Solar Energy for a Decarbonised Future - Knowledge Transfer for Environmental Education and Awareness (SolAware)

Summer Training 2023-2024

Session 6: Application of Power Converters in a PV System and New Solar Technology

A Project Funded by the British Council Between University of Mosul & Teesside university on Research Environment

This Session is divided into two parts

Application of Power Converters in a PV system(Part1)

New Solar Technology and the challenge of Building Large Solar Power Plant(Part 2)

Application of Power Converters in a PV system(Part1)

Learning objective

This lecture is to learn about power electronics application in a PV system.

- **Introduction to Power electronics.**
- **Types of Converters.**
- **Application of power converters in renewable energy.**
- **DC-DC converters and their topologies.**
- **Voltage control.**
- **Inverters and its application in PV systems.**
- **Bi-directional Inverter.**
- **Charge Controller and MPPT Controller.**
- **Power Optimizer.**

Application of Power Converters in a PV system

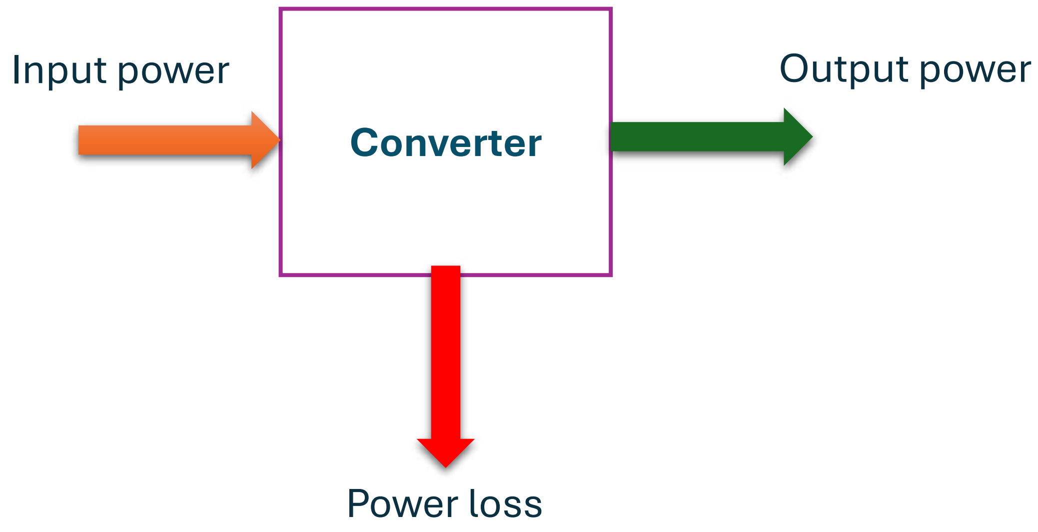
Introduction to Power Converters

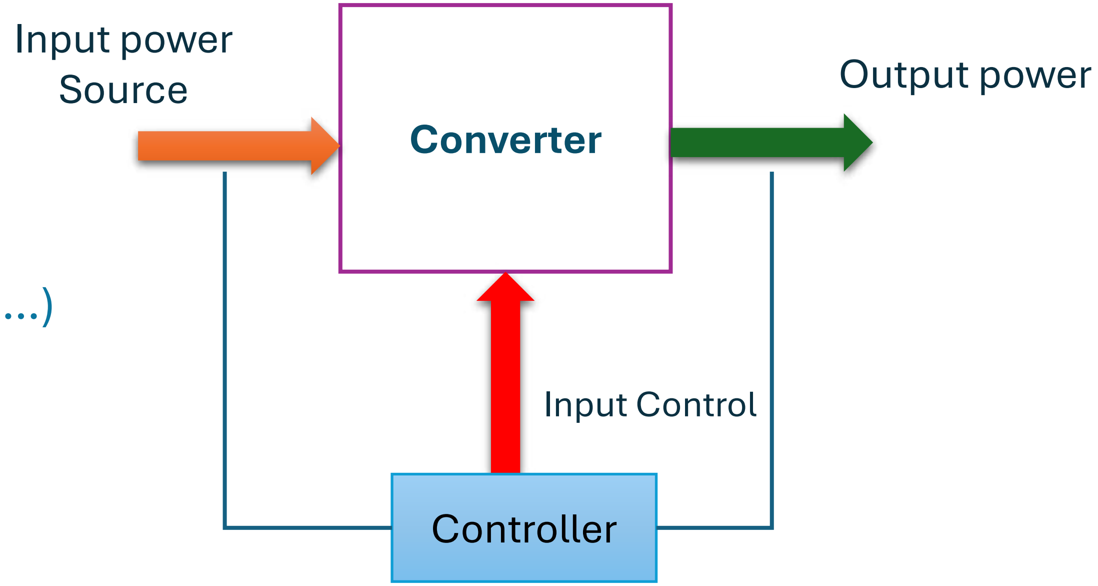
- The term converts mean to transforms one form to another form. In converters, the electrical power is converted from one form to another form.
- Which means the change of voltage or current magnitude and the change in frequency.
- To achieve high conversion efficiency and this is desirable. The efficiency can be defined as the ration of output power to input power. For power converters, the efficiency is about 97%.

$$\text{Efficiency, } \eta = \frac{Power\ output}{Power\ input}$$

$$\text{Efficiency, } \eta = \frac{Power\ output}{Power\ output + Power\ loss}$$

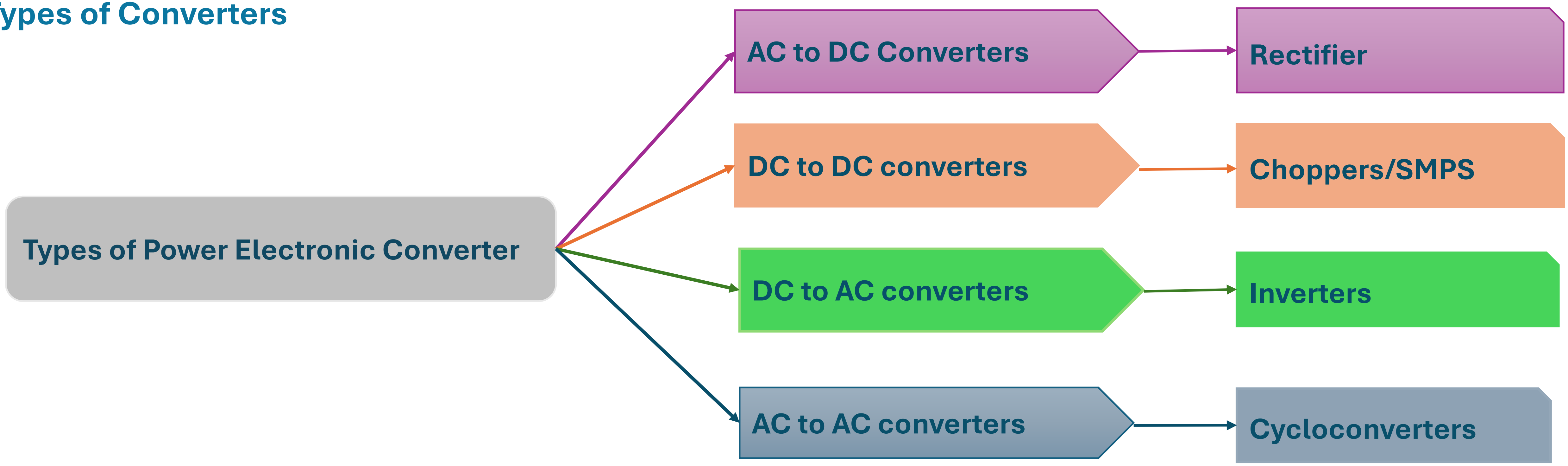
- A power converter consists of active (Diode, transistors, SCR etc...) and passive components (resistor, inductor, capacitor, etc...)





Application of Power Converters in a PV system

Types of Converters



Focus will be on DC-to-DC (SMPS) converters and DC to AC
&
Their applications in PV systems

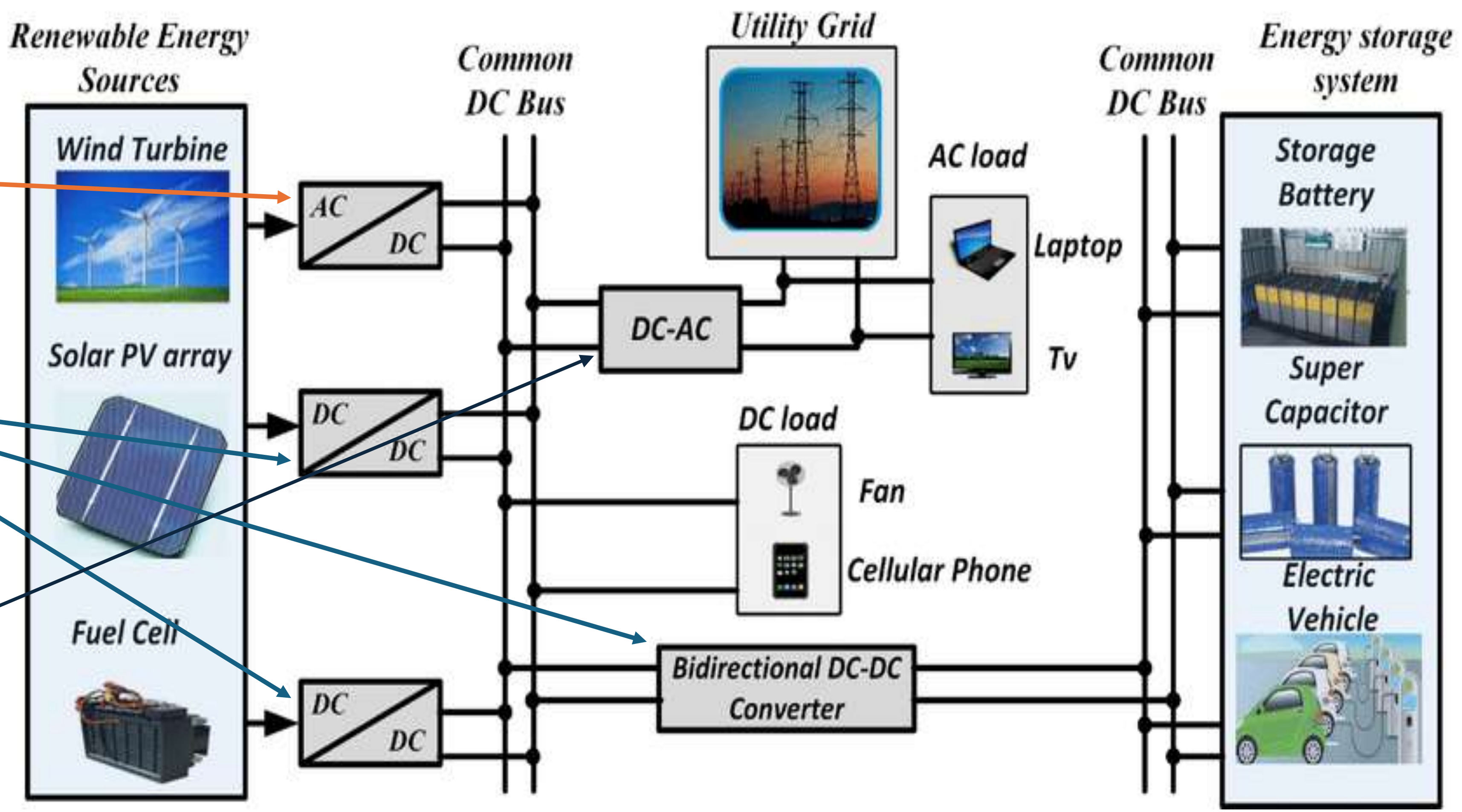
Application of Power Converters in a PV system

Application of Power Converters in Renewable Energy

Application of Rectifier

Application of SMPS

Application of Inverters



In PV systems SMPS and Inverters are mostly used.

DC-DC Converters

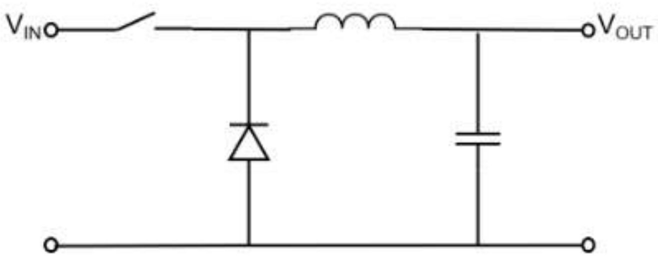
Overview - DC to DC converters (Switch Mode Power Supply –SMPS)

- Configuring the components of DC-DC converters in different ways will lead to the forming of various power circuit topologies.
- All the circuit topologies have the same types of components including capacitor (C), inductor (L), load resistor (R), and the lossless semiconductor components.
- The selection of the topology is mainly dependent on the desired level of regulated voltage, since DC-DC converters are applied to produce regulated DC voltage with a DC level different from the input DC voltage.
- The output level can be higher or lower than the DC input voltage.
- *Types of DC-DC converters:*
- Buck Converters (Step-down).
- Boost Converters (Step-up).
- Buck-Boost Converters(Step up/down).
- Bi-directional Converters.

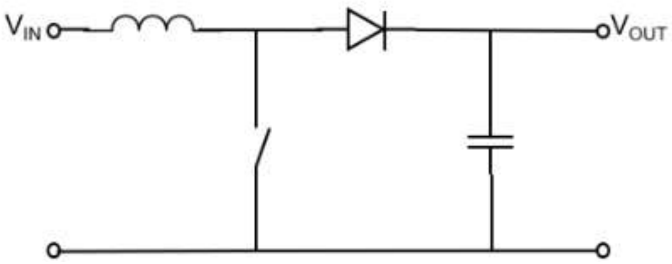
DC-DC Converters Topology

As mentioned earlier, the circuit topology construction will decide the type of converter is required for the desired application.

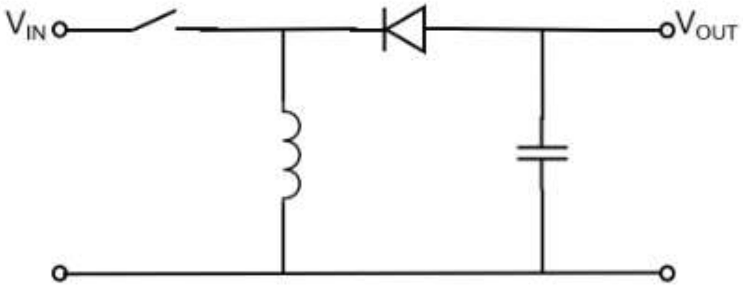
Buck Converter



Boost Converter



Buck-Boost Converter



What are the differences in each topology? How to remember which topology represent which converter?

All the circuits have common components – Switch (MOSFET), Diode, Inductor and Capacitor. However, their arrangement is different.

Buck – After the input source comes switch. A Diode in parallel to capacitor and source. An Inductor is between the diode and the capacitor.

Boost – After the input source comes Inductor. Switch in parallel to capacitor and source. Diode is between the switch and the capacitor.

Buck-Boost – After the input source comes Inductor. An inductor in parallel to capacitor and source. A diode is between the inductor and the capacitor, but with change of polarity (Boost).

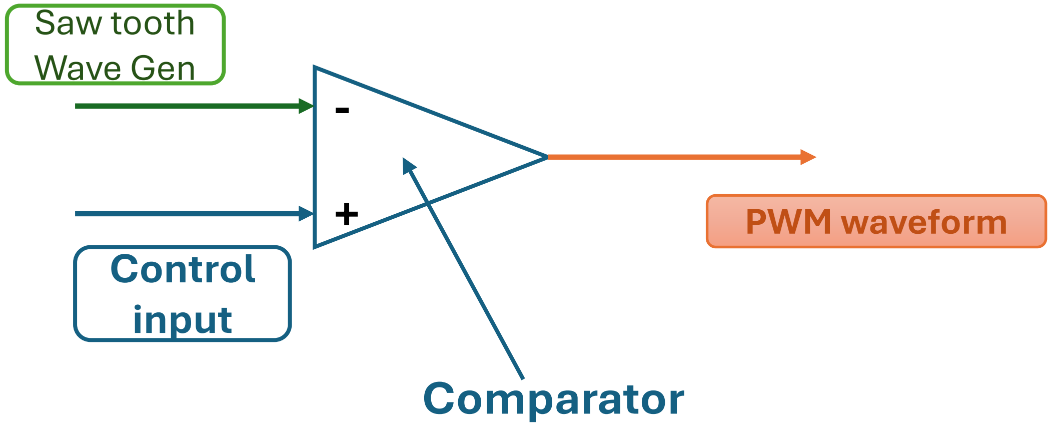
DC-DC Converters Topology

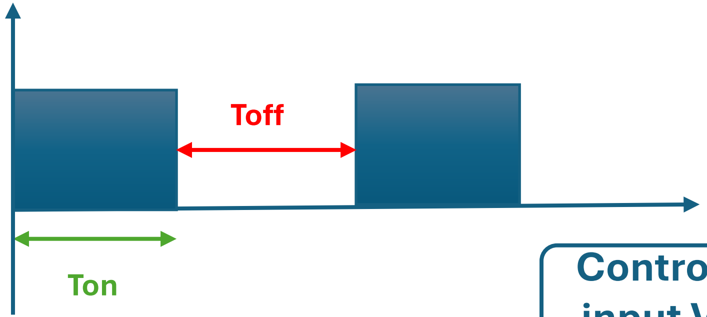
BUCK Converter.

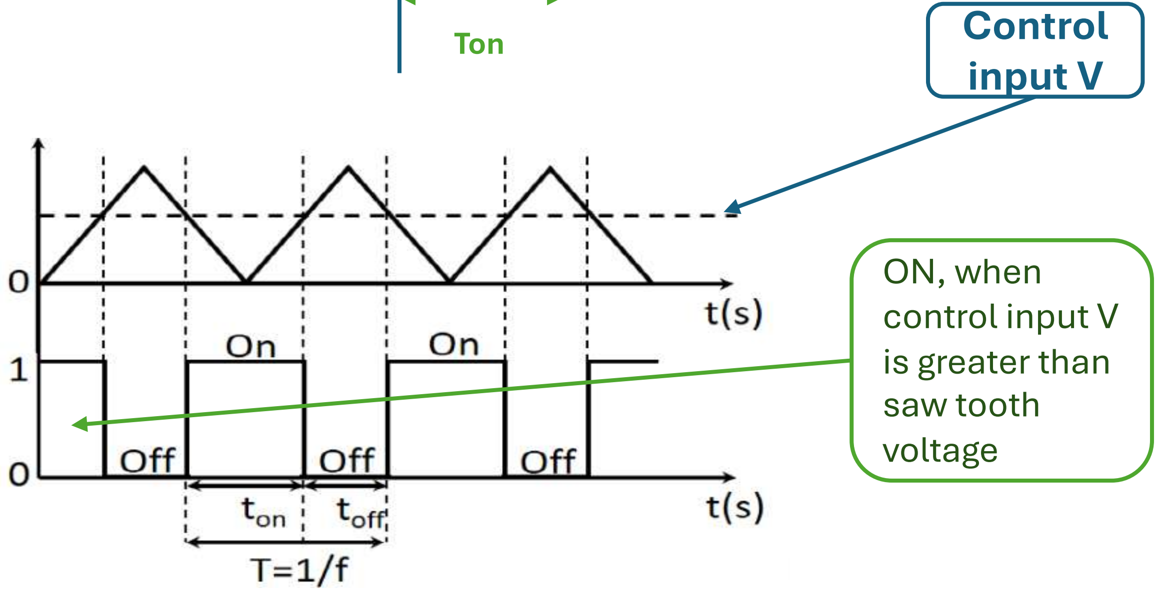
For all the converters, there is a semiconductor switch usually MOSFET.

- ❑ Converting input voltage to lower or higher output voltage depends on controlling the power switch, usually by using pulse width modulation (PWM) signal.
- ❑ Duty cycle comes when there is ON/OFF state. This is the ratio of ON time over total time period of the switching frequency.
- ❑ Duty cycle is written as D or δ = $\frac{Ton}{T} = \frac{Ton}{Ton+Toff}$
- ❑ Duty cycle comes handy when we will learn MPPT.

How PWM signal is generated?







DC-DC Converters Topology- Voltage Control

Buck Converter

- The output-input relationship of a buck converter is given by $\boldsymbol{V_{out}}$ **= δ** $\boldsymbol{V_{in}}$. The δ is inversely proportional to the $\boldsymbol{V_{in}}$.

Where $\delta = \frac{Ton}{T} = \frac{Vcontrol}{Vsawtooth}$

$$V_{out} = \frac{Vcontrol}{Vsawtooth} V_{in}.$$

- The V_{out} can be controlled if we vary the duty ratio δ.
- **The frequency of the repetitive sawtooth waveform determines the <u>switching frequency</u>.**

Boost Converter

- The output-input relationship of a Boost converter is given by $\frac{Vout}{Vin} = \frac{1}{1-\delta}$

Rearranging the equation gives $\boldsymbol{\delta = 1 - \frac{Vin}{Vout}}$, The δ is inversely proportional to the ratio of $\frac{Vin}{Vout}$. Typically, the boost converters have a maximum duty cycle around 0.8 to 0.9. Also, the maximum output voltage is limited to around 2-4 times the input voltage.

Buck-Boost Converter

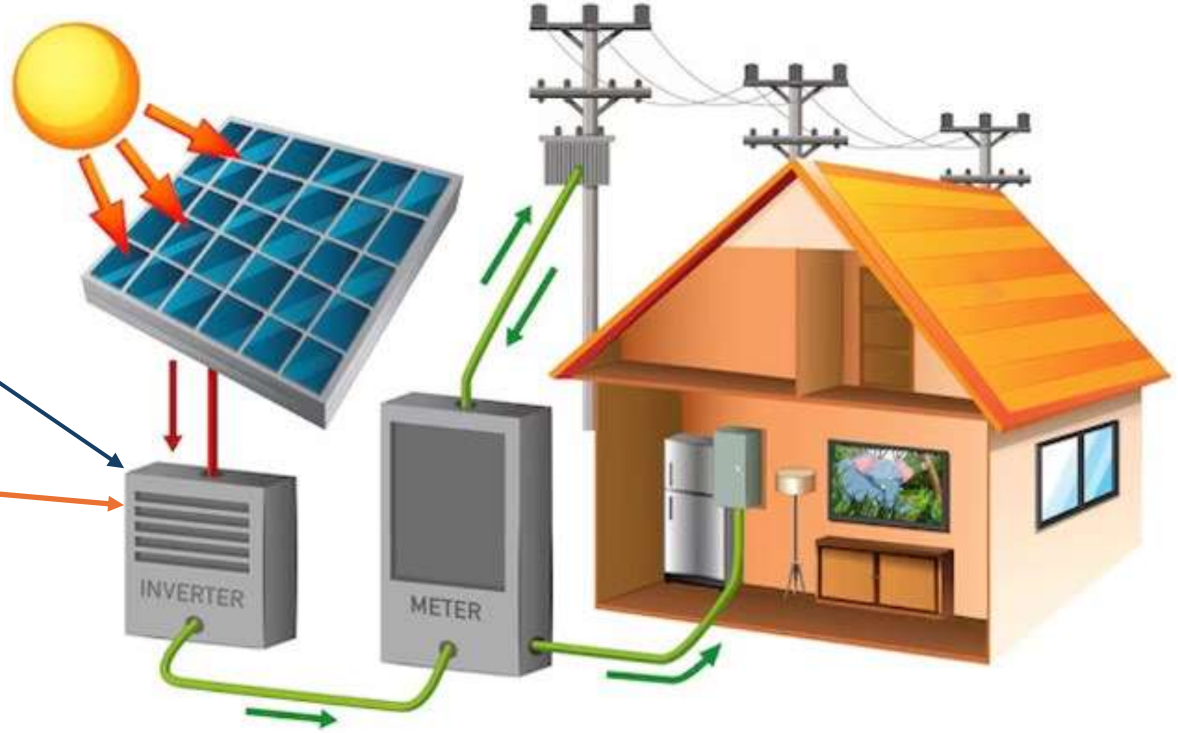
- The output-input relationship of a Buck - Boost converter is given by $\boldsymbol{\frac{Vout}{Vin} = \frac{\delta}{1-\delta}}$ **or Vout = Vin** $\boldsymbol{\frac{\delta}{1-\delta}}$

Inverter

What is an Inverter?

Converts DC to AC.

The AC output will have variable frequency and magnitude.



Frequency is 50Hz (most parts of the world) or 60Hz (USA and Canada). Output voltage 240V or 120V (single phase). For three phase the voltage is mostly between 400 and 415V. For the USA it is 208 or 480V. ***Depending on the application, (the input and output) voltage, current and power is selected***.

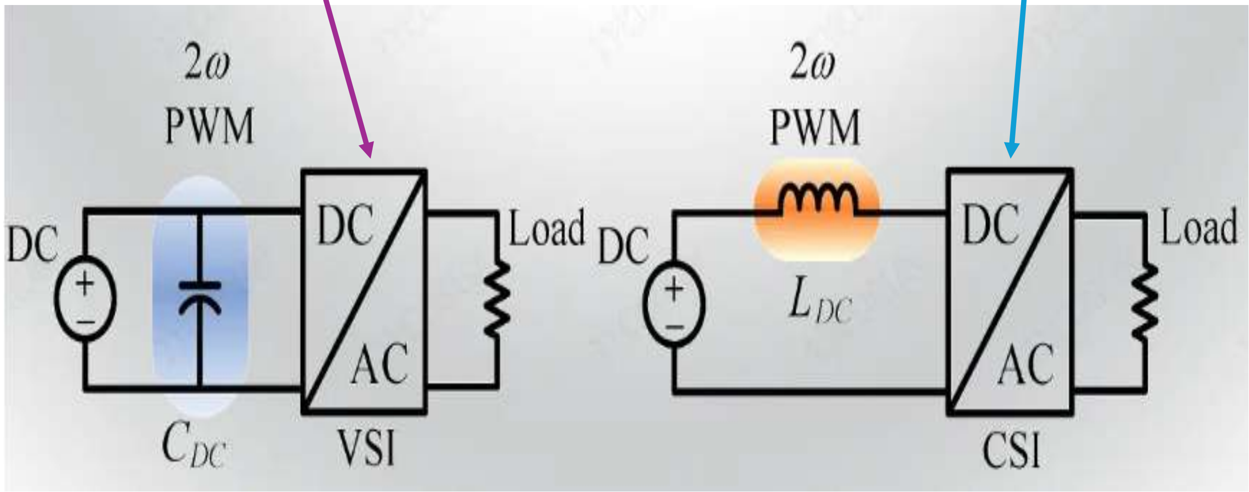
Inverter

Inverter Topology

- Two types of circuit topologies are used:

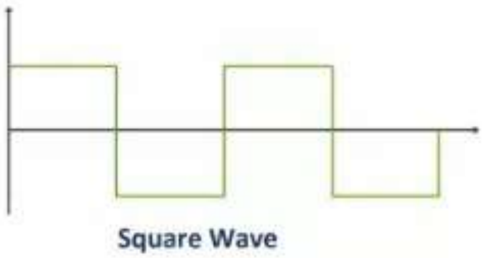
Voltage source inverter (VSI)

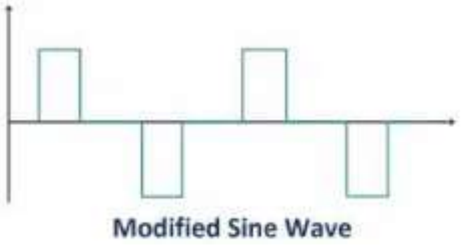
Current source inverter (CSI)

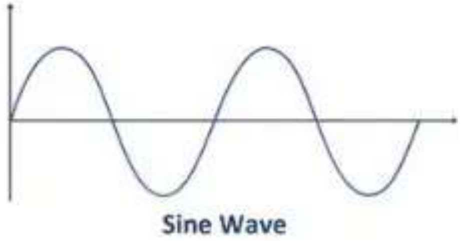


What type of output wave forms are produced?

- Square
- Sine
- Modified Sine







A pure sine wave output is preferred as many electrical products are designed to work best with since wave.

Inverters in PV systems- Applications

- Focus on – Voltage source Inverters (VSI).

Applications of VSI in industries and sectors.

Renewable energy: converting the DC output of solar panels into grid-compatible AC power, facilitating the integration of solar energy into the power grid.

Motor Drives: They are commonly employed in variable frequency drives for electric motors, offering precise control over motor speed and torque.

Uninterruptible Power Supplies (UPS):VSIs provide a reliable source of AC power during grid outages, ensuring uninterrupted operation of critical systems such as data centres and medical facilities

Grid-tied systems: Utilized in grid-tied systems where renewable energy sources, such as wind or solar power, are connected to the electrical grid.

Portable power: The VSI converts the DC power from the batteries into AC for variety of AC devices.

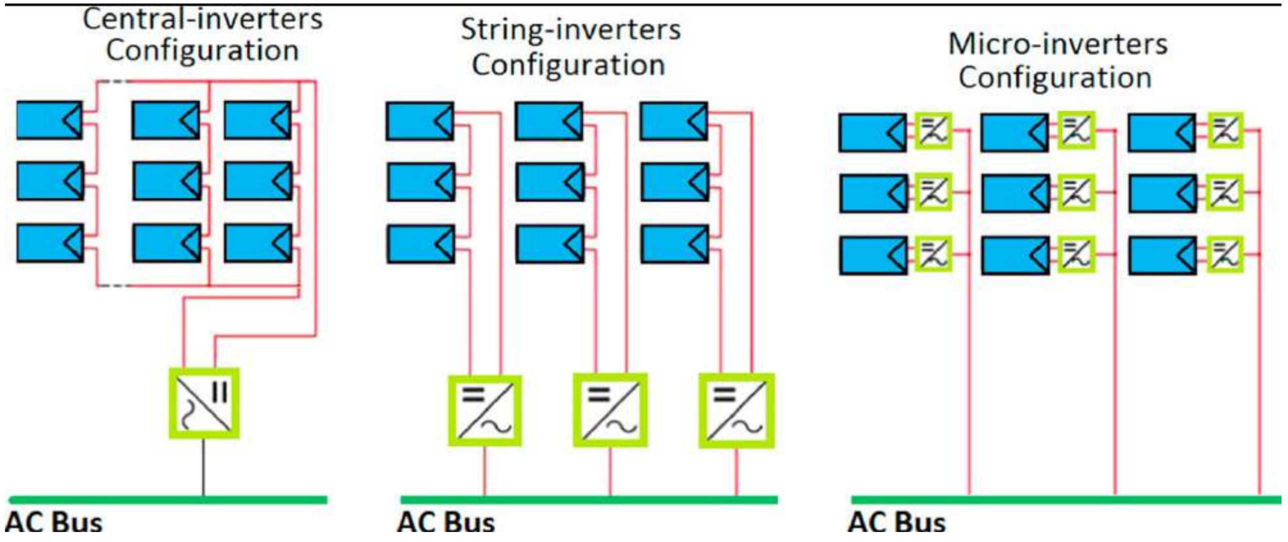
Inverters in PV system - Types

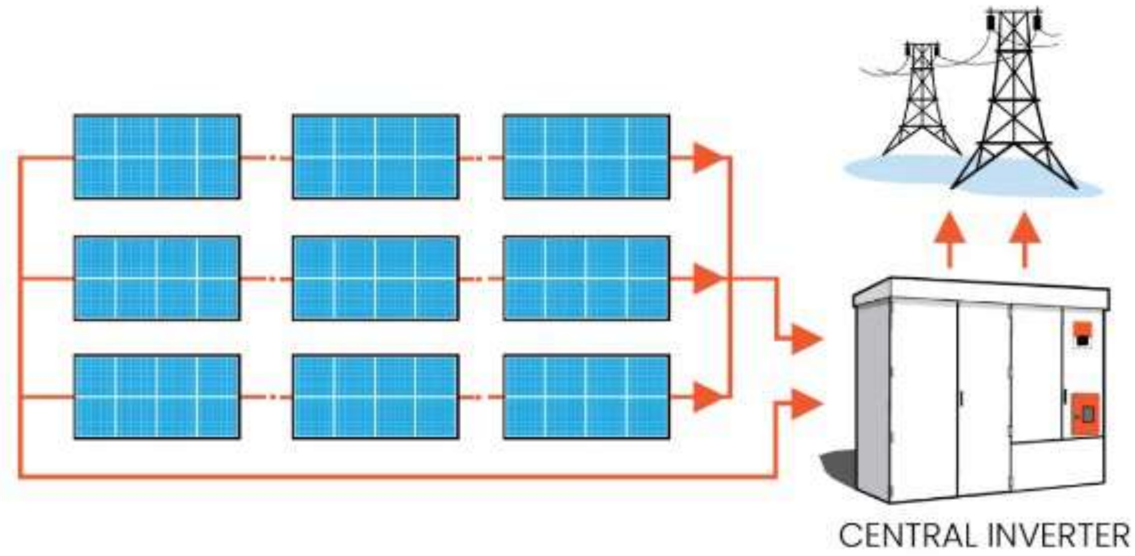
3 types of solar inverters are available in the market. Let's get familiar with those inverters and their configuration.

Central Solar Inverter

String Solar Inverter

Solar Micro Inverter





Inverters in PV system - Types

Advantages and Disadvantages of the 3 inverters

Central Inverter/String Inverter

Advantages	Disadvantages
Higher efficiency (95-98%).	Single point failure will lead to entire system down.
Lower cost per watt of installed capacity.	Performance is affected by module mismatch and shading, as all the modules are connected in series.
Easier installation & Maintenance.	
Suitable for large/medium scale solar installations.	Limited flexibility is system design and module placement.

Micro Inverter

Advantages	Disadvantages
Module-level power optimisation, improving performance under shading and mismatch condition.	Higher cost per watt of installed capacity.
	Lower overall system efficiency (typically 95%) due to multiple power conversion stages.
Increased system flexibility and design option.	
Safety – Each module has its own inverter.	Increased maintenance complexity- Multiple inverters
Easier system expansion or module replacement.	Higher failure rates due to large number of inverters.

In summary, central inverters offer higher efficiency and lower cost, but lack flexibility and have a single point of failure. Micro-inverters provide module-level optimization and flexibility, but at a higher cost and with increased maintenance complexity. String inverters strike a balance between cost, efficiency, and design flexibility, making them a popular choice for medium-sized solar installations.
The choice between these inverter types depends on the specific requirements of the solar installation, such as system size, shading conditions, future expansion plans, and cost considerations.

Inverters in PV system - Types

Can we use any inverter as central, string or micro?

- No, we cannot. Because there are specific design and functionality requirements that distinguish central string, and micro inverters.

Central Inverters:
- Central inverters are designed for large-scale, utility-scale solar installations, typically ranging from tens of kilowatts to multiple megawatts.
- They feature high power handling capabilities, often in the range of 10 kW to 1 MW or more.
- Central inverters are engineered to handle the combined input from multiple series-connected solar strings.
- They often include advanced grid-integration features and can be integrated into complex monitoring and control systems.

String Inverters:
- String inverters are designed for medium-sized solar installations, typically ranging from a few kilowatts to tens of kilowatts.
- They can handle the input from multiple series-connected solar panels (a "string") and are optimized for this configuration.
- String inverters have power ratings typically ranging from 2 kW to 20 kW.
- They often include features like maximum power point tracking (MPPT) to optimize energy harvest from the connected solar strings.

Micro Inverters:
- Micro-inverters are designed to be installed at the individual solar panel level, typically with power ratings of 250-400 watts.
- They convert the DC output from a single solar panel into AC power, providing module-level optimization and control.
- Micro-inverters are not suitable for use as central or string inverters due to their low power handling capabilities.

Inverters in PV system - Types

Central, String and Micro inverters

Central Inverter – Grid

Technical data and types

Product Type designation	PVS980-58 2.0 MVA -1818kVA-I	PVS980-58 2.1 MVA -1909kVA-J	PVS980-58 2.2 MVA -2000kVA-K	PVS980-58 2.3 MVA -2091kVA-L
Input (DC)				
Maximum recommended PV power ($P_{PV,max}$) 1)	2909 kWp	3056 kWp	3200 kWp	3346 kWp
Maximum DC current ($I_{max (DC)}$)	2400 A	2400 A	2400 A	2400 A
DC voltage range, mpp ($U_{DC, mpp}$) at 35 °C	850 to 1500 V	893 to 1500 V	935 to 1500 V	978 to 1500 V
DC voltage range, mpp ($U_{DC, mpp}$) at 50 °C	850 to 1100 V	893 to 1100 V	935 to 1100 V	978 to 1100 V
Maximum DC voltage ($U_{max (DC)}$)	1500 V	1500 V	1500 V	1500 V
Number of MPPT trackers	1	1	1	1
Number of protected DC inputs	8 2) to 24 (+/-)	8 2) to 24 (+/-)	8 2) to 24 (+/-)	8 2) to 24 (+/-)
Output (AC)				
Maximum power ($S_{max (AC)}$) 3)	2000 kVA	2100 kVA	2200 kVA	2300 kVA
Nominal power ($S_{N(AC)}$) 4)	1818 kVA	1909 kVA	2000 kVA	2091 kVA
Maximum AC current ($I_{max (AC)}$)	1925 A	1925 A	1925 A	1925 A
Nominal AC current ($I_{N(AC)}$)	1750 A	1750 A	1750 A	1750 A
Nominal output voltage ($U_{N(AC)}$) 5)	600 V	630 V	660 V	690 V
Output frequency 5)	50/60 Hz	50/60 Hz	50/60 Hz	50/60 Hz
Harmonic distortion, current 6)	< 3%	< 3%	< 3%	< 3%
Distribution network type 7)	TN and IT	TN and IT	TN and IT	TN and IT
Efficiency				
Maximum 8)	98.8%	98.8%	98.8%	98.8%

https://www.fimer.com/sites/default/files/FIMER_PVS980-58-from1818to2091_EN_RevC.pdf

Inverters in PV system - Types

Central, String and Micro inverters

Central Inverter – off grid

Model Name	S6-GR1P2.5K	S6-GR1P3K	S6-GR1P3.6K	S6-GR1P4K	S6-GR1P4.6K	S6-GR1P5K	S6-GR1P6K
Input DC							
Recommended max. PV power	3.75 kW	4.5 kW	5.4 kW	6 kW	6.9 kW	7.5 kW	9 kW
Max. input voltage	550 V	600 V					
Rated voltage	250 V	330 V					
Start-up voltage	60 V	120 V					
MPPT voltage range	50-450 V	90-520 V					
Max. input current	14 A / 14 A						
Max. short circuit current	22 A / 22 A						
MPPT number/Max. input strings number	2/2						
Output AC							
Rated output power	2.5 kW	3 kW	3.6 kW	4 kW	4.6 kW	5 kW	6 kW
Max. apparent output power	2.8 kVA	3.3 kVA	4 kVA	4.4 kVA	5 kVA	5 kVA	6 kVA
Max. output power	2.8 kW	3.3 kW	4 kW	4.4 kW	5 kW	5 kW	6 kW
Rated grid voltage	1/N/PE, 220 V / 230 V						
Rated grid frequency	50 Hz / 60 Hz						
Rated grid output current	11.4 A / 10.9 A	13.6 A / 13.0 A	16.0 A / 15.7 A	18.2 A / 17.4 A	20.9 A / 20.0 A	22.7 A / 21.7 A	27.3 A
Max. output current	13.3 A	15.7 A	16.0 A	21.0 A	23.8 A	25.0 A	27.3 A
Power Factor	>0.99 (0.8 leading - 0.8 lagging)						
THDi	<3%						
Efficiency							
Max. efficiency	97.3%	97.3%		97.6%		97.7%	

https://cdn.shopify.com/s/files/1/0257/3103/9284/files/Datasheet_S6-GR1P_2.5-6_K.pdf?v=1674565124

Inverters in PV system - Types

Central Inverter – Hybrid

A hybrid inverter is a type of inverter that can handle both grid-tied and off-grid (or standalone) operations. It is designed to work in both grid-connected and grid-independent modes, making it a versatile option for solar power systems.

The key features of a hybrid inverter are:

Dual-mode operation:

Grid-tied mode: In this mode, the hybrid inverter can feed the excess solar power back into the grid, similar to a standard grid-tied inverter.

Off-grid mode: When the grid is unavailable, the hybrid inverter can operate in standalone mode, drawing power from the solar panels and/or a battery bank to power the connected loads.

Battery integration:

Hybrid inverters are designed to integrate with a battery storage system, allowing the storage of excess solar energy for use during grid outages or at night.

This enables the system to provide backup power and continue operating even when the grid is down.

Advanced energy management:

Hybrid inverters often include advanced energy management features, such as the ability to prioritize self-consumption, optimize battery charging/discharging, and manage the flow of power between the grid, solar panels, and batteries.

Expandability:

Hybrid inverters can be designed to accommodate future system expansions, such as adding more solar panels or increasing battery storage capacity.

Inverters in PV system - Types

Hybrid Inverter

INPUT DATA (PV)

Max. DC Input Power (per string)	7.5kWp
Start-up Voltage	150V
Max. PV Voltage	580V
MPPT Range	120V - 550V
Nominal Voltage	360V
Max. Short Circuit Current (per string)	20A
Max. Input Current (per string)	15A
MPPT Tracker / No. of Strings per MPPT Tracker	2/1

OUTPUT DATA (AC)

Nominal AC Output Power	3600W
Max. Apparent Power Output to Utility Grid	3800VA
Max. Output Current	16A
Nominal Voltage / Range	230V (180 - 272) VAC
Frequency Range	50 / 60 Hz; ±5 Hz
Power Factor (Full Load)	>0.99
Power Factor Range	0.8 Lagging... 0.8 Leading
THDI (Nominal Power)	<3%
AC Connection	Single Phase

Inverters in PV system - Types

Micro Inverter

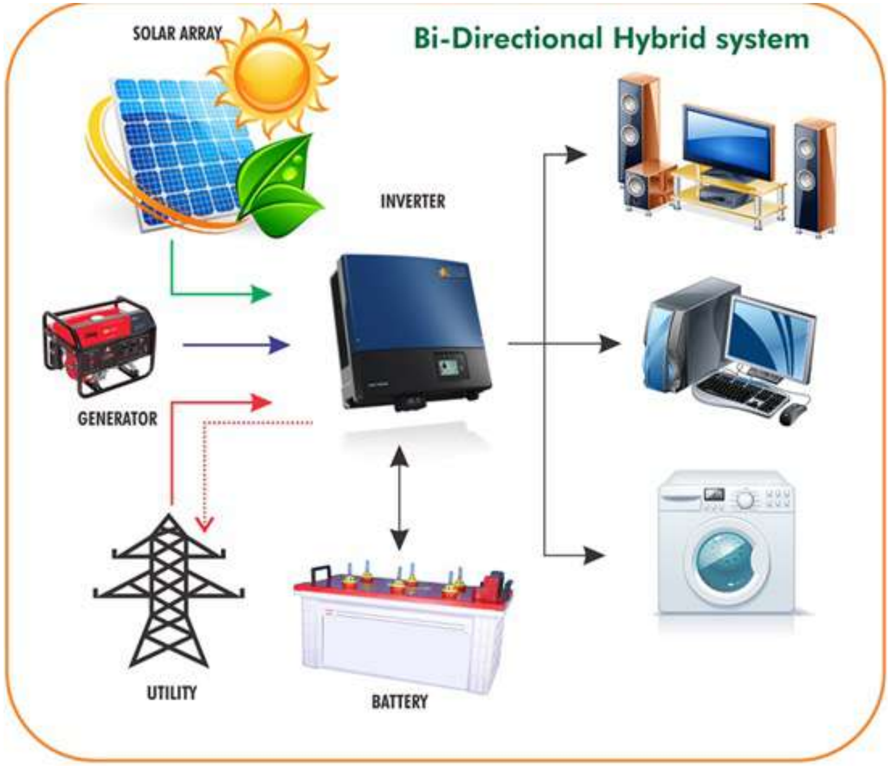
Input Data(DC)			
Model	BYM500/VMI500	BYM550/VMI550	BYM600/VMI600
Recommended Input Power (STC)	(400~700)W Single, 60~75 full/120~150 sub cells (300~450)W*2 Parallel, 72~75 full/144~150 sub cells		
MPPT voltage range	24V-50V		
Operating voltage range	16V-60V		
Maximum DC input voltage	60V		
Maximum short circuit input current	20A		
Maximum continuous input current	18A		
Output Data(AC)			
Rated Output Power	500VA	550VA	600VA
Peak output power	520VA (Vac≥230, Vmp≥34)	570VA (Vac≥230, Vmp≥35)	620VA (Vac≥230, Vmp≥36)
Nominal voltage/range	230V/176-265V		
Nominal frequency/range	50Hz/60Hz (46.5-62)Hz		
Maximum continuous output current	2.27A	2.5A	2.73A
Harmonic Distortion	<3%		
Power Factor	>0.99 (default)		

Inverters in PV system – DC/AC bidirectional Inverter

A bidirectional DC/AC converter, also known as bidirectional inverter, is a power electronic device that can convert power in both directions between a DC source/load and an AC source/load.

Modes of operation:

- Power flow from DC to AC (inverter mode).
- Power flow from AC to DC (rectifier mode).



Working Principle	
Inverter Mode	**Rectifier Mode**
The DC input power (e.g., from a renewable energy source or energy storage system) is fed into the bidirectional converter.	When the bidirectional converter operates in the rectifier mode, it can convert AC power (e.g., from the grid) into DC power.
The converter uses power electronic switches (typically IGBTs or MOSFETs) to convert the DC input into a controlled AC output.	The converter's control system rectifies the AC input and regulates the DC output voltage and current.
The converter generates a sinusoidal AC waveform by rapidly switching the power electronic switches in a specific sequence.	This allows the AC power to be used to charge an energy storage system (e.g., a battery bank) or to power DC loads.
The converter's control system ensures that the generated AC output is synchronized with the grid or local AC loads in terms of voltage, frequency, and phase. This allows the DC power to be fed into the AC grid or used to power AC loads	

Inverters in PV system – DC/AC bidirectional Inverter

- Bi-directional converters are primarily used in applications where power needs to be transferred in both directions, such as in energy storage systems, hybrid/electric vehicles, and grid-tied renewable energy systems.
- A bi-directional converter can not only convert the voltage level but also control the direction of power flow, allowing it to charge or discharge a battery or energy storage system.
- The control of a bi-directional converter is more complex, as it needs to manage the direction of power flow and the voltage/current levels on both the input and output sides.

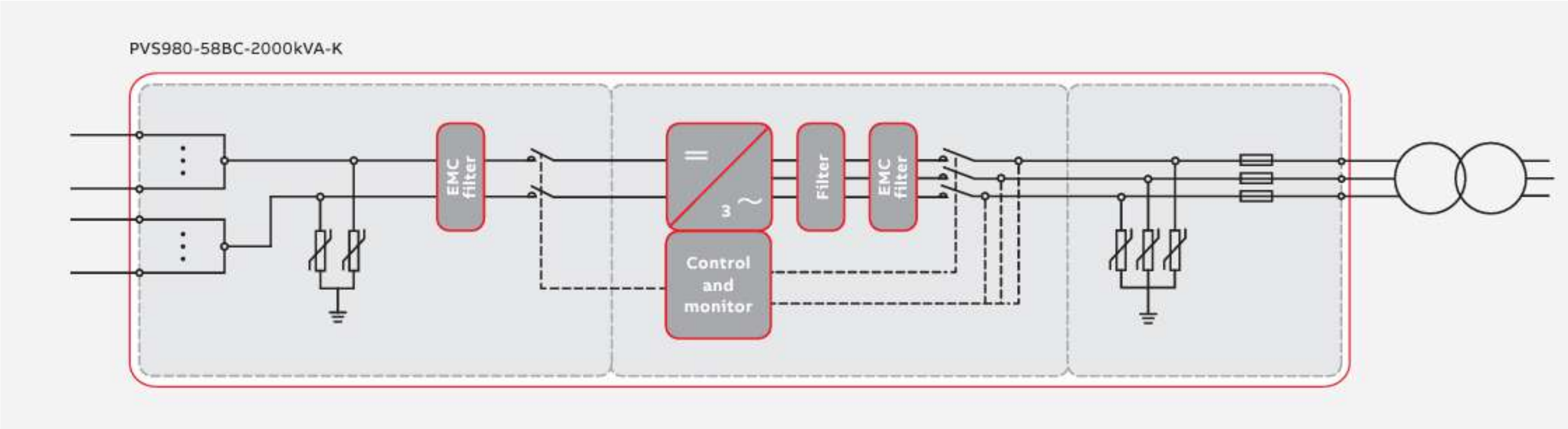


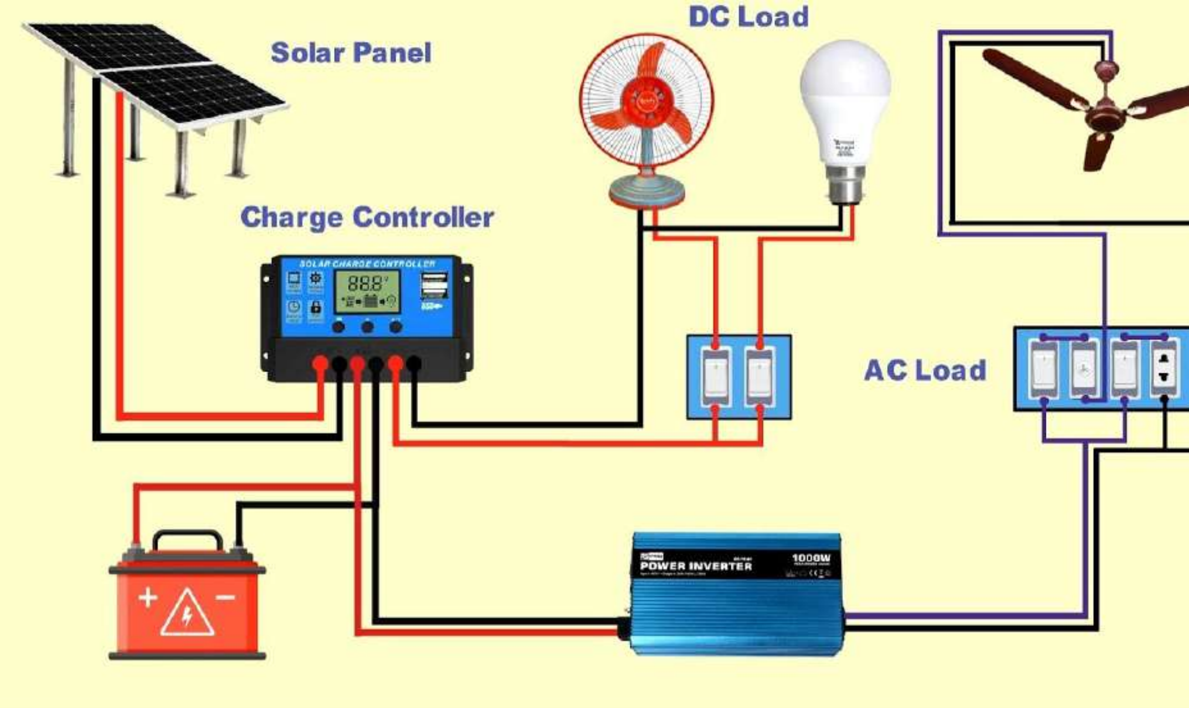
ABB PVS980-58BC bidirectional converter block diagram

https://www.fimer.com/sites/default/files/PVS980-58BC_bidirectional_converter_for_energy_storage_applications_flyer_RevD_EN.pdf

Charge Controller and MPPT Controller

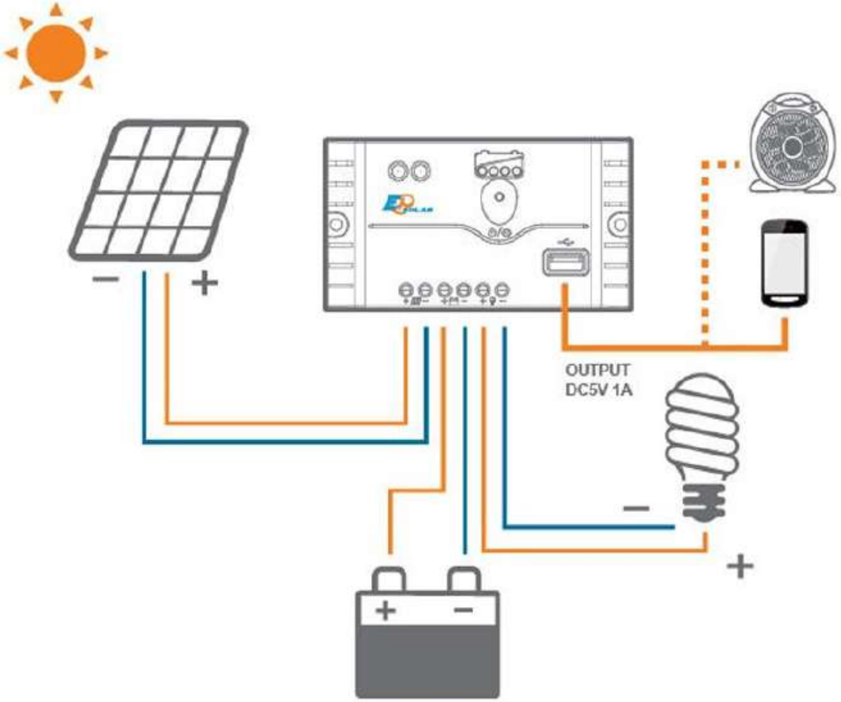
Introduction to Charge Controller

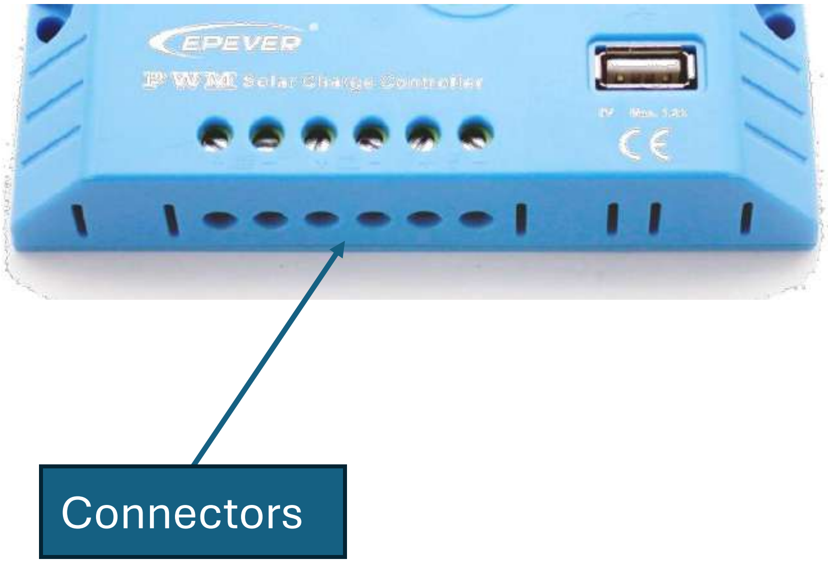
- Charge or Pulse width Modulation (PWM) controller is used to manage the charging the batteries.
- Regulate and control the voltage and the current of the battery.
- Protects battery from over charging or over discharging.
- Voltage is pulled down to battery voltage.
- Cheaper, however not very efficient (up to 60% power can be lost)



Charge Controller and MPPT Controller

Charge Controller Model





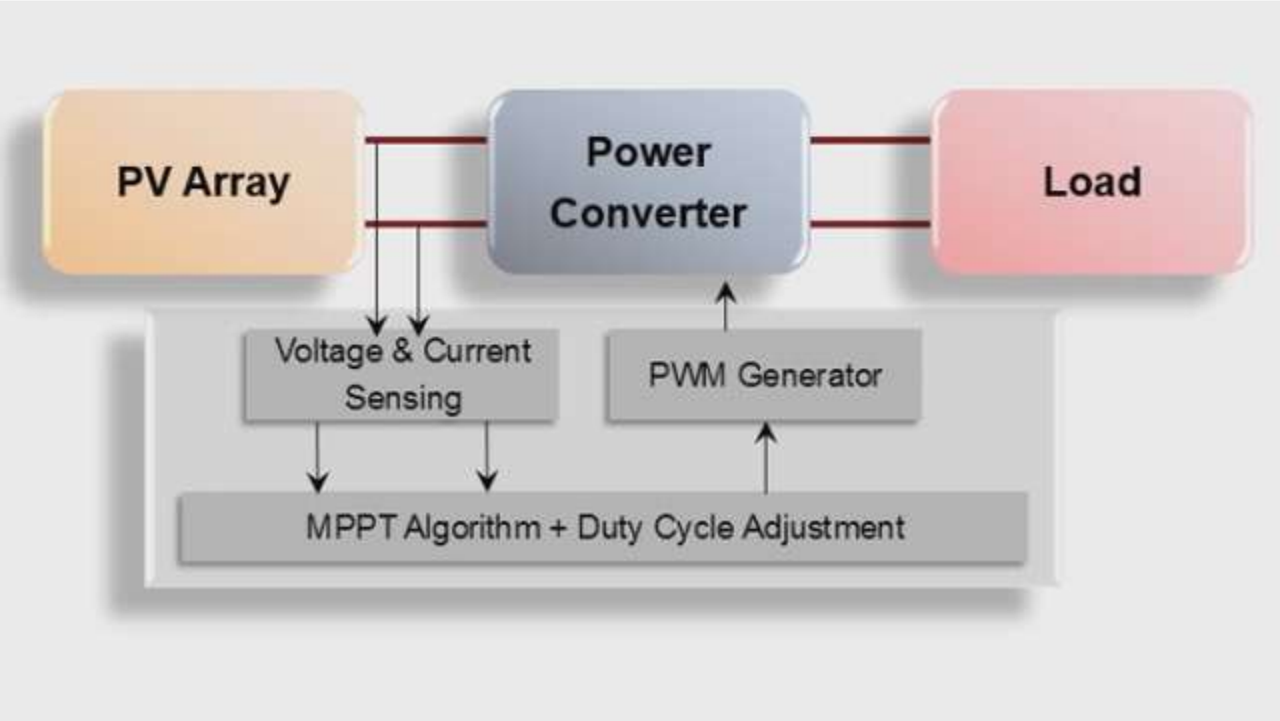
Model	LS0512EU	LS1012EU	LS1024EU	LS2024EU
Nominal system voltage	12VDC		12/24VDC	
Rated battery current	5A	10A	10A	20A
Max. battery voltage	16V		32V	
Max. PV open circuit voltage	30V		50V	

https://www.sunstore.co.uk/wp-content/uploads/2017/02/LS-EU%20Spec.pdf

Charge Controller and MPPT Controller

MPPT (Maximum Power Point Tracker)

- Far advanced then PWM controller and used P&O (Perturb and Observation) algorithm to ensure maximum power.
- The algorithm adjust the PV operating point at or close to the peak power point of the PV panel under varying conditions, like changing solar irradiance, temperature, and the load.
- The MPPT algorithms are typically used in the controller designs for PV systems.



Charge Controller and MPPT Controller

MPPT Controller Model

Different model with different ratings

	RVR20	RVR30	RVR40
Nominal System Voltage	12/24V	12/24V	12/24V
Rated Load Current	20A	20A	20A
Max Solar Input Voltage	100V DC	100V DC	100V DC
Max Solar Input Power	12V/260W, 24V/520W	12V/400W, 24V/800W	12V/520W, 24V/1040W
Self Consumption		≤ 100mA/12V, ≤ 58mA/24V	
Charge Circuit Voltage Drop		≤ 0.26V	
Discharge Circuit Drop		≤0.15V	
Temperature Compensation		-3mV/°C/2V	
Dimensions	210 x 151 x 59.5mm, 8.27 x 5.94 x 2.34in	238 x 173 x 72.5mm, 9.37 x 6.81 x 2.85in	238 x 173 x 72.5mm, 9.37 x 6.81 x 2.85in
Mounting Oval		7.66 x 4.70mm / 0.30 x 0.18in	
Max Terminal Size	10mm² 8AWG	10mm² 8AWG	10mm² 8AWG
Net Weight	1.4kg / 3.08 lb	1.4kg / 3.08 lb	2.0kg / 4.41 lb

Current rating – Max 20A

Voltage rating – Max 100V

https://www.renogy.com/content/RNG-CTRL-RVR40/RVR203040-Datasheet.pdf

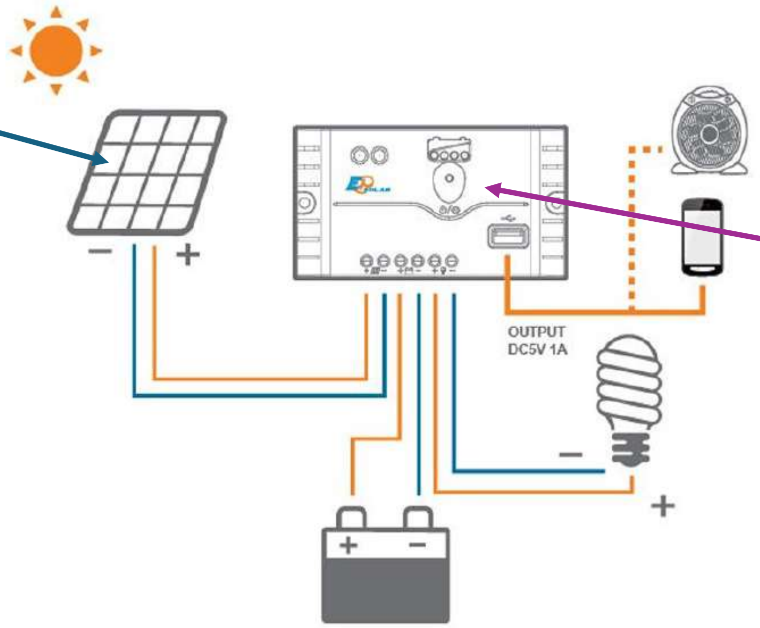
Charge Controller and MPPT Controller

Which one to select Charge or MPPT Controller?

Let's have a look at this example with charge controller.

Model	LS0512EU	LS1012EU	LS1024EU	LS2024EU
Nominal system voltage	12VDC		12/24VDC	
Rated battery current	5A	10A	10A	20A
Max. battery voltage	16V		32V	
Max. PV open circuit voltage	30V		50V	

Pin = 100W
Voc = 20V
Isc = 5A



LS0512EU
I = 5A
V = 13.5V

12V Battery

The charging voltage should be higher than the battery voltage. PWM controller will bring the voltage down close to battery voltage.
Therefore, the PWM charge controller will charge the battery at (P=VI) = 13.5V x 5A = 67.5W.
Panel is delivering 100W. 67.5W of power is used and rest (32.5W) gets wasted. Efficiency of 67.5%

Charge Controller and MPPT Controller

Let's do the same calculation using MPPT charge controller

MPPT will charge the battery at 13.5V, however will increase the current to 7.2A. The output power will be

P = 13.5 x 7.2 = 97.2W, which is almost equal to solar panel power. The efficiency is 97.2% and low power loss 2.8W.

The MPPT is more efficient and more flexible with voltage and current whereas, the PWM controller is less efficient and less flexible.

The drawback is MPPT charge controller is expensive however, PWM controller is cheap.

The PWM charge controller brings the voltage down and keep the current constant.

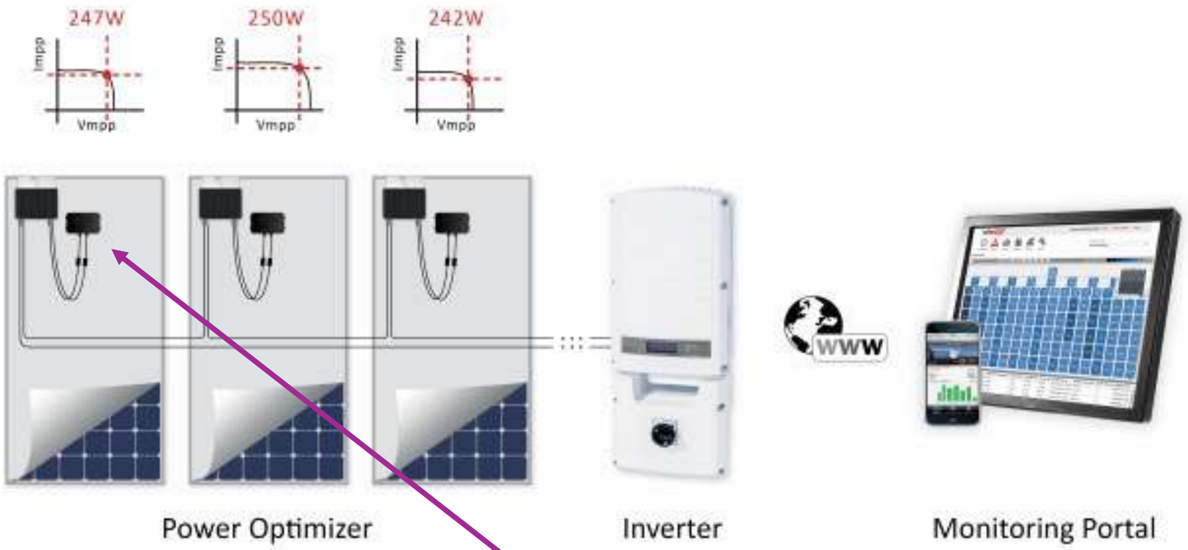
The MPPT charge controller increases the current.

Power Optimizer in Solar panel

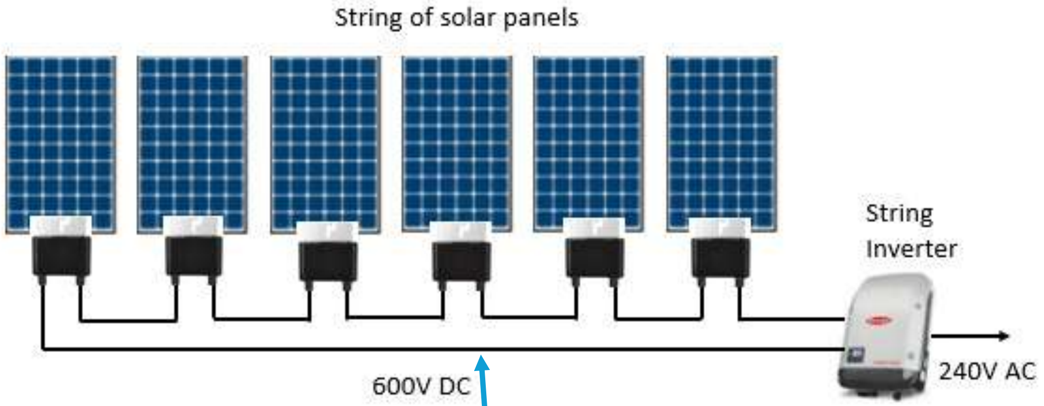
What is a power optimizer?

- A power optimizer are DC/DC converter attached at the module level. It maximise the DC power output in case a solar module is shaded.

Solar Edge Optimizer



Power optimizer is connected at the back of the panel.



Optimizer connected to Inverter

Power Optimizer in Solar panel

Power Optimiser

	S440	S500	S500B	S650B	UNIT
INPUT					
Rated Input DC Power[1]	440[2]	500[3]		650	W
Absolute Maximum Input Voltage (Voc)	60		125	85	Vdc
MPPT Operating Range	8 – 60		12.5 – 105	12.5 – 85	Vdc
Maximum Short Circuit Current (Isc) of Connected PV Module	14.5[2]	15			Adc
Maximum Efficiency	99.5				%
Weighted Efficiency	98.6				%
Overvoltage Category	II				
OUTPUT DURING OPERATION					
Maximum Output Current	15				Adc
Maximum Output Voltage	60		80		Vdc

https://knowledge-center.solaredge.com/sites/kc/files/se-power-optimizer-s-series-datasheet.pdf

Power Optimizer in Solar Panel

How the optimizer works?

At normal condition: Without Optimizers.

200W	200W	200W	200W

Total Power from 4 panels = 200 x 4 = 800W

Identical panel, V = 25V and I = 8A.
P = 200W

Shahed – 10%

When 1 panel got shaded, let's say 10%.

200W To 180W	200W To 180W	200W To 180W	180W

Total Power from 4 panels = 180 x 4 = 720W.

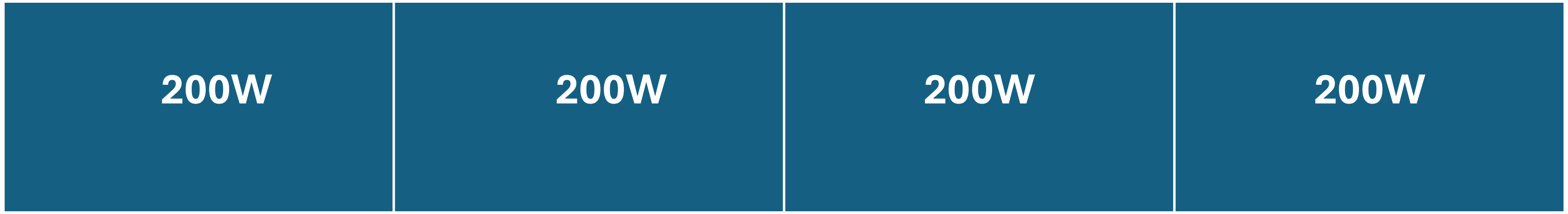
The affected panel will reduce the power to 180W. Hence, affecting the other panel. Recall, in series string if one panel is affected then it will impact other panels and current flow will be dominated by affected panel.

Power lost by 10%

Power Optimizer in Solar Panel

How the optimizer works?

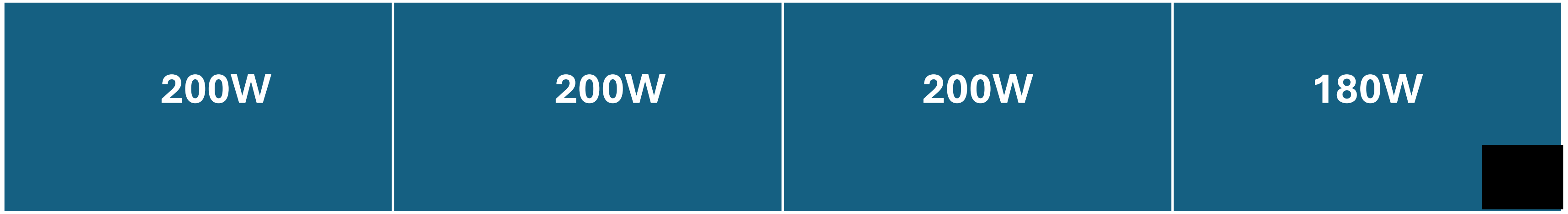
At normal condition: With Optimizers.



Total Power from 4 panels = 200 x 4 = 800W

Identical panel, V = 25V and I = 8A.
P = 200W

When 1 panel got shaded 10%



Total Power from 4 panels = (200X 3) + 180 W= 780W.

Other panels remain unaffected when optimisers are installed.

Power lost by 2.5%

Power Optimizer in Solar Panel

- Optimizers can be installed in all the panels or only the affected one.
- Some manufacturer i.e. solar edge require you to fit their optimizer in all the panels. However, another manufacturer “Tigo” does not require you to install in all the panels.
- Optimizers are handy when there is a diffuse shading.
- For hard shading, the optimizers perform little or not at all.
- If the current is reduced 20% or above in the shaded panel, the bypass diode will bypass all the current.

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New Solar Technology and the challenge of Building Large Solar Power Plant(Part 2)

New Solar Technology- An Overview

Solar power has become an increasingly important source of renewable energy in recent years, as the world seeks to transition away from fossil fuels and towards more sustainable forms of electricity generation.

With time the solar technology is improving and over the last one decade we have seen huge development and reduction of price.

At the early stage, the efficiency of the solar panel was only 10% which has been improved significantly and reached almost 25%.

Traditional silicon-based solar photovoltaic (PV) panels have dominated the market for decades, a new wave of solar technologies is emerging that promise to further improve the efficiency, cost-effectiveness, and versatility of solar power

New Solar Technology – Upcoming Trends

Increased Efficiency of Solar Panels

The continuous improvement in the efficiency of solar panels remains a significant trend. Materials and design advances enable panels to convert more sunlight into electricity, making solar installations more practical and cost-effective for a broader range of applications.

Expansion of Bifacial Solar Panels

Bifacial solar panels, which capture sunlight from both sides, are becoming more popular. This technology significantly boosts energy production, making solar installations more productive and economical.

Rise of Building-Integrated Photovoltaics (BIPV)

BIPV integrates solar technology into building materials like roofing and windows. This trend not only enhances aesthetic appeal but also expands the application of solar technology in urban environments.

Growth in Solar Energy Storage

The advancement of energy storage technologies, such as lithium-ion and solid-state batteries.

Smart Solar System

IoT and AI are being used for real-time monitoring and optimizing the energy production, enhancing the efficiency and effectiveness of solar power systems.

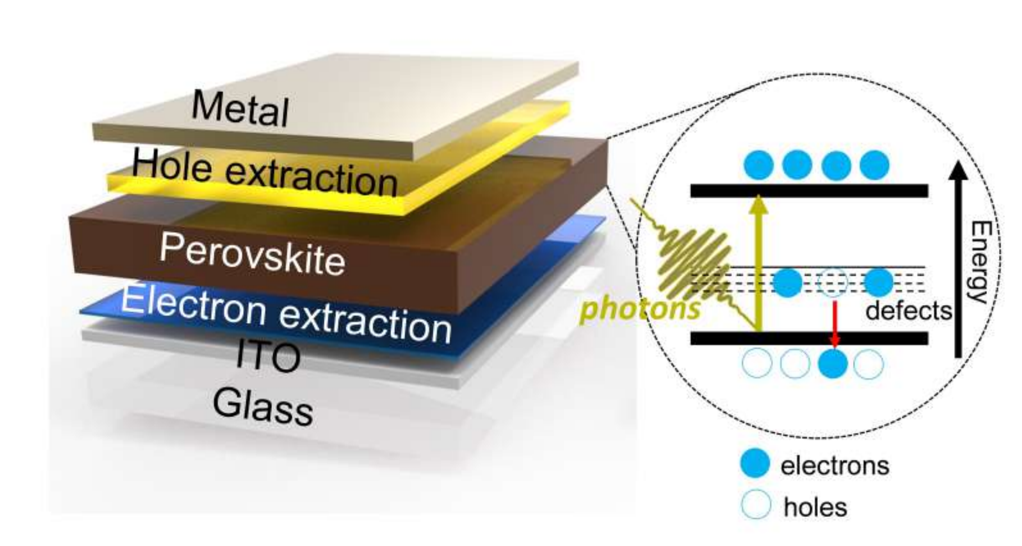
NEW SOLAR TECHNOLOGY- TECHNOLOGIES

Perovskite Solar Cells.

Perovskite cells have achieved **lab efficiencies surpassing 33%**, a significant leap over traditional silicon cells

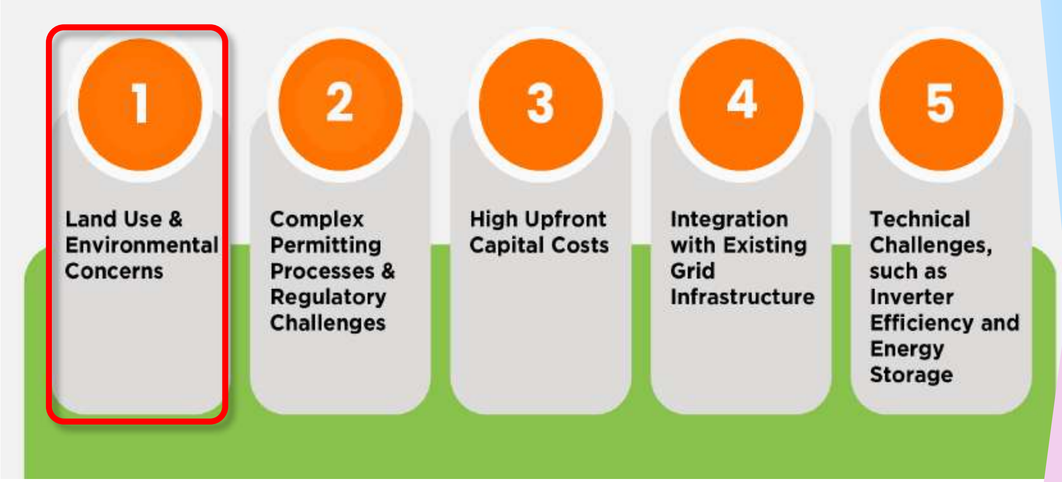
Perovskite is much better at absorbing light across almost all visible wavelengths, allowing it to convert more sunlight into electricity.

The solution processability of perovskite materials enables low-cost and scalable manufacturing



Challenge of Building Large Solar power Plant

Building larger solar power plants poses many challenges that must be addressed to ensure their success. Here are some challenges:



Land Use and Environmental Concerns

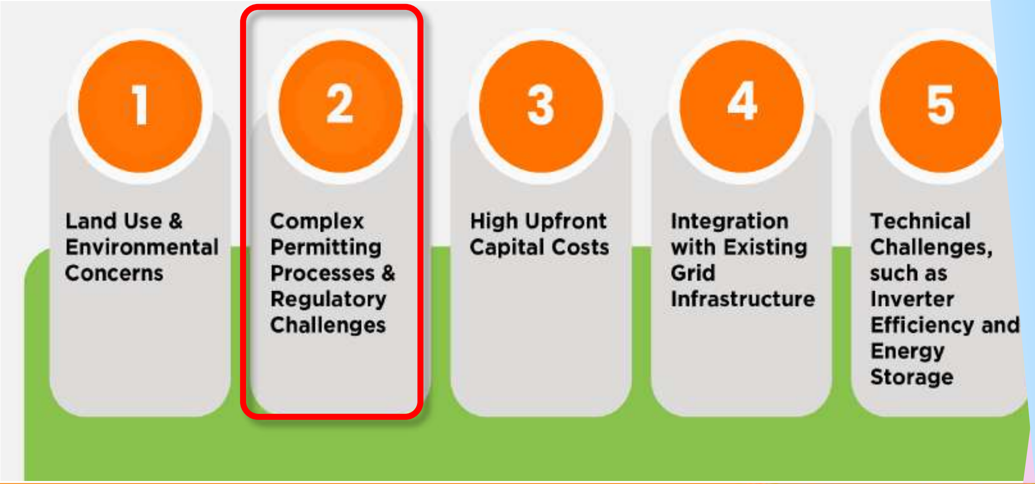
One of the biggest challenges of building larger solar power plants is finding suitable land for construction. Large solar power plants require significant land, which can be challenging to find in densely populated areas.

Global Energy Transformation Available: https://www.irena.org//media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_Report_GET_2018.pdf

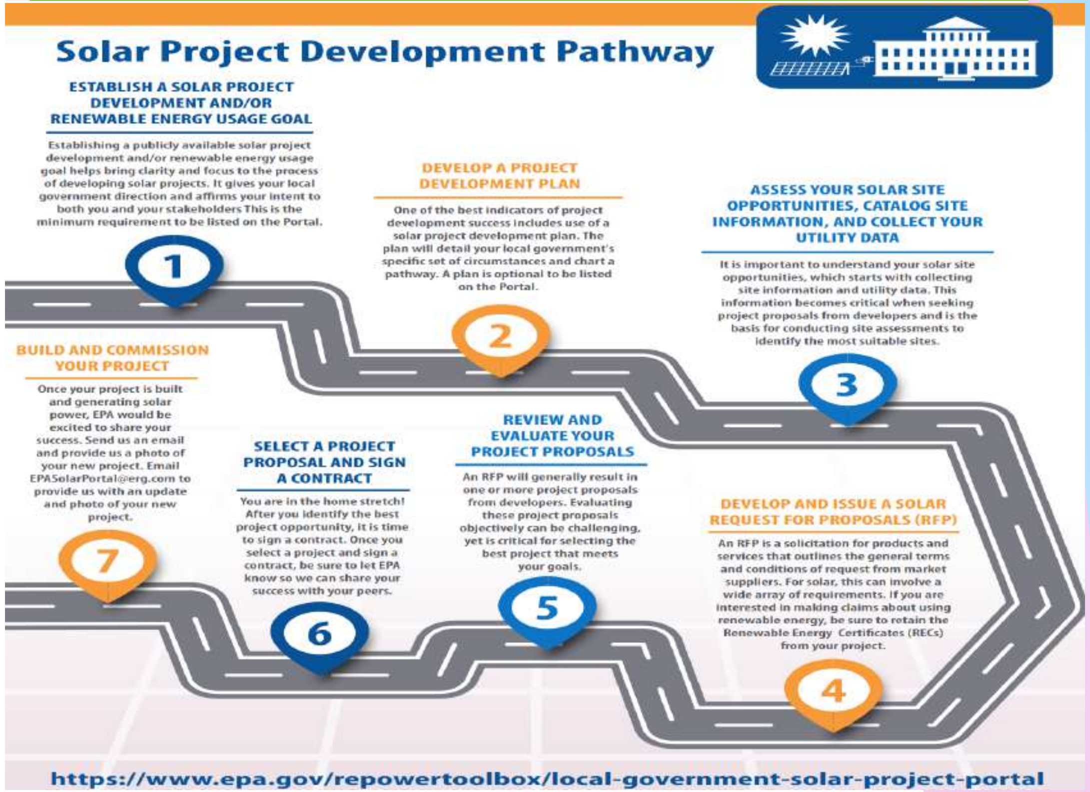
Challenge of Building Large Solar power Plant

Complex Permitting Process

- Building a large solar power plant requires a complex set of permits and approvals from various regulatory agencies.
- It can be time-consuming and costly, and delays can significantly impact project timelines and budgets. To overcome these challenges, developers must thoroughly understand the regulatory landscape and work closely with local governments to ensure compliance.



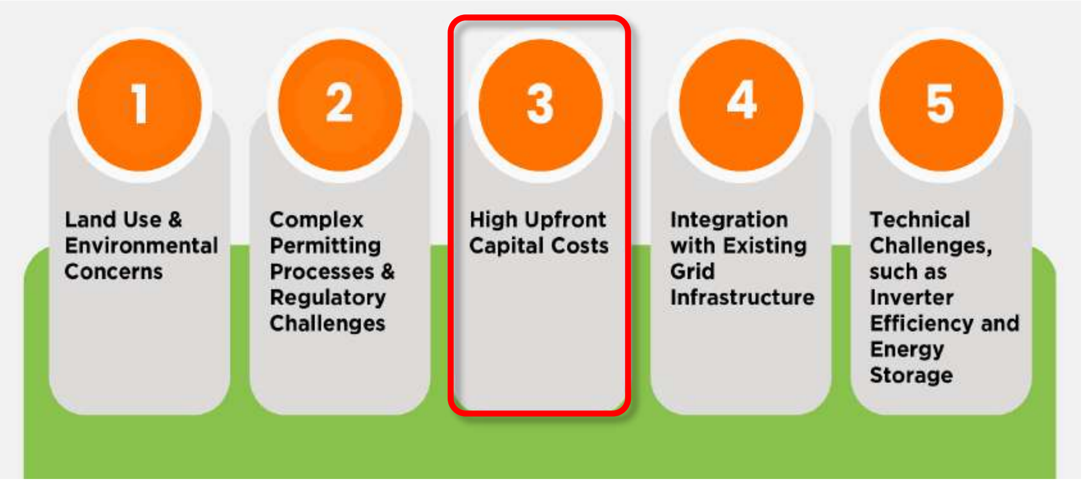
- Step 1: Establish a solar project development and/or renewable energy usage goal
- Step 2: Develop a project development plan (optional)
- Step 3: Assess your solar site opportunities; catalog site information and collect your utility data
- Step 4: Develop and issue a solar Request for Proposals (RFP)
- Step 5: Review and evaluate your project proposals
- Step 6: Select a project proposal and sign a contract
- Step 7: Build and commission your project



Challenge of Building Large Solar power Plant

High Upfront Capital Costs

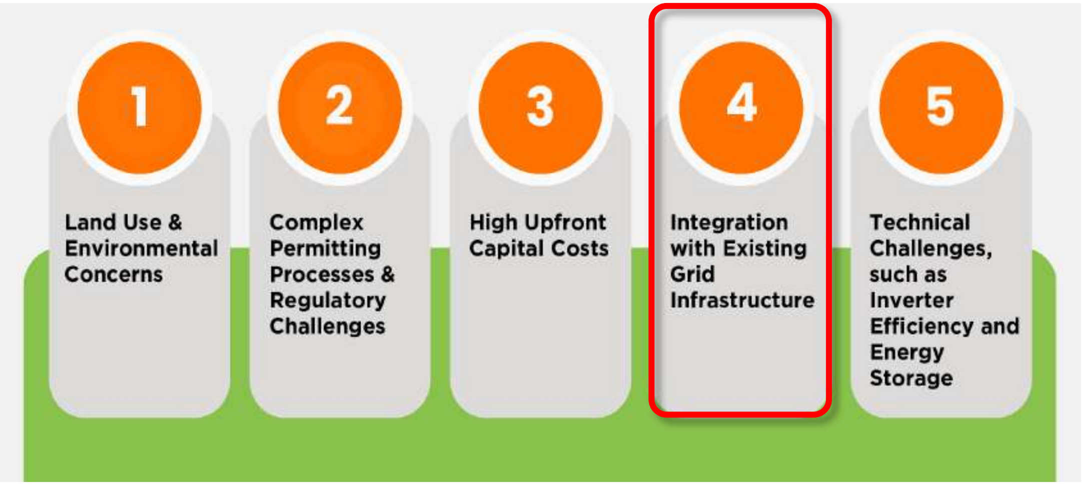
- Another challenge is the high upfront capital costs.
- Building a large solar power plant requires significant equipment, infrastructure, and labor investment.
- In order to tackle these difficulties, it is necessary to come up with approaches for financing, such as exploring opportunities for government grants, as well as collaborating with other businesses to split expenses.



Challenge of Building Large Solar power Plant

Integration with Existing Grid infrastructure

- Large solar power plants need to be integrated with the existing grid infrastructure to guarantee efficient and reliable delivery of power to customers.
- However, It can be a complex process as the plant must be able to handle fluctuations in both demand and supply.
- To address these problems, utilities and grid operators should ensure that their projects are integrated into the existing grid infrastructure.



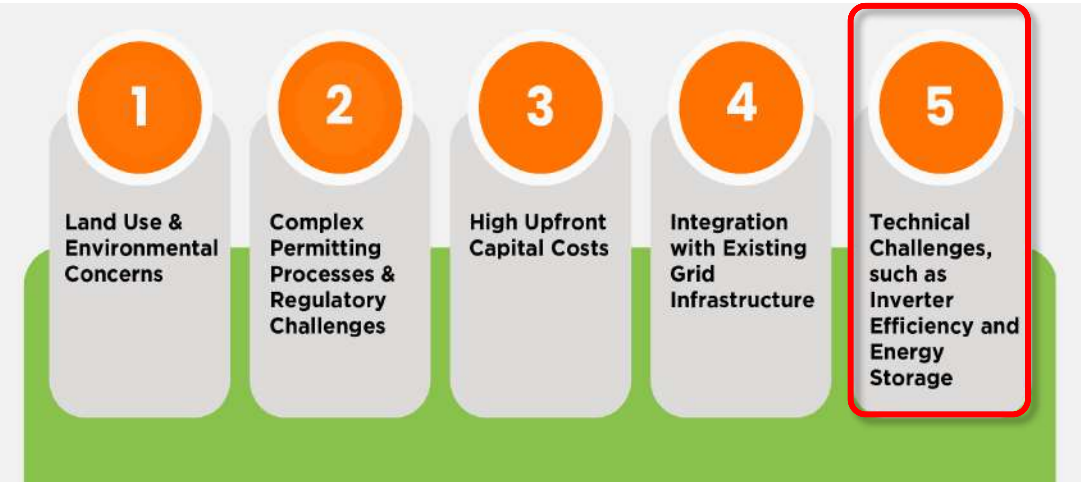
Challenge of Building Large Solar power Plant

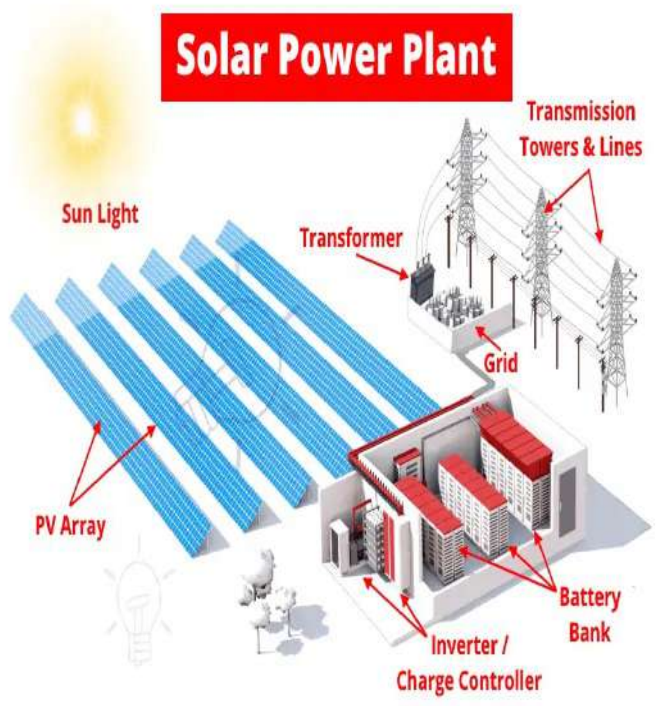
Technical Challenges Such as Inverter, Efficiency, and Energy Storge

- Larger scale solar power plants pose many technical challenges, such as inverter efficiency and energy storage. Inverter efficiency is critical to ensuring the solar power plant can deliver power to customers efficiently and reliably.

- Energy storage is also essential for ensuring the solar power plant can provide power when the sun is not shining.

- By collaborating closely with engineers and technical experts, challenges can be solved to implement proficient and successful systems for enhancing inverter efficiency and energy storage.





Occupational Risks in Installing and Maintaining Solar Energy Systems

People who live near or around big solar panels with a lot of PV plates that have been coated with dangerous materials have every right to wonder what, if any, health risks these materials pose to the public.

In this presentation, we will deal with the main safety and health risks and their impacts on workers and people nearly during the construction, operation, maintenance, and dismantling of solar farms.

Global Energy Transformation Available: https://www.irena.org//media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_Report_GET_2018.pdf

Solar PV Electrical Safety

According to the U.S. Bureau of Labor Statistics, **solar photovoltaic installer jobs** are expected to **grow 51%** between 2019 and 2029, increasing at a much higher rate than the average of all occupations. **Learn how to stay safe** while working with or around solar panels.

Statistics*

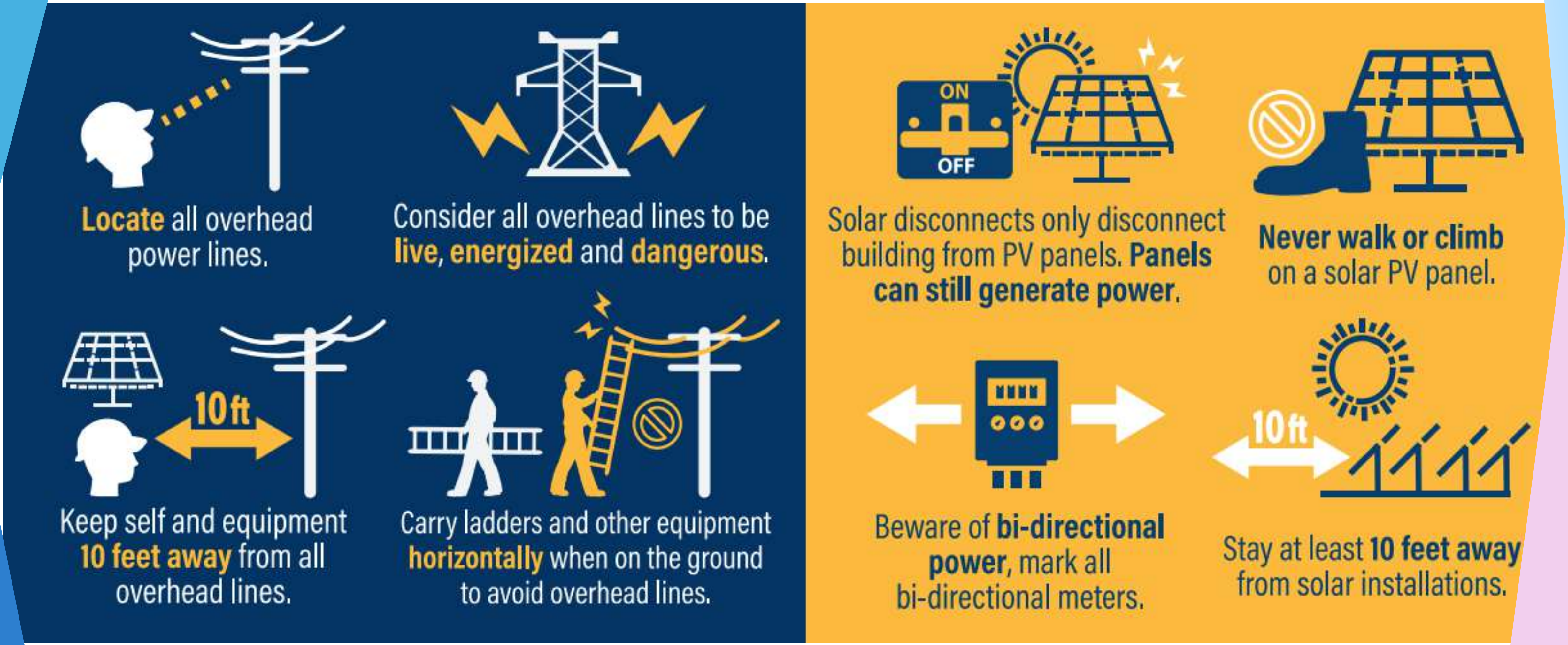
51% — **expected growth** in solar PV installer jobs by 2029 making it the 3rd fastest growing occupation.

650 — Between 2011 and 2019, 650 solar PV installers were **injured on the job.**

1-5 YEARS — 51% of **injured** solar PV installers were employed for 1-5 years.

*U.S. Bureau of Labor Statistics

PV Installation Electric Safety



*U.S. Bureau of Labor Statistics

The First Category of Safety is Hazardous Materials Content

- Arc Flash & Electric Shock: Prevention and protection
- Fire Hazards: Fire prevention and response

The Second Category of Safety is Site Safety

- Lifting Safety
- Ladder Safety
- Fall Protection & Trip Safety
- Solar Plumbing Safety
- Power Tools Safety etc.




Global Energy Transformation Available: https://www.irena.org//media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_Report_GET_2018.pdf

The Third Category Presence of Toxic Materials

- The constriction process comprises mechanical clearance of farm site, digging of trenches for underground wiring/ cabling.

- PV panels consist of polymer, glass, aluminum, copper and semiconductor materials, silicon which remain intact even when broken. None of these elements are very toxic and considering the small quantities of their uses, it can be confidently health hazards to workmen and the general public.

- System components like racking, wiring, inverter, transformers (containing oil for cooling of coils) to boost the inverter output voltage to utility level.

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