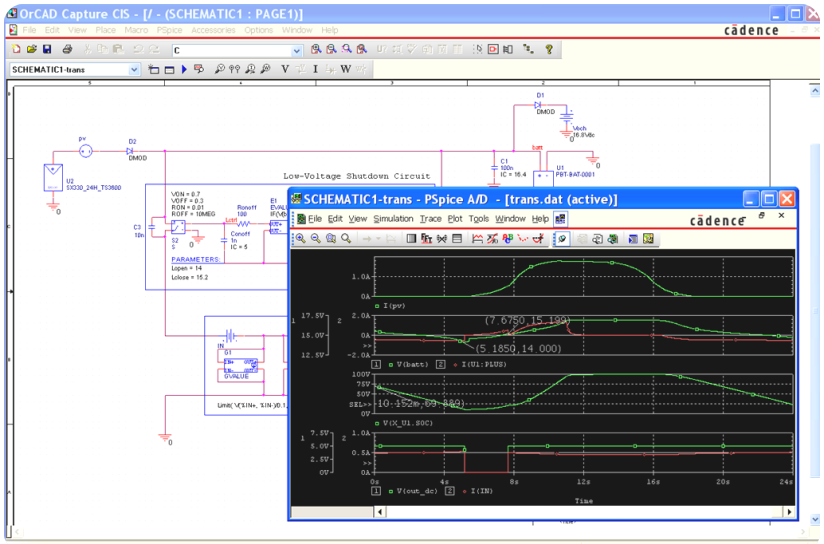



# Design Kit

## PV Lead-Acid Battery System (DC Out)

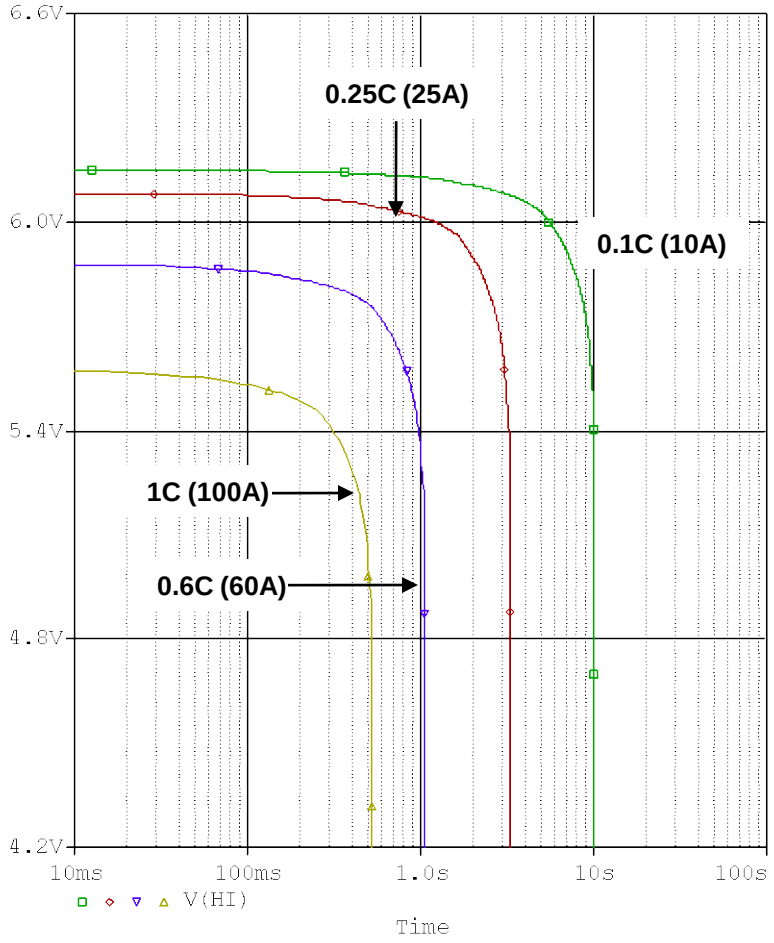
# Contents

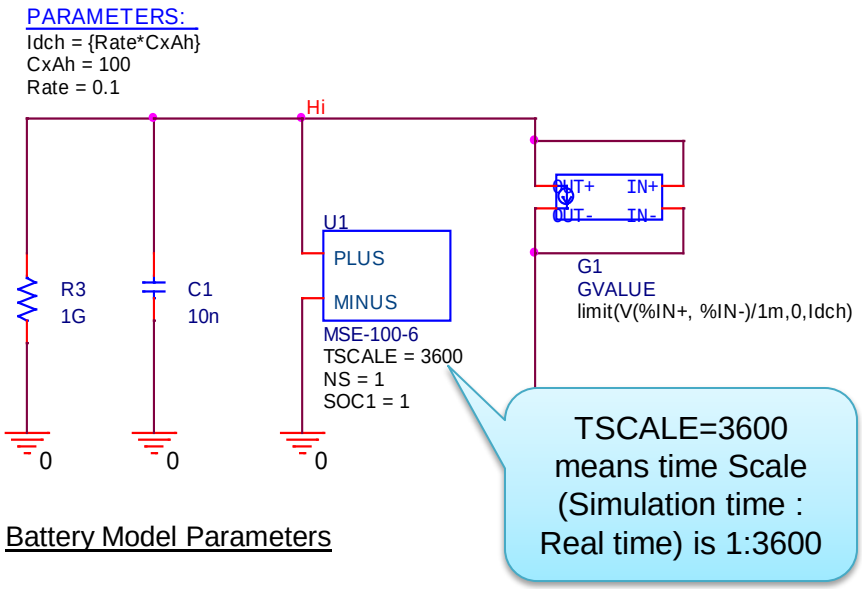
# 1.1 Lead-Acid battery Specification

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



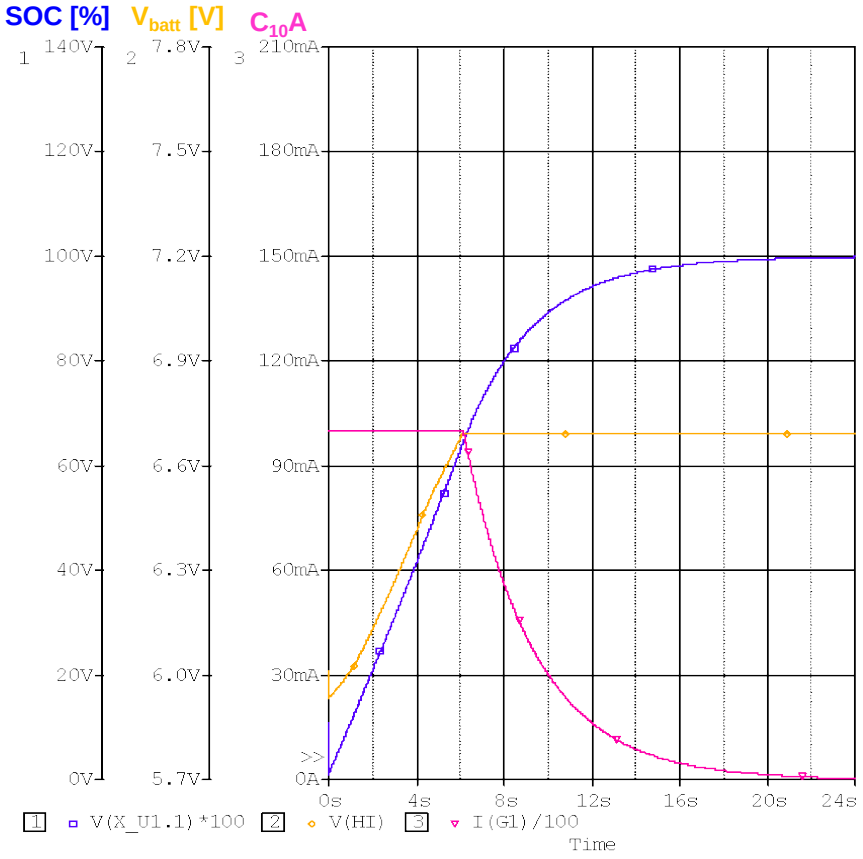



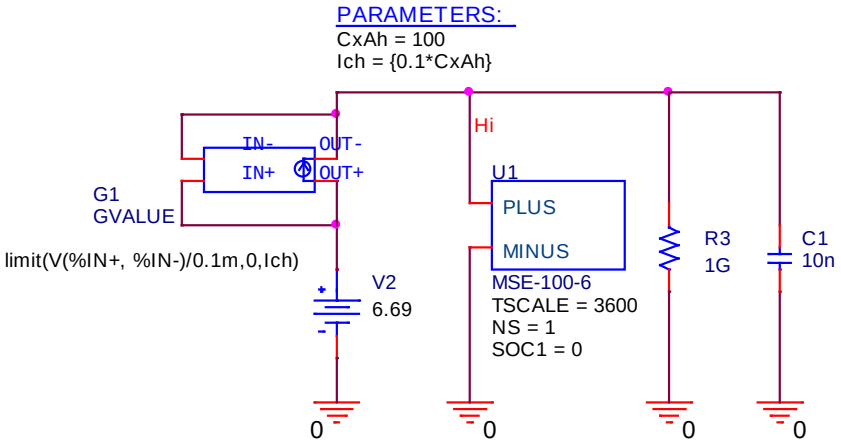

Battery Model Parameters

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

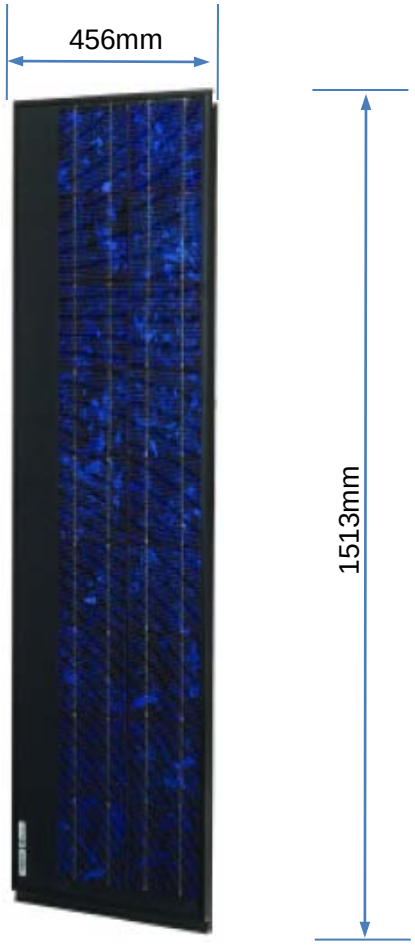
## Charging Time

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

# 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]

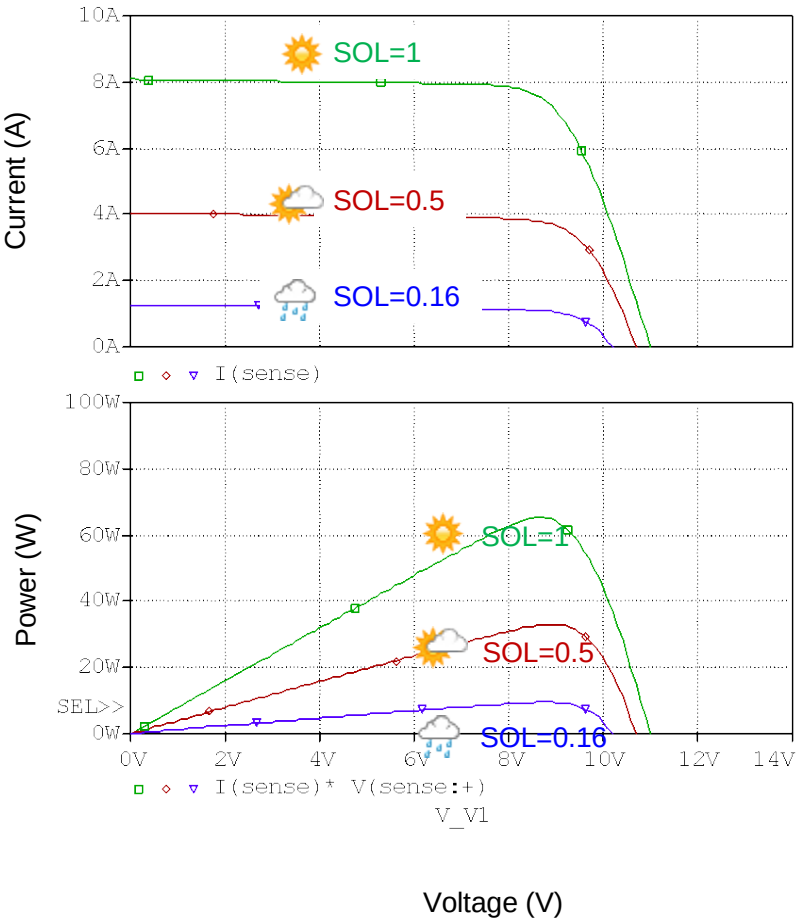


# 2.2 Output Characteristics vs. Incident Solar Radiation


U2
BP365TS
SOL = 1

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

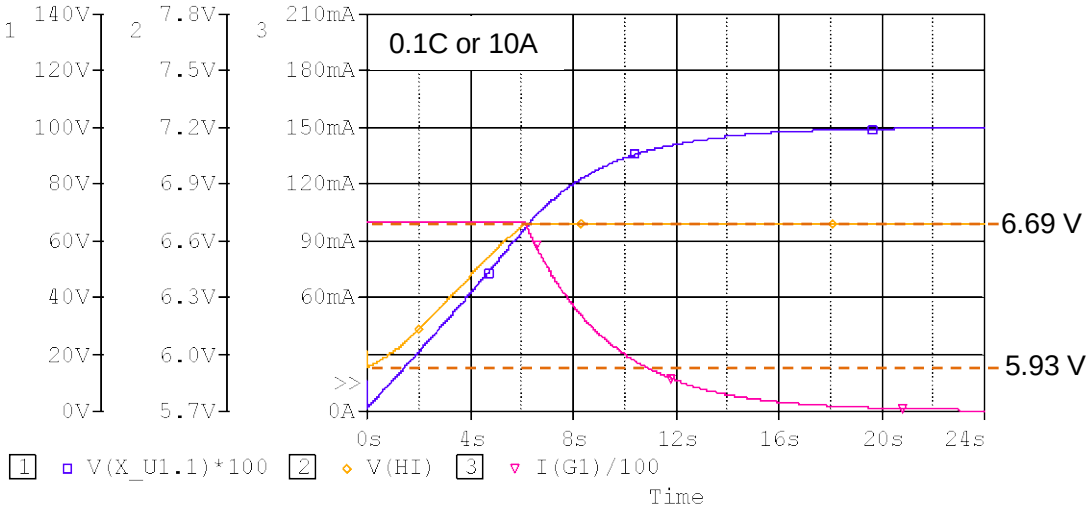
BP365TS Output Characteristics vs. Incident Solar Radiation



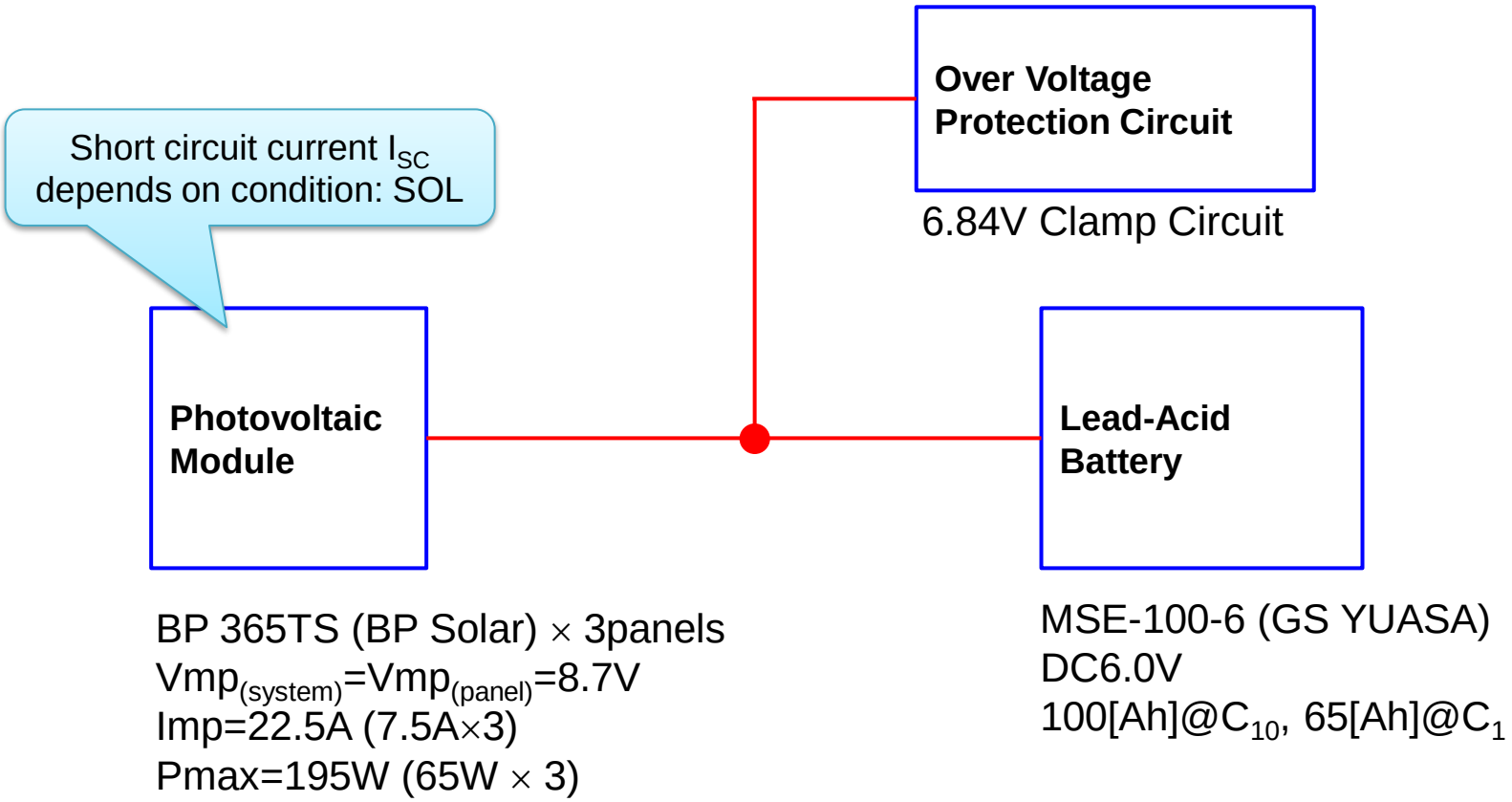
# 3. Solar Cell Battery Charger

- 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.

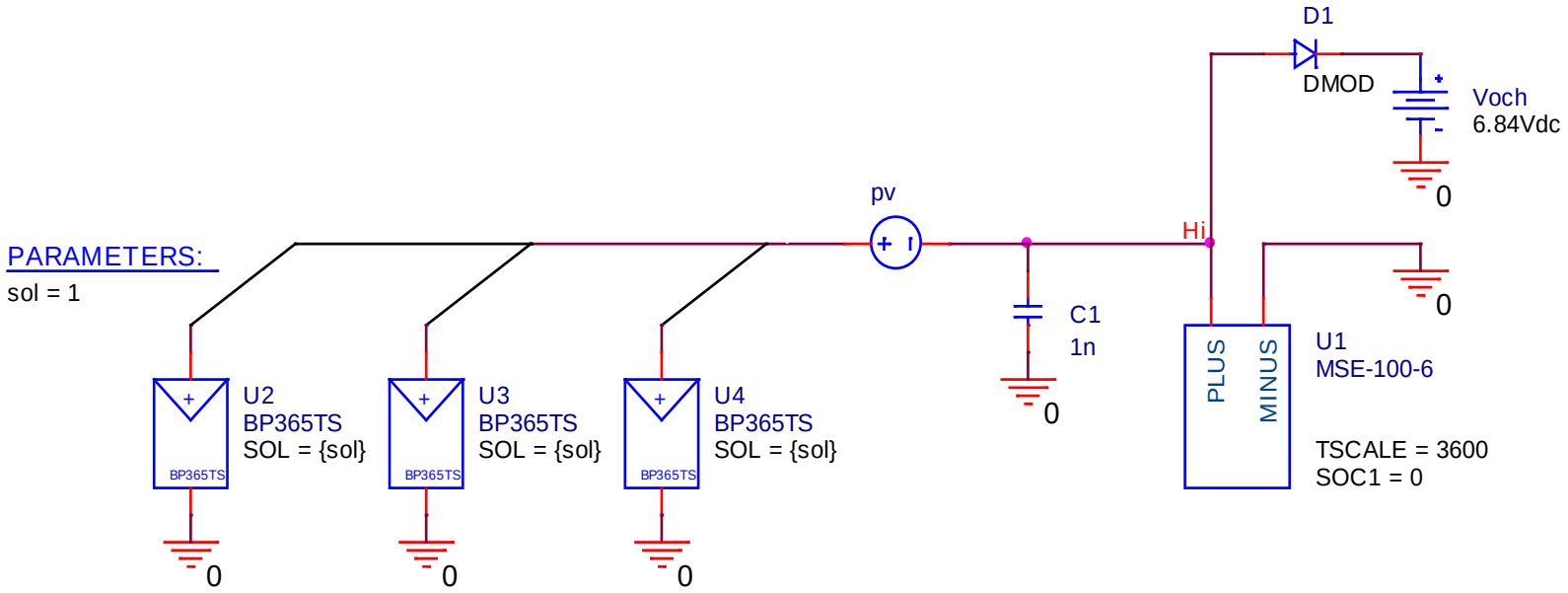
- <u>MSE-100-6</u>
  - Charging time is approximately 24 hours with charging rate 0.1C or 10A
  - Voltage during charging with 0.1C is between 5.93 to 6.69 V



# 3.1 Concept of Simulation PV Lead-Acid Battery Charger Circuit

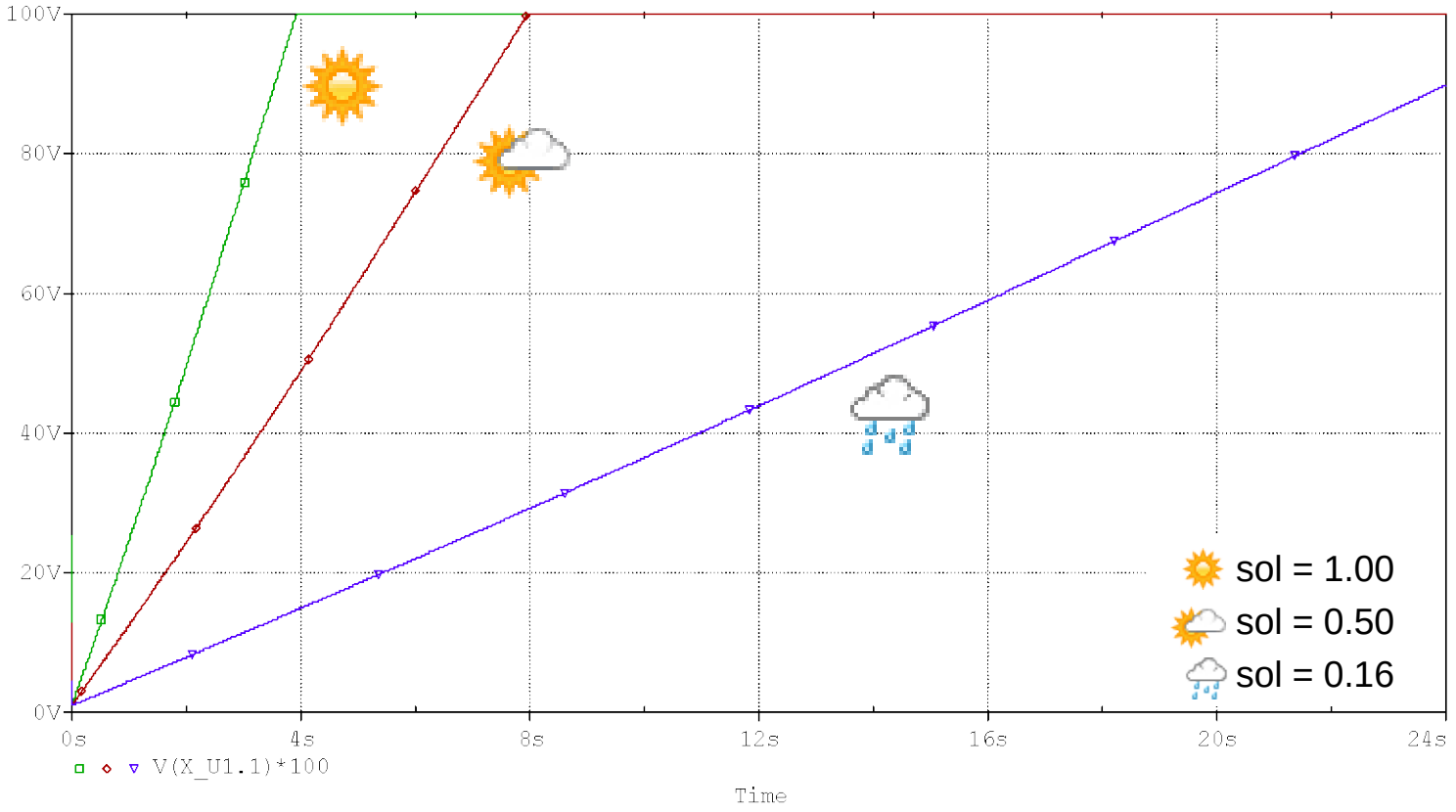


# 3.2 PV Lead-Acid Battery Charger Circuit



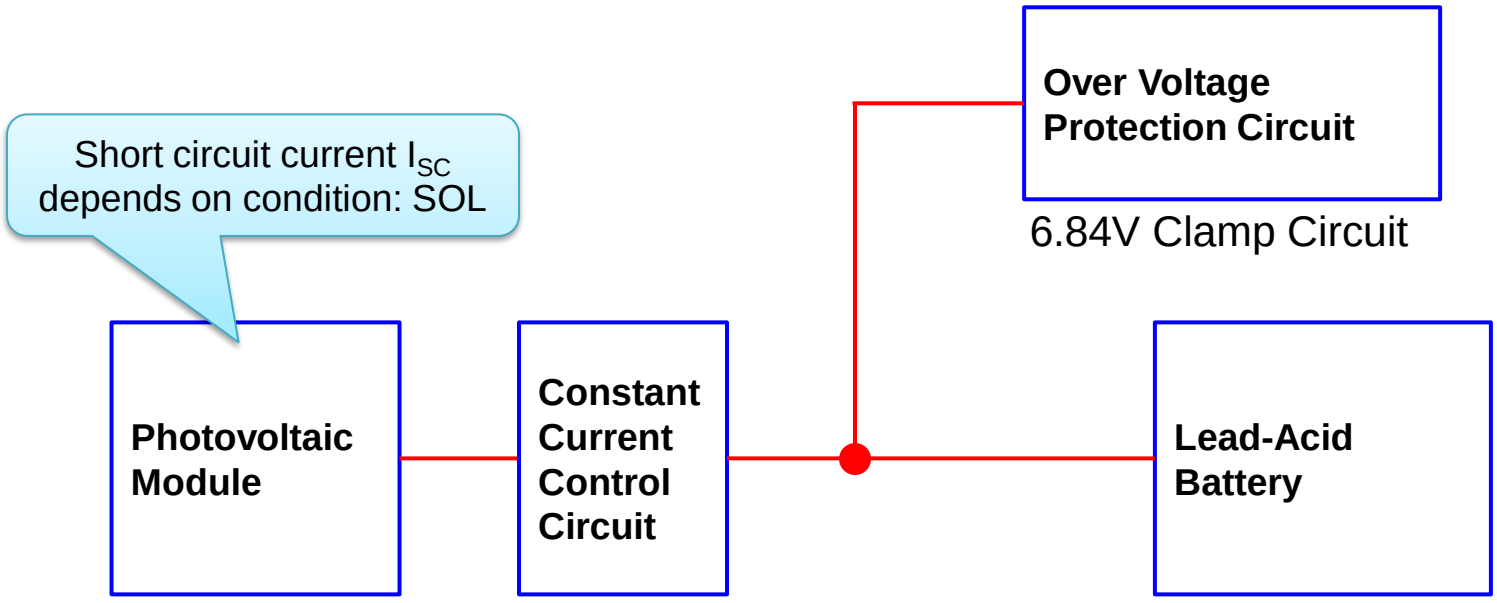

- Input value between 0-1 in the "PARAMETERS: sol = " to set the normalized incident radiation, where SOL=1 for AM1.5 conditions.

# 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

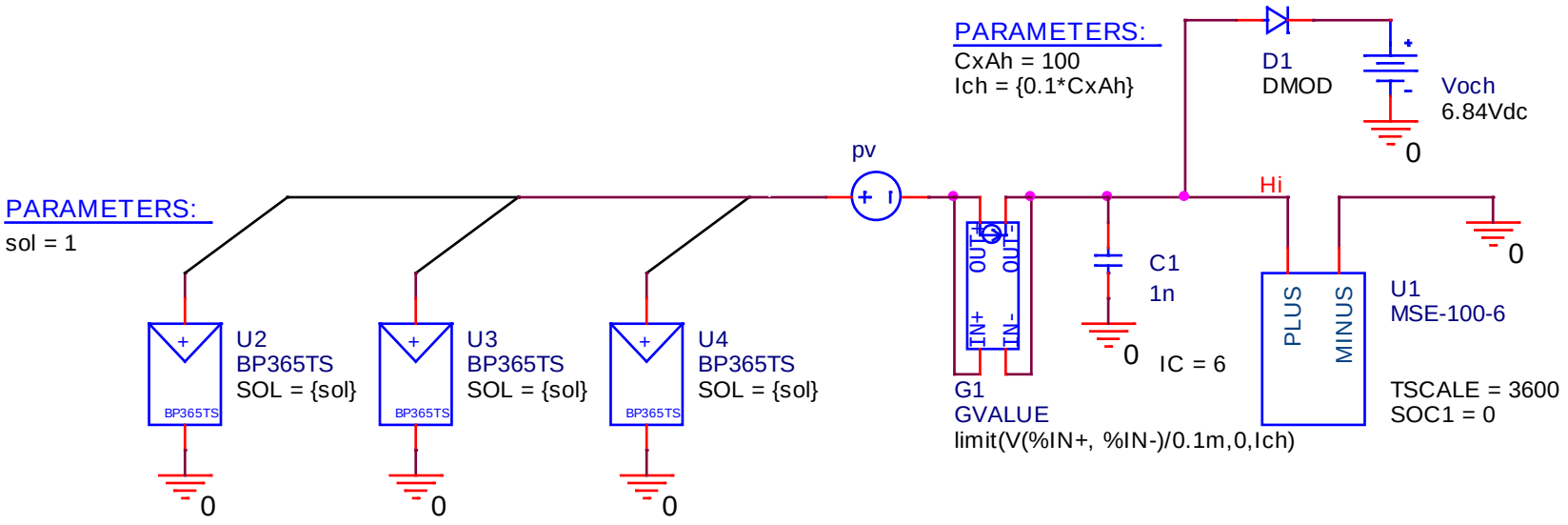



BP 365TS (BP Solar) × 3panels
$Vmp_{(system)}=Vmp_{(panel)}=8.7V$
Imp=22.5A (7.5A×3)
Pmax=195W (65W × 3)

$I_{charge}$=0.1C (10A)

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

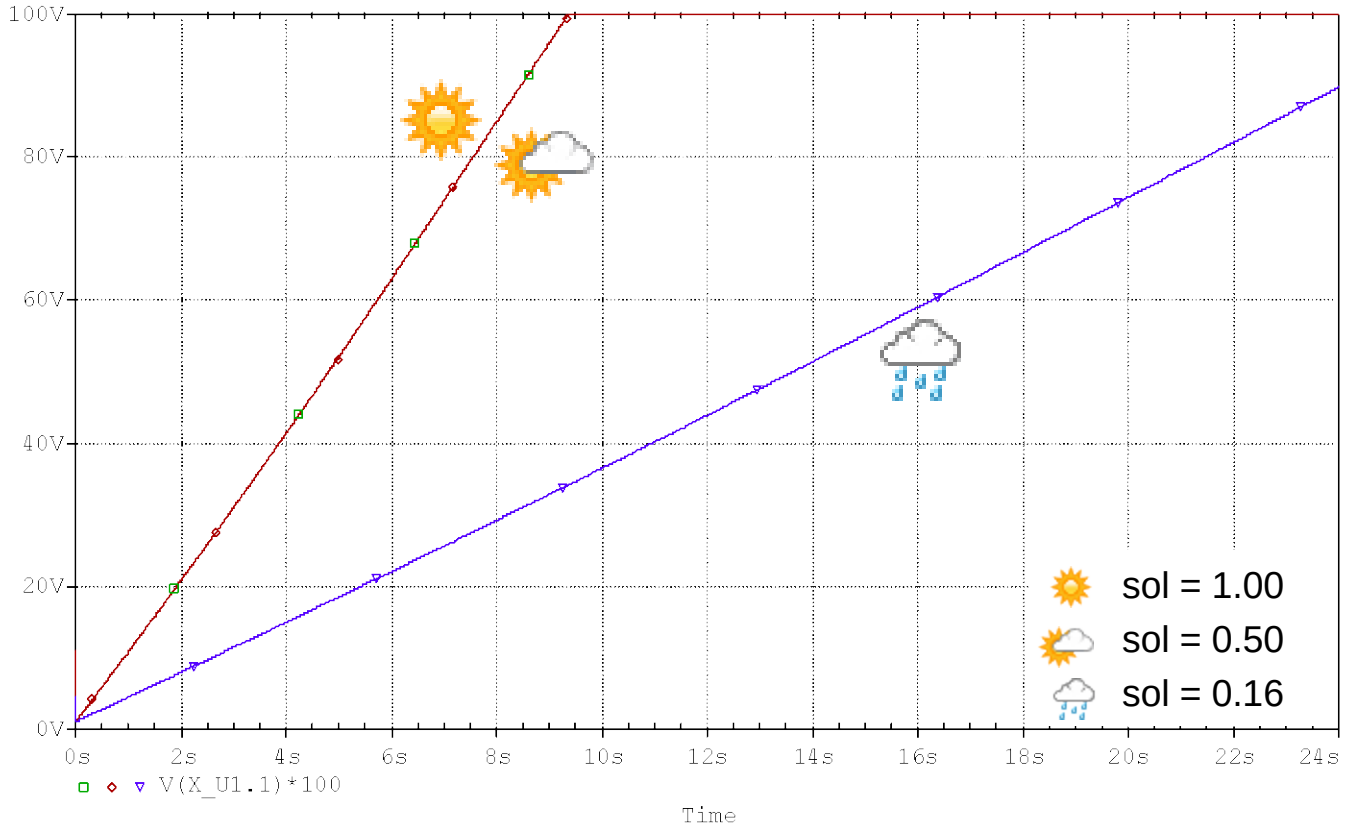
# 3.5 Constant Current PV Lead-Acid Battery Charger Circuit




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

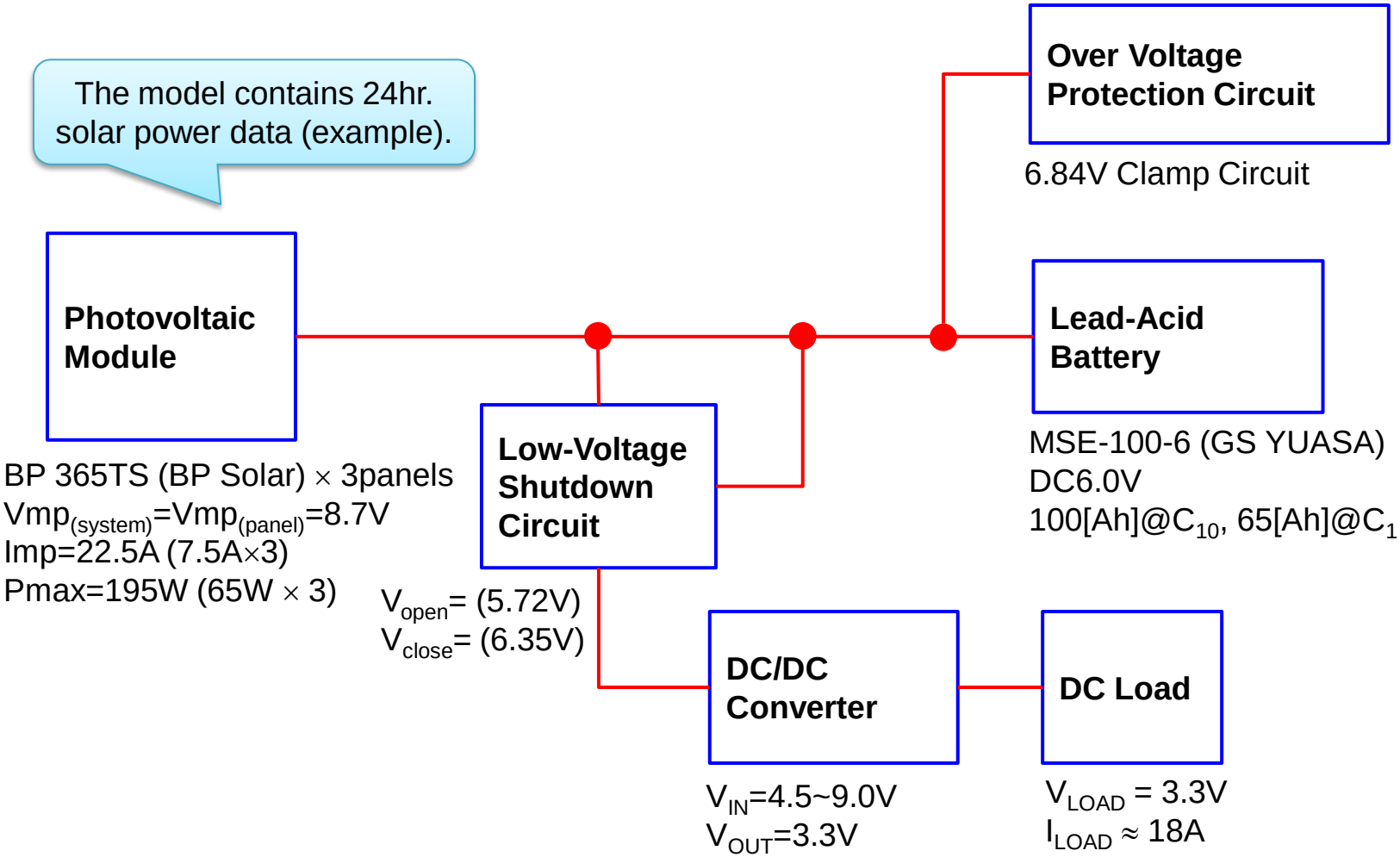
- Input the battery capacity (Ah) and charging current rate (e.g. 0.1*CxAh) in the
- "PARAMETERS: CxAh = 100 and rate = 0.1 " to set the charging current.

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

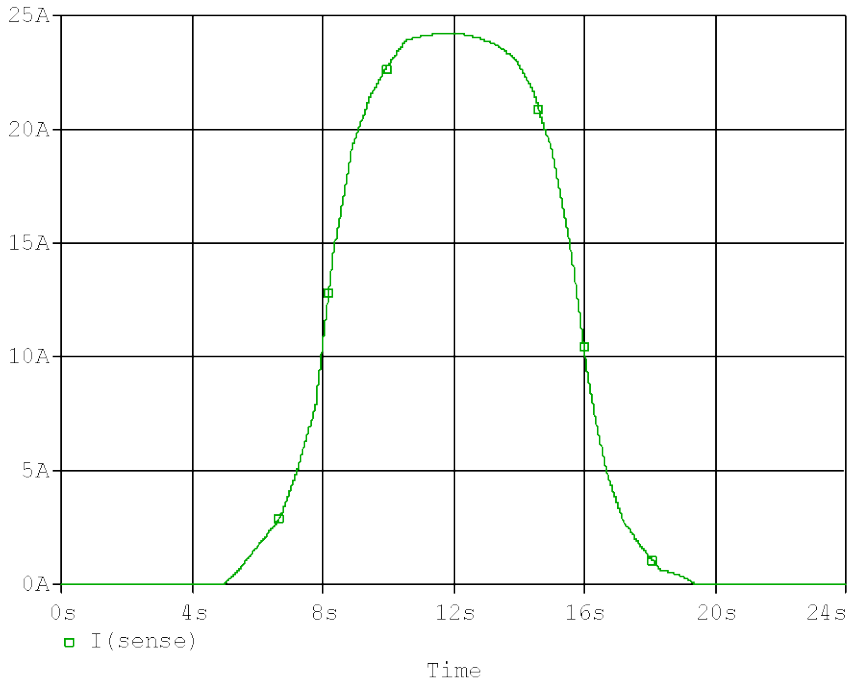


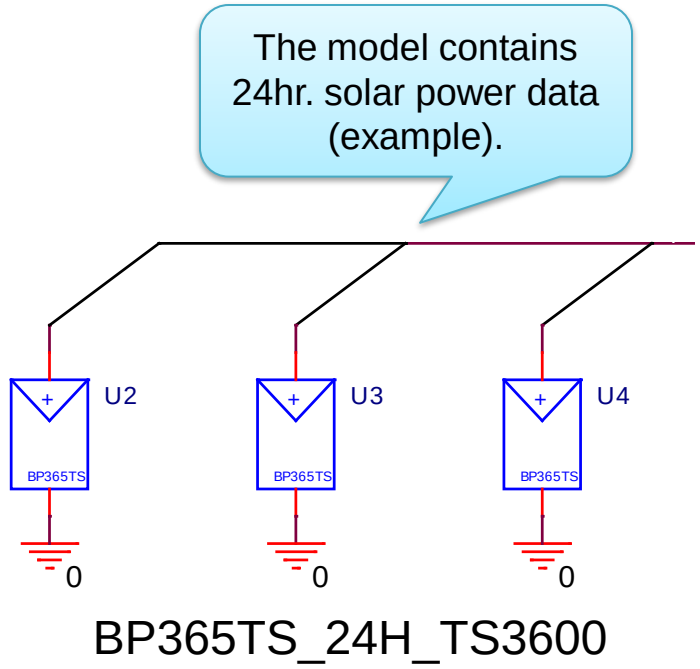

- Simulation result shows the charging time for sol = 1, 0.5, and 0.16. If PV can generate current more than the constant charge rate (0.1), battery can be fully charged in about 9.364 hour.

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



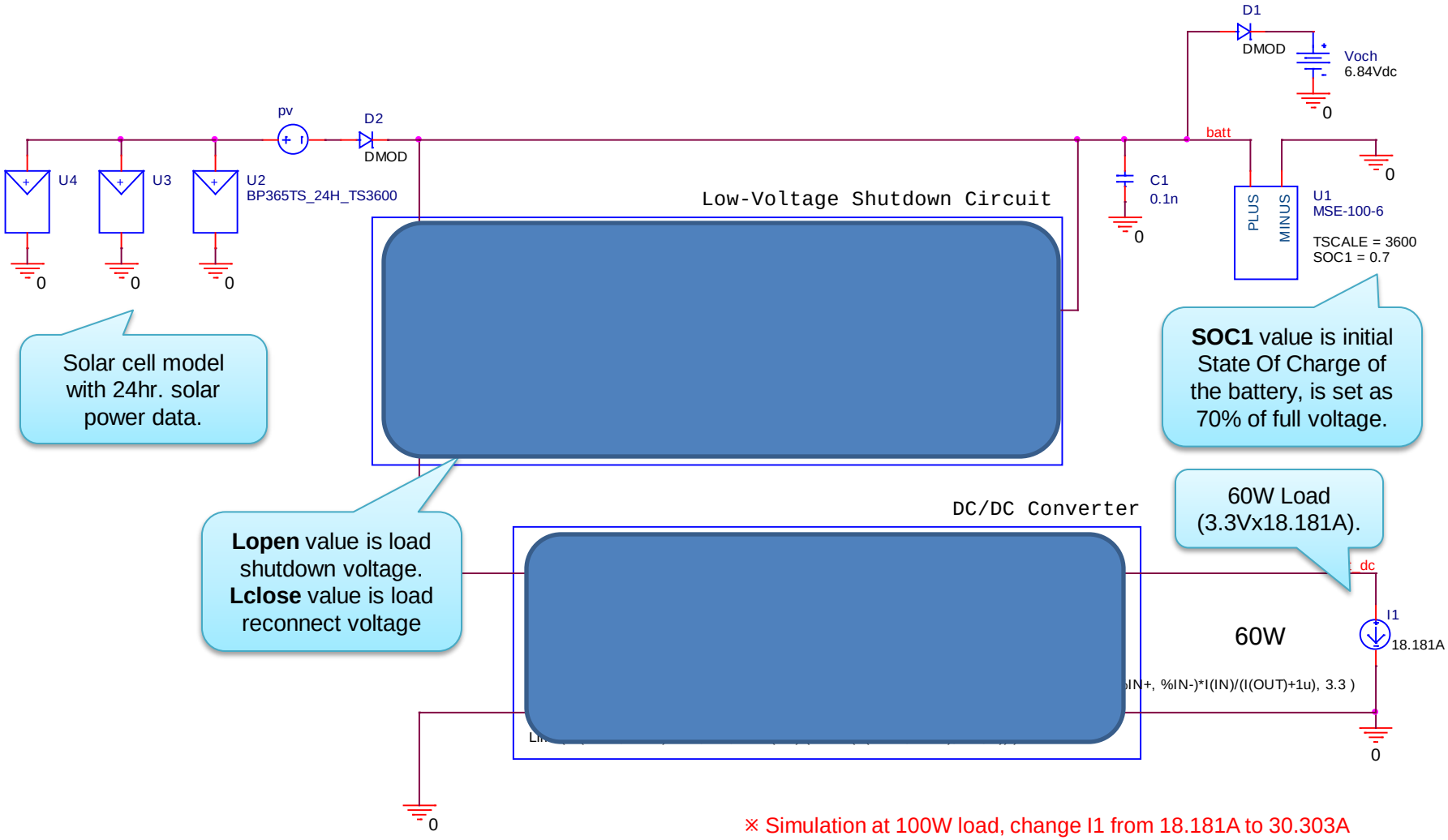
# 4.2 Short-Circuit Current vs. Time (24hr.)



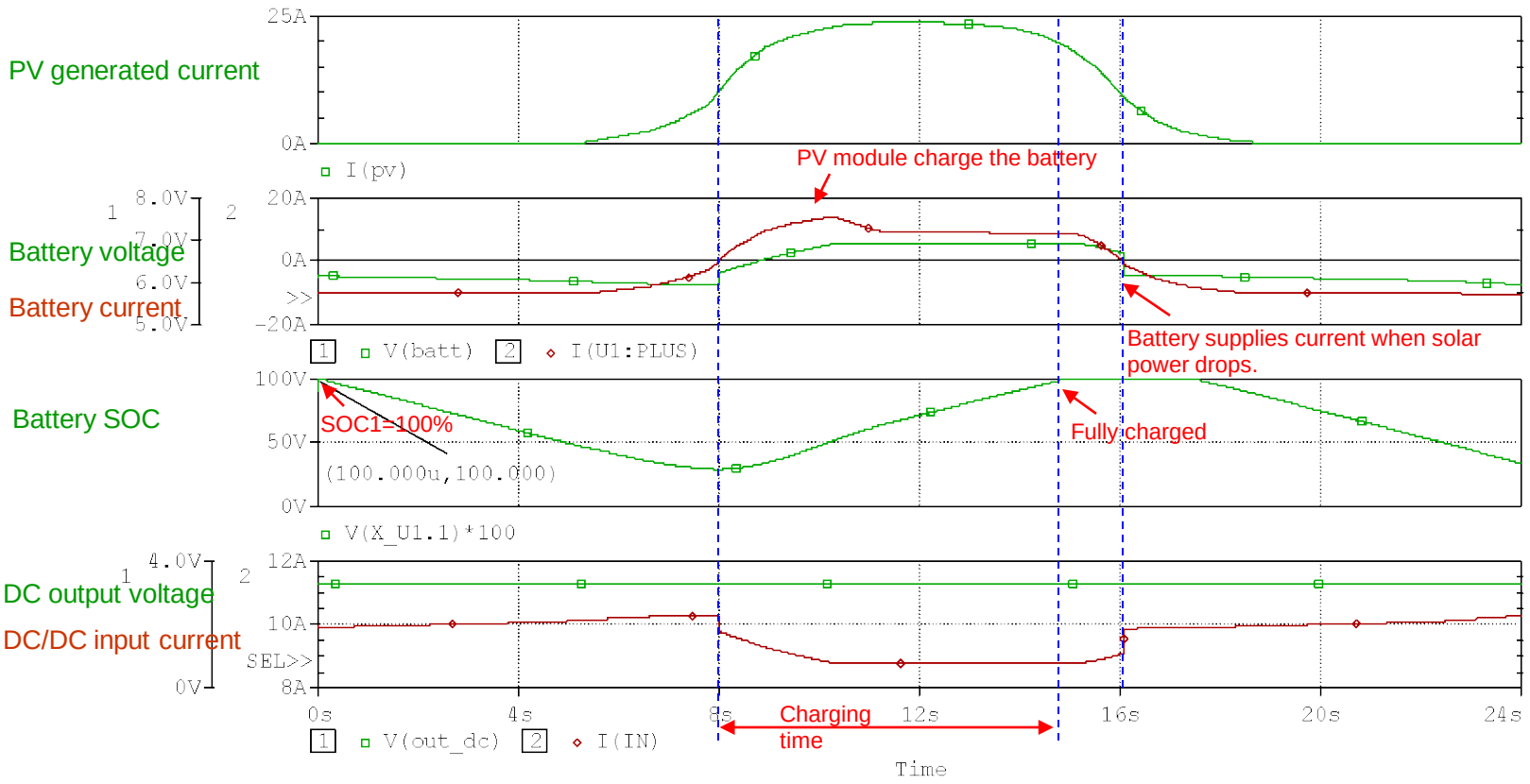




- Short-circuit current vs. time characteristics of photovoltaic module BP365TS for 24hours as the solar power profile (example) is included to the model.

# 4.3 PV-Battery System Simulation Circuit

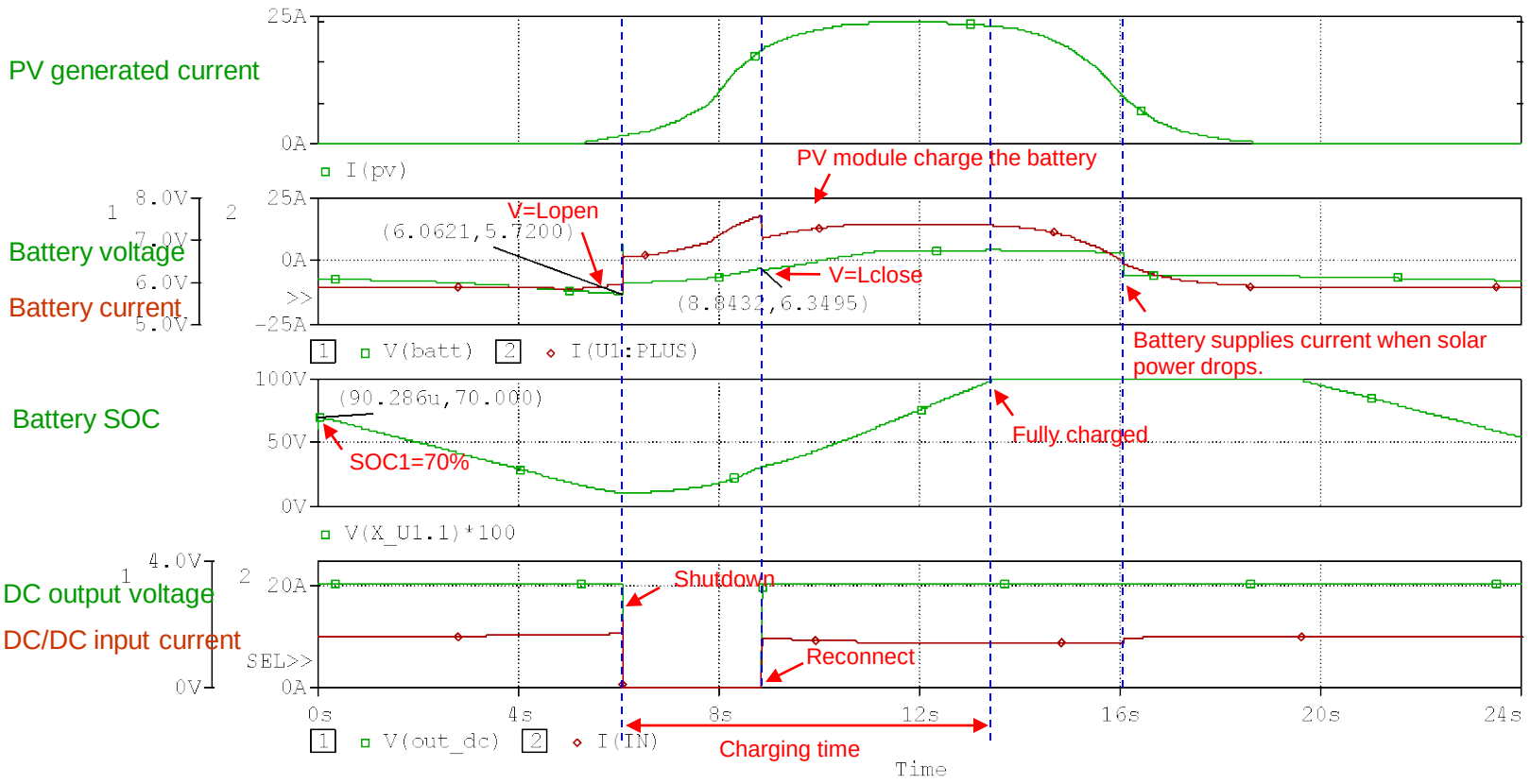


# 4.3.1 Simulation Result (SOC1=100, IL=18.18A or 60W load)




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

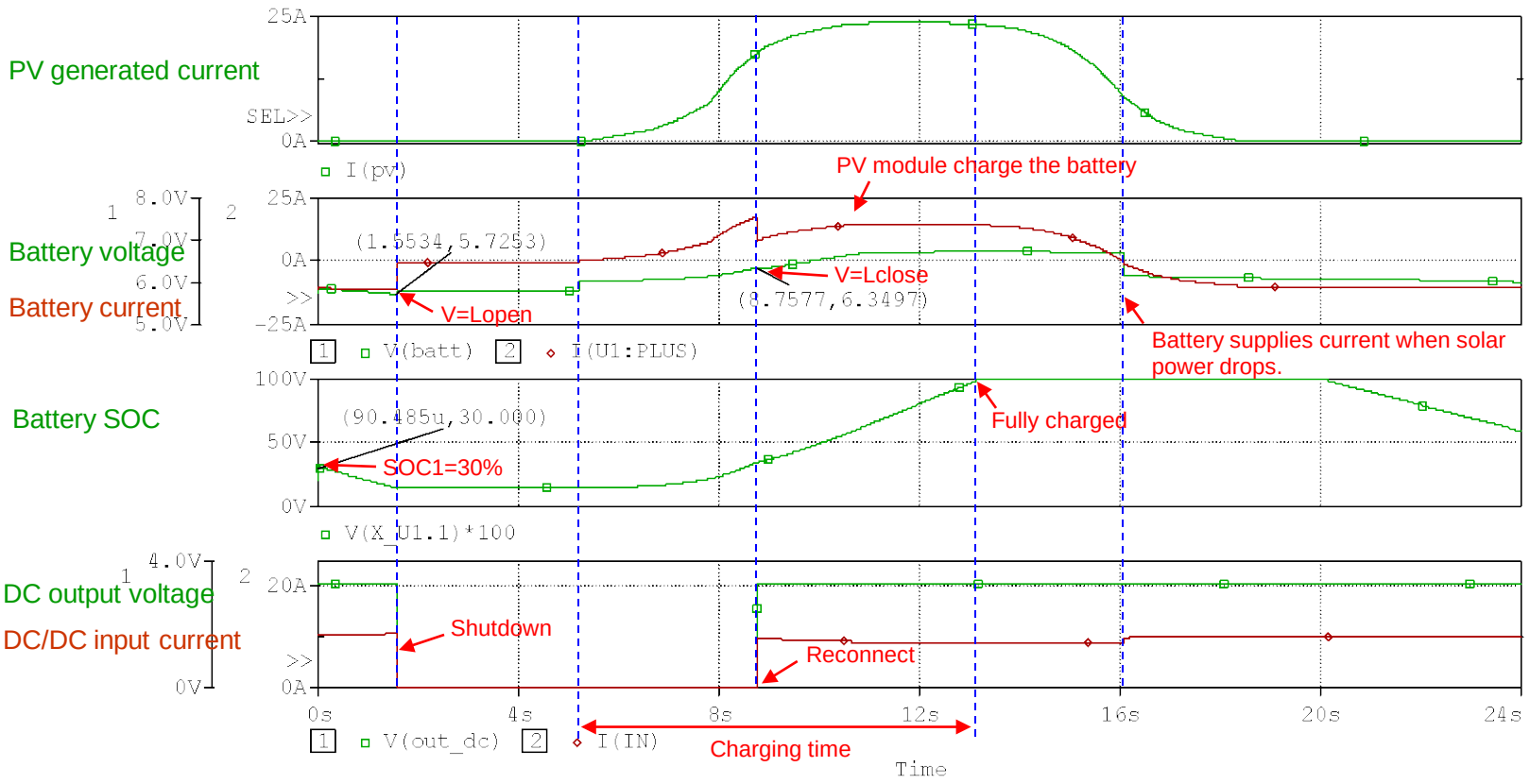
# 4.3.2 Simulation Result (SOC1=70, IL=18.18A or 60W load)




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

- .Options ITL4=30

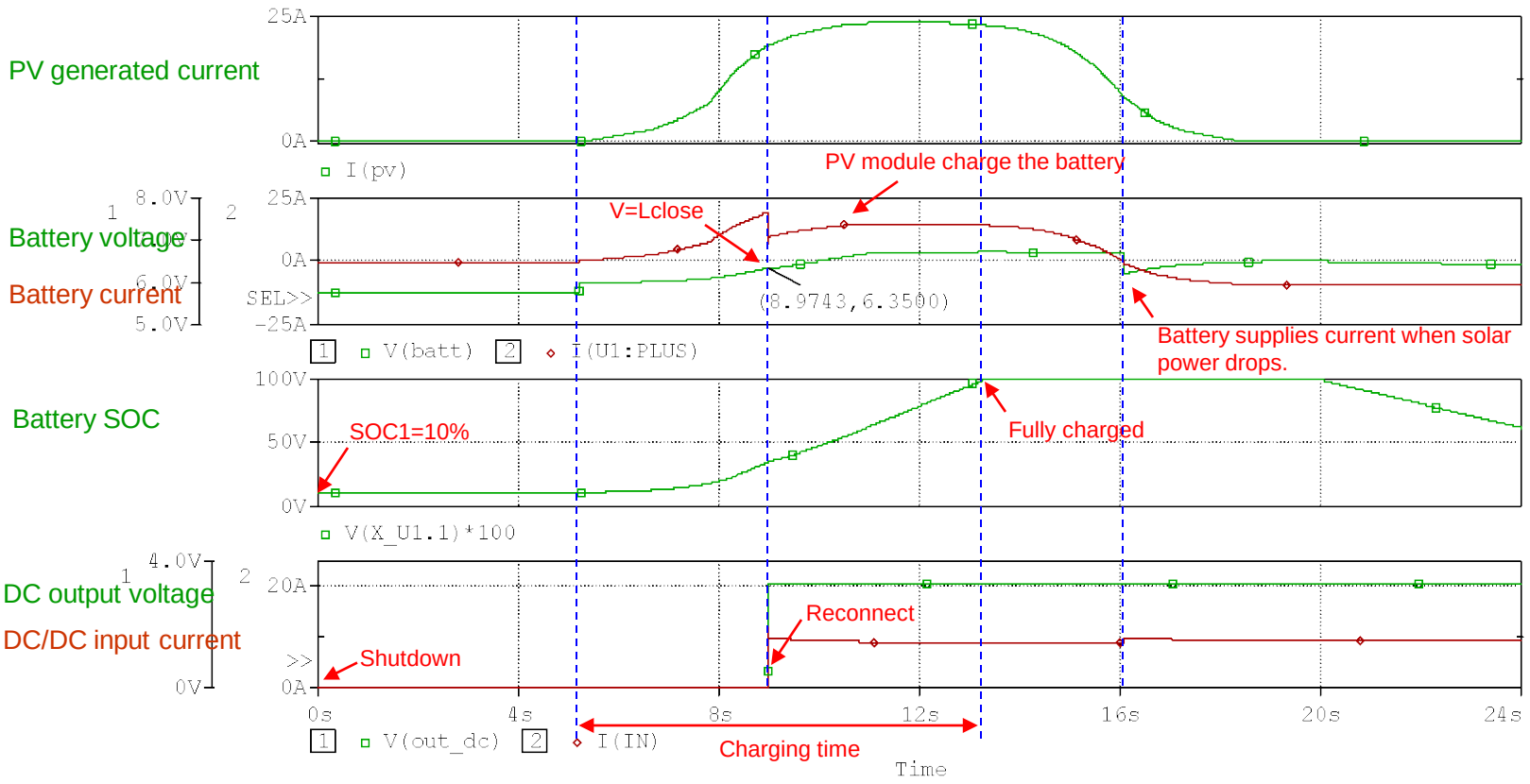
# 4.3.3 Simulation Result (SOC1=30, IL=18.18A or 60W load)




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

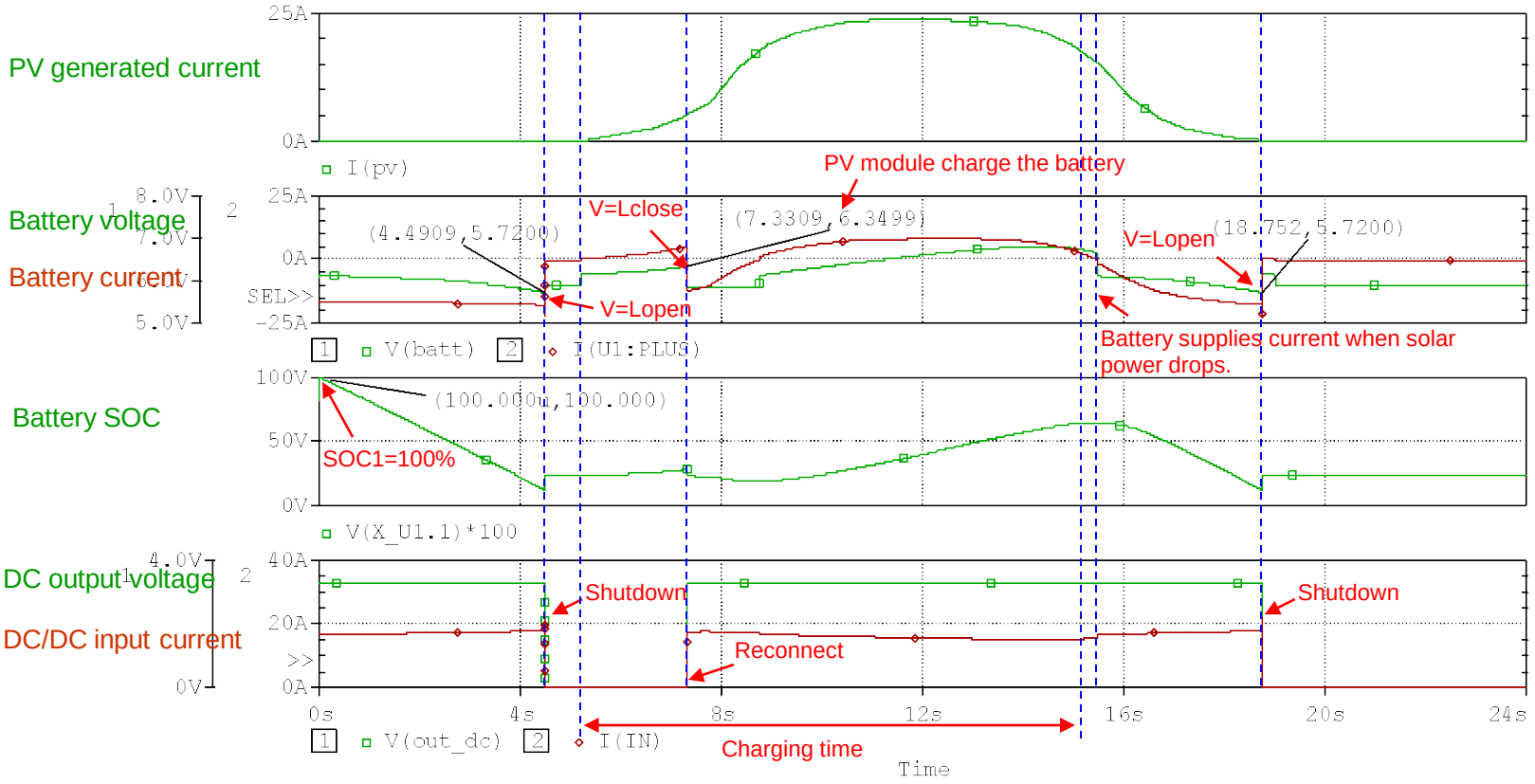
- .Options ITL4=30

# 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).

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|---|---|
| 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 |