One-Year Simulation in One Minute

Simulation of an Energy Storage System used on a power grid

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Objectives

- Demonstrate SimPowerSystems capabilities to simulate an electrical circuit and control system, in phasor mode, for a full-year period in less than one minute of simulation time.
- Illustrate concepts related to Energy Storage Systems (ESS).
- Show how to use public solar data time-series (TMY3 files) and how to create typical load profiles.
- Provide a tool to assist in determining appropriate ratings (power & capacity) for a generic ESS to be used on a distribution power system.

Distribution Power System

The electrical grid of the example represents a typical North American Utility distribution system. It consists of a 120-kV transmission system equivalent supplying a 25-kV distribution substation. Several feeders are connected to the 25-kV bus of the substation. One of them supplies the power to a community that owns the PV farm and an energy storage system. The grounding transformer connected at the 25-kV bus provides a neutral point and limits the overvoltage on the healthy phases during a single-phase fault. Its zero-sequence impedance is three times the value of the grid positive sequence impedance.

Thanks to the Phasor solution of the Powergui block, this grid can be simulated in a very short time even if the simulation period is one year. Phasor solution is the ideal algorithm if you are only interested in the changes to magnitude and phase of all voltages and currents in your circuit. You do not need to solve all differential equations (state space model) resulting from the interaction of R, L, and C elements. You can instead solve a much simpler set of algebraic equations relating the voltage and current phasors. This is what the Phasor solution method does at a particular specified frequency (60 Hz in this example).

Dynamic Load Model

The Dynamic Load model implements a three-phase, three-wire dynamic load based on load profiles. The active power P and reactive power Q absorbed by the load vary as function of positive-sequence voltage V and load profiles data. P & Q vary as follows:

```
P=P_LoadProfile*(V/Vo)^np & Q=Q_LoadProfile*(V/Vo)^nq
```

The profiles are daily load profiles specified on an hourly basis. They are stored in the **`LoadProfile_Datasets.mat`** file.

For each load profile, the user specifies summer and winter data. Two sets of profiles are provided. The **`Build_LoadProfile_Datasets.m`** MATLAB script assist the user in creating additional load profiles.

PV Farm and TMY3 Data

The TMY3 data block converts TMY3 solar irradiance data to Power. This power signal is fed to the PV Farm block that converts power signal to currents.

TMY3 are data files for the typical meteorological year (TMY) data sets derived from the 1961-1990 and 1991-2005 National Solar Radiation Data Base (NSRDB) archives. The files contain hourly values of solar radiation and meteorological elements for a one-year period. These files have been produced by NREL's Electric Systems Center under the Solar Resource Characterization Project, which is funded and monitored by the U.S. Department of Energy's Energy Efficiency and Renewable Energy Office.

The user can select one from 242 US station locations for solar time-series data. The user can choose the Global Horizontal Irradiance (GHI) or the Direct Normal Irradiance (DNI) as irradiance values to be used by the simulation. The irradiance values for all locations are stored in the `StationData_NEW.mat` file This file is loaded automatically at mask initialization.

Energy Storage System (ESS)

The Energy Storage System block contains the following components:

- Control system
- Unavailability monitor
- Stored energy calculator
- SPS Power-to-Current model and a 240/600V step-up Transformer.

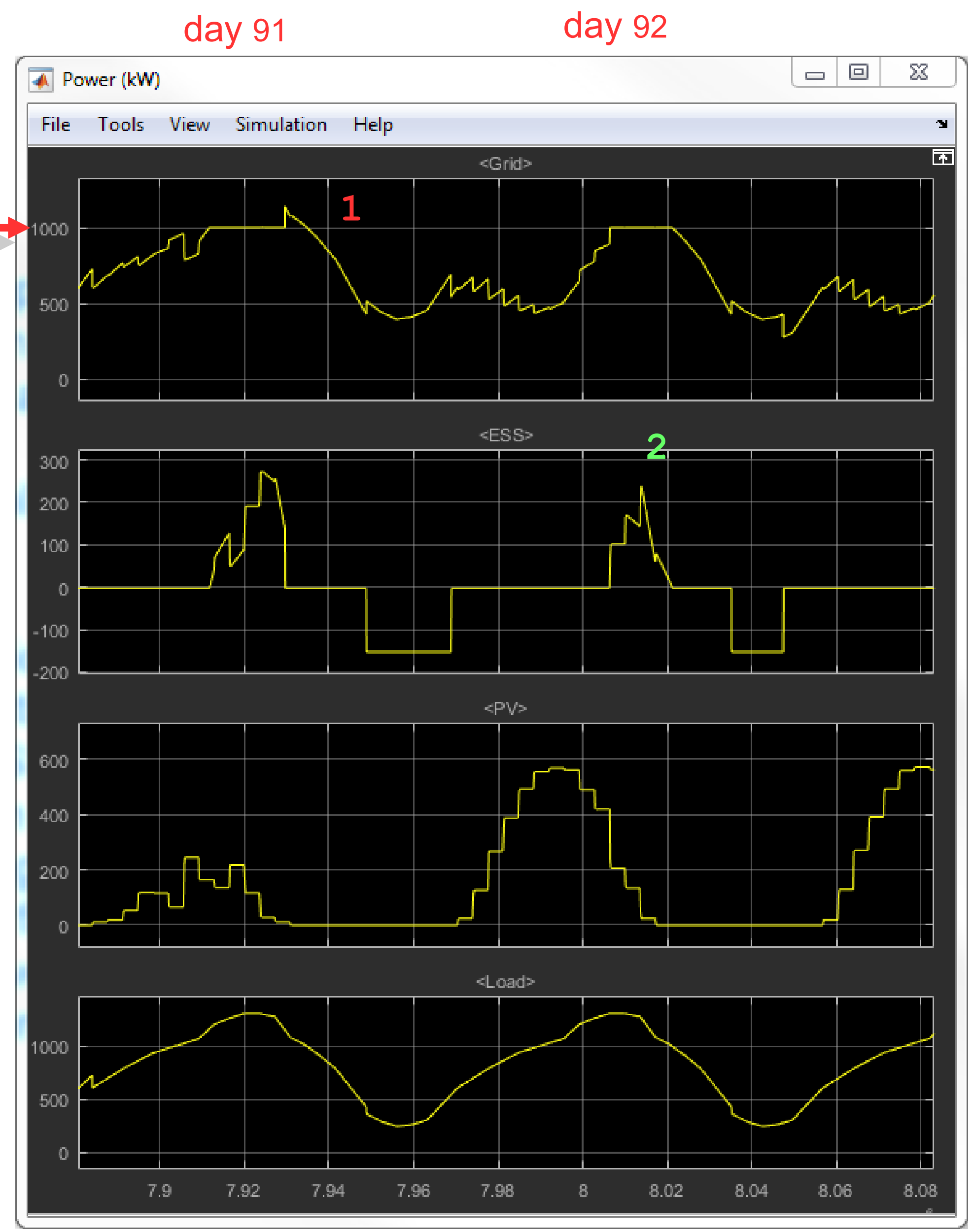
At any given time during the day, the control system determines the required power from the ESS in order to maintain the power below the specified value of the Maximum power allowed from the grid. This power signal is fed to a Power-to-Current block connected to a 240/600V step-up transformer. Although the power rating and capacity of the modeled ESS are respectively specified in kW and kWh as for a Battery Energy Storage System (BESS), this ESS could represent several types of storage systems, such as Flywheels, Compressed Air, Super Capacitors, Pumped Hydro, Superconducting Magnetic.

Scenario

Obviously, a multitude of applications related to energy storage systems and smart grids can be studied and validated using a SimPowerSystem model such as this ESS demo. Applications could be as diverse as financial energy arbitrage, line congestion mitigation, equipment deferral, solar power smoothing, spinning reserve, voltage support, etc.

In our case, a simple scenario has been chosen to illustrate one usage of this demo: The objective is to determine appropriate sizing (power & capacity) of an ESS equipment connected to a 600V community electrical system, in order to prevent the community from purchasing more power than agreed with the Utility company. Based on a given load profile, PV farm output, ESS power rating and capacity, the simulation will give the number of unavailability for a full year. This sizing study can be performed for various locations around the US.

Simulation



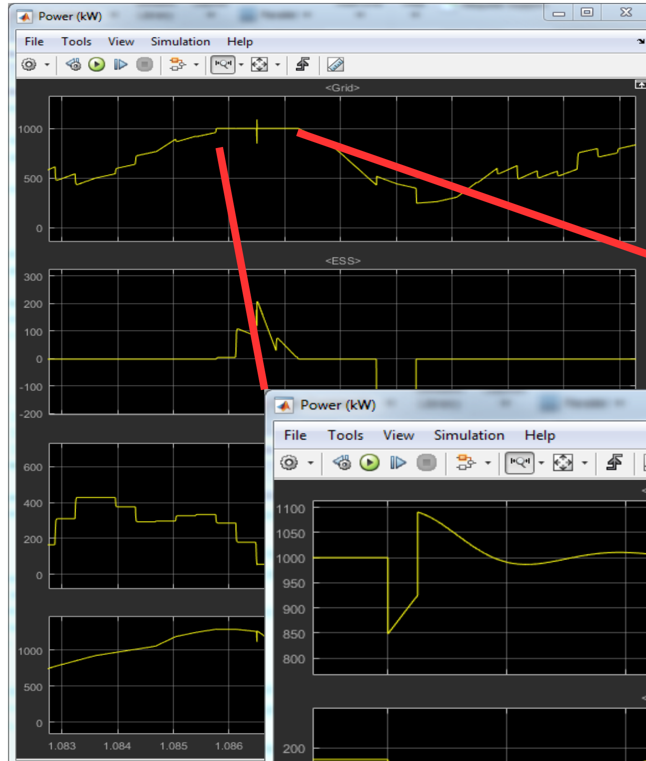
The figure on the right shows two day results where the ESS control system determines the power required from the ESS, to avoid exceeding the maximum power allowed from the grid (1000 kW for this simulation)

1 On day 91, the ESS was not able to provide the necessary amount of power, and the community has no choice to buy more power from the grid.

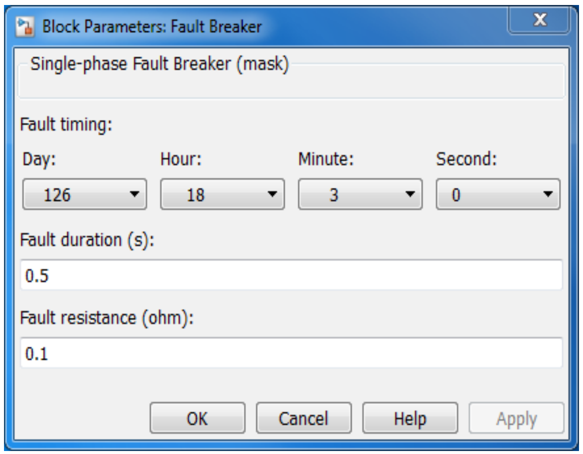
2 On day 92 the ESS output was sufficient to avoid exceeding the maximum power allowed.

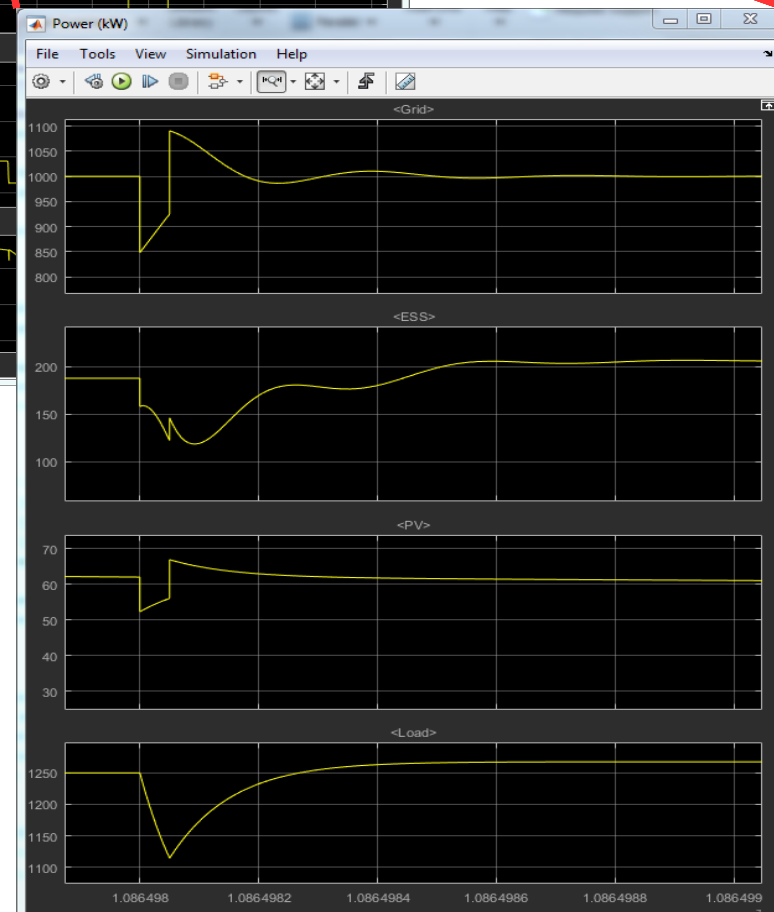
Simulation

day 126



Zoom around 18h03m00s





The figure on the right shows a zoom on the transient caused by a fault at Bus B4, at 18h03 on day 126 (May 6th).

The Phasor solution produced simulation results to the milisecond precision at the programmed fault timming.

References

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4. Energy storage Association Website: http://energystorage.org/

5. National Renewable Energy Laboratory Website: http://www.nrel.gov/learning/re_solar.html

6. Users Manual for TMY3 Data Sets, S. Wilcox and W. Marion