



Information Exchange Meeting with CONSUEL

Completion Inspections and Periodic Inspections at PV Power Plants in Japan

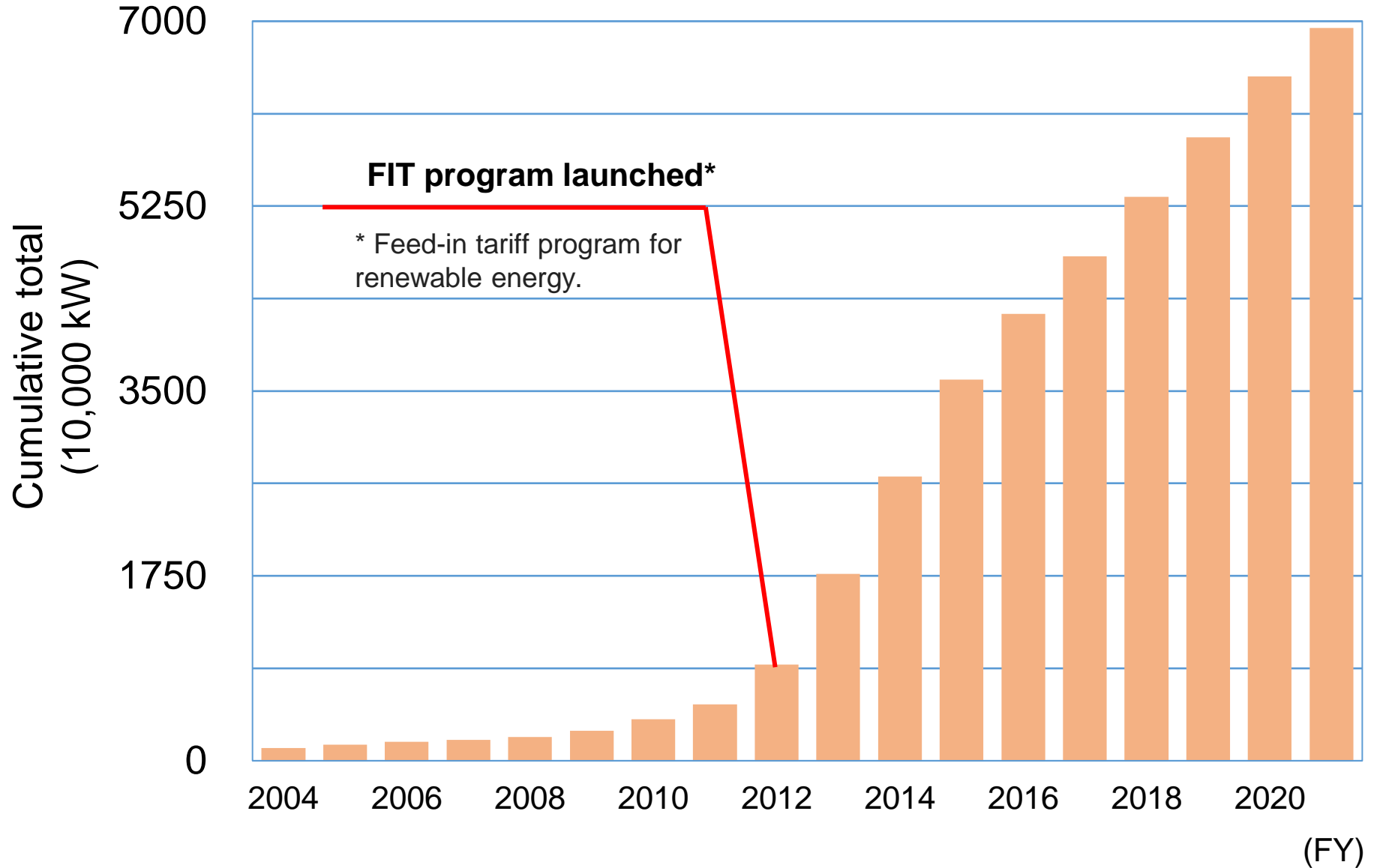
Forum of Electrical Safety Inspection Associations

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PV Power Generation Capacity (Output) Installed in Japan





Since the start of the FIT program, PV power generation facilities from 10kW to less than 50kW have been met with accidents caused by natural disasters, including modules being blown around and arrays collapsing.



Fires caused by panel damage



Growing social demand for ensuring the safety of power generation facilities resulted in expansions to the scope of security regulations.



Revisions to Laws on PV Power Generation Facilities (March 2023)

| Classification | Electric Facilities for General Use | Electric Facilities for Small Businesses | Electric Facilities for Private Use |
|--|-------------------------------------|--|-------------------------------------|
| Power output | Less than 10 kW | 10 kW or more Less than 50 kW | 50 kW or more Less than 500 kW |
| Obligation to comply with the Technical Standards for Electric Equipment | Yes | Yes | Yes |
| Obligation to maintain electrical facilities in conformity with the Technical Standards for Electric Equipment | No | No → Yes | Yes |
| Pre-use self-check | Not required | Not required → Required | Not required → Required |

Must appoint licensed chief engineer



Inspections for PV Power Generation Facilities

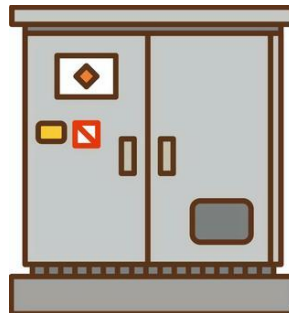
- Completion inspection
Checking that electrical facilities comply with the Technical Standards for Electric Equipment before they are used.
- Periodic inspection
Identifying the degree of deterioration and abnormalities during operation in order to maintain sound conditions through proper maintenance.

- Inspection under power outage conditions

Inspection frequency: Once a year

- Inspection under operating conditions

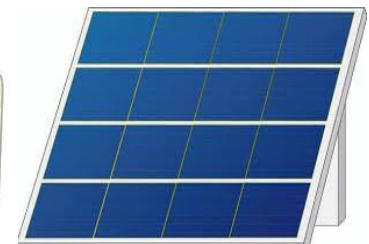
Step-up
transformers



PCS



Arrays



Inspection frequency: Once every 2-6 months

Once every 6 months



Inspections for PV Power Generation Facilities

| Items | Completion inspection | Periodic inspection | |
|--|-----------------------|---------------------|--------------------------|
| | | During outage | During operation |
| Visual inspection | ○ | ○ | ○ |
| Grounding resistance measurements | ○ | ○ | — |
| Insulation resistance measurements | ○ | ○ | Leak current measurement |
| Protective equipment test | ○ | ○ | — |
| Dielectric strength test | ○ | * | — |
| Unit interlock test | ○ | * | — |
| Control power loss test | ○ | * | — |
| Load rejection test | ○ | * | — |
| Load test | ○ | * | — |
| Circuit breaker related test | ○ | * | — |
| Remote monitoring control test | ○ | * | — |
| Checks of the design load, support structure, etc. | ○ | * | — |

* Tests carried out as necessary based on inspections results.



Determination criteria

Must not violate the Technical Standards for Electric Equipment.

Checking method

In completion inspections, checks are carried out to determine whether the power generation facility has been installed in compliance with the construction plan.

In periodic inspections, checks are carried out to find any changes to or deterioration of the facility.





Grounding Resistance Measurements

Determination criteria

Check that the grounding resistance of protective grounding applied to each device are within specified values.

| Application | Prescribed value |
|---|---|
| High-voltage equipment 600 VAC or higher, or 750 VDC or higher | 10 Ω or less |
| Low voltage equipment exceeding 300V | 10 Ω or less |
| Low voltage equipment 300V or lower | 100 Ω or less |
| To prevent voltage rise on the low voltage side of a circuit during a high and low voltage contact in transformers. | Tens of Ω to no more than hundreds of Ω^* |

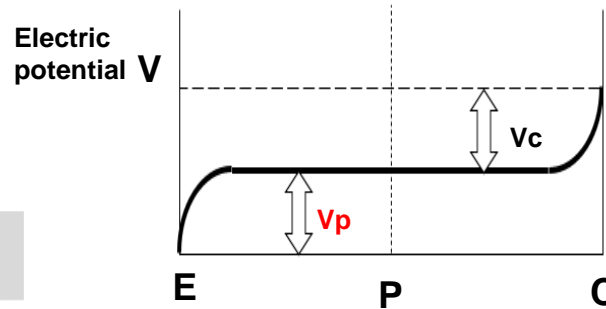
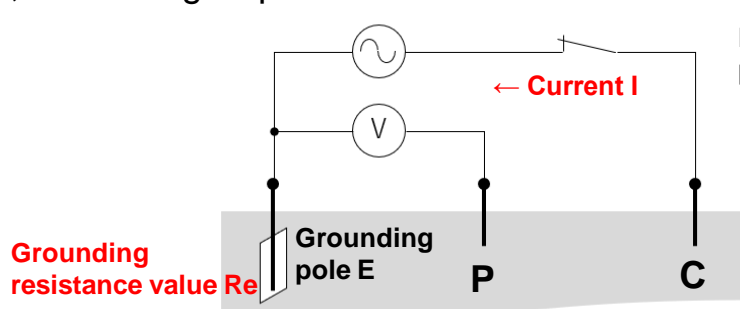
* Depending on ground-fault protection conditions

Checking method

Generally, the voltage drop method is used to measure the grounding resistance value.

[Voltage drop method]

Auxiliary poles P and C are driven into the ground at a distance away from ground line E, and ground resistance R_e is obtained based on current I that is caused to flow by the AC voltage applied between E and C, and voltage V_p between E and P.



Grounding resistance value $R_e = \frac{V_p}{I}$



Determination criteria

Check that insulation resistance values in electric circuits and electrical machinery/equipment are within prescribed limits.

| Classification of low-voltage circuits by voltage used | | Insulation resistance |
|--|--|-----------------------|
| 300 V or lower | Where voltage-to-ground* is 150 V or lower | 0.1 MΩ or greater |
| | Other cases | 0.2 MΩ or greater |
| Over 300 V | | 0.4 MΩ or greater |

* For grounded electric circuits, this refers to voltage between the circuit and ground, and for ungrounded circuits, refers to voltage between circuits.

Checking method

Apply DC voltage to the electric circuit and measure the resistance value between it and the ground.





Determination criteria

Check that electrical circuits and machinery/equipment have insulation performance appropriate for the voltage used.

Checking method

Determination criteria: The equipment shall have the performance to withstand the test voltage applied continuously between the circuit and the ground for **10 minutes**.

| Type of electric circuit | Test voltage |
|--------------------------|--|
| AC | AC voltage 1.5 times the maximum working voltage (500 V if this comes to lower than 500 V) |
| DC | DC voltage 1.5 times the maximum working voltage (open circuit voltage), or AC voltage equal to the same (500 V if this comes to lower than 500 V) |
| PCS | Normal voltage-to-ground for systems that have been checked to conform to the electrical performance prescribed in the standard. |
| Module | Test is waived for modules that have been checked to conform to the electrical performance prescribed in the standard. |



Determination criteria

Check that circuit breakers, fault indicators, alarm devices, open/close indications on circuit breakers, etc., are in good working order.

Checking method

Check that circuit breakers and other devices work together by actually operating the relay or by manually closing the contacts.

Major relays

- Ground-fault overvoltage relay
- Ground-fault relay
- Ground-fault directional relay
- Overcurrent relay

Major circuit breakers

- Vacuum circuit breaker
- Wiring circuit breaker
- Power fuse

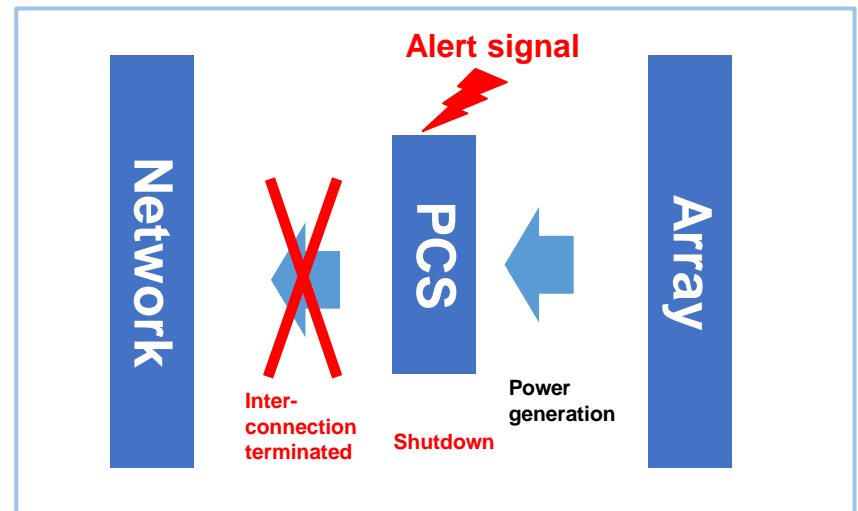
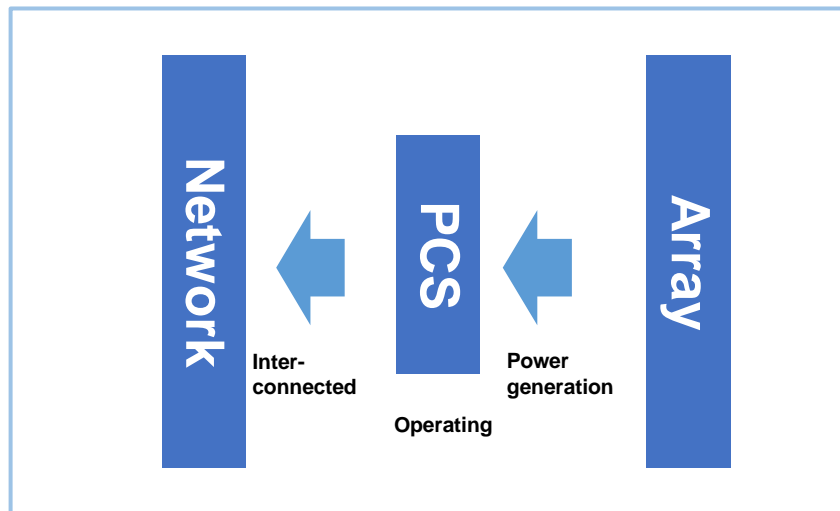


Determination criteria

The power generation facility shall automatically and safely shut down, and associated alarms, indicators, etc., shall operate normally.

Checking method

Operate the power generation facility under a light load, simulate accidents for each of the electrical and mechanical elements that cause the unit interlock to be activated, and trigger the associated protective relay devices in response to actual operations or by manually closing the contacts.





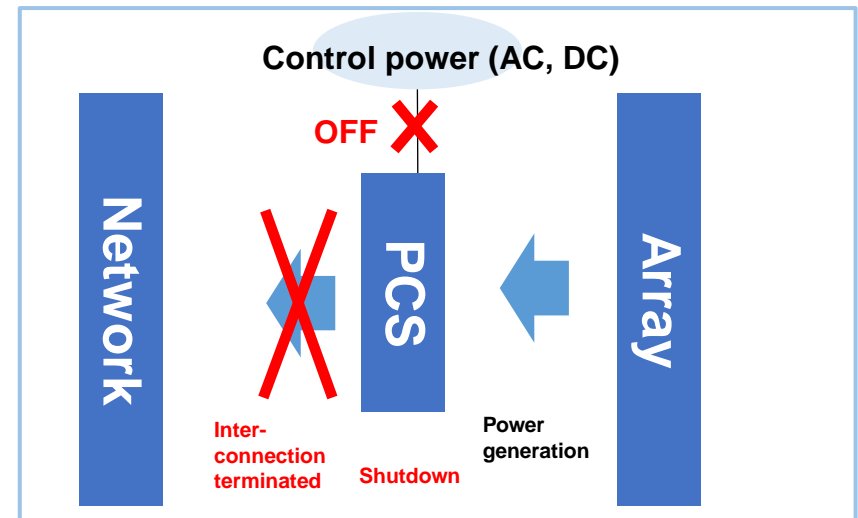
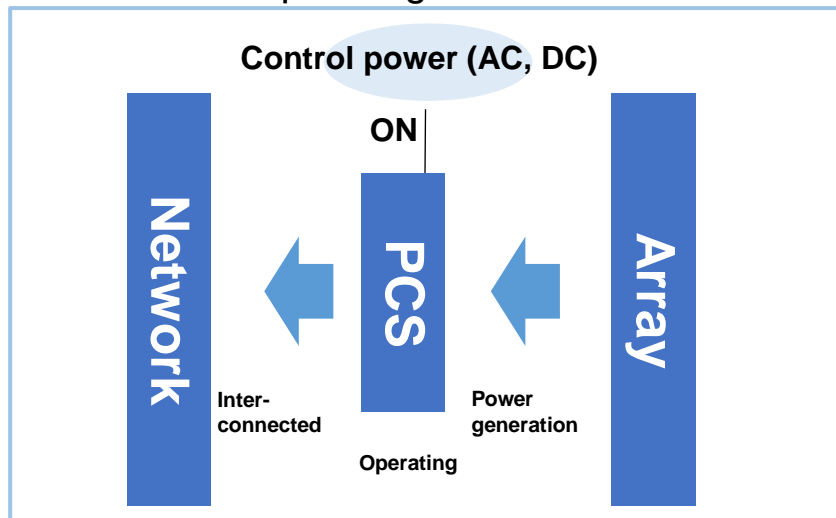
Determination criteria

The power generation facility shall automatically and safely shut down, and associated alarms, indicators, etc., shall operate normally.

Additionally, there shall be no anomalies in the measurement results, and circuit breakers and switches shall operate normally.

Checking method

Measure voltage and current, and check the opening and closing of circuit breakers and switches as well as alarms and indicators when the power generation facility's control power is shutdown while operating.





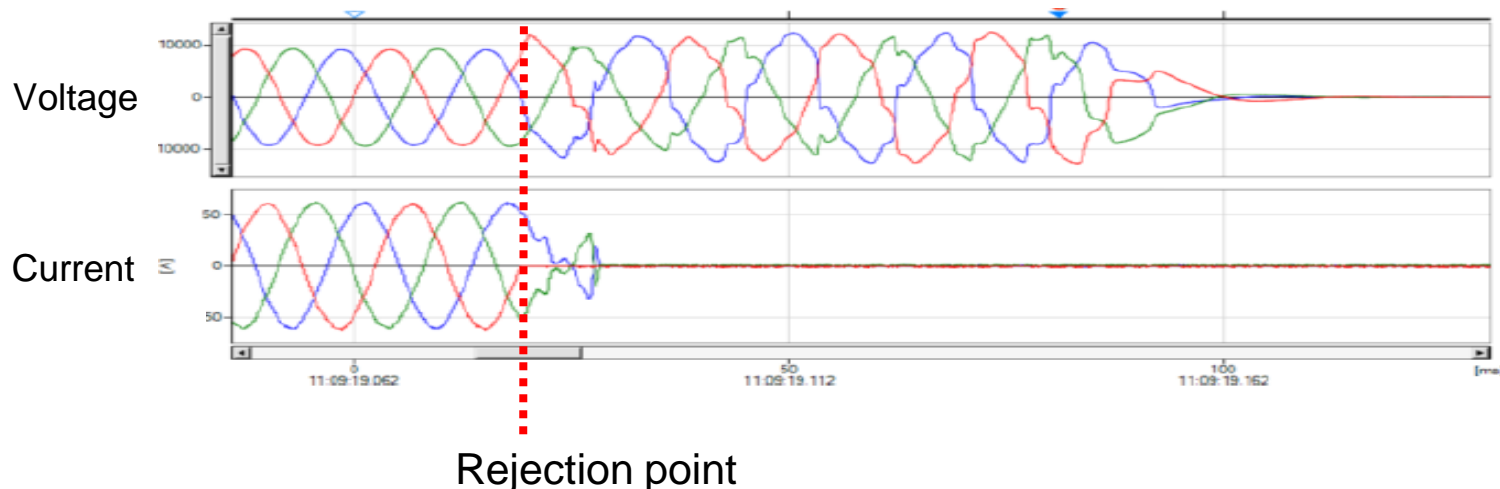
Determination criteria

The transient changes in voltage at load rejection shall be within the limit value, and the power generation facility shall automatically and safely shut down.

Checking method

Record and check the transient changes in generated voltage when load is rejected.

Start by rejecting load at 1/4 load operation. If no problems are found here, increase loads in stages to 2/4, 3/4 and 4/4 of load operation.





Determination criteria

No abnormality shall be found when the power generation facility is operated at its rated operation.

Checking method

Operate the power generation facility continuously, maintaining the rated output, rated voltage, and rated power factor as much as possible until the temperature of various components of the equipment reaches saturation, and check the inverter, transformer, etc., for any abnormal rises in temperature, abnormal vibration, abnormal sounds, etc., as well as for any voltage distortion, etc.

Examples of allowable temperatures for different electrical equipment

| PV power generation equipment | Max. allowable temperature |
|-------------------------------|--------------------------------|
| Transformer | Ambient temperature plus 60° C |
| PCS | 60° C |
| Switch, circuit breaker | 75° C |

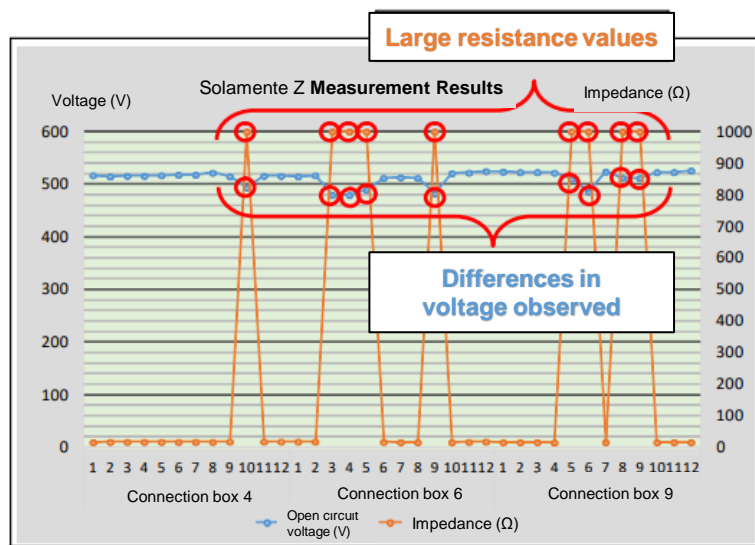


Objective

Check strings for any initial defects and their polarity, and check to see that there are no abnormalities such as breaks or misconnections.

Checking method

Measure open circuit voltage and resistance values, and diagnose by comparing these values with design values and values from other individual strings.



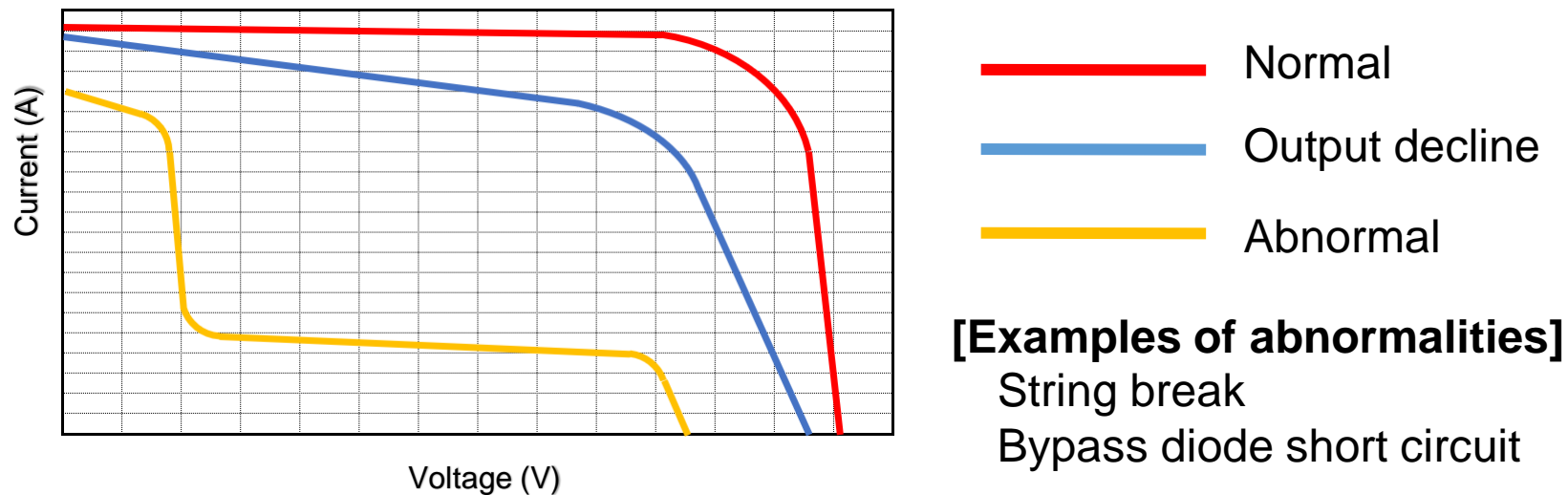
| Failure mode | Failure modes by string and their identification | |
|----------------------------|--|------------------|
| | Open circuit voltage | Resistance value |
| Normal | Normal | Low |
| Cluster break | Low | Very high |
| High cluster resistance | Normal | High |
| Bypass diode short circuit | Low | Low |



Objective

Check strings for any initial defects and their polarity, and check to see that there are no abnormalities such as breaks or misconnections. Save these results as records of their initial performance, and use them later in diagnoses of output degradation over time.

Checking method



[Examples of abnormalities]

String break

Bypass diode short circuit

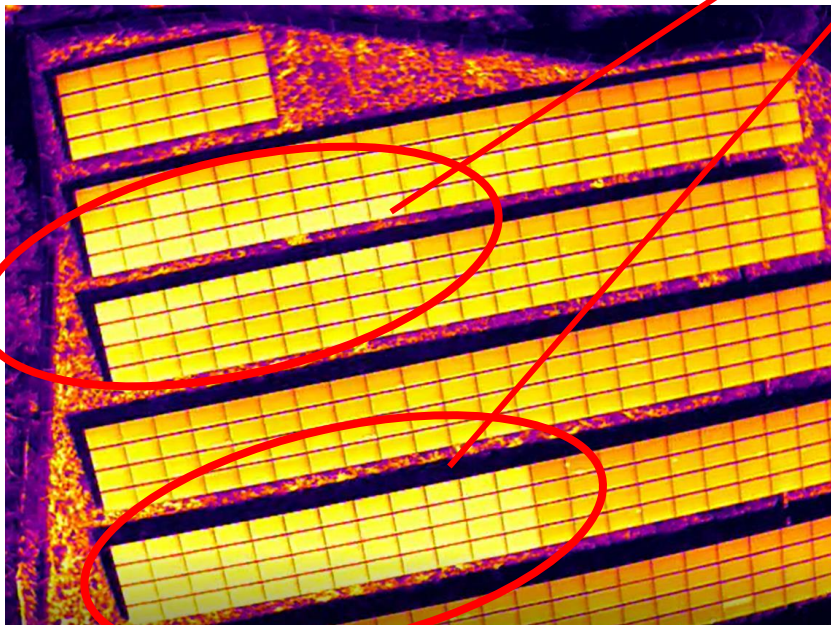
I-V characteristics



Using drones

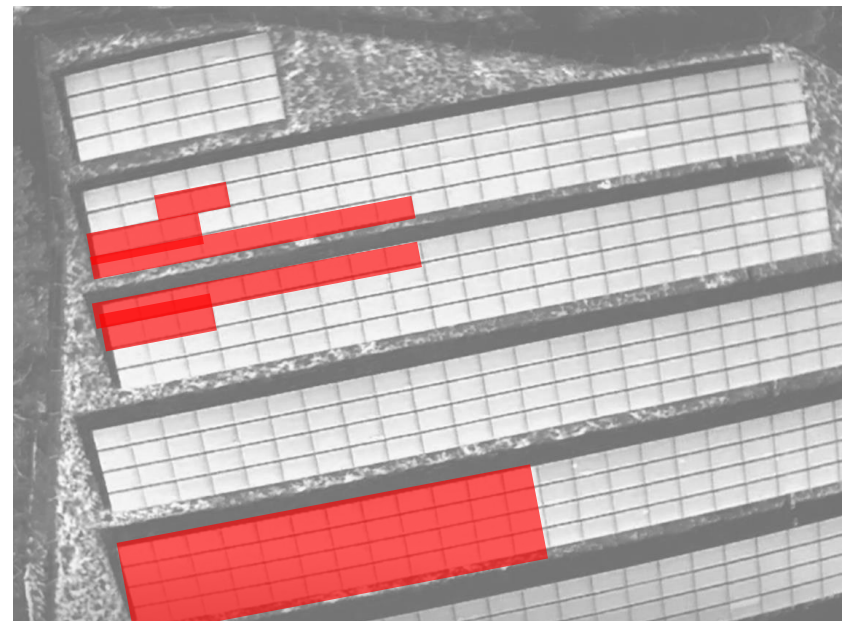


Aerial
photography



Heated areas

Module failure areas





Summary

Electrical safety in Japan is ensured through completion inspections and periodic inspections based on technical standards set by the government.

Regarding PV power generation facilities, the government has just recently increased its involvement to ensure the safety of small-scale power generation facilities, which it had not previously covered.

Proper maintenance is expected to ensure a safe and high quality supply of energy.