Impact of PV Energy Resources on the Quality of power of the Electrical Power System

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Agenda

1. The Scene in Thailand
2. Power Quality Phenomena.
3. Renewable Energy: Wind.
4. Renewable Energy : PV.
5. Effects of Harmonics
6. Harmonics: Mitigation
7. Harmonics: Effects of Capacitors.
8. FACTS

AEDP Plan (2015-2036)

Renewable Energy	As of 2015	Target in 2036
1. Solar Cell	1,298.51 MW	6,000 MW
2. Wind Energy	224.47 MW	3,002 MW
3. Biomass	2,451.82 MW	5,570 MW
4. Biogas (Wastewater/sludge)	311.50 MW	600 MW
5. Biogas (Energy crops)	Pending	680 MW
6. Waste (Municipal Solid Waste)	65.72 MW	500 MW
7. Waste (Industrial Waste)	Pending	50 MW
8. Small Hydro Power	142.01 MW	376 MW
9. Hydro Power	Pending	2,906.40 MW*
Total in MW	**4,494.03 MW**	**19,684.40 MW**
BioDiesel	4.2 Million Liters/day**	14 Million Liters/day
Ethanol	5.04 Million Liters/day**	11.30 Million Liters/day

Remarks: * Current Capacity
** As of February 2016
- Include only the selling electricity to Energy Utilities.

Renewable Energy: PV

- The photovoltaic (PV) energy is the most promising source of energy since it is pollution free and abundantly available everywhere in the world.
- PV energy is especially beneficial in remote sites like deserts or rural zones where the difficulties to transport fuel and the lack of energy grid lines make the use of conventional resources impossible.

Basic Composition of a Solar Photovoltaic System

- The basic solar photovoltaic (PV) system consists of the solar panels, containing several solar cells, which convert sunlight to electricity and an inverter which is interface between the solar panels and the load.

- The inverter transforms the direct current (DC) generated by the solar panels into alternating current (AC) compatible with the requirements of the load.
- Two main configurations for solar PV systems; with and without energy storage.

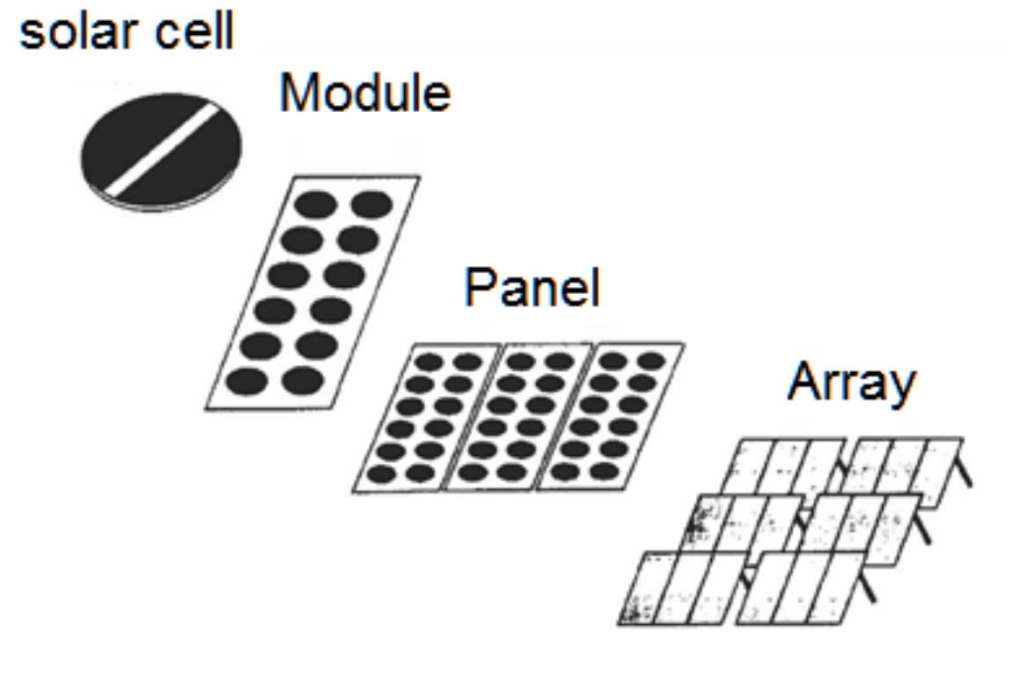
- If AC power is required, an inverter is used to transform the DC supplied by the batteries to AC. In some cases, DC distribution is preferred to conversion to AC power as it reduces losses.

- For PV systems without energy storage, power is only available from the PV system when the sun is shining.
- One subset of these systems is those known as grid-connected or grid-tied systems. For these systems, the electricity grid is the load.

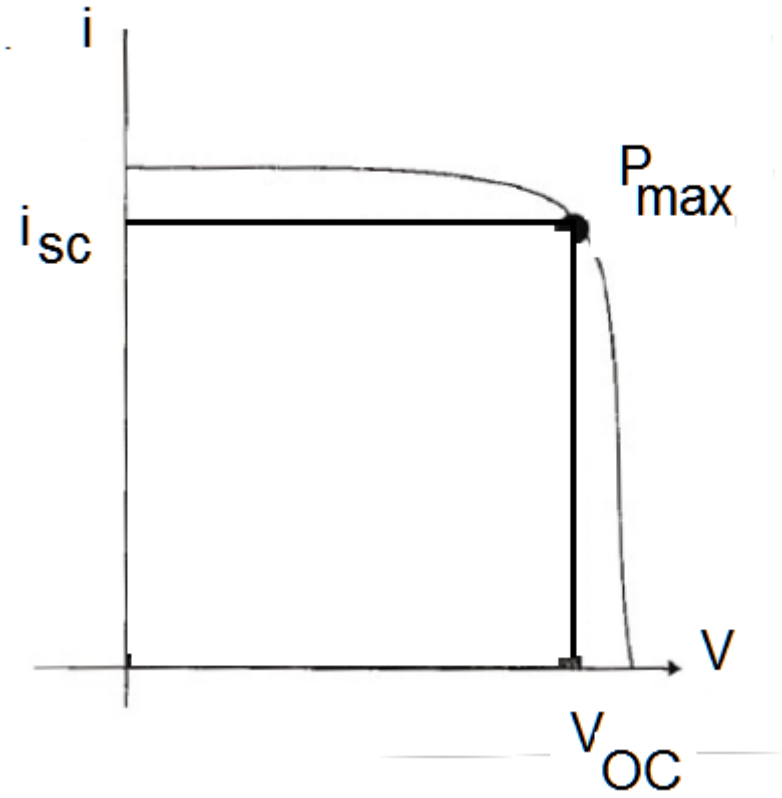
- A solar cell is a semi-conductor device which has much in common with diodes and transistors.
- Two main commercial solar cell manufacturing technologies currently used. These are crystalline silicon cells and thin film cells.

- Solar panels consist of solar modules connected to achieve the desired panel shape and power ratings.
- Solar modules consist of a number of solar cells.
- The overall solar panel has the same characteristic behaviour as the cells and modules which make it.

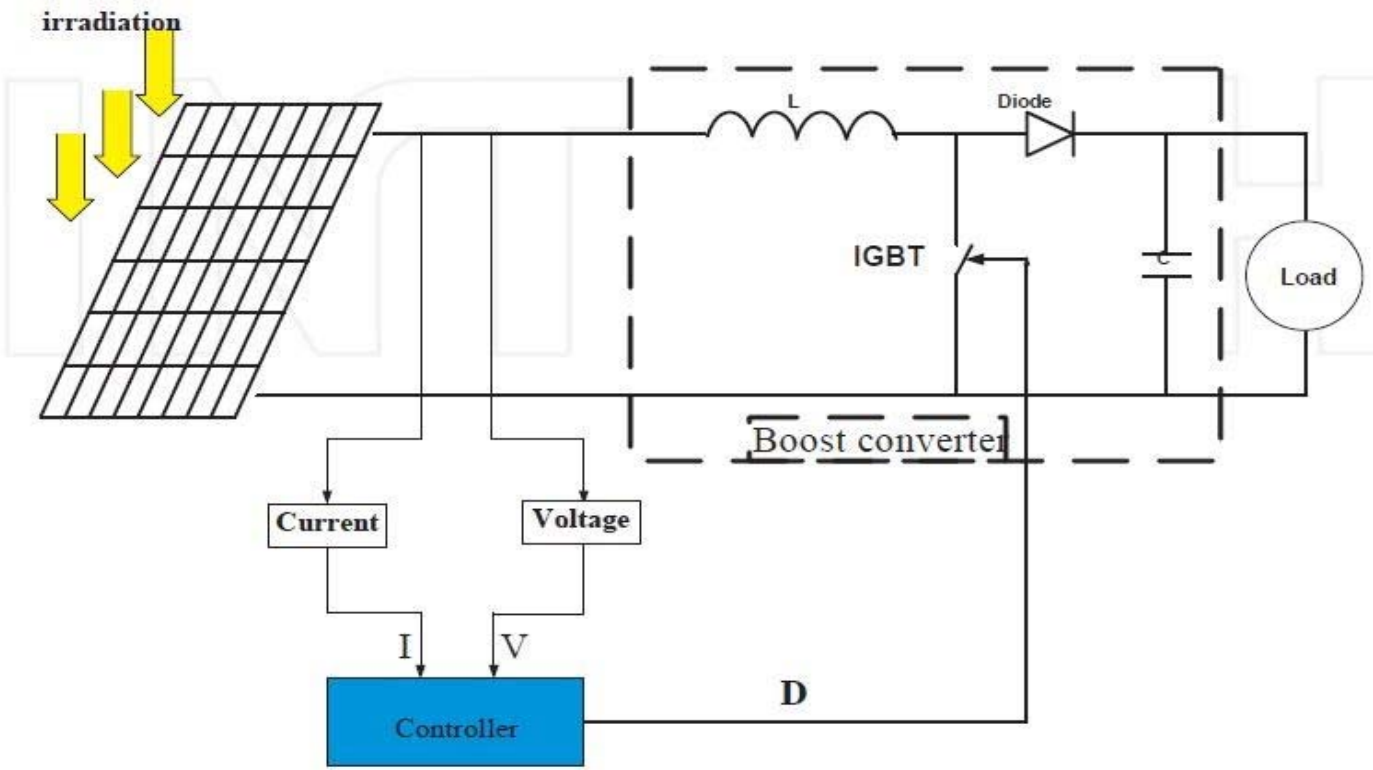
- Commercial solar panels range in rated power from around 2 W up to 300 W with maximum voltages of approximately 12 V – 35 V DC.
- A number of solar panels connected together is known as an array.


solar cell
Module
Panel
Array

Solar Cell Electrical Output Characteristics



Unified Diagram of PV System



MPPT

- An MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid.
- They convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries.

- Many MPPT methods have been presented, such as the hill climbing, incremental conductance and the P&O.
- These algorithms consist of introducing a crisp values positive or negative (decrease or increase) all around the actual photovoltaic generator (PVG) operating point.

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- From the previous power point position, the trajectory of the new one helps the algorithm to decide on the command output value.
- This algorithm may fail to act as an accurate MPPT because of the used crisp value (step size) that is mainly fixed by trial and tests running.

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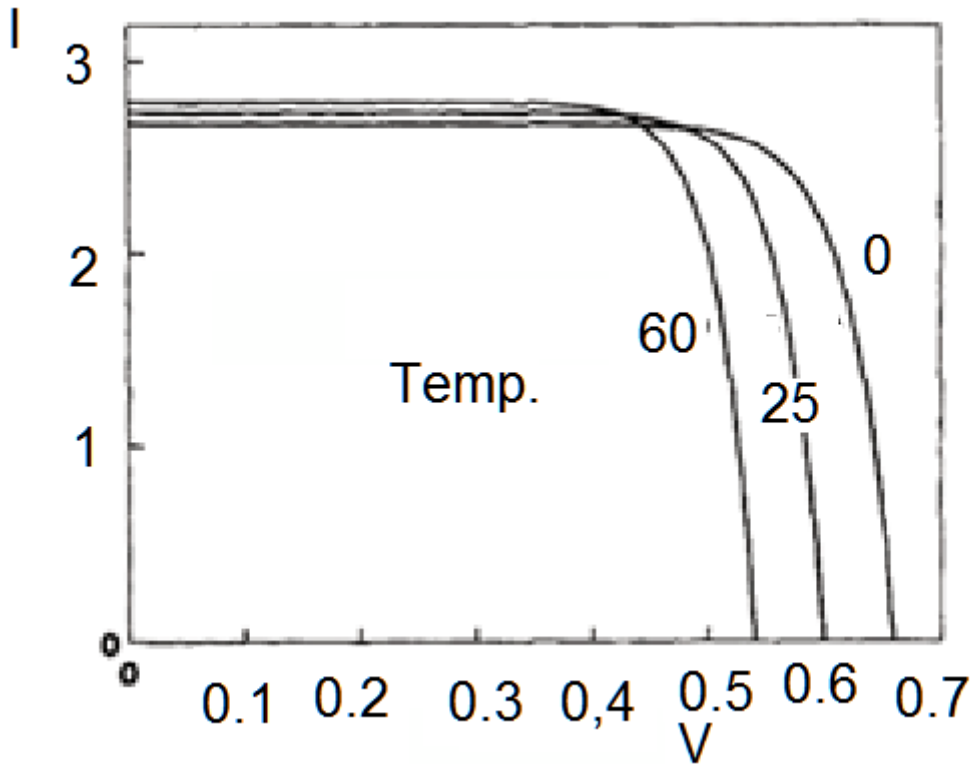
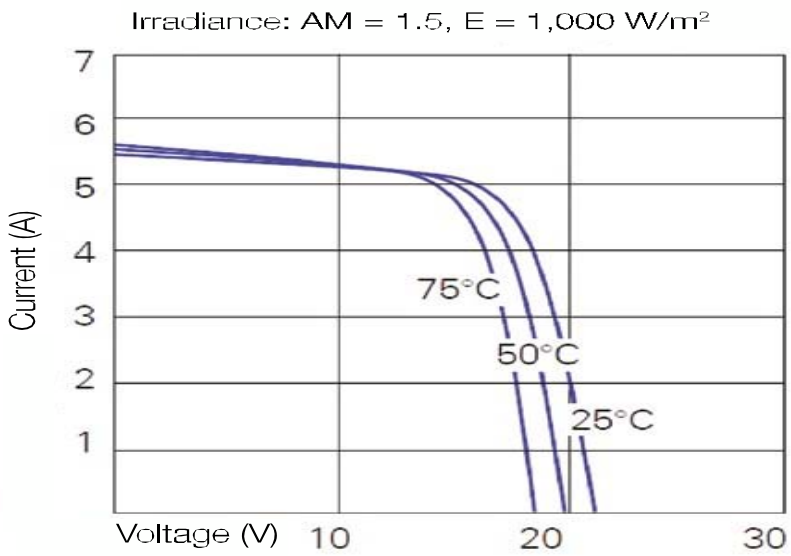
Factors Affecting Solar Cell Output

- Three factors affect the output of solar PV cells.
- Operating temperature
- Sun intensity
- Sun angle


I
3
2
1
0
0
Temp.
60
25
0
0.1
0.2
0.3
0,4
0.5
0.6
0.7
V


Irradiance: AM = 1.5, E = 1,000 W/m²
Current (A)
7
6
5
4
3
2
1
75°C
50°C
25°C
Voltage (V)
10
20
30

- Due to the intermittent nature of the solar irradiance, PV plants cause voltage fluctuations in the grid.
- Single-phase PV inverters commonly used in single family houses are likely to cause voltage unbalance.

- The magnitude of the voltage fluctuations and unbalance at the PV plant point of connection depends on the network impedance and especially in weak rural networks the problems may become severe.

- Conventionally, voltage fluctuations have caused concerns mainly due to light luminosity changes which are characterized by short-term and long-term flicker indices

- The introduction of compact fluorescent light (CFL) and light emitting diode (LED) lighting the sensitivity of lights to voltage fluctuations has generally decreased

- Some non-dimmable LED lights have shown even larger sensitivity to voltage changes than incandescent lights and halogen lighting is still widely used.

- Voltage fluctuations may also cause additional stress and shorten the life of switch-mode power supplies, adjustable-speed drives (ASDs) and other electronic equipment having a full wave rectifier with smoothing capacitor at the mains input stage.

- The main reason is the increased RMS ripple current, which causes temperature rise and accelerates the aging processes of the capacitor.
- Voltage unbalance may cause additional stress to electronic equipment using three-phase rectifiers in the mains input stage due to the transition of the rectifier stage from three-phase operation to single phase operation.

Rapid voltage changes and flicker

- Rapid power variations caused by shading due to, for example, passing clouds are a typical phenomenon in PV systems.
- Rapid and large power variations may cause flicker, additional stress to electrical equipment and malfunction of sensitive equipment in the network.

Transient currents at inverter start-up and shut-down

- Current transients or bursts associated with the inverter start-up in the morning and shut-down in the evening were observed in both inverters.
- The current transients have an adverse effect on the voltage quality and may cause additional stress to other electrical equipment connected to the network.

Harmonic current distortion

- Harmonic currents produced by the inverter depend on the instantaneous power produced by the inverter and the amount of voltage harmonics present in the grid.