INTRODUCTION TO GRID-CONNECTED PHOTOVOLTAIC POWER SYSTEM

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Contents

1. Solar photovoltaic (PV) technology

(Source: https://www.clean-energy-ideas.com/

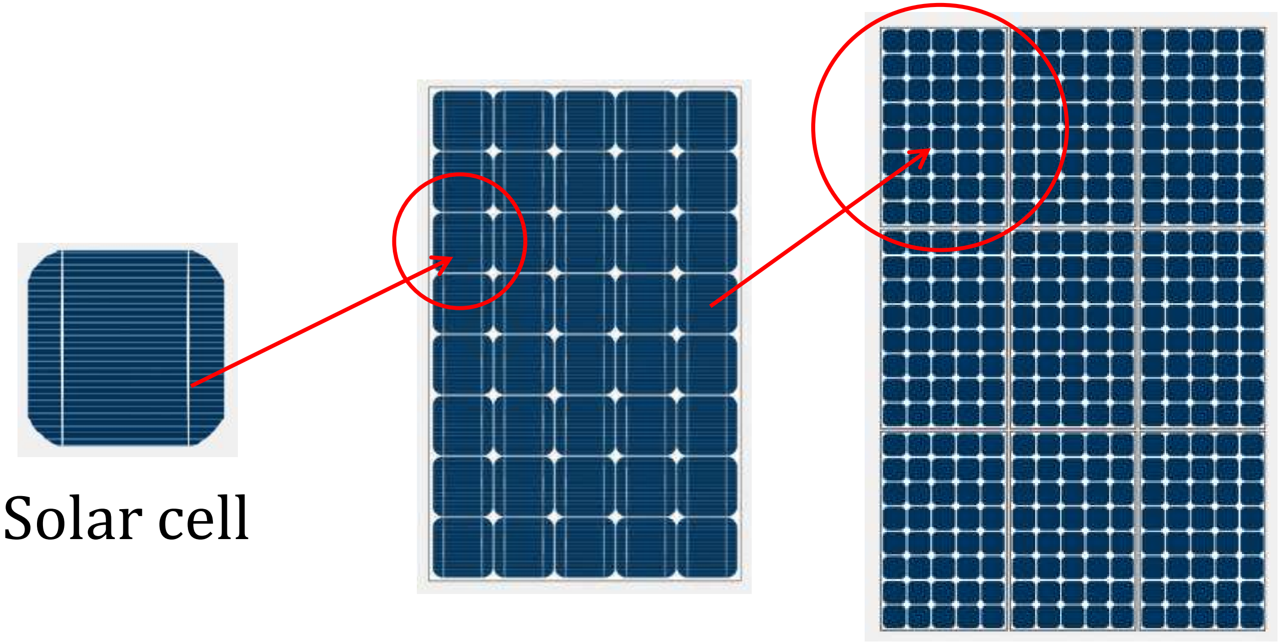
Solar thermal as water heater

Solar PV as electric generator

1. Solar photovoltaic (PV) technology

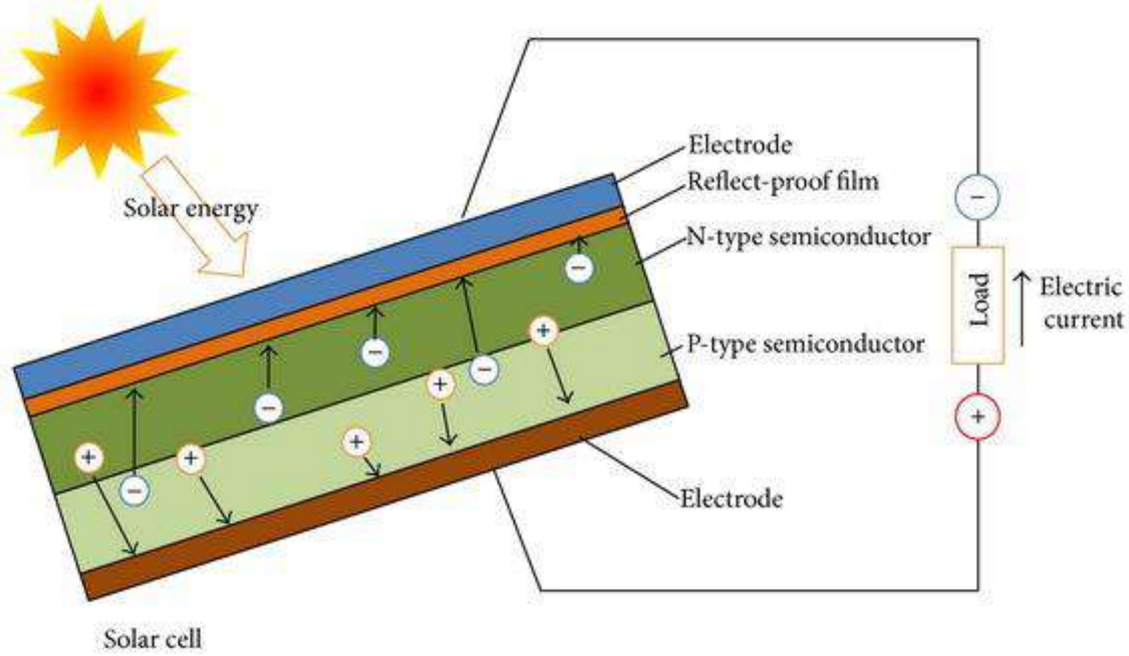
Operating Principle of Solar Cell

Convert the energy from sunlight directly into electricity (DC form).



Solar cell

PV module



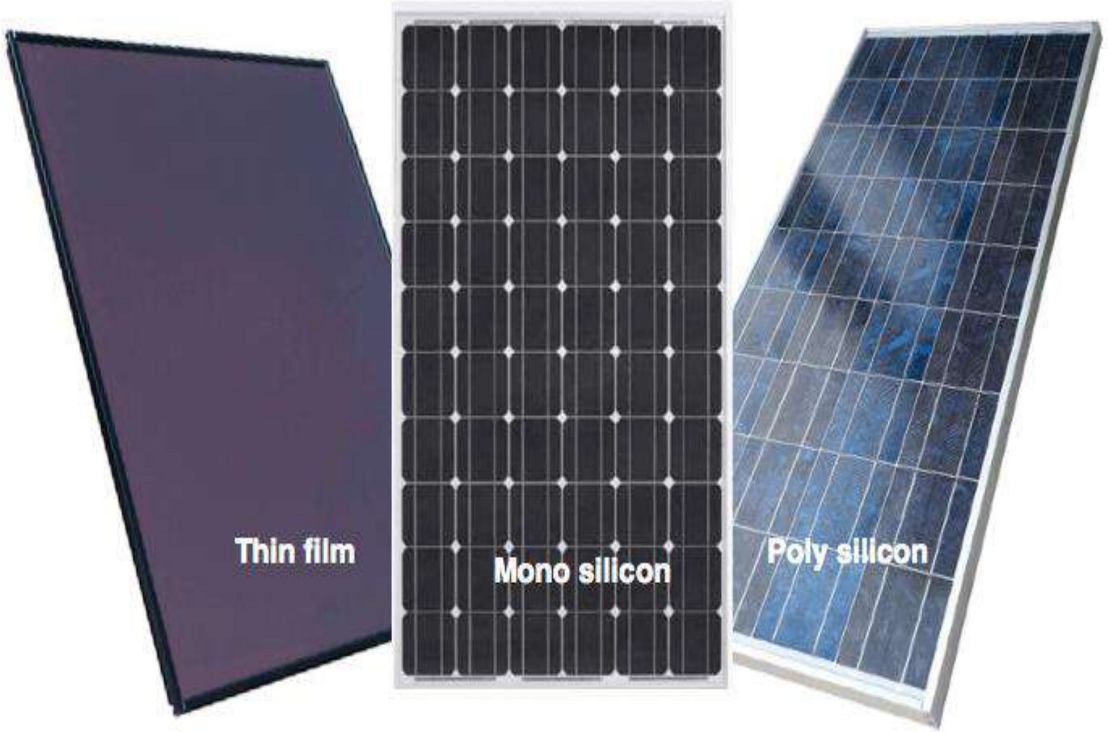
PV Array

4

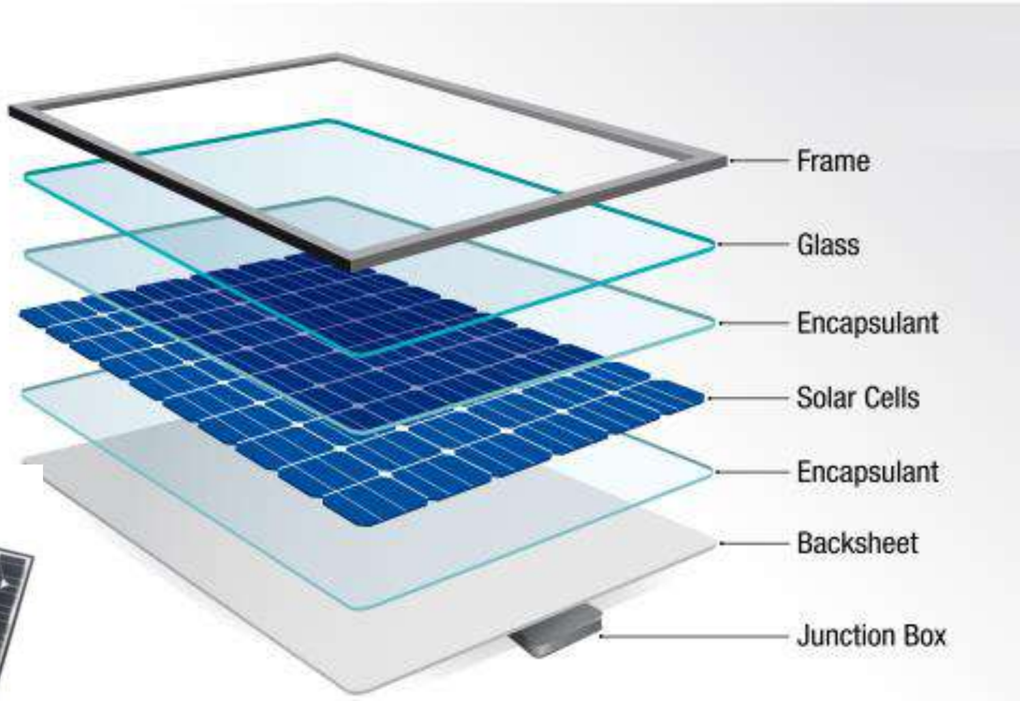
1. Solar photovoltaic (PV) technology

Common types of PV technology

Mono-facial PV modules

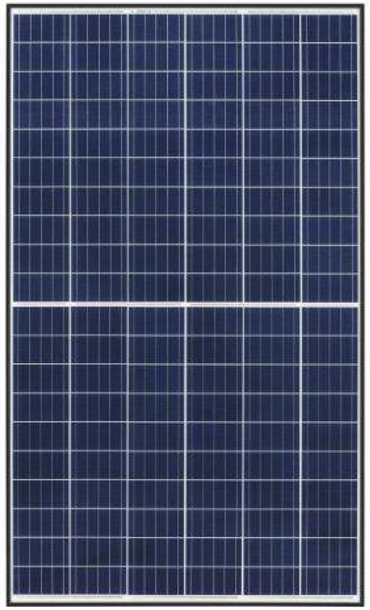


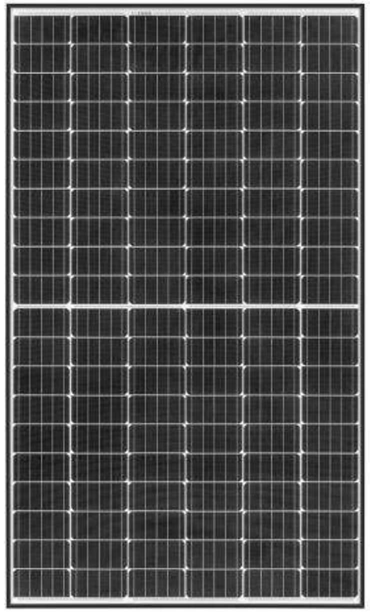
Hybrid



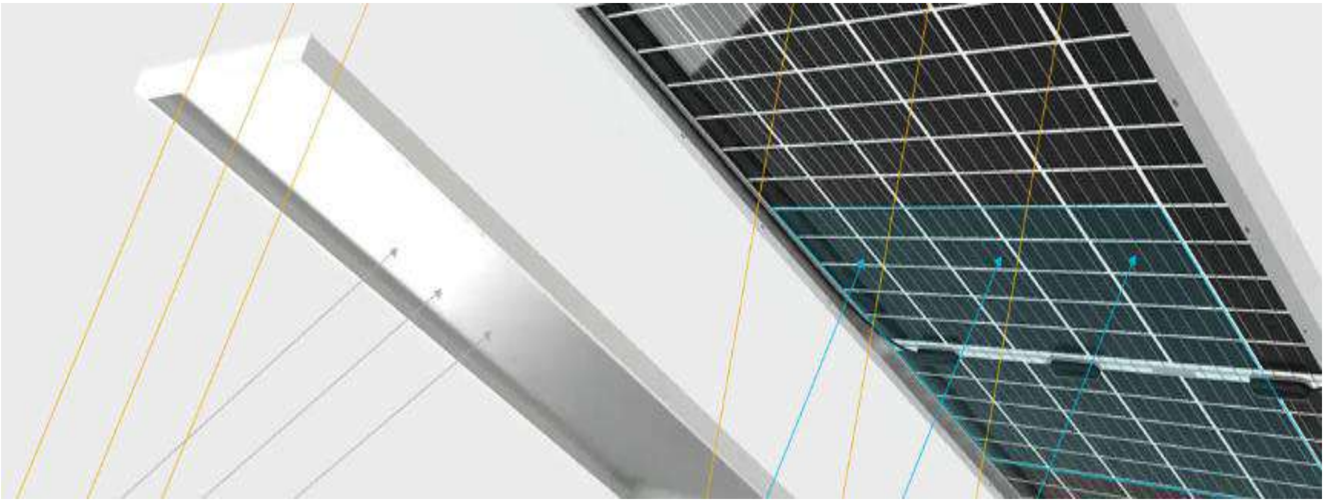
1. Solar photovoltaic (PV) technology

Half-cut cell PV modules



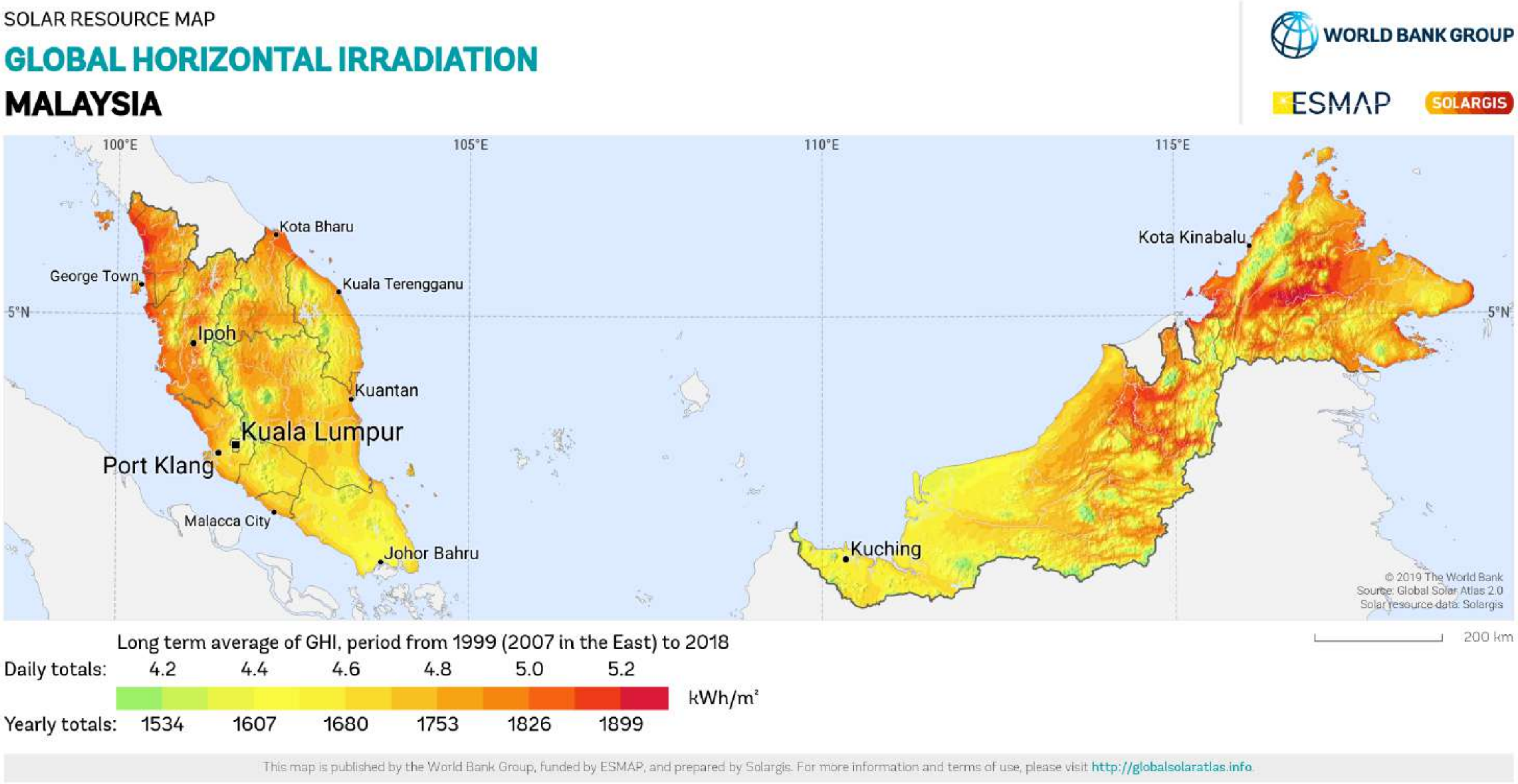


Bi-facial PV modules



1. Solar photovoltaic (PV) technology

SOLAR RESOURCES FROM SOLARGIS

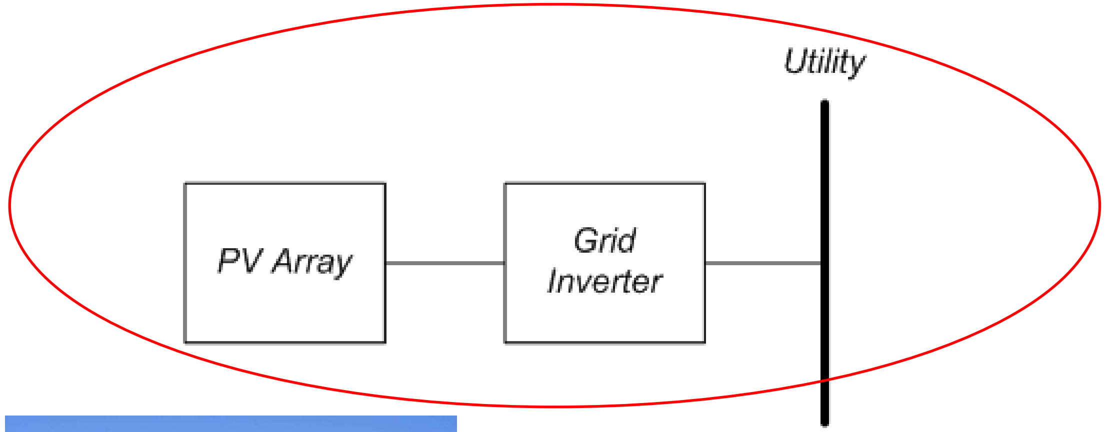


https://solargis.com/maps-and-gis-data/download/malaysia

2. Grid-connected PV (GCPV) system

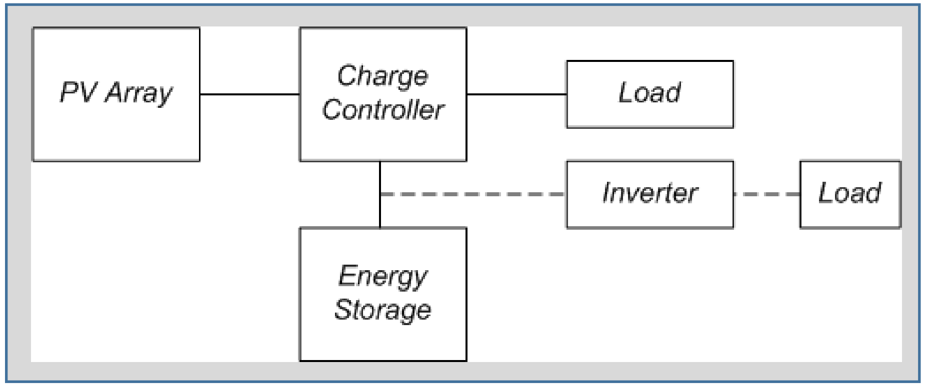
Two types application of PV

Grid-connected PV system (GCPV)

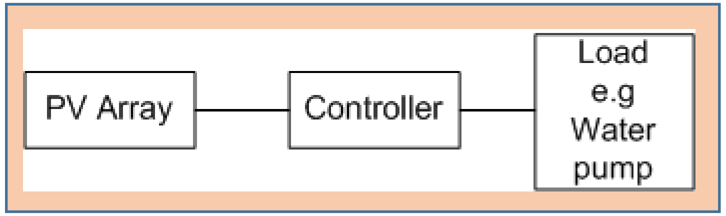


Off-grid PV system (OGPV)

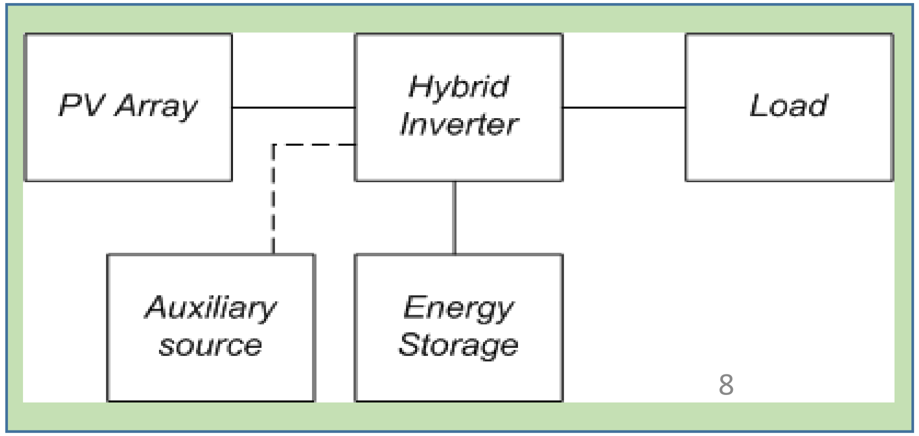
OGPV system with charge controller



Direct coupled OGPV system

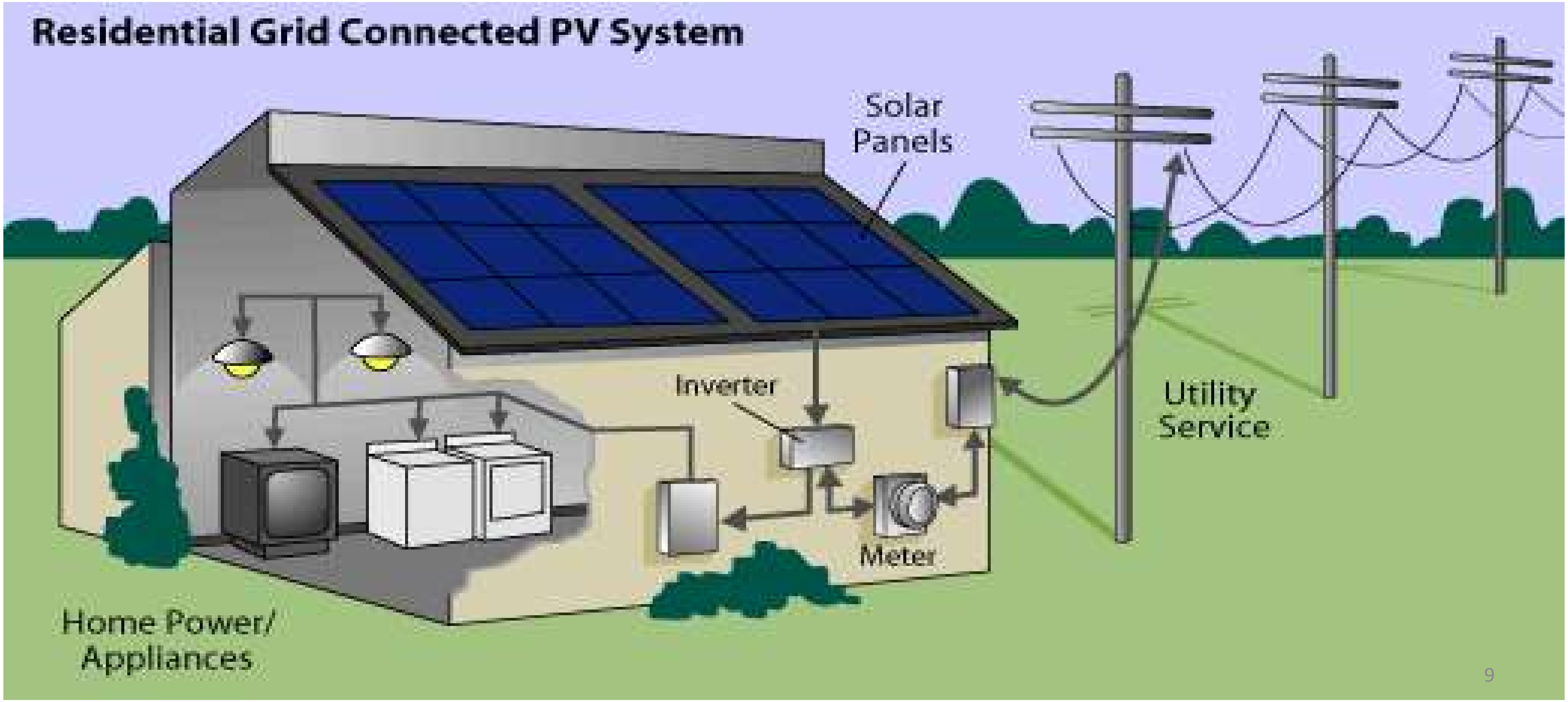


OGPV system with hybrid inverter



2. Grid-connected PV (GCPV) system

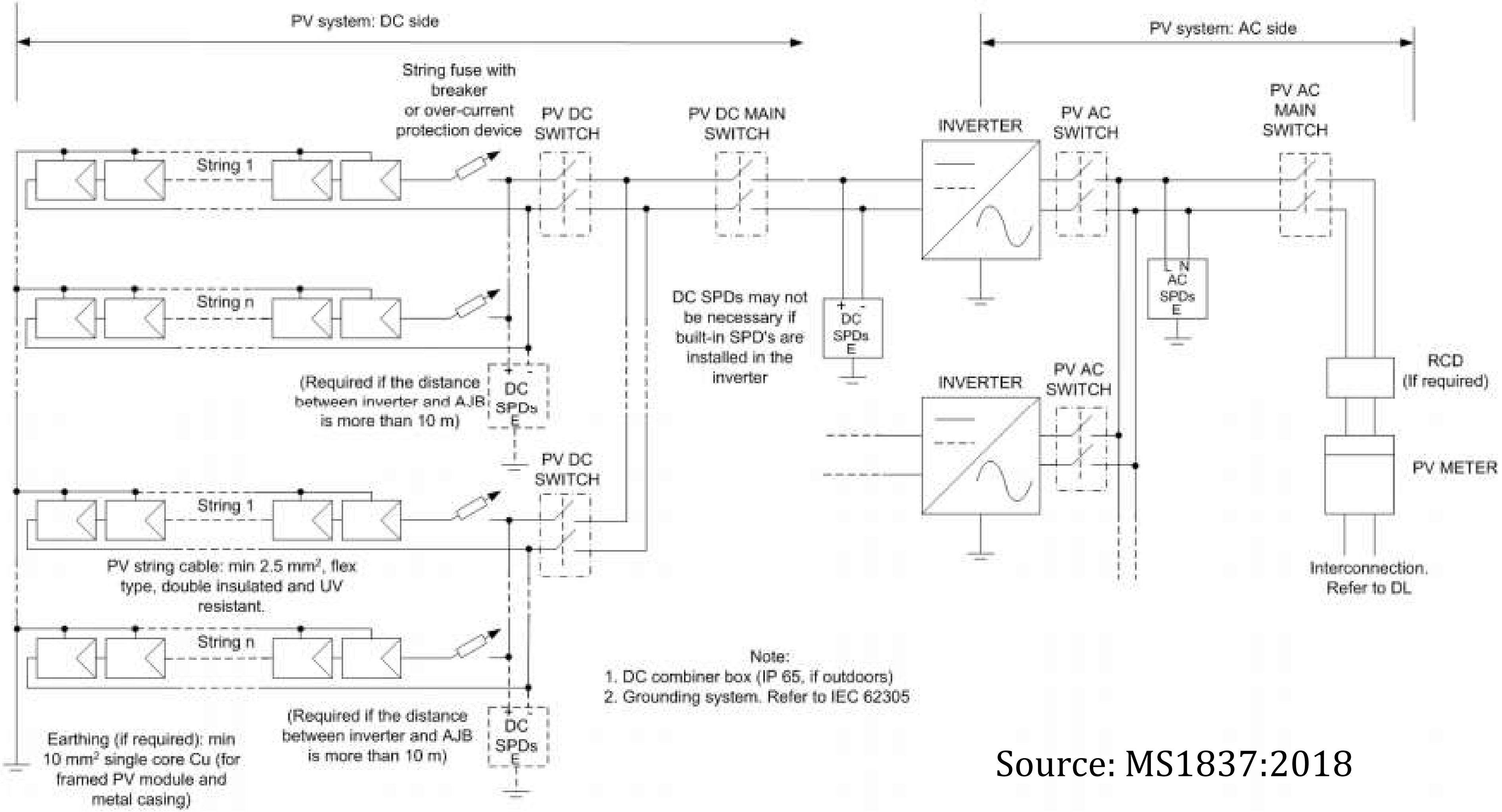
PRINCIPLE OPERATION OF GCPV SYSTEM

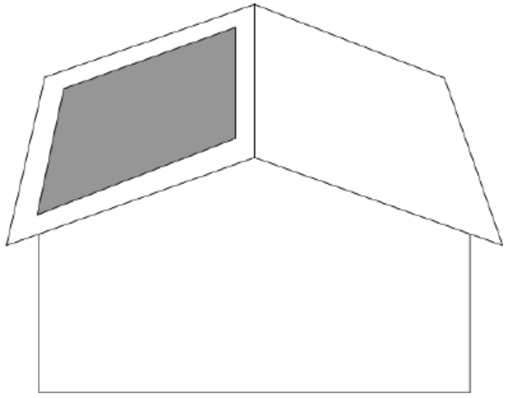


2. Grid-connected PV (GCPV) system

SINGLE-PHASE GCPV SYSTEM

Circuit diagram with single MPPT inverter





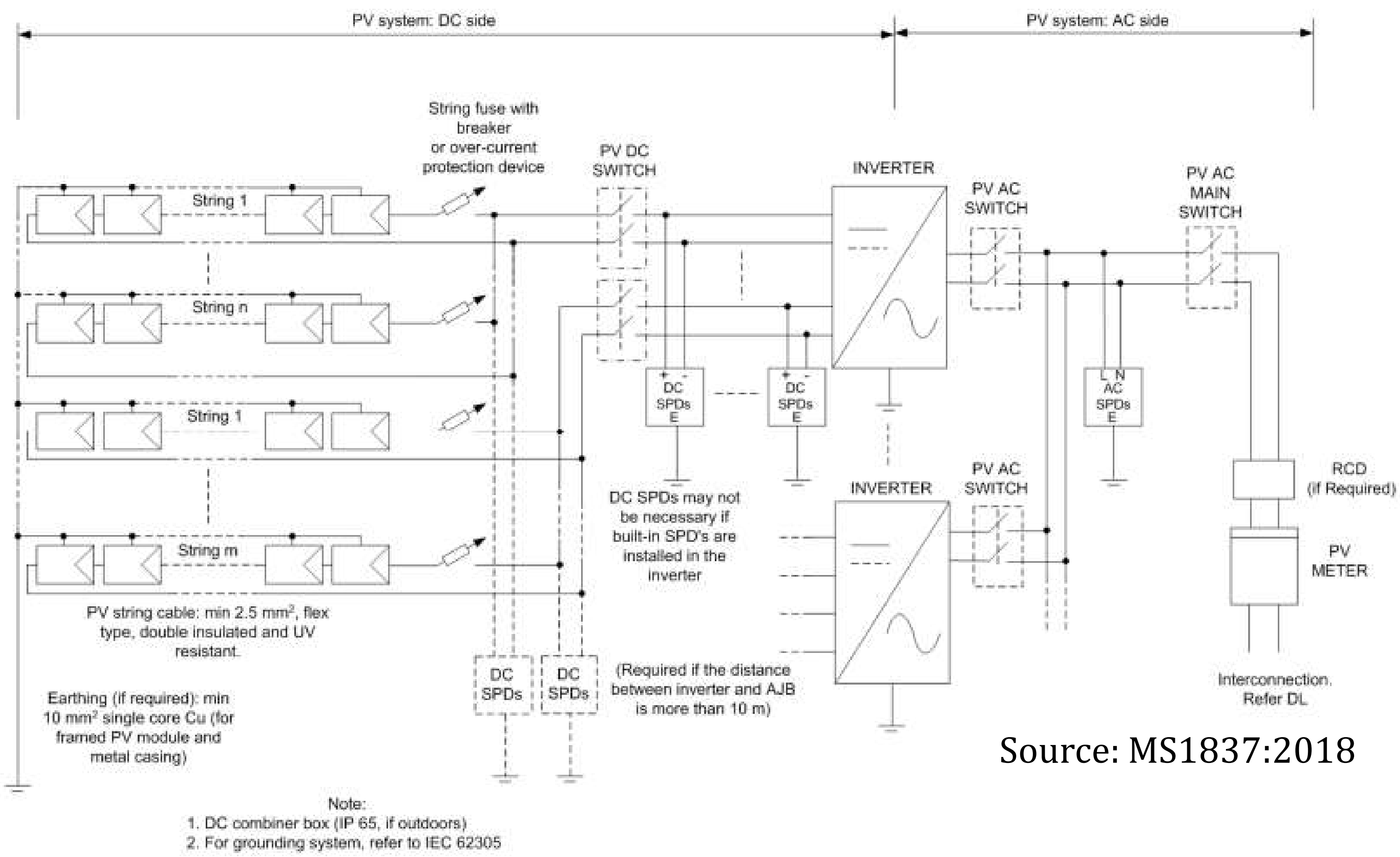
Source: MS1837:2018

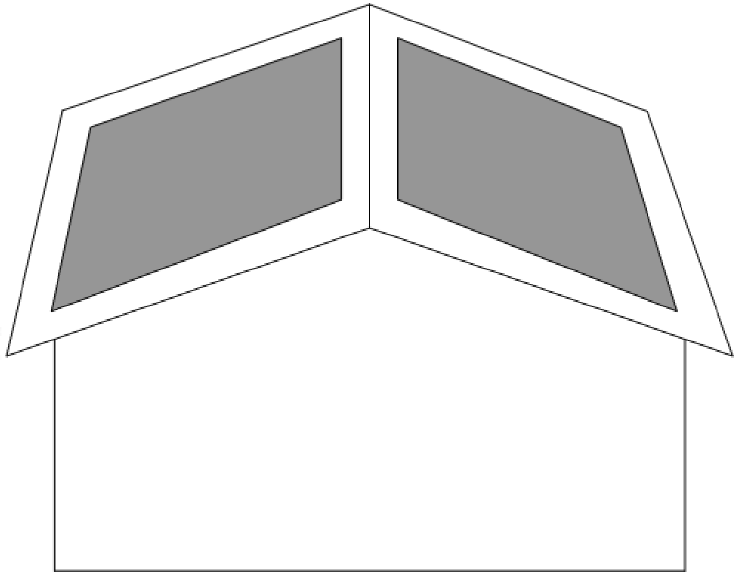
Figure 1. Schematic diagram of a single-phase grid-connected PV system with single MPPT inverter

2. Grid-connected PV (GCPV) system

SINGLE-PHASE GCPV SYSTEM

Circuit diagram with multiple MPPT inverter





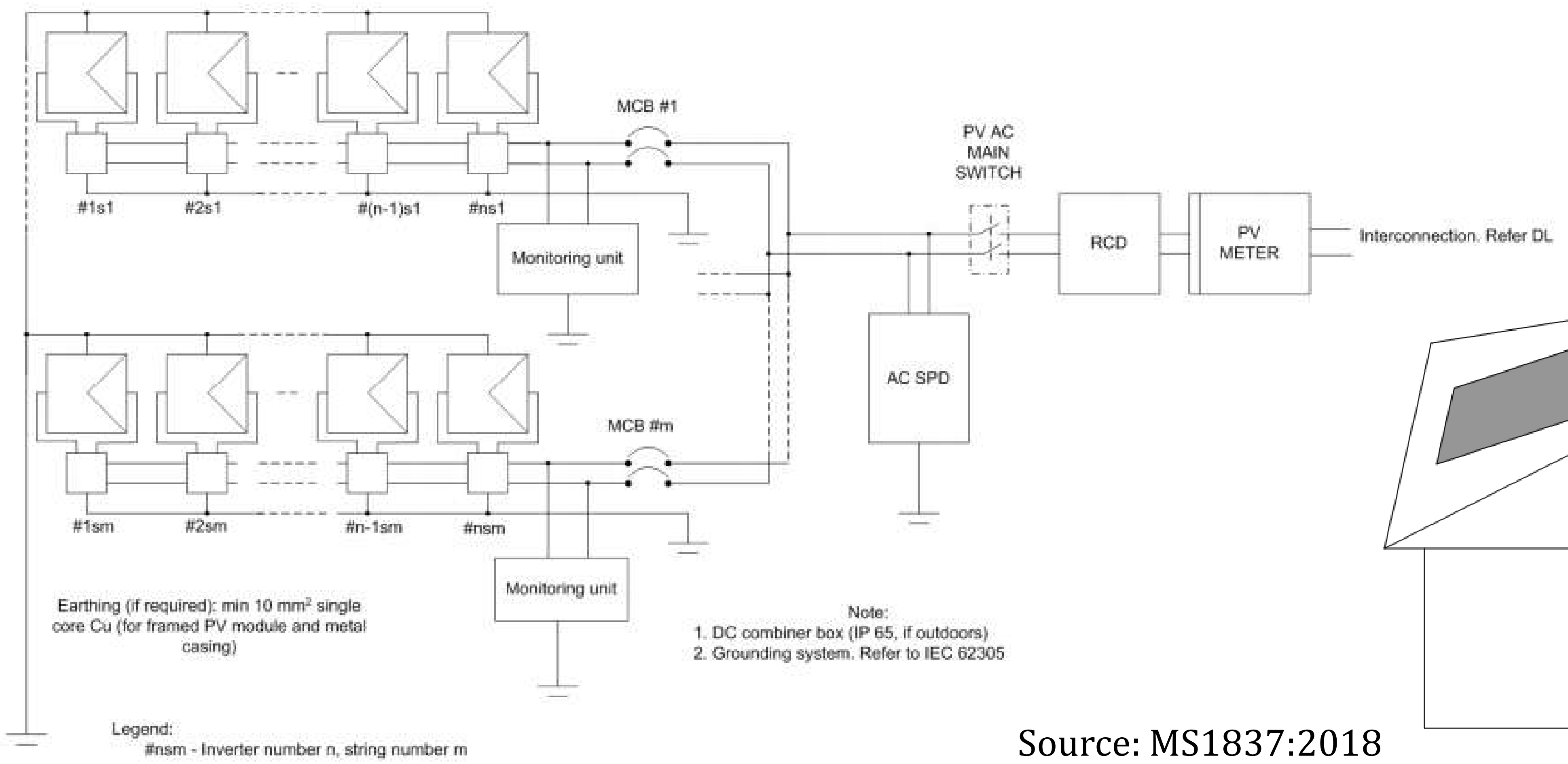
Source: MS1837:2018

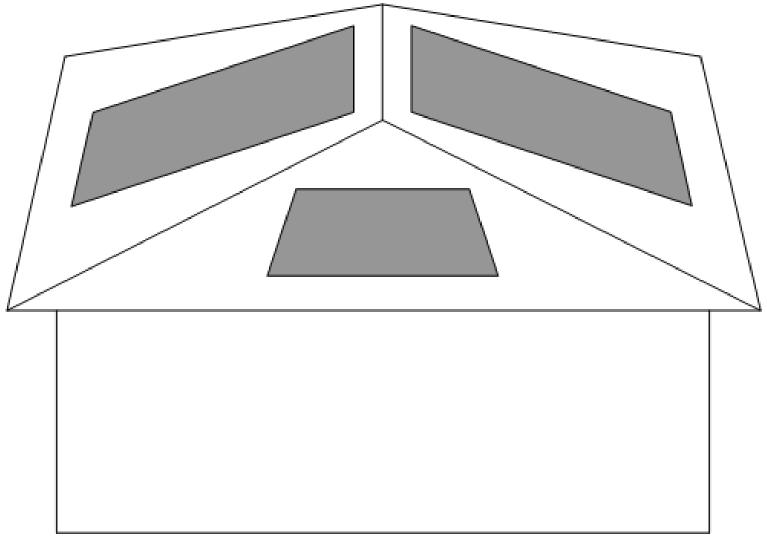
Source: MS1837:2018

2. Grid-connected PV (GCPV) system

SINGLE-PHASE GCPV SYSTEM

Circuit diagram with micro-inverter



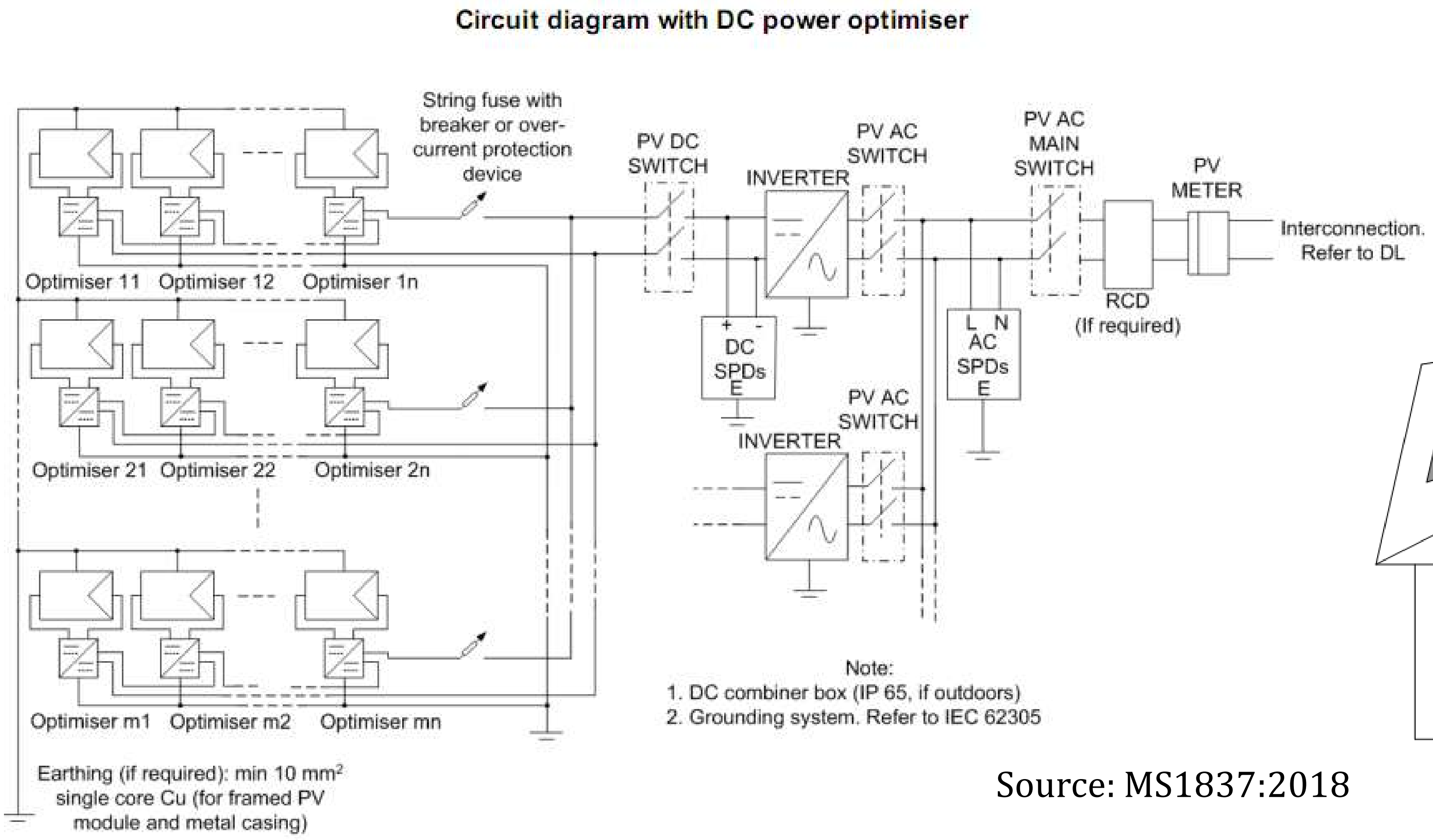


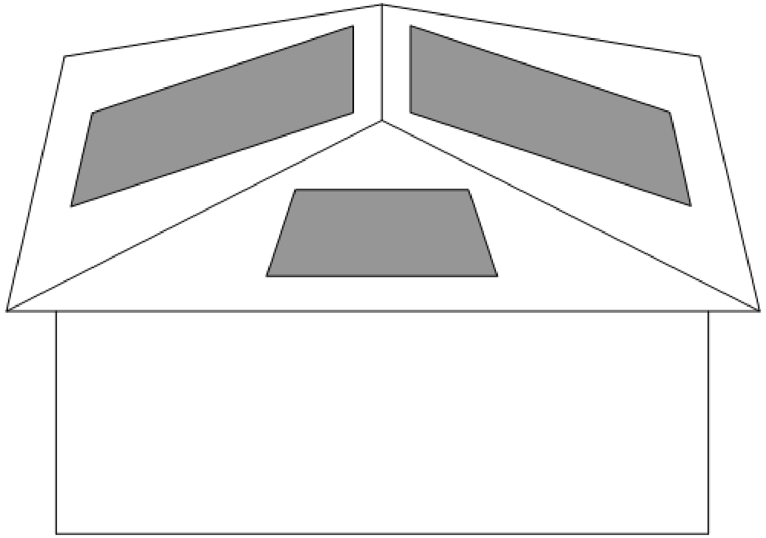
Source: MS1837:2018

Figure 5. Schematic diagram of a single-phase grid-connected PV system with micro-inverter

2. Grid-connected PV (GCPV) system

SINGLE-PHASE GCPV SYSTEM



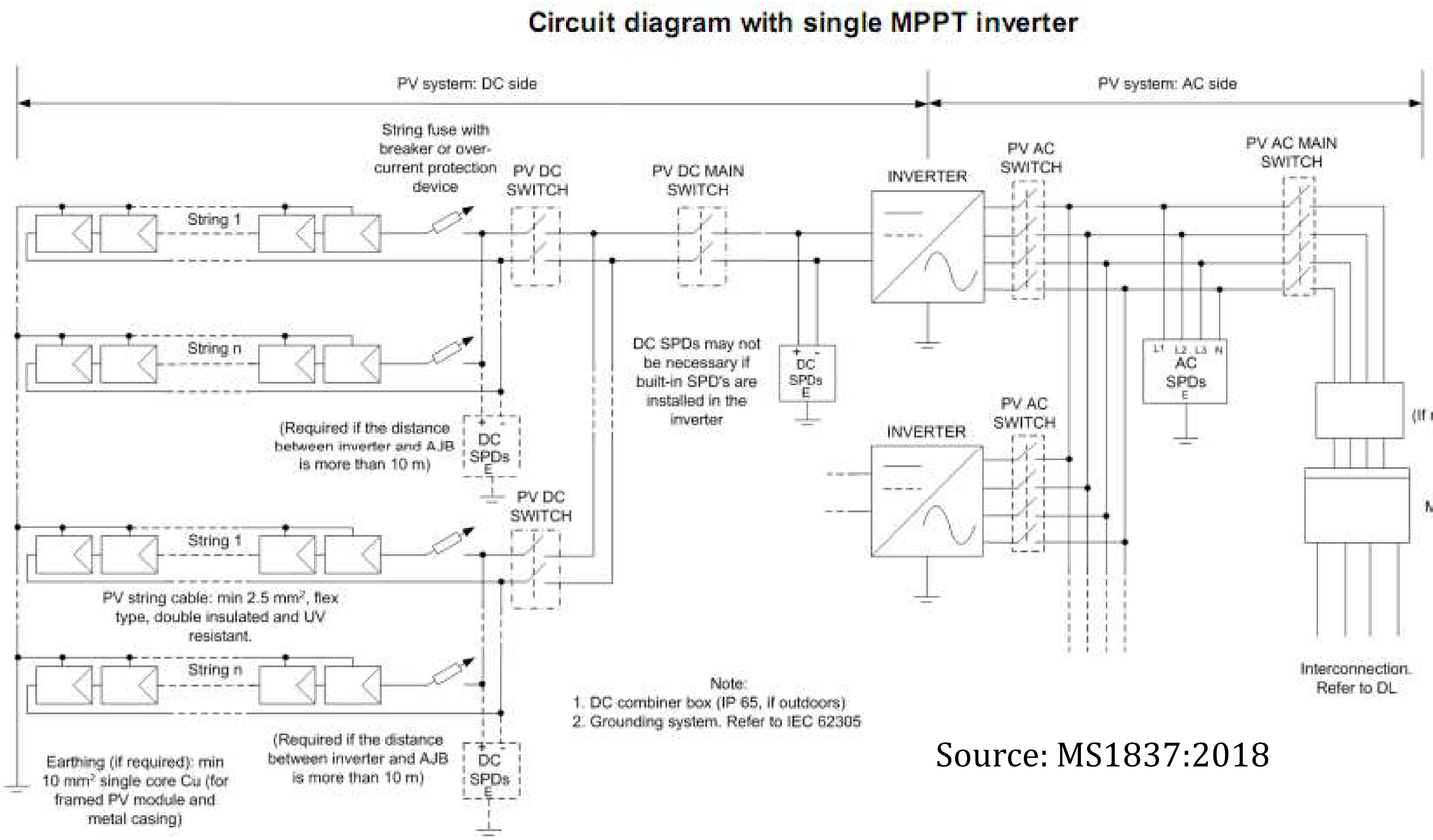


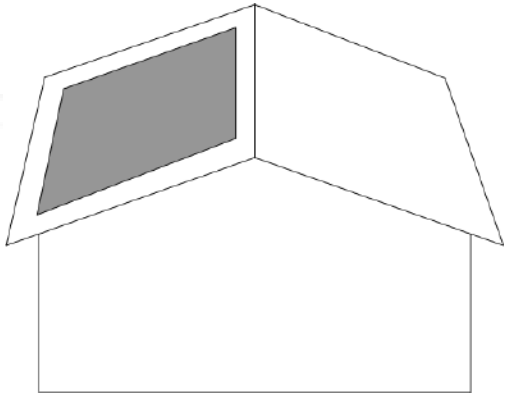
Source: MS1837:2018

Figure 6. Schematic diagram of a single-phase grid-connected PV system with DC power optimiser

2. Grid-connected PV (GCPV) system

THREE-PHASE GCPV SYSTEM



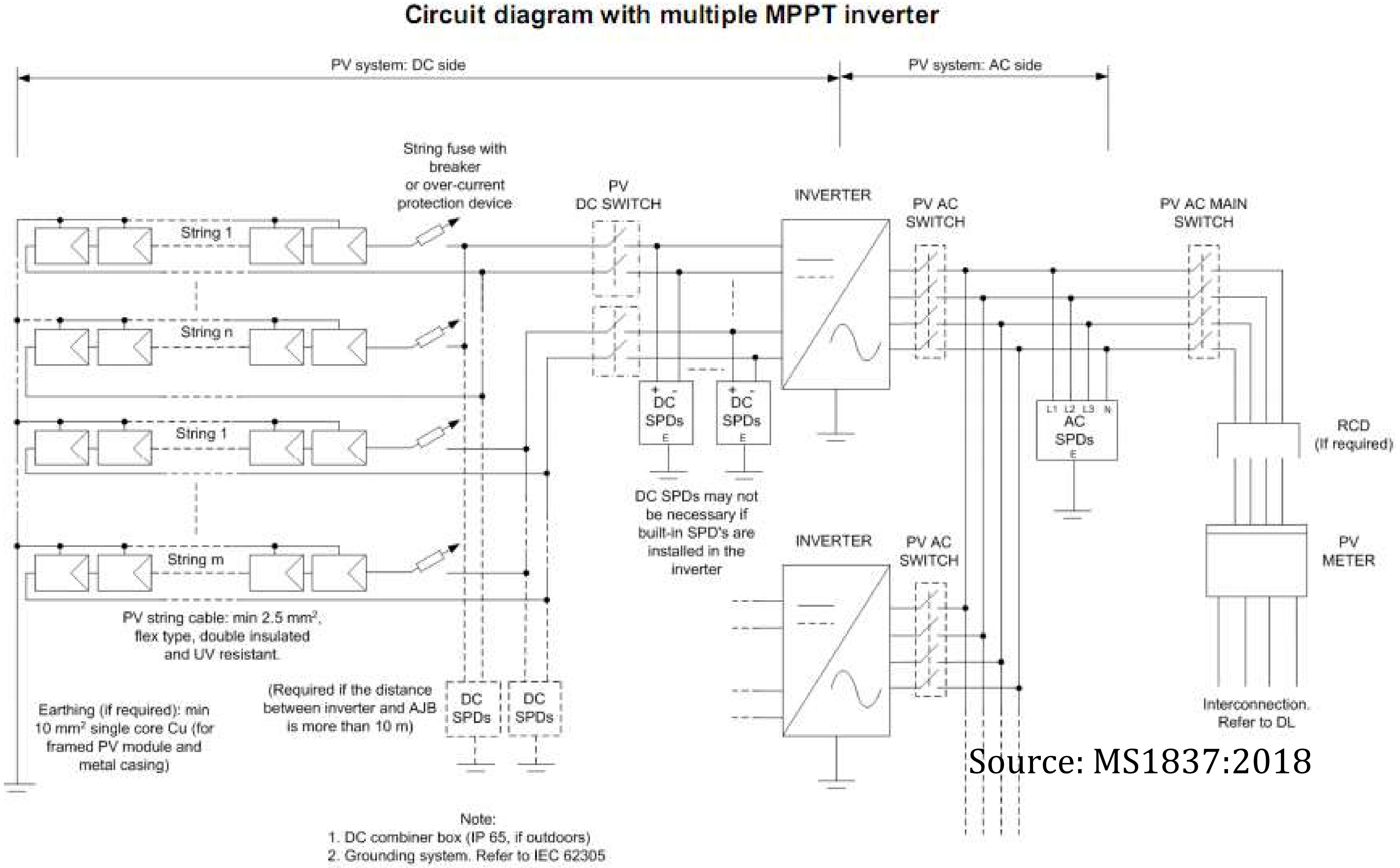


Source: MS1837:2018

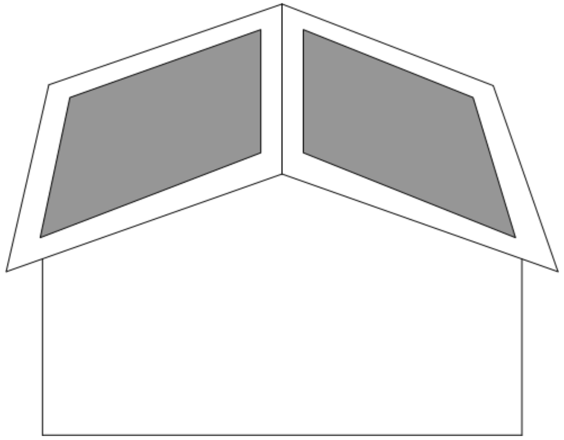
Source: MS1837:2018

2. Grid-connected PV (GCPV) system

THREE-PHASE GCPV SYSTEM



Source: MS1837:2018



Source: MS1837:2018

2. Grid-connected PV (GCPV) system

DISTRIBUTED GCPV SYSTEM

Small power generations (GCPV system) are located wide spread such as residential house, factory, commercial building etc

23 kWp grid-connected PV system

A typical grid-connected for residential house.

2. Grid-connected PV (GCPV) system

DISTRIBUTED GCPV SYSTEM

Source: https://pvms.seda.gov.my/pvmonitor/

2. Grid-connected PV (GCPV) system

CENTRALISED GCPV SYSTEM

8 MWp solar farm at Melaka, Malaysia

50 MWac solar farm at Sepang, Selangor, Malaysia

10 MW solar farm at Gebeng, Pahang, Malaysia

50 MW solar farm at Gambang, Pahang, Malaysia

2. Grid-connected PV (GCPV) system

CENTRALISED GCPV SYSTEM

FLOATING PV SYSTEM

Source: https://www.ciel-et-terre.net/project/sungai-labu-108-kwp/

3. Grid inverter technology

Operating Principle of Grid Inverter

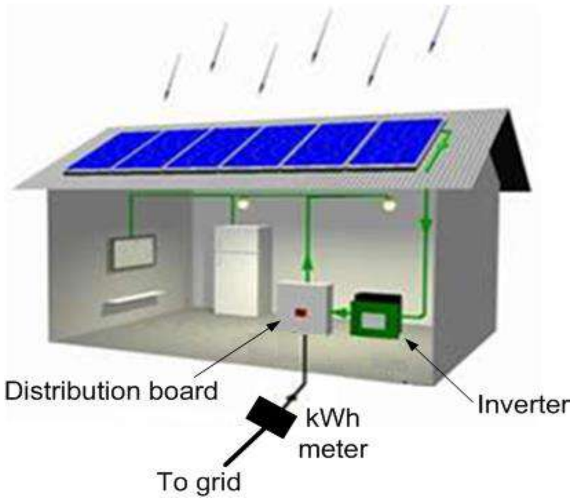
Standard Features

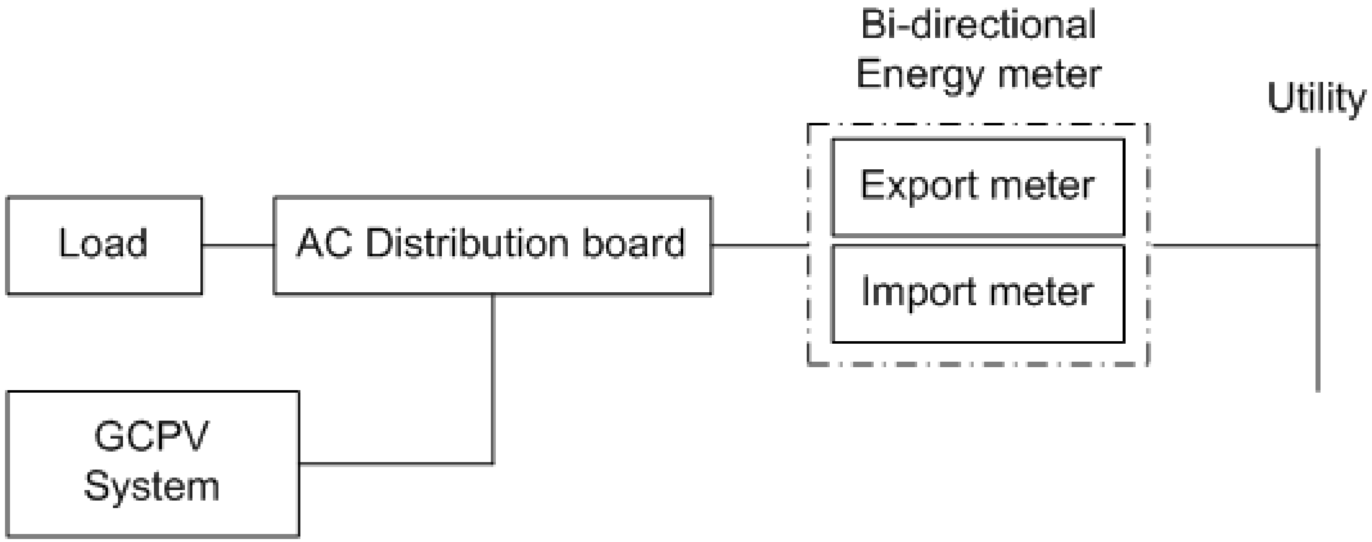
- Only works with the present of grid supply.
- Turns on if:
  - Input DC voltage is within the inverter's input voltage range.
  - AC voltage present and its value is within the operating range of the inverter.
  - Frequency of the grid is within the operating limit.
  - The inverter's temperature is within the operating limit.
- Optimum operating if:-
  - The DC input voltage is within MPPT voltage range of the inverter.
- Damage if:
  - The input voltage is higher than the maximum input voltage of the inverter.
  - Voltage surges from DC side or AC side i.e. due to lightning
- Turns off if:
  - Input voltage is less than the minimum input voltage
  - Grid voltage is not present or outside the operating range
  - Frequency of the grid is not stable or outside the operating range
  - Exceed temperature limit

4. Net energy metering (NEM) scheme

INDIRECT CONNECTION

- The power from the PV array flows to the load through distribution board.
- However, the grid voltage must always present.
- Applications for:-
  - Reduce energy consumption from the grid i.e. reduce electricity bill
  - Reduce Maximum Demand (MD) for MV system during daytime.
  - The surplus power generated by GCPV system flows to the grid (NEM).
  - Applicable for Net Energy Metering (NEM) and Self Consumption (SelCo) scheme





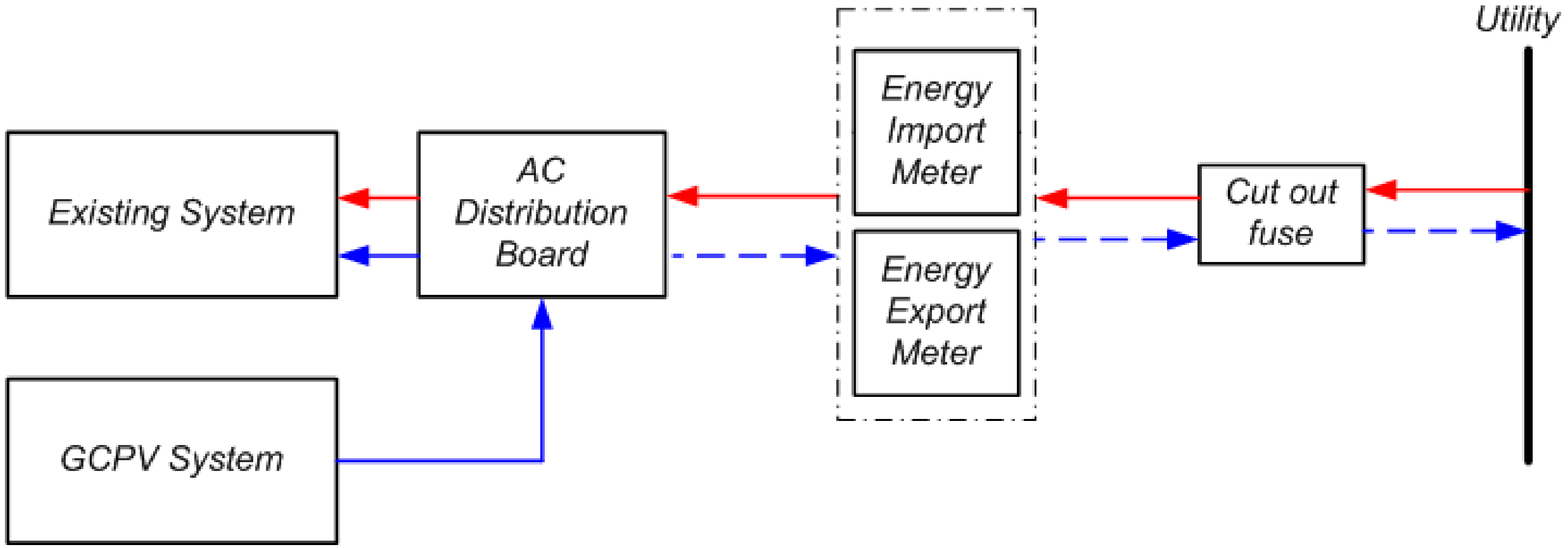
4. Net energy metering (NEM) scheme

INDIRECT CONNECTION

NET ENERGY METERING SCHEME (2017 – 2020)

Things to consider:-

1. Safety
2. Compliance to regulatory requirements
3. Cost
4. Minimum changes to the existing electrical network
5. Connect to DB which nearest to the load



A typical block diagram of NEM scheme for residential (LV)

Expected energy generation per month:
At least 100 kWh/kW per month

4. Net energy metering (NEM) scheme

<u>Advantages:</u>

(1) renewable energy - use a widely available renewable energy source - the sun - no fossil fuel, no greenhouse gas, no pollutant emissions , environmental friendly, economic and social sustainability development strategy

(2) Required only sunlight

(3) Simple to install at any scale

(2) Fed power to the grid – with or out battery

(3) PV can be used as building materials and decorative materials

(4) Improve the load balance of the power system and reduce line losses.

(5) Low OPEX - solar energy is cheap to maintain, saving you time and money

(6) Reduced electricity

- Reduced kWh
- Reduced MD

(7) If no sunlight or not enough sunlight– power consumed from the grid automatically – buy energy from TNB

(8) If more power generated than needed – power send to the grid – offset power to TNB

(9) Long duration energy generation .Typically 25 years at 20% degradation

4. Net energy metering (NEM) scheme

Example: Electricity bill

Billing Period : 01.04.2021 - 30.04.2021 (30 hari)
Tariff : D:Industrial

Tariff Block (kWh)	Cons. (kWh)	Rate (RM)	Amount (RM)
200	200.00	0.3800	76.00
>200	77,290.00	0.4410	34,084.89
Total Import	**77,490.00**		**34,160.89**

Tariff Block (kWh)	Cons. (kWh)	Rate (RM)	Amount (RM)
200	0.00	0.3800	0.00
>200	17,015.00	0.4410	7,503.61
Total Export	**17,015.00**		**7,503.61**

Details		ST Non Applicable	ST Applicable	Total
Consumption (kWh Import)	kWh	77,490.00	0.00	77,490.00
Consumption	RM	34,160.89	0.00	34,160.89
ICPT Rebate (RM 0.02/kWh)	RM	-1,549.80	0.00	-1,549.80
Current Month Usage	RM	32,611.09	0.00	32,611.09
RE Fund (1.6%)	RM			546.57
Current Charges (Import)	**RM**			**33,157.66**
kWh Export: 17,015.00	RM	-7,503.61		-7,503.61
Current Charges (Export)	**RM**			**-7,503.61**
Total Net Usage	**RM**	**0.00**	**0.00**	**25,654.05**

Meter No.	Meter Factor	Meter Reading		Cons.	Unit
		Previous	Current		
M1	1.00000	830,490	858,160	27,670	kWh (I)
	1.00000	221,640	233,250	11,610	kVARh
	1.00000	29,800	37,450	7,650	kWh (E)
M2	1.00000	1,932,492	1,982,312	49,820	kWh (I)
	1.00000	389,981	408,319	18,338	kVARh
	1.00000	50,918	60,283	9,365	kWh (E)

TNB Careline 1-300-88-5454

LPC NEM

For more information on bill and previous payments, please visit
http://www.mytnb.com.my
or contact
TNB Hotline
1-300-88-5454
Untuk gangguan bekalan atau kerosakan lampu jalan TNB sila hubungi melalui telefon / SMS
15454

For enquiries, please contact TNB Office:
[redacted]

1% surcharge applies for payments after 30 days from the date of the bill in accordance with the Licensee Supply Regulations 1990

Additional Information:
Power Factor : 0.93
Load Factor : 0.19

Validity of Cheque Payment is subject to bank's clearance

NEM Balance: 0 kWh
NEM Balance: RM0.00

NEM Balance Expiry Date: 31/12/2021

27,670 + 49,820 = 77,490 kWh

7,650 + 9,365 = 17,015 kWh

4. Net energy metering (NEM) scheme

<u>**Disadvantage:**</u>

1) Climatic dependent. It cannot generates electricity at night or in rainy days.
2) Required large area to generate large energy
3) High CAPEX

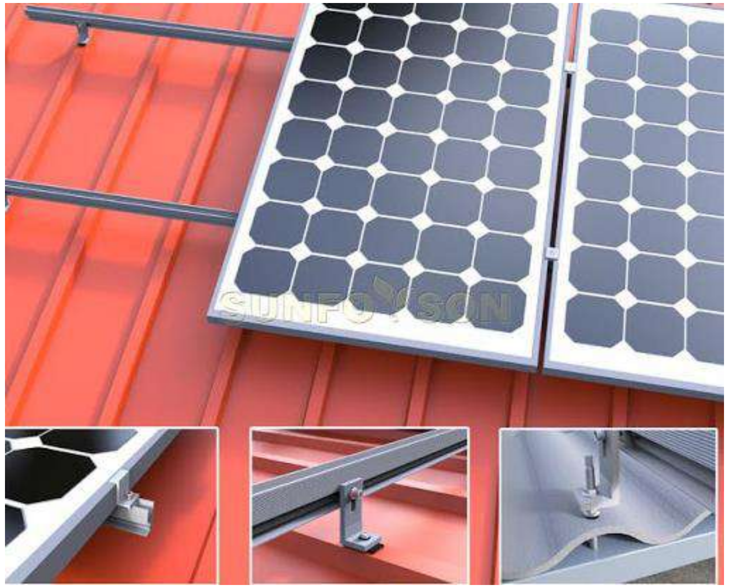
Further detail on NEM, please visit SEDA website:

http://www.seda.gov.my/reportal/nem/

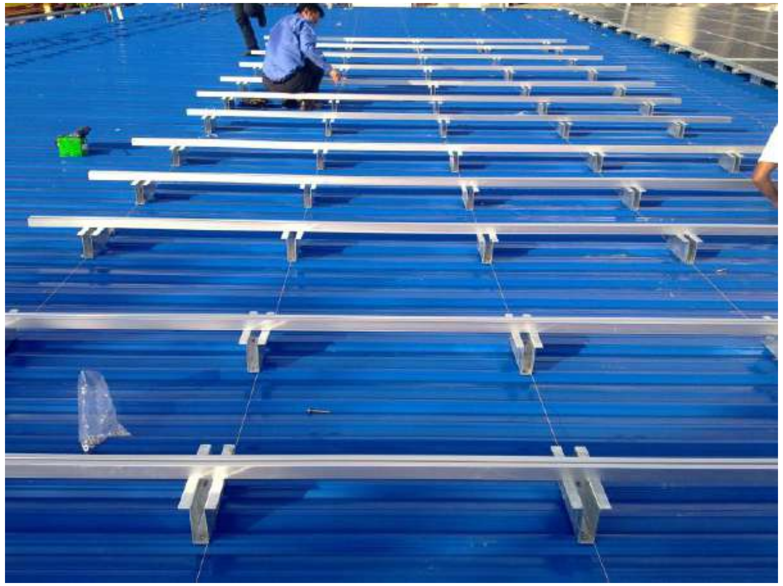
Registered PV Service Provider Directory – SEDA Malaysia:

http://www.seda.gov.my/directory/registered-pv-service-provider-directory/

5. Rooftop mounting structure



5. Rooftop mounting structure






6. Possible factors de-rate the power output of PV system

The actual output power produces from a PV module exposed under actual climate condition depend on:-

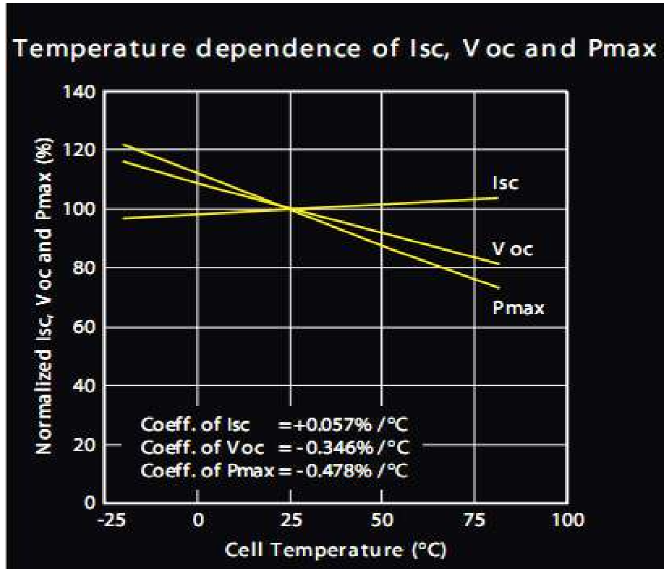
- Light Induced Degradation (LID)
- Potential Induced Degradation (PID)
- Crack or micro crack; it might happen during manufacturing, transportation or construction.
- Snail trails
- Faulty bypass diode; short circuit or open circuit
- Manufacturing quality; soldering of grid
- Solar irradiance –shading, soiling, scratch glass surface, tilt angle and orientation
- Module temperature – depend on air ventilation under the module
- Power tolerance – depend on PV manufacturer
- Aging – degrading over time as specified by PV manufacturer
- Poor installation

6. Possible factors de-rate the power output of PV system

Environmental Factors

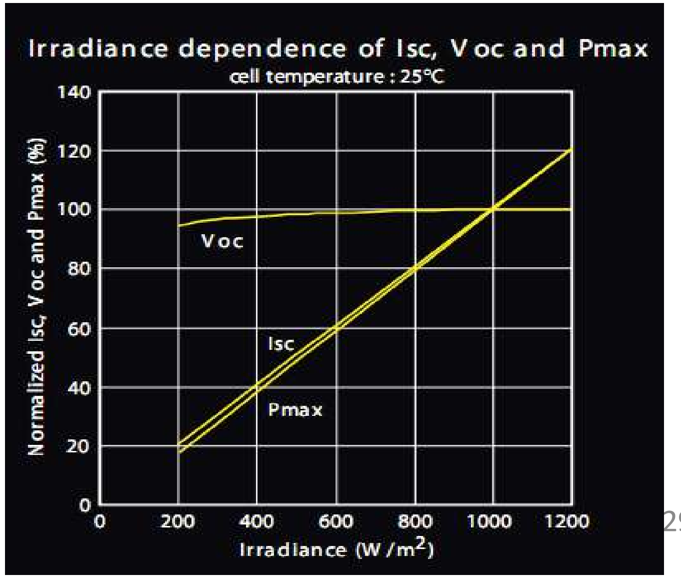
The effect of module temperature on its output:

- marginal effect on current.
- significant effect on voltage.
- Significant effect on the power.
- Types of mounting structure give effect on the air ventilation under the PV module. Less air circulation could increase module temperature.



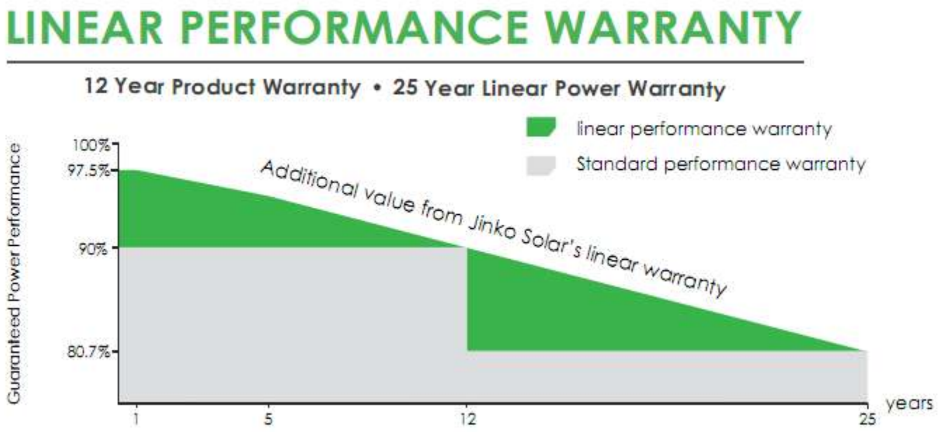
The effect of solar irradiance on its output:

- almost linear effect on current.
- almost linear effect on power.
- marginal effect on voltage.



6. Possible factors de-rate the power output of PV system

Aging factor



1. Module mismatch
2. Temperature
3. Soiling
4. Shading
5. Solar irradiance
6. Power loss in the cable
7. Power loss in the inverter
8. Aging

At highest solar irradiance, total power losses typically between 10 – 15%

7. Power output and reliability issues of GCPV system

1. Avoid shading
2. Keep PV modules clean
3. Tilt angle
4. Orientation
5. Keep PV module at low temperature
6. Choose good quality and reliable PV modules e.g. Bloomberg bankability
7. Good quality components
8. Use proper tools during installation
9. Follow standards e.g. MS1837, MS2692




7. Power output and reliability issues of GCPV system

Guidelines of Selection PV modules

1. Bloombergy Tier 1 list
2. BloombergyNEF bankability rating

Quarter 4.

Manufacturer	Capacity	Manufacturer	Capacity
LONGi	35,200	Waaree	2,200
Jinko	27,500	Phono Solar	2,200
Trina Solar	23,650	Neo Solar	1,980
JA Solar	16,500	REC Group	1,980
Canadian Solar	15,400	Hengdian	1,760
Risen	13,860	ET Solar	1,760
QCells	11,770	HT-SAAE	1,650
Suntech	11,000	Adani	1,650
GCL Systems	7,920	Renesola	1,650
Talesun	7,700	Vikram	1,320
First Solar	7,150	Boviet	1,320
Eging	5,720	Ulica	1,100

7. Power output and reliability issues of GCPV system

Related Standards on PV modules

IEC Standards

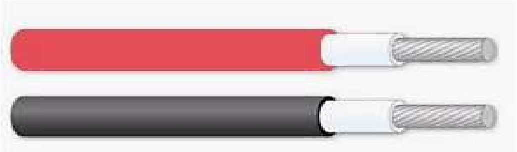
1. IEC 61215 Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval.
2. IEC 61701 Salt mist corrosion testing of photovoltaic (PV) modules
3. IEC 62716 Photovoltaic (PV) modules – Ammonia corrosion testing
4. IEC TS 62804-1 Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon
5. IEC 61730 – Photovoltaic (PV) module safety qualification

7. Power output and reliability issues of GCPV system

Special tool
MC4 crimping tools

7. Power output and reliability issues of GCPV system

- BOS components are all components in GCPV system except PV modules.
- The BOS components consist of the following items:
  - DC and AC cable
  - Array Junction Box (AJB)
  - DC and AC fuse
  - DC and AC SPD
  - DC and AC breaker
  - Grid inverter
  - Energy meter
  - Structure
  - Ducting
  - Connector
  - etc









7. Power output and reliability issues of GCPV system


MALAYSIAN STANDARD

MS 1837:2018

Installation of grid-connected photovoltaic (PV) system
(Second revision)

ICS: 27.160

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DEPARTMENT OF STANDARDS MALAYSIA


MALAYSIAN STANDARD

MS 2692:2020

Testing and Commissioning of Grid-Connected Photovoltaic System

ICS: 19.080, 27.160

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DEPARTMENT OF STANDARDS MALAYSIA

http://www.jsm.gov.my/web/msonline

8. Maintenance

Schedule maintenance

Shading

Cleaning

8. Maintenance

Schedule maintenance

Corrosion

8. Maintenance

Schedule maintenance

9. Monitoring

Requirements

Sensors and datalogger

- Shall install the following sensors:-
  - Plane of array and horizontal plane solar irradiance sensor(s)
  - Module and ambient temperature(s)
  - Wind sensor
- Datalogger
- Use IEC 61724:2010 PHOTOVOLTAIC SYSTEM PERFORMANCE MONITORING – GUIDELINES FOR MEASUREMENT, DATA EXCHANGE AND ANALYSIS

9. Monitoring

Requirements

Electrical parameters

- Datalogger – continuously logged every 5 minutes
  - Time and date
  - DC voltage for each MPPT channel
  - DC current for each MPPT channel
  - AC power output
  - AC voltage
  - Frequency
  - Plane of array and horizontal plane solar irradiance
  - Module and ambient temperature
  - Wind speed

Pyranometer

Reference cell type

10. Common complaints

Client complaints:-

1. Sudden drop of energy output
2. No output power or inverter turn off
3. Energy generated was not as expected
4. Inverter blinking
5. Penalty due to low power factor by the utility (Case of industry)

11. Proposal by Service Provider

1. Comply with all constraints
   a. Space area
   b. Budget
   c. Target energy generation
   d. Authority constraints
2. PVSyst simulation report
   a. System configuration
   b. Annual production probability; P50, P90 and P95
   c. Monthly energy generation
   d. Monthly PR
3. Financial analysis e.g. up to 10 years
4. Standard compliances; MS1837 and MS2692

12. PV system cost index

2007 ~ RM 37k per kW
2021 ~ RM3K to RM4K per kW
Expected payback period 4 ~ 6 years

Financial Summary	
System Size - KWp	240.24
CAPEX - Rm	552,552
Capital Allowance - Rm	(132,612)
Investment Tax Allowance - Rm	-
Payback = CAPEX / Cost Avoided	3.80
Project Internal Rate of Return	26.48%

END