Case Studies of

Power Quality Surveys

using

Model 3196 Power Quality Analyzer

HIOKI E.E. CORPORATION

July 2005
Rev. 5

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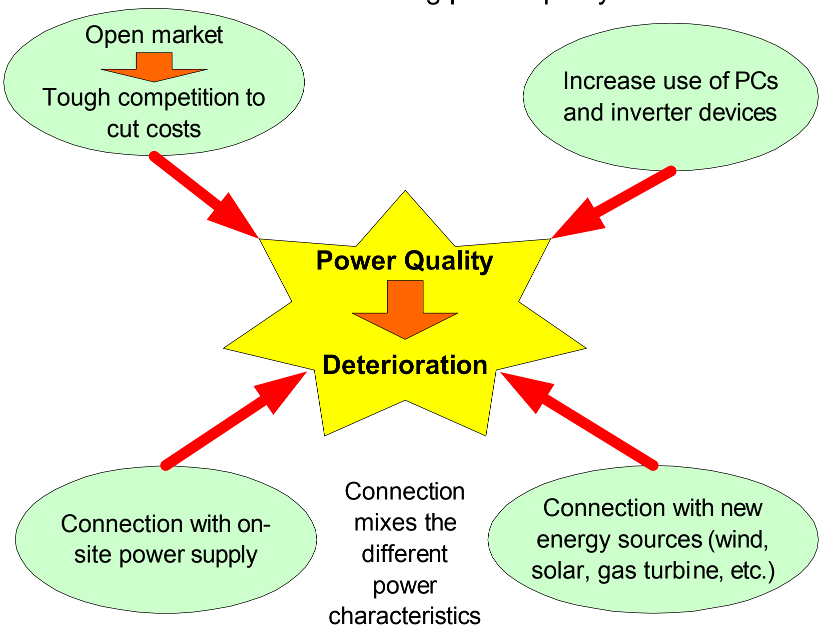
Power Quality Basics

Current Power Supply Environment

Various factors can contribute to worsening power quality



Power Quality Standards

International

Standard	Title	Published	Comment
IEC 61000-4-7	General guide on harmonics and inter-harmonics measurements and instrumentation, for power supply systems and equipment connected thereto	1991 2002 revised	Actualization of inter-harmonic concept (from revision)
IEC 61000-4-15	Flicker meter - Functional and design specifications	1997 2003 A1	120V/60Hz added in amendment
IEC 61000-4-30	Testing and measurement techniques Power Quality measurement methods	2003	New standard

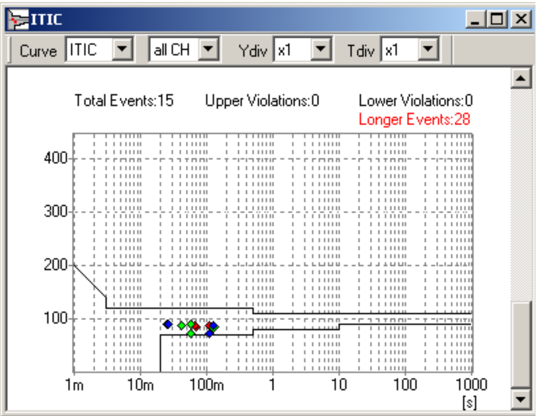
Europe

Standard	Title	Published	Comment
EN50160	Voltage Characteristics of electricity supplied by public distribution systems	1995, 1999 revised	General power quality standard

U.S.A.

Standard	Title	Published	Comment
IEEE 1159	IEEE Recommended Practice for Monitoring Electric Power Quality	1995	Anomaly voltage Classification of basic terms
IEEE 519	IEEE Recommended Practice and Requirements	1992	Standards for harmonic limit values
IEEE 446	IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications	1995	Describes the CBEMA curve
ANSI C84.1	Electrical Power Systems and Equipment - Voltage Ratings (60Hz)	1995	Voltage limit values

ITIC (CBEMA) curve

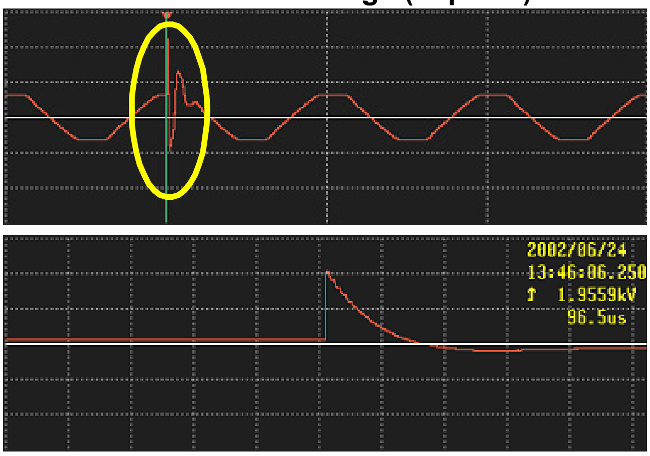


The ITIC curve judges the allowable level of voltage RMS fluctuation from the voltage swell, voltage dip and interruption events.
The analysis is made by the period and depth of each event according to the limit value of the ITIC curve.

The ITIC (Information Technology Industry Council) curve is the most recent version of the older CBEMA (Computer and Business Equipment Manufacturers Association) curve. Both were created by CBEMA. The original CBEMA curve was widely used in the U.S.A.

Main Power Quality Parameters

1. Transient overvoltage (impulse)



1) **Phenomenon**

Radical changes in voltage with high voltage peaks

2) **Cause**

- Lightning strikes
- Power circuit switching
- Closure of inductive circuits
- Arc to the ground
- Load switching
- Contact of a bouncing relay

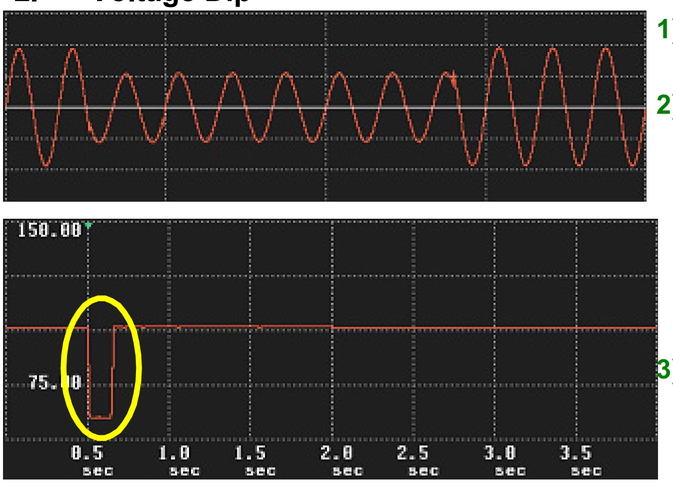
3) **Damage**

- Destruction of power supplies of equipment
- Equipment reset

4) **Analysis**

- Waveform (Maximum voltage level, Rise time, Phase angle, Fluctuation, Repeatability)
- The faster rise time means a closer occurring point.

2. Voltage Dip



1) **Phenomenon**

Instantaneous drop of RMS voltage

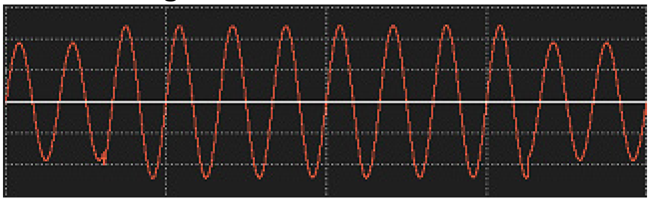
2) **Cause**

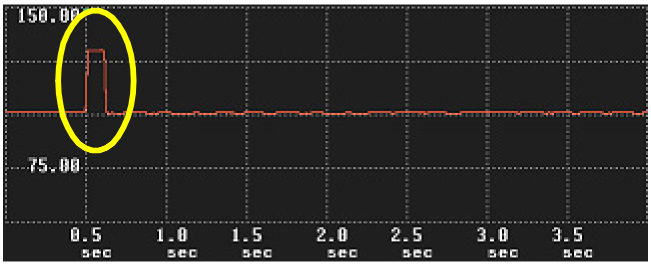
- Large inrush current by turning on heavy loads
- Accident in the distribution network (Lightning, snow, ice, contact of birds/ trees, effects of accidents)
- Short-circuit

3) **Damage**

- Stop or equipment reset

3. Voltage Swell





1) **Phenomenon**

Instantaneous rise of RMS voltage

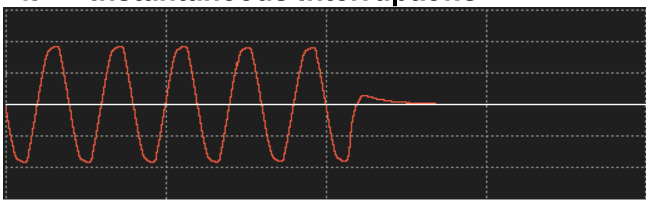
2) **Cause**

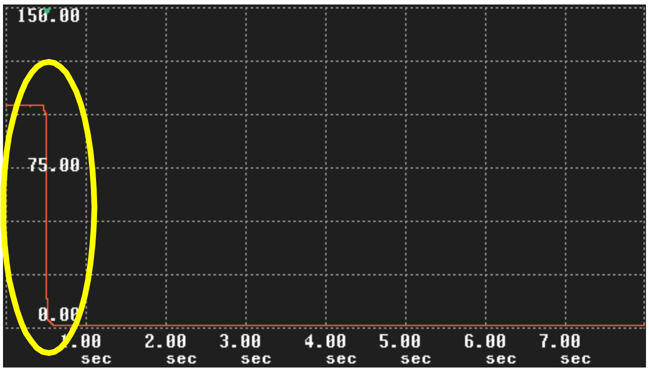
- Lightning strikes
- Introducing heavy loads

3) **Damage**

- Destruction of power supplies in equipment

4. Instantaneous Interruptions





1) **Phenomenon**

Instantaneous or short/long term power outage

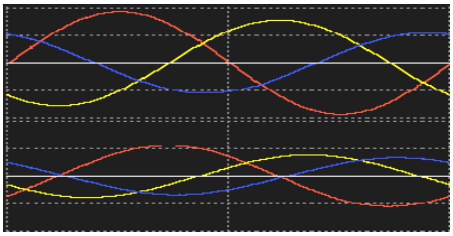
2) **Cause**

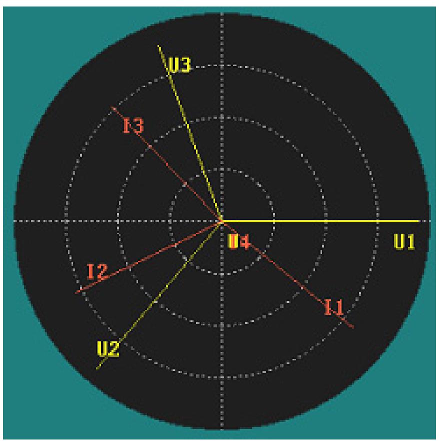
- Accident on distribution network (Lightning, snow, ice, contact of birds/ trees, effects of accidents)
- Short-circuit

3) **Damage**

- Stop or equipment reset

5. Unbalance Factor





1) **Phenomenon**

Imbalance of each phase in 3-phase system

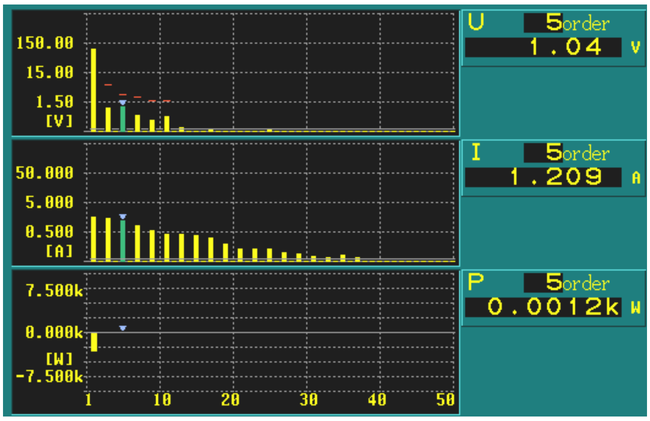
2) **Cause**

- Imbalance of loads by 1-phase load connection (especially long distribution lines)
- Transformer capacity difference at receptacle

3) **Damage**

- Overheating of a 3-phase inductive motor or transformer
- Stop equipment by 3E relay tripping (over-current, missing phase, reverse-phase)
- Uneven motor rotation

6. Harmonics



1) **Phenomenon**

Voltage or current waveform distortion

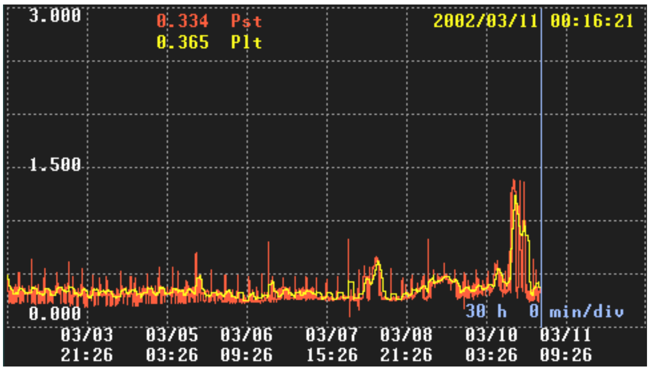
2) **Cause**

- Thyristor powered conversion devices
- Inverter, Variable frequency drives

3) **Damage**

- Overheating, burning, abnormal sounds or vibration sound caused by the inflow of harmonic current to the equipment
- Malfunctions due to the harmonics voltage (overheating or burning of reactor for phase advancing capacitor)

7. Flicker



No.	Date	Time	Pst	Plt
1196	03-10	22:46:21	0.238	0.411
1197	03-10	22:56:21	0.302	0.409
1198	03-10	23:06:21	0.337	0.413
1199	03-10	23:16:21	0.229	0.410
1200	03-10	23:26:21	0.304	0.369
1201	03-10	23:36:21	0.331	0.369
1202	03-10	23:46:21	0.318	0.365
1203	03-10	23:56:21	0.356	0.370
1204	03-11	00:06:21	0.620	0.386
1205	03-11	00:16:21	0.334	0.365

1) **Phenomenon**

Regularly repeated voltage impulses spanning one or more cycles which cause flicker in the lighting device

2) **Cause**

- Arc/blast furnaces
- Arc welding

3) **Damage**

- Flicker in the lighting device
- Equipment malfunction

CASE STUDY 1

Inrush Current and Current RMS Value of an Industrial Dryer

Environment:

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

Problem:

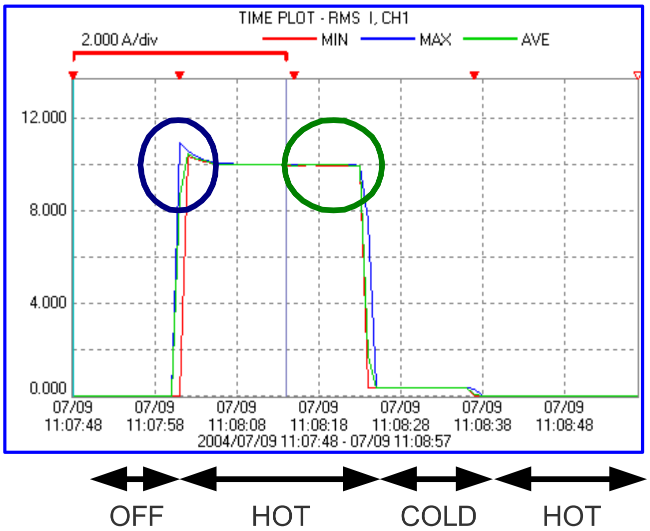
This is a simple simulation example.

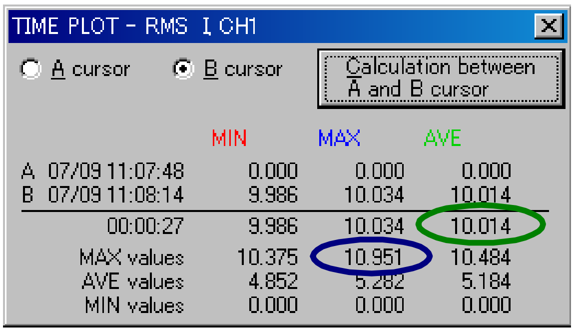
Analysis:

By using an industrial dryer (100V AC, 1kW, 50/60Hz), the RMS fluctuation and inrush current are measured while switching the dryer from "OFF=>ON=>COLD=>OFF."

Note:
Model 9694 Clamp on Sensor is clamped to the 10-turn coil with a CT setting 0.1.

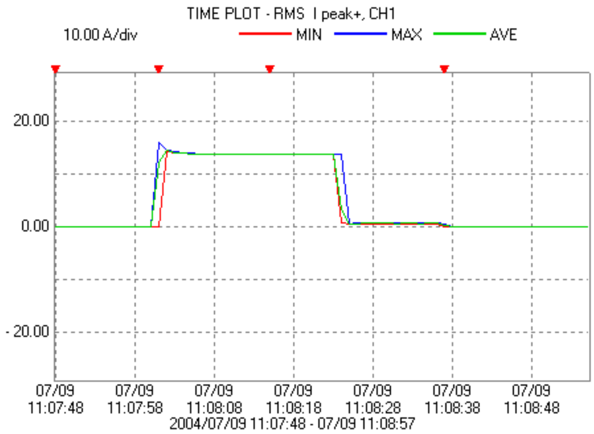
To record the inrush current event waveform, use the **current peak** event.
To record the waveform while the dryer is continuously operating in HOT, using the **manual event** ([ESC]+[EVENT]) is effective.

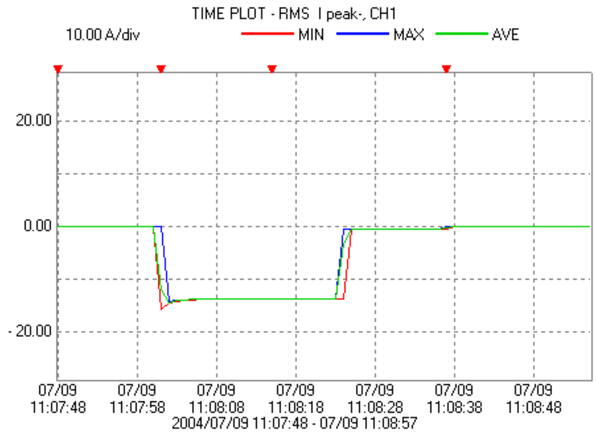




The current value while a dryer is working is 10Arms, but the start-up current rises to 10.951Arms.

Current RMS Value Fluctuation

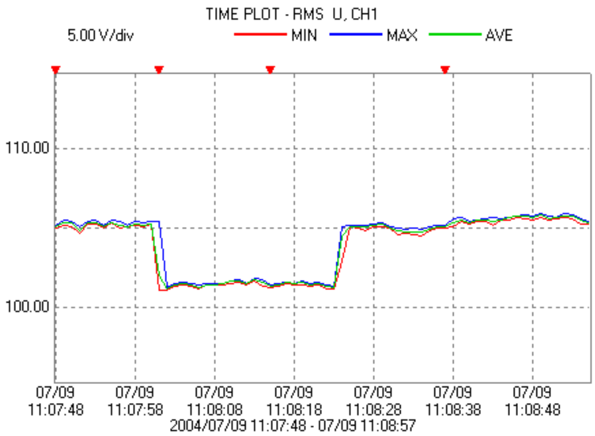


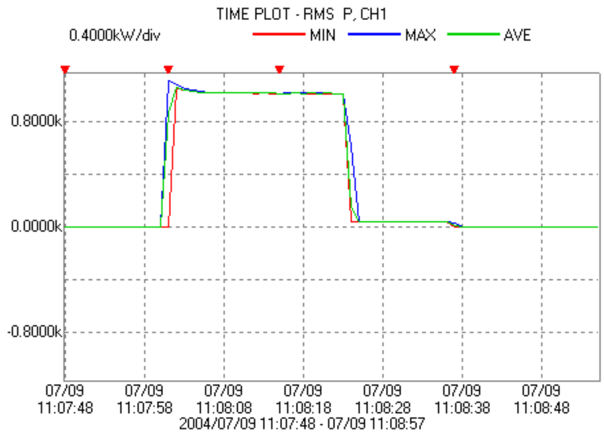


Fluctuation of Current Waveform Peak (+) **Fluctuation of Current Waveform Peak (-)**

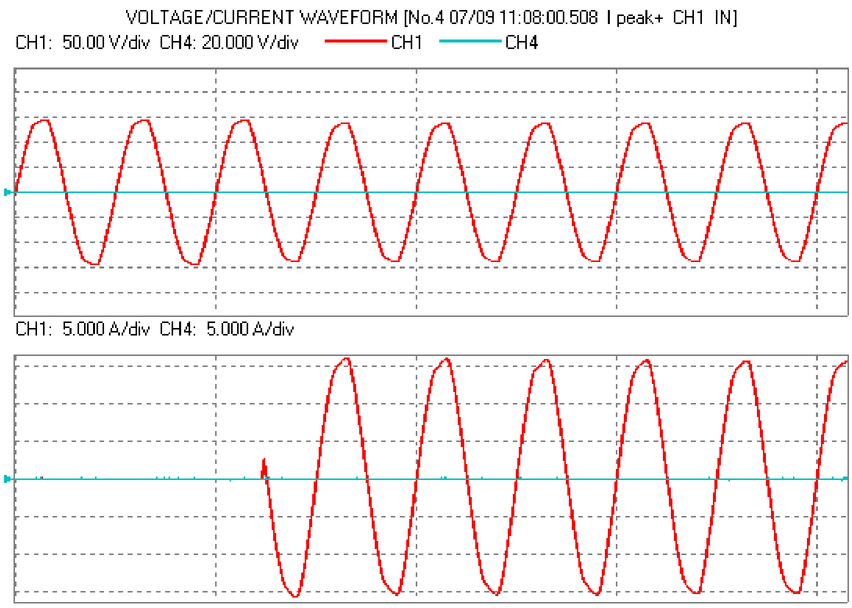
A voltage drop of about 4Vrms is measured when the dryer is in operation.

The maximum power is 1.1071kW





Fluctuation of Voltage RMS Value **Fluctuation of Active Power RMS Value**



Inrush Current Waveform

CASE STUDY 2

Voltage Drop Caused by Wiring Impedance

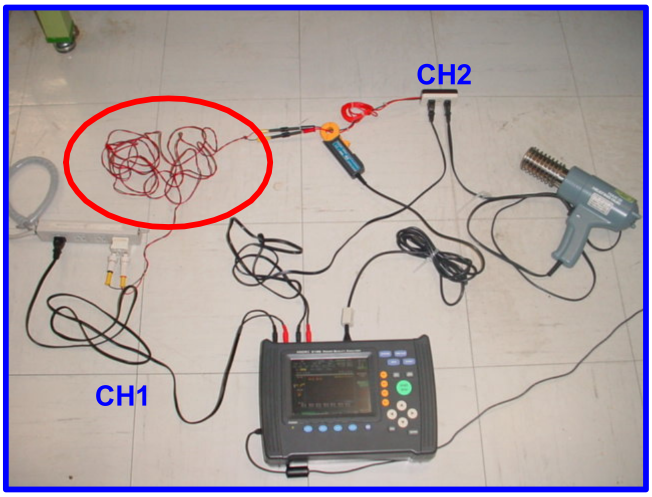
Environment:

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

Problem:

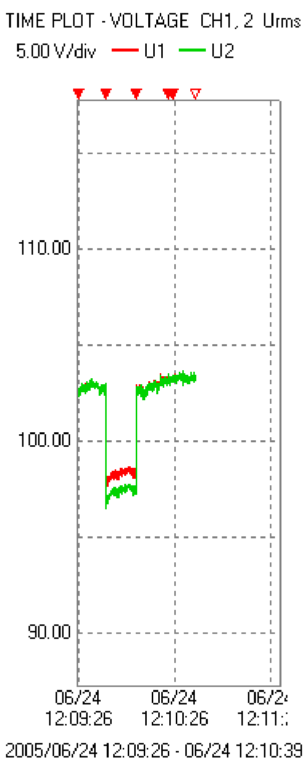
This is an easy simlulation similar to Case Study 1 to monitor the voltage drop caused by wiring impedance. The voltage at a load shows the voltage drop to the supply side when the wire is thin and long.

Analysis:

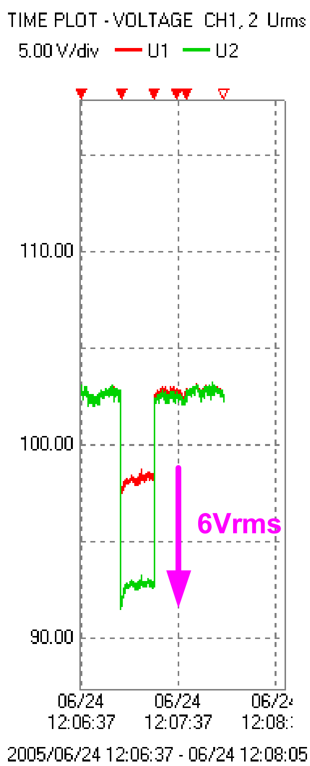


When switching an industrial dryer (100V AC, 1kW, 50/60Hz) from OFF to HOT to COLD and back to OFF, confirm the difference in voltage drop between short and long wirings.

1) When wiring is short
(low wiring impedance without the wires circled in red)
2) When wiring is long
(high wiring impedance with wires circled in red)



1) Short Wiring



2) Long Wiring

Voltage RMS Value Fluctuation

Voltage at power supply side

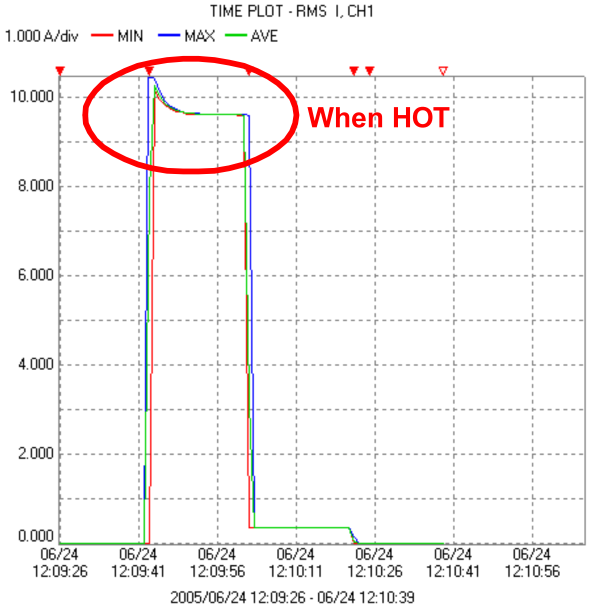
U1 (CH1: red) is the voltage not affected by the wiring impedance.

Voltage at consumption side

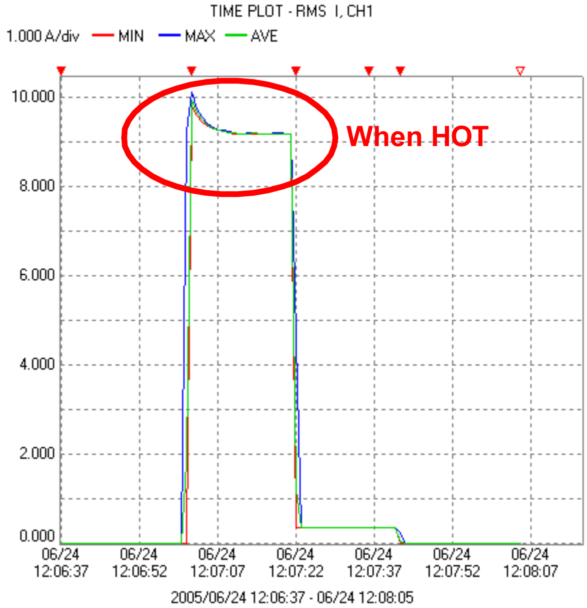
U2 (CH2: green) is the voltage affected by the wiring impedance.

By adding high wiring impedance, the voltage drops for 6Vrms on the consumption side.

The wiring impedance of the wires circled in red is 0.6-Ohm.
The voltage drop is calculated by using the Ohm's Law such that "0.6-Ohm x 10A = 6Vrms."

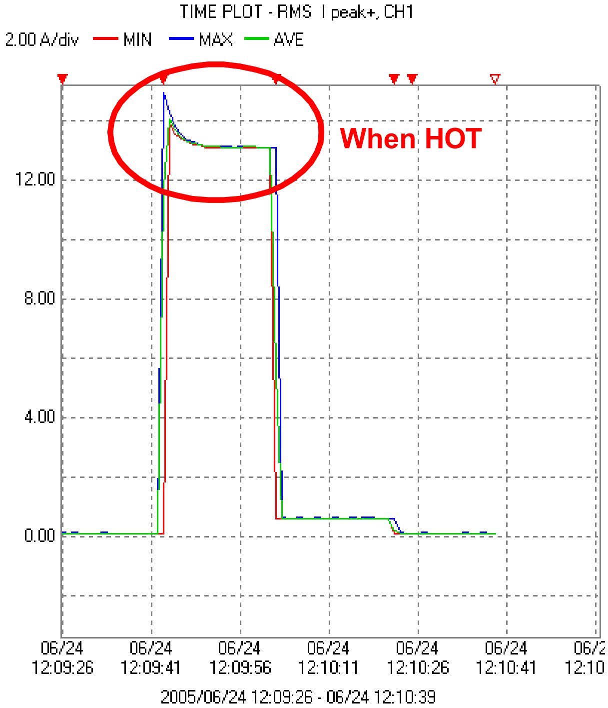


1) Short Wiring

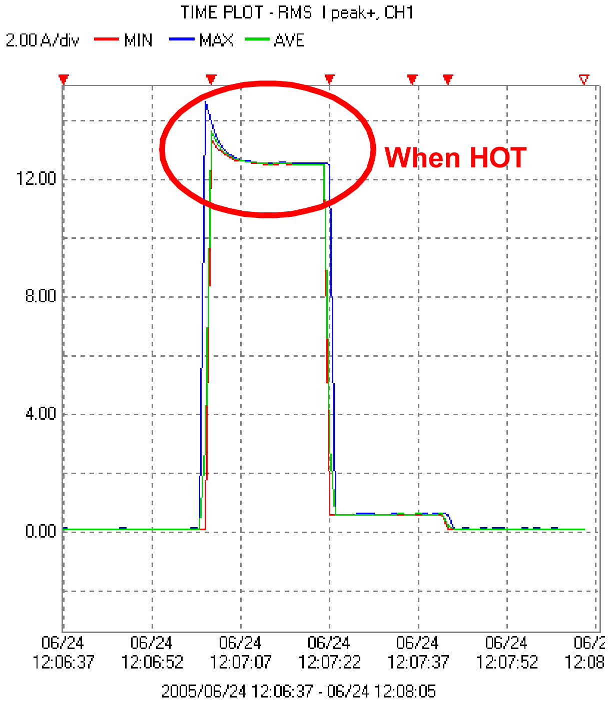


2) Long Wiring

Current RMS Value Fluctuation



1) Short Wiring



2) Long Wiring

Current Peak Value Fluctuation

In this dryer example, the current consumption at a load is slightly reduced when the wirng is long.

The dryer is **a resistive load**, so that the current consumption, which means the power consumption, is reduced by the voltage drop.

If **a constant power controlled load** is connected, the power consumption is stable despite the voltage drop. Therefore, the current consumption increases.

CASE STUDY 3

Transients Caused by Glow Fluorescent Lighting

Environment:

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

Problem:

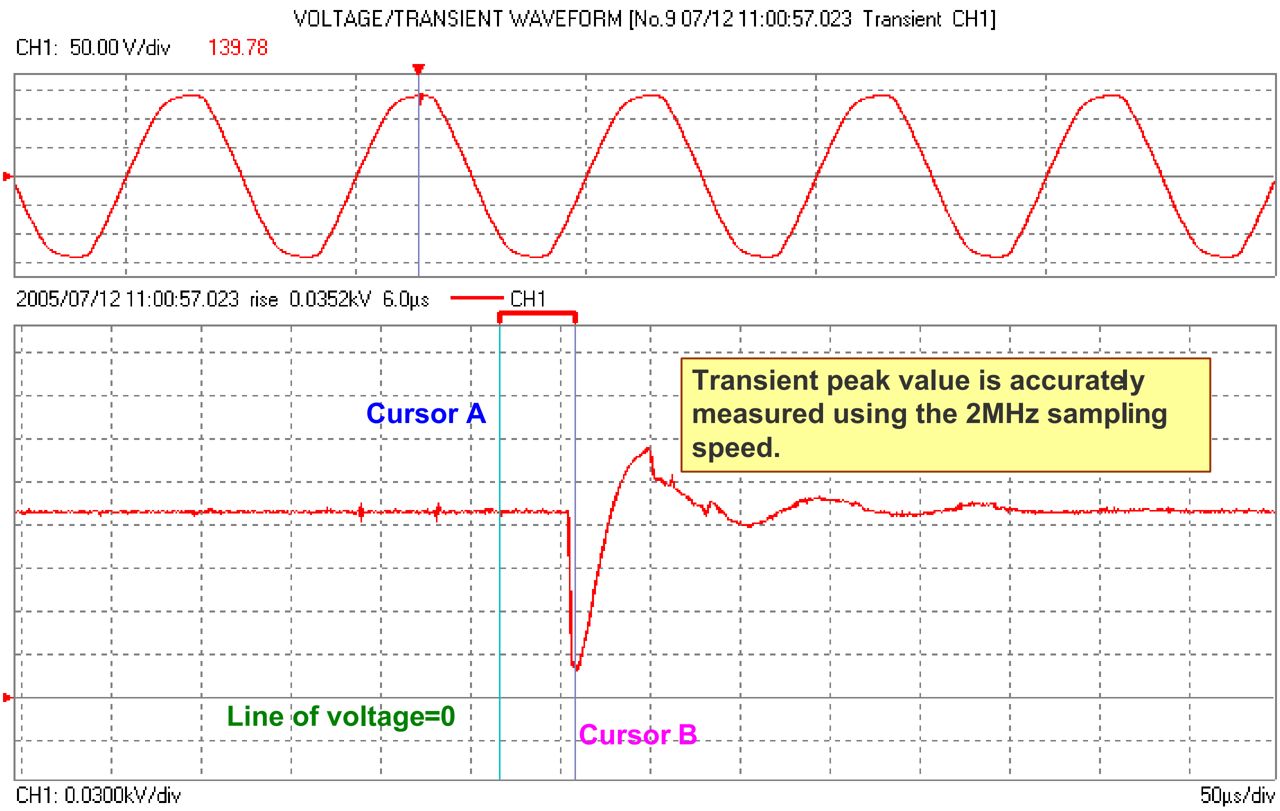
This is an example of measuring transient overvoltage when turning on glow fluorescent lighting.

Analysis:

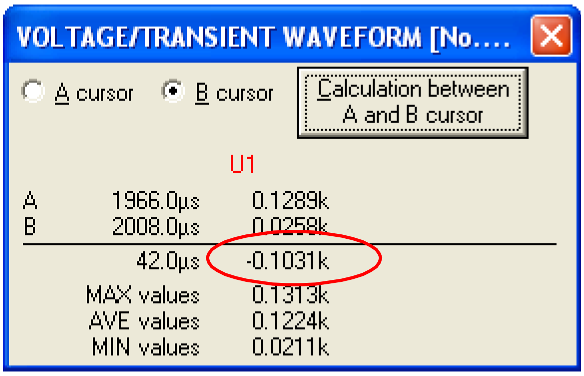
A glow fluorescent light incorporates a glow lamp and is widely recognized as a low-cost alternative to fluorescent lighting.

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.

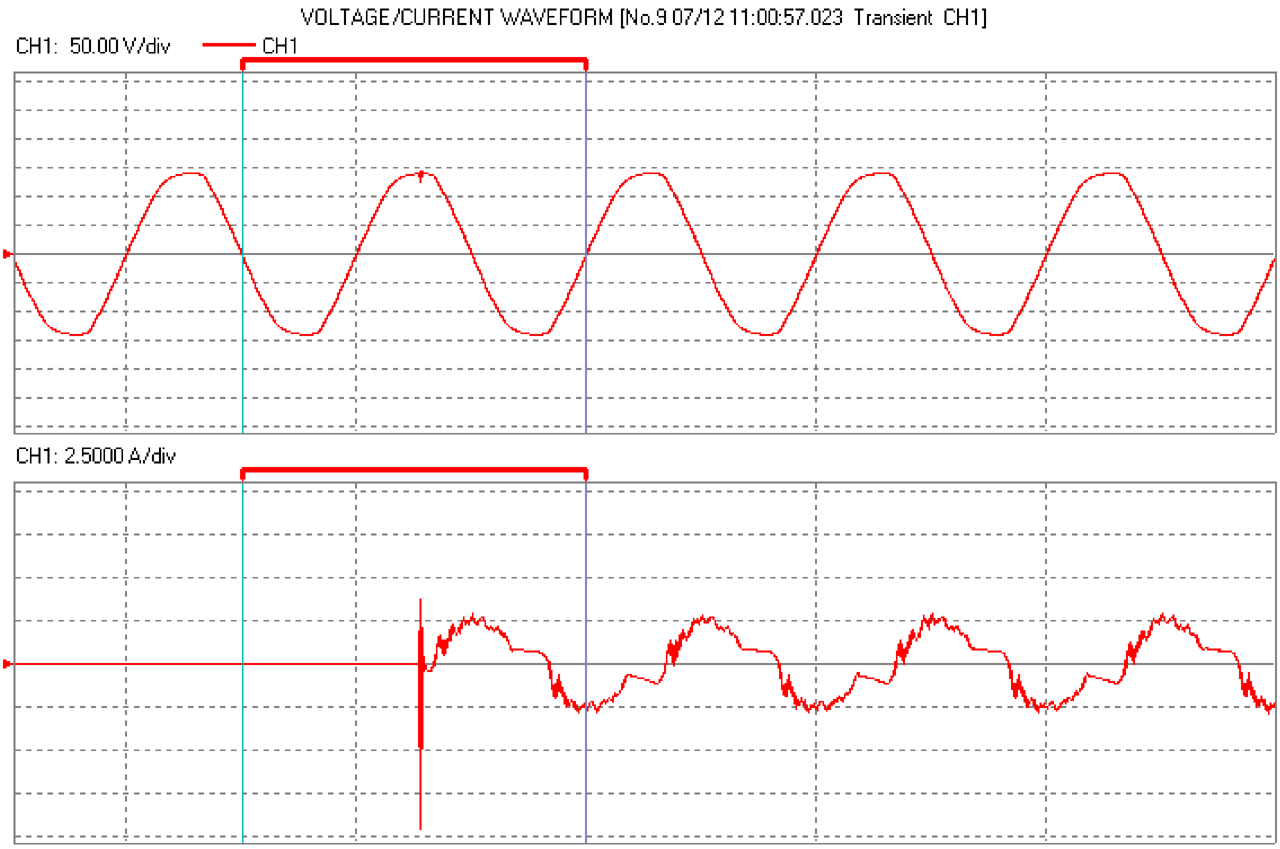
Transient overvoltage is generated at the first flash of a glow lamp, which affects electronic equipment located nearby.



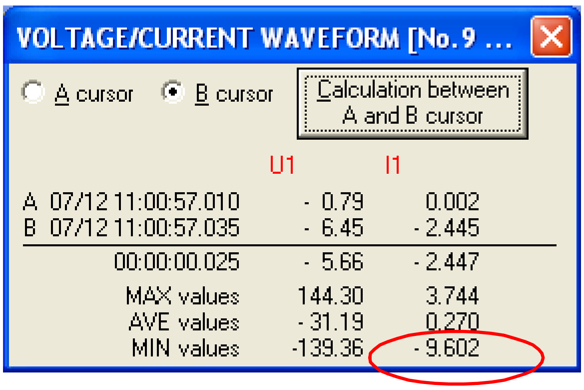
Voltage and Transient Waveforms When Turning On the Fluorescent Light



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



Voltage and Current Waveforms When Turning On the Fluorescent Light



When transient overvoltage 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 to the negative direction.

CASE STUDY 4

Switching of Power Factor Correction Capacitor

Environment:

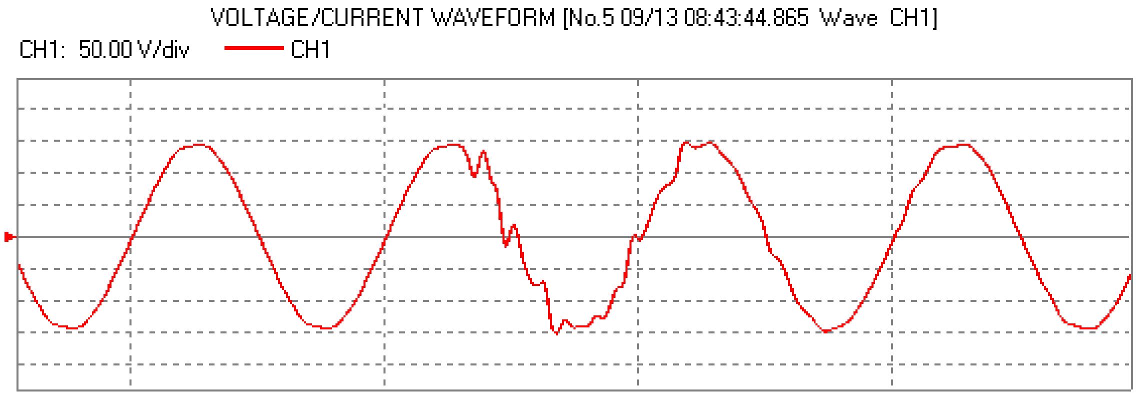
Target: 1-phase 2-wire, 100V circuit

Problem:

The power supply of equipment is damaged.

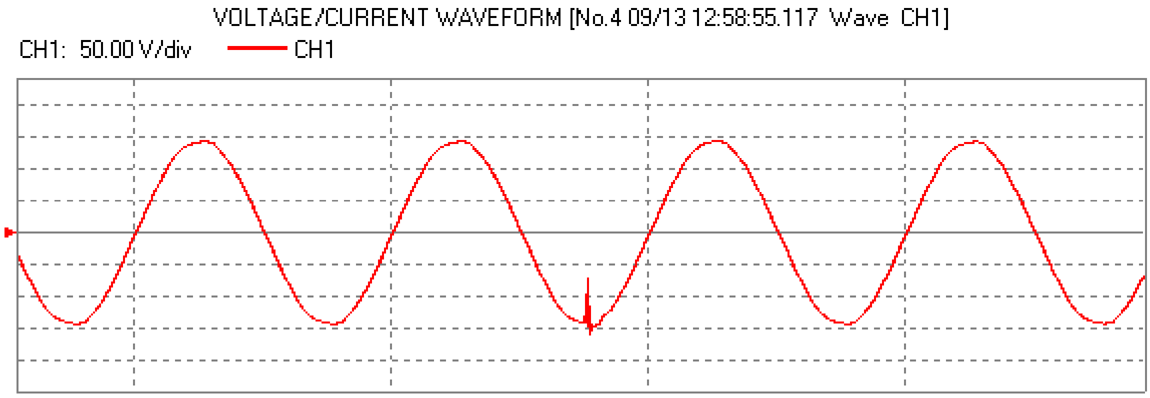
Analysis:

Some events are recorded by measurement.
The switching waveform, which occurs during the power factor correction capacitor switching, is detected. This kind of voltage waveform is recorded when the power factor correction capacitor is installed in a facility. The switching noise comes through the low-voltage circuit without a filtering device.



Voltage Noise Waveform 1 (By the voltage waveform distortion event)

Also, 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 (By the voltage waveform distortion event)

Note:

To detect intermittent noise, the **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 5

Voltage Dip (Instantaneous Voltage Drop) - at Receptacle

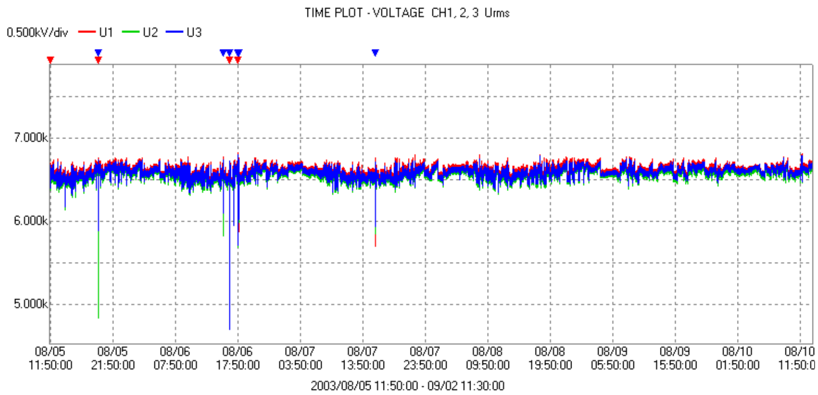
Environment:

Target: HIOKI headquarters building,
3-phase 4-wire, 6.6kV receptacle, Secondary side of PT

Measured period: 1 year from June 2003 to May 2004

Problem and 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 (August5 to 7, 2003). The residual voltage is very low and a long period is detected on CH3 (T-R phase) as 4.708kV for 109ms.



Voltage Fluctuation

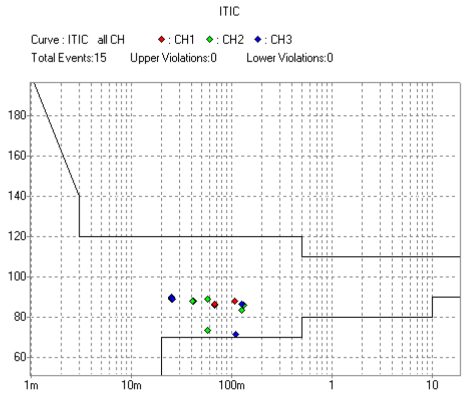
Measurement Result Classification

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

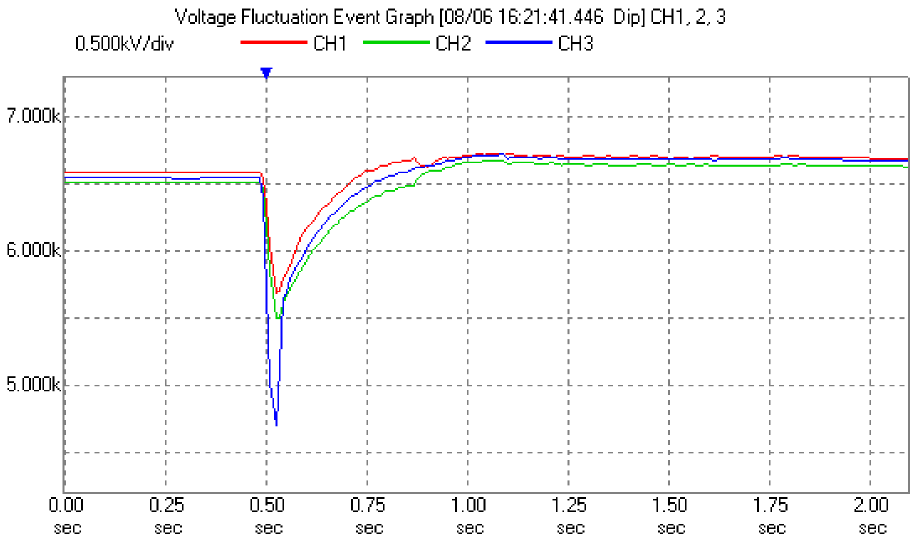
Swell, Dip, Interruption

Voltage u (% of Uref)	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
88 ≤ 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

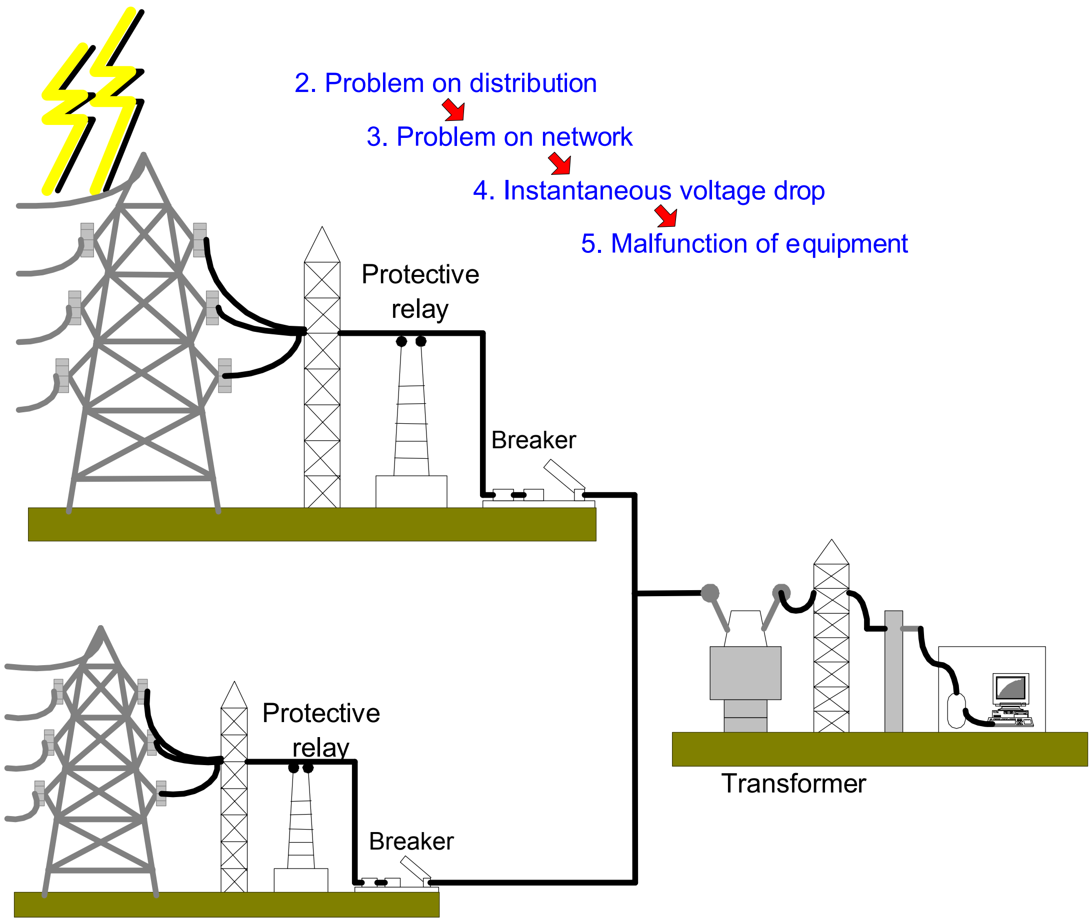
Classification in EN50160 mode
(Simultaneous events on 3 phases are counted as one.)



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



Event Voltage Fluctuation 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 and it shorts the distribution cable and tower. Then, the fault current flows and the voltage drops.

To remove this fault, the circuit breaker takes effect , but the voltage drops until that time (approx. 0.07 to 2s).

This is the instantaneous voltage drop (voltage dip) caused by a lightning strike.

CASE STUDY 6

Voltage Dip (Instantaneous Voltage Drop) - at Distribution Panel

Environment:

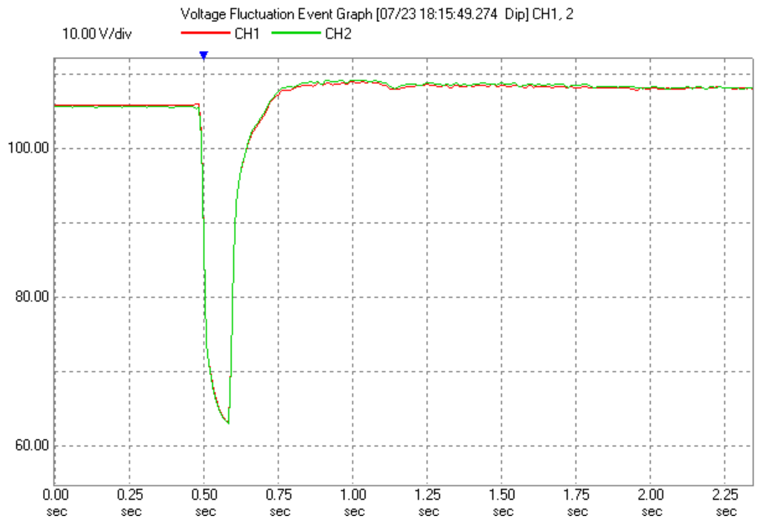
Target: HIOKI headquarters building, East side, 5th floor
3-phase 3-wire, 200V distribution panel

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

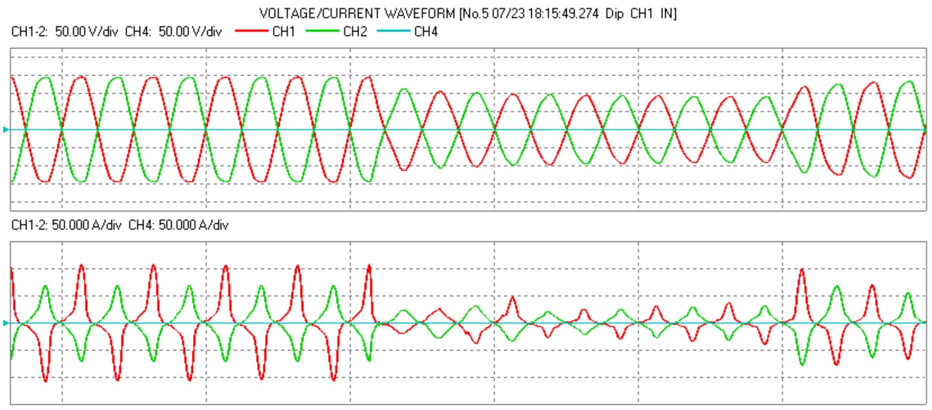
Problem and Analysis:

4 voltage dips caused by lightning were detected during measurement (different period than Case Study 3). 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 are unpreventable by the power distribution companies. Therefore, users should take appropriate countermeasures such as connectinga UPS to their PCs.

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



Event Voltage Fluctuation at the 2nd Voltage Dip



Voltage and Current Waveforms at the 2nd Voltage Dip

CASE STUDY 7

Transient Overvoltage

Environment:

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

Problem:

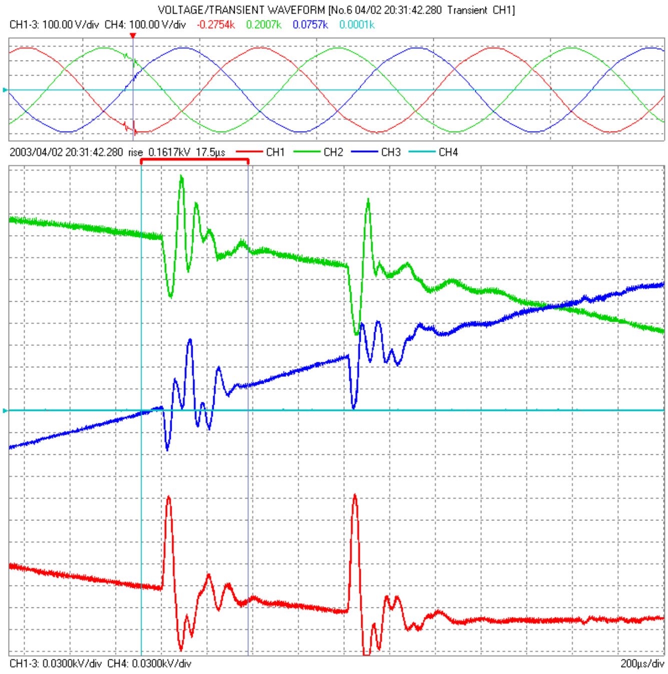
The screen of equipment does not correctly display.

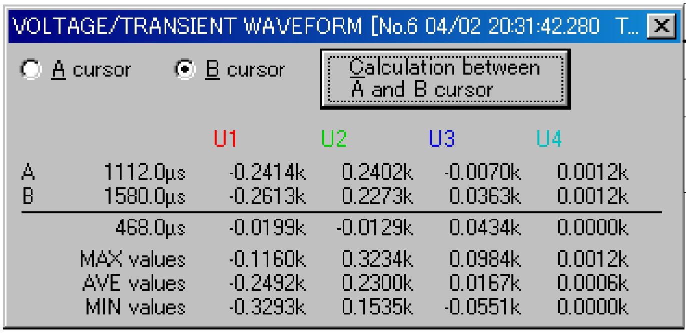
Analysis:

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

Analysis of transient 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.





		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 Overvoltage

Note:

The threshold set at 1/2 of the waveform peak value is effective for the transient overvoltage.
For example, set the threshold at 0.07kV for the 100Vrms circuit, and 0.14kV for the 200Vrms cicuit.

CASE STUDY 8

Periodical Instantaneous Voltage Drop

Environment:

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

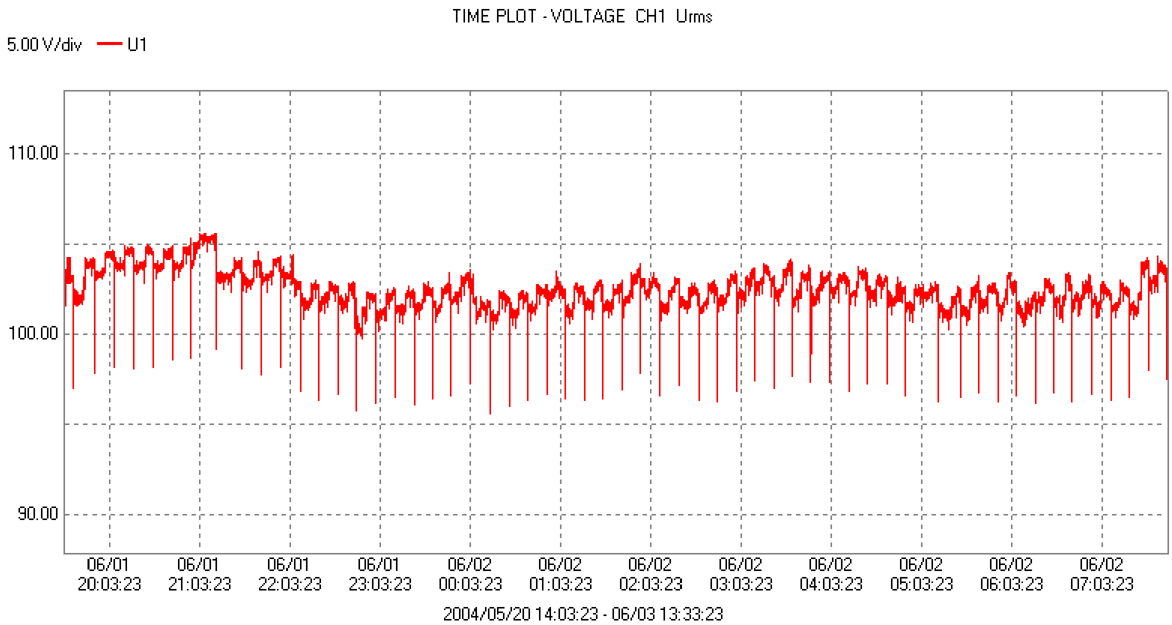
Problem:

No apparent trouble is detected, but the voltage fluctuation is big.

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 every 13 minutes.



Voltage Fluctuation

The cause of the instantaneous voltage drop every 13 minutes is assumed to originate 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 ON/OFF of the thermostat,

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.

CASE STUDY 9

General UPS Switching Waveform

Environment:

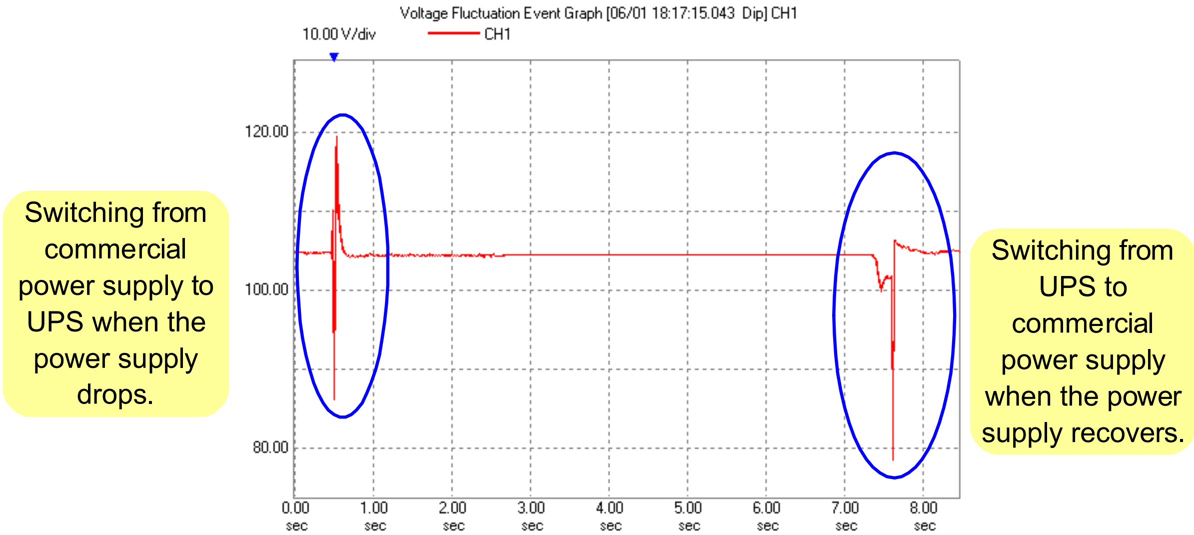
Target: UPS for a desktop PCs sold in retail stores (1-phase 2-wire, 100V)

Problem and Analysis:

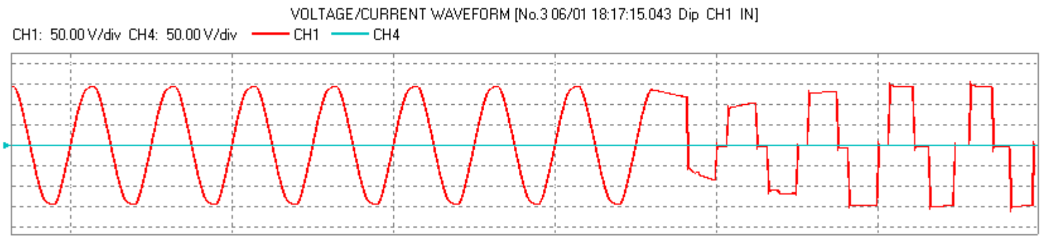
Most low cost UPS used for general purposes output a square wave. However, most people assume that a sine wave is output. Here is a sample waveform output by the UPS.

1) Low cost inverter (variable frequency drive) type
2) Commercial purpose without a compensation function for the voltage distortion, etc.

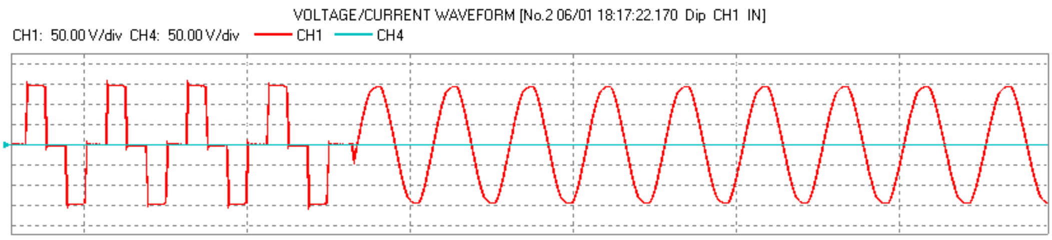
Note that the voltage swell or dip occurs in switching if the UPS does not compensate for the period.



Event Voltage Fluctuation 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 10

Voltage Waveform Noise & UPS Switching

Environment:

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

Problem:

Malfunction of equipment

Analysis:

68 "Wave (voltage waveform distortion)" events were recorded during an 18-day measurement period using the following settings on Model 3196. All events are of the same type.

SYSTEM

MEASURE | EVENT VOLTAGE | EVENT POWER | U Harmonics | I Harmonics | P Harmonics | P

	123ch	4ch
U Transient	0.4800kV	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 of Model 3196

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 17:31:17.398	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.

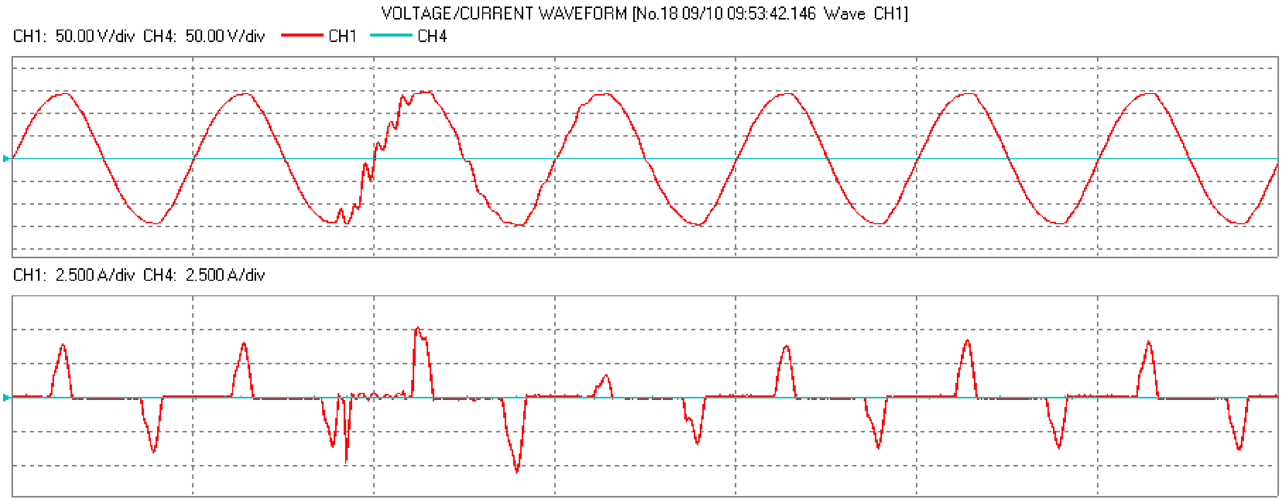
No.1: Not switched to a sine wave after the waveform noise

No.2: Switched to a sine wave after the waveform noise

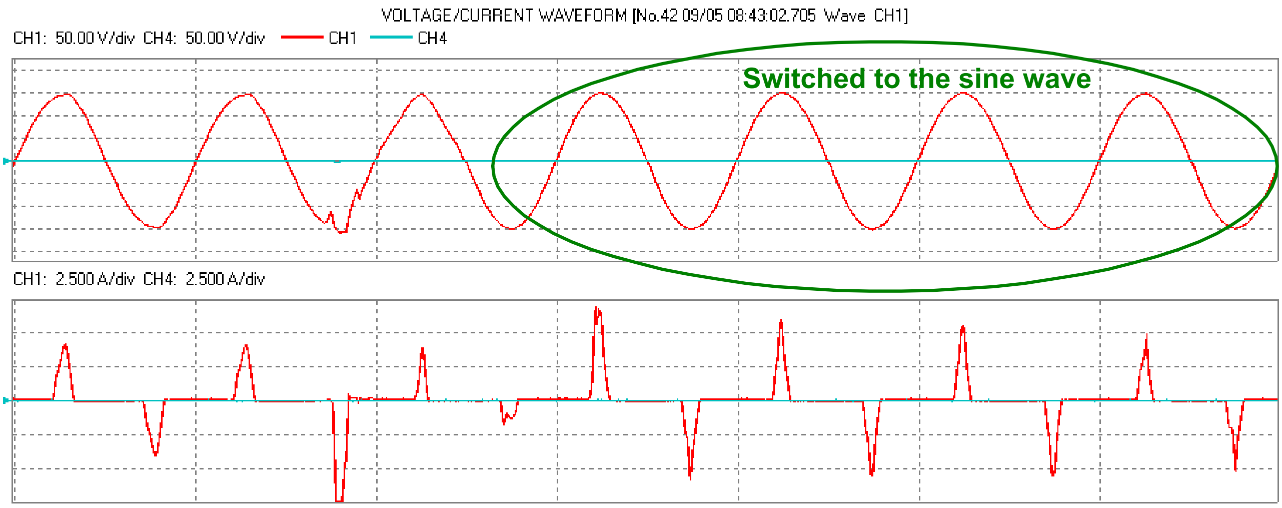
We can assume that the events "switched to a sine wave after the waveform noise" were due to the switching to the UPS output (stand-by system).

It appears that waveform No.1 has a higher noise level and should be switched to the UPS output. However, waveform No.2 shows a bigger difference in the current waveform when the voltage waveform shows the noise. Therefore, we can assume that a transient overvoltage occurs simultaneously when this event occurs. Unfortunately, the transient overvoltage is not detected, because its threshold is set at 0.480kV (480V).

We propose setting the threshold at 1/2 of the waveform peak (70V= 0.0718kV for 100V circuit)



No.1: Not Switched to the Sine Wave after the Waveform Noise



No.2 Switched to the Sine Wave after the Waveform Noise

CASE STUDY 11

Voltage Dip in a Factory

Environment:

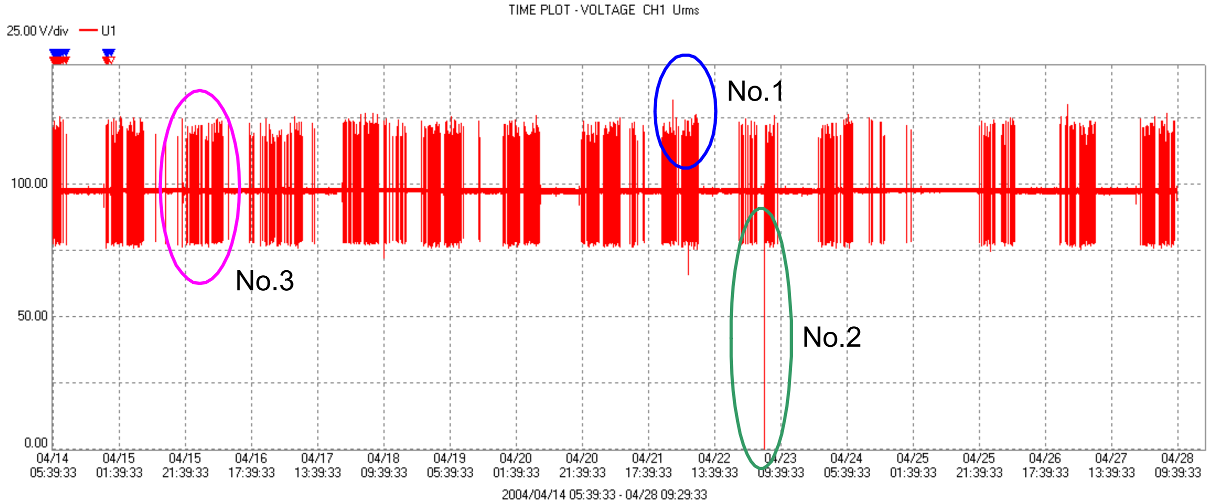
Target: A factory in Southeast Asia, 1-phase 2-wire, 100V circuit

Problem:

Power supply is damaged.

Analysis:

1. Voltage fluctuation



Voltage Fluctuation

The following power characteristics were concluded from 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 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. The situation of voltage dip occurrence demonstrates the same tendency.

This is the analysis of one voltage dip event.

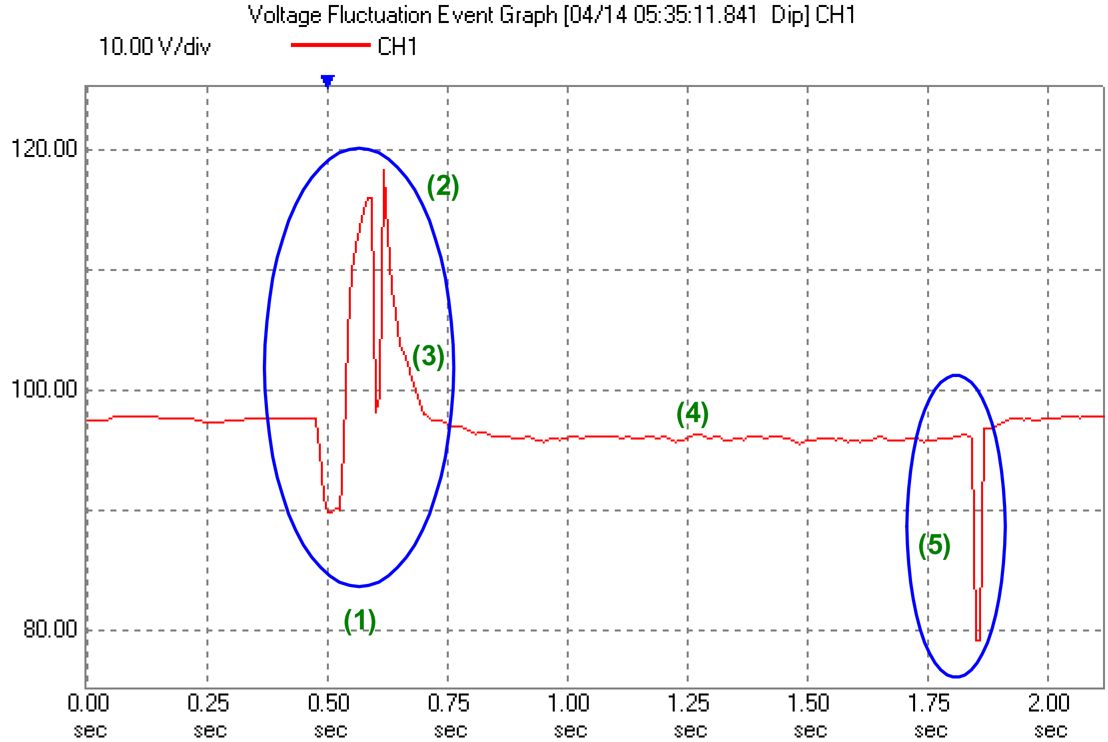
(1) When the depth of the voltage dip reaches 90Vrms, the power supply is switched from the commercial supply to the UPS.

(2) When the power supply is switched to the UPS, the voltage RMS value increases to 116Vrms (125Vrms maximum).

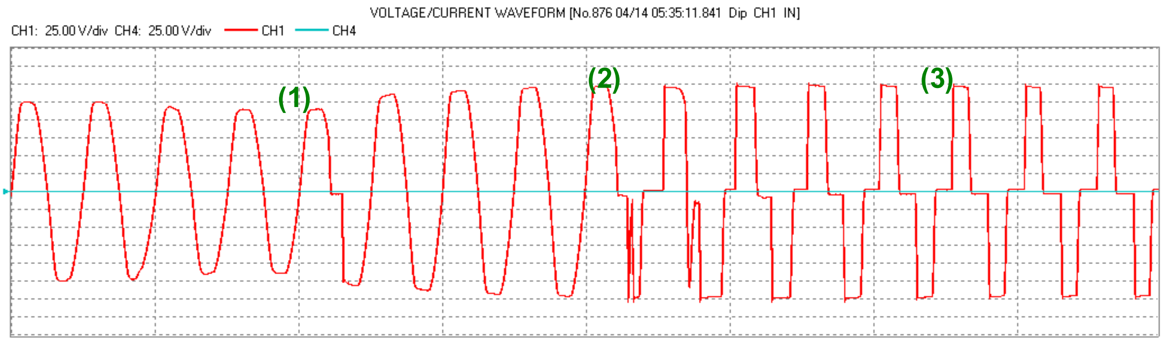
(3) The voltage waveform changes from the sine wave to the square wave in the UPS supply.

(4) The square wave continues for about 1.25s

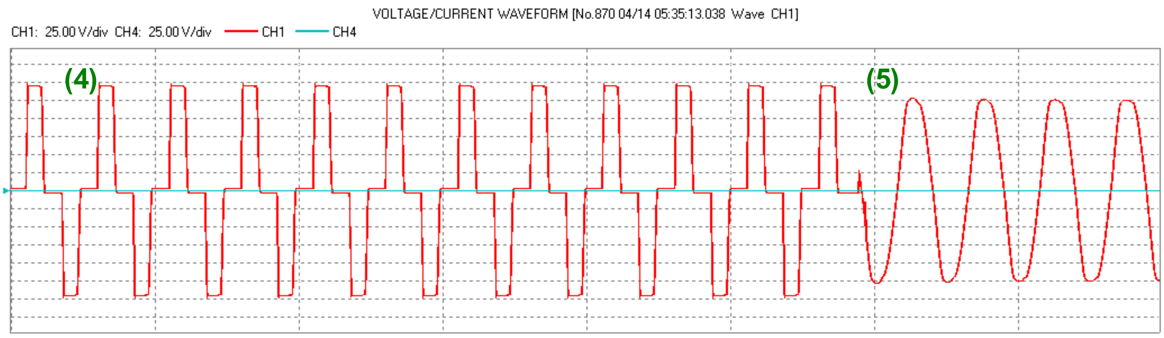
(5) The power supply is changed from the UPS to the commercial supply later. Upon this switching, the voltage drops to 78Vrms (75Vrms minimum) for a short period.



Event Voltage Fluctuation 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) The voltage dip occurs when the commercial power recovers and the power supply is switched from the UPS to the commercial supply.

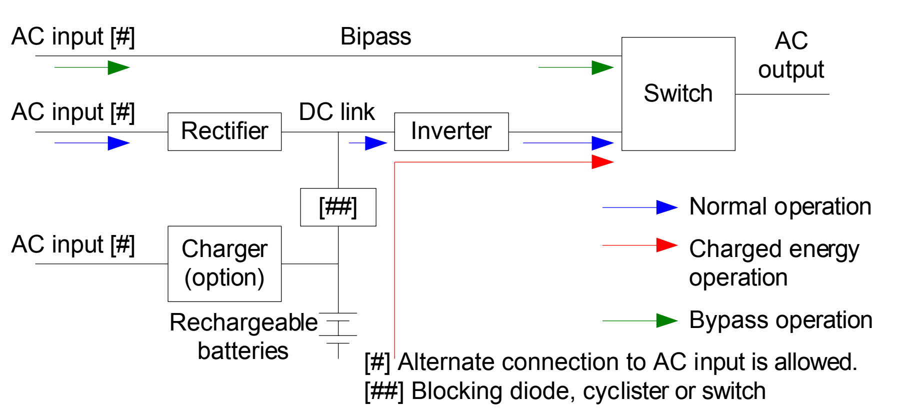
4. Countermeasures

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 albeit more costly "on-line UPS system", the dips and swells can be reduced during UPS switching.

<table>
<tr><td>Circuit example of
Stand-By Power System</td><td>
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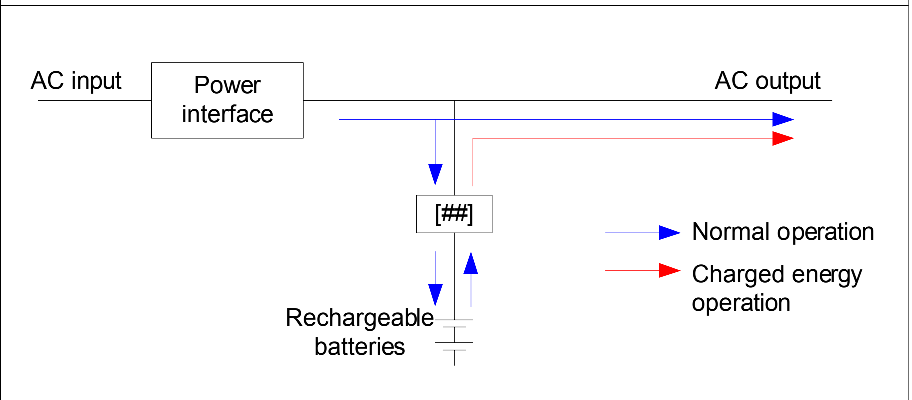
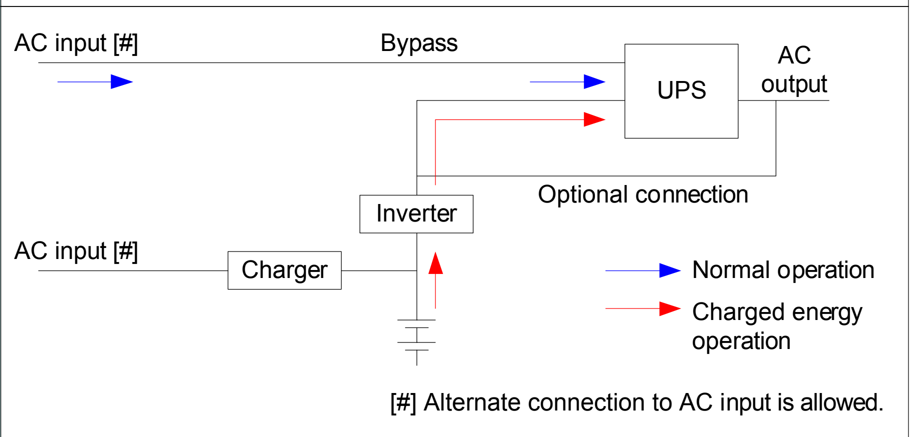
<tr><td>Circuit example of
On-Line UPS System</td><td>
</td></tr>
<tr><td>Circuit example of
Line-Interactive System</td><td>
</td></tr>
</table>

CASE STUDY 12

Inflow and Outflow of Harmonics

Environment:

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

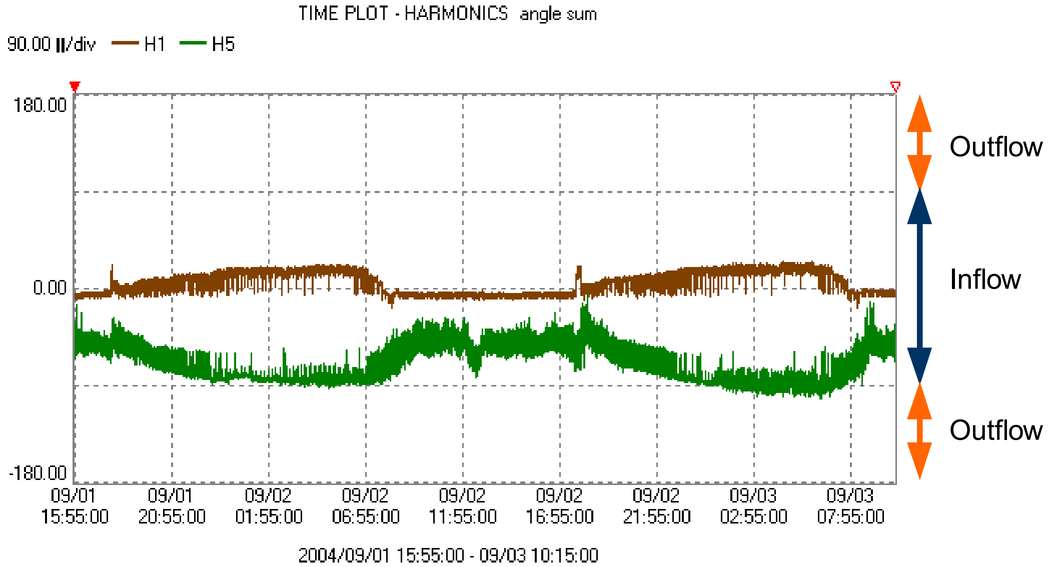
Analysis:

This is an example of inflow and outflow judgement taken as a result of harmonics measurement

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 (θsum). When it is between -90 to 0 to +90 degrees, it is inflow. Conversely, outflow is determined when the sum is in between -180 to -90 or +90 to +180 degrees.

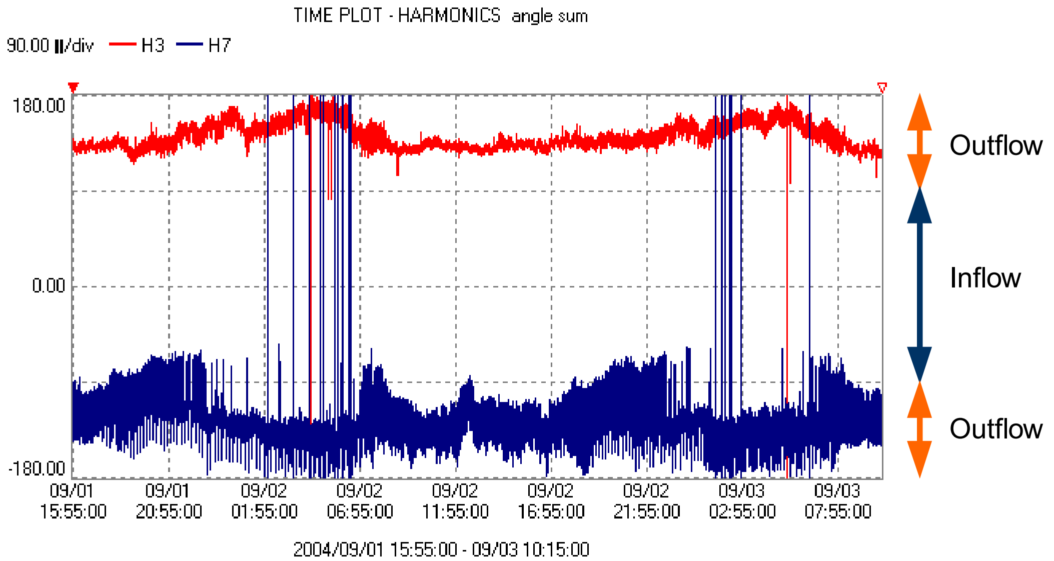
The fundamental wave (brown) is consumption (inflow) as shown below.

Most of 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 in the graph below. The 7th (blue) harmonic is outflow.
The data shows with the vertical lines that the phase difference exceeds 180 degrees and returns to -180 degrees (or vice versa).

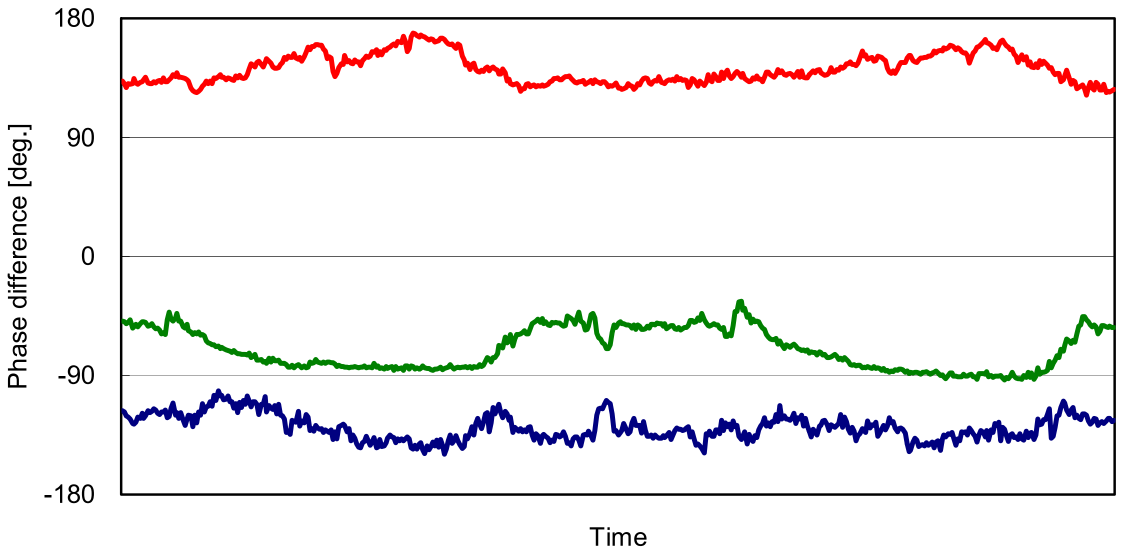


Time Plot of Harmonic Voltage-Current Phase Difference (3rd and 7th harmonics)

Model 9624 PQA HiVIEW and Model 9624-10 PQA HiVIEW Pro show the harmonic time plot graph by connecting the maximum and minimum values in each interval with a horizontal line. Therefore, a rapid change is reflected in the time plot graph.

However, the judgment of inflow and outflow is not easy to make using that time plot graph, so we recommend converting the data to CSV format and creating a graph with "AvePhasesum" of the relevant harmonics order only (without using "MaxPhasesum" and "MinPhasesum"), to determine the inflow and outflow.

Example 1



Red: 3rd harmonic, **Green**: 5th harmonic, **Blue**: 7th harmonic

Example 2

Date	Time	AvePhasesum (5)	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**

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

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

Official Report of the Ministry of Economics and Industries in Japan:

"Guideline for Harmonics Deterrence Countermeasures on Demand-Side that receives High-Voltage or Special High-Voltage" (September 30, 1994)

* The following shows the limit values which measurement instruments can detect.

-1. Harmonics Voltage (Total Harmonic Voltage Distortion)

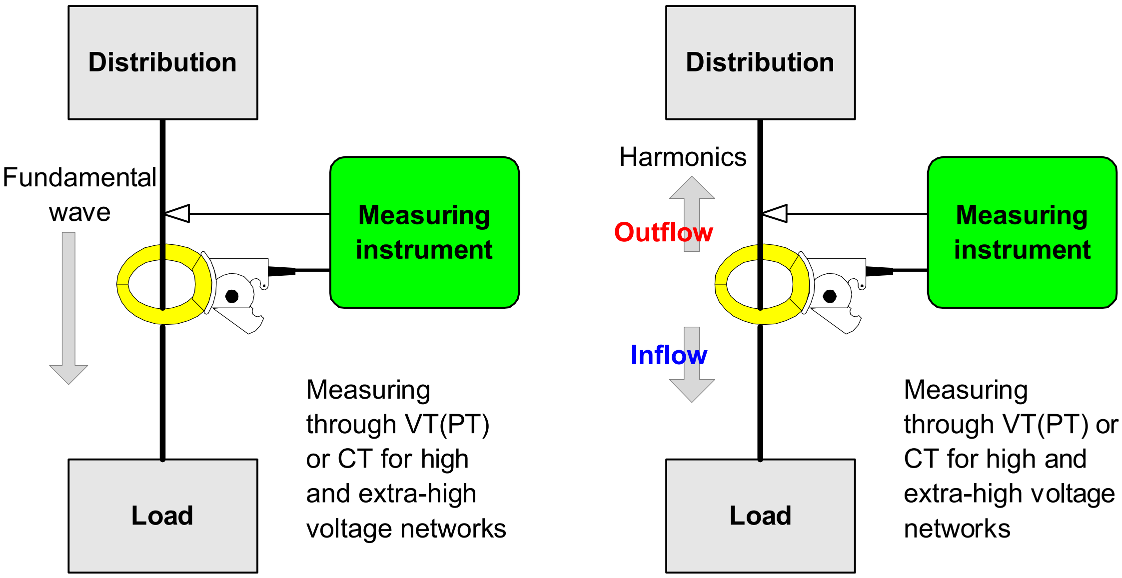
5% at 6.6kV system, 3% at special high-voltage system

-2. Harmonics Current

Upper limit values of **harmonics outflow current** (mA) per 1kW Contracted Power

Order / Voltage [kV]	5th	7th	11th	13th	17th	19th	23rd	Higher than 23rd
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	**Distribution side** (The harmonics generated by distribution is bigger than the harmonics generated by load.)
Outflow	The harmonics flow from load to distribution	**Load side** (The harmonics generated by load is bigger than the harmonics generated by distribution.)

<Reference> Harmonic Inflow/Outflow judgment on a measurement instrument

-1. Judgment by harmonic power

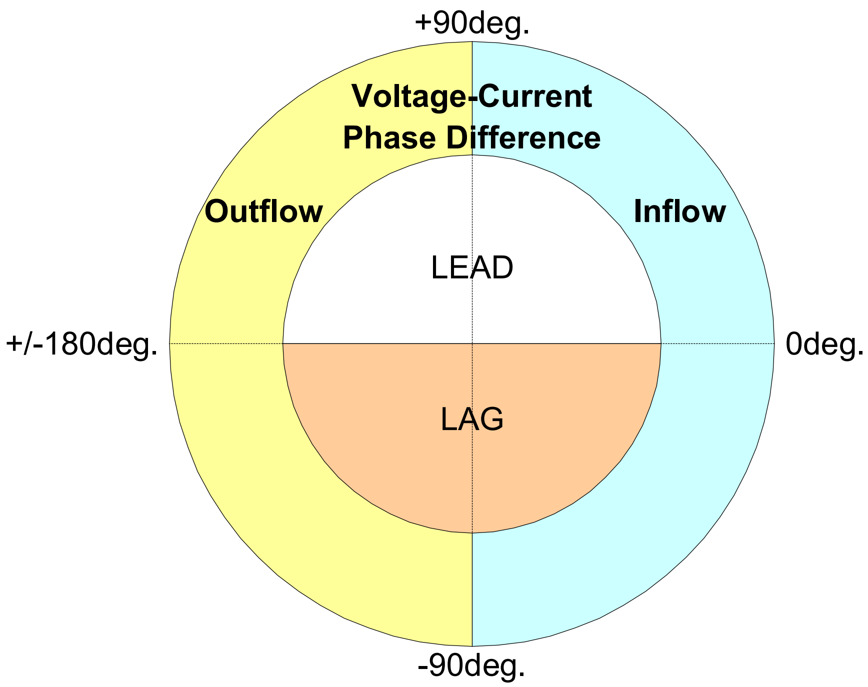
Judge the inflow/outflow by the polarity of the harmonic (effective) power. (Judge each phase and each order independently.)

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 by the harmonic voltage-current phase difference

Judge the inflow or outflow by 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 "sum" value.



	Harmonic voltage-current phase angle
Inflow	-90 to 0 to +90 degrees
Outflow	-180 to -90 degrees, +90 to +180 degrees

Problem	Judge to see if the high harmonic current level exceeds the limit. Do not watch the harmonic current amplitude level. Then, judge the inflow or outflow by watching the harmonic voltage-current phase difference.

APPENDIX

Power Quality Survey Procedures

Power quality survey procedures

Step 1: Purpose
Step 2: Location of problem (measurement target)
Step 3: Advanced confirmation at site (collecting the site information)
Step 4: Measure using a power quality analyzer
- 4-1. Normal condition measurement
- 4-2. Time plot recording for a certain period
- 4-3. Selecting the event parameters and thresholds
- 4-4. Long period measurement

Step 1: Purpose

Clearly confirm the purpose of the investigation: Purpose 1 or Purpose 2?

1. **Researching the condition of the power quality**
   There is no specific problem with the power supply, but the condition of the power quality at the site needs to be known.
   - Periodical power quality statistic research
   - Research before installing electric equipment
2. **Investigating the cause of a power abnormality**
   A quick solution needs to be found to counteract a problem with the power supply.

Step 2: Location of problem

Specify where the problem is occurring (identify the measurement site)

- If measurement at multiple sites is possible, detecting the cause of the problem can be easier and faster.

1. Network circuit inside a substation (Power companies only)
2. Receptacle point (high/low voltage)
3. Transformer panel, Distribution panel
4. Power supply for electric equipment (Outlet, etc.)

Points to confirm

1. **Frequency:**
   50/60Hz
2. **Wiring:**
   1P2W/1P3W/3P3W2M/3P3W3M/3P4W
3. **Neutral line measurement:**
   ON/OFF (CH4)
4. **Nominal voltage:**
   100V to 600V

Step 3: Advanced confirmation at site (collecting site information)

Collect as much site information as possible

1	**Details of power supply problem**	Destruction, Damage, Malfunction
2	**Period of power supply problem**	Constant, Periodic, Intermittent
3	**Confirm the overall site**	Existence of other equipment having the power supply problem, Working cycle of main electric equipment, Added or replaced equipment in the site, Power distribution network check at the site

Main electric equipment and power distribution network

1	**Main electric equipment**	Large copy machines, UPS, Elevators, Air-compressors, Air-conditioners compressors, Battery chargers, Cooling equipment, Air-handlers, Timer controlled lighting, Transmission drive equipment
2	**Power distribution network**	Defect or deterioration on conduits, Overheat or noise on transformers, Oil leakage, Overheat or loose on circuit breakers

Step 4: Measure using a power quality analyzer

Start measurement by using a power quality analyzer

1	**Normal condition measurement**	Confirm the instantaneous value in the VIEW screen of 3196. **Voltage level, Voltage waveform, Current waveform, Voltage waveform distortion (THD)**
2	**Time plot recording for a certain period**	Record the power supply fluctuation without setting events (15min to 1 day). ***3196 settings*** **Rec.Data: Power, MAX/MIN/AVE (recommended)** **P&Harm, MAX/MIN/AVE (to record harmonic fluctuation** This can be omitted when urgent measurement is required.
3	**Selecting the event parameters and thresholds**	Limit the number events to as few as possible at the beginning. **Minimum required events** **Swell: 110%** **Dip: 90%** **Interruption: 10%** **Waveform distortion: 5% to 15%*** **Transient: 100V to 200V* (for 100V circuit)** *Set the thresholds smaller and increase them gradually if too many events are being recorded.
4	**Load period measurement**	***3196 settings*** **MemoryFull: LOOP** **AutoSave: Binary**

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