Simple Swing Model Simulator

The Simple Swing Model Simulator (SSMS) is an application that provides illustrations and demonstrations of a small power system that has generators, loads, and storage. It is intended to roughly emulate the Micro-grid in a Box (MGB) used in the demonstrations for the Resilient Control Systems class. Generators and loads have periodic (daily, weekly, seasonal, etc) variations as well as “random” variations. For the model data from Idaho Falls Power that is provided through the wind for schools website gives realistic variations (see http://wind-for-schools.caesenergy.org/wind-for-schools/IF_Power.html). The website was collecting and displaying real-time data up until May of 2013 but has unfortunately quit providing the latest data. For this simulator, one year of data collected at 10 minute intervals is used. The data is played back and repeated, starting at a random point in the collection, at a much faster than real-time rate to make the simulation dynamic for short demonstrations. The storage device in the system represents a large battery or pumped hydro storage system. It is connected to the electric system to either provide power when necessary or store energy when excess is available.

SSMS illustrates what happens when the needed energy (load) and provided energy (generation) do not match. Since the generators and some of the loads are big spinning machines generating 60hz alternating current, the grid has rotating kinetic energy that helps keep the frequency stable. When there is excess generation the machines tend speed up driving the frequency higher. The opposite is true when there is more load than generation: the frequency decreases. The relationship to the power balance, kinetic energy, and the frequency of the system is given in the Swing Equation, thus the name of the model. Those interested can find the details of the swing equation in John Grainger. Power system analysis. McGraw-Hill, New York, 1994 or other textbooks or papers on power systems.

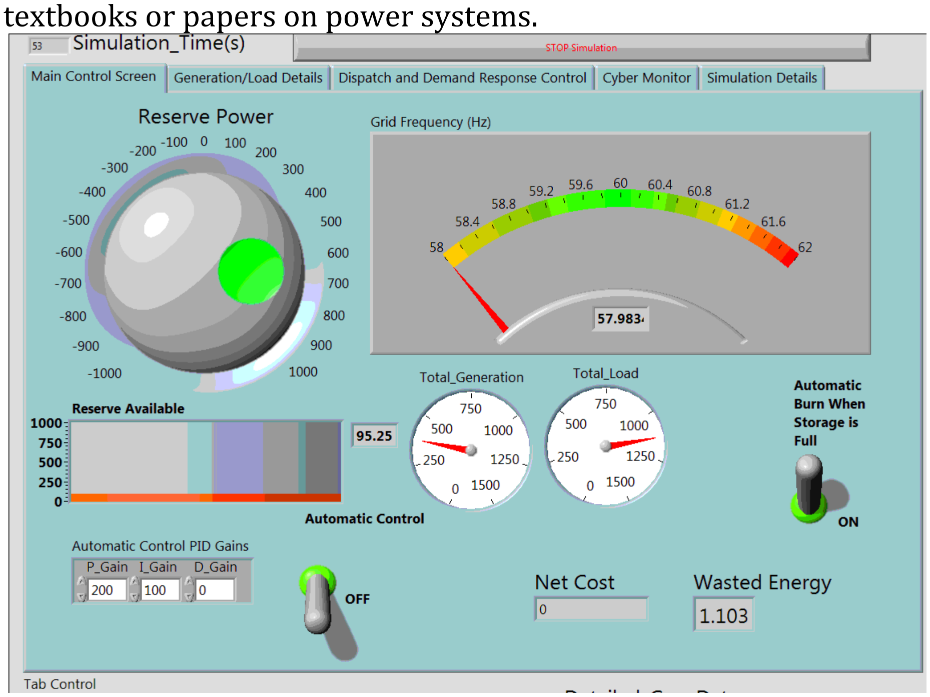

Figure 1. Screen Capture of SSMS User Interface.

The SSMS has a user interface, Figure 1, that is broken into tabs with a summary gauges and controls on the first tab and other items of interest on other tabs. It is not intended to be a realistic control room but to provide an interface to for experiments and observation of the power system. So go ahead and try some things. The first tab shows:

1. The frequency of the grid is a prominent gauge. As described in (http://consultkirby.com/files/TM2003-41_Freq_Control.pdf), frequency must be kept in a narrow frequency band near 60hz to prevent damage to expensive equipment. SSMS is set to "trip" or shutdown if the frequency goes outside a +/- 2hz window.
2. The load/generation meters show the current generation and load totals. When there is a difference the frequency will start to vary as described above based on the swing equation.
3. A storage system is controlled with a knob to provide power from the storage device called reserve power. Adjusting this knob can compensate for the difference in the total generation and total load. TRY IT: Turn the automatic control switch off and try to adjust this power to keep the frequency stable. If the frequency is too high, turn the knob counter-clockwise to take power away from the grid. If the frequency is too low, turn the knob clockwise to add power to the grid. Since the grid has relatively high variability in generation and load and low amount of inertia, you will likely find this challenging. But it will provide some intuition into why you want automatic control for this part of the control. NOT a place for humans in the loop.
4. A gauge of reserve energy available shows how much energy has been stored and is available for use with the reserve power knob. If you run out of stored energy, the reserve power will go to ZERO even though the setting is different. If the storage is filled no more power can be absorbed from the grid with this system.
5. Automatic control switch and gains enable and configure the feedback control though the reserve energy setting. Set this switch to ON to use feedback to determine the reserve power setting. The error in the frequency from 60 hz times the P-Gain (proportional gain) determines the value along with Integral and Differential gains. Those with some control systems background may be familiar with the affects of these gains. TRY adjusting these gains and see how it affects the stability of the system.
6. Two other boxes are used to display a summary of advanced features to be discussed later. The first is Cost. On another tab there are a selection of buttons to request additional power or cut loads of customers that have agreed to allow "demand response". There is a cost in power bought or power not sold that is tracked here. A goal would be to satisfy your customers at the lowest cost possible. NOTE: a grid failure is a sure way to have all customers dissatisfied. The energy wasted value is a measure of power burned when there is no more room for storage. If you click the automatically burn energy switch on that the system will not let the frequency run away but the generated energy for which demand is lacking is

wasted. Thus, a second goal of an operator would be to waste a low amount of energy.

In brief, the second tab shows more details of the energy generation and loads of the system. You will note a high variability in the wind energy produced. In the simulator it is a simple linear relationship to the wind speed. As you run the program obverse the rapid change in wind generation compared to hydroelectric generation. The third tab has three choices for each generation dispatch and load demand response choices that have a cost and duration associated with them. The scenarios are fixed in the current version. If you ask for generation it will start and last for the duration shown. The cost (rate*duration*power) will be added to your cost field on the first tab. The demand response will cut power to a customer of a given amount for a set duration. The disruption will also be added to your net cost metric based on the amount of revenue lost by not selling this energy. Though not given here a maximum amount of outage for a DR customer is most likely part of any realistic contract—they will likely get mad if you consistently disrupt them.

A tab for future expansion on cyber issues is left blank for the time being and the final tab has setting to configure the simulator for different scenarios. Examples are the amount of inertia, the amount of hydro and wind power, and the generation and demand response scenarios as well as other settings. Those interested may want to play with these—such as adding to the amount of wind versus hydro, etc. Currently the software does not support saving these settings to a file.

The program is developed in National Instrument's Labview. For really industrious students it can be made available as source code.