Recent trends and Importance of Power Electronics:

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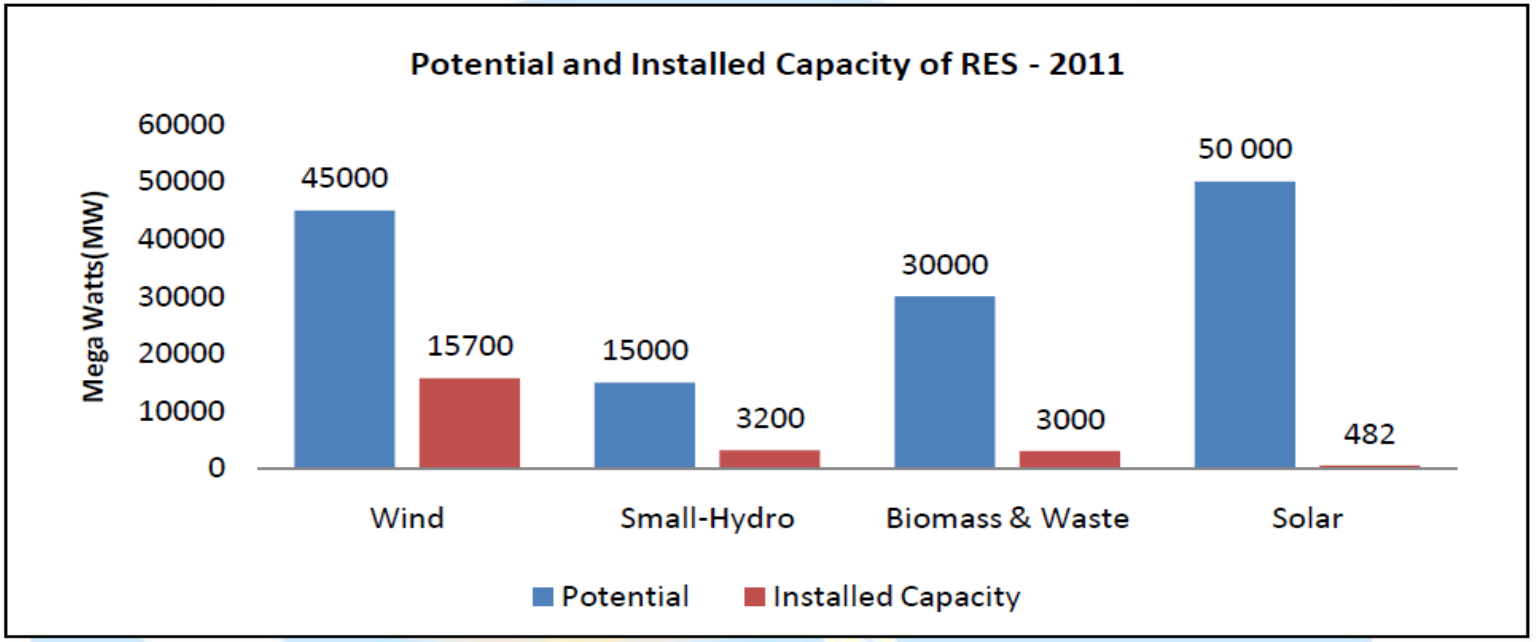
Need for going towards renewable energy sources:

- Fossil-fuel exhaustion
- environmental problems caused by conventional power generation(global warming)
- Tremendous Growth in harvesting technologies of renewable energy sources
- Reduced cost in semiconductor fabrication technology (solar panel)

Major Renewable energy sources

- Hydro energy(renewable if installed capacity ≤ 25MW)
- Solar energy
- Wind energy
- Tidal energy
- Geothermal energy
- Biomass energy

installed capacity of renewable energy sources in India (2011)



(source :MNRE (2011))

In terms of all renewable energy categories, India is currently ranked fifth in the world with 15,691.4 MW grid-connected and 367.9 MW off-grid renewable-energy based power capacity

installed capacity of renewable energy sources in India (2014)

Total Renewable Energy Installed Capacity (31 Dec 2014)[3]

Source	Total Installed Capacity (MW)
Wind Power	22,465.03
Solar Power (SPV)	3,062.68
Small Hydro Power	3,990.83
Biomass Power	1,365.20
Bagasse Cogeneration	2,800.35
Waste to Power	107.58
Total	**33,791.74**

Source: Wikipedia and MNRE

Early days Difficulties in using renewable energy sources

- Highly uncertain sources of energy, mainly depends on weather condition (less reliable)
- Low efficiency
- Not economic due to high initial installation costs and large space requirement (solar).

Solar energy conversion process

General steps involved in solar power conversion

- Extracting maximum power from solar panels using best MPPT technique.
- Boosting the low voltage output of panels to a high value suitable for inversion to AC.
- Inversion using a two level or multilevel inverter

- **MPPT Technique**

- Fill factor (FF) = $\frac{V_{mp} * I_{mp}}{V_{oc} * I_{SC}}$

  (FF =0.7 to 0.8 for good panel)

- $R_{mp} = \frac{V_{mp}}{I_{mp}}$ (at MPP)

- So for maximum power extraction load should be equal to R_{mp}

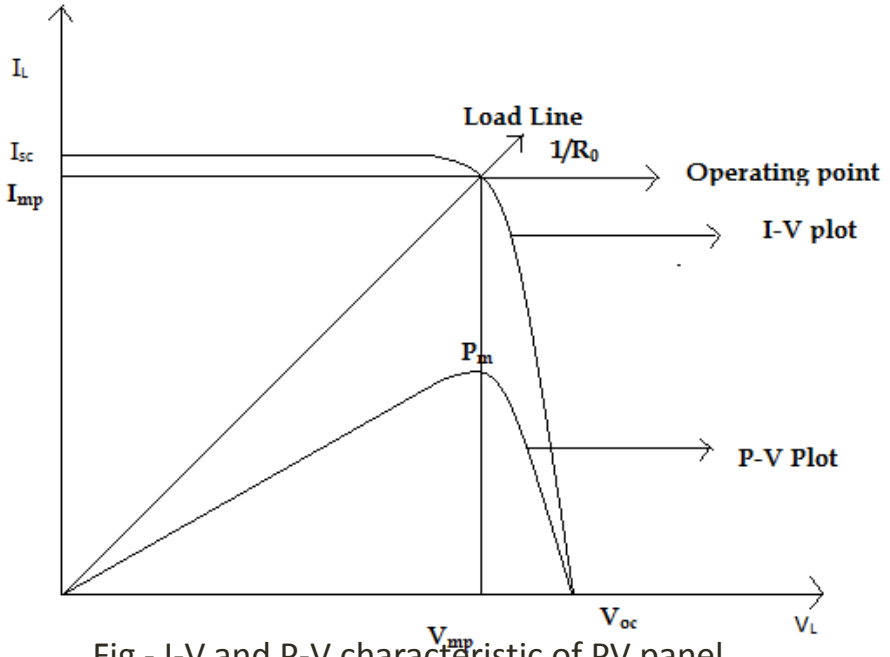
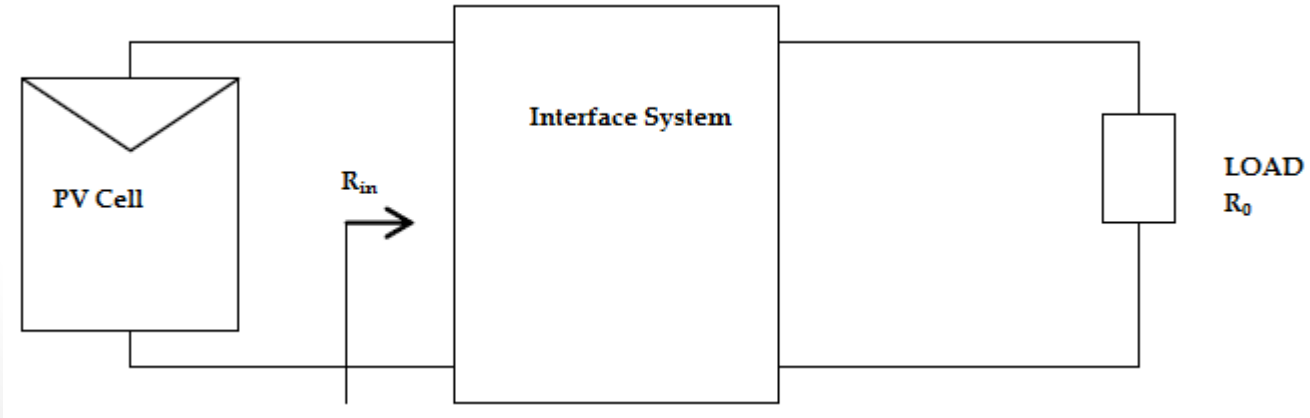


Fig - I-V and P-V characteristic of PV panel



DC-DC Converter

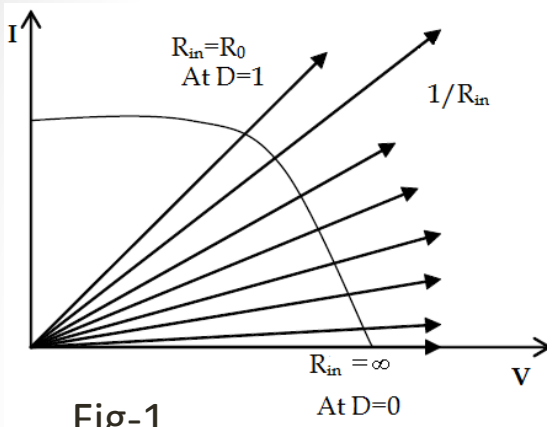


Fig-1

For Buck converter

$$R_{in}=\frac{R_0}{D^2}$$

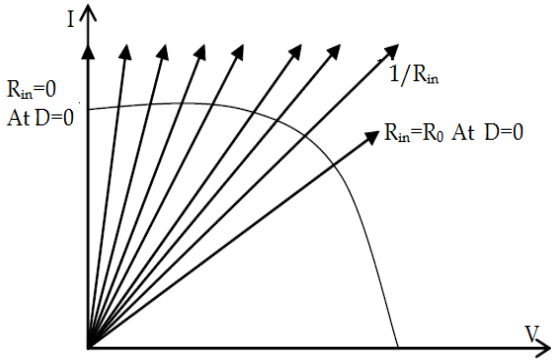


Fig-2

For Boost converter

$$R_{in}=R_0(1-D)^2$$

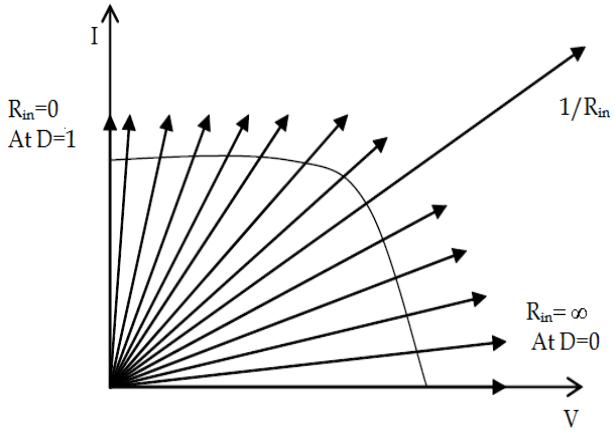
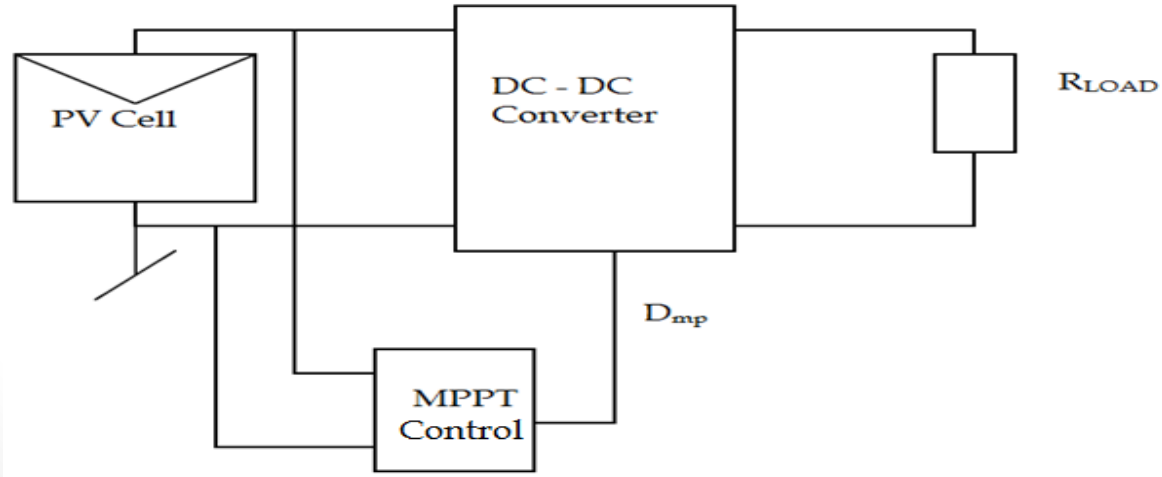


Fig -3

For Buck-Boost converter

$$R_{in}=R_0(\frac{1-D}{D})^2$$



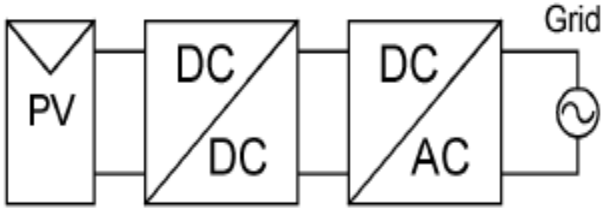
Typical MPPT Control Methods

- **Perturb and observe method** - Here terminal voltage PV panel is varied to get the maximum power point
- **Incremental conductance Method** – Here incremental conductance is compared with instantaneous conductance to reach the maximum power point
- **Fractional open circuit voltage method** – As $V_{mpp} \approx kV_{oc}$ $(.71 \leq k \leq .78)$,so by measuring V_{oc} and comparing it with instantaneous terminal voltage maximum power point is determined
- **Fractional short circuit current method** –

  As $I_{mpp} \approx kI_{sc}$ $(.78 \leq k \leq .92)$,so by measuring I_{sc} and comparing it with instantaneous cell current maximum power point is determined
- **Ripple correlation control method** – Here by measuring the terminal voltage ripple of the cell and cell current ripple maximum power point is tracked

MPPT techniques	PV array Dependent?	True MPPT?	Analog/ Digital	Periodic Tuning?	Convergence speed	Implementation Complexity	Sensed parameter
Hill Climbing/PO	No	Yes	Both	No	Varies	Low	Voltage, Current
IncCond	No	Yes	Digital	No	Varies	Medium	Voltage, Current
Fractional V_{oc}	Yes	No	Both	Yes	Medium	Low	Voltage
Fractional I_{sc}	Yes	No	Both	Yes	Medium	Medium	Current
RCC	No	Yes	Analog	No	Fast	Low	Voltage, Current

Different types of solar power conversion arrangements

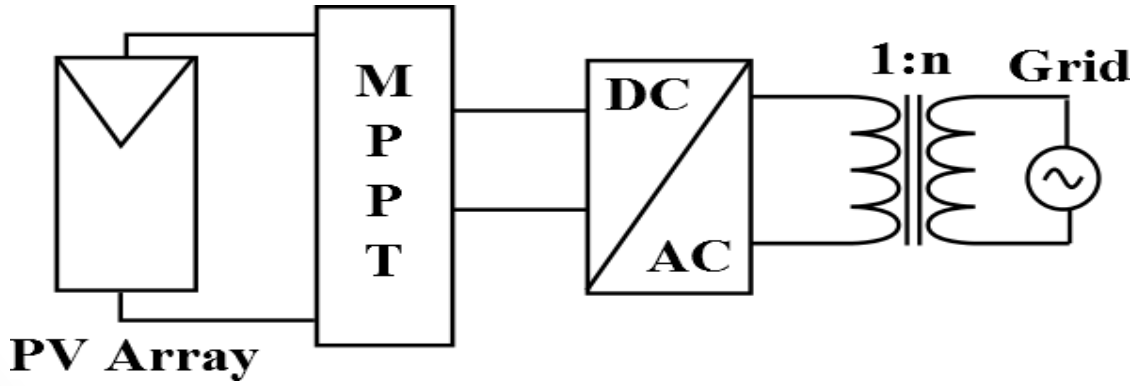


- **Simple two stage process**
- DC-DC converter includes boosting and suitable MPPT technique.
- DC-AC converter inverts the boosted DC voltage to AC voltage having equal magnitude as grid voltage in case of grid tied configuration .
- **Disadvantageous**
- This common topology requires a large electrolytic capacitor, which might reduce the lifetime of the overall system

Continues…

- **Voltage level shifting using transformer on the grid side**

In this method instead of boosting the PV array output voltage, directly inversion is carried out with a suitable inverter configuration and PWM method. Then the output voltage of the inverter is stepped up to grid level.



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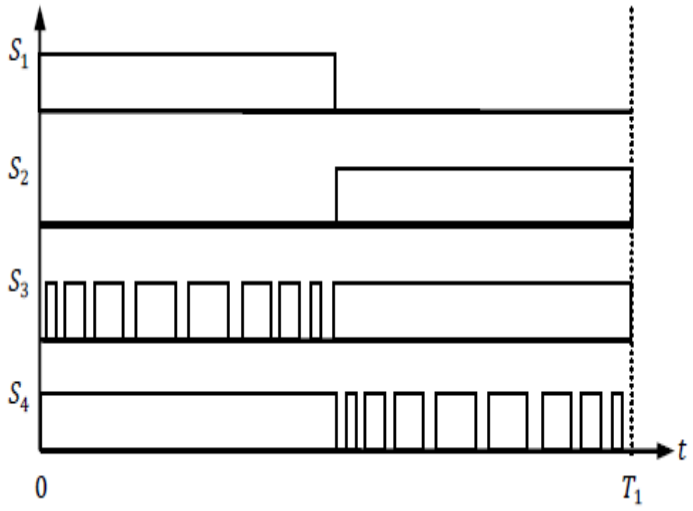
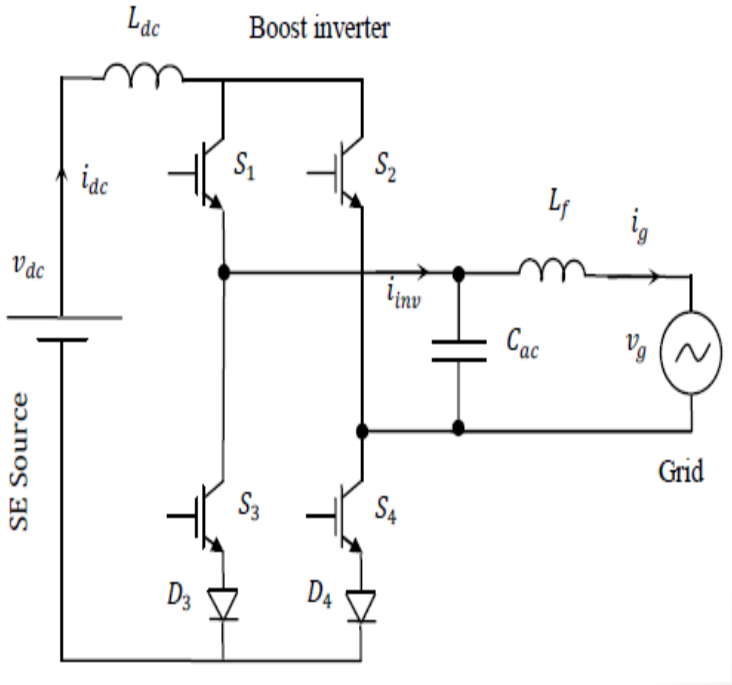
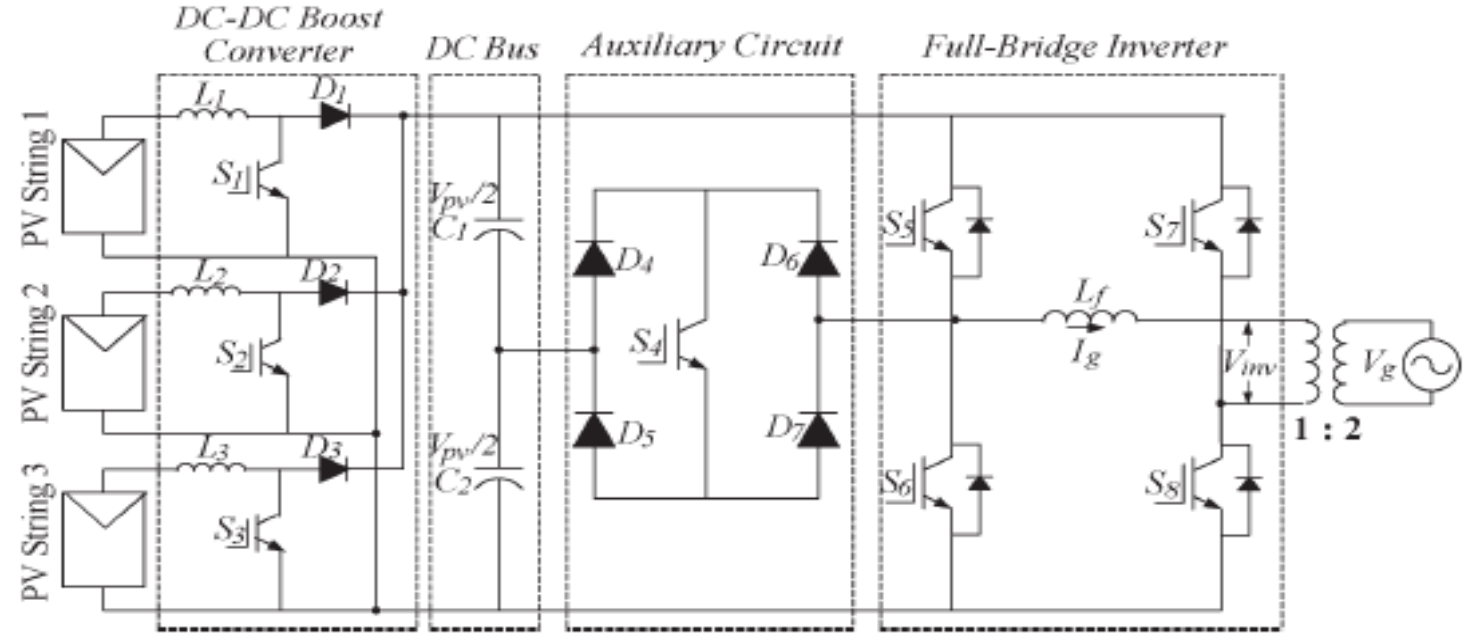
- Single stage conversion using boost inverter(CSI) (“A Switching Pattern for Single-Phase Single-Stage Current Source Boost Inverter” , Ali K. Kaviani(SM), Behrooz Mirafzal, IEEE 2012)





Recent multilevel inverter topologies for solar applications

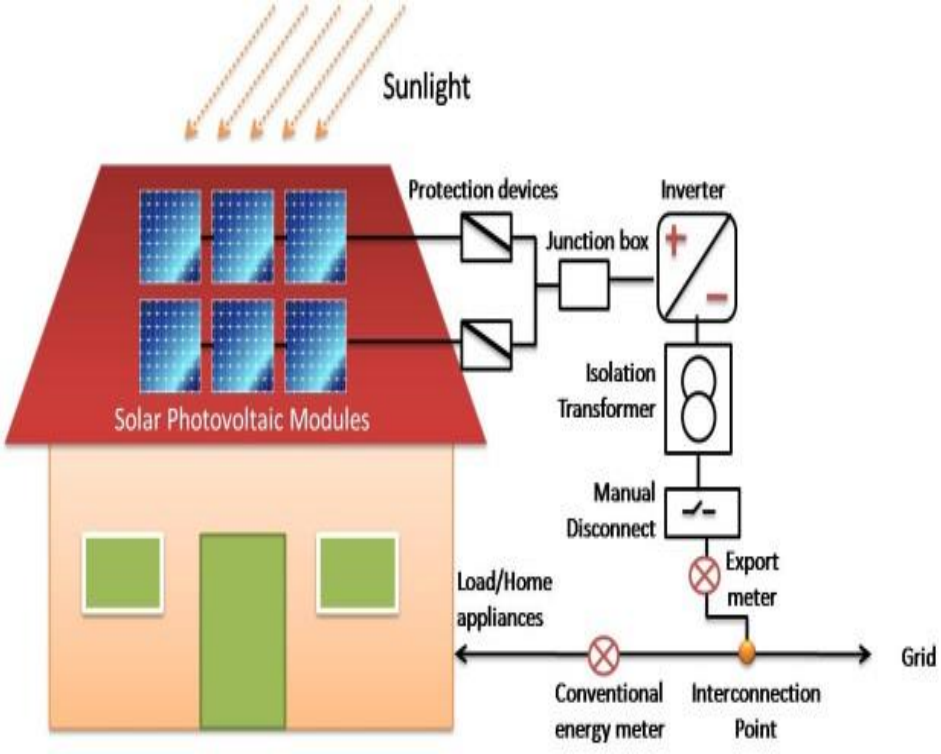
- Multistring Five-Level Inverter With Novel PWM Control Scheme for PV Application Nasrudin A. Rahim, *Senior Member, IEEE*, and Jeyraj Selvaraj, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 57, NO. 6, JUNE 2010



PV generation systems : classification

- On-Grid PV generation system(grid tied)
- Off-Grid PV generation system(stand alone)
- Hybrid PV generation system(combination of grid tied and stand alone)

On-Grid PV generation system(grid tied)



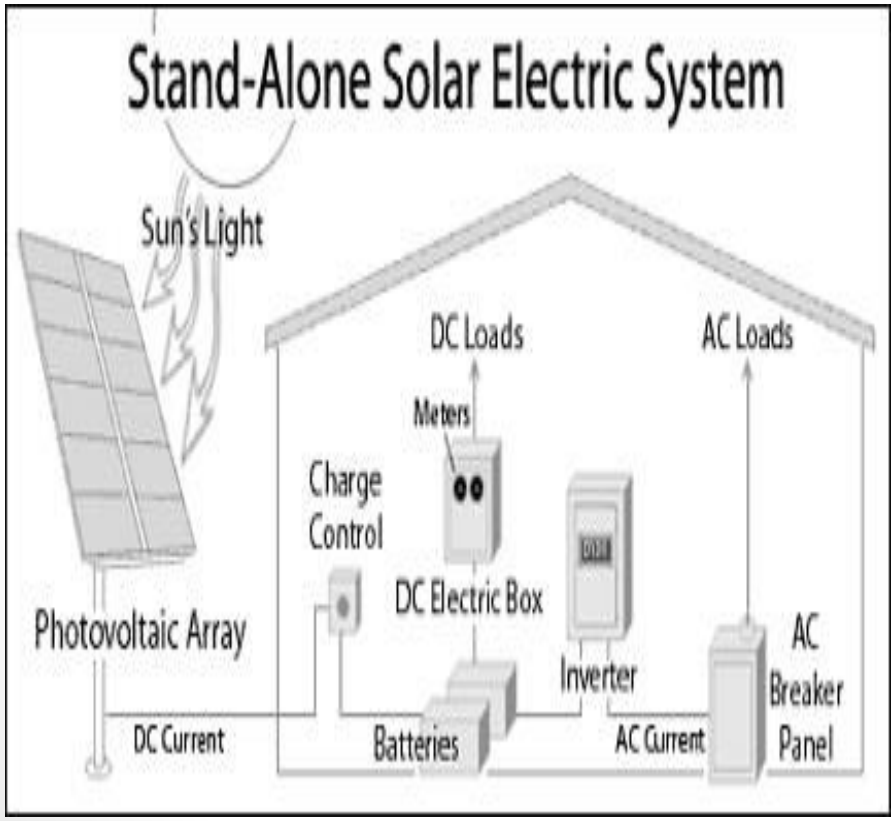
Main advantages:

1) Simple and effective
2) Easy to feed/draw power from grid

Disadvantages:

1)Grid failure will cause ineffective utilization of PV generation system

Off-Grid PV generation system (typical stand alone)



Advantages:

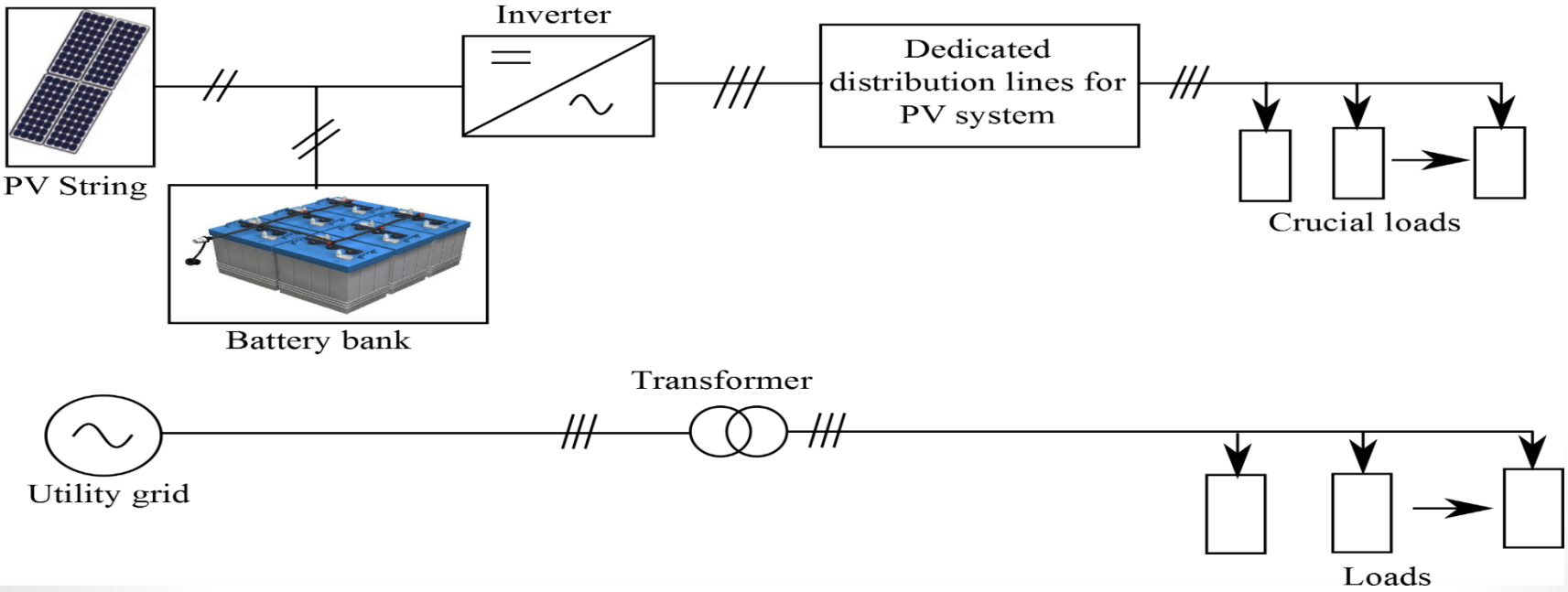
1)Independent of grid

Disadvantages:

1) Battery banks for energy storage are needed(depending on the load)
2) Less efficient compared to on-grid system

solar power for crucial loads
grid for normal loads

- **Dedicated distribution lines are required for solar power distribution to crucial loads, which makes the system more costly.**



Battery back-up requirement

Typical power generating capacity (in Telangana) of the **1Mw** solar plant is **1.6M units** (data got from tata solar)
i.e. **4000 units** power generation per day.
So it can supply

180kw load for **24 hrs**
OR
200kw load for **20 hrs**
OR
400kw load for **10 hrs** and so on..

Assuming 6hrs sun-light (average)
Calculations for storage requirement for 4hrs with 400kw load
Power transferred from solar system to load is 6*400kW = 2400 units
Power from Battery backup 4*400kW = 1600 units

*** This proposition required separate distribution system for emergency load**

Battery back-up requirement

Commercially available solar battery (max) is **2000AH @ 2V** So each battery can store 4 units of energy.

- To give 4 hrs of back up **400 batteries** are required (assuming **100%** efficiency)
- **533 batteries** are required (assuming **75%** efficiency) (Approximately)
- with **75%** efficiency loss will be **400 units** (as overall system it results 10% efficiency reduction

Calculations for storage requirement for 14hrs with 200kw load

Power transferred from solar system to load is 6*200kW = 1200 units

Power from Battery backup 14*400kW = 2800 units

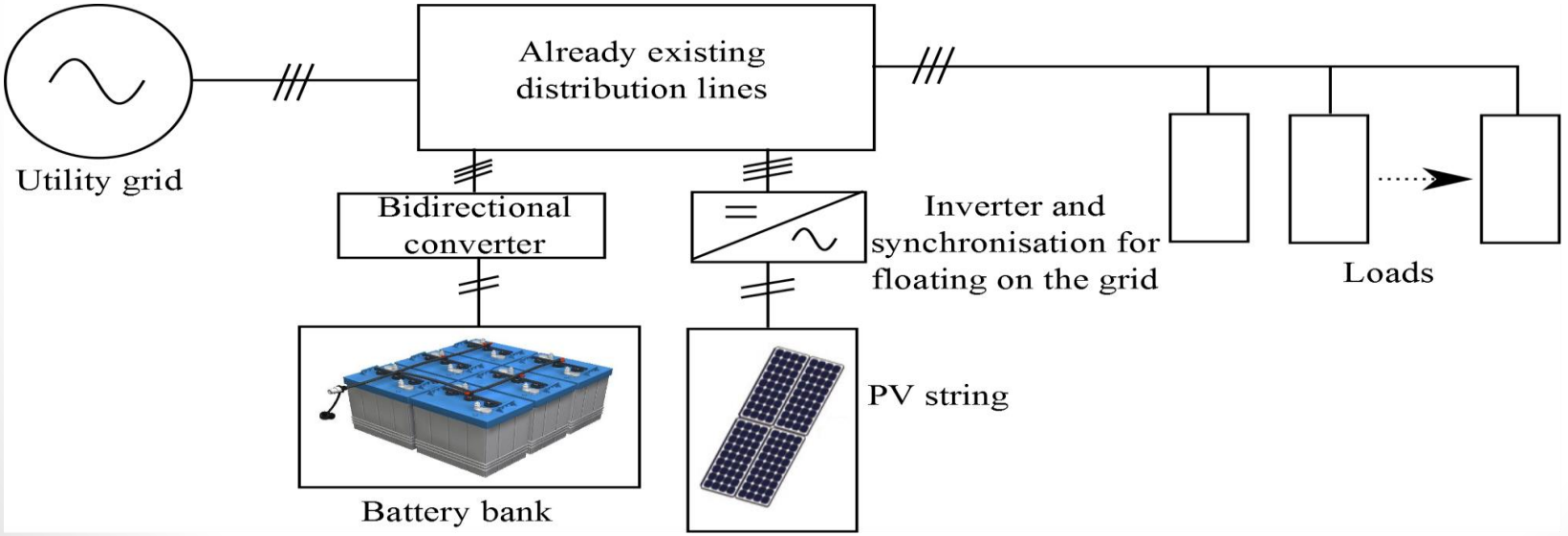
- To give **14 hrs** of back up **700 batteries** are required (assuming **100%** efficiency)
- **933 batteries** are required (assuming **75%** efficiency) (Approximately)
- with **75%** efficiency loss will be **700 units** (as overall system it results **17.5%** efficiency reduction)

Typical battery size is 480*350*340mm, weight is 130kg 600 cycles (approx.)

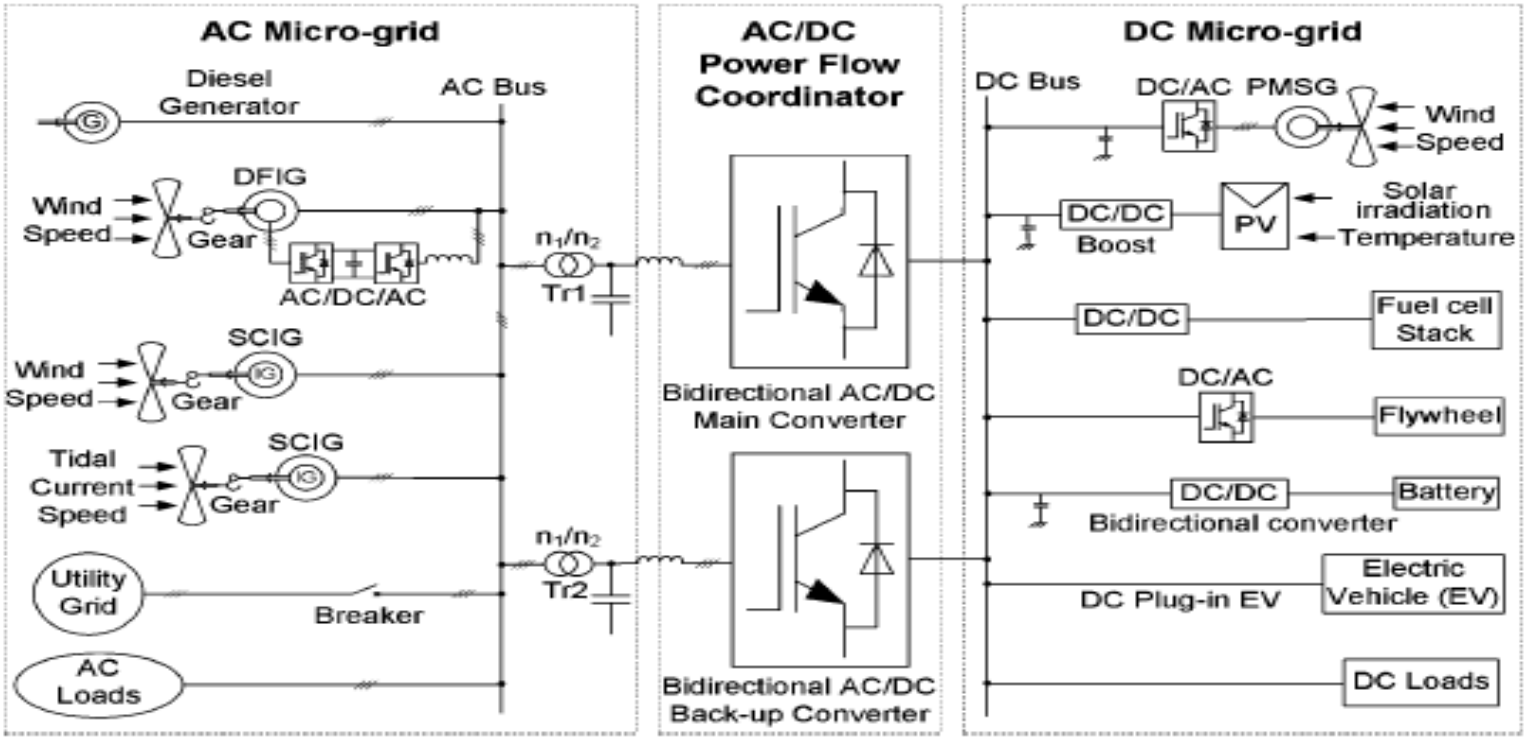
Plan2: with grid but no solar power injected to grid (floating on the grid)

For peak load duration : Grid, solar panels and battery back up will supply the load
Normal load duration: solar panels will charge battery as well as supply some of the loads , remaining loads are supplied from the grid.

- **Existing distribution lines can be used for the solar power distribution**



Hybrid AC/DC micro grid



Sources : Xiong Liu*, Student Member, IEEE*, Peng Wang*, Member, IEEE*, and Poh Chiang Loh*, Member,* IEEE TRANSACTIONS ON SMART GRID, VOL. 2, NO. 2, JUNE 2011

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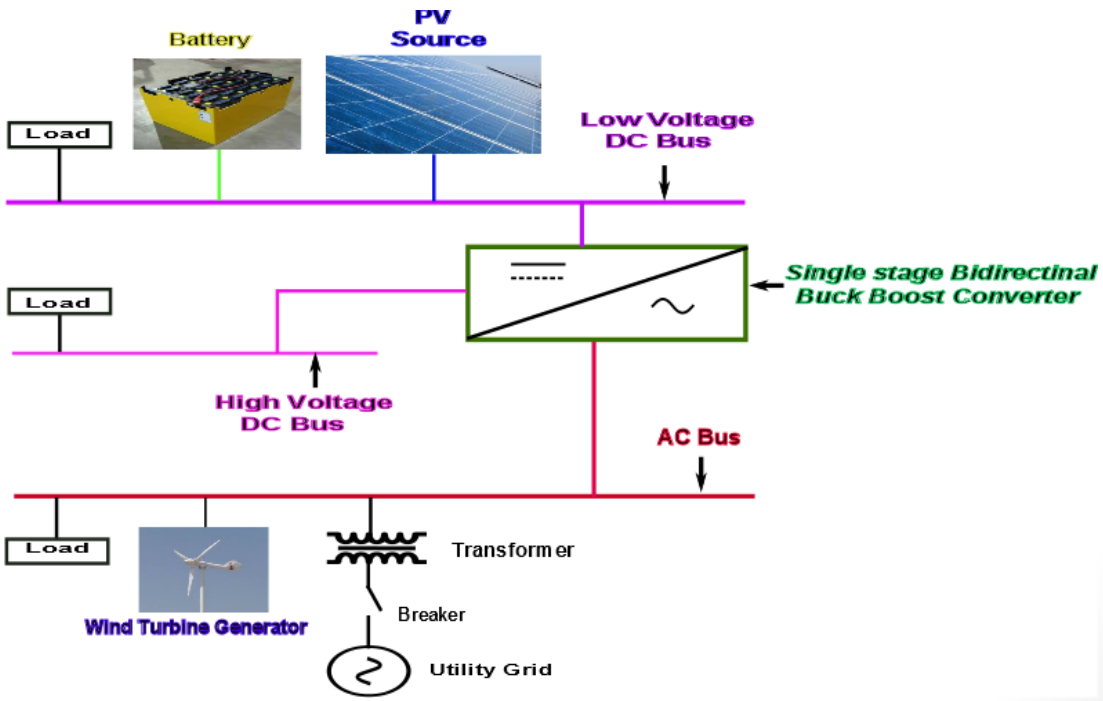
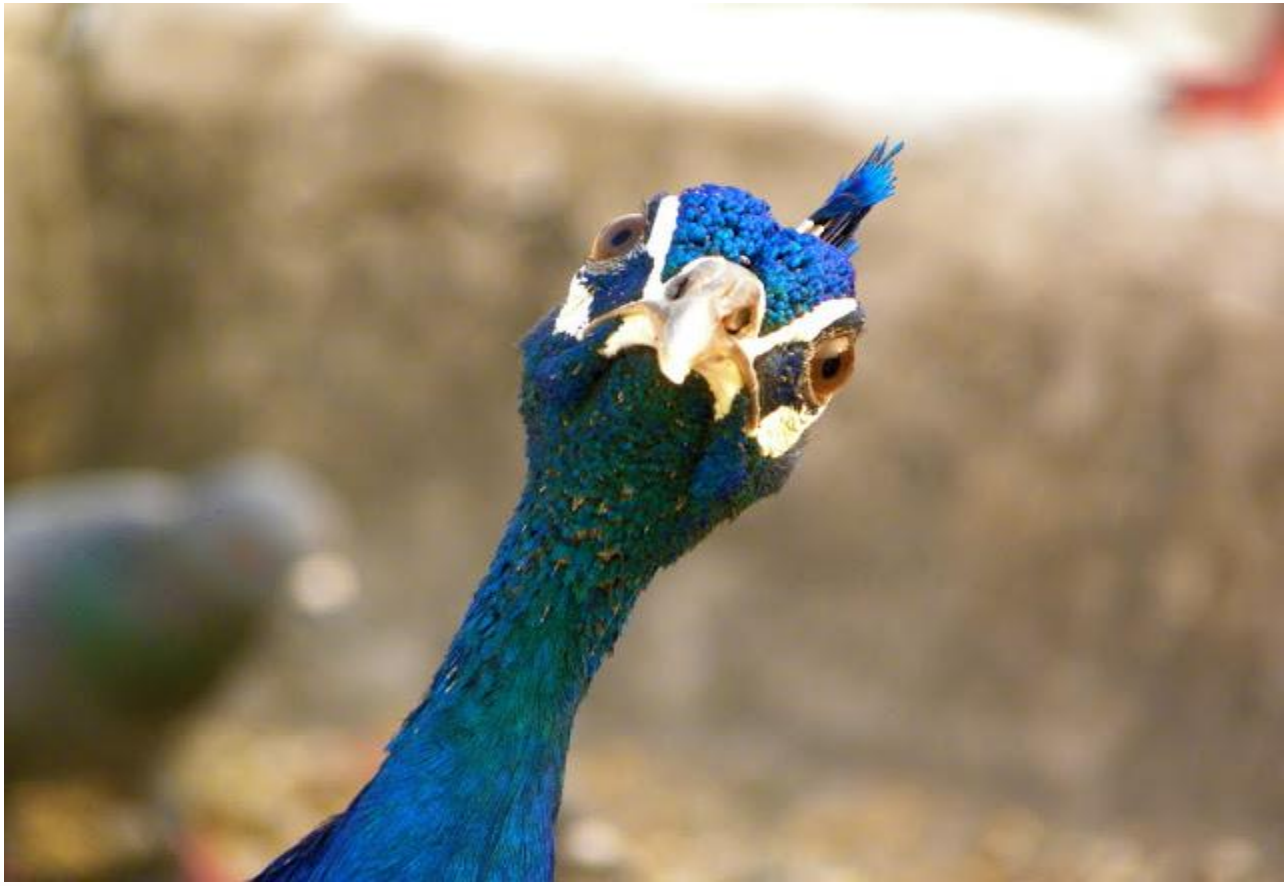
- AC-DC hybrid micro grid is formed by tying AC micro grid and DC micro grid together with the help of bi-directional converters which effectively reduces the number of conversion stages.



AC-DC hybrid Microgrid

Questions?



Thank you