

DOE/OE Transmission Reliability Program

Advanced Applications R&D

Powerline Conductor
Accelerated Testing (PCAT)

Principal Investigator: Philip Irminger

Oak Ridge National Laboratory

irmingerp@ornl.gov

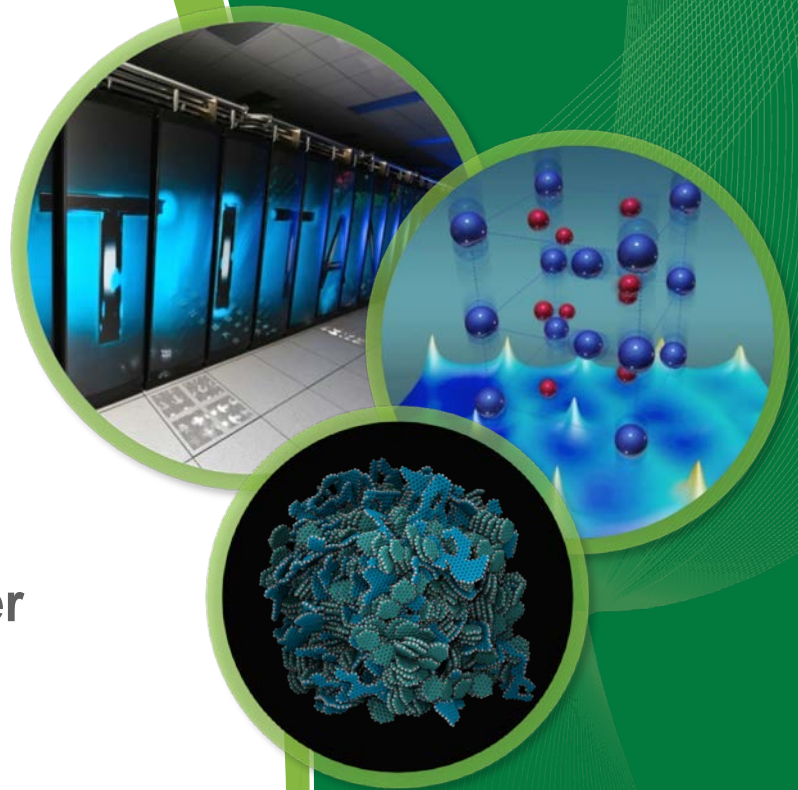
Team: Dan King, Drew Herron, Zhi Li,

Ben Ollis, Mark Buckner, Joe Gracia

June 7- 8, 2016

Washington, DC

Current Vendor: General Cable with E3X coating



Topics to Address

- Recap on what is PCAT and why is it here?
- Previous Capabilities & Challenges
- Status of Current Upgrades & General Cable E3X Test Results & planned testing



Recap - History: Powerline Conductor Accelerated Testing Facility – Why is it here?

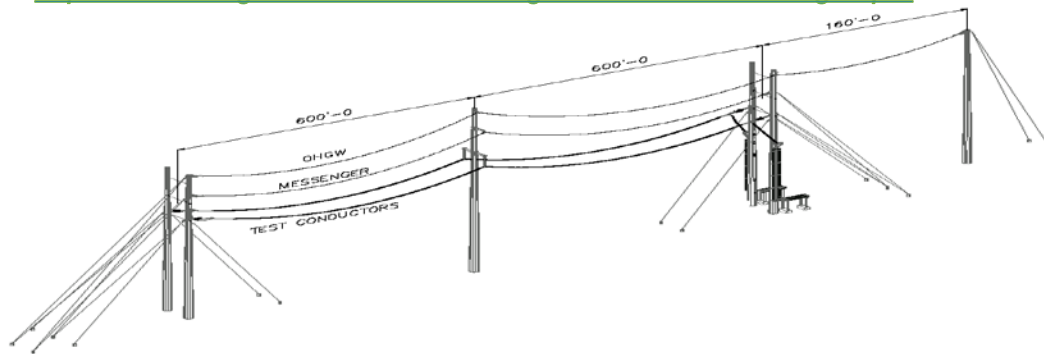
2002 - National Transmission Grid Study

- One of the 51 Recommendations -

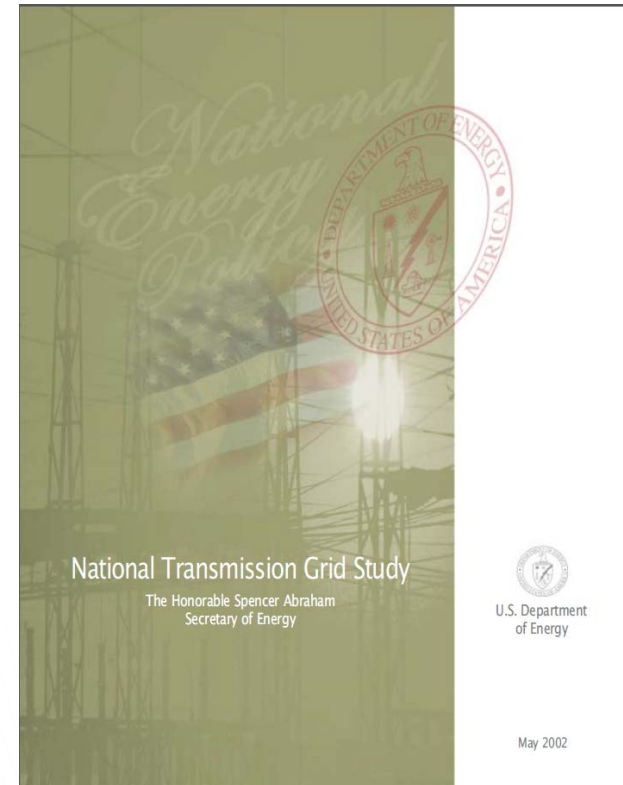
“DOE will develop national transmission-technology testing facilities that encourage partnering with industry to demonstrate advanced technologies in controlled environments.

Working with TVA, DOE will create an industry cost-shared transmission line testing center at DOE 's Oak Ridge National Laboratory (with at least a 50 percent industry cost share).”

<http://www.ferc.gov/industries/electric/gen-info/transmission-grid.pdf>

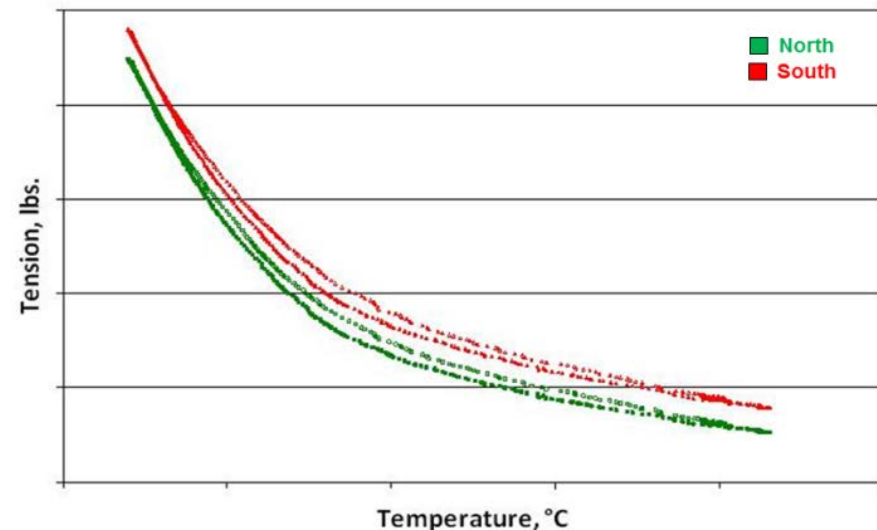
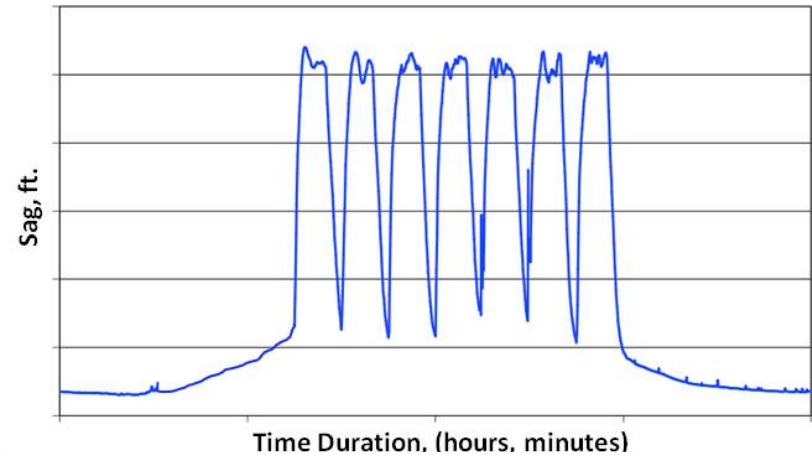


Originally built for the 3M Composite Conductor development, now available for any manufacturer to validate their product.



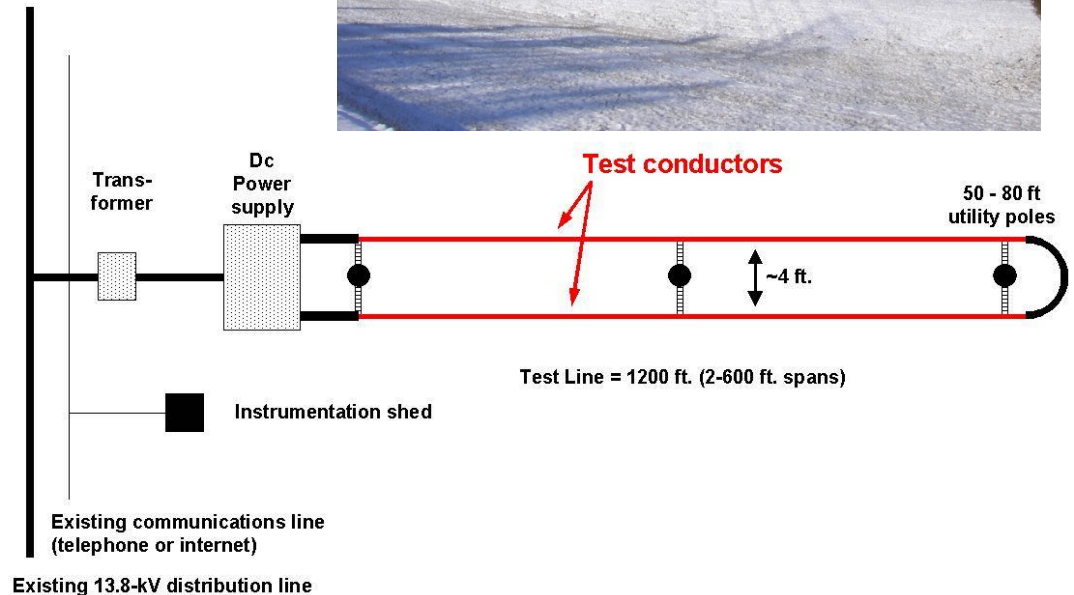
Recap: Past Accomplishments

- PCAT has been in operation for over 10 years
- The PCAT facility has been used to test many different conductors and sensors:
 - 3M 477 kcmil ACCR
 - 3M 675 kcmil ACCR
 - Southwire 1113 kcmil ACSR FO
 - Power Donut2
 - 3M 1272 kcmil ACCR
 - 3M 795 kcmil ACCR
 - Southwire C7 Overhead Conductor
 - Currently General Cable E3X Coated Conductor

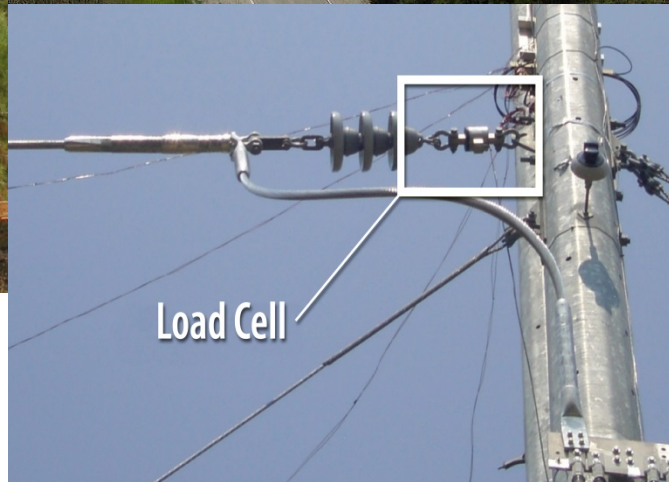
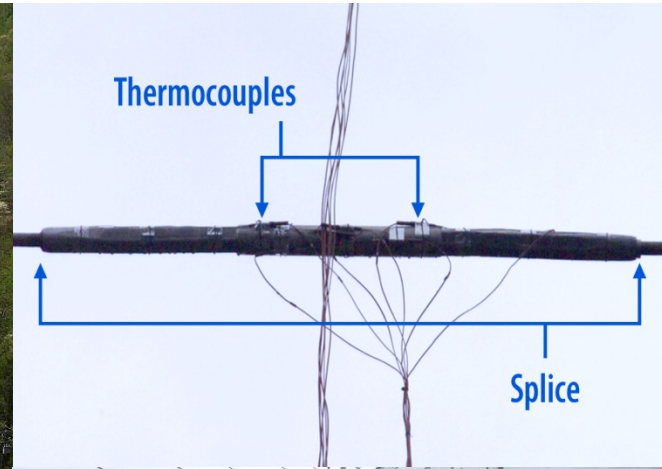
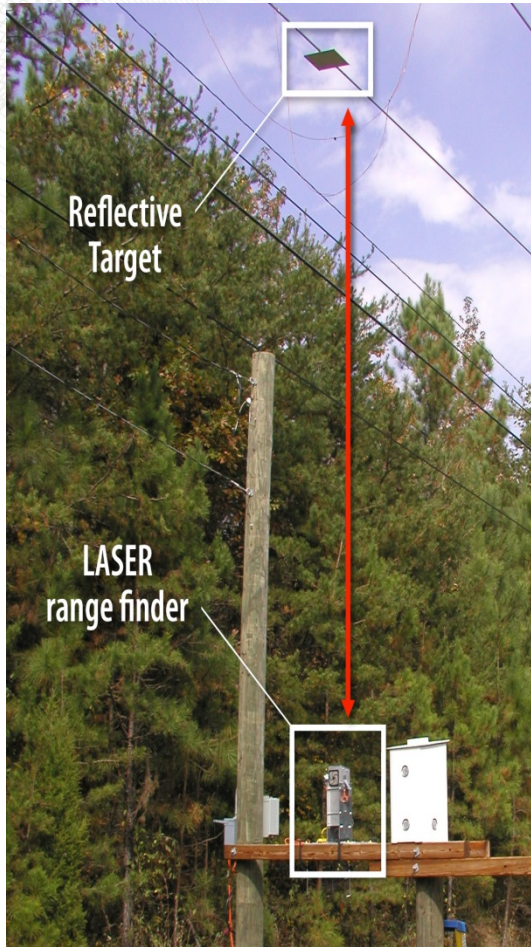


Recap - Capabilities: Powerline Conductor Accelerated Testing Facility

- Testing Capabilities
 - Thermal / Mechanical Cycling
 - Current / Temperature Ramp
 - Current / Temperature Steps and Hold
 - Controlled current testing
 - Controlled temperature testing
- Facility
 - 2400 feet of conductor
 - two 600 foot spans
 - 3 towers
 - 0 to 400 Vdc
 - 0 to 5,000 Adc
 - Conductor and accessories
 - Tested up to 300°C
 - can go higher if needed



Recap: Existing Infrastructure



Recap: Conductors are installed by TVA using conventional industry practices



Typical installation is ~ 3-4 days



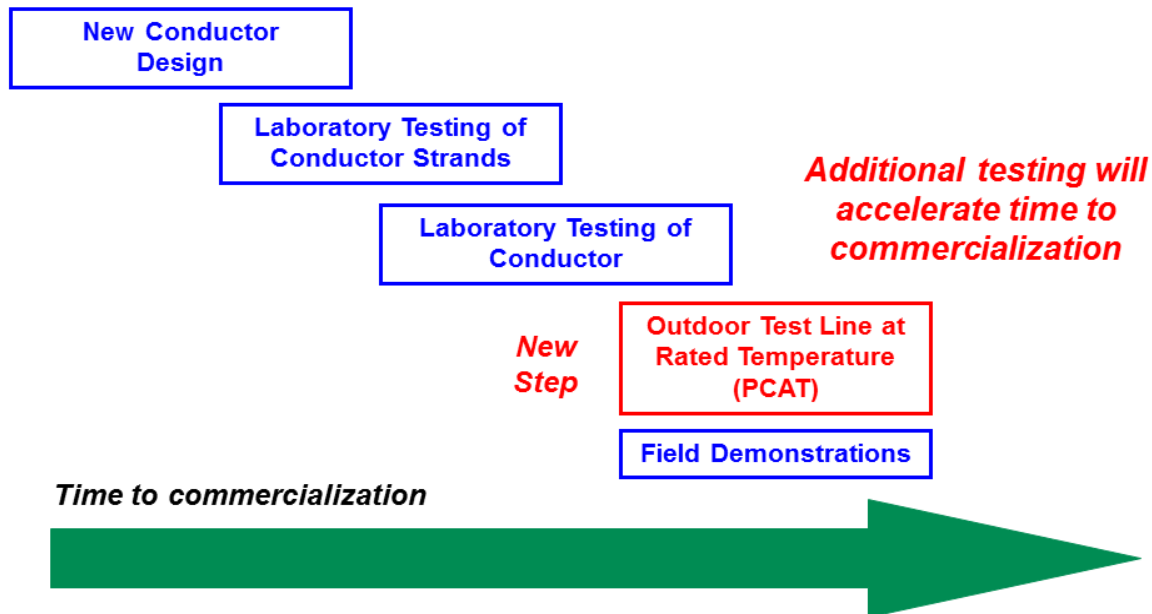
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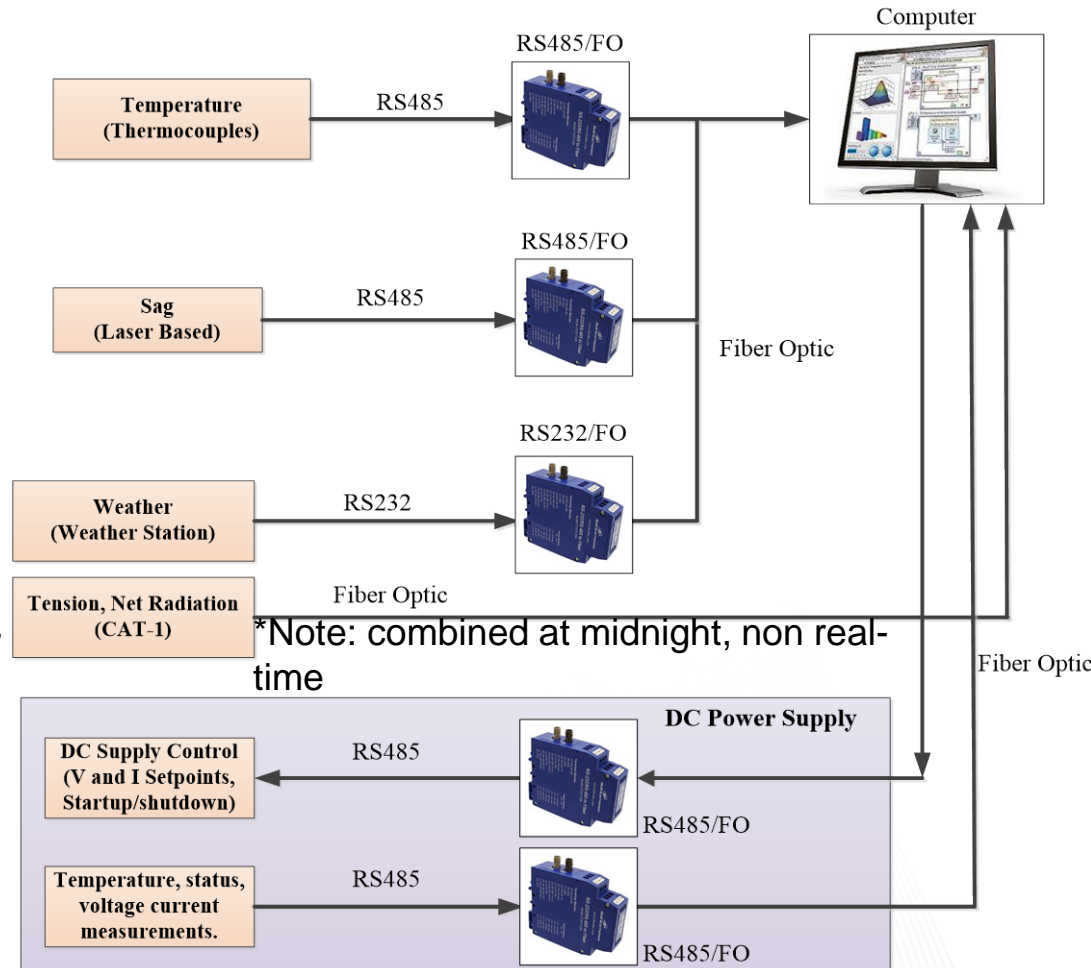
Where PCAT fits?

- PCAT provides a unique transmission conductor testing facility to augment utility field tests and demonstrations
- Each conductor test undertaken in collaboration with industrial partner



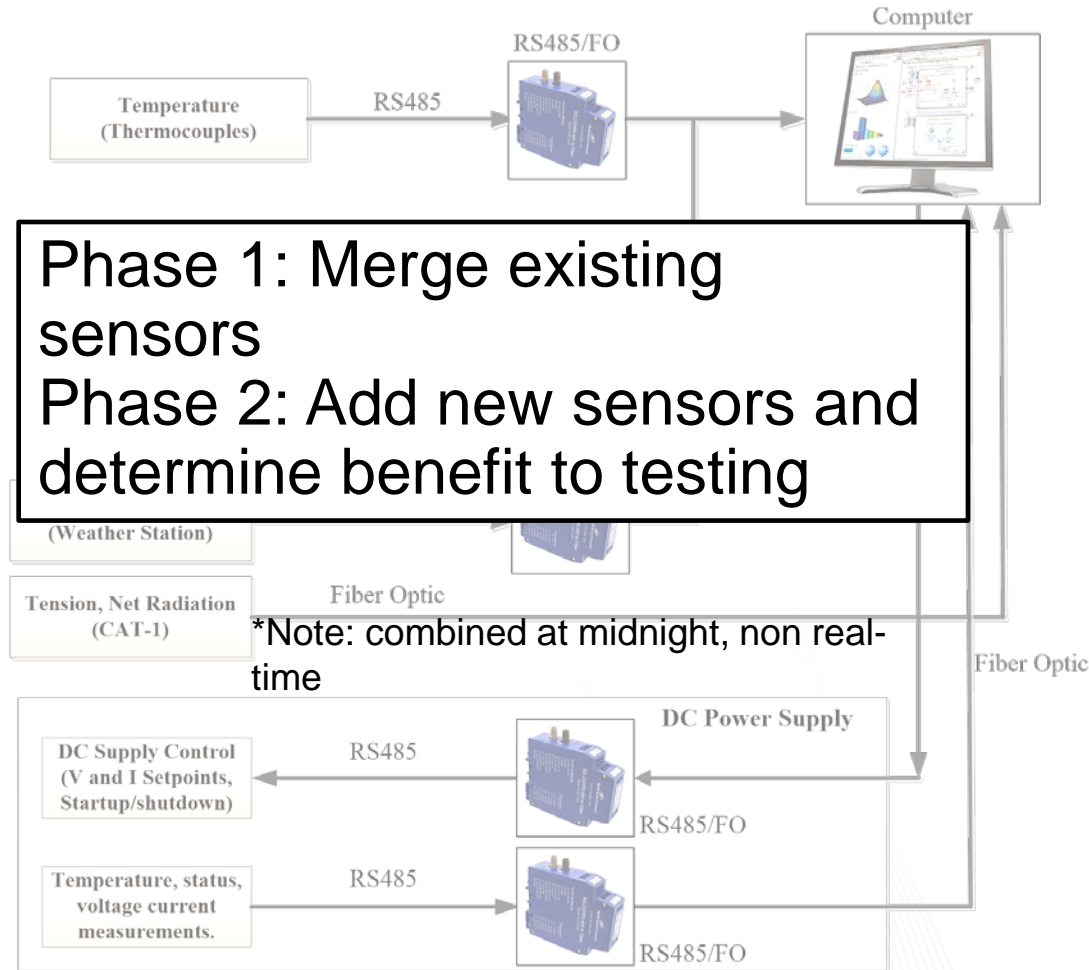
Historical Data Collection – Visual Basic

- Conductor/accessory temperature
 - Surface contact or conductor core
 - Up to 128 thermocouples
- Applied current and voltage
 - Measured by power supply
- Conductor sag
 - Laser at mid-span
- Conductor tension
 - Load cells on both circuits
- Weather
 - Ambient temperature, wind speed, wind direction
 - Conductor net radiation sensor
- PC-based data acquisition system
 - 10 second polling, 1 minute data archive



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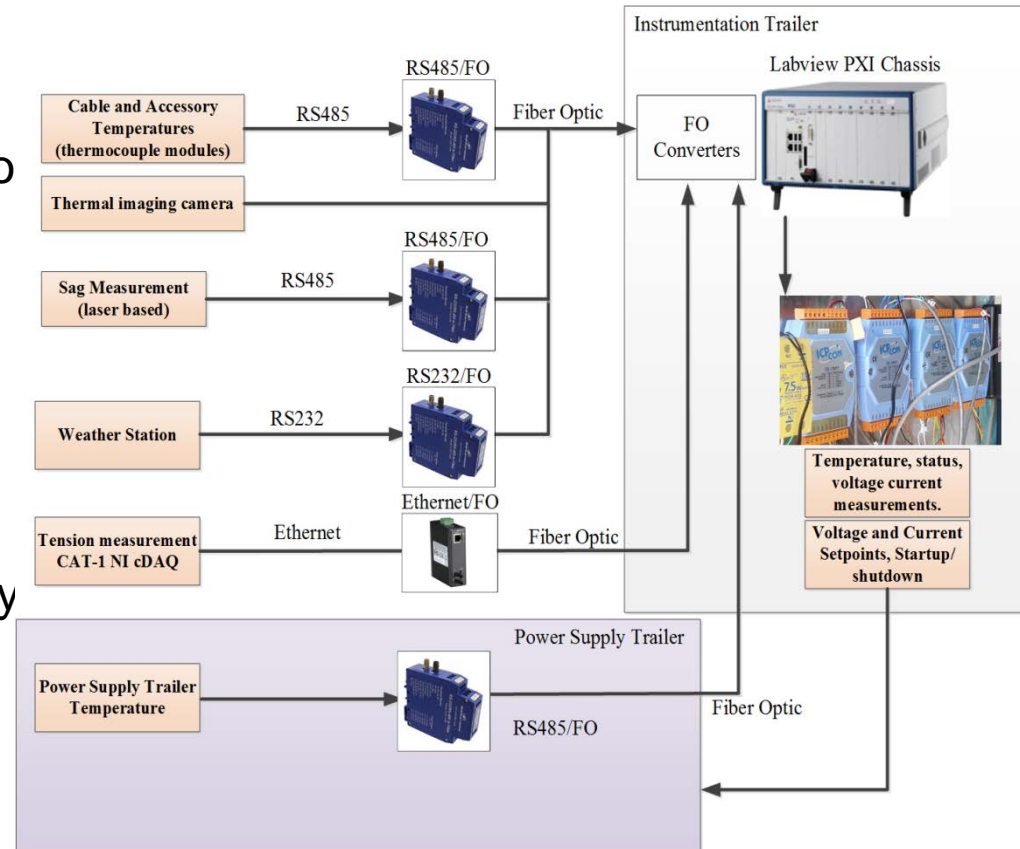
Historical Challenges to Testing

- Lightning strikes have damaged many sensors
- System lacked flexibility to adapt test plans and analysis to meet specific vendor needs:
 - Legacy software was in Visual Basic, original programmer has since retired.
 - 9 different sets of VB files
 - Many isolated locations in order to modify tests
- Measurement resolution
 - Inability to investigate short duration phenomena
- Inability to detect bad data
 - Unable to validate measurements using multiple sources (diverse measurement technologies)



Current Activities

- Rehabilitating PCAT Data Acquisition, Controls, and Visualization:
 - Enabled CRC Checksum on all DCON modules
 - Full transition from Visual Basic to LabVIEW.
 - Integrated thermal imaging of conductor
 - Replaced CAT-1 system with NI cDAQ
 - Improved User Interface, Control Modes and Playback Functionality
- Continue testing
 - Currently testing General Cable ACSS Drake 795 Conductor
 - One side coated, One side non-coated
 - Plans to do a swap out of conductor at end of cycling.



Thermocouple Upgrade

- Thermocouple modules all updated to I-7018-R modules
 - Higher rating, so far no failures in past year
- Every channel individually checked to ensure valid identification and labeling
- Added open circuit thermocouple detection to the module enabling identification of unused thermocouples
- Enabled CRC checksum in the module and code to minimize bad data



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CAT-1 Challenges and Opportunities

- Sensors provided great interface for Tension, Wind, and Temperatures
 - Designed for low resolution status updates across a system
 - Designed for a cell modem connection with console interface
 - Relied on solar panel and battery to remain operational
 - Expensive to add at other end of line
 - Overdesigned in non-beneficial ways for our use
-
- **Were able to integrate into a direct connect NI cDAQ system using existing sensors**



CAT-1 Replacement

- 4 slot NI cDAQ
 - Utilize ethernet to fiber converter and existing fiber connection
- NI 9237 for Tension Measurement
- NI 9219 for Thermistor measurements and Voltage measurements
 - Ambient Temperature
 - Net Radiation Sensor
 - Wind Direction
 - Wind Speed
- **Can easily duplicate setup at end tower**



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Selected Thermal Camera

- Purchased A310f 15° FLIR Camera



Planned Installation Site
2nd at other end once
validated



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Camera Integration

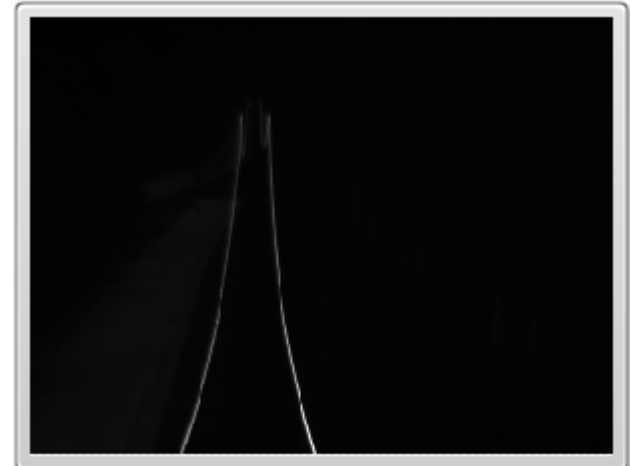
- Shroud to minimize impact of solar and weather



- Mid-cycle, conductor heating up

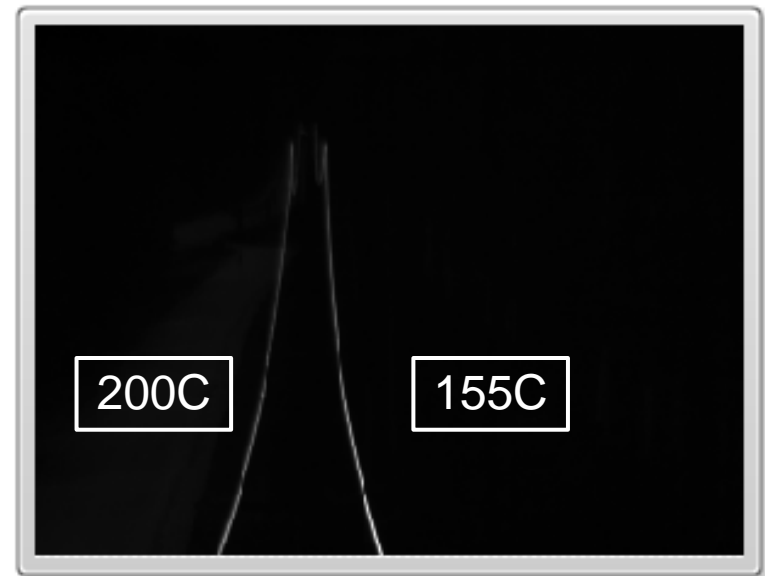


- Conductor fully heated

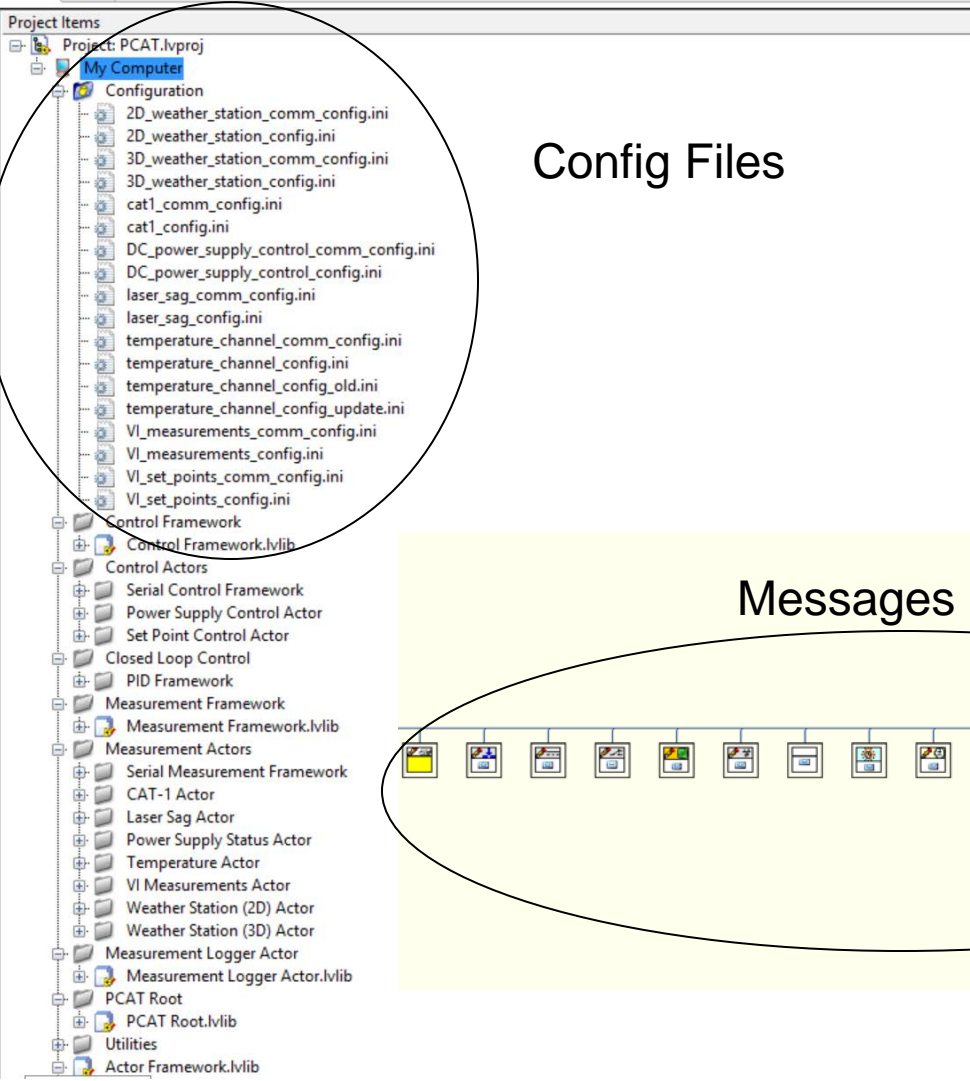


Camera Hurdles

- In order to view the section of line, it is a very wide field of view
- Emissivity of the coated and uncoated conductors are different leading to misrepresentation of temperature
- Road and surrounding objects appear hotter at low temperatures
- Picture is highly dependent on threshold values
 - Currently set to dynamic based upon highest temperature
 - Plan to experiment with fixed threshold



PCAT LabVIEW implementation using Actor Framework



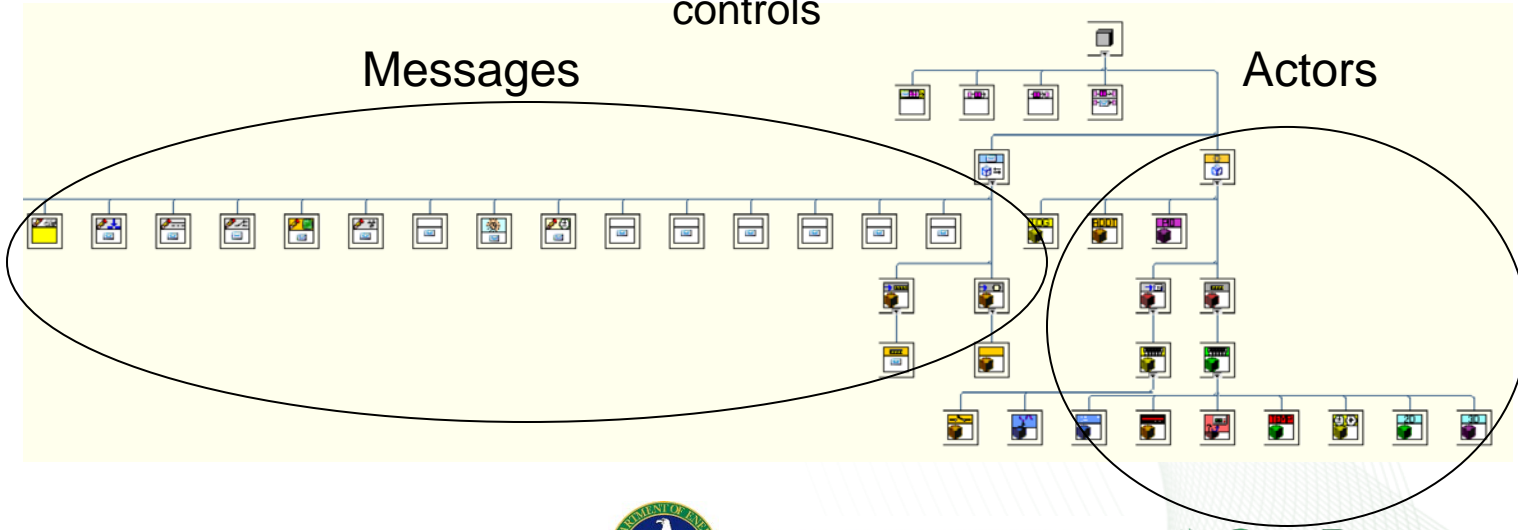
Config Files

Advantages

- Measurements, processing, and controls performed asynchronously and in parallel
- Allows adding new measurement or control capabilities without affecting current functionality
- Enables rapid development of additional measurements and new controls

Messages

Actors



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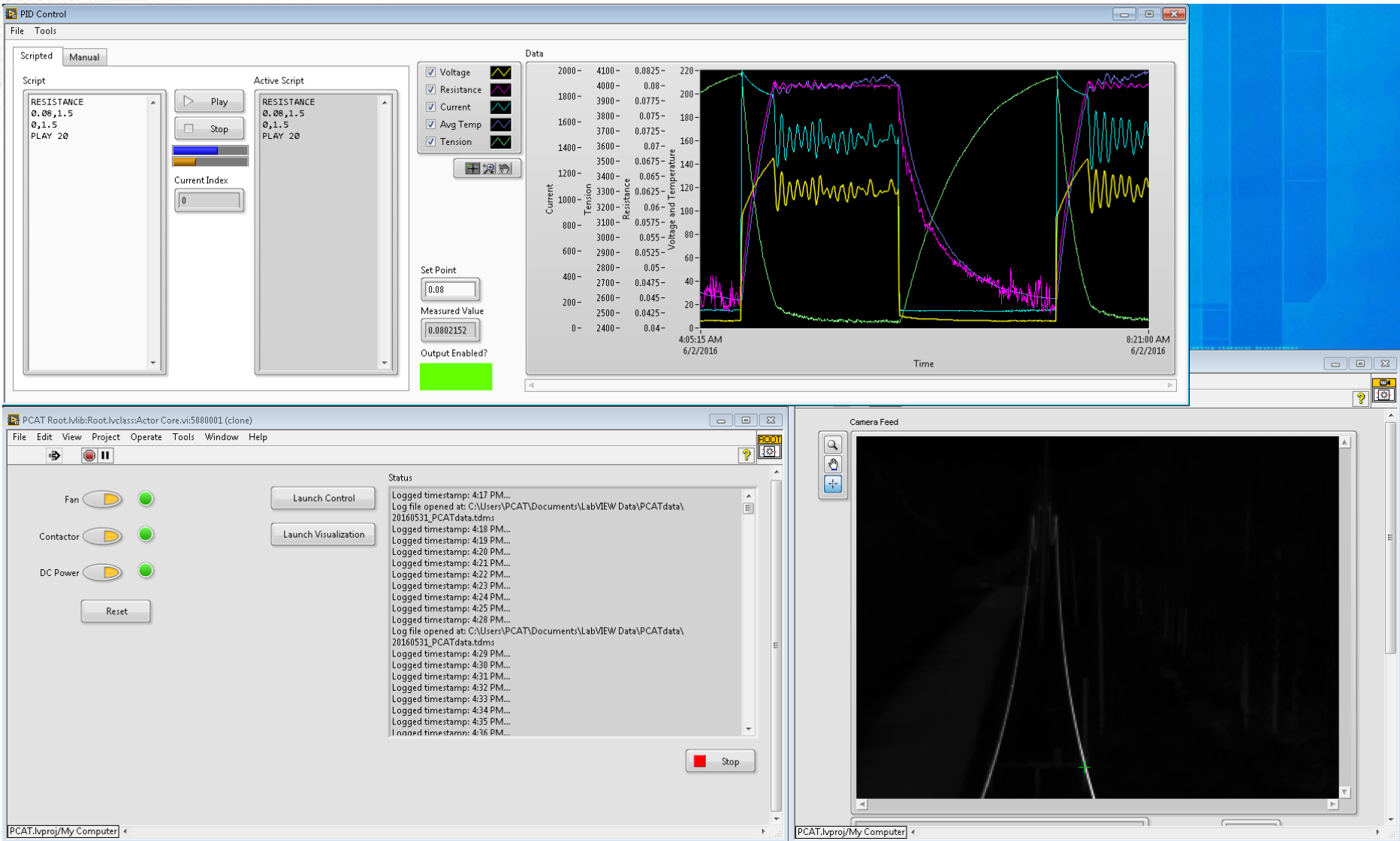
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Added/Supported Control modes

- Event classification
 - Enables parsing of data for particular tests along with description of test
- Constant Resistance
 - Directly correlated to temperature
- Constant Current
- Constant Tension
 - Directly correlated to temperature of each side
 - Ability to control to parameters of either side
- Constant Temperature
- Scripted Operation
- Repeat Capability

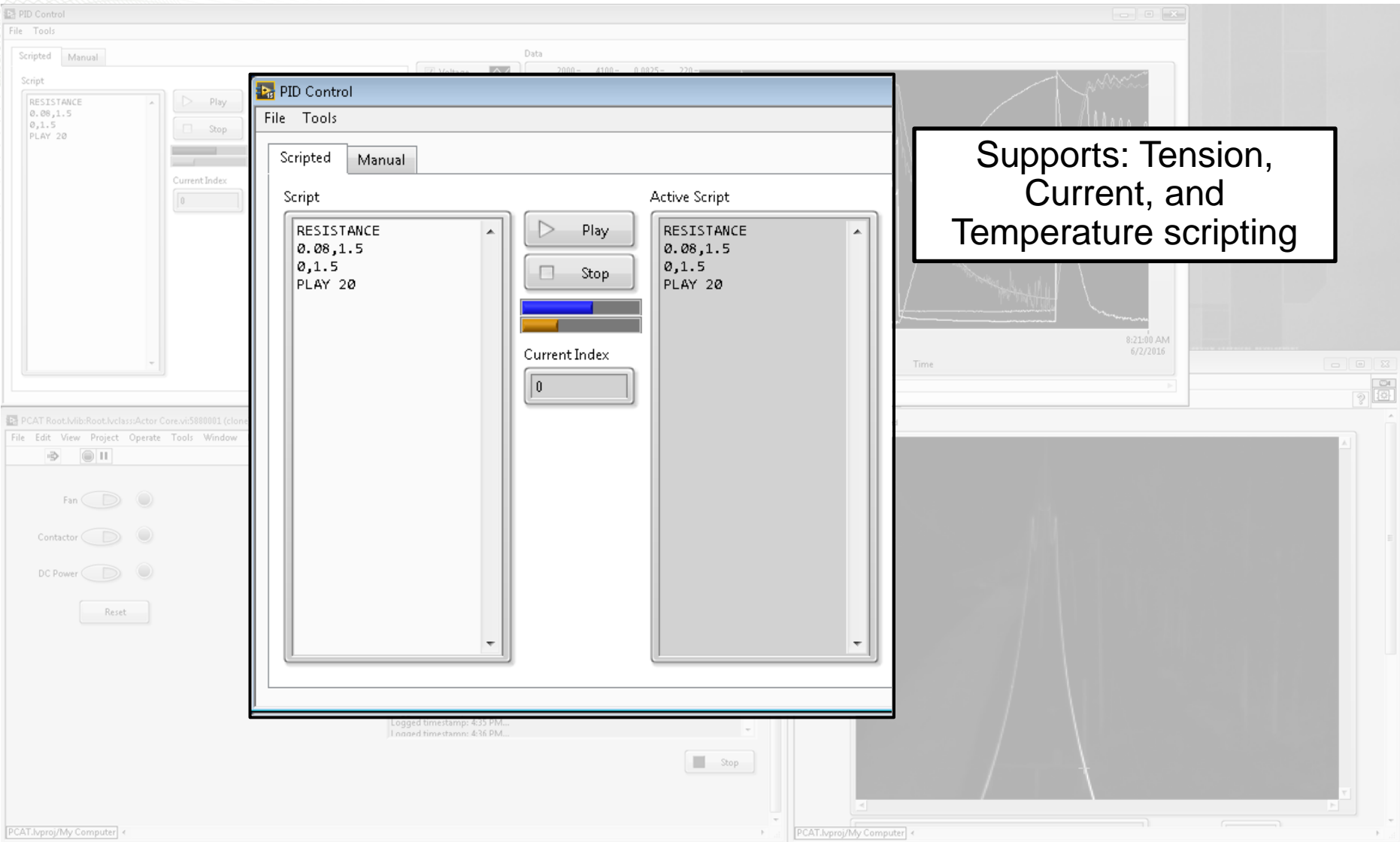


Improved User Interface – Scripted Operation

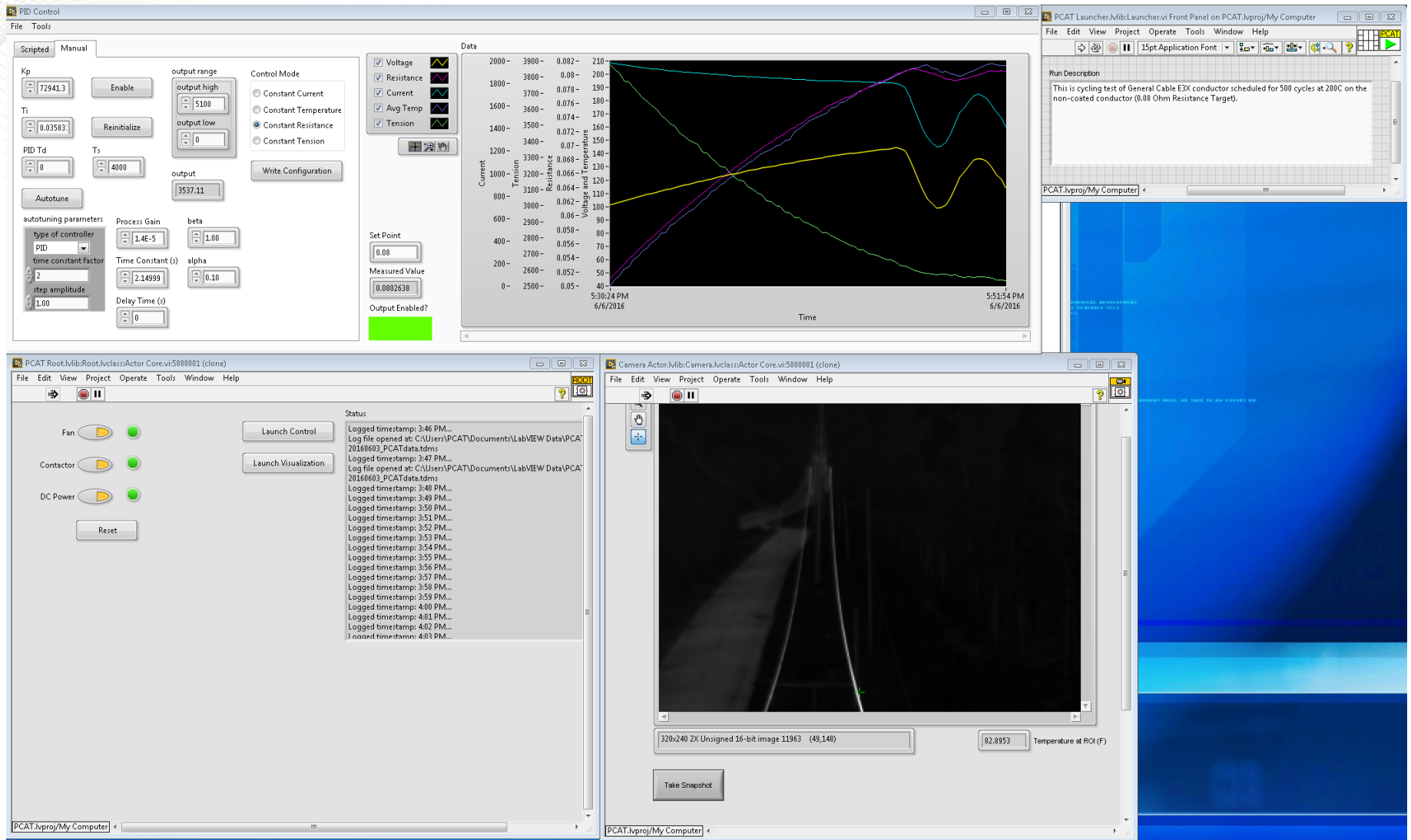


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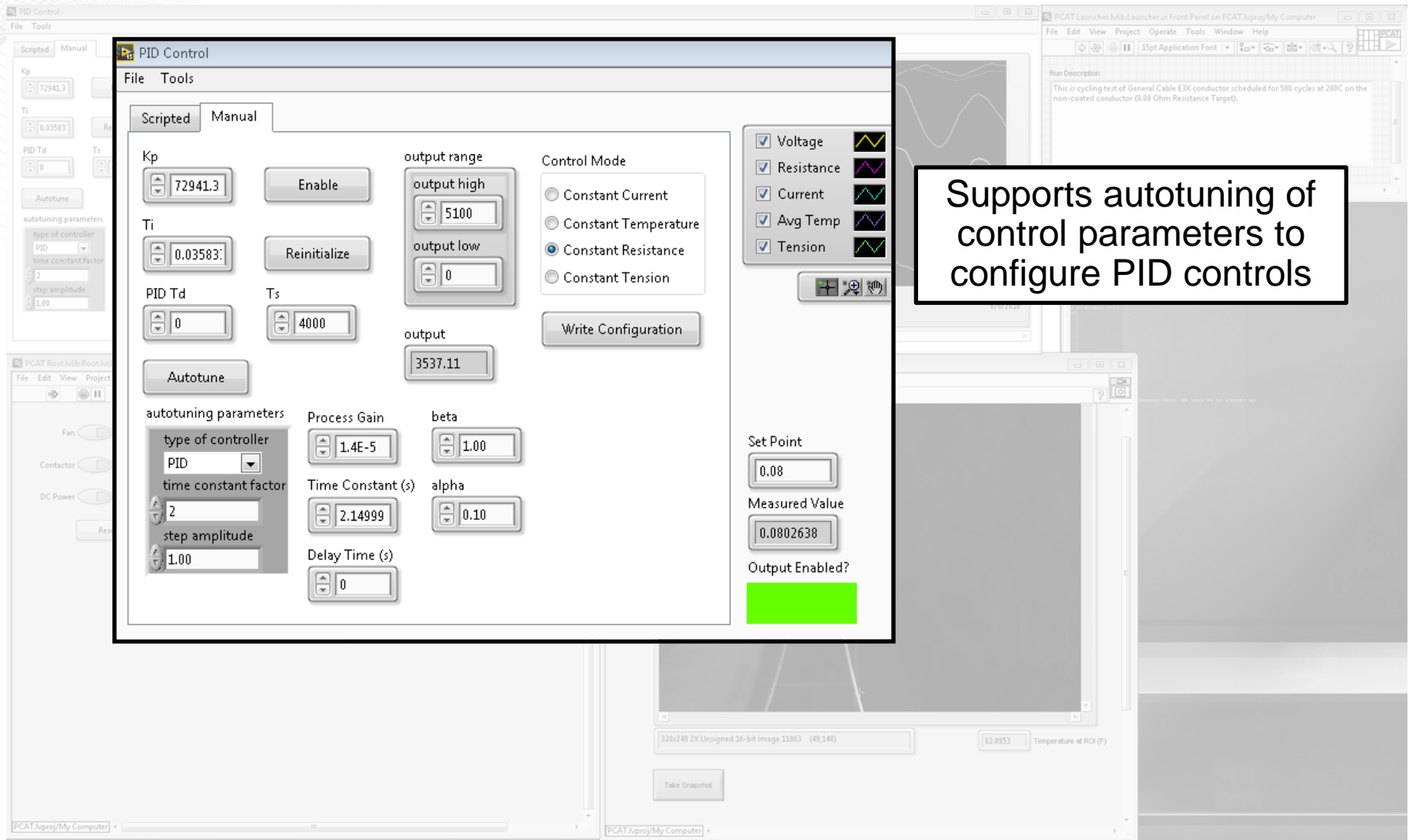
Supports: Tension,
Current, and
Temperature scripting



Improved User Interface – Manual Operation



Improved User Interface – Manual Operation



Supports autotuning of control parameters to configure PID controls

Data Playback Capabilities

PCAT Visualization.vi

File

Test name: EventLog_20160603_1547.tdms

Powerline Conductor Accelerated Testing Facility

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Description: This is cycling test of General Cable E3X conductor scheduled for 500 cycles at 200C on the non-coated

Event: 2016/06/04 - 08:20 PM Set Point set to 0.000000.

Temperature (C)

Time

3:48 PM 6/3/2016 12:00 PM 6/4/2016 12:00 AM 6/5/2016 12:00 PM 6/5/2016 12:00 AM 6/6/2016 01:10 PM 6/6/2016

Playback Speed: 1200x

Wind Direction

Wind Speed

Tension 1 (lbf): 2972.79

Tension 2 (lbf): 3363.31

Current (Amps): 135.669

Resistance (Ohms): 0.0590

Tension (lbf)

Current (A)

Resistance (Ohm)

Time

3:48 PM 6/3/2016 12:00 PM 6/4/2016 12:00 AM 6/5/2016 12:00 PM 6/5/2016 12:00 AM 6/6/2016 01:10 PM 6/6/2016

STOP

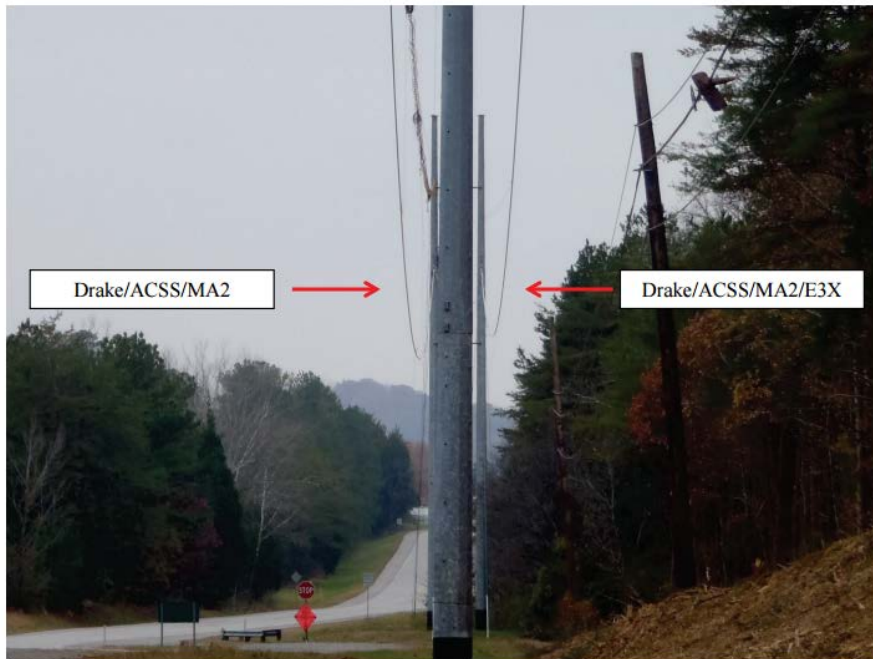


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Initial Testing Report




- ORNL and General Cable released preliminary report showing comparison of ACSS with and without the E3X coating
- Plans to release full report after cycle testing finishes

<http://info.ornl.gov/sites/publications/files/Pub59272.pdf>

ORNL/TM-2015/549

Preliminary Report on Oak Ridge National Laboratory Testing of Drake/ACSS/MA2/E3X™



Approved for public release.
Distribution is unlimited.

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Dan King
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Cody Davis
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Gord Baker
Vijay Mhetar
Phil Overholt
Zhi Li
Michael Starke
Ben Ollis

December 2015

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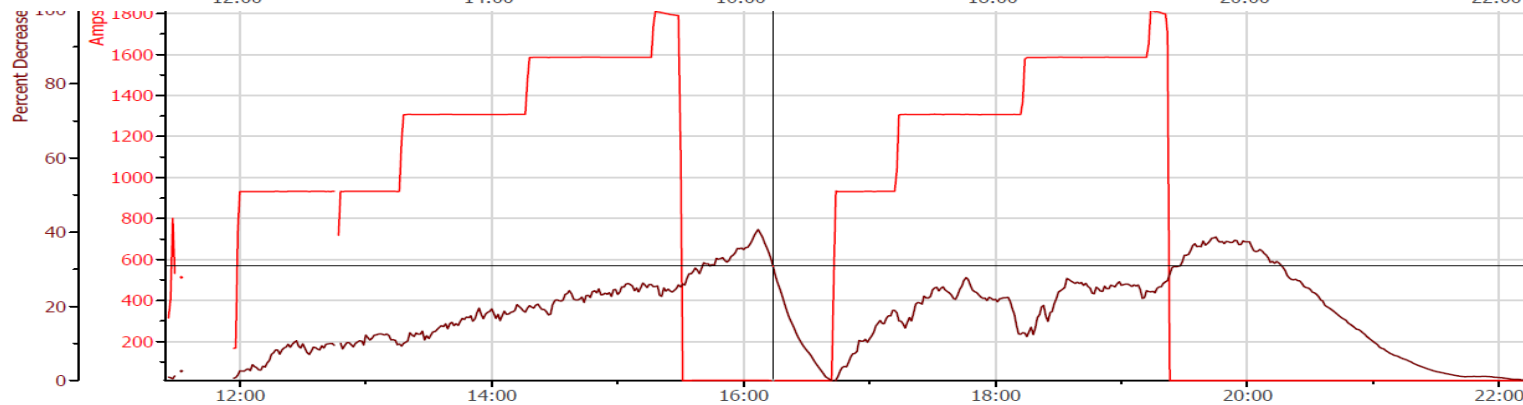
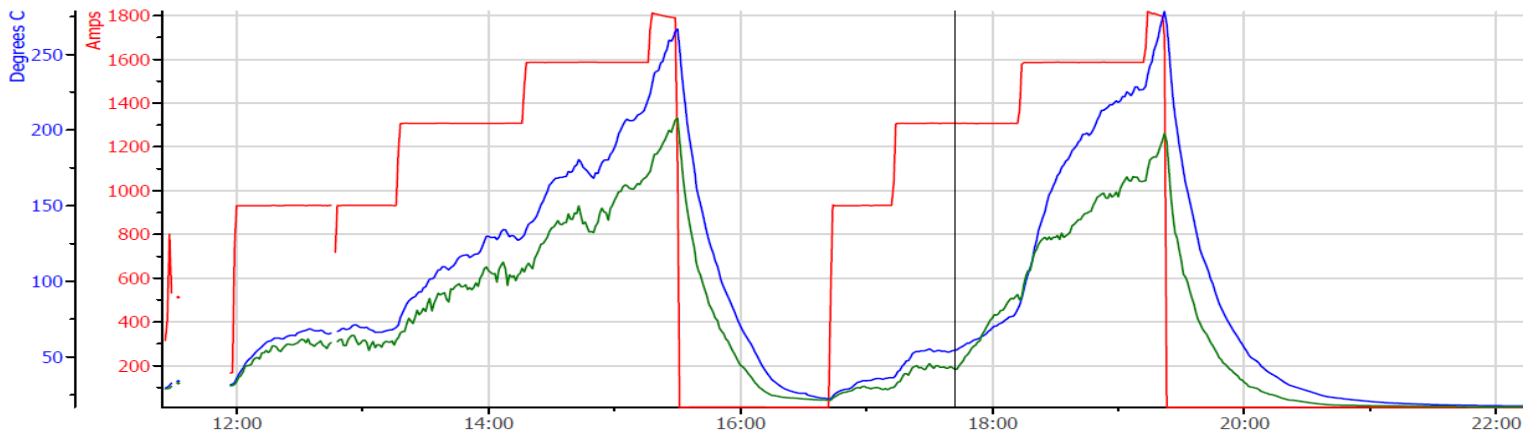


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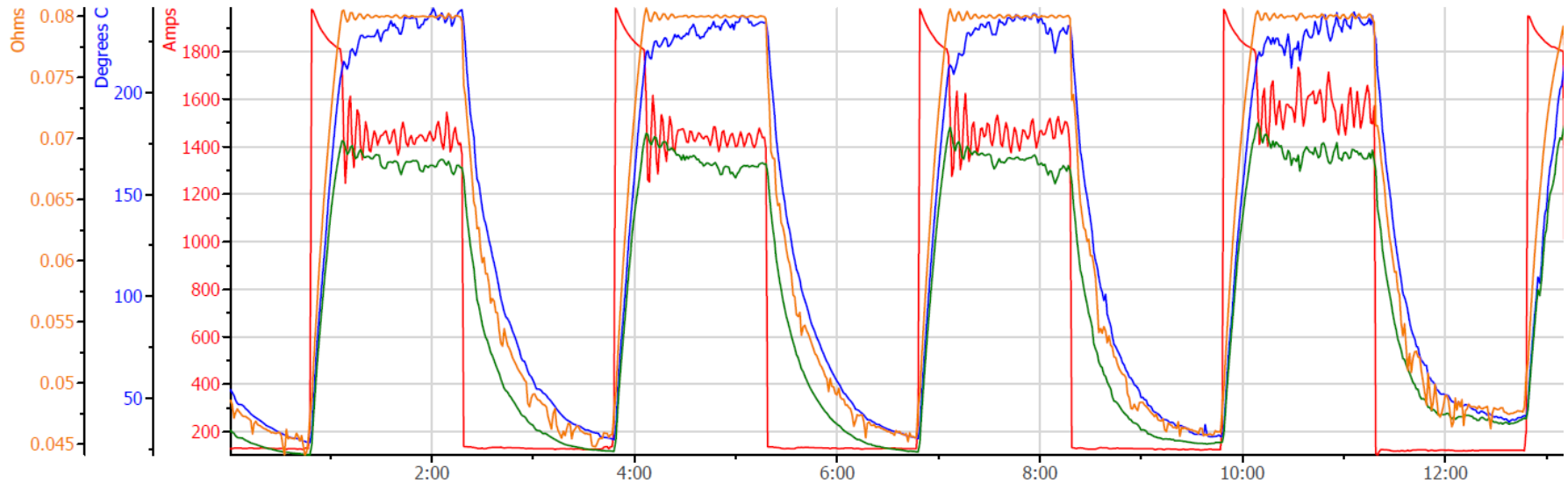
Current Ramp Test – 5/2/2016

Timing	Current (A)	Temperature Specular Control (°C)	Temperature Coated Conductor (°C)	Percent Decrease in Temperature
Start	932	75	-	10%
Step 1	1308	125	-	20%
Step 2	1587	180	-	25%
Step 3	1867	250	-	25%
Cooldown				As high as 40%



Thermal/Mechanical Cycling Test – 200 C

- Will be cycled 500 times at 200C for the uncoated conductor
 - Using target of 0.08 Ohms currently
 - May switch to tension control



Risk Factors

- Benefits of new sensor data
 - Can the infrared thermal camera be utilized to get the actual temperatures?
 - What other sensor data is useful
- Opening of data viewing from outside the lab
 - Firewall issues, authentication of login
- Unfavorable weather conditions
 - Because sustained bad weather is not predicted, this is only a minor risk to the schedule.



Future Activities

- Continue conductor testing
 - General Cable has a 2nd conductor lined up
 - Initial discussion with CTC along with collaboration with General Cable for E3X coating
- Integrate 3D wind speed sensor
- Integration of weather forecast
- Integrate rain gauge measurement
- Enhance Real-time controls
- Addition of cloud camera feed
- Addition of end tower voltage
- Additional sensors at end tower
- Conversion of older data to .tdms for comparison



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Q&A

