Electronics Sector Skill Council

Scaling Solar Skills

Ashwini K Aggarwal, *PhD, FIETE, Certified NABCEP PV Associate*

Director-Government Affairs; Co-Chair Solar & LED NOS committee

Jun 2020

Nov'20: SPV Design Workshop Agenda

Date	Time	Session Name	Speaker/ Master Trainer	Detailed Agenda
7-Nov-20	11:00 AM - 11:10 AM	Inaugration Session	Mr. PVG Menon, CEO ESSCI	1. Introduction to The Solar Labs design platform 2. Presentation on software features 3. Case Study 4. Demo of Online Course developed by The Solar Labs & Enrollment
	11:10 AM - 11:20 AM	About the Program	Dr. Ashwini Aggarwal, SME & Chair Solar Skills NOS Committee, ESSCI and Director-GA, Applied Materials	
	Beyond 11:20 AM	Training Start	Mr. Rachit, The Solar Labs	
8-Nov-20		Online Solar PV Design Course	self practise	The trainee is expected to complete the online course on Solar PV Design in preparation for Day 3.
10-Nov-20	11 AM - 1 PM	Detailed Site Design, Solar Access, Shading and Loss Calculations	Mr. Rachit, The Solar Labs	1. Detailed Site Design 2. Walkthrough of 1 complex RCC Site design of 400 kW 3. Presentation on Solar Access, Shading & Loss calculations
17-Nov-20	11 AM - 1 PM	Manual SPV Design of Solar PV on-grid, off-grid and hybrid sites/ A quick view of PV Syst; Sketchup Skelion and Helioscope	Dr.Ashwini Aggarwal	1. Design Checking & Doubt Clearing Session 2. Diagnosis of created sites with trainer
	01 PM - 01:15 PM	Wrap Up Session	Mr. Devraj Singh	

Overview of other SPV Design software

- PV Syst

https://www.youtube.com/watch?v=_aQ-E8KRIps

- Earliest software; standard for most utility design- lacks good CAD capabilities, limited shading and heat-access maps

- Sketchup with Skellion

https://www.youtube.com/watch?v=Oqb_3djwj0c

- Excellent CAD features for site design but -Lacks detailed generation; loss analytics-normally complements PV Syst

- Helioscope

https://www.youtube.com/watch?v=D4fHHMeBDDU

- Very Efficient Cloud software that delivers quite practical SPV designs with essential RT SPV CAD design, generation-loss analysis, shading and heat-access maps with BOM

Solar PV System Design

Basics of Design for Residential spaces

Ashwini K Aggarwal, *PhD, FIETE, Certified NABCEP PV Associate*

Director-Government Affairs; Co-Chair Solar & LED NOS committee

Designing Solar PV Systems

Understanding Solar Energy Potential…

Solar Power

At the Earth's surface, the solar energy density is approximately 1,000 W/m^2 for a surface perpendicular to the Sun's rays at sea level on a clear day. [Source: Sunlight: Composition and Power - Wikipedia]

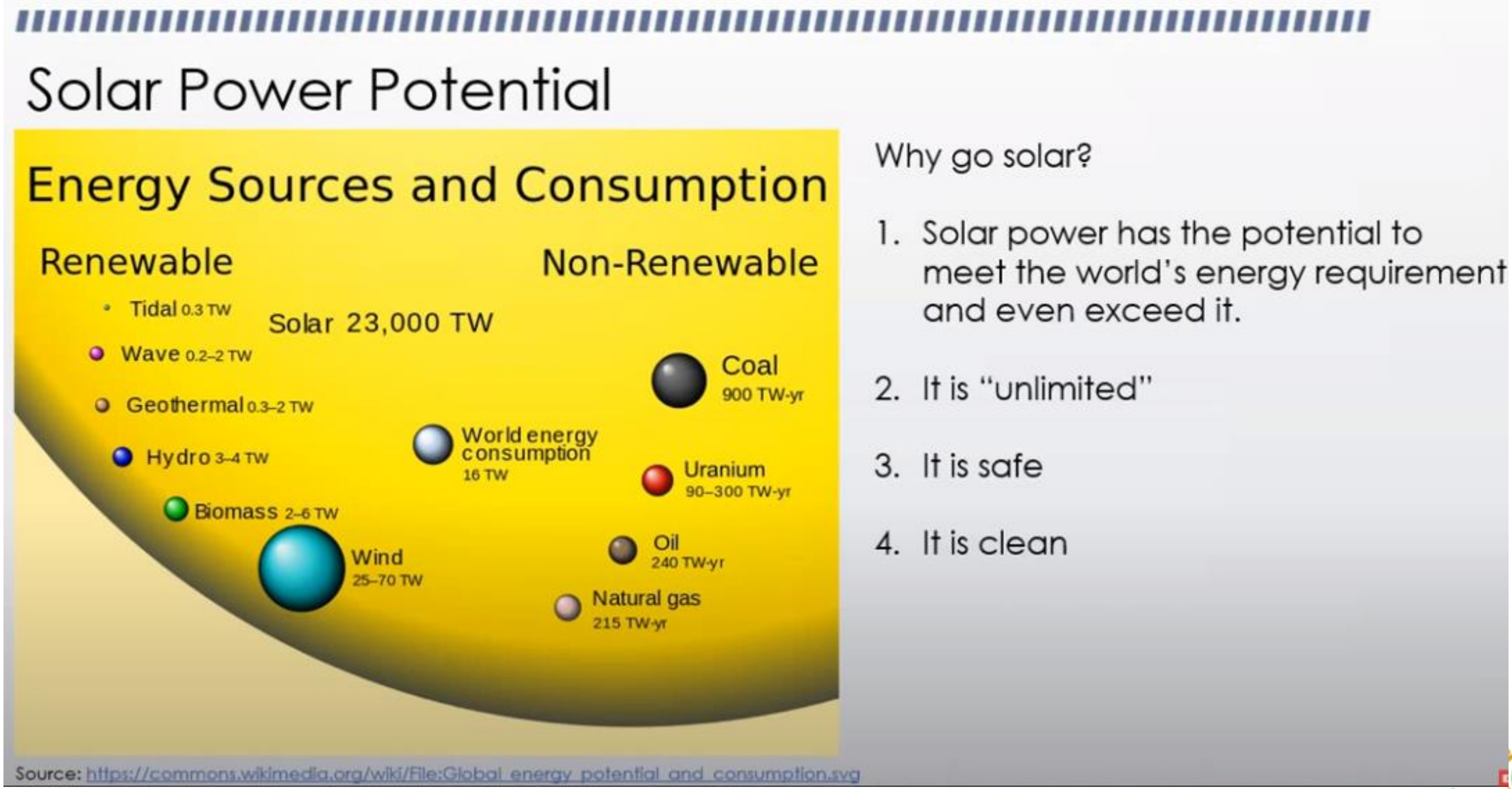
Example: A 50 m^2 roof area receives about 200,000 watts (200kW) of energy for 4 hours of sun. ***

1,000 W/m^2 x 50 m^2 x 4 hours = **200,000 Watts (200kW)**

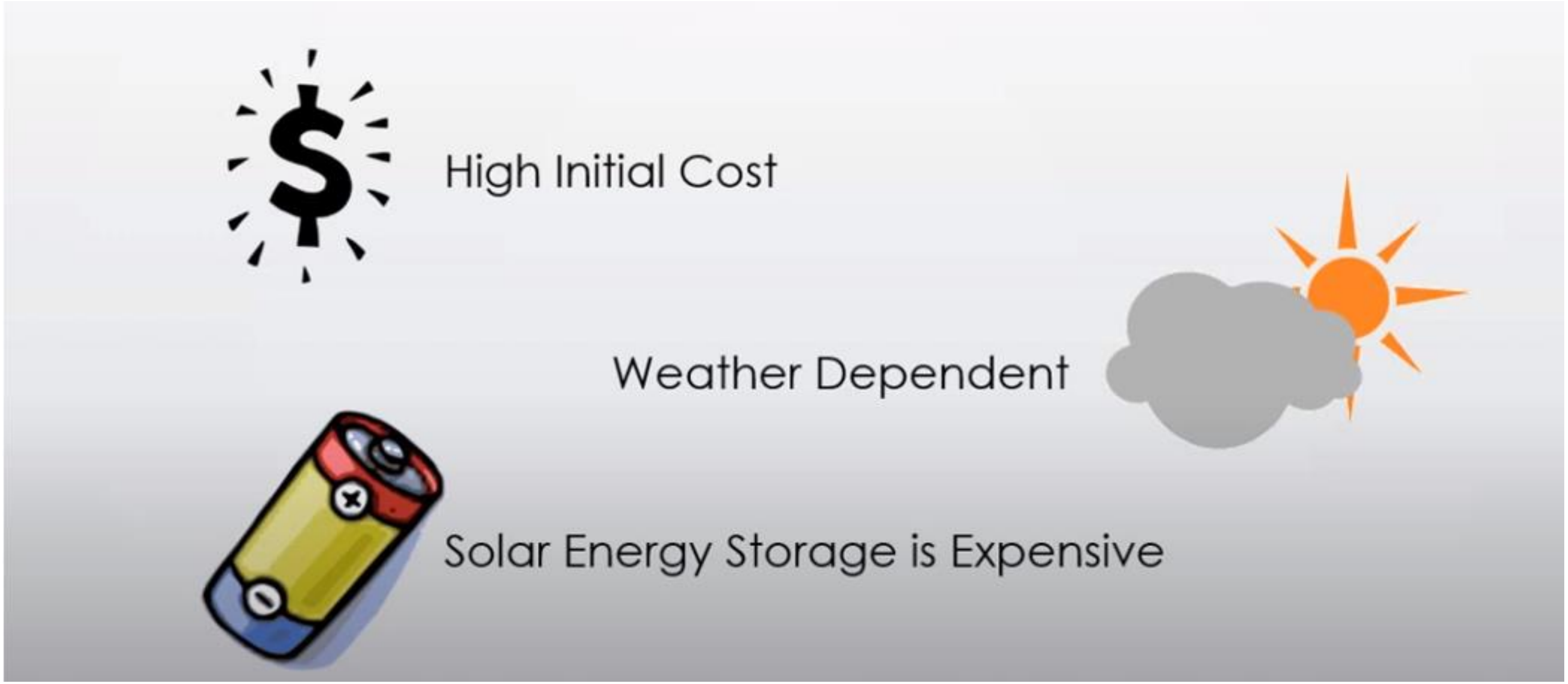
Conversion efficiency of solar energy to electrical energy not factored in.

ESCI

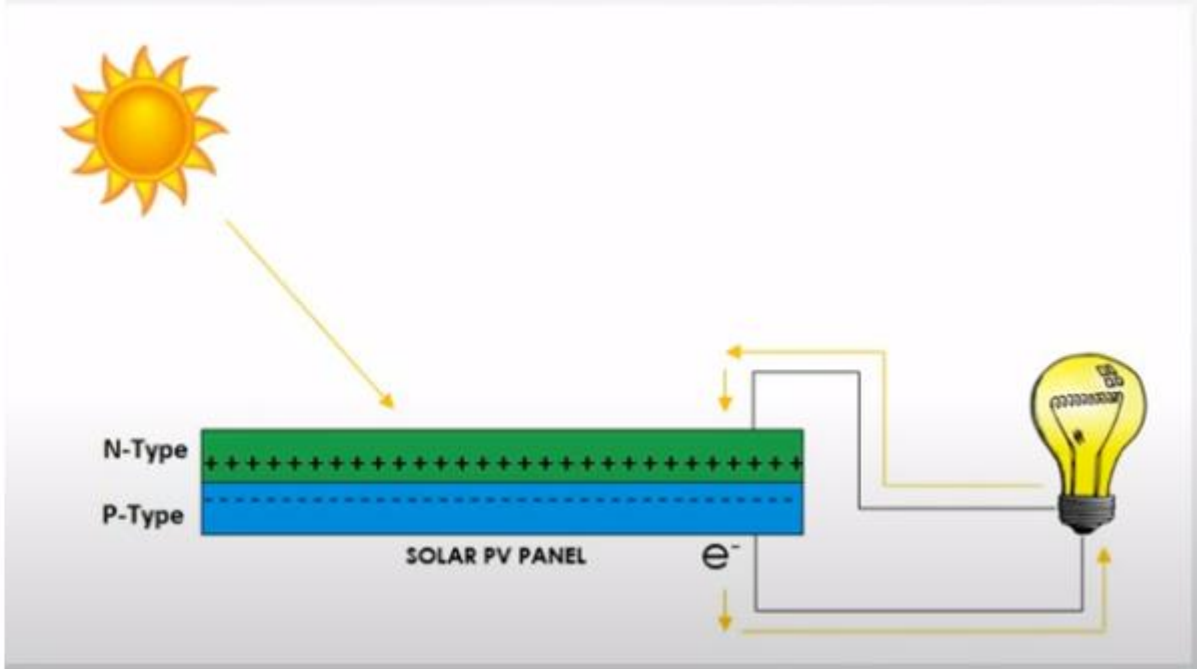
Understanding the solar energy potential…



Disadvantages of using Solar



How do solar panels convert solar energy to electrical energy?



A Solar Panel is an assembly of photovoltaic cells that converts solar energy to electrical energy.

When a photon of sunlight knocks an electron free, the electric field will push that electron out of the silicon junction – current flows!

Types of Solar PV Panels (cSi , thin films…)

Monocrystalline	Polycrystalline
Made from single crystal silicon	Made from silicon fragments melted together
Darker Color (Black)	Lighter Color (Bluish)
Efficiency is in the range of 15% to 20%	Efficiency is between 14% to 16%
Longer Life Span (~ 25 years) ***	Shorter Life Span ***
Expensive	Cheaper

*** Solar PV panels can still work (with degraded efficiency) beyond their expected lifespans. Efficiency ~ 80%

Balance of System (the other equipments)

Part 1. Introduction to Solar Power System

Part 2. Different Type of Solar Power Set-ups (On-Grid, Off-Grid, and Hybrid)

Part 3. On-Grid System Design and Calculations

Part 4. Off-Grid System Design and Calculations

Part 5. Hybrid System Design and Calculations

SOLAR POWER SYSTEM

Basic Design and Calculations for Residential Spaces

Part 2 of 5 – **SOLAR POWER SYSTEM SET-UPS**

SPV Configurations

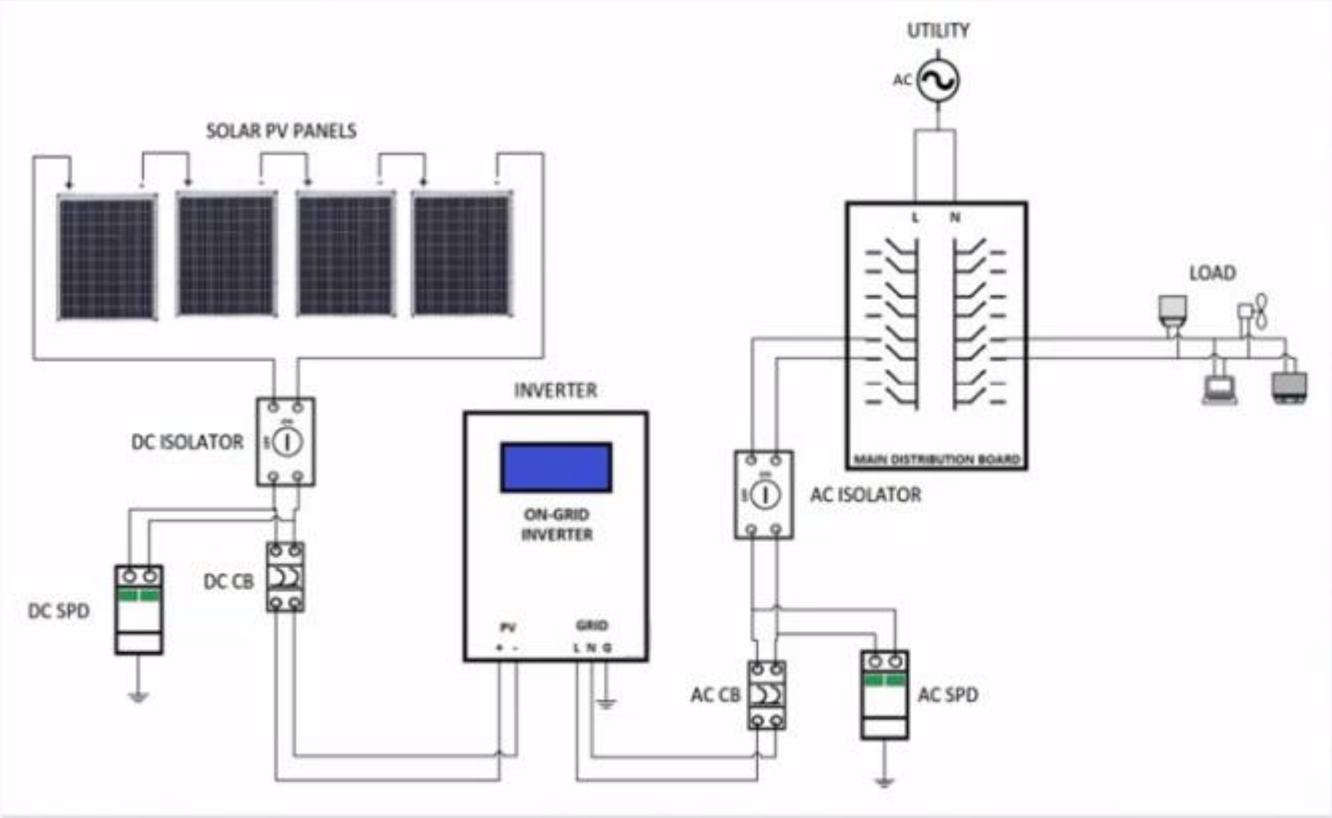
- **On-Grid/Grid-Tie** – Most common type of solar power system set-up due to its simplicity, lowest initial investment cost, and fastest ROI. This system does not need a battery bank and is connected to the electricity grid. On-Grid system allows the export of excess generated power back to the grid and is paid back in tariff by the electric company, this is called "Net-Metering". The Net-Metering should be applied with you electric provider.

- **Off-Grid** – This is commonly installed in remote areas where there is no electricity grid. This set-up requires a battery bank to store the harvested energy for use during the night or cloudy days.

- **Hybrid** – This set-up is the combination of both the On-Grid and Off-Grid configurations. The system is connected to the electricity grid but it also has a battery bank for energy storage.

SPV On-Grid / Grid Tie System

ON-GRID SYSTEM



PROS

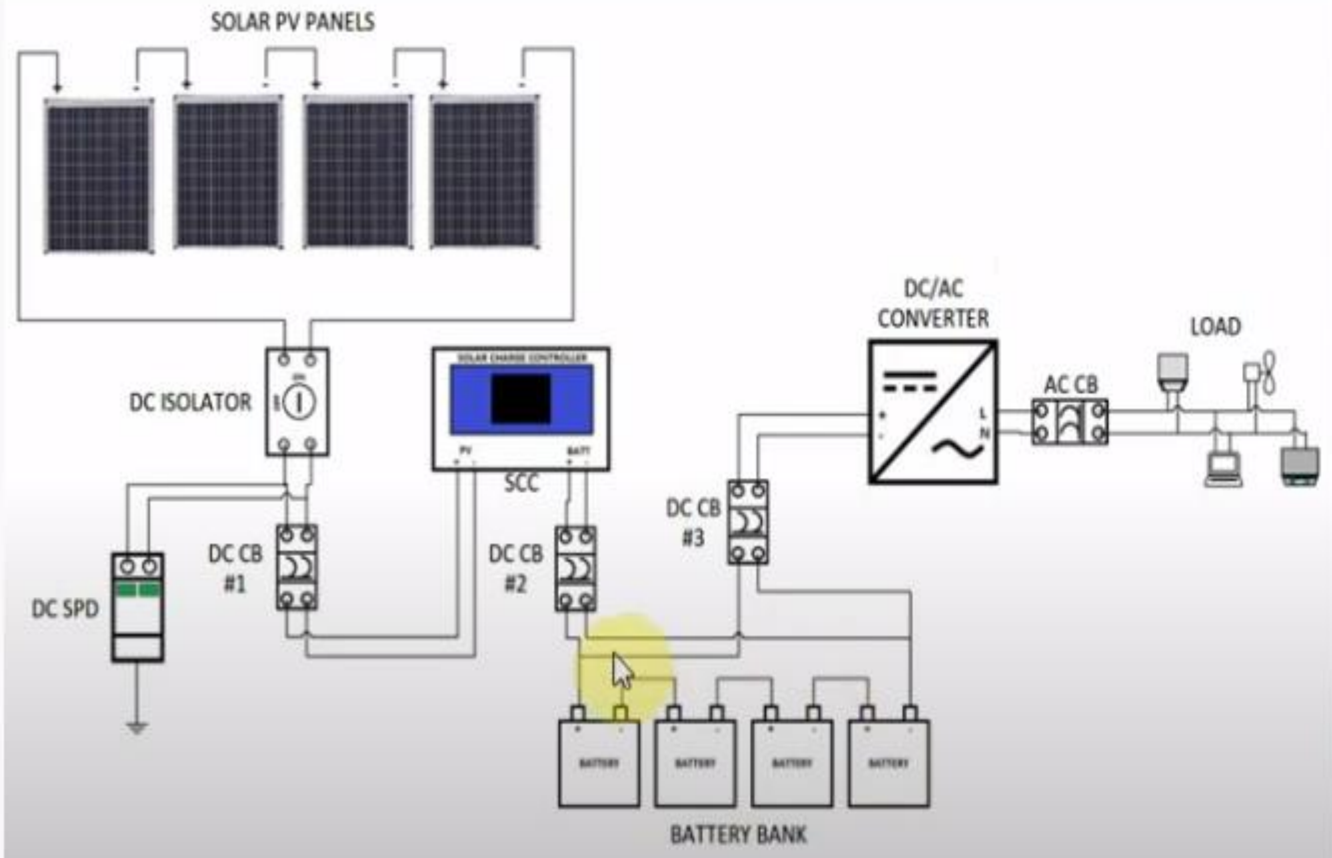
1. As mentioned, the On-Grid system is still connected to the electric grid.
2. It is the cheapest set-up as it only constitutes two (2) main equipment: Solar Panels and Inverter.
3. Energy demand will be complemented by the electric grid.
4. Excess electricity can be exported back to the grid and will be credited for faster ROI.

CONS

1. On-Grid Solar Power Systems are not able to function during blackouts for safety reasons.

SPV Off-grid System

OFF-GRID SYSTEM



PROS

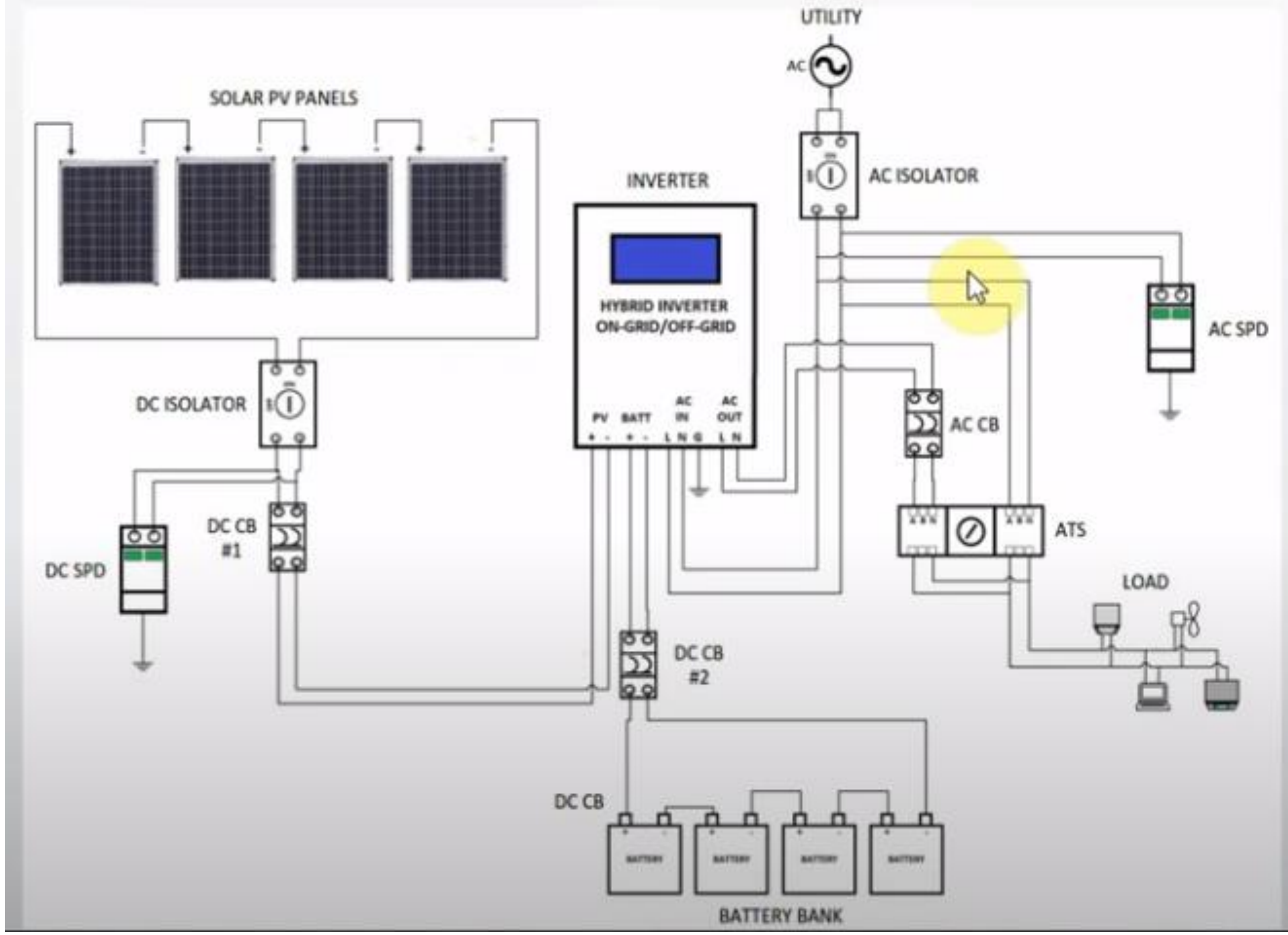
1. A properly designed Off-Grid system can provide electricity for 24/7.
2. Can provide electricity in remote areas.
3. Totally independent of the grid.

CONS

1. Consists of four (4) major components: Solar Panels, Solar Charge Controller (SCC), Battery Bank, and DC to AC Inverter.
2. Requires battery for storage.
3. High cost for batteries.
4. Batteries have short life spans (3-5 years).

SPV Hybrid Systems

HYBRID SYSTEM



PROS

1. During the day, the solar power will provide electricity to the load and at the same time charge the batteries.
2. At night, the batteries will provide power to the load.
3. Energy demand can be complemented by the electric grid.
4. Excess power generated by the solar panels can be exported back to the grid.

CONS

1. Consists of four (4) major components: Solar Panels, Inverter, Battery Bank, and Automatic Transfer Switch (ATS)
2. Requires battery for storage.
3. High cost for batteries.
4. Batteries have short life spans (3-5 years).

Part 1. Introduction to Solar Power System

Part 2. Different Type of Solar Power Set-ups (On-Grid, Off-Grid, and Hybrid)

Part 3. On-Grid System Design and Calculations

Part 4. Off-Grid System Design and Calculations

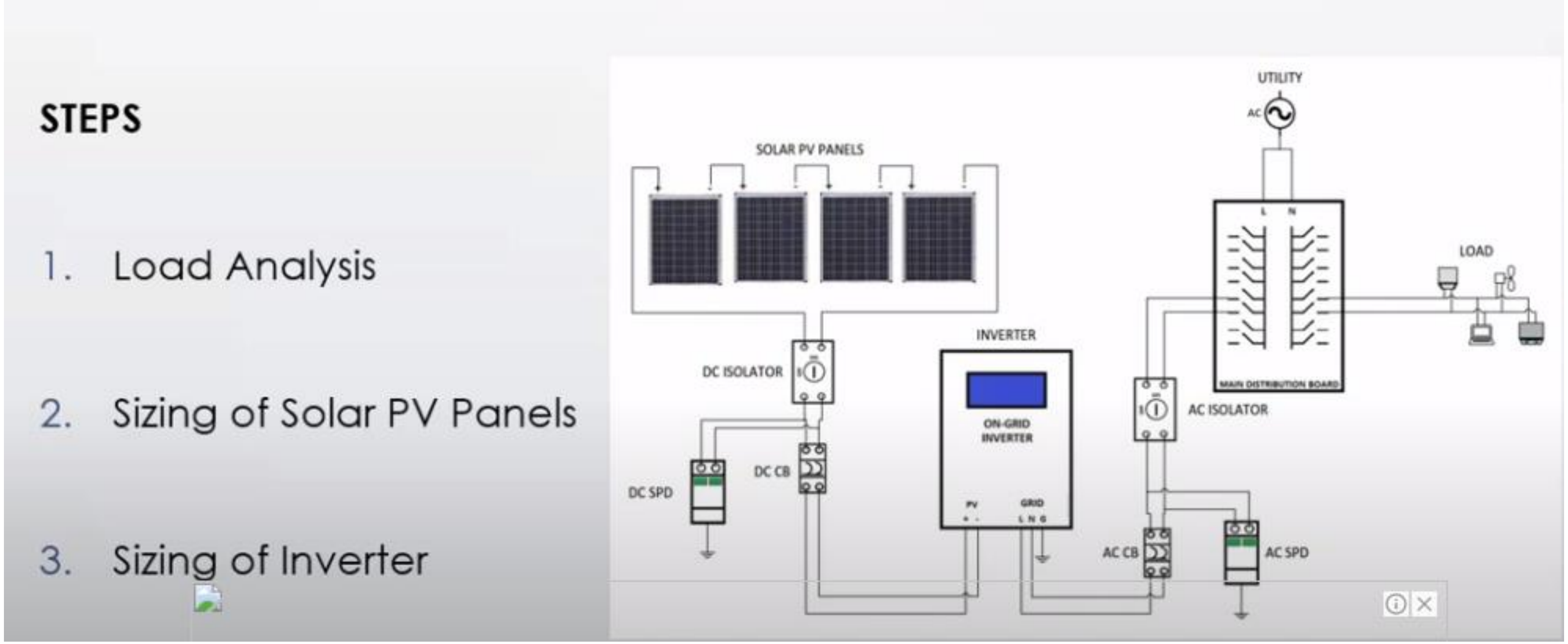
Part 5. Hybrid System Design and Calculations

SOLAR POWER SYSTEM

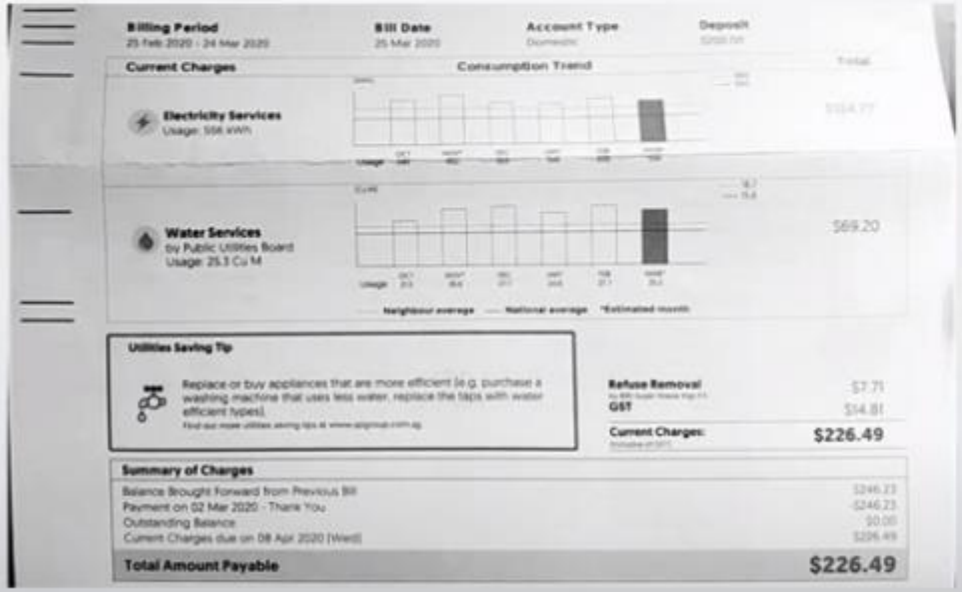
Basic Design and Calculations for Residential Spaces

Part 3 of 5 – **ON-GRID SYSTEM DESIGN AND CALCULATIONS**

On-grid Solar PV System Design Steps



Step 1: Load Analysis


Billing Period
25 Feb 2020 - 24 Mar 2020
Bill Date
25 Mar 2020
Account Type
Deposit
Current Charges
Consumption Trend
Electricity Services
Water Services
by Public Utilities Board
Usage: 25.3 Cu M
$69.20
Utilities Saving Tip
Replace or buy appliances that are more efficient (e.g. purchase a washing machine that uses less water, replace the taps with water efficient types).
Refuse Removal
$7.71
GST
$14.81
Current Charges:
$226.49
Summary of Charges
Balance Brought Forward from Previous Bill
Payment on 02 Mar 2020 - Thank You
Outstanding Balance
Current Charges due on 08 Apr 2020 (Wed)
Total Amount Payable
$226.49

Check your monthly consumption and divide it by 30 days to get the daily power consumption.

For Example:

Monthly Consumption = 170 kWh

Daily Consumption = 170 kWh/30 days

Daily Consumption = 5.67 kWh/day

Step 2: PV Panel Sizing

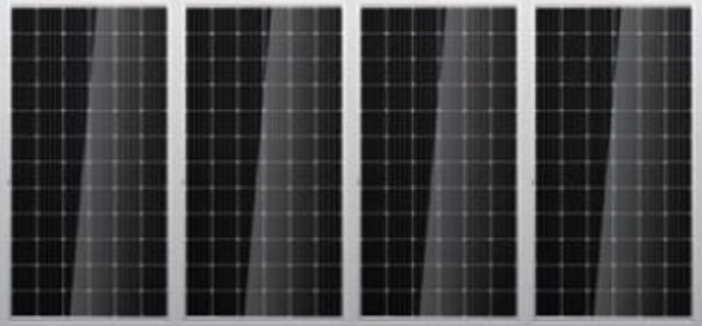
P_R = 380 W
V_{OC} = 48.8 V
I_{SC} = 9.94 A
Eff = 19.5%

Daily Consumption = 5.67 kWh
Sun Peak Hours *** = 5 hrs

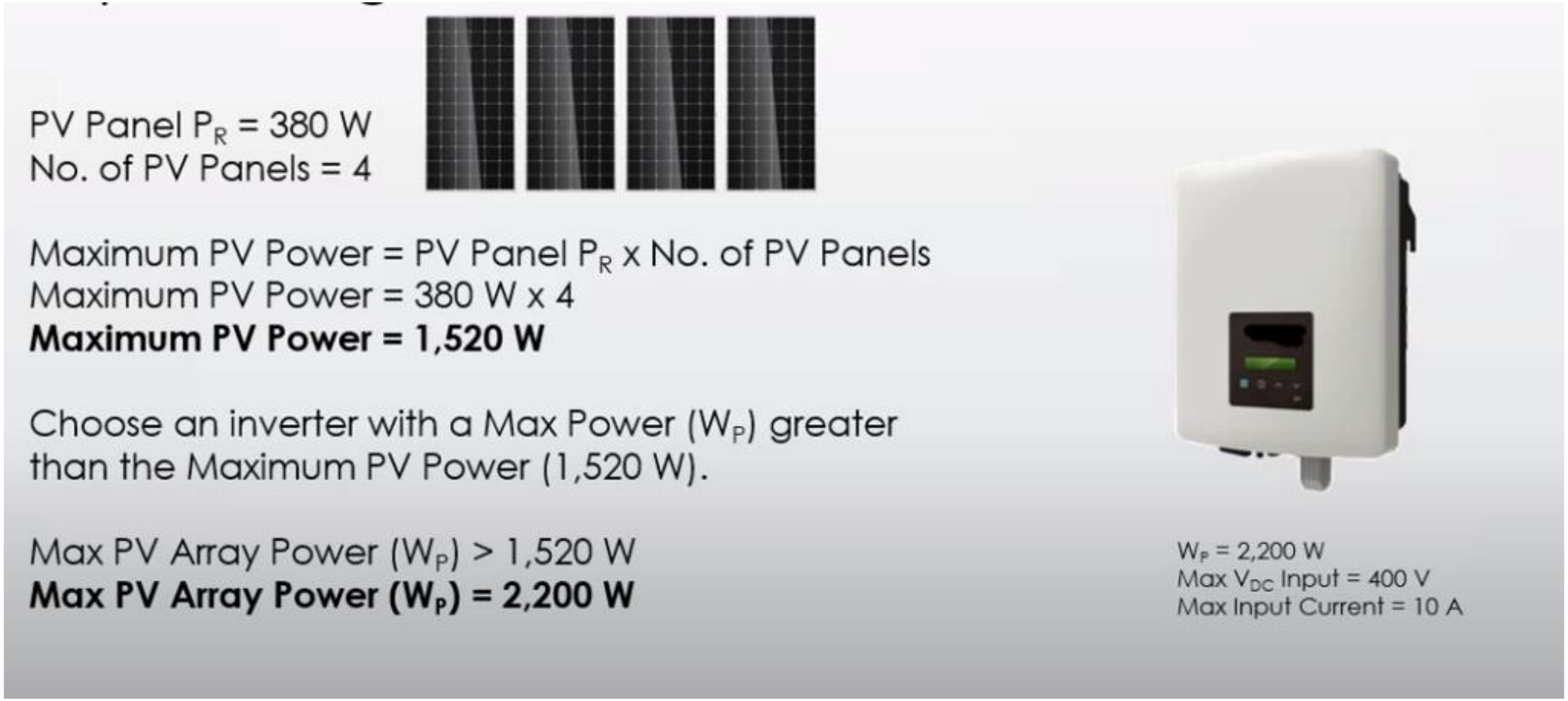
***Sun Peak Hours - Duration at which the intensity of sunlight is 1,000W/sqm. Dependent on location.

PV Power = (Daily Consumption / Sun Peak Hours) x 1.3
PV Power = (5.67 kWh/5 hrs) x 1.3
PV Power = 1.475 kW (1,475 W)

No. of PV Panels = PV Power / PV Panel P_R
No. of PV Panels = 1,475 W / 380 W
No. of PV Panels = 3.88
No. of PV Panels = ~4



Step 3 : Sizing the PV Inverter



Step 3: Sizing the PV inverter (matching other parameters)

P_R = 380 W
V_{OC} = 48.8 V
I_{SC} = 9.94 A
Eff = 19.5%

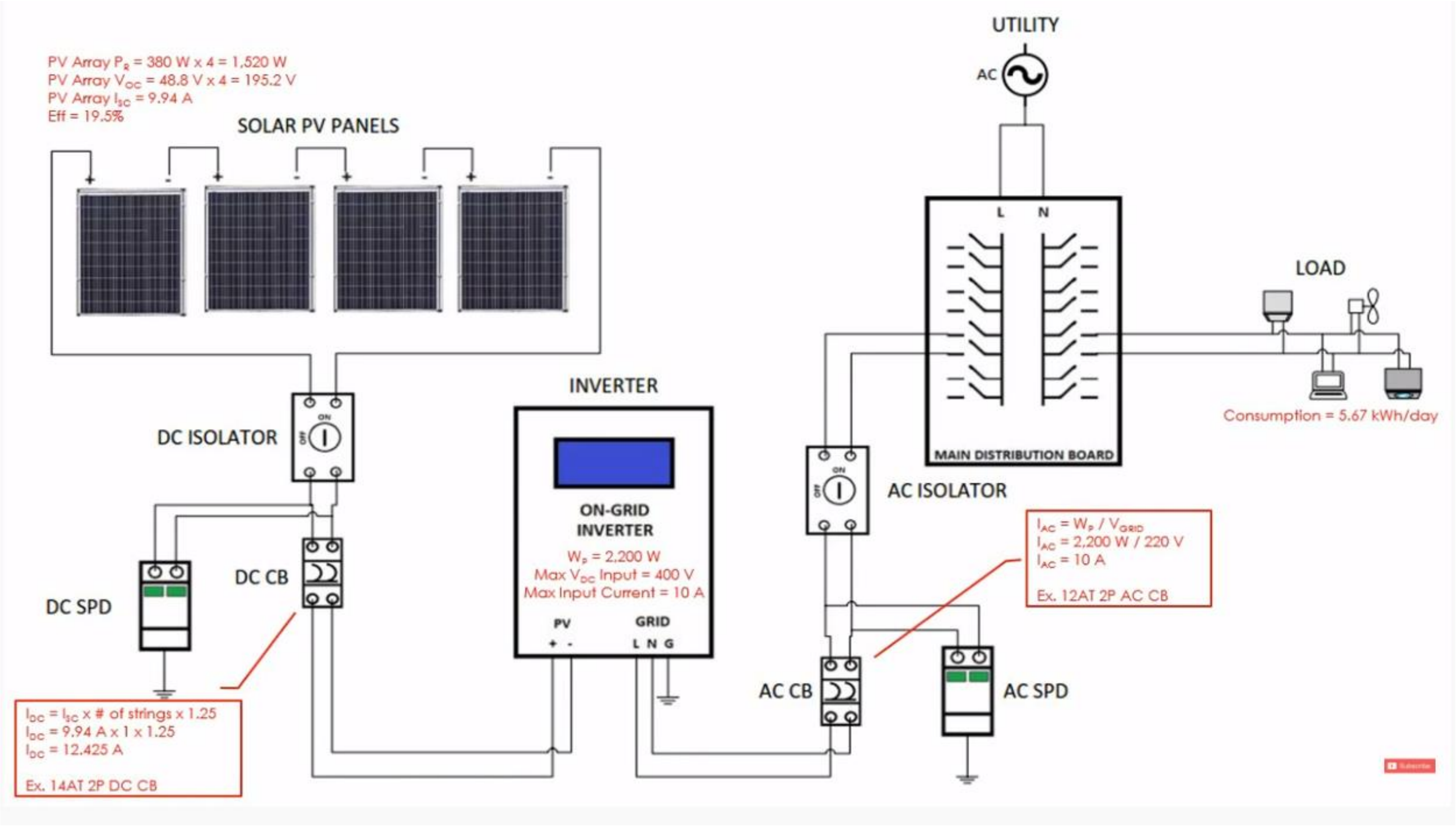
Make sure that the voltage and current output of your Solar PV Array does not exceed the voltage and current input of your inverter.

PV Array V_{OUT}(series) = V_{OC} x No. of PV Panels
PV Array V_{OUT}(series) = 48.8 V_{DC} x 4
PV Array V_{OUT}(series) = 195.2 V_{DC}
PV Array V_{OUT}(series) (195.2 V_{DC}) < Max V_{DC} Input (400 V_{DC})

PV Array I_{SC}(series)(9.94 A) < Max Input Current (10A)

W_P = 2,200 W
Max V_{DC} Input = 400 V
Max Input Current = 10 A

Step 4: Designing the Solar PV Circuit DB elements



SOLAR POWER SYSTEM

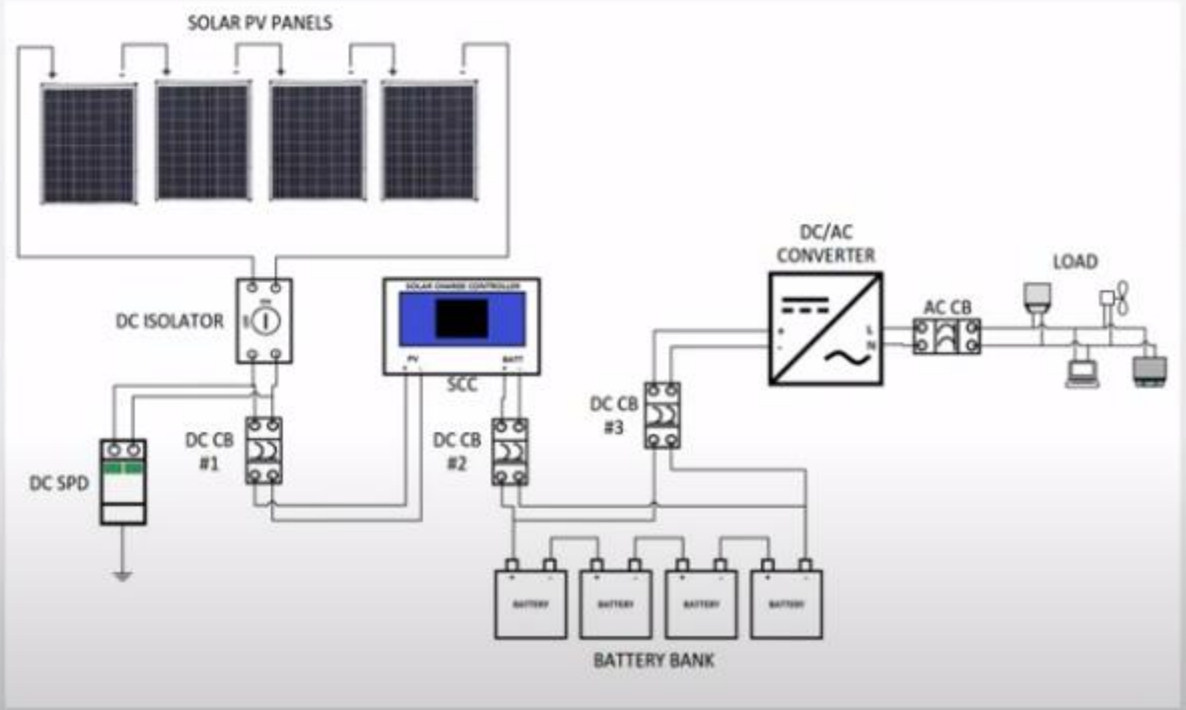
Basic Design and Calculations for Residential Spaces

Part 4 of 5 – **OFF-GRID SYSTEM DESIGN AND CALCULATIONS**

Off-grid SPV Design Steps

STEPS

1. Load Analysis
2. Sizing of Solar PV Panels
3. Sizing of Battery Bank
4. Sizing of Inverter
5. Sizing of Solar Charge Controller



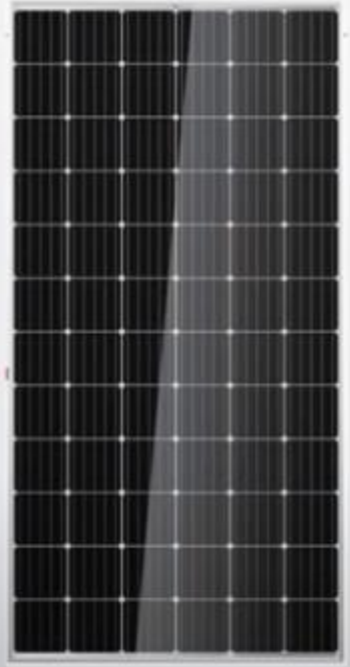
Step 1 Load Analysis

Equipment	Power (W)	Qty	Total Power (W)	Duration (Hrs)	Power Consumption (Wh)
LED Lights					
LED TV					
Electric Fan					
Fridge					
Laptop					
Washing Machine					

Step 1. Load Analysis

Equipment	Power (W)	Qty	Total Power (W)	Duration (Hrs)	Power Consumption (Wh)
LED Lights	9	4	36	7	252
LED TV	80	1	80	5	400
Electric Fan	65	2	130	8	1,040
Fridge	250	1	250	10	2,500
Laptop	80	1	80	4	320
Washing Machine	250	1	250	2	500
				TOTAL	5,012 Wh/day

Step 2: Sizing of PV Panels

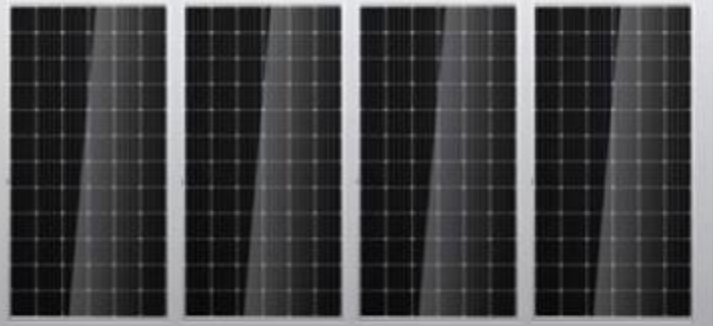


P_R = 380 W
V_{OC} = 48.8 V
I_{SC} = 9.94 A
Eff = 19.5%

Daily Consumption = 5.012 kWh
Sun Peak Hours = 5 hrs
***Sun Peak Hours - Duration at which the intensity of sunlight is 1,000W/sqm. Dependent on location.

PV Power = (Daily Consumption / Sun Peak Hours) x 1.3
PV Power = (5.012 kWh/5 hrs) x 1.3
PV Power = 1.303 kW (1,303 W)

No. of PV Panels = PV Power / PV Panel P_R
No. of PV Panels = 1,303 W / 380 W
No. of PV Panels = 3.43
No. of PV Panels = ~4



Step 3: Sizing the battery bank

V_R = 12 V
$Batt_{RATING}$ = 250 Ah
D.O.D. = 50%
Eff = 85%

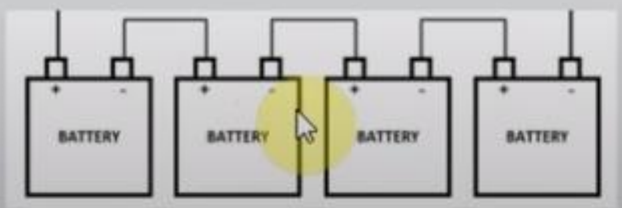
Battery Bank Capacity = Daily Consumption / (D.O.D. x Eff x System Voltage)
Battery Bank Capacity = 5.012 kWh / (0.5 x 0.85 x 48 V)
Battery Bank Capacity = 245.69 Ah

No. of Strings = Battery Capacity / $Batt_{RATING}$
No. of Strings = 245.69 Ah / 250 Ah
No. of Strings = 0.98 ~1

No. of Series = System Voltage / V_R
No. of Series = 48 V / 12 V
No. of Series = 4

Guidelines on System Voltage

12 V – Small installations (< 1200 W)
24 V – Medium sized installations (1200 W to 2400 W)
48 V – Large installations (> 2400 W)



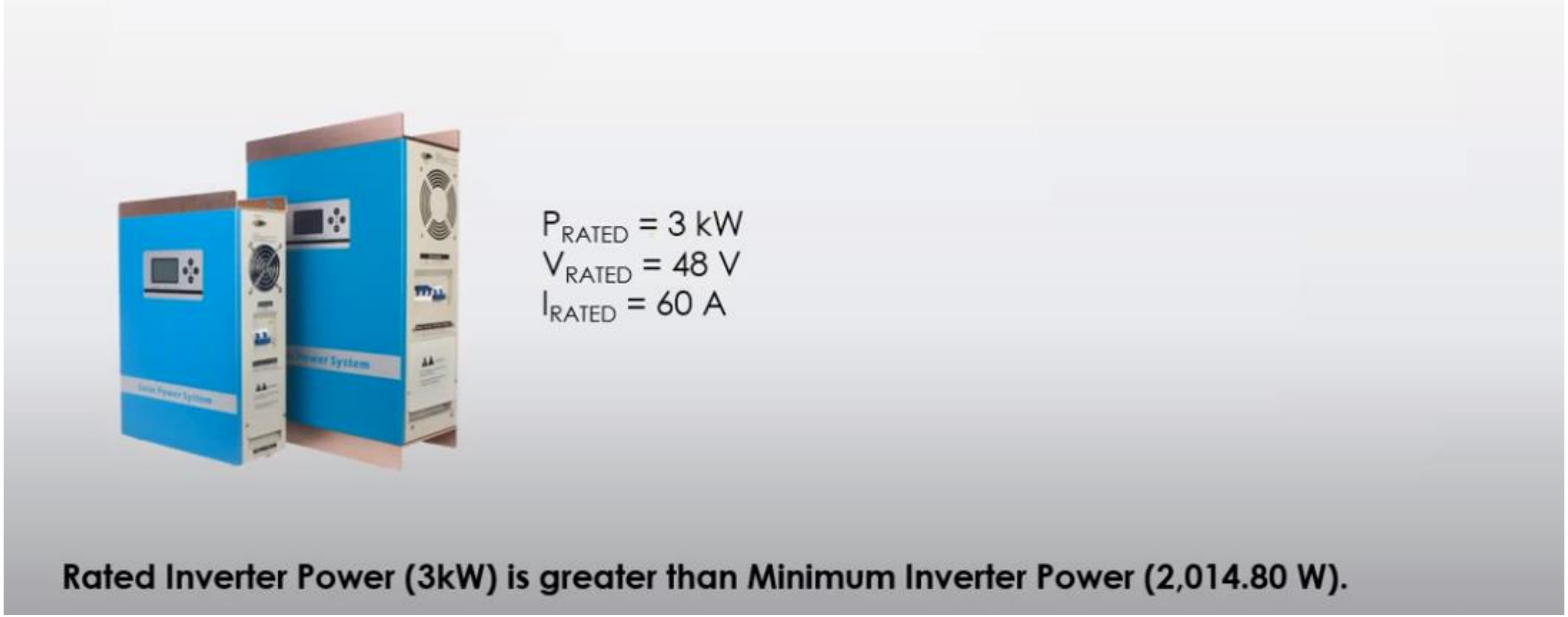
No. of Strings = 1 (Parallel Connections)
No. of Series = 4

Step 4: Sizing the Inverter

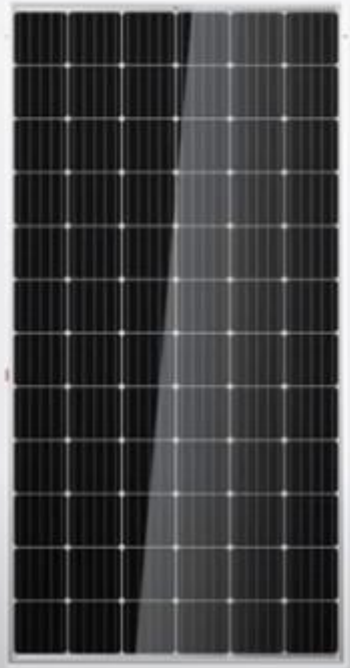
To account for the surge power, motor loads are multiplied by 2 or 3 while the rest by 1.3.

Equipment	Power (W)	Qty	Total Power (W)	Multiplier	Total Power
LED Lights	9	4	36	1.3	46.8
LED TV	80	1	80	1.3	104
Electric Fan	65	2	130	2	260
Fridge	250	1	250	3	750
Laptop	80	1	80	1.3	104
Washing Machine	250	1	250	3	750
				MINIMUM INVERTER POWER	**2,014.80 W**

Step 4. Sizing the Inverter



Step 5: Sizing the Solar Charge Controller



P_R = 380 W
V_{OC} = 48.8 V
I_{SC} = 9.94 A
Eff = 19.5%

V_{max} = 200 V
I_{CC} (Rated) = 50 A

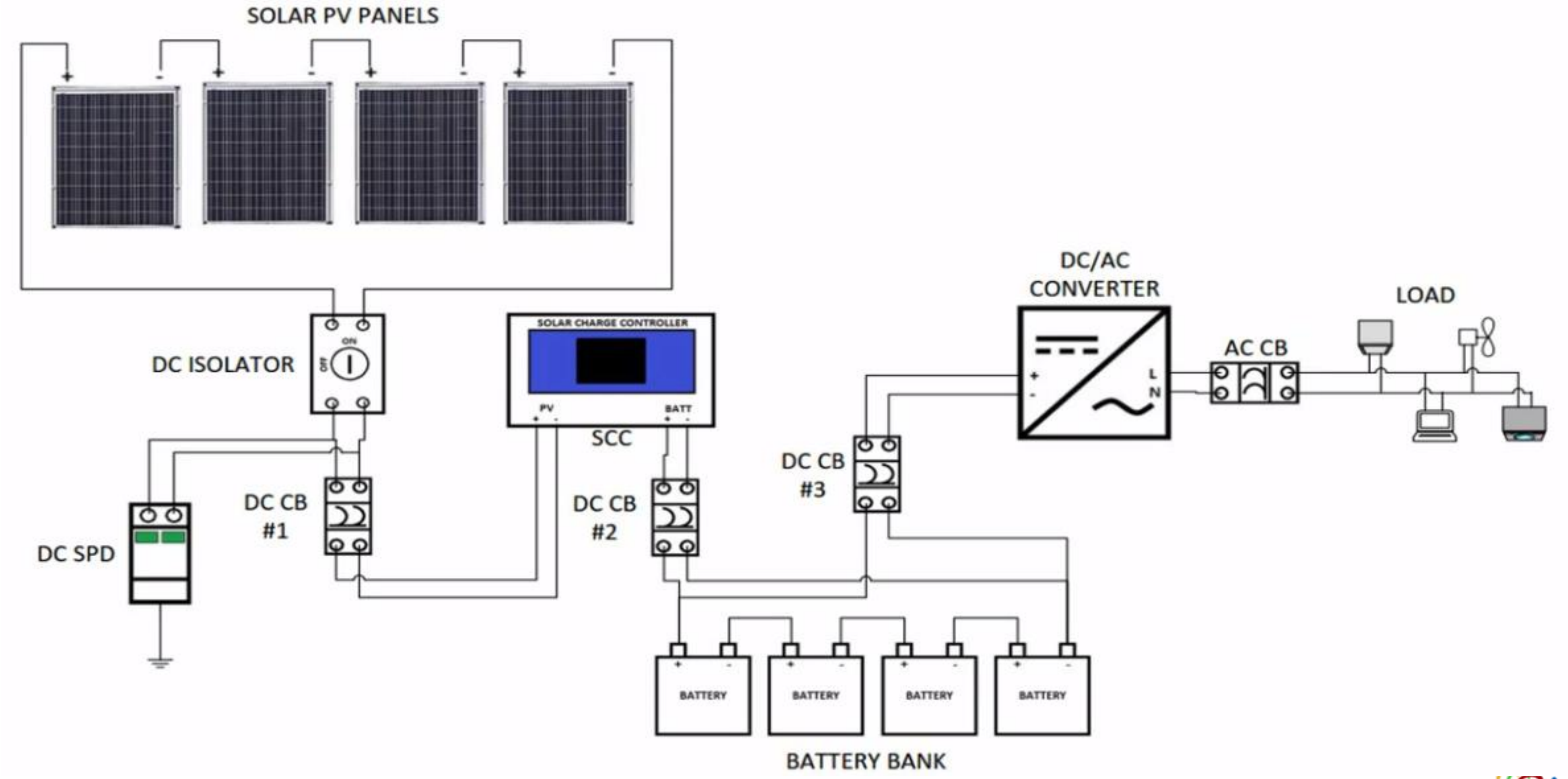
Solar PV Connection (Series & Strings):

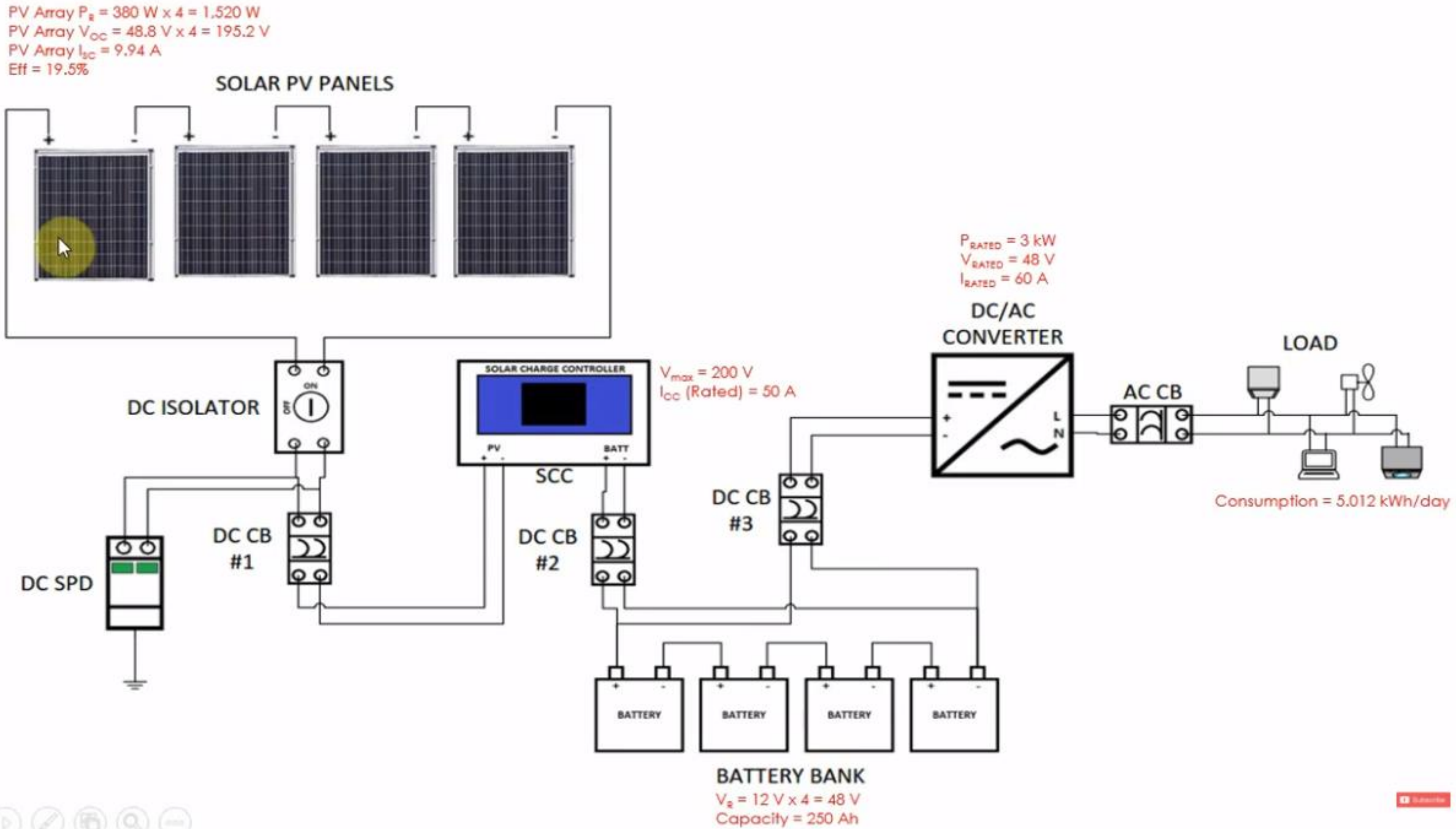
No. of Series = V_{max} / V_{OC}
No. of Series = 200 V / 48.8 V
No. of Series = 4.09 ~ 4

No. of Strings = No. of PV Panels / No. of Series
No. of Strings = 4 / 4
No. of Strings = 1 (Parallel Connection)

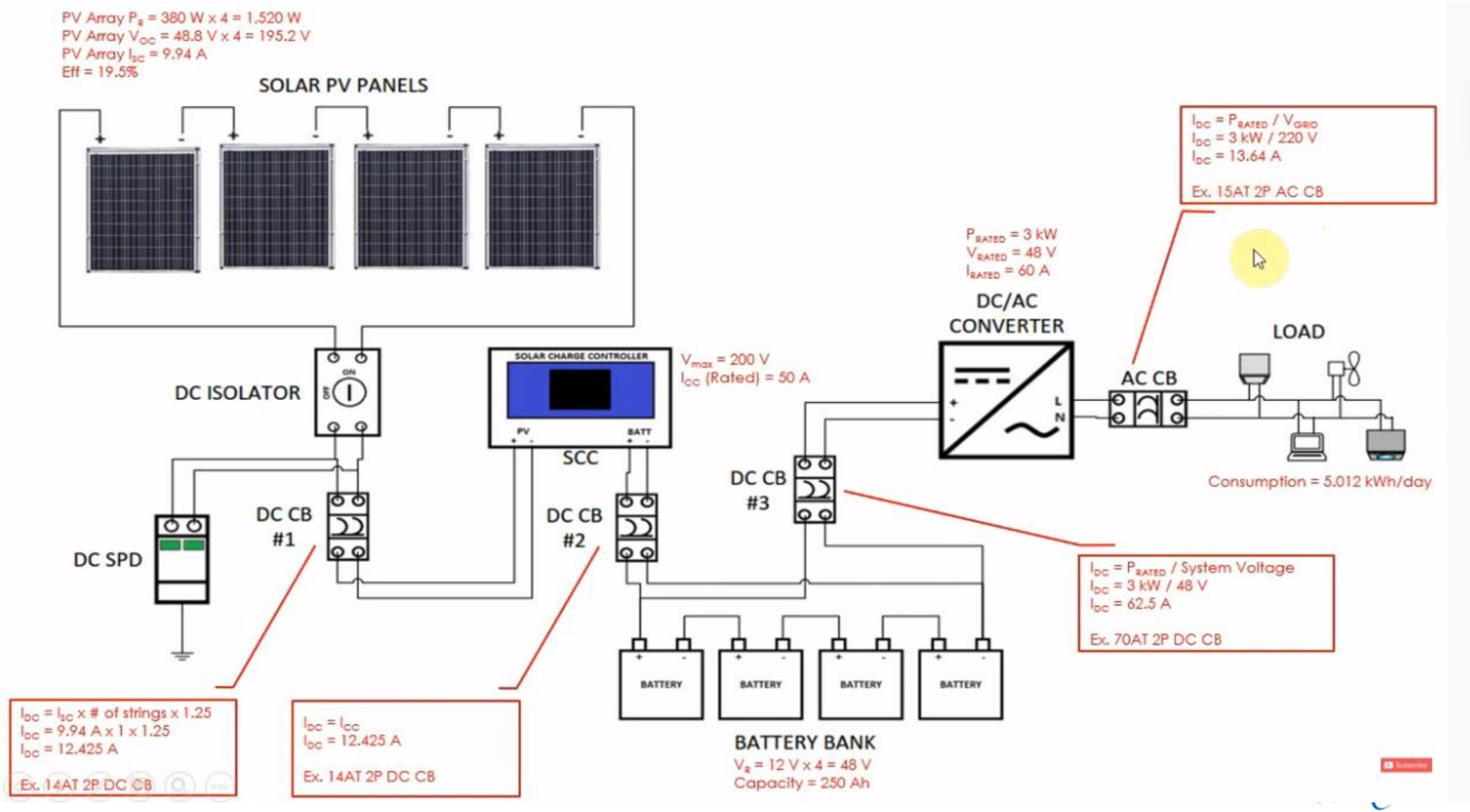
I_{CC} = I_{SC} x No. of Strings x 1.25
I_{CC} = 9.94 A x 1 x 1.25
I_{CC} = 12.425 A (Less than the I_{CC} (Rated) of the SCC)

Designing the SPV SLD





PV Array P_R = 380 W x 4 = 1,520 W
PV Array V_{OC} = 48.8 V x 4 = 195.2 V
PV Array I_{SC} = 9.94 A
Eff = 19.5%
SOLAR PV PANELS
DC ISOLATOR
ON
OFF
SOLAR CHARGE CONTROLLER
PV
BATT
SCC
V_{max} = 200 V
I_{CC} (Rated) = 50 A
DC SPD
DC CB #1
DC CB #2
DC CB #3
P_{RATED} = 3 kW
V_{RATED} = 48 V
I_{RATED} = 60 A
DC/AC CONVERTER
L
N
AC CB
LOAD
Consumption = 5.012 kWh/day
BATTERY
BATTERY
BATTERY
BATTERY
BATTERY BANK
V_R = 12 V x 4 = 48 V
Capacity = 250 Ah



PV Array P_R = 380 W x 4 = 1,520 W
PV Array V_OC = 48.8 V x 4 = 195.2 V
PV Array I_SC = 9.94 A
Eff = 19.5%
SOLAR PV PANELS
DC ISOLATOR
ON
OFF
SOLAR CHARGE CONTROLLER
PV
BATT
SCC
V_max = 200 V
I_CC (Rated) = 50 A
DC SPD
DC CB #1
DC CB #2
DC CB #3
P_RATED = 3 kW
V_RATED = 48 V
I_RATED = 60 A
DC/AC CONVERTER
L
N
AC CB
LOAD
Consumption = 5.012 kWh/day
I_DC = P_RATED / V_GRID
I_DC = 3 kW / 220 V
I_DC = 13.64 A
Ex. 15AT 2P AC CB
I_DC = P_RATED / System Voltage
I_DC = 3 kW / 48 V
I_DC = 62.5 A
Ex. 70AT 2P DC CB
BATTERY
BATTERY
BATTERY
BATTERY
BATTERY BANK
V_R = 12 V x 4 = 48 V
Capacity = 250 Ah
I_DC = I_SC x # of strings x 1.25
I_DC = 9.94 A x 1 x 1.25
I_DC = 12.425 A
Ex. 14AT 2P DC CB
I_DC = I_CC
I_DC = 12.425 A
Ex. 14AT 2P DC CB

SOLAR POWER SYSTEM

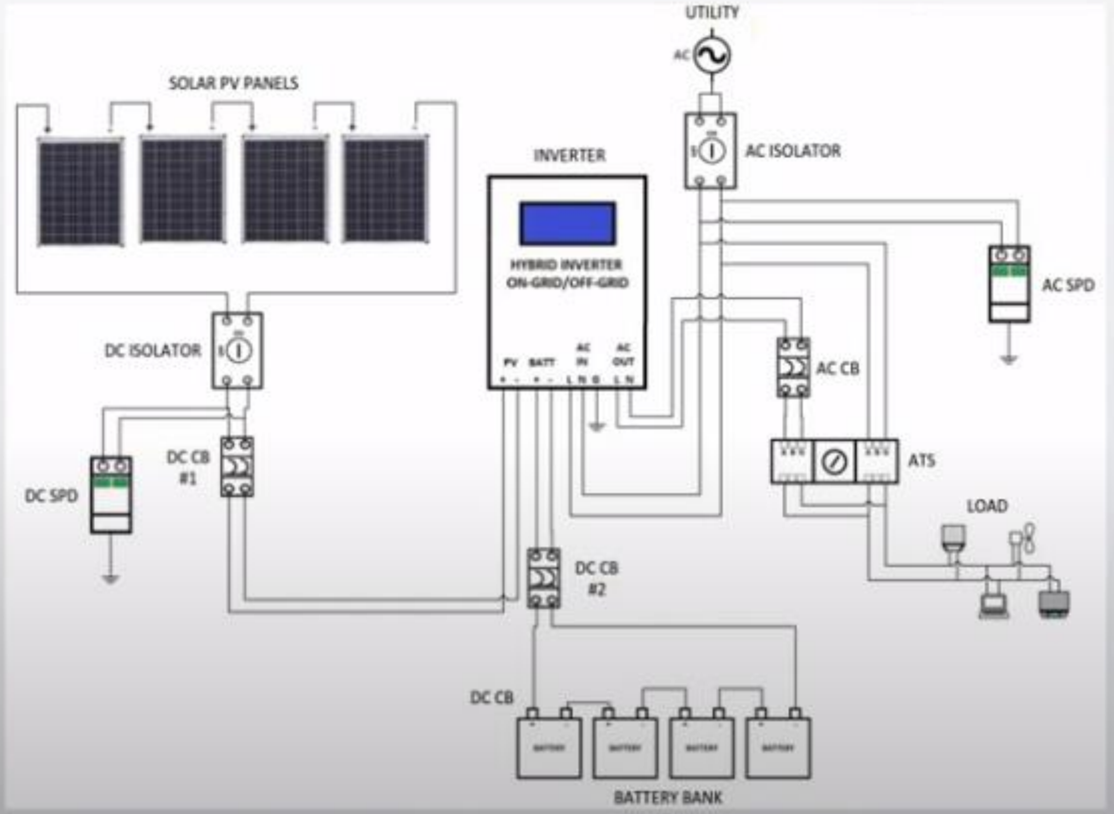
Basic Design and Calculations for Residential Spaces

Part 5 of 5 – **HYBRID SYSTEM DESIGN AND CALCULATIONS**

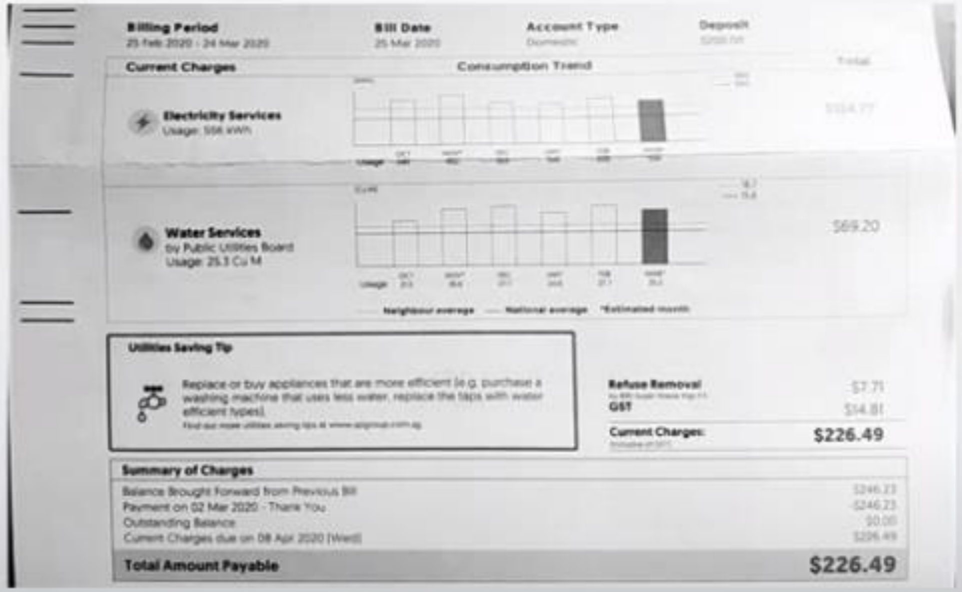
Hybrid SPV Design Steps

STEPS

1. Load Analysis
2. Sizing of Solar PV Panels
3. Sizing of Inverter
4. Sizing of Battery Bank



Step 1: Load Analysis



Check your monthly consumption and divide it by 30 days to get the daily power consumption.

For Example:

Monthly Consumption = 170 kWh

Daily Consumption = 170 kWh/30 days
Daily Consumption = 5.67 kWh/day

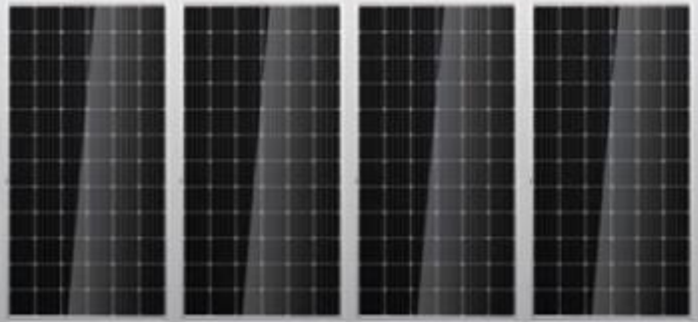
Step 2: PV Panel Sizing

P_R = 380 W
V_{OC} = 48.8 V
I_{SC} = 9.94 A
Eff = 19.5%

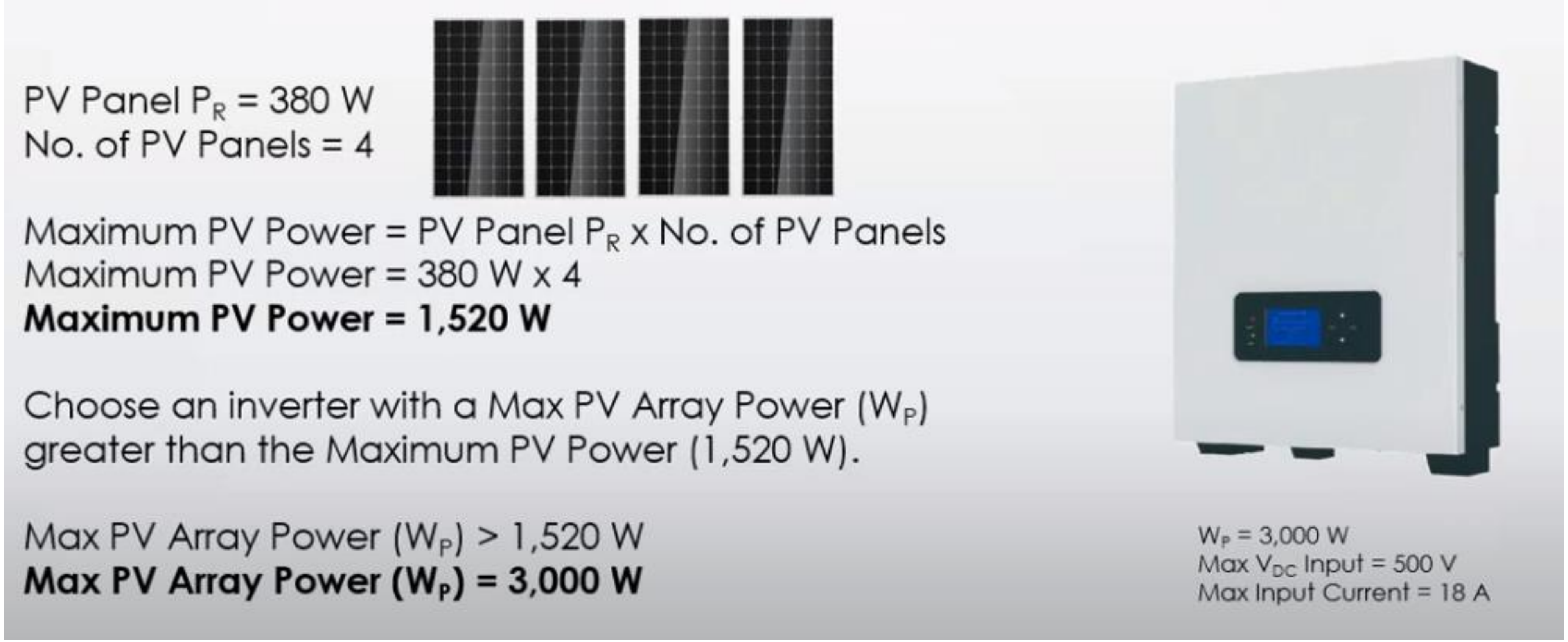
Daily Consumption = 5.67 kWh
Sun Peak Hours *** = 5 hrs
***Sun Peak Hours - Duration at which the intensity of sunlight is 1,000W/sqm. Dependent on location.

PV Power = (Daily Consumption / Sun Peak Hours) x 1.3
PV Power = (5.67 kWh/5 hrs) x 1.3
PV Power = 1.475 kW (1,475 W)

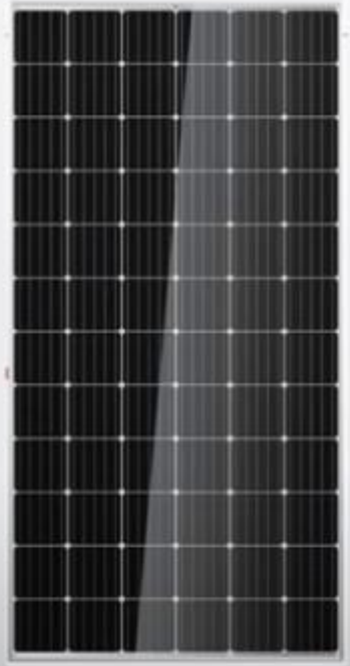
No. of PV Panels = PV Power / PV Panel P_R
No. of PV Panels = 1,475 W / 380 W
No. of PV Panels = 3.88
No. of PV Panels = ~4



Step 3 : Sizing the PV Inverter



Step 3: Sizing the PV inverter (matching other parameters)



P_R = 380 W
V_{OC} = 48.8 V
I_{SC} = 9.94 A
Eff = 19.5%

Make sure that the voltage and current output of your Solar PV Array does not exceed the voltage and current input of your inverter.

PV Array V_{OUT}(series) = V_{OC} x No. of PV Panels
PV Array V_{OUT}(series) = 48.8 V_{DC} x 4
PV Array V_{OUT}(series) = 195.2 V_{DC}
PV Array V_{OUT}(series) (195.2 V_{DC}) < Max V_{DC} Input (500 V_{DC})

PV Array I_{SC}(series)(9.94 A) < Max Input Current (18A)

W_P = 3,000 W
Max V_{DC} Input = 500 V
Max Input Current = 18 A

ESCI

Step 4. Load Analysis for battery bank sizing

Equipment	Power (W)	Qty	Total Power (W)	Duration (Hrs)	Power Consumption (Wh)
LED Lights	9	4	36	7	252
LED TV	80	1	80	5	400
Electric Fan	65	2	130	8	1,040
Fridge	250	1	250	10	2,500
Laptop	80	1	80	4	320
Washing Machine	250	1	250	2	500
				TOTAL	5,012 Wh/day

Step 4: Sizing the battery bank

V_R = 12 V
$Batt_{RATING}$ = 250 Ah
D.O.D. = 50%
Eff = 85%

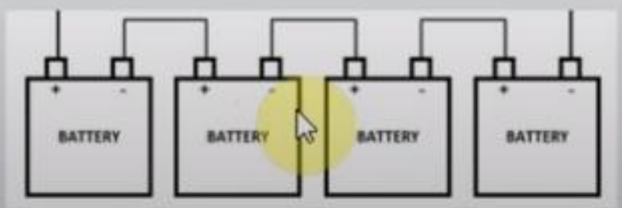
Battery Bank Capacity = Daily Consumption / (D.O.D. x Eff x System Voltage)
Battery Bank Capacity = 5.012 kWh / (0.5 x 0.85 x 48 V)
Battery Bank Capacity = 245.69 Ah

No. of Strings = Battery Capacity / $Batt_{RATING}$
No. of Strings = 245.69 Ah / 250 Ah
No. of Strings = 0.98 ~1

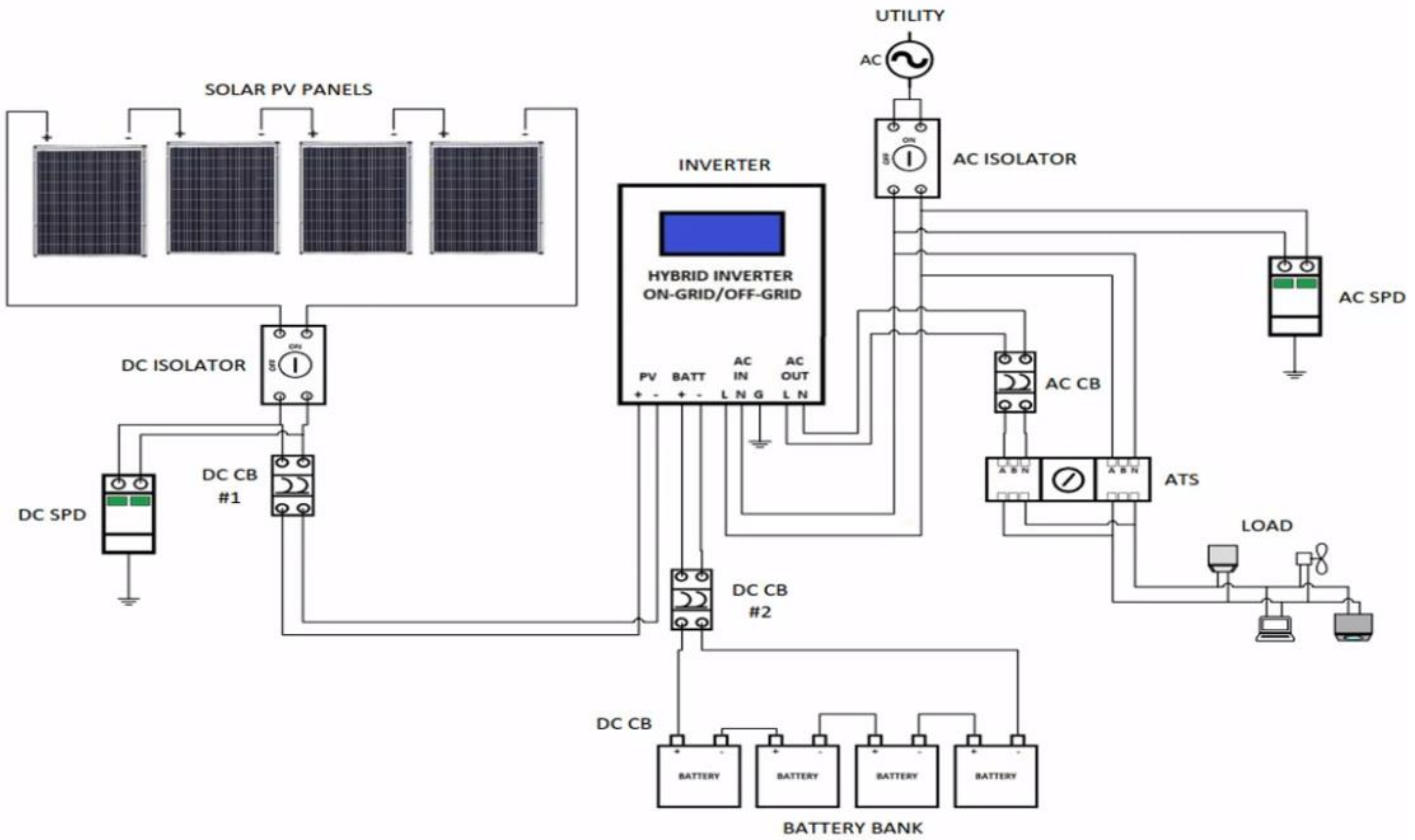
No. of Series = System Voltage / V_R
No. of Series = 48 V / 12 V
No. of Series = 4

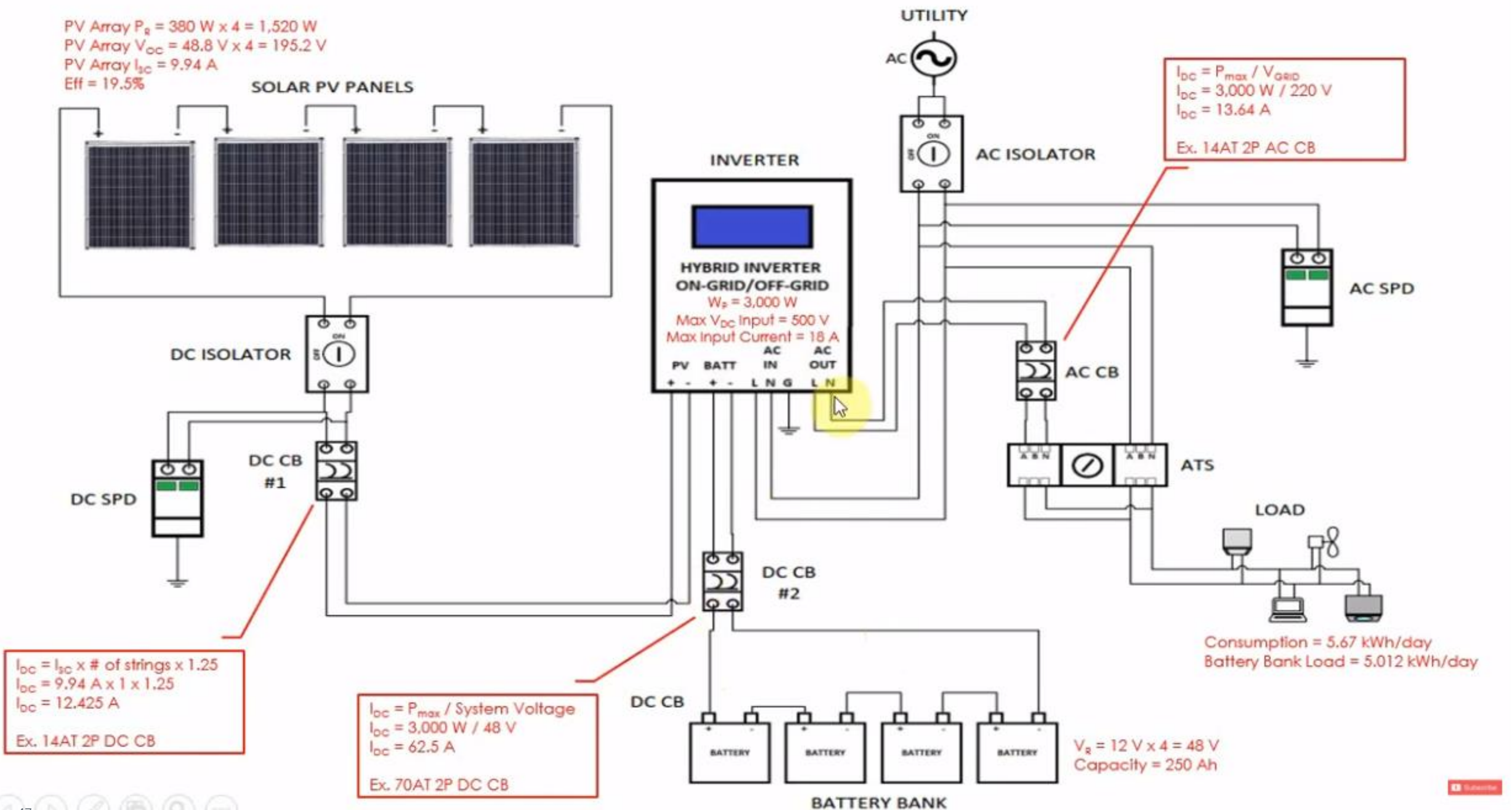
Guidelines on System Voltage

12 V – Small installations (< 1200 W)
24 V – Medium sized installations (1200 W to 2400 W)
48 V – Large installations (> 2400 W)



No. of Strings = 1 (Parallel Connections)
No. of Series = 4


UTILITY
AC
AC ISOLATOR
SOLAR PV PANELS
INVERTER
HYBRID INVERTER
ON-GRID/OFF-GRID
PV
BATT
AC IN
AC OUT
+ -
+ -
L N G
L N
AC SPD
DC ISOLATOR
AC CB
DC CB #1
DC SPD
ATS
LOAD
DC CB #2
DC CB
BATTERY
BATTERY
BATTERY
BATTERY
BATTERY BANK



PV Array P_R = 380 W x 4 = 1,520 W
PV Array V_OC = 48.8 V x 4 = 195.2 V
PV Array I_SC = 9.94 A
Eff = 19.5%
SOLAR PV PANELS
UTILITY
AC
AC ISOLATOR
I_DC = P_max / V_GRID
I_DC = 3,000 W / 220 V
I_DC = 13.64 A
Ex. 14AT 2P AC CB
INVERTER
HYBRID INVERTER
ON-GRID/OFF-GRID
W_P = 3,000 W
Max V_DC Input = 500 V
Max Input Current = 18 A
PV BATT AC IN AC OUT
AC SPD
DC ISOLATOR
AC CB
ATS
DC SPD
DC CB #1
LOAD
DC CB #2
I_DC = I_SC x # of strings x 1.25
I_DC = 9.94 A x 1 x 1.25
I_DC = 12.425 A
Ex. 14AT 2P DC CB
Consumption = 5.67 kWh/day
Battery Bank Load = 5.012 kWh/day
I_DC = P_max / System Voltage
I_DC = 3,000 W / 48 V
I_DC = 62.5 A
Ex. 70AT 2P DC CB
DC CB
BATTERY
V_R = 12 V x 4 = 48 V
Capacity = 250 Ah
BATTERY BANK

How Temperature affects string size (Cold)…

- Cooler, brighter conditions gives more power
- As temperature falls below STC (Standard Test conditions of 25 Celsius), Voc increases -> typical PV module temp coefficient is -0.33 %Volts /degree celsius
- As brightness increases, current increases

- Given :

Coldest Temp: -15 degree Celsius

Module Voc : 35 V

Inverter Max Input Voltage: 600V

<u>What is the max # of modules that you can connect in a string?</u>

- Answer:

Temp Delta: 25+15 degrees

% Increase in voltage: 40*(1/300)=.132

Increase in Voltage/module

=35 (1+.132)= 39.62V

Max # of Modules in string for given inverter:

600/39.62V = 15.14

Or 15

How Temperature affects string size (Hot)…

- As Module temperature increases beyond STC, Voc falls and power generated falls
- As temperature rises above STC (Standard Test conditions of 25 Celsius), Voc falls -> typical PV module temp coefficient is -0.40 %Volts /degree Celsius
- String size for hot temperature determines the shortest string size else the inverter will not turn ‘on’

- Given :

Hottest Module Temp: +70 degree Celsius

Module Vmp : 30 V

Inverter Min Input Voltage: 250V

What is the min # of modules that you can connect in a string?

- Answer:

Temp Delta: 25-70=45 degrees

% decrease in voltage: 45*(0.4/100)=.18

Decrease in Voltage/module

=30 (1-.18)= 24.6V

Min # of Modules in string for given inverter:

250/24.6V = 10.16

Or 11 modules

Selecting the Wire Size

- Ampacity is the current carrying capacity of the conductor
- Factors that influence the Ampacity :

✓Thickness of wire

✓wire temperature

✓Insulation

✓Air Flow around the wire

- Minimize power losses in the wiring system

✓Thicker, shorter wires

✓Proper connections to prevent hot-points

- Typically use 4 or 6 mm wires in RT SPV sites.

✓I recommend 6mm wires as it will minimize power losses

✓For earthing, we use GI strips – or I recommend thicker copper wires

Overview of other SPV Design software

- PV Syst

https://www.youtube.com/watch?v=_aQ-E8KRIps

- Sketchup with Skellion

https://www.youtube.com/watch?v=Oqb_3djwj0c

- Helioscope

https://www.youtube.com/watch?v=D4fHHMeBDDU

- Other software include:
  - Aurora, HOMER, Sundat…

- Earliest software; standard for most utility design- lacks good CAD capabilities, limited shading and heat-access maps

- Excellent CAD features for site design but -Lacks detailed generation; loss analytics-normally complements PV Syst

- Very Efficient Cloud software that delivers quite practical SPV designs with essential RT SPV CAD design, generation-loss analysis, shading and heat-access maps with BOM

- *SolarLabs is VERY FUNCTIONAL, Indigenous software gaining traction with most of the Indian EPC, Solar SIs*

To Summarize

- A good SPV project starts with a good, well-engineered, optimized design
- However, a SPV engineer is more than a designer – he is a combination of civil engineer, mechanical engineer, electrical engineer, safety engineer…and more…
- Complete slides shared on

www.india-inspires.com

ESSCI

Ashwini K Aggarwal, *PhD, FIETE*
Director-Government Affairs | Applied Materials India Pvt Ltd
Past Chairman 2017-18, India Electronics & Semiconductor Association
SME-Solar, Chairperson NOS Committee ESSC
Mobile +91 9910 555 970
AMAT Tie line : # 9575 4432

/xlashwini /xlAshwini

http://www.appliedmaterials.com
http://www.India-inspires.com