An Optically Isolated, High-Voltage, IGBT-Based Inverter for DER Applications

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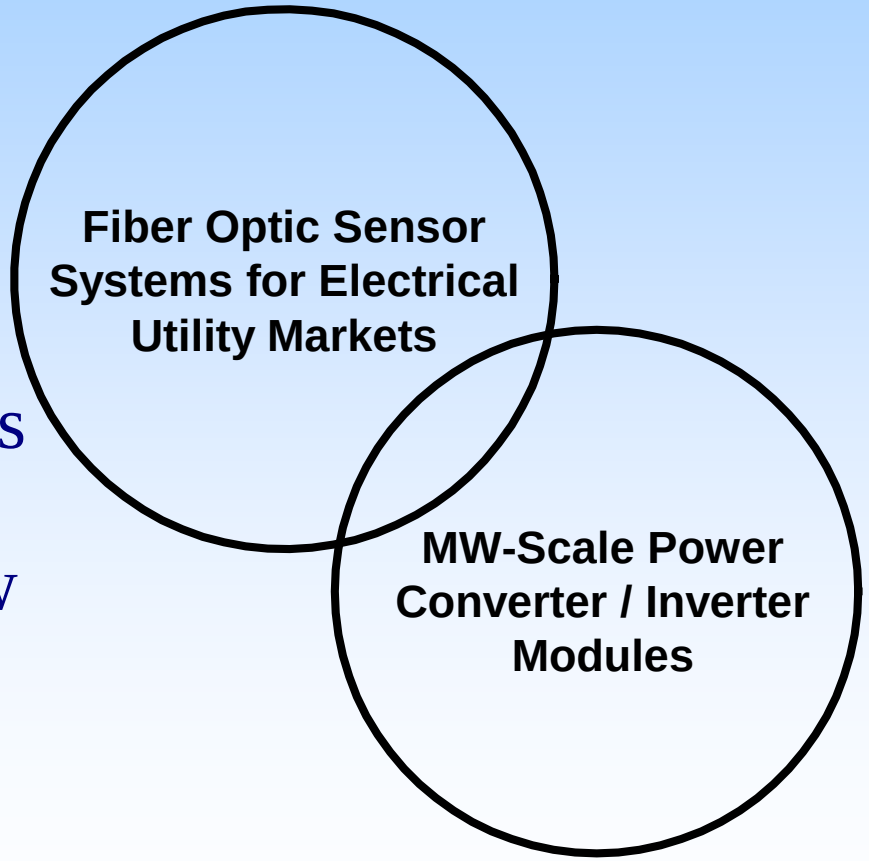
Airak's Mission

- Design & manufacture electrical power monitoring systems for utility-scale distributed generation markets
- Apply optical technologies to solve challenging problems, resulting in new products and licensing opportunities for partners



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Airak's Inverter Technology

- Next-Generation Approach
  - Convert Energy to Usable Power
  - Do so at a Reasonable Price
- Three Main Characteristics Distinguish Inverter from Competing Products
  - Optical Sensors & Communications/Control Systems
  - Modular & Standardized
  - Self-Contained Cooling System

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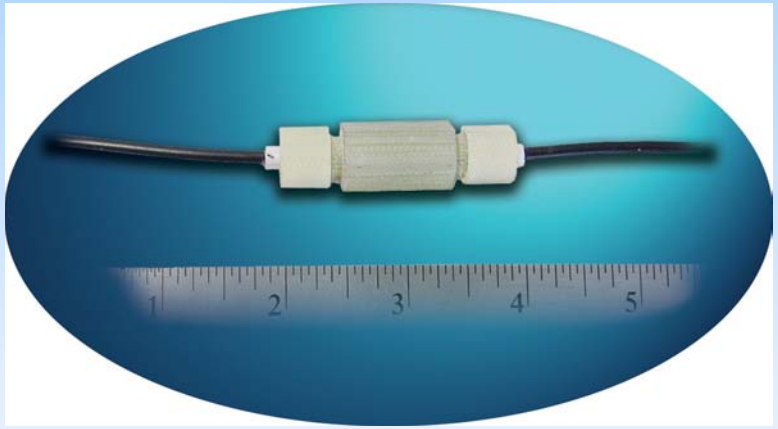
Optical Current/Voltage Sensors for Converter and Switchgear Monitoring

- Improves Safety & Reliability in Power Converters
- Allows Converter to be Smaller, Weigh Less
- Industry Qualified
  - MIL-STD901-D (Shock)
  - MIL-STD-167-1 (Vibration)
  - -40C to 85C Temperature
  - IEEE 15KV Insulation Class

Optical Current Sensor



Optical Voltage Sensor

BEST OF SENSORS EXPO 2003

R&D 100

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Power Converter/Inverter
Features Advantages Benefits

Optically Interconnected Sensors & Comms/Control	Immune to Radio Frequency Interference, Improved Safety	Higher Reliability Fast! Sensors → Smaller Footprint → Inverters have Higher Power Density Increased Personnel & Equipment Safety
Modular, Smaller Size Packaging	Lower Weight & Smaller Size	Install in Space Constrained Areas Greater Power Density - more Power/$ Standardization of Components
Self Contained Heatpipe Cooling System	No External Cooling Components Degraded Mode Operation Possible	No Monthly Maintenance - $$$ Savings in Filters, Pump Maintenance Improved Reliability - Increased Production Capacity

Competitive Advantages

- Only One Other >100 KW Heat Pipe Inverter
  - GE Innovation Series Converter
  - Non-Optical, Lower Power Capacity
- Airak Controls IP – Patents Pending / Awarded
  - Optical Sensors – Voltage & Current (US 9,756,781 & Others)
  - Optically Interconnected Power Inverters (US 6,972,972)
- Standardized Modularity
  - Substantial Manufacturing Savings

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Selected Inverter System Summary Specifications

- $ per KW @ 2.1MW: $219 / KW (loaded), no quantity
- 76 KW/cu. ft. @ 2.1 MW
- Total Weight: ~1450 lbs per 3 phases
- System Efficiency: 96.7%, All Losses (18.7 KW @ 5 KHz per Phase)
- Peak Power Tested: 2KV @ 1,100A
- Typical Temp Rise
  - @ fs=5 KHz → 1 deg/25 KW,
  - @ fs=4 KHz → 1 deg/32 KW,
  - @ fs=3 KHz → 1 deg/42 kW → 50C rise @ 2.1 MW

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Inverter Program Status

- Program Officially Ended in June 2006
- Currently have 4, 2-MW Inverter Phase Legs Ready for Deployment in Operational Environment
- Need Commercial Partner and Limited Engineering $$$ for Deployment and Engineering Support;
- Airak Will License Patented Inverter Designs and Hardware/Software to Strategic Partner

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Overall SBIR Program Successes

- 2 Issued Patents, 2 Pending Patents Directly Associated to Program
- Optical Sensors Perfected on Program Led to Securing $2.5M of Funding from U.S. Navy, and Resulted in:
  - MIL-SPEC Qualification (Vibration, Shock, Temp)
  - IEEE 15KV Metal Clad Busbar Certification
  - Installation on 13.8 KV/2000A Switchgear in October 2005; no failures
- Over $103K in Specialized Contract Work and Sensor Sales (2006)

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Overall SBIR Program Successes (con't)

- Optical Sensors have Attracted in Excess of $250K of Angel Investment (Sept. '06)
  - Creation of Optical Distribution Monitoring System (ODMS)
  - Comprehensive Market Research on Value of Monitoring Medium Voltage Distribution Completed in March 2006, Performed w/ Municipal Utility
  - 12.4KV Distribution Pilot Launched May 30th, 2006 – no failures despite highest rainfall recorded in shortest period (12"/4 days) and highest recorded temperature (103 deg F)
- Presently Expanding Present Distribution Monitoring Pilot with Existing Utility and Developing 2nd Pilot with a Western IOU.
- Next Round of Investment being Raised to Accelerate ODMS Deployment – Opportunity for Strategic Partnerships

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The System Solution - Airak ODMS

*A Breakthrough in Medium-Voltage Current Sensing Technology**

- Airak patented system solution, the Optical Distribution Monitoring System (ODMS), is composed of
  - fiber optic sensor hardware,
  - communication subsystem, and
  - visualization monitoring software
- Airak's sensors install quickly to overhead or switchgear conductors, enabling immediate visibility into medium-voltage load dynamics and power quality events as well as significantly reducing cost of ownership
- Visualizing MV distribution load and power quality allows utility to manage aging assets and balance operations and maintenance with existing dollars

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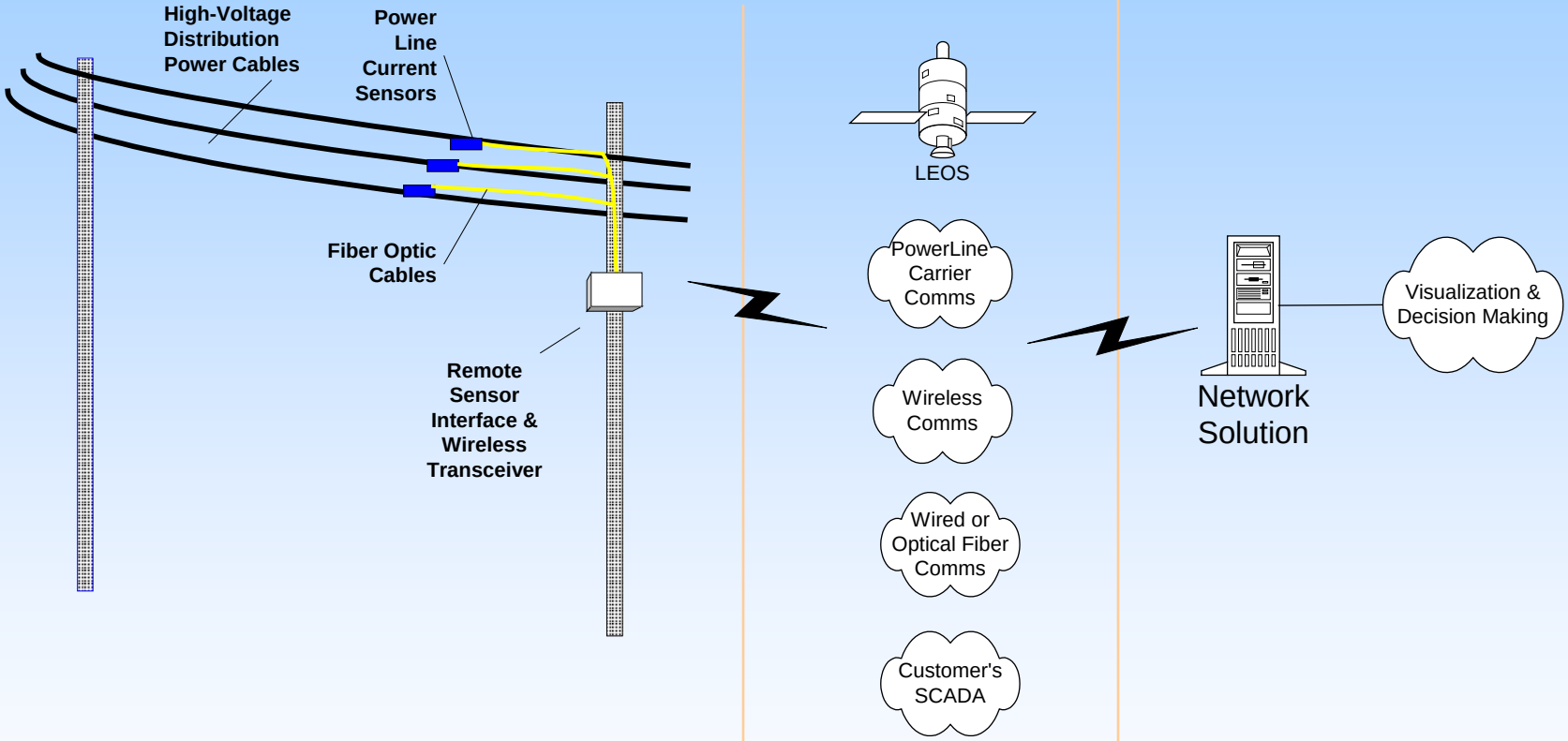
**Medium-Voltage: 480V to 38KV*

Airak's ODMS: Utility Power Monitoring Solution



Airak Optical Sensors & Electronics

Communications System

Airak Database & Visualization Software

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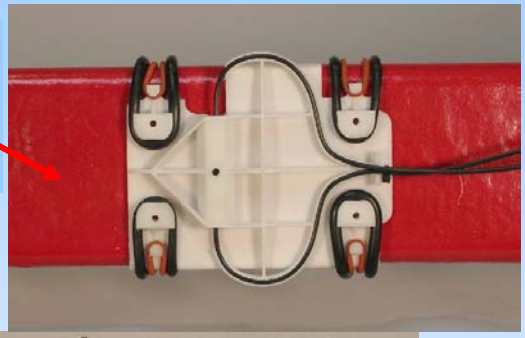
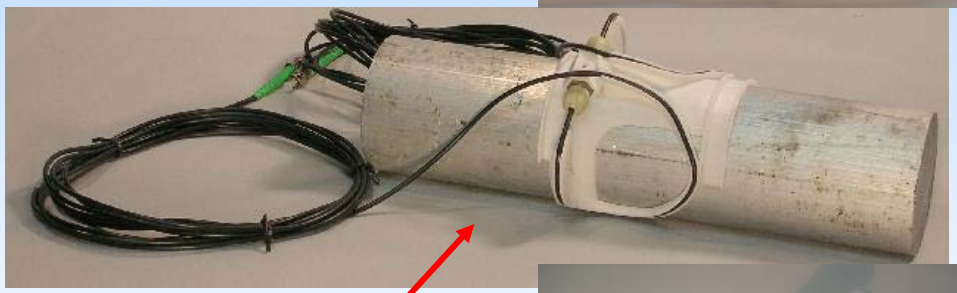
Typical Busbar Installation (Switchgear Equipment)

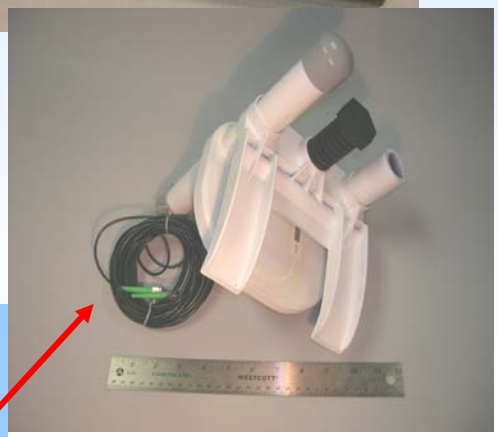
- Benefits for Customer:
  - No Disassembly of Equipment (Big Time Cost Savings)
  - Easy to Install (Less than 2 Minutes)
  - Safe (Isolated)
  - Only Optical Current Sensor Qualified for:
    - ✓ IEEE 15KV Insulation Class
    - ✓ MIL-STD-167-1 Vibration
    - ✓ MIL-STD-901-D Shock
    - ✓ -40C to 85C Temperature

15KV Busbar Sensor





22.5KV 3" Solid Conductor Sensor



34.5KV Overhead Sensor

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Pole-Mounted Electro-Optics

- Benefits for Customer:
  - Complete Data Acquisition, Processing, Storage (up to 1 GB)
  - "Internet Ready"
  - Digital and/or Analog Output Options Available
  - Flexible User Interface:

- Ethernet
  - Web Interface
  - Modbus TCP
- Serial
  - RS232
  - RS485
  - Modbus
- Wireless
  - CDMA "Plug and Play"

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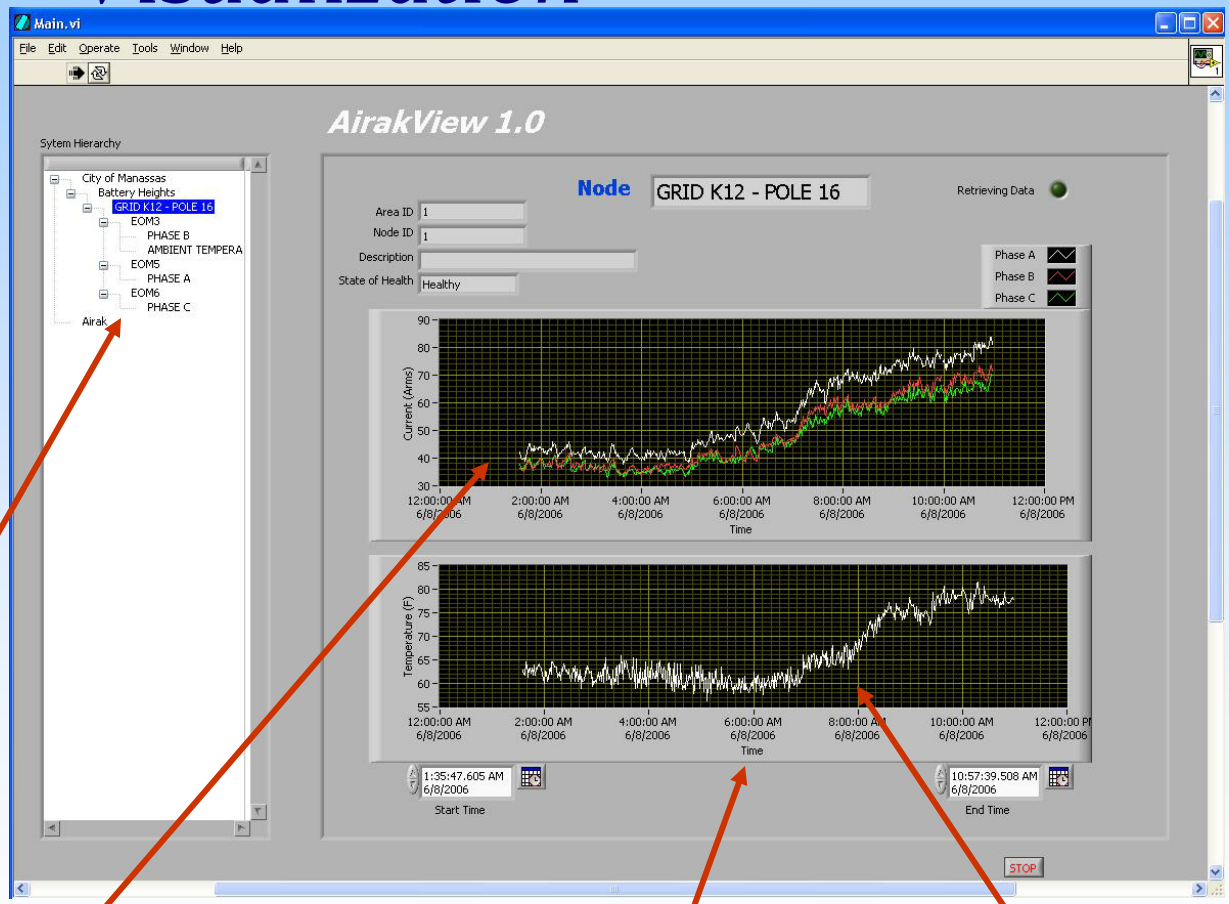
Real-time & Historical Load Visualization

- AirakView™ provides the user to remotely view sensor information
  - load current
  - temperature
  - power quality (harmonics)
- Alarm capability triggered on thresholds
  - Send emails



Installation Hierarchy

3-Phase Load Information

Time Stamp

Ambient Temperature

Note: Actual Display of Manassas Monitor

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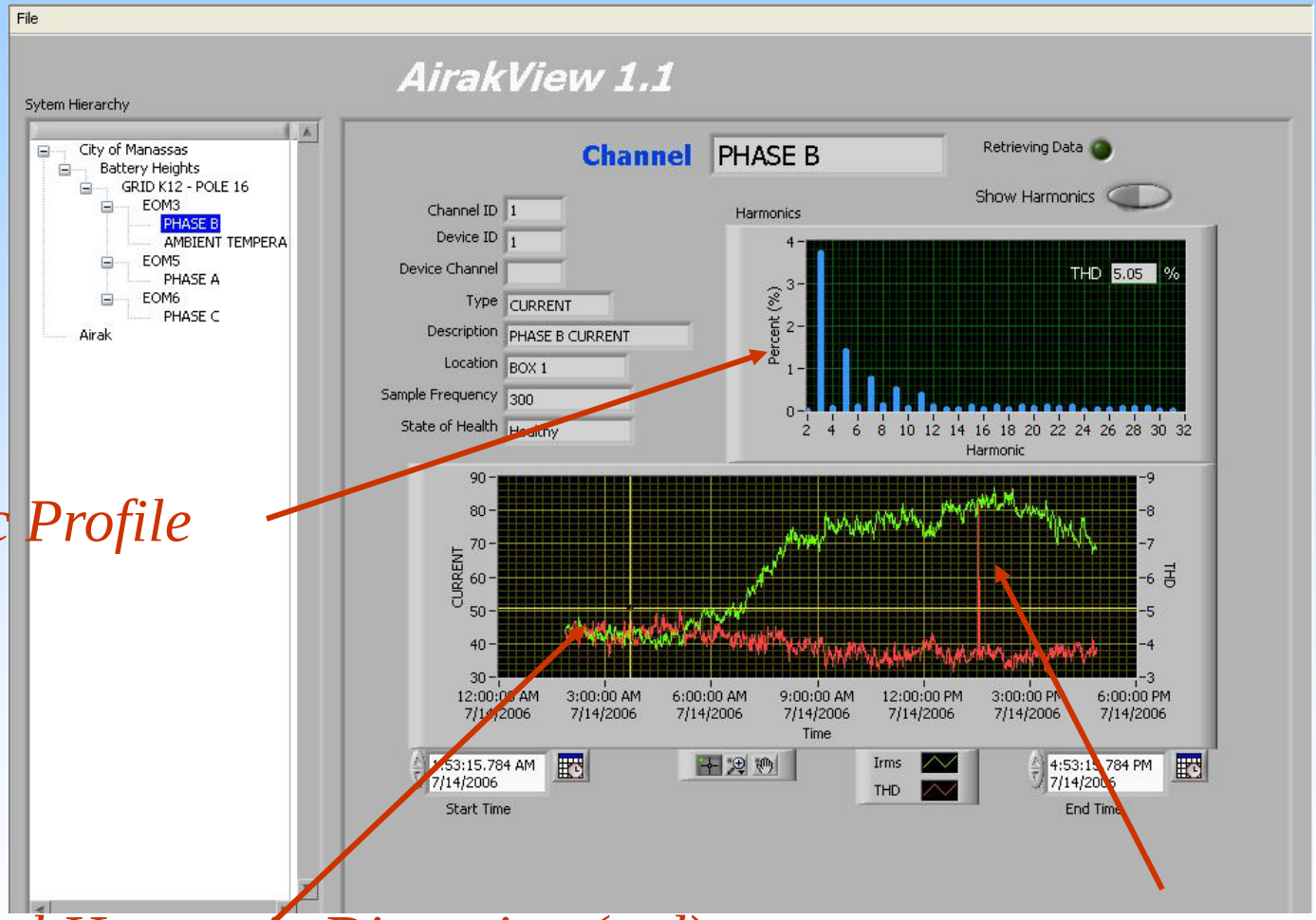
Real-Time and Historical Load Visualization



Harmonic Profile

Total Harmonic Distortion (red) + Phase B Current Load (green)

Abnormal Power Quality Event

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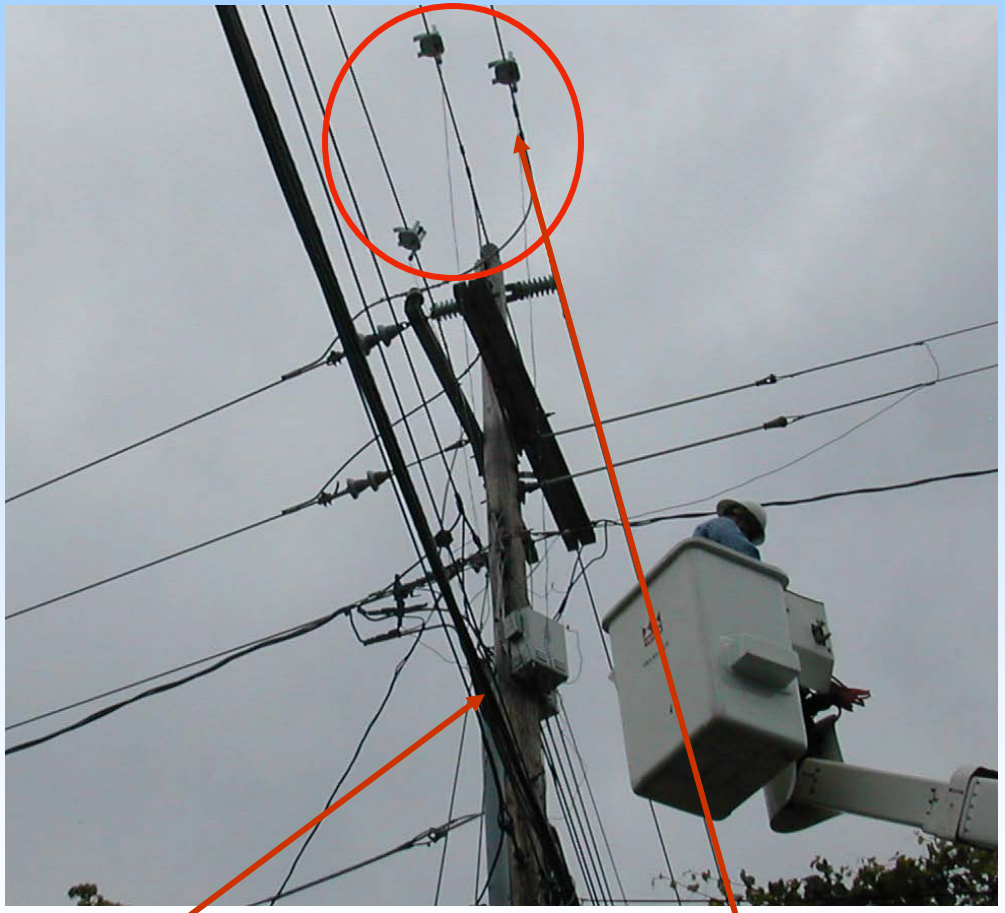
Typical Overhead Installation

- Benefits for Customer:
  - No Outages to Install
  - Easy to Install (via Hotstick)
  - Safe (Isolated)
  - Lightweight



Electronics & Communications

Overhead Optical Current Sensors

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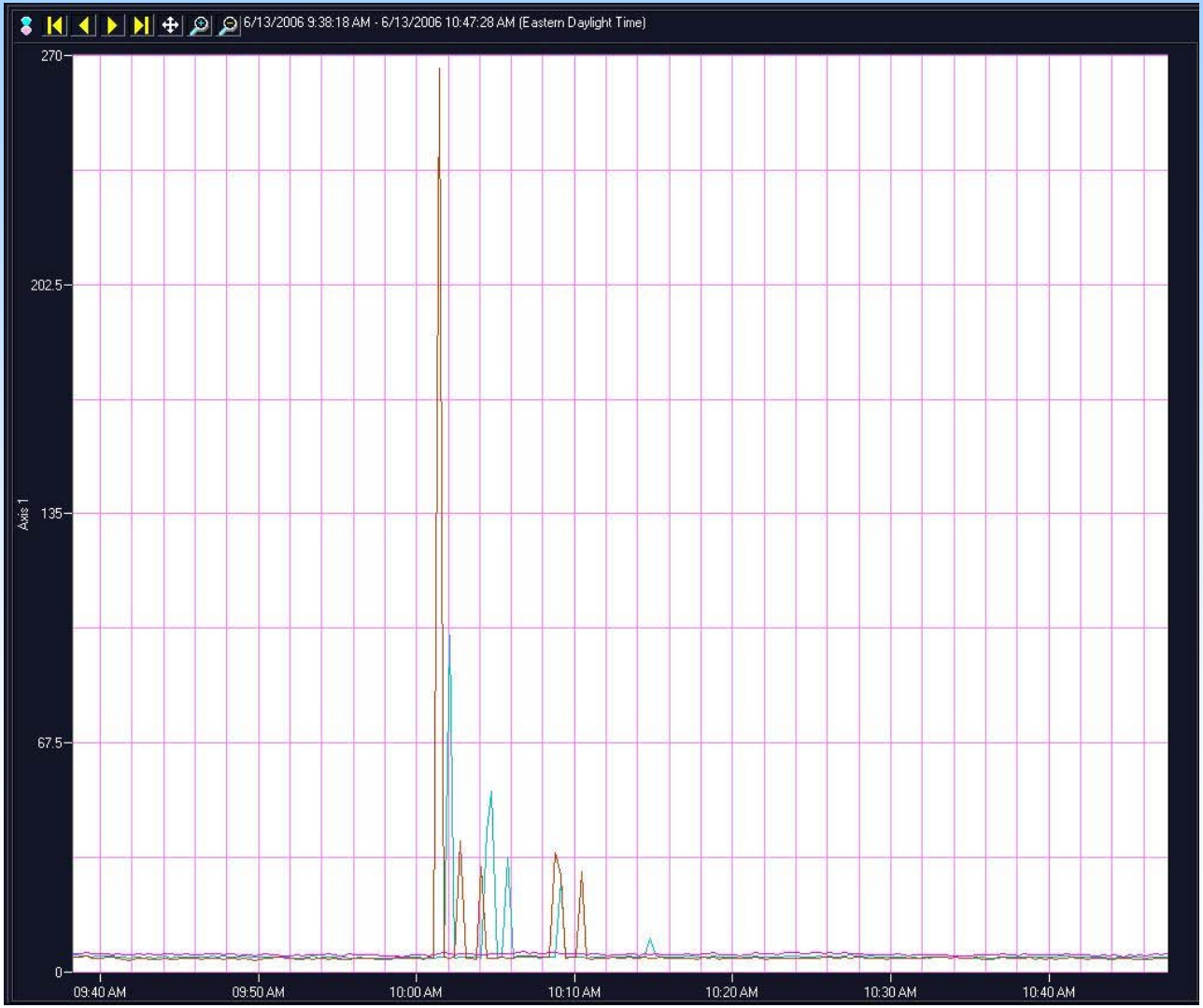
Example of Multi-phase THD Events

- Phases A&B Current Only
- Significantly Impact Power Quality
- Suspect Backfeed of MG Set or Partial Discharge w/in Xfmr



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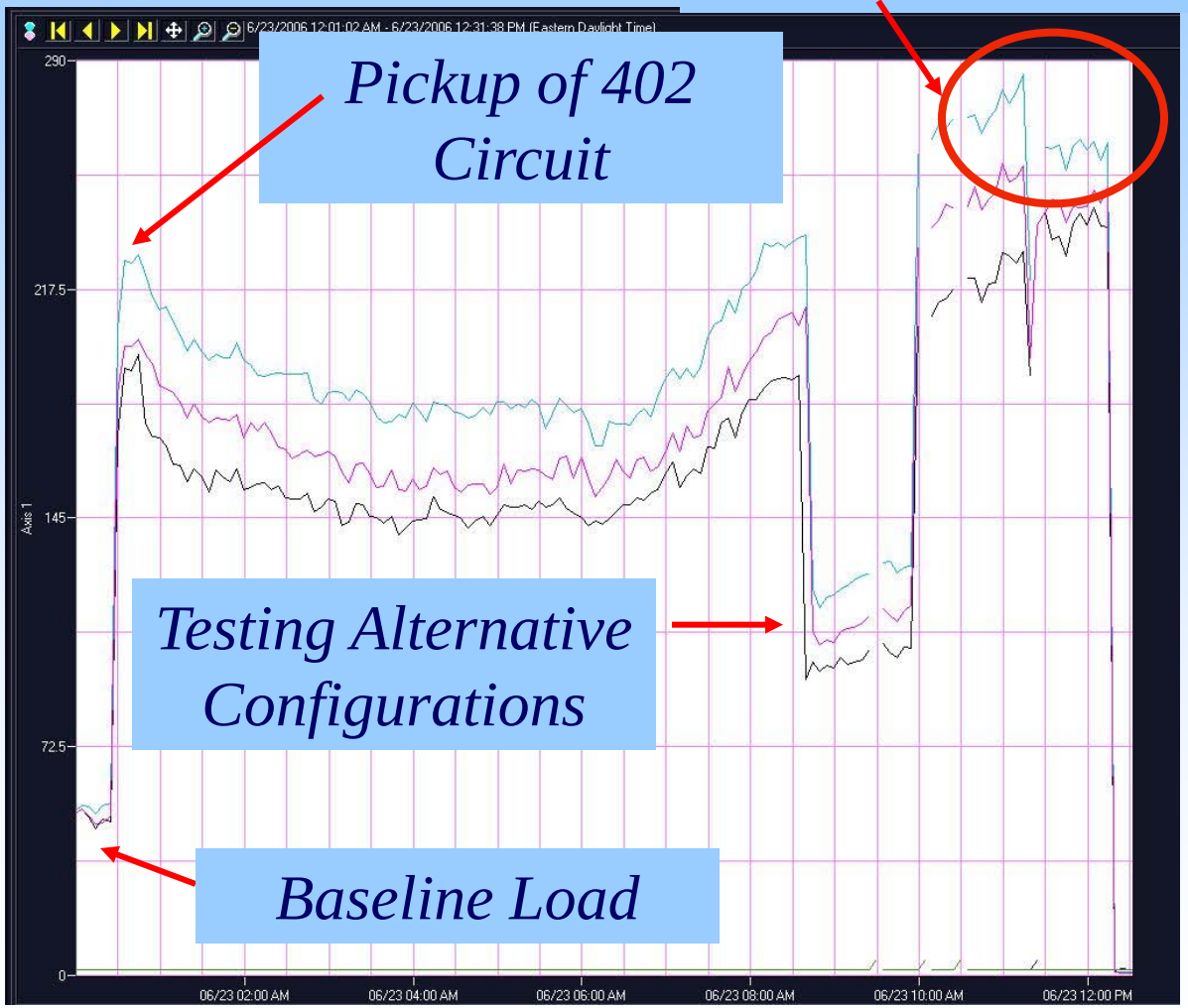
Make Real-Time Load Configuration Changes

- Period of Severe Thunderstorms
- Provided Real-time Confidence to Operate within Current Rating Margins
- Allowed Power Flow for Additional 12-hours



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Summary

- Inverter Program
  - Economical MW-scale building blocks achieved with high performance and manufacturing modularity
  - Inverters are ready for field demonstration & licensing to strategic partner
  - MW program created two technologies, one which has received two significant awards and two issued/two pending patents

- Optical Sensors Program
  - Technologies created on MW inverter program have generated nearly $2.5M in Government acquisition revenue
  - Program attracted $250K in outside angel investment for ODMS technology
  - ODMS provides visibility into the distribution “black hole”, allowing utilities to better manage aging assets and available dollars
  - 1st commercial MV pilot launched in May ’06 and being built-out; additional pilots being planned

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Acknowledgements

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Sandia National Laboratories

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