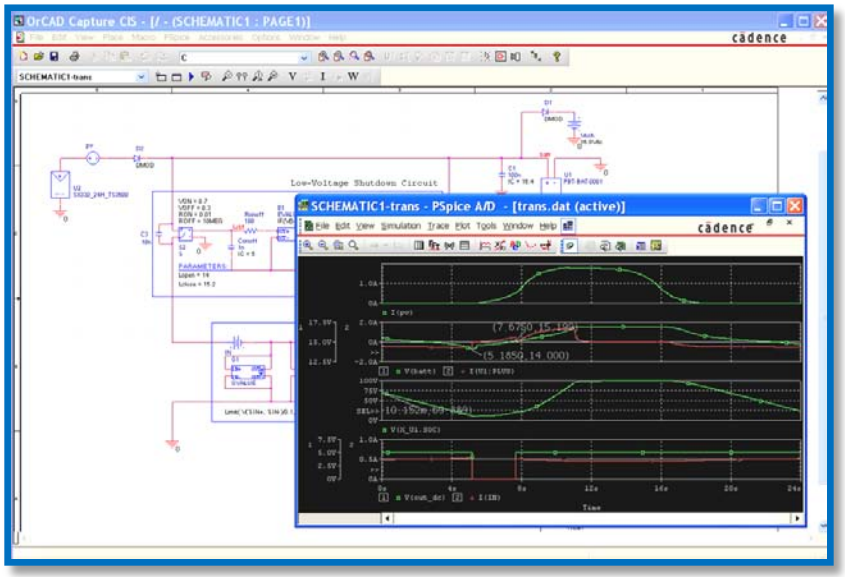


Design Kit

PV Li-Ion Battery System

Contents

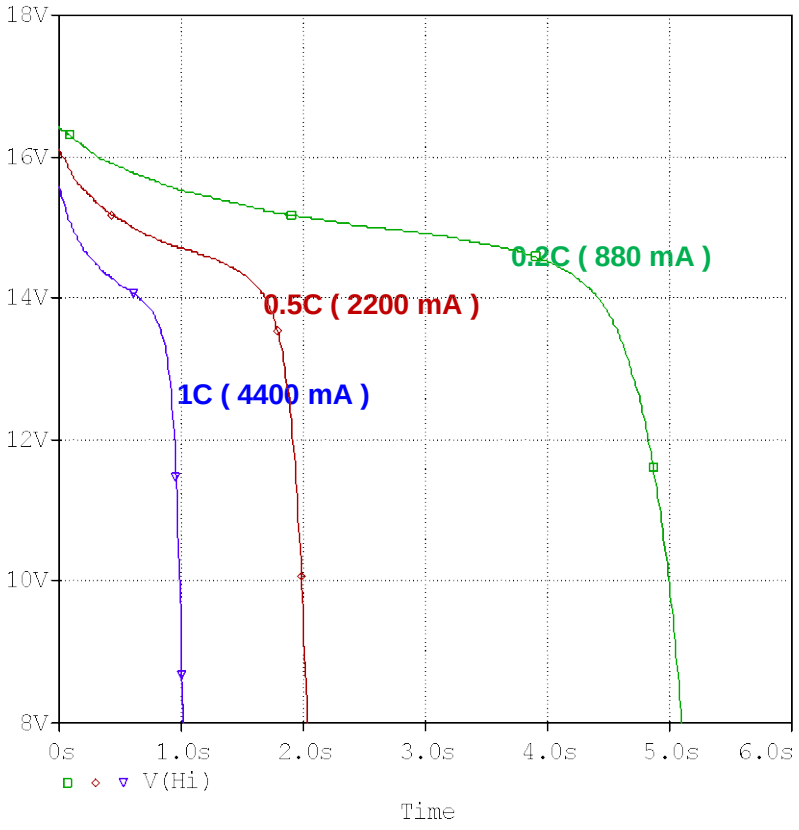
	Slide #
1. Lithium-Ion Batteries Pack	
1.1 Lithium-Ion Batteries Pack Specification	3
1.2 Discharge Time Characteristics	4
1.3 Single Cell Discharge Characteristics	5
1.4 Charge Time Characteristics	6
2. Solar Cells	
2.1 Solar Cells Specification	7
2.2 Output Characteristics vs. Incident Solar Radiation	8
3. Solar Cell Battery Charger	9
3.1 Concept of Simulation PV Li-Ion Battery Charger Circuit	10
3.2 PV Li-Ion Battery Charger Circuit	11
3.3 Charging Time Characteristics vs. Weather Condition	12
3.4 Concept of Simulation PV Li-Ion Battery Charger Circuit + Constant Current	13
3.5 Constant Current PV Li-Ion Battery Charger Circuit	14
3.6 Charging Time Characteristics vs. Weather Condition + Constant Current	15
4. Simulation PV Li-Ion Battery System in 24hr.	
4.1 Concept of Simulation PV Li-Ion Battery System in 24hr	16
4.2 Short-Circuit Current vs. Time (24hr.)	17
4.3 PV-Battery System Simulation Circuit	18
4.3 PV-Battery System Simulation Result	19-23
Simulations index	24

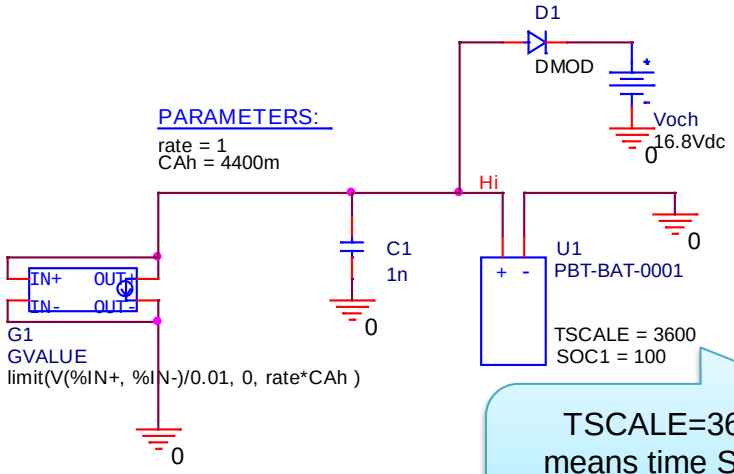
1.1 Lithium-Ion Batteries Pack Specification

BAYSUN's Lithium-Ion Batteries Pack : Power Battery Plus (PBT-BAT-0001)

- Capacity.....65[Wh], 4400[mAh] (Approximately)
- Rated Current.....3[A]
- Input Voltage.....20.5 [Vdc]
- Output Voltage.....12.8 ~ 16.4 [Vdc] (4 cells)
- Charging time.....5[hours] (Approximately)

1.2 Discharge Time Characteristics





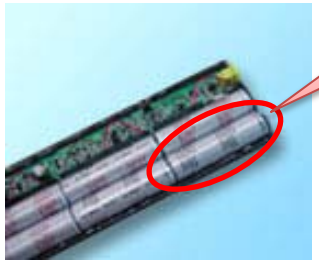
TSCALE=3600 means time Scale (Simulation time : Real time) is 1:3600

Batteries Pack Model Parameters

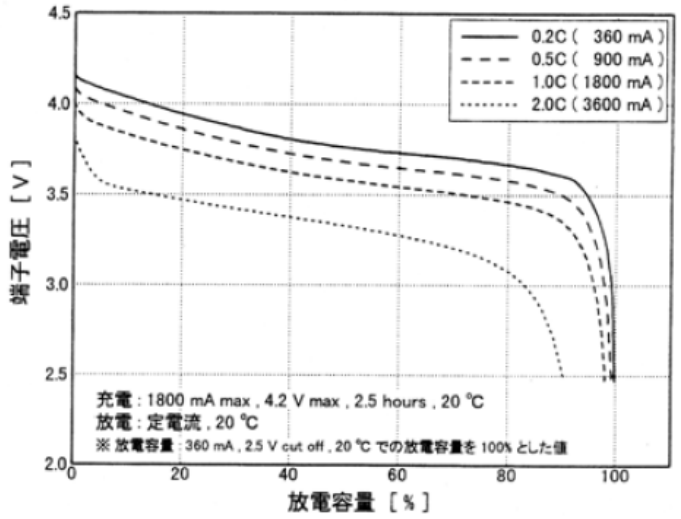
NS (number of batteries in series) = 4 cells
C (capacity) = 4400 mA
SOC1 (initial state of charge) = 100%
TSCALE (time scale) , simulation : real time
1 : 3600s or
1s : 1h

Discharge Rate : 0.2C(880mA), 0.5C(2200mA), and 1C(4400mA)

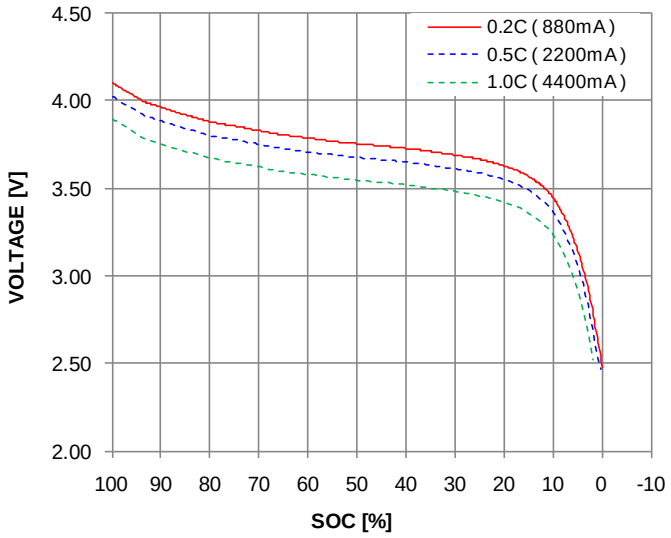
1.3 Single Cell Discharge Characteristics



Measurement

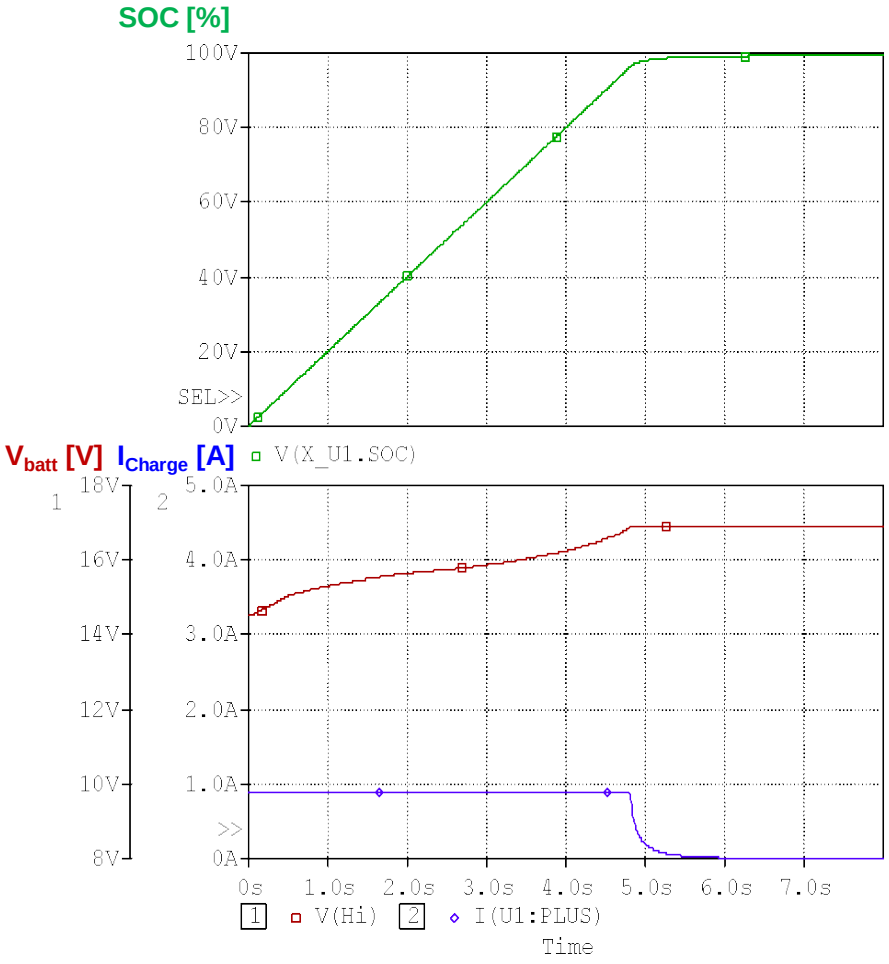


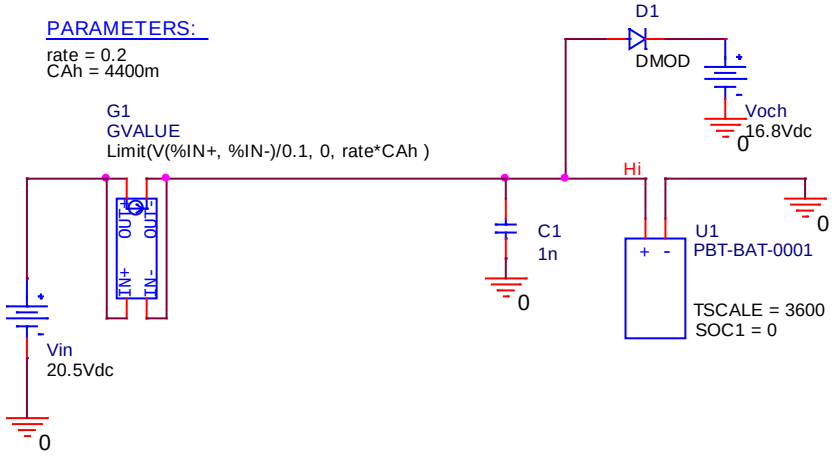
Simulation



- Single cell discharge characteristics are compared between measurement data and simulation data.

1.4 Charge Time Characteristics





Batteries Pack Model Parameters

NS (number of batteries in series) = 4 cells
C (capacity) = 4400 mA
SOC1 (initial state of charge) = 100%
TSCALE (time scale) , simulation : real time
1 : 3600s or
1s : 1h

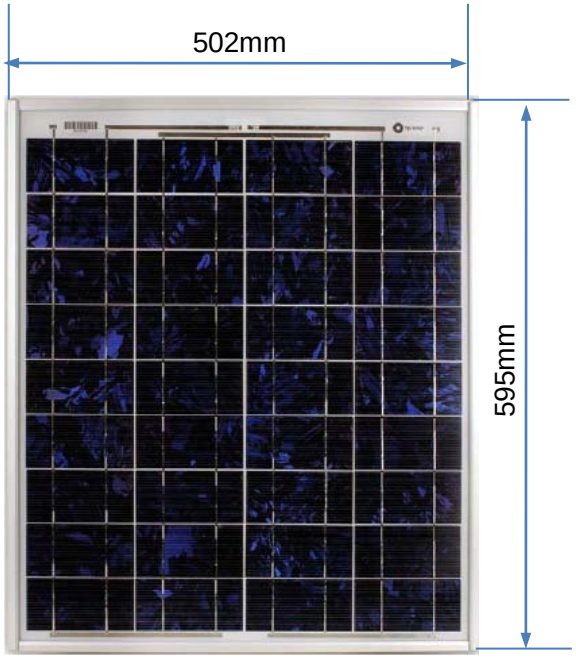
Charger Adaptor

Input Voltage = 20.5 Vdc
Input Current = 880 mA(max.)

2.1 Solar Cells Specification

BP Solar's photovoltaic module : SX330

- Maximum power (P_{max}).....30[W]
- Voltage at Pmax (V_{mp}).....16.8[V]
- Current at Pmax (I_{mp}).....1.78[A]
- Short-circuit current (I_{sc}).....1.94[A]
- Open-circuit voltage(V_{oc}).....21.0[V]

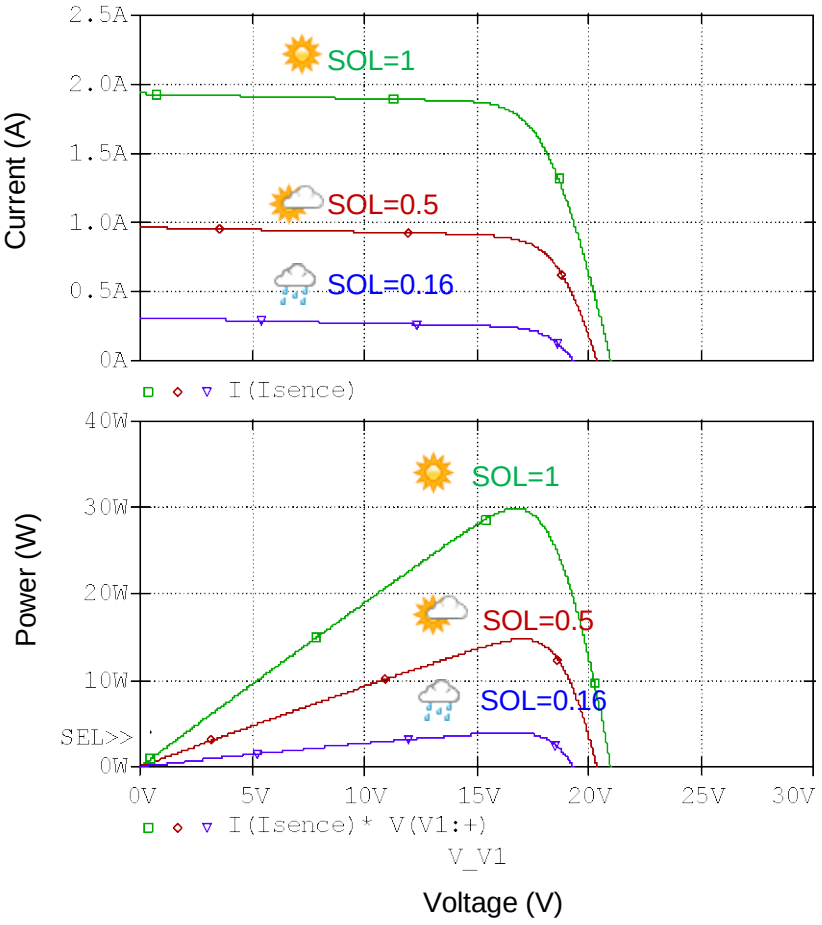


2.2 Output Characteristics vs. Incident Solar Radiation

U1
SX330
SOL = 1

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

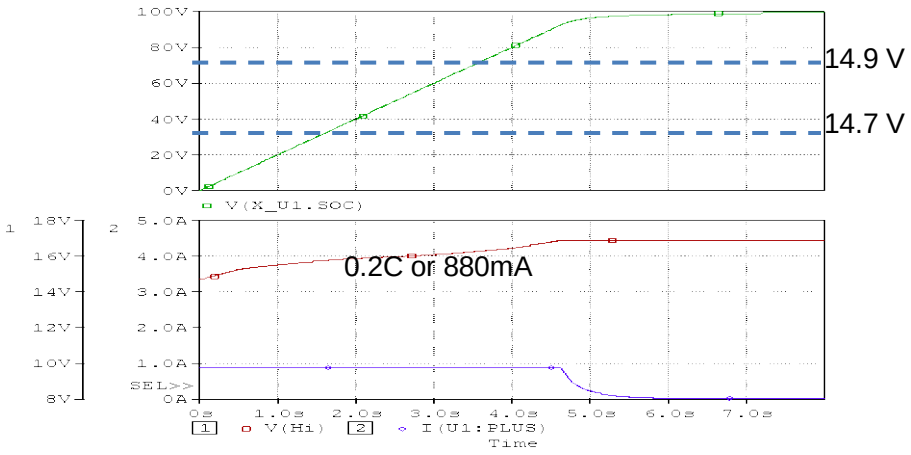
SX330 Output Characteristics vs. Incident Solar Radiation



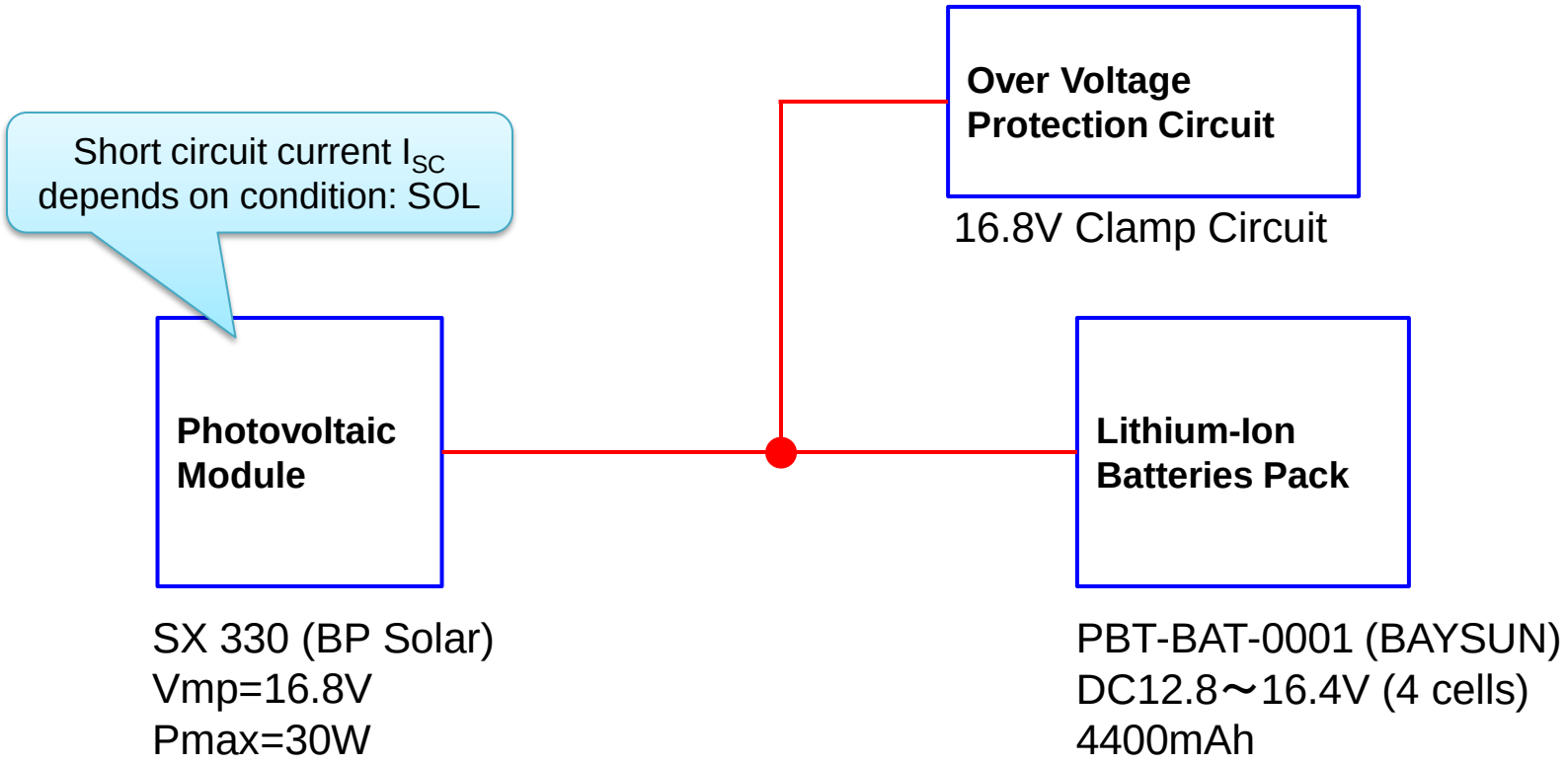
3. Solar Cell Battery Charger

- Solar Cell charges the Li-ion batteries pack (PBT-BAT-001) 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 batteries pack charging voltage.

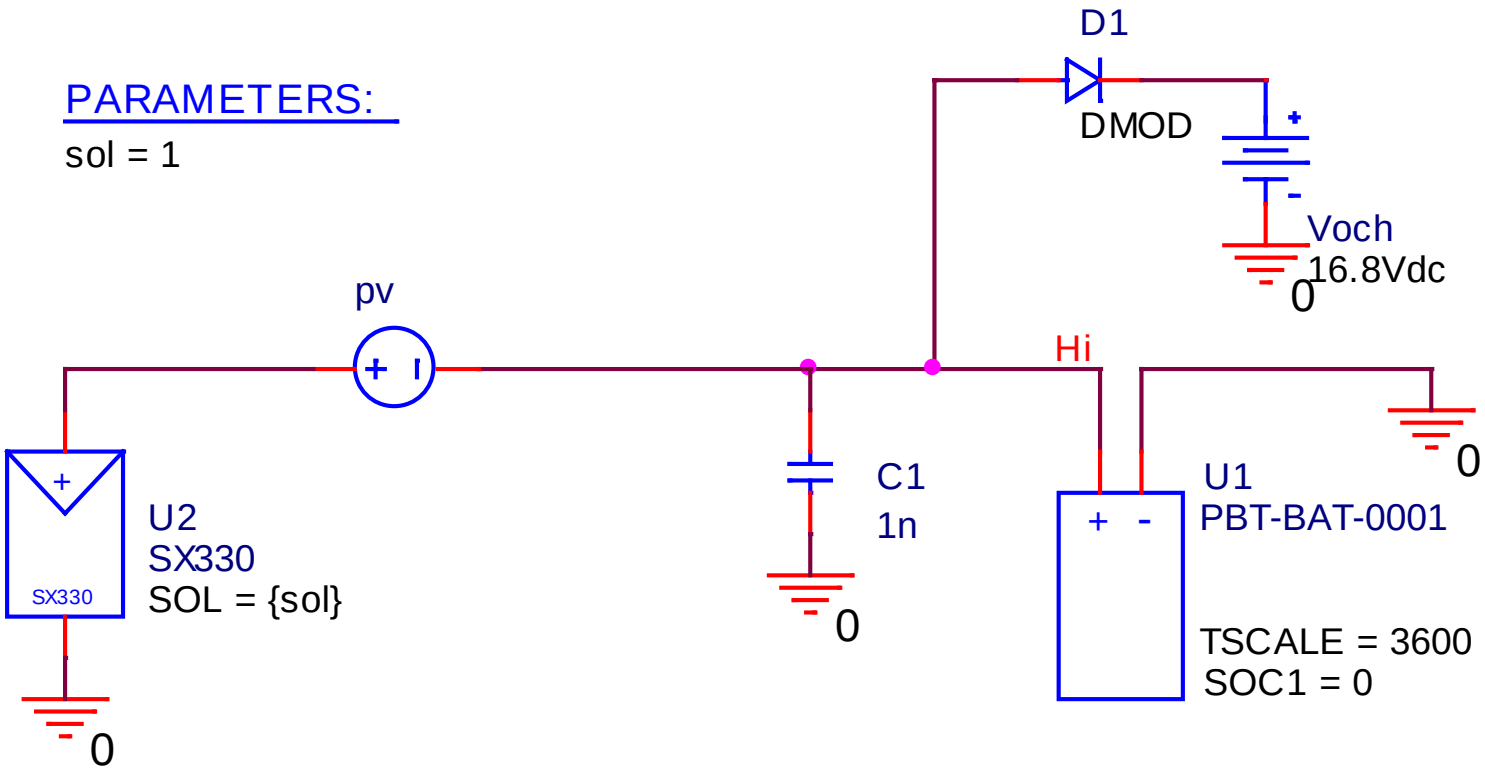
- <u>PBT-BAT-0001 (Li-ion batteries pack)</u>
  - Charging time is approximately 5 hours with charging rate 0.2C or 880mA
  - Voltage during charging with 0.2C is between 14.7 to 16.9 V



3.1 Concept of Simulation PV Li-Ion Battery Charger Circuit

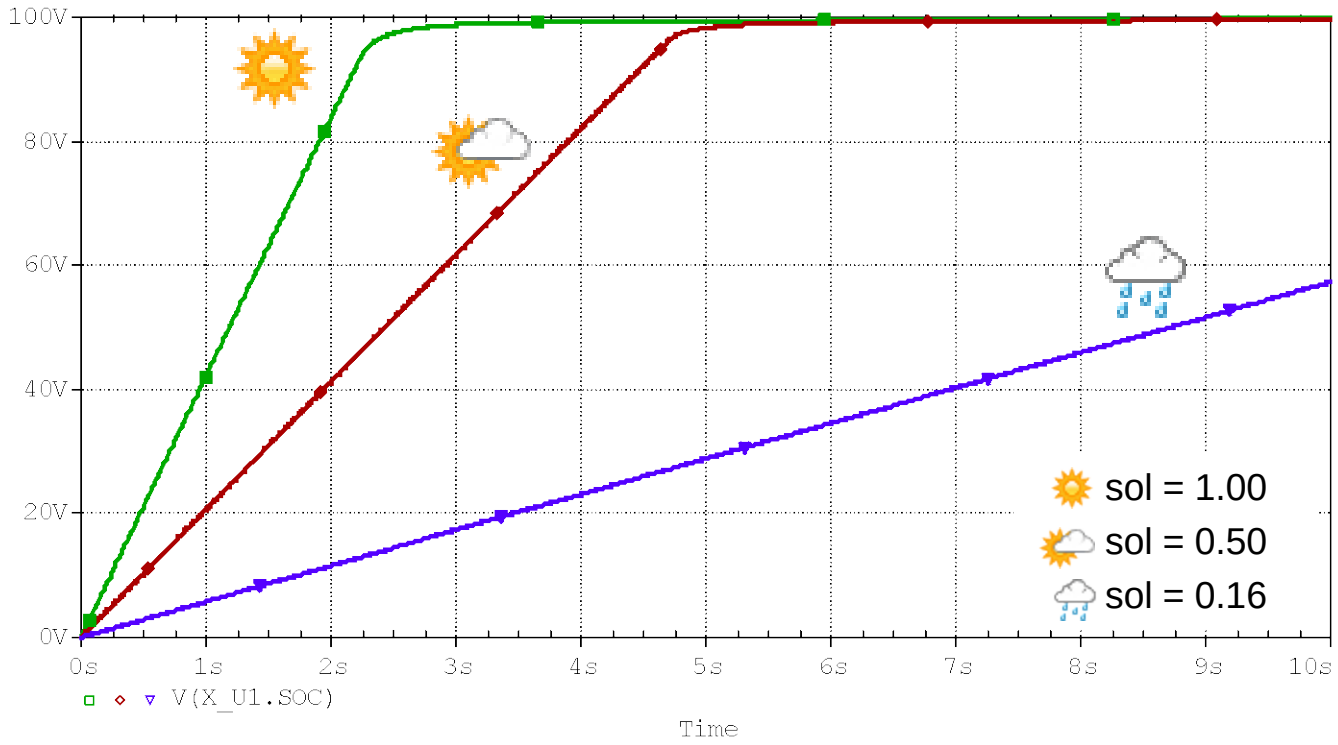


3.2 PV Li-Ion Battery Charger Circuit



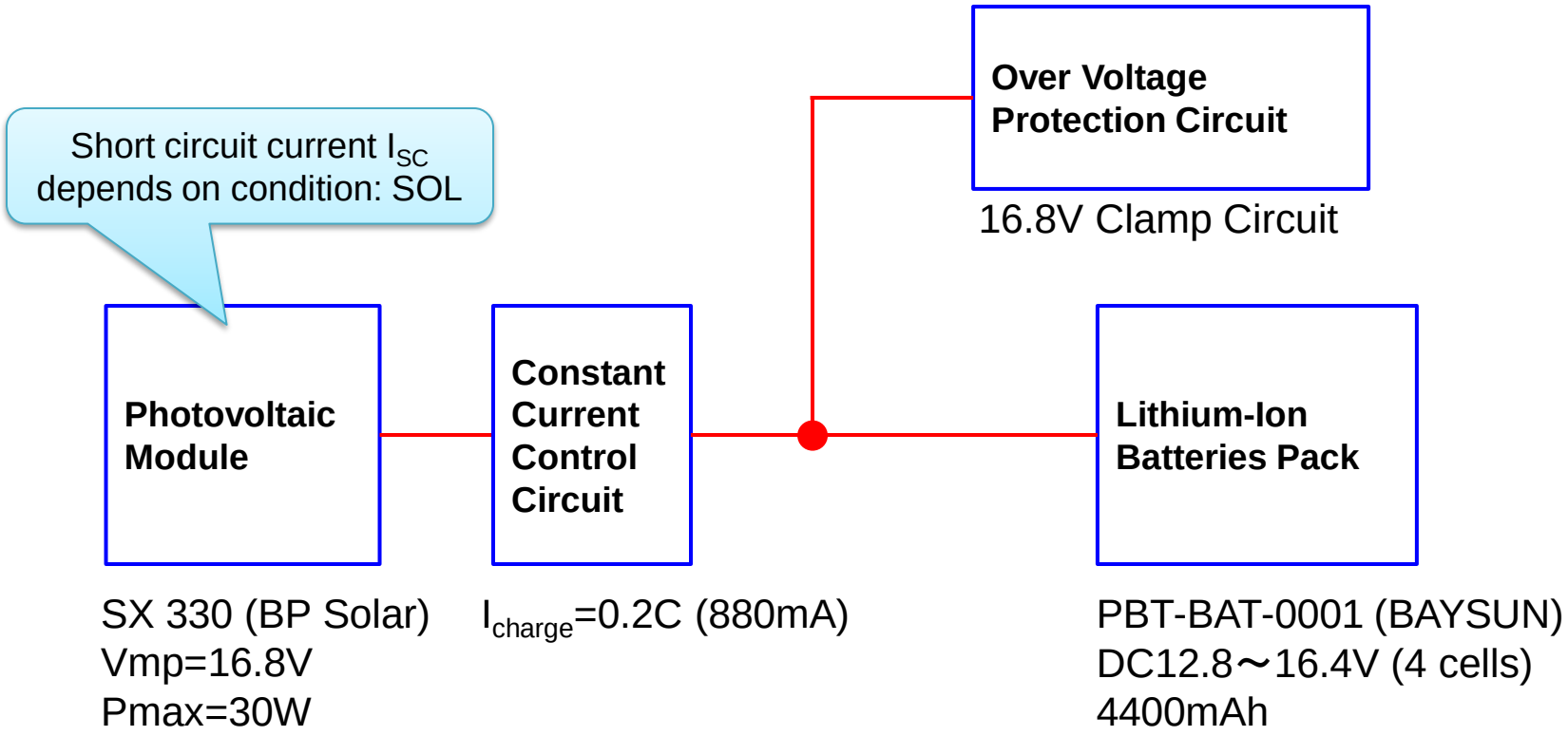
- Input value between 0-1 in the "PARAMETERS: sol = " to set the normalized incident radiation, where SOL=1 for AM1.5 conditions.

3.3 Charging Time Characteristics vs. Weather Condition

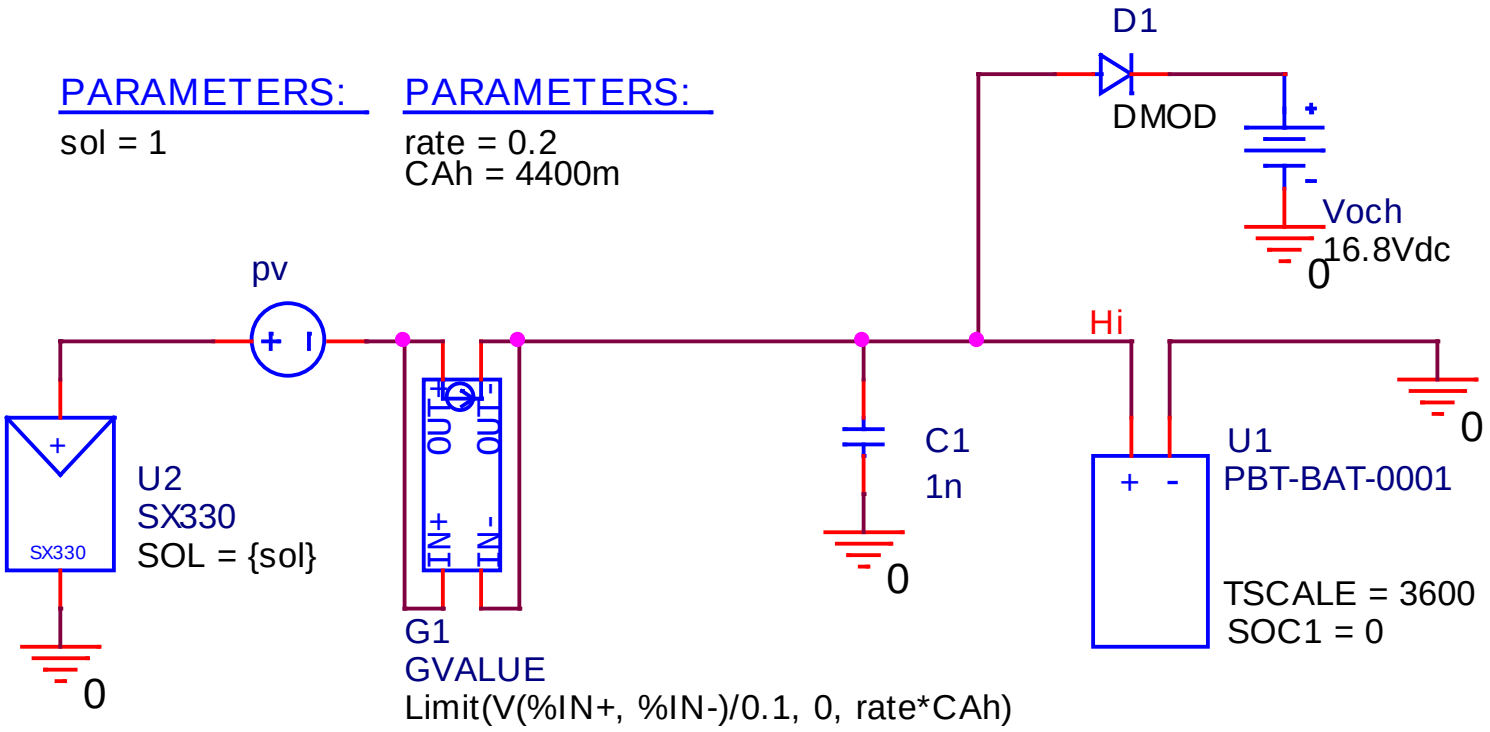


- Simulation result shows the charging time for sol = 1, 0.5, and 0.16.

3.4 Concept of Simulation PV Li-Ion Battery Charger Circuit + Constant Current

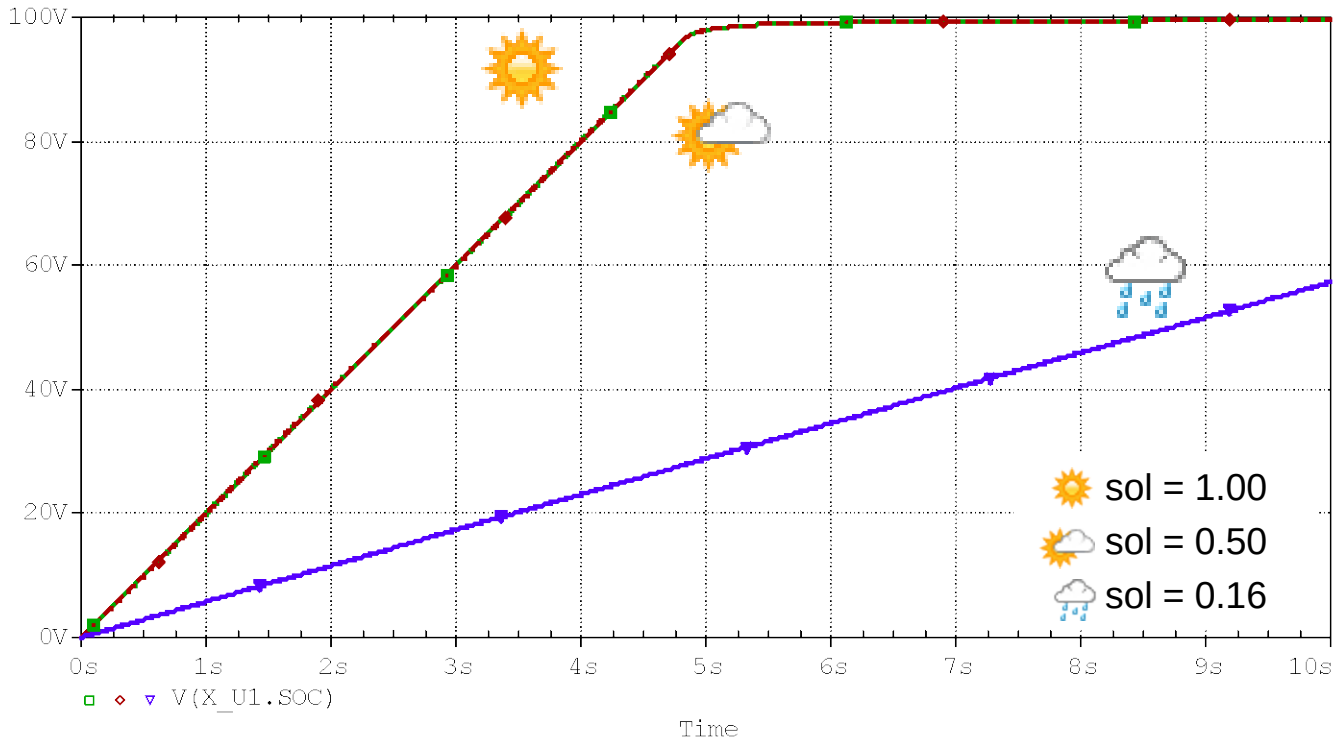


3.5 Constant Current PV Li-Ion Battery Charger Circuit



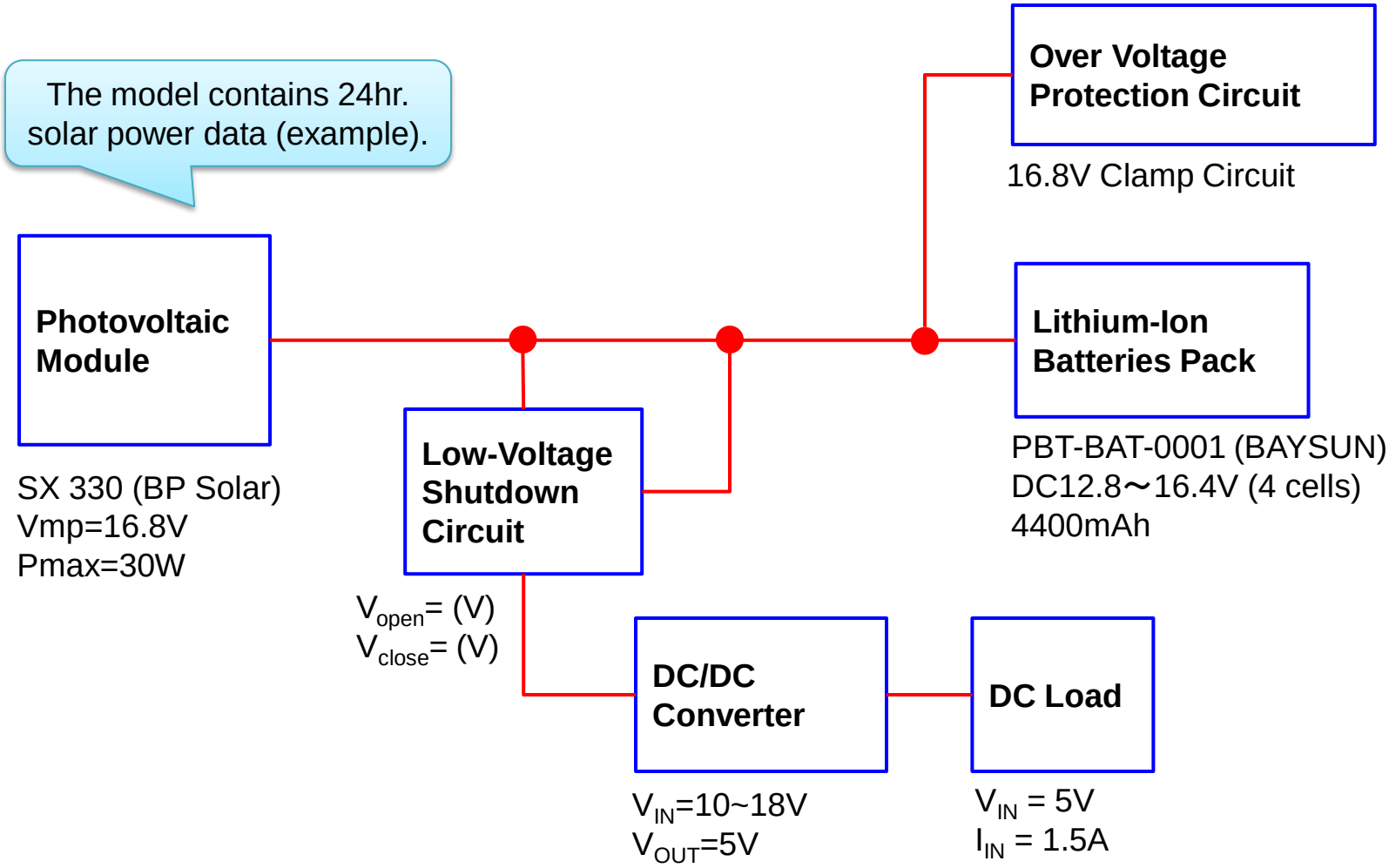
- Input the battery capacity (Ah) and charging current rate (e.g. 0.2*CAh) in the
- "PARAMETERS: CAh = 4400m and rate = 0.2 " to set the charging current.

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

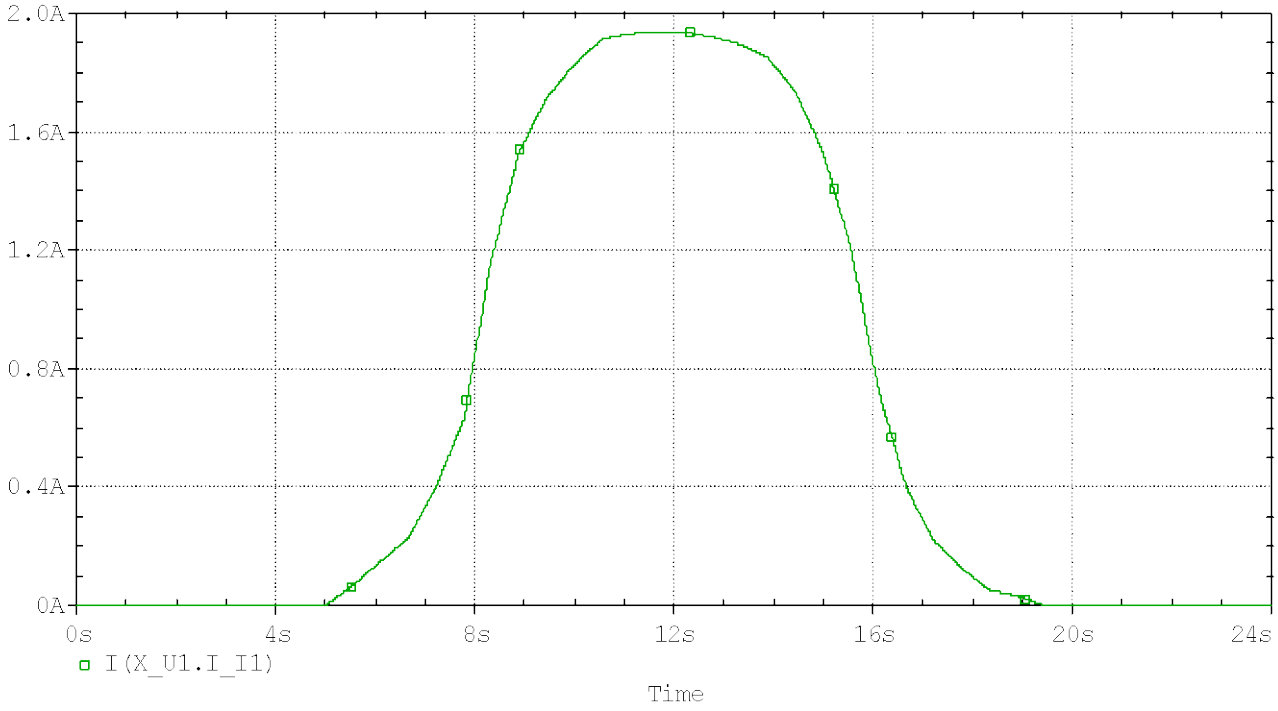


- Simulation result shows the charging time for sol = 1, 0.5, and 0.16. If PV can generate current more than the constant charge rate (0.2A), battery can be fully charged in about 5 hour.

4.1 Concept of Simulation PV Li-Ion Battery System in 24hr.



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

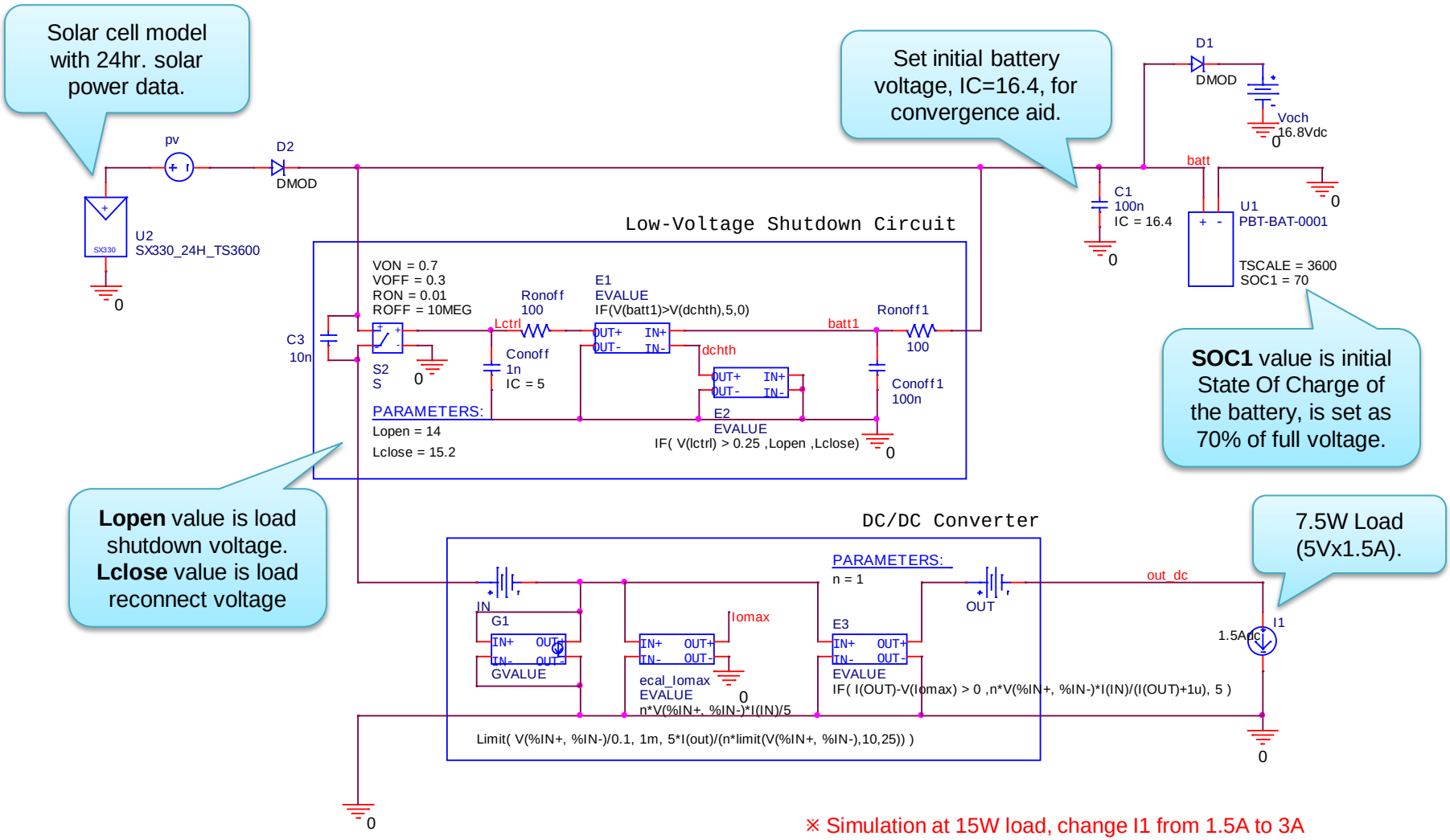


The model contains 24hr. solar power data (example).

U2
SX330_24H_TS3600

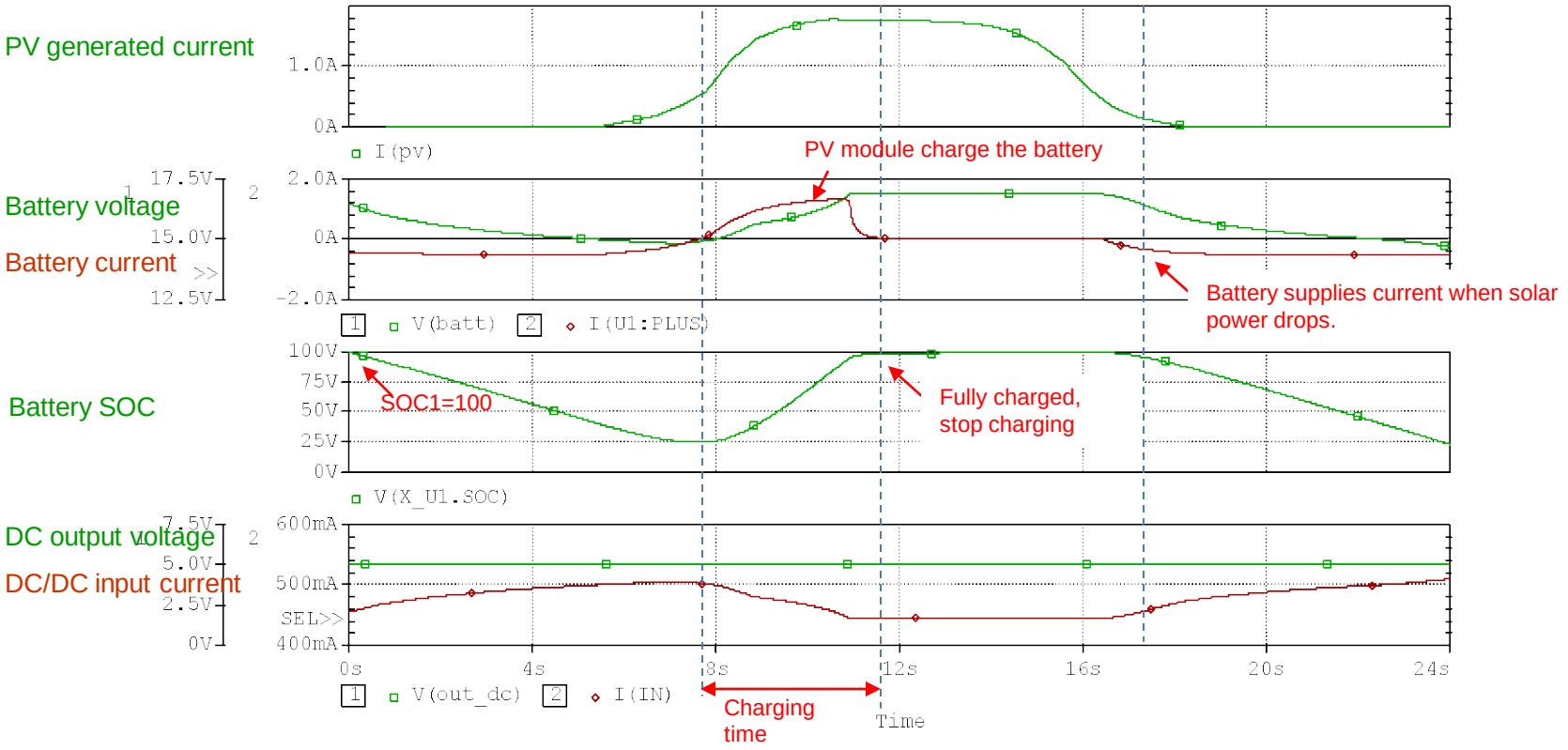
- Short-circuit current vs. time characteristics of photovoltaic module SX330 for 24hours as the solar power profile (example) is included to the model.

4.3 PV-Battery System Simulation Circuit



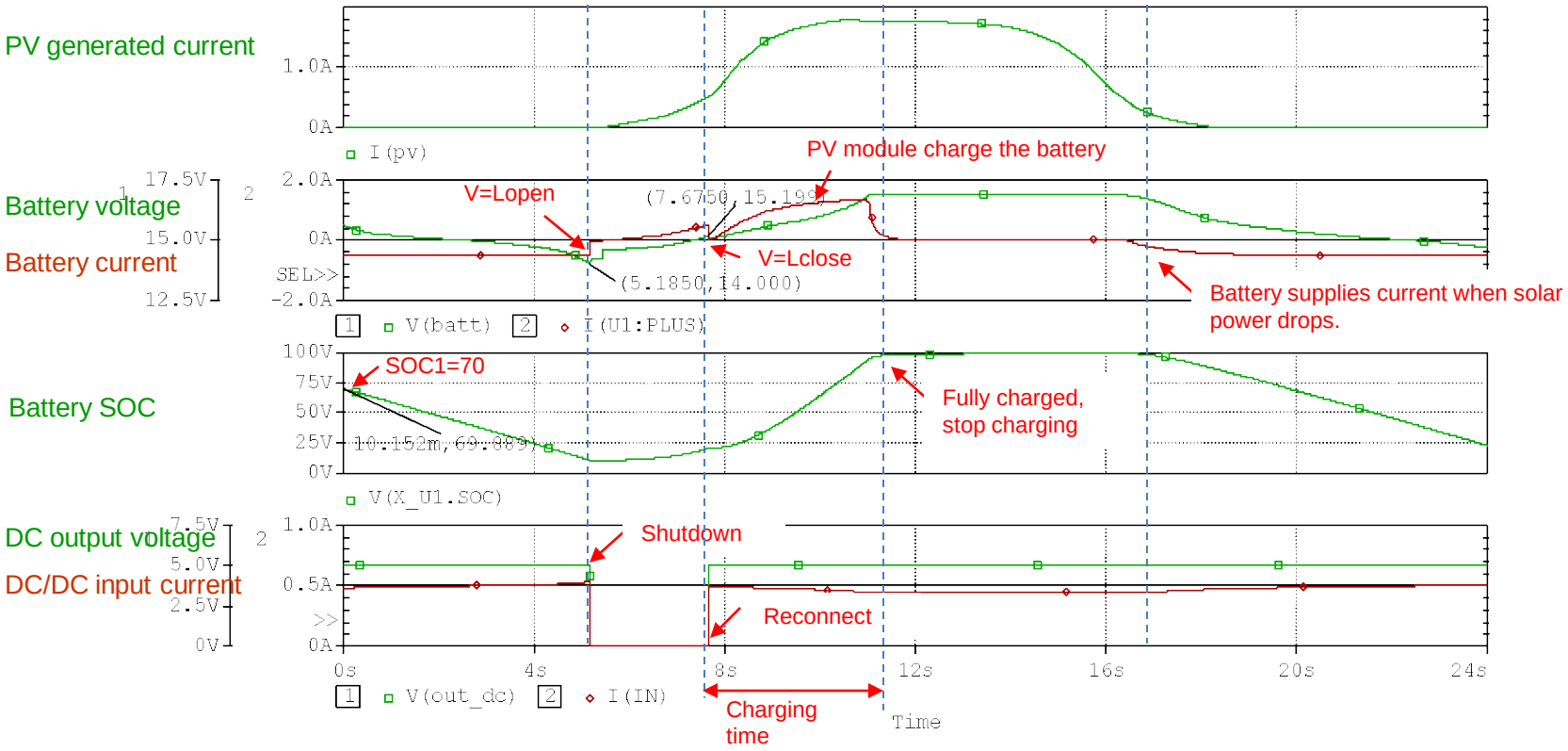
※ Simulation at 15W load, change I1 from 1.5A to 3A

4.3.1 Simulation Result (SOC1=100)



- C1: IC=16.4
- Run to time: 24s (24hours in real world)
- Step size: 0.01s
- .Options ITL4=1000

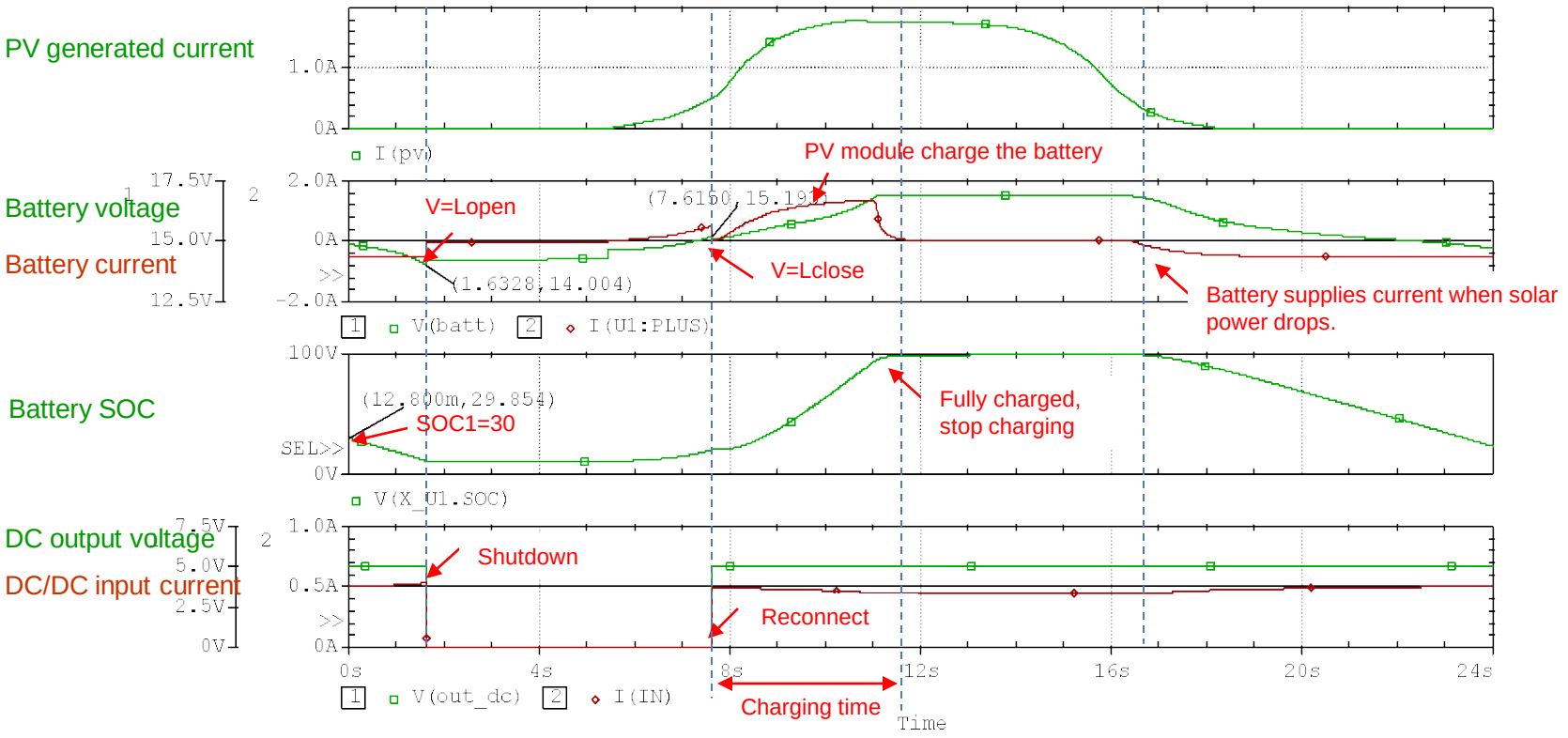
4.3.2 Simulation Result (SOC1=70)



- C1: IC=16.4
- Run to time: 24s (24hours in real world)
- Step size: 0.01s
- SKIPBP

- .Options ITL4=1000

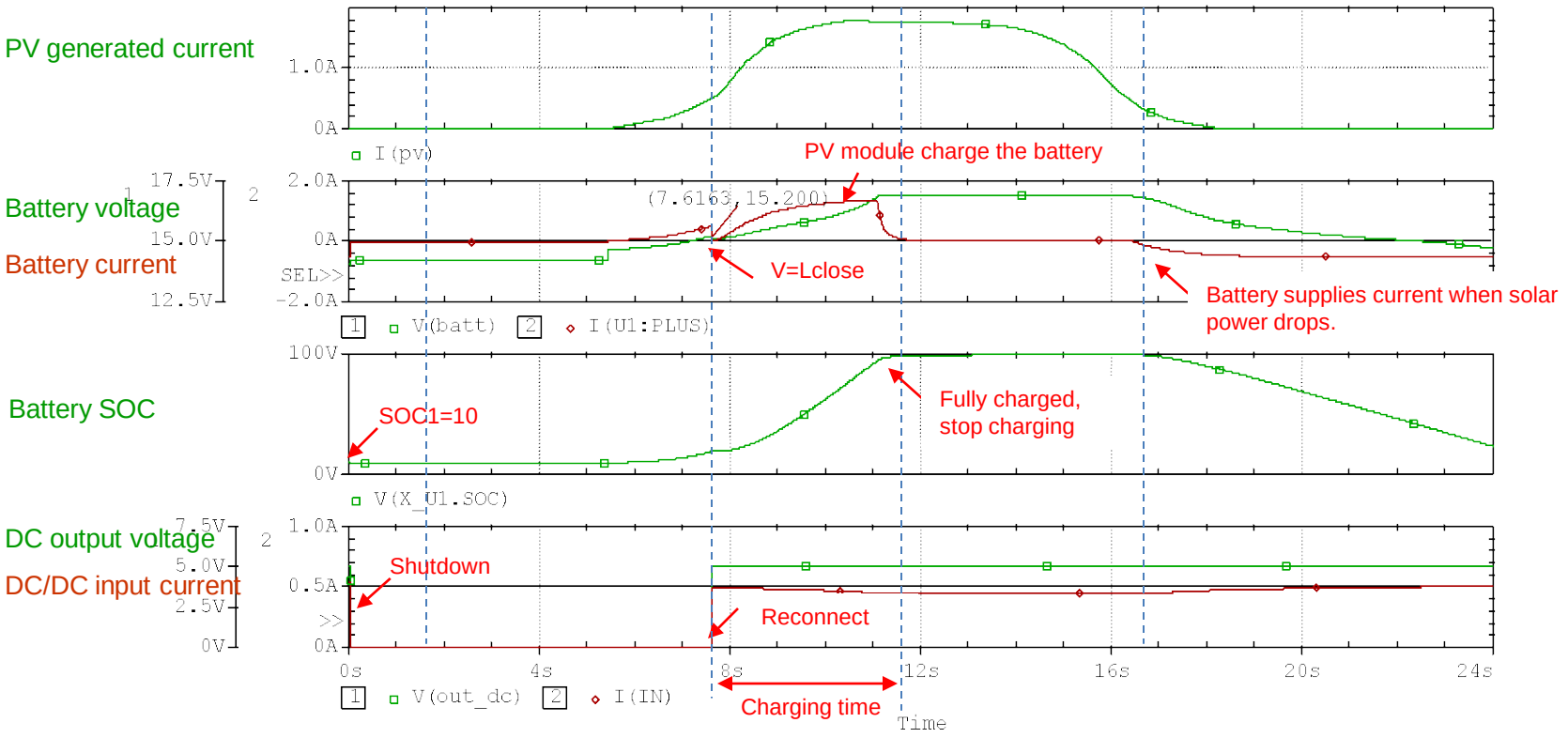
4.3.3 Simulation Result (SOC1=30)



- C1: IC=15
- Run to time: 24s (24hours in real world)
- Step size: 0.01s
- Total job time = 2s

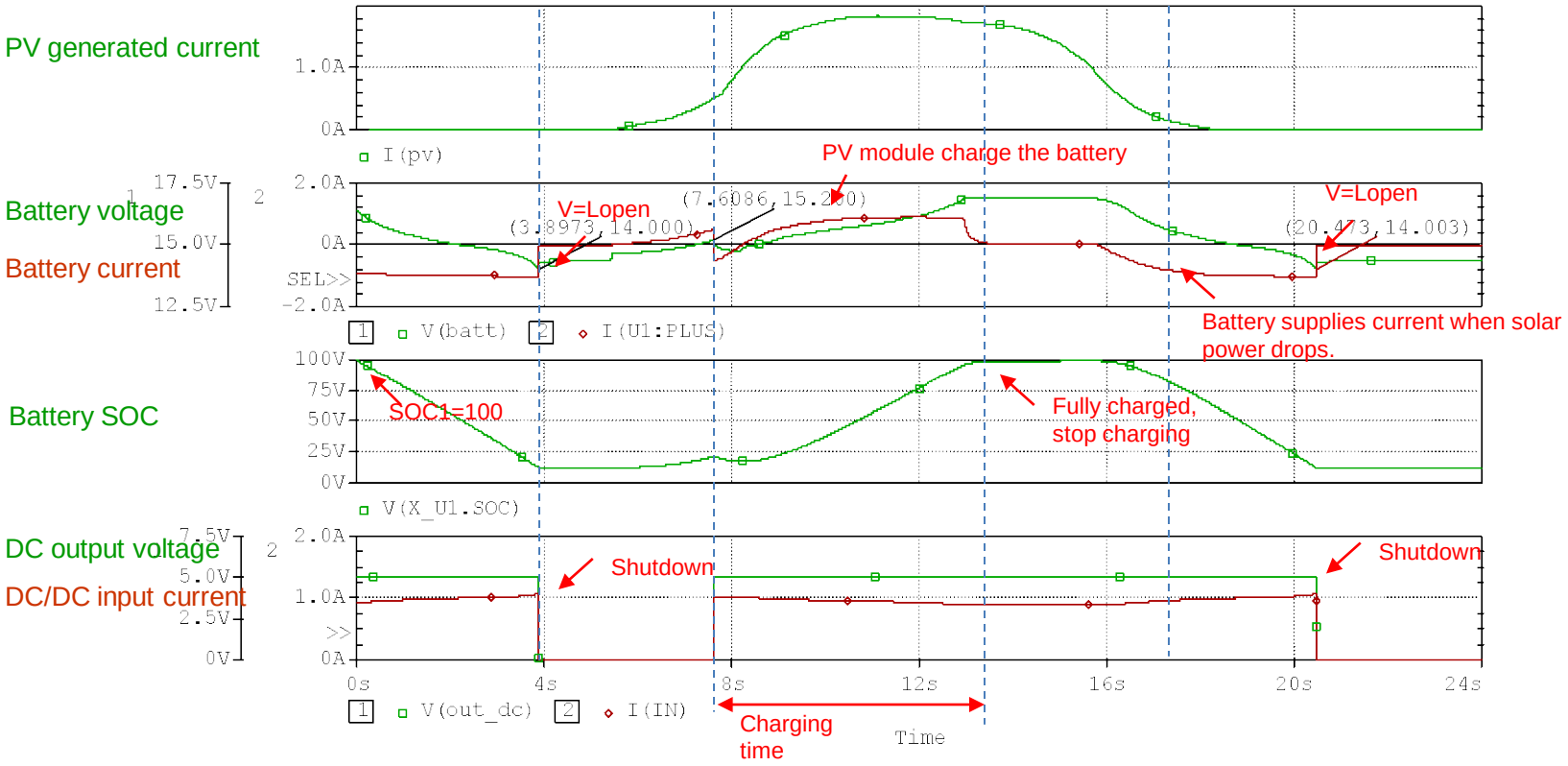
- .Options ITL4=1000

4.3.4 Simulation Result (SOC1=10)



- C1: IC=14.4
- Run to time: 24s (24hours in real world)
- Step size: 0.01s
- SKIPBP
- .Options RELTOL=0.01
- .Options ITL4=1000

4.3.5 Simulation Result (SOC1=100, IL=3A or 15W load)



- C1: IC=16.4
- Run to time: 24s (24hours in real world)
- Step size: 0.001s
- .Options ITL4=1000

4.3.4 Simulation Result (Example of Conclusion)

The simulation start from midnight(time=0). The system supplies DC load 7.5W.

- If initial SOC is 100%,
  - this system will never shutdown.
- If initial SOC is 70%,
  - this system will shutdown after 5.185 hours (about 5:11AM.).
  - system load will reconnect again at 7:40AM (Morning).
- If initial SOC is 30%,
  - this system will shutdown after 1.633 hours (about 1:38AM.).
  - system load will reconnect again at 7:37AM (Morning).
- If initial SOC is 10%,
  - this system will start shutdown.
  - this system will reconnect again at 7:37AM (Morning).
- With the PV generated current profile, battery will fully charged in about 4.25 hours.

The simulation start from midnight(time=0). The system supplies DC load 15W.

- If initial SOC is 100%,
  - this system will shutdown after 3.897 hours (about 3:54AM.).
  - system load will reconnect again at 7:37AM (Morning).
  - this system will shutdown again at 8:28 PM (Night).
- With the PV generated current profile, battery will fully charged in about 5.5 hours.

Simulations index

Simulations	Folder name
1. PV Li-Ion Battery Charger Circuit.....	charge-sol
2. Constant Current PV Li-Ion Battery Charger Circuit.....	charge-sol-const
3. PV-Battery System Simulation Circuit (SOC1=100).....	sol_24h_soc100
4. PV-Battery System Simulation Circuit (SOC1=70).....	sol_24h_soc70
5. PV-Battery System Simulation Circuit (SOC1=30).....	sol_24h_soc30
6. PV-Battery System Simulation Circuit (SOC1=10).....	sol_24h_soc10
7. PV-Battery System Simulation Circuit (SOC1=100, 15W).....	sol_24h_soc100_15W