

Guidebook for Power Quality Measurement

Helpful Hints for Measurement and Case Studies



HIOKI E. E. CORPORATION

Table of Contents

1. Why Do We Measure Power Quality?
2. IEC61000-4-30
3. Power Quality Survey Procedures
4. Power Quality Parameters and Events
5. Case Studies
 - Case Study 1 Voltage Drop by Cable Impedance
 - Case Study 2 Transients caused by Glow Fluorescent Lighting
 - Case Study 3 Switching of Power Factor Compensation Capacitor
 - Case Study 4 Voltage Dip by Lightning Strikes - at Receptacle
 - Case Study 5 Voltage Dip by Lightning Strikes - at Distribution Panel
 - Case Study 6 Transient voltage
 - Case Study 7 Periodical Instantaneous Voltage Drop
 - Case Study 8 General UPS Switching Waveform
 - Case Study 9 Voltage Waveform Noise & UPS Switching
 - Case Study 10 Voltage Dip in a Factory
 - Case Study 11 Inflow and Outflow of Harmonics
 - Case Study 12 High-Order Harmonics Caused by Inverter Equipment
 - Case Study 13 Conductive Noise
 - Case Study 14 Solar Power Generation
 - Case Study 15 Wind Power Generation
 - Case Study 16 Synchronization to the GPS Clock (PQ3198)
 - Case Study 17 Remote Operation and Measurement (PQ3198)
 - Case Study 18 Effective Usage of CH4 (PQ3198)
6. Recording Method of TIME PLOT and Event Waveform
7. Terminology

Appendix 1

Details of Quick Setup of Model PQ3198

1.

Why Do We Measure Power Quality?

The worsening of power quality is a huge concern because of the increase in the use of power electronic devices using inverters, an increase of unbalanced loads like large furnaces or rectifiers, and generally more complicated power distribution due to an increase in grid connections for new energy sources, etc.

Poor power quality causes trouble in receptacle/transmission equipment and electronic equipment malfunctions. For example, harmonics is known to generate burn-out reactors and defective noise in capacitors. Also, impulse noise and voltage drops stop control systems that are dependent on a computer.

Power supply network problems caused by poor power quality is a common problem for both electric power suppliers and users. However, it is not easy to identify whether the cause of poor power supply quality is at the supplier's system or the user's system. Based on this situation, power quality measurement is necessary to understand the actual cause of power quality problems as well as to consider and analyze for effective countermeasures.

2.

IEC61000-4-30

IEC61000-4-30 is the international standard stipulating how power quality should be measured, and measuring instruments certified to be in compliance with IEC61000-4-30 will have reliable and repeatable measurement results regardless of the original manufacturer.

The items included in this standard are limited to phenomena spreading in the power supply system, which are the frequency, supply voltage amplitude (RMS value), flicker, dip/swell/interruption of supply voltage, Transient voltage, supply voltage unbalance, harmonic voltage, inter-harmonic voltage, signaling on supply voltage, and rapid voltage fluctuation.

In addition, IEC61000-4-30 classifies the measurement methods and capabilities of measuring instruments into 2 classes of A and S. The most reliable power quality measurement can be made by Class A instruments. The requirements for Class A are not only stipulated in terms of functions and accuracy, but also include the measurement algorithms and time clock accuracy.



Classification of Power Quality Measuring Instruments

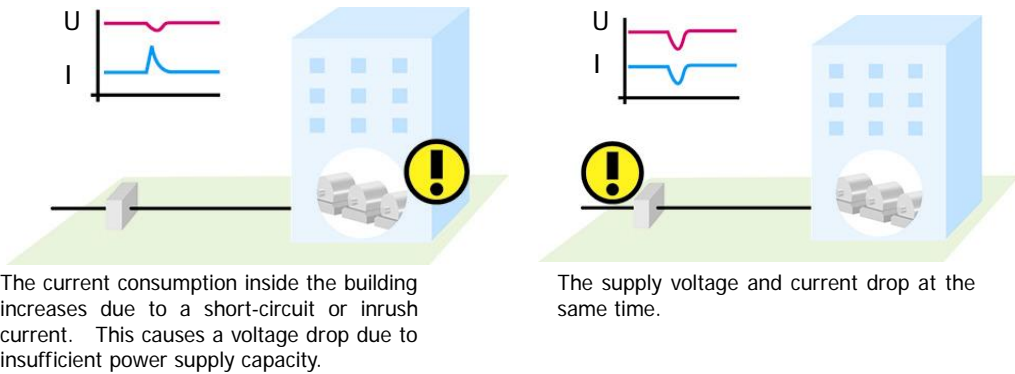
Class	Applications
Class A	Used when precise measurements are necessary, for example, for contractual applications that may require resolving disputes, verifying compliance with standards, etc. The detailed measurement methods and techniques are defined, such as the time-clock accuracy, RMS value calculation method and data processing method, etc.
Class S	Used for qualitative surveys, trouble-shooting applications and other applications where low uncertainty is not required.

HIOKI PQ3198 is certified Class A and delivers Class A performance.

Tips for Identifying the Cause of Power Quality Problems

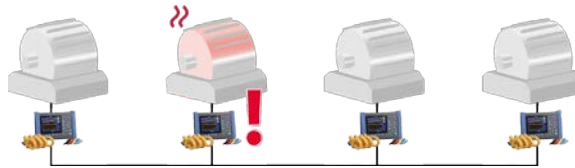
- **Record the trend of voltage and current at the receptacle!**

If the voltage drops during the increase of current consumption in a building, the cause is considered to come from inside the building. On the other hand, if both the voltage and current drop, the cause is attributed to equipment or anomaly outside the building. It is important to determine where to measure as well as to measure the current itself.



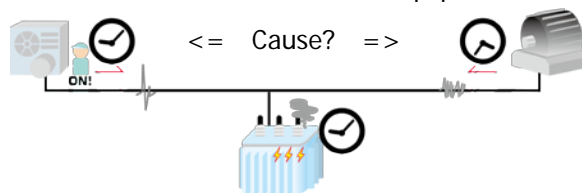
- **Check the power trend!**

Equipment in overload condition is often the cause of trouble. By knowing the power trend, it is easier to identify the actual equipment or location that is causing the problems.



- **Check WHEN the event occurred!**

When an event is recorded, equipment that is in operation or restarting during that time can be the cause of the problem. By accurately identifying what time the event occurred and when the problem subsided, it can be easier to determine which equipment or location could have caused the problems.



- **Check for heat and faulty sounds generated in equipment!**

Overheating or faulty sounds coming from a motor, transformer or cable are signs that there are problems due to overload or harmonics.



Step 1: Purpose

(1) Survey power quality Go to Step 3

- Periodic power quality statistics survey
- Survey before and after installing new equipment
- Load survey
- Predictive maintenance



Power quality?

(2) Troubleshooting Go to Step 2

- Detecting the cause of malfunction/damage to equipment
- Consider countermeasures for power supply troubles

Power trouble?

Step 2: Understanding the trouble (where to measure)

(1) What kind of trouble has occurred?

- Main electronic equipment
Large copy machine, UPS, Elevator,
Air compressor, Air-conditioning compressor,
Battery charger, Cooling equipment,
Air handler, Timer controlled lighting,
Variable frequency drive, etc.
- Distribution
Damage or decay on conduit (electric cable pipe),
Overheat, noise or oil leakage on transformer,
Opening or overheat on circuit breaker, etc.

What to
measure?

What?

When?

Where?

Assumed cause?



(2) When did the trouble occur?

- Always, Periodic, Intermittent
- Specific time or date

(3) Where and What should be measured?

- Voltage, Current, (Power) --- Always recommended
 - The cause can be identified much easier by analyzing the voltage and current trends during the time the problem occurred
- Measure multiple locations simultaneously – makes it easier to identify the source of the problem
 - Circuits in the transmission station (power utilities only)
 - Receptacle (high voltage, low voltage)
 - Distribution panel
 - Outlet or power supply terminal for electronic equipment

(4) What is the assumed cause?

- Voltage problem
RMS value fluctuation, Waveform distortion, Transient voltage, High-order harmonic
- Current problem
Leakage current, Inrush current

Step 3: Know the Measurement Site

Collect information about the measurement site, including:

- Circuit wiring
- Nominal supply voltage
- Frequency
- Necessity of neutral line measurement and DC voltage measurement
- Current capacity
- Other information about facilities, including:
Existence of other power quality detection equipment, main electronic device running cycle, newly added or removed equipment, distribution network design, etc.

Step 4: Measure

Measure using a power quality analyzer.

Useful functions of the HIOKI PQ3198

✓ Wiring check

Provides easy connection to the measurement circuit, and gives confirmation of correct connection.



✓ Quick Setup

Select the situation and the PQ3198 will automatically set the event detection thresholds.

(Manually customize settings afterwards.)



✓ VIEW screen

View the instantaneous input values and waveforms.



You can measure and record various phenomena simultaneously by using a HIOKI power quality analyzer.

Brief Overview of Quick Setup

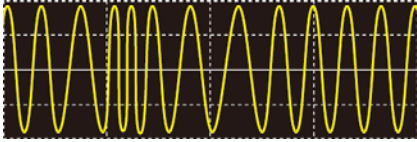
U Events	Detects the fault voltage
Standard Power Quality	Measures the basic power quality items
Inrush Current	Detects inrush current
Recording	Records RMS values only without detecting events
EN50160	Long term power quality survey according to the EN50160 standard

Please refer to Appendix 1 for more information.

4. Power Quality Parameters and Events

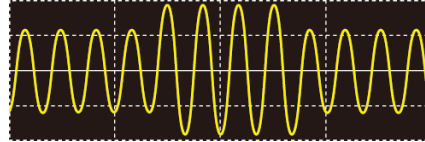
The power quality parameters are the items required for surveying or analyzing power trouble. By measuring the power quality parameters, you can gain a thorough understanding of the power quality status. Threshold values are set on the power quality analyzer to detect the "fault value" or "fault waveform" for the power quality parameters. Then, the PQA identifies an "event" when the input exceeds the thresholds. (Actual trouble does not always occur at event detection because thresholds are set by assuming certain fault values.)

Frequency fluctuation



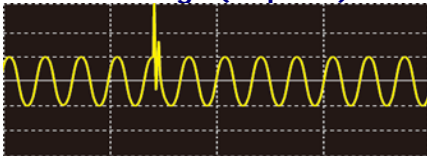
This occurs due to a change of effective power balance between supply and consumption, or an excessive increase or decrease of the load. Varying rotation speeds of synchronous generators, the most common type of generator used in utility power systems, may be the cause of frequency fluctuations.

Voltage Swell (Surge)



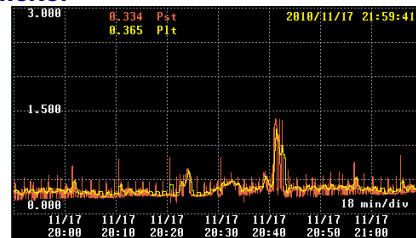
This is the instantaneous voltage increase caused by lightning strikes, opening or closing of a power supply circuit, high capacitor bank switching, ground short circuit, or cutting a heavy load, etc. It may also occur due to the grid connection of a new energy source (solar power, etc.). A sudden increase in voltage may damage or reset the power supply of equipment.

Transient voltage (Impulse)



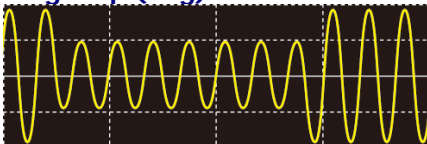
This is the voltage change generated by a lightning strike, contact problem and closing of a circuit breaker/relay. It is often a rapid change and consists of high peak voltage. Damage to an equipment's power supply or reset function often occurs near the generation point due to its high voltage.

Flicker



Flicker is a periodically repeated voltage fluctuation caused by a furnace, arc welding or thyristor controlled load. Nowadays, this cause mostly come from the setting of the function to detect power failure in the PV's power conditioners. It may cause lights to flicker and equipment to malfunction. When the flicker value is high, most people feel uncomfortable because of the flickering lights.

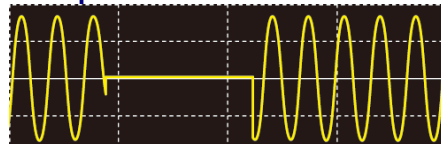
Voltage dip (Sag)



Most sags are caused by the natural phenomena like thunder and lightning. It is represented by an instantaneous voltage drop caused by the cutting off of the power supply circuit due to a short circuit to the ground or high inrush current generation when starting a large motor, etc.

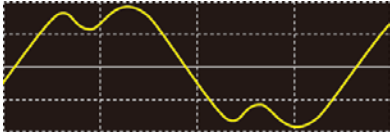
Due to the voltage drop, it may cause a stop or reset of equipment, turn off lighting, speed change or stop of motor, and synchronization error of synchronous motors or generators.

Interruption



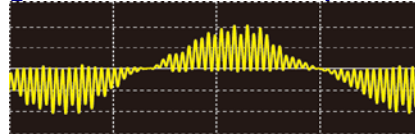
This is a power outage over an instantaneous, short or long period. It is caused by accidents such as lightning strikes or tripping of the circuit breaker because of a short-circuit. Recently, UPS are widely used to protect PCs, but this type of equipment may also cause a stop or reset of equipment.

Harmonics



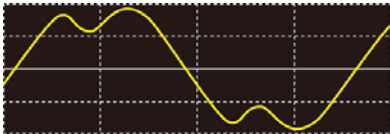
Harmonics are generated by semi-conductor control devices in the power supply of equipment as a result of distorted voltage and current waveforms. When the harmonic component is big, it may cause serious accidents such as overheating or noise in motors or transformers, burn out reactors in phase compensation capacitors, etc,

High-order harmonic component



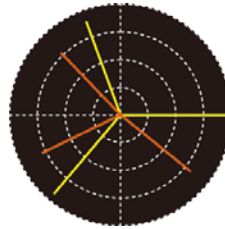
This is a noise component higher than several kHz generated by the semi-conductor control device in the power supply of equipment, and may contain various frequency components. High-order harmonic components may damage the power supply of equipment, reset equipment or introduce abnormal noise in equipment such as TVs or radios.

Inter-harmonics



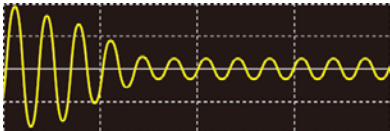
This is generated by a voltage/current waveform distortion caused by an electronic frequency converter, cycle converter, Scherbius system, inductive motor, welder or arc furnace, etc., and consists of non-integer orders of the fundamental frequency. Inter-harmonics may cause damage, malfunction or deterioration of equipment due to the zero-cross shift of the voltage waveform.

Unbalance



Unbalance is generated by the increase or decrease of load connected to each phase, partial running equipment, voltage/current waveform distortion, voltage drop, or reverse phase voltage, etc. The phenomenon may cause revolution faults, an increase in noise, and less torque in a motor. Also, it may cause a 3E breaker to trip, transformers to overheat, or a loss increase in a capacitor smoothing rectifier, etc.

Inrush current



(Current waveform)

This is an instantaneous high current flowing at the time equipment is powered on. Inrush current may cause relays to malfunction, circuit breakers to open, impact on the rectifier, unstable power supply voltage, and/or equipment to malfunction or reset.

5.

Case Studies

Case Study 1

Voltage Drop Caused by Cable Impedance

Environment

Target: 1-phase 2-wire, 100V circuit

Problem

Malfunction and damage to equipment

(This is a simulation to evaluate the effect of a voltage drop caused by cable impedance.)

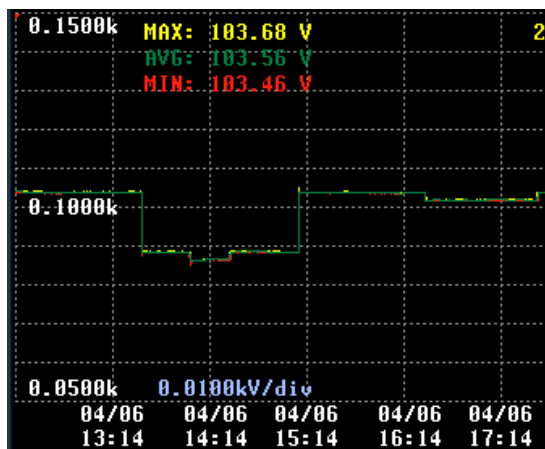
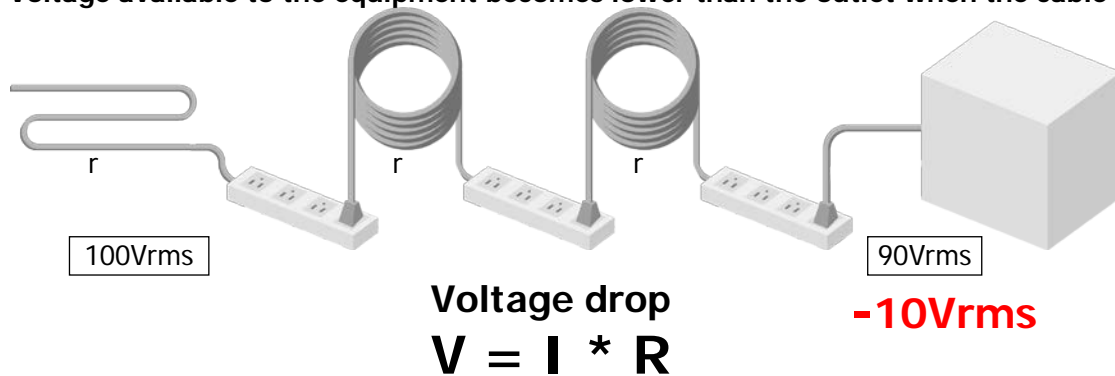
Analysis

Voltage supplied to equipment drops to less than 90V because of cable impedance.

The power supply voltage may fall below the allowable voltage of the equipment and the power may be lost.

In addition, this may cause the equipment to malfunction or becomes damaged.

Voltage available to the equipment becomes lower than the outlet when the cable is long.



The cable impedance used in this simulation is measured at 1Ω.

When a 10A load current flows to this cable, a 10Vrms drop occurs based on Ohm's law ($1\Omega * 10A = 10V$).

Case Study 2

Transient Voltage Caused by Glow Fluorescent Lighting

Environment

Target: 1-phase 2-wire, 100V circuit

Problem

This is an example of how Transient voltage is measured when turning on glow fluorescent lighting.

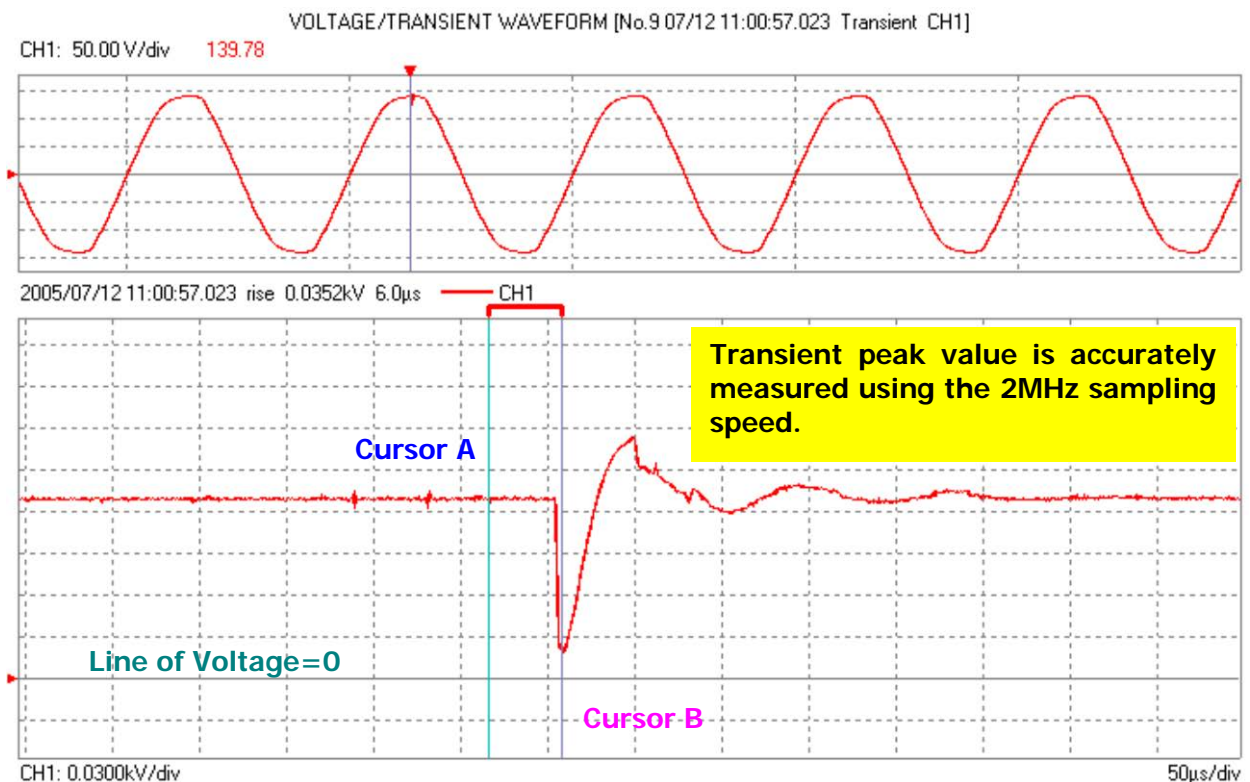
Analysis



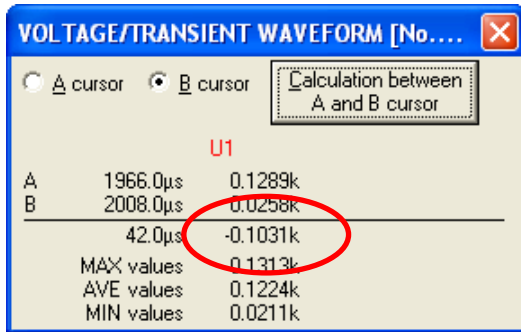
A glow fluorescent light incorporates a glow lamp and is widely recognized as a low-cost fluorescent lighting system.

A fluorescent light needs to be warmed-up for its electrodes to be switched on. A glow lamp is provided for this purpose. It flashes to warm-up the electrodes before the fluorescent light is actually turned on.

Transient voltage is generated at the first flash of a glow lamp, which affects electronic equipment located nearby.

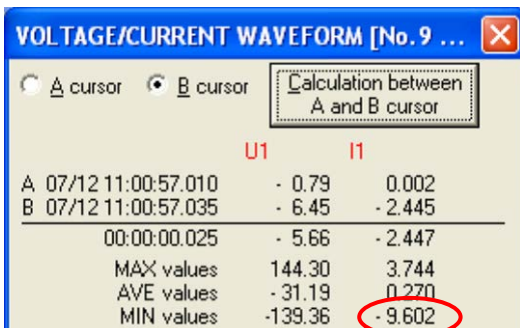
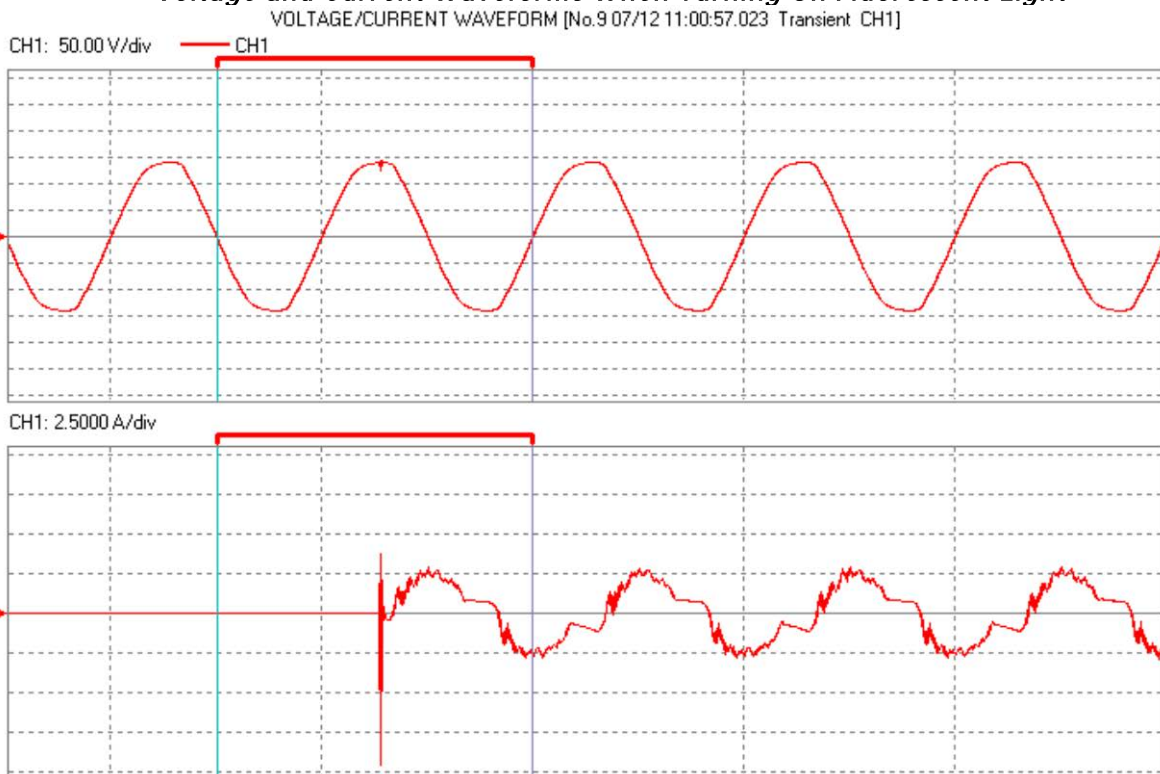


Voltage and Transient Waveforms When Turning On the Fluorescent Light



The power is turned on at the voltage waveform peak (128.9V) and the generated transient voltage is 103.1V in the negative direction.

Voltage and Current Waveforms When Turning On Fluorescent Light



When transient voltage occurs, a high current flows instantaneously.

This example is measured by using a 10-turn coil without a CT ratio setting.

The screen shot on the left shows that 0.9602A of current flowed instantaneously in the negative direction.

Case Study 3

Switching of a Power Factor Compensation Capacitor

Environment

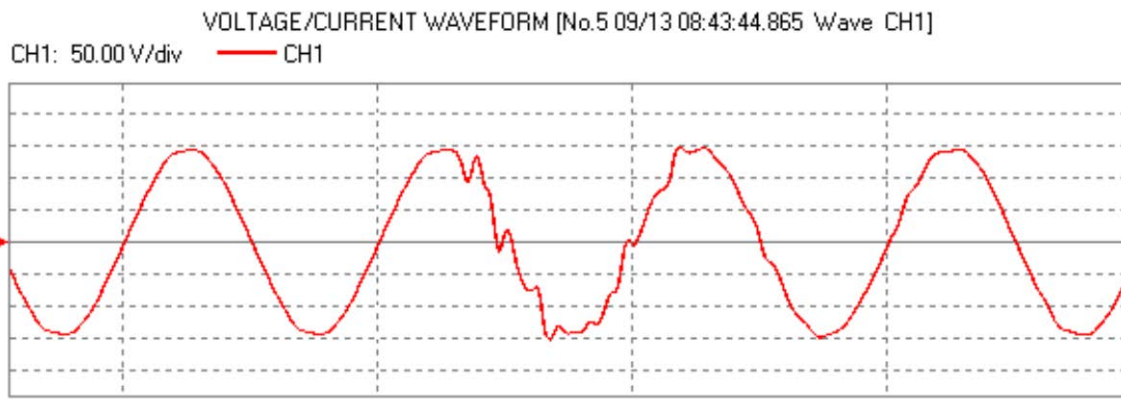
Target: 1-phase 2-wire, 100V circuit

Problem

The power supply of equipment is damaged.

Analysis

Some events were recorded during measurement. A switching waveform, which occurred during the power factor compensation capacitor switching, was detected. This kind of voltage waveform is recorded when a power factor compensation capacitor is installed in a facility. The switching noise comes through the low-voltage circuit without a filtering device.

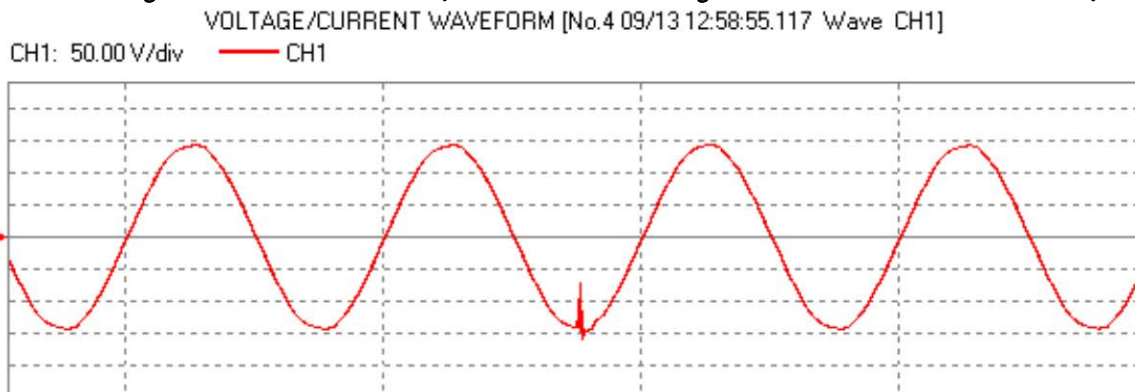


Voltage Noise Waveform 1 (based on the voltage waveform distortion event)

In addition, a transient (impulse) voltage waveform is detected.

This kind of waveform occurs when the voltage waveform is affected by the start-up current of equipment.

Voltage Noise Waveform 2 (based on the voltage waveform distortion event)



Note

To detect intermittent noise, analyzing a **voltage waveform distortion event** is effective. The voltage waveform distortion event is set as the percentage of the voltage range. A setting from 10% to 15% is recommended.

Case Study 4

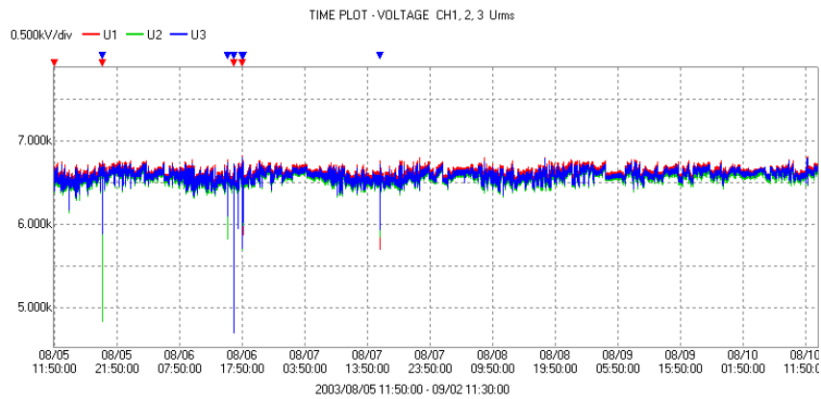
Voltage Dip caused by Lightning Strikes – at the Receptacle

Environment

Target: HIOKI headquarters building, 3-phase 4-wire, 6.6kV receptacle, Secondary of PT
 Measured period: 1 year from June 2003 to May 2004

Problem & Analysis

While measuring for 1 year at the receptacle of a 3-phase 6.6kV circuit, a voltage dip is detected only during a lightning strike. This voltage dip occurred 6 times in 3 consecutive days (August 5th to 7th, 2003). The residual voltage is very low and a long voltage dip period is detected on CH3 (T-R phase) as 4.708kV for 109ms.



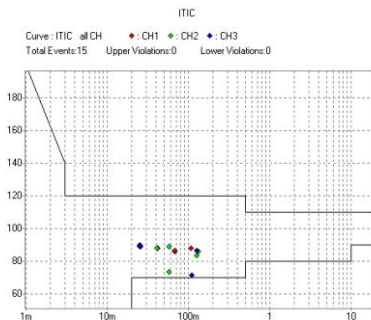
Voltage Fluctuation

Measurement Result Classification
 Display From : 08/05 11:40 To : 09/02 11:30

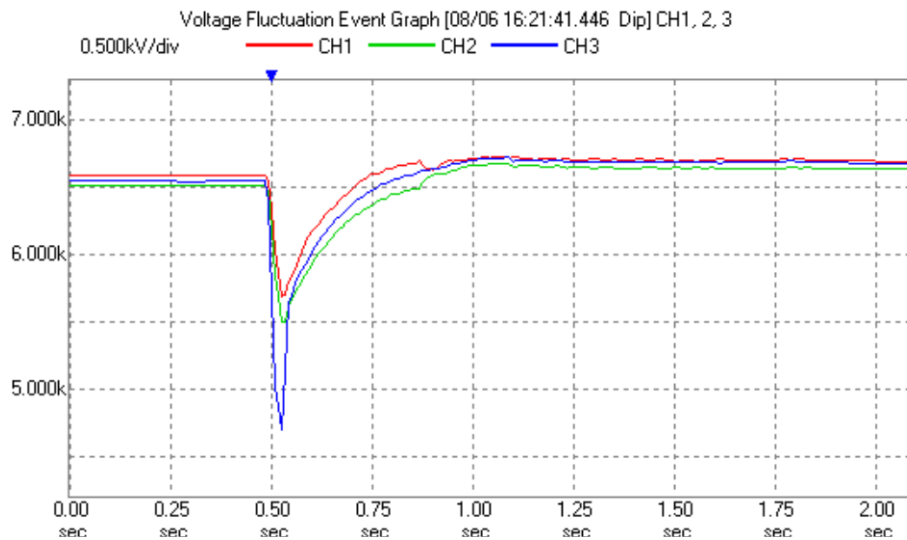
Voltage u (% of Uref)	Duration t [s]							
	0.5cyc < t ≤ 100m	100m < t ≤ 500m	500m < t ≤ 1	1 < t ≤ 3	3 < t ≤ 20	20 < t ≤ 60	60 < t ≤ 180	180 < t
180 < u	0	0	0	0	0	0	0	0
160 < u ≤ 180	0	0	0	0	0	0	0	0
140 < u ≤ 160	0	0	0	0	0	0	0	0
120 < u ≤ 140	0	0	0	0	0	0	0	0
110 < u ≤ 120	0	0	0	0	0	0	0	0
90 ≤ u < 90	2	0	0	0	0	0	0	0
80 ≤ u < 88	1	1	0	0	0	0	0	0
75 ≤ u < 80	0	0	0	0	0	0	0	0
2 ≤ u < 75	1	1	0	0	0	0	0	0
0 ≤ u < 2	0	0	0	0	0	0	0	0

Swell, Dip, Interruption

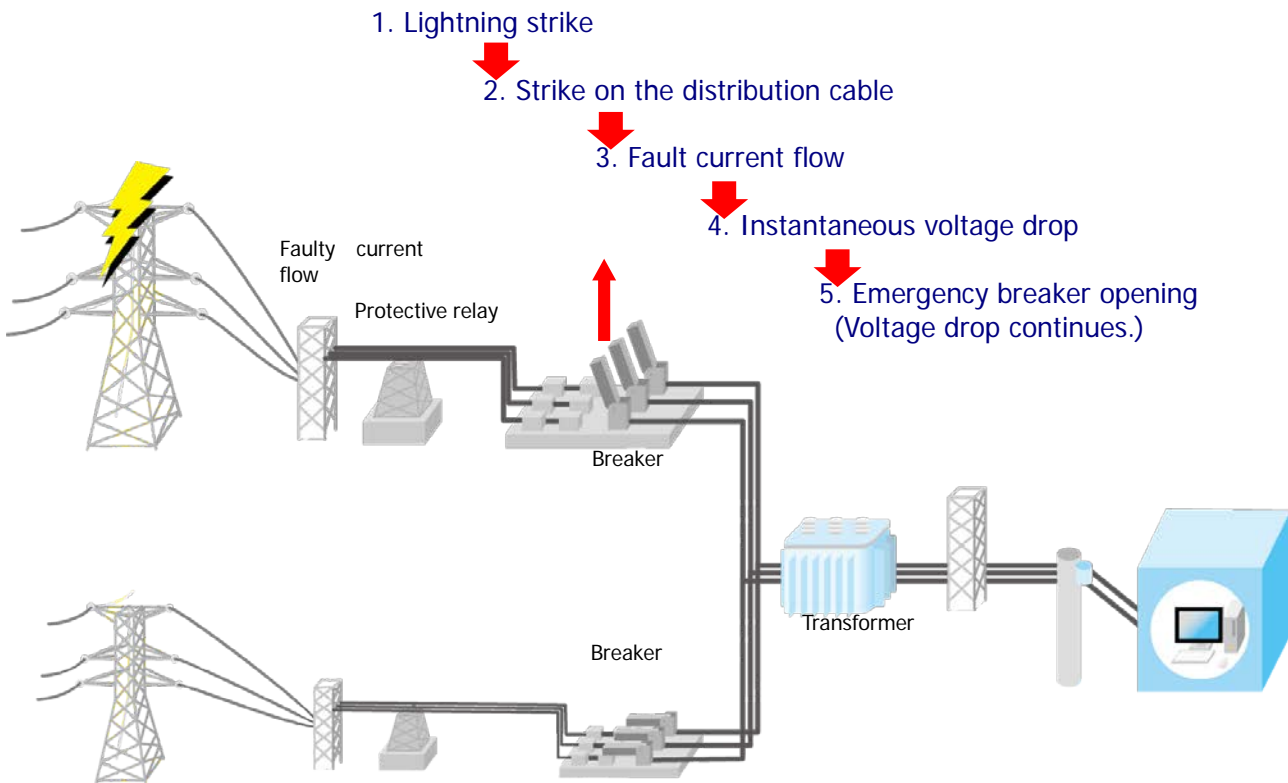
Classification in EN50160 mode (Simultaneous events on 3 phases are counted as one)



Voltage Dip Evaluation using the ITIC Curve
 (plotted for each phase separately)



***Event Voltage Fluctuation (RMS value trend per wavefore)
of the Lowest Residual Voltage and the Shortest Period Voltage Dip***



Path of a Voltage Dip

The instantaneous high voltage is generated by a lightning strike which shorts the distribution cable and tower. Then, the fault current flows and the voltage drops. To remove this fault, the circuit breaker trips, but the voltage drops continues until that time (approx. 0.07s to 2s). This represents an instantaneous voltage drop (voltage dip) caused by a lightning strike.

Case Study 5

Voltage Dip caused by Lightning Strikes – at the Distribution Panel

Environment

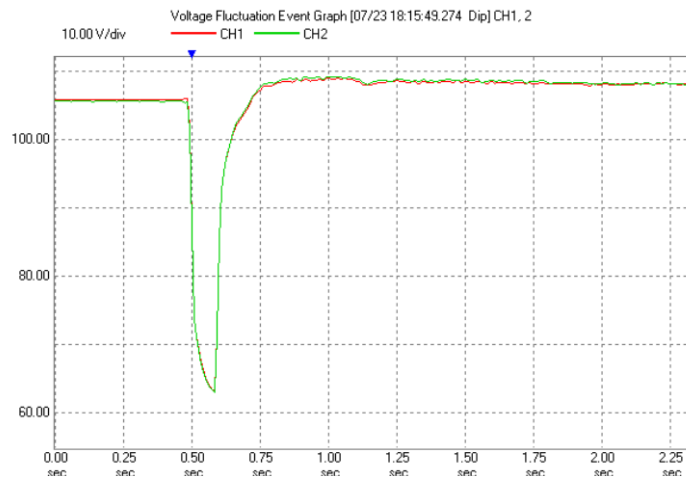
Target: HIOKI headquarters building, East side, 5th floor, 1-phase 3-wire, 200V distribution panel

Measured period: From June 9, 2002 to August 9, 2002

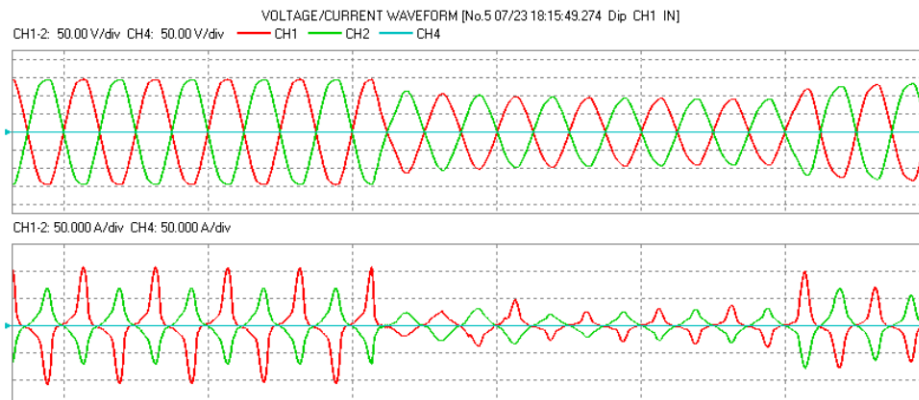
Problem & Analysis

4 voltage dips caused by lightning were detected during measurement (different period than Case Study 4). The distribution panel (1-phase 3-wire) was affected by the voltage dip that occurred at the high voltage distribution network. The table below shows the residual voltage and period of each voltage dip. Voltage dips caused by lightning cannot be prevented by power distribution companies. Therefore, users should take appropriate countermeasures such as connecting a UPS to their PCs.

	Residual voltage	Period
1 st voltage dip	47Vrms	117ms
2 nd voltage dip	63Vrms	109ms
3 rd voltage dip	82Vrms	50ms
4 th voltage dip	56Vrms	116ms



Event Voltage Fluctuation at the 2nd Voltage Dip



Voltage and Current Waveforms at the 2nd Voltage Dip

Transient voltage

Environment

Target: Factory, 3-phase 3-wire, 200V circuit

Problem

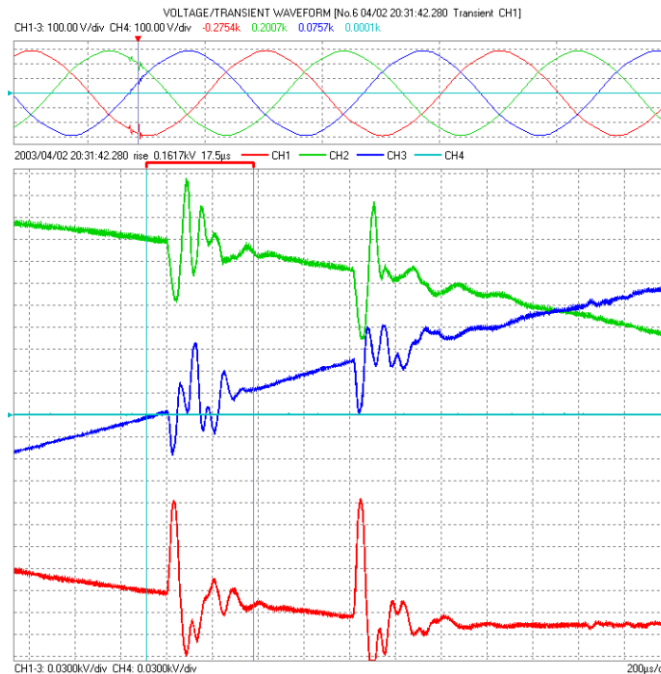
The screen of equipment does not display correctly.

Analysis

A Transient voltage was detected in all events occurring several times during the measurement. Unfortunately, the cause of the transient could not be determined.

Analysis of transient voltage waveform

- 1) Occurred on all 3 phases (R-S, S-T, T-R) simultaneously
- 2) Occurred twice in 1 cycle of the commercial waveform, and the interval between 2 events is 820µs
- 3) The level is between 120V to 260V peak-to-peak
- 4) The frequency is between 10kHz and 30kHz



VOLTAGE/TRANSIENT WAVEFORM [No.6 04/02 20:31:42.280 T...					
Calculation between A and B cursor					
	U1	U2	U3	U4	
A	1112.0µs	-0.2414k	0.2402k	-0.0070k	0.0012k
B	1580.0µs	-0.2613k	0.2273k	0.0363k	0.0012k
	468.0µs	-0.0199k	-0.0129k	0.0434k	0.0000k
MAX values		-0.1160k	0.3234k	0.0984k	0.0012k
AVE values		-0.2492k	0.2300k	0.0167k	0.0006k
MIN values		-0.3293k	0.1535k	-0.0551k	0.0000k

	U1	U2	U3
Max. value	-116.0V	323.4V	98.4V
Min. value	-329.3V	153.5V	-55.1V
Transient p-p value	213.3V	169.9V	153.5V

Analysis of Transient voltage

Note

A threshold set at 1/2 of the waveform peak value is effective for detecting Transient voltage. For example, set the threshold at 70V for a 100Vrms circuit, and 140V for a 200Vrms circuit.

Periodical Instantaneous Voltage Drop

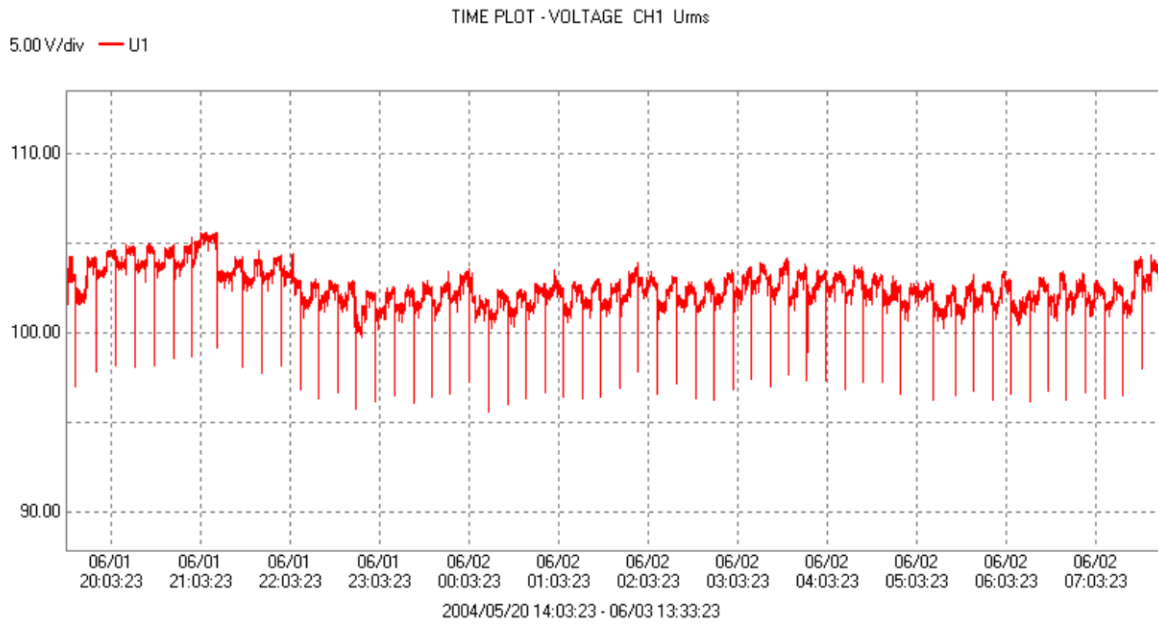
Environment

Target: Retail store, 1-phase 2-wire, 100V outlet
 Measured period: 2 weeks

Analysis

When analyzing the voltage RMS value fluctuation, the following two phenomena were observed. (The graph shows measurement during 12 hours in the night for a period of 2 weeks.)

- 1) Maximum value: 106.70Vrms, Average value: 102.53Vrms, Minimum value 93.25Vrms
- 2) Instantaneous voltage drop occurred at about every 13 minutes.



Voltage Fluctuation

The cause of the instantaneous voltage drop every 13 minutes is assumed to have originated from an electronic device connected to the line as this outlet is turned on or works periodically via a timer.

The device may have a high inrush current – common in equipment such as laser printers, copy machines, electric heaters, etc. A laser printer consumes current periodically, and causes a voltage drop as a result of its start-up current consumption. An electric heater also causes a voltage drop from the periodic inrush current coming from the power cycling of the thermostat.

Recommendation: There are many instantaneous voltage drops, but the minimum voltage is 93.25Vrms which is about 7% lower than the nominal voltage. Most equipment works normally at this voltage level. However, the customer should be careful when adding a new load.

General UPS Switching Waveforms

Environment

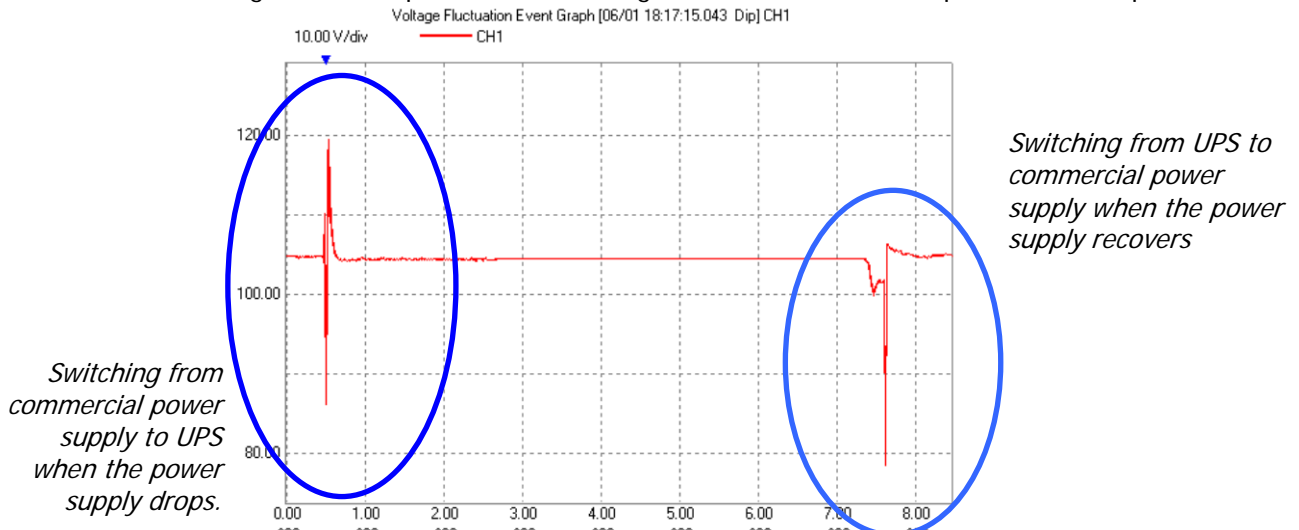
Target: UPS for a desktop PCs sold in retail stores (1-phase 2-wire, 100V)

Problem & Analysis

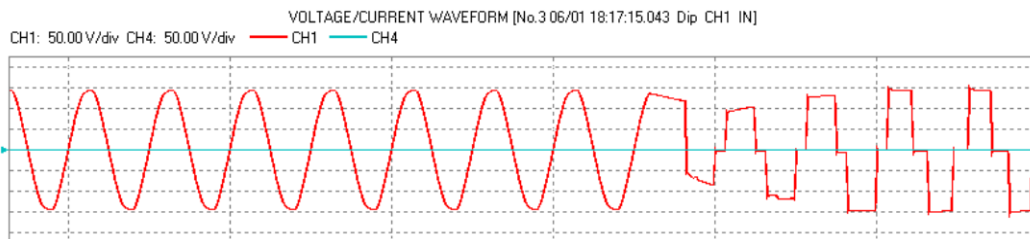
Most low cost UPS used for general purposes output a square wave. However, most people assume that a sine wave is output. Here is a sample waveform output by a UPS.

- 1) Low cost inverter type
- 2) Commercial-type without a compensation function for the voltage distortion, etc.

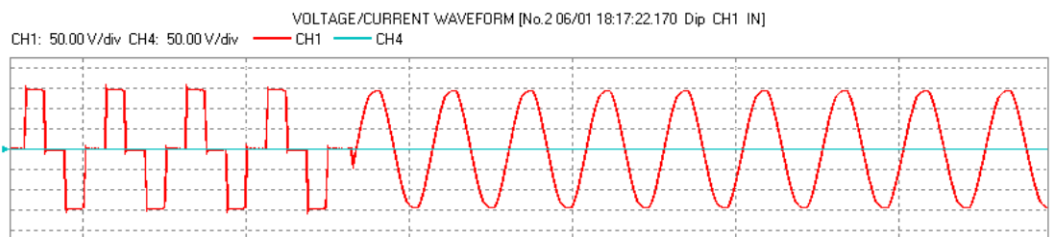
Note that the voltage swell or dip occurs in switching if the UPS does not compensate for the period.



Event Voltage Fluctuation (RMS value trend per waveform) of UPS Output



Voltage Waveform when the Power Supply Drops
(switching from commercial power supply to UPS)



Voltage Waveform when the Power Supply Recovers
(switching from UPS to commercial power supply)

Case Study 9

Voltage Waveform Noise & UPS Switching

Environment

Target: 1-phase 2-wire, 100V circuit

Problem

Equipment has malfunctioned

Analysis

68 "Wave (voltage waveform distortion)" events were recorded during an 18-day measurement period using the following settings. All events are of the same type.

SYSTEM					
MEASURE	EVENT VOLTAGE	EVENT POWER	U Harmonics	I Harmonics	P Harmonics
U Transient	123ch 0.4800kV	4ch OFF			
Urms SWEL	110.00 %				
Urms DIP	90.00 %				
Urms Interrupt	10.00 %				
Event Record	FIFO				
Frequency	5.000 Hz				
U Wave	6%				
External	OFF				
Hysteresis	1.000 %				

Event Settings

EVENT LIST				
No.	Date	Time	Event Category	CH
8	09/12	08:40:32.380	Wave	CH1
9	09/12	08:40:31.963	Wave	CH1
10	09/11	17:33:35.660	Wave	CH1
11	09/10	17:31:17.998	Wave	CH1
12	09/10	17:31:17.998	Wave	CH1
13	09/10	17:31:16.947	Wave	CH1
14	09/10	17:31:16.731	Wave	CH1
15	09/10	17:31:16.715	Wave	CH1
16	09/10	13:28:47.798	Wave	CH1
17	09/10	09:53:42.346	Wave	CH1
18	09/10	09:53:42.146	Wave	CH1
19	09/09	08:43:48.862	Wave	CH1
20	09/09	08:43:35.686	Wave	CH1
21	09/09	06:48:52.122	Wave	CH1
22	09/09	06:48:45.008	Wave	CH1
23	09/09	06:48:44.674	Wave	CH1
24	09/09	06:48:44.458	Wave	CH1
25	09/09	06:48:44.425	Wave	CH1
26	09/09	06:48:44.108	Wave	CH1
27	09/08	17:30:36.544	Wave	CH1
28	09/08	14:00:48.953	Wave	CH1
29	09/08	09:21:38.157	Wave	CH1
30	09/08	08:43:44.715	Wave	CH1
31	09/07	15:47:13.970	Wave	CH1
32	09/07	15:46:09.039	Wave	CH1
33	09/05	09:04:01.211	Wave	CH1
34	09/05	09:04:00.778	Wave	CH1
35	09/05	09:04:00.561	Wave	CH1
36	09/05	09:04:00.344	Wave	CH1
37	09/05	09:03:59.944	Wave	CH1
38	09/05	08:43:32.802	Wave	CH1
39	09/05	08:43:03.670	Wave	CH1
40	09/05	08:43:03.454	Wave	CH1
41	09/05	08:43:02.904	Wave	CH1
42	09/05	08:43:02.705	Wave	CH1
43	09/04	17:22:05.873	Wave	CH1
44	09/04	09:55:02.191	Wave	CH1
45	09/04	08:45:00.711	Wave	CH1
46	09/03	15:37:31.984	Wave	CH1
47	09/03	07:21:50.563	Wave	CH1
48	09/01	17:26:17.674	Wave	CH1
49	09/01	17:26:17.325	Wave	CH1
50	09/01	17:26:17.041	Wave	CH1
51	09/01	17:26:16.842	Wave	CH1
52	09/01	17:26:16.641	Wave	CH1
53	09/01	17:26:16.425	Wave	CH1
54	09/01	17:26:16.408	Wave	CH1
55	08/29	16:50:50.509	Wave	CH1
56	08/29	15:49:22.128	Wave	CH1
57	08/26	08:35:13.135	Wave	CH1
58	08/26	06:48:39.531	Wave	CH1
59	08/26	06:48:36.996	Wave	CH1
60	08/26	06:48:36.813	Wave	CH1
61	08/26	06:48:35.429	Wave	CH1
62	08/26	06:48:34.178	Wave	CH1
63	08/26	06:48:33.962	Wave	CH1
64	08/26	06:48:33.761	Wave	CH1
65	08/26	06:48:31.510	Wave	CH1
66	08/26	04:47:19.788	Wave	CH1
67	08/26	04:47:19.604	Wave	CH1
68	08/25	22:14:00.102	Wave	CH1
69	08/25	19:20:59.470	Wave	CH1
70	08/25	14:01:57.110	Ext (Start)	

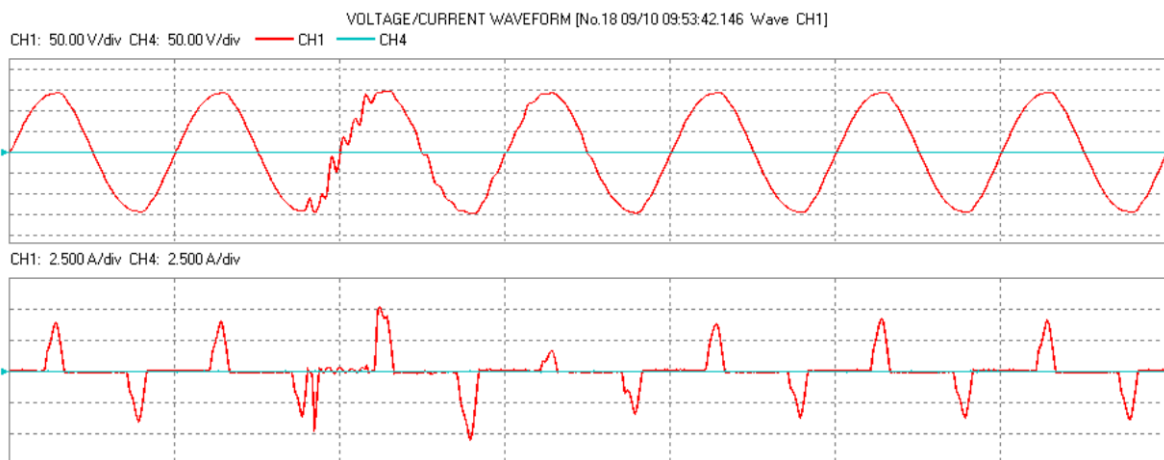
Event List

Next, the waveform of each "wave" event was checked, and 2 types of events were found.

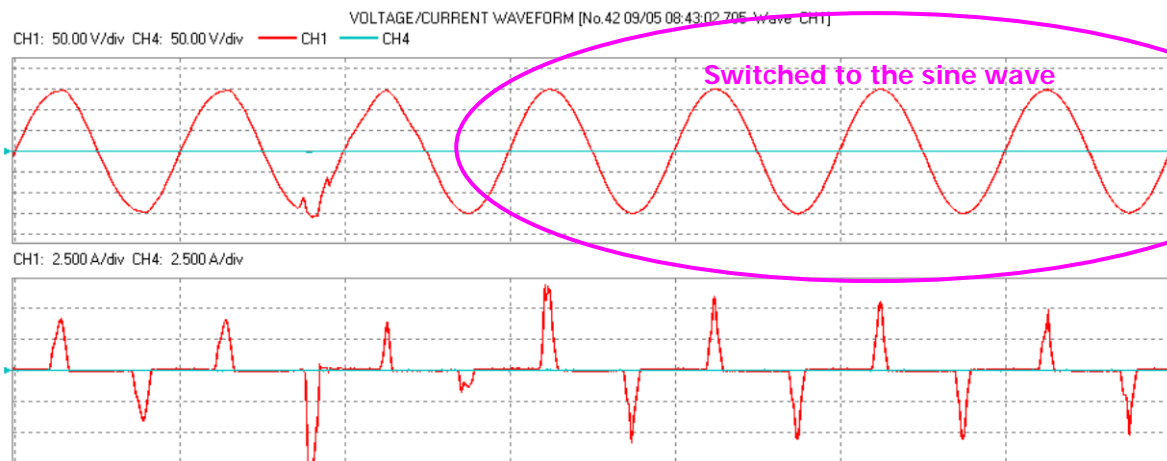
- Type 1: Not switched to a sine wave after the waveform noise
- Type 2: Switched to a sine wave after the waveform noise

We can assume that the events classified as "switched to a sine wave after the waveform noise" were due to the switching to the UPS output (stand-by system).

It appears that Type 1 has a higher noise level and should be switched to the UPS output. However, Type 2 shows a bigger difference in the current waveform when the voltage waveform shows the noise. Therefore, we can assume that a Transient voltage occurs simultaneously when this event occurs. Unfortunately, the Transient voltage is not detected, because its threshold is set at 480V. It is recommended that the threshold be set at 70V (equivalent to 1/2 of the wave peak value) for a 100Vrms circuit



Type 1: Not Switched to the Sine Wave after the Waveform Noise



Type 2: Switched to the Sine Wave after the Waveform Noise

Voltage Dip at a Factory

Environment

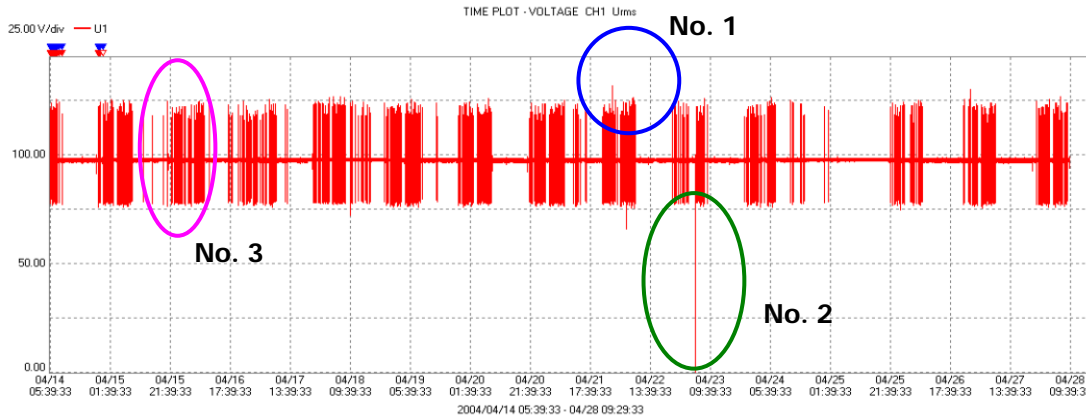
Target: A factory, 1-phase 2-wire, 100V circuit

Problem

The power supply is damaged

Analysis

1. Voltage fluctuation



Voltage Fluctuation

The following power characteristics were concluded from analyzing this 2-week voltage fluctuation graph.

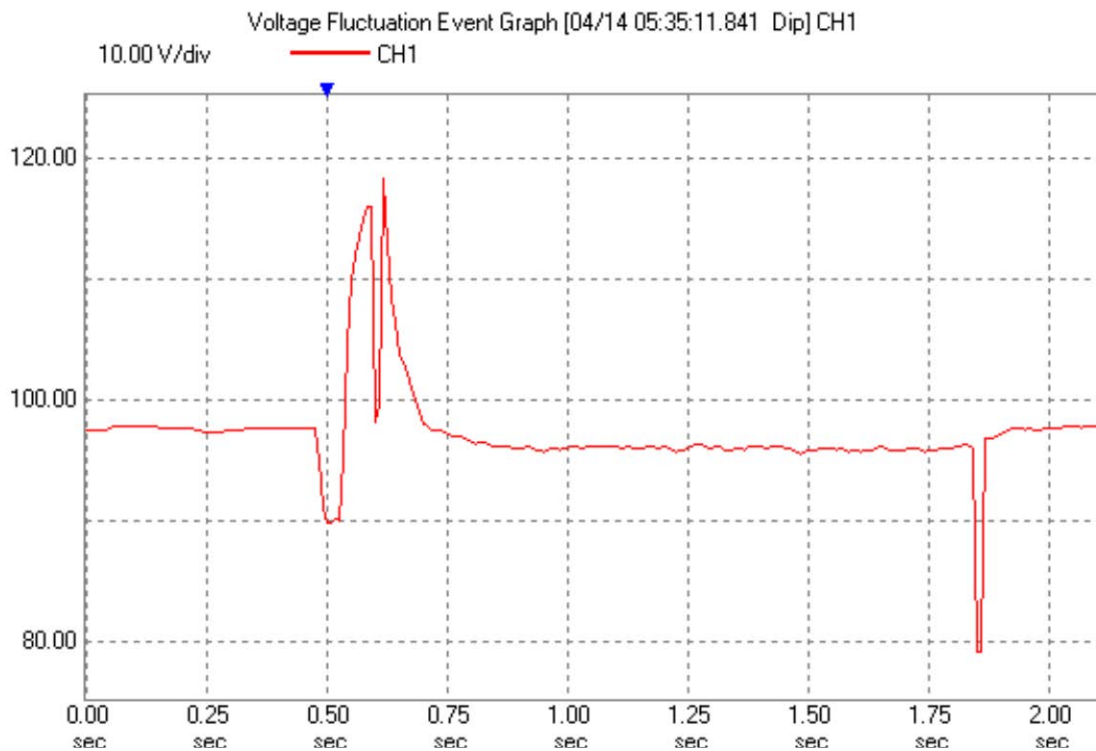
	Supply voltage	Voltage fluctuation graph	Voltage value
1	Maximum	No. 1 (blue)	131.67Vrms
2	Minimum	No. 2 (green)	0.15Vrms
3	Average		98Vrms

Unfortunately, sufficient event data was not recorded in No. 1 and No. 2, so that detailed analysis was not possible. The important point to note is that a large voltage fluctuation occurred between 9 p.m. and 9 a.m. everyday (No. 3), and the fluctuation was large at about 50V (between 75Vrms and 125Vrms).

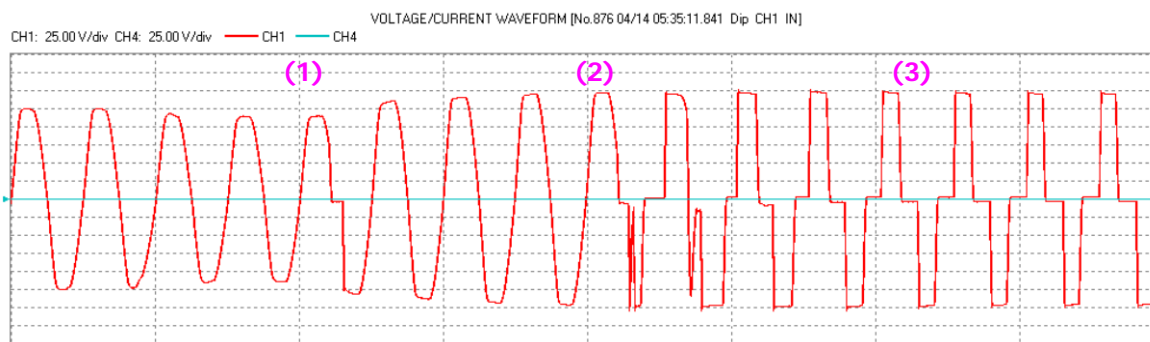
2. Event Data

The voltage dip (instantaneous voltage drop) occurred frequently at night. Only 5 voltage dips were detectable in a 1s period. All voltage dip situations demonstrated the same tendency. This is the analysis of one voltage dip event.

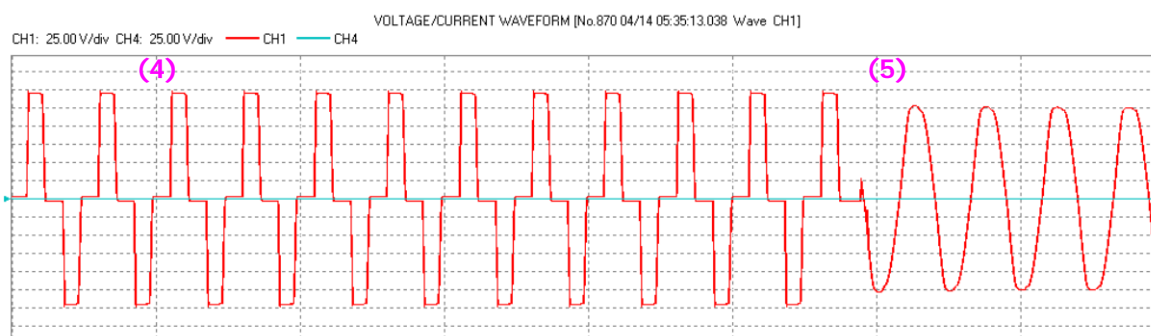
- 1) When the depth of the voltage dip reaches 90Vrms, the power supply is switched from the commercial supply to the UPS.
- 2) When the power supply is switched to the UPS, the voltage RMS value increases to 116Vrms (125Vrms maximum).
- 3) The voltage waveform changes from the sine wave to the square wave in the UPS supply.
- 4) The square wave continues for about 1.25s.
- 5) The power supply is changed from the UPS to the commercial supply later. Upon this switching, the voltage drops to 78Vrms (75Vrms minimum()) for a short period.



Event Voltage Fluctuation (RMS value trend per waveform) at the Voltage Dip Occurrence



Voltage Waveform at the Start of the Voltage Dip



Voltage Waveform at the End of the Voltage Dip

3. Summary of analysis

- 1) Worse power supply quality occurs frequently at night (9 p.m. to 9 a.m.)
- 2) Worse power quality phenomena starts when the voltage dips.
- 3) Voltage swell occurs when switching from the commercial power to the UPS due to the voltage dip.
- 4) Voltage dip occurs when the commercial power recovers and the power supply is switched from the UPS to the commercial supply.

4. Countermeasures

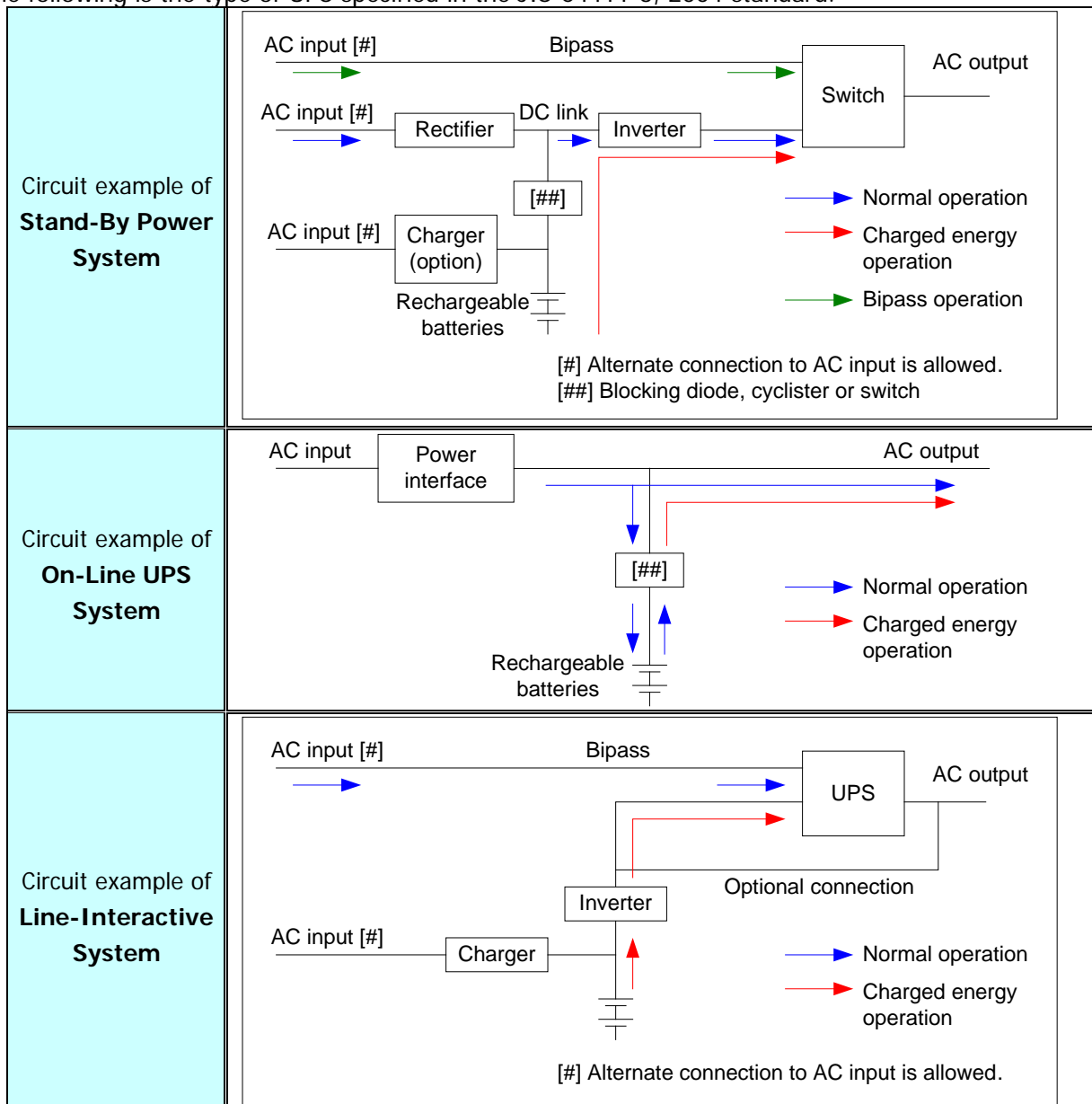
- 1) Primary solution

Frequent switching to the UPS because of a voltage dip is not favorable. It appears that overload current flows to the equipment due to voltage dips and swells. To solve this problem without fail, the power supply should be stabilized to prevent the occurrence of a voltage dip.

- 2) Alternative solution

The UPS is used as a “stand-by power system (SPS)”. By changing it to an although more costly “on-line UPS system”, the dips and swells can be reduced during UPS switching.

The following is the type of UPS specified in the JIS C4411-3, 2004 standard.



Investigating the Flow of Harmonics

Environment

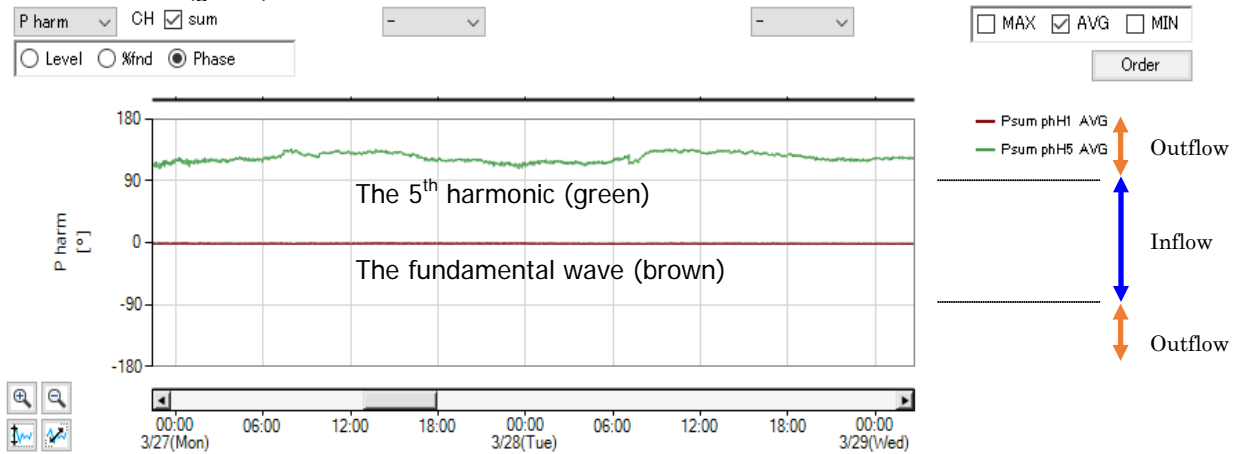
Target: 3-phase 3-wire (3P3W2M), 6.6kV circuit

Analysis

While measuring harmonics, the direction of the flow of harmonics can be investigated at the same time. Using a 3-phase 3-wire set up, the overall inflow and outflow of a 3-phase installation are judged by the harmonic voltage-current phase difference (P harm/phase/sum). When it is between -90° to 0° to $+90^\circ$, it is identified as an inflow. Conversely, outflow is determined when it is between -180° to -90° or $+90^\circ$ to $+180^\circ$.

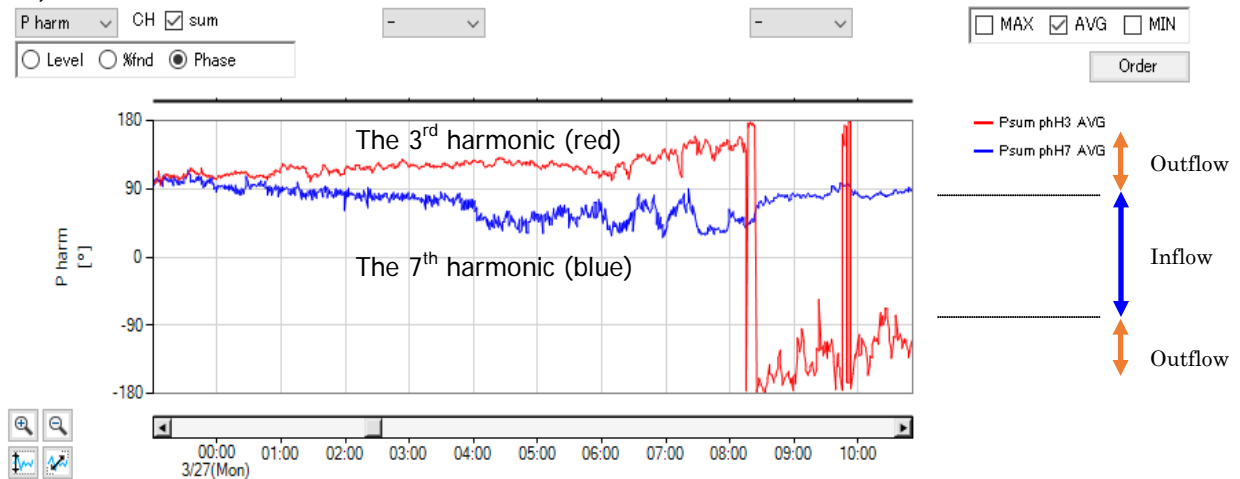
The fundamental wave (brown) is consumption (inflow) as shown below.

The 5th harmonic (green) is also inflow.



Time Plot of Harmonic Voltage-Current Phase Difference (fundamental and 5th harmonic)

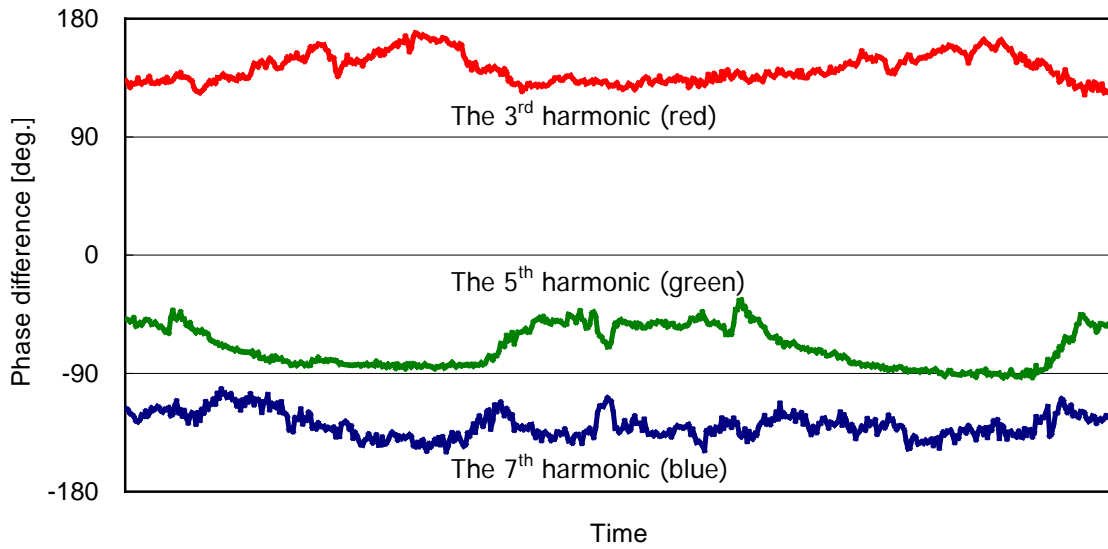
The 3rd harmonic (red) is outflow as shown in the graph below. The 7th harmonic (blue) is outflow. The data shows with the vertical lines that the phase difference exceeds 180° and returns to -180° (or vice versa).



Time Plot of Harmonic Voltage-Current Phase Difference (3rd and 7th harmonics)

We recommend judging the inflow or outflow by using the "Pharm/phase/AVG" graph in the harmonic time plot graph on the PC application software PQ ONE.

<Judgment Example 1>



<Judgment Example 2>

Date	Time	Psum_phH5_AVG	Inflow / Outflow
2004/9/3	6:50:00	-93.07	Outflow
2004/9/3	6:55:00	-90.63	Outflow
2004/9/3	7:00:00	-84.20	Inflow
2004/9/3	7:05:00	-89.23	Inflow
2004/9/3	7:10:00	-87.79	Inflow
2004/9/3	7:15:00	-87.42	Inflow
2004/9/3	7:20:00	-87.16	Inflow
2004/9/3	7:25:00	-86.08	Inflow
2004/9/3	7:30:00	-79.51	Inflow
2004/9/3	7:35:00	-84.34	Inflow
2004/9/3	7:40:00	-80.74	Inflow
2004/9/3	7:45:00	-78.41	Inflow

Example of Using MS Excel

Formula
`=IF(ABS(C2)>90,"Outflow","Inflow")`

<Reference> **Guideline for the Harmonics of a Distribution Network (Japan)**

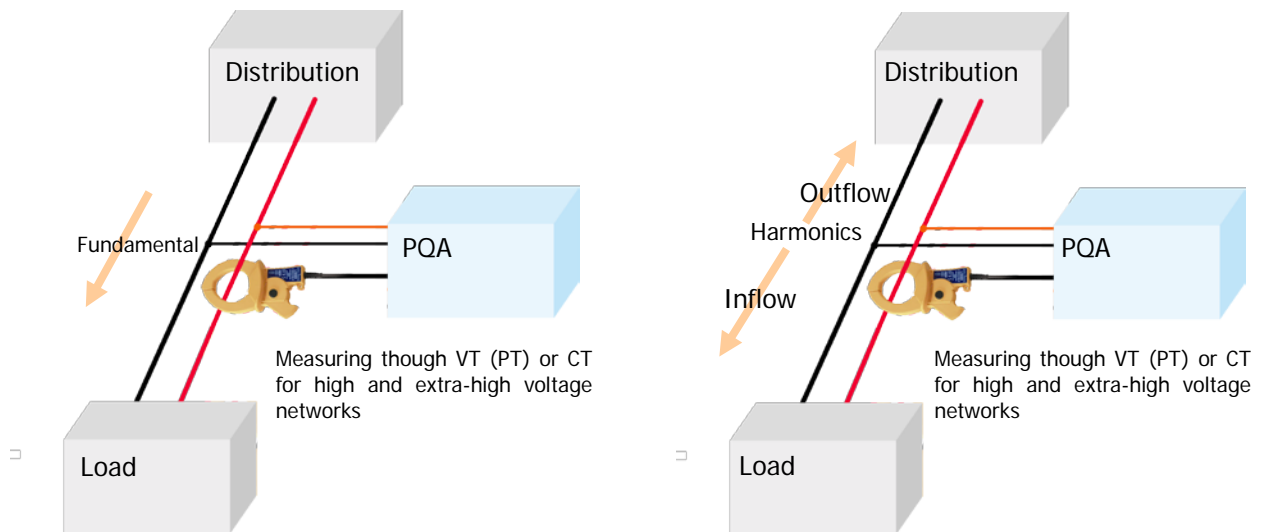
Official Report from the Ministry of Economics and Industries in Japan
 “Guideline for Harmonics Deterrence Countermeasures on Demand-Side that receives High Voltage or Extra High-Voltage” (established in September 1994, revised in April 2014)

- 1) Harmonic Voltage (Total Harmonic Voltage Distortion)
 5% at 6.6kV system, 3% at extra high-voltage system
- 2) Harmonic Current

Upper limit values of harmonic outflow current (mA/kW) per 1kW of Contracted Power

Order	5 th	7 th	11 th	13 th	17 th	19 th	23 rd	Higher than 23rd
Voltage [kV]								
6.6	3.5	2.5	1.6	1.3	1.0	0.9	0.76	0.70
22	1.8	1.3	0.82	0.69	0.53	0.47	0.39	0.36
33	1.2	0.86	0.55	0.46	0.35	0.32	0.26	0.24
66	0.59	0.42	0.27	0.23	0.17	0.16	0.13	0.12
77	0.50	0.36	0.23	0.19	0.15	0.13	0.11	0.10
110	0.35	0.25	0.16	0.13	0.10	0.09	0.07	0.07
154	0.25	0.18	0.11	0.09	0.07	0.06	0.05	0.05
220	0.17	0.12	0.08	0.06	0.05	0.04	0.03	0.03
275	0.14	0.10	0.06	0.05	0.04	0.03	0.03	0.02
500	0.07	0.05	0.03	0.02	0.02	0.02	0.01	0.01

<Reference> **Concept of inflow and outflow of harmonics**



	Condition	Cause
Inflow	The harmonics flow from distribution to load.	The reason is very likely to be attributed to the distribution side (The harmonics generated by distribution is bigger than the harmonics generated by load.)
Outflow	The harmonics flow from load to distribution.	The reason is very likely to be attributed to the load side (The harmonics generated by load is bigger than the harmonics generated by distribution.)

Because harmonic is a vector containing amplitude and phase components, if there are multiple harmonics, you will not be able to determine the source solely from the flow direction. In fact, the almost all power supplies contain harmonics, so it is difficult to determine the origin of the harmonic simply by looking at the inflow and outflow.

<Reference> Harmonic inflow/outflow judgment on a measuring instrument

1. Judgment based on harmonic power

Judge the inflow or outflow according to the polarity of the harmonic (effective) power. (Judge each phase and each order independently.)

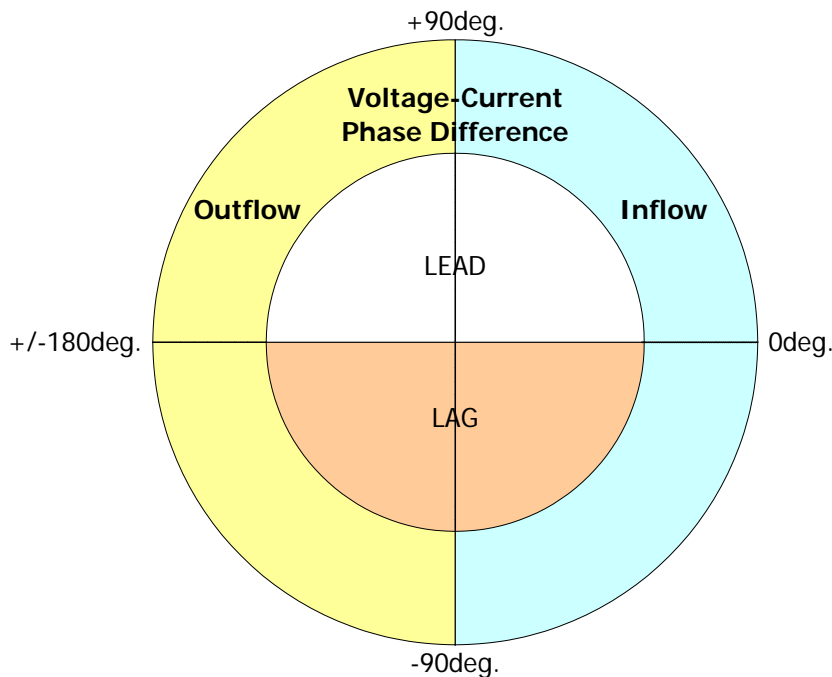
Inflow	Harmonic power is + (positive).
Outflow	Harmonic power is - (negative).

Problem	The higher the order, the smaller the harmonics power level.
	The smaller level makes it difficult to judge the polarity accurately, thus making it difficult to judge inflow and outflow.

2. Judgment based on the harmonic voltage-current phase difference

Judge the inflow or outflow according to the harmonic voltage-current phase difference (difference between harmonic voltage phase angle and harmonic current phase angle).

For 3-phase 3-wire (3P3W2M or 3P3W3M) installations, we recommend using the harmonic voltage-current phase difference of the "sum" value.



	Harmonic voltage-current phase angle difference
Inflow	+90° to 0° to +90°
Outflow	-180° to -90° or +90° to +180°

Recommendations	Measure the harmonic for a long duration, observe the amplitude level of the harmonic current to see if it is high or exceeds the limit. Then, while considering the operating status of the equipment, make an assumption about the source of the harmonic. Chart the start/stop time of the suspected equipment, and compare the harmonic level as well as the correlation between the inflow and outflow of the harmonic voltage-current phase angle difference to make a clear determination.
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Case Study 12

High-Order Harmonics Caused by Inverter Equipment

If the power supply of equipment includes a semiconductor control device, high frequency noise (higher than several kHz) may be generated by distorted voltage and current waveforms.

The RMS value of such a noise is called "high-order harmonics".

It may contain various frequency components, and becomes a noise higher than multiples of 10V once it is affected by resonance of cables, etc. This voltage noise causes equipment to malfunction or become damaged, and may also be received by TVs and radios in the same building or neighborhood.

Environment

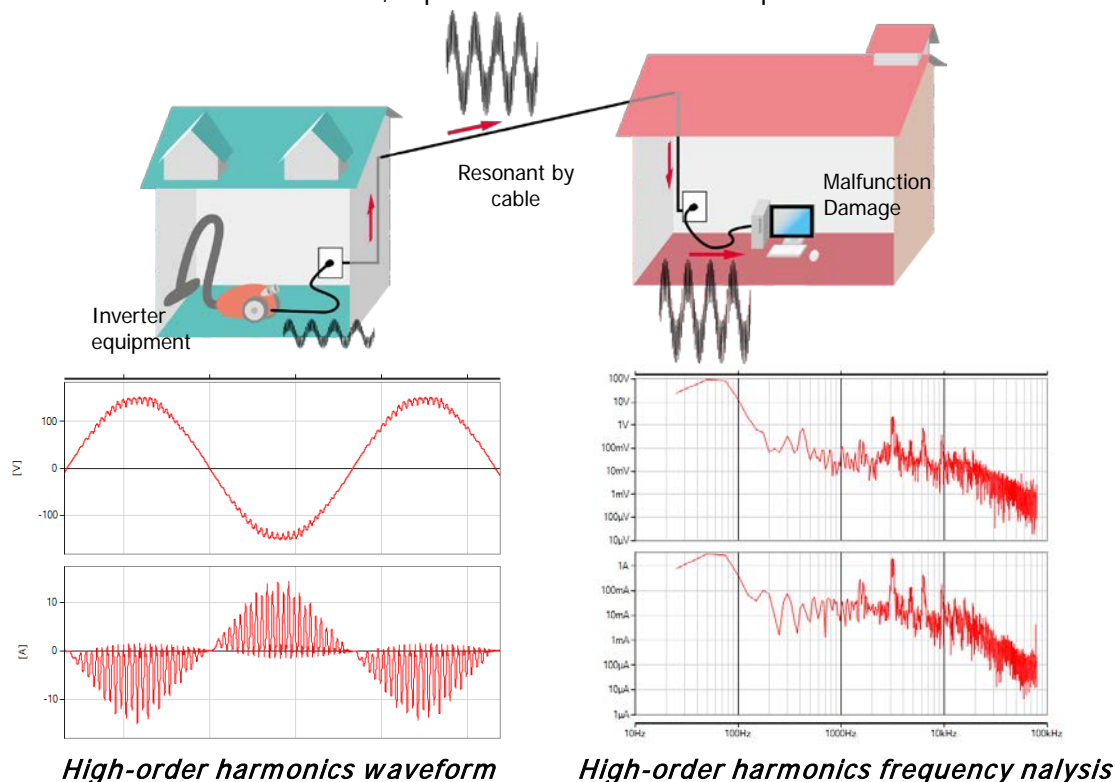
Target: 1-phase 2-wire, 100V circuit

Problem

- Equipment malfunction or damage
- Receiving problems with TV and radio signals in the neighborhood

Analysis

High-order harmonics are often higher in frequency than the 50th order harmonic, so it cannot be detected by conventional harmonic analysis. By using the high-order harmonic function of Model PQ3198, the sum of high frequency noise can be easily detected. The critical frequency varies, but such noise may exceed 10V in resonance due to the resistance, capacitance or inductance component of the cables.

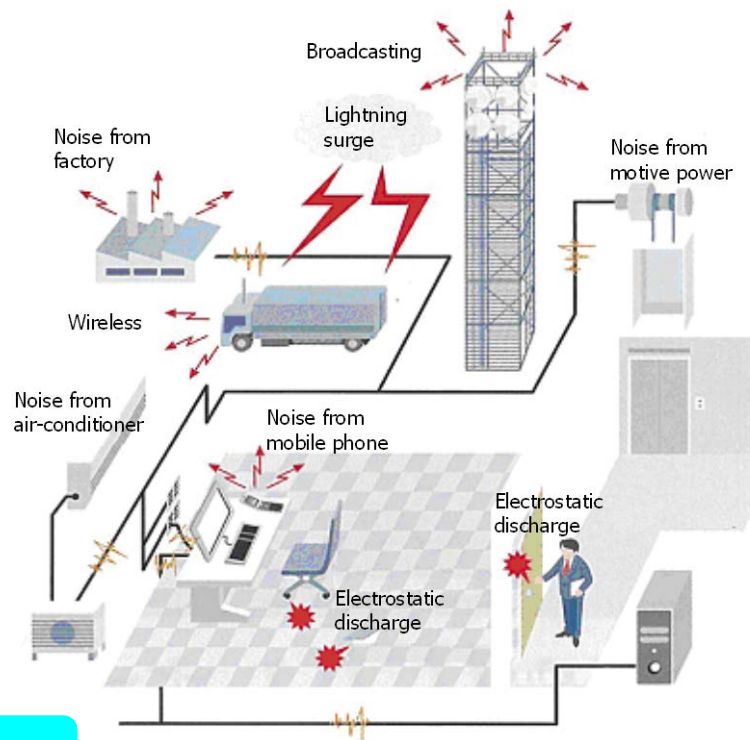


Usually, the noise generated by equipment, and particularly its power supply, is regulated by the IEC61000-3-3 (Flicker), IEC61000-3-2 (Harmonics), IEC61000-3-12 (Total harmonic distortion), etc. However, the measurement object is up to the 40th order (2kHz on 50Hz, 2.4kHz on 60Hz) only. Also, the frequency regulated by the power supply terminal disturbance voltage (CISPR 22/EN55022, etc.) is 150kHz or higher. As such, there is no standard or regulation for noise in the several 10kHz range. The PC application software PQ ONE can be used for frequency analysis of higher harmonics. The source of the noise might come from the device that has a high switching frequency.

Conductive Noise

Environment

Conductive noise is electrical noise spreading from various paths. It spreads from the Transient voltage (lightning strike surge), electrostatic, high-order harmonics, etc. through the power supply, signal and grounding cables. Also, noise generated by magnetic fields is called "radiation noise".



Problem

- Equipment malfunction or damage
- Receiving problems with TV and radio signals in the neighborhood

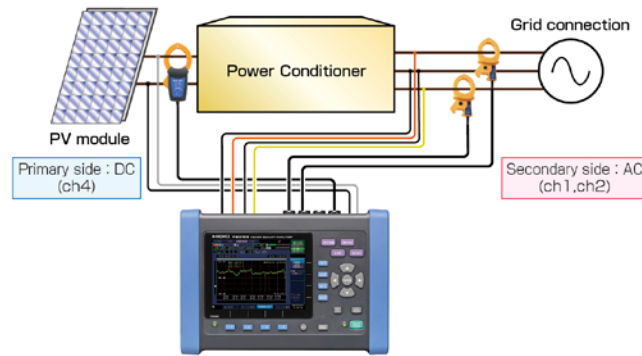
Analysis

Conductive noise is often high frequency noise. As such, the following measurement can be effective. In addition, you can cover up to 100MHz of frequency by using HIOKI Model 3144-20 Noise Search Tester or 3145-20 Noise HiLogger.

- Transient voltage
Generated by lightning strikes, switching from generation to consumption, grid switching, etc. This can cause malfunction to equipment and solar power generation systems, etc.
- Harmonics, High-order harmonics

Environment

Target:



A power conditioner supplies the power (outputs the current) to the grid by using the voltage difference between grid voltage and output voltage. Also, it constantly monitors the grid voltage and frequency so that it can adjust the output voltage and frequency as required.

Problem

- Inverter controlled equipment stops because it detects a fault on the commercial power supply
- Malfunction of peripheral equipment
- Power cannot be sold back to the utility company due to voltage fluctuation of the commercial power supply (especially when the voltage increases)

Due to fluctuation of neighboring load conditions, the voltage of the commercial power supply fluctuates, causing the safety system of the power conditioner to prevent the selling of the power.

Analysis

The following items should be measured simultaneously:

- Voltage fluctuation
- Frequency fluctuation

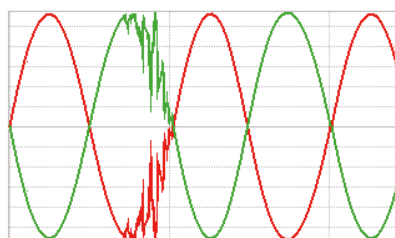
Model PQ3198 can measure the 10s average frequency required for Class A classification of the IEC61000-4-30 standard. In addition, the PQA can measure the average frequency of 200ms aggregation and 1 cycle frequency. By using these additional capabilities, it helps to confirm the stability of the output frequency from a power conditioner.

- Transient voltage, Waveform distortion

This is often generated by lightning strikes, switching from generation to consumption, grid switching, etc. It causes malfunction in equipment and solar power generation system, etc.

- Inrush current
- Harmonics (Both voltage and current)
- High-order harmonics
- Flicker

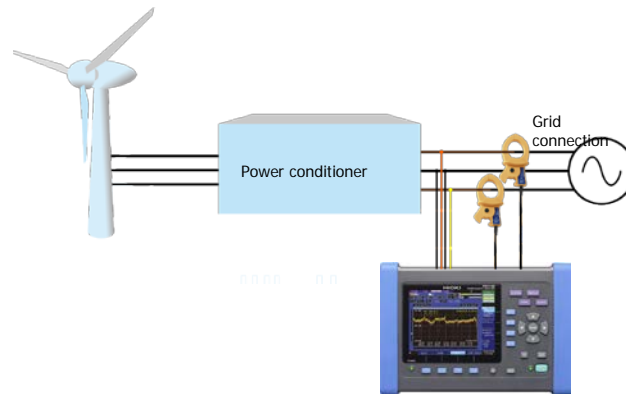
Also, power and integrated power (consumption, re-generation) can be measured simultaneously with the power quality parameters.



Voltage waveform at grid switching

Environment

Target:



Problem

- Inverter controlled equipment stops when detecting a fault in the commercial power supply

Measurement

The following items should be measured simultaneously:

- Voltage fluctuation
 - The output voltage fluctuates regardless of the demand caused by the wind speed difference.
- Frequency fluctuation
- Transient voltage, Waveform distortion
 - Generated by lightning strikes and grid switching
- Inrush current
- Harmonics
- High-order harmonics
- Flicker

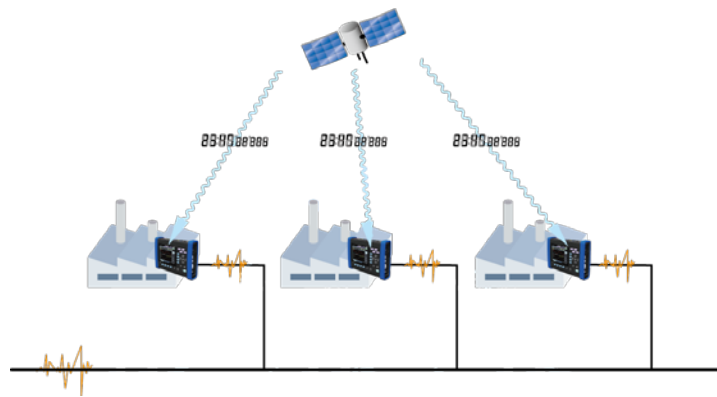
Synchronization to the GPS Clock (PQ3198)

Purpose

To measure the spread of lightning strikes or power outages, power quality should be measured at multiple points under the same time clock.

Model PQ3198 can synchronize its time clock to the UTC (Coordinated Universal Time) clock with $\pm 2\text{ms}$ accuracy by using the optional PW9005 GPS Box.

This allows you to measure power quality under the same time clock at any location. In addition, the PQ3198 conforms to Class A performance of the IEC61000-4-30, so that the measurement results are within accuracy for all units



Case Study 17

Remote Operation and Measurement (PQ3198)

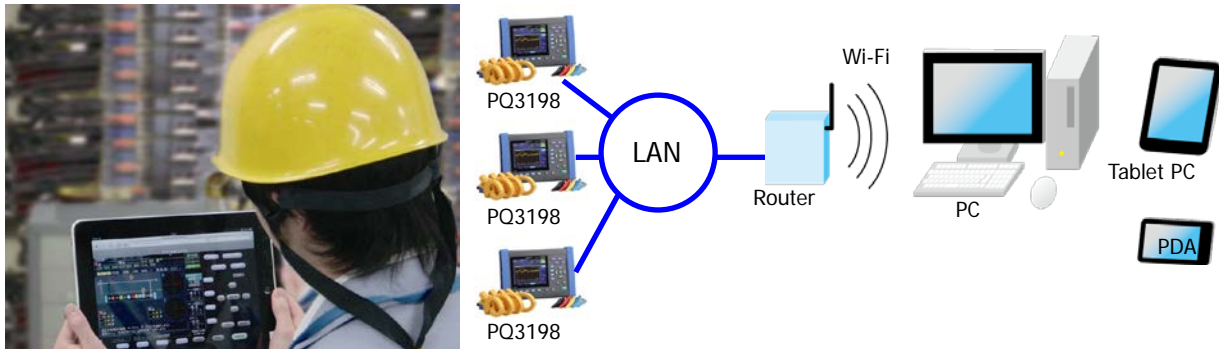
Purpose

Remotely operate and monitor the unit installed at a customer's site.

Method

Connect to the LAN network and monitor measurements using the HTTP server function without using any special software.

Connection example using wireless LAN



Screen example on a PC when using the HTTP server function



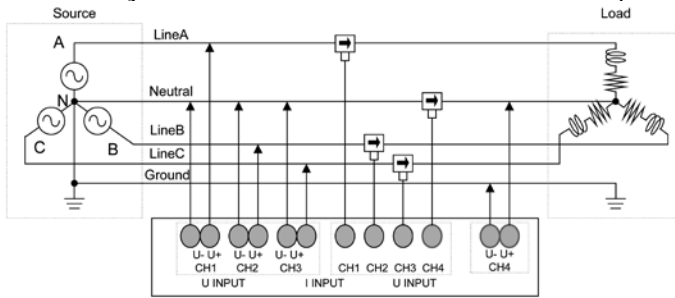
Operate in the same manner as the actual unit by pressing the buttons.

The automatic screen refresh rate is 0.5s at its fastest.

Case Study 18

Effective Utilization of CH4 (PQ3198)

CH4 is usually used to measure the neutral line of a 3-phase 4-wire system.

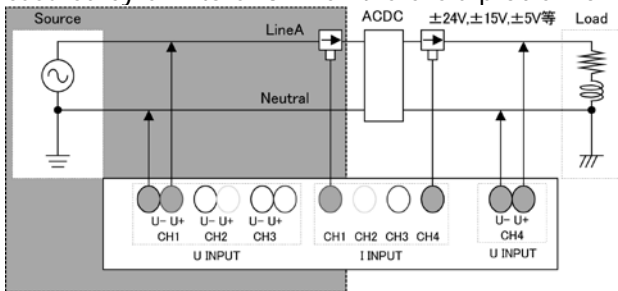


Because CH4 is isolated from the other channels, the following applications are also possible.

1. DC measurement

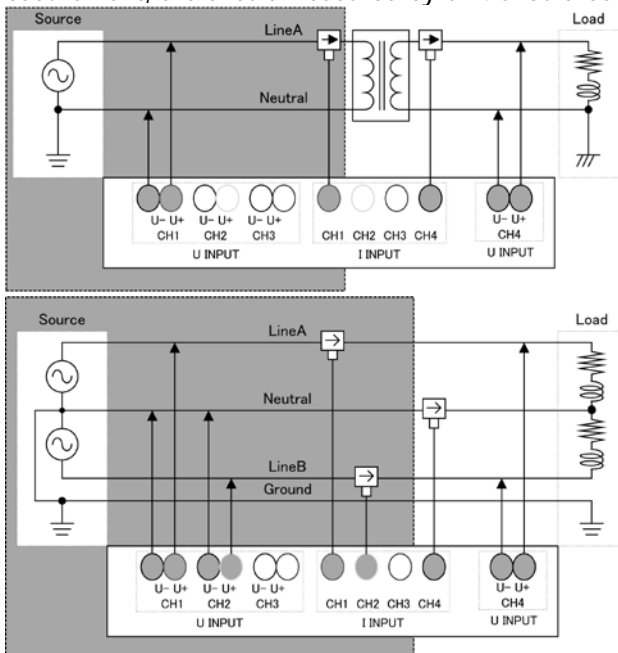
This has wide applications for monitoring the DC power supply system or the internal power supply system of equipment.

Model PQ3198 can detect events for DC values, allowing you to see the impact to the AC power supply measured by CH1 to CH3 when there is a problem on the DC power supply.



2. 2-circuit measurement

Model PQ3198 can measure another circuit from CH1 to CH3 (except power values). For precise measurement, the circuit measured by CH4 should be synchronized to the circuit measured by CH1 to CH3.

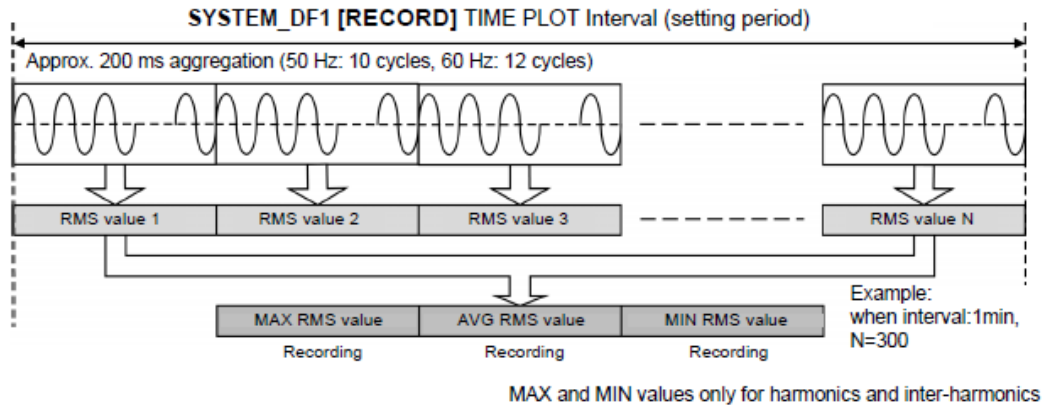


6.

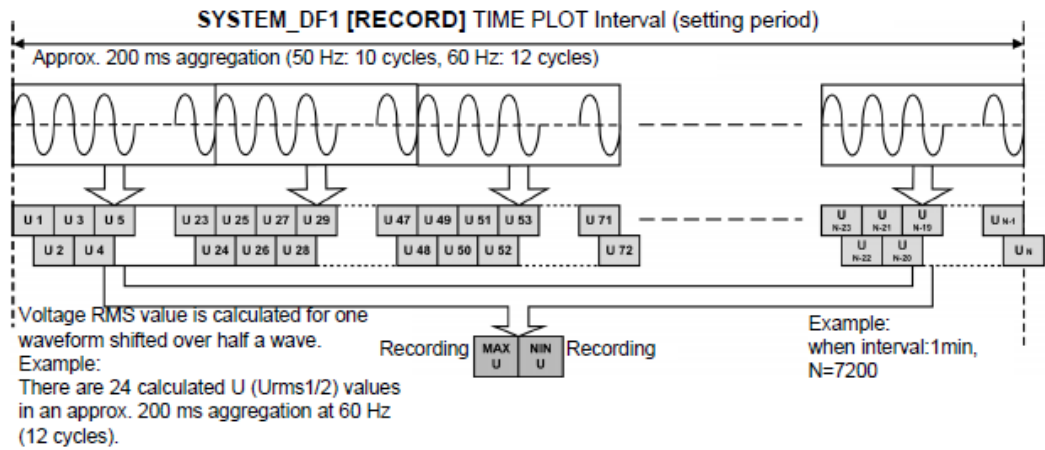
Recording Method of TIME PLOT and Event Waveform

1. Recording method of TIME PLOT

-1. Trends of RMS values and harmonics

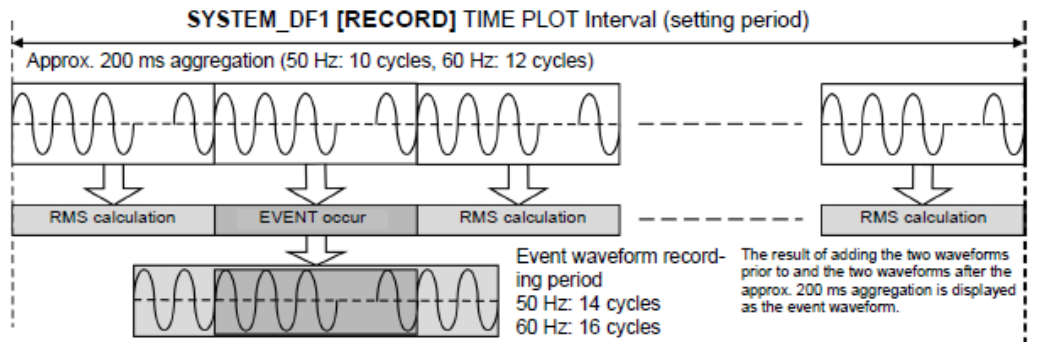


-2. Detailed trends

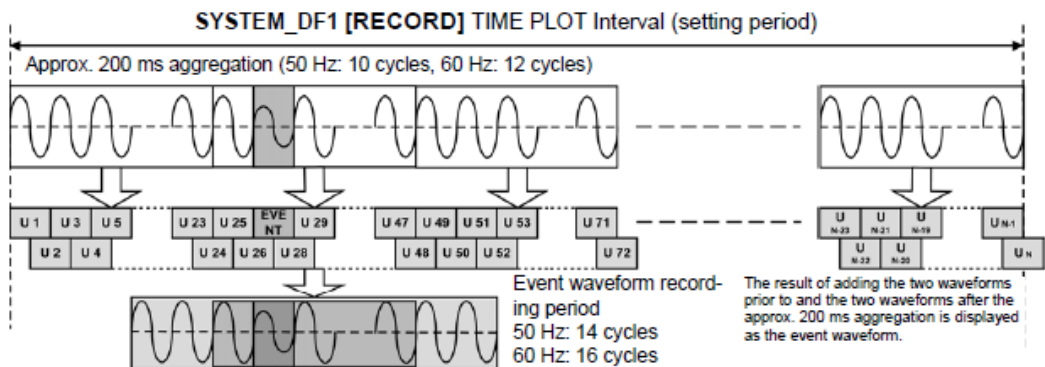


2. Recording method of event waveform

-1. Events using 200ms aggregation measured items



-2. One or half-wave measured values



10-sec frequency (Freq10s)

The measured frequency value as calculated according to IEC61000-4-30, consisting of a 10-second average of the frequency. We recommend measuring this characteristic for at least one week.

Active power

Power that is consumed when doing work.

Active power demand

The average active power used during a set period of time (usually 30 minutes).

Apparent power

The (vector) power obtained by combining active power and reactive power. As its name suggests, apparent power expresses the "visible" power and comprises the product of the voltage and current RMS values.

Binary data

All data other than text (character) data. Use binary data when analyzing data with the PC application software PQ ONE.

Continuous event function

Functionality for automatically generating a set number of events in succession every time a target event occurs. Events after the initial event are recorded as continuous events. This functionality allows an instantaneous waveform of up to 1s in duration to be recorded after the event occurs. However, continuous events are not generated when an event occurs while continuous events are occurring. Additionally, continuous event generation stops when measurement is stopped. Use this function when you wish to observe a waveform at the instant an event occurs as well as subsequent changes in the instantaneous waveform. For the PQ3198, a waveform of up to 1s in duration will be recorded.

EN50160

A European power supply quality standard that defines limit values for supply voltage and other characteristics. The PC application software PQ ONE can be used with data from the PQ3198 to perform standards-compliant evaluation and analysis.

Event

Power supply quality parameters are necessary in order to investigate and analyze power supply issues. These parameters include disturbances such as transients, dips, swells, interruptions, flicker, and frequency fluctuations. As a rule, the term "event" refers to the state detected based on thresholds for which abnormal values and abnormal waveforms for these parameters have been set. Events also include timer and repeat event settings, which are unrelated to power supply quality parameters.

External event function

Functionality for generating events by detecting a signal input to the instrument's external event input terminal and recording measured values and event waveforms at the time of detection. In this way, events are generated based on an alarm signal from a device other than the PQ3198. By inputting an operating signal from an external device, an operation start or stop trigger can be applied in order to record waveforms with the PQ3198.

Flag

A marker used to distinguish unreliable measured values occurring due to disturbances such as dips, swells, and interruptions. Flags are recorded as part of the TIMEPLOT data status information. The concept is defined by the IEC61000-4-30 standard.

Flicker

A disturbance caused by a voltage drop that results when equipment with a large load starts up or when a large current flows under a temporary high-load state. For lighting loads, flicker primarily manifests itself as blinking. Electric-discharge lamps such as fluorescent and mercury-vapor lights are particularly prone to the effects of flicker. When temporary dimming of lights due to voltage drops occurs frequently, it produces a flickering effect (caused by repeated dimming) that produces an extremely unpleasant visual sensation. Measurement methods can be broadly divided into IEC flicker and $\Delta V10$ flicker. In Japan, the $\Delta V10$ method is most frequently used.

Frequency cycle (Freq_wav)

The frequency of a single waveform. By measuring the frequency cycle, it is possible to monitor frequency fluctuations on an interconnected system at a high degree of detail.

Harmonic content percentage

The ratio of the K-order size to the size of the fundamental wave, expressed as a percentage using the following equation:

$$K\text{-order wave} / \text{fundamental wave} \times 100 [\%]$$

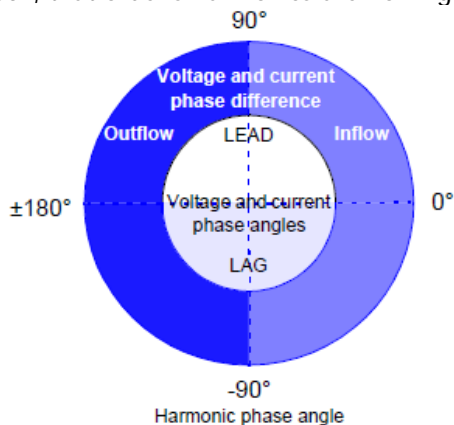
By observing this value, it is possible to ascertain the harmonic component content for individual orders. This metric provides a useful way to track the harmonic content percentage when monitoring a specific order.

Harmonics

A phenomenon caused by distortions in the voltage and current waveforms that affect many devices with power supplies using semiconductor control devices. In the analysis of non-sine waves, the term refers to one RMS value among the components with harmonic frequencies.

Harmonics phase angle and phase difference

The harmonic voltage phase angle and harmonic current phase angle are expressed in terms of the synchronized source's fundamental component phase. The difference between each order's harmonic component phase and the fundamental component phase is expressed as an angle ($^{\circ}$), and its sign indicates either a lagging phase (negative) or leading phase (positive). The sign is the reverse of the power factor sign. The harmonic voltage-current phase angle expresses the difference between each order's harmonic voltage component phase angle and harmonic current component phase angle for each channel as an angle ($^{\circ}$). When using the sum display, the sum of each order's harmonic power factor (calculated from the sums of harmonic power and harmonic reactive power) is converted to an angle ($^{\circ}$). When the harmonic voltage-current phase angle is between -90° and $+90^{\circ}$, that order's harmonics are flowing toward the load (inflow). When the harmonic voltage-current phase angle is between $+90^{\circ}$ and $+180^{\circ}$ or between -90° and -180° , that order's harmonics are flowing from the load (outflow).



High-order harmonic component

The noise component at and above several kHz. For the PQ3198, the term refers to RMS values for the noise component at 2 kHz and above. By measuring the high-order harmonic component, it is possible to monitor harmonic noise at the 50th and higher order emitted by switching power supplies, inverters, LED lighting, and other devices. Recently, increases in the switching frequencies used by switching power supplies and inverters have resulted in the problematic introduction of noise in excess of 10 kHz into power supply lines.

IEC6000-4-7

An international standard governing measurement of harmonic current and harmonic voltage in power supply systems as well as harmonic current emitted by equipment. The standard specifies the performance of a standard instrument.

IEC6100-4-15

A standard that defines testing techniques for voltage fluctuation and flicker measurement as well as associated measuring instrument requirements.

IEC61000-4-30

A standard governing testing involving power quality measurement in AC power supply systems and associated measurement technologies. Target parameters are restricted to phenomena that are propagated in power systems, specifically frequency, supply voltage amplitude (RMS), flicker, supply voltage dips, swells, (momentary) interruptions, Transient voltages, supply voltage unbalance, harmonics, inter-harmonics, supply voltage carrier signals, and high-speed voltage variations. The standard defines measurement methods for these parameters as well as the necessary instrument performance. It does not define specific thresholds.

Inrush current

A large current that flows temporarily, for example when an electric device is turned on. A inrush current can be equal to or greater than 10 times the current that flows when the device is in the normal operating state. Inrush current measurement can be a useful diagnostic when setting circuit breaker capacity. The inrush current event is detected by using the RMS value of half-cycle of the current waveform.

Inter-harmonics

All frequencies that are not a whole-number multiple of the fundamental frequency. Inter-harmonics include intermediate frequencies and inter-order harmonics, and the term refers to RMS values for the spectral components of electrical signals with frequencies between two contiguous harmonic frequencies. (Inter-harmonics of the order 3.5 assume a drive of 90 Hz or similar rather than a frequency synchronized to the fundamental wave of an inverter or other device. However, inter-harmonics do not generally occur in high-voltage circuits under present-day conditions. Most inter-harmonics are currently thought to be caused by the circuit load.)

Interruption

A phenomenon in which the supply of power stops momentarily or for a short or long period of time due to factors such as a circuit breaker tripping as a result of a power company accident or power supply short-circuit.

ITIC curve

A graph created by the Information Technology Industry Council plotting voltage disturbance data for detected events using the event duration and worst value (as a percentage of the nominal input voltage). The graph format makes it easy to quickly identify which event data distribution should be analyzed. The PC application software PQ ONE can be used to create ITIC curves using PQ3198 data.

K factor

Shows the power loss caused by the harmonic current in transformers. Also referred to as the

"multiplication factor." The K factor (KF) is formulated as shown below:

$$KF = \frac{\sum_{k=1}^{50} (k^2 \times Ik^2)}{\sum_{k=1}^{50} Ik^2}$$

k: Order of harmonics

Ik: Ratio of the harmonic current to the fundamental wave current [%]

Higher-order harmonic currents have a greater influence on the K factor than lower-order harmonic currents.

Purpose of measurement

To measure the K factor in a transformer when subjected to maximum load. If the measured K factor is larger than the multiplication factor of the transformer used, the transformer must be replaced with one with a larger K factor, or the load on the transformer must be reduced. The replacement transformer should have a K factor one rank higher than the measured K factor for the transformer being replaced.

LAN

LAN is the abbreviation of Local Area Network. The LAN was developed as a network for transferring data through a PC within a local area, such as an office, factory, or school. This device comes equipped with the LAN adapter Ethernet 10/100Base-T. Use a twisted pair cable to connect this device to the hub (central computer) of your LAN. The maximum length of the cable connecting the terminal and the hub is 100 m. Communications using TCP/IP as the LAN interface protocol are supported.

Manual event function

Functionality for generating events when the MANU EVENT key is pressed and recording the measured value and event waveform at that time. In this way, events can be generated as a snapshot of the system being measured. Use this functionality when you wish to record a waveform but cannot find another event that defines the desired phenomenon or when you wish to record data manually to avoid the generation of too many events.

Measurement frequency (f_{nom})

The nominal frequency of the system being measured. Select from 50 Hz/60 Hz/400 Hz. (The measurement frequency is automatically set during the simple configuration process.)

Multiple-phase system treatment

Method for defining the start and end of events such as dips, swells, and interruptions in multiple-phase systems, for example systems with 3 phases

Dip:

A dip begins when the voltage of at least one channel is less than or equal to the threshold and ends when voltage readings for all measurement channels exceed (threshold + hysteresis voltage).

Swell:

A swell begins when the voltage of at least one channel exceeds the threshold and ends when voltage readings for all measurement channels are less than or equal to (threshold + hysteresis voltage).

Interruption:

An interruption begins when voltage readings for all channels are less than or equal to the threshold and ends when the voltage of a user-specified channel is greater than or equal to (threshold + hysteresis).

Nominal input voltage (U_{din})

The value calculated from the nominal supply voltage using the transformer ratio. The nominal input voltage is defined by IEC61000-4-30.

Nominal supply voltage (U_c)

Typically, the system's rated voltage U_n . When a voltage that differs from the rated voltage is applied to the contact in accordance with an agreement between the electricity provider and the customer, that voltage is used as the nominal supply voltage U_c . The nominal supply voltage is defined by IEC61000-4-30.

Nominal voltage (U_{ref})

The same voltage as the nominal supply voltage (U_c) defined by IEC61000-4-30 or the rated voltage (U_n).

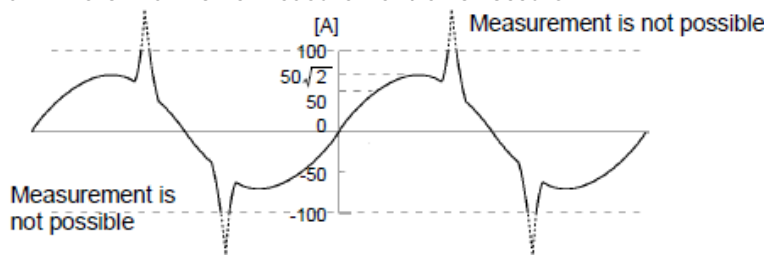
$$\text{Nominal voltage } (U_{ref}) = \text{nominal input voltage } (U_{din}) \times VT \text{ ratio}$$

Out of Crest factor

The crest factor expresses the size of the dynamic range of input on the measurement device and can be defined with the following expression.

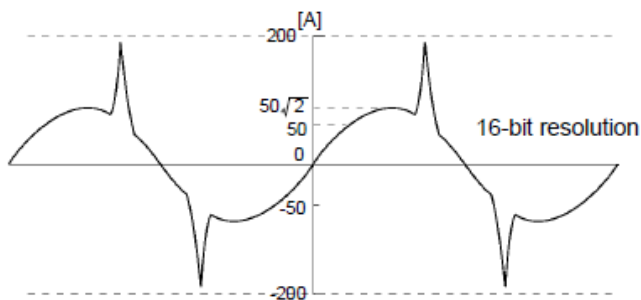
$$\text{Crest factor} = \text{crest value (peak value)} / \text{RMS value}$$

For example, when measuring a distorted wave with a small RMS and a large peak on a measurement device with a small crest factor, because the peak of the distorted wave exceeds the detection range of the input circuit, an RMS or harmonic measurement error occurs.



A measurement device with a small crest factor
(When the crest factor is 2 for a 50 A range)

When you increase the measurement range, the peak does not exceed the input circuit's detection range, but because the resolution of the RMS decreases, measurement errors may occur.



Crest factors of the PW3198
(The crest factor of the current input area is 4.)

However, when a measurement that exceeds the peak is input, it appears outside the crest factor and you are informed of data that contains measurement errors.

Power factor (PF/DPF)

Power factor is the ratio of effective power to apparent power. The larger the absolute value of the power factor, the greater the proportion of effective power, which provides the power that is consumed, and the greater the efficiency. The maximum absolute value is 1. Conversely, the smaller the absolute value of the power factor, the greater the proportion of reactive power, which is not consumed, and the lower the efficiency. The minimum absolute value is 0.

For this device, the sign of the power factor indicates whether the current phase is lagging or leading the voltage. A positive value (no sign) indicates that the current phase is lagging the voltage. Inductive loads (such as motors) are characterized by lagging phase. A negative value indicates that the current phase is leading the voltage. Capacitive loads (such as capacitors) are characterized by leading phase.

The power factor (PF) is calculated using rms values that include harmonic components. Larger harmonic current components cause the power factor to deteriorate. By contrast, since the displacement power factor (DPF) calculates the ratio of effective power to apparent power from the fundamental voltage and fundamental current, no voltage or current harmonic component is included. This is the same measurement method used by reactive power meters installed at commercial-scale utility customers' facilities.

Displacement power factor, or DPF, is typically used by the electric power system, although power factor, or PF, is sometimes used to measure equipment in order to evaluate efficiency. When a lagging phase caused by a large inductive load such as a motor results in a low displacement power factor, there are corrective measures that can be taken to improve the power factor, for example by adding a phase advance capacitor to the power system. Displacement power factor (DPF) measurements can be taken under such circumstances to verify the improvement made by the phase advance capacitor.

Reactive power

Power that does not perform actual work, resulting in power consumption as it travels between the load and the power supply. Reactive power is calculated by multiplying the active power by the sine of the phase difference ($\sin \theta$). It arises from inductive loads (deriving from inductance) and capacitive loads (deriving from capacitance), with reactive power derived from inductive loads known as lag reactive power and reactive power derived from capacitive loads known as lead reactive power.

Reactive power demand

The average reactive power used during a set period of time (usually 30 minutes).

RMS current refreshed each half-cycle

PQ3198: The RMS value of the current waveform every half-cycle.

PQ3100: The RMS value of one current waveform overlapped every half-cycle.

RMS value

The root mean square of instantaneous values for a quantity obtained over a particular time interval or bandwidth.

RMS voltage refreshed each half-cycle

The RMS value of one voltage waveform overlapped every half-cycle.

RS-232C

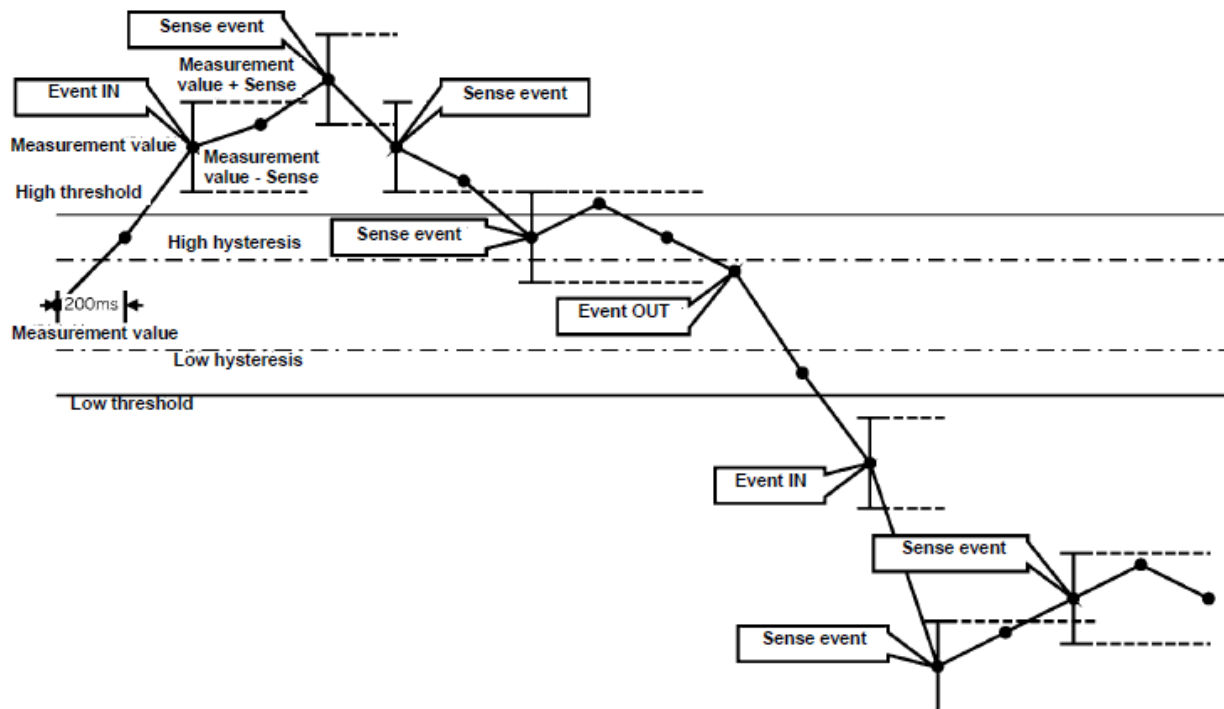
The RS-232C is a serial interface established by the EIA (Electronics Industries Association), and conforms to the specifications for DTE (data terminal equipment) and DCE (data circuit terminating equipment) interface conditions. Using the signal line part of the RS-232C specifications with this unit allows you to use an external printer or GPS box.

SD memory card

A type of flash memory card and used in the PQ3198 to store measured data.

SENSE

Measured values are continuously compared with the range defined by (the measured value the last time the event occurred + the sense threshold) and (the measured value the last time the event occurred - the sense threshold). When the value falls outside this range, a sense event occurs, and the sense range is updated.



Slide reference voltage

The voltage used as the reference for judging voltage dip and swell thresholds. The slide reference voltage is calculated from a 1st-order filter with a time constant of 1 minute relative to RMS values. Although the fixed nominal input voltage value is usually used as the reference voltage, dips and swells can be detected when the voltage value is fluctuating gradually by using the fluctuating voltage value as the reference.

Text data

A file containing only data expressed using characters and character codes.

TIME PLOT interval

The recording interval. This setting applies to TIMEPLOT and SD memory card recording.

Timer event function

Functionality for generating events at a set time interval and recording the measured value and event waveform at that time. This function allows you to capture instantaneous waveforms and other data regularly, even if no abnormalities have occurred. Use this functionality when you wish to record a waveform at a fixed time interval.

Total harmonic distortion factor (THD)

THD-F:

The ratio of the size of the total harmonic component to the size of the fundamental wave, expressed as a percentage using the following equation:

$$\frac{\sum(\text{from 2nd order})}{\text{fundamental wave}} \times 100[\%] \quad (\text{PQ3198, calculated to the 50}^{\text{th}} \text{ order})$$

This value can be monitored to assess waveform distortion for each item, providing a yardstick that indicates the extent to which the total harmonic component is distorting the fundamental waveform. As a general rule, the total distortion factor for a high-voltage system should be 5% or less; it may be higher at the terminal point of the system.

THD-R:

The ratio of the size of the total harmonic component to the size of RMS values, expressed as a percentage using the following equation:

THD-F is typically used.

$$\frac{\Sigma(\text{from 2nd order})}{\text{RMS value}} \times 100[\%] \quad (\text{PQ3198, calculated to the 50}^{\text{th}} \text{ order})$$

Unbalance factor

Unbalanced (symmetrical) 3-phase voltage (current)

Three-phase AC voltage (current) with equal voltage and current magnitude for each phase and 120° phase separation.

Unbalanced (asymmetrical) 3-phase voltage (current)

Three-phase AC voltage (current) with equal voltage and current magnitude for each phase and 120° phase separation.

Though all of the following descriptions refer to voltage, they apply to current as well.

[Degree of unbalance in 3- phase alternating voltage]

Normally described as the voltage unbalance factor, which is the ratio of negative-phase voltage to positive-phase voltage

$$\text{Voltage unbalance factor} = \frac{\text{Negative - phase voltage}}{\text{Positive - phase voltage}} \times 100[\%]$$

Zero-phase/positive-phase/negative-phase voltage

The concept of a zero-phase-sequence/positive-phase-sequence/negative phase-sequence component in a three-phase alternating circuit applies the method of symmetrical coordinates (a method in which a circuit is treated so as to be divided into symmetrical components of a zero phase, positive phase, and negative phase).

Zero-phase-sequence component:

Voltage that is equal in each phase. Described as V_0 . (Subscript 0: Zero-phase-sequence component)

Positive-phase-sequence component:

Symmetrical three-phase voltage in which the value for each phase is equal, and each of the phases is delayed by 120 degrees in the phase sequence a->b->c. Described as V_1 . (Subscript 1: Positive-phase-sequence component)

Negative-phase-sequence component:

Symmetrical three-phase voltage in which the value for each phase is equal, and each of the phases is delayed by 120 degrees in the phase sequence a->c->b. Described as V_2 . (Subscript 2: Negative-phase-sequence component)

If V_a , V_b , and V_c are given as the three-phase alternating voltage, the zero-phase voltage, positive-phase voltage, and negative voltage are formulated as shown below.

$$\begin{aligned} \text{Zero-phase voltage } \dot{V}_0 &= \frac{\dot{V}_a + \dot{V}_b + \dot{V}_c}{3} \\ \text{Positive-phase voltage } \dot{V}_1 &= \frac{\dot{V}_a + a\dot{V}_b + a^2\dot{V}_c}{3} \\ \text{Negative-phase voltage } \dot{V}_2 &= \frac{\dot{V}_a + a^2\dot{V}_b + a\dot{V}_c}{3} \end{aligned}$$

a is referred to as the "vector operator." It is a vector with a magnitude of 1 and a phase angle of 120 degrees. Therefore, the phase angle is advanced by 120 degrees if multiplied by a , and by 240 degrees if multiplied by a^2 . If the three-phase alternating voltage is balanced, the zero-phase voltage and negative-phase voltage are 0, and only positive phase voltage, which is equal to the effective value of the three-phase alternating voltage, is described.

Unbalance factor of three-phase current

Used in applications such as the verification of power supplied to electrical equipment powered by a 3-phase induction motor.

The current unbalance factor is several times larger than the voltage unbalance factor. The less a three-phase induction motor slips, the greater the difference between these two factors. Voltage unbalance causes such phenomena as current unbalance, an increase in temperature, an increase in input, a decline in efficiency, and an increase in vibration and noise. U_{unb} must not exceed 2%, and I_{unb} must be 10% or less. In a 3P4W system with an unbalanced load, the U_{unb0} and I_{unb0} components indicate

the current that flows to the N (neutral) line.

USB-F (USB function)

An interface for exchanging data with a host controller (typically a computer) connected with a USB cable. For this reason, communication between functions is not possible.

UTC (Coordinated universal time)

The official time used worldwide. Although UTC is almost identical to Greenwich Mean Time (GMT), which is based on astronomical observations, UTC is determined by measuring 1 SI second using an atomic clock. Regular adjustments ensure that GMT and UTC differ by no more than 1 second.

Voltage dip

A short-lived voltage drop caused by the occurrence of a inrush current with a large load, such as when a motor starts. When recording voltage and current trends at the power service inlet, you can determine whether you should look for the cause of the dip inside or outside the building. If the voltage drops while the building's current consumption rises, the cause likely lies inside the building. If the voltage and current are both low, the cause is likely to lie outside the building.

Voltage swell

A phenomenon in which the voltage rises momentarily due to a lightning strike or the switching of a high-load power line.

Zero, positive, and negative phases

The positive phase can be considered normal 3-phase power consumption, while the negative phase functions to operate a 3-phase motor backwards. The positive phase causes the motor to operate in the forward direction, while the negative phase act as a break and causes heat to be generated, exerting a negative impact on the motor. Like the negative phase, the zero phase is unnecessary. With a 3-phase 4-wire connection, the zero phase causes current to flow and heat to be generated. Normally, an increase in the negative phase causes an increase of the same magnitude in the zero phase.

Appendix 1

Details of Quick Setup (PQ3198)

	U Events	Standard Power Quality	Inrush Current	Recording	EN50160
Main purpose	Abnormal voltage detection	Basic power quality measurement	Inrush current	Measured value recording	EN50160 standard
Connection	Set by the user				
Clamp sensor	Set by the user				
CT/PT ratios	Set by the user				
Measurement frequency	Automatic detection				
Nominal voltage	Automatic detection				
Flicker	Pst/Plt	Pst/Plt	Pst/Plt	Pst/Plt	Pst/Plt
Measurement RMS voltage	Default	Default	Default	Default	Default
THD	THD_F	THD_F	THD_F	THD_F	THD_F
Power factor	PF	PF	PF	PF	PF
Repeat setting	OFF	OFF	OFF	OFF	OFF
Recording items	P&Harm	All Data	P&Harm	All Data	All Data
TIME PLOT interval	1 minute	10 minutes	1 minute	10 minutes	10 minutes
Current range	Automatic detection	Automatic detection	Max. range	Automatic detection	Automatic detection
Event hysteresis	1%	1%	1%	1%	2%
Transient voltage	70%	70%	OFF	OFF	100%
Voltage swell	110%	110%	OFF	OFF	110%
Voltage dip	90%	90%	OFF	OFF	90%
Interruption	10%	10%	OFF	OFF	1%
Frequency	±5Hz	±0.5Hz	OFF	OFF	±0.5Hz
Frequency cycle	OFF	OFF	OFF	OFF	OFF
Voltage waveform peak	150%	150%	OFF	OFF	170%
Voltage DC fluctuation	±10%	±10%	OFF	OFF	OFF
Current waveform peak	OFF	200%	300%	OFF	OFF
RMS voltage	10% SENSE ±10V	10% SENSE ±10V	OFF	OFF	OFF
RMS current	OFF	50% SENSE: OFF	OFF	OFF	OFF
Inrush current	OFF	OFF	200%	OFF	OFF
Active power	OFF	OFF	OFF	OFF	OFF
Apparent power	OFF	OFF	OFF	OFF	OFF
Reactive power	OFF	OFF	OFF	OFF	OFF
Power factor	OFF	OFF	OFF	OFF	OFF
Voltage unbalance (Zero phase, negative phase)	OFF, 3%	OFF, 3%	OFF, OFF	OFF, OFF	OFF, 2%
Current unbalance (Zero phase, negative phase)	OFF, OFF	OFF, OFF	OFF, OFF	OFF, OFF	OFF, OFF
Harmonic voltage					
Fundamental	OFF	OFF	OFF	OFF	As per EN50160 limit values
0 th	OFF	5% of nominal	OFF	OFF	
3 rd /5 th /7 th /9 th /11 th	OFF	10% of nominal	OFF	OFF	

	U Events	Standard Power Quality	Inrush Current	Recording	EN50160
Harmonic current					
Fundamental	OFF	OFF	OFF	OFF	OFF
0 th	OFF	5% of range	OFF	OFF	OFF
3 rd /5 th /7 th /9 th /11 th	OFF	OFF	OFF	OFF	OFF
Harmonic power					
Fundamental	OFF	OFF	OFF	OFF	OFF
0 th	OFF	OFF	OFF	OFF	OFF
3 rd /5 th /7 th /9 th /11 th	OFF	OFF	OFF	OFF	OFF
Harmonic voltage-current phase difference	OFF	OFF	OFF	OFF	OFF
THD voltage	5%	7%	OFF	OFF	OFF
THD current	OFF	OFF	OFF	OFF	OFF
K factor	OFF	OFF	OFF	OFF	OFF
High-order harmonic voltage	OFF	OFF	OFF	OFF	OFF
High-order harmonic current	OFF	OFF	OFF	OFF	OFF
Voltage waveform	±15%	±10%	OFF	OFF	OFF

- When the RMS voltage is less than 3% f.s. of the range, 5% of the range is used as the upper limit, and 0% of the range is used as the lower limit.
- When the voltage peak value is less than 3% f.s. of the range, 5% of the range is used as the threshold.
- Harmonic voltage and current distortion factor calculation are turned off when the harmonic voltage is less than 3% f.s. of the range.
- A value of 10% of the range is used as the threshold when the current and power reference value (measured values) are 10% or less of the range.
- Changing VT or CT after simple configuration causes the threshold and sense to change (this also applies when not using simple configuration).
- As a rule, settings not included in the table are set to OFF (other than manual events).
- When EN50160 is selected, the EN50160 analysis function using the PC application software PQ ONE is only available when the interval time is set to 10 minutes.

EN50160 harmonic voltage limits

Odd harmonics				Even harmonics	
Not multiple of 3		Multiple of 3			
Order h	Relative voltage (Un)	Order h	Relative voltage (Un)	Order h	Relative voltage (Un)
5	6.0%	3	5.0%	2	2.0%
7	5.0%	9	1.5%	4	1.0%
11	3.5%	15	0.5%	6 to 24	0.5%
13	3.0%	21	0.5%		
17	2.0%				
19	1.5%				
23	1.5%				
25	1.5%				

Un = Nominal voltage (Uref)

