GCPV systems in Malaysia: How are the systems performing

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1. DEFINITION OF PV MODULE FAILURE BY IEA-PVPS T13

- A PV module failure is an effect that :-
  (1) degrades the module power and which is not reversed by normal operation
  or
  (2) creates a safety issue.

- A PV module failure is relevant for the warranty when it occurs under conditions the module normally experiences.

- This definition is useful for a PV module manufacturer who is responsible for all failures which are caused by its product.

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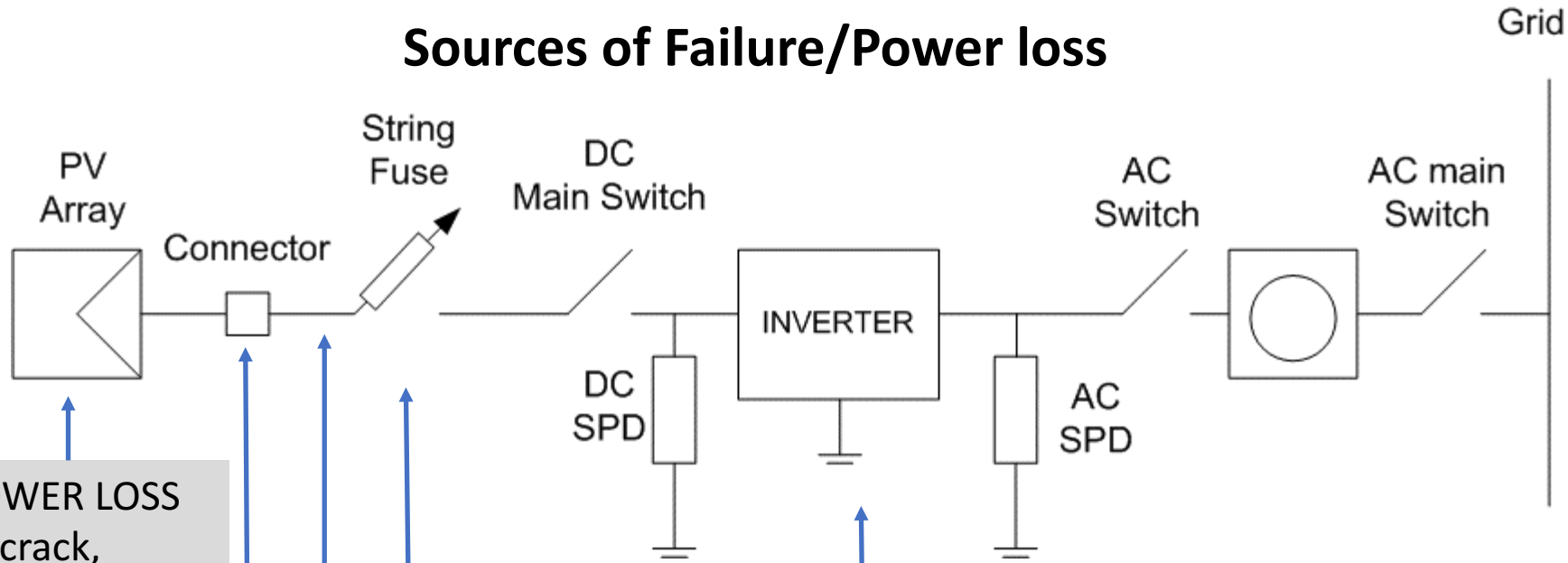
2. SOURCE OF FAILURE OR POWER LOSS ON DC SIDE



PV FAILURE OR POWER LOSS
- LID, PID, micro crack, soldering, snail trails

INSTALLATION
- Partial shading, crack, micro crack, heat

COMPONENT FAILURE
- Bypass diode

AGING

Damage/Inefficient inverter/LCD screen faded

DC SPD Unit damage/melt/Leakage

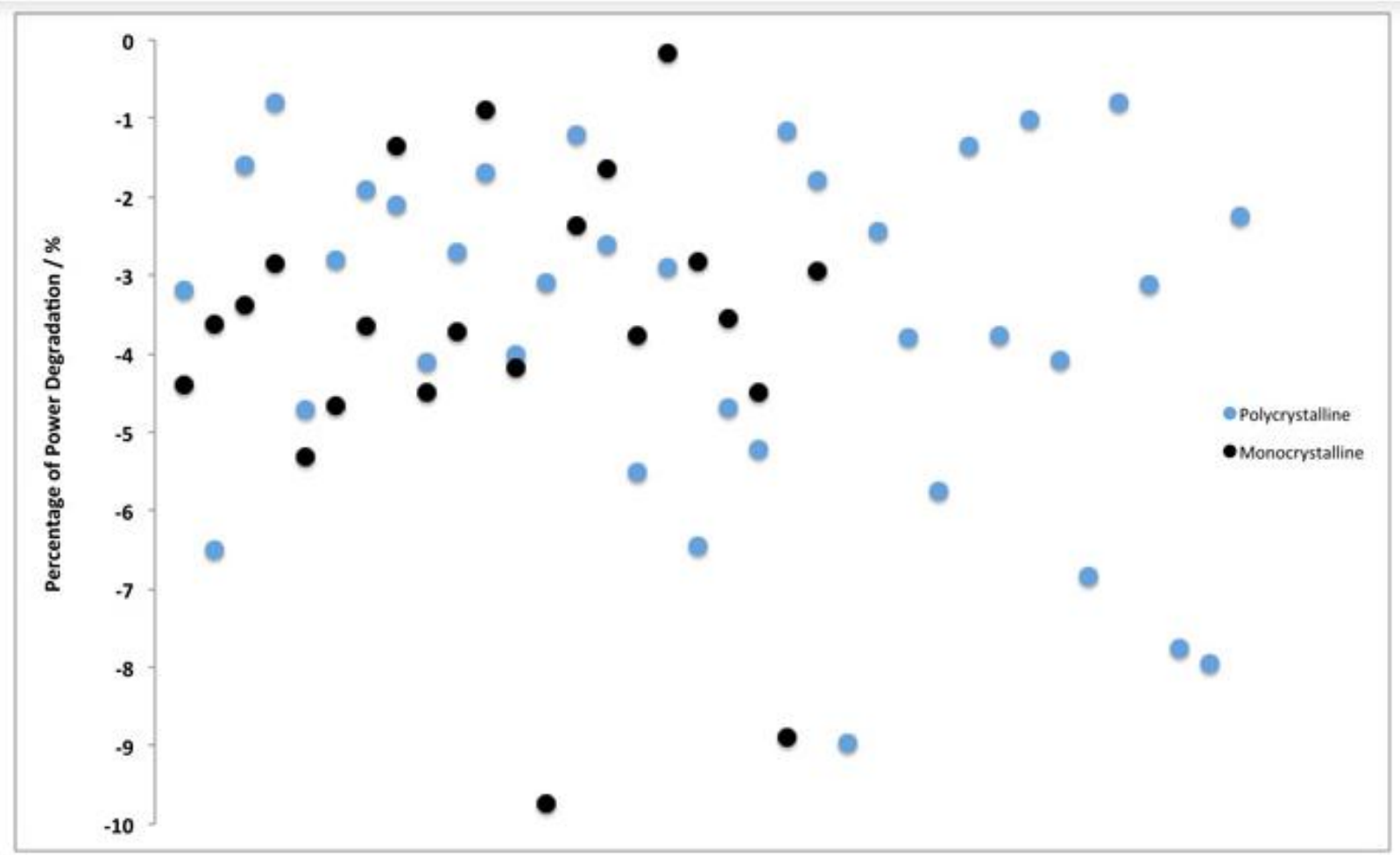
Fuse Blown

Cable power loss

Not compatible connector

3. PV MODULE – Light Induced Degradation (LID)

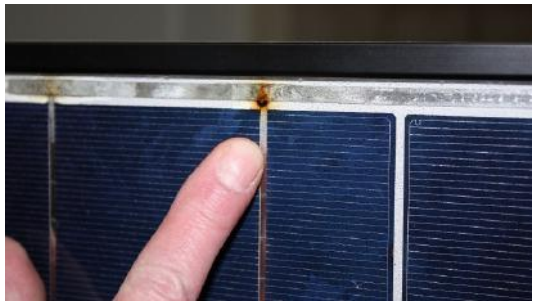
Light Induced Degradation (LID) conducted by **sunlight** (real or simulated).



- 58 modules, different brand.
- 3 days of sun exposure
- Approximately 57% shows power loss more than 3%

3. PV MODULE – Faulty module

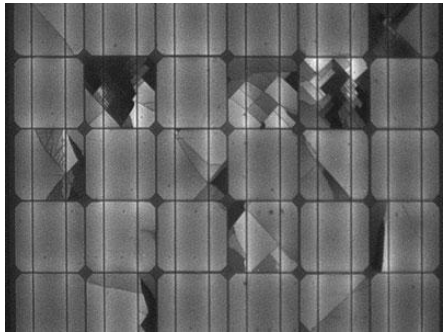
Faulty soldering



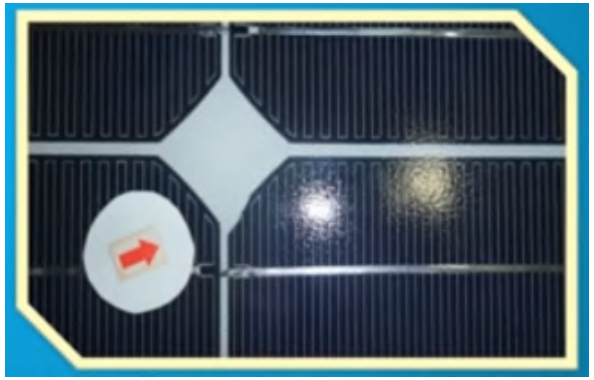
Snail Trail

Interrupted Contact Fingers

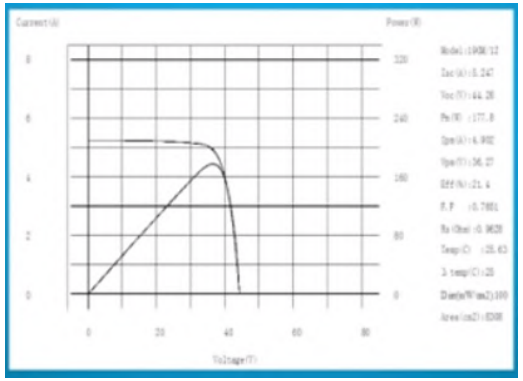
Microcrack test using electroluminescence (EL) crack detection



Broken Cell



Off-Spec Module Performance



3. PV MODULE – Cell Short Circuit Fault

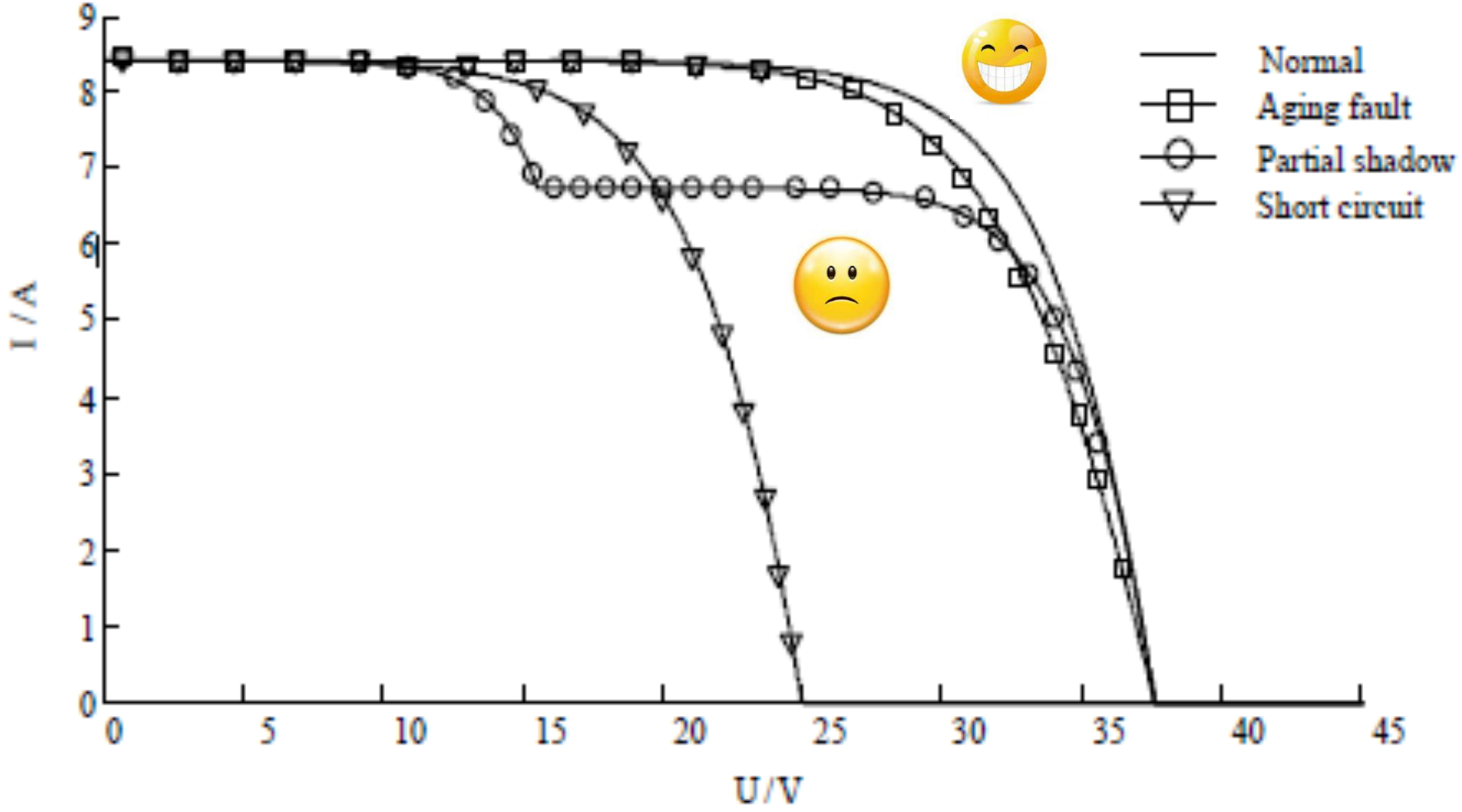
$$N_{sc} = \frac{Voc_{theory} - Voc_{measured}}{Uoc}$$

Where

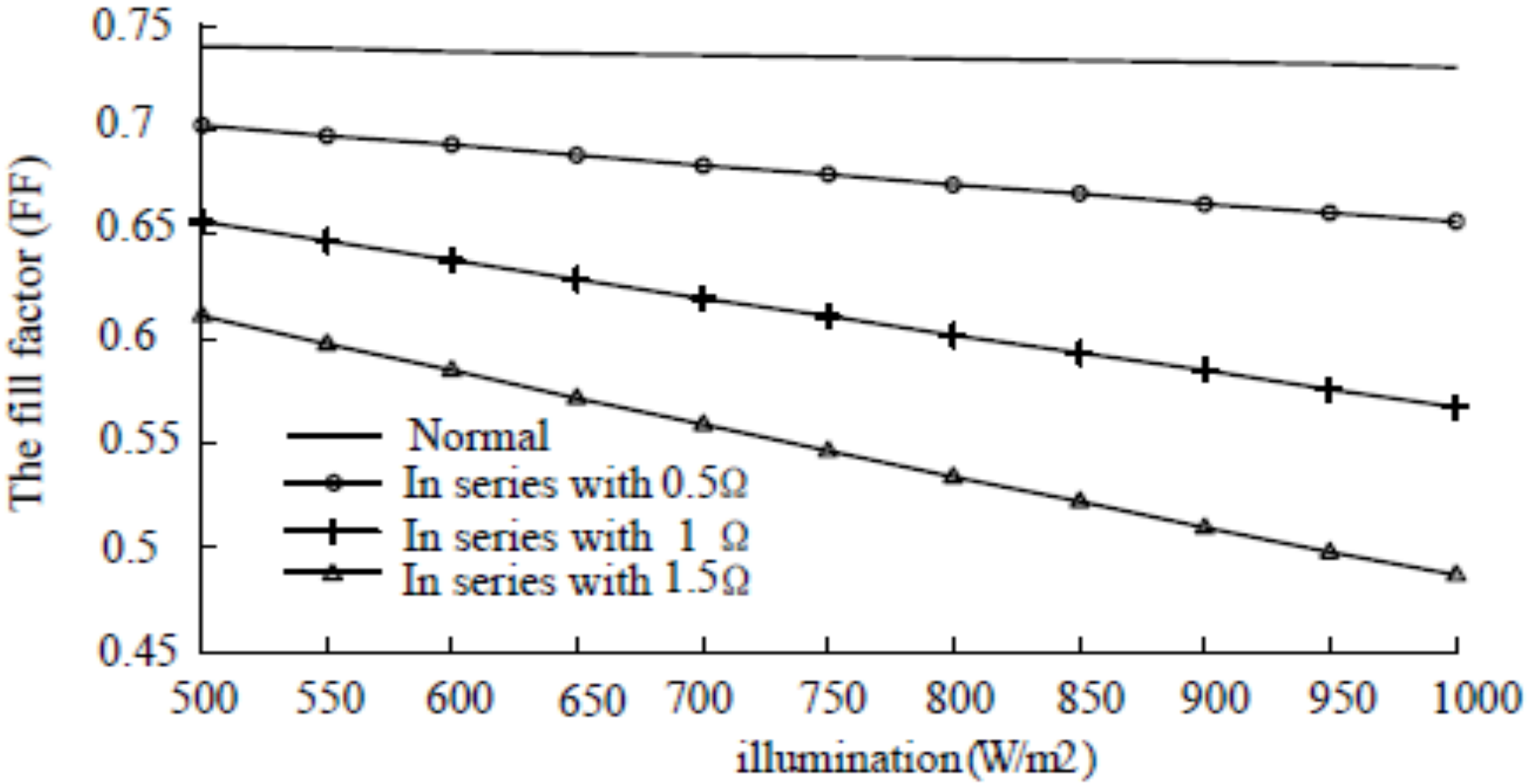
Voc_{theory}	Theoretical open circuit voltage (V)
$Voc_{measured}$	Measured open circuit voltage (V)
Uoc	Average open circuit voltage of the cells in PV module.

If N_{sc} >1, it can be determined that the short circuit fault has occurred.

3. PV MODULE – Aging factor using IV Curve



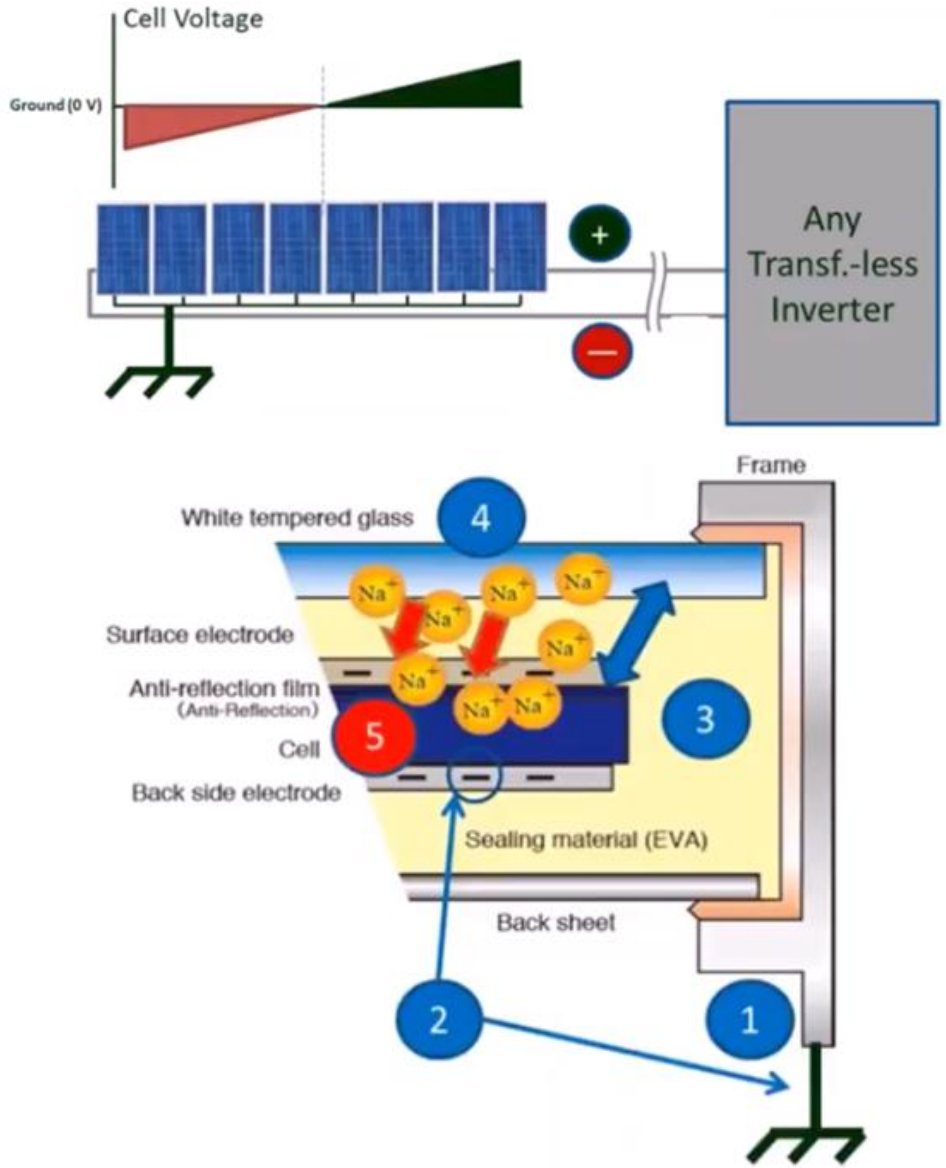
3. PV MODULE – Aging Factor Using FF



$$FF = \frac{I_m V_m}{I_{sc} V_{oc}}$$

- When the value of FF is less than 0.7, it can be judged that the module is in a failed state of aging.

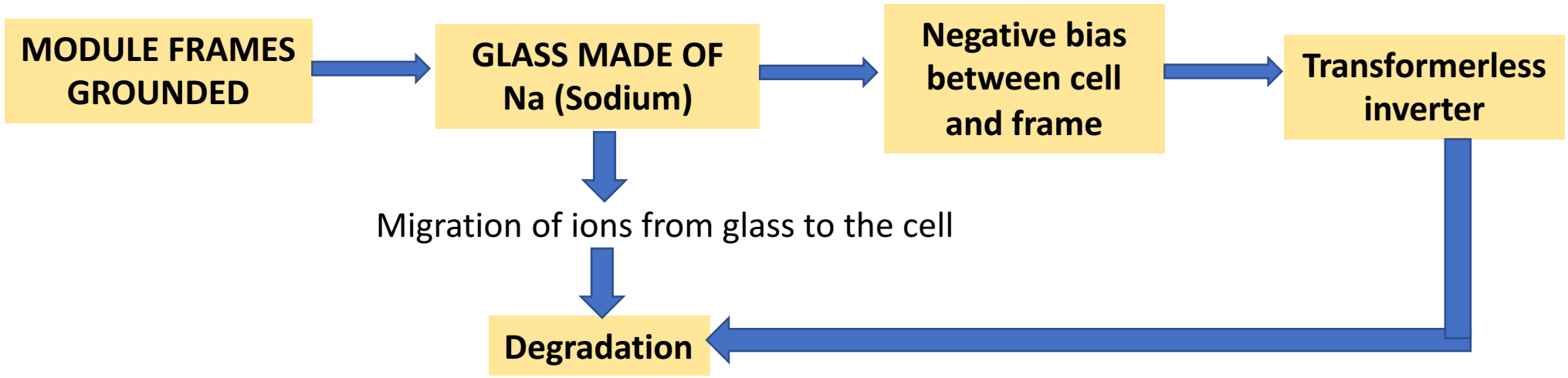
3. PV MODULE – What is Potential Induced Degradation (PID)?



1. Module frames are grounded
2. There is a voltage diff. between the frames and the cells with a negative voltage.
3. This voltage may cause a migration of mobile ions through the module either towards or away from the cells
4. Mobile positive sodium ions (Na+) contained in the glass substrate can migrate towards the cells.
5. Crystalline defects permit the ingression of these sodium atoms, which results in **module degradation**

3. PV MODULE – Identifying PID on Site

PID FORMULA



- PID is not visible to the naked eye.
- Tests to detect PID in operational sites:-
    - IV Curves
    - Electroluminescence images
    - Power drop

- If detected at early stage, PID may be reversible.

3. PV MODULE - How to mitigate PID?

PREVENTION

- IEC62804 standard - Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation - Part 1: Crystalline silicon
- Inverter that allow negative array terminal grounded

RECOVERY

- Ground the negative pole of the inverter but not always possible.
- Retrofit using PID recovery box e.g. OMRON PID, PIDBULL, SMA

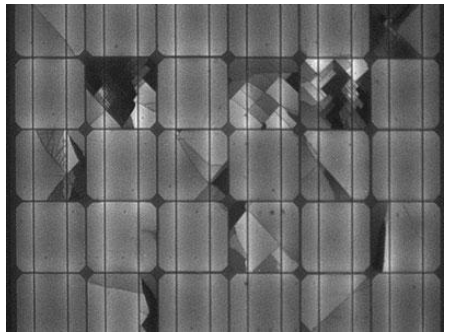
3. PV MODULE – Soiling factor

Required regular cleaning

4. INSTALLATION – quality

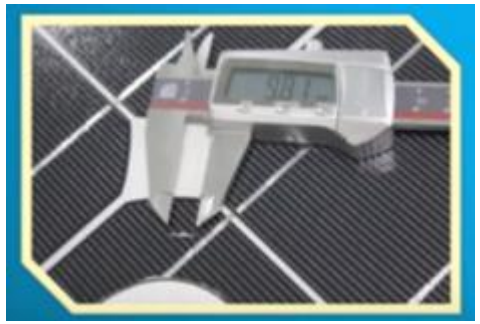
Glass Breakage

Microcrack test using electroluminescence (EL) crack detection



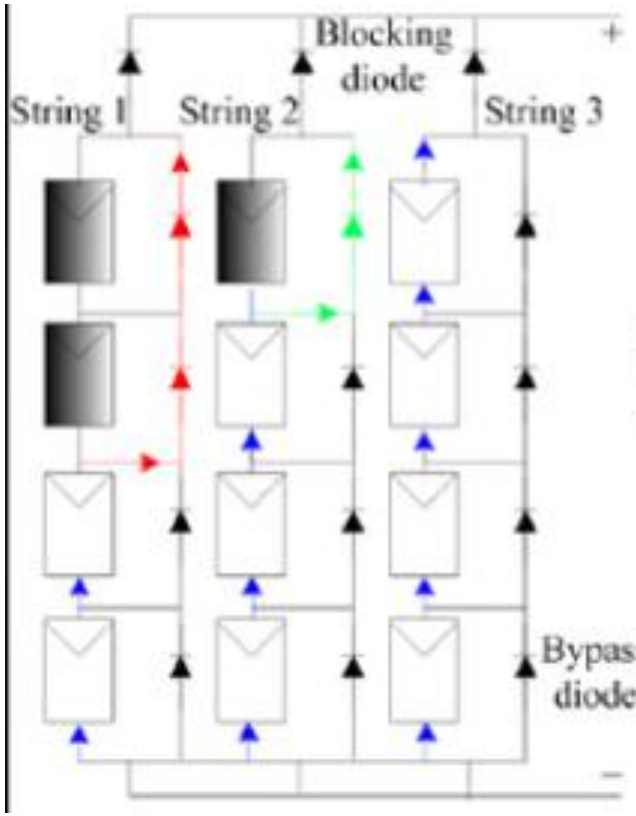
Connector Melted

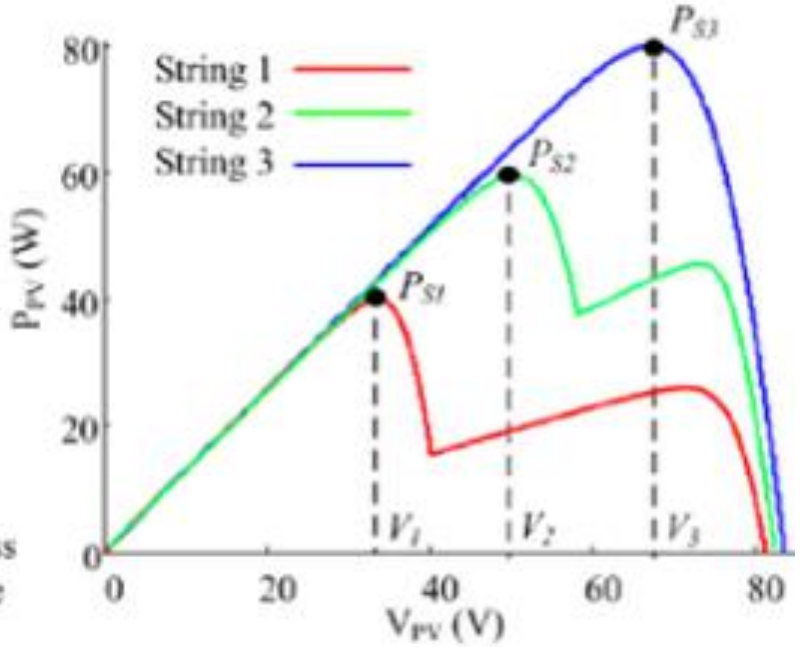
- Scratches on Glass



4. INSTALLATION – Partial Shading

- Partial shading





5. DC SPD - Damage

Design flaw?
Installation?
Quality of component?
Natural disaster?

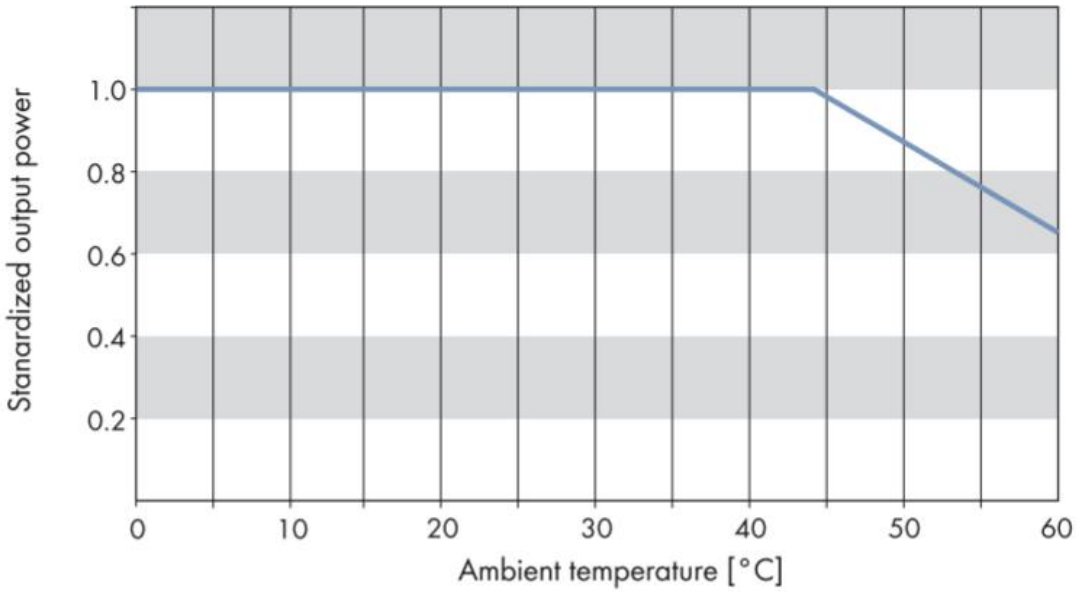
6. INVERTER – direct sunlight

- IP65

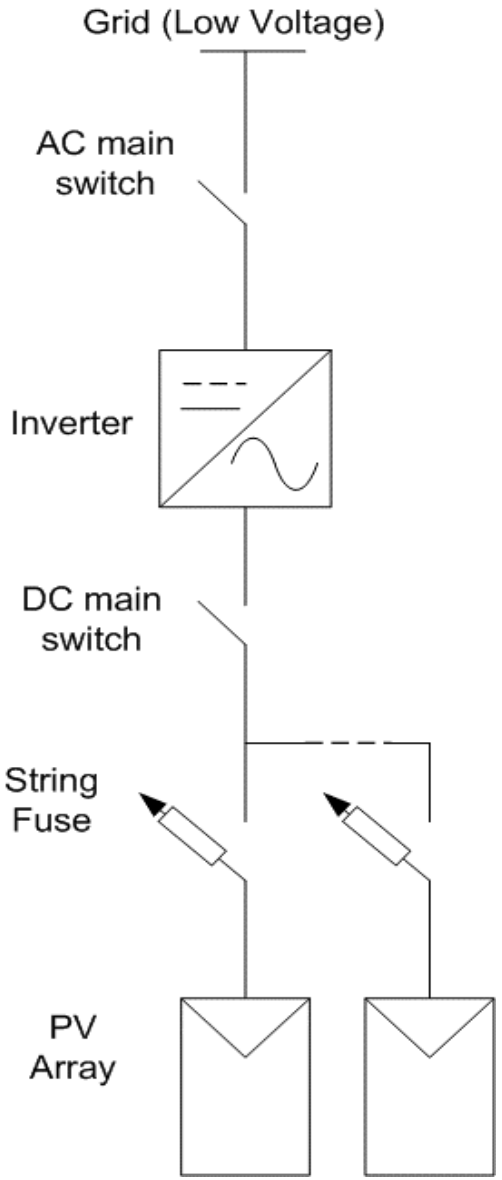
  Solid - Protection against ingress dust.

  Liquid – Protection against jet water.

- Effect of direct sunlight : -
  - Power de-rate due to temperature.
  - LCD display



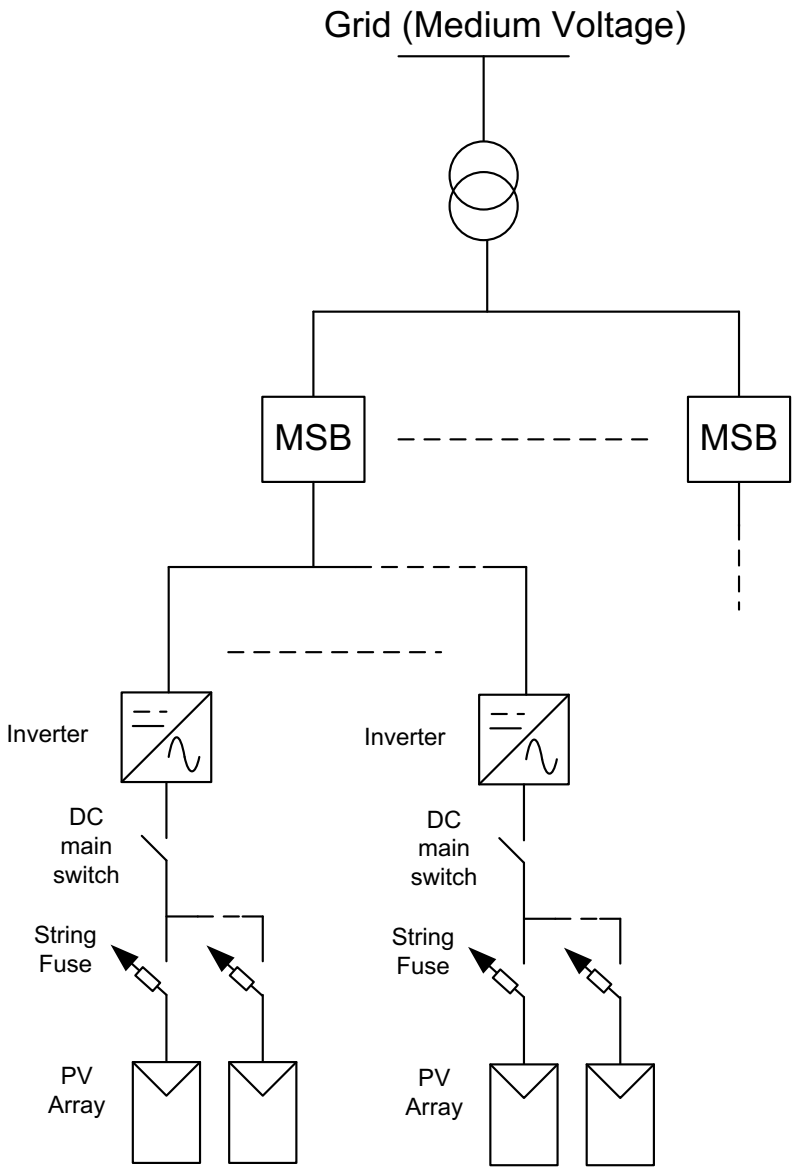
7. CASE STUDY



Four case studies

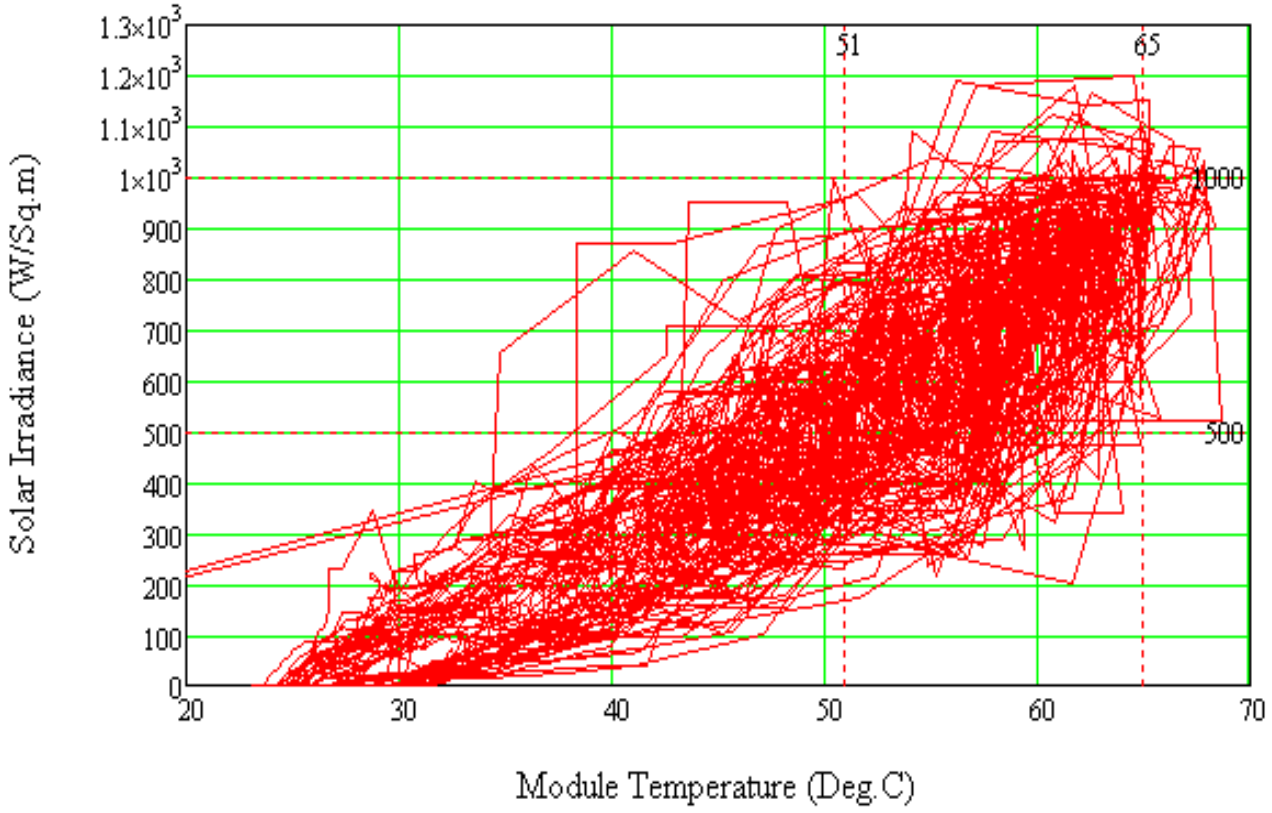
- **2 roof top system**
  - Good system 😁
  - Bad system 😕
  - Both system operating more than 5 years

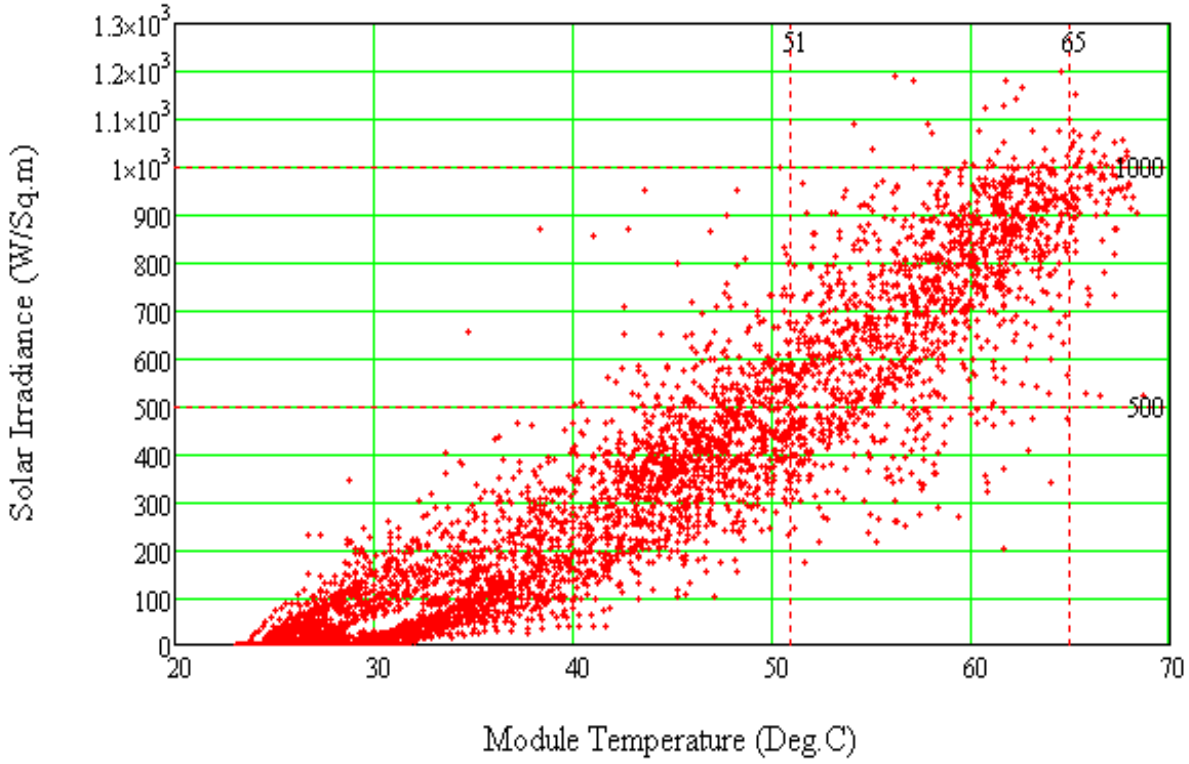
- **2 free standing Solar farm scale**
  - Good system 😁
  - Bad system 😕
  - Both system are operating more than 3 years



8. ROOF TOP SYSTEM –Relationship between Solar Irradiance and Module Temperature

Relationship between solar irradiance and module temperature. Retrofitted on metal deck.

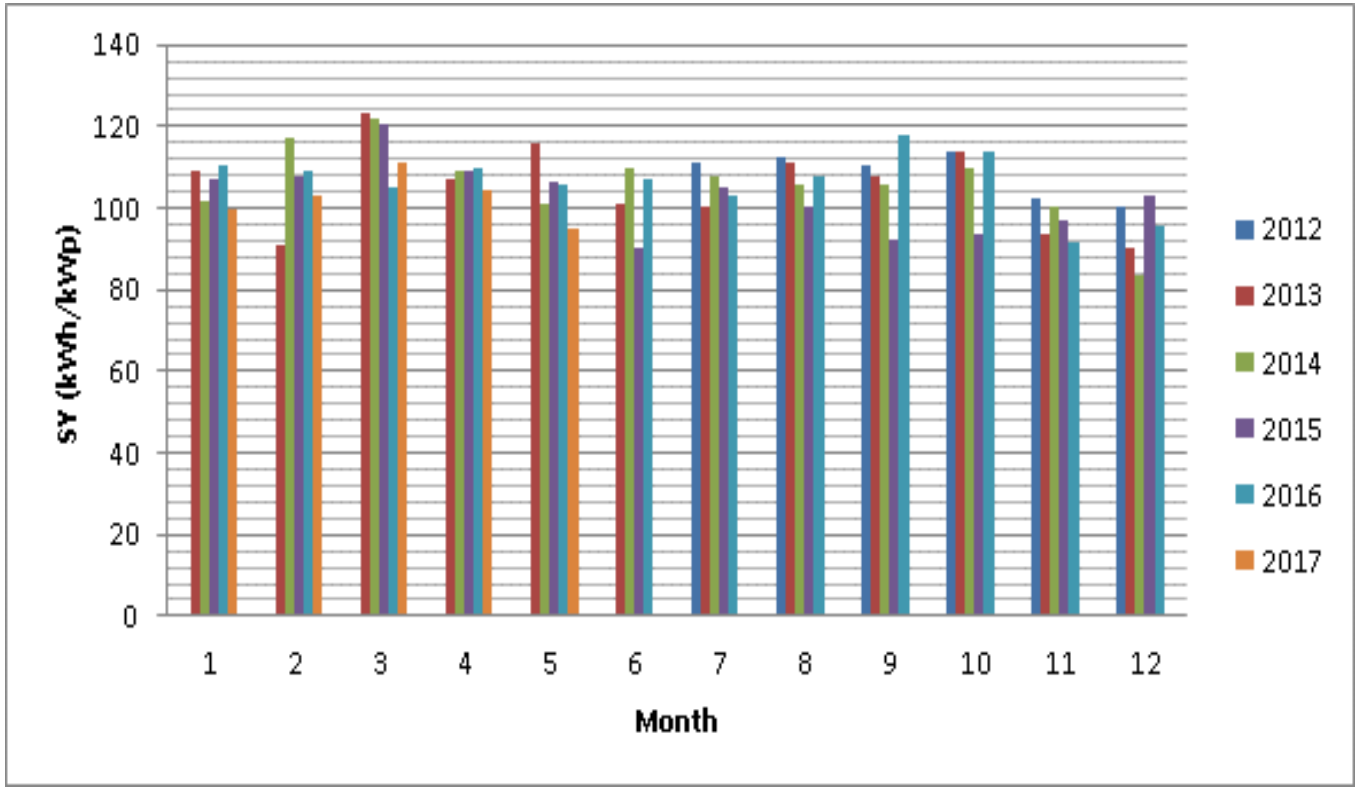




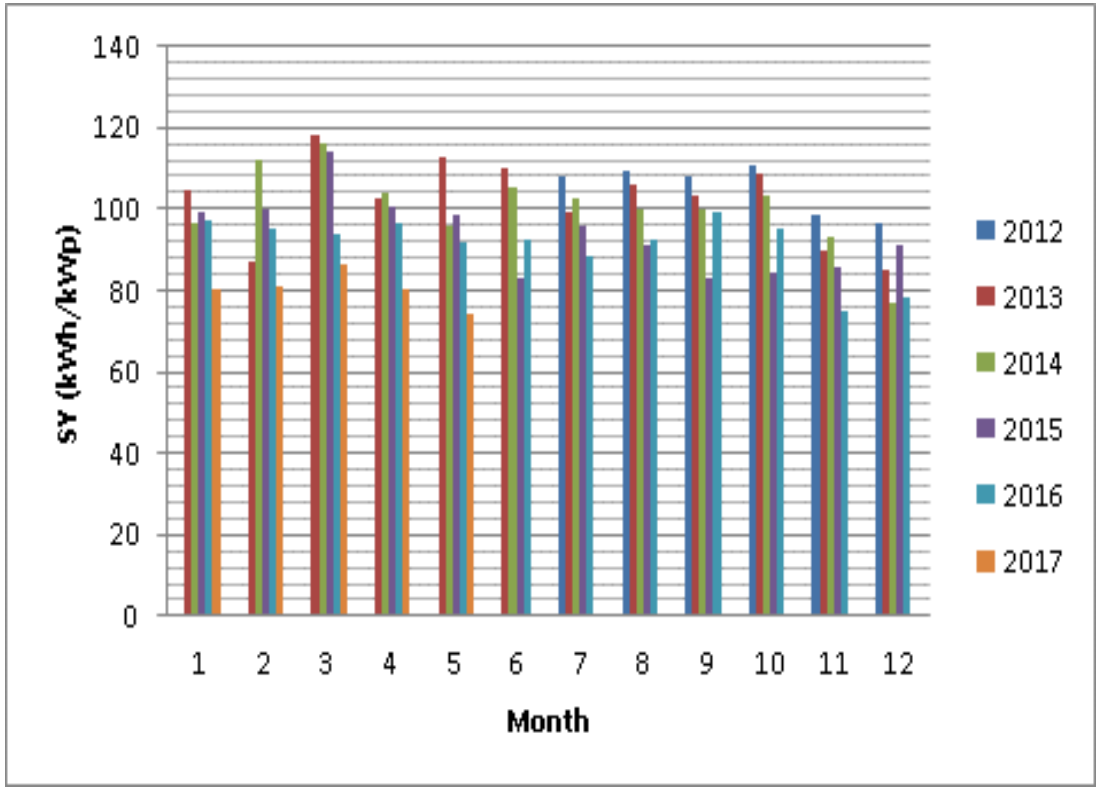
Note: Solar Irradiance (G) varies faster than Module Temperature (Tm)

8. ROOF TOP SYSTEM – Specific Yield

GOOD SYSTEM
Average Monthly SY > 100 kWh/kWp)



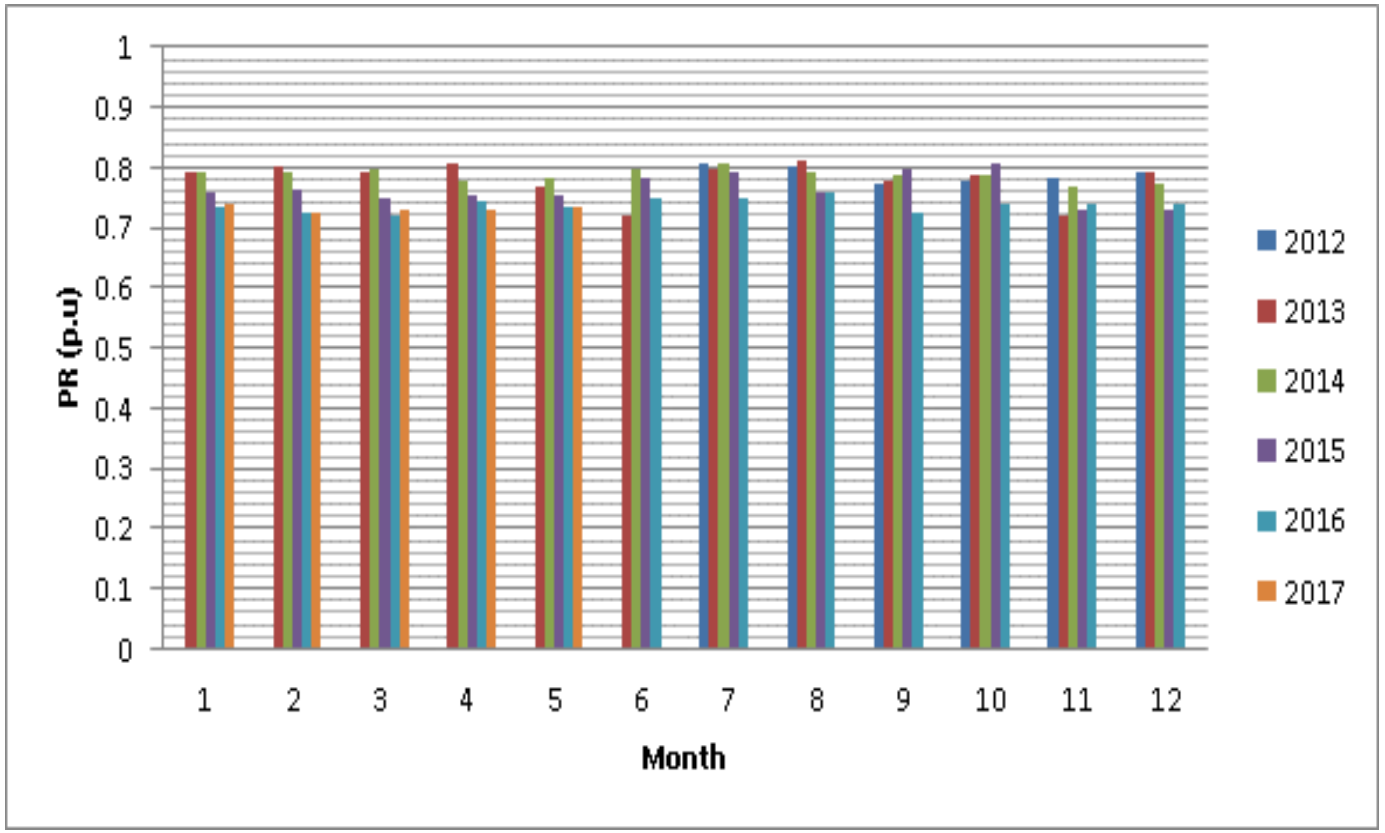
BAD SYSTEM



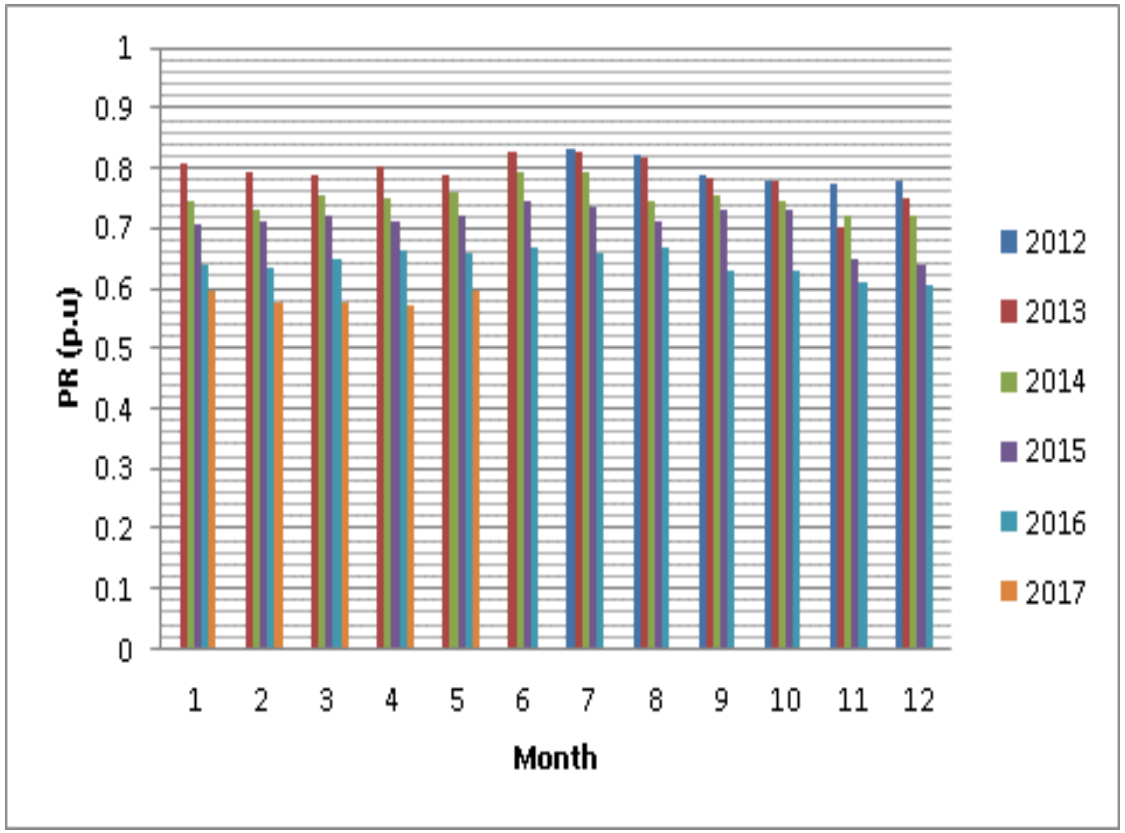
8. ROOF TOP SYSTEM – Performance Ratio

The performance ratio is a measure of the quality of a PV plant that is independent of location and it therefore often described as a quality factor.

GOOD SYSTEM
Average monthly PR > 0.75



BAD SYSTEM



Optimum analysis period = 1 year
Minimum analysis period = 1 month

8. ROOF TOP SYSTEM - Factors influence the PR value

$$PR = \frac{E_{measured}(kWh)}{E_{ideal}} = \frac{E_{measured}(kWh)}{P_{array\_stc} \times PSH_{period}}$$

PR > 75% good system

Environmental factors :-

- Temperature of the PV module and ventilation
- Solar irradiation, incomplete use of irradiance by reflection from the module front surface
- power dissipation
- The sensors are in the shade or soiled
- PV module in the shade or soiled

8. ROOF TOP SYSTEM - Factors influence the PR value

Other factors :-

- Recording period
- Conduction losses
- Efficiency factor of the PV modules
- Efficiency factor of the inverter
- Differences in solar cell technologies of the measuring gage and of the PV modules
- Orientation of the measurement gage
- Aging
- system down-time
- component failures
- Light induced Degradation ~ Power stabilization 3% for 1st year operation. Power degradation ~ 0.8%.

8. ROOF TOP SYSTEM - Factors influence the PR value

- PR values are typically reported on a monthly or yearly basis.
- Values calculated for smaller intervals, such as weekly or daily, may be useful for identifying occurrences of component failures.
- Decreasing yearly values may indicate a permanent loss in performance

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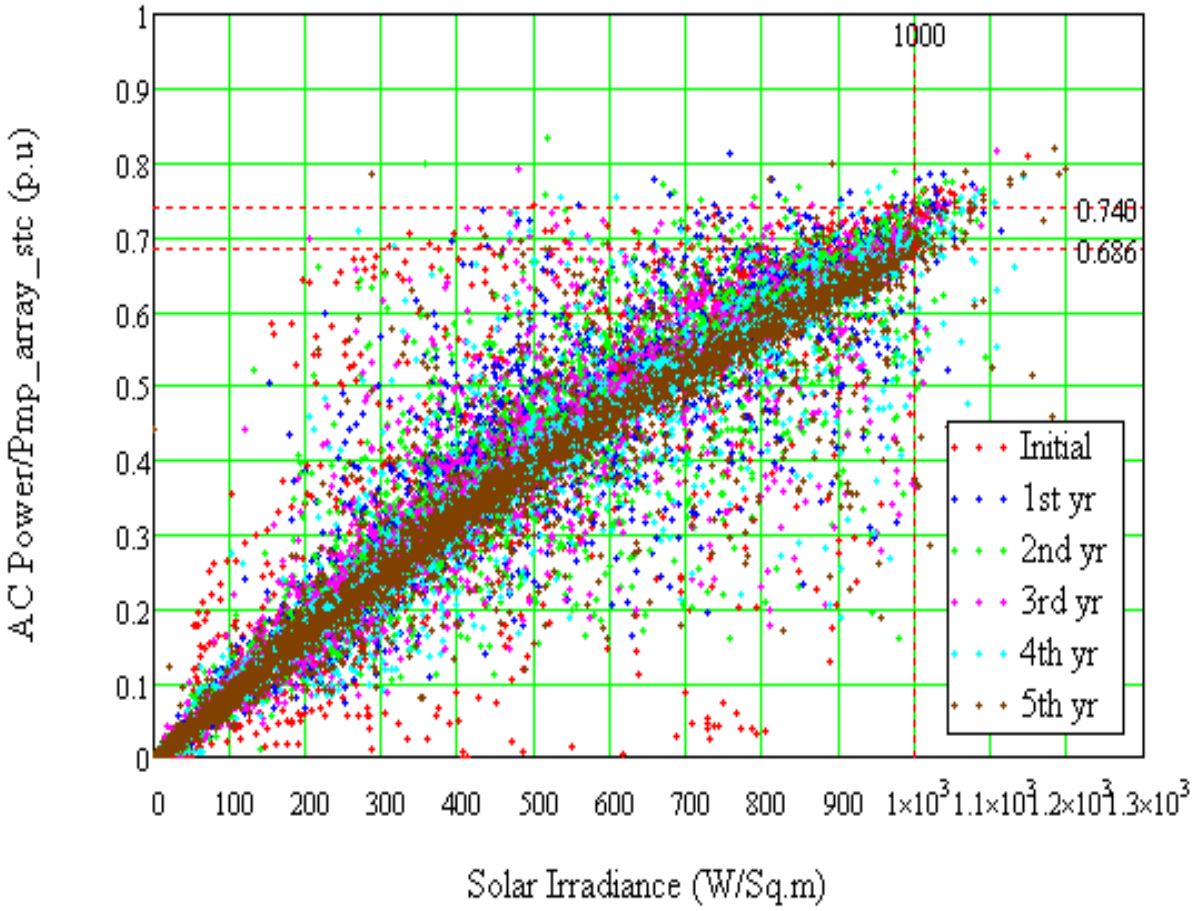
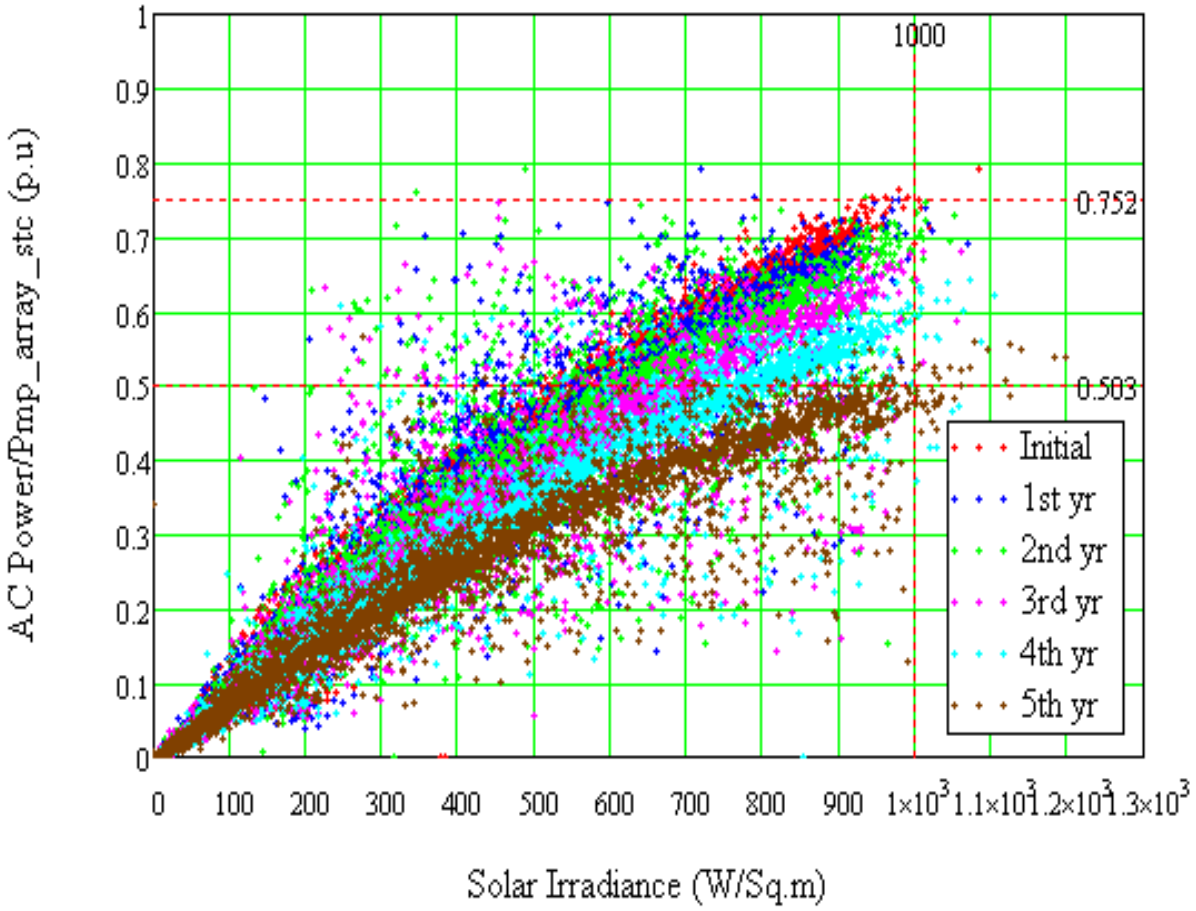
8. ROOF TOP SYSTEM – AC Power Output

GOOD SYSTEM



AC power drop: 7.29%

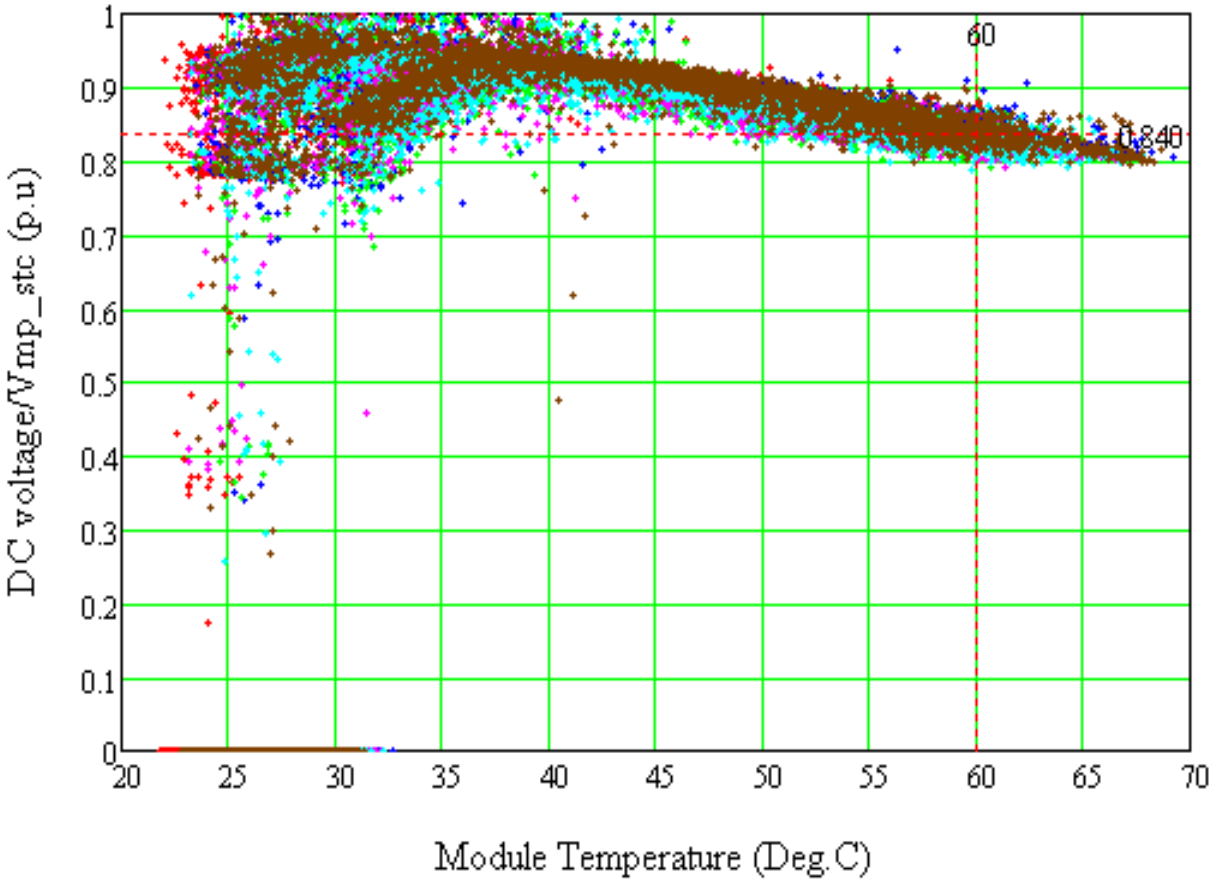
BAD SYSTEM



AC power drop: 33.11%

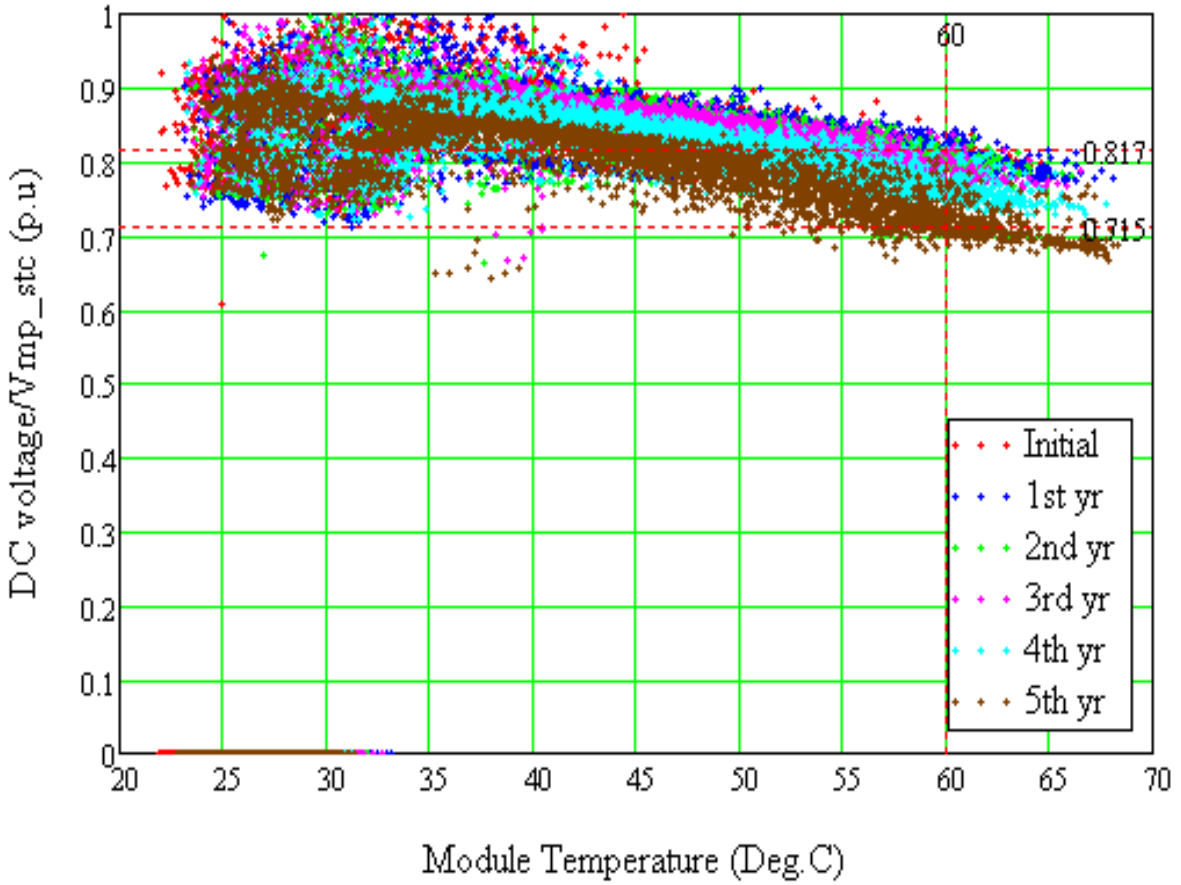
8. ROOF TOP SYSTEM – DC String Voltage

GOOD SYSTEM



String voltage drop: Insignificant

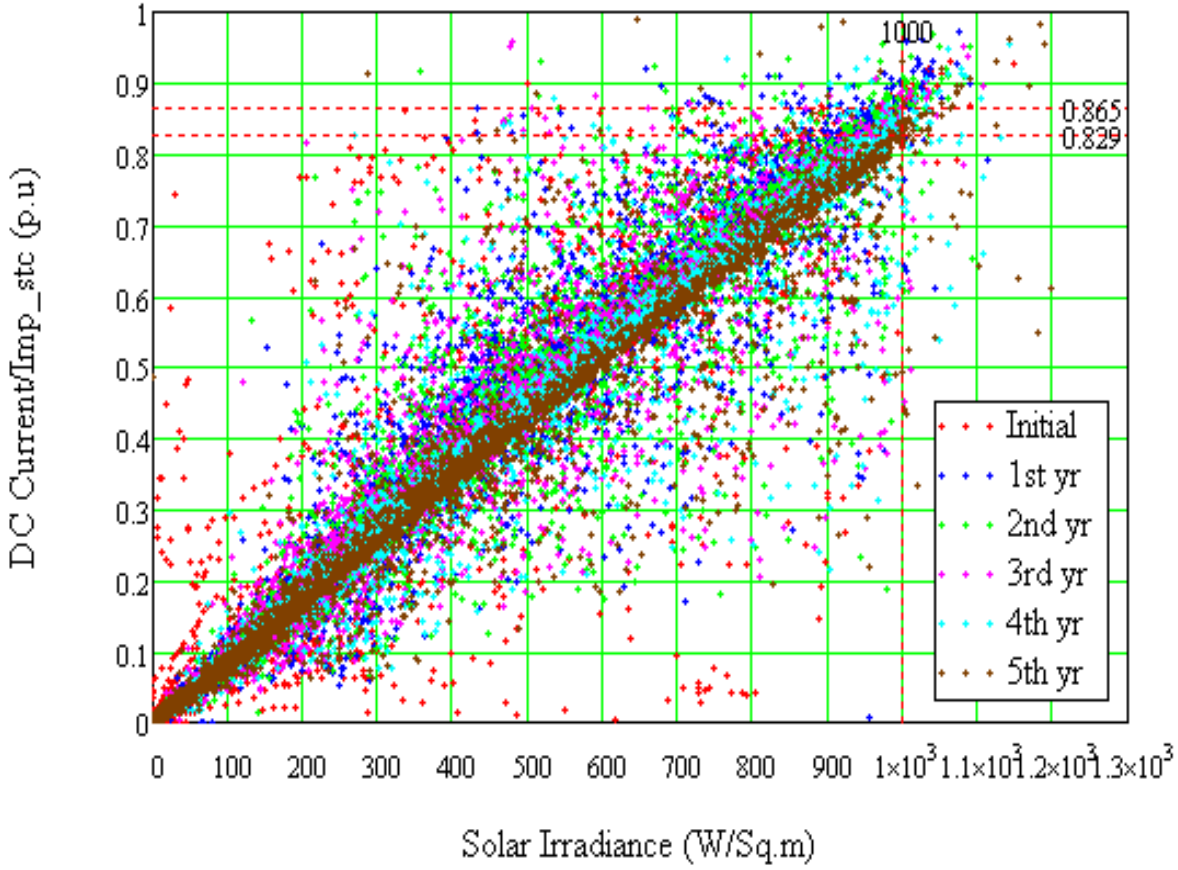
BAD SYSTEM



String voltage drop: 12.48%

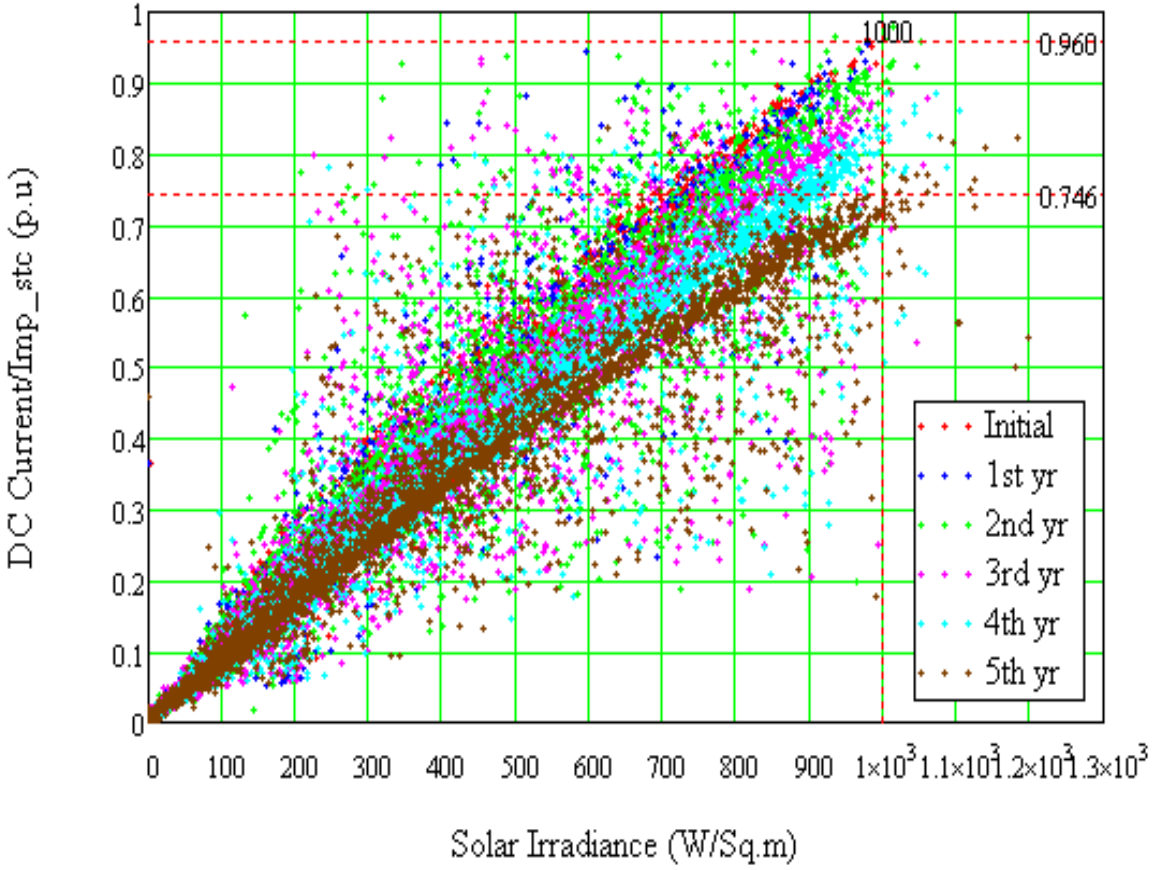
8. ROOF TOP SYSTEM – DC String Current

GOOD SYSTEM



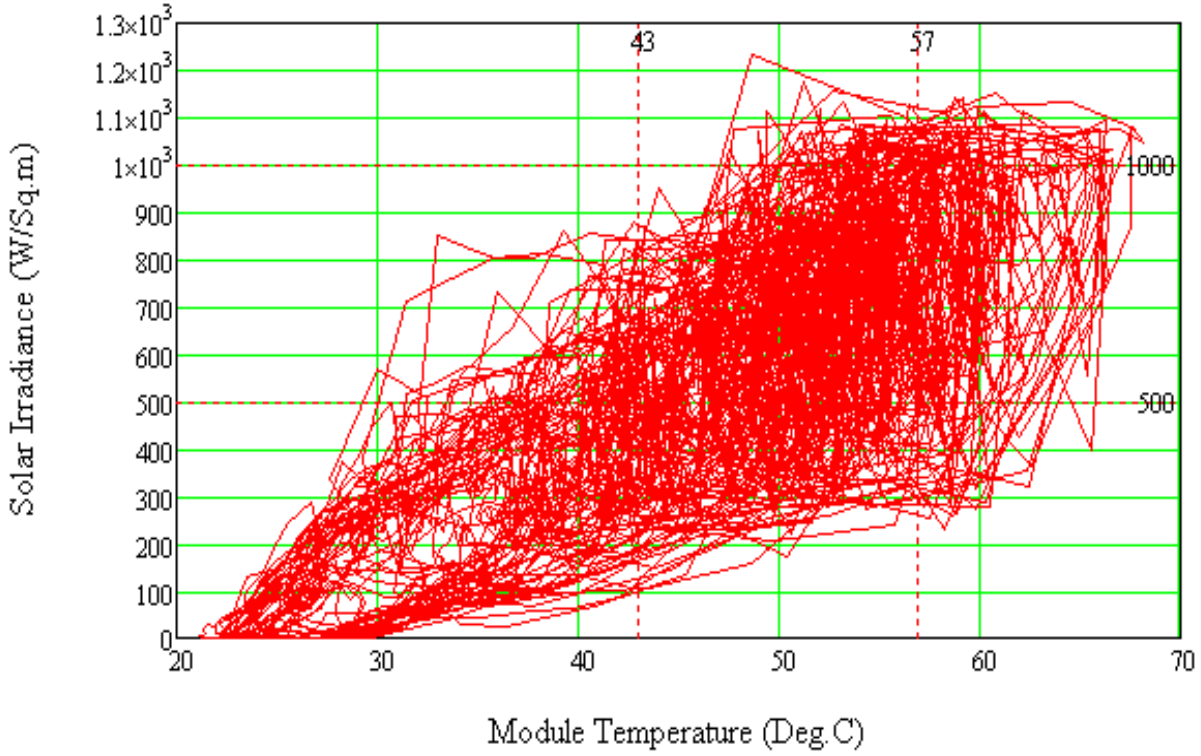
String current drop: 4.16%

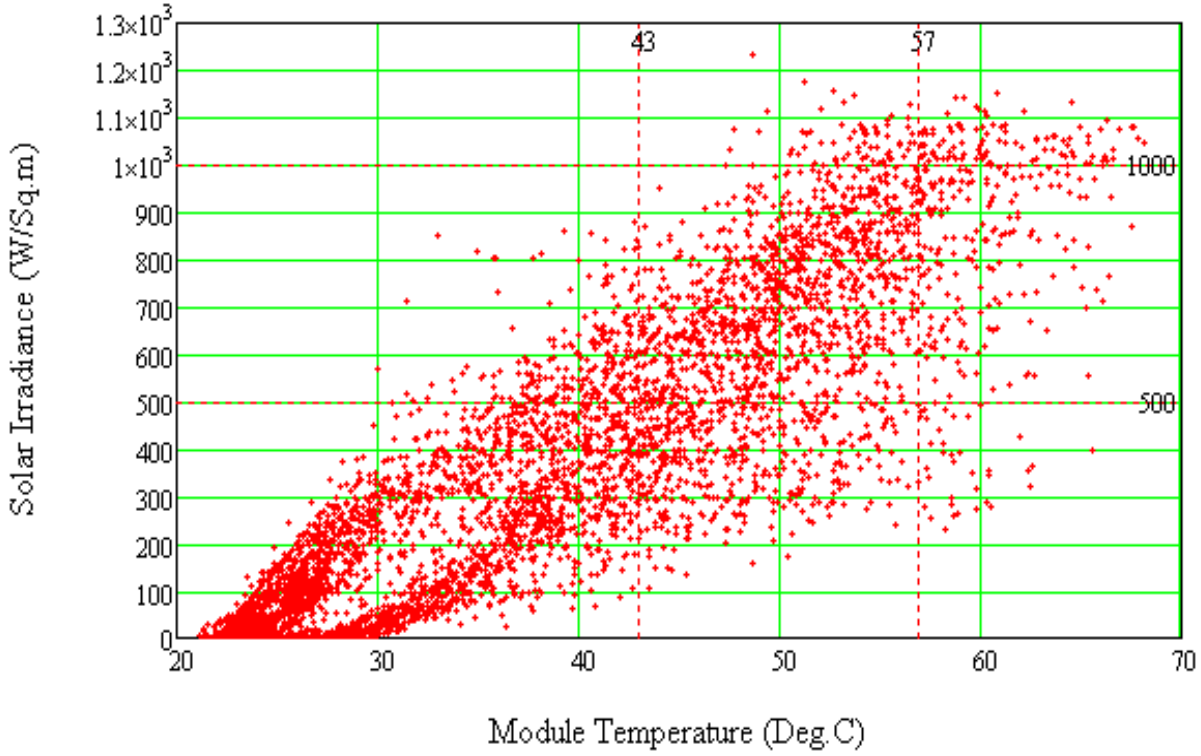
BAD SYSTEM



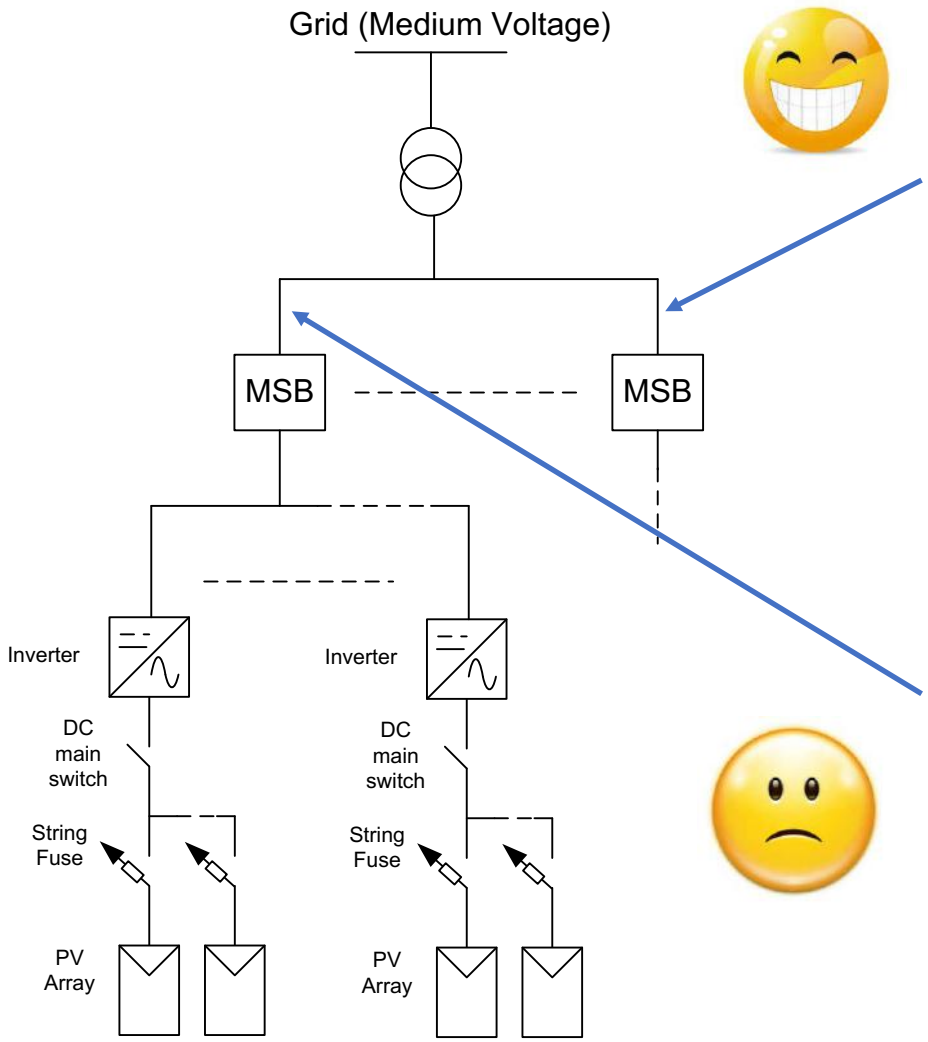
String current drop: 22.19%

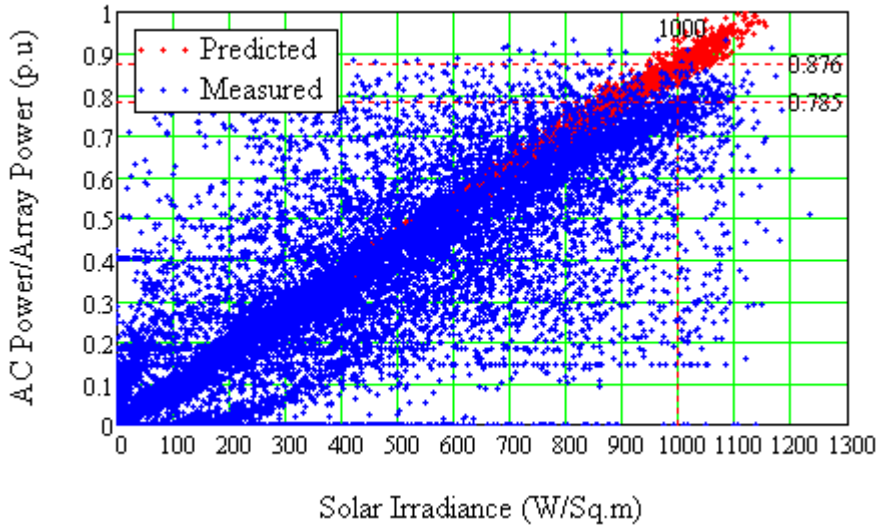
9. FREE STANDING STRUCTURE - Relationship between solar irradiance and module temperature





9. FREE STANDING STRUCTURE - AC power output at MSB

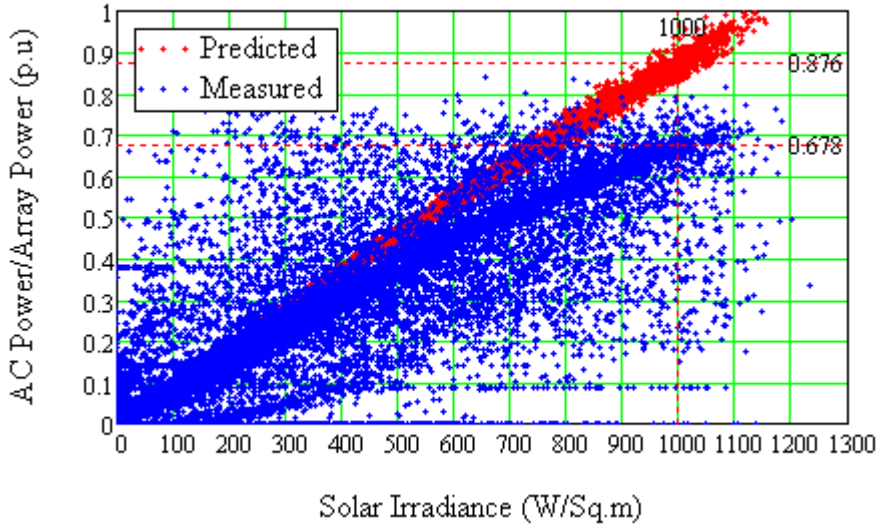




Power drop: 10.3%

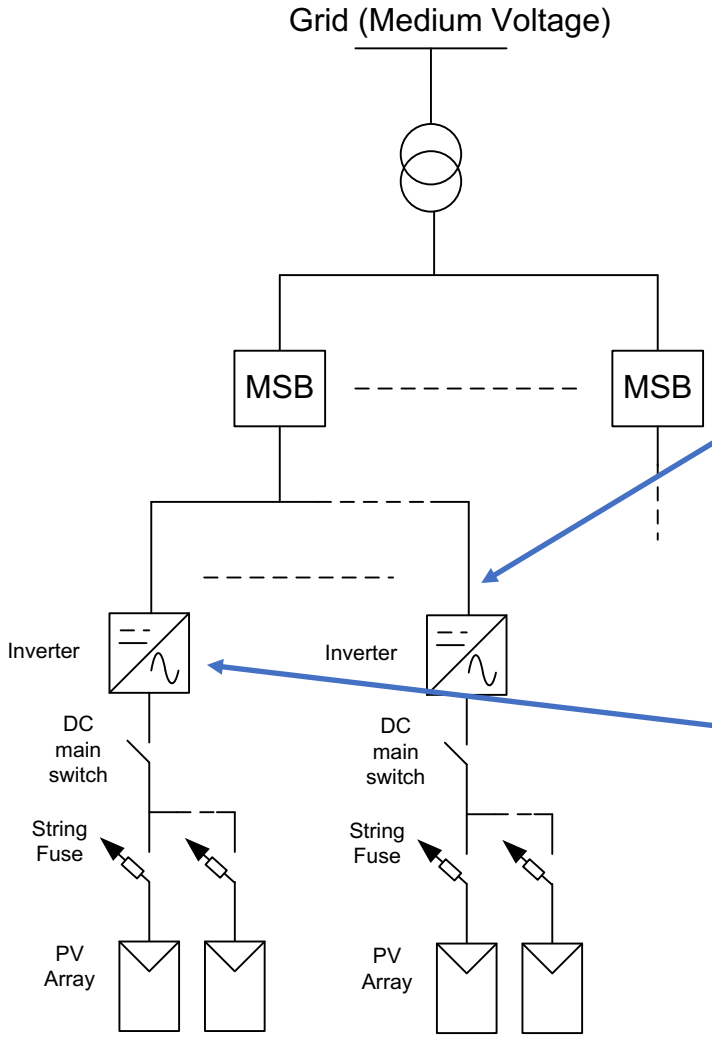
Power drop due to: -

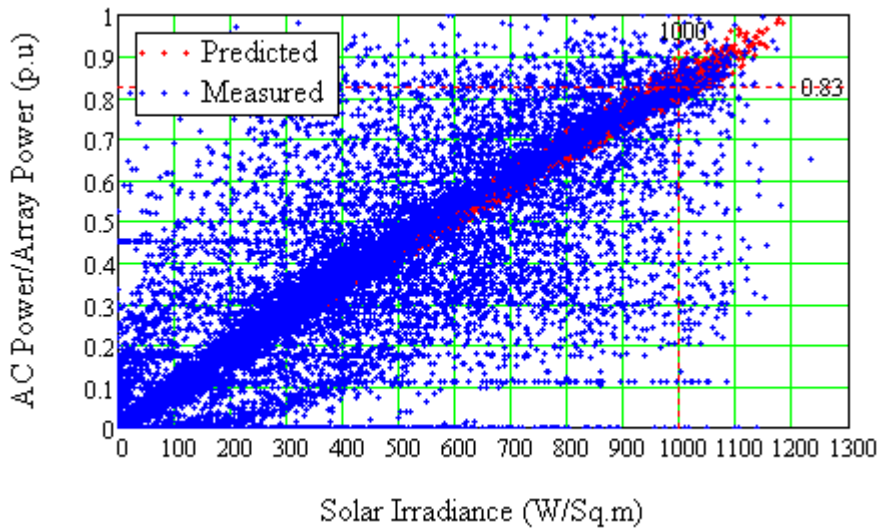
1. Cable lose
2. Temperature
3. Dirt
4. Inverter
5. Anomaly factor
   a. Hot spot
   b. Micro crack
   c. Bypass diode
   d. PID
   e. LID



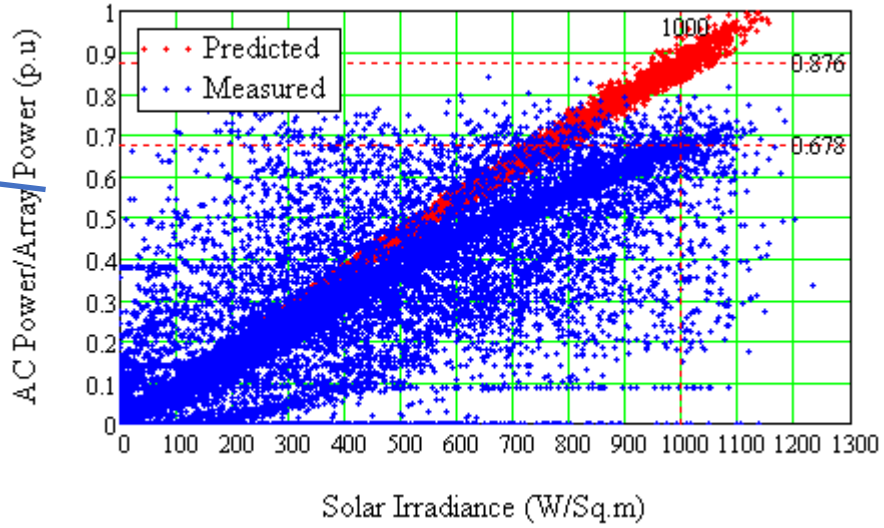
Power drop: 22.6%

9. FREE STANDING STRUCTURE - AC power output at inverter





Power drop: insignificant



Power drop: 22.6%

10. CONCLUSION

1. Comparing the simulated output power with the measured output power, if the output power loss rate exceeds 15%, it can be judged that an abnormal power loss has occurred
2. Taking into account the irradiation of several measurement points where the abnormal power loss occurred, if the irradiation drops suddenly, it can be judged that the power loss comes from the shadow, elsewise it comes from the faults
3. Using the open circuit voltage of the module to determine whether the short circuit fault has occurred and roughly estimate the number of cells which are short-circuited
4. Calculating the fill factor (FF) based on the condition of irradiation and temperature. It can determine whether the aging fault has occurred and obtain the degree of the aging fault based on the value of FF.

THANK YOU