System Advisor Model (SAM) – SimpliPhi Power Battery Modeling Instructions

The following are recommended instructions for modeling SimpliPhi Power battery systems in NREL’s System Advisor Model (SAM).

Limitations:

1. Battery systems must be modeled coupled with solar PV generation; SAM does not allow for standalone battery systems at this time
2. SAM only allows for distributed generation (grid-tied) systems to be modeled; it does not allow for off-grid, microgrid, or backup power systems at this time
3. SAM does not automatically determine the optimum battery system size and configuration for an application. The user would need to determine this based on the customer load, utility rates, solar PV generation, and other sizing and economic constraints. It is recommended to perform iterations within SAM to find optimal battery system sizing for the intended application that can include a parametric analysis (see Parametric Simulations in SAM help section).

Assumptions:

1. High granularity electricity consumption (load) data at 15-minute intervals or less should be used to model charging and discharging of battery systems
2. Solar PV system is adequately sized and designed according to the electricity load and site conditions
3. Input instructions were based on modeling one PHI 3.5 kWh / 48V battery system with external hybrid solar inverter. If scaling up on number of batteries for your modeled system, then use the appropriate multipliers for applicable input values
   ➔ Note: when scaling up the number of batteries, always ensure that the C/2 charge rate and parallel wiring connections (i.e., constant voltage, additive current) are maintained
4. The PHI 3.5 battery system can be operated in DC-coupled or AC-coupled configuration. The instructions shown in this guide are for an AC-coupled system
   ➔ Note that only minor input changes are needed to switch to a DC-coupled configuration – see section 7 below
**Instructions:**

1. **Navigate to the Battery Storage tab:**

   ![Battery Storage Tab](image1)

2. **From the pick-list in the top-left corner, select ‘Enable battery’:**

   ![Enable Battery](image2)

3. **In the Chemistry section, from the Battery type pick-list, select ‘Lithium Ion: Lithium Iron Phosphate (LFP)’:**

   ![Battery Type Select](image3)
4. Enter the Battery Bank Sizing values. It is recommended to use the ‘Set desired bank size’ function instead of ‘Specify cells’. For example, one PHI 3.5 battery operating at its prescribed C/2 charge rate and DC ratings would have the following inputs:

![Battery Bank Sizing](image)

5. Enter the following (DC) Voltage Properties values for the PHI 3.5 battery. It is recommended to select the ‘Use voltage model’ function instead of ‘Use input voltage table’ for curve specifications:

![Voltage Properties](image)

6. Enter the following value for ‘Cell capacity’ in the Current and Capacity section. The Computed Properties will automatically update based on this input:

![Current and Capacity](image)

7. Enter the power conversion efficiencies into the Power Converters section. Note that these are the power conversion efficiency parameters of the charge controllers and accommodating battery management systems (BMS), not the inverter efficiencies. Inverter efficiencies are handled in the Inverter page of SAM, as applied to the solar PV system.
For DC-coupled systems, select the ‘DC Connected’ option and enter the ‘DC to DC conversion efficiency’ of the charge controller/BMS to be used. Note that SAM assumes that DC-coupled systems include a DC power optimizer (e.g., solar MPPT) and accounts for its electrical losses using a loss percentage on the Losses page.

For AC-coupled systems, select the ‘AC Connected’ option and enter the two power conversion efficiency values of the charge controller/BMS to be used.

For example, using an Outback Radian GS8048A inverter (with a CEC weighted efficiency of 92.5% input into the Inverter page) along with a FLEXmax 80 charge controller in an AC-connected system, the power conversion efficiencies would be entered as follows:

8. Enter any applicable loss values into the Ancillary Power Losses section. For the PHI 3.5 battery system there are negligible anticipated ancillary losses. Therefore, the default ‘Loss Input’ option will be selected with the input loss values left blank (i.e., in the defaulted “Edit values…” mode):

9. Select the Storage Dispatch Controller mode best suited for your application. Consult the SAM Battery Storage help section for an overview of each available option. For this example, a residential system in California, offsetting the high electricity rates during on-peak times is the desired application. Therefore, the ‘Manual dispatch’ mode option was selected, along with ‘PV
meets load before charging battery’ sub-option. Note that the dispatch parameters will be entered in step #11 below.

![Diagram showing storage dispatch controller options]

10. Enter values into the Charge Limits & Priority section. For the PHI 3.5 battery, it is recommended to use a Minimum State of Charge of 20% and Maximum State of Charge of 100%, yielding a depth of discharge (DOD) of 80%. This offers the highest cycle life for the battery. Also, enter the following values for ‘Initial state of charge’ and ‘Minimum time at charge rate’:

![Table showing charge limits & priority]

11. If Manual Dispatch mode was selected in the Storage Dispatch Controller section (per step #9 above), then the Manual Dispatch Model section will illuminate and will require inputs to be entered to proceed. In this example, the on-peak time-of-use period is weekdays (all months) from 4-9PM and, as such, it is desired for the battery system to discharge during this time – as much as its capacity will allow.

Since all energy will be charged from the solar PV system to the battery, Period 1 will be selected as noted below with no associated Charge from Grid or Discharge values entered.

Period 2 will discharge the available battery system’s capacity. Note that a value of 20% of the battery’s available capacity is assigned (meaning 20% of the total 80% depth-of-discharge of the battery will be discharged for every hour during Period 2). This value was used in this example because it is desired to discharge the battery system evenly over each hour of the peak-time period. To calculate the discharge % capacity for your application, simply divide 100% by the number of hours in the discharge period (e.g., 100% ÷ 5 = 20%). Since no energy will be charged from the grid to the battery in this example, the Charge from Grid column will remain unchecked for all periods.

For this example, the battery system has been configured to be charged by the solar PV system as much as possible during anytime outside of 4-9PM on weekdays while discharging strictly during the 4-9PM on-peak timeframe, also on weekdays. Period 1 has time-grid values entered as “1” while Period 2 has time-grid values entered as “2”.
12. Enter the following values for Cycle Degradation in the Battery Lifetime section for the PHI 3.5 battery:

<table>
<thead>
<tr>
<th>Period</th>
<th>Charge from PV</th>
<th>Charge from grid</th>
<th>Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
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<td>Yes</td>
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<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

13. Select ‘None’ in the Calendar Degradation sub-section, since degradation is handled in the Cycle Degradation section above:
14. In the Battery Bank Replacement section, select the ‘Replace at specified schedule’ option and enter values for replacement cost and escalation above inflation. In this example, a value of $430/kWh was used for replacement cost assuming half the current MSRP for one PHI 3.5 battery ($860/kWh ÷ 2 = $430/kWh) after an allotted 10-year replacement time. A battery cost escalation above the inflation rate of 2% was also assumed. The actual scheduled replacement of the battery system is determined by SAM using the parameters from the Battery Lifetime and Custom Degradation sections above along with the model outputs calculated by SAM (i.e., number of cycles per year in combination with DOD and annual degradation). It is assumed that due to the 10-year PHI 3.5 lifetime that scheduled replacement will be in year 11 of the project life-cycle.

15. Enter the following values into the Thermal Behavior section. These will remain constant for all applications using the PHI 3.5 battery system:
16. To enter costs associated with the battery system, navigate to the System Costs tab:

17. Enter applicable values into the Direct Capital Costs section. This includes the Battery bank cost (in $/kWh dc) and Inverter cost along with balance of system equipment, installation labor, installer margin and overhead, and contingency costs. Note that aside from the battery bank, costs are lumped together with those of the solar PV system and, due to the nature of SAM’s input method, must be entered in a consolidated manner.

18. Enter applicable values into the Indirect Capital Costs section. Note that these costs are also lumped together with those of the solar PV system will vary amongst applications and system sizes.

19. Verify the Total installed cost is correct per the Total Installed Cost section. SAM automatically calculates this based on cost inputs entered. Also, enter applicable values into the Operation and Maintenance Costs section.
20. Save all the inputs from your SAM project, as entered into the Battery Storage and System Costs sections, either by navigating to File=>Save per below or by clicking Ctrl-S on your keyboard:

See below for further SAM resources
SAM Help Resources:

SAM provides a thorough user guide and help section with reference information pertaining to battery system modeling. To access the help section, follow these instructions:

1. Click ‘Help’ in the upper-right portion of the screen:

2. From the Help section, navigate to the Battery Storage section (defaulted if Help is accessed from Battery Storage section within SAM) and scroll down through the provided information for overview, definitions, and parameter options.

3. Numerous other guides and whitepapers describing SAM’s functionality in addition to webinars and training sessions are made available on the NREL SAM website: [here](#).