a computer program for the numerical integration of above differential equations using the trapezoidal integration method. Compute the system response (rotor position, $\delta(t)$, and rotor speed, $\omega(t)$) for this system using the following time

steps: (a) 1.0 millisecond, (b) 0.1 millisecond, and (c) 0.01 millisecond. Graph the results.

- Write a computer program for the numerical integration of above differential equations using the quadratic integration method. Compute the system response (rotor position, $\delta(t)$, and rotor speed, $\omega(t)$) for this system using the following time steps: (a) 1.0 millisecond, (b) 0.1 millisecond, and (c) 0.01 millisecond. Graph the results.
- Write a report summarizing your work and the results. State your observations and conclusions.

Consider the post-fault conditions:

- For the post-fault period (0.25<t<1.5 seconds) define the differential equations and initial conditions that govern the system. For initial conditions, use your best results from the previous task.
- Write a computer program for the numerical integration of above differential equations using Eulers's method. Compute the system response (rotor position, $\delta(t)$, and rotor speed, $\omega(t)$) for this system using the following time steps: (a) 1.0 millisecond, (b) 0.1 millisecond, and (c) 0.01 millisecond. Graph the results.
- Write a computer program for the numerical integration of above differential equations using the trapezoidal integration method. Compute the system response (rotor position, $\delta(t)$, and rotor speed, $\omega(t)$) for this system using the following time steps: (a) 1.0 millisecond, (b) 0.1 millisecond, and (c) 0.01 millisecond. Graph the results.
- Write a computer program for the numerical integration of above differential equations using the quadratic integration method. Compute the system response (rotor position, $\delta(t)$, and rotor speed, $\omega(t)$) for this system using the following time steps: (a) 1.0 millisecond, (b) 0.1 millisecond, and (c) 0.01 millisecond. Graph the results.
- Write a report summarizing your work and the results. State your observations and conclusions.

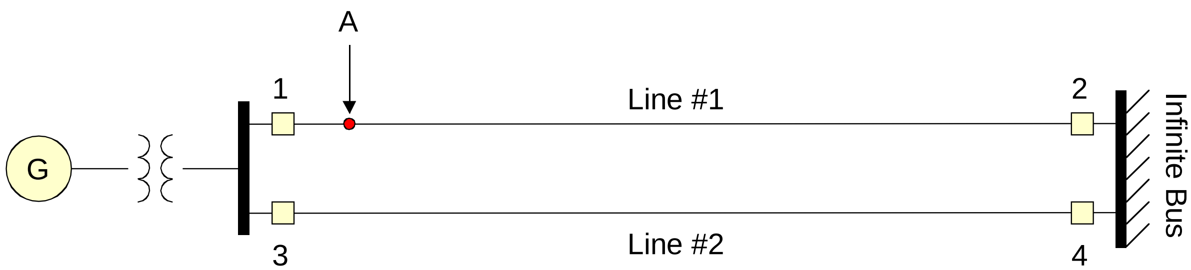

Figure 1. A Simplified Three Generator System

Generator: $z_d' = j0.18\ pu, \quad H = 2.8\ seconds$

Transformer: $S = 200\ MVA, \quad 18kV/115kV, \quad z_1 = z_2 = z_0 = j0.08\ pu$

Each Line: $115\ kV, \quad z_1 = z_2 = j0.12\ pu, \quad z_0 = j0.30 \quad @100MVA\ and\ 115\ kV$

ECE4321 TERM PROJECT C
Spring 2009

Parametric Investigation of Distance Relay Performance

Due Last Day of Classes

Parametric Investigation of Distance Relay Performance

Objective

The objective of this assignment is to perform a parametric investigation of distance relay performance. The performance of this relay is based on correct estimation of fault distance.

Problem Statement

Consider a typical transmission circuit which may parallel other transmission circuits. Figure 1 provides a suggested configuration of the system. For this system or a similar configuration (of your choice) compute the performance of a distance relay parametrically (the suggested parameters are defined below). The results should be tabulated in terms of the error versus parameter values. The suggested parameters for the parametric study are:

Ground wire size
Tower ground impedance
Soil resistivity
Fault impedance
Distance of other transmission circuit (centerpoint to centerpoint)
Distance to the fault

The minimum number of parameter combinations is defined in Table 1 (Note: AW=ALUMOWE). The suggested test system is given in Figure 1. You are encouraged to experiment and possibly construct your own test system.

Table 1: Suggested Parameter Range

Ground Wire Size	Tower Ground R (ohms)	Soil Resistivity Ohm.meters	Fault Impedance (ohms)	Distance of Other Circuit	Distance to Fault (% of Line)
HS5/16	10 ohms	50	0.0	40 ft	10.0
AW7#9	80 ohms	600	0.2 ohms	100 ft	70.0

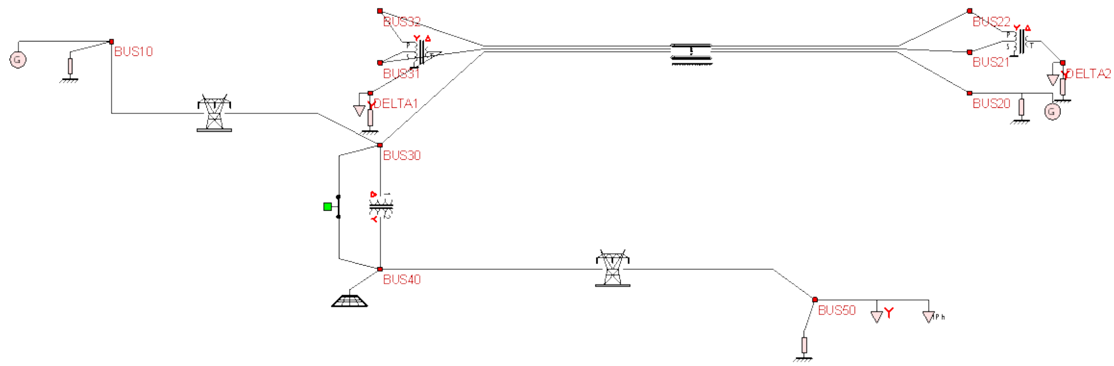

Figure 1. Suggested Test System

Procedure

Step 1: Define the relay settings. For this purpose consider a system with the following parameters:

Ground wire size: 5/16HS steel
Tower ground impedance: 25 ohms
Soil resistivity: 100 ohm.meters
Fault impedance: zero
Distance of other transmission circuit (centerpoint to centerpoint)
Transformer grounding: solidly grounded

For this system compute the pos, neg and zero sequence parameters of the line. Compute the settings of the relay by rounding off as follows: impedance magnitude: 0.1 ohms, phase angle: 0.1 degree, compensation factor: 0.1. The computed settings will remain constant for the remaining analysis.

Step 2: For each combination of parameters generate a study case file with a known fault location – a total of 64 files.

Step 3: Perform the fault analysis for each one of the files. Using the results from the program compute the distance relay "reading" and compute the error.

Step 4: Upon analysis of all cases, graph the results using appropriate axes and parametrically with respect to the selected parameters. Study the results and form your conclusions and observations.

Final Report Preparation

The final report should have (as a minimum) the following structure:

Introduction and Scope
Description of the System Model
Description of the Parameters Considered
Simulation Results
Conclusions and Observations