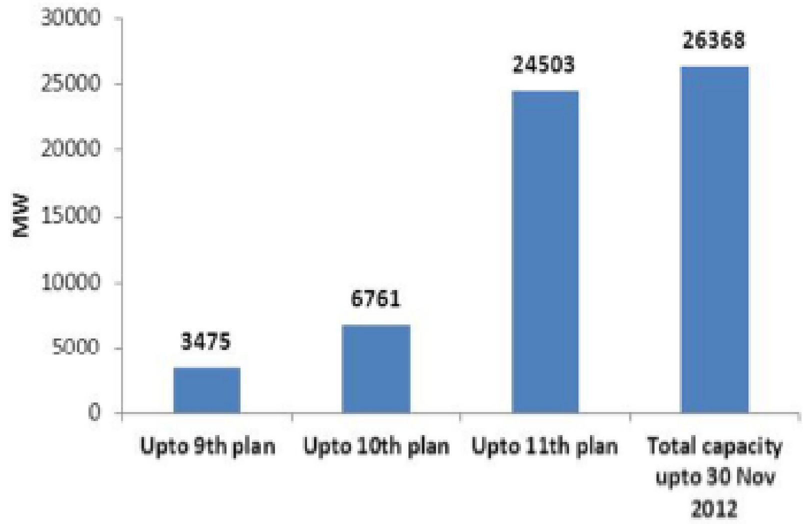
RENEWABLE ENERGY

Technology Till Today……

Indian Power Sector

Type of Power	Total Installed capacity In MW As on 30-11-2015	%
Thermal	1,95,604	69.5
❖Coal ❖Gas ❖Oil	1,70,138 24,473 994	60.5 8.7 0.4
Hydro(Renewable)	42,623	15.2
Nuclear	5,780	2.1
RES Total	36,741 2,81,423	13.3

Further, the Government of India has projected capacity addition of 72,400 MW by end of the Thirteenth Plan (2022), of which solar is expected to contribute 28%. The policy thrust to renewables has been significant and specific targets have been announced to accelerate the deployment of renewable energy. The National Action Plan on Climate Change (NAPCC, 2008) envisages a dynamic RPO target of 10% at the national level for 2015 with an annual increase of 1% so as to reach around 15% by 2020.



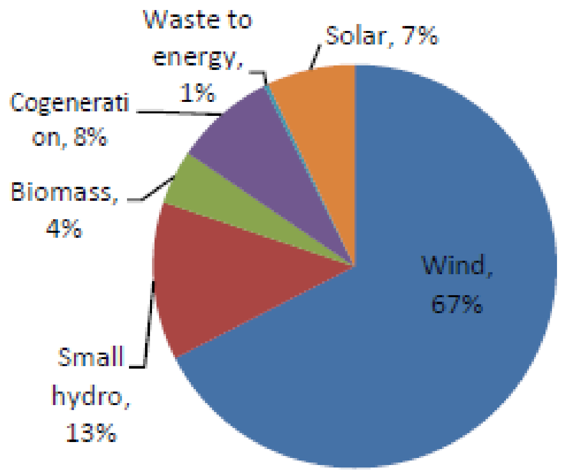
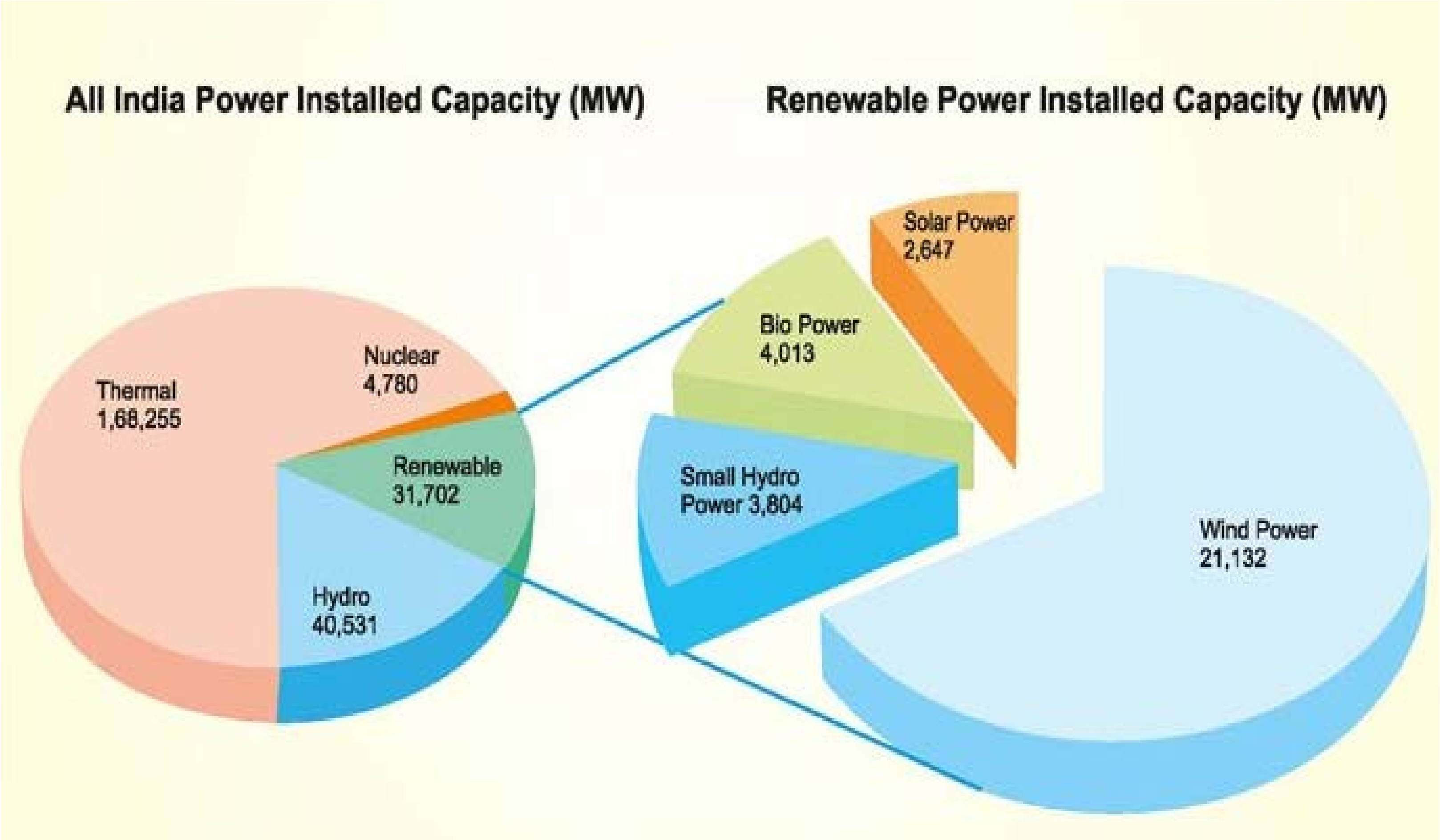


Figure 2 Plan-wise growth of the renewable energy capacity in India

Figure 1 Break-up of grid interactive capacity (As on 30 October 2013)

Source: (MNRE, 2013)

Renewable Energy Generation: Sector wise



RE Sector in India

- We currently generate approximately 13.3% + 15.2% (Hydro) of our electricity using RES power.
- The installed capacity in RES sector is 3,641.00 MW + 42,623 MW (Hydro ~Renewable).
- Total Installed Capacity till today is 2,81,423.00 MW (as on Nov. 30, 2015).

Renewable Energy Sources

Source	**Potential(MW)**	**Achieved(MW)** As on 31.3.2015
Bio-Mass	62000	1410.20
Wind-Power	45000	23444
Small Hydro Power	15000	4055.36
Co-generation-Biogas	5000	3008.35
Waste to Energy	5000	115.08
Solar Power -Total	35776.96	3743.97

Perception on Renewable energy

Solar and wind power are intermittent and mostly unavailable when most required.

- It may create more tripping and maintenance problems.
- It may disturb power quality due to injection of harmonics.
- It may over load existing transformers.
- It may lead to grid instability.

Can Renewable energy at strategic locations improve Power Quality?

- Even if the generation from solar and wind are intermittent , it provides active power and voltage support to the grid and substantially reduces system losses.
- Modern inverters are capable of providing both active and reactive power support. They have fault ride through capability and provide support during recovery from fault.
- Inverter PWM can ensure low TIF and distortion.

Solar power in India

- India is densely populated and has high solar insolation, an ideal combination for using solar power in India.
- Announced in November 2009, the Government of India proposed to launch its Jawaharlal Nehru National Solar Mission under the National Action Plan on Climate Change with plans to generate up to 20,000 MW grid-based solar power, 2,000 MW of off-grid solar power and cover 20 million sq metres with collectors by the end of the final phase of the mission in 2020. Achieving this target would establish India as a global leader in solar power generation.

MNRE - GRID-INTERACTIVE POWER

(CAPACITIES IN MW) AS 0N 31/10/2015

• **Wind Power**	24677.72
• **Solar Power**	4579.24
• **Small Hydro Power**	4161.90
• **Bio-Power (Biomass & Gasification and Bio gas Cogeneration)**	4550.55
• **Waste to Power**	127.08
• **Total**	38096.49

Jawaharlal Nehru National Solar Mission (JNNSM)

- Launched by the Government of India in January 2010.
- JNNSM is one of the major global initiatives in promotion of solar energy technologies.
- Mission aims to achieve grid tariff parity by 2022
- One of the eight Missions under National Action Plan on Climate Change.

MNRE - RE POWER 2022 (TENTATIVE) CAPACITY IN MW

Region	Solar	Wind	SHP	Biomass
Northern	31120	8600	2450	4149
Western	28410	22600	125	2875
Southern	26531	28200	1675	2612
Eastern	12237		135	244
N-Eastern	1205		615	
All India	99533	60000	5000	10000

Photovoltaic generators operations

- Photovoltaic generators are usually operated in a fashion to extract maximum power from it, under the given operating conditions.
- Many methods for tracking the Maximum Power Point (MPP) are proposed and implemented, Perturb & Observe (P & O) and Incremental Conductance being widely used MPP Tracking (MPPT) algorithms.
- Because the power generation is fluctuating, there is a need for energy storage system-which smoothens the output power.
- Also, energy storage allows the excess power to be stored and used when photovoltaic generation is absent.

De-rated/off-MPP PV operation

- General trend to avoid the use of energy storage system is to de-rate the photovoltaic generator, i.e., operate it to deliver power lower than its maximum power and keep the remaining power as reserve.
- By de-rating and proper control of photovoltaic generators, not only the use of energy storage devices are eliminated-but they can participate in frequency regulation.
- The control of a photovoltaic generator consists of two loops, outer voltage/power control loop and inner current control loop.
- The photovoltaic generator should have sufficient reserve, i.e., **derated amount of power** in case of storage free system or enough storage capacity if there is energy storage.
- Most of the power industries are opting for PV-DG combination set/ PV with storage system.

Impacts of PV on AC grid system

- PV impacts on distribution systems can be either steady-state or dynamic in nature, and they include:
  - changes in network voltage profiles, including voltage rise and unbalance
  - changes in feeder loading, including potential equipment and component overload
  - Reduction of effective inertia in the system(especially in weak system)
  - frequent operation of voltage-control and regulation devices, such as load tap changers (LTCs), line voltage regulators (VRs), and capacitor banks

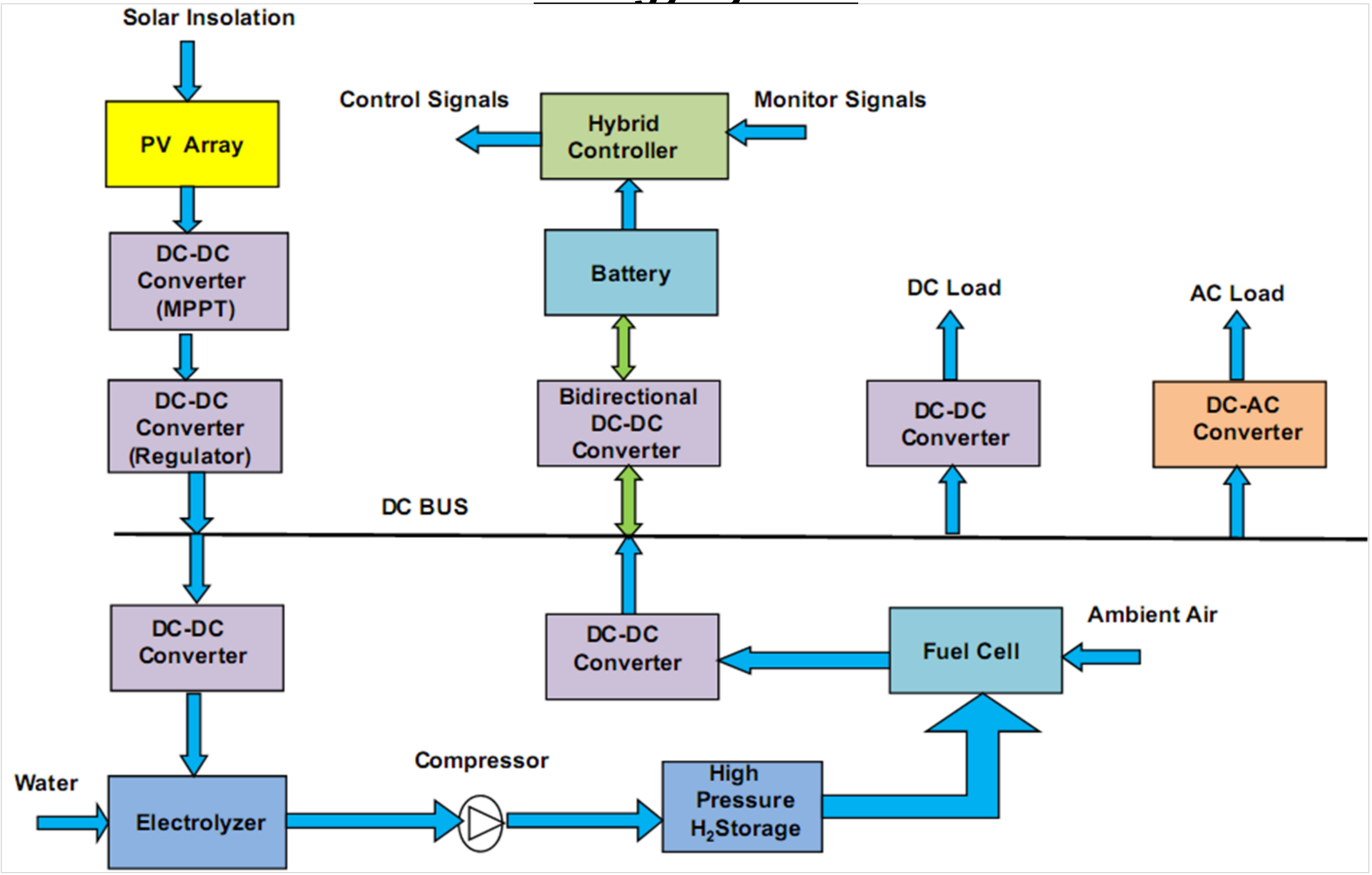
Impacts of PV on AC grid system

- power quality, PV intermittency may lead to voltage fluctuation issues.
- Over current and over voltage protection, including mal-operation of over current protection equipment and temporary over voltage (TOV).
- change in electric losses, where relatively large reverse power flow may increase losses.
- variations in power factor of a feeder or system, which may have economic impacts on local distribution companies purchasing power from larger utilities.

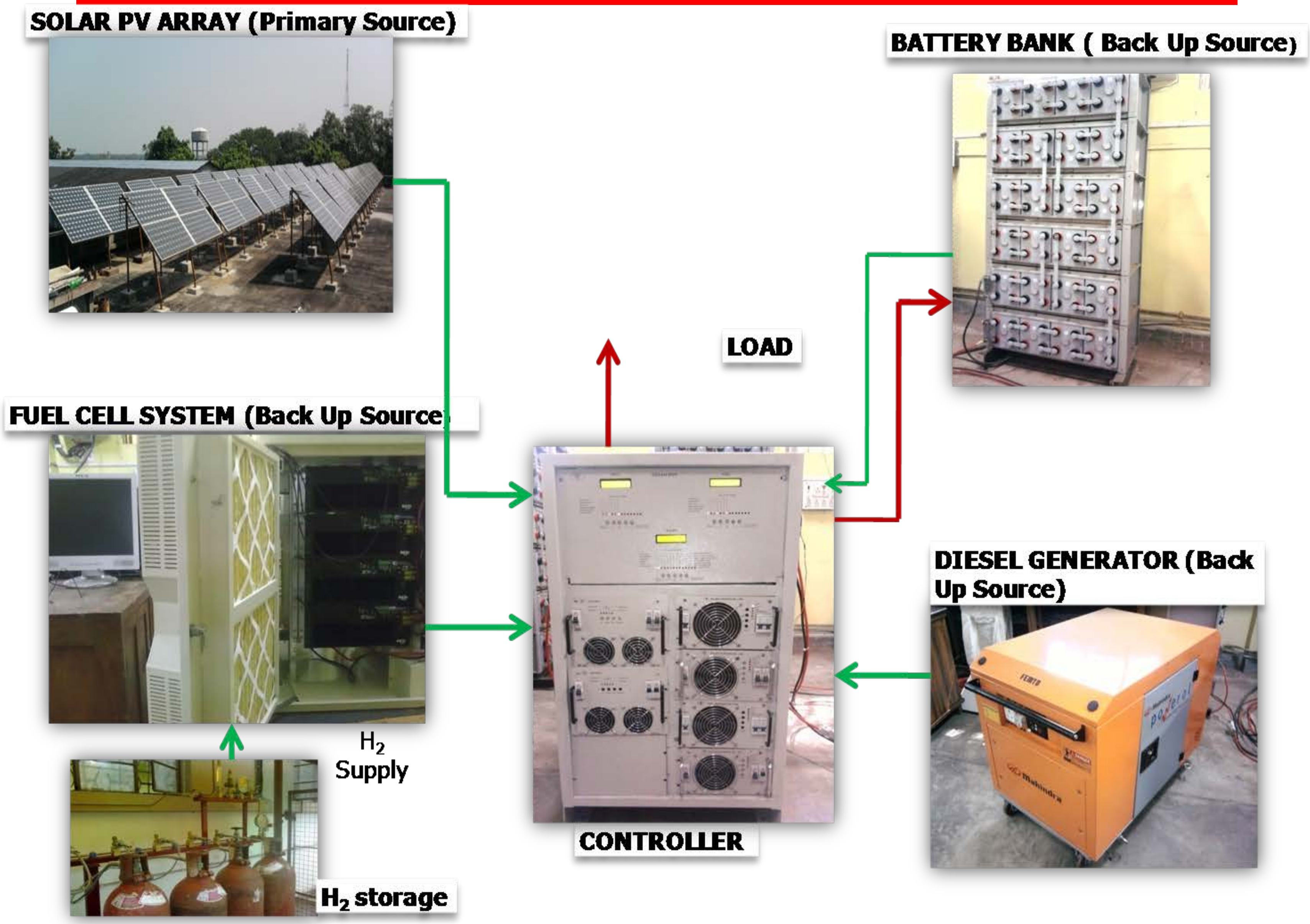
Increase in PV can lead to reverse power flow conditions at section, feeder, and substation levels.

- Reverse power flow can negatively affect protection coordination and operation of line voltage regulators.
- As distribution feeders are typically designed for unidirectional power flows, this situation may noticeably affect the over current protection coordination of the distribution system.
- Therefore specific studies must be done on a feeder-by-feeder basis to select the most adequate protection strategy and design if high penetration of utility-scale PV-DG plants is expected.
- Reverse power flow can also affect the operation of Voltage Regulators, and they must be evaluated under control modes that allow bidirectional power flow (e.g., cogeneration or bidirectional modes) to avoid potential voltage violations.
- Hence, any selected operation mode for voltage regulators should be truly bidirectional and assessed for no-PV cases with opposite power flow expected at night or low-PV generation conditions.

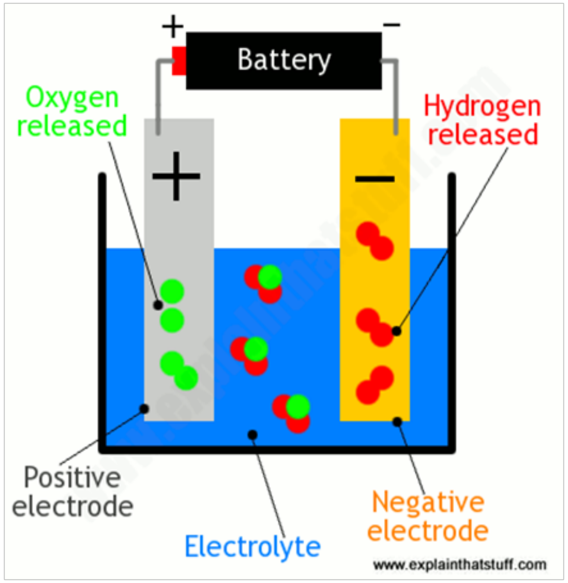
A typical stand-alone PV-Fuel cell-Battery hybrid energy system



SPV-FC-BATTERY-DG Hybrid Energy Power Plant



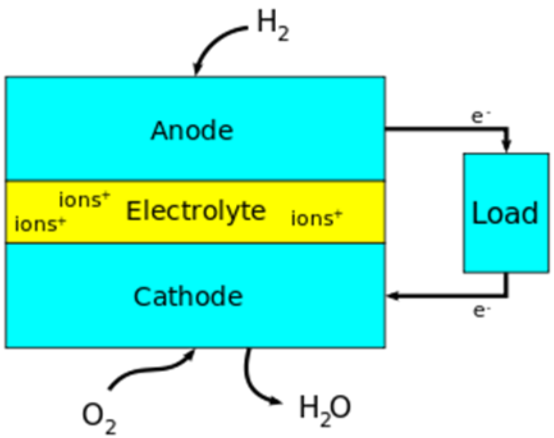
How does an electrolyzer work?



When the power is switched on, water (H_2O—shown here as two red blobs joined to one green one) Splits into positively charged hydrogen ions (hydrogen atoms missing electrons, shown in red) and negatively charged oxygen ions (oxygen atoms with extra electrons, shown in green).

The positive hydrogen ions are attracted to the negative terminal and recombine in pairs to form hydrogen gas (H_2).*Likewise,the negative oxygen ions are drawn to the positive terminal and recombine in pairs there to form oxygen gas (O_2).*

Fuel Cell



The electrolyte substance usually defines the *type* of fuel cell.The most common fuel is hydrogen.

- The anode catalyst breaks down the fuel into electrons and ions. The anode catalyst is usually made up of very fine platinum powder.

- The cathode catalyst turns the ions into the waste chemicals like water or carbon dioxide. The cathode catalyst is often made up of nickel but it can also be a nano material-based catalyst.

- A typical fuel cell produces a voltage from 0.6 V to 0.7 V at full rated load. Voltage decreases as current increases, due to several factors.

Superconducting Magnetic Energy Storage (SMES)

- A novel technology that stores electricity from the grid within the magnetic field of a coil comprised of superconducting wire with near-zero loss of energy.

- A grid-enabling device that stores and discharges large quantities of power almost instantaneously. It is capable of releasing high levels of power within a fraction of a cycle to replace a sudden loss or dip in line power for maintaining grid reliability especially with today's increasingly congested power lines and the high penetration of renewable energy sources, such as wind and solar.
- A typical SMES consists of two parts – cryogenically cooled superconducting coil and power conditioning system – which are motionless and result in higher reliability than many other power storage devices. Ideally, once the superconducting coil is charged, the current will not decay and the magnetic energy can be stored indefinitely.

Benefits of SMES

- Improves power quality for critical loads and provides carryover energy during momentary voltage sags and power outages.
- Improves load leveling between renewable energy sources (wind, solar) and the transmission and distribution network.
- Environmentally beneficial as compared to batteries; superconductivity does not rely on a chemical reaction and no toxins are produced in the process.
- Enhances transmission line capacity and performance – SMES features a high dynamic range, an almost infinite cycling capability, and an energy recovery rate close to 100%.
- Ultra-high field operation enables long-term storage SMES systems in a compact device with cost advantages in material and system costs.

The PV/FC hybrid power system

Components

PV generator, Electrolyzer, hydrogen storage tank and fuel cell.

Configurations

1). PV, battery, FC feed by an external hydrogen tank;

2). PV, FC, electrolyzer and hydrogen tank

3). PV, battery, FC, electrolyzer and hydrogen tank.

The optimum design, control strategy, economic and performance of a PV/FC hybrid power generation system without battery storage taking into account all losses in the system.

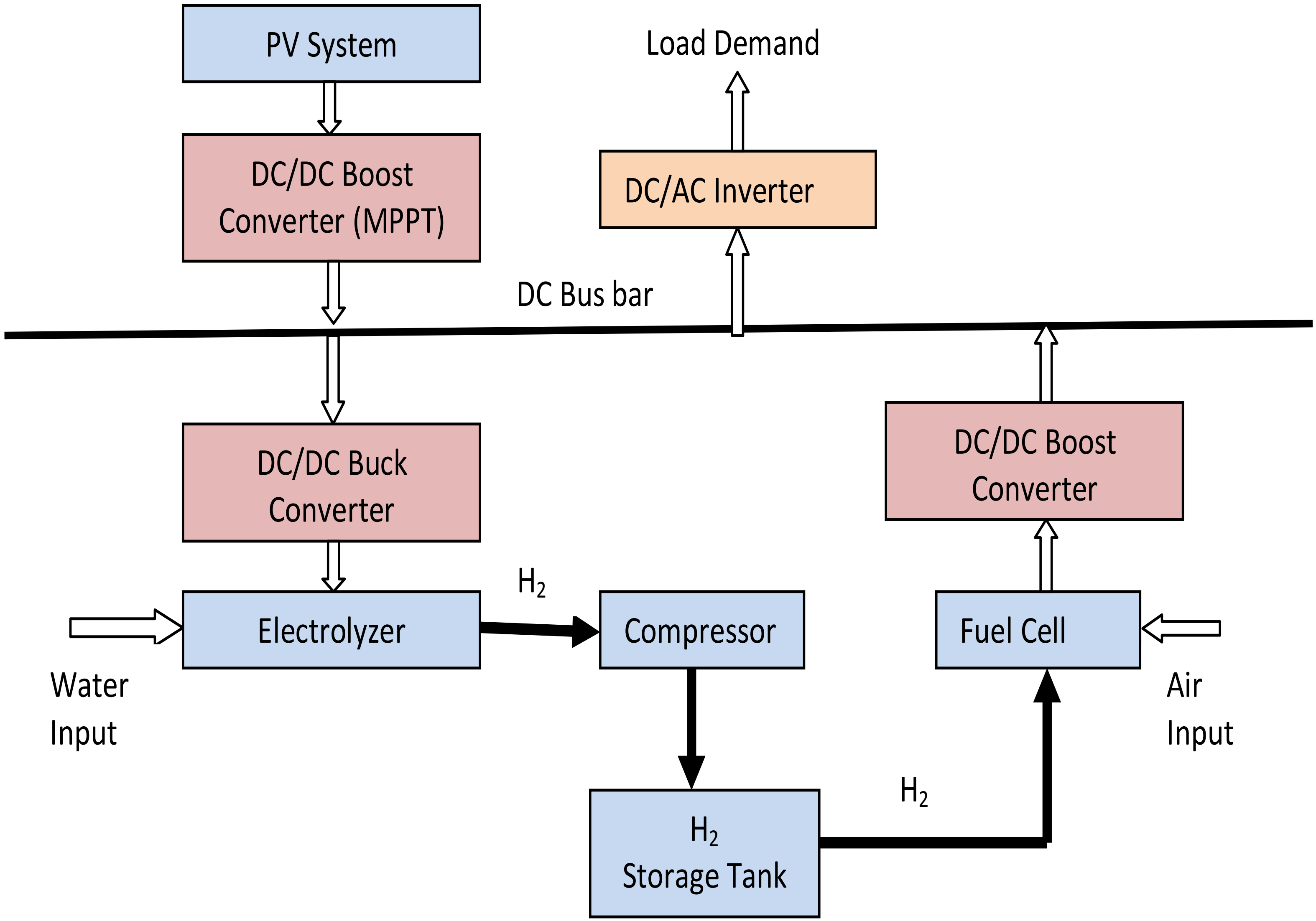


Fig. 1 *Schematic diagram of PV/FC hybrid power system*