Power Quality Case Studies

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Reference :

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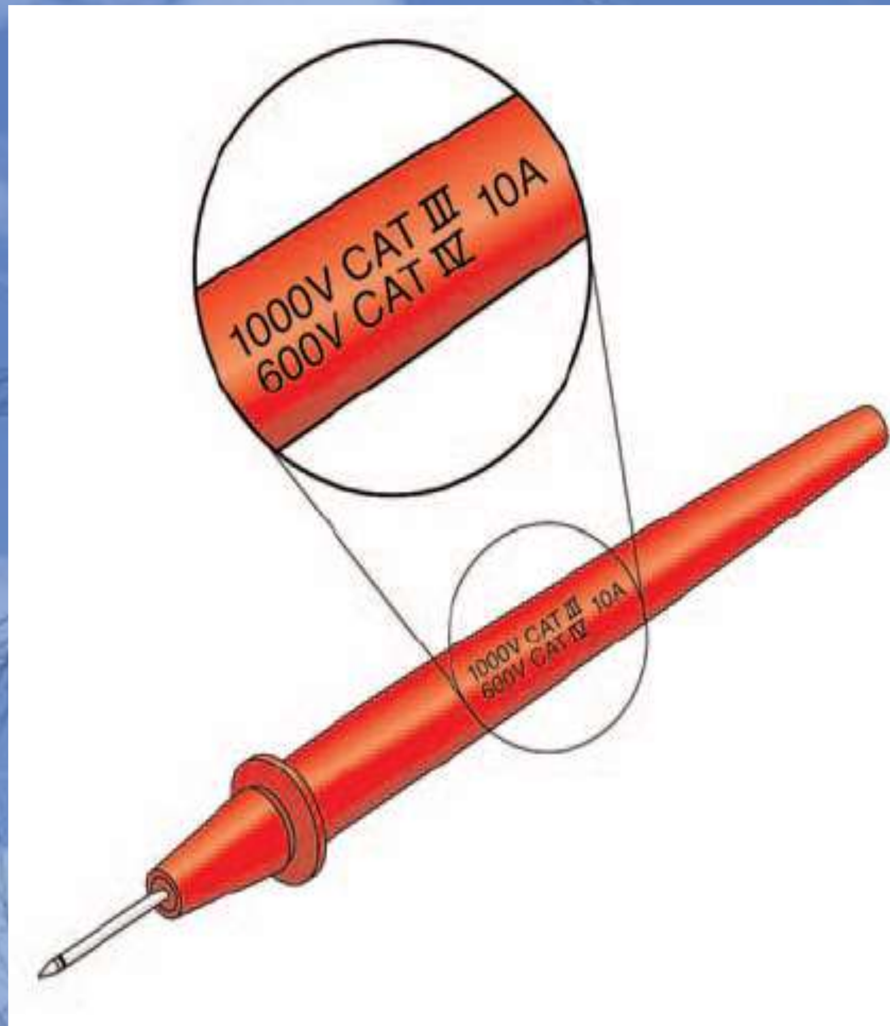
چند نکته در خصوص دستگاه های اندازه گیری

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.
Class B	Used for statistical surveys, and contractual applications where there are no disputes.


1000V CAT III 10A
600V CAT IV

Rated Voltage	IEC 61010-1 2nd Edition			UL 61010B-1 (UL 31111-1)		
	CAT IV	CAT III	CAT II	CAT III	CAT II	CAT I
150V	4,000V	2,500V	1,500V	2,500V	1,500V	800V
300V	6,000V	4,000V	2,500V	4,000V	2,500V	1,500V
600V	8,000V	6,000V	4,000V	6,000V	4,000V	2,500V
1,000V	12,000V	8,000V	6,000V	8,000V	6,000V	4,000V
Resistance	2 ohms	2 ohms	12 ohms	2 ohms	12 ohms	30 ohms

Measurement Category I:

This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

Measurement Category II:

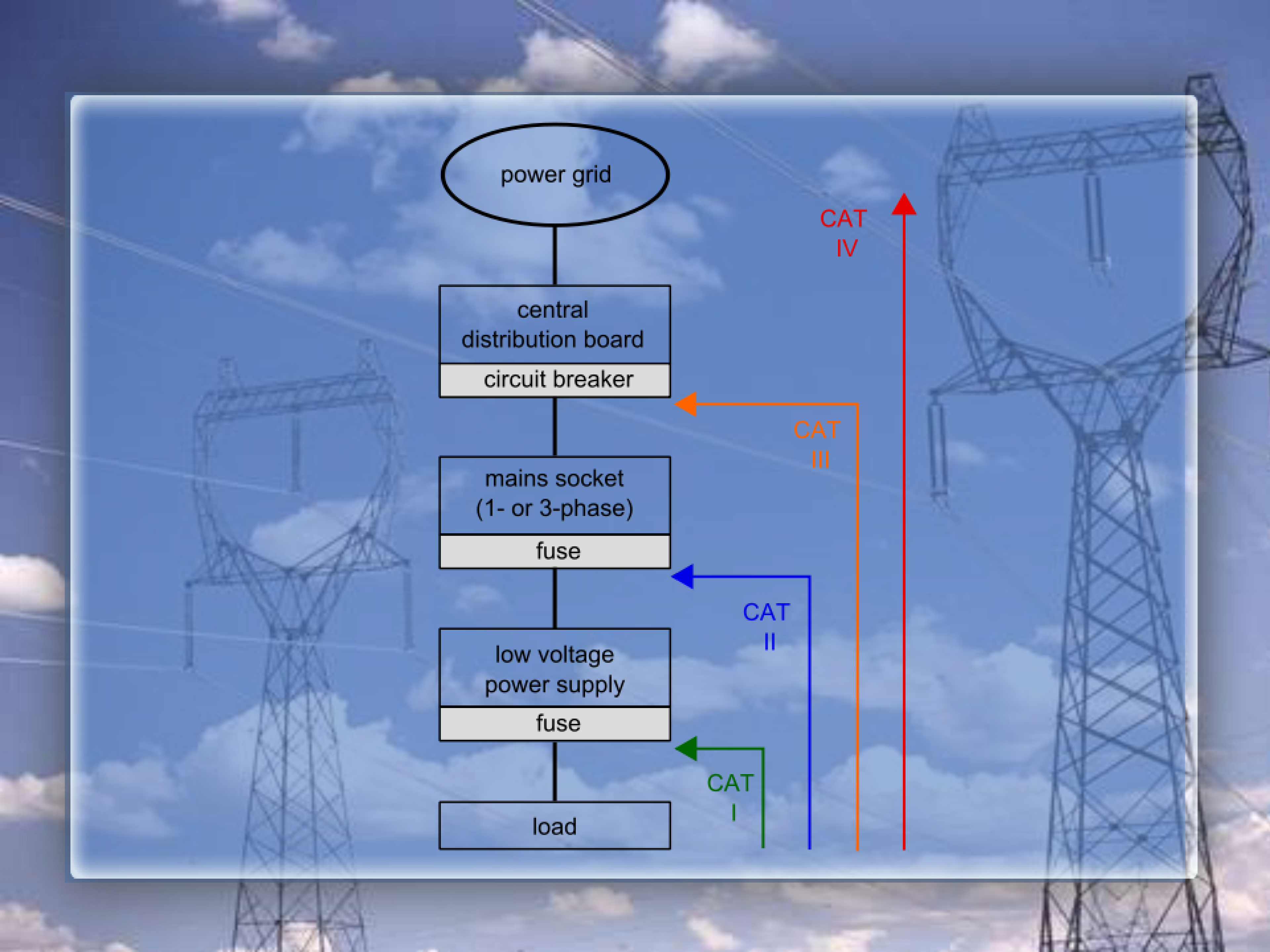
This category refers to local-level electrical distribution, such as that provided by a standard wall outlet or plug in loads (for example, 115 AC voltage for U.S. or 200 AC voltage for Europe). Examples of Measurement Category II are measurements performed on household appliances, portable tools, and similar modules.

Measurement Category III:

This category refers to measurements on hard-wired equipment in fixed installations, distribution boards, and circuit breakers. Other examples are wiring, including cables, bus bars, junction boxes, switches, socket outlets in the fixed installation, and stationary motors with permanent connections to fixed installations.

Measurement Category IV:

This category refers to origin of installation or utility level measurements on primary over-current protection devices and on ripple control units.


power grid
central distribution board
circuit breaker
mains socket (1- or 3-phase)
fuse
low voltage power supply
fuse
load
CAT IV
CAT III
CAT II
CAT I

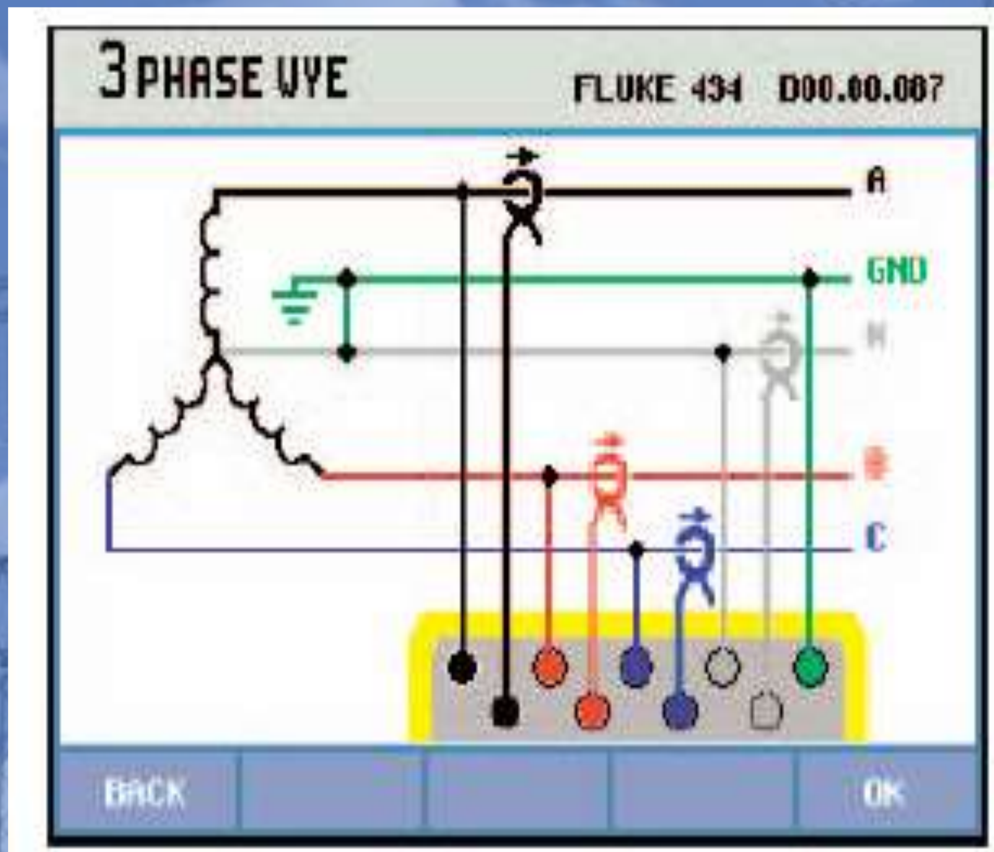
Overheated transformer

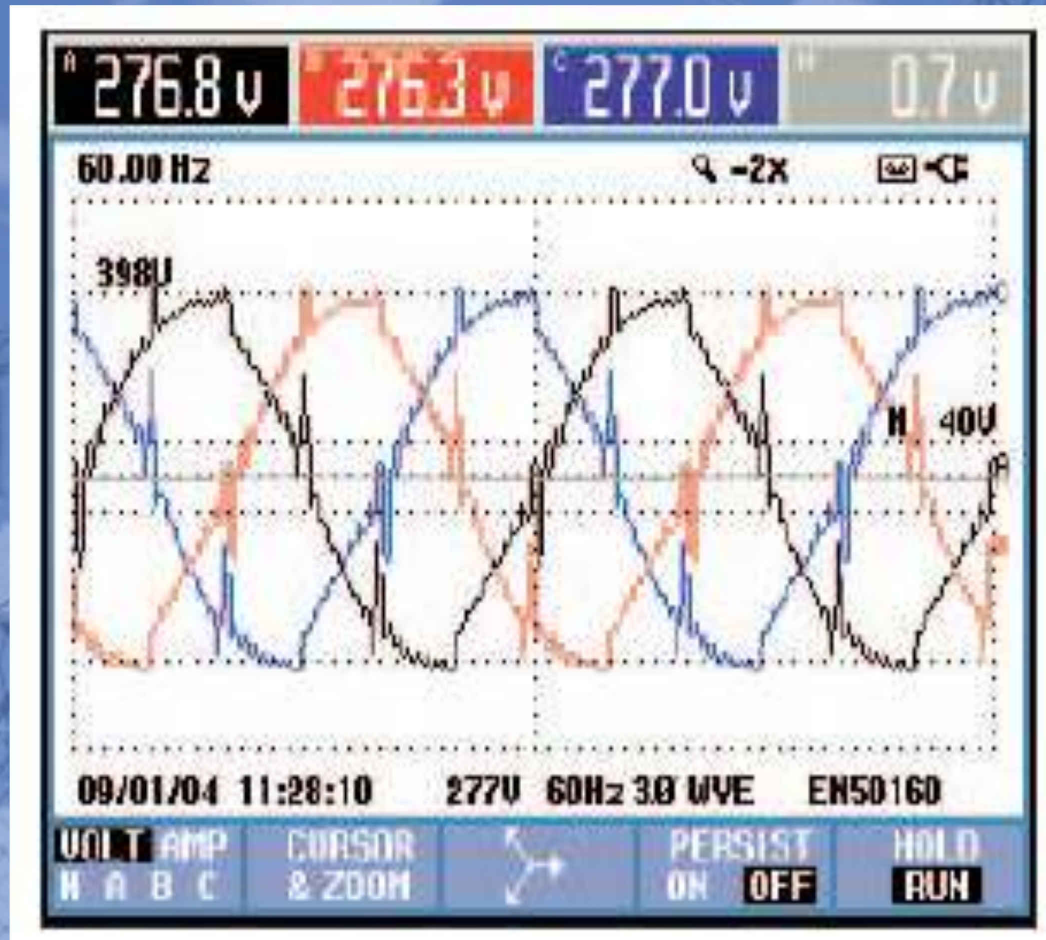
Problem description

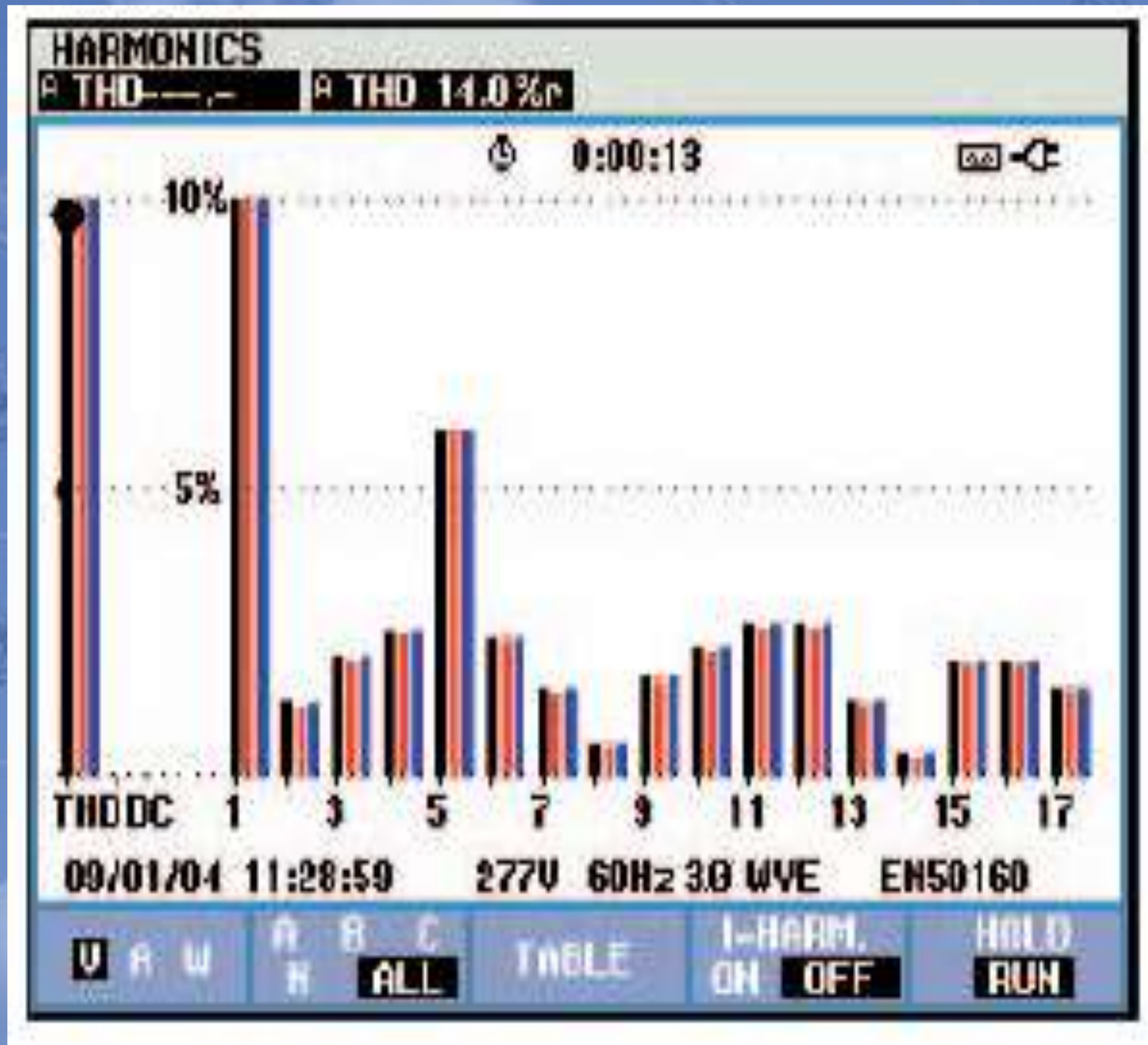
You could almost call it a happy accident. During a routine job at a large industrial facility, an electrical maintenance worker set a plastic kit on top of a nearby transformer. By the time he reached back for it a few minutes later, it had started to melt!

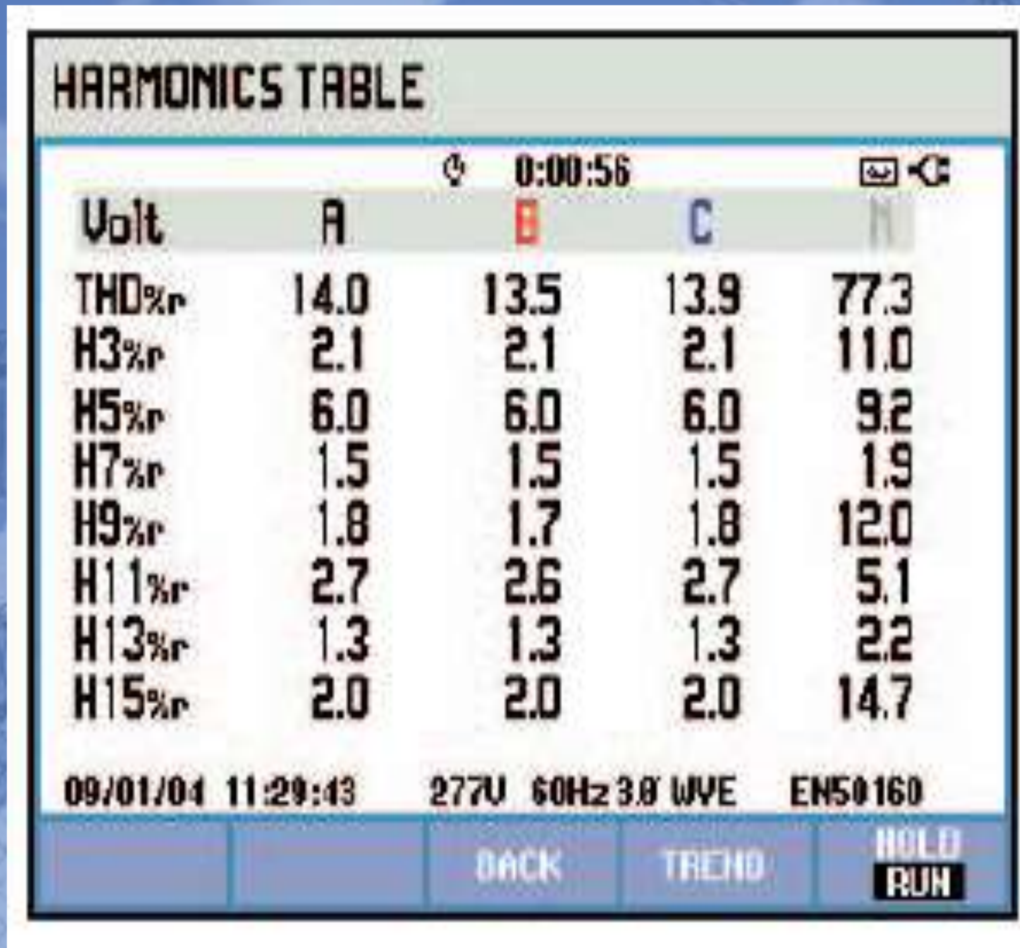
Measurements and Analysis

Measuring tools: Fluke 434 Power Quality Analyzer


3 PHASE WYE
FLUKE 434
D00.00.007
A
GND
B
C
BACK
OK


276.8 v
276.3 v
277.0 v
0.7 v
60.00 Hz
-2X
398V
N 40V
09/01/04 11:28:10
277V 60Hz 3.0 WYE
EN50160
VOLT AMP
N A B C
CURSOR
& ZOOM
PERSIST
ON OFF
HOLD
RUN


HARMONICS
A THD---.-
A THD 14.0%r
0:00:13
10%
5%
THD DC 1 3 5 7 9 11 13 15 17
09/01/04 11:28:59 277V 60Hz 3.0 WYE EN50160
V A W
A B C
N ALL
TABLE
I-HARM.
ON OFF
HOLD
RUN



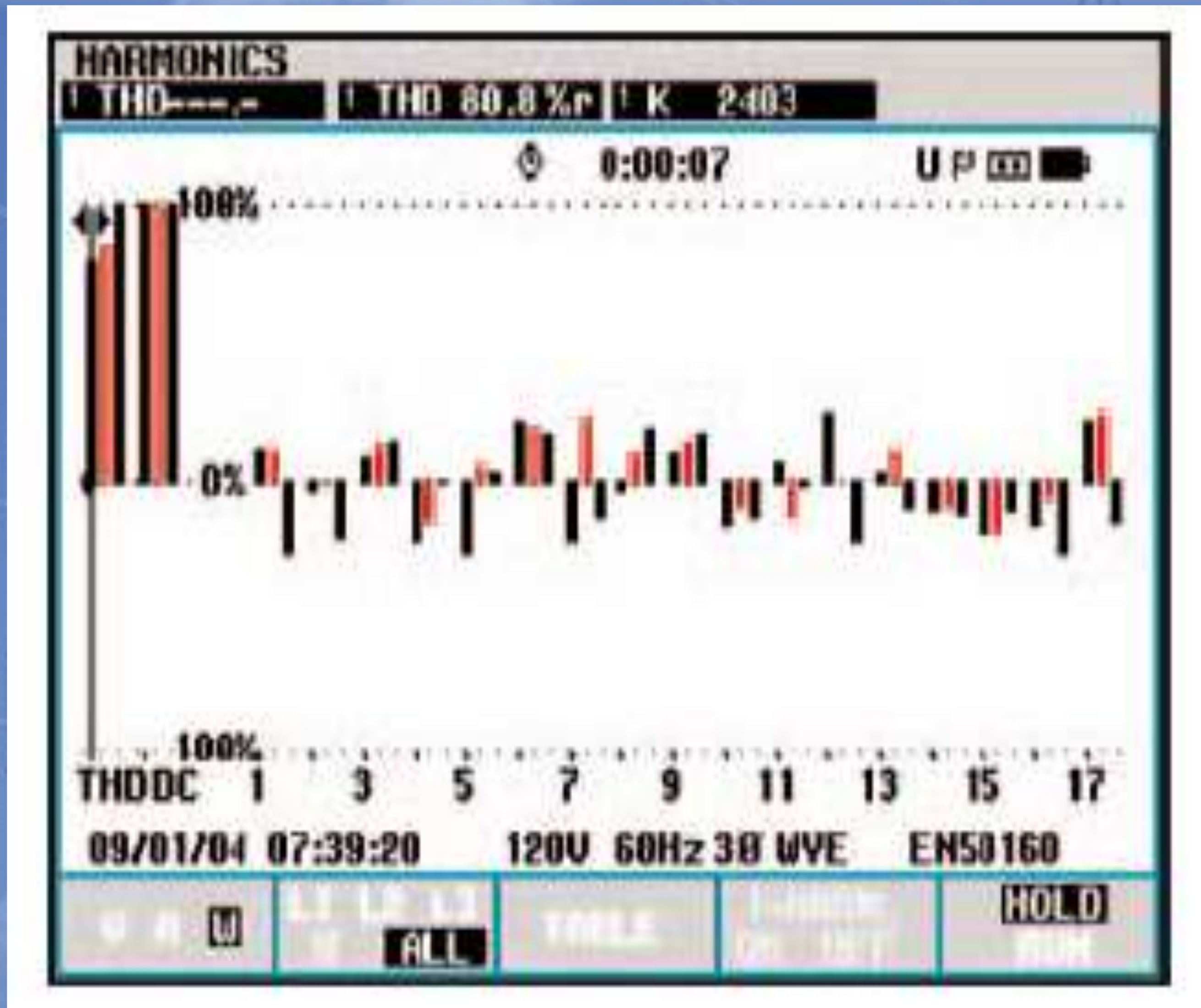
HARMONICS TABLE

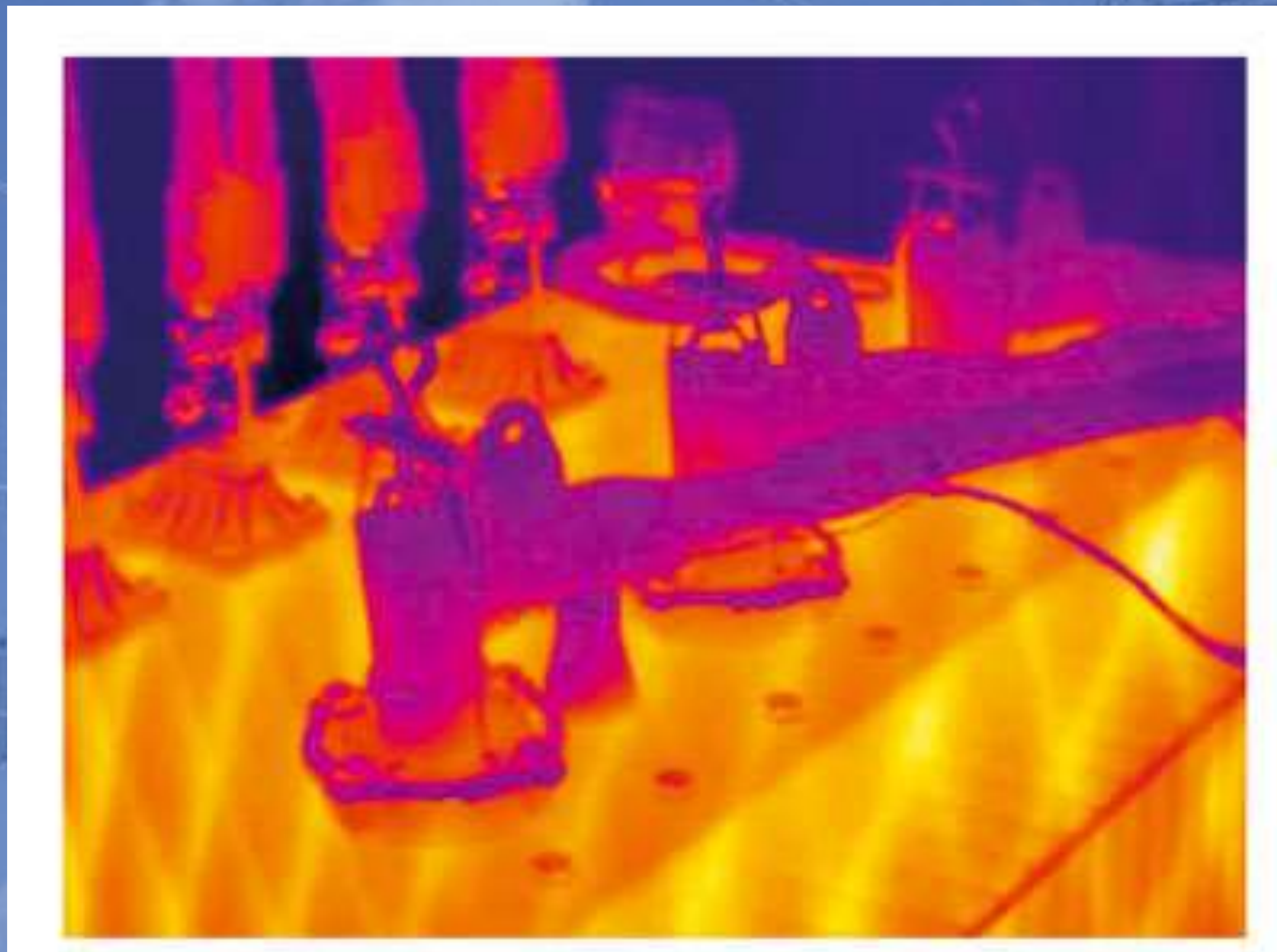
0:00:56

Volt	A	B	C	N
THD%r	14.0	13.5	13.9	77.3
H3%r	2.1	2.1	2.1	11.0
H5%r	6.0	6.0	6.0	9.2
H7%r	1.5	1.5	1.5	1.9
H9%r	1.8	1.7	1.8	12.0
H11%r	2.7	2.6	2.7	5.1
H13%r	1.3	1.3	1.3	2.2
H15%r	2.0	2.0	2.0	14.7

09/01/04 11:29:43 277V 60Hz 3.0 WYE EN50160

BACK TREND HOLD RUN


HARMONICS
THD 80.8 %r
K 24.03
0:00:07
100%
0%
100%
THD DC 1 3 5 7 9 11 13 15 17
09/01/04 07:39:20
120V 60Hz 3Ø WYE
EN50160
ALL
HOLD



Above thermal and daylight images show uneven heating in the windings of a three phase step-down transformer, most likely due to harmonics.

The vibrating transformer

Problem description

This case history comes from an electrical contractor. Several of this contractor’s clients operate large commercial buildings. One of these clients asked for help with a large transformer that had suddenly started vibrating and making a loud buzzing sound. The client was concerned that the transformer was ready to fail and he would be faced with an expensive replacement

Transformer size: 1500 kVA
Transformer configuration: Delta/wye, 480 V 3-phase secondary
Secondary load: Motors , lighting, and office machines for a large office building
Note: The client says the transformer is lightly loaded because many of the tenants have recently moved to a new location.

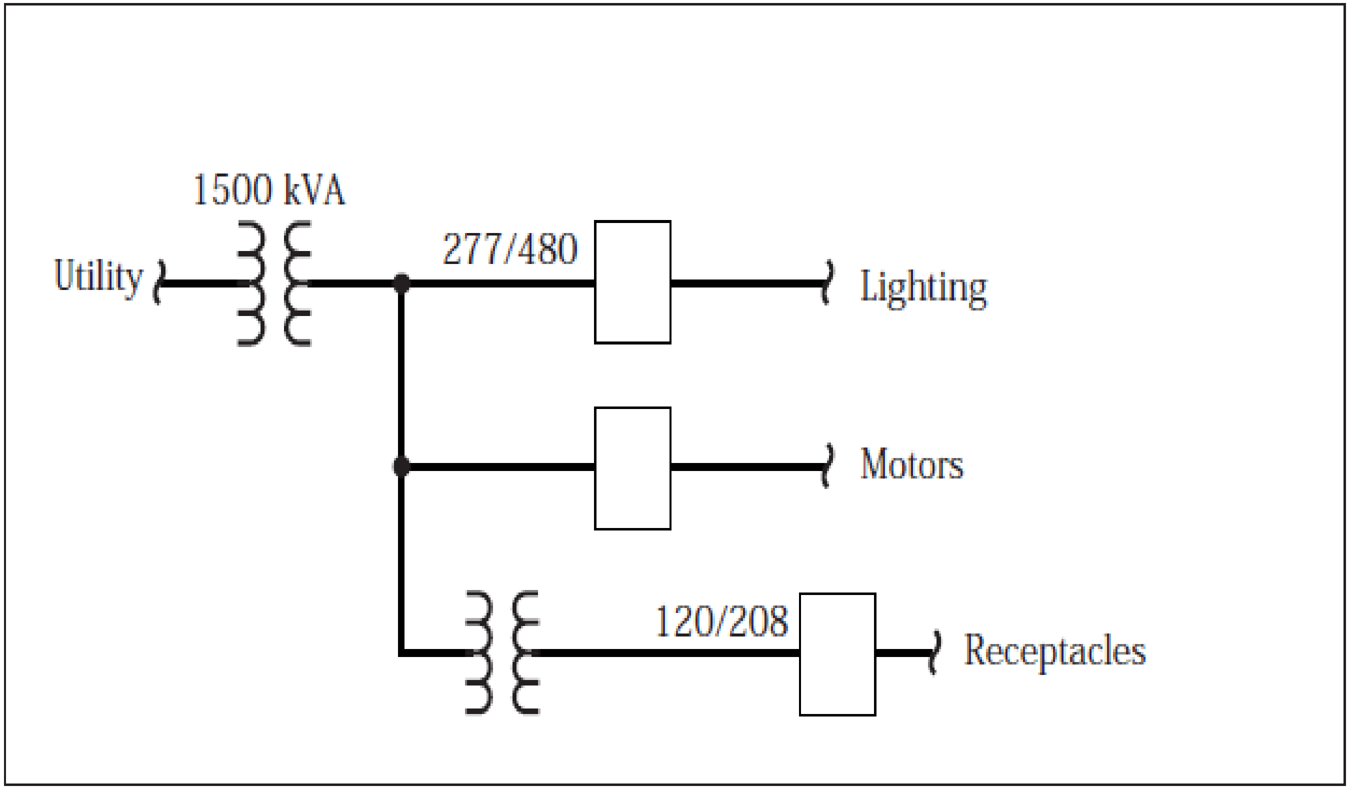


Fig. 1 Partial one-line diagram of large commercial building

Measurements and Analysis

Measuring tools: Fluke 43B Power Quality Analyzer

Measurement data

The engineer recorded the following data using the Fluke 43B:

Secondary voltage total harmonic distortion: 2.7 %

Secondary voltage balance: within 1 %

Secondary current: 57 A rms

Secondary current spectrum:

Fundamental 55 A

2nd harmonic 1.6 A

3rd harmonic 2.5 A

4th harmonic 0.7 A

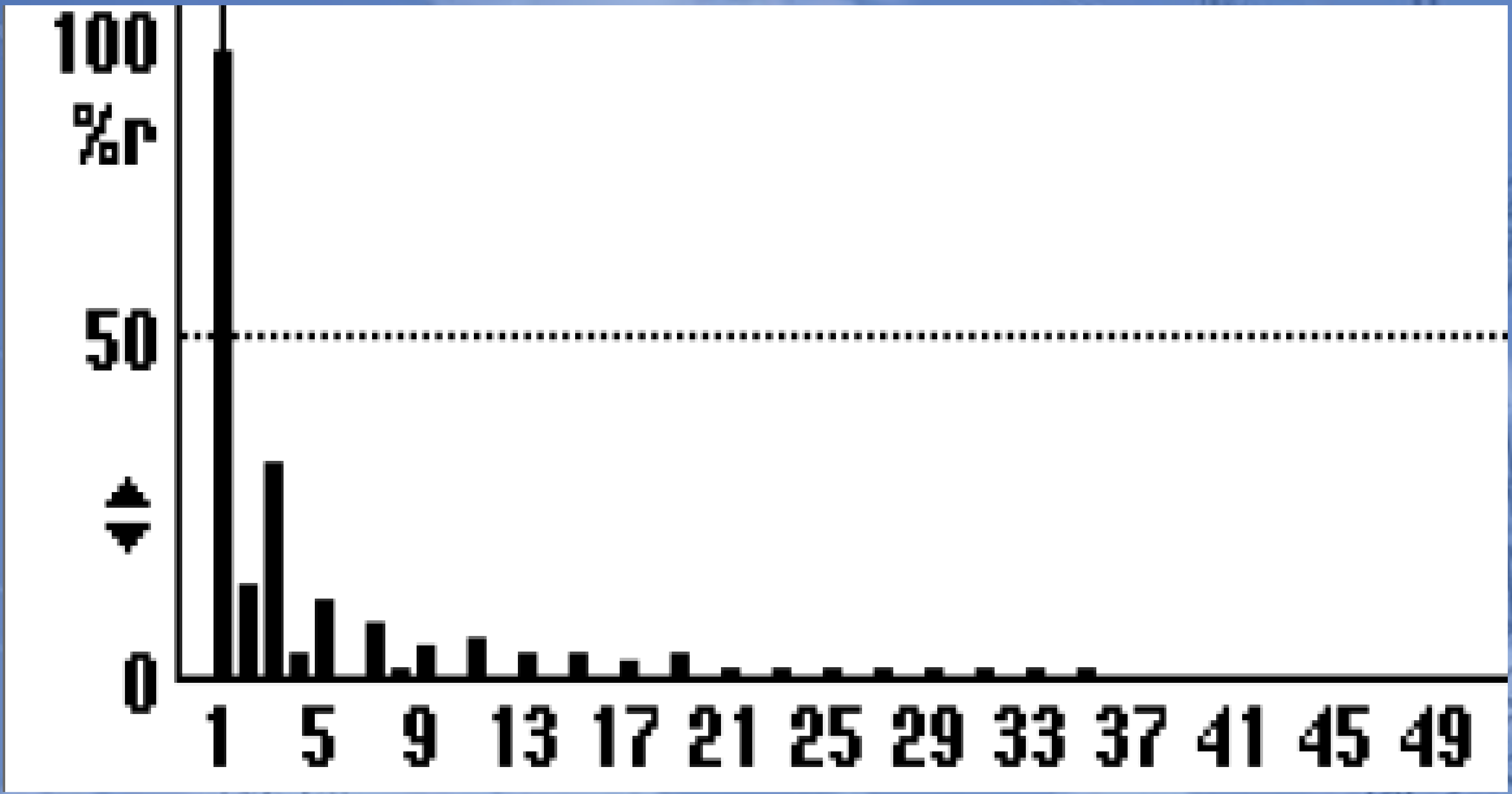
5th harmonic 2.4 A

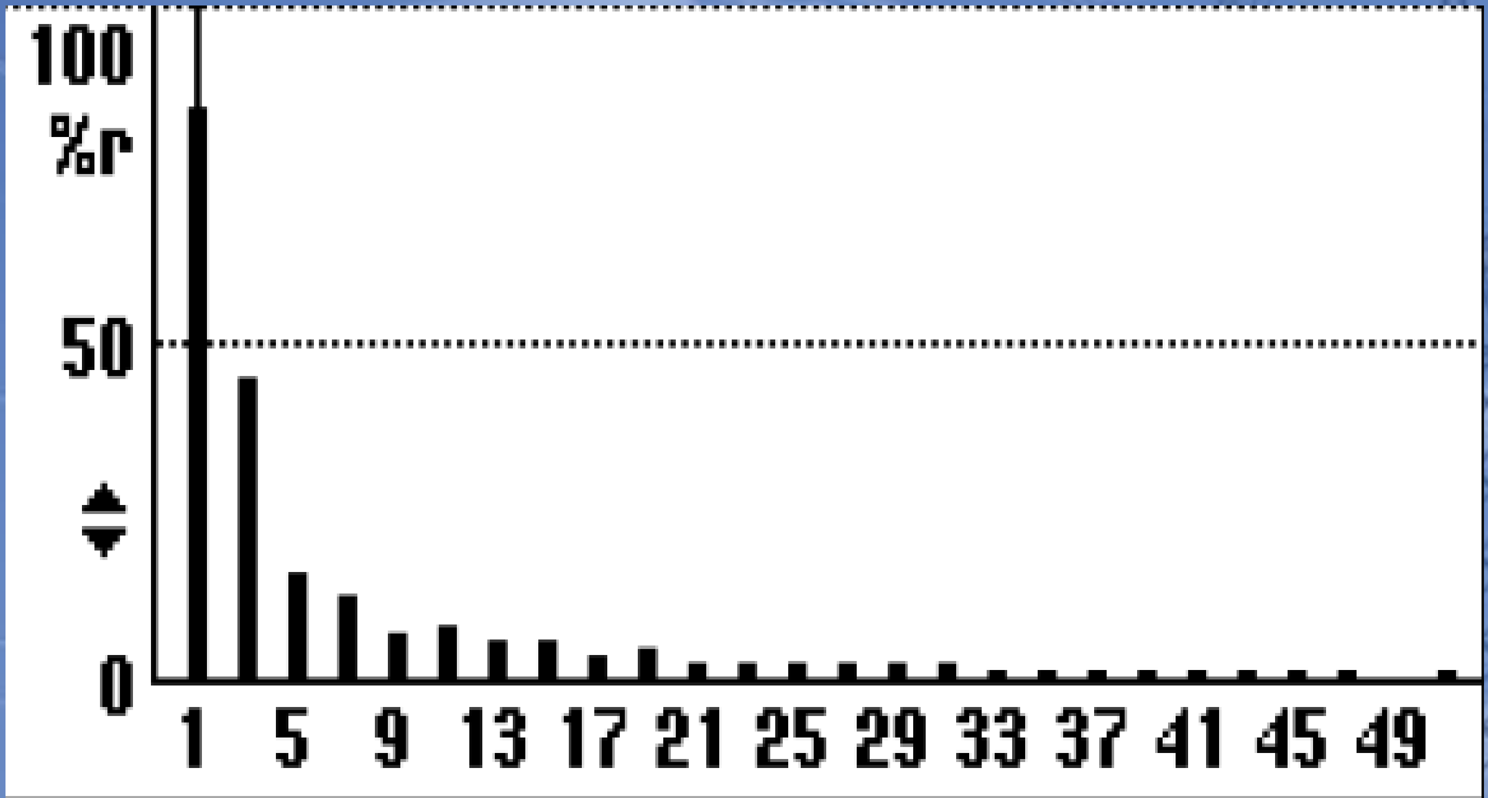
6th harmonic 0.4 A

7th harmonic 4.0 A

Theory and analysis

The voltage measurements do not show anything abnormal. The voltage total harmonic distortion is well within the maximum allowable value of 5 %. Voltage balance between phases also looks good. The secondary current of 57 A indicates the client was correct in stating the transformer was lightly loaded. No overheating was noted.


100
%r
50
0
1
5
9
13
17
21
25
29
33
37
41
45
49



2 Example of a normal ac current spectrum with all odd harmonics

Solution

The engineer asked if any large motor drives were operating. The plant manager confirmed that one large drive was operating a ventilation fan. The engineer instructed the plant manager to have the drive shut off. When the drive was shut off, the transformer immediately stopped vibrating.

Malfunctioning traffic light

Problem description

This case history came from an electric utility engineer assigned to maintain the power systems for several small towns in the western U.S. The case history began with a call from a local police department. The officer explained that the traffic light at the main intersection of town was randomly malfunctioning.

Sometimes it worked fine, while other times it generated unacceptably long delays in one direction or the other. Normally when a traffic light fails, it will not work at all. In this case, however, the problem was intermittent. Therefore, the engineer suspected the problem was due to an interaction with the power system, rather than a failure within the traffic light itself.

The engineer’s investigation showed that three facilities (a barbershop, a small café and an automotive machine shop) shared the transformer secondary that supplied power to the traffic light. See Fig. 1.One of the keys to troubleshooting a problem is determining what changed just prior to the appearance of the problem. Visits to the barbershop and café didn’t reveal anything meaningful.

The machine shop, however, had a different story. The shop had just installed a new brake lathe they were using to resurface brake drums and rotors for cars and trucks. The lathe was equipped with a dc motor powered by a dc adjustable speed drive.

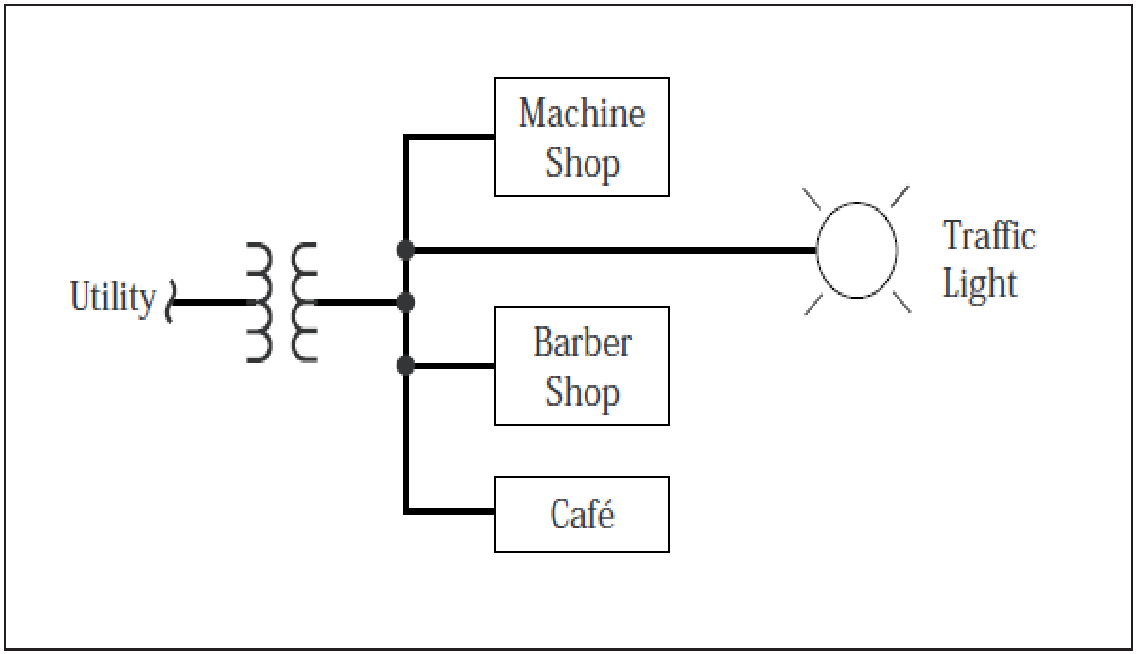


Fig. 1 One-line diagram showing power supplied to the traffic light

Measurements and Analysis

Measuring tools: Fluke 43B Power Quality Analyzer

Theory and analysis

Machine tool applications need high torque at low speeds, and dc motor/drive configurations serve this need well. The input rectifier circuit in a dc drive is designed to provide variable amounts of current to meet the torque and speed requirements of the motor. A commonly used circuit configuration uses silicon controlled rectifiers (SCRs) to provide the variable current. The SCR circuit produces commutating spikes as one rectifier is turned off before the next rectifier is turned on.

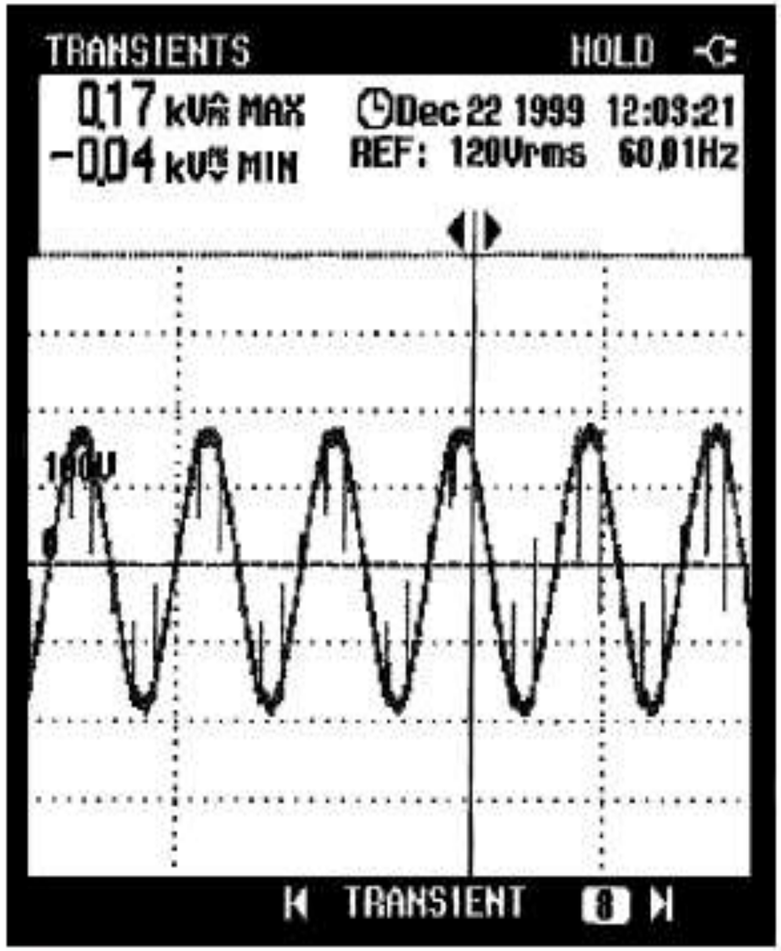


Fig. 2 Voltage spikes from a dc adjustable speed drive

Three phase motor failure

Problem Description :

For three years in a row, a particularly large three-phase motor would fail twice a year. The facility maintenance manager called in both the electrical contractor and the motor manufacturer, who pointed fingers at each other but failed to resolve anything on site. The facility was left in the middle, with no corrective action, cyclical motor repair costs, and lost production from the repeated downtimes.

Tired of what was clearly a pattern failure, the facility manager hired an independent consultant. The consultant told the facility manager he would perform a complete power quality survey of the electrical distribution system feeding the motor, determine its operating characteristics and work from there to solve the problem.

Measurements and Analysis

Measuring tools: Fluke 434 Power Quality Analyzer

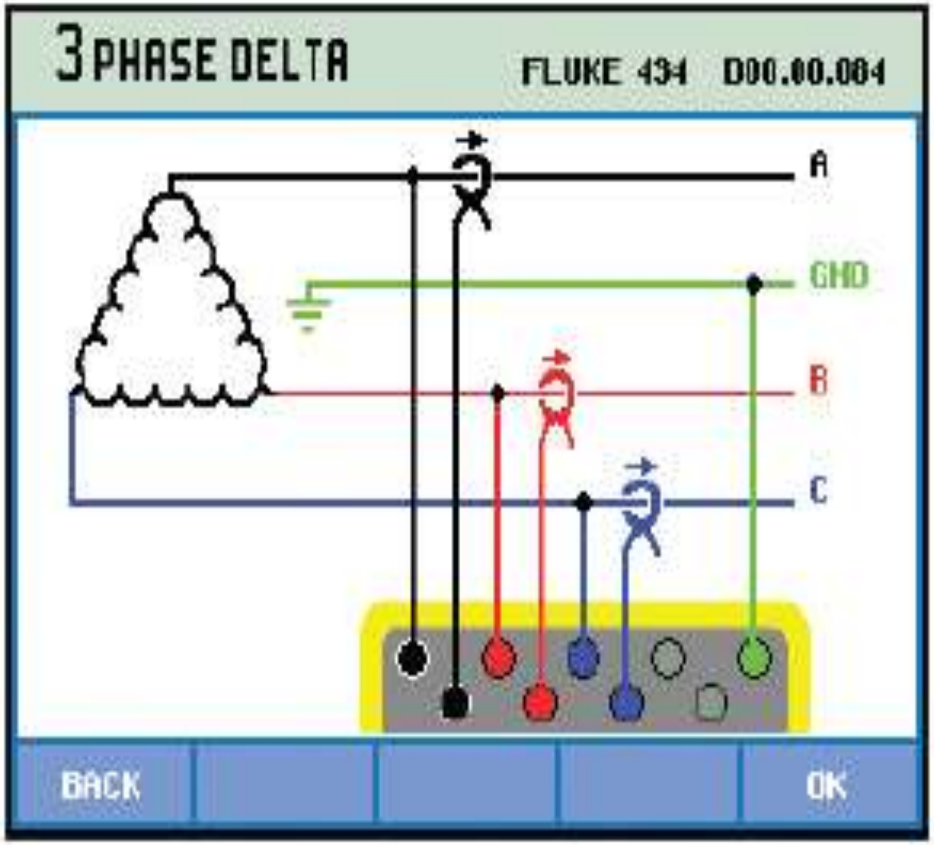


Fig. 1 Three phase Delta

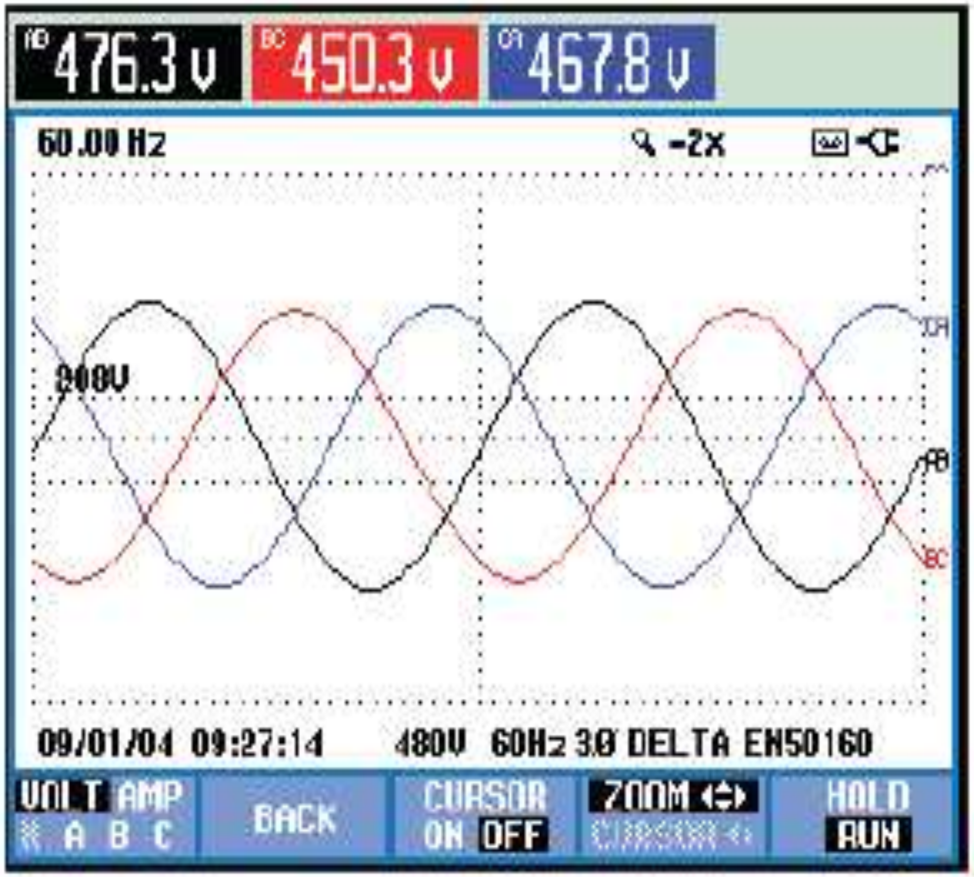


Fig. 2 Unbalance voltage wave

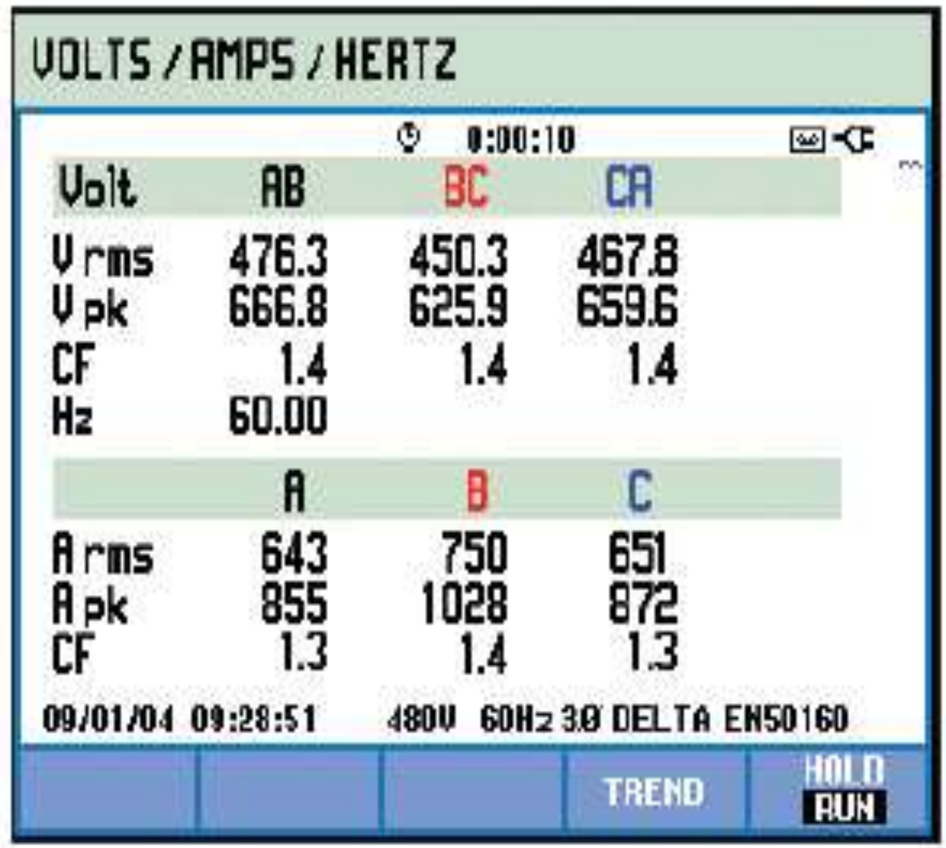


Fig. 3 Unbalance voltage wave

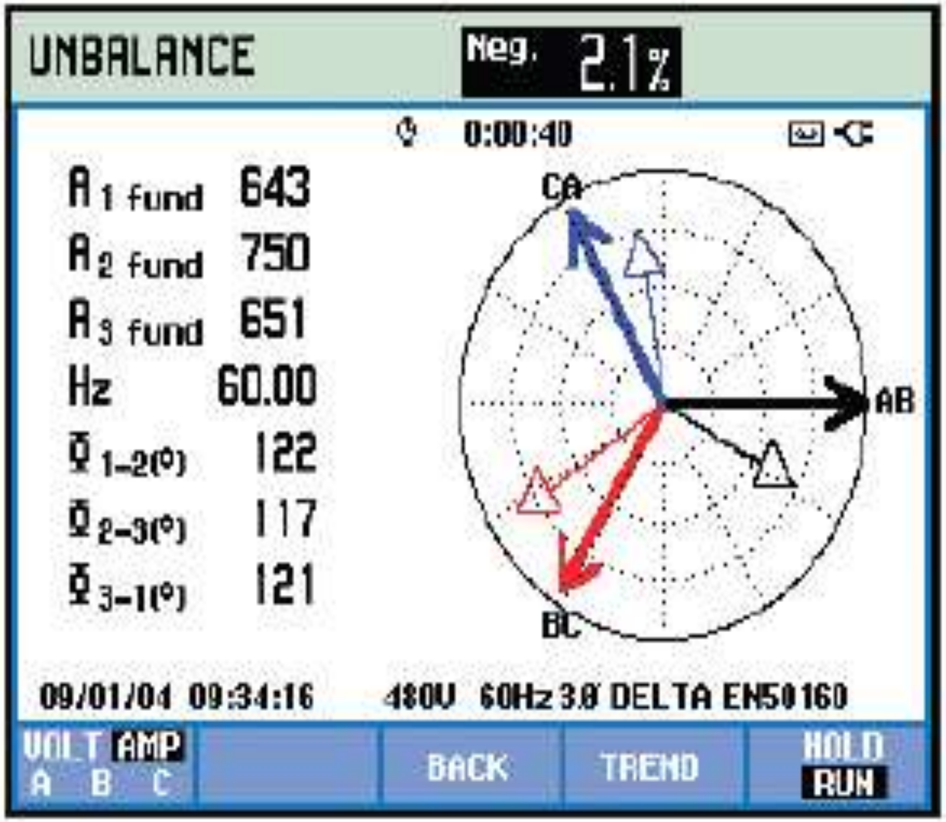


Fig. 4 Unbalanced phaser amp

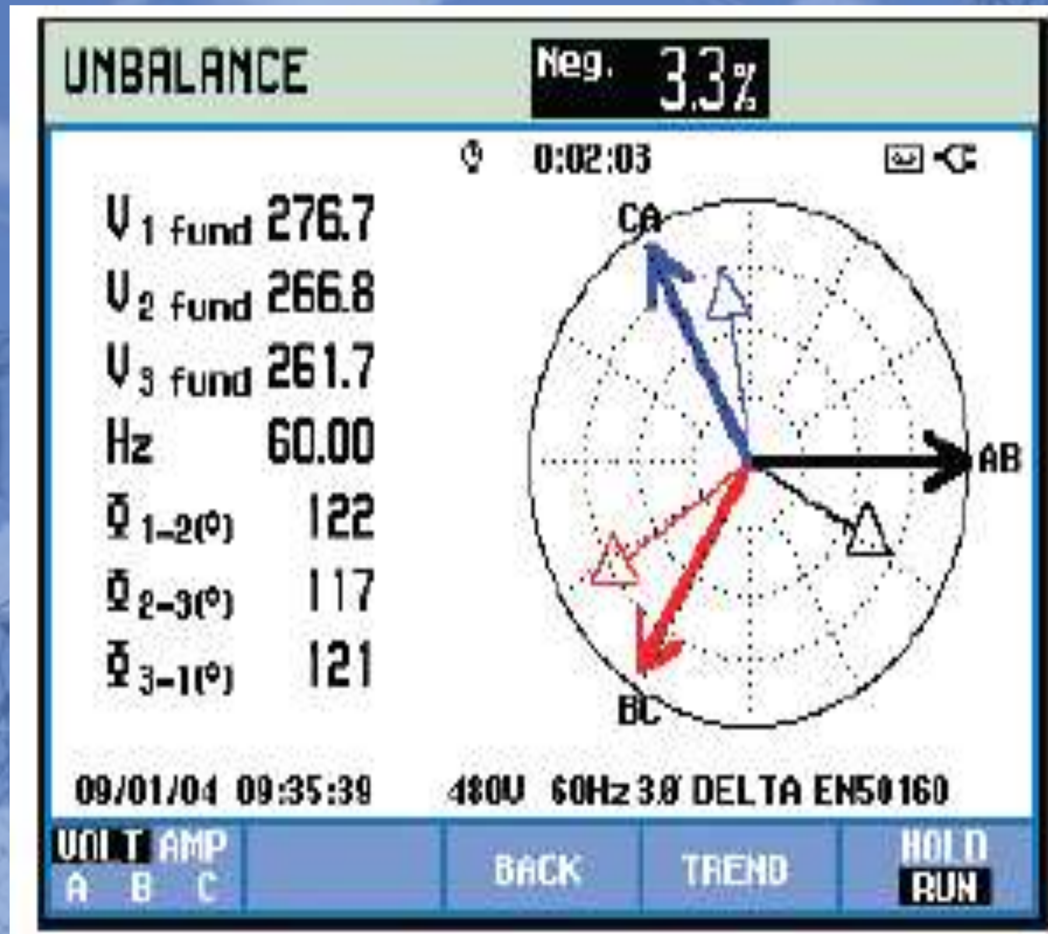

UNBALANCE
Neg. 3.3%
0:02:03
V1 fund 276.7
V2 fund 266.8
V3 fund 261.7
Hz 60.00
Φ1-2(°) 122
Φ2-3(°) 117
Φ3-1(°) 121
CA
AB
BC
09/01/04 09:35:39
480V 60Hz 3Ø DELTA EN50160
UNIT AMP
A B C
BACK
TREND
HOLD
RUN

Fig. 6 Unbalanced table

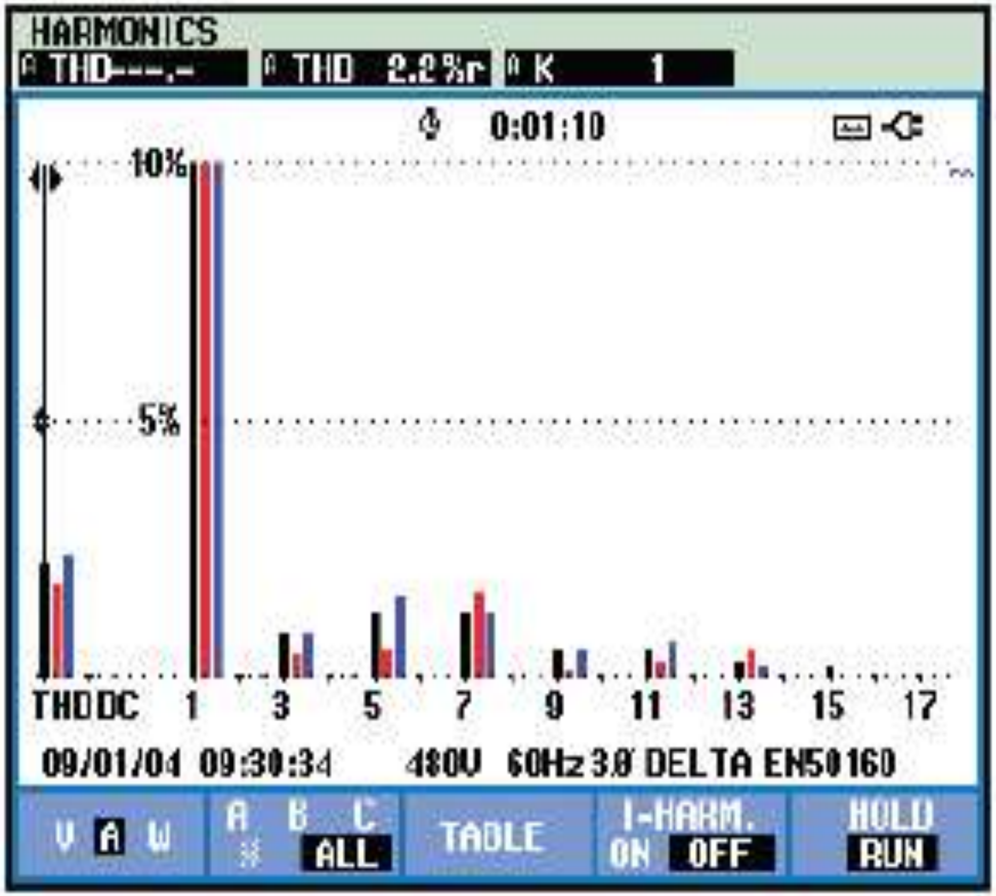


Fig. 7 Harmonics

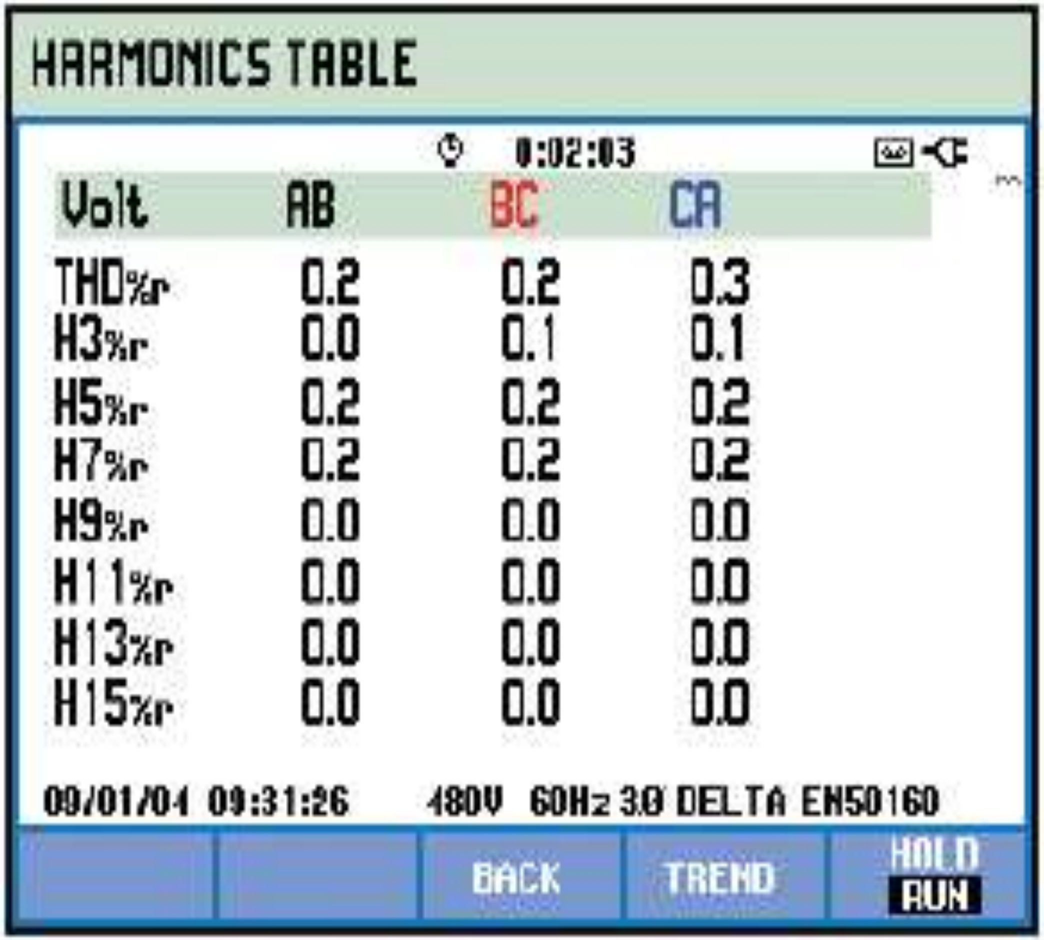
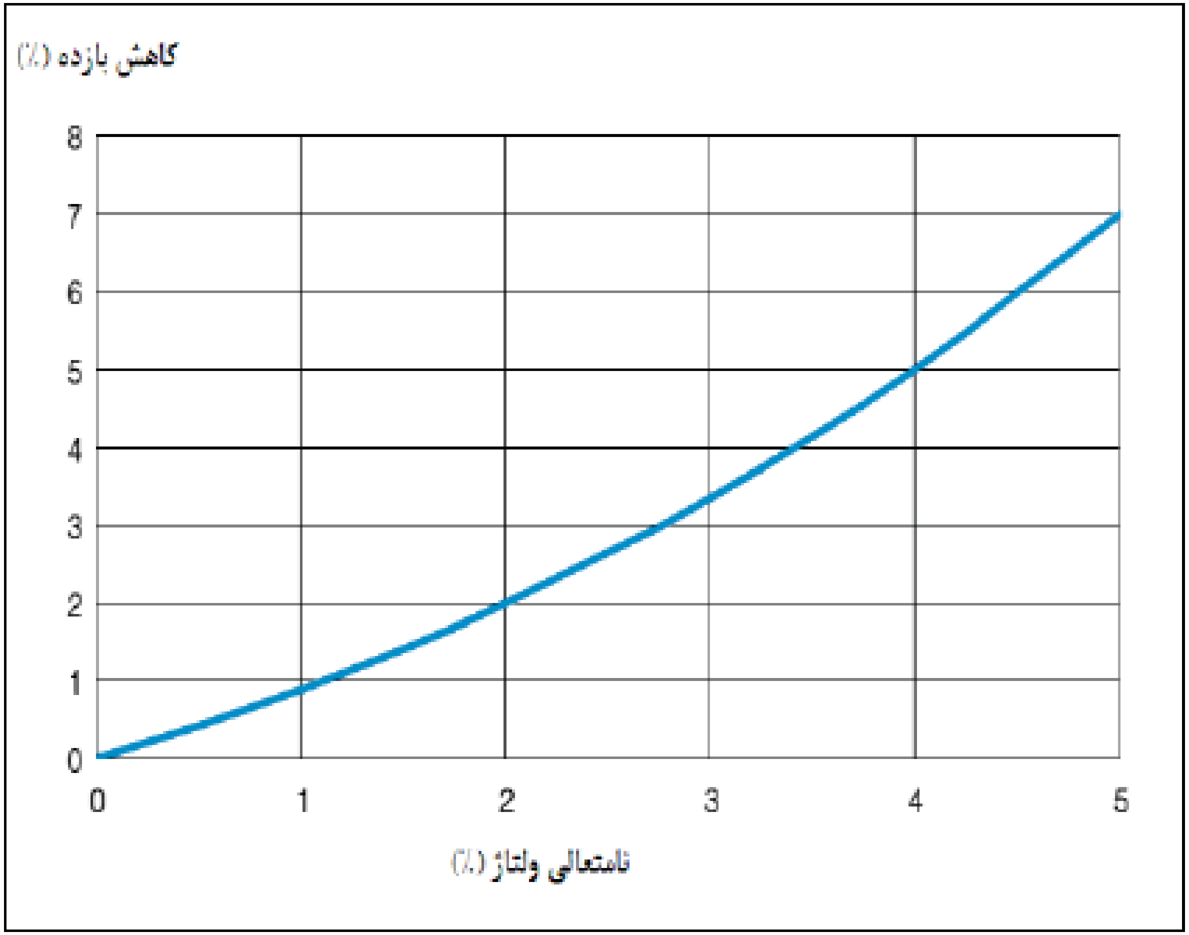


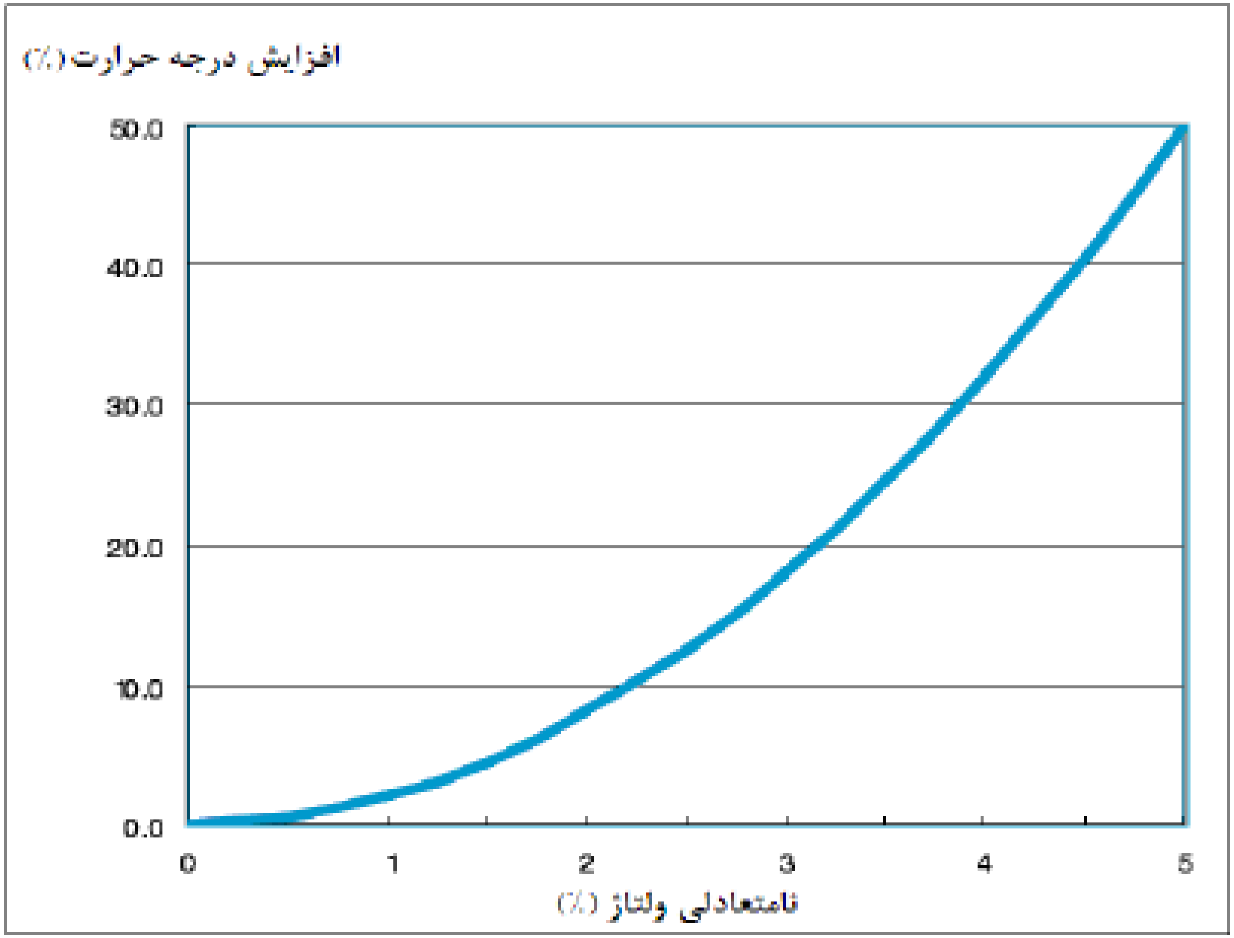
Fig. 8 Harmonics table

Analysis

From his measurements, he could see that an unbalance was causing an excessively large phase current value. He checked the motor specifications and confirmed that phase current exceeded the motor's FLA (Full Load Amperage) rating. The consultant traced the voltage unbalance to a set of equipment installed three years ago. It turned out that all of the internal single-phase loads were connected to the same phase.



شکل (۴) – کاهش بازده موتور بر اثر نامتعادلی ولتاژ



شکل (۷) – اثر نامتعادلی ولتاژ بر افزایش درجه حرارت موتور

جدول (۱) – بازده موتور نمونه در شرایط ولتاژ نامتعادل

بار موتور (٪)	بازده موتور بر حسب ٪ در صد نامتعادلی ولتاژ		
	Un	٪۱	٪۲/۵
۱۰۰	۹۴/۴	۹۴/۴	۹۳/۰
۷۵	۹۵/۲	۹۵/۱	۹۳/۹
۵۰	۹۶/۱	۹۵/۵	۹۴/۱

Effects of Harmonic Sequences

Sequence	Rotation	Effects (from skin effect, eddy currents, etc.)
Positive	Forward	Heating of conductors, circuit breakers, etc.
Negative	Reverse	Heating as above + motor problems
Zero	None	Heating, + add in neutral of 3-phase, 4-wire system

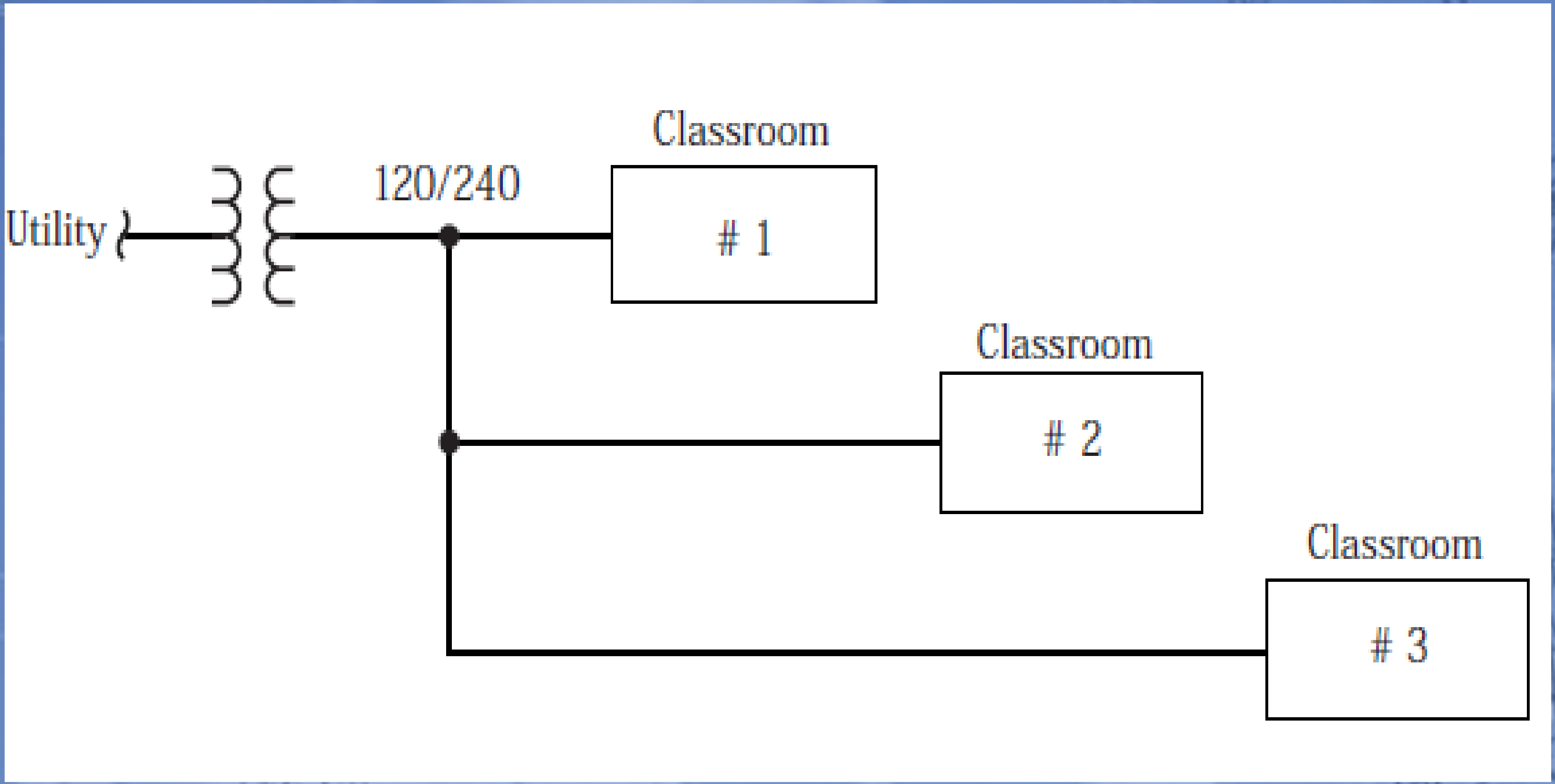
Overhead Problem @ Classrooms

Half wave rectifier

Problem description

This case history involves an electrician who works for a large suburban school district. One winter morning, the electrician received a call from a local school. The caller said a transformer supplying power to three portable classrooms as making a “chattering” noise, as if something were loose inside (Fig. 1).Load measurements showed the transformer was heavily loaded, but not overloaded. The loads included lights, electric heat, and a few computers. Most of the load was electric heat, due to cold winter weather.

The electrician had arrived near lunchtime and the school had a staggered lunch schedule, two of the classrooms were unoccupied. In third classroom the teacher was making a presentation with overhead slides. The electrician returned to the transformer to examine the current waveforms. As he was making measurements, the chattering noise suddenly stopped. The electrician rushed back to the occupied classroom and asked the teacher, “What did you just now turn off?” The teacher pointed to two overhead projectors, which were plugged into the same receptacle.



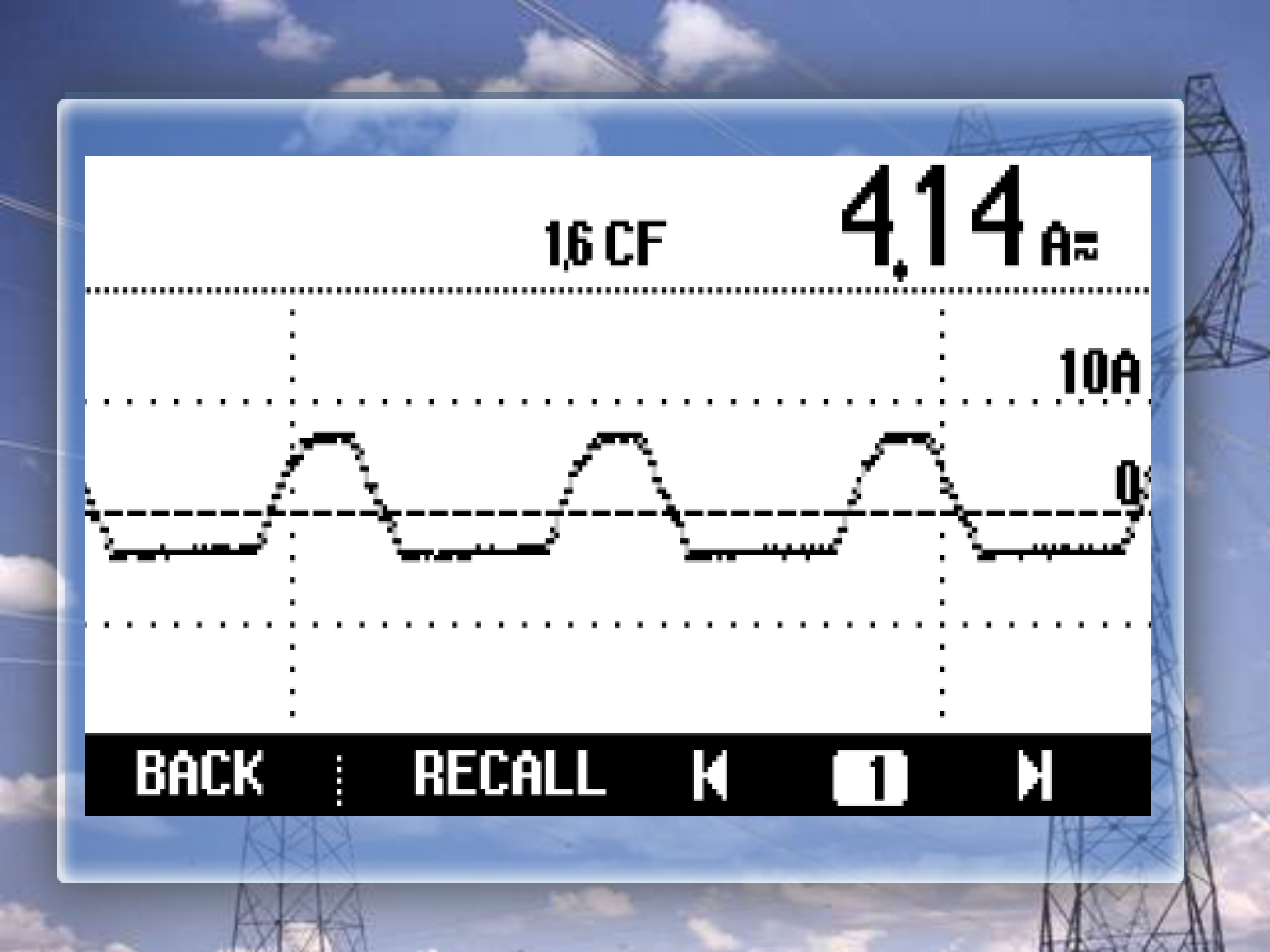
Utility
120/240
Classroom
1
Classroom
2
Classroom
3

Measurements and Analysis

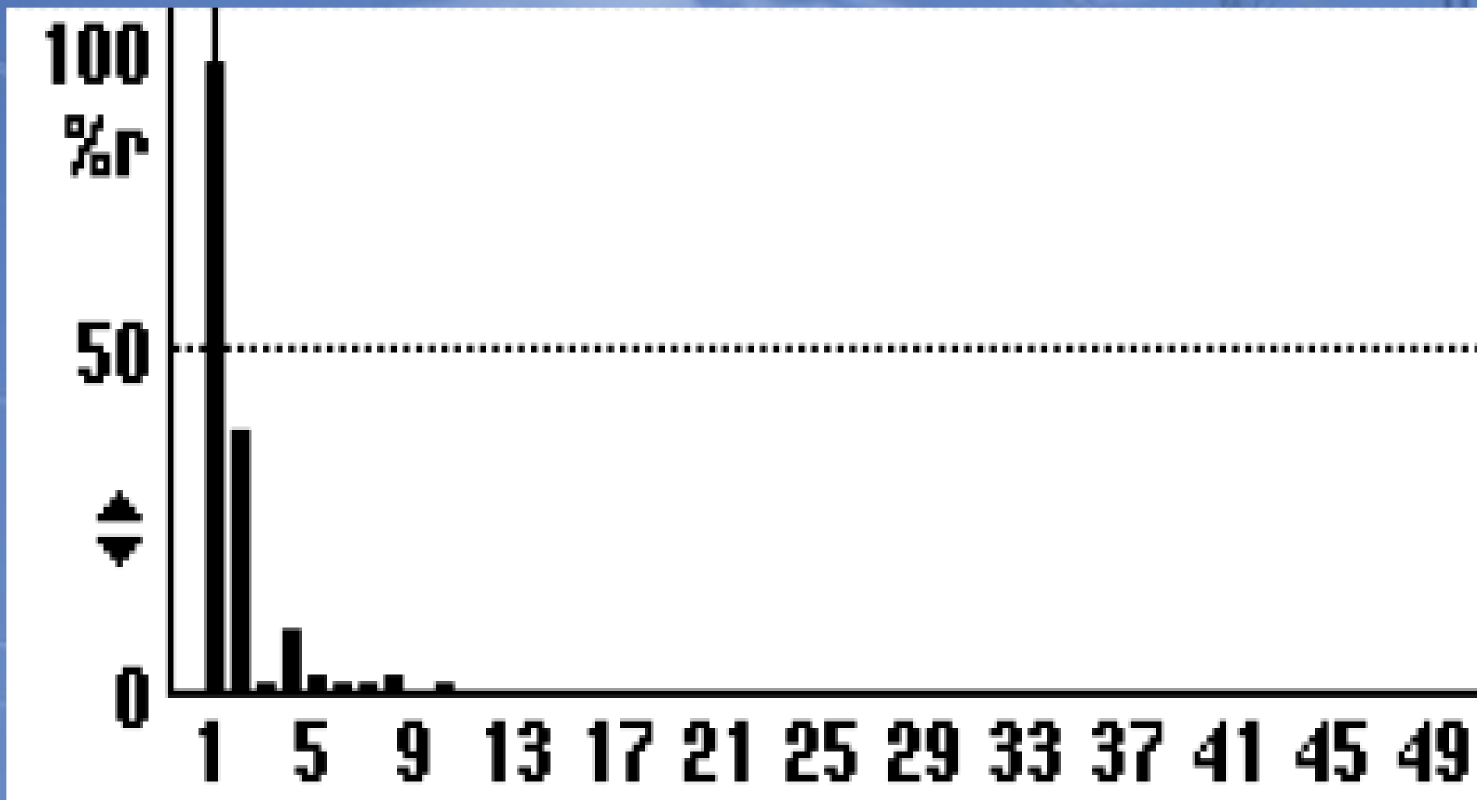
Measuring tools: Fluke 43B Power Quality Analyzer

Measurements

The electrician displayed the waveform of current drawn by one of the overhead projectors. The waveform showed half-wave rectification by the projector (Fig. 2). Testing of other overhead projectors used at the school showed that all of the older units produced the same effect, but the newer units did not.



1,6 CF
4,14 A≂
10A
BACK
RECALL
1


100
%r
50
0
1 5 9 13 17 21 25 29 33 37 41 45 49

Theory and analysis

Some older electrical devices use half wave rectifiers to reduce power consumption, e.g. a hair dryer with a “high/low” switch. These devices generate dc current which will unbalance the magnetic flux The process of going in and out of saturation will produce strange noises from the transformer core. The school’s transformer was heavily loaded, which reduced its tolerance for dc current. Compounding the problem, two projectors were connected to the same branch circuit — thereby doubling the amount of dc current.

هارمونیکها و عدم تعادل!

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Symmetrical components	Positive sequence	Negative sequence	Zero sequence[2]
	1	2	3
	4	5	6
Harmonic order	7	8	9
	10	11	12
	...	...	...
	$3k+1$	$3k+2$	$3k+3$ for $k=0,1,2,3,\ldots$

هارمونیکهای مضرب ۳ و تلفات سیم نول

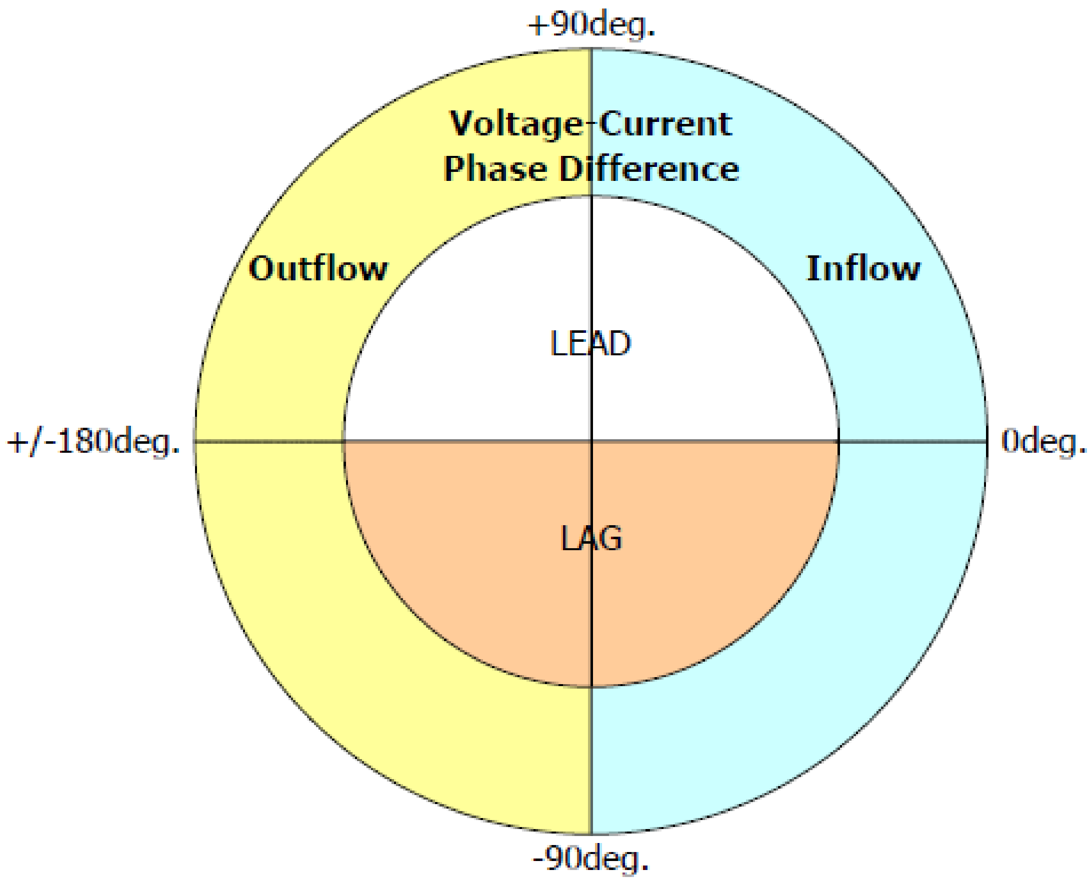
یک روش ساده برای جهت یابی هارمونیکها

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.

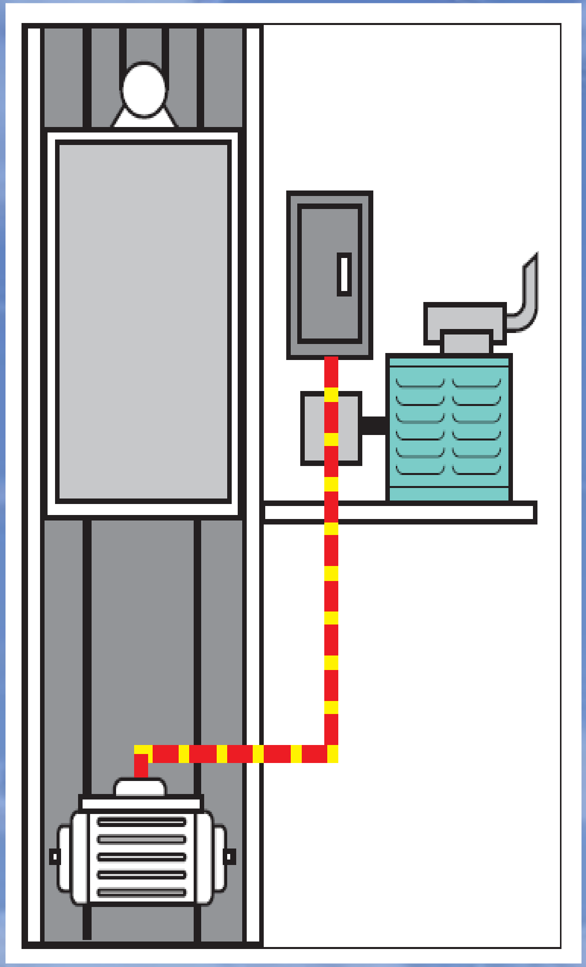


	Harmonic voltage-current phase angle difference
Inflow	+90° to 0° to +90°
Outflow	-180° to -90° or +90° to +180°

Elevator trips emergency generator breaker

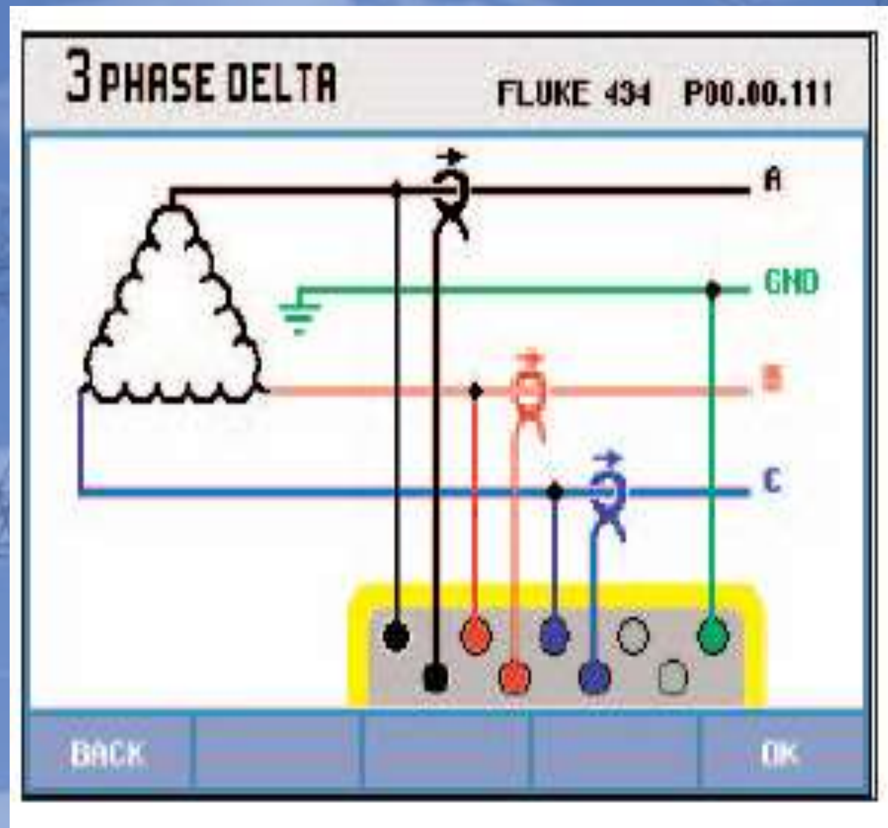
Problem Description :

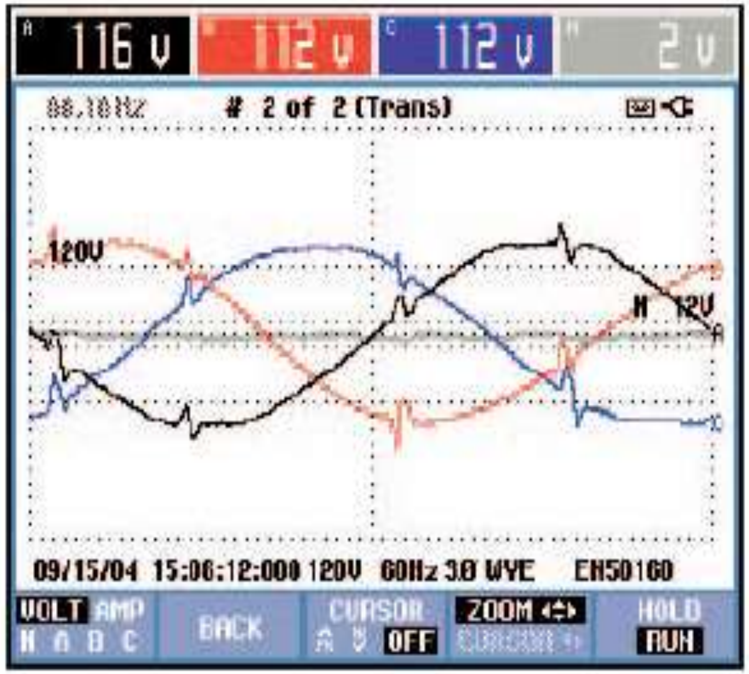
A large commercial building had just finished an elevator equipment upgrade — but they hadn’t been able to bring the elevator back into normal operation. For some reason, whenever the emergency power generator was called on to supply energy, its protection circuit breaker would trip. The upgrade was intended to bring the original DC elevator up to a state-of-the-art system, with better elevator control, operation, energy efficiency, reduced maintenance costs, and tenant satisfaction. Despite all the efforts some problems were still unresolved.



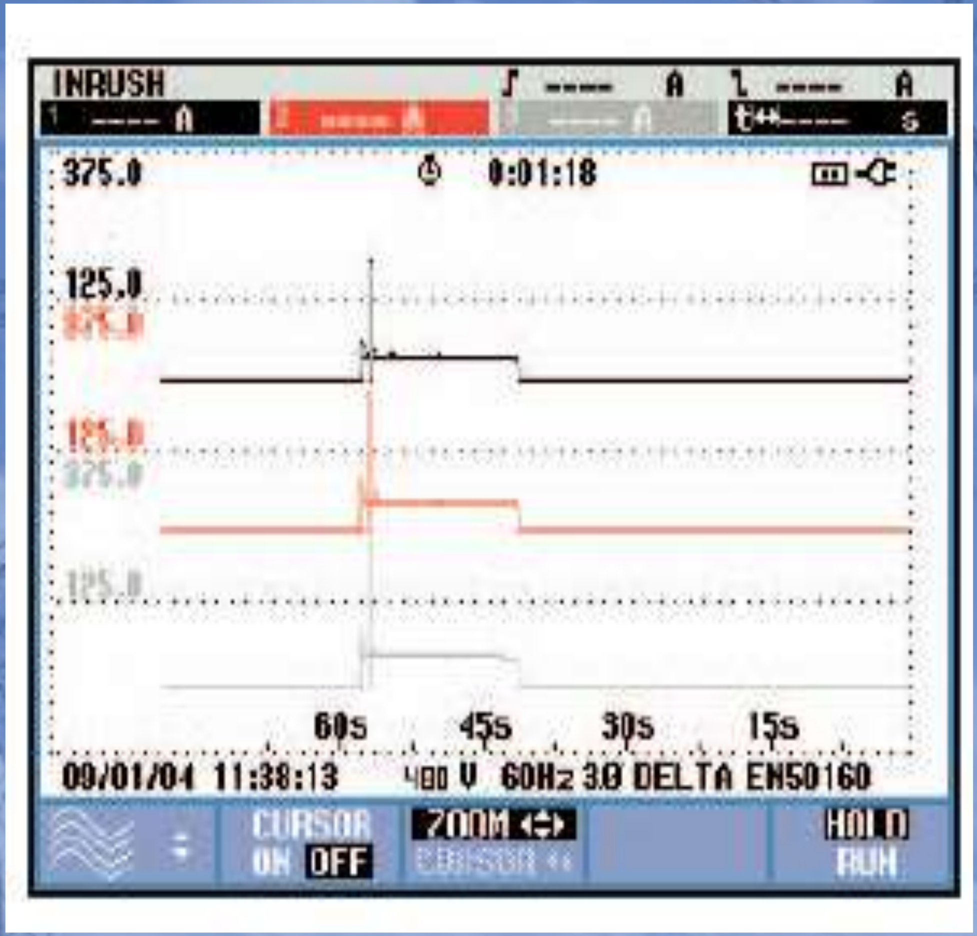
Measurements and Analysis

Measuring tools: Fluke 434 Power Quality Analyzer


3 PHASE DELTA
FLUKE 434 P00.00.111
A
GND
B
C
BACK
OK



Sample screen.



INRUSH
375.0
0:01:18
125.0
125.0
60s
45s
30s
15s
09/01/04 11:38:13
400 V 60Hz 3.0 DELTA EN50160
CURSOR
ON OFF
ZOOM
HOLD
RUN

For some reason, the elevator system wasn't sensing the power fault condition. So, every time emergency power was reapplied, the elevator system started to perform a normal start-up — and that much inrush and start-up current on top of normal operations exceeded the rating of the power emergency protection circuit breaker

Solution:

A simple adjustment to the elevator power fault sensing circuit allowed the new system to properly perform the individual elevator car power failure procedure. In the process, facilities verified the protection circuit breaker settings and adjusted them back to the proper set points.

The malfunctioning medical machine

Problem description:

This case history is a classic example of the importance of a systematic approach to solving a problem. It involves a contractor who works with several high-technology manufacturing plants. The case began with an on-site visit to a building manager who was frustrated with his electrical system. According to the manager, nothing electrical in his building seemed to work properly and no one had been able to determine why or offer a solution. The manager went on to say that three of his electricians had quit and that he was now in real trouble.

The contractor asked many questions — trying to get a more detailed picture of the problem. This effort proved fruitless, so the contractor asked to be taken to that part of the building where the problems were the worst. He was following the axiom, “When in doubt, start at the victim load.” In a far corner, a large medical machine was going through a critical test procedure. The machine was equipped with a large display screen, a keyboard and a control panel with several cables and hoses leading to other pieces of equipment.

The operator display screen showed the test procedure was in progress. Next to the machine was a workbench set up for circuit board repair. The workbench had a soldering iron, a lighted magnifying lens and a fan. The workbench power strip plugged into the same receptacle as the large medical machine. As the contractor watched, the person at the workbench reached over and turned on the fan. At that moment, the operator display screen momentarily went blank and then came back on with the words “Program Reset” displayed in large letters.

Measurements and Analysis

Measuring tools: Fluke 43B Power Quality Analyzer

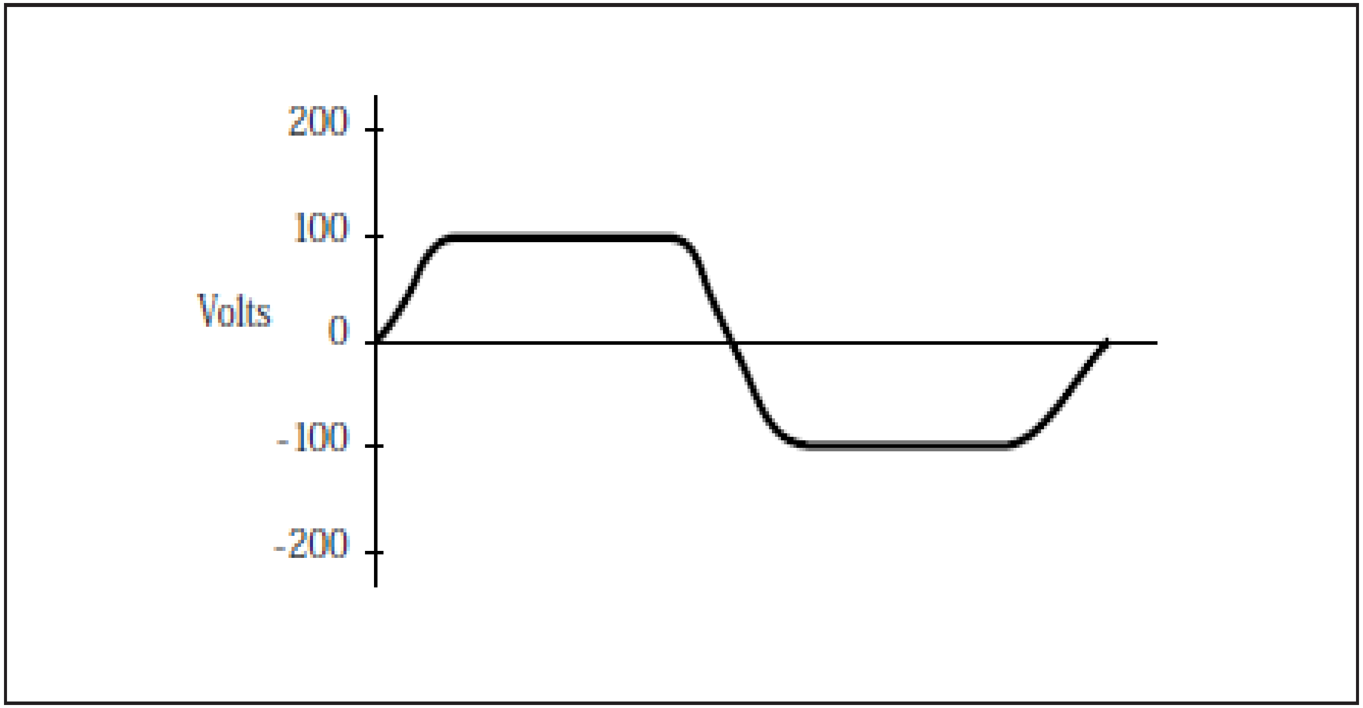


Fig. 1 Waveform of voltage supplying the medical machine (simulated)

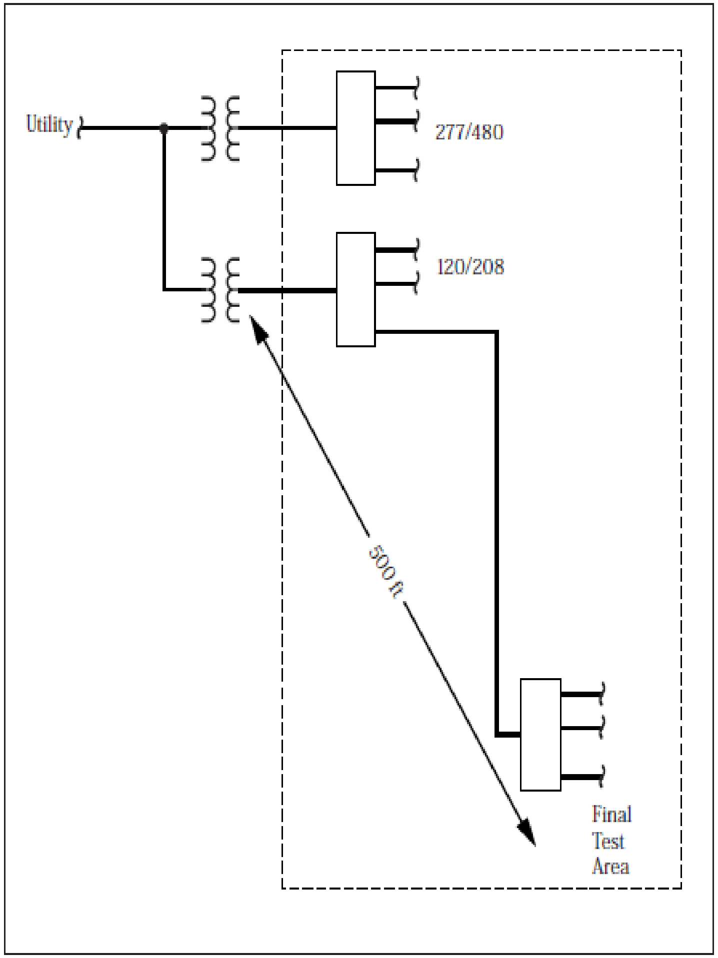


Fig. 2 Partial one-line diagram of the high-tech manufacturing plant

Theory and analysis :

Since the medical machine’s internal circuits operated on low voltage dc, the internal power supply would have a diode/capacitor input circuit that required a certain minimum peak voltage for proper operation. The nameplate on the medical machine showed the machine needed a supply voltage between 100 and 135 V rms ac. The engineers who designed the machine and specified the nameplate assumed the supply voltage would be a sine wave, so the minimum peak would be 141 V peak (100 x 1.41).

Since the measured value of the peak input voltage was only 135 V, the machine was running on a peak voltage that was already 6 V below the absolute minimum required. When the fan was turned on, the surge current drawn by the fan motor further reduced the voltage to a point where the power supply of the machine went out of regulation. This is what caused the machine to reset.

Solution :

The problem of voltage peak clipping (flat-topping) is common in high-tech buildings. Many of the buildings now in use were not designed to handle the vast array of computers and non-linear loads so typical today. In this case, extensive rewiring would be necessary to reduce the voltage drop between the transformer and the load. An alternative would be to move the most sensitive loads closer to the transformer.

نویز و زمین

– نویز سیگنال الکتریکی تصادفی است که از کوپلاژ مدارات مختلف با مدار مورد نظر حاصل می شود.

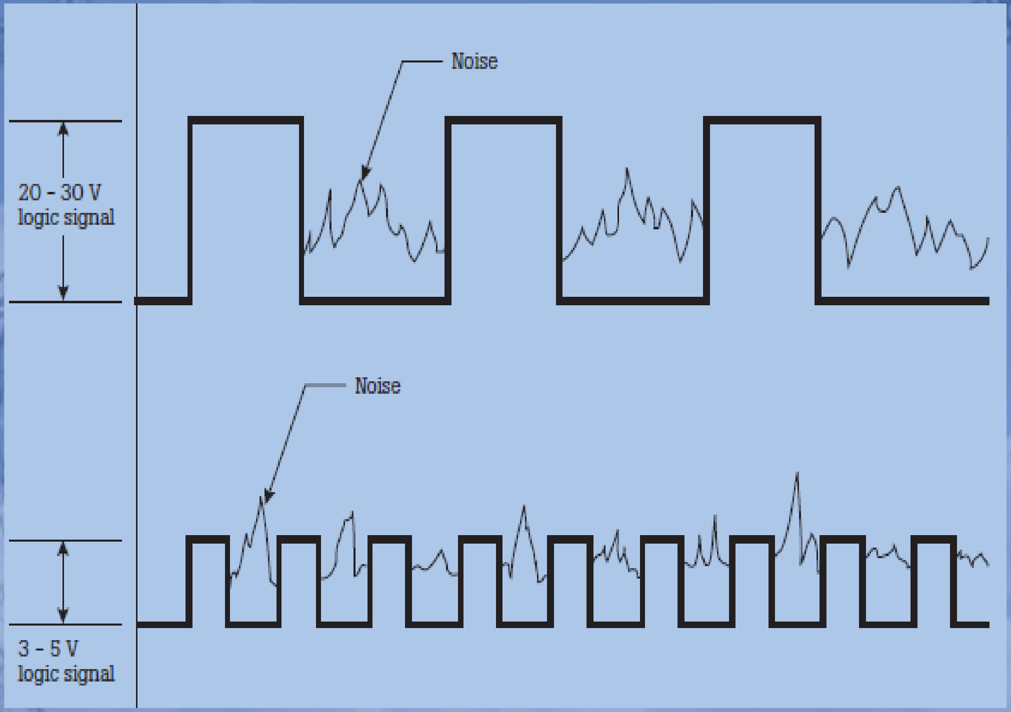
– سیگنال نویز باعث تخریب سیگنالهای حامل اطلاعات می شود.

– هر چند نویز هم در مدارات قدرت و هم در مدارات سیگنال ظاهر می شود، اما در مدارات سیگنال اهمیت بیشتری دارد.

– هر چه دامنه ولتاژ یک مدار سیگنال پایینتر باشد، در مقابل نویز آسیب پذیر تر خواهد بود.

نسبت سیگنال به نویز مشخص می کند که وضعیت انتقال صحیح سیگنالهای داده تا چه حد پتانسیل موفقیت دارد.

نسبت سیگنال به نویز (S/N)



از دیگر ویژگیهای نویز طیف گسترده فرکانسی و فرکانسهای بالای سیگنال نویز است که نیازمند تحلیلهای حوزه فرکانس و لحاظ نمودن امپدانس موجی و معادلات موج سیار در محاسبات است.

انواع کوپلاژ :

۱– خازنی

۲– سلفی

۳– هدایتی (Conductive)

۴–تداخلات فرکانس رادیویی

کوپلاژهای هدایتی از مهمترین منابع نویز هستند. ایجاد لوپهای زمین به علت پتانسیلهای مختلف الکترود زمین، القای ولتاژ در اسکرین کابلهای کنترلی و مخابراتی و نشتی جریانبین فاز نول نویز تولید می کنند.

Common mode-noise voltage

بین هادیهای حامل جریان و سیم زمین (دارای دامنه و فاز یکسان در تمامی ولتاژهای فاز به زمین است). به عبارت دیگر از هادیهای فاز عبور نمی کند بلکه از نول یا زمین عبور می کند. این همان مولفه صفر است.

Normal mode-noise voltage

بین هادیهای حامل جریان حرکت می کند. پس در یک فاز مشخص قابل اندازه گیری است.

برای کاهش اثرات تداخلات فرکانس رادیویی که در آن مدار قربانی مثل آنتن گیرنده عمل می کند راهکارهای زیر وجود دارد :

استقاده از چوکها

استفاده از فیبرهای مخابراتی و زوجهای به هم تابیده در سیستمهای مخابراتی

استفاده از شیلد در سیستمهای کنترلی

استفاده از فیلترهای شانت

کوپلاژهای هدایتی و تداخل رادیویی
کوپلاژهای فاصله دور نامیده می شوند

Conducted Noise

مقاومت

RFI (10 KHZ to 10 MHZ)

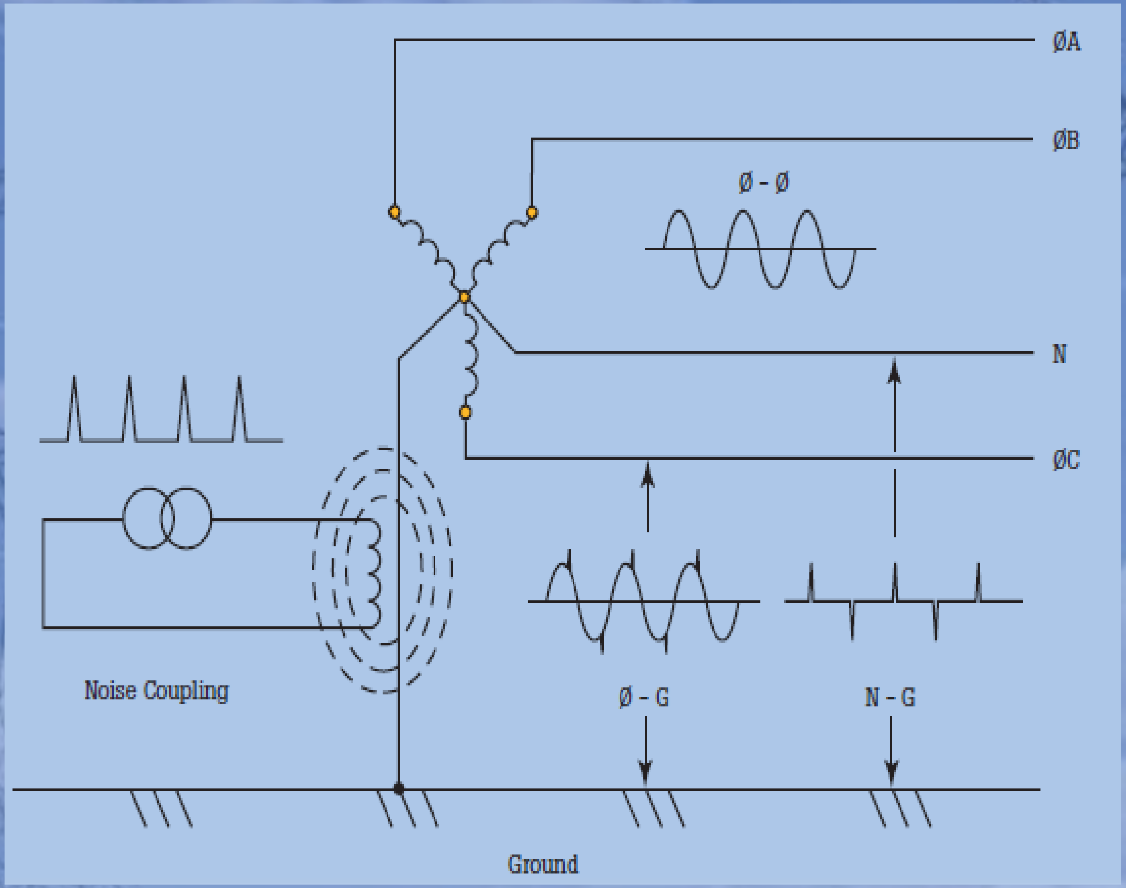
سطح تحت تشعشع

Capacitive Coupling
فرکانس و ولتاژ

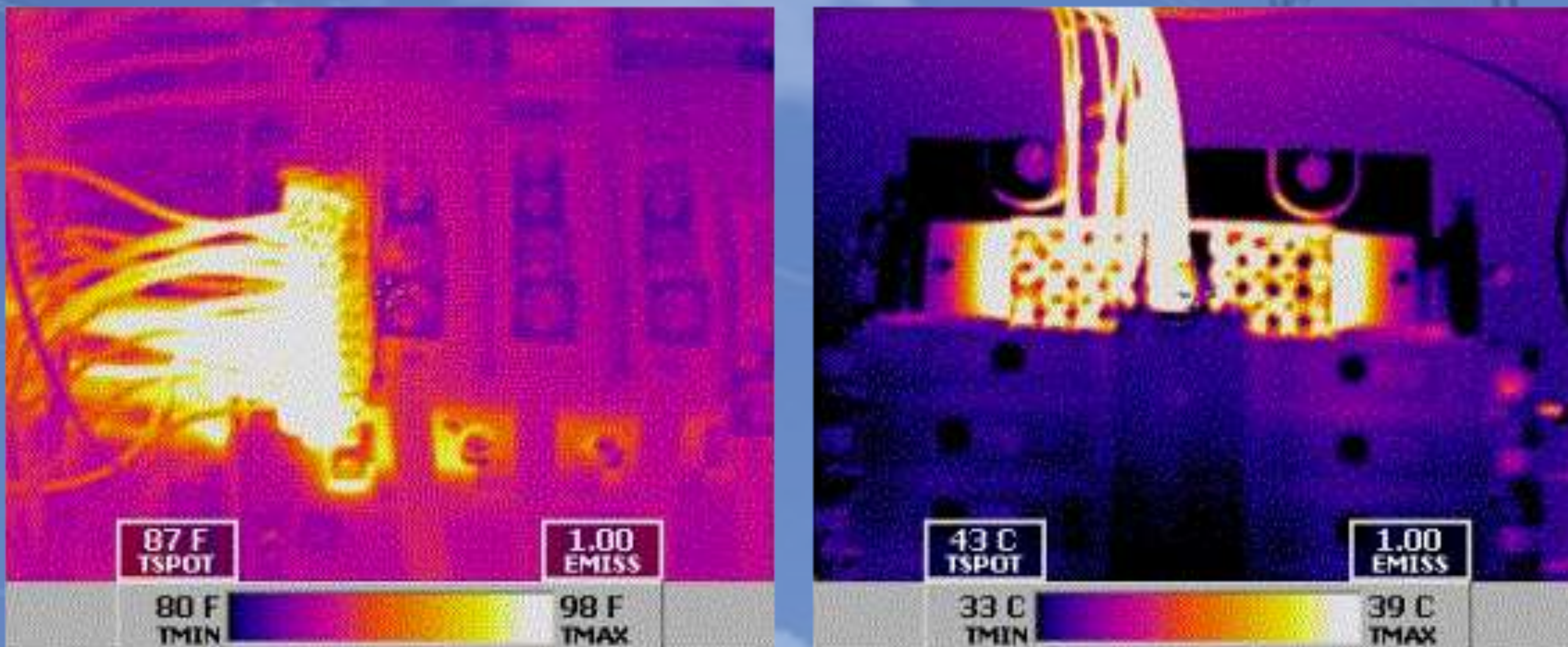
Inductive Coupling
جریان، نرخ تغییر جریان، نزدیکی دو مدار،
تعداد حلقه ها

در انتقال ترانزینتها نقش مهمی دارند
و کوپلینگهای اثر نزدیک نامیده می شوند

Differential Mode, Common Mode



داغ شدن نوترال



Above thermal images show an overheated neutral bus bar caused by third order, zero sequence harmonic currents.

اشتباه در تشخیص به دلیل خطای دستگاه اندازه گیری

Multimeter performance comparison average responding vs. true-rms

Meter Type	Measuring Circuit	Sine Wave Response*	Square Wave Response*	Distorted Wave Response*
Average Responding	Rectified Average x 1.1	Correct	10 % high	Up to 50 % low
True-rms	RMS Calculating converter. Cal-culates heating value.	Correct	Correct	Correct

*Within multimeter's bandwidth and crest factor specifications.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