Standard Specifications of PCS

First edition	March 12, 2020
Second edition	August 25, 2020
Third edition	June 4, 2021
Fourth edition	December 6, 2021
Fifth edition	April 14, 2022
Sixth edition	September 14, 2023
Seventh edition	April 9, 2024

The Japan Electrical Manufacturers' Association

Revision Record

Revisions in the second edition (August 25, 2020)

- Replaced the order of 2(4) and (5) and added explanation for (5)
- Added new item 2(6) (expanded the flicker countermeasure to 1 Hz)

Revisions in the third edition (June 4, 2021)

1. Added explanation of reference value for UFR settling value
3. Added new error for rated output

Revisions in 4th edition (December 6, 2021)

2. (7) added (Flicker prevention STEP3.2)

Revisions in the 5th edition (April 14, 2022)

4. Allowable frequency in parallel added

Revisions in the 6th edition (September 14, 2023)

4. (3) "Separate settling values should be settable for 50Hz and 60Hz areas" deleted
5. Addition of an example of Islanding operation occurrence when a high voltage cutout is opened on a pole transformer

Revisions in the 7th Edition (April 9, 2024)

2. Added calculation delay time for frequency change and reactive power change start time in step injection
4. Added operating waveform examples and notes on allowable frequency in parallel

Purpose of this document release

In the development of power conditioners, the specifications are based on related regulations such as the Grid Interconnection Regulations, etc. However, there have been calls for an industry standard since different companies have different specifications because they are not included in the Grid Interconnection Regulations, etc. Therefore, we have decided to publish the standard specifications as an industry standard and use them as a guide for design.

These are design guidelines and do not exclude other specifications. It does not apply retroactively to models produced to date. We hope you will take this into consideration when developing new models in the future.

With regard to "2. Standard specifications for frequency feedback method with step injection," we recommend that this be reflected in the actual equipment in view of the current situation where some power companies require this as a standard countermeasure against the flicker that is currently occurring.

1. Standard specifications for UFR/ OFR (limited to FRT-compatible models)

- UFR and OFR shall be able to be timed and level-established independently of each other.

- The level of UFR shall be

<50Hz area >
47.5 to 49.5Hz can be set.
The settling value should include 0.5Hz (=1%) increments.

<60Hz area>
57.0 to 59.4Hz can be set.
The settling value should include 0.6Hz (=1%) increments.

- Time limits should be able to be set from 0.5 seconds to 2.0 seconds, respectively. The settling value should include increments of 0.5 seconds. For standard settling values, refer to the grid interconnection rules and other related rules.

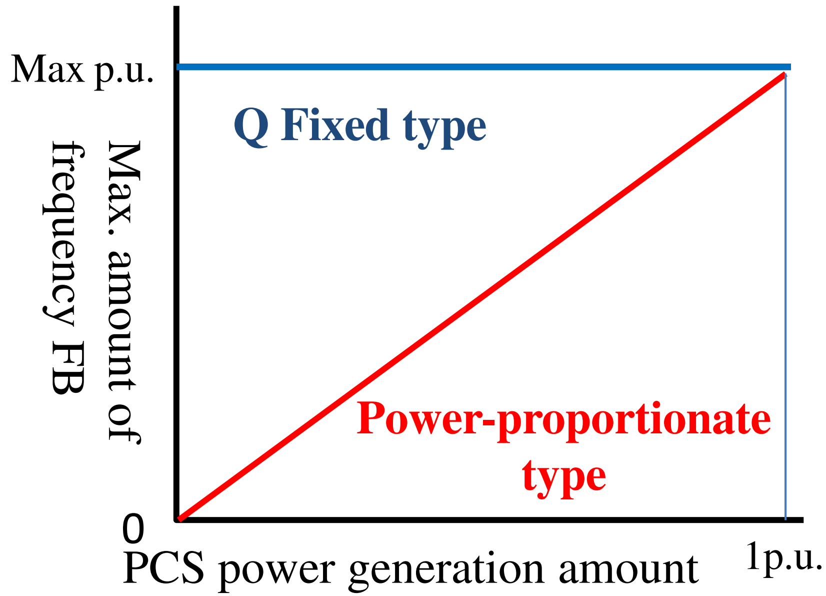
Reference: (as of May 2021)
The information on the change of the standard settlement value of UFR has been announced by the Wide-Area Electric Power Promotion Organization and each power transmission and distribution company.
Please note that the standard settlement values are subject to change depending on system conditions, so please be aware of the latest information. Quote. ：https://www.occto.or.jp/oshirase/sonotaoshirase/2019/190426_hatudensetubi_ufr_onegai.html

2. Standard specification for frequency feedback system with step injection.

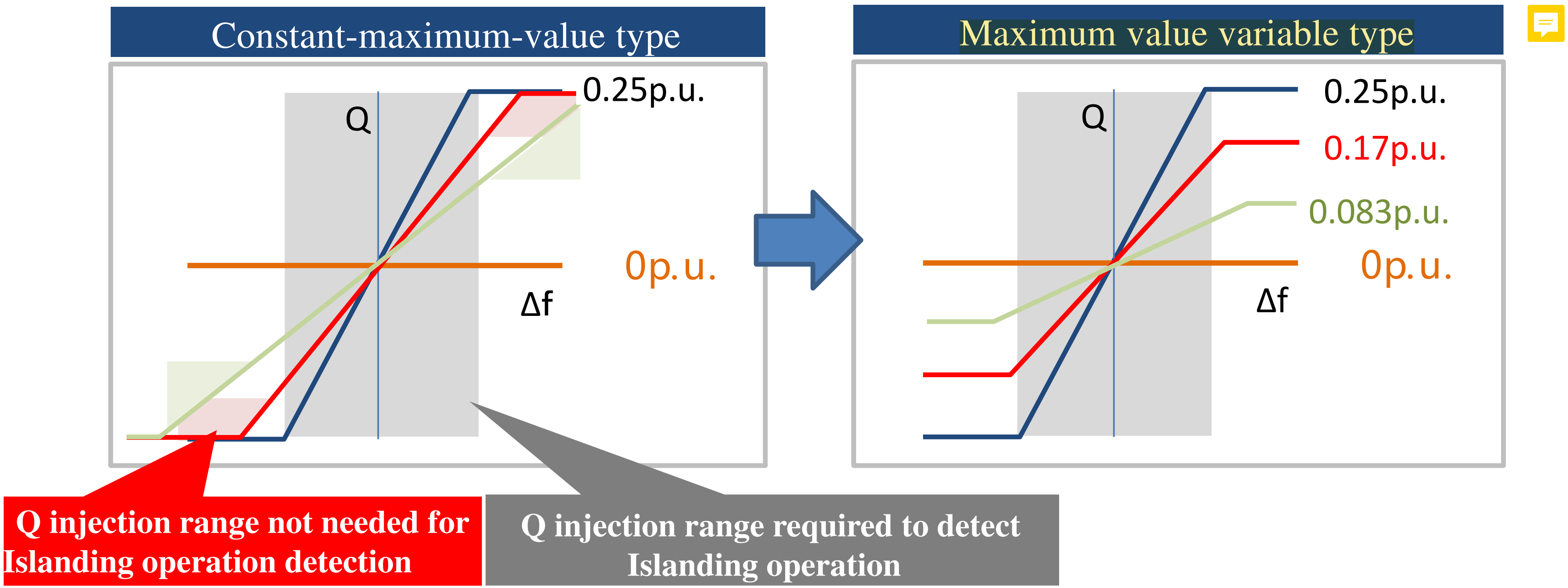
The JEM 1498 has been established as the standard active Islanding operation detection method. *This item (2. Standard specifications for frequency feedback method with step injection) also applies to the standard for three-phase machines, JEM 1505:2020.

1. In terms of the slope of the gain in the frequency deviation-injected reactive power characteristic, from the viewpoint of preventing flicker, a gain slope greater than 0.25PU/0.3Hz as specified in the grid interconnection regulation is undesirable, and a smaller slope is desirable. It should be noted that if the slope is large, the amount of injected reactive power increases in response to slight changes in frequency, which may cause flicker.
2. The system shall have a software switch or other switching means to allow intermediate values (e.g., 100%, 30%, 0%) to be set for the above slopes. The 100% and 0% setting values are mandatory. The switching means shall be operable by workers on site. This will be an effective means of implementing on-site countermeasures in the event of flicker.

3. Even when a 0% slope is set, the Islanding operation detection algorithm shall operate and the Islanding operation detection operation shall be enabled. This is an effective means of implementing local countermeasures when grid conditions require such countermeasures, although consultation with the general transmission and distribution utility is necessary.
4. The amount of injected reactive power shall be proportional to the output power (active power). In the case of models in which the injected reactive power is fixed at a certain value regardless of the active power, the amount of reactive power will be relatively large when the output power is small.



5. The maximum amount of reactive power injection should be adjustable. This is an effective means of preventing unnecessary injection of reactive power at large frequency changes that are unnecessary for the detection of Islanding operation, and of reducing the injection of reactive power due to grid disturbances. When the gain of the frequency feedback is reduced, the maximum value of reactive power should also be reduced to avoid unnecessary injection of reactive power for the detection of Islanding operation. (See the figure below for the characteristics of the variable maximum value type.)



(Reference) Advantages of Variable Maximum Reactive Power Injection Type

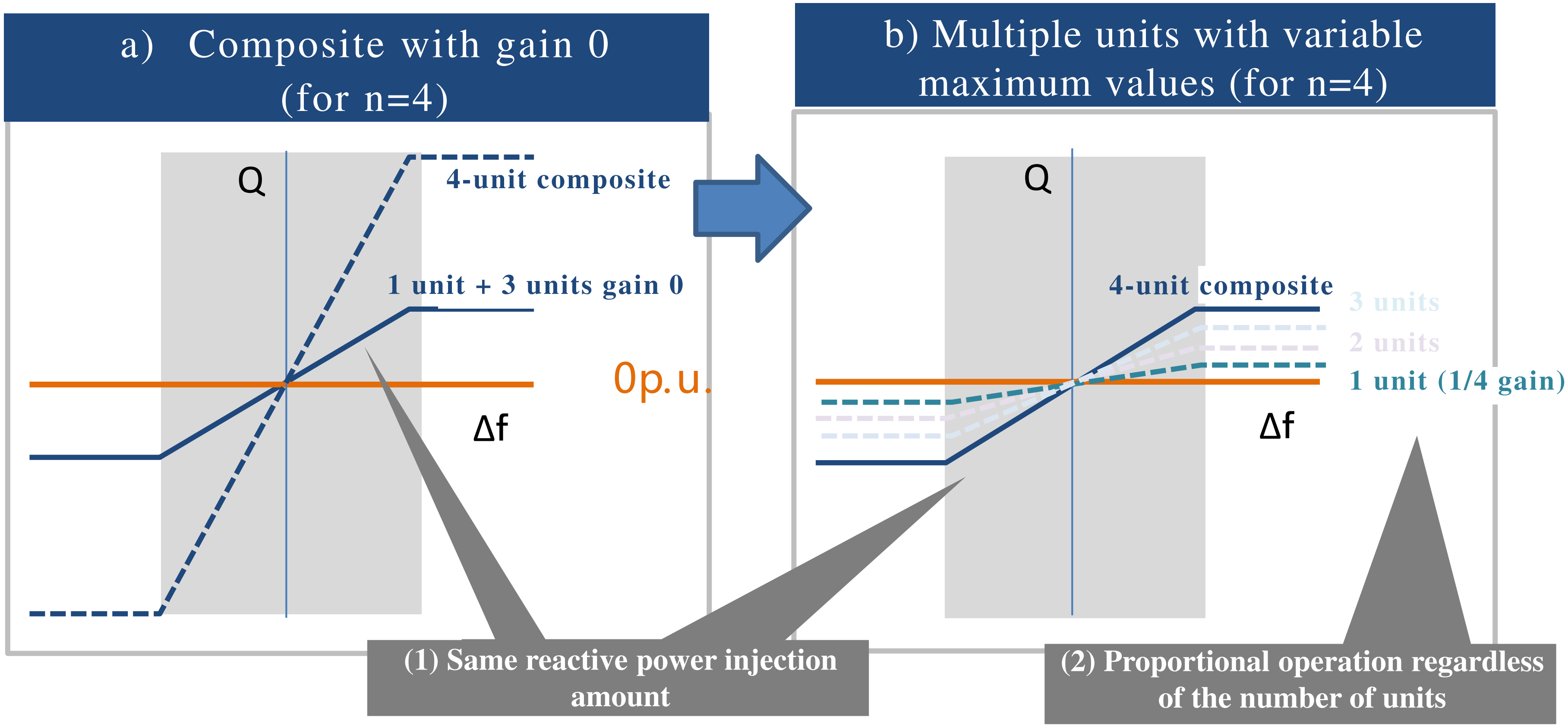
As a flicker countermeasure, for example, one out of four units may be operated with normal gain and three units with gain 0.

(a) Synthesis with gain 0: 1 unit with normal gain and n-1 units with gain 0 (method used for products installed in the market)

(b) Synthesis of n units of a product with multiple units of a variable maximum value type with the gain set to 1/n and the maximum injection amount set to 1/n

In these two cases, the reactive power injection amount is the same. (Figure 1)

In other words, the maximum value variable type has the same effect regardless of the number of PCSs installed at the power plant (Figure 2), which has the advantage of simplifying operation.



2. Standard specification for frequency feedback system with step injection.

6. The detection algorithm in "8.3 Disturbance detection 2 (continuous detection of low-amplitude frequency fluctuations)" of JEM1498 shall be **500 ms** to enable reactive power oscillation suppression control even for 1 Hz flicker. This is to contribute to system stabilization by attenuating reactive power injection even when lower frequency flicker occurs due to system conditions or other equipment.

JEM 1498:2017 8.3 Provisions for disturbance detection 2 (low amplitude frequency fluctuation continuous detection)
(Name: Flicker prevention STEP 3.0)
Within **165 ms** after the detection of a frequency deviation exceeding ±0.01 Hz, a frequency deviation exceeding 0.01 Hz is not detected with a polarity different from that of the detected frequency deviation.

↓

Changes specified in this section
(Name: Flicker prevention STEP3.1)
Within **500 ms** after detection of a frequency deviation exceeding ±0.01 Hz, a frequency deviation exceeding 0.01 Hz shall not be detected with a polarity different from the polarity of the detected frequency deviation.
This change is referred to as "Flicker Prevention STEP 3.1.

7. The detection algorithm in “8.3 Disturbance detection 2 (Continuous detection of low-amplitude frequency fluctuations)” of JEM1498 shall add the condition in paragraph b) below to (6). The algorithm shall shift the device to the standby state regardless of the flicker frequency, and shall consider a time limit that does not affect the detection of Islanding operation.

Change specified in this section from the provisions of JEM 1498:2017 8.3 Disturbance detection 2 (Low amplitude frequency fluctuation continuous detection)

(Name: **Flicker prevention STEP3.2**)

8.3 Disturbance detection 2

(Low amplitude frequency fluctuation continuous detection)

1. **Condition for continuous detection of low amplitude frequency fluctuation**

The condition for continuous detection of low amplitude frequency fluctuation is that either of the following a) or b) is satisfied.

a. If a frequency deviation exceeding 0.01 Hz of a different polarity from that of the detected frequency deviation is detected within 500 ms after the detection of a frequency deviation exceeding ±0.01 Hz (calculated according to 5.1), the number of low-amplitude frequency deviation detection counts is increased by one. Repeat this process until the number of low-amplitude frequency deviation detection counts reaches 12.

b. When the frequency deviation becomes within ±0.01 Hz after detecting a frequency deviation exceeding ±0.01 Hz (calculation is based on 5.1), regardless of the number of low-amplitude frequency deviation detections, after 500 ms.

This measure is referred to **as " Flicker Prevention STEP 3.2.”**

STEP 3.2 includes STEP 3.1 because paragraph a) above has the same conditions as STEP 3.1.

(Reference) Explanation of conditions added in STEP3.2 (1/2)
Added condition part (explained in the previous page)

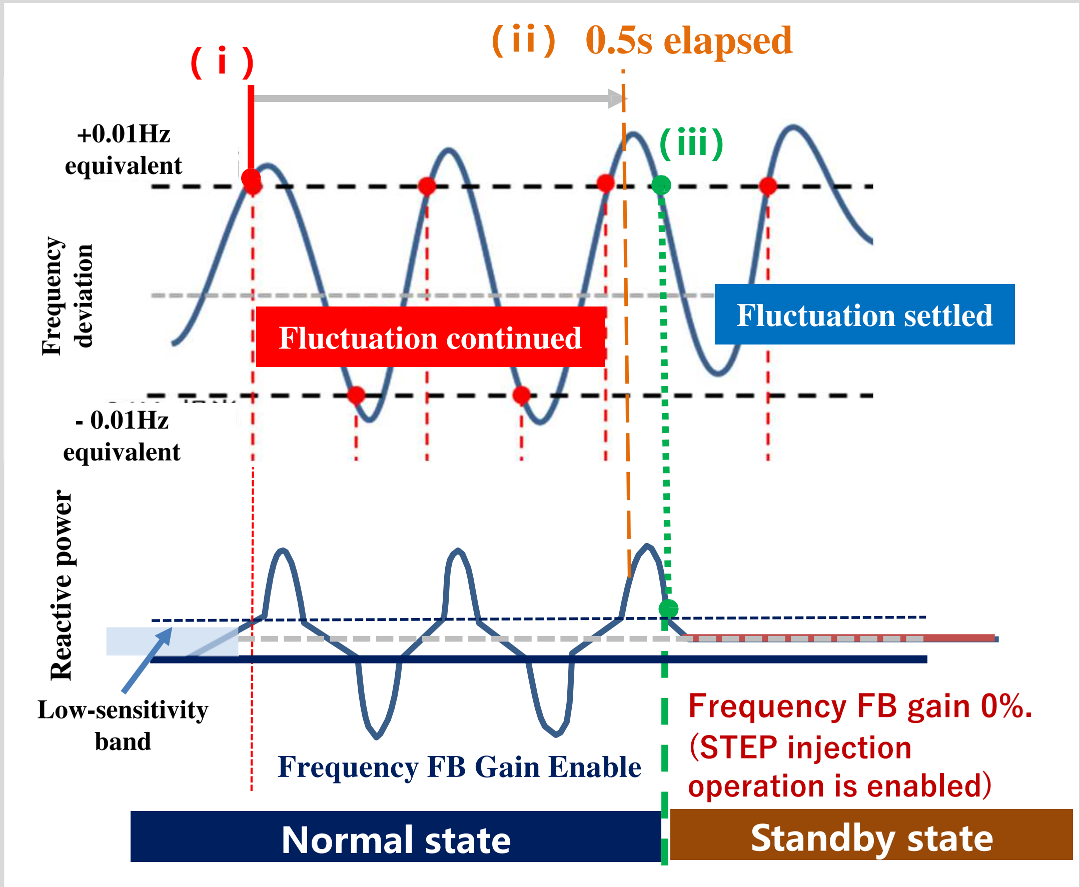
(i)

b) **After detecting a frequency deviation exceeding ±0.01 Hz (calculated according to 5.1), the frequency deviation becomes within ±0.01 Hz after 500 ms,** regardless of the number of low-amplitude frequency deviation detections. (iii) (ii)

The detection logic in paragraph b) above is shown in the left diagram following the steps.

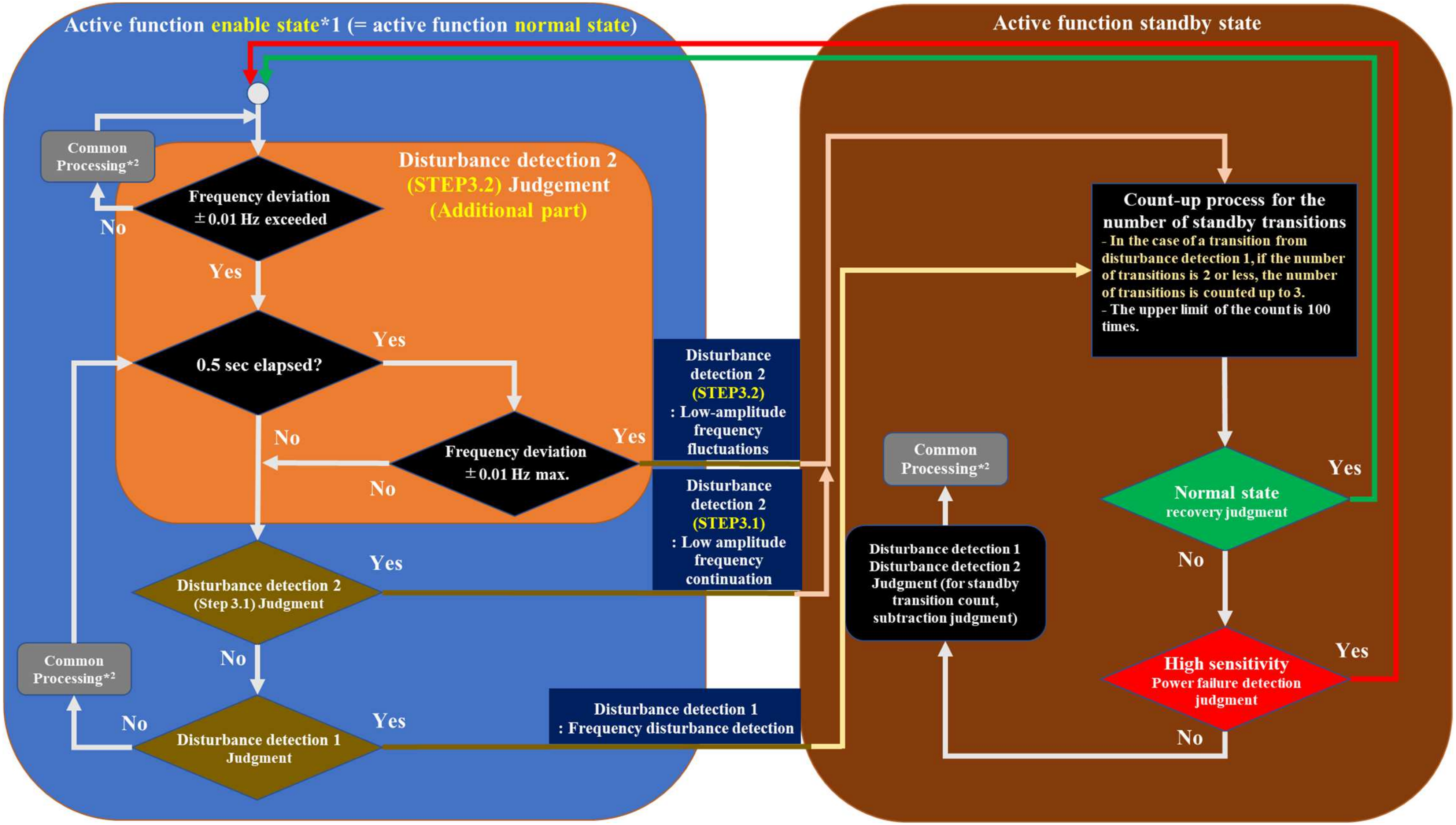
This condition judges that disturbance detection 2 (continuous detection of low amplitude frequency fluctuation) has been established when the condition in STEP 3.1 or clause b) is satisfied.

Note that the normal state is maintained while waiting for 0.5 s to elapse in (ii).



(Reference) Explanation of Conditions Added in Flicker Prevention STEP3.2 (2/2)

The operation on all pages, expressed in terms of a judgment flow, is shown in the figure below.



＊1 "Normal state" of active function is written together with " Active state" of active function to avoid misunderstanding.

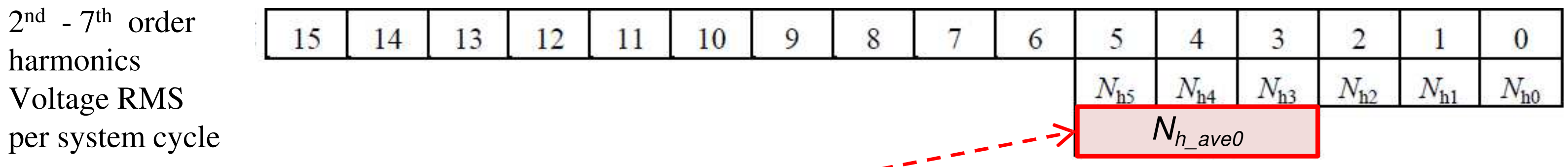
＊2 To indicate state transitions, the following processes are described collectively as common processes and details are omitted.

((Example of common processing) Judgment of Islanding operation detection, measurement processing necessary for other functional operations and judgments such as step injection, subtraction processing of the number of standby transitions, and output stop judgment.

(Reference) Supplementary explanation to Figure 11 in JEM1498 / 1505

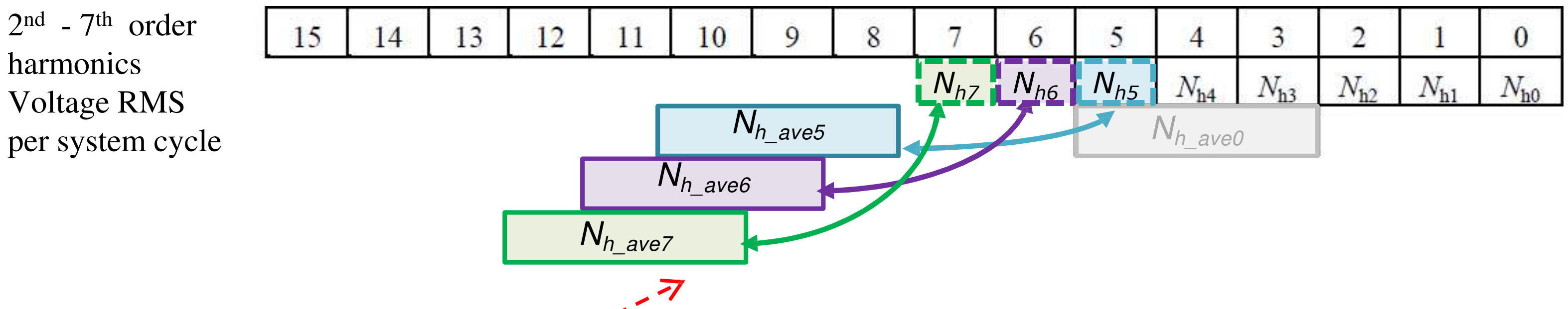
Fig. 11 Conditions for returning to the normal state of the active function in the event of harmonic voltage fluctuations

N_{h_ave0} and N_{h_avei} are not shown in Figure 11, but please refer to the figure below.



The condition for determining the presence of harmonic voltage fluctuation is when the following two conditions are satisfied.

- $(N_{h0} - N_{h\_ave0}) > \alpha$ [V]
- $(N_{h1} - N_{h\_ave0}) > \alpha$ [V]



However, α is the threshold of the latest cycle calculated by auto-tuning and is defined by the following equation.

$$\alpha = \max\left[\left(N_{hi} - N_{h\_avei}\right)\right]_{i=5}^{50} + 1[V] \qquad \text{(In case of 50Hz)}$$

$$\alpha = \max\left[\left(N_{hi} - N_{h\_avei}\right)\right]_{i=6}^{60} + 1[V] \qquad \text{(In case of 60Hz)}$$

(Reference) Supplementary explanation for the reactive power oscillation suppression operation of JEM1498 / 1505

Supplementary explanation to Section 8.4, paragraph d) and Figure 8.

In Section 8.4, paragraph d), the statement **"as an optional condition"** means that it is not mandatory to install the device in the product. If it is installed, the product shall be designed with sufficient care as stated in **"However, there shall be no unnecessary recovery".**

The concerns with unnecessary recovery are the transition to the normal state of the active function due to the arbitrary condition of high-sensitivity power failure detection during flicker generation and the inhibition of the prevention effect of flicker generation due to the repeated operation of unnecessary recovery.

As for the surge in harmonics of the standard setting function, the auto-tuning function shown in Figure 11 is a function to prevent unnecessary recovery.

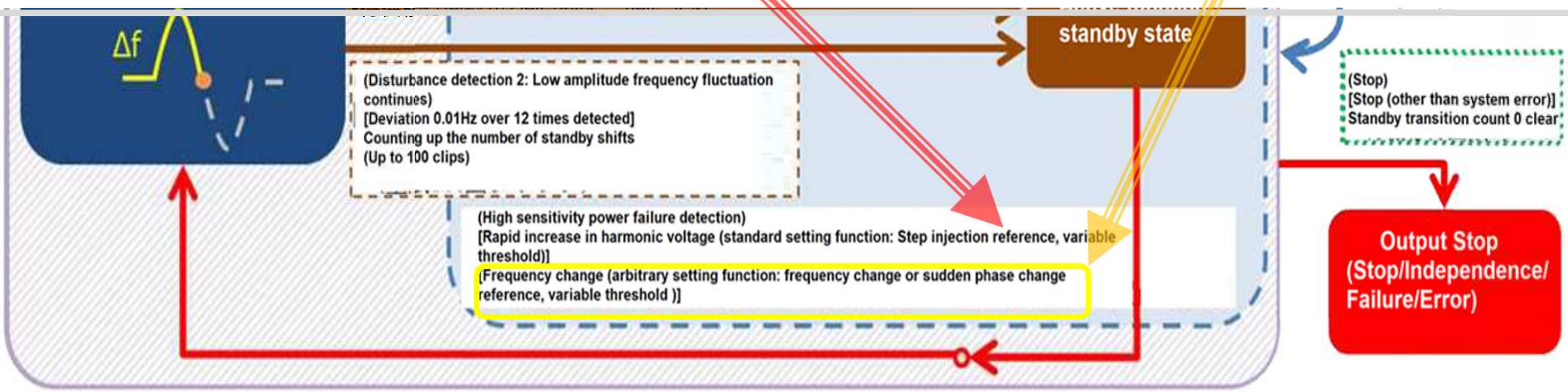
Please refer to the above and give sufficient consideration to prevent unnecessary recovery.

Ref: JEM1498 Chapter 8.4

8.4 Conditions for return to the active function normal state from the active function standby state

d) Other conditions may be added as **optional conditions**, such as monitoring frequency change and state transition to the active function normal state when the frequency change meets the specified conditions. However, there shall be **no unnecessary recovery**

Ref : JEM1498 Fig 8



2. Standard specification for frequency feedback system with step injection.

(8) From the frequency change point, the start time of the frequency feedback reactive power change shall be within 1.5 cycles + 10 ms.

(Reference) Results of detailed study
Minimum: 0.5 cycles (10 ms at 50 Hz, 8 ms at 60 Hz)

Maximum: 1.5 cycles + 10 ms (at 50 Hz: 40 ms, at 60 Hz: 35 ms)

(9) For step injection, the time between the harmonic surge or fundamental surge and the start of reactive power change shall be within 4.5 cycles.

(Reference) Results of detailed study
Minimum: 1 cycle (20ms at 50Hz, 16ms at 60Hz)
Maximum: 4.5 cycles (at 50 Hz: 90 ms, at 60 Hz: 75 ms)

3. Rated output margin of error of PCS

The tolerance of the rated output of PCS shall be ±5%.
Overload capacity shall not be provided.

Explanation

In the past, it was not unusual for PCSs to be capable of outputting 10% more than their rated capacity as an overload capacity. However, in the certification system, the test standard changes depending on whether the rated output is 100% or 110%, and it also affects the certified capacity of equipment, so the rated output is clarified.

4. Allowable frequency in parallel operation

The following technical requirements for allowable frequency in parallel were discussed and approved by the Grid Code Study Group of the Organization for the Promotion of Wide-Area Transmission and Distribution of Electricity (OCCTO) and will be stipulated in the grid interconnection technical requirements of each general transmission and distribution utility.

The power generation facilities shall be equipped with a device or function to confirm that the grid frequency is lower than the allowable frequency in parallel (60.1Hz (60Hz area), 50.1Hz (50Hz area)) when the generators are in parallel.

Applicable power source type: All power sources

Applicable capacity: All capacity

The following design standards are provided as technical guidelines for implementing this requirement.

(1) Moving average measurement time width of frequency (window)

Time equivalent to the number of 50/60 cycles of grid voltage (equivalent to 1 sec.)

(Note) One second of measurement time width may be the number of cycles of the corresponding grid voltage waveform (50 cycles for 50 Hz area, 60 cycles for 60 Hz area).

(2) Data acquisition interval during moving average measurement 100ms or less

(3) Allowable frequency settable range in parallel

50.1Hz to 51.0Hz / 60.1Hz to 61.0Hz

19 steps, 0.05Hz increments (common to 50/60Hz area) Level

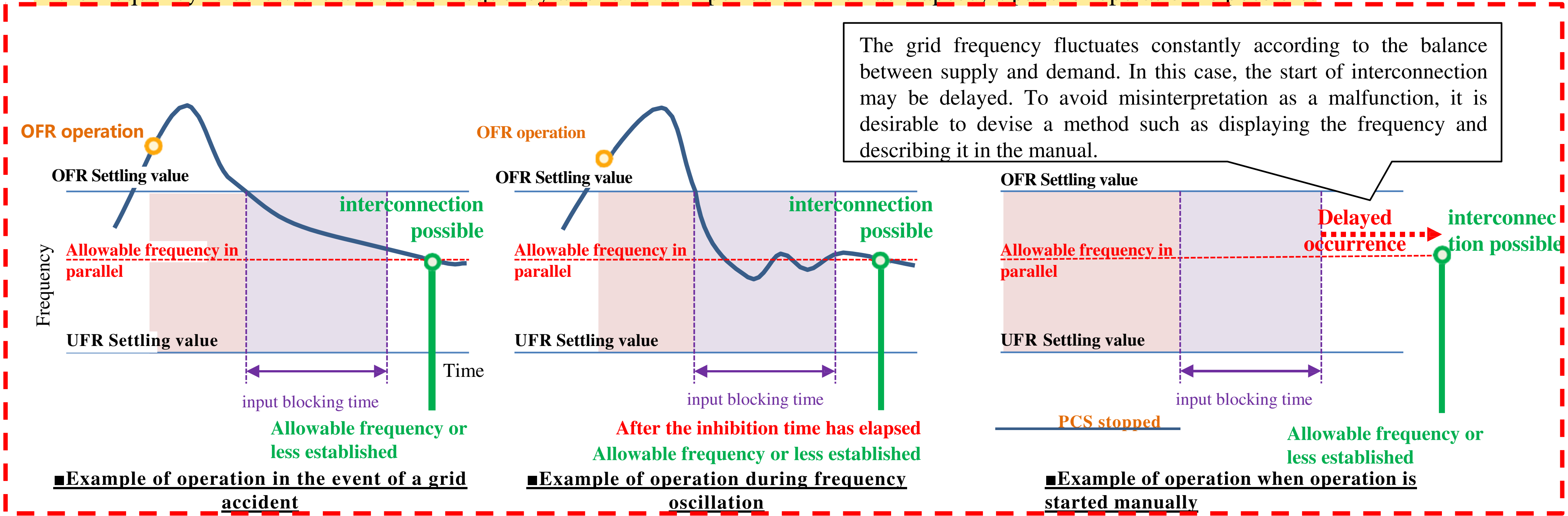
Settable independently from OFR and UFR.

(4) Design frequency measurement accuracy
±0.1% (±0.05/0.06Hz)
(Note 1) This accuracy is only the target accuracy for design, and differs from the error allowed in type testing, etc.
(Note 2) Do not parallel at frequencies exceeding 0.1 Hz above the constant value.

(5) Time limit for determining allowable frequency in parallel
Not specified.
If the frequency falls below the allowable frequency, the system can be interconnected immediately.

(6) Operation when the allowable frequency is exceeded after the start of parallel operation
Operation continues until OFR is reached.
Even if the frequency becomes 50.2 Hz after the parallel operation, for example, it is not necessary to disconnect.

(7) Action when the allowable frequency is exceeded during a certain period of time (150~300 seconds) after the power is restored
No need to recount the input blocking time.
If the frequency is below the allowable frequency after a certain period of time has elapsed, a parallel operation is possible.



5． Example of Islanding operation of PCS when the high voltage cutout of a pole transformer is opened(1/3)

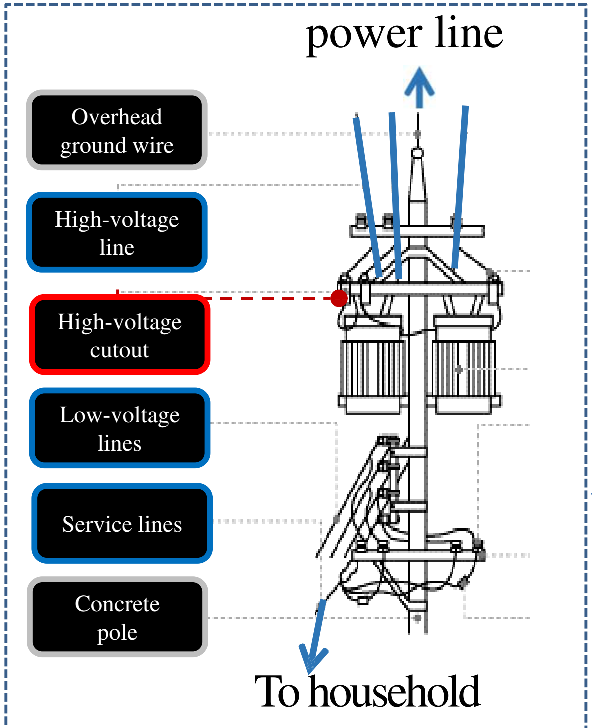
CASE When workers of a general transmission and distribution utility, etc., opened the high-voltage cutout of a pole transformer for a low-voltage outage operation, an event occurred in which the PCS installed at a residence continued Islanding operation.

<u>What is Islanding operation when the high-voltage cutout of a column transformer is opened?</u>

When the high voltage side of a pole transformer is opened, the pole transformer itself is not disconnected from the low voltage line as seen from the PCS that is connected to the low voltage line.

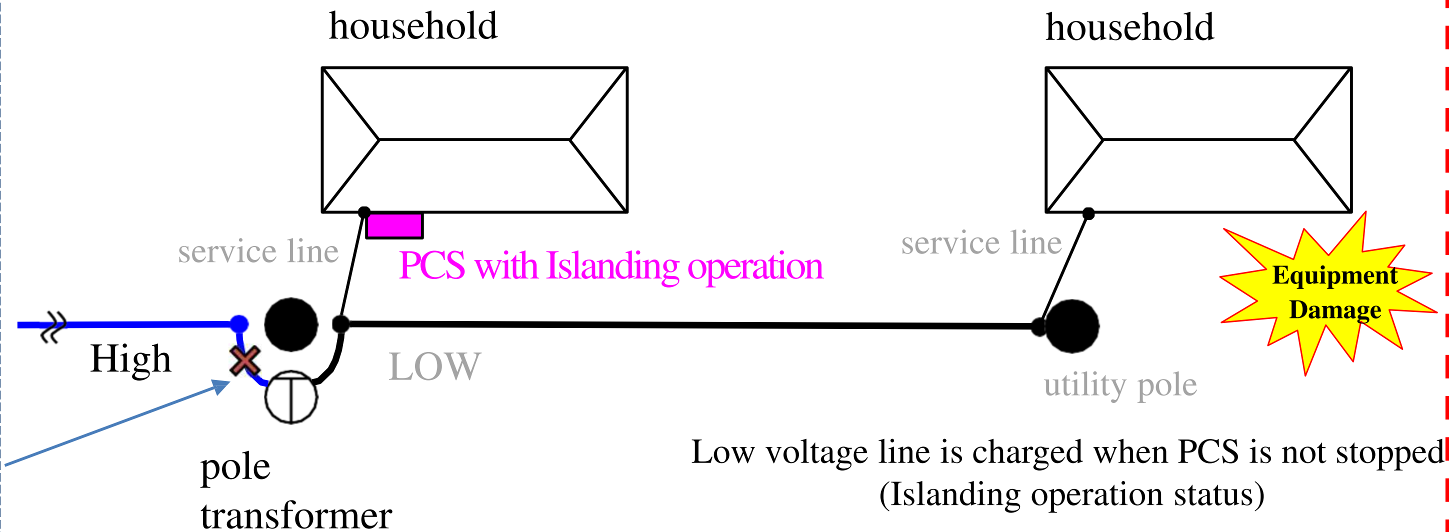
At the moment when the high-voltage cutout is opened, the pole transformer is magnetically saturated because power is supplied from the PCS to the unloaded pole transformer on the high-voltage side. Due to this magnetic saturation phenomenon and PCS control, the PCS, which should have detected Islanding operation and stopped when the low-voltage line lost power due to the release of the high-voltage cutout, did not stop.

This led to damage to other consumer equipment located in the area where Islanding operation was performed..



Standard pole diagram of a utility pole

Source: Chubu Electric Power Co.

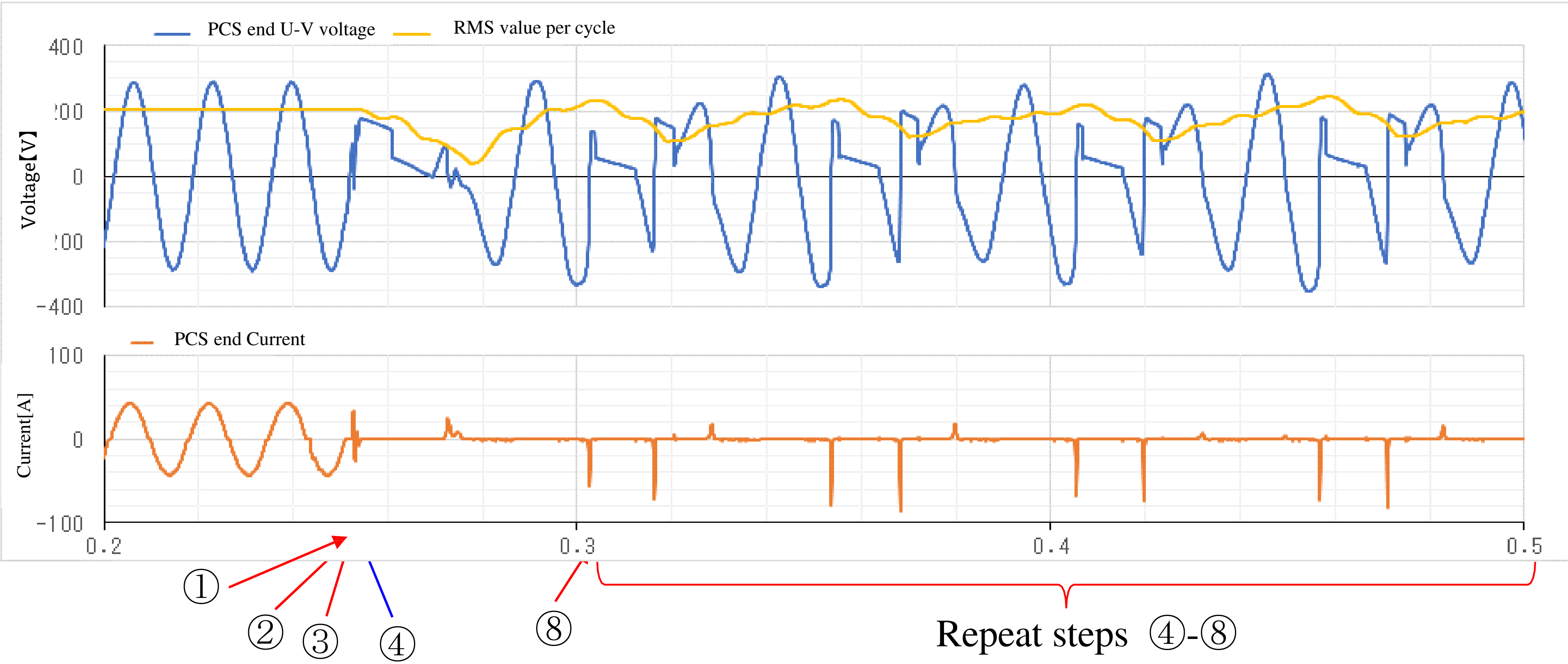


5. Example of Islanding operation of PCS when the high voltage cutout of a pole transformer is opened(2/3)

Mechanism of continued Islanding operation (typical example)

Model: Multi-input energy storage system with reverse power flow

(1) When the high-voltage cutout release is implemented.
(2) When the PCS is in Islanding operation with the high voltage side of the pole transformer open.
(3) The voltage applied from the PCS causes magnetic saturation in the pole transformer, resulting in overcurrent.
(4) Pulse removal operation is performed to protect the equipment, and the current stops.
(5) Output voltage drops due to current stoppage by pulse removal operation
(6) Output voltage drops, FRT is detected incorrectly, and transition to FRT state occurs.
(7) In FRT state, output current increases to maintain output and output voltage rises accordingly.
(8) The pole transformer is magnetically saturated again by the applied voltage, resulting in overcurrent generation. The product in question was designed to disable the function to prevent Islanding operation in the FRT state, so the above repetitive actions (4) to (8) occurred and the Islanding operation continued.



5. Example of Islanding operation of PCS when the high voltage cutout of a pole transformer is opened(3/3)

<Problems and Reasons>

- The Islanding operation prevention function was disabled in the FRT state.

➢ The condition in which the Islanding operation prevention function does not work properly deviates from the rules of electric engineering interpretation and grid interconnection regulations, etc., and fails to ensure safety against electric shock to operators and the public.

- In the FRT state, the instantaneous overvoltage protection function was disabled.

➢ The protection against overvoltage to the PCS itself and to the customer facilities (equipment) in the area where Islanding operation occurred was not secured.

＜Concerns at the time of occurrence>

- When the high-voltage cutout is opened, the PCS continues Islanding operation, which may cause an electric shock if the operator thinks that the low-voltage side is blacked out.
- There is a concern that home appliances may malfunction due to unstable voltage supply.

＜Example of countermeasures in this case>

The design does not disable the Islanding operation prevention function and the instantaneous overvoltage protection function even in the FRT state. Even if the pulse extraction to prevent overcurrent due to magnetic saturation of the pole transformer operates, the design does not disable the Islanding operation prevention function and the instantaneous overvoltage protection function in the FRT state, thereby preventing repeated operation.

Requirements from the case study

<u>Protection functions such as Islanding operation prevention function and instantaneous overvoltage protection function shall not be disabled even in the FRT state.</u>