Electric Power Systems Project
Transient Stability and Power System Dynamics

Objective:

Gain experience and insights in the transient stability simulation software to determine critical clearing times and look at the impact of variation of the network parameters on its stability.

Background on 37 Bus APL System

The one-line diagram of the Aggieland Power and Light (APL working at 50 Hz) grid is shown in Figure 1.

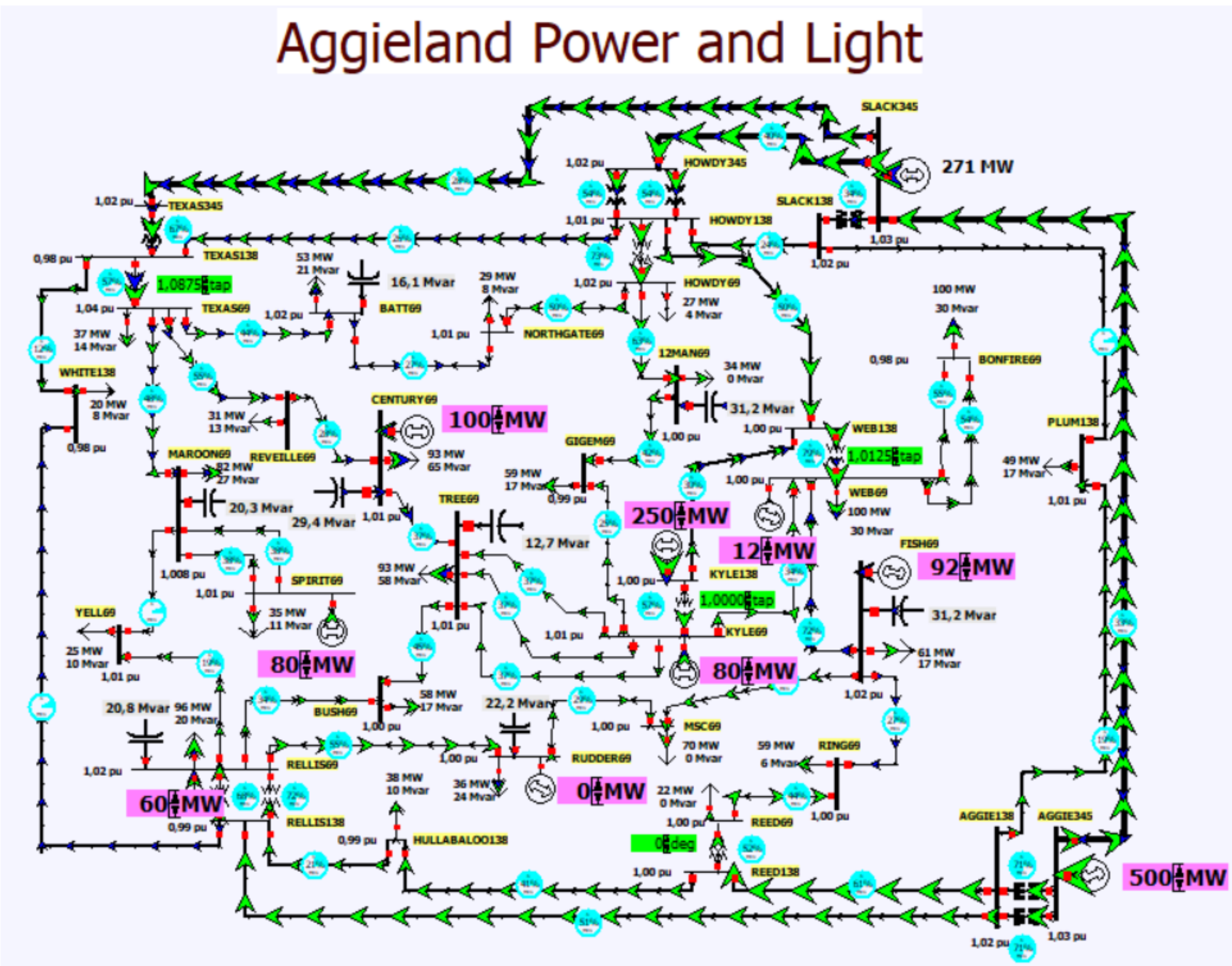


Figure 1: 37 Bus APL System

Procedure for Running Transient Stability on the APL System

1. Start PowerWorld Simulator. Open the Project_2 case. The system has been set up to run transient stability with several contingencies predefined for the lab. Select **Add Ons, Transient Stability** to display the Transient Stability form. This add-on will be used throughout the lab for transient stability simulations, as shown in Figure 2.

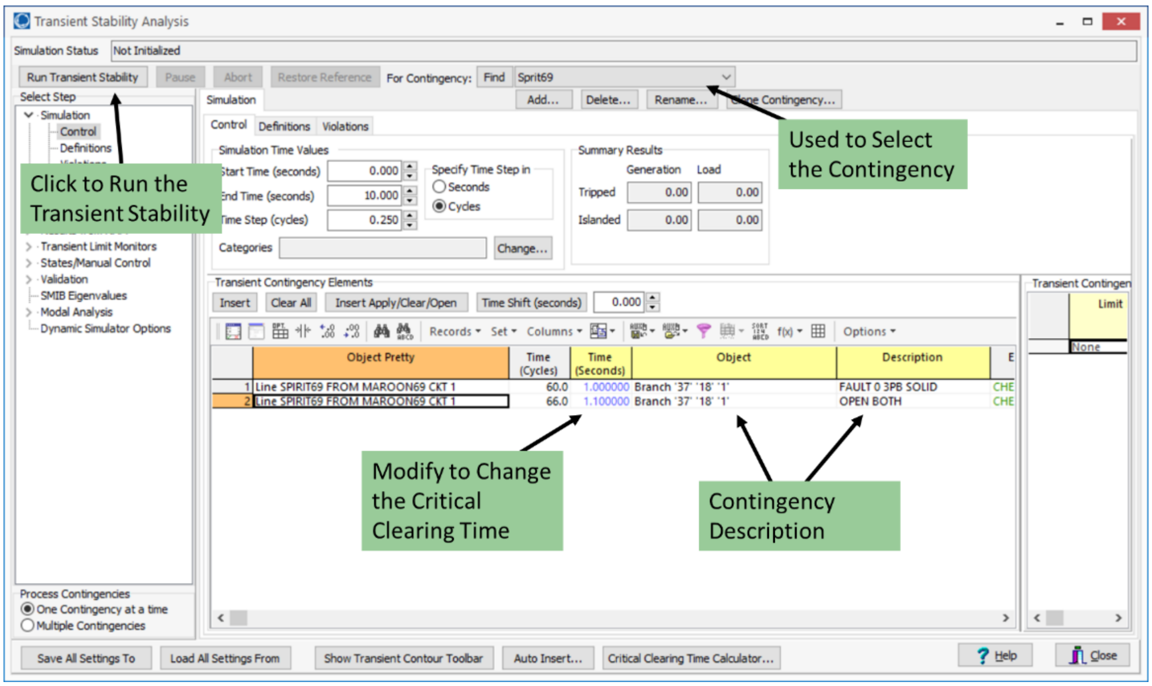


Figure 2: Transient Stability Form

2. For the first transient stability contingency, select the Century69 contingency. This contingency applies a balanced three-phase fault at a time equal to 1.0 seconds right at the bus where the generator is connected. After 0.1 seconds, the fault is cleared. Then run the simulation by clicking on the **Run Transient Stability** button. A graph showing the time-varying generator rotor angles will appear at the end of the simulation. Save a copy of this graph for your report and comment it.

3. Iteratively change the time the transmission line is opened to determine the critical clearing time for this fault (to an accuracy of 0.01 seconds – critical time is defined as the longest time the fault can be applied without one of the generators losing synchronism). The critical clearing time is the time difference between when the fault is applied (i.e., time = 1.0 seconds) and the largest clearing time. Save a copy of the rotor angle graph for the critical clearing time for your report and record the critical clearing time.

4. Next, change the assumed H value for the Century69 generator: you must right-click the generator on the one-line diagram and select **Generator Information Dialog**; then, on the **Stability, Machine Models** page, change the **H** value from 3.0 to 5.0 [s]. Select **OK** to save your change and close the dialog.

Again, calculate the critical clearing time for the Century69 contingency. Did the change in the critical clearing time match your expectations?

5. Change H for the Century69 generator again, reset it to 3 s and select the Century69 – SLG contingency. This contingency applies a Single Line to Ground (SLG) fault at 1.0 seconds right at the bus where the generator is connected. After 0.1 seconds, the fault is cleared. Comment the new results obtained.

6. **Close the case without saving and reopen it**. Change the contingency to Web69, which simulates a fault on the 69 kV transmission line between Web and Kyle substations, which is cleared by opening the line. Do you get the results you expected? What happens if you increase the output of Web69 to 60 MW? Compute clearing times and discuss the behavior at synchronization loss in the two cases.

7. Compare the critical clearing times obtained in PowerWorld for all the five predefined contingencies (except the SLG case) with the critical clearing times computed using the equal area criterion (EAC). The two already analyzed contingencies should be considered <u>in their original status</u>, i.e., H_Century69 = 3 s and P_Web69 = 12 MW (you can close and reopen the case to return to the first configuration of the system). Comment the results obtained.

The deadline to deliver the project is 21/12/2025 at 23:59
<u>The report should not exceed 15 pages</u>

FREQUENTLY ASKED QUESTIONS (FAQ) – Project 2

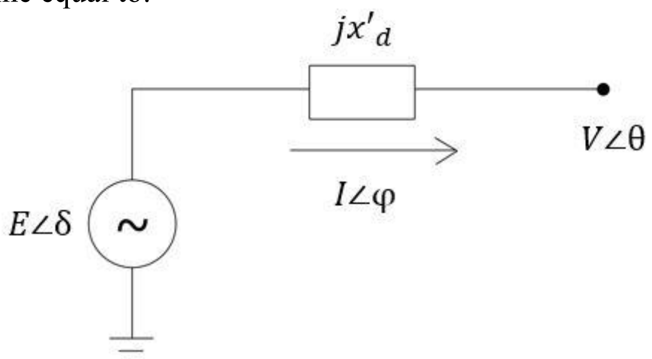
About exercise 7:

In the slides of the course, the following expressions are stated to define the critical clearing angle and the critical clearing time due to the Equal Area Criterion:

$$\delta_{cr} = arccos[-cos(\delta_0) + sin(\delta_0)(\pi - 2\delta_0)] \quad (1)$$

$$t_{cr} = \sqrt{\frac{4H(\delta_{cr}-\delta_0)}{\omega_s P_m}} \quad (2)$$

With δ in rad, H in s, P_m in p.u, $\omega_s = 2\pi f_s$ where f_s is the nominal frequency of the system in Hz. These expressions (1) and (2) were stated considering the generated active power of a synchronous machine equal to:



$$P_e = \frac{VEsin(\delta - \theta)}{x'_d}$$

The voltage angle of the terminal bus θ is considered as reference (θ = 0). However, the terminal bus of the faulted generator is not automatically set as a reference in the PowerWorld Simulator for every contingency simulated. So, what you need to do is to measure the angle θ and consider it in the expressions to calculate δ_{cr} and t_{cr}. The expressions (1) and (2) now become:

$$\delta_{cr} = arccos[-cos(\delta_0 - \theta_0) + sin(\delta_0 - \theta_0)(\pi - 2(\delta_0 - \theta_0))] \quad (3)$$

$$t_{cr} = \sqrt{\frac{4H(\delta_{cr}-(\delta_0-\theta_0))}{\omega_s P_m}} \quad (4)$$

Or, you can directly use the *power angle*.

<u>In the PowerWorld simulator:</u>

- How to measure and plot θ: 'Run mode > Add Ons > Trans. Stab. Sim. > Menu on the left, click on Plot, Plot Designer > Device type: Bus > V Angle (rad) > Choose the referred bus in the list > Click on Add > Run Transient Stability'
- How to check f_s: 'Add Ons > Trans. Stab. Sim. > Menu on the left, click on Options > Power system model > Nominal system frequency'.
- How to check P_m and the referred base: double-click on the generator.
- The power angle is the difference between the internal machine voltage and the terminal voltage → Power angle = rotor angle – voltage bus angle.
- The rotor angle is the position of the rotor relative to the reference voltage $\bar{V}$ (where $\bar{V} = |V|\angle 0$).
- Angle Reference Options: generator <u>Rotor Angles</u> in a transient stability simulation are calculated compared to an angle reference. To check the angle reference: Add Ons > Trans. Stab. Sim. > Menu on the left, Options > Results Options.