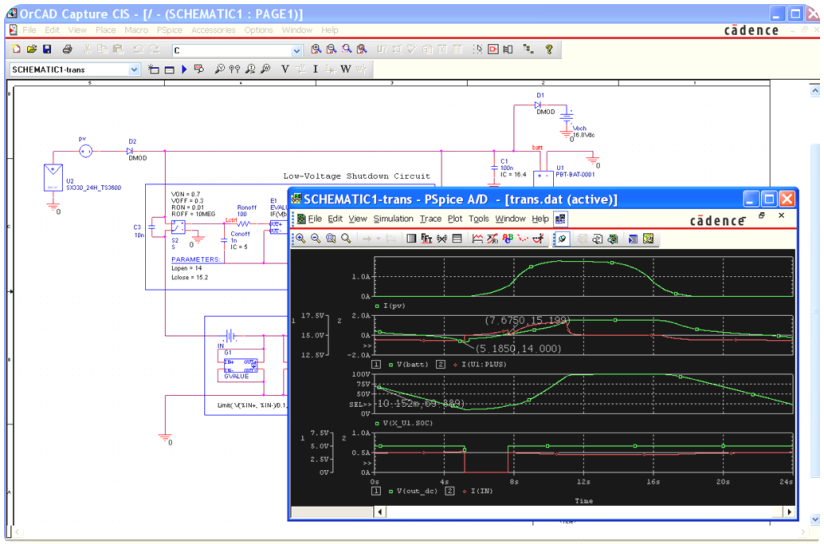


Design Kit

PV Lead-Acid Battery System (DC Out)

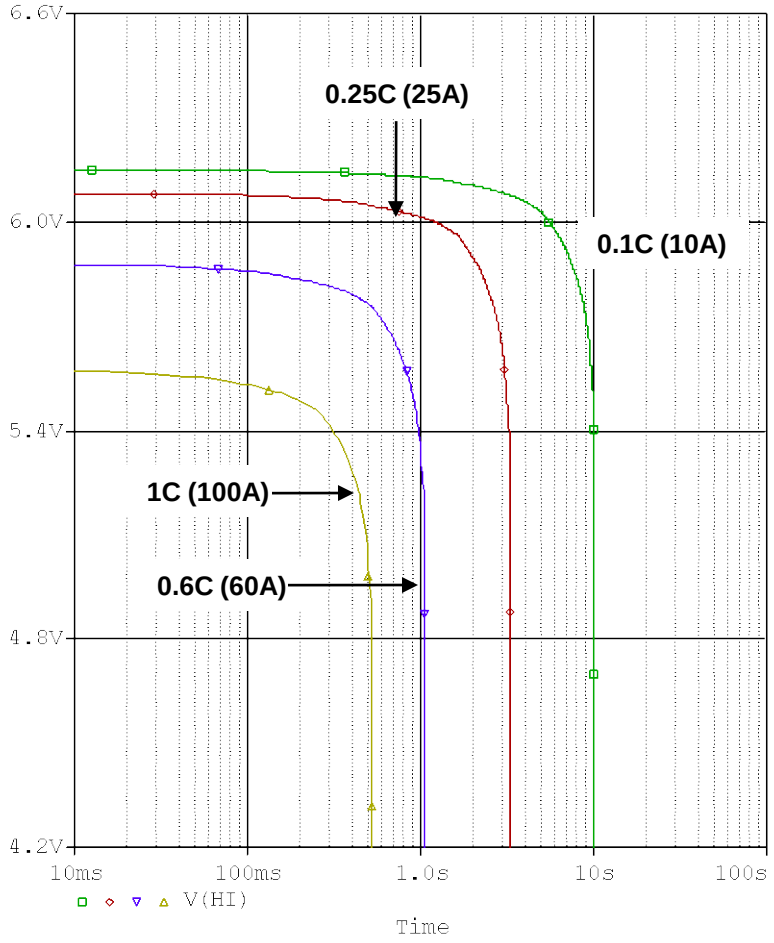
Contents

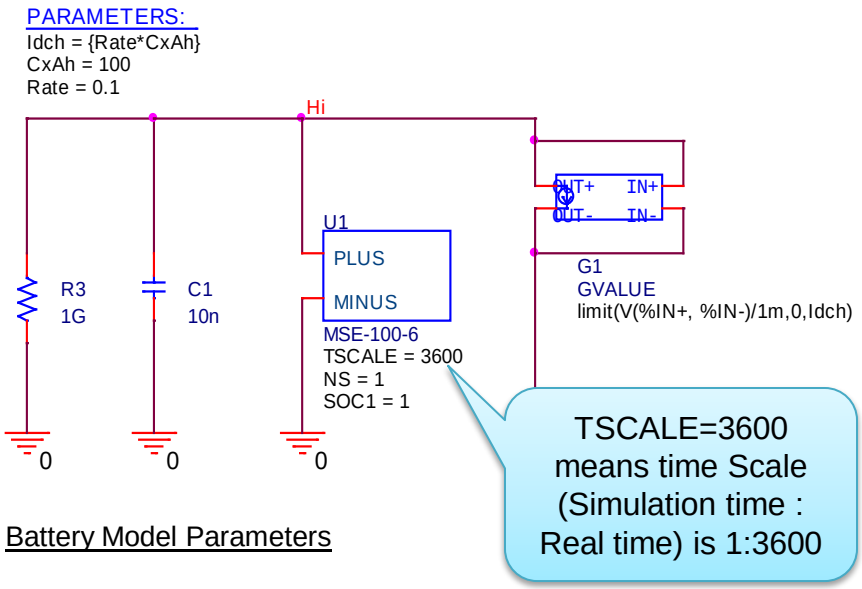
1.1 Lead-Acid battery Specification

GS YUASA's Lead-Acid : MSE-100-6

- Nominal Voltage..... 6.0 [Vdc]
- Capacity..... 100[Ah]@C_{10}, 65[Ah]@C_1
- Rated Charge..... $0.1C_{10}A$
- Input Voltage..... 6.69 [Vdc]
- Charging time..... 24 [hours] @$0.1C_{10}A$

1.2 Discharge Time Characteristics



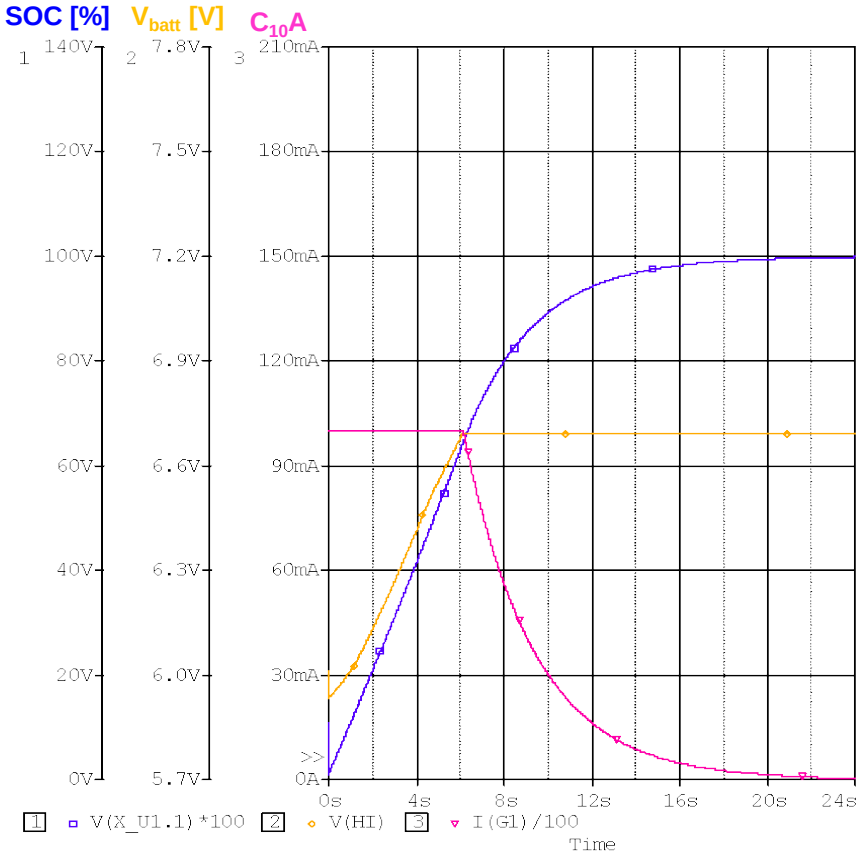


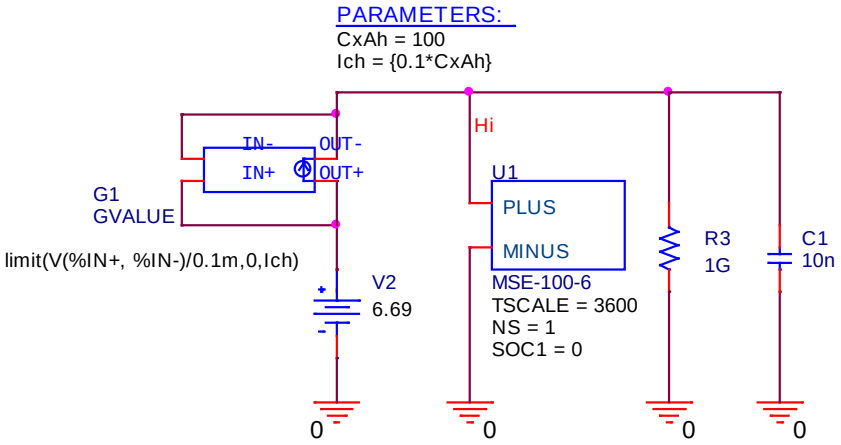
Battery Model Parameters

NS (number of batteries in unit) = 1 cell
C (capacity) = 100[Ah]@C_{10}
SOC1 (initial state of charge) = “1” (100%)
TSCALE (time scale) , simulation : real time
1 : 3600s or
1s : 1h

Discharge Rate : 0.1C(10A), 0.25C(25A) , 0.6C(60A), and 1C(100A)

1.3 Charge Time Characteristics





Battery Model Parameters

NS (number of batteries in series) = 1 cell
C (capacity) = 100[Ah]@C_{10}
SOC1 (initial state of charge) = “1” (100%)
TSCALE (time scale) , simulation : real time
1 : 3600s or
1s : 1h

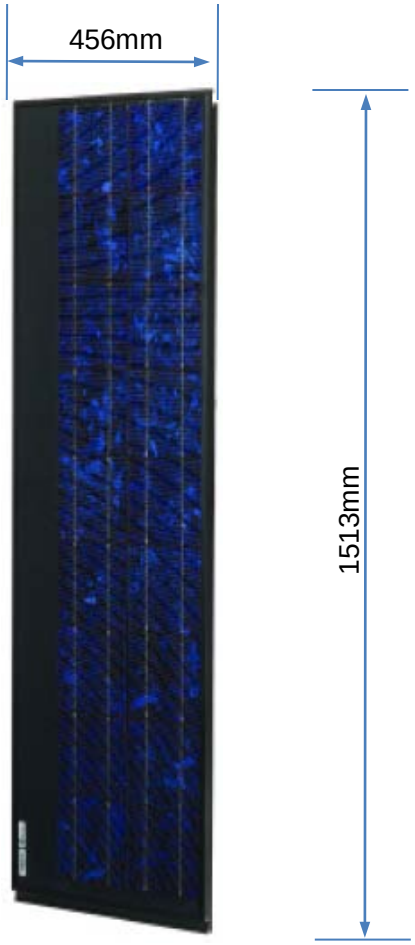
Charging Time

Input Voltage = 6.69 Vdc
Input Current = 10 A @0.1C_{10}

2.1 Solar Cells Specification

BP Solar's photovoltaic module : BP365TS

- Maximum power (P_{max}).....65[W]
- Voltage at Pmax (V_{mp}).....8.7[V]
- Current at Pmax (I_{mp}).....7.5[A]
- Short-circuit current (I_{sc}).....8.1[A]
- Open-circuit voltage(V_{oc}).....11.0[V]

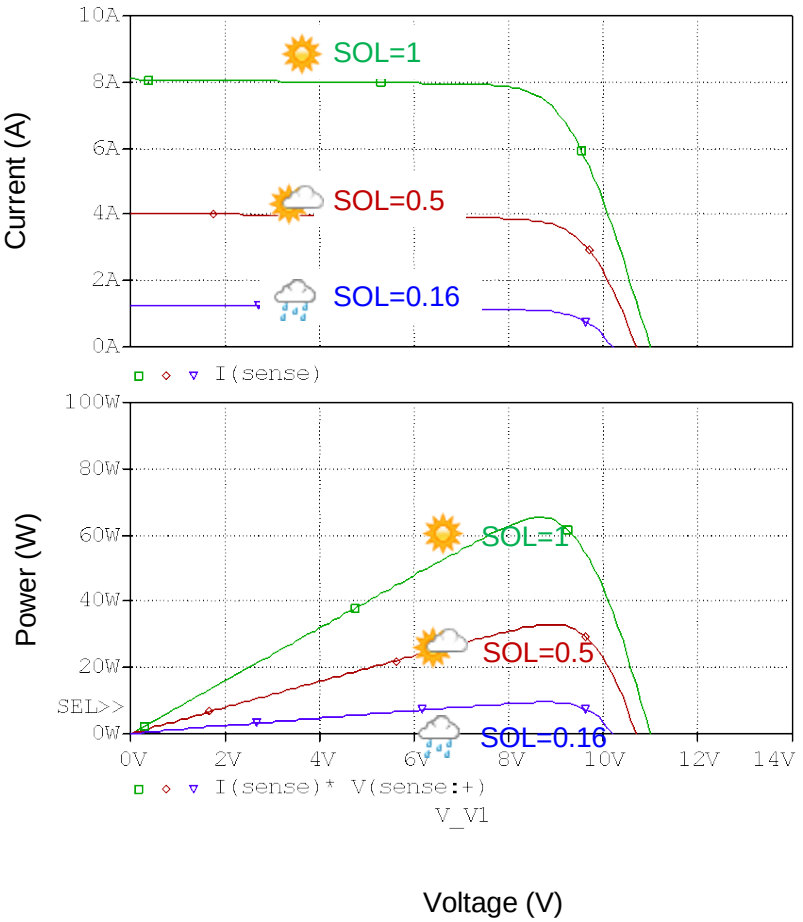


2.2 Output Characteristics vs. Incident Solar Radiation

U2
BP365TS
SOL = 1

Parameter, SOL is added as normalized incident radiation, where SOL=1 for AM1.5 conditions

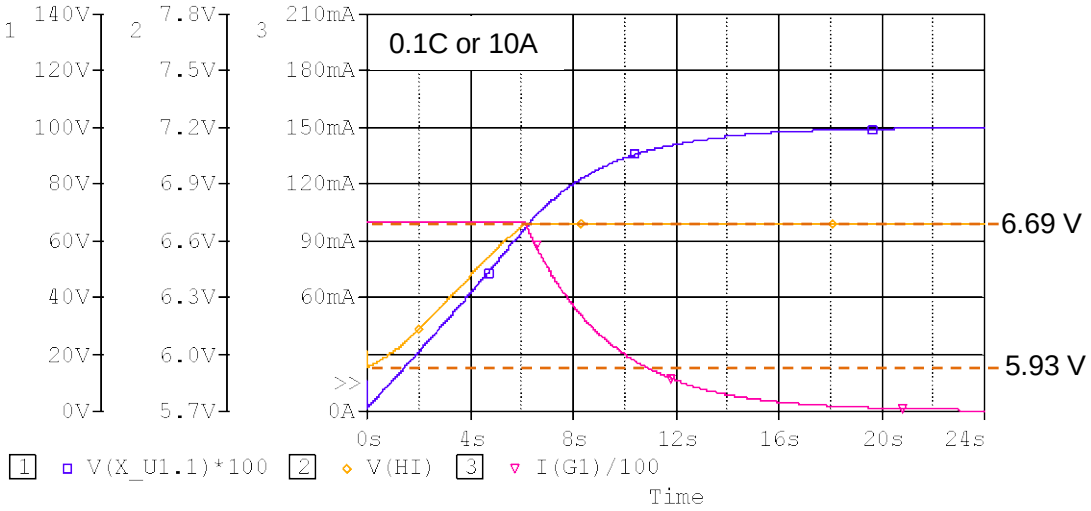
BP365TS Output Characteristics vs. Incident Solar Radiation



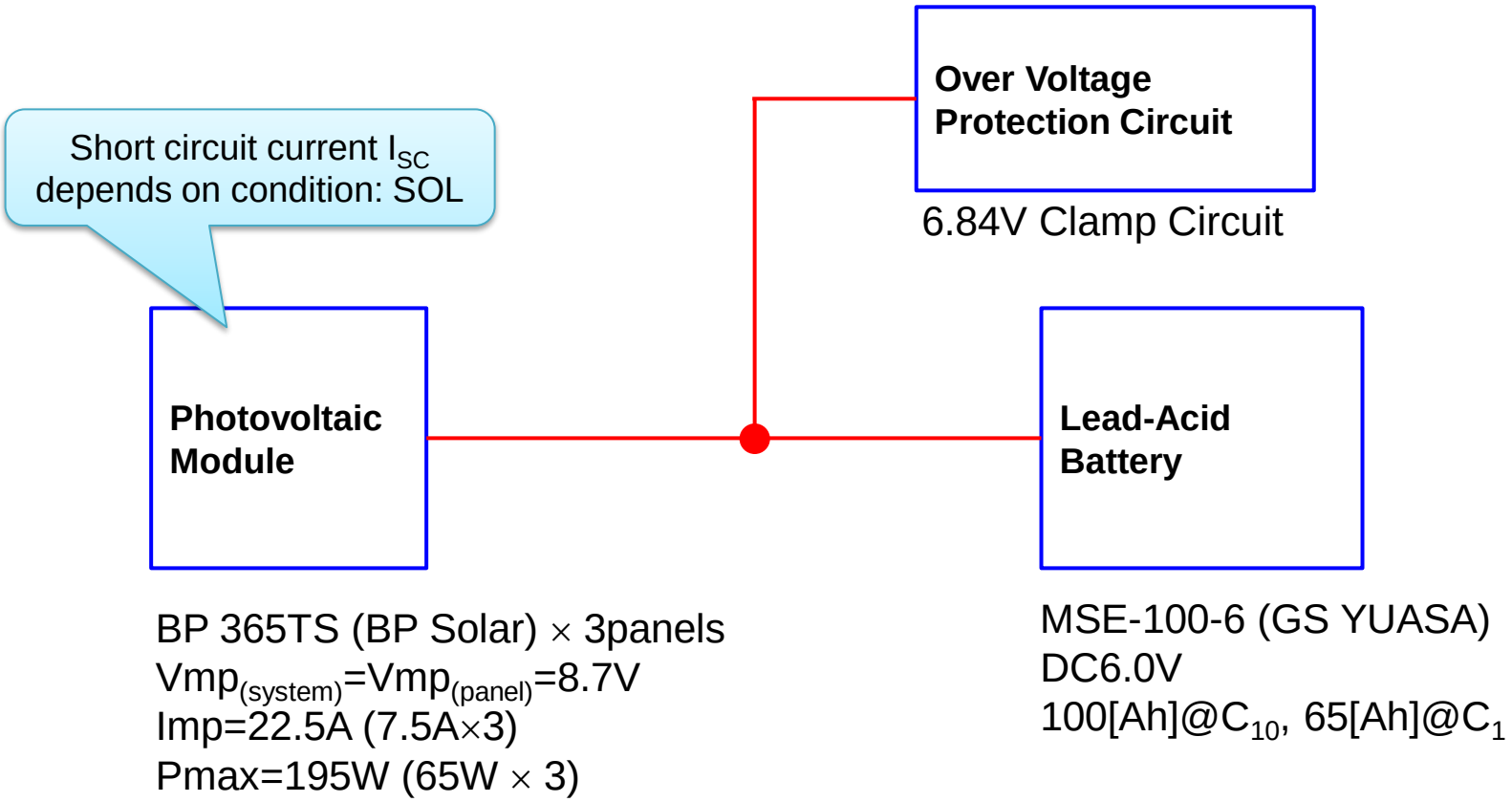
3. Solar Cell Battery Charger

- Solar Cell charges the Lead-Acid Battery (MSE-100-6) with direct connect technique. Choose the solar cell that is able to provide current at charging rate or more with the maximum power voltage (Vmp) nears the battery charging voltage.

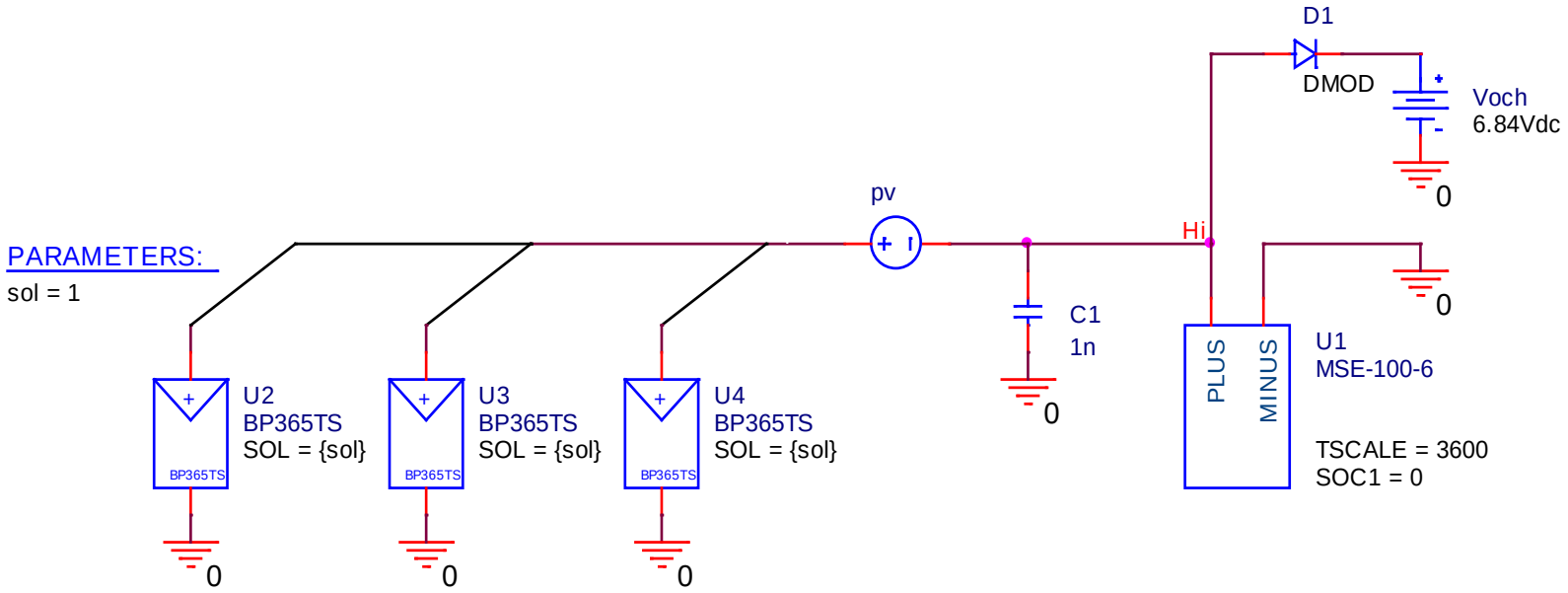
- <u>MSE-100-6</u>
  - Charging time is approximately 24 hours with charging rate 0.1C or 10A
  - Voltage during charging with 0.1C is between 5.93 to 6.69 V



3.1 Concept of Simulation PV Lead-Acid Battery Charger Circuit

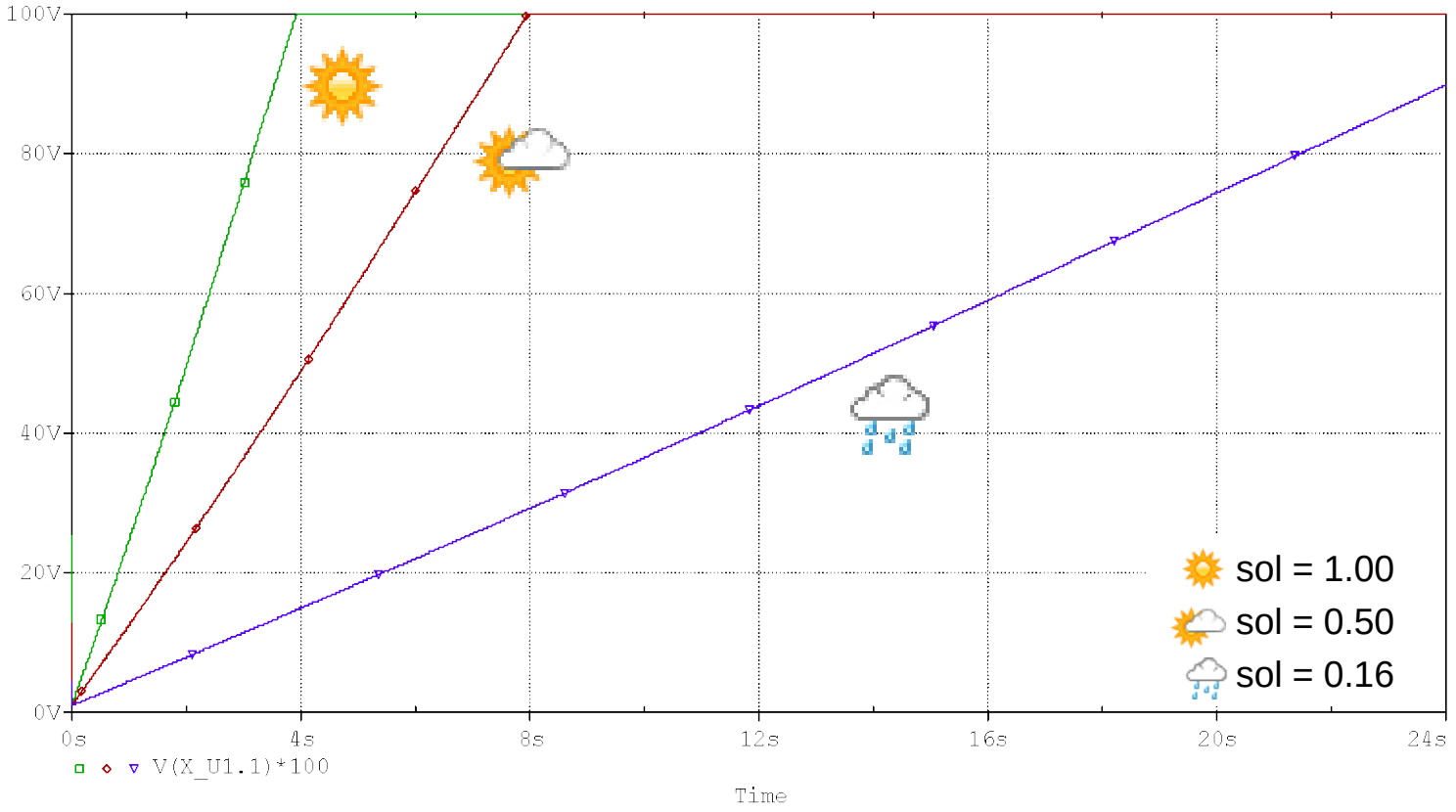


3.2 PV Lead-Acid Battery Charger Circuit



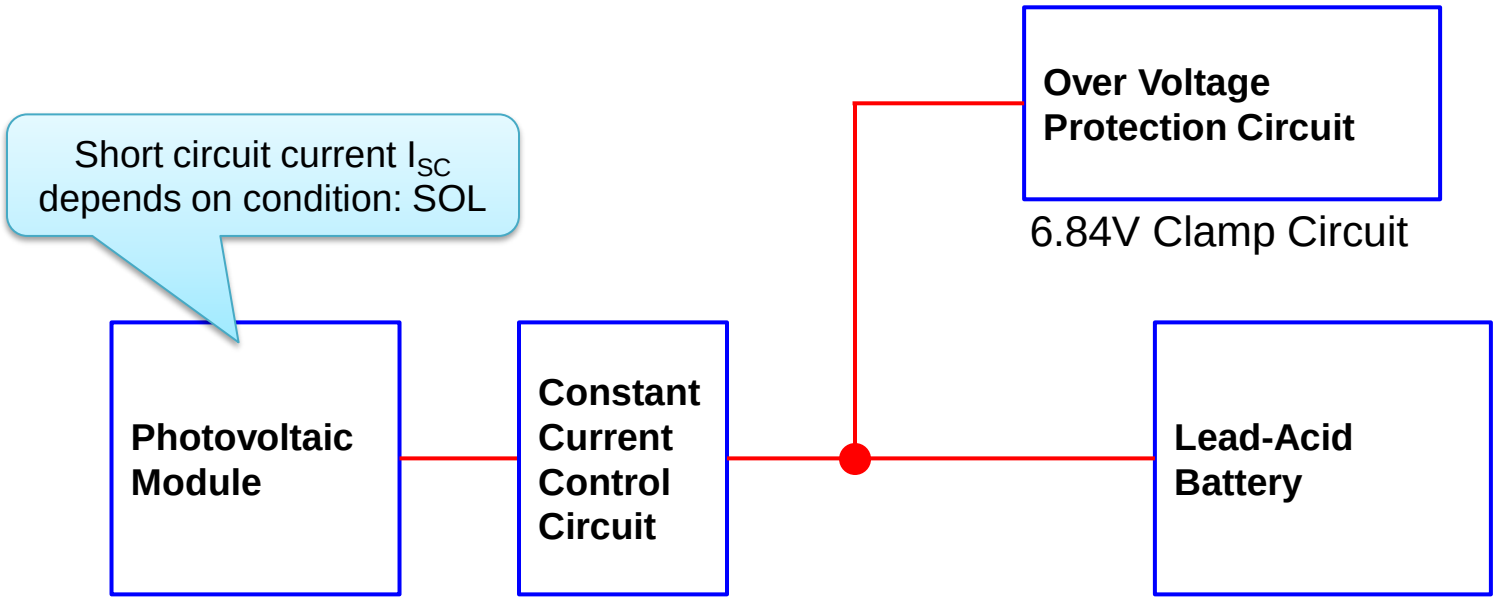
- Input value between 0-1 in the "PARAMETERS: sol = " to set the normalized incident radiation, where SOL=1 for AM1.5 conditions.

3.3 Charging Time Characteristics vs. Weather Condition



- Simulation result shows the charging time for sol = 1, 0.5, and 0.16.

3.4 Concept of Simulation PV Lead-Acid Battery Charger Circuit + Constant Current

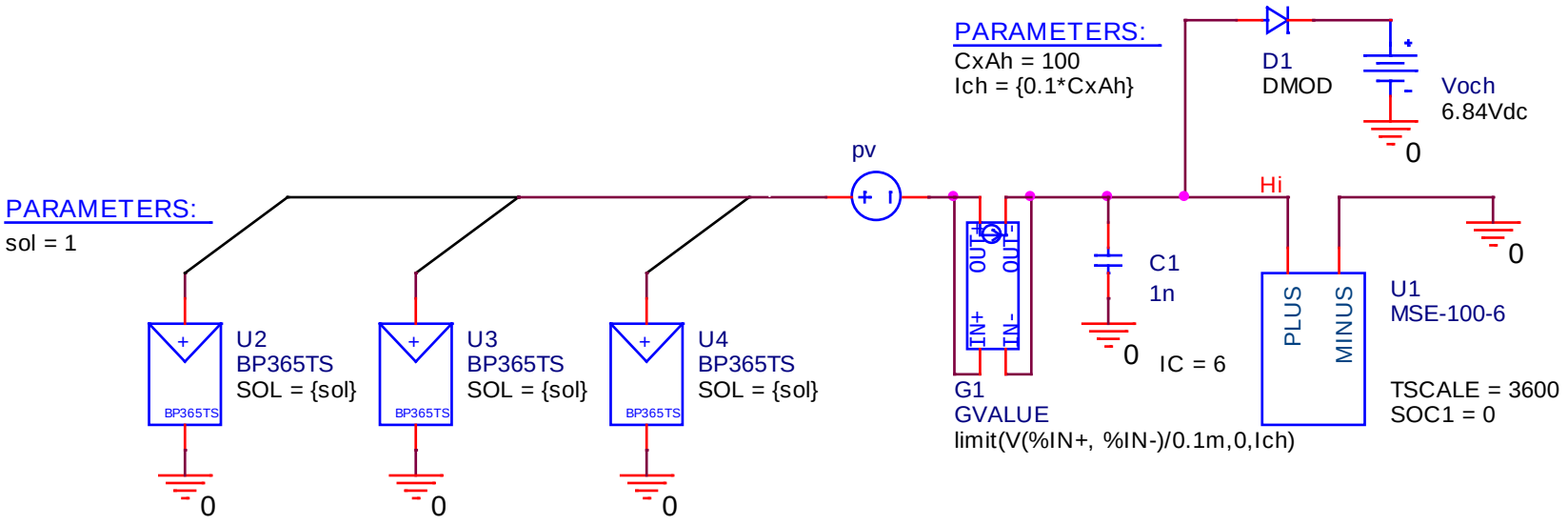


BP 365TS (BP Solar) × 3panels
$Vmp_{(system)}=Vmp_{(panel)}=8.7V$
Imp=22.5A (7.5A×3)
Pmax=195W (65W × 3)

I_{charge}=0.1C (10A)

MSE-100-6 (GS YUASA)
DC6.0V
100[Ah]@C_{10}, 65[Ah]@C_1

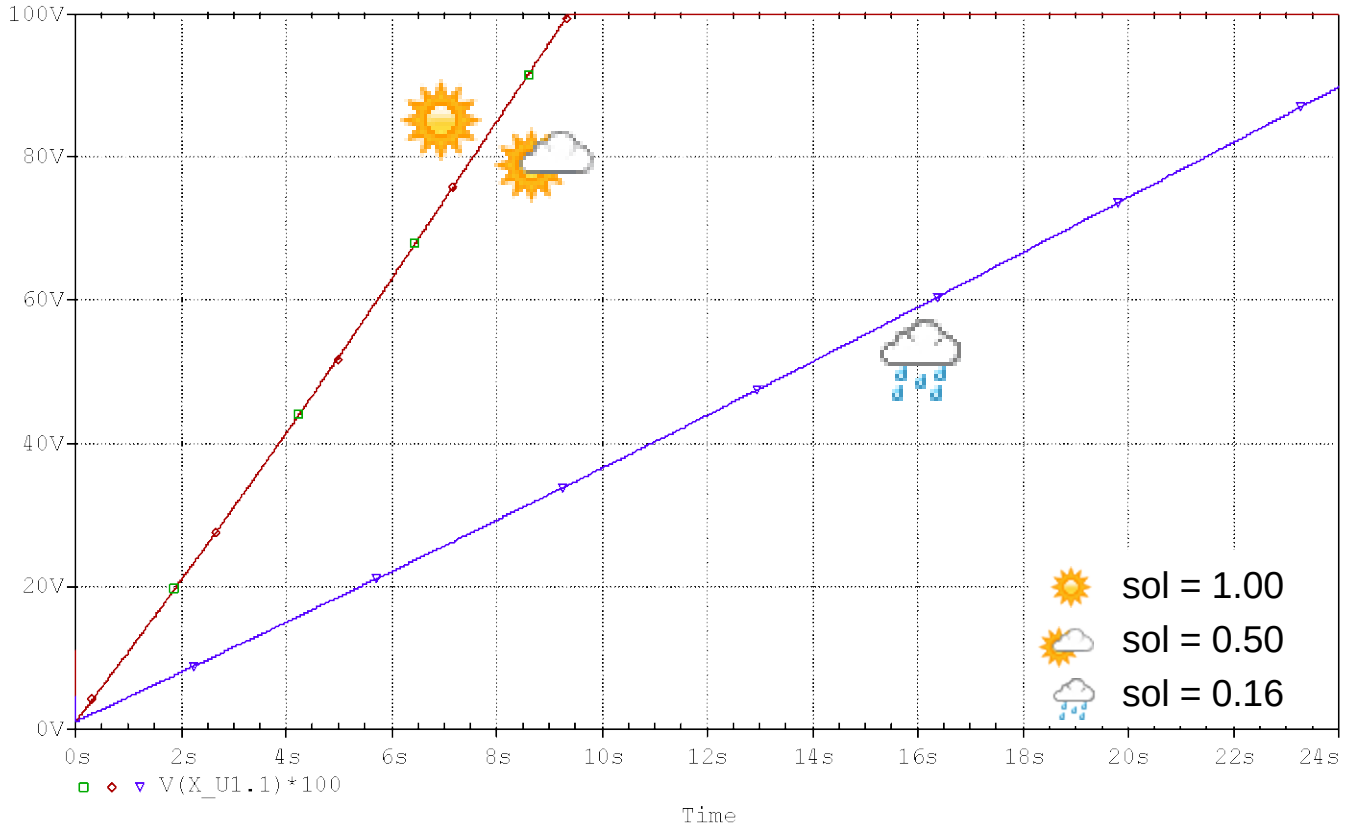
3.5 Constant Current PV Lead-Acid Battery Charger Circuit



$Vmp_{(system)}=Vmp_{(panel)}=8.7V$
Imp=22.5A
Pmax=195W

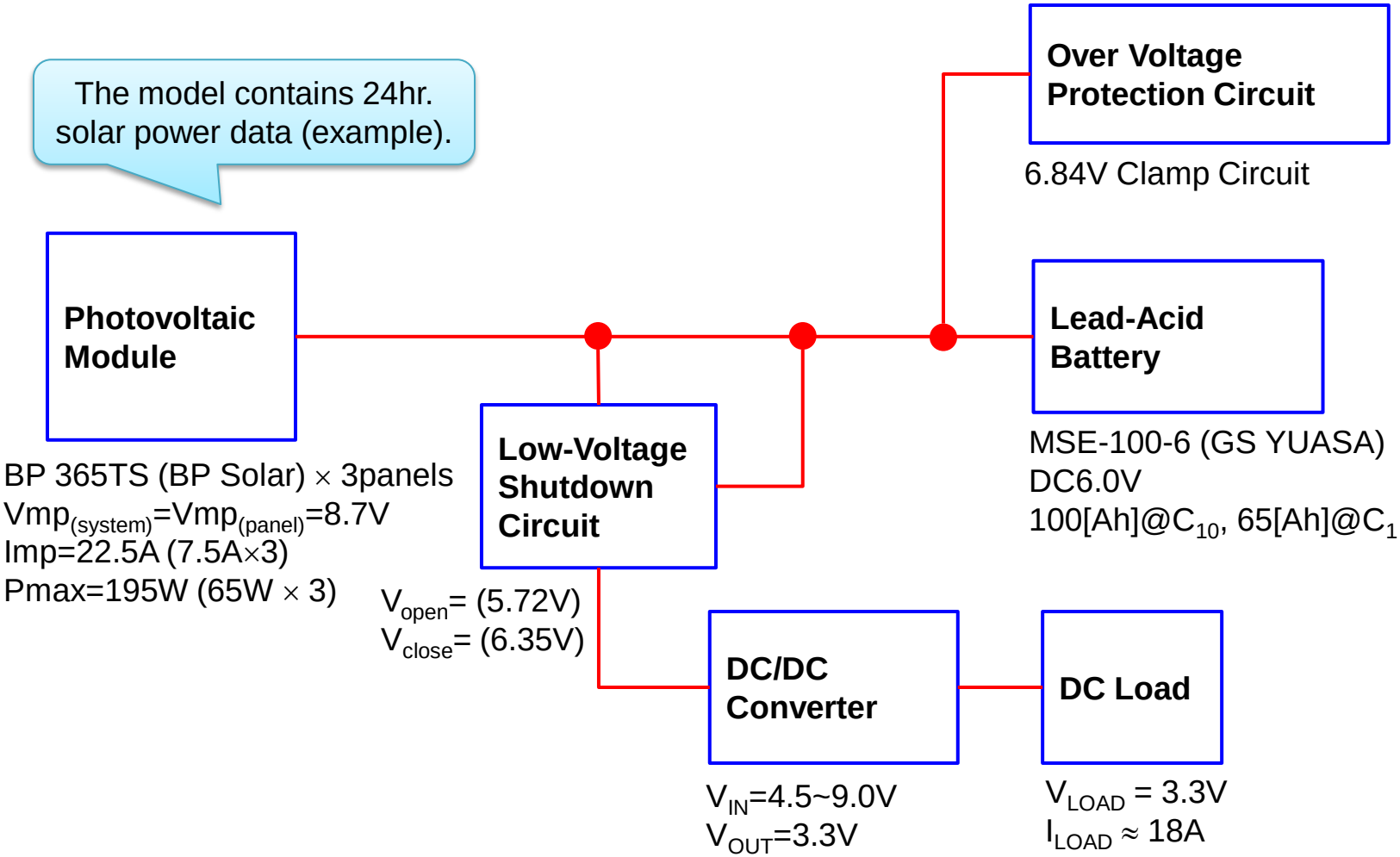
- Input the battery capacity (Ah) and charging current rate (e.g. 0.1*CxAh) in the
- "PARAMETERS: CxAh = 100 and rate = 0.1 " to set the charging current.

3.6 Charging Time Characteristics vs. Weather Condition (Constant Current)

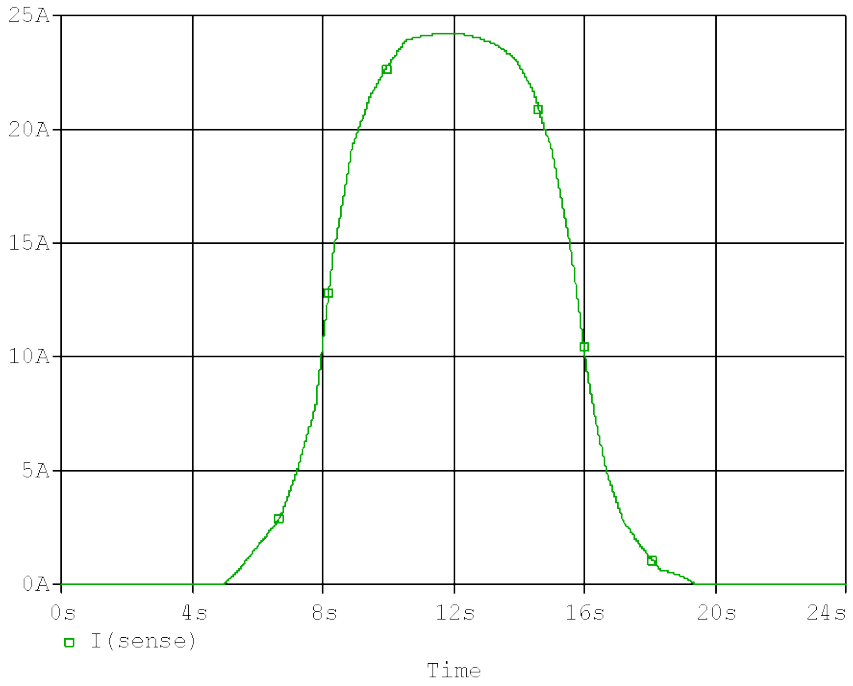


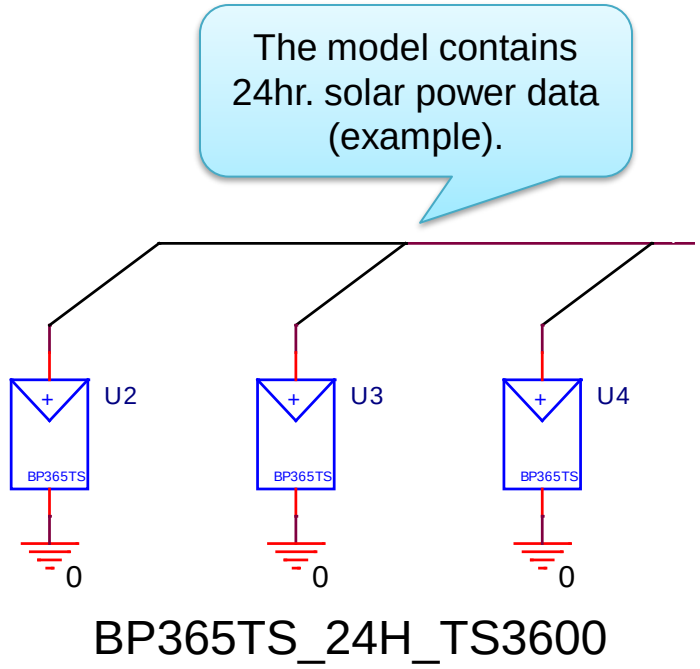
- Simulation result shows the charging time for sol = 1, 0.5, and 0.16. If PV can generate current more than the constant charge rate (0.1), battery can be fully charged in about 9.364 hour.

4.1 Concept of Simulation PV Lead-Acid Battery System in 24hr.



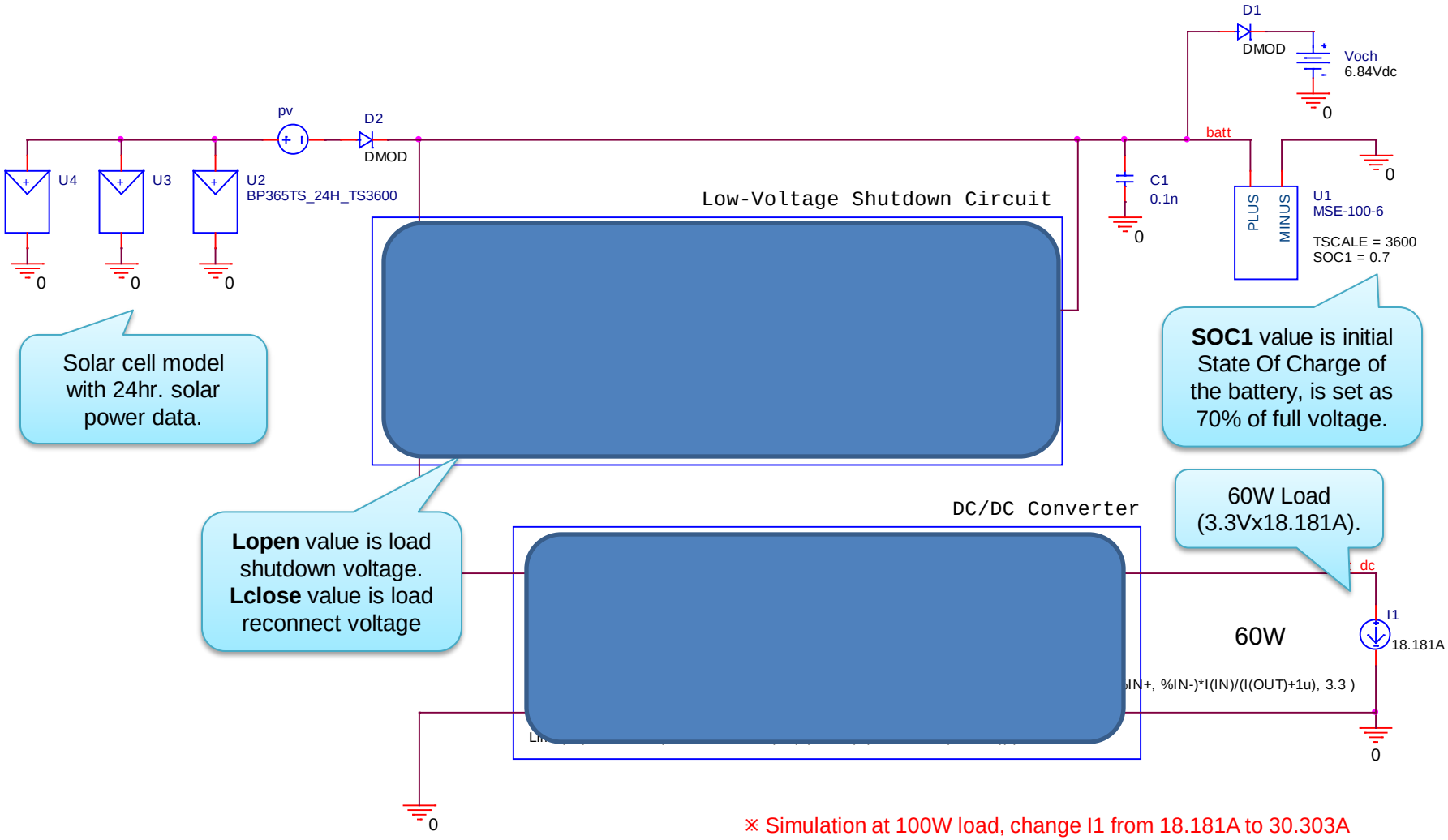
4.2 Short-Circuit Current vs. Time (24hr.)



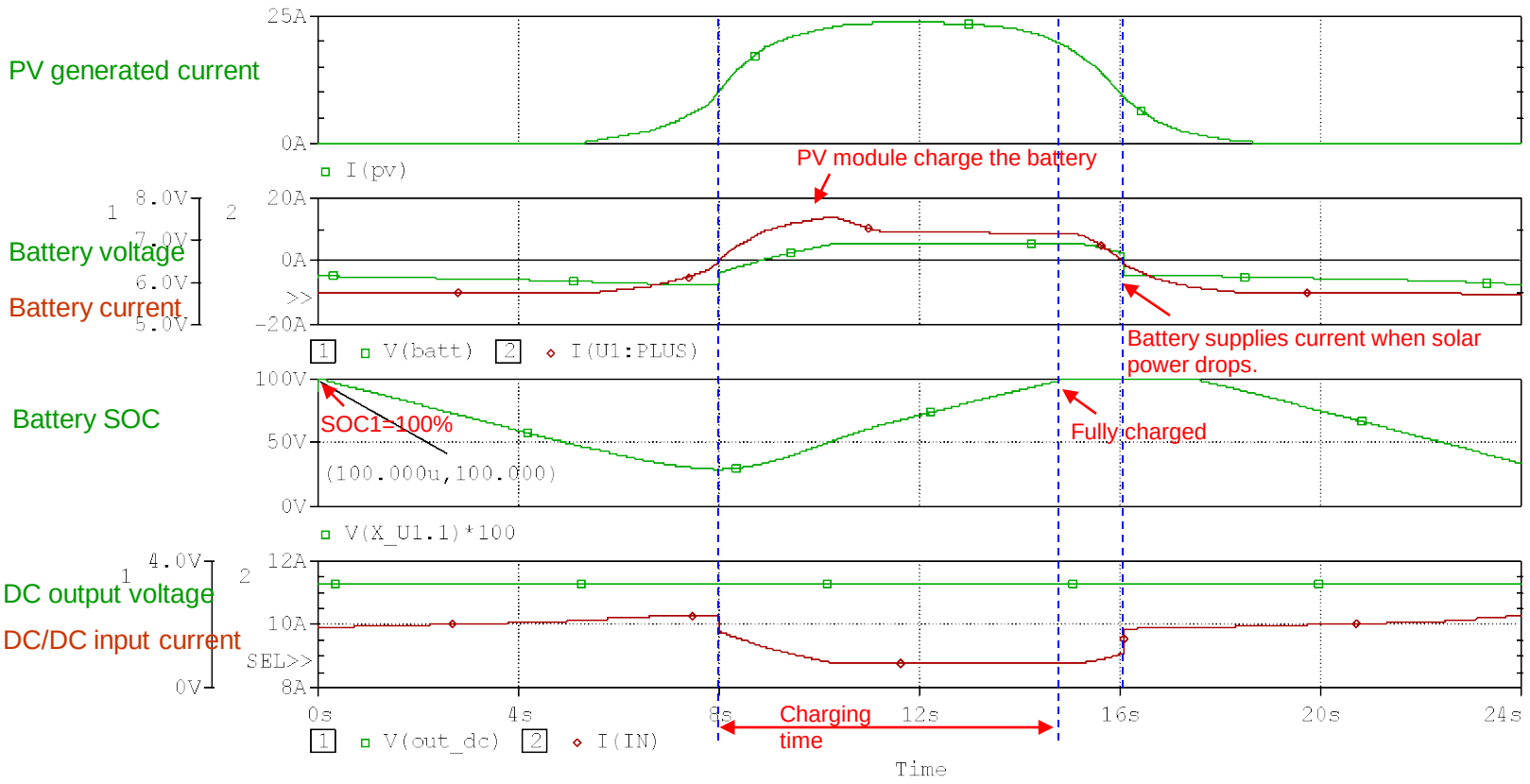


- Short-circuit current vs. time characteristics of photovoltaic module BP365TS for 24hours as the solar power profile (example) is included to the model.

4.3 PV-Battery System Simulation Circuit

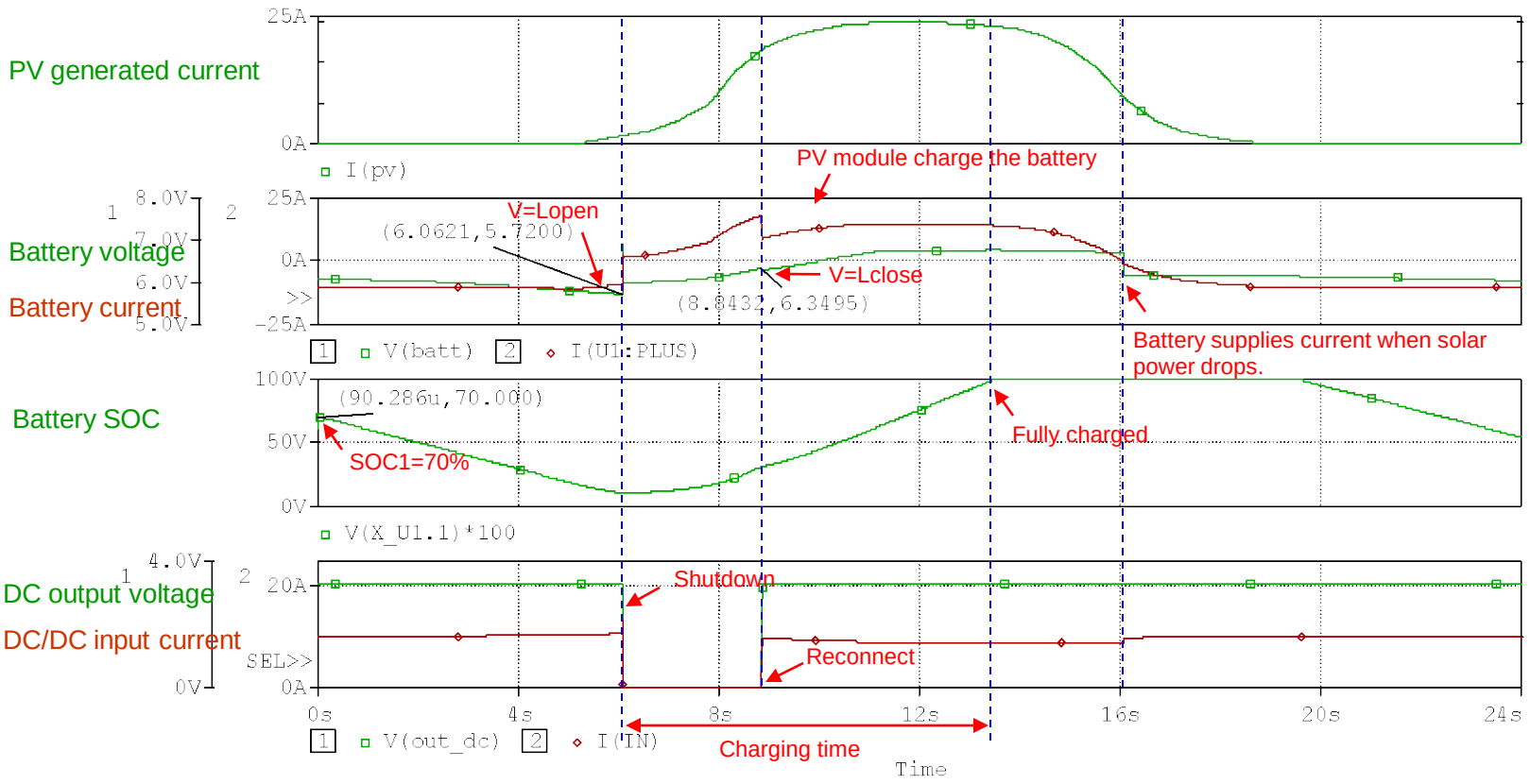


4.3.1 Simulation Result (SOC1=100, IL=18.18A or 60W load)



- Run to time: 24s (24hours in real world)
- Step size: 0.01s

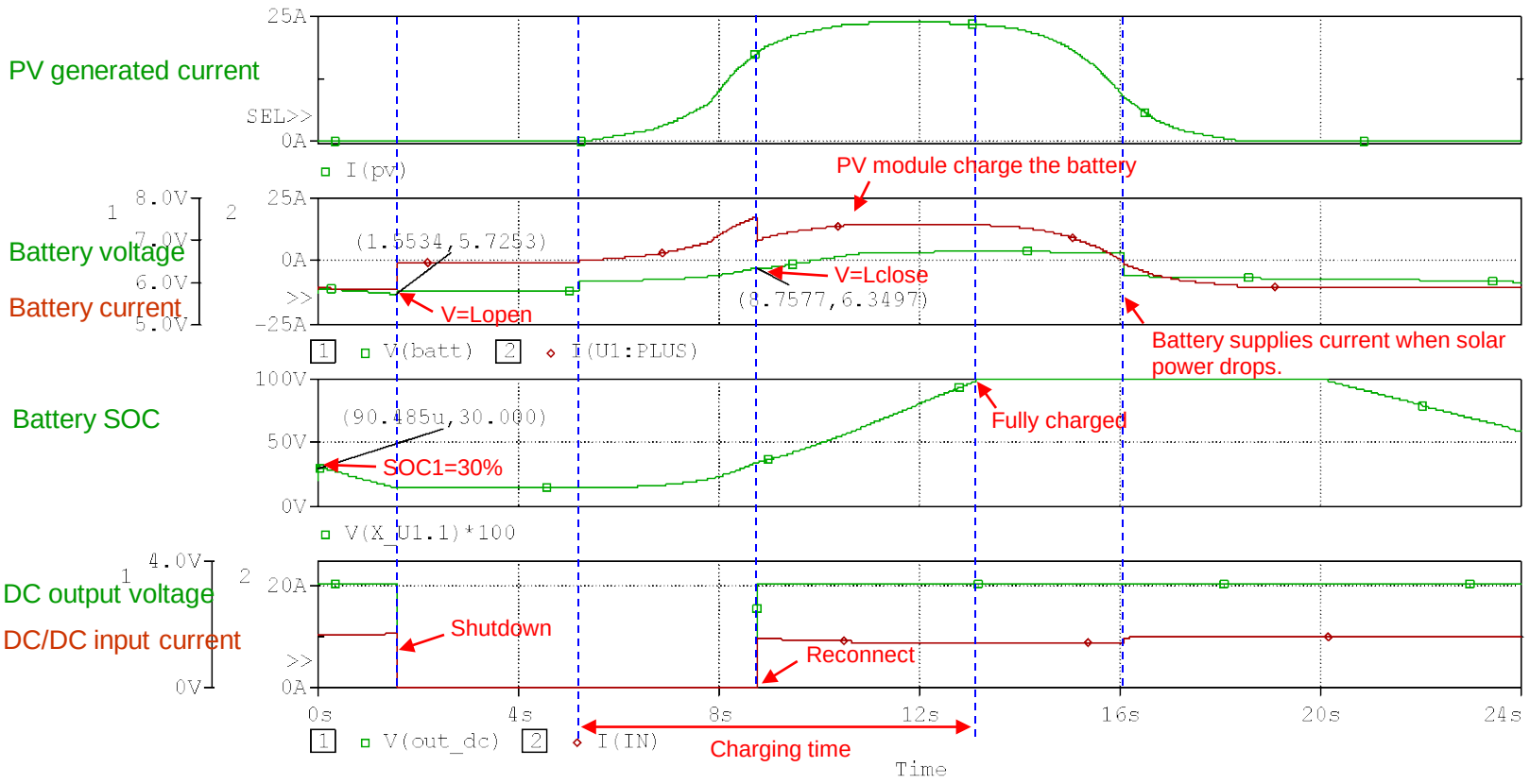
4.3.2 Simulation Result (SOC1=70, IL=18.18A or 60W load)



- Run to time: 24s (24hours in real world)
- Step size: 0.01s

- .Options ITL4=30

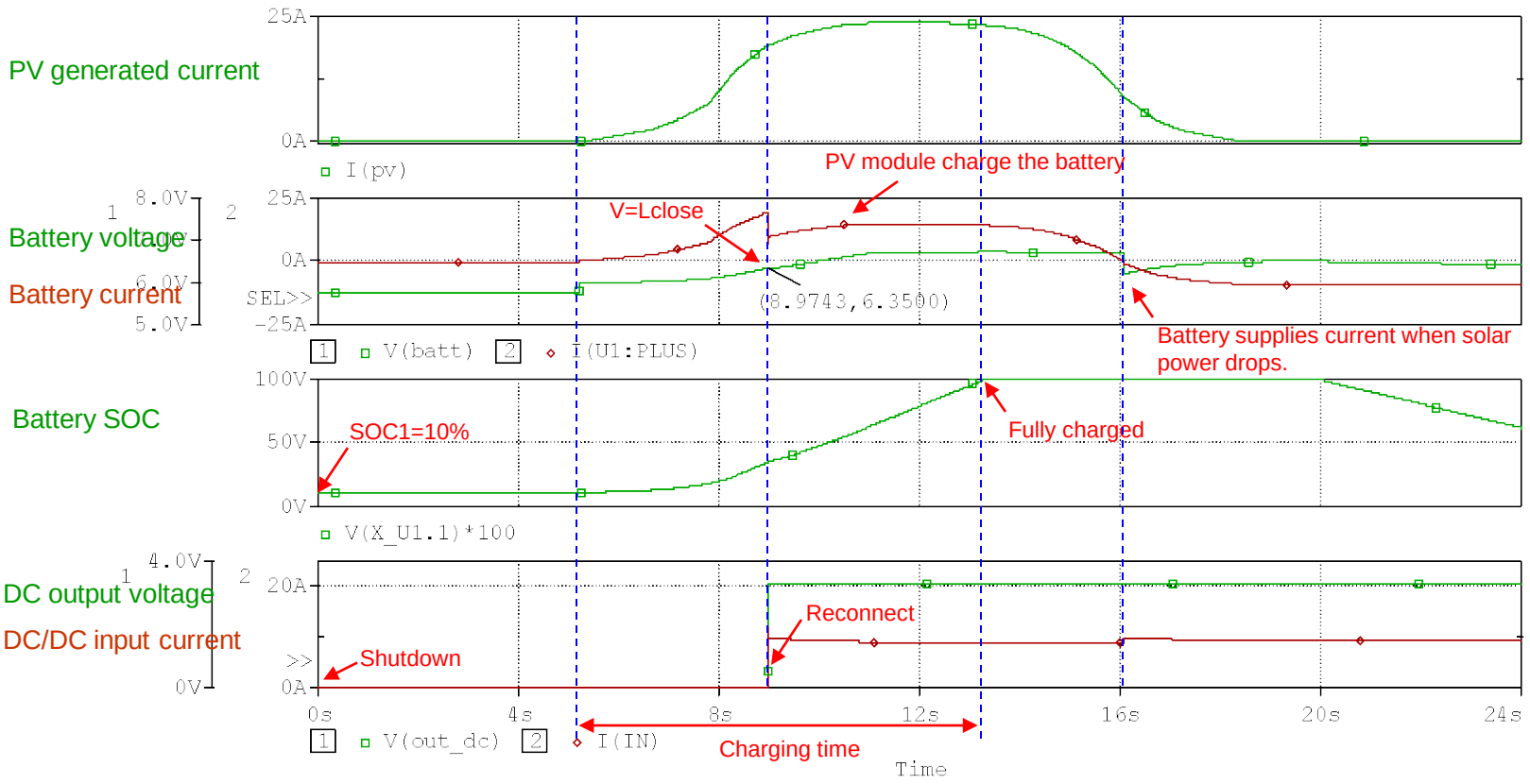
4.3.3 Simulation Result (SOC1=30, IL=18.18A or 60W load)



- Run to time: 24s (24hours in real world)
- Step size: 0.01s

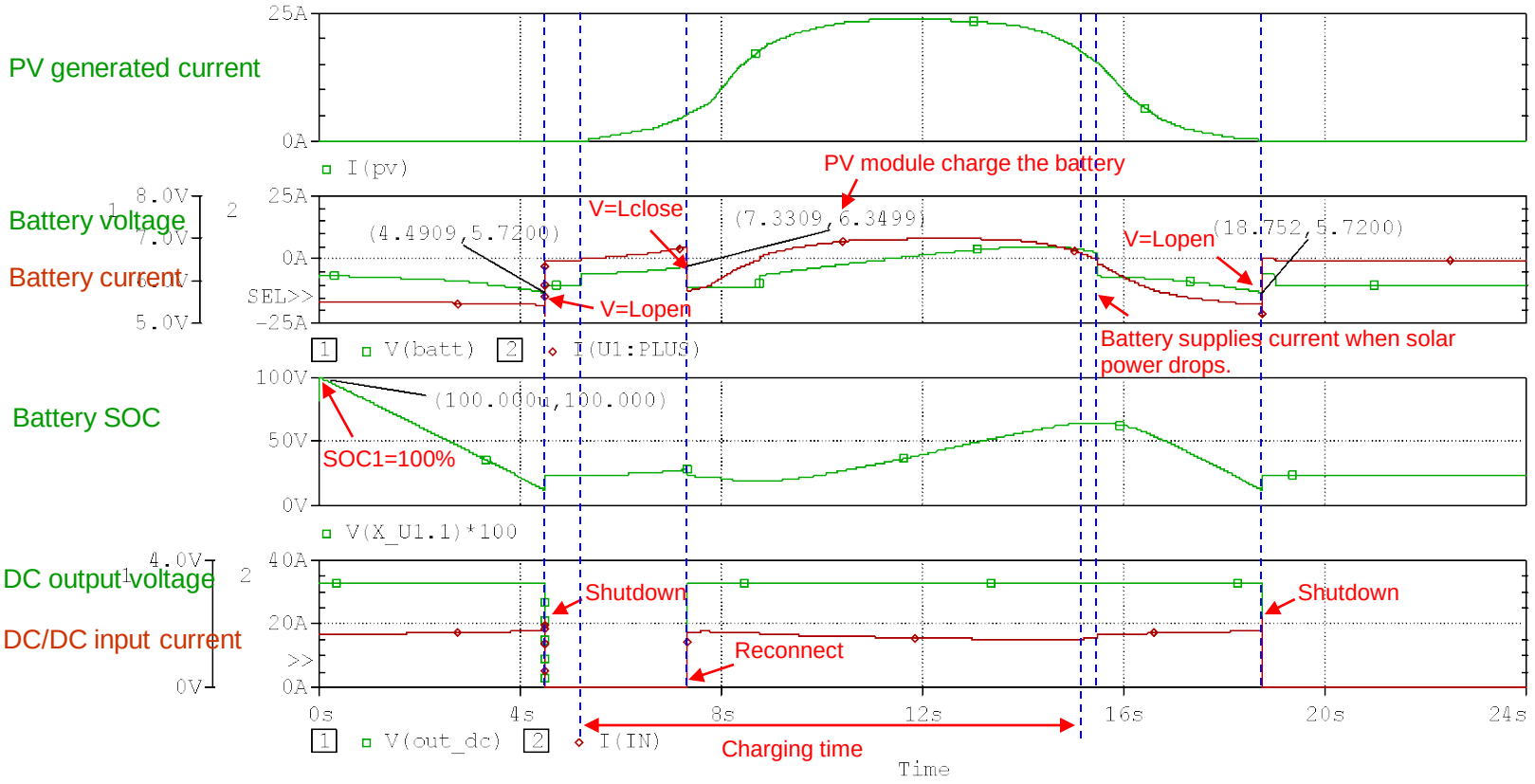
- .Options ITL4=30

4.3.4 Simulation Result (SOC1=10, IL=18.18A or 60W load)



- Conoff: IC=0
- Run to time: 24s (24hours in real world)
- Step size: 0.01s

4.3.5 Simulation Result (SOC1=100, IL=30.30A or 100W load)



- Run to time: 24s (24hours in real world)
- Step size: 0.01s

- .Options ITL4=30

4.4 Simulation Result (Example of Conclusion)

The simulation start from midnight(time=0). The system supplies DC load 60W.

- If initial SOC is 100%,
  - this system will never shutdown.
- If initial SOC is 70%,
  - this system will shutdown after 6.062 hours (about 6:04AM.).
  - system load will reconnect again at 8:51AM (Morning).
- If initial SOC is 30%,
  - this system will shutdown after 1.553 hours (about 1:33AM.).
  - system load will reconnect again at 8:46AM (Morning).
- If initial SOC is 10%,
  - this system will start shutdown.
  - this system will reconnect again at 8:58AM (Morning).
- With the PV Panel generated current profile, battery will fully charged in about 8.087 hours.

The simulation start from midnight(time=0). The system supplies DC load 100W.

- If initial SOC is 100%,
  - this system will shutdown after 4.491 hours (about 4:30AM.).
  - system load will reconnect again at 7:20AM (Morning).
  - this system will shutdown again at 6:45PM (Night).

Simulations index

Simulations	Folder name
1. PV Lead-Acid Battery Charger Circuit.....	charge-sol
2. Constant Current PV Lead-Acid Battery Charger Circuit.....	charge-sol-const
3. PV-Battery System Simulation Circuit (SOC1=100, 60W).....	sol_24h_60W_soc100
4. PV-Battery System Simulation Circuit (SOC1=70, 60W).....	sol_24h_60W_soc70
5. PV-Battery System Simulation Circuit (SOC1=30, 60W).....	sol_24h_60W_soc30
6. PV-Battery System Simulation Circuit (SOC1=10, 60W).....	sol_24h_60W_soc10
7. PV-Battery System Simulation Circuit (SOC1=100, 100W).....	sol_24h_100w_soc100