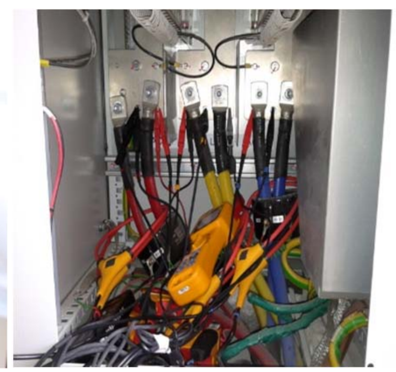
The Use of Power Electronics in Harvesting Solar Energy - Malaysia



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UMPEDAC

WHERE WE ARE?

Melayu Malaysia
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http://www.um.edu.my
Adult and Child
& Adolescent
Psychiatrist, Dr Hamidin
Specialist Clinic
Islamic Teaching
College Hostel
Football groung
Stadium Hoki
Jalan Bukit Pantai
Tnb Museum
Bekalan Air
Jalan Kipas
Masjid Ar-rahman Um
Fakulti Undang
Undang Um
Jalan Pantai Baru
Balai Polis Panta
Komplecks Sukan Tnb
Drive 6 min
2.9 km
Wisma R&D
University Malaya
Sungai Pantai
Masjid Menara Tm
Tm Annexe 1
Pullman Kuala
Lumpur Bangsar
Menara Tm
Stadium Telekom
Lengkok Pantai Baharu
MCCHR Pusat Rakyat
Jalan 2/83a
Stesen Putra Lrt
Kerinchi(kj20)
NetAxis Sdn Bhd
Tm Annexe 2
Jalan Pantai Baru
Lebuhraya Persekutuan

0UR LABORATORIES

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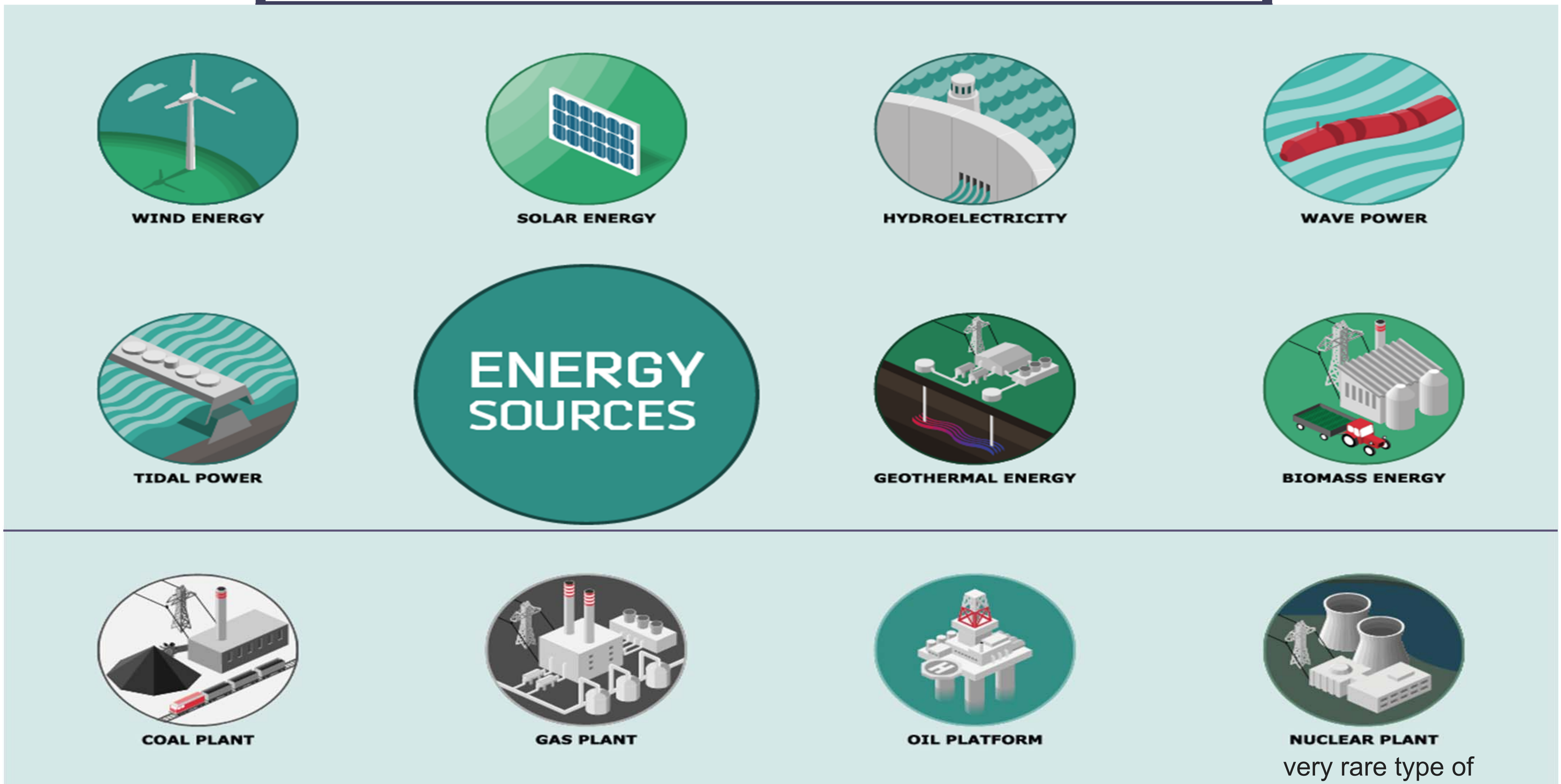
Renewable and non-Renewable Energy

◆ *Professor Ir. Dr. Nasrudin Abd Rahim*

Introduction: Renewable and Non-Renewable Energy Sources



very rare type of uranium, U-235.

Source: https://www.behance.net/bhj

Power Electronics – Enabling Technology

Professor Ir. Dr. Nasrudin Abd Rahim

Power Electronics – Enabling Technology

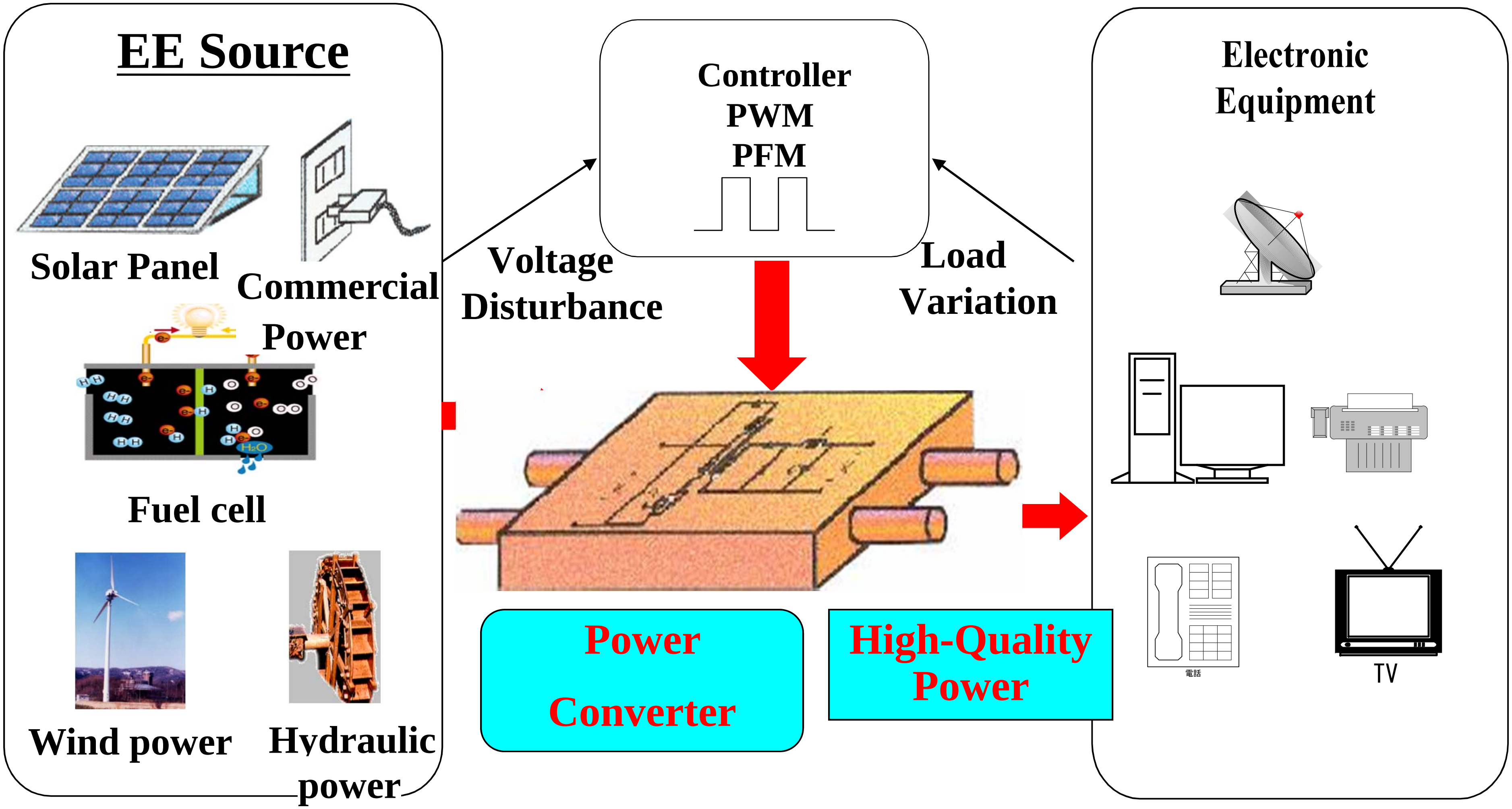
The study of processing, and of controlling, the flow of electrical energy, by supplying voltages and currents to the load or vice-versa. It is the technology that allows the use of solid state electronics and the use of high switching frequency for energy conversion circuits, which is the key to a smaller, lighter, and more efficient power processors.

Power Electronics – Enabling Technology (con't)

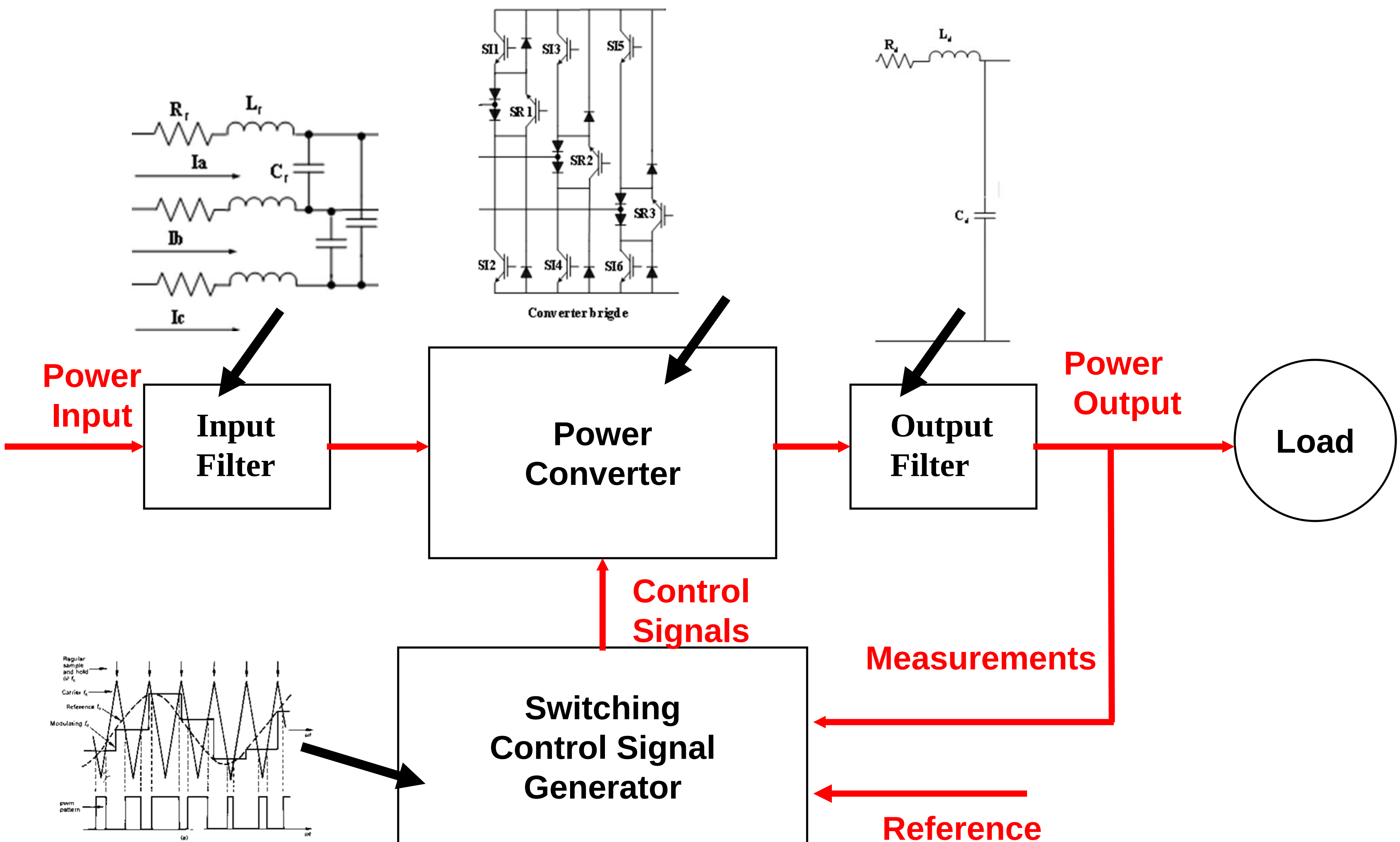
Silicon carbide (SiC) and gallium nitride (GaN) VS IGBT

- Higher voltages
- more rugged with longer lifetimes, and
- switch much faster than conventional semiconductor devices.
- Silicon-carbide inverters attained 99 percent efficiency (two percent higher than conventional converters)

Power Electronics – Enabling Technology (con't)

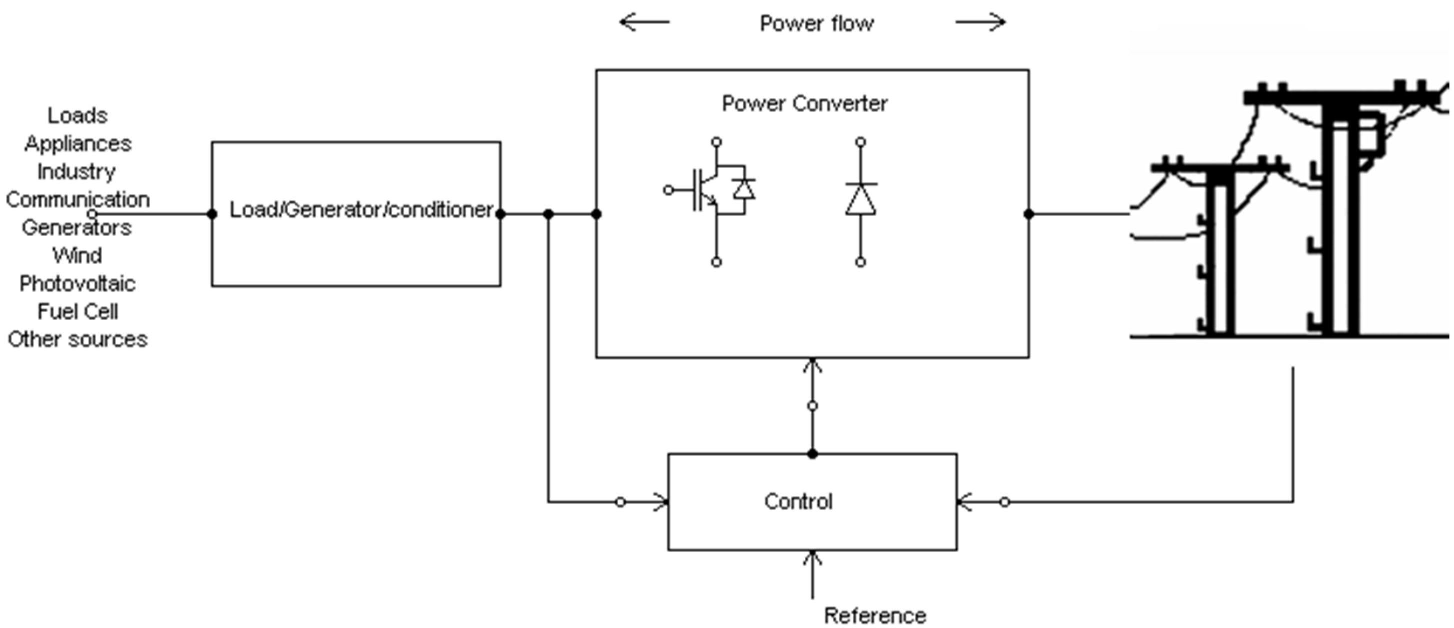


Power Electronics – Enabling Technology (con't)



Power Electronics Application for Renewable Energy Systems

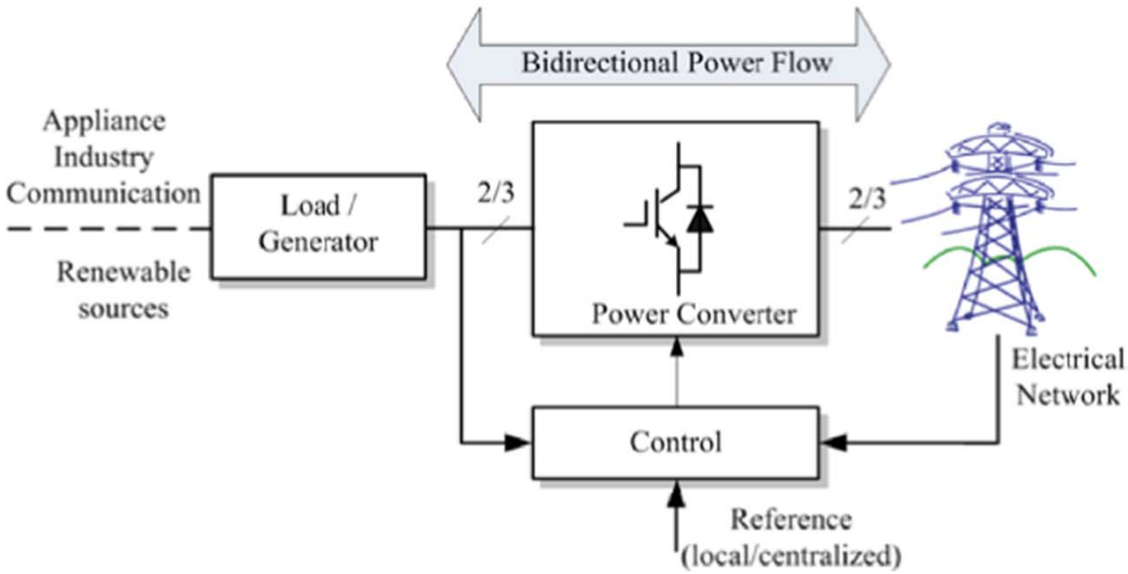
… is to convert energy, from one stage into another stage, to the grid (alternative voltage), with the highest possible efficiency and the lowest cost, while maintaining a superior performance.



Typical Power Electronics System for Renewable Energy

Important issues for the Power Converter

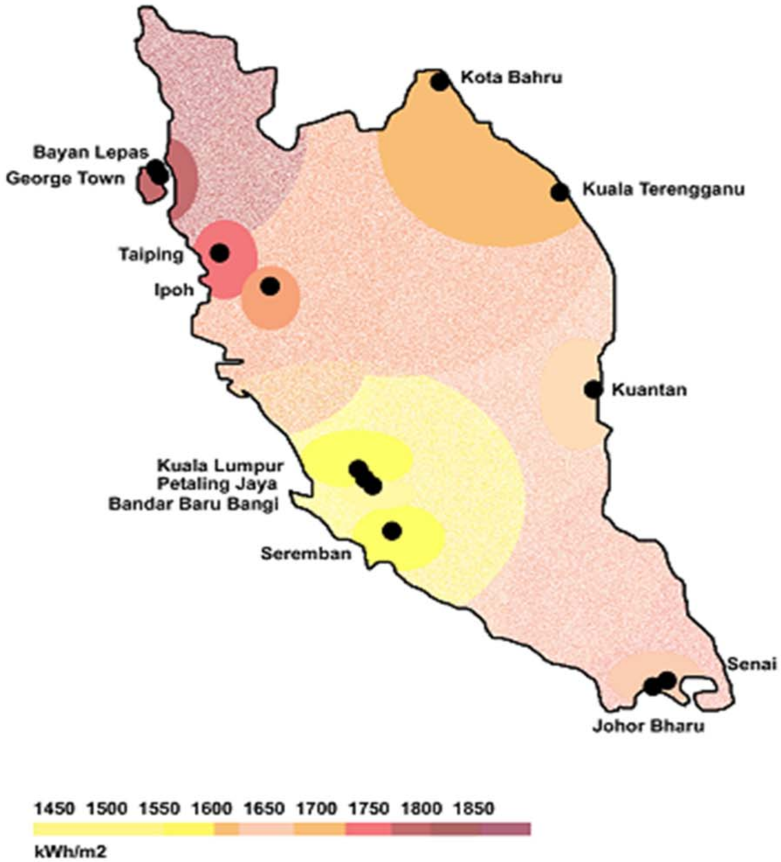
- Reliability
- Efficiency
- Cost
- Volume
- Protection
- Power electronics enabling technology
- Control active and reactive power
- Ride-through and monitoring



Solar PV System

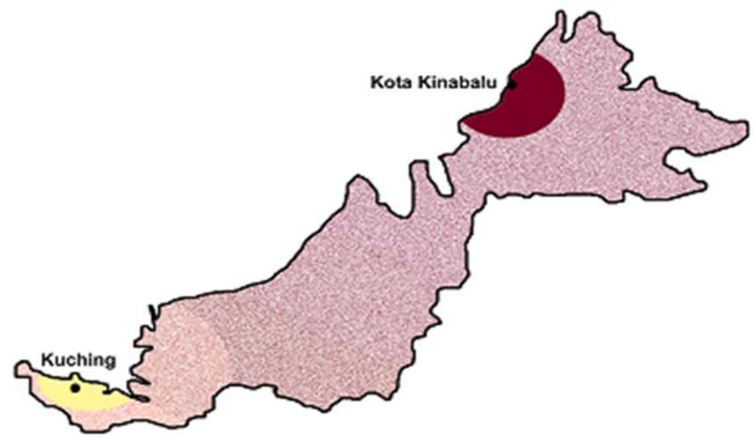
◆*Professor Ir. Dr. Nasrudin Abd Rahim*

Solar Irradiance in Malaysia



Irradiance (Yearly average value - global)

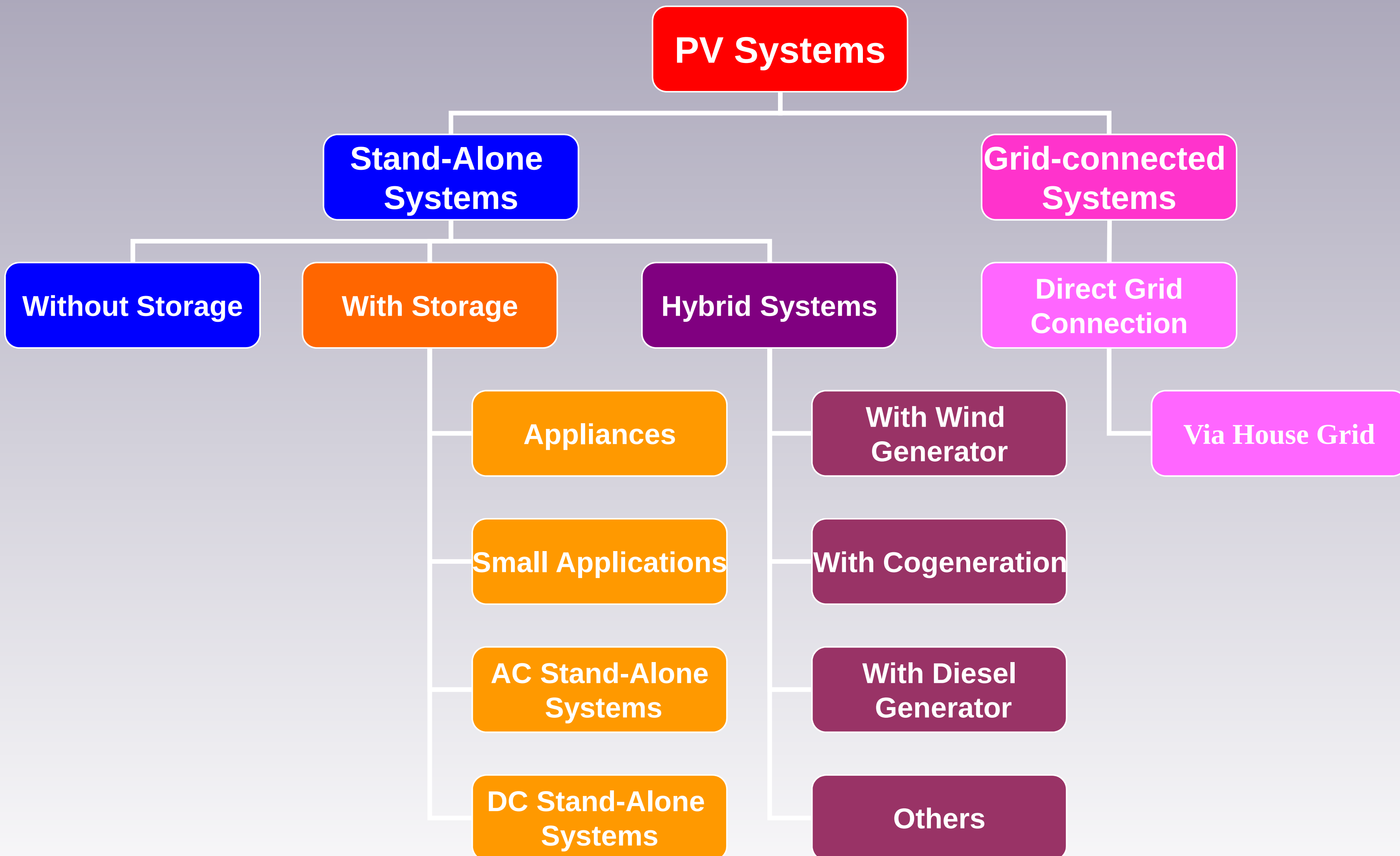
Kuching	1470 kWh/m2
Bandar Baru Bangi	1487 kWh/m2
Kuala Lumpur	1571 kWh/m2
Petaling Jaya	1571 kWh/m2
Seremban	1572 kWh/m2
Kuantan	1601 kWh/m2
Johor Bharu	1625 kWh/m2
Senai	1629 kWh/m2
Kota Bahru	1705 kWh/m2
Kuala Terengganu	1714 kWh/m2
Ipoh	1739 kWh/m2
Taiping	1768 kWh/m2
Georg Town	1785 kWh/m2
Bayan Lebas	1809 kWh/m2
Kota Kinabalu	1900kWh/m2



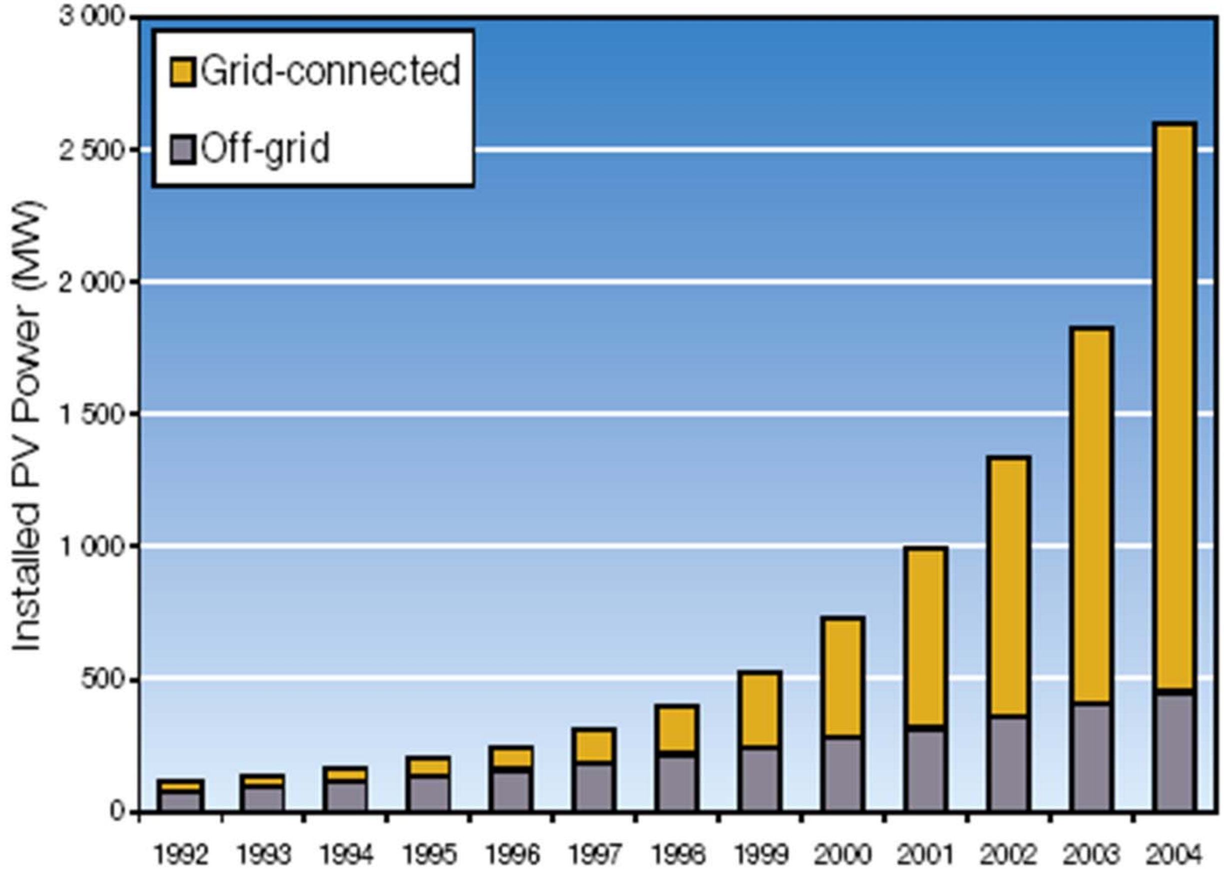
Grid Connected and Off Grid PV System

Professor Ir. Dr. Nasrudin Abd Rahim

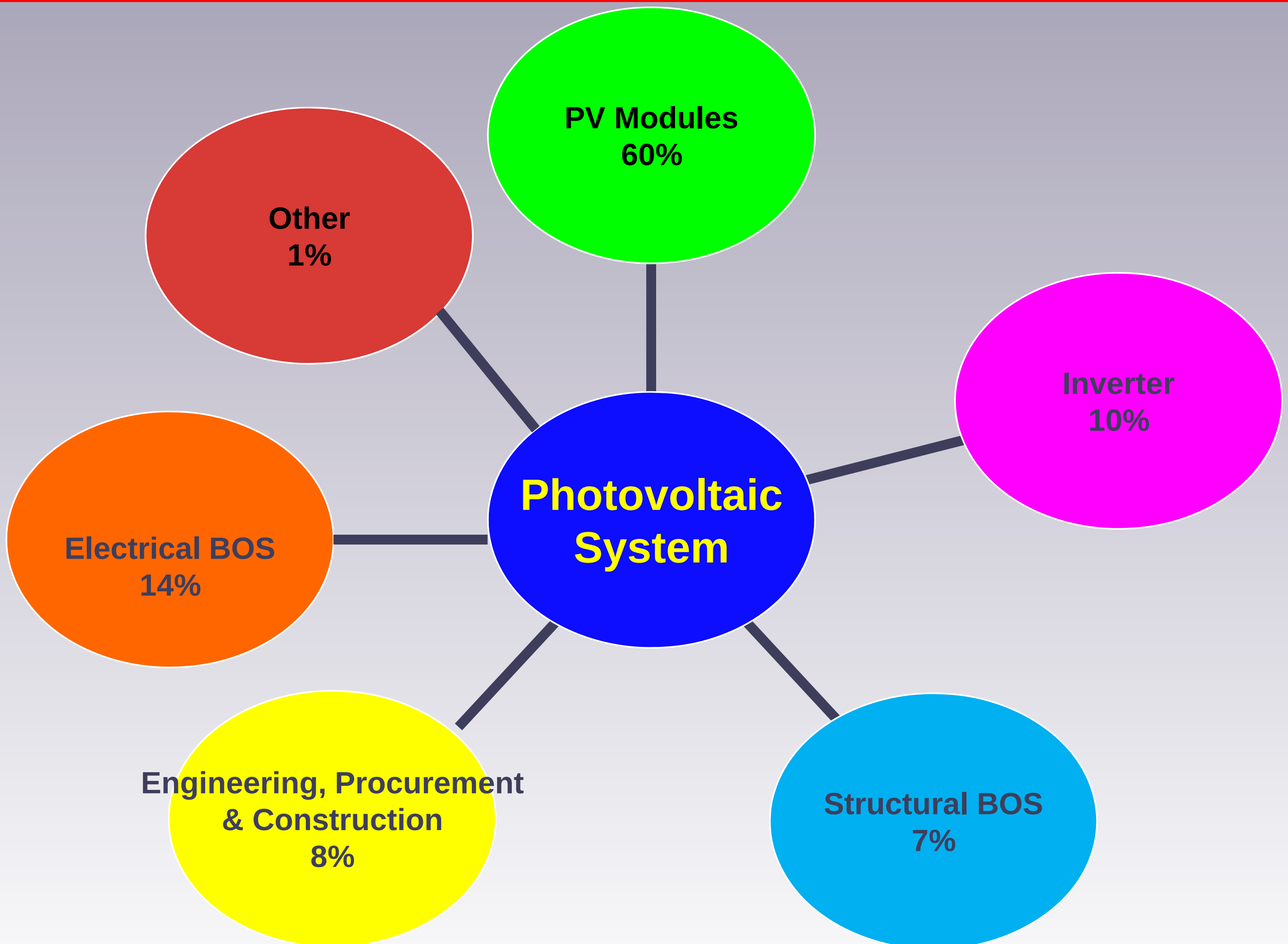
Solar PV Systems



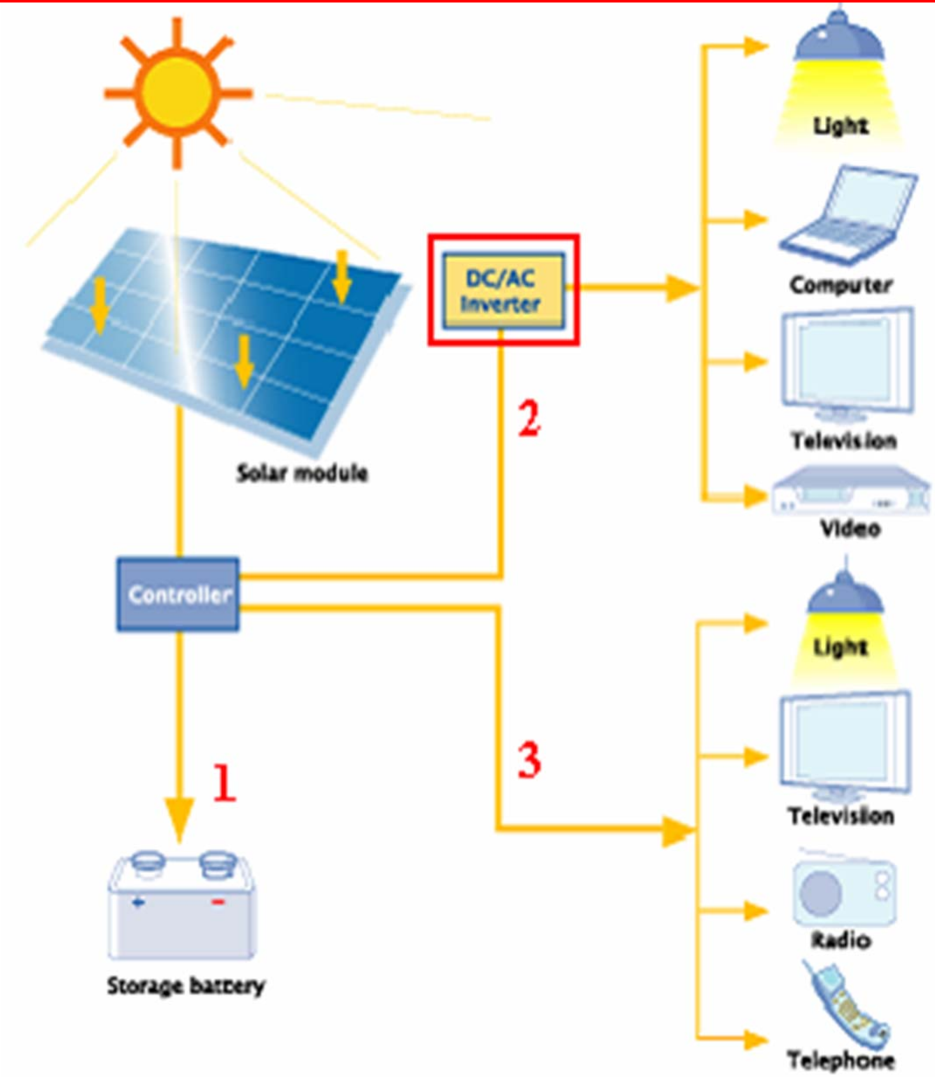
Cumulative grid-connected and off-grid PV power installed in countries reporting, under IEA PVPS program, 1992-2004



Cost PV Systems



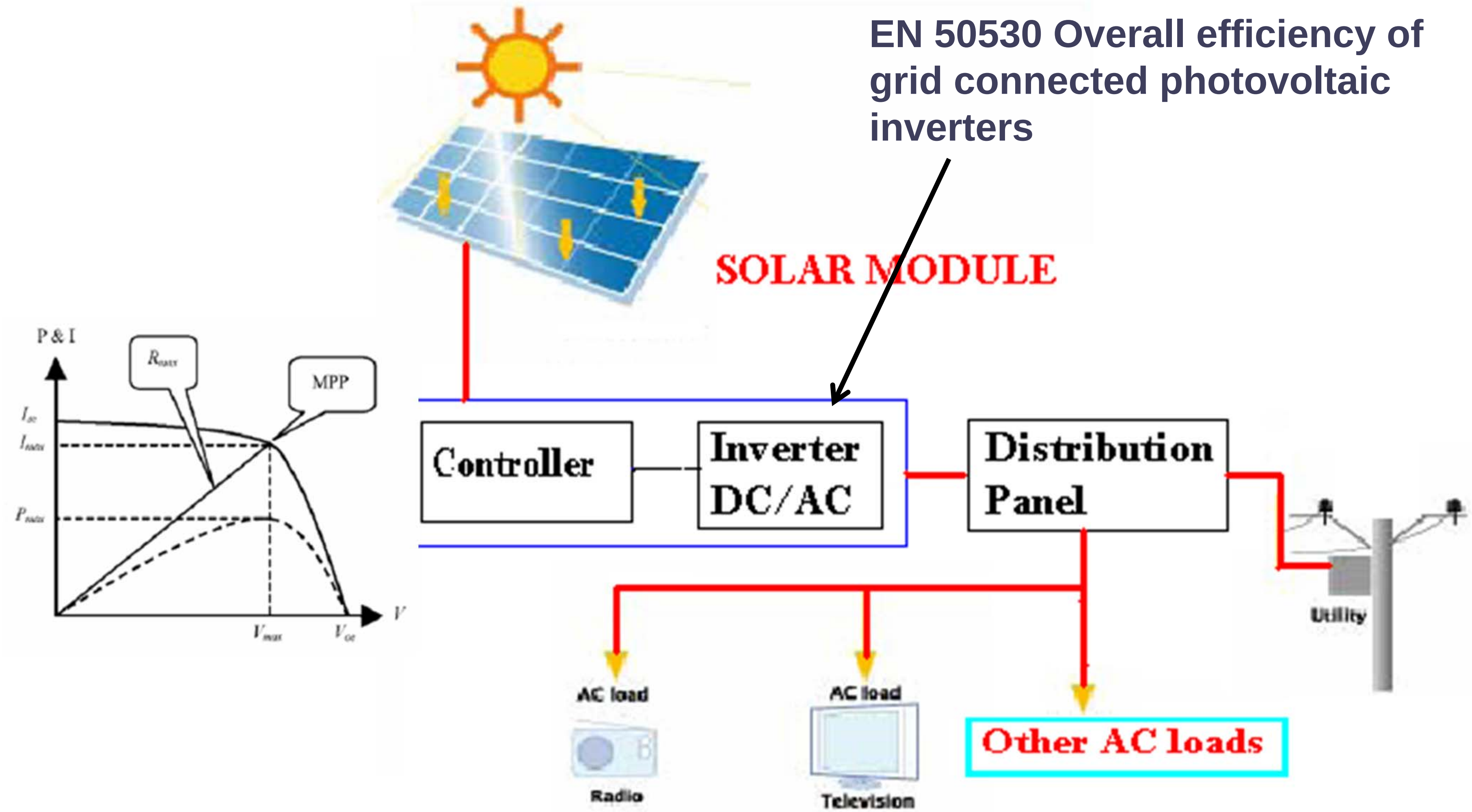
PV Stand Alone System



- Off-grid
- Suitable for isolated areas
  - Island
  - Eco-tourism
- Storage battery needed

Grid-Connected PV Inverter System

EN 50530 Overall efficiency of grid connected photovoltaic inverters



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PV Inverter

PV INVERTERS

Commercial PV inverter efficiency for state of the art brand products is **98% and higher** (98.8% reported).

Market share for **string inverters is estimated to be 42%** (mostly for residential, small and medium commercial applications).

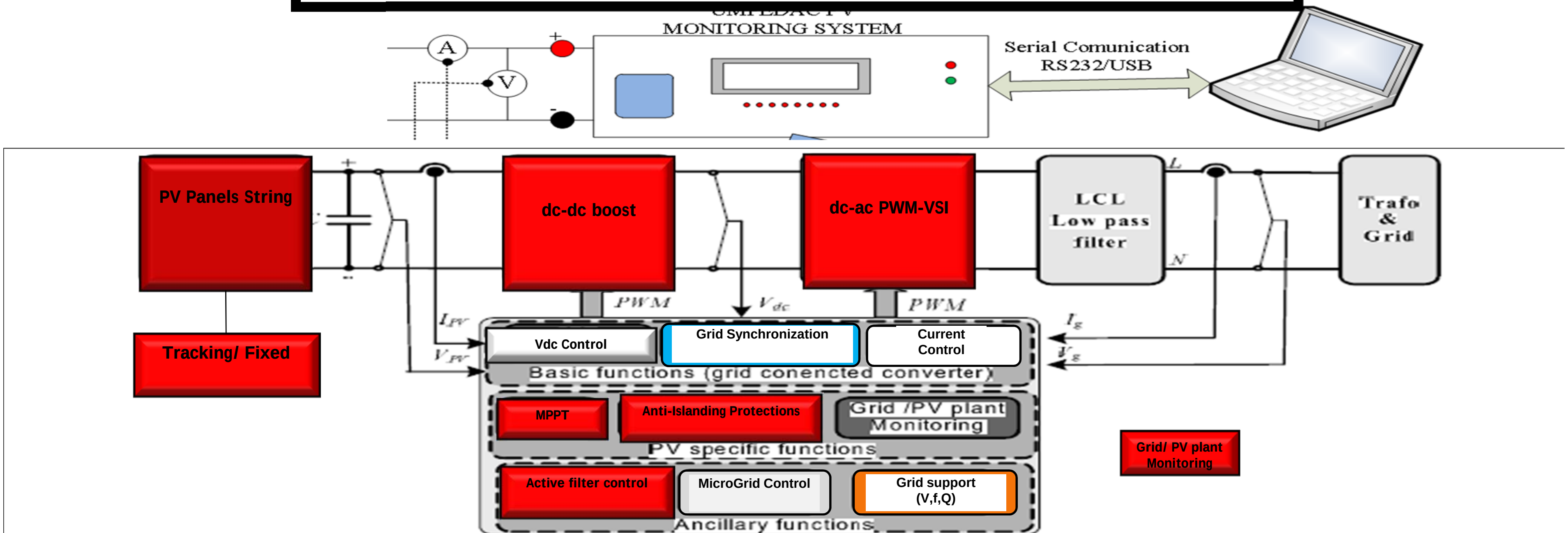
Central inverters ~ 54% (large commercial and utility-scale systems.

Micro-inverter is about ~1%. **2 GWp of DC-DC converters** – power optimizer (2016).

<u>New Trends of Inverters</u>

- New features for **grid stabilization and optimization of self consumption.**
- **Storage unit** included in the inverter.
- Utilization of **innovative semiconductors (Sic or GaN)** which allow very high efficiencies and compact design.

GRID-CONNECTED PV INVERTER SYSTEM



Basic functions – common for all grid-connected inverters

Grid current control
- THD limits imposed by standards
- Stability in case of grid impedance variations
- Ride-through grid voltage disturbances (not required yet!)

DC voltage control
- Adaptation to grid voltage variations
- Ride-through grid voltage disturbances (optional yet)

Grid synchronization
- Required for grid connection or re-connection after trip.

PV specific functions – common for PV inverters

Maximum Power Point Tracking – MPPT
- Very high MPPT efficiency in steady state (typical > 99%)
- Fast tracking during rapid irradiation changes (dynamical MPPT efficiency)
- Stable operation at very low irradiation levels

Anti-Islanding – AI as required by standards (VDE0126, IEEE1574, etc)

Grid Monitoring
- Operation at unity power factor as required by standards
- Fast Voltage/frequency detection

Ancillary Support – (future?)

Voltage Control
Frequency control
Fault Ride-through
Q compensation
DVR

Evolution of Inverter Features 1990-2000

1980s - bulky, heavy, difficult to install, unreliable, efficiency 85% - 90%; strictly, devices for converting DC to AC

1991 - the early 1990s saw the 1st large scale series production of PV inverters

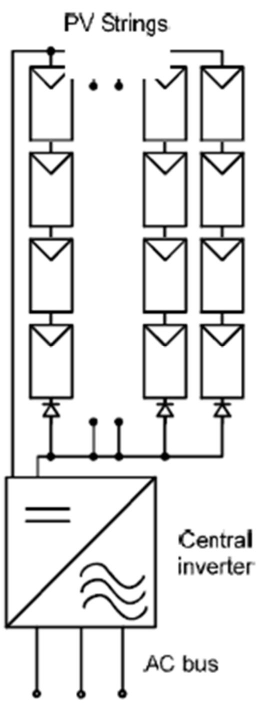
1995 1st string inverter; allows connection of modules in series, modular systems, higher systems efficiency and reliability

Late 1990s Basic data acquisition system, “plug and play” installation

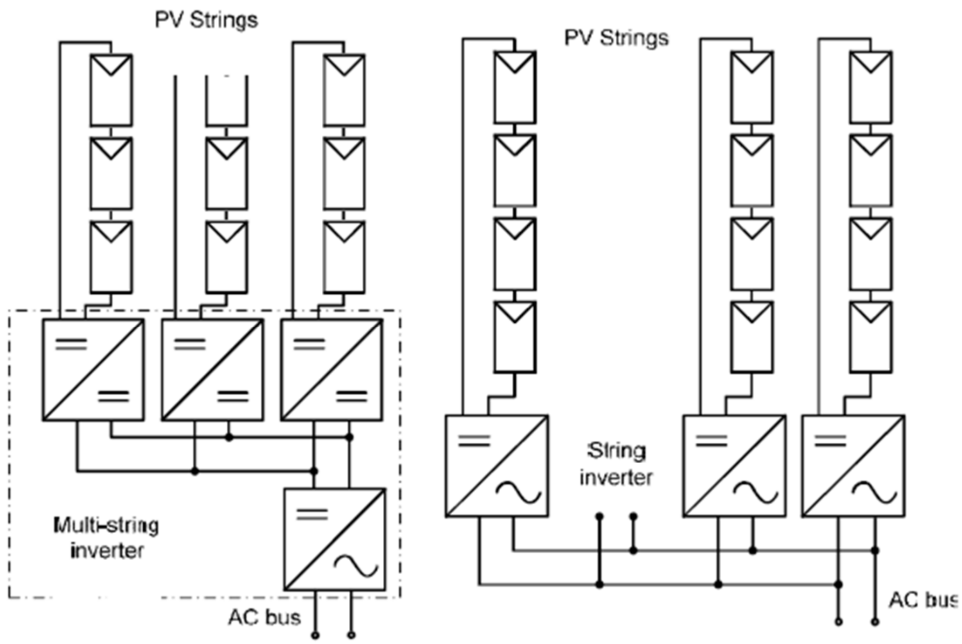
- Transformerless and high frequency designs reached η ≥ 95%;

Reliability improved, warranties 2 to 5 years.

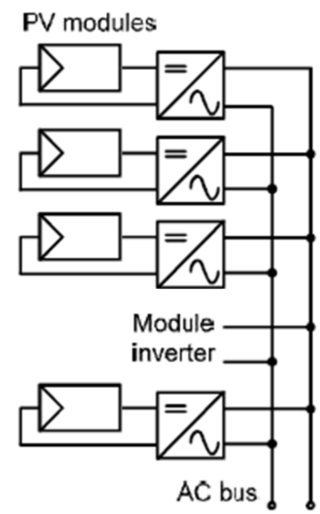
PV Systems configuration



Central Inverters



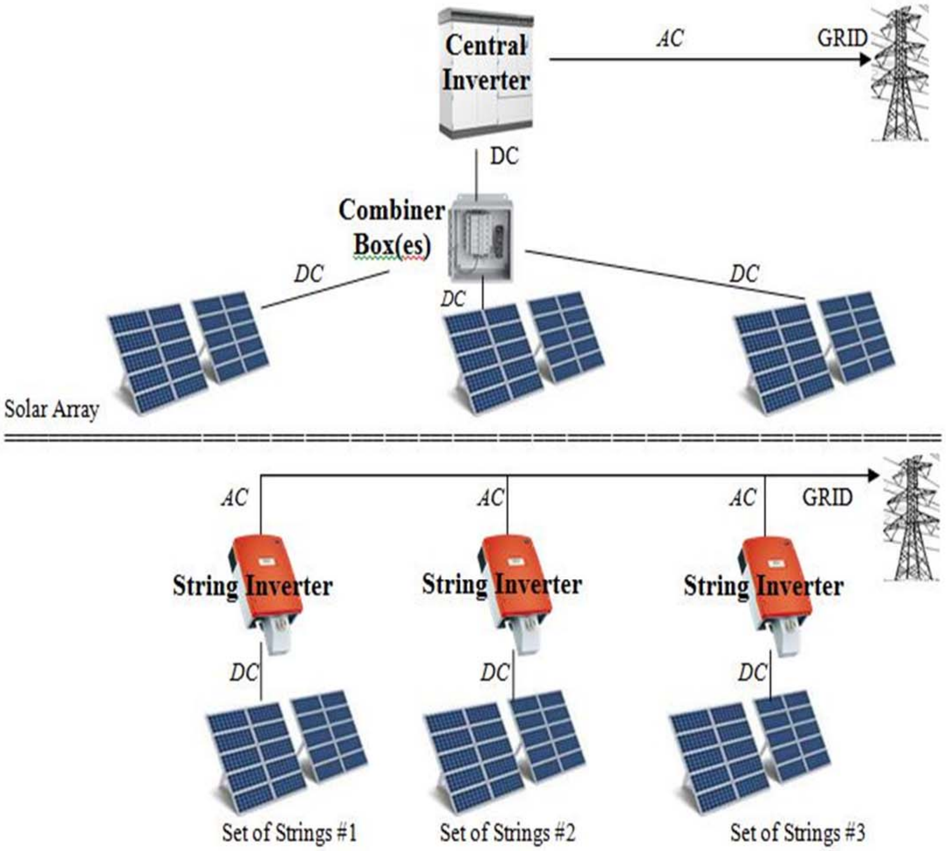
String (Multi) Inverters



Module Inverters

PV Central & String Inverters

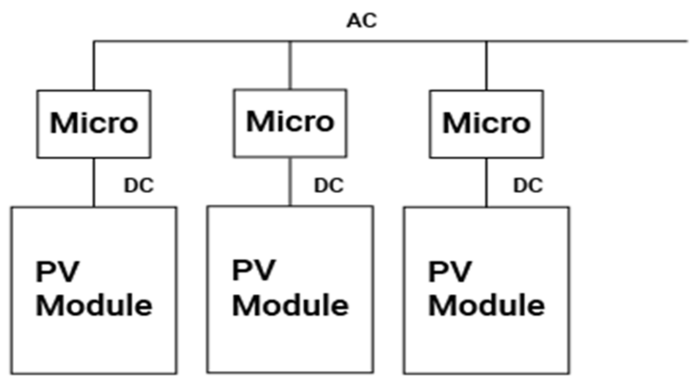
http://www.pennenergy.com



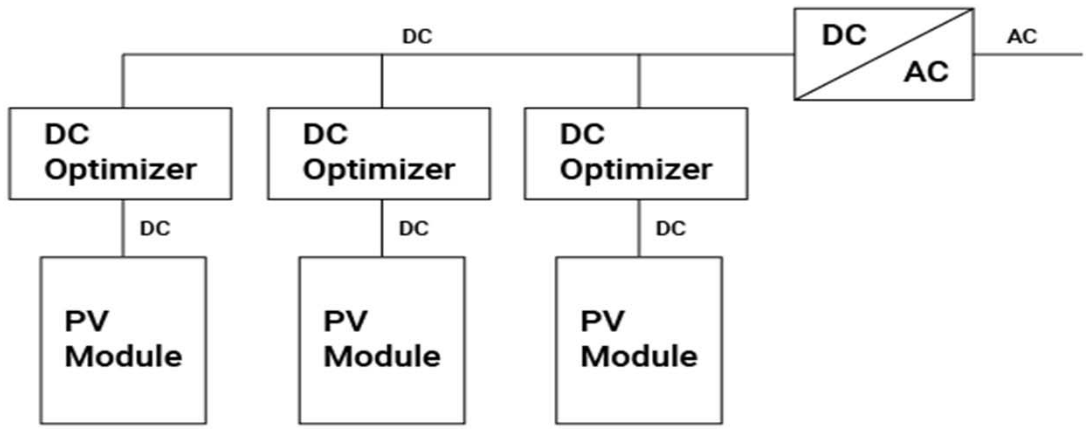
http://cenergypower.com

Micro inverter Vs DC Optimizer

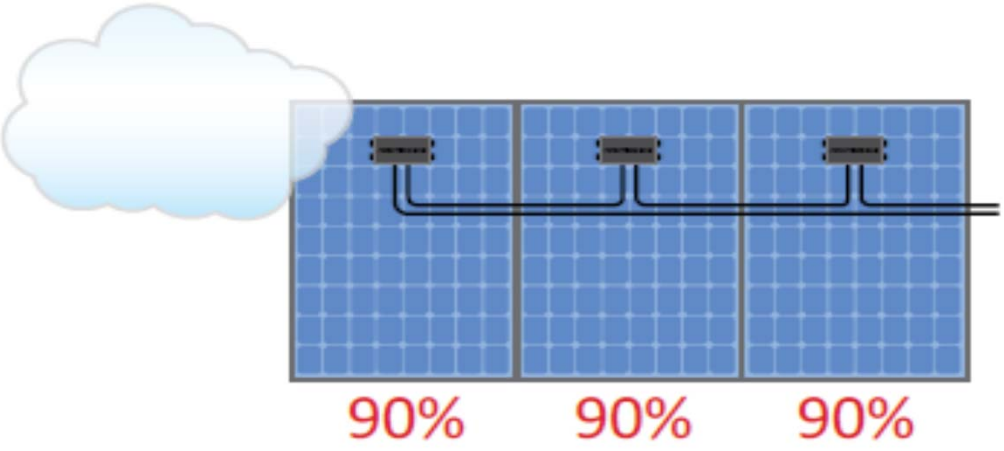
Micro Inverter System



DC Optimizer System

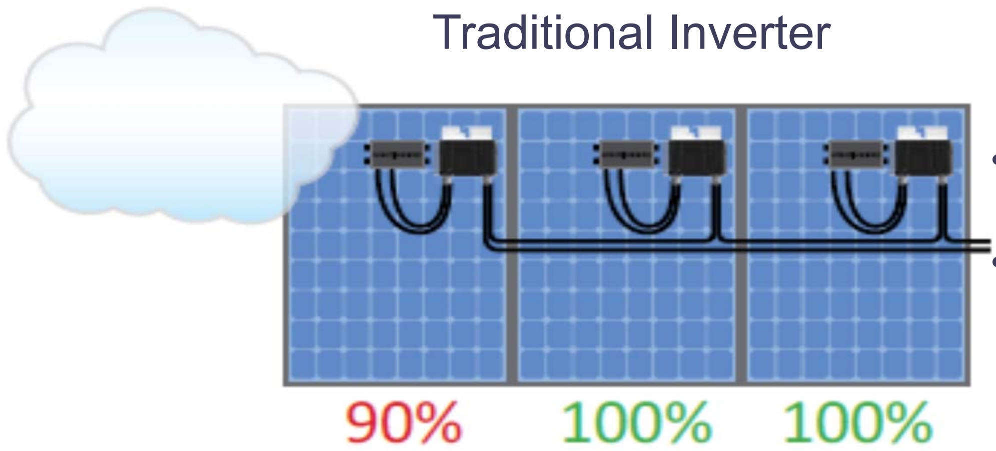


Tradional Inverter Vs DC optimizer



Traditional Inverter

- Weak modules reduce the performance of all modules in the string/bypass.
- Power losses due to module mismatch.



DC Optimizer

- Maximum power produced and tracked from each module individually.
- 2%-10% more energy from the PV system.

Source: SolarEdge Technologies, Inc.

PV Inverters

Central ("String") Inverters

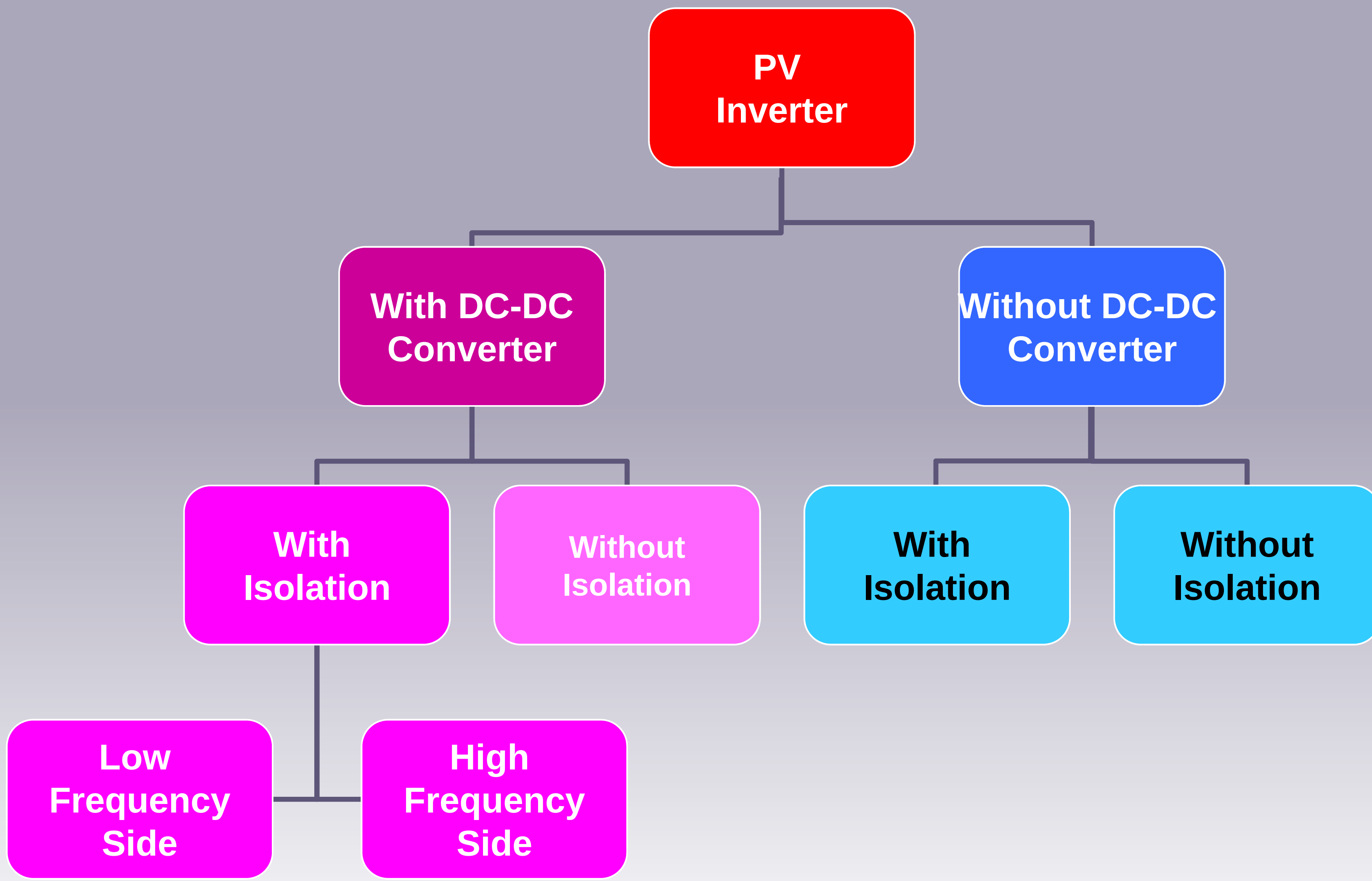
Typical Cost: $0.18-$0.25/W
10-15 year warranty Modules are connected in a series
The entire array is jeopardized by one module
9% shading can result in 54% array performance loss

Micro Inverters

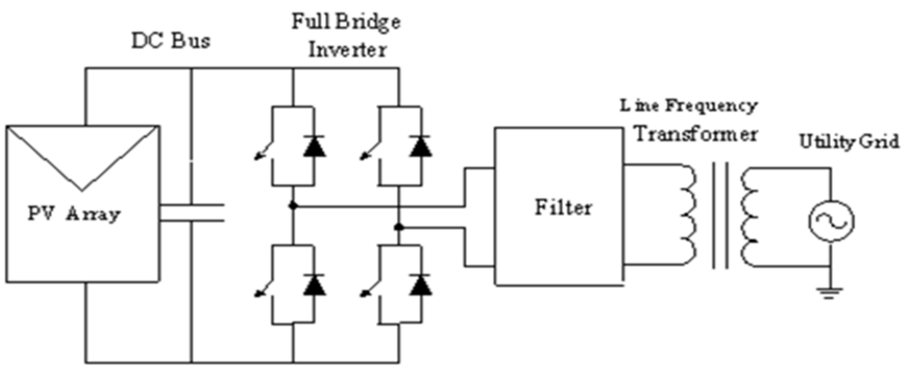
Located on each module
Typical Cost: $0.35-$0.45/W
20-25 year warranty
Easily pinpoint issues (independently controlled modules)

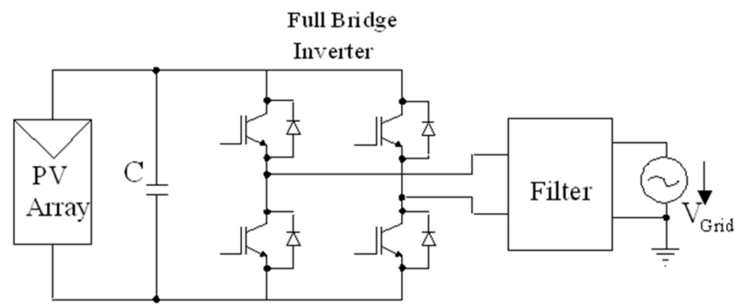
Source: www.renewablegreenenergypower.com

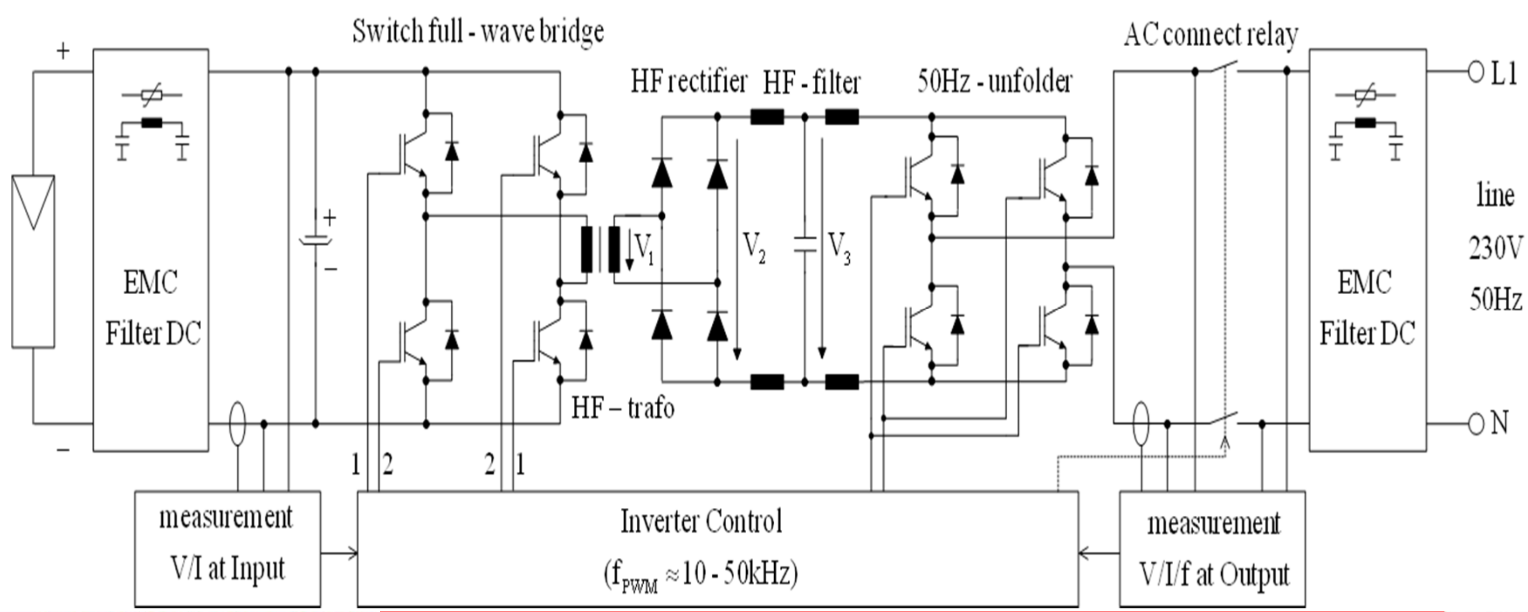
Power Configurations of PV Inverters



PV grid Connected Inverter







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High-Efficiency DC-to-DC Converter with Low Input Current Ripple for Maximum Photovoltaic Power Extraction

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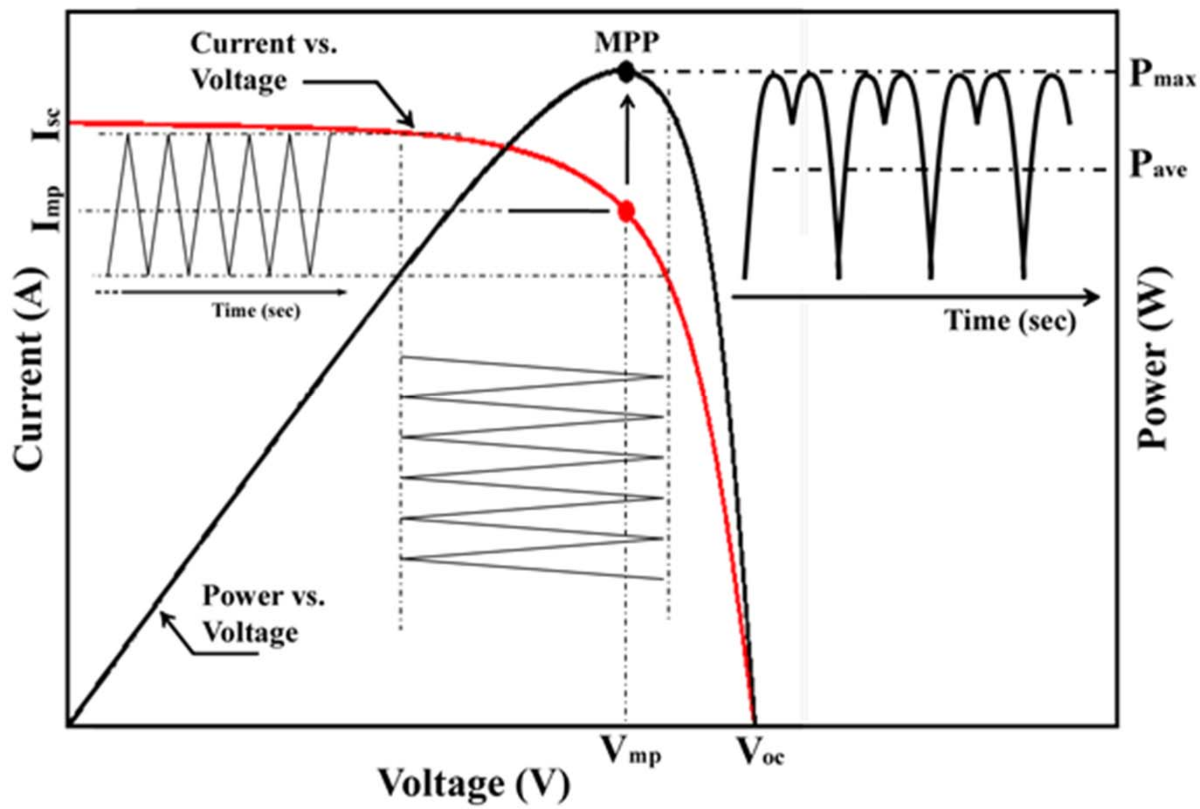
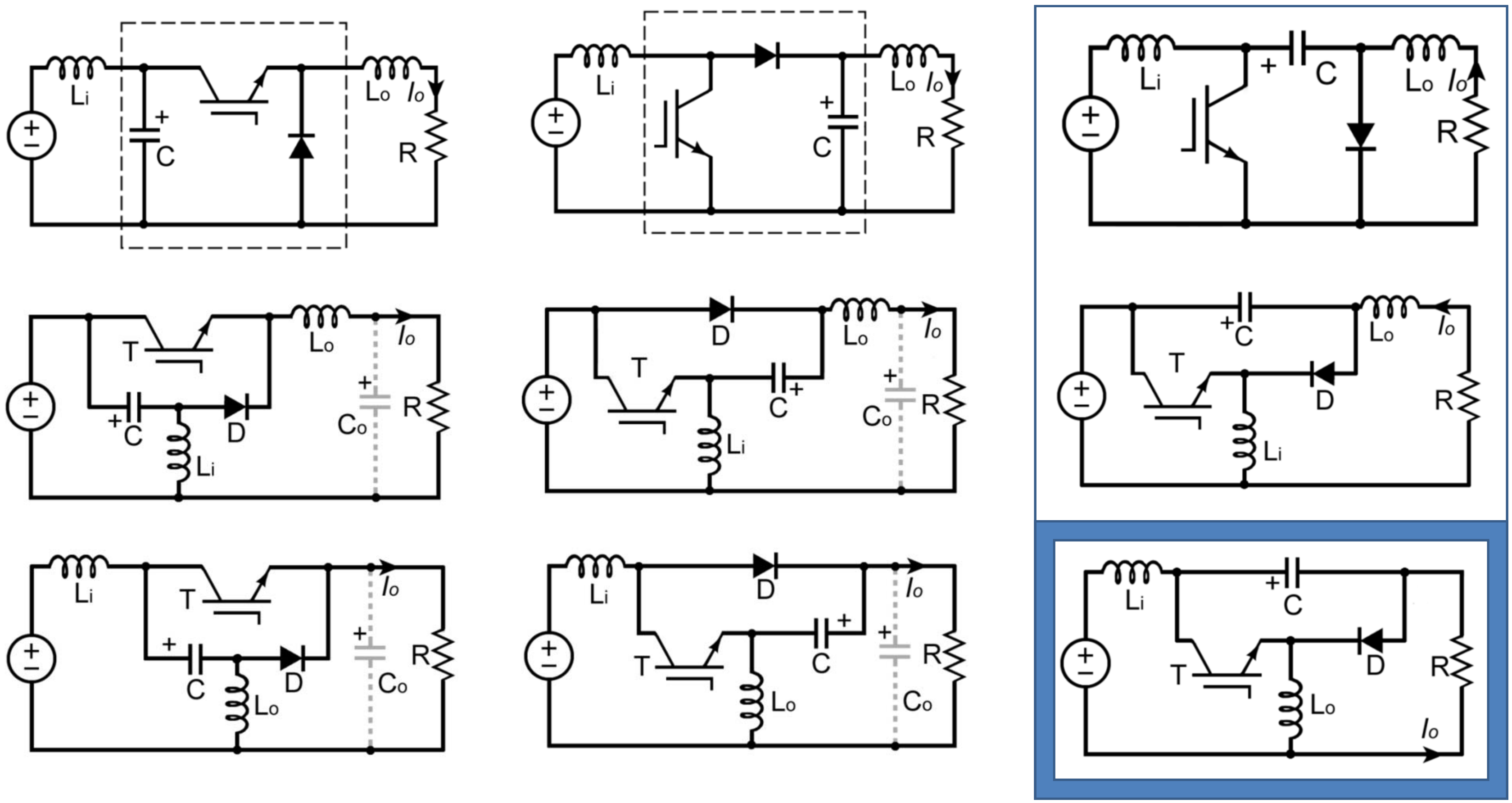
EFFECT OF INPUT RIPPLE CURRENT ON THE PV POWER



Current with *5%* ripple of I_{mppt} would result in *2.7%* power drop.
Current with *8%* ripple of I_{mppt} would result in 6.83% power drop.

DC-TO-DC SWITCHING CONVERTERS

Step-down | Step-Up | Step-Up/Down

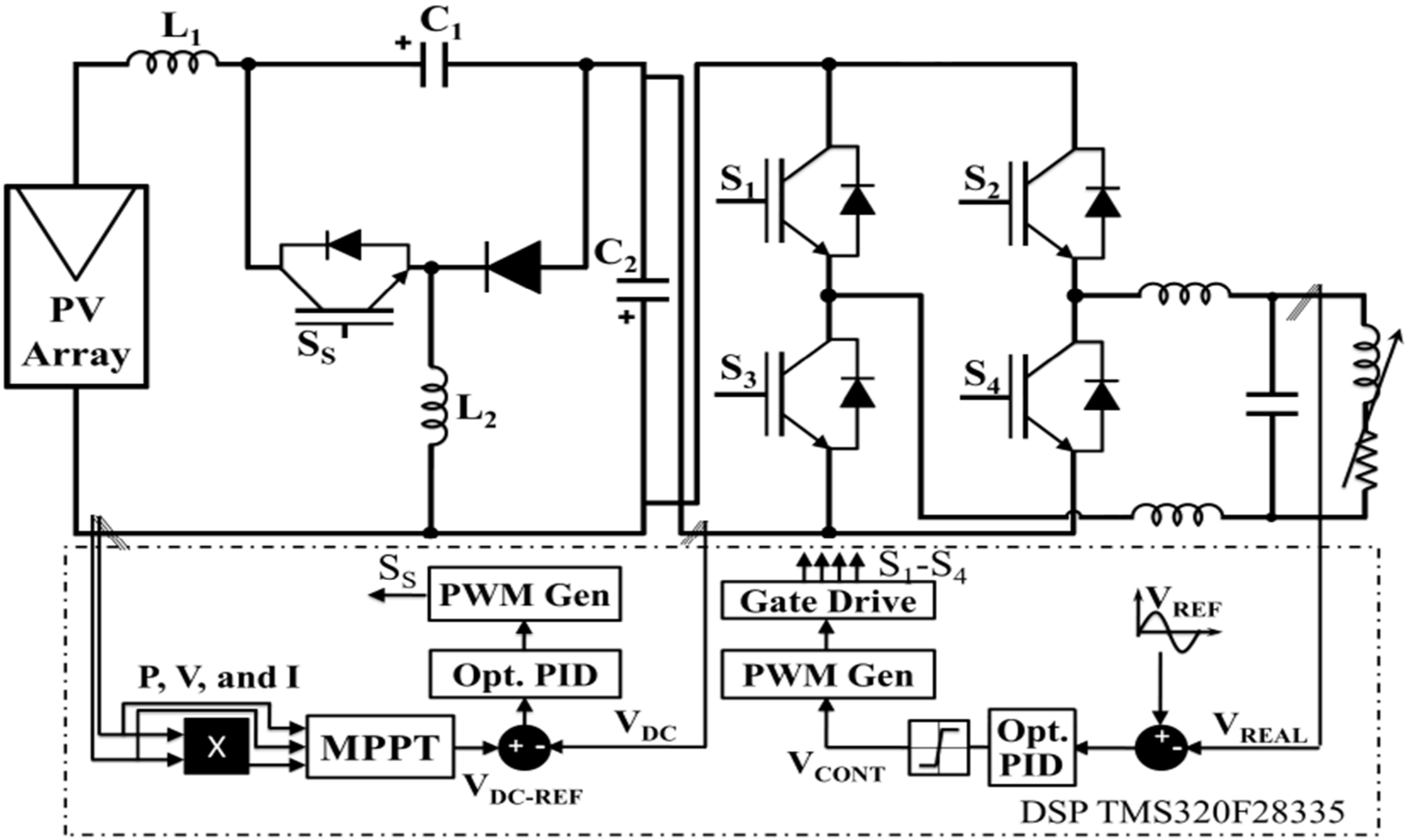


Cuk

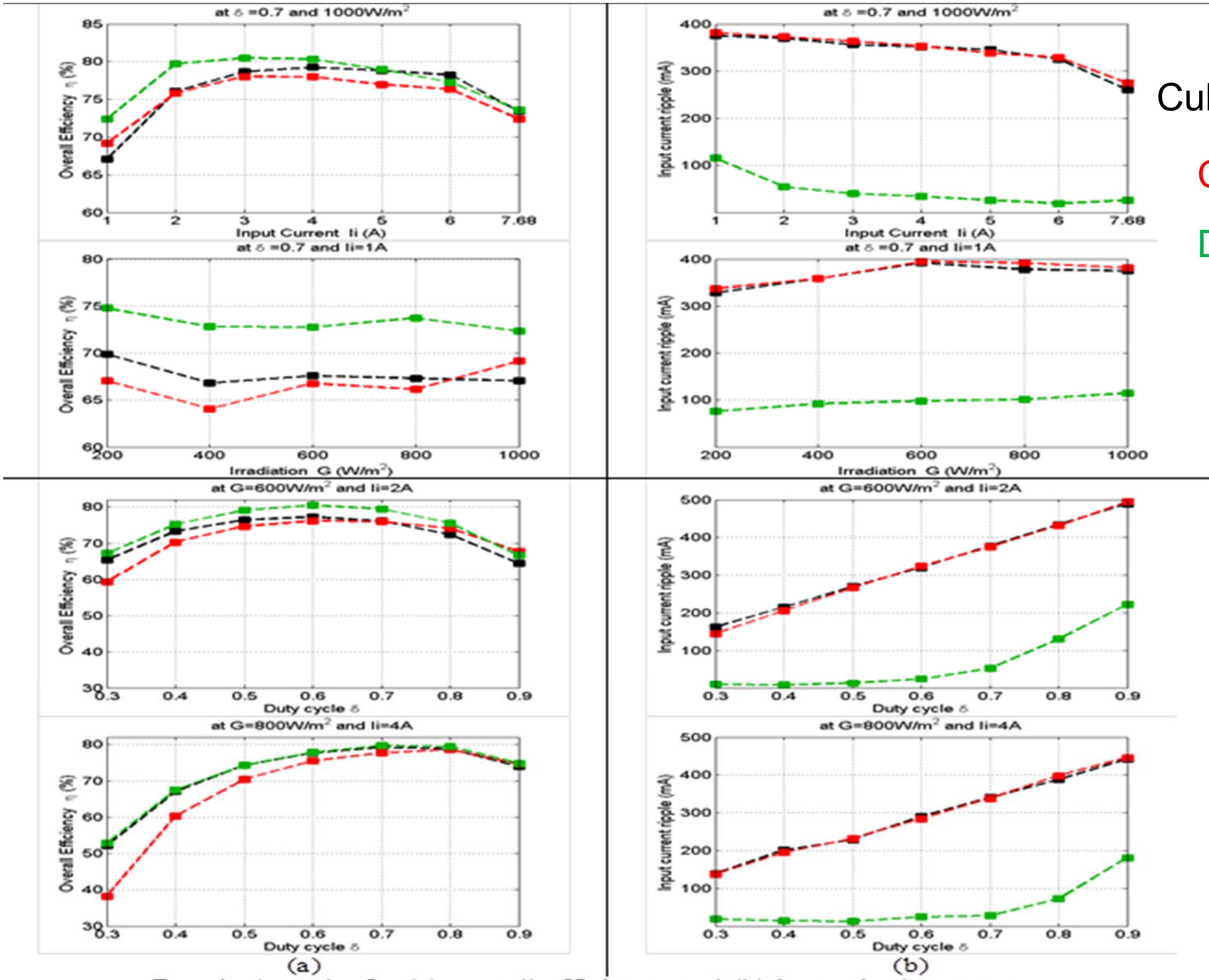
C

D

DC-TO-DC D type With Inverter



EFFICIENCY & RIPPLE CURRENT VS INPUT CURRENT, IRRADIATION, AND DUTY CYCLE



Practical results for (a) overall efficiency and (b) input ripple current.

Cuk

C

D

/

Single Phase PV Inverter System with Isolating Transformer

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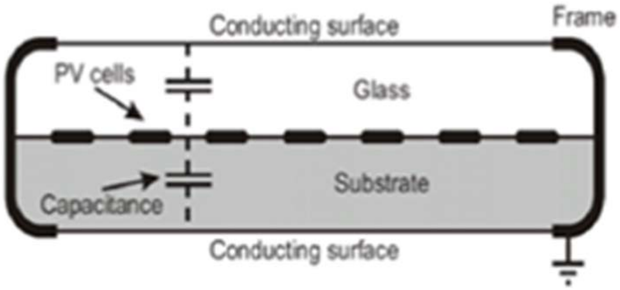
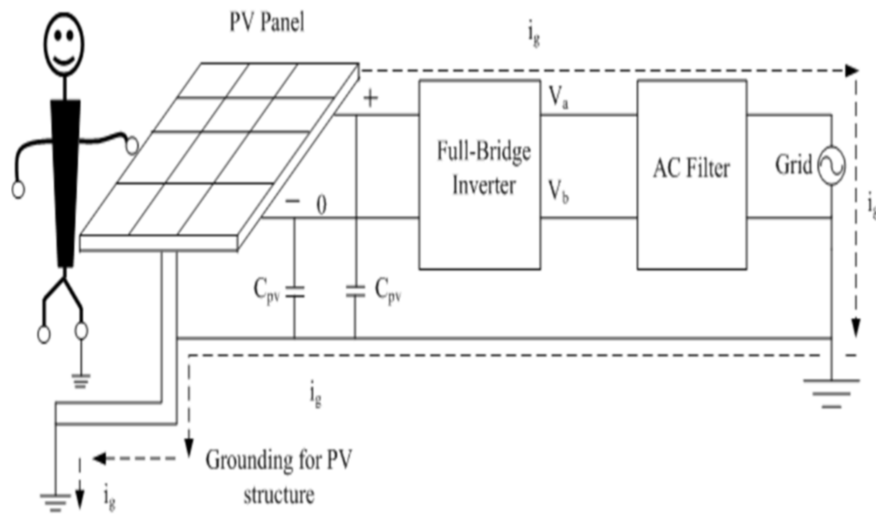
Common Mode Current & Parasitic Capacitance



- High efficiency (>95%)
- Leakage current problem
- Safety issue



Crystalline-silicon cells 50 – 150 nF/kWp
Thin-film cells up to 1uF/kWp (Increase under Conditions e.g humidity, dust or installation mode)

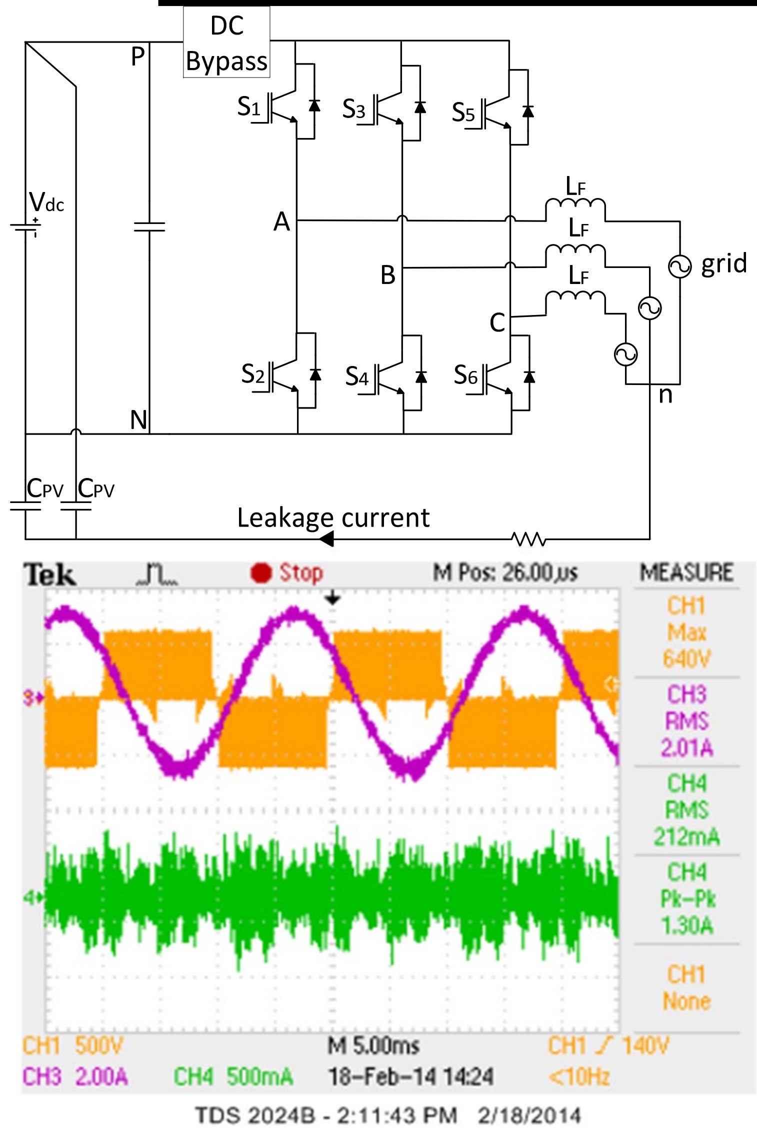
Problems: i) Common mode voltage
ii) Leakage current

•German standard, VDE0126-1-1, the amplitude of ground leakage current must be less than 300mA r.m.s to avoid electrical hazard when the PV array is touched .

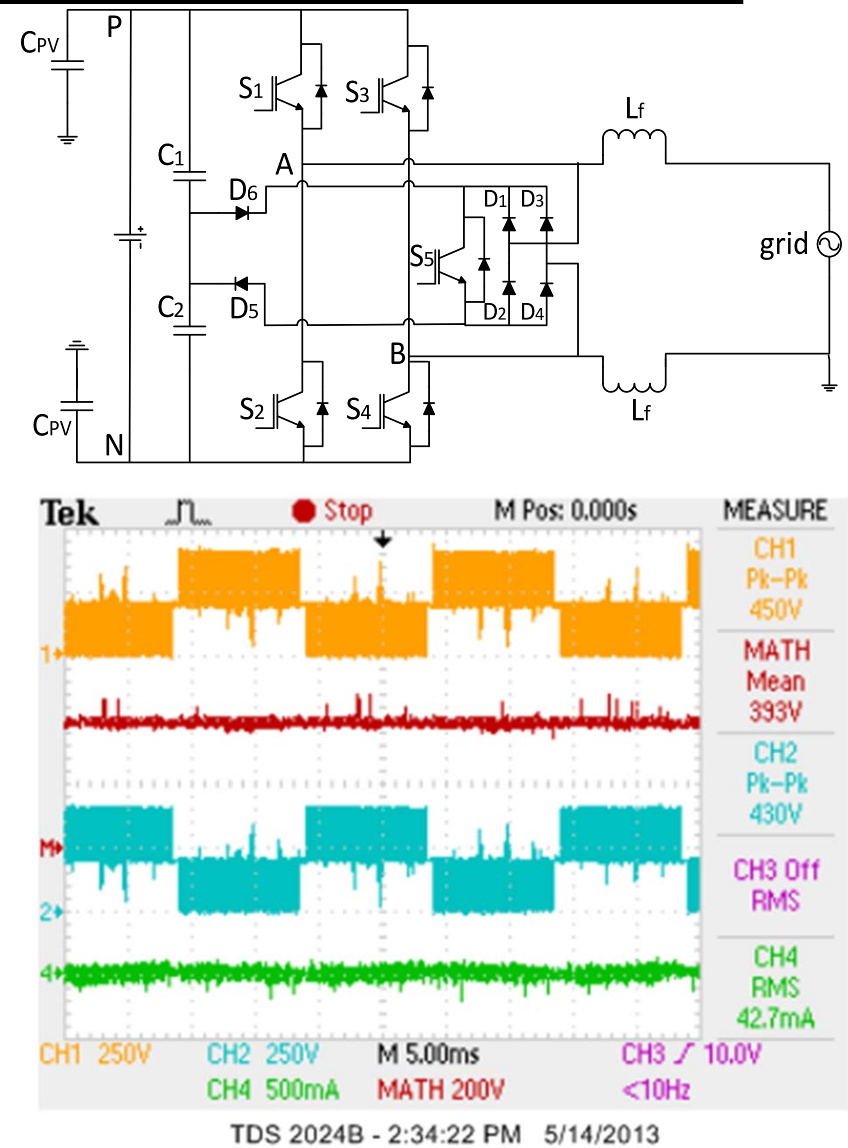
(Va0 +Vbo)/2 – common mode voltage

In motor application, the common-mode voltage results in
i) causing fault activation of current detection circuits and desired electromagnetic interference (EMI).
ii) damage to motor bearings

MDPWM & HBZVR-D

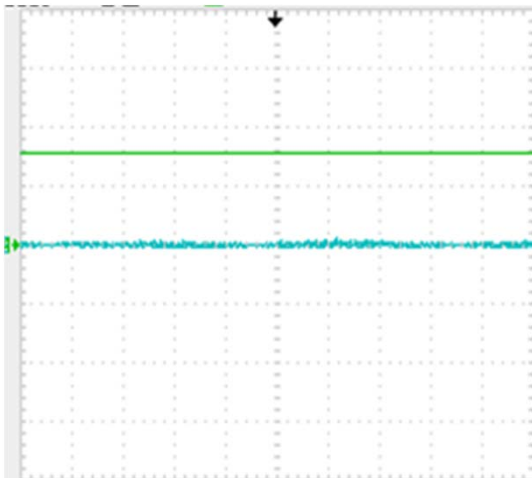


Proposed Three Phase Modified Discontinuous PWM



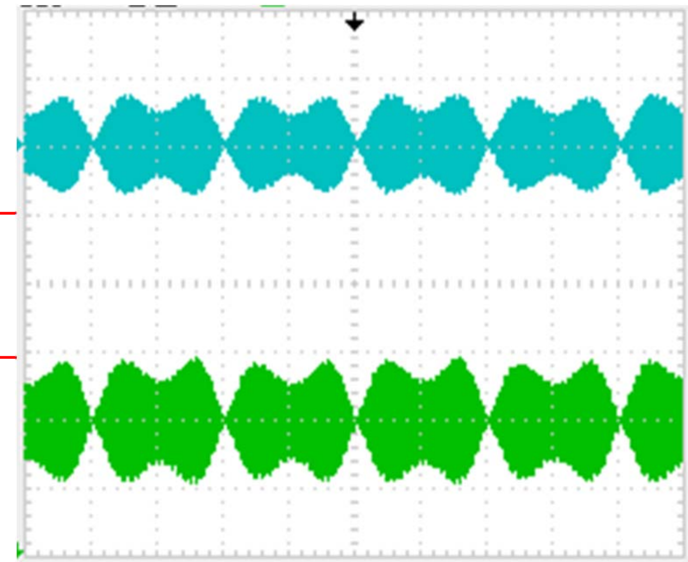
H-bridge zero-voltage state rectifier with diode (HBZVR-D)

Common Mode Voltage & Ground Leakage Current



Common Mode Voltage

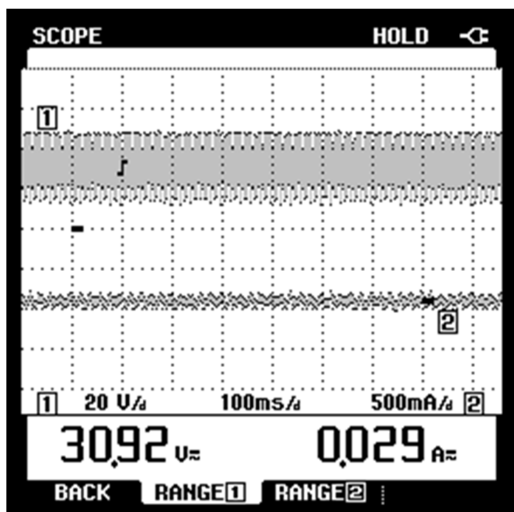
Ground Leakage Current



Bipolar Switching H-Bridge Inverter

Unipolar Switching H-Bridge Inverter

Unipolar Switching HB-ZVR Inverter



Common Mode Voltage

Ground Leakage Current

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Maximum Power Point Tracking

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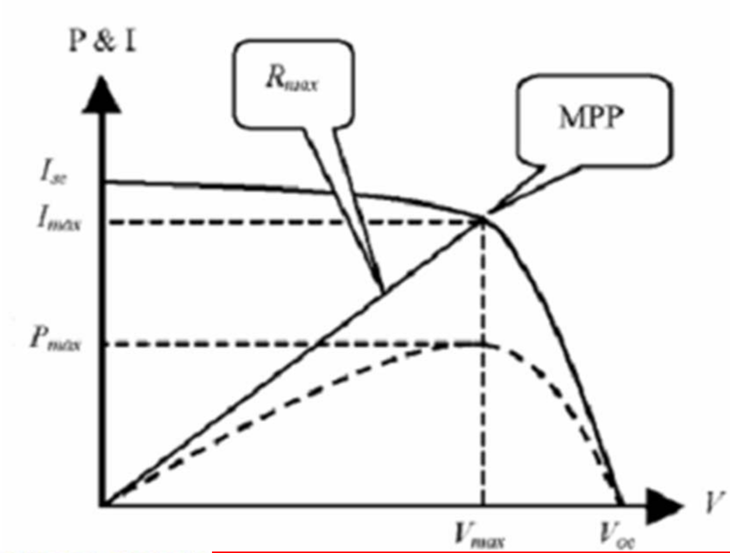
Maximum Power Point Tracking

The DC power input to an inverter depends on which point in the current voltage (I-V) curve of the PV array it is working at. Ideally, the inverter should operate at the maximum power point (MPP) of the PV array.

The MPP is variable throughout the day, mainly as a function of environmental conditions such as irradiance and temperature, but the inverter directly connected to the PV arrays has an MPP tracking that can be defined as a method to extract maximum power from the PV arrays.



Three methods commonly used:-

1) Constant Voltage
2) Perturbation & Observation
3) Incremental Conductance

Perturbation and Observation Method

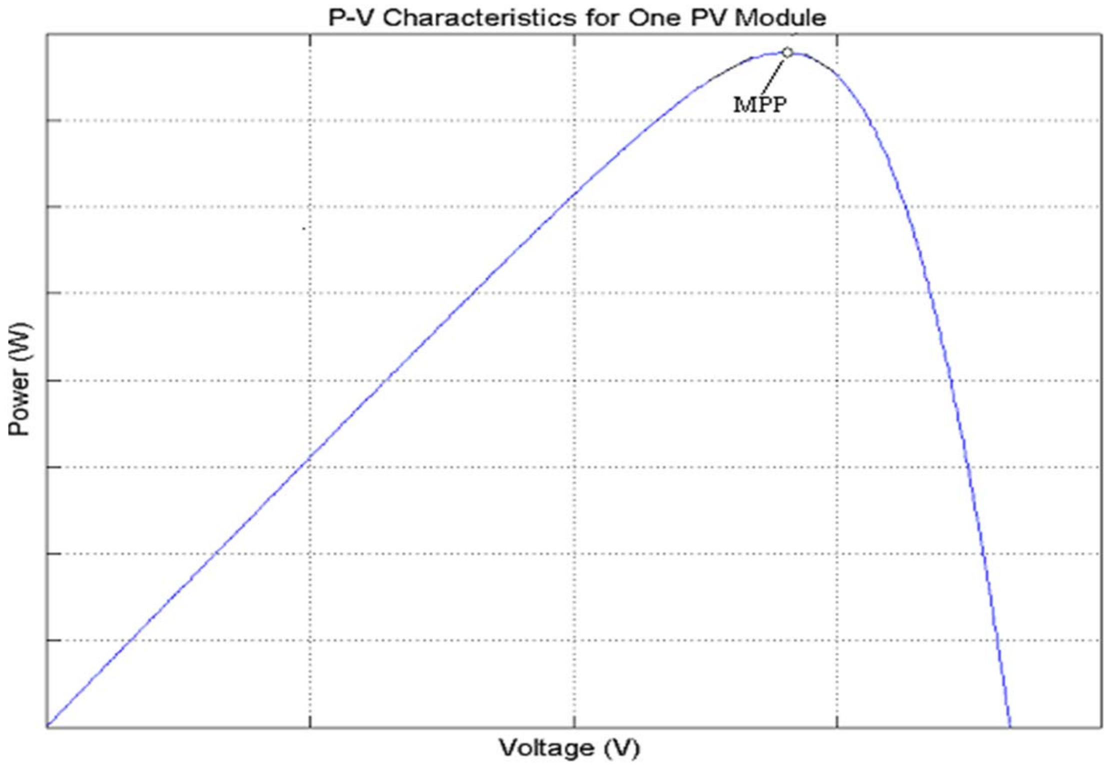
Hill climbing MPPT method

Current, and voltage, measured

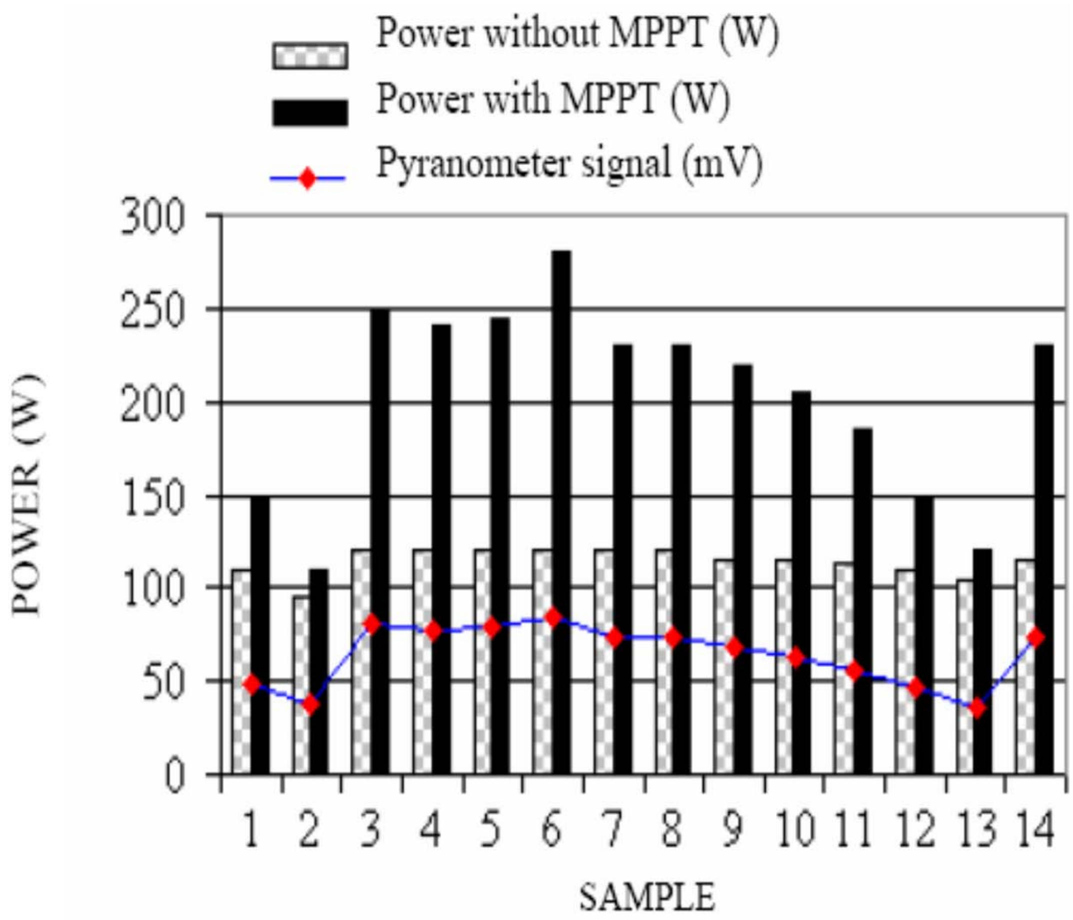
Power calculated & compared to the previous perturbation cycle, and changes made to the duty cycle

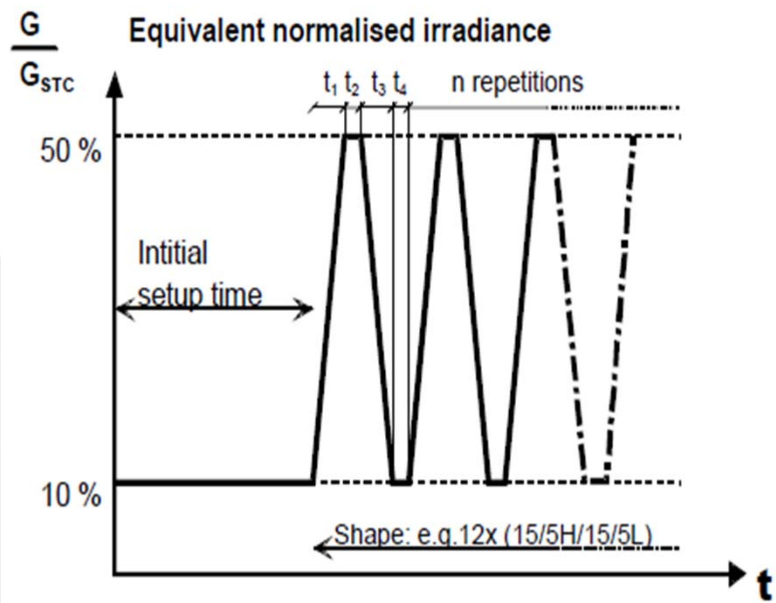
ΔP > 0, duty cycle increased

ΔP < 0, duty cycle decreased



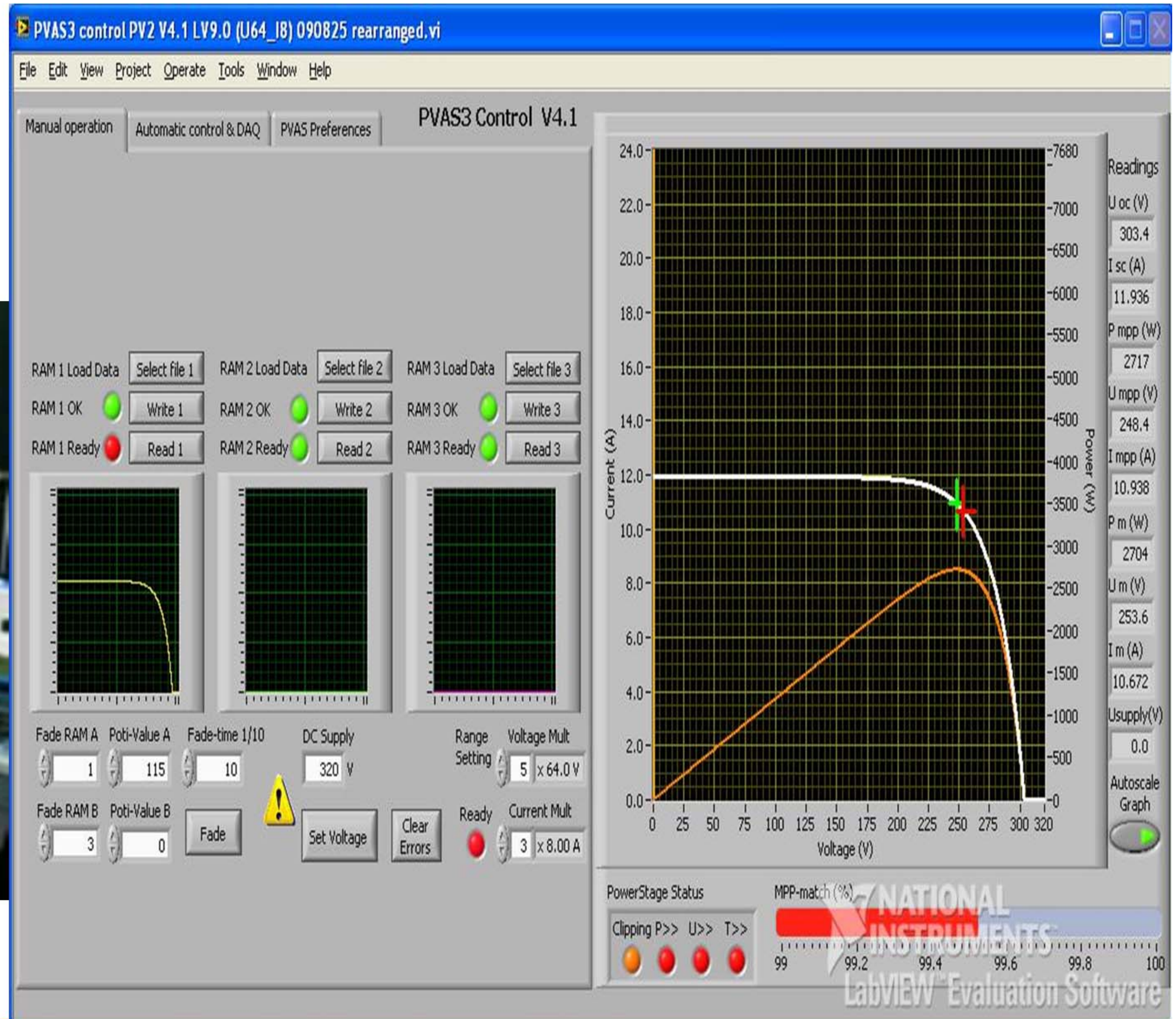
With & Without Maximum Power Point Tracking





EN 50530 Overall efficiency of grid connected photovoltaic inverters

Maximum Power Point Tracking



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ISSUES:TO HARVEST MAXIMUM POWER

By using P&O in the situation, more probably **local maximum point** is
tracked. Then, maximum power cannot be harvested from the panels.

Solutions of the issues

•**Machine learning method**, the method uses machine learning technique to determine the global MPP in a period of time.

Disadvantages: **learning method requires powerful computing units.**

•MPPT distributions, the method is to **decentralize the MPPT function to a local tracker which is attached on each panel.**

Disadvantages: MPPT distribution ... **e hardware component-co** ... **n efficiency.**

Anti-Islanding System

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Non Islanding Requirements

1. Utilities, along with the PV distributed resource owner, can be found liable for electrical damage to customer equipment connected to their lines, resulting from voltage or frequency excursions to beyond the acceptable ranges.

2. Islanding may create a hazard for utility line-workers or the public by causing a line assumed to be disconnected from all energy sources to remain energized.

3. Re-closing into an island may result in re-tripping the line or in damaging the distributed resource equipment or other connected equipment, owing to out-of-phase closure.

4. Islanding may interfere with the manual, or the automatic, restoration, of normal service by the utility.

Test 7: Anti Islanding

Table: International and Malaysian Standard of Disconnection and Reconnection time

Standard	IEC 61727	Malaysia
Disconnection time	≤0.1s	≤0.6s
Reconnection time	≥5 min	≥2 min

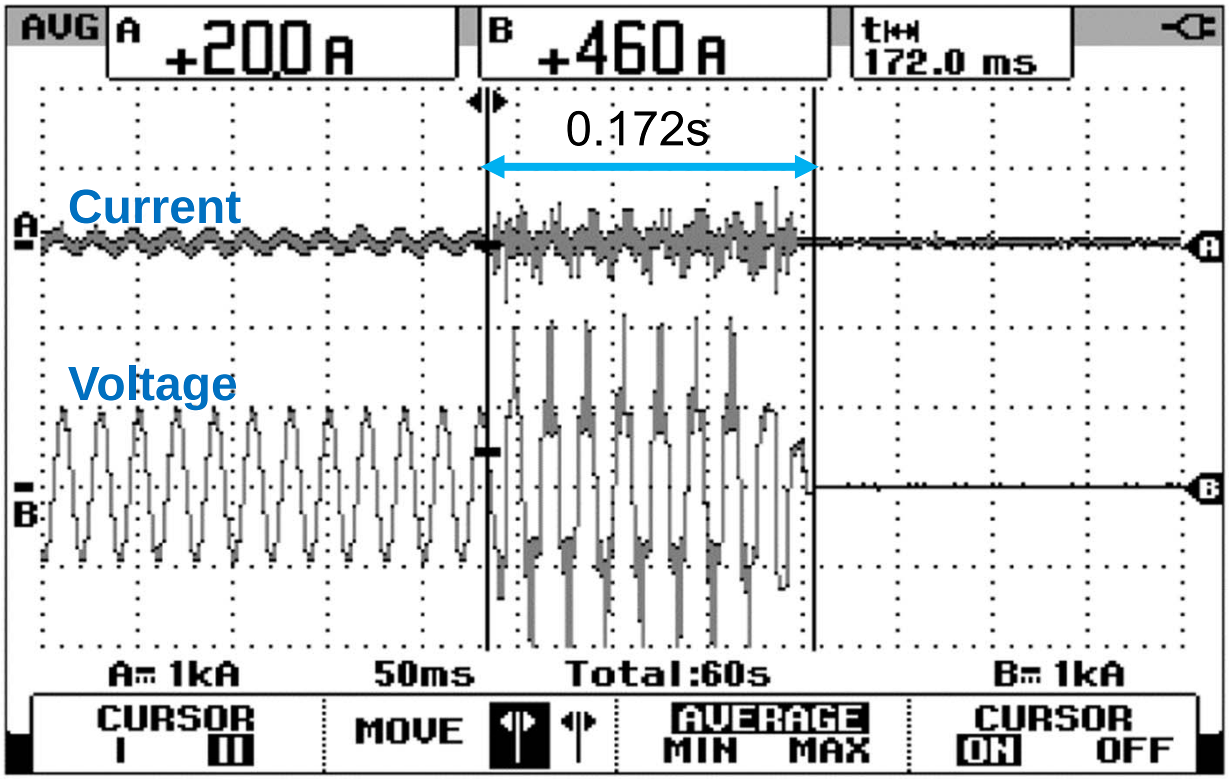
(a) Low Power Inverter ≤10kW

Standard	IEC 61727	Malaysia
Disconnection time	≤0.1s	≤0.6s
Reconnection time	≥5 min	≥5 min

(b) High Power Inverter >10kW

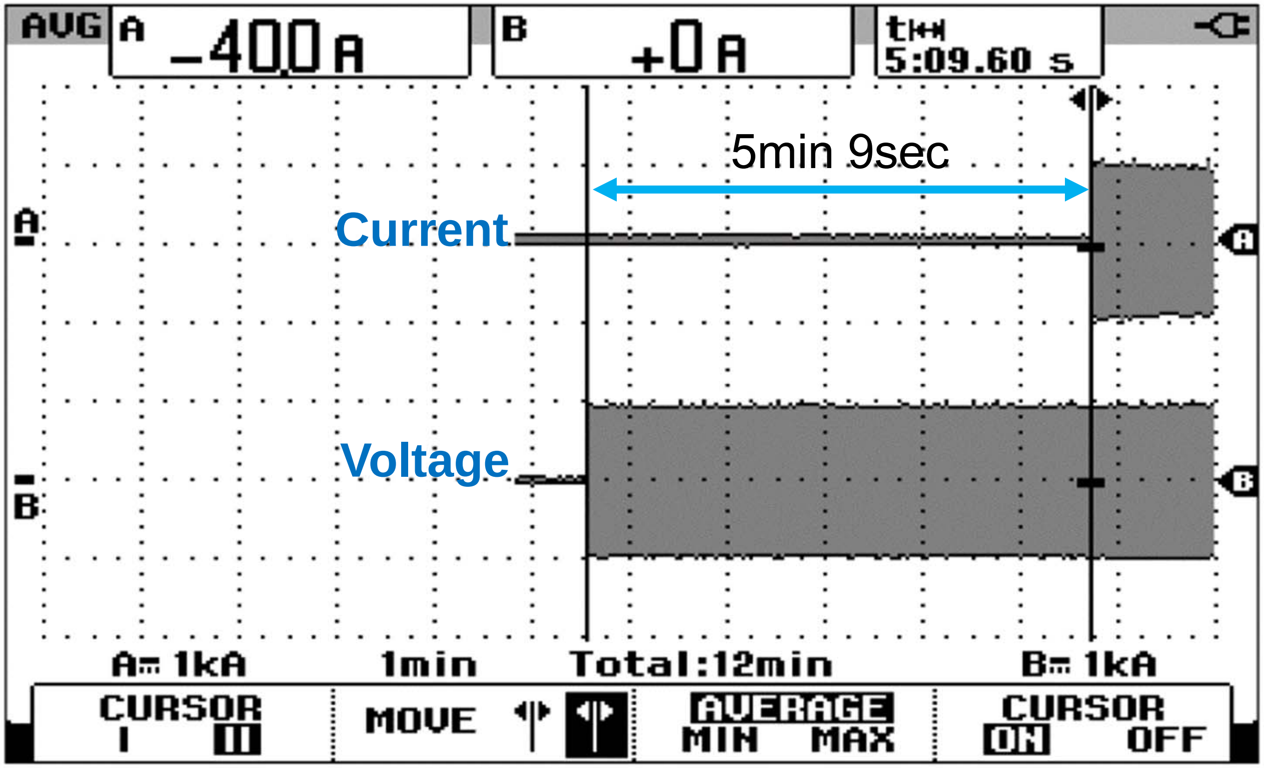
Test 7: Anti Islanding

Disconnection time



Test 7: Anti Islanding

Reconnection time



Next Generation PV Inverter Performance

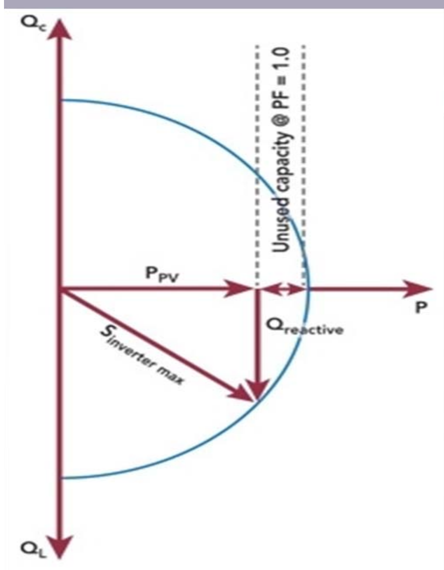
Less weight
Compact
Ease of handling
Better heat dissipation

Manufacturing Design

Higher Efficiency

Additional Safety Features

- Centralized safety management (real-time indication of the system's DC voltage.
- Arc fault detection and interruption (arc within the string)
- When inverter shut down, power optimizer in safety modes.



New Generation Inverter

Better Reliability

Mean time between failure
•Currently 5 to 10 yrs
•Target > 10 yrs, by:
improving quality control, better heat dissipation, reducing complexity

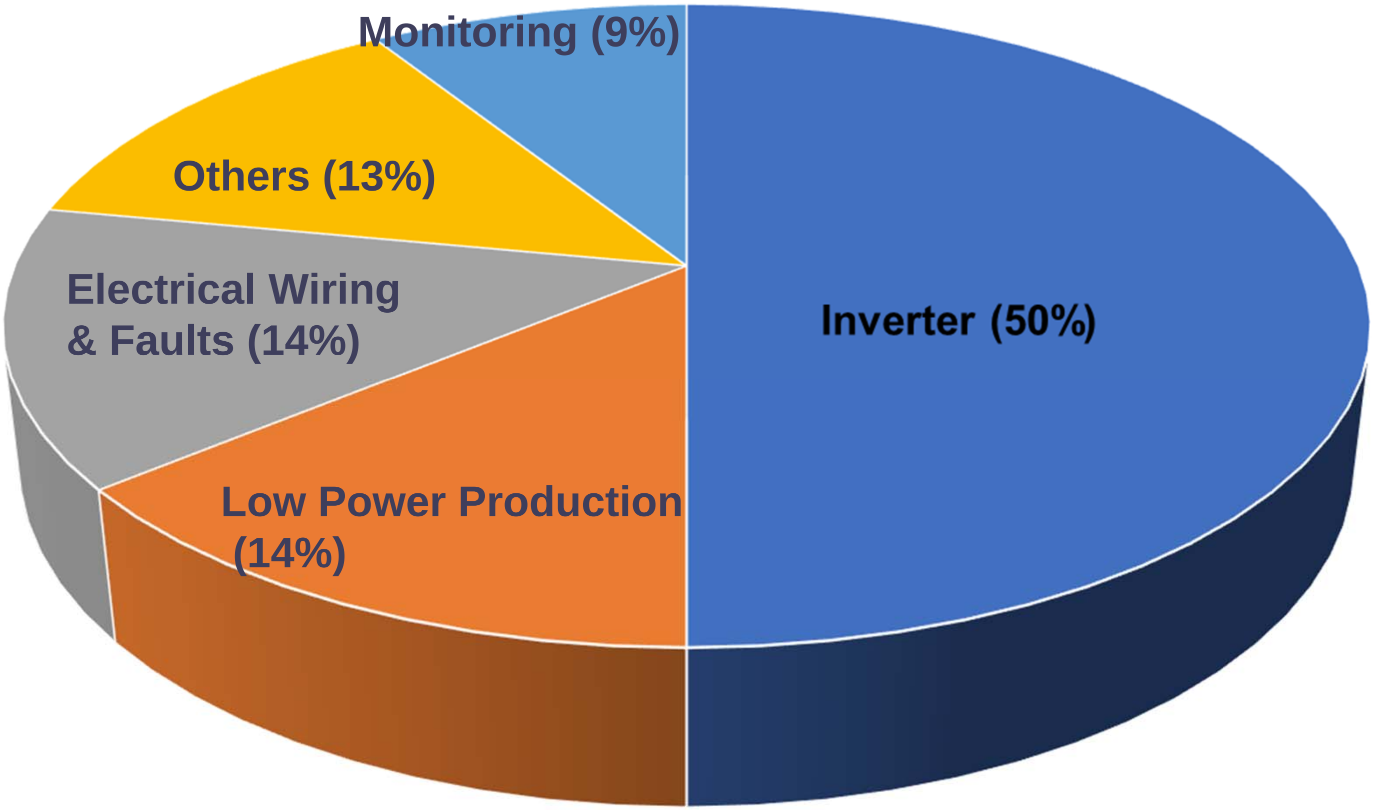
Advanced Communication Capabilities

Universal Communication Std., relaying more comprehensive system information (cloud based monitoring platform), enabling advanced diagnostic features & communication with the utility, smart energy management, supporting grid stability.

Lower Cost

50% reduction from the current price by increased production volume & learning- curve improvement

PV Inverter Power Conversion Reliability (Residential, Commercial and Utility)

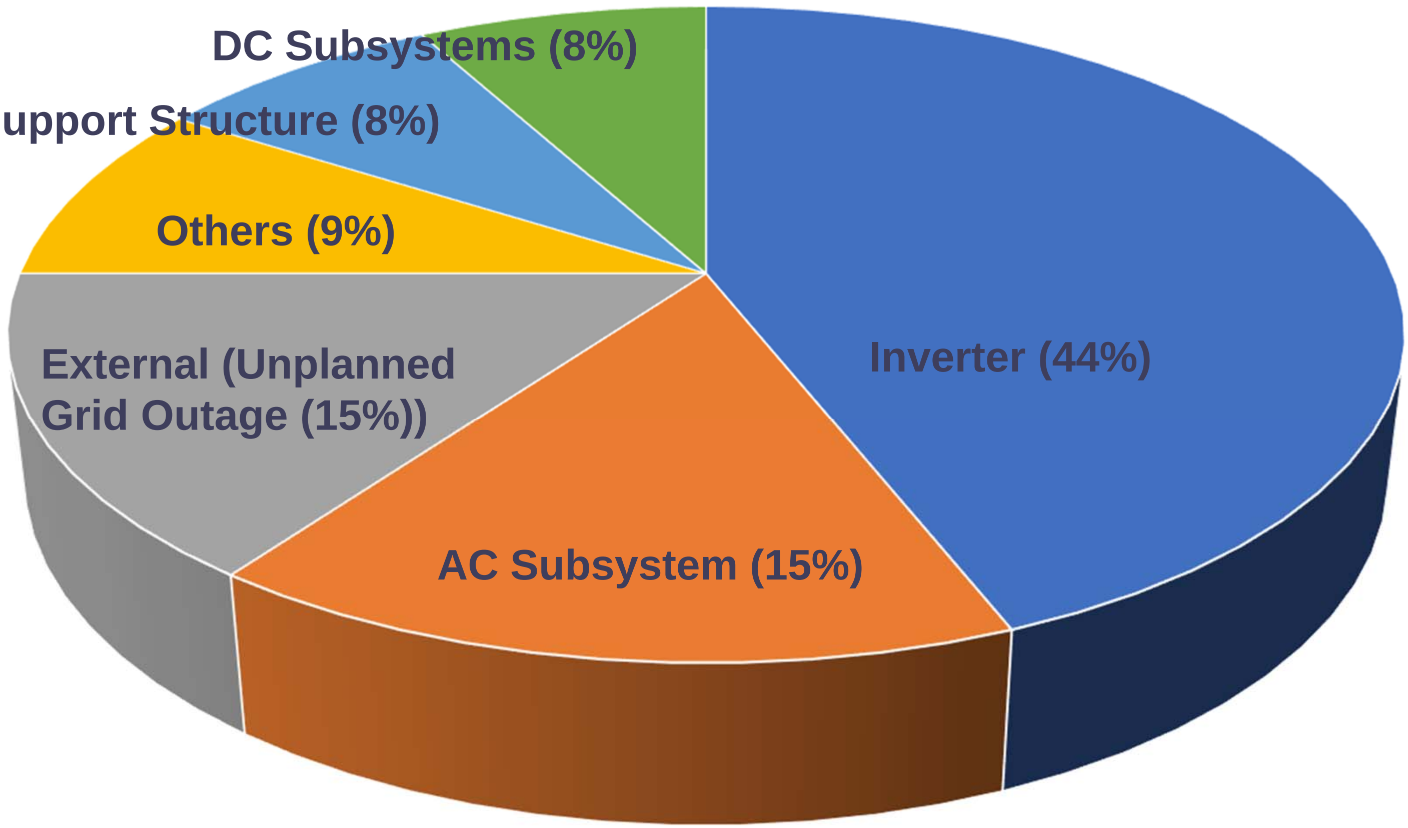


"Other" includes roof leaks/water in conduit/boxes, damaged tiles, dirty array, rattling modules, bird/rodent issues, and other damage.

AC subsystem comprises everything between the inverter and the generation meter.

Sources: A status review of photovoltaic power conversion equipment reliability, safety, and quality assurance protocols, Peter Hacks et al. Renewable and Sustainable Energy Reviews Volume 82, Part 1 February 2018, Pages 1097-1112

PV Inverter Power Conversion Reliability (Commercial & Utility)

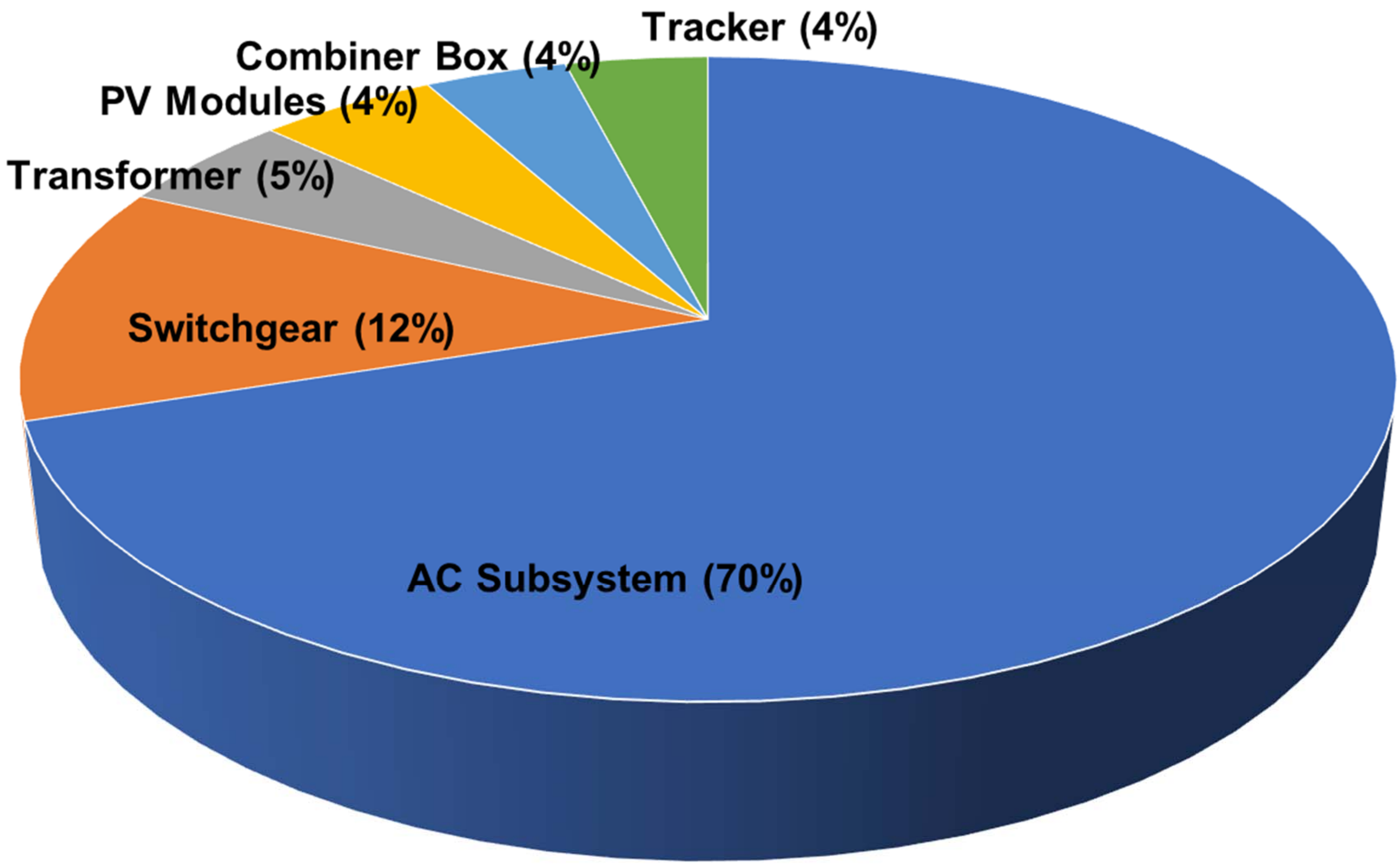


"Other" includes roof leaks/water in conduit/boxes, damaged tiles, dirty array, rattling modules, bird/rodent issues, and other damage.

AC subsystem comprises everything between the inverter and the generation meter.

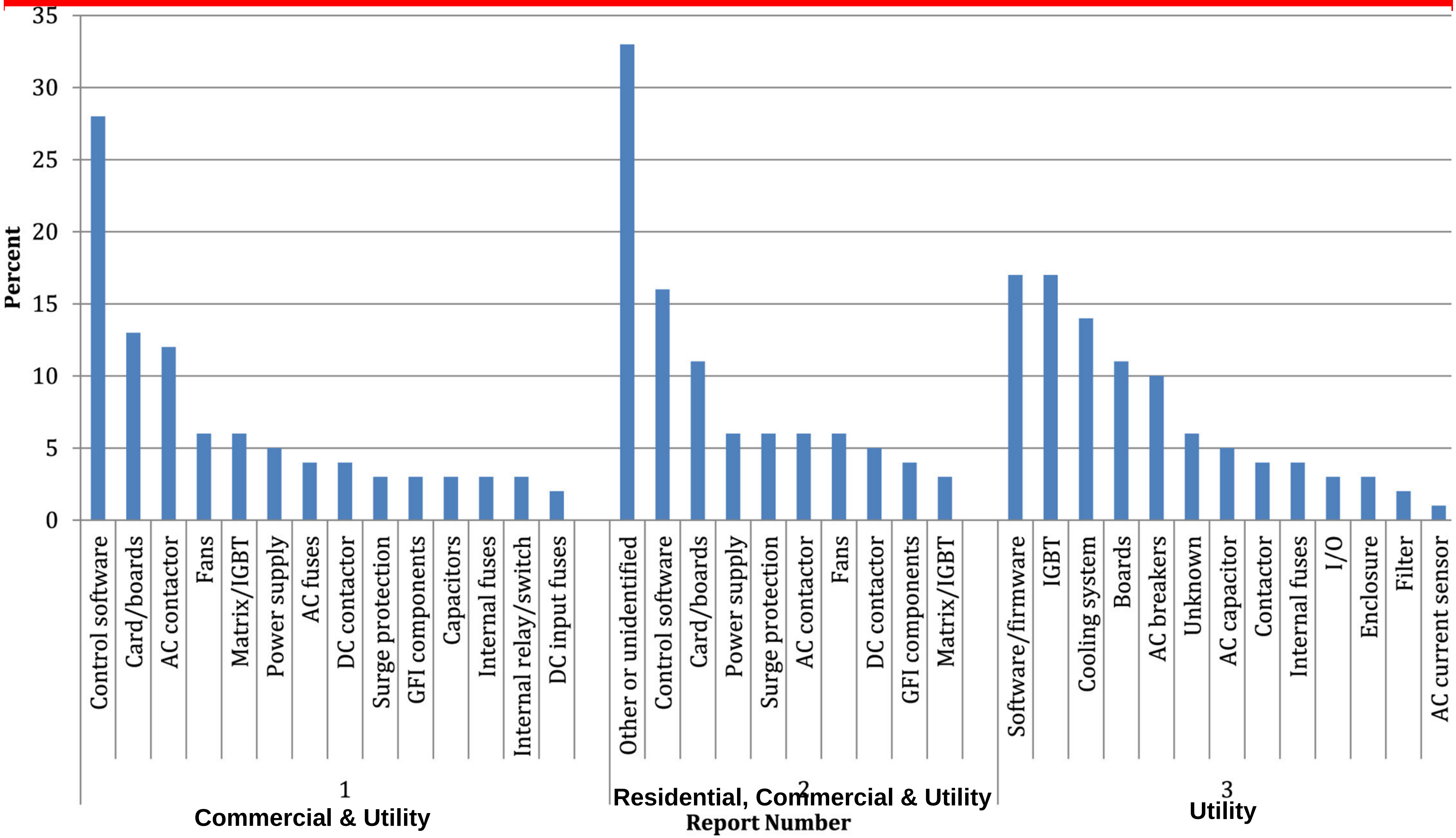
Sources: A status review of photovoltaic power conversion equipment reliability, safety, and quality assurance protocols, Peter Hacks et al. Renewable and Sustainable Energy Reviews Volume 82, Part 1 February 2018, Pages 1097-1112

PV Inverter Power Conversion Reliability Utility



Sources: A status review of photovoltaic power conversion equipment reliability, safety, and quality assurance protocols, Peter Hacks et al. Renewable and Sustainable Energy Reviews Volume 82, Part 1 February 2018, Pages 1097-1112

PV Inverter Power Conversion Reliability



Sources: A status review of photovoltaic power conversion equipment reliability, safety, and quality assurance protocols, Peter Hacks et al. Renewable and Sustainable Energy Reviews Volume 82, Part 1 February 2018, Pages 1097-1112

GFI-Central Management Server

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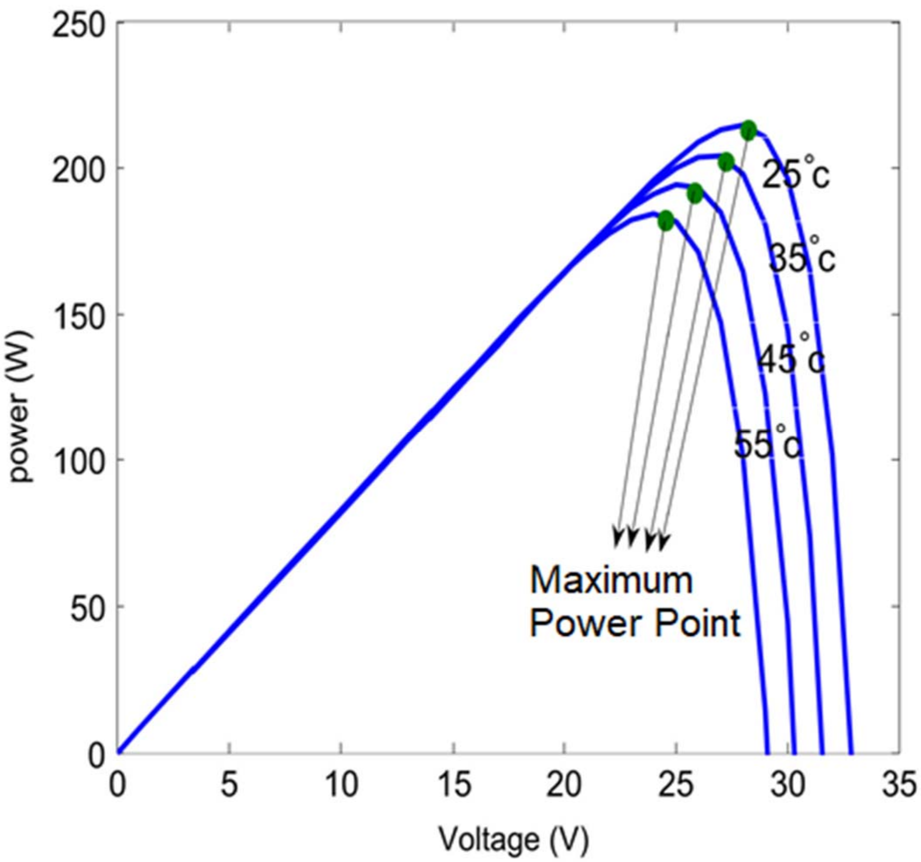
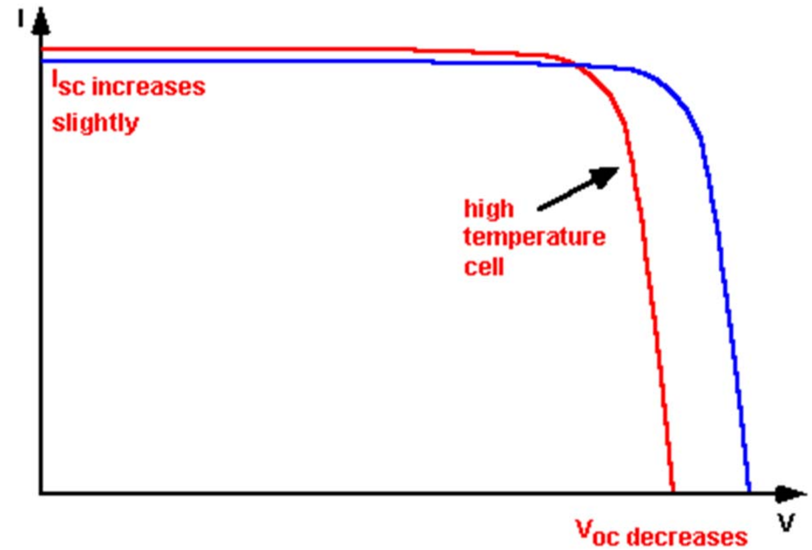
KUALA LUMPUR
Producing Leaders Since 1905

PV Modules

External Factors Influencing PV System Performance

Temperature





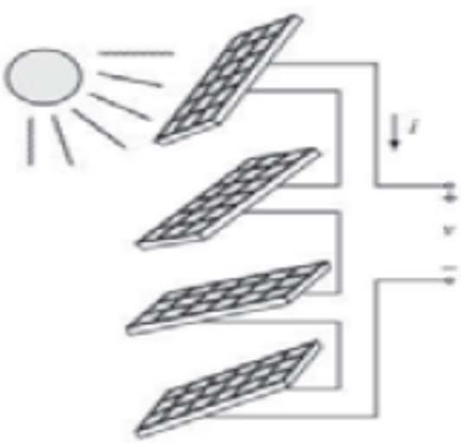
The hotter the cell material is, the more resistance there is and the slower the electrons can move through it. The parameter most affected by an increase in temperature is the open-circuit voltage.

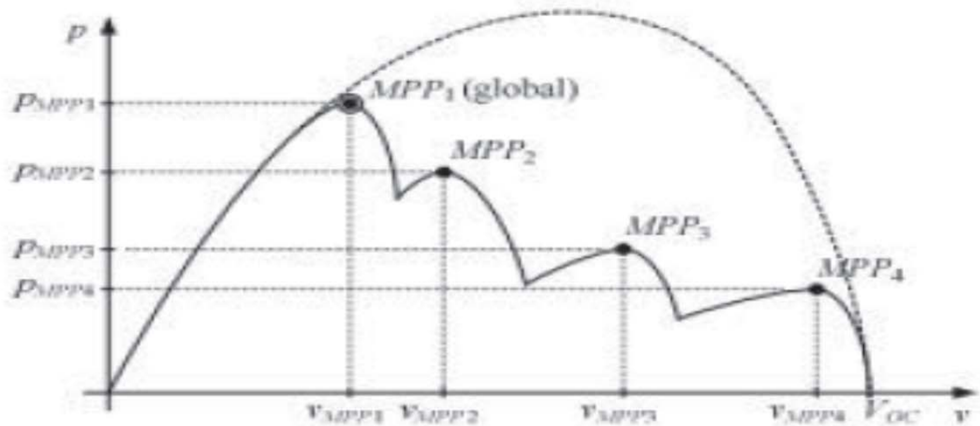
External Factors Influencing PV System Performance

Degradation types used for the evaluation of the failures.

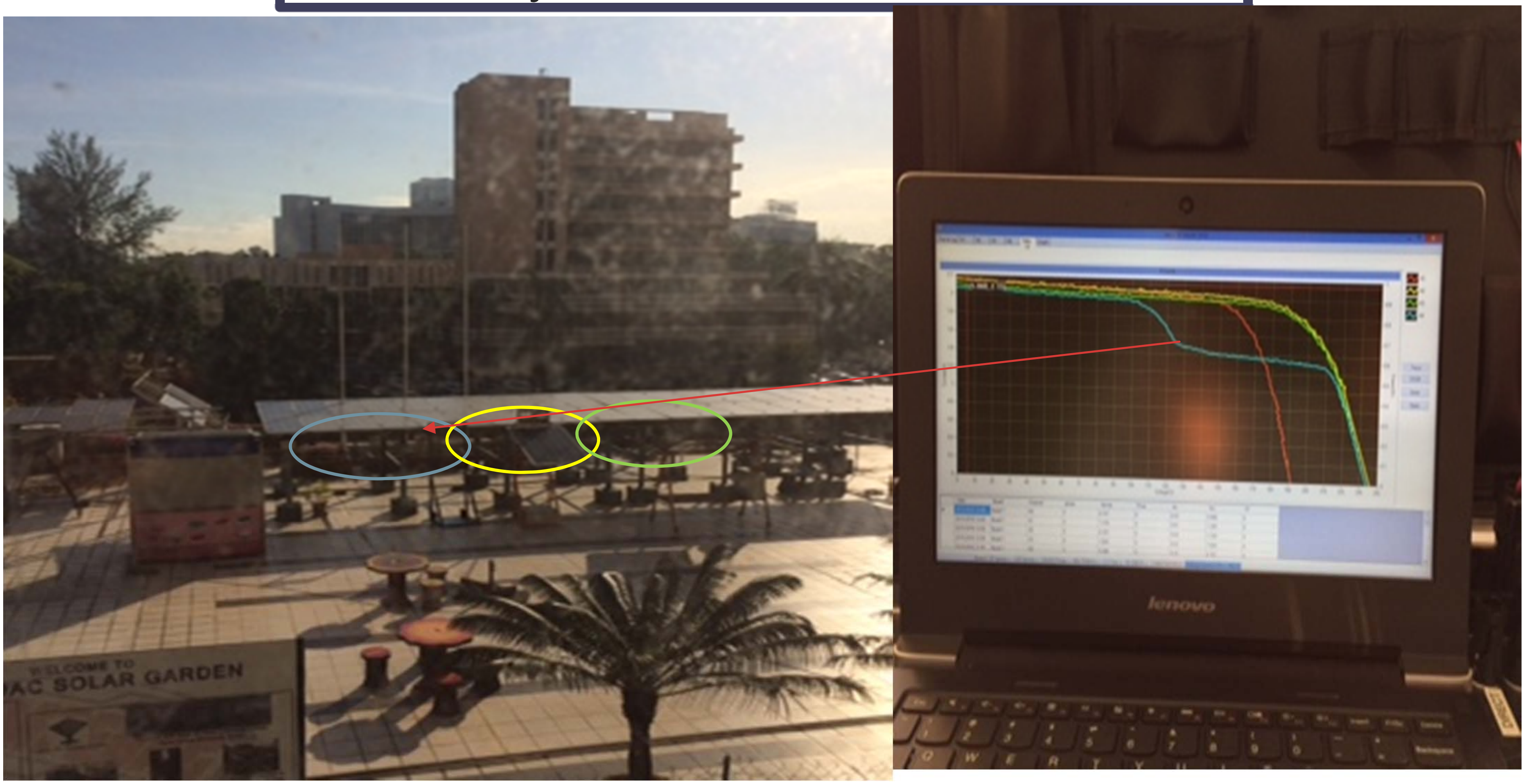
Delamination,
Defect backsheet,
Defect junction box, Junction box detached,
Frame breakage/bown/defect,
Discolouring of pottant,
Cell cracks,
Burn marks,
Potential induced shunts (often named PID),
Potential induced corrosion (often with thin-film modules),
Disconnected cell or string interconnect ribbon,
Defective bypass diode/wrong dimensioned,
Corrosion/abrasion of AR coating,
Isolation failure,
CdTe: back contact degradation
Hail -> glass breakage/cell breakage,
Direct lightning stroke -> defect glass/frame and defect bypass diodes,
Animal -> bite/corrosion/dirt , Biofilm soiling, Dust soiling.

External Factors Influencing PV System Performance



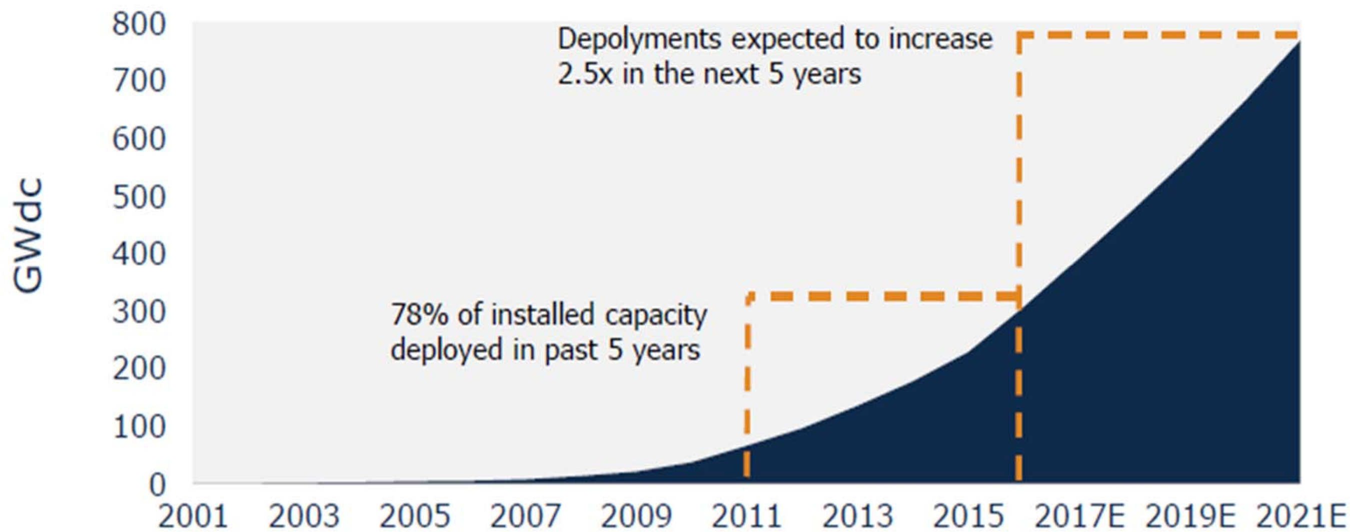


External Factors Influencing PV System Performance



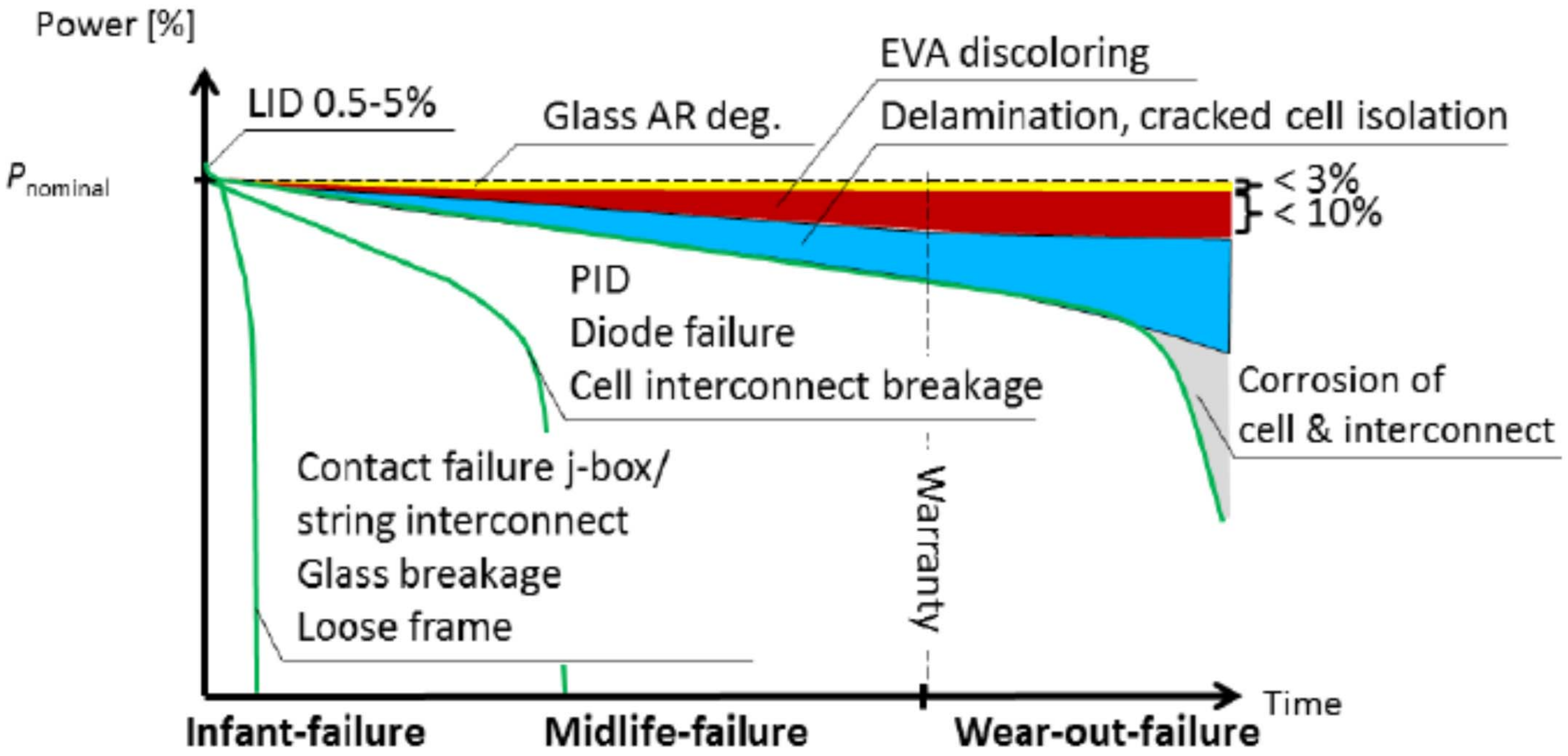
The angle of the sun changes through the year, trees and other barriers may become shading issues in different seasons. It all depends on the size, height, and proximity of surrounding barriers.

CUMULATIVE INSTALLED GLOBAL PV CAPACITY & GLOBAL BLENDED MODULE PRICE



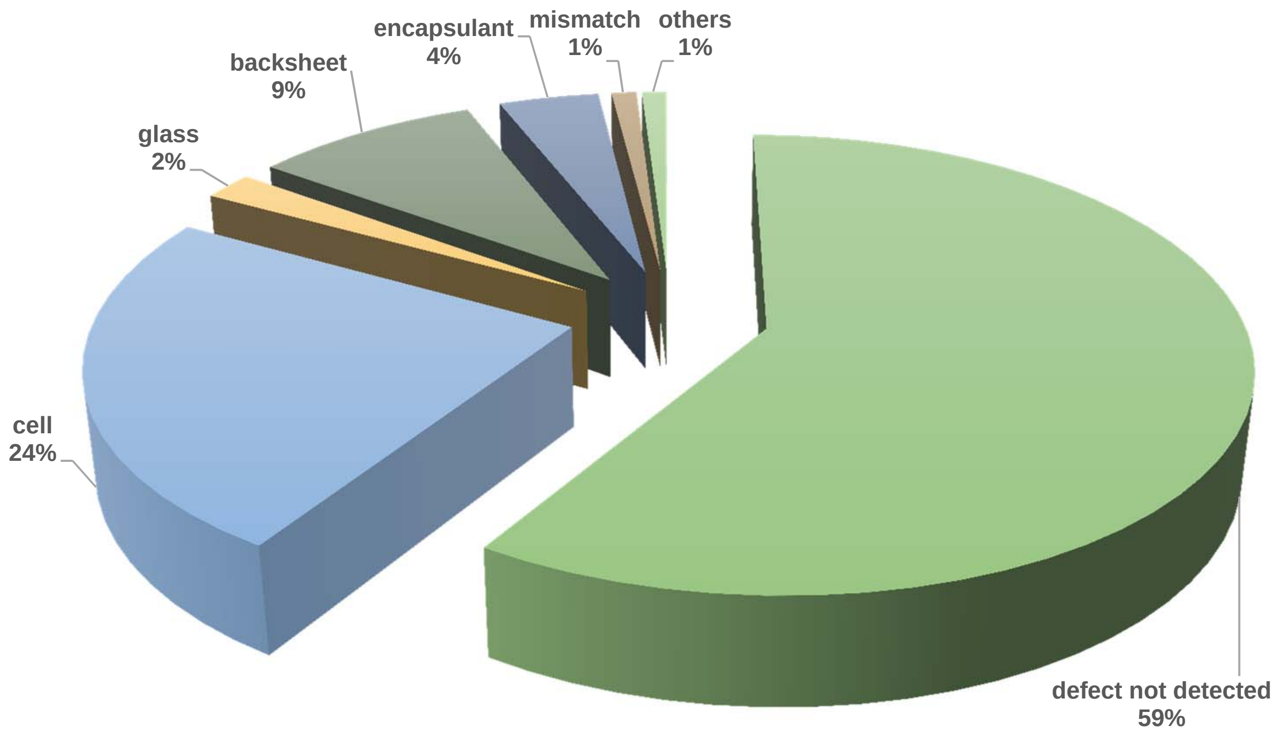
Source: GTM Research

AGING MECHANISMS LEADING TO PV MODULE DEGRADATION

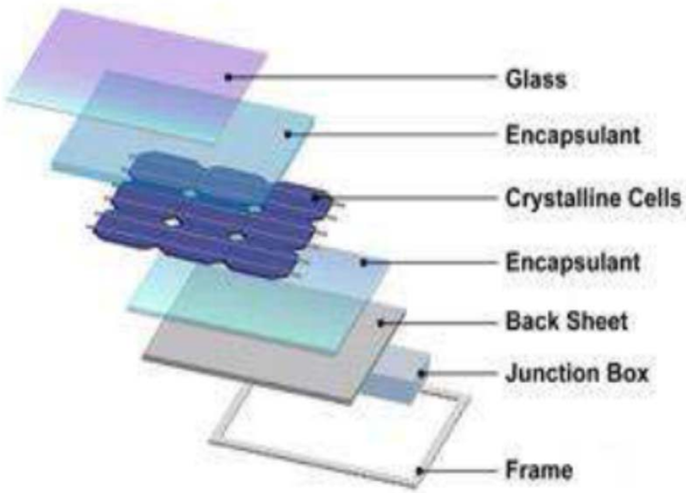


Source: IEA PVPS 2014

Failure Categorization



Glass/Superstrate	Broken, etched, hazed glass
Encapsulant	Discoloration/delaminatio n
Cell/Interconnect	Corrosion, hot spot, broken interconnect, snail trails, cracks, burn marks
Backsheet	Cracking, yellowing, delamination

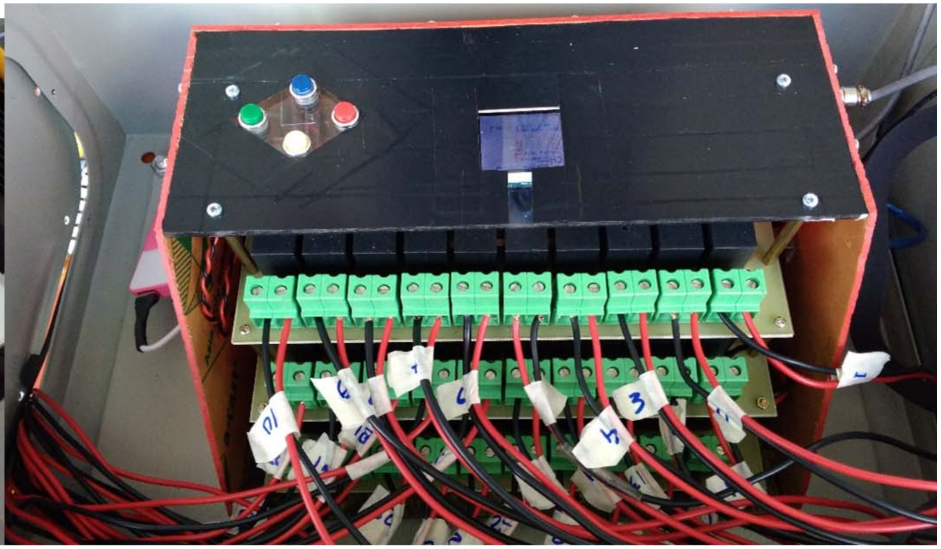


Failure Categorization

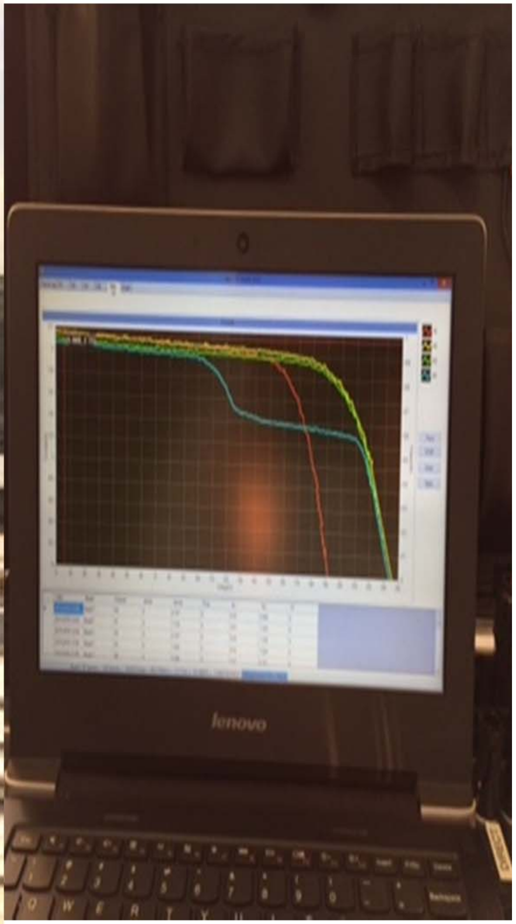
Glass/glass module with specific ionomer encapsulant type that has proven to have insufficient adhesion, showing delamination and corrosion.

IEA-PVPS T13-09:2017

30 CHANNEL PV TRACER – OUR PRODUCT

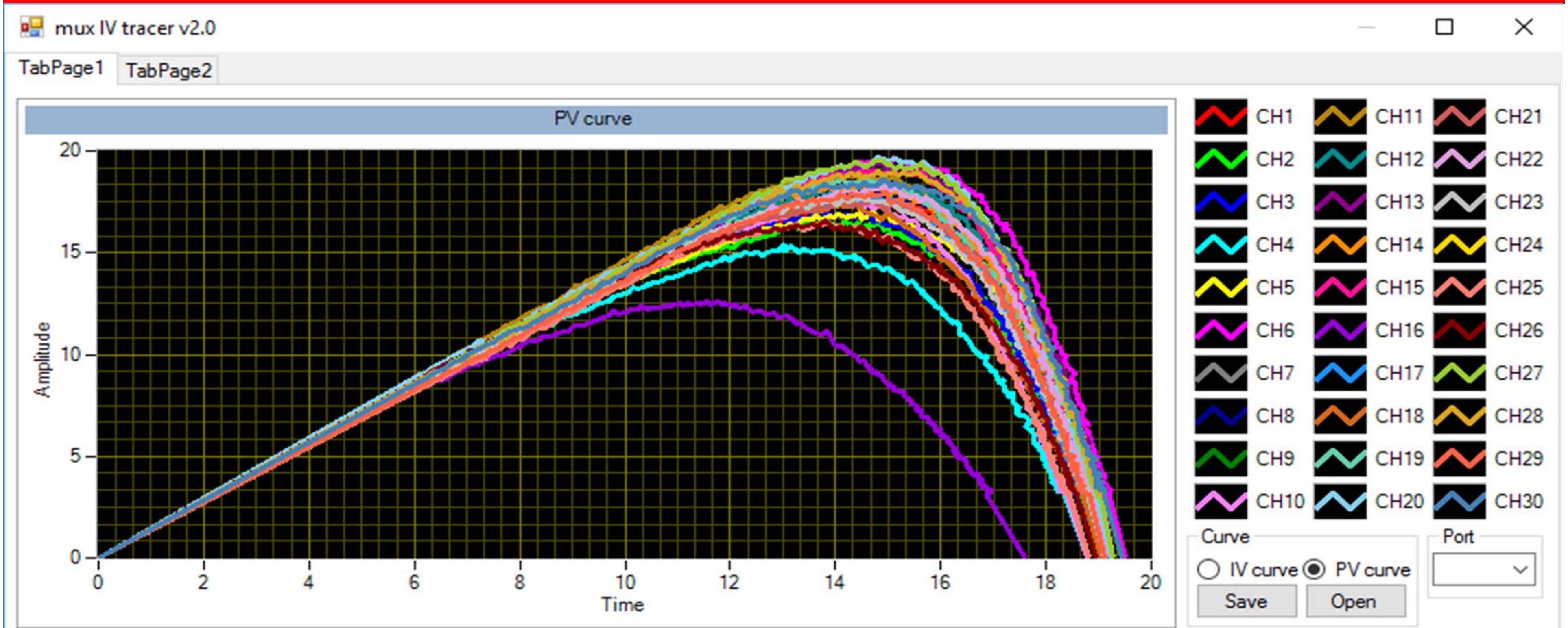


External Factors Influencing PV System Performance



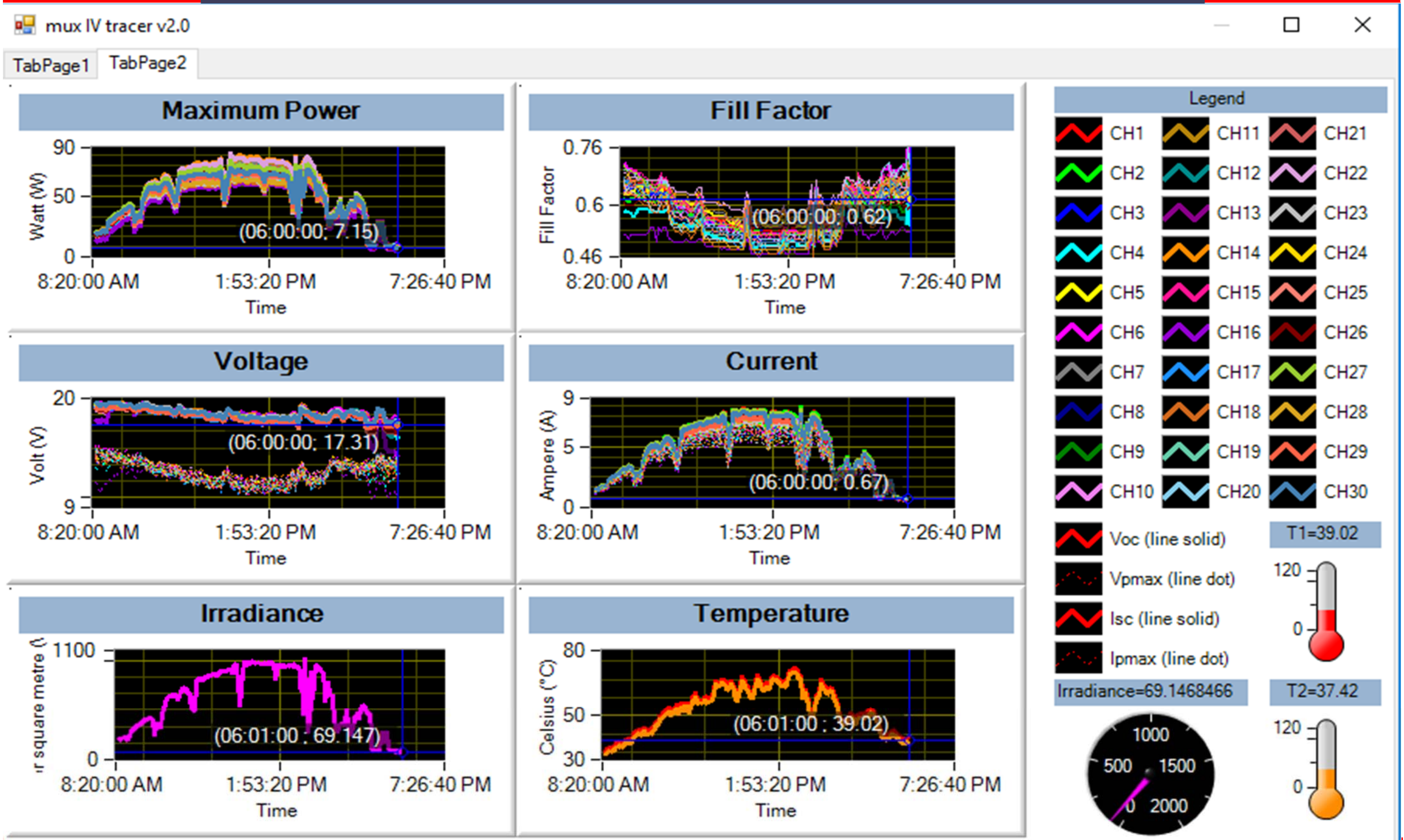
The angle of the sun changes through the year, trees and other barriers may become shading issues in different seasons. It all depends on the size, height, and proximity of surrounding barriers.

Solar PV Module Performance



DateTime	Channel	Ipmax	Vpmax	Pmax	Isc	Voc	FF
28/3/2018 8:25 AM	26	1.2	13.83	16.54	1.44	18.96	0.61
28/3/2018 8:25 AM	27	1.31	14.91	19.58	1.44	19.29	0.71
28/3/2018 8:25 AM	28	1.28	14.82	19.02	1.43	19.43	0.68
28/3/2018 8:25 AM	29	1.27	14.11	17.98	1.38	19.1	0.68
28/3/2018 8:25 AM	30	1.25	14.91	18.71	1.42	19.43	0.68
28/3/2018 8:30 AM	1	1.28	14.68	18.84	1.51	19.19	0.65

Solar PV Module Monitoring



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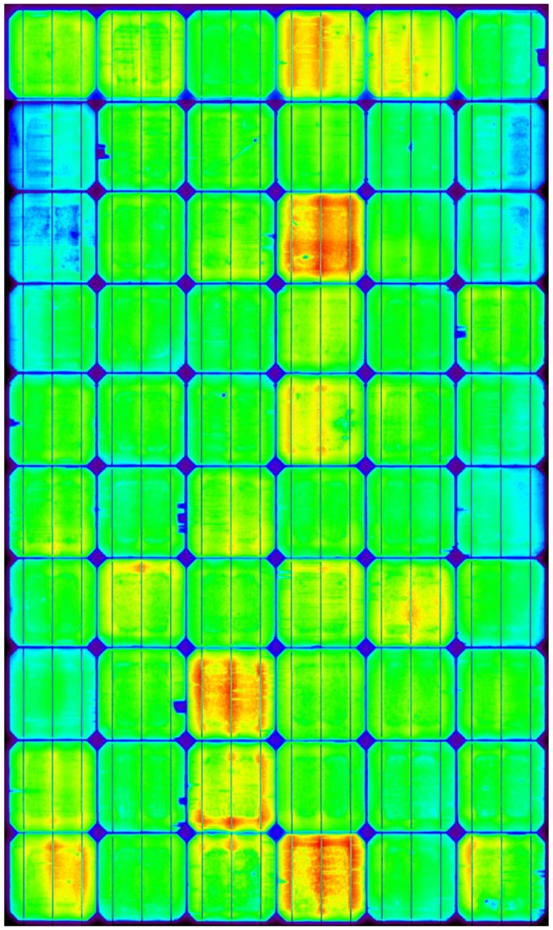
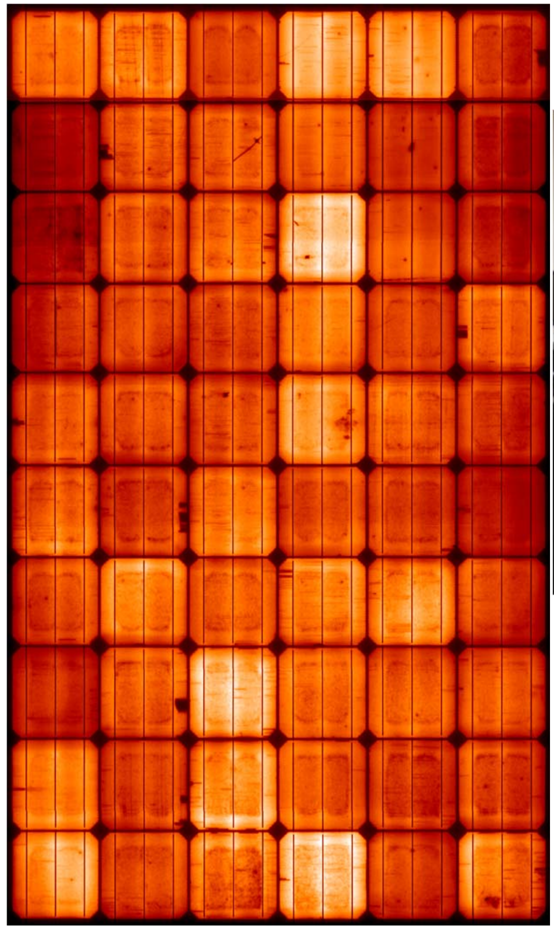
◆*Professor Ir. Dr. Nasrudin Abd Rahim*

UMPEDAC

Electroluminescence imaging and Power measurement test on PV Module according to IEC 61215

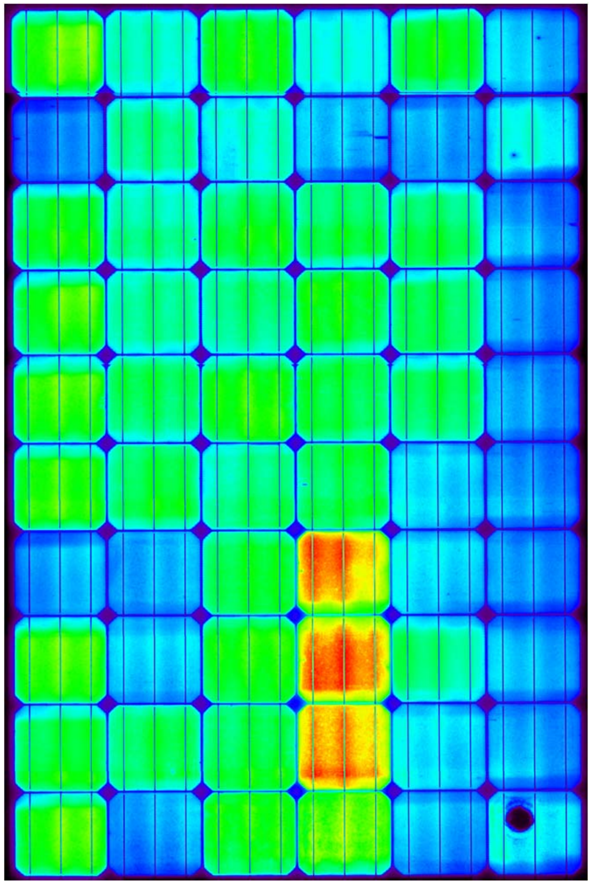


Blue coloured cell indicates lower performance; Green indicates medium, and yellowish red indicates the highest performance.

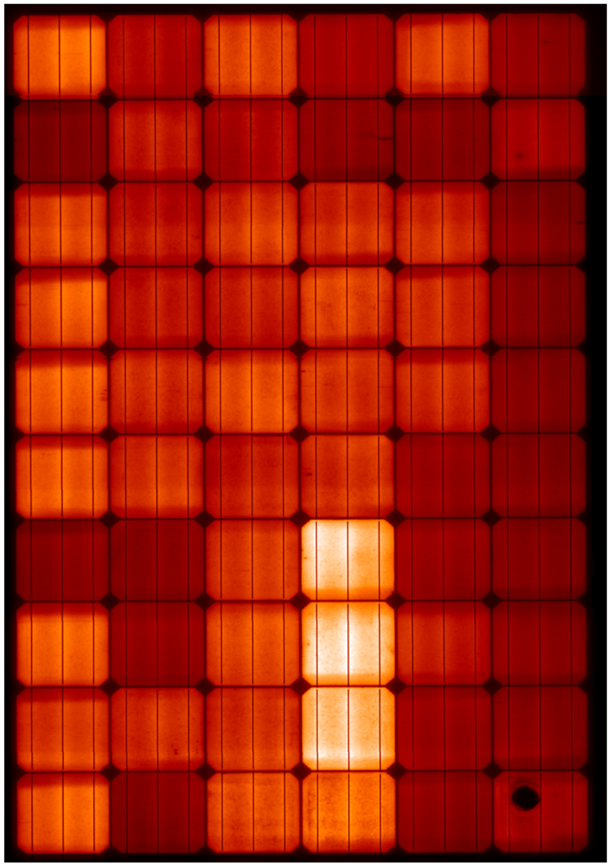


Higher brightness indicates the higher performance: Dark spots, lines or areas are the damages within cells.

Electroluminescence imaging and Power measurement test on PV Module according to IEC 61215



Blue coloured cell indicates lower performance; Green indicates medium, and yellowish red indicates the highest performance.



Higher brightness indicates the higher performance: Dark spots, lines or areas are the damages within cells. The Large black spot at the right end corner cell is hot spot damage.

Conclusions

- Power electronics has developed along path driven by development in power switching device and power converter topologies.

- The challenges for power electronics in the renewable energy are to find technical solutions to the least possible cost for large series production.

- The lowest cost design is only possible by combining the knowledge and efforts of several disciplines and by close cooperation between component, module, and system designs.

- Many of the future contributions of Power Electronics to the renewable energy will continue to result from unanticipated breakthroughs in materials and devices that are creatively applied to control and process the flow of electrical energy.

THANK YOU