

Single-Phase Battery System: A Generic Example

Written for PSCAD v4.5 and V4.6

1. General Description of the Battery System

This document outlines the implementation of a single-phase Battery system in PSCAD. Figure 1 shows the Battery system on the main canvas of “BatteryModelSinglePhaseMay2017.pscx”. A general description of the system and the functionality of each module are given to explain how the system works and what functionality can be expected from this system.

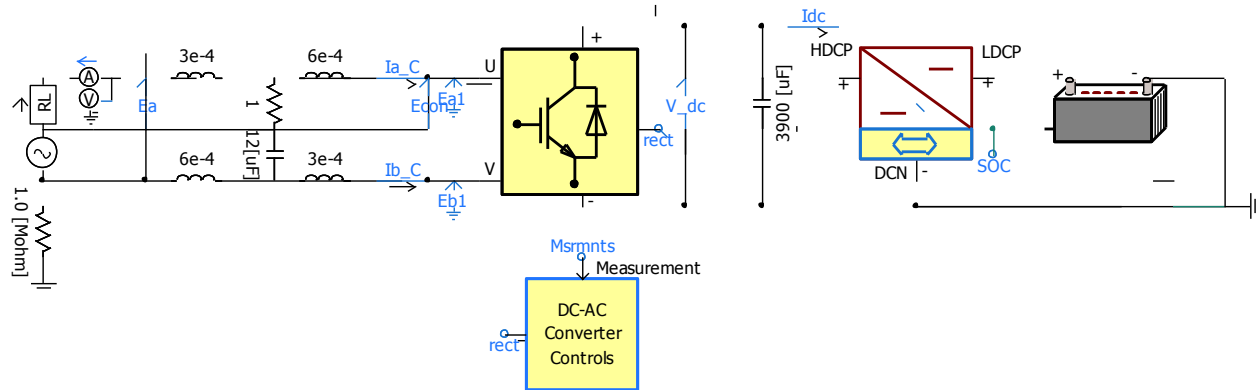


Figure 1: Overall battery system connected to a single-phase grid via DC-DC and DC-AC converters

The battery is connected to a DC-DC converter (Buck/Boost converter). The DC-DC converter operates as a Buck or Boost converter to charge or discharge the Battery. The DC-DC converter connects to the DC-AC converter via a DC Link system of 3900 micro F capacitors. The DC-AC converter controls the DC voltage (V_{dc}) on the DC Link.

Note

See Appendix A to set up the simulation correctly.

2. Battery

Figure 2 shows the battery model and its parameters. Double click on the Battery module shown as follows (it can be found in the main canvas) to see the circuit.

The DC voltage rating for the battery is defined as 200V. This model is based on a few simplifying assumptions and has some limitations [1].

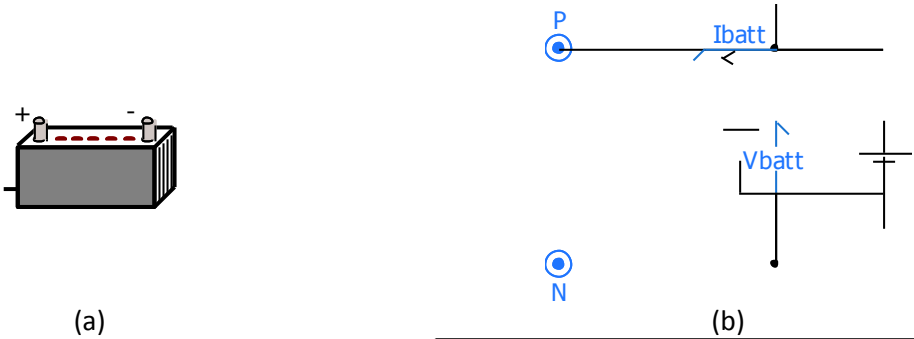
Assumptions:

- During the charge and discharge cycles, the internal resistance is assumed to be constant.
- The amplitude of the current does not have any effect on the internal resistance.
- The discharge characteristics curve of the battery is used to derive the battery parameters, since the discharge and charge characteristics are assumed to be the same.

- The amplitude of the current does not have any effect on the capacity of the battery (No Peukert effect).
- Temperature does not change the model's behavior.
- Self-discharge of the battery is not represented.
- Charge and discharge history does not affect battery characteristics (i.e. No hysteresis).

Limitations:

- The battery voltage cannot be negative and the maximum battery voltage is not limited.
- The capacity of the battery cannot be negative and the maximum capacity is not limited.



(c)

Configuration	
General	
Battery name	Bat1
Data entry	Shepherd model
Nominal voltage	0.2 [kV]
Rated capacity	0.000365 [kA*hr]
Loss of capacity at nominal cur	50 [%]
Initial state of charge	100 [%]
Outputs	
State of Charge [%]	SOC

(d)

Shepherd Model	
General	
Nominal Capacity	0.95 [pu]
ResistiveDrop	0.001 [pu]
Voltage at Exponential Point	1.03 [pu]
Capacity at Exponential Point	0.4 [pu]
Fully Charged Voltage	1.15 [pu]

Figure 2: Battery modeled and parameters

3. Buck/Boost Converter

The Buck/Boost converter is shown in Figure 3. It is connected to the battery (Low voltage: 200V) on the right side and connects to DC link system on the left side (High voltage: 250V).

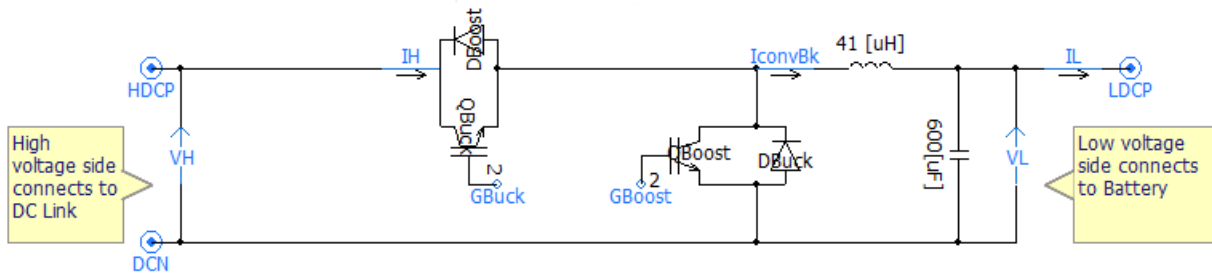


Figure 3: Buck/Boost converter

3.1 Upper level control system and ratings

The upper level control system is shown in Figure 4. This control system is manual and also achievable in the “Graphs_and_Controls” module.

The control panel “Charger On/Off” is to enable/disable the Buck/Boost converter manually. This controller can also be provided automatically based on an over-voltage or an over-current protection system.

The other controller is “Mode” which controls the mode of operation for the converter. In other words using this control the battery can be charged or discharged. This controller is also manual. However it can be programmed automatically based on a power management system.

The SOCpermit is a signal that does not permit charging or discharging when SOC is above 100% or less than 5% respectively.

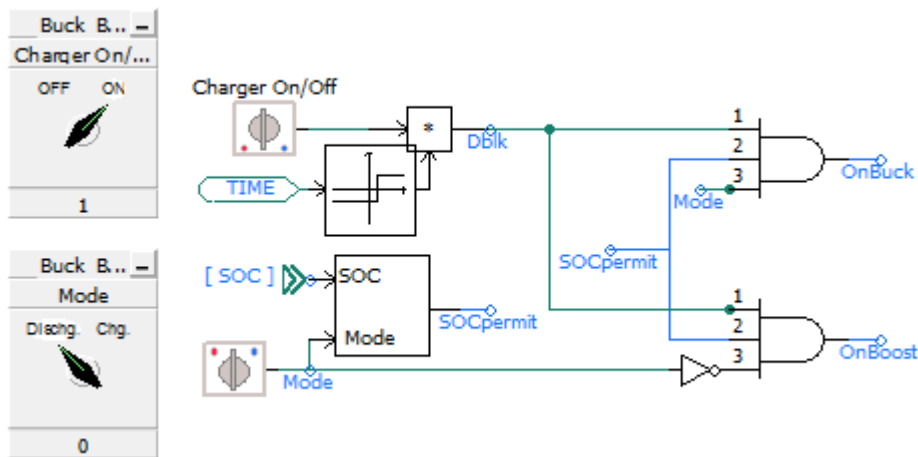


Figure 4: Upper level controllers

The reference voltage can be selected for the converter using the slider shown in Figure 5. This value is selected based on the ratings of the battery which is 200V.

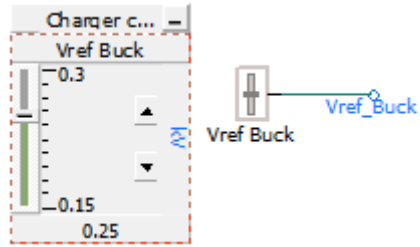


Figure 5: Variable input slider showing the reference voltage

To protect the converter and the battery from over-currents maximum charging and discharging allowable currents are selected and shown in Figure 6. For example, these values may be calculated or obtained from the datasheet of the semiconductor switches.

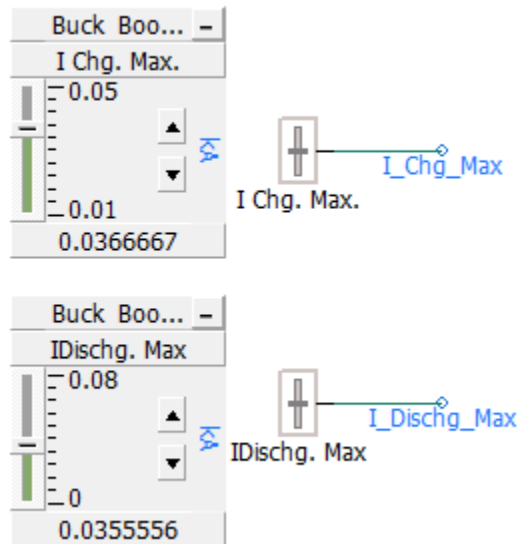


Figure 6: Variable input slider showing the maximum allowable currents for the converter during charging and discharging mode

3.2 Lower level controllers

When the converter operates at charging mode, the Buck converter is enabled (see Figure 4). The Buck controller is shown in Figure 7 where the reference voltage is compared against the low voltage side voltage (VL). The error signal applies to a PI controller with KpBuck and TiBuck coefficients.

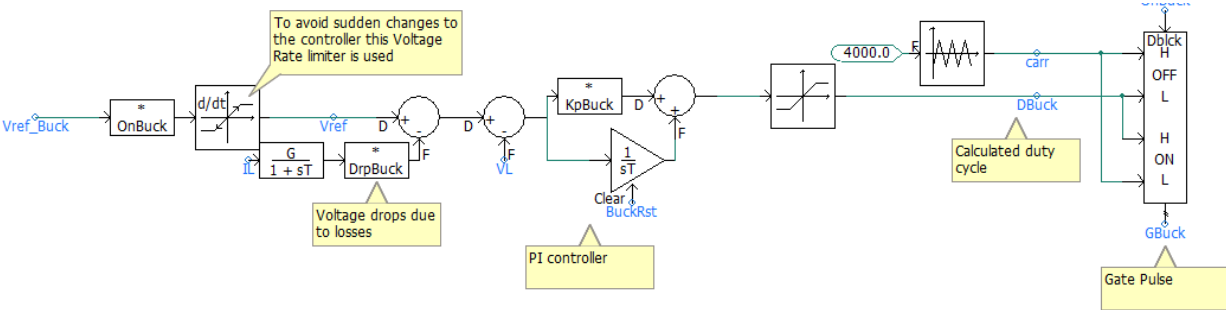


Figure 7: The charger controller for Buck converter

To protect the Buck converter and Battery against high currents the duty cycle of the converter is limited based on a function of the maximum allowable current (I_chg_Max) as shown in Figure 8.

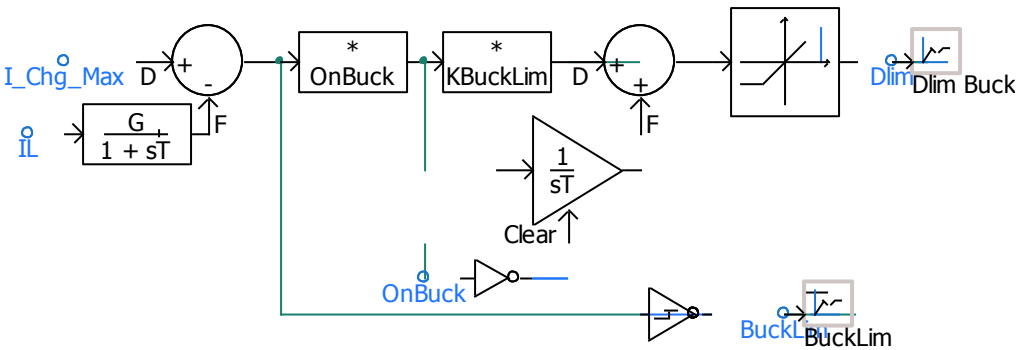


Figure 8: Overcurrent protection to limit the duty cycle of the Buck converter during charging

When the converter operates at discharging mode, the Boost converter is enabled (see Figure 4). The Boost controller is shown in Figure 9 where the reference voltage is compared against the low voltage side voltage (VL). The error signal applies to a PI controller with KpBoost and TiBoost coefficients.

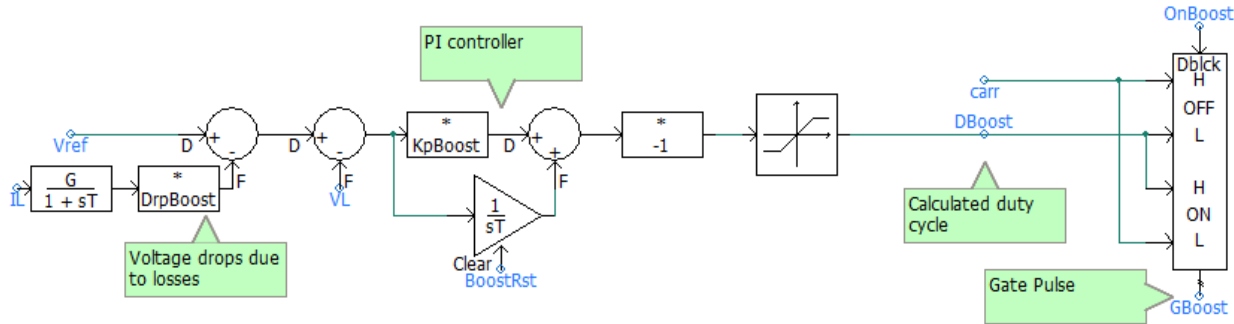


Figure 9: The discharger controller for Boost converter

To protect the Boost converter and Battery against high currents the duty cycle of the converter is limited based on a function of the maximum allowable current (I_{dischg_Max}) as shown in Figure 10.

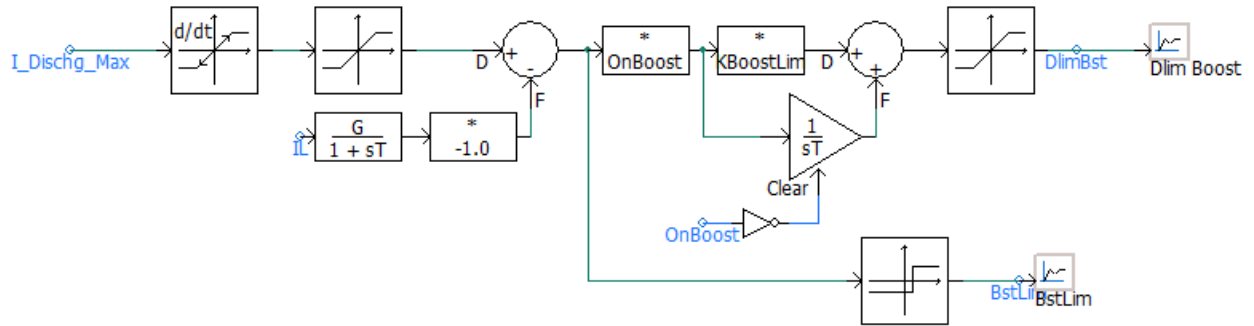


Figure 10: Overcurrent protection to limit the duty cycle of the Boost converter during discharging

4. DC-AC converter

The DC-AC converter is shown in Figure 11. It is connected to the AC system on the nodes “U” and “V”. And connects to DC link system (High voltage: 250V) on the nodes “DC_P” and “DC_N”.

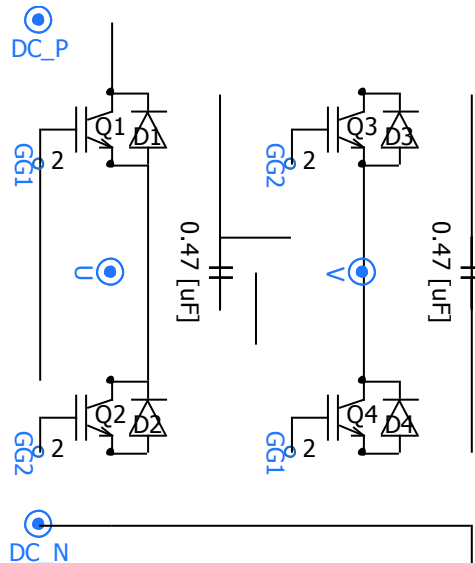


Figure 11: DC-AC converter

The controllers of the DC-AC converter are provided in a separate module shown in Figure 12.

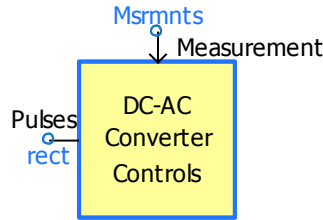


Figure 12: DC-AC converter controllers

4.1 Upper level control system and rating

The upper level control system is shown in Figure 13. This control system is manual and also achievable in the “Graphs_and_Controls” module.

The “DC-AC Conv” is to enable/disable the DC-AC converter manually. This controller can also be provided automatically based on an over-voltage or an over-current protection system. The converter starts to operate after 0.5 sec to ensure that the AC grid system reaches its steady state condition.

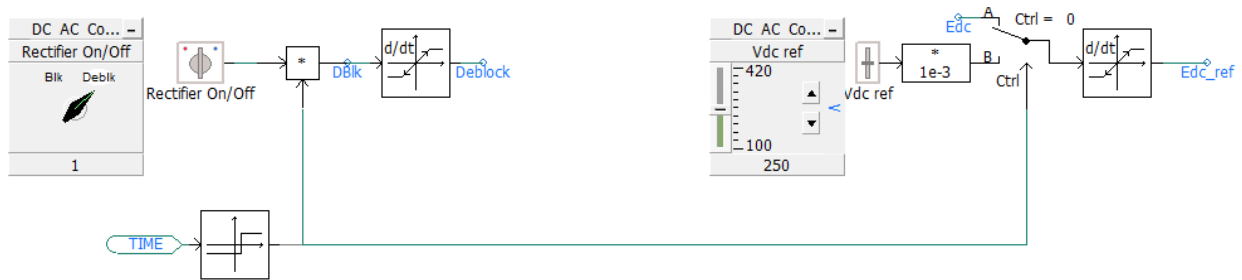


Figure 13: DC-AC converter upper level controller and variable input slider showing the reference voltage

The reference voltage can be selected for the converter using the slider shown in Figure 13. This value is selected based on the rated voltage of DC link which is 250V.

4.2 Lower level controllers

The DC voltage and the AC voltage are controlled using PI controllers. When the converter operates at charging mode, the Buck converter is enabled (see Figure 14).

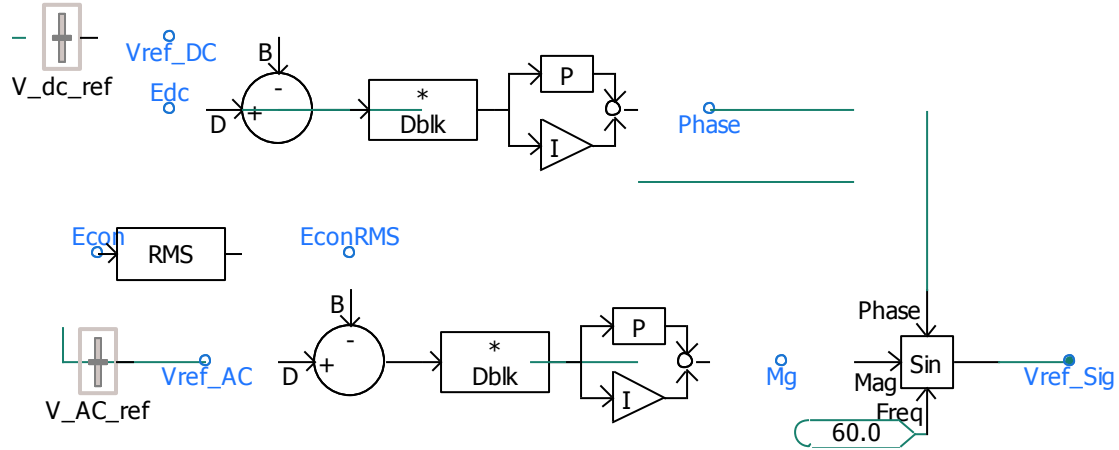


Figure 14: DC voltage and AC voltage controllers

5. Simulation results

5.1 Simulation results for discharging mode

The battery is at 100 percent state of charge (SOC) at the beginning. The dynamic of the system for discharging mode of operation is shown in Figure 15. The State of charge (SOC) slowly reduces to 5 % when the SOCprmit block the controllers and shut down the converter. The current increases while the voltage decreases during the discharge process. Please note that the discharging process is exaggerated to shorten the simulation time. Otherwise it may take hours to discharge a battery fully.

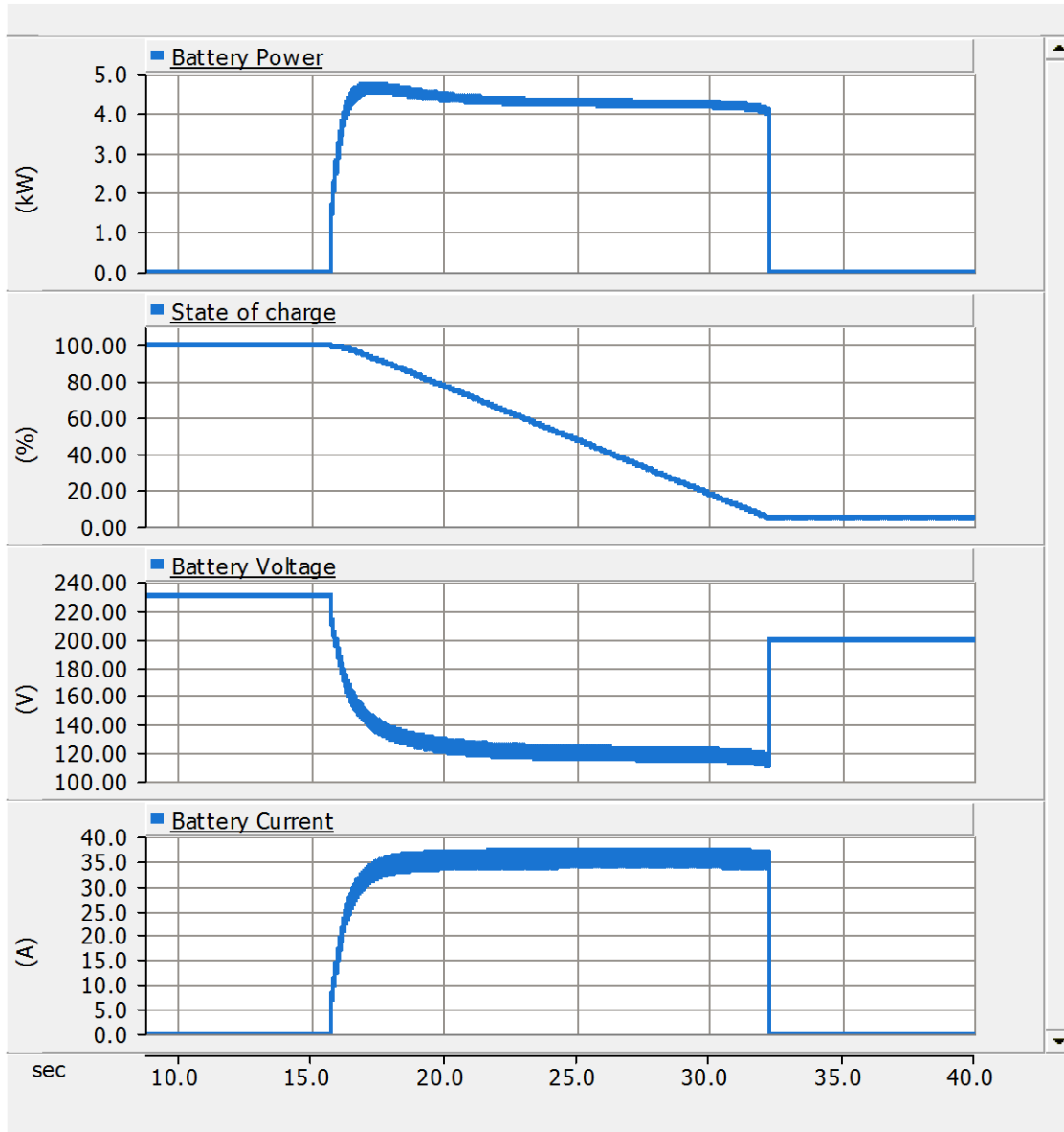


Figure 15: Discharging mode of operation and simulation results

5.2 Simulation results for charging mode

The dynamic of the system for charging mode of operation is shown in Figure 16. SOC increases until it reached 100% and the SOCpermit block the converter to stop it from charging more.

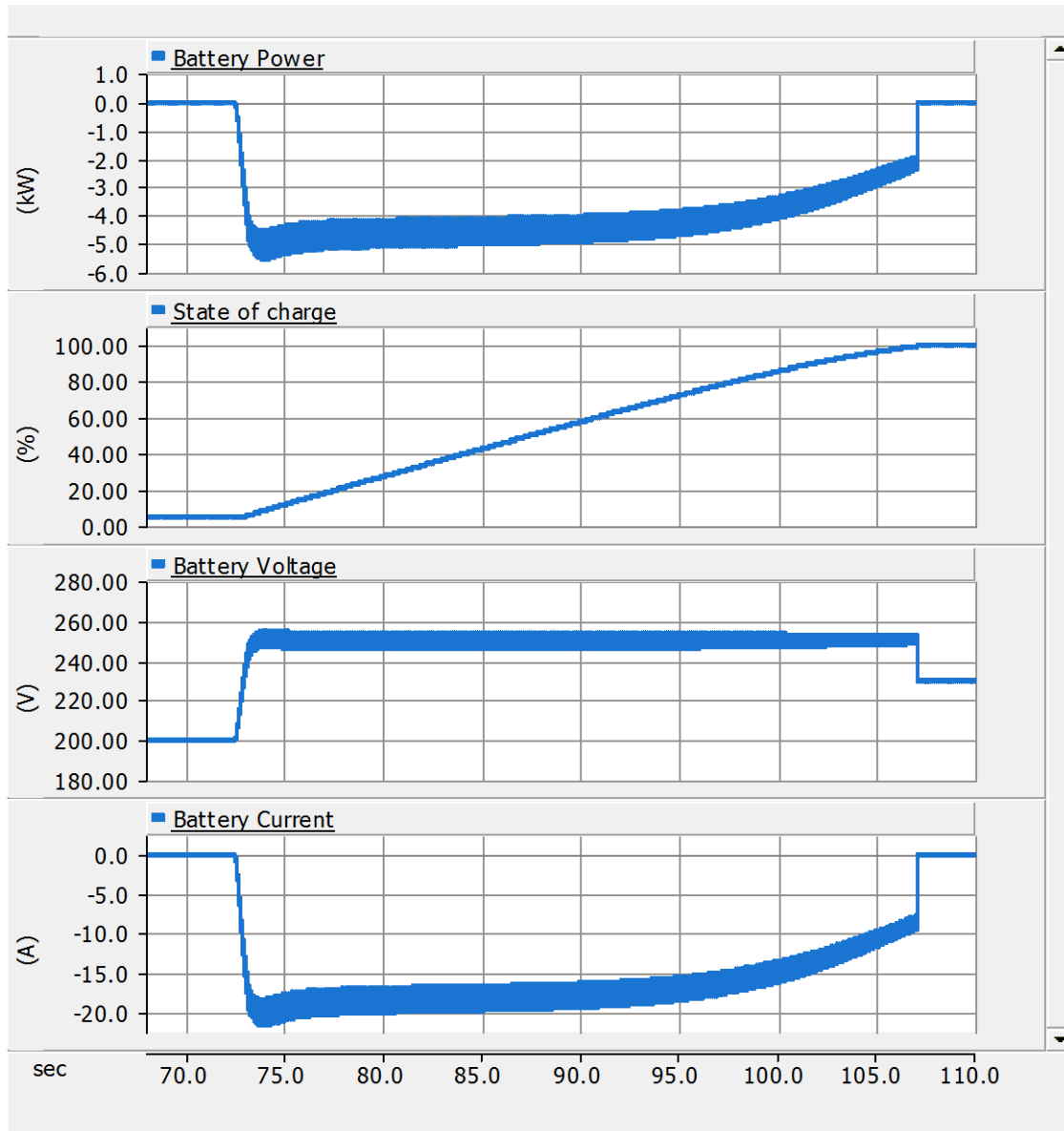


Figure 16: Charging mode of operation and simulation results



6. Reference

- [1] Tremblay, O., Dessaint, L.-A., Dekkiche, A.-I., A Generic Battery Model for the Dynamic Simulation of Hybrid Electric Vehicles, Vehicle Power and Propulsion Conference, 2007, VPPC 2007, IEEE vol., no., pp.284-289, 9-12 Sept., 2007.

Appendix: How to set up the simulation

Please load the library (Battery_Model_v2.pslx) in to PSCAD and link the library to one of the .lib file (Battery_Model_v2.lib they are in the zip file “ lib.zip ”). In each folder there is one .lib file which is compatible with associated compiler.

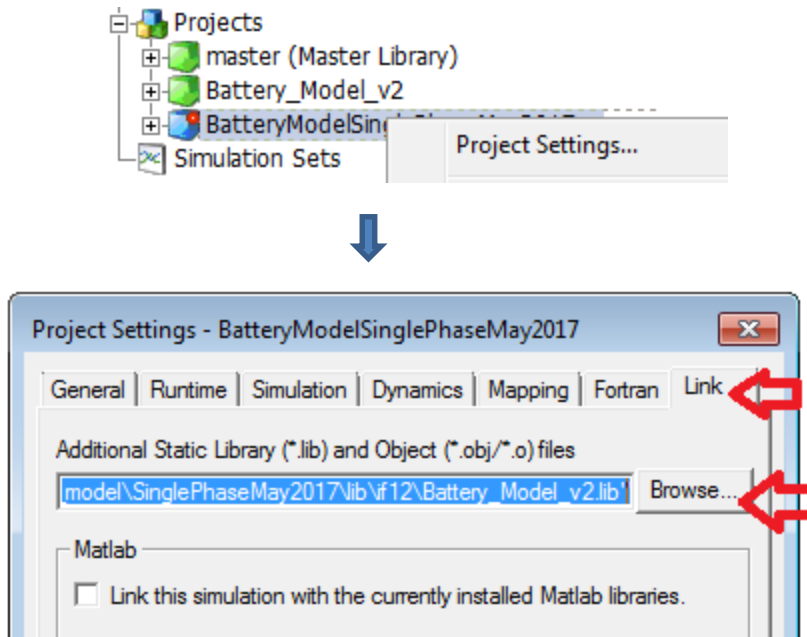
For example:

The .lib file in “ if15 ” is compatible with Intel-Fortran Version 15 compiler

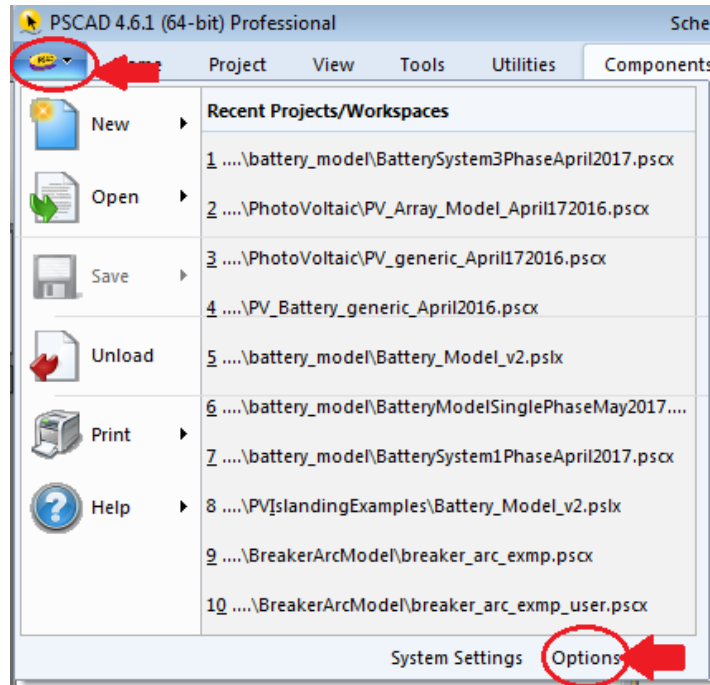
Or

The .lib file in “ gf42 ” is compatible with GFortran version 4.2 compiler

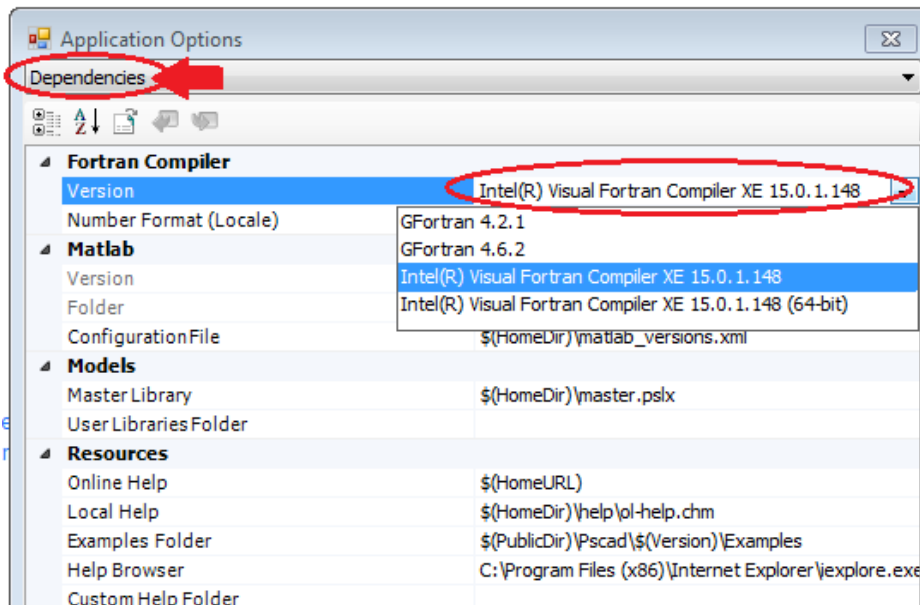
To link to the library a right-click on the Library title in the workspace window, and selecting Project Settings from the pop-up menu. The following figure shows the procedure.



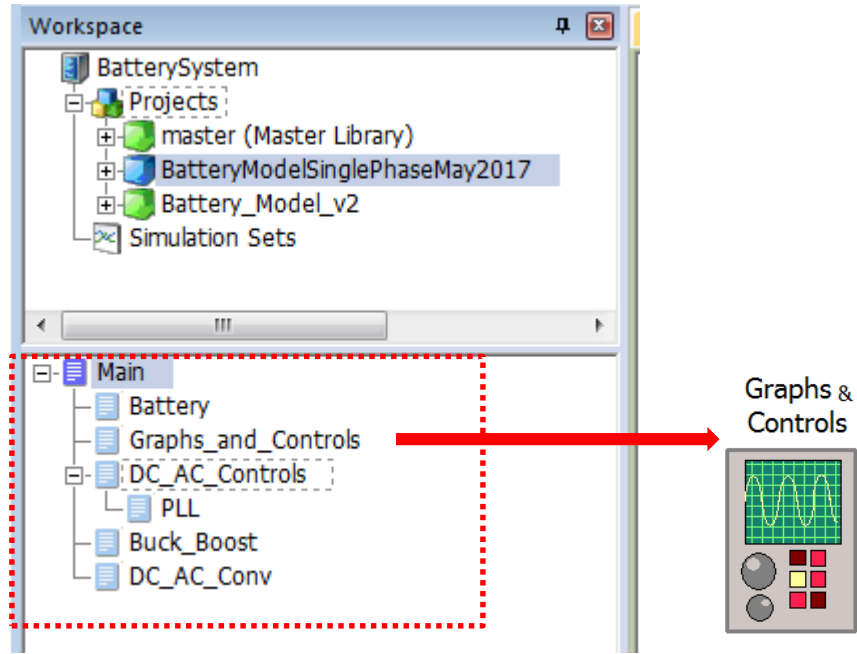
The following procedure shows how to determine the compiler for PSCAD.



Click on the “Option” a new window opens as follows: the “Dependencies” shows which compilers are installed.



Also the project three shows the sub-modules in the simulation. Click on the modules to navigate between them. For example to see the graphs and to controls click on the “Graphs_and_Controls” module or double click on the module shown as follows (it can be found in the main canvas).



Also the signals in the canvas can be traced using “virtual wires” option shown as follows. The simulation must be compiled to activate “virtual wires”.

