Non-Contact/Invasive Sensor System for Real-time Transmission Line Monitoring & Optimization

Prometheon Devices

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DOE Phase II SBIR Contract: DE-FG02-05ER84159
DOE Project Manager/Officer: Mr. Gil Bindewald

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Mr. Steven J. Syracuse, President & Chief Technology Officer
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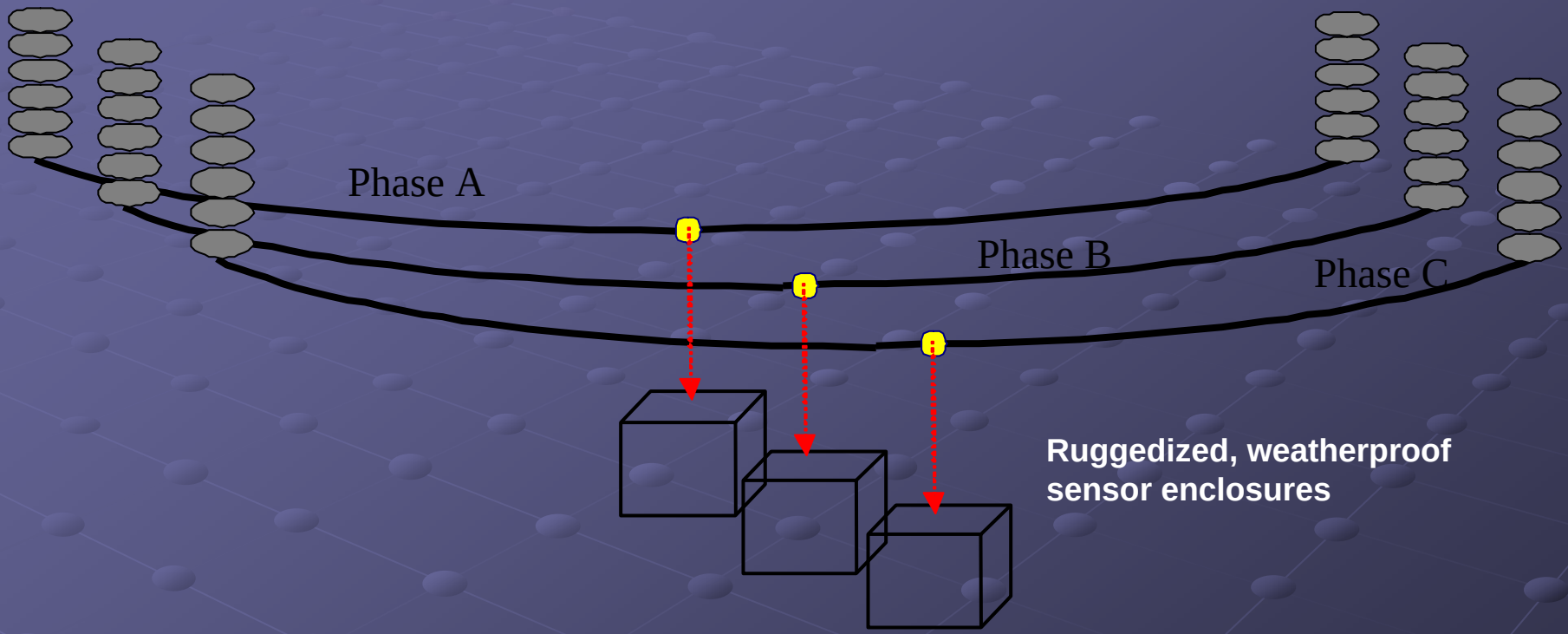
Technology Description: RTTL-Monitoring System

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

RTTL-Monitoring System: Features and Advantages

- **Entirely non-contact/invasive configuration, deployment, installation, calibration, and operation.**
- **Fully secure (AES-encrypted) wireless, real-time communication of all critical operating parameters.**
- **High reliability/longevity, proven, off-the-shelf solar-battery power supply.**
- **Designed for remote, autonomous, reliable *field-and-forget operation*.**
- ***Does not require* specialized equipment and/or utility field crew presence/participation/supervision for installation and/or calibration.**
- ***Does not require* outages for installation, calibration, & maintenance.**
- **Operation and Accuracy *not adversely affected* by rain, wind, fog, smoke, hail, snow, ice, or any combination thereof.**
- **Capable of direct burial and physically secure, subsurface operation.**

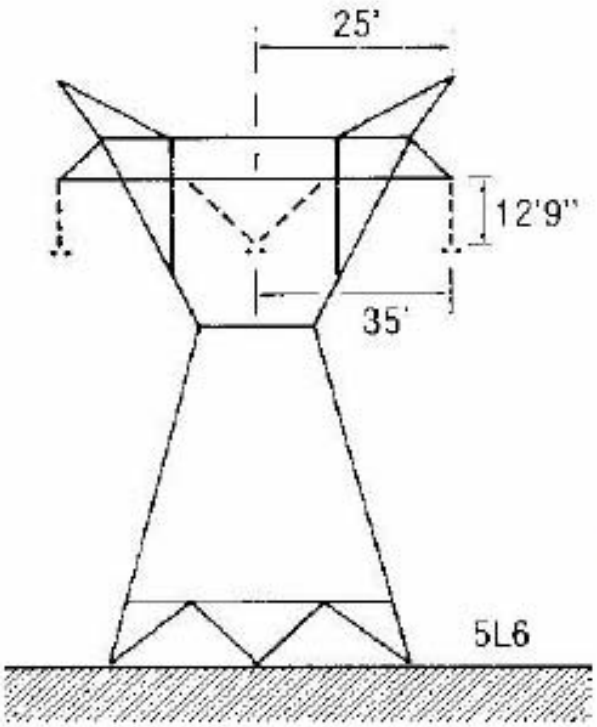
Simplified RTTL-Monitoring System Field Arrangement



Ruggedized, weatherproof sensor enclosures

Transducers are located in enclosures under the nadirs of the 3 overhead phase conductor spans, A, B, and C, at, or just below, ground level.

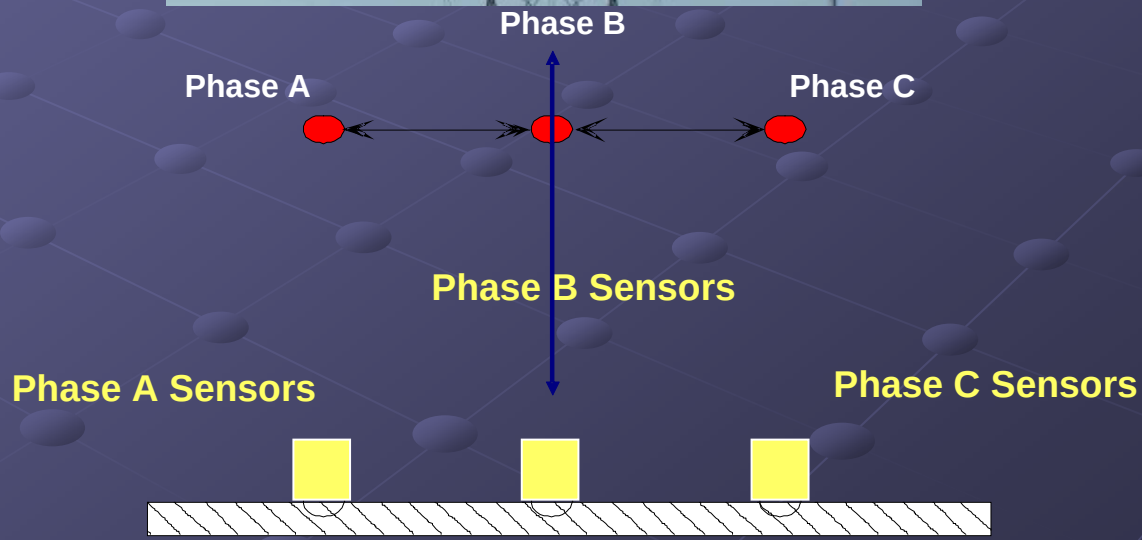
Pilot Test Site: Duke Energy Newport-Richmond 500 kV Tie



Duke Energy Newport-Richmond 500 kV Tie

Fort Mill, SC.

Simplified Cross-Sectional Layout: RTTL-Monitoring System



RTTL-Monitoring System Field Hardware 3/07:

Surface Deployment; Battery/Laptop-based Operation

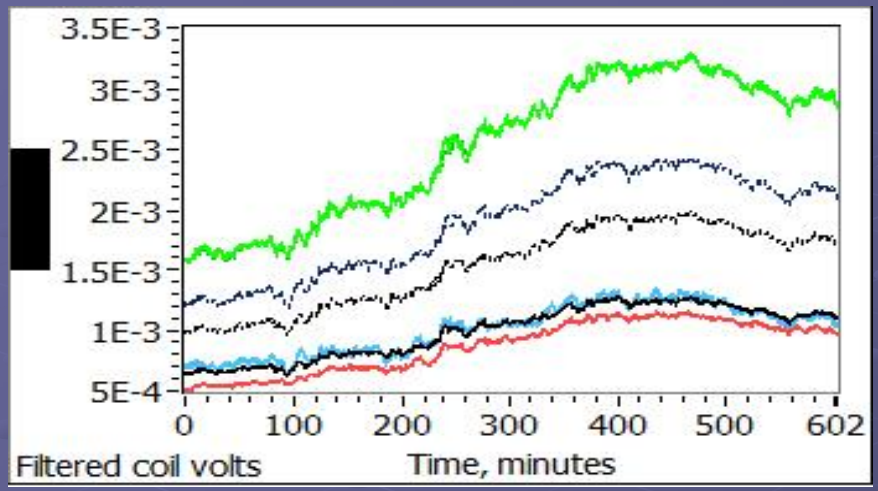
Field Transducers Sub Phase A (foreground), B, & C

Front End Analog and ADC Electronics Package

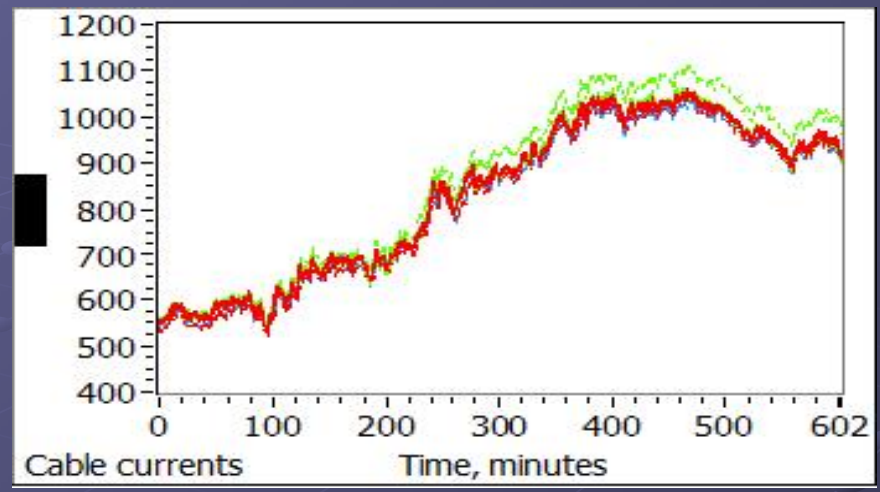
Detail of Field Transducers Located Sub Phase C

Laptop-based Data Acquisition, Signal Processing, Analysis, Data Display, and Logging

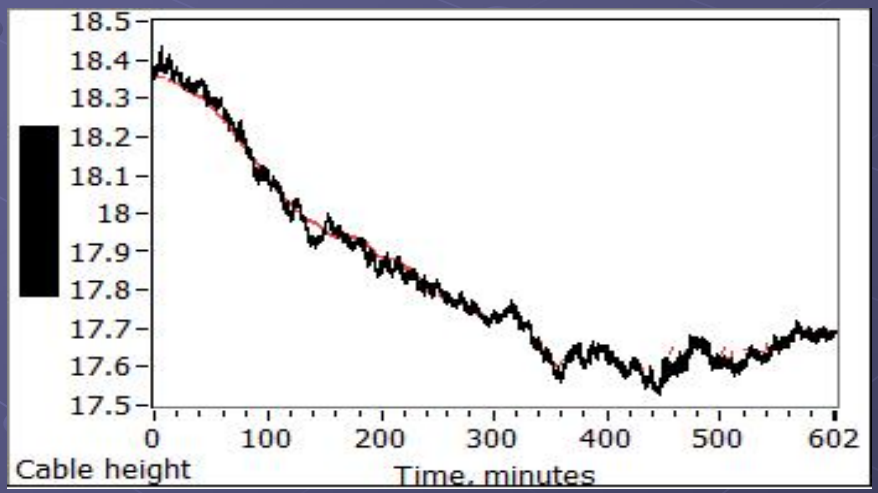
RTTL-Monitoring System Detail: Laptop Field Display



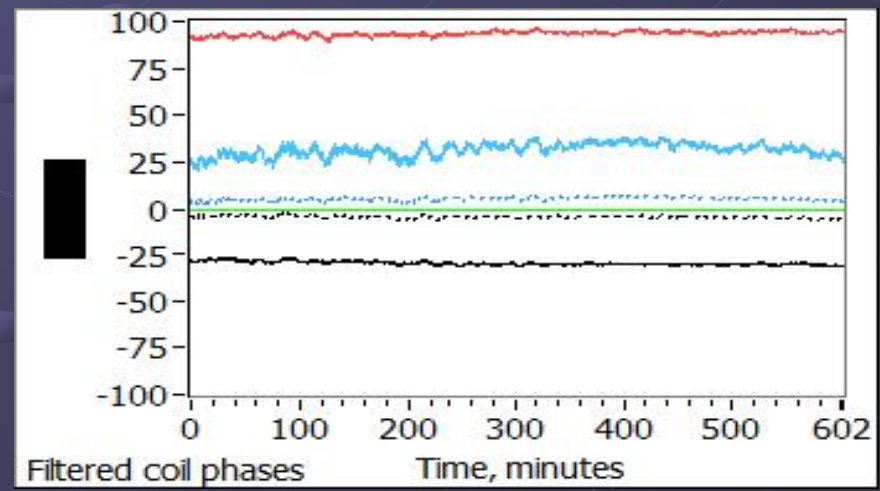
Transducer Outputs: Voltage



Computed Phase Currents



Computed Conductor Clearance

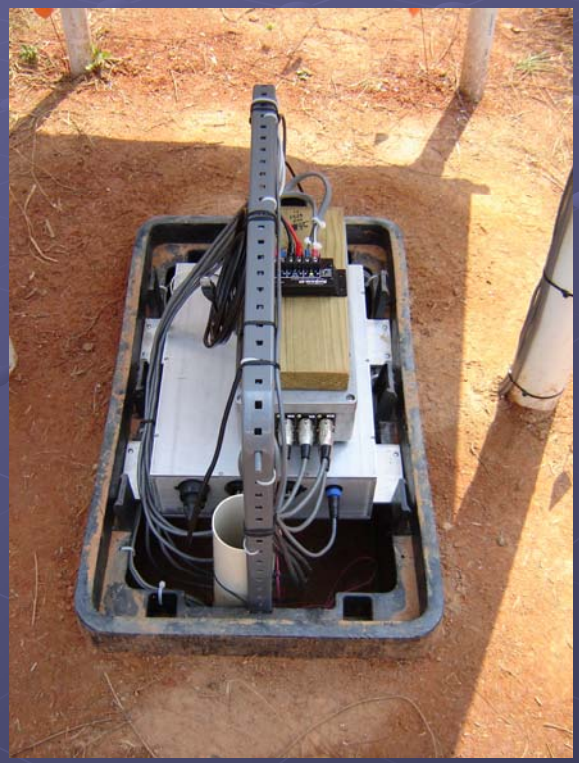


Transducer Outputs: Phase

RTTL-Monitoring System Field Hardware 9/07:

Sub-surface deployment; fully autonomous operation

Field Transducer Direct Burial Sub Phase B



System Field PC, Power Supply, and Front End ADC & Electronics Package

Detail of Transducer Enclosure sub Phase C

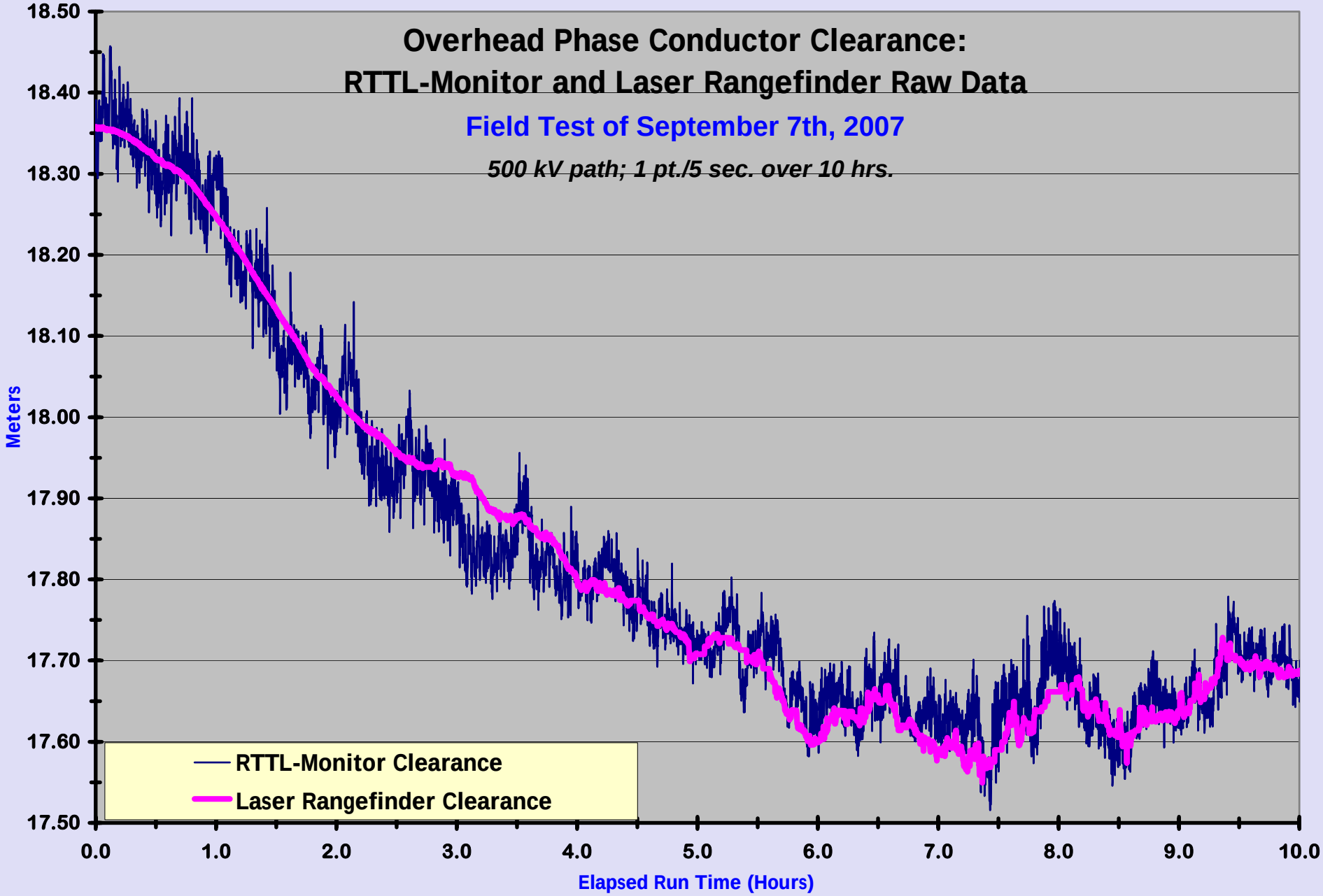
Field PC-Based Data Acquisition, Signal Processing, Logging, & Fully Secure, Encrypted, Wireless Communications

RTTL-Monitoring System in Place & Operating sub Newport-Richmond 500 kV Tie

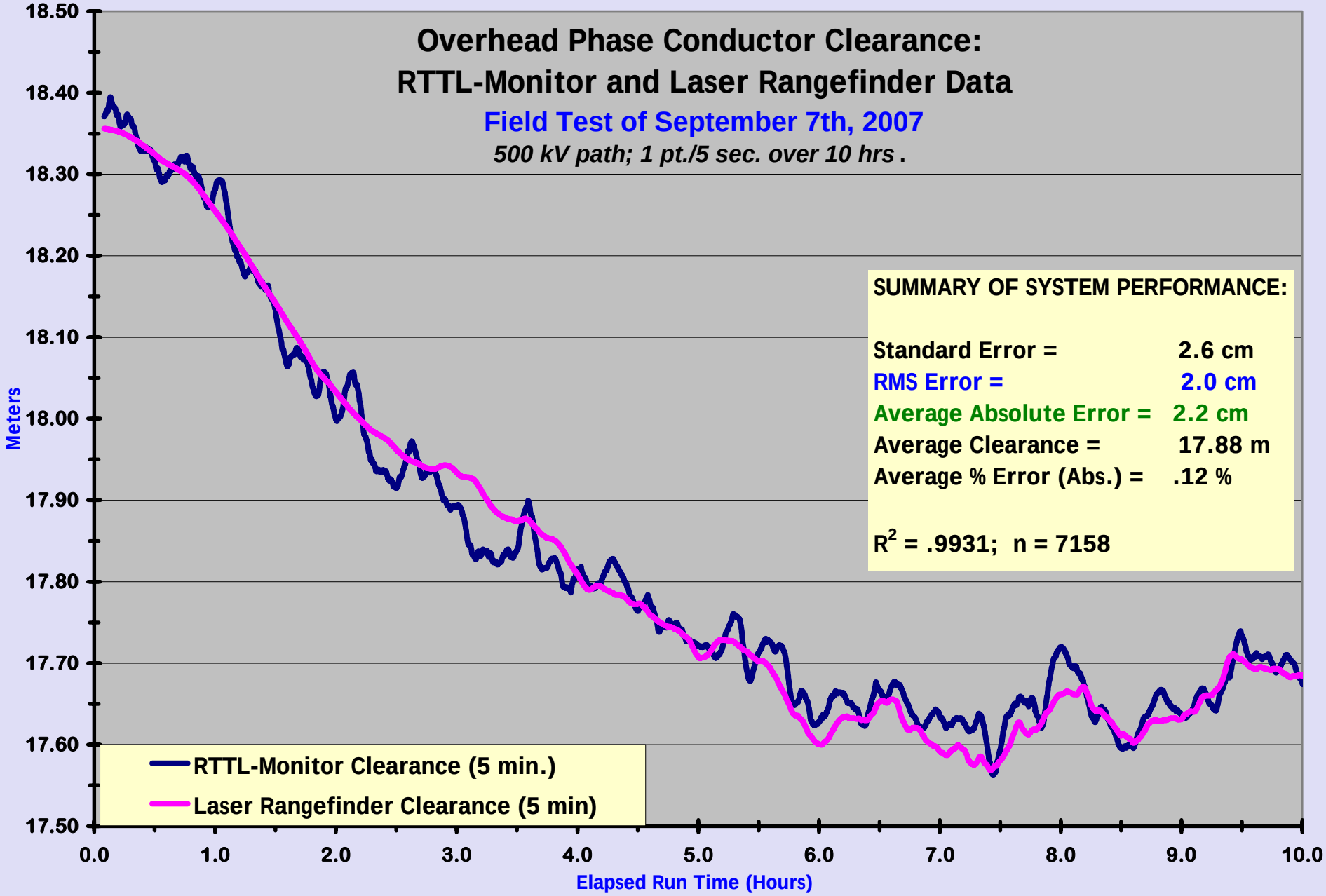
RTTL-Monitoring System Performance (10/2007)

- **Phase Conductor Height/Clearance/Sag**
  - Accuracy = 3 cm, or ~ 0.10%, @ ~ 18 m.
    - ✓ Design goal of 1% Accuracy
  - RTTL-Monitor - Laser Rangefinder clearance correlation = 99.3%
- **Phase Conductor Currents**
  - System can discriminate and measure individual phase conductor currents
  - Accuracy = 9 amps, or ~ 0.80%, @ ~ 830 A.
    - ✓ Design goal of 1% Accuracy
  - Duke Energy CT – RTTL-Monitor current correlations @ 99.93%
- **Phase Conductor Temperature**
  - Developed Clearance vs. Max. Conductor Temperature Calibration
    - R^2 > 99.1% for 34 field measurements taken through 9 04 2007
    - Based on analysis of HR IR images, each capturing 4 m of OH conductor.
    - Accuracy (preliminary) = ± 3.5 C
    - Design goal of ± 2 C. Accuracy

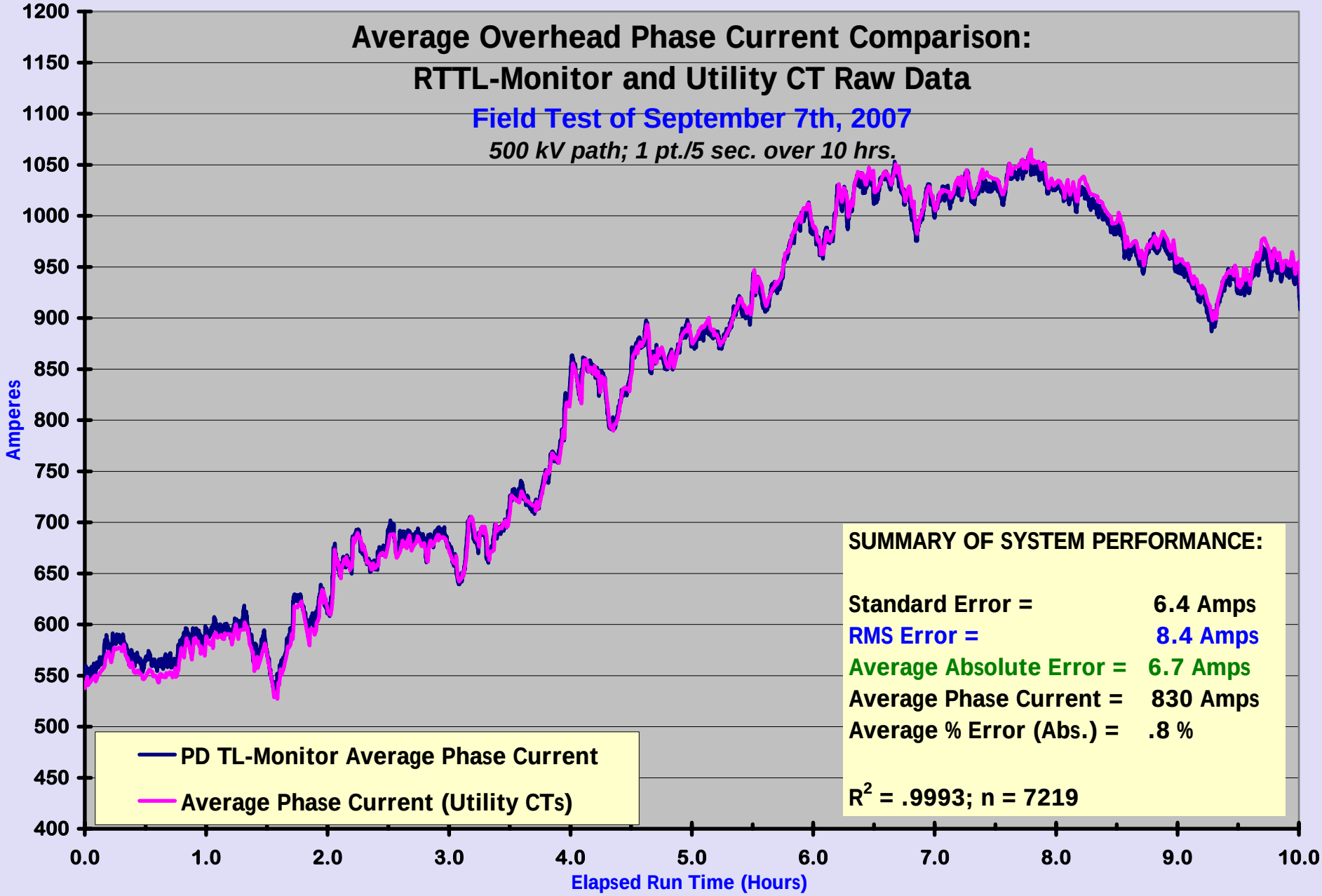
System Performance: Phase Conductor Clearance



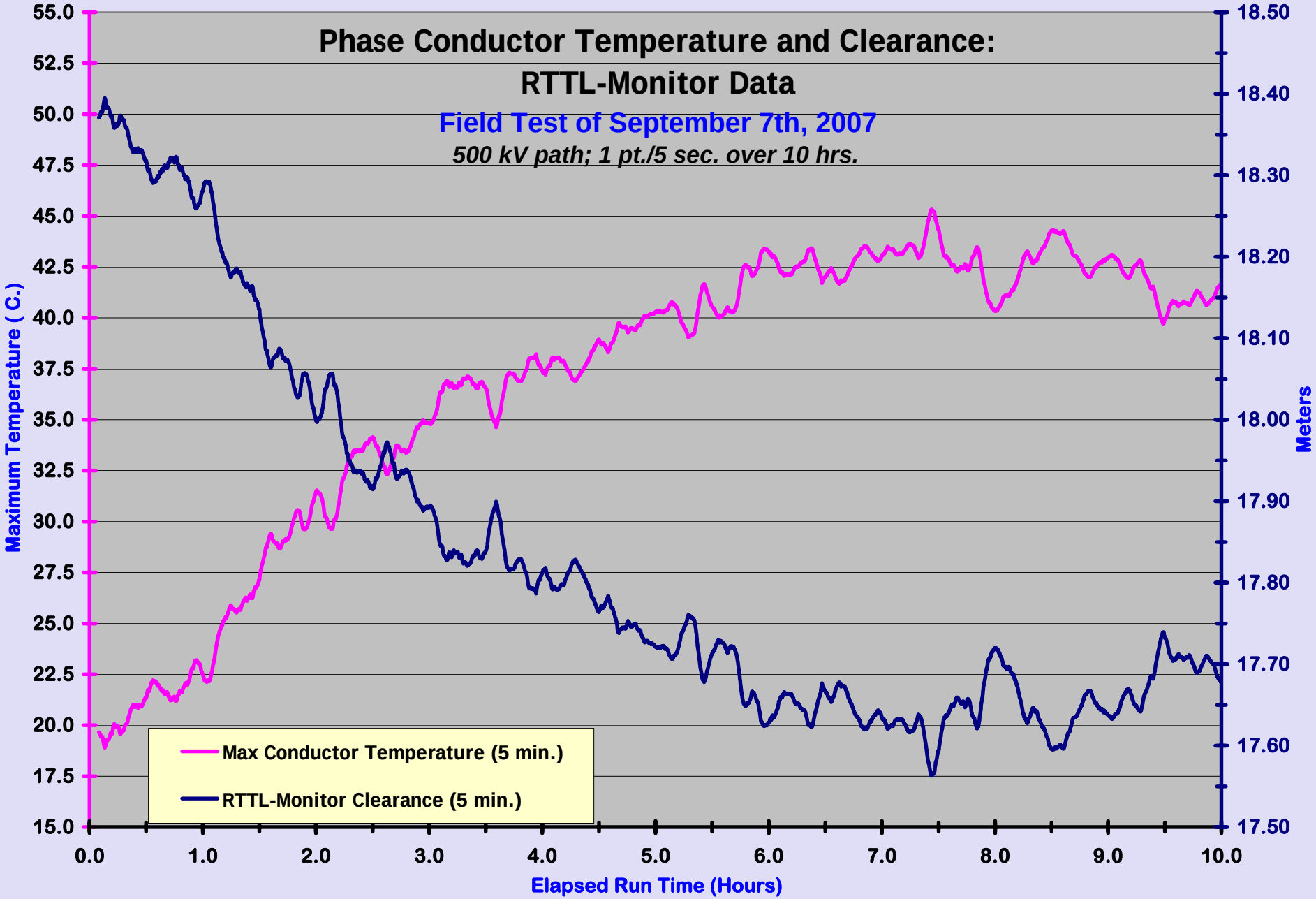
System Performance: Phase Conductor Clearance



System Performance: Phase Conductor Current

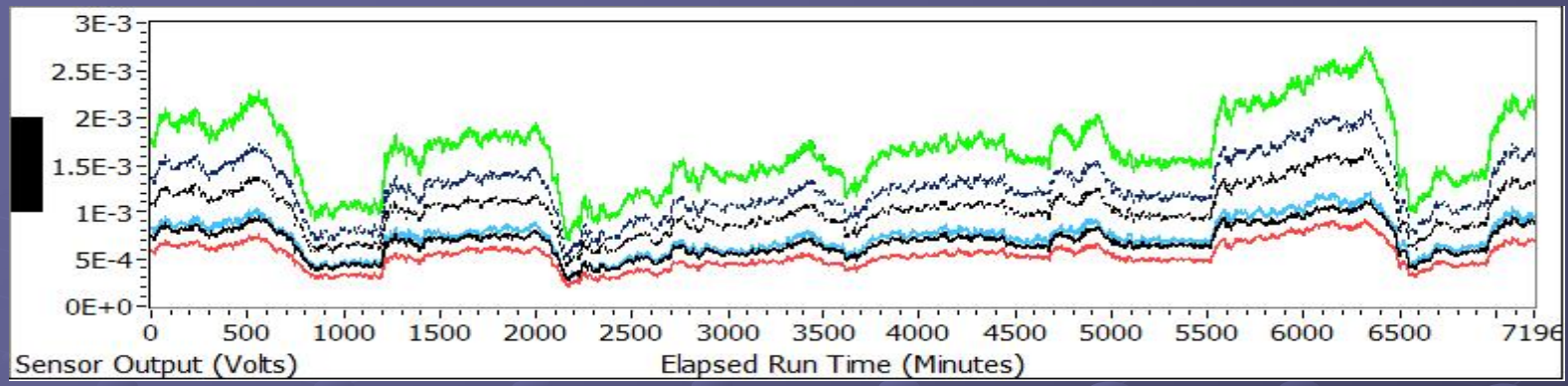


System Performance: Phase Conductor Temperature



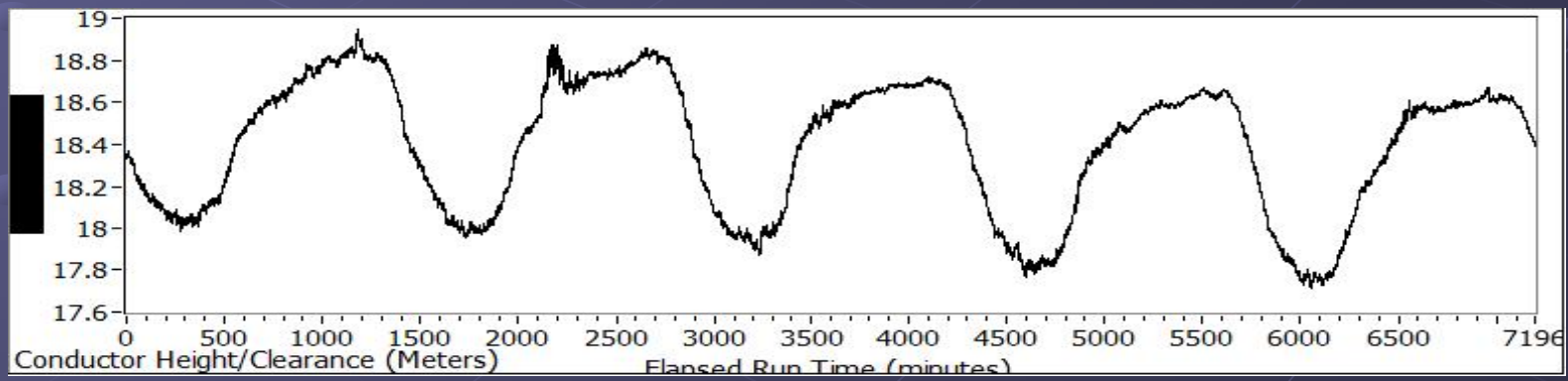
RTTL-Monitoring System: Long Term Field Performance

Transducer Outputs (Volts)



Computed Phase Currents (Amps)

Computed Conductor Height/ Clearance



Recent System Research

- **Phase Angles based on Phase Current Waveform Processing**
  - Monitor absolute current vector phase angles
    - System determines the absolute and relative phase angles to .1 degrees
    - Clear discrimination of three individual phase conductors
    - Can resolve phase angles to .01 degrees
- **Frequency based on Phase Current Waveform Processing**
  - Added frequency tracking based on phase current waveforms
    - System determines the relative frequency to .01 Hz
    - Clear discrimination of three individual phase conductors
    - Can resolve 1 mHz, or better
    - Currently referenced to internal System Clock
    - Needs to be referenced to GPS time/frequency Standard

Present Efforts & Near-Term Goals: 10/07 – 8/08

- **Conduct Long-Term, Unattended, Self-Powered, RTTL-Monitoring**
  - ✓ *Transition from Laptop to Solar/Low-Power Field PC Platform (7/2007)*
  - ✓ *Underground system and secure PC/Electronics/Power Supply on-site (7/2007)*
  - ✓ *Long term testing commenced 10/2007*
- **Implement Secure Web Interface to Enable RT Reporting to End-Users**
  - ✓ *Implement Fully-Wireless Command, Control, and Communications (10/07)*
  - **Develop and deploy secure web-display; add Sag to display (11/07)**
  - **Develop and deploy secure End-User interface (12/07)**
- **Complete Ampacity Algorithm Development, Implement, and Test/Validate**
  - ✓ *Complete instantaneous Ampacity algorithm (11/07)*
  - **Develop predictive Ampacity Algorithms: 15 m; 30 m; 45 m; Emergency**
  - **Implement in Secure End-User Web Interface (12/07 - 1/08)**
  - **Test against IEEE 738, the CIGRE Standard, and SAG10 (1/08 - 4/08)**
- **Conduct Long-Term Validation of Sag/Clearance, Phase Current, and Temperature Accuracy**
  - **Test/Validate against IEEE 738, the CIGRE Standard, and SAG10 (1/08 - 4/08)**
- **System Performance Improvements:**
  - **Improve Conductor Temperature Accuracy to ± 2° C. (2/08 - 4/08)**
  - **Develop RT Dynamic Rating Algorithms: Instantaneous; 15 m; 30 m; 45 m; Emergency**
  - **Develop cumulative time at temperature and time at sag/clearance histograms**
- **Determination & Long-Term Validation of Resolution & Precision of Sag/Clearance, Phase Current, and Maximum Conductor Temperature**

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