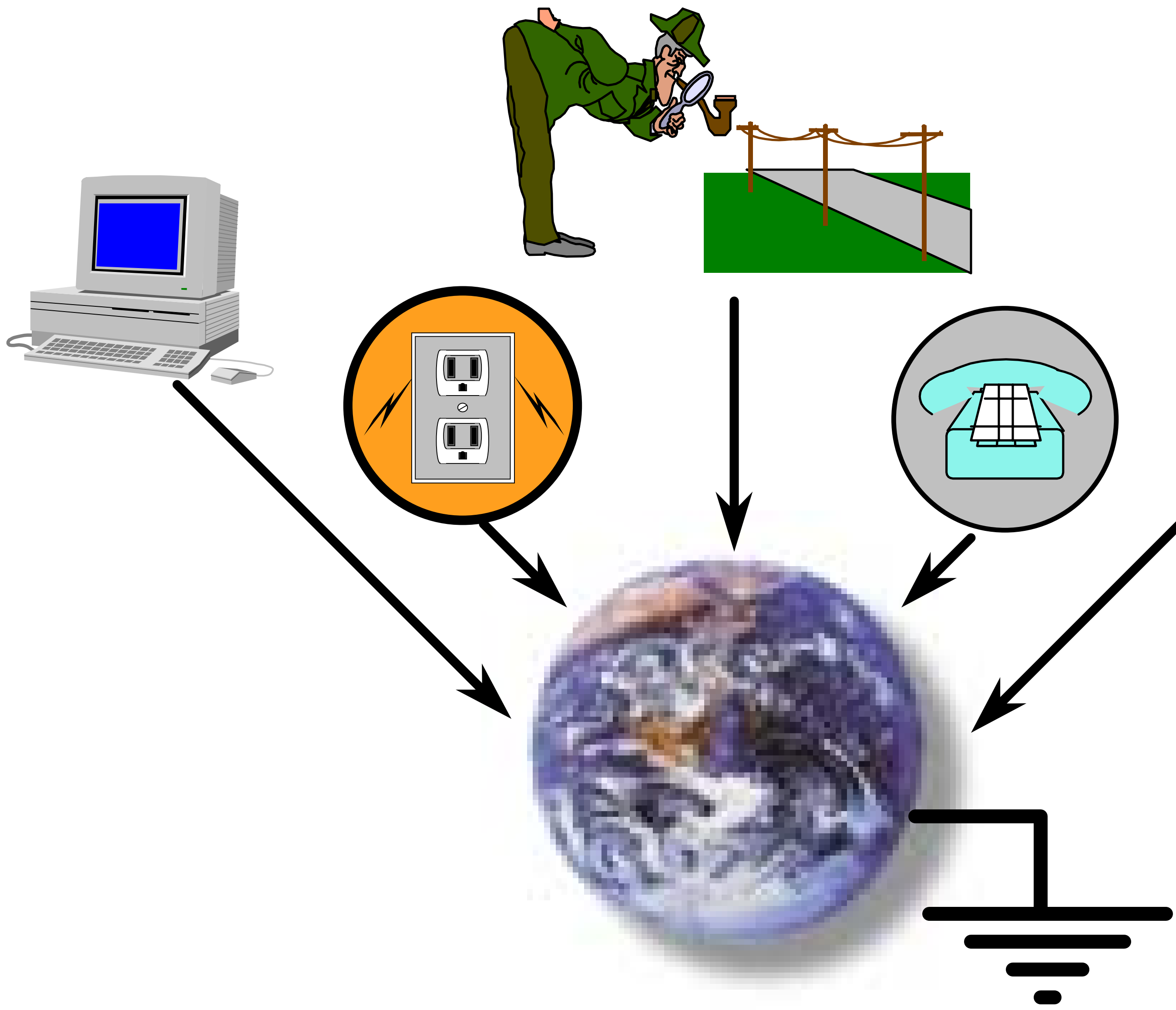
Section 8: Power Quality Audits

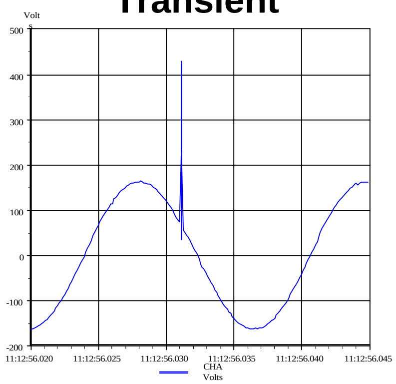


NORTHERN TECHNOLOGIES, INC.

The “Usual Suspects”

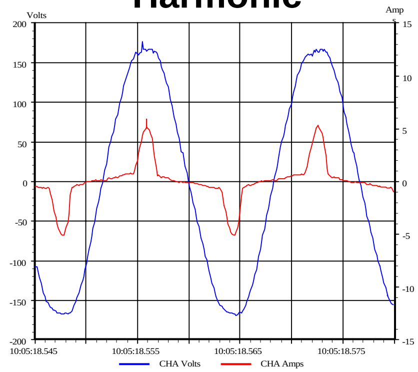
Typical Power Anomalies Illustrated

Transient



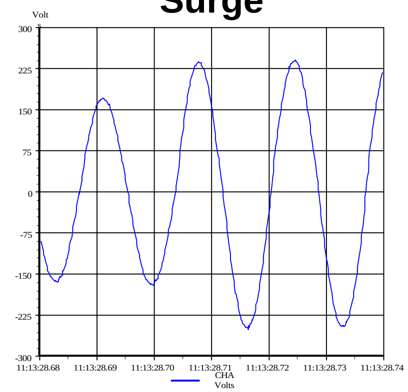
Typical Causes
- Lightning
- SCR-Controlled Loads
- Variable Speed Drives
- Contact & Relay Closure
- Load Startup or Disconnect
- Power Factor Correction
- Photocopiers/laser Printers

Harmonic



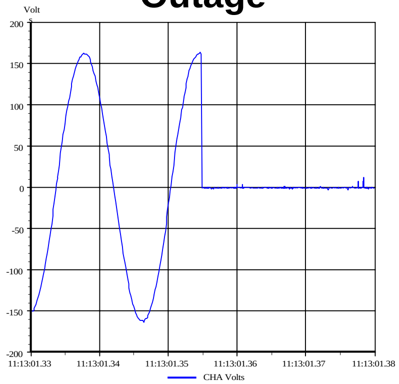
Typical Causes
- Switchmode Power Supplies
- Computers
- Electronic Ballast
- Electronic Phone Systems

Surge



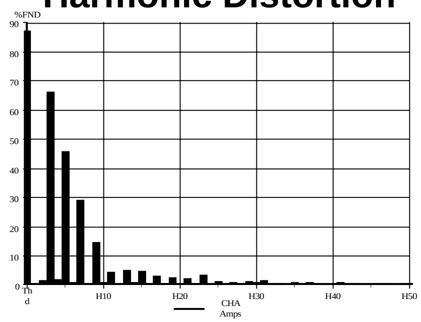
Typical Causes
- Removal of Large Loads
- Lightly Loaded Distribution System
- Utility Power Fault
- UPS/Motor Generator Instability

Outage



Typical Causes
- Faulty Wiring or Circuit Breakers
- Utility Power Fault
- Alternative Power Source Failure
- Local Circuit Breaker Failure

Harmonic Distortion

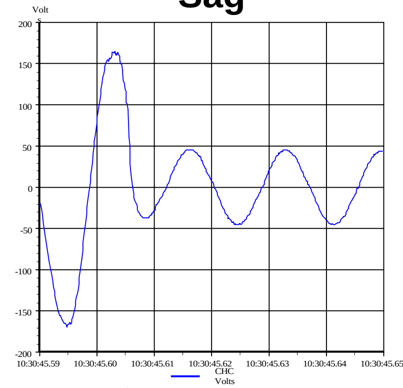


Total RMS: 1.97 Amps

Total harmonic distortion:	**87.00 %FND**
Even contribution (H02-H50):	**2.64 %FND**
Odd contribution (H03-H49):	**87.03 %FND**

Harmonic Distortion: Distortion caused by frequency components that are integer multiples of the fundamental frequency.

Sag



Typical Causes
- Faulty Wiring or Circuit Breakers
- Load Startup or Disconnect
- Utility Power Fault
- Faults and Shorts
- UPS/Motor Generator Instability

Performing a Power Quality Audit

1. **Investigate the Power Quality Problem**
   - **What is being damaged and how?**

2. **Perform Site Analysis Identifying Possible Causes.**
   - **External (Lightning/Utility Anomalies.)**
   - **Internal (Other Equipment/Grounding.)**

3. **Evaluate Results and Provide Solutions**

Performing a Power Quality Audit

1. Investigate the Power Quality Problem

- When did the problem start?
- What type of equipment is experiencing problems?
- What is its sensitivity of the equipment?
- What type of malfunctions are occurring?
- When do the problems occur?
- Are the problems constant, periodic, or sporadic?
- Are there any recent changes at this facility?
- What other equipment is at this facility?

Performing a Power Quality Audit

2. Performing Site Analysis

A Visual Inspection

- Grounding & Bonding, service entrances (AC, Telco), & TVSS Installation.

Power Monitoring

- Monitoring of Lines Feeding Effected Equipment (AC, Communication Lines, Telco Lines, etc.)

Environmental Monitoring

- Monitoring of Environmental Conditions May be Required!

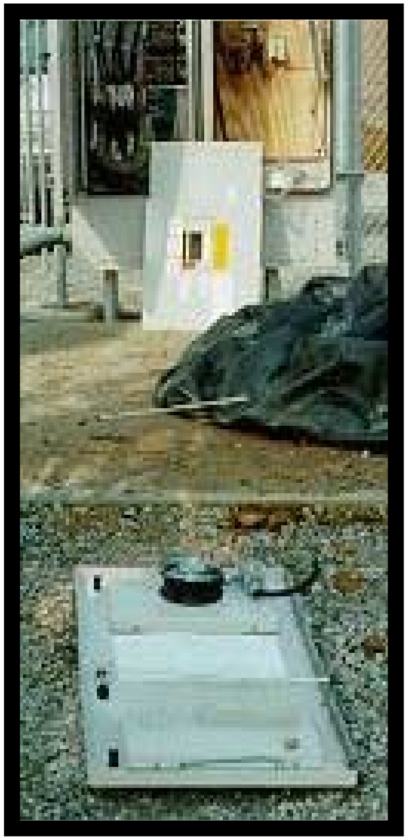
Visual Inspection Audit Results

- **90% of Trouble Sites Have at Least One of These:**
  - **Lacking or Poor AC Service Neutral-to-Ground Bond:**
    - **This violates NEC and is a Safety Hazard!**
  - **Improper RF or Tower Grounding:**
    - **Tower legs and coax shields must be bonded to the buried ground system!**
  - **Poor, if any, Telco Service Entrance Grounding/Bonding:**
    - **All telco-related equipment must be bonded to ground.**
  - **Lacking, Inappropriate, or Improper TVSS Installation:**
    - **AC, Telco, and RF TVSS Installation is Critical.**
  - **Poor Soil, Electrode Interface with Soil, or Ground Loops**

Visual Inspection Results

How Do We Identify The Cause?

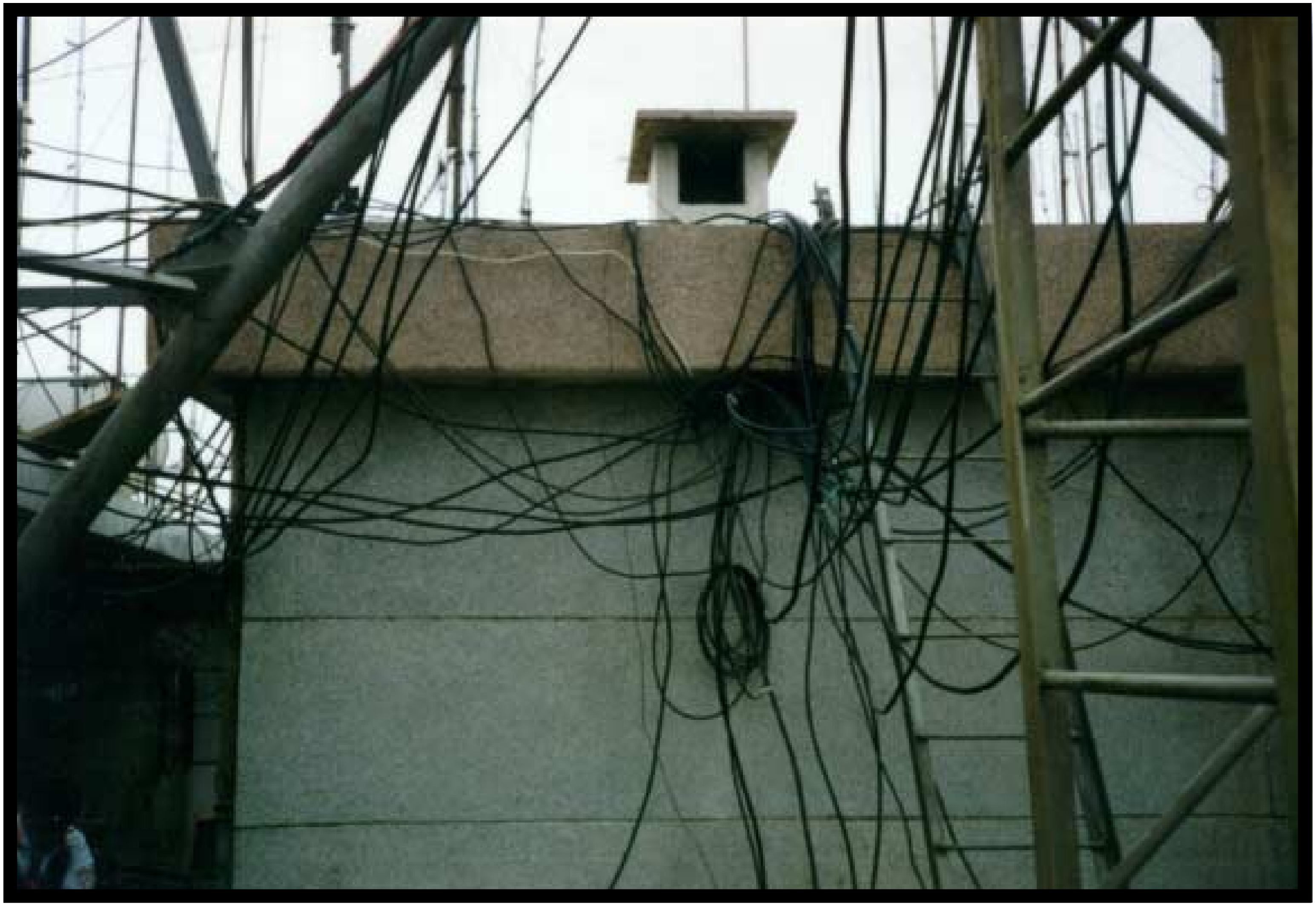
- **Some are relatively simple to identify:**



- **Others require more in-depth investigation**

Visual Inspection Cont.

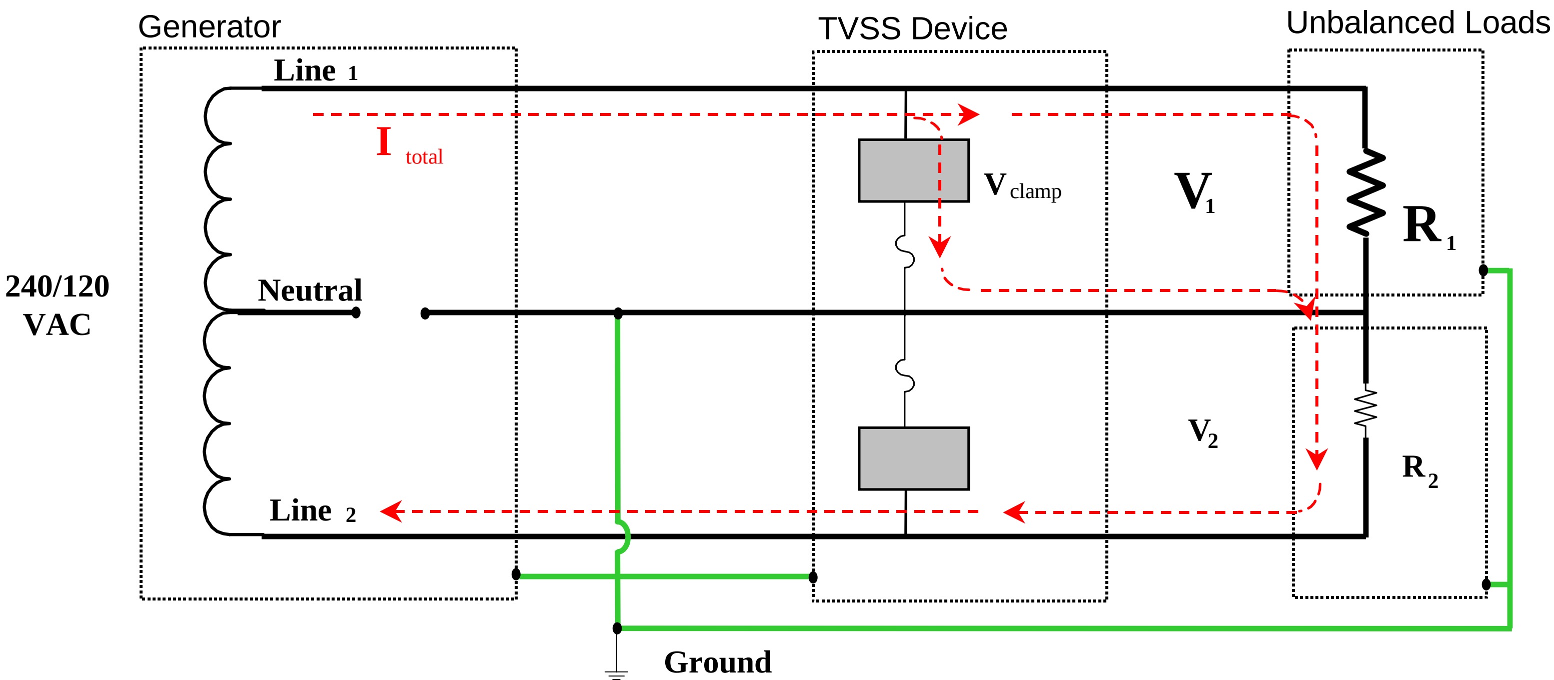
- **It always helps to have an organized facility to audit!**



Visual Inspection Cont.

- **Line-to-Neutral, Long-Term Overvoltage Condition**

Overvoltage from Floating Neutral

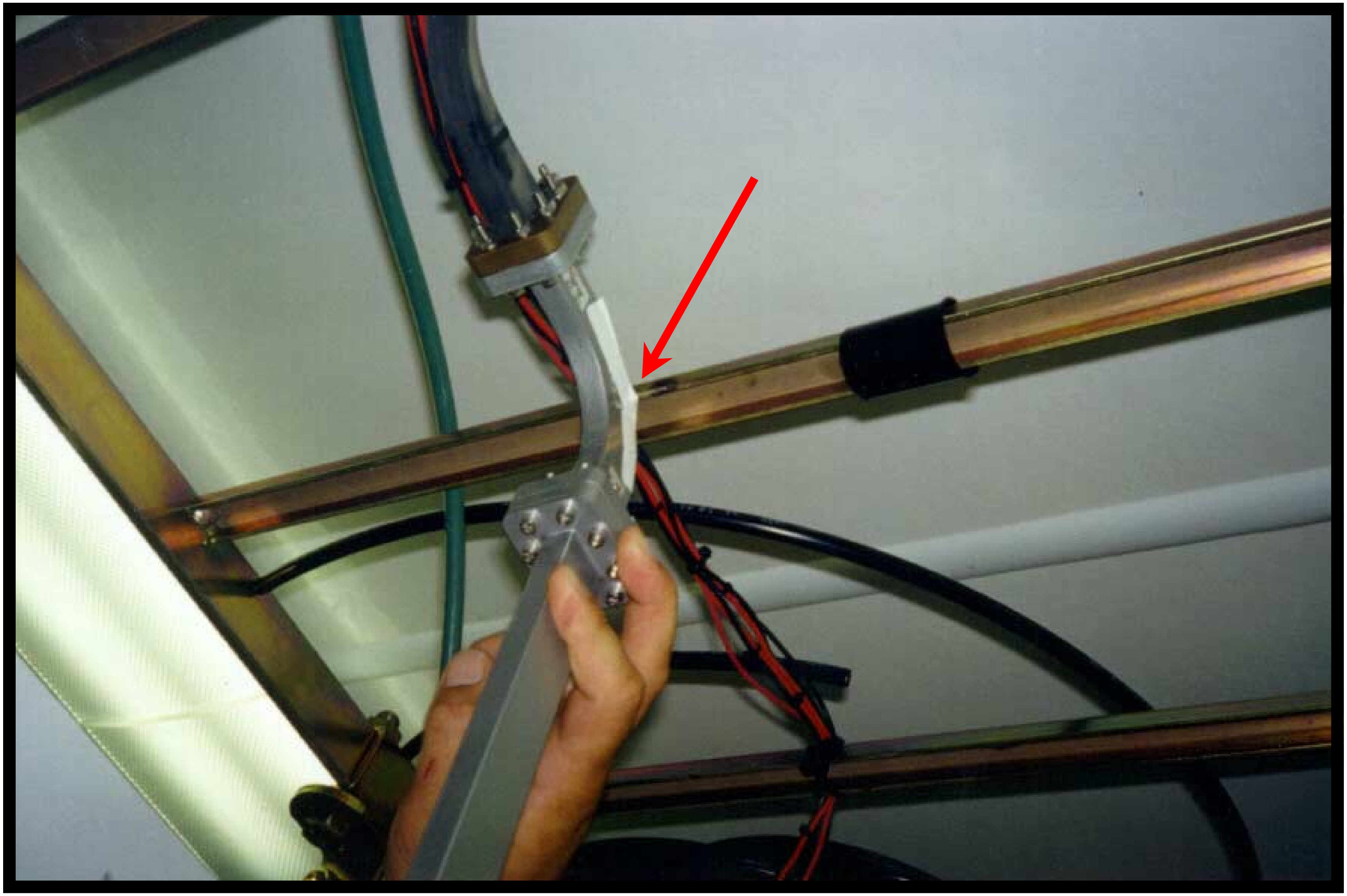


- **With balanced loads, $V_1 = V_2$ and floating neutral is not apparent.**
- **With unbalanced loads, $I_{total} = 240 / (R_1 + R_2)$ and initially $V_1 = I_{total} * R_1$.**
  - **If $V_1 > V_{clamp}$ the TVSS device will clamp, dividing the current I_{total}.**
  - **Current through the TVSS may not clear the TVSS fuse.**
  - **The TVSS may operate continually, generating heat until it opens internally.**

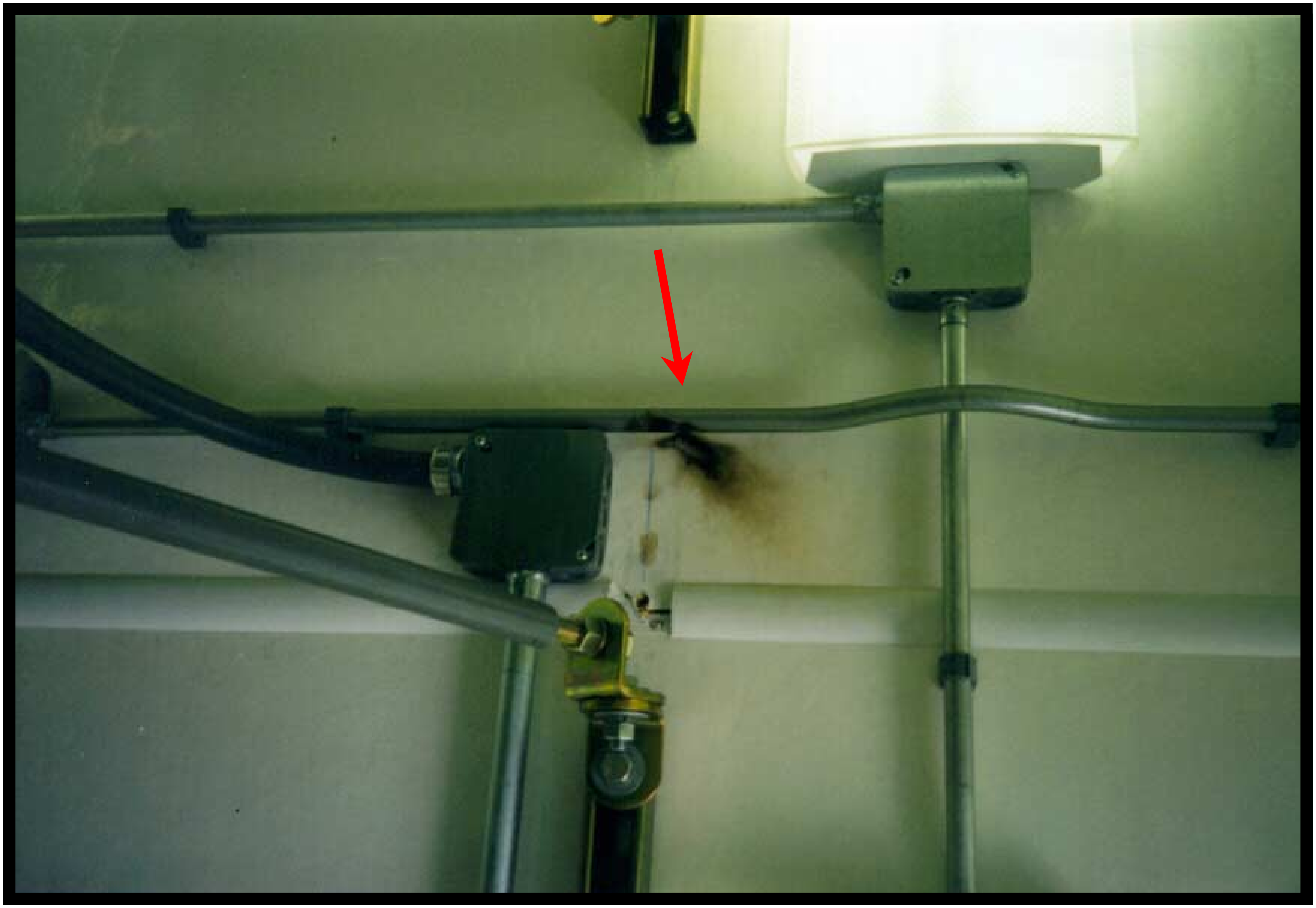
Visual Inspection Cont.

- **Neutral-to-Ground, Long-Term Overvoltage Condition**

Visual Inspection Cont.



Visual Inspection Cont.

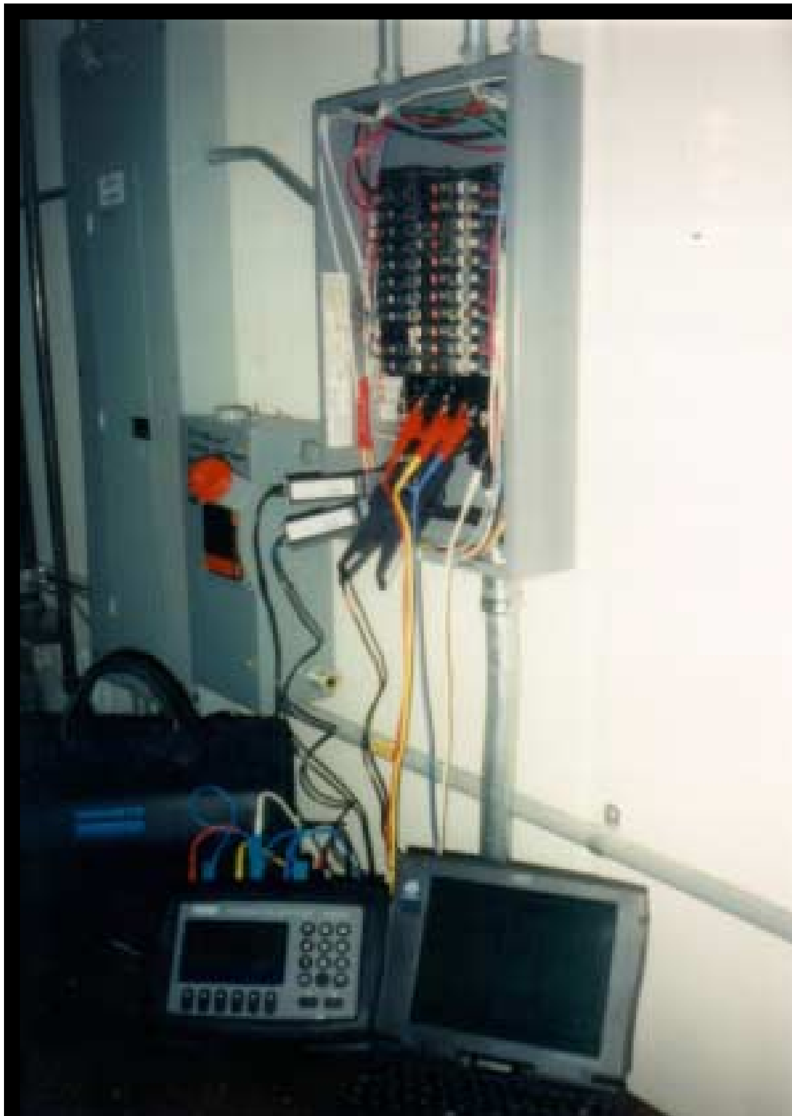


Power Monitors: Features

- **Easily Configured Voltage / Current Probes**
  - Easy to handle and manipulate
  - Triggering / Display parameters easy to configure and display
- **Capabilities of Graphical Display**
  - Zooming / Panning / Displaying multiple channels
- **Modular Interface**
  - Paper printouts
  - Download information to data files
  - Interface to computer
- **Flexible Measurement Modes**
  - Frequency Domain (THD, Harmonic Content)
  - Temperature / Humidity / etc.

Power Monitoring Cont.

- **Tools of the trade**



Power Monitoring Cont.

- **Tools of the trade**

Completing The Analysis

3. Evaluate Results and Provide Solutions

- **Indicate potential safety hazards immediately!**
- **Weigh the gathered data and possible solutions with equipment needs and tolerances.**
- **Compile data into useful information and simulations for easy analysis.**
- **If possible, provide more than one solution so the client can analyze potential investments.**

Industry Standards (Reference Awareness)

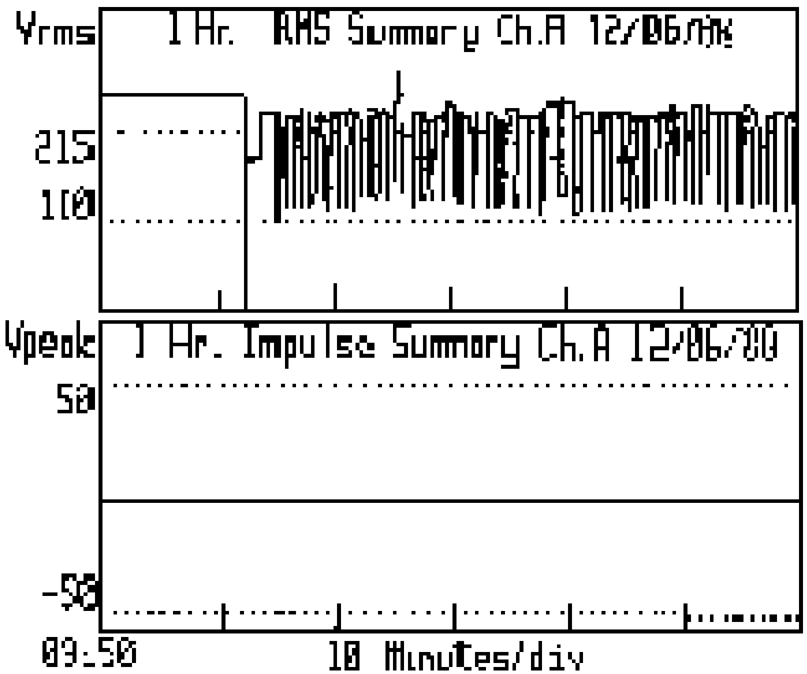
- **National Electrical Code (NEC)**
  - **Basic information for safe wiring & configuration**
- **IEEE Emerald Book - Std 1100-1992**
  - **Recommended Practice for Powering and Grounding Sensitive Electronic Equipment**
- **IEEE Orange Book - Std 446-1980**
  - **Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications**
- **IEEE Buff Book - Std 242-1986**
  - **Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems**

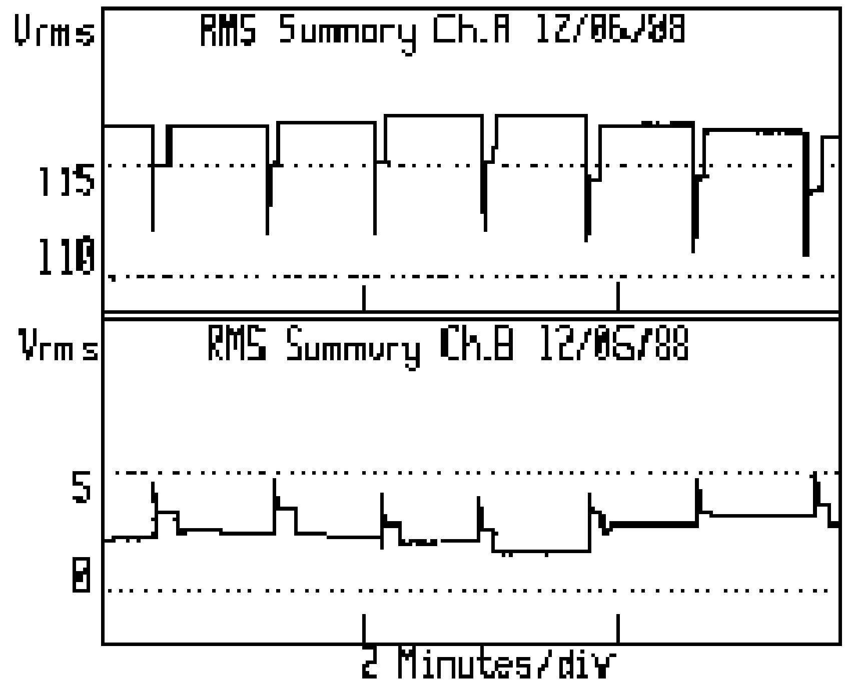
Case Studies

Case Study: RMS Sags

Symptoms: Intermittant failures of computer system in engineering laboratory.

Problem: Repetitive sags in the RMS voltage, beginning just after 10 a.m. When the scope resolution was increased, the regular nature of the sags was seen.

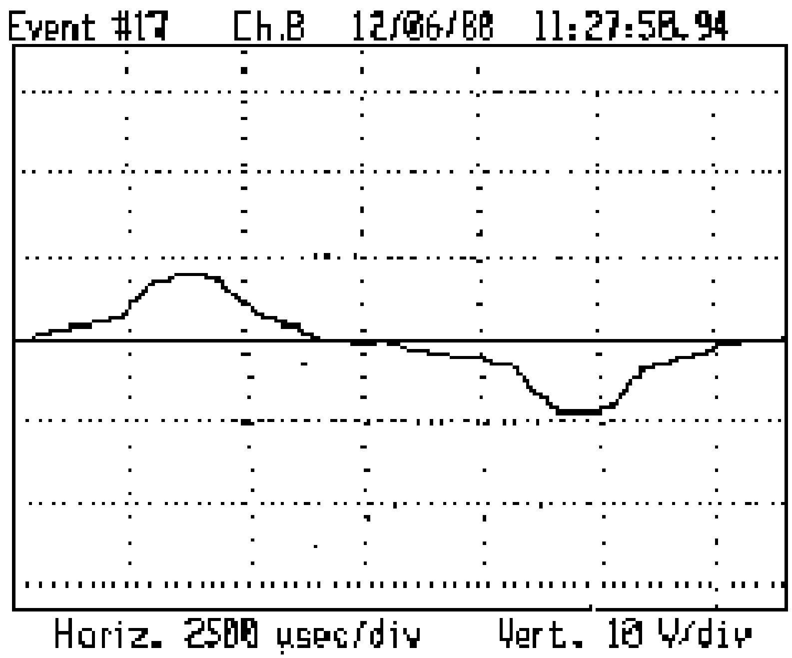




Case Study: RMS Sags

Solution: The uniform repetition of the events indicated automatic switching of another load on the line. Judging by the the N-G waveform shown, it was a linear one.

The discovered load, a laser printer, was moved to another branch circuit to solve the problem. The fusing heater in the printer switched on regularly, drawing high current. This caused the sags, and the resulting computer errors.



Case Study: Impulses from Utility

Location: Medical Clinic with sensitive CT Scan systems.
Voltage was 480 Delta input fed through 480 - 208Y/120 V transformer.

Symptoms: CT Scan systems were experiencing repeated computer lockups and component failures.

Measurements: Data was taken at the service entrance of the building (Figure 1) and at the output of the isolation transformer (Figure 2).

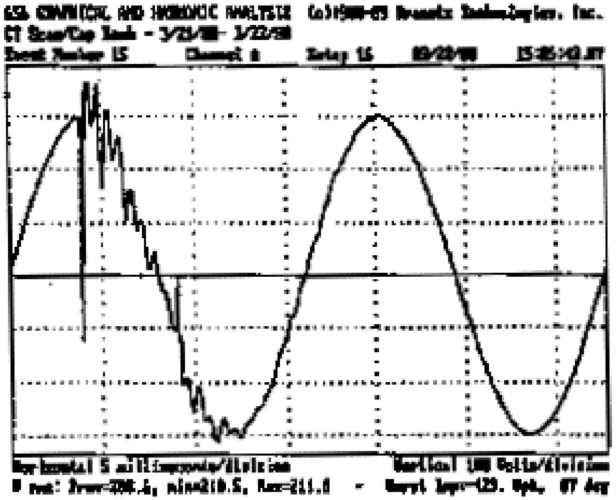


Figure1: Power Factor Capacitor Bank Switching
Measured at the Service Entrance

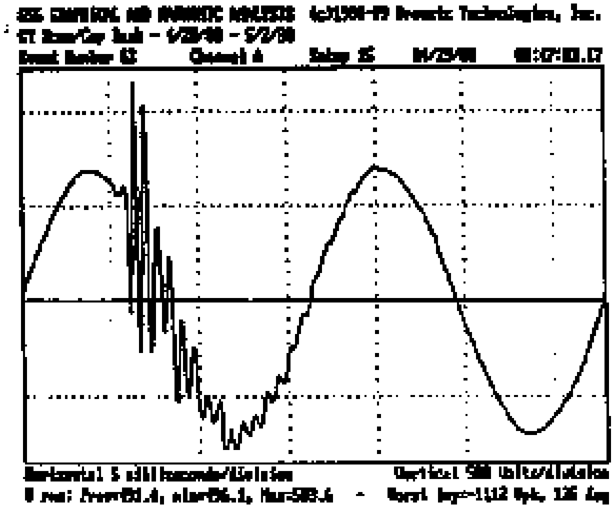
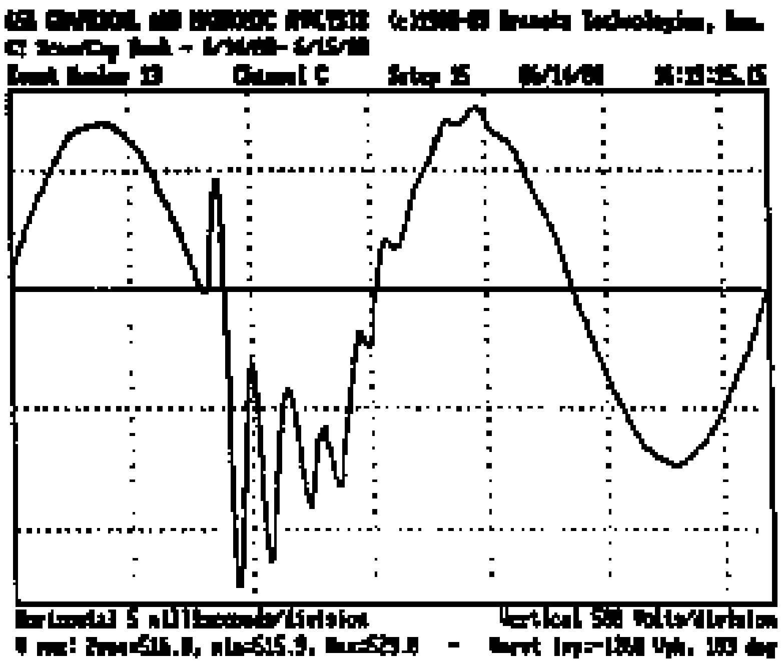


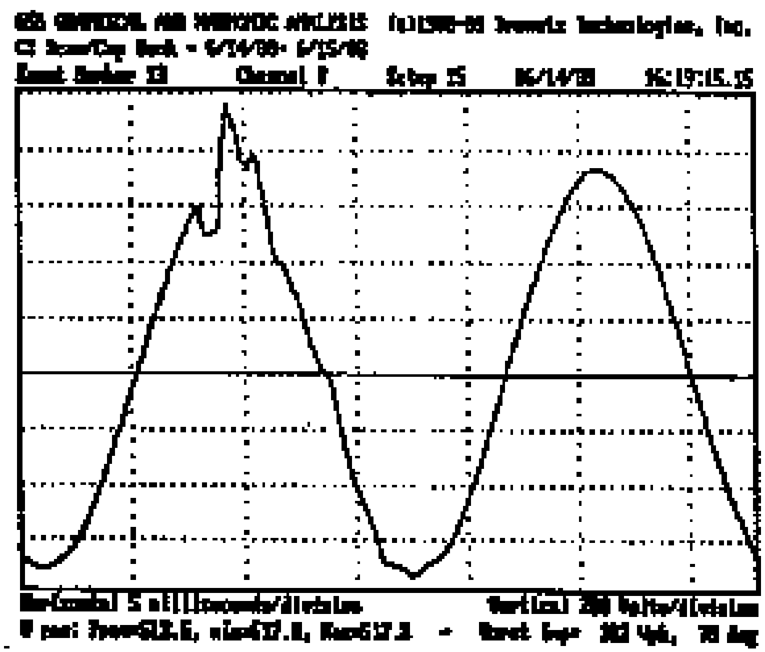
Figure2: Power Factor Capacitor Bank Switching
Measured at Isolation Transformer

Case Study: Impulses from Utility

Solution: Installation of an active-tracking filter designed to trap the 1 kHz disturbances and Transient Voltage Surge Suppression for overvoltage limitation was installed prior to the isolation transformer.



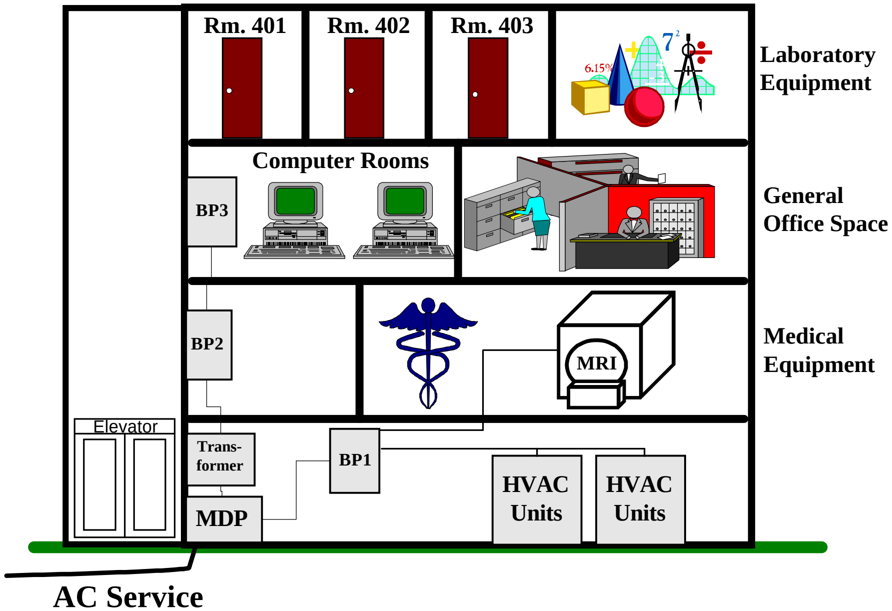
INPUT: Waveshape at input to filter/TVSS stage.



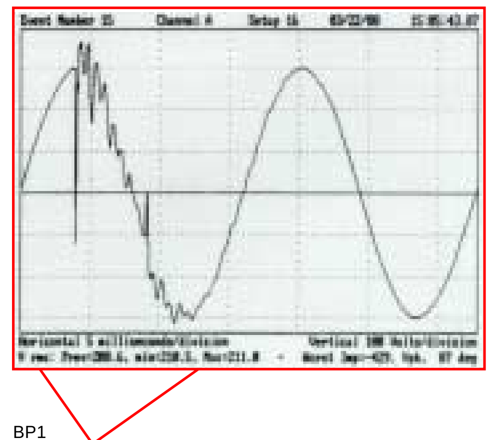
OUTPUT: Attenuated waveshape at output to filter/TVSS stage.

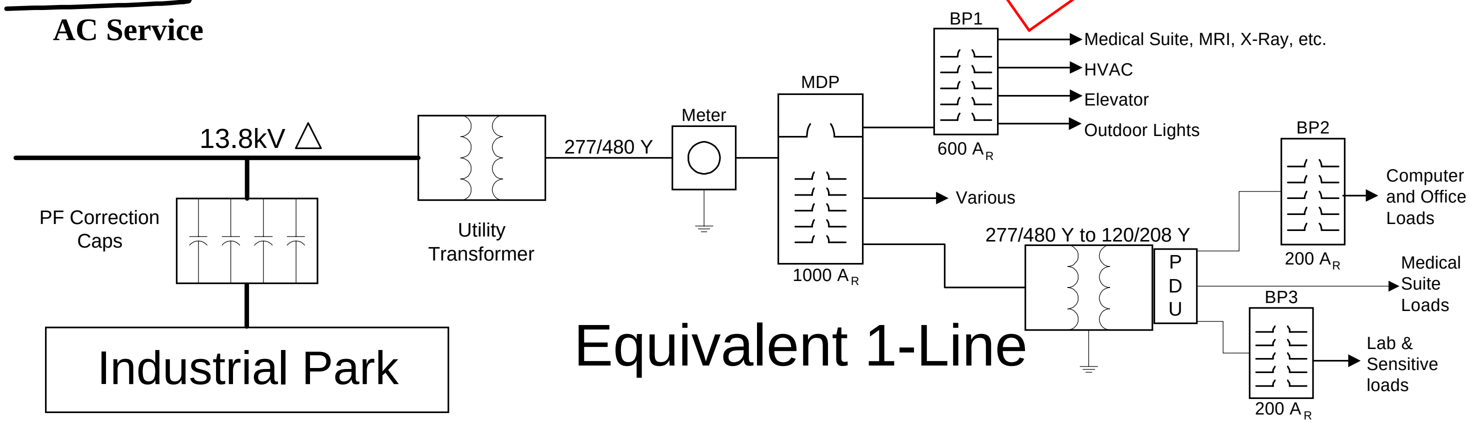
Case Study: Impulses from Utility

TYPICAL HIGH-RISE WITH MULTIPLE TENANTS



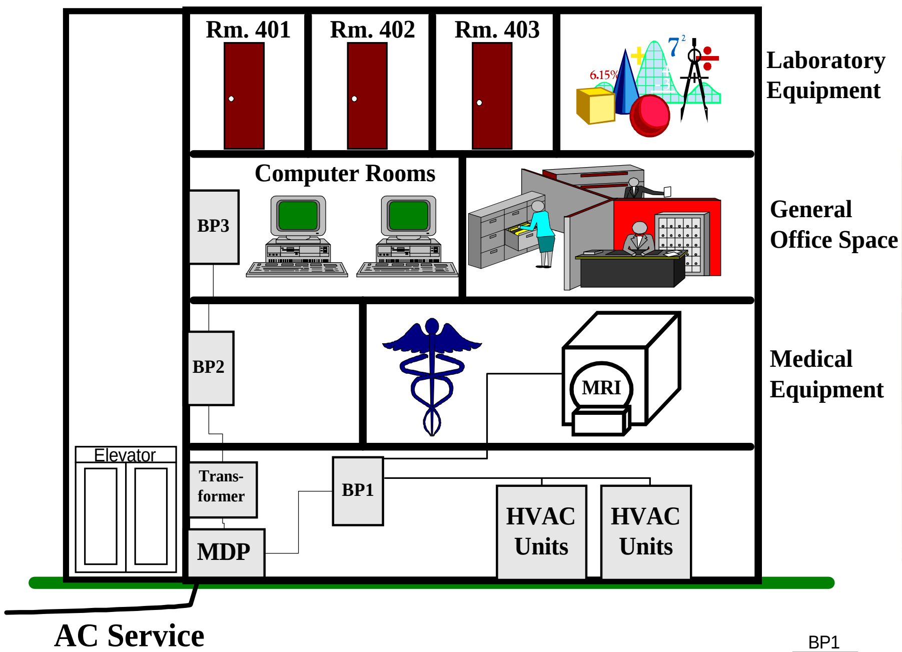
POWER FACTOR (PF) CORRECTION CAPACITOR CASE



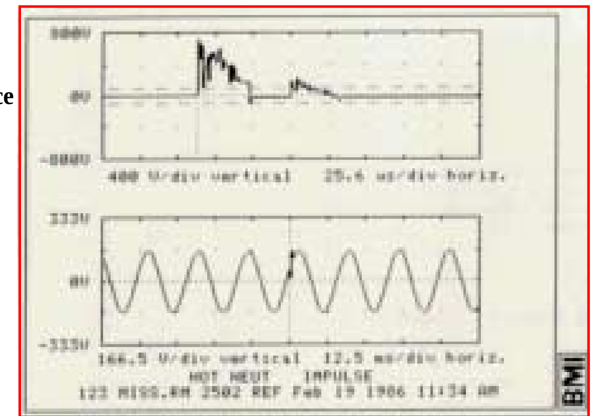


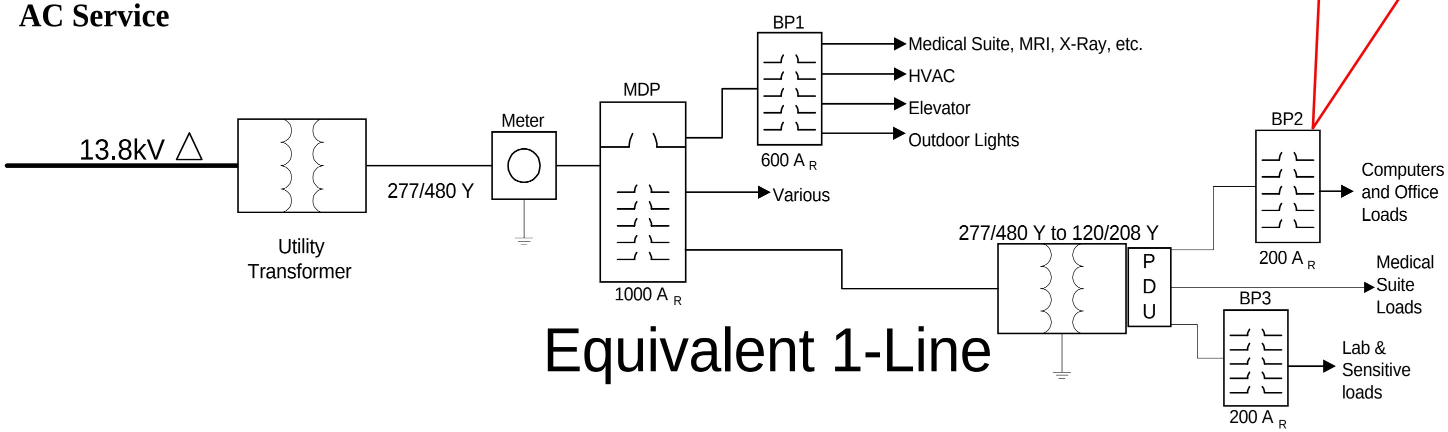
Case Study: Impulses from Utility

TYPICAL HIGH-RISE WITH MULTIPLE TENANTS



INDUCTIVE LOAD REMOVED CASE





Equivalent 1-Line

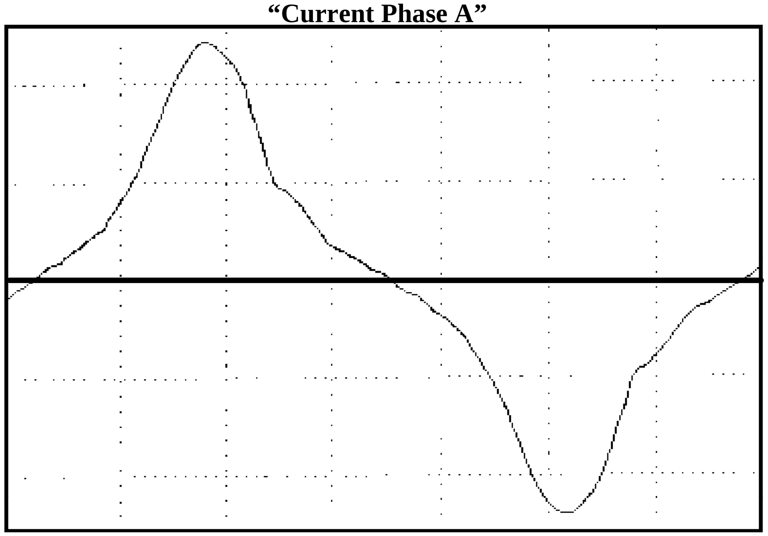
Case Study: Harmonics

Location: Office building with PCs, terminals, copiers and other office equipment
Voltage was 208Y/120 Volts, 4-Wire and Ground.

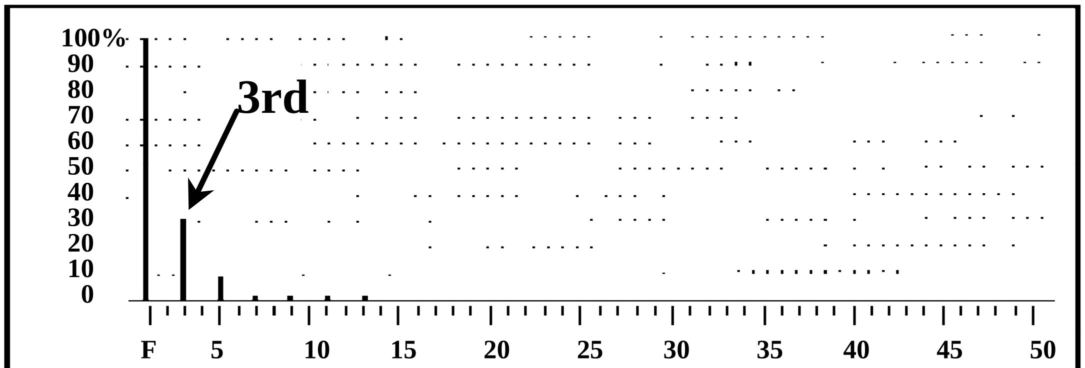
Symptoms: Overload behavior - Dist. transformers were overheating, breakers were tripping, etc.

Measurements: Neutral currents were extremely high (~475 Amps) and non-sinusoidal.
THD was 32% with high 3rd order harmonics.

Dranetz Printout: Graphical and Harmonic Printout
"Current Phase A"



Horizontal 2500 microseconds/div Vertical 200 Amps/div
A rms: Prev = 82.10, min = 183.8, max = 262.9 - Worst Impulse = 0 Apk, 0 deg



HARMONIC NUMBER:	50	3rd:	30.8%	Phase:	266 deg
TOTAL HARMONIC DISTORTION:	32 3%	5th:	8.9%	Phase:	84 deg
ODD CONTRIBUTION:	32.3%	7th:	2.0%	Phase:	288 deg
EVEN CONTRIBUTION:	0.4%	11th:	1.6%	Phase:	81 deg

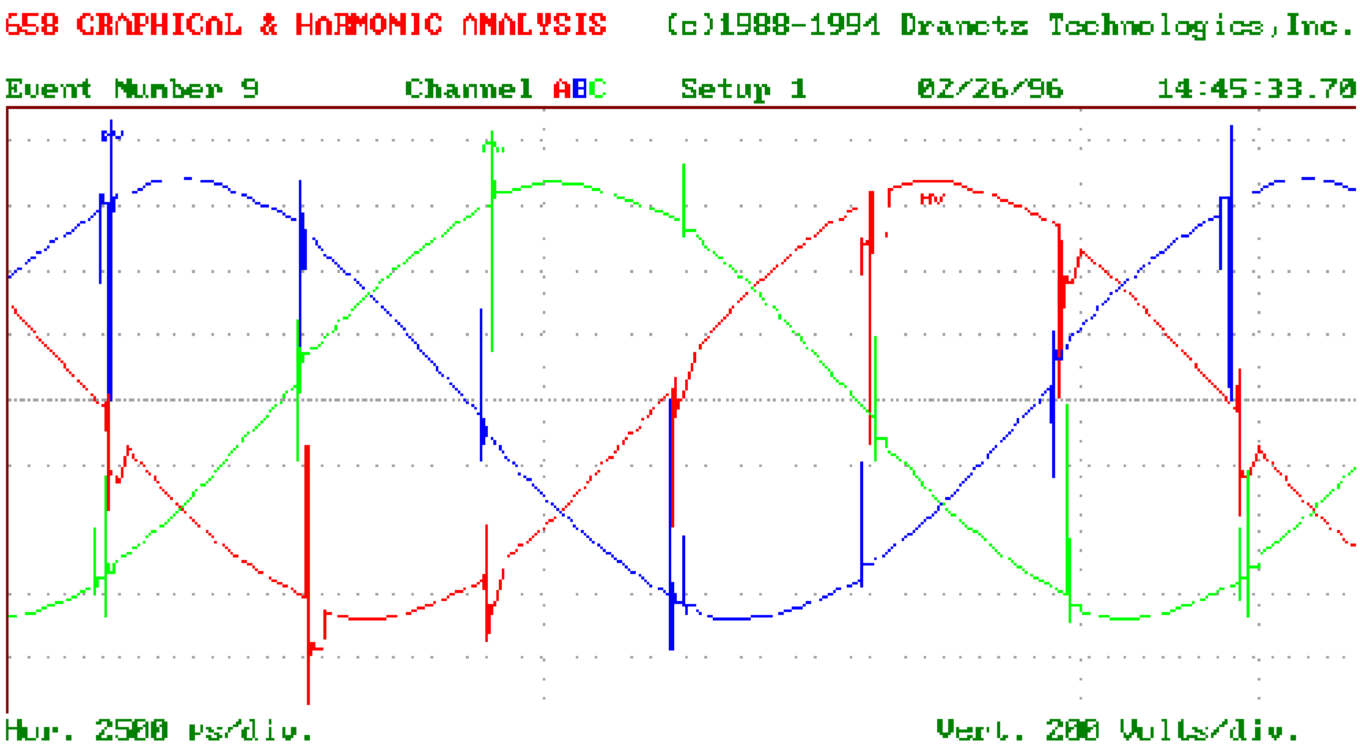
Horizontal: Harmonic Number Vertical: % of Fundamental
Frequency: 60.0 Hz

Solution: Short-term - Oversizing Neutral conductors and de-rating transformers to a more conservative level (~60%).
Long-term - Investigate K-rated transformers and filter options.

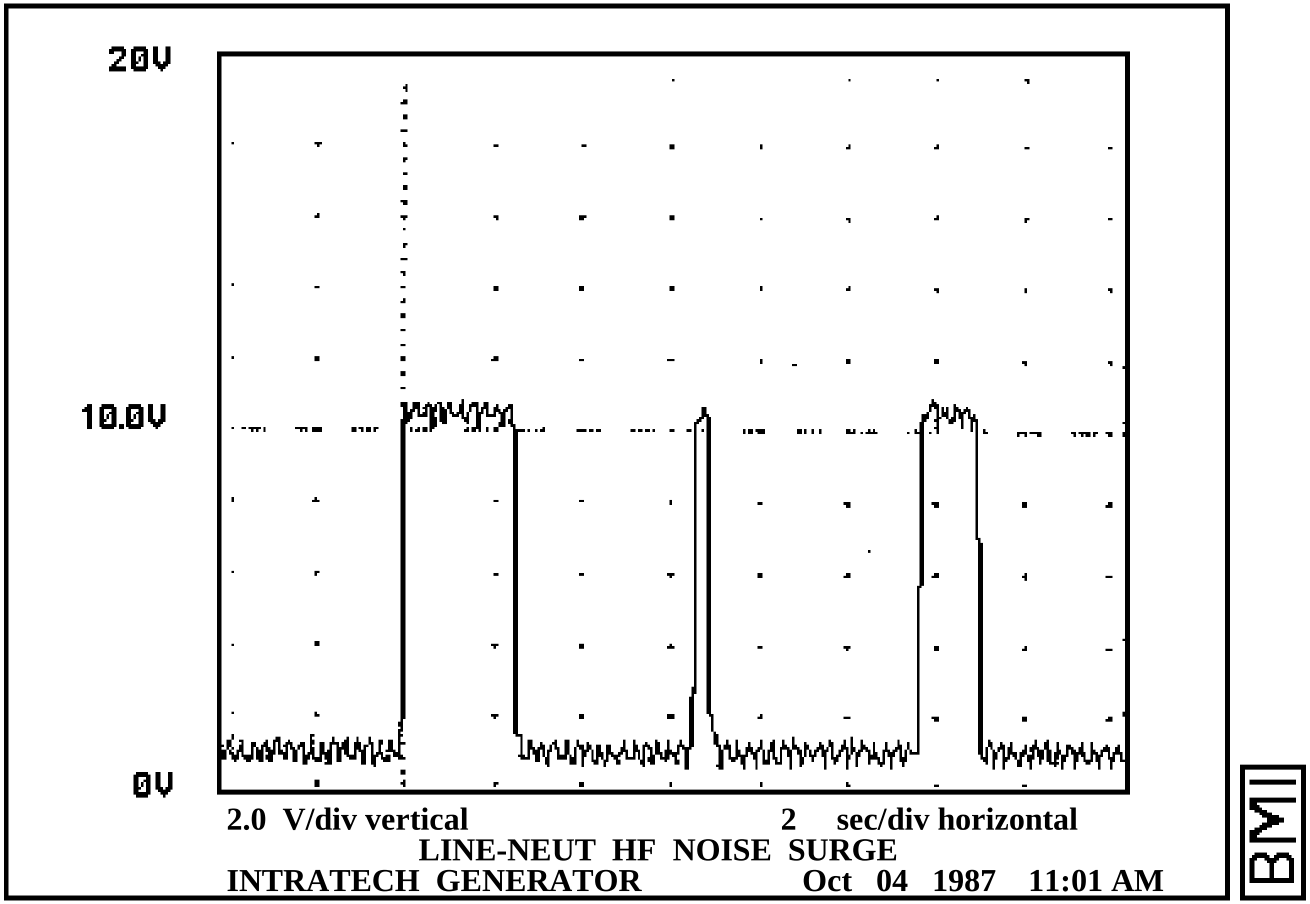
Repetitive Voltage Transients - Voltage Notches Caused by Damaged Bridge Rectifier Diodes

(Timing problems for electronic loads, clocks may run faster,

SCRs and switching diodes can be damaged)



HFN Surge - Local RF Transmission



Line-Neutral HF Noise Surge **Intratech Generator**

Thank You!

Please Remember

to Fill Out Your

Evaluation Forms!