Non-Contact Sensor System for Real-Time High-Accuracy Monitoring of Overhead Transmission Lines

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Real-Time Transmission Line Monitor (RT-TLM)

- High accuracy, purely electromagnetic, fully passive, real-time, autonomous field sensor system.
- Simultaneous determination, monitoring, and wireless communication of HV transmission conductor sag/clearance, phase current, ampacity, and maximum conductor temperature.
- Ground-based system is far less expensive (in terms of total installed/operational cost) than existing, commercial transmission line monitoring and rating products.
- Designed for simple, low-cost field deployment, installation, and calibration.
- Located in existing ROWs under overhead phase conductors.

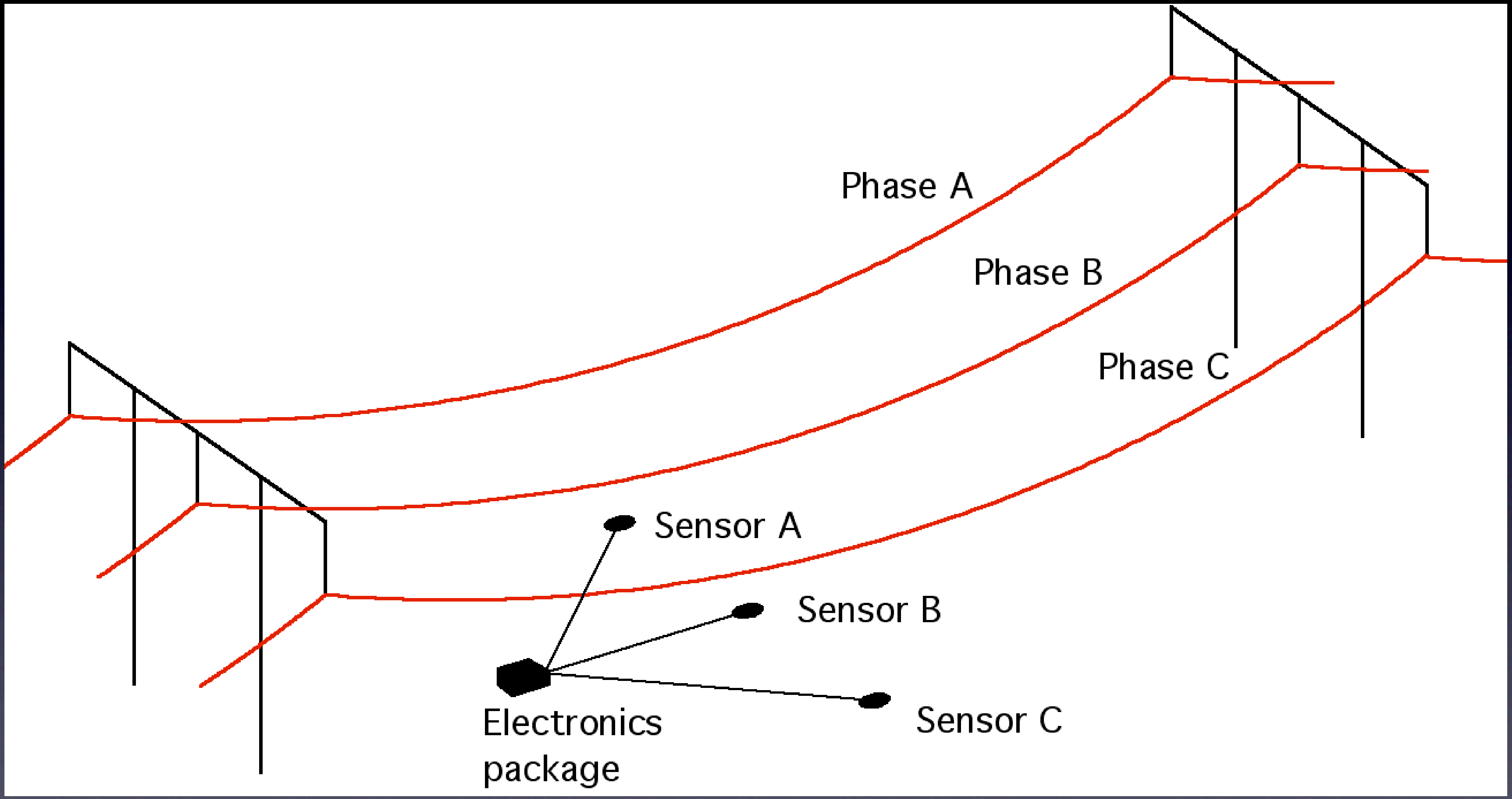
RT-TLM: Features and Advantages

- Entirely non-contact, non-invasive installation, calibration, and operation.
- Fully secure, real-time communication of data.
- Solar powered with battery backup.
- Remote, autonomous, reliable field-and-forget operation.
- Does not require utility field crew for installation and calibration.
- Does not require outages for installation, calibration, & maintenance.
- Operation and accuracy not affected by rain, wind, fog, smoke, hail, snow and ice.
- Direct burial allows physically secure, subsurface operation.

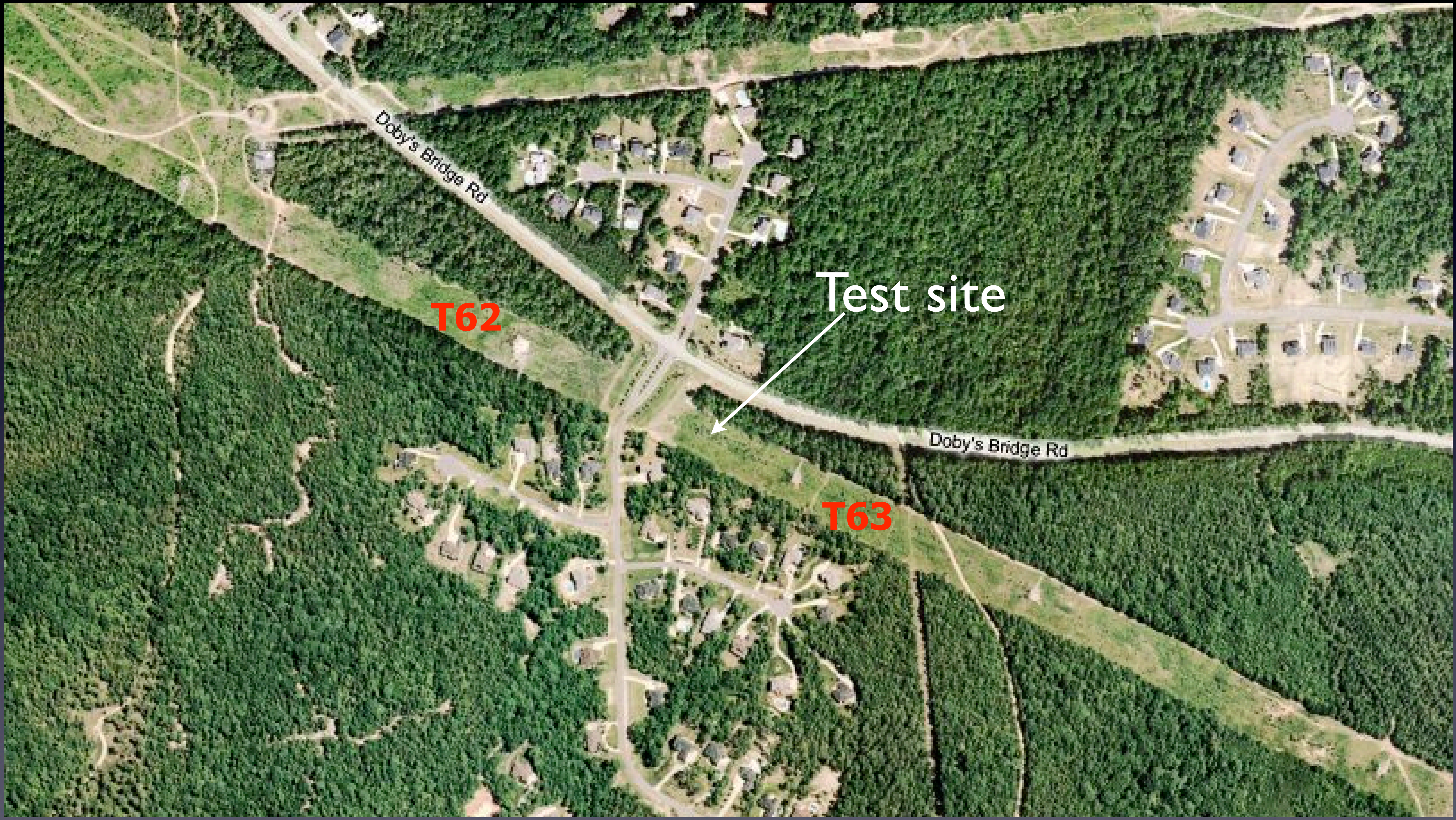
RT-TLM Prototype Performance

Measurement	Accuracy, 99% confidence	Notes
Clearance	+/- 0.12 meters	At ~18.5 meters.
Temperature	+/- 7 C	Using temperature-clearance calibration
Phase Currents	+/- 22 Amps	At 830 Amps
Update rate	Every 5 seconds	
Data latency	< 30 seconds	
Feature		
Measurement method	Non-contact AC magnetic field sensing.	
Ampacity estimation	Consistent with IEEE Standard 738-1993.	
Power supply	Solar with battery backup.	
Communication	Wireless EVDO (cell-phone) network link.	

RT-TLM Deployment: Duke Energy

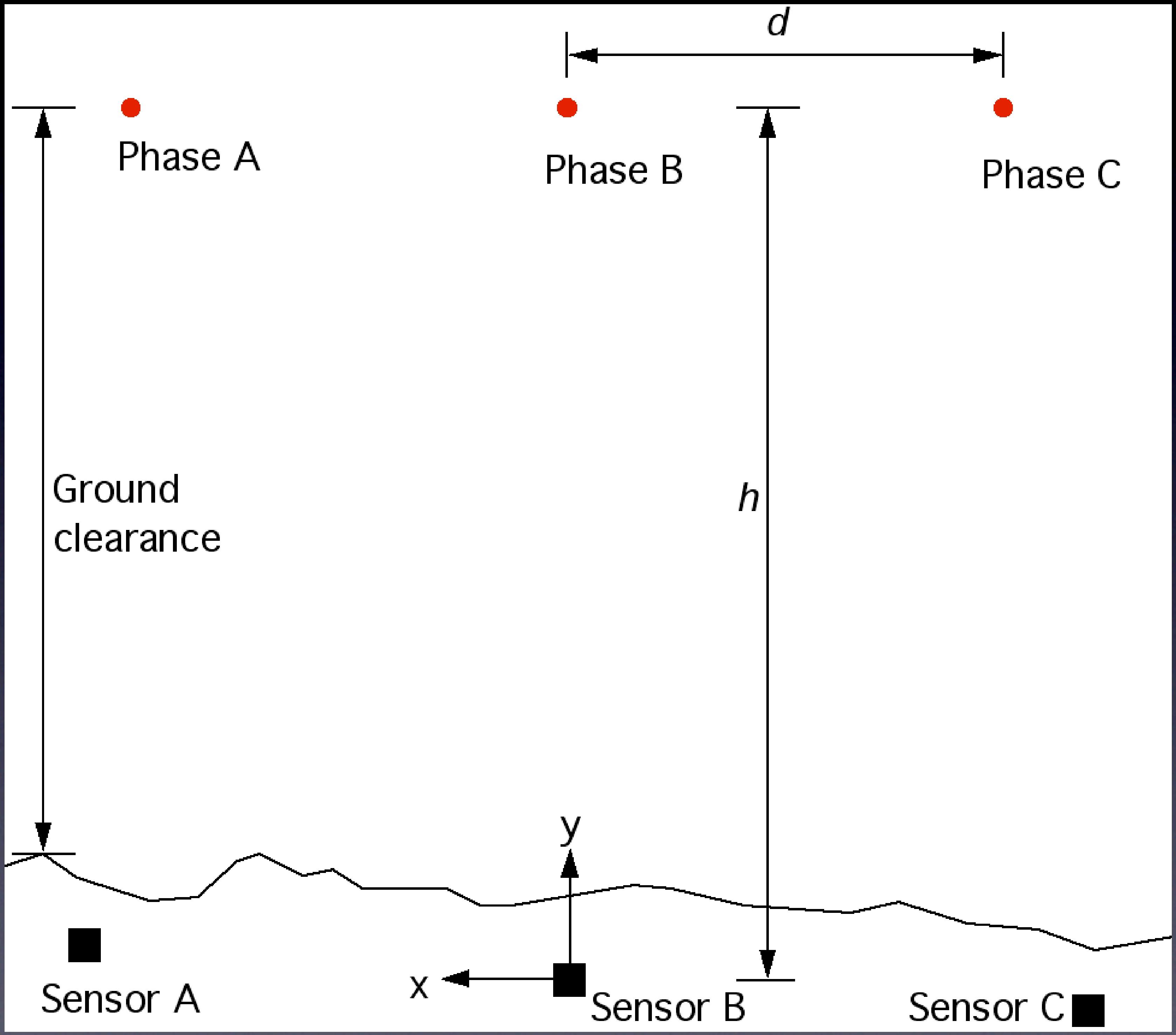


Field Test Site:
Duke Energy Newport-Richmond 500 kV Tie
Fort Mill, SC.



Sensor Placement Cross-Section

- **Sensors placed underground.**
- **Exact location not critical.**
- **Terrain, slope does not affect accuracy.**
- **System reports *h*, the conductor height above the sensors.**



Prototype Sensor Installation

- Subsurface operation began August, 2007
- 4th Generation Sensor Assembly

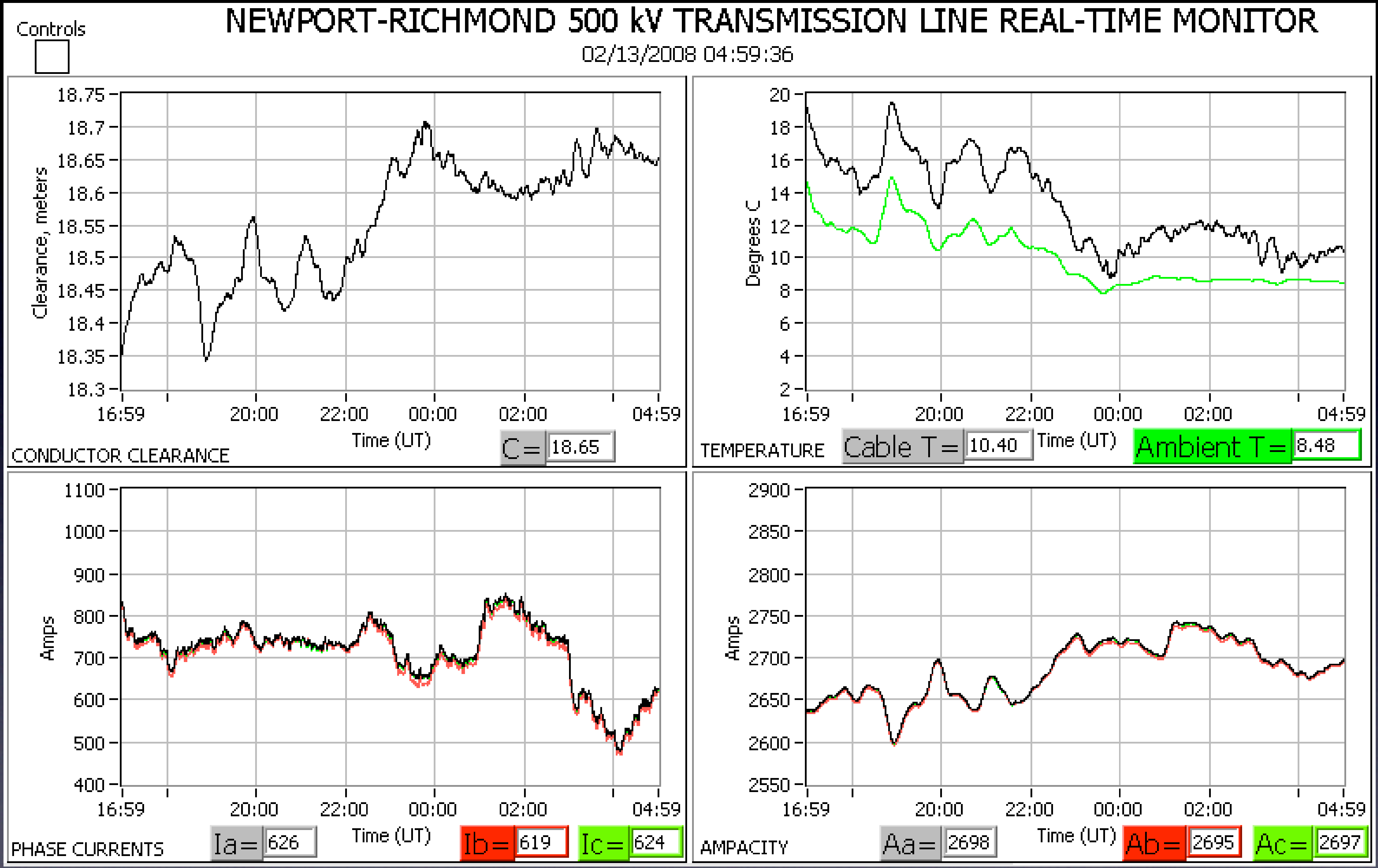
5th Generation Sensor

- Watertight assembly
- Greatly reduced volume
- Simplified installation
- Reduced installation time.

RT-TLM Electronics Package: Duke Energy, Newport-Richmond 500 kV.

Solar panel and prototype electronics package

RT-TLM Web Display



Displays: real-time clearance, conductor temperature, phase currents & ampacity

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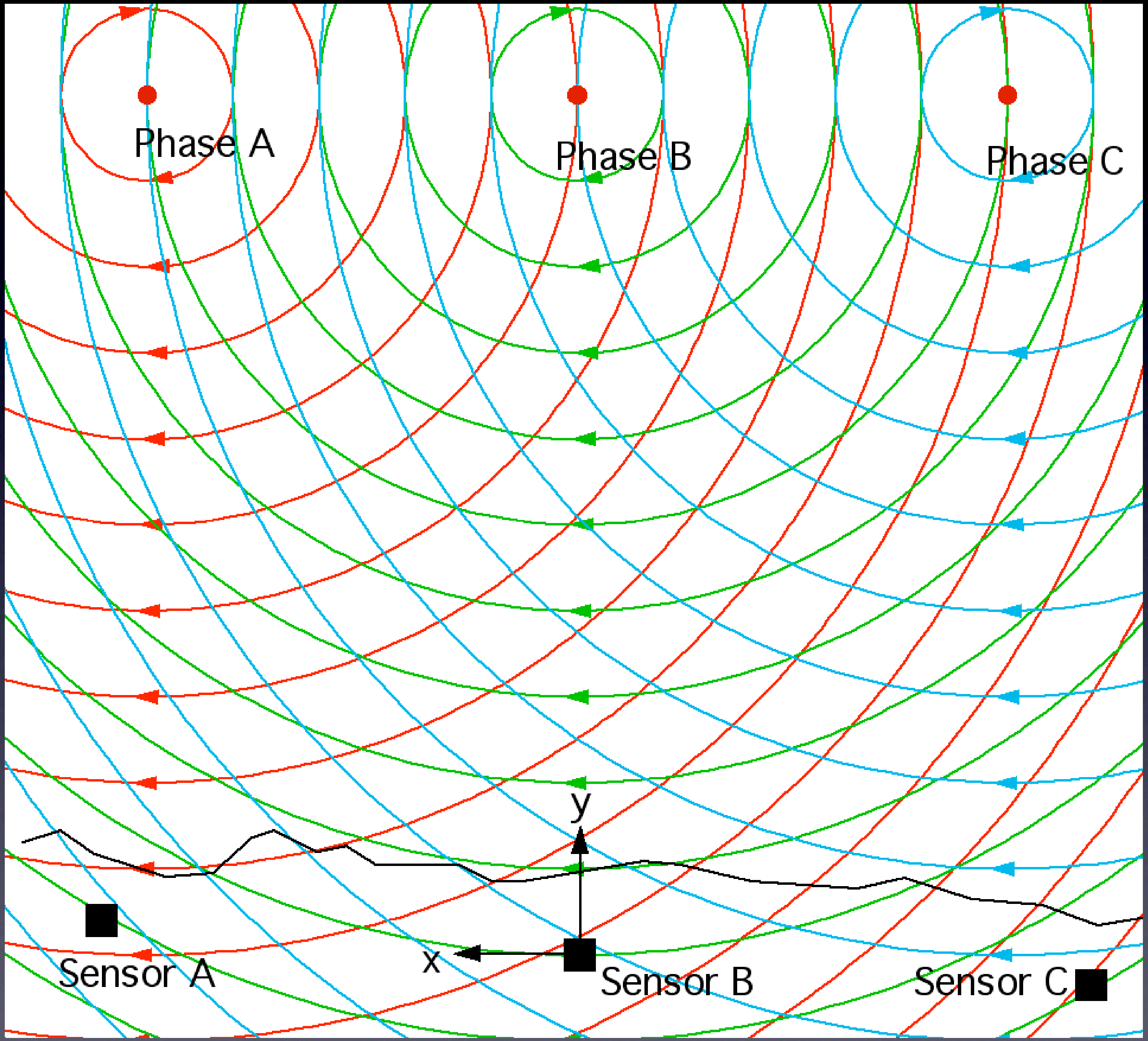
Installation and Calibration

1. Identify transmission line span; critical span preferred.
2. Place sensors and electronics in prepared subsurface locations; lay cables.
3. Laser survey as-installed sensor locations and overhead spans.
4. Connect electronics, solar panel; take calibration data with laser range finder, and I.R. camera cable temperature data.
5. Cover sensors and electronics with dirt.
6. Analyze calibration data, apply results to base-station software.
7. System functional.
8. Laser range-finder and I.R. camera will certify long-term accuracy.

Measurement Principle: *monitor amplitudes and phases of conductor AC magnetic fields.*

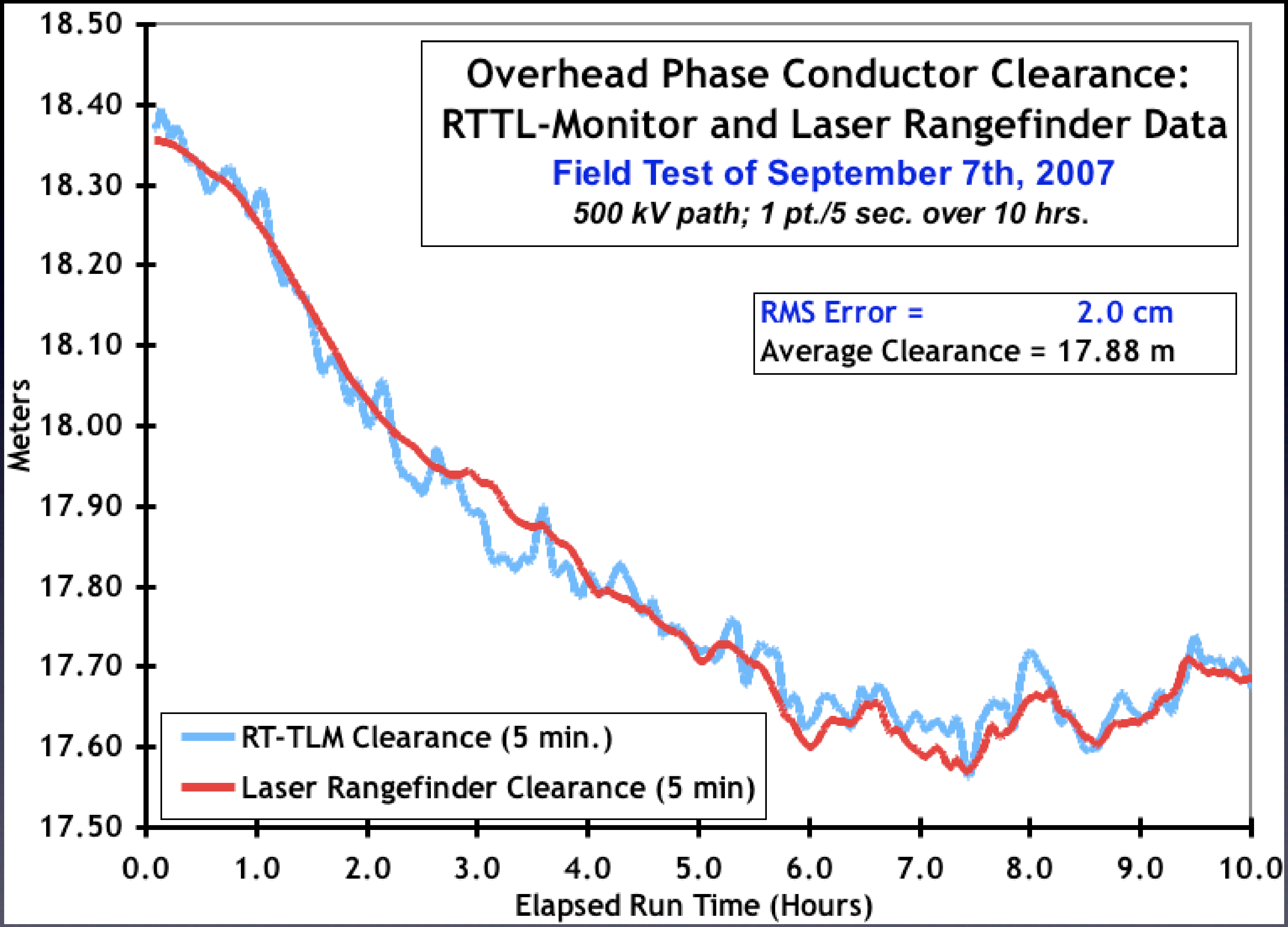
- Each phase generates individual magnetic field
- Fields combine in unique amplitude and phase combinations at each sensor
- Software determines cable heights, currents from sensor data



Conductor Clearance Validation: 9/2007

Conductor clearance measured by:

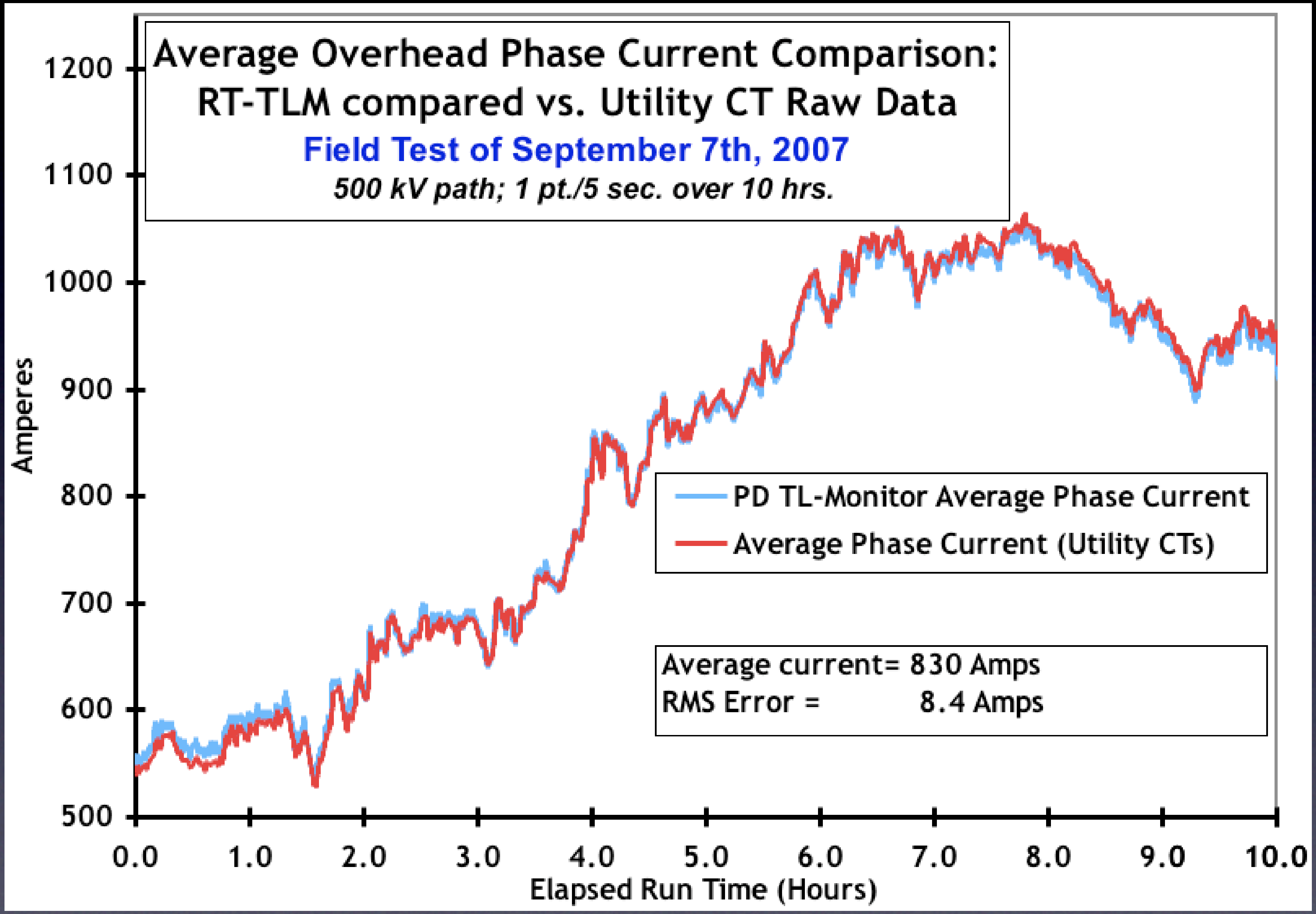
- **Promethean RT-TLM**
- **Laser range finder.**
- **Data has been smoothed with a 5 minute window.**



Phase Current Validation: 9/2007

Current, average of three phases, as determined by:

- **Promethean RT-TLM**
- **CT data provided by Duke Energy**
- **No smoothing**



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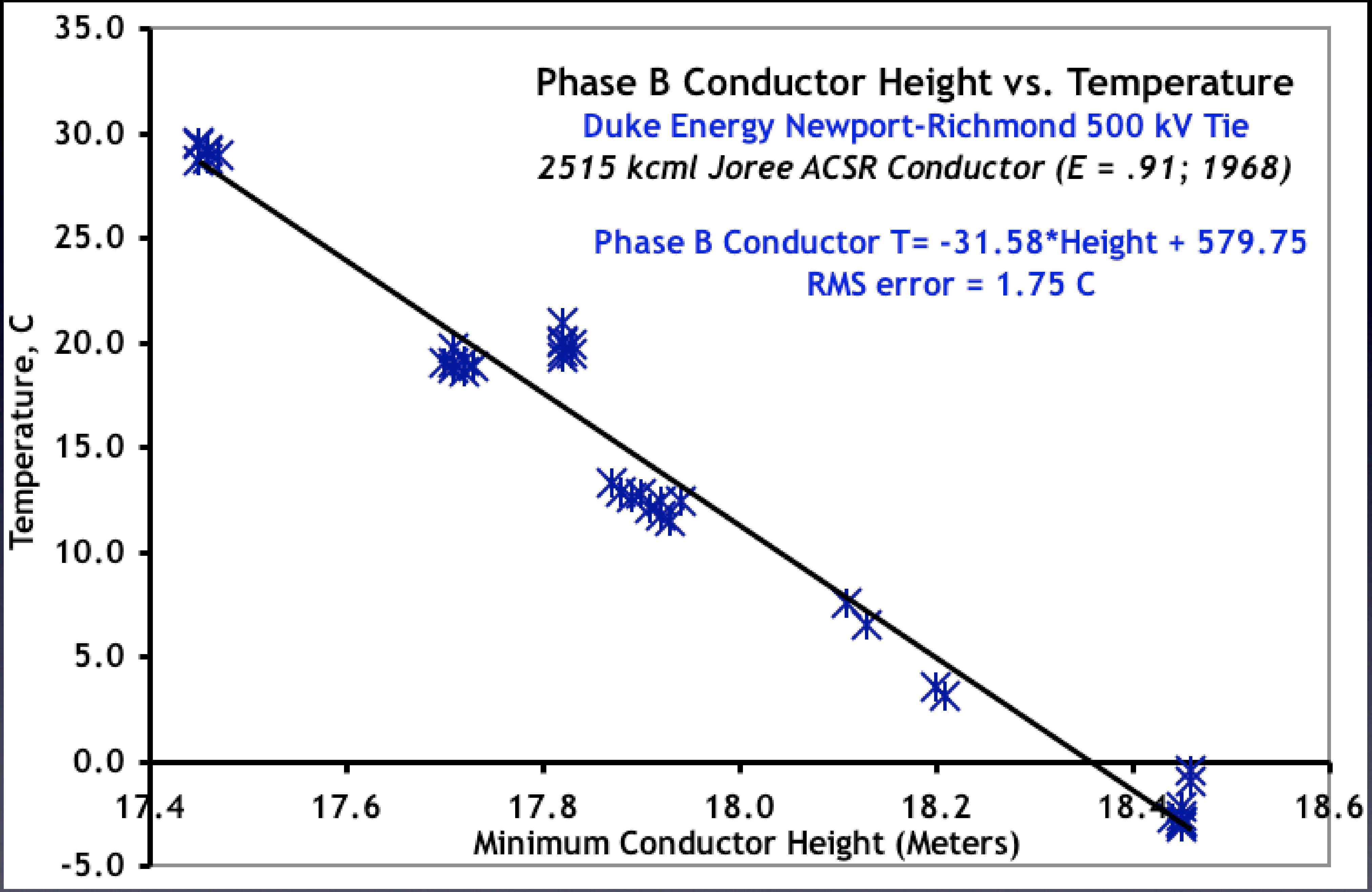
Clearance-Temperature Calibration

- **Plot shows:**
- **Laser range-finder measured height**
- **I.R. camera measured conductor temperature**
- **Linear fit serves as a height-to-temperature conversion and calibration.**



Present status

- Prototype system running for seven months, in subsurface implementation.
- RT-TLM vs laser range finder height comparisons stable to ~3 cm, or ~1 degree C over this time period.
- DOE funding lasts though Summer 2008

Additional Measurement Capabilities

- Ice detection and loading
- Wind driven conductor motion; mechanical loading
- Galloping
- Detection of mechanical anomalies

Present Efforts & Near-Term Goals: Summer 2008

- **Replace 1st generation fully autonomous RT-TLM prototype with 2nd generation, low-power, small footprint, "pre-production" system**
- **Install several 2nd generation systems under heavily loaded, or dynamically/persistently congested, transmission paths to:**
  - **monitor and report in real-time on critical operating parameters during the 2008 Summer Peak**
  - **demonstrate long-term system reliability and accuracy**
  - **expand conductor temperature & ampacity estimation data sets; improve and validate ampacity estimation algorithm**
  - **allow dynamic real-time rating and operation during the 2008 Summer Peak**

➡ **Promethean Devices is now looking for qualified test/evaluation sites**

- Thank you!

- Questions?

NEWPORT-RICHMOND 500 kV TRANSMISSION LINE REAL-TIME MONITOR

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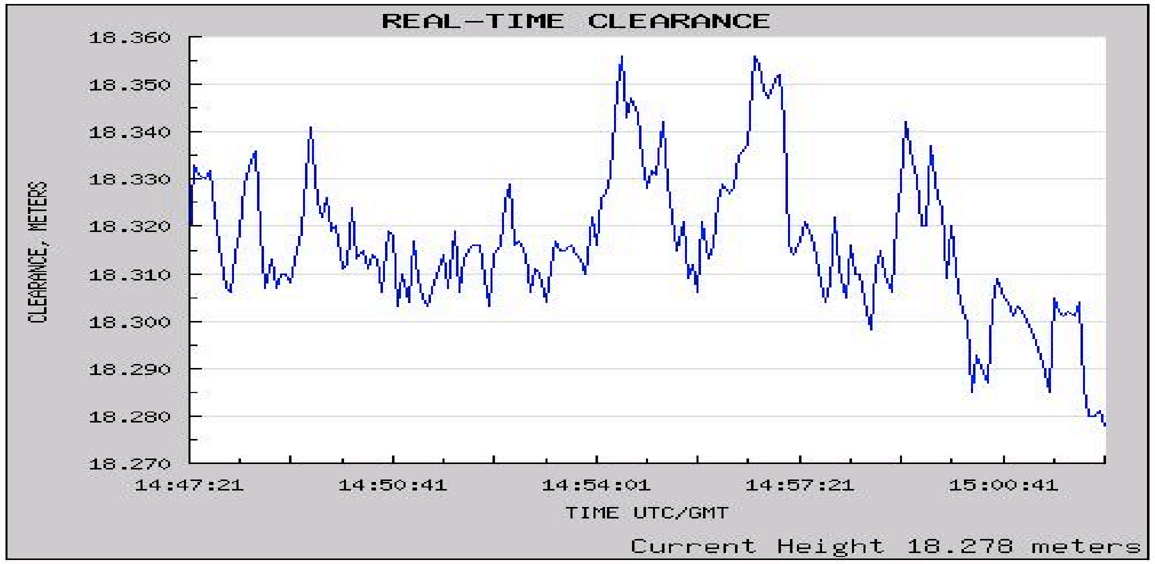

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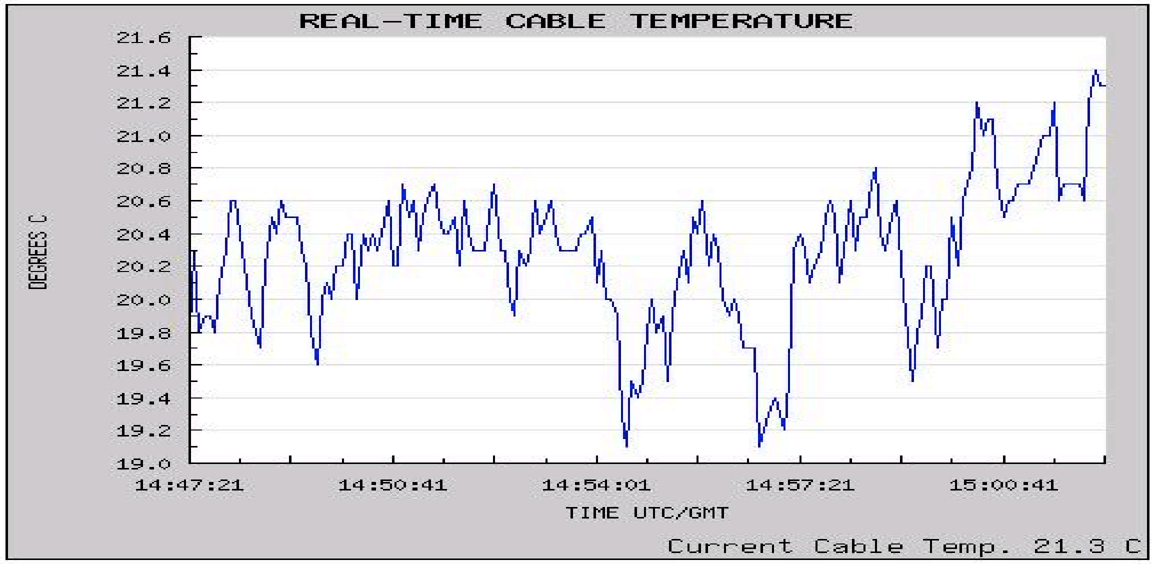

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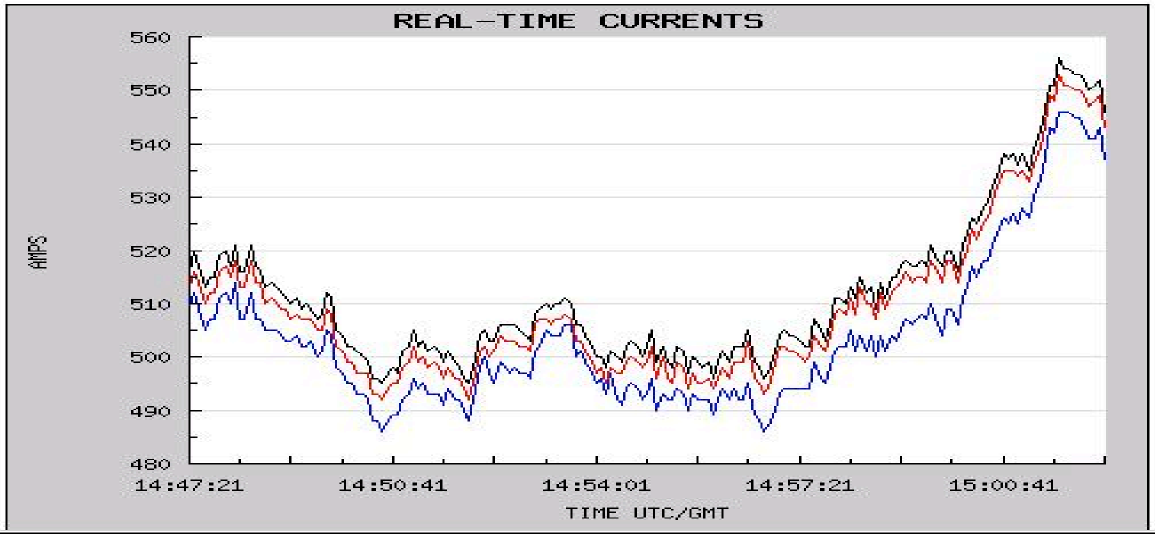

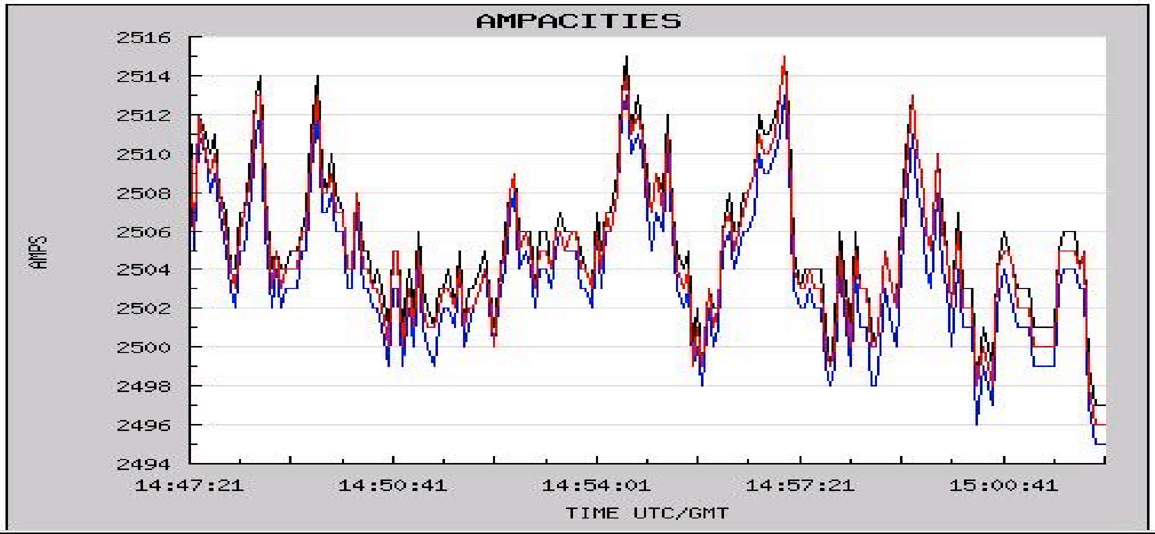

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