

# Capturing Generator Rotor Angle and Field Quantities – SDG&E Experience and Approach to Using Nontraditional Generator Measurements

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# Serving the San Diego Area

## SDG&E

- Sub

- Reg

- Saf

3.4

- 1

- 8

- 4,10

San

(25 cities)



unties

# SDG&E System Overview

- 1,800 miles of electric transmission lines
- Two major substations
- 8,100 miles of electric distribution lines
- 6,200 miles of gas distribution lines
- 4,300 miles of water distribution lines

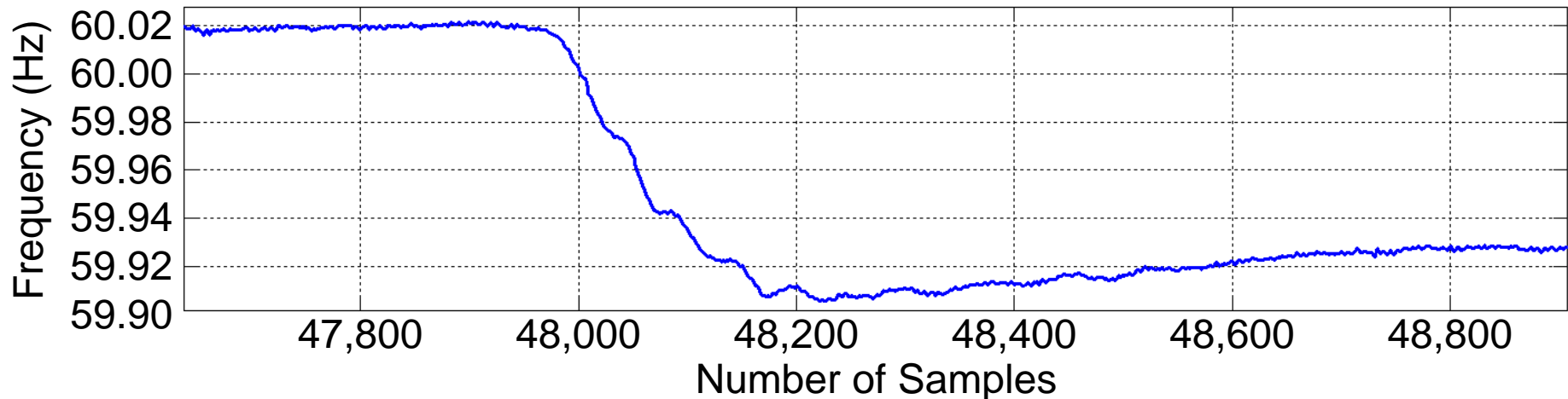


# Initiating Project and Establishing Goals

- Acquiring field quantities for generator model validation
- Analyzing interaction of mechanical and electrical quantities
- Verification of generator parameters per NERC MOD-025 thru MOD-027 requirements
- Continuous condition assessment
- Developing real-time condition assessments based on physical parameters

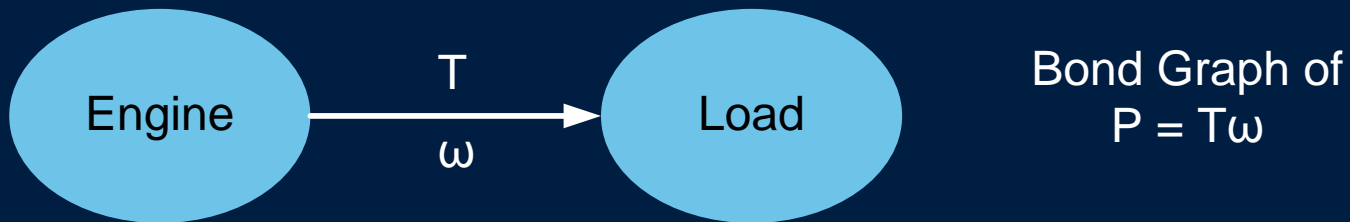
# Motivation

- Power system stability studies primarily deal with transients in (power) angle, voltage, and frequency
- Typical transient effects in ac frequency are due to power loss

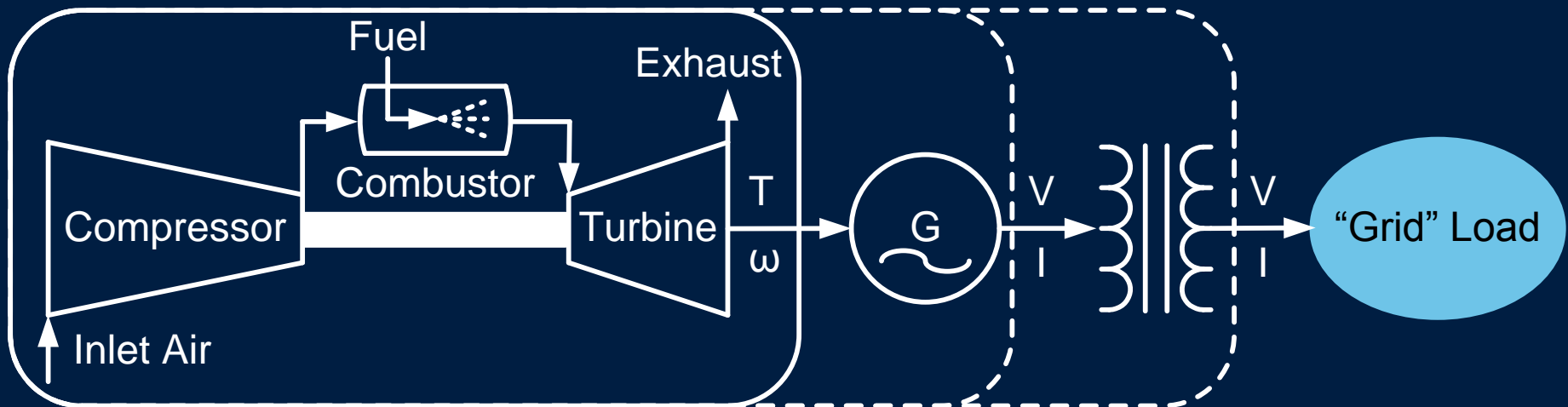


# Motivation

Transient effects are due to dynamic coupling and interaction dynamics between generation and load

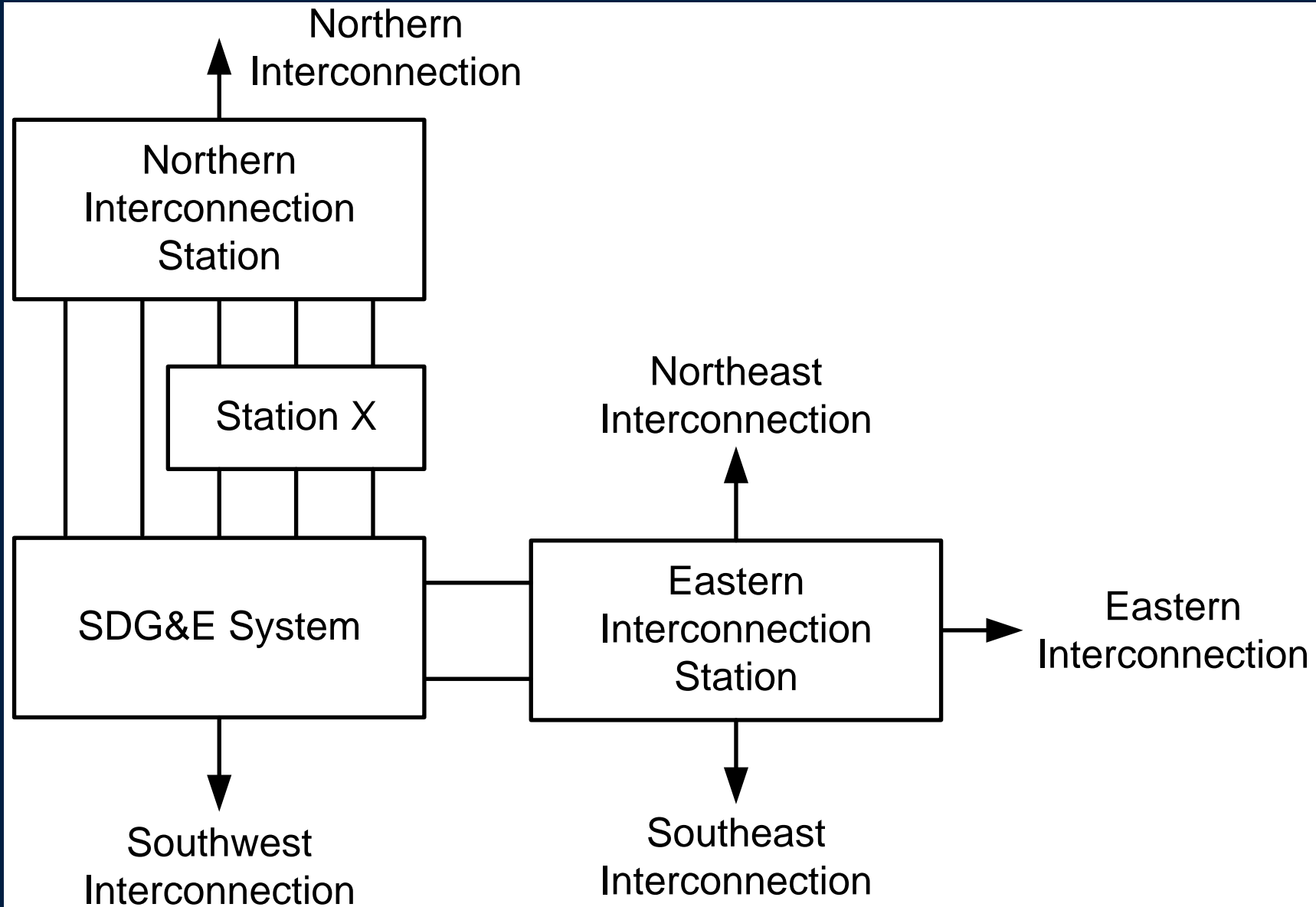


For grid-tied turbine / generator interaction



We can assume interaction is "one way from grid"

# Major Interconnections





# Selecting the Site

## Combined Cycle Plant



2 Gas Turbine Generators  
1 Steam Turbine Generator

Map data ©2015 Google



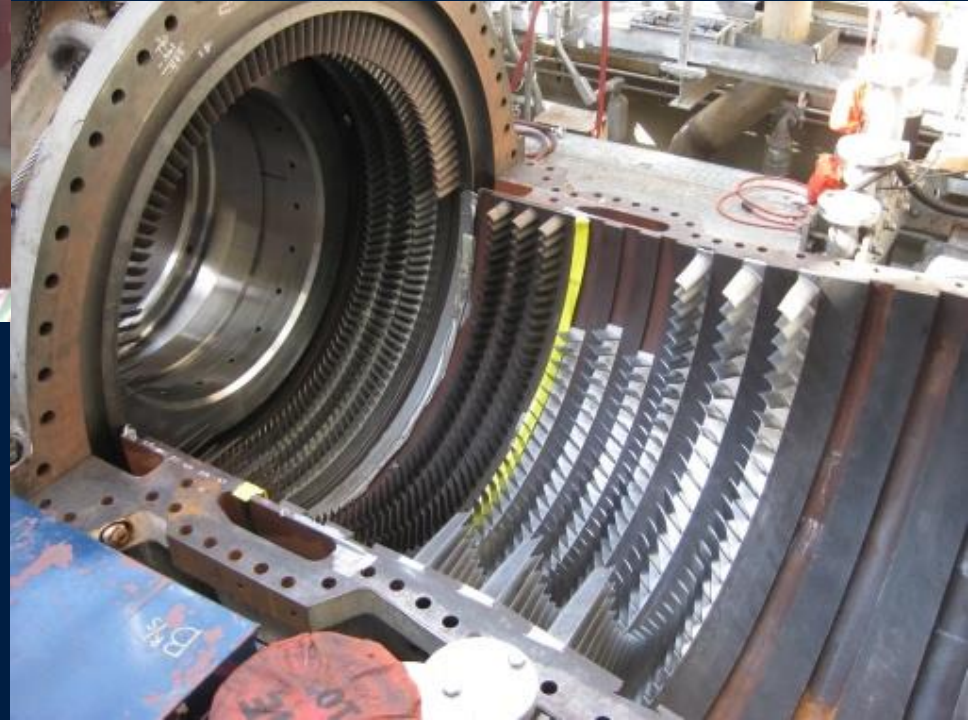
# Taking Advantage of Opportunities

February 2014 Plant Shutdown

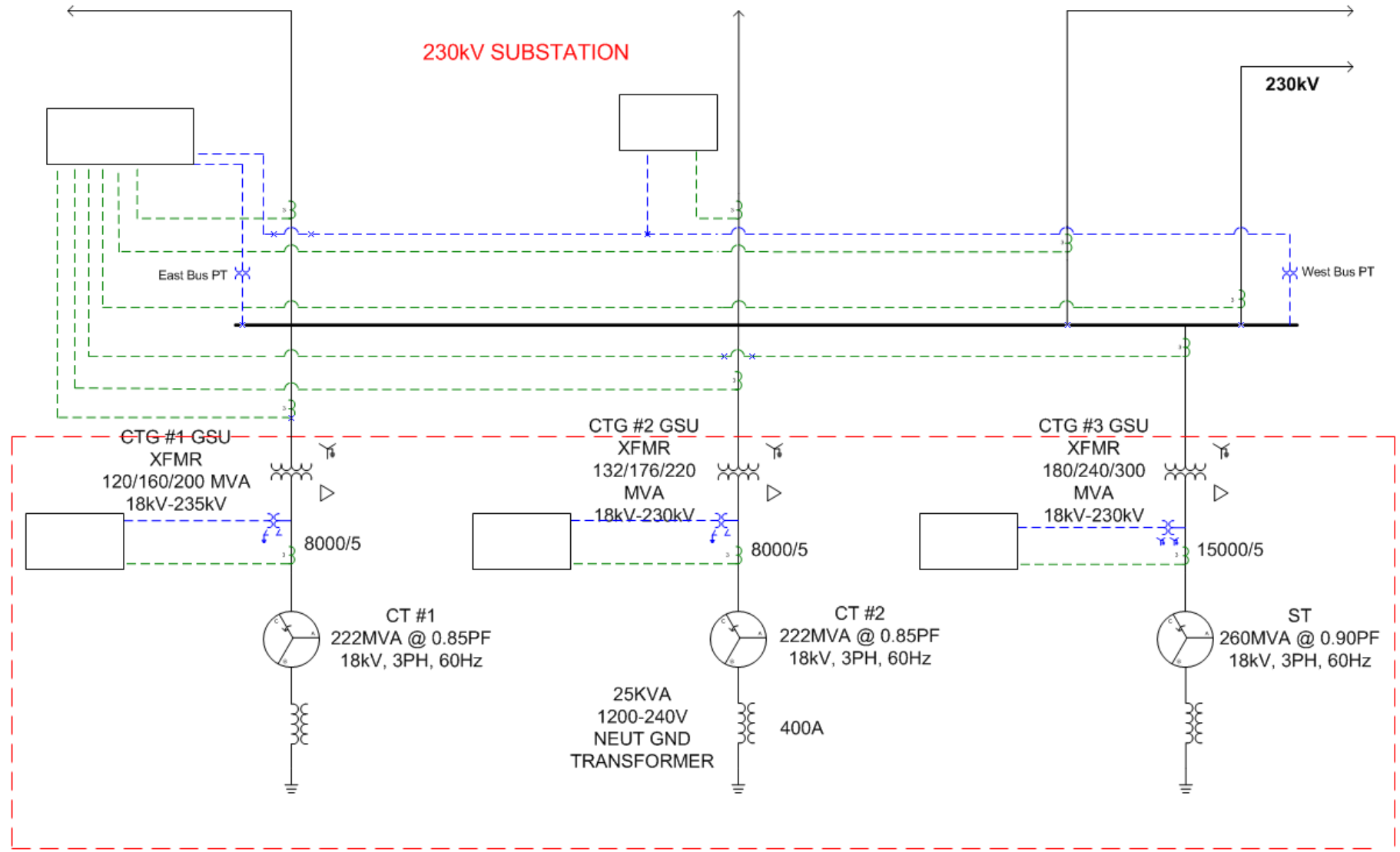
40,000-Hour  
Maintenance



Complete Overhaul  
of All Machines

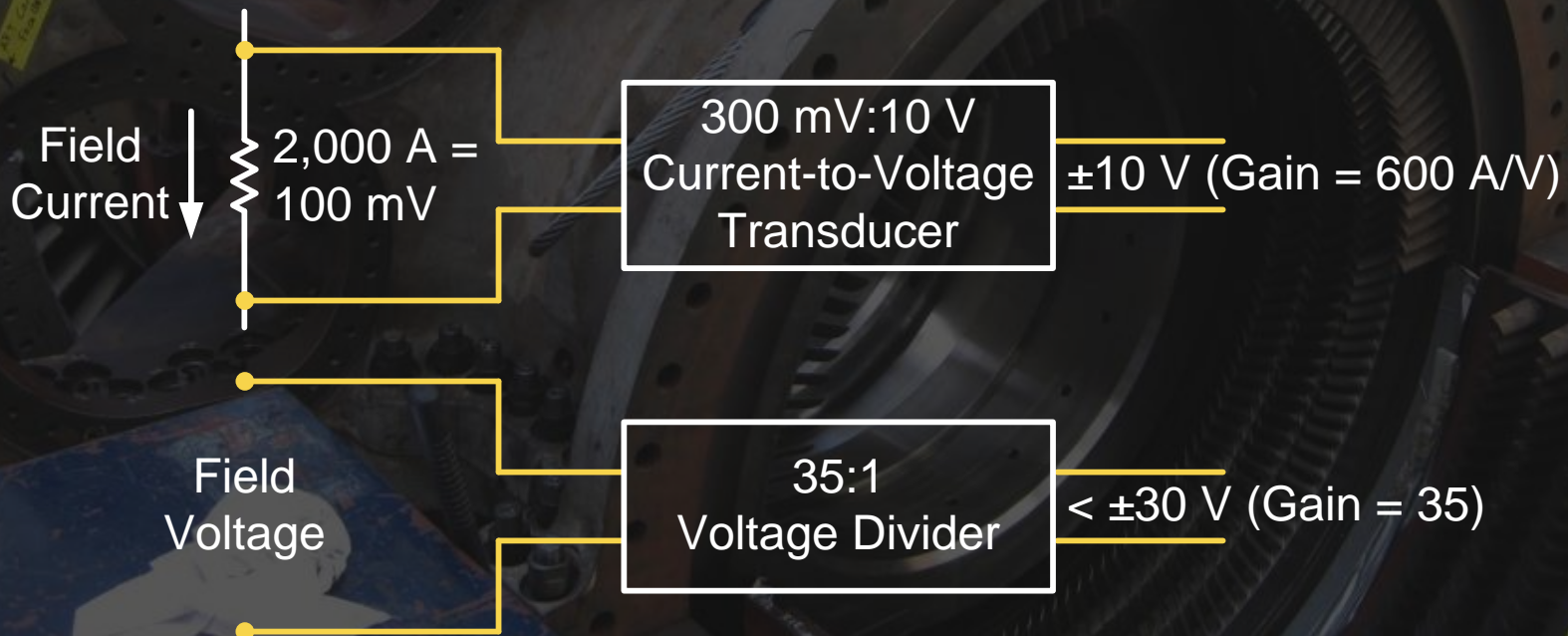


# One Line



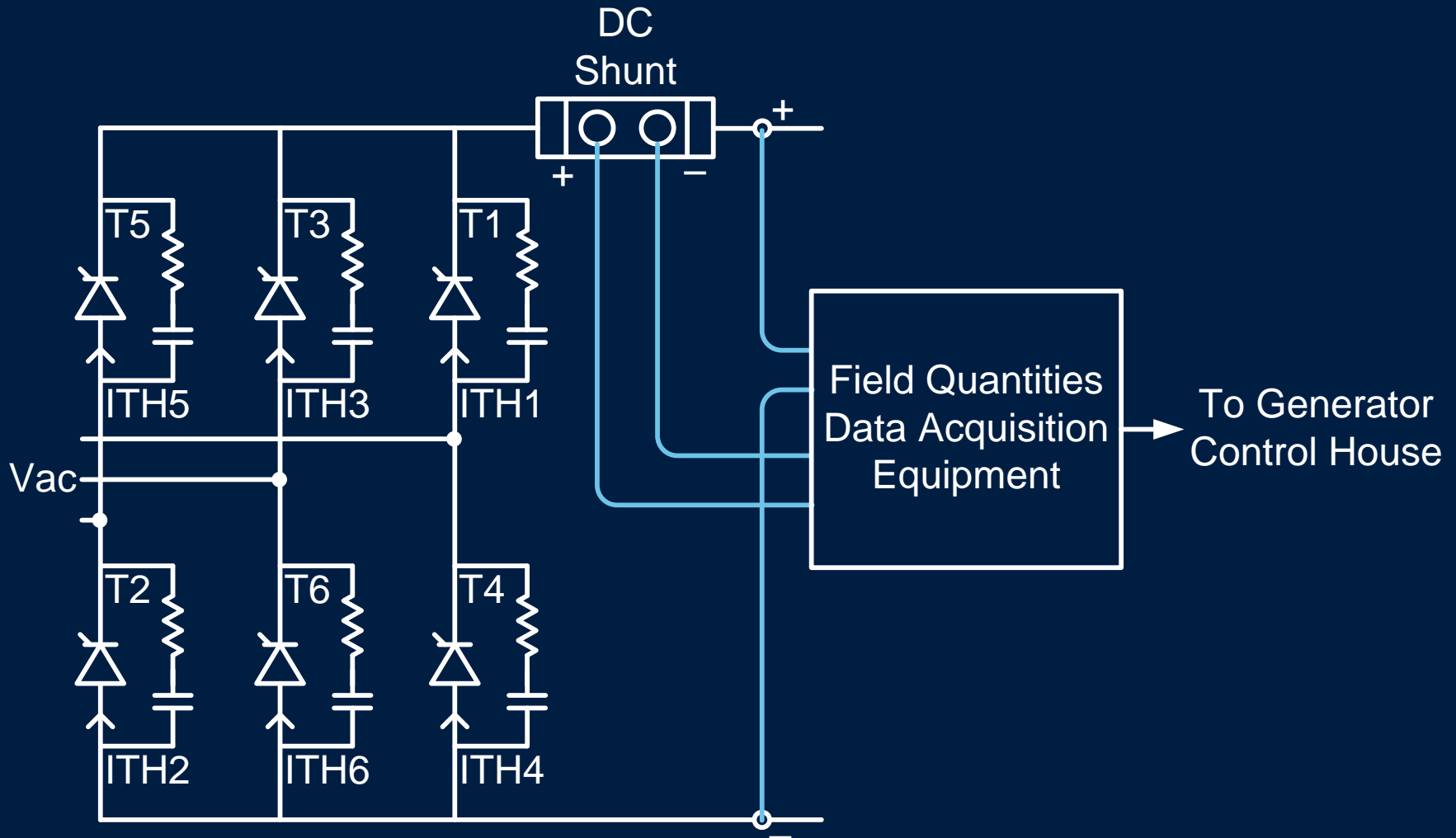
# Instrumenting Machines to Capture New Data

- Generator rotor angle
- Field voltage
- Field current

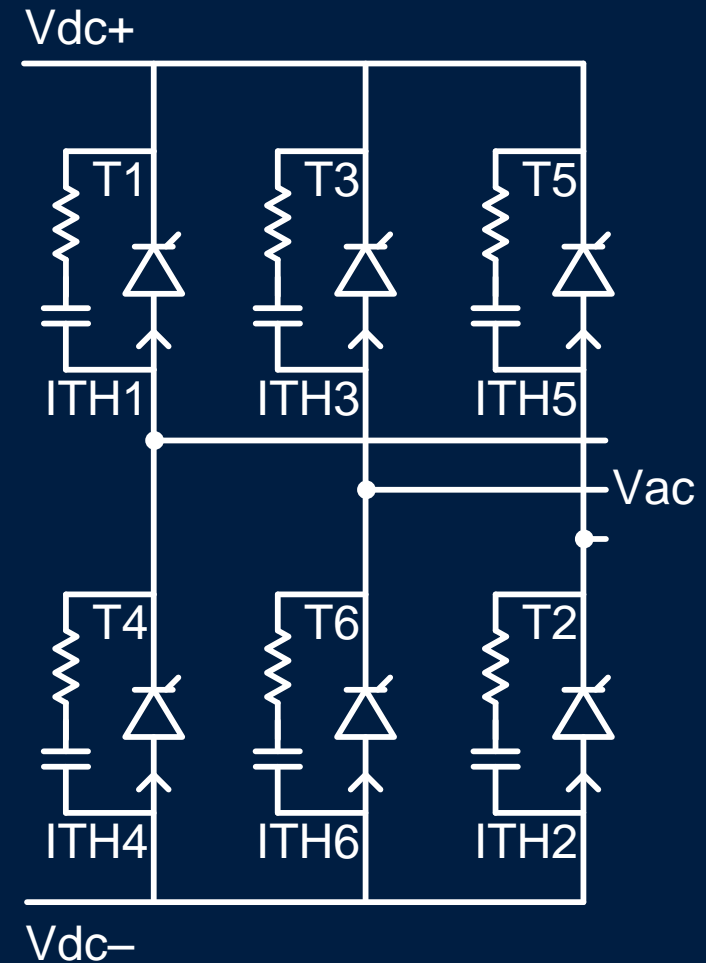
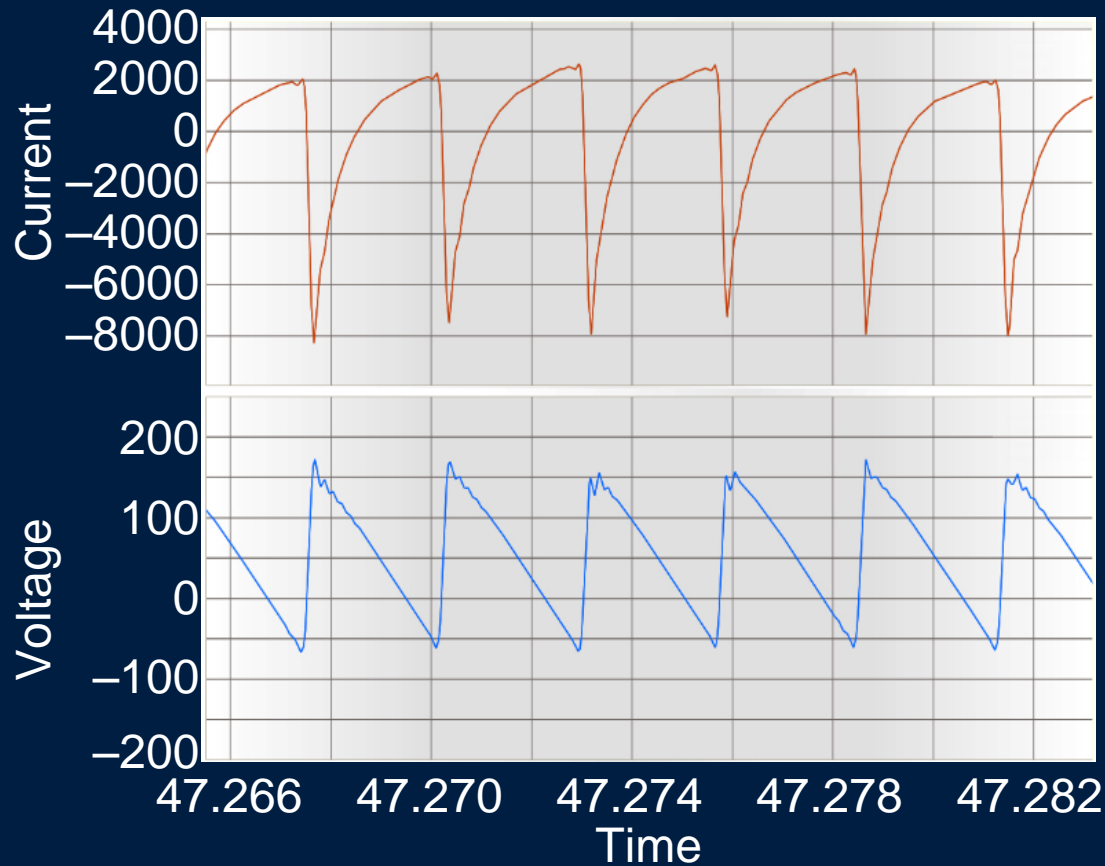




# How Do We Capture Field Quantities?



# Creating the Rotating Magnetic Field



# Instrumenting the Field Quantities

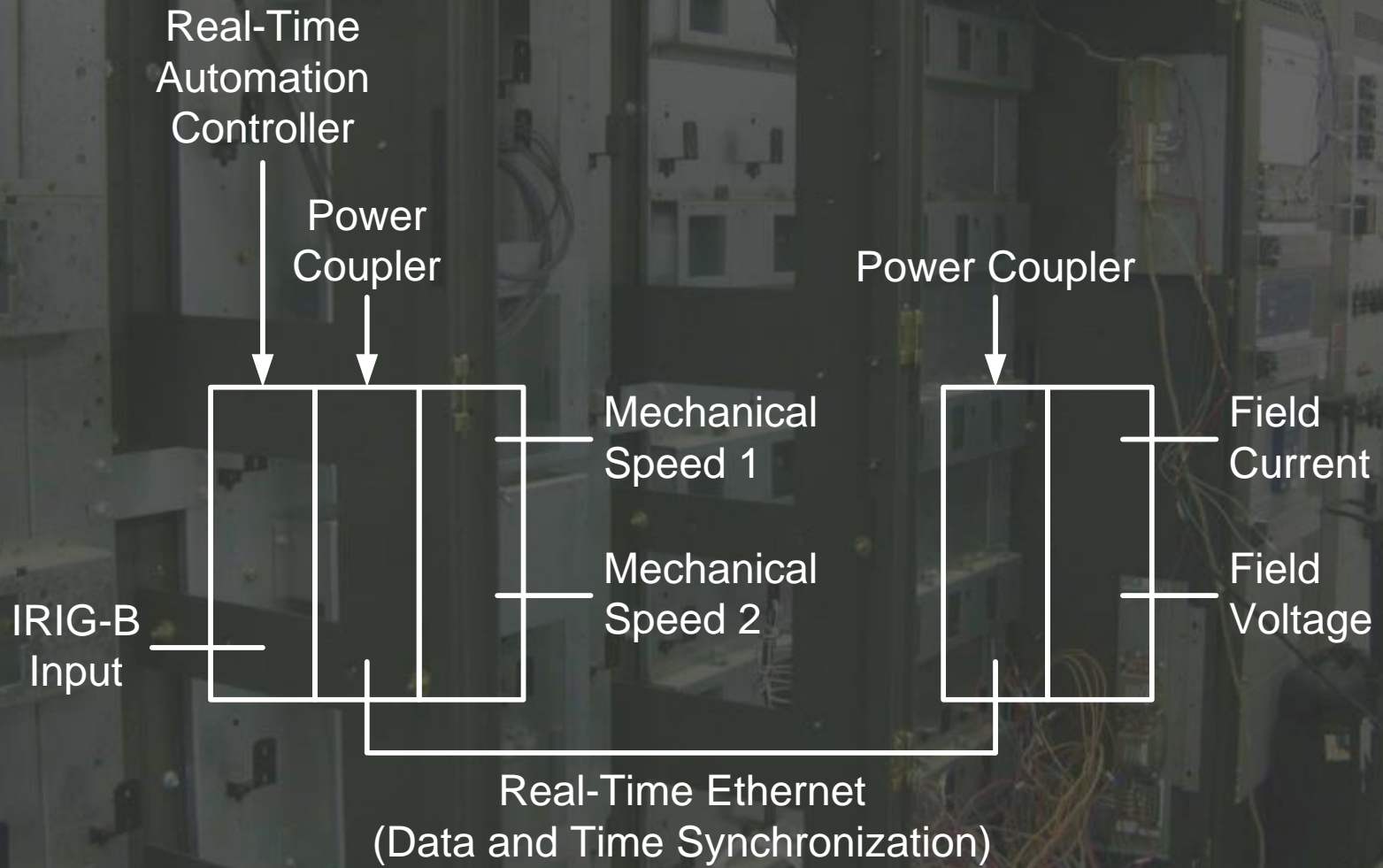


DC Bus

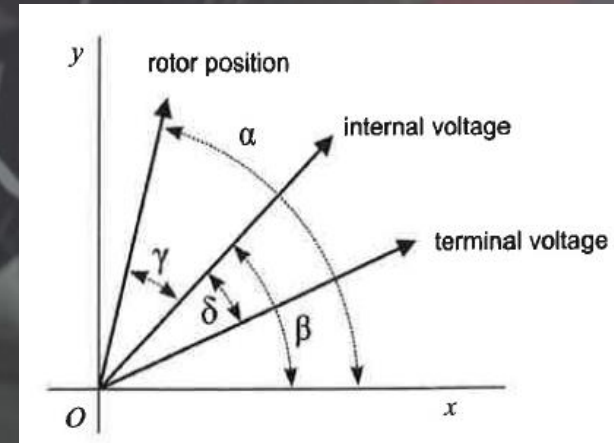
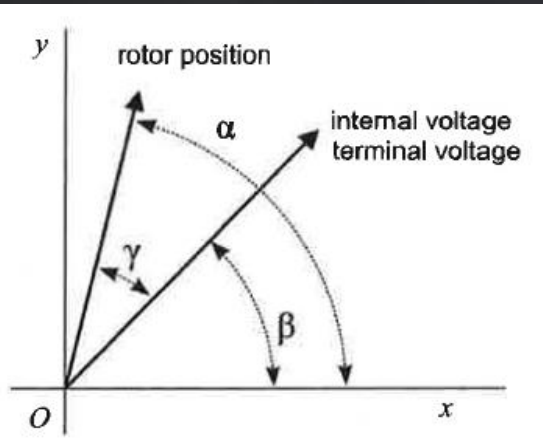
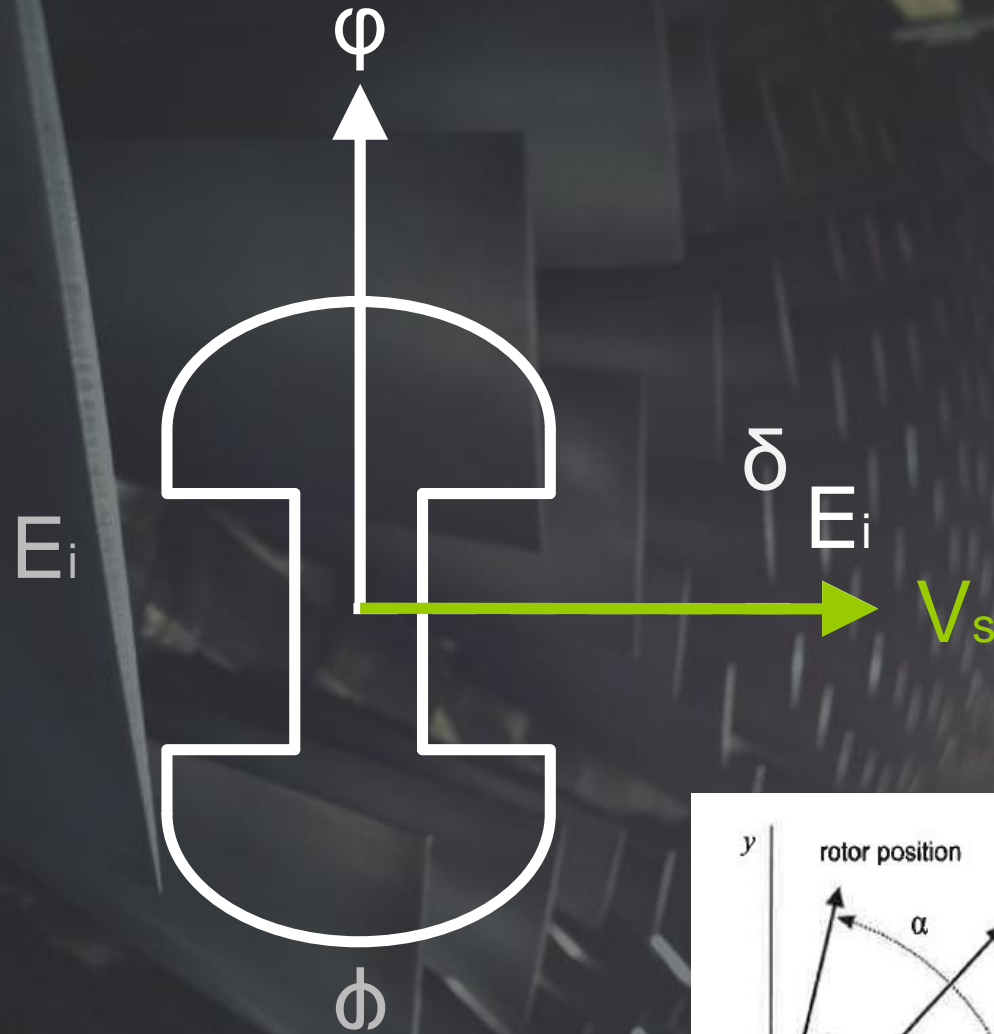




# Architecting a Solution

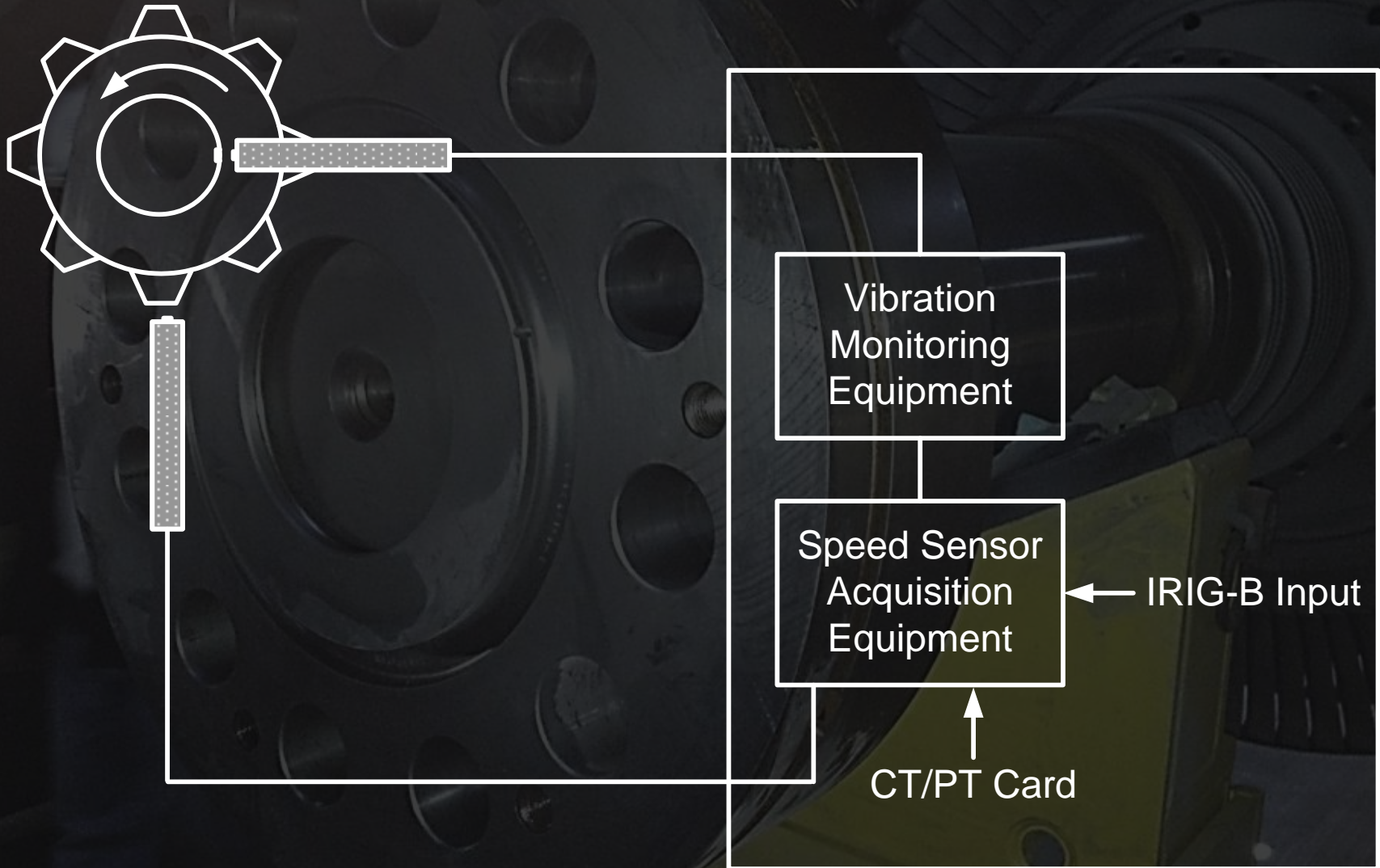


# Angle of Rotor Relative to What?



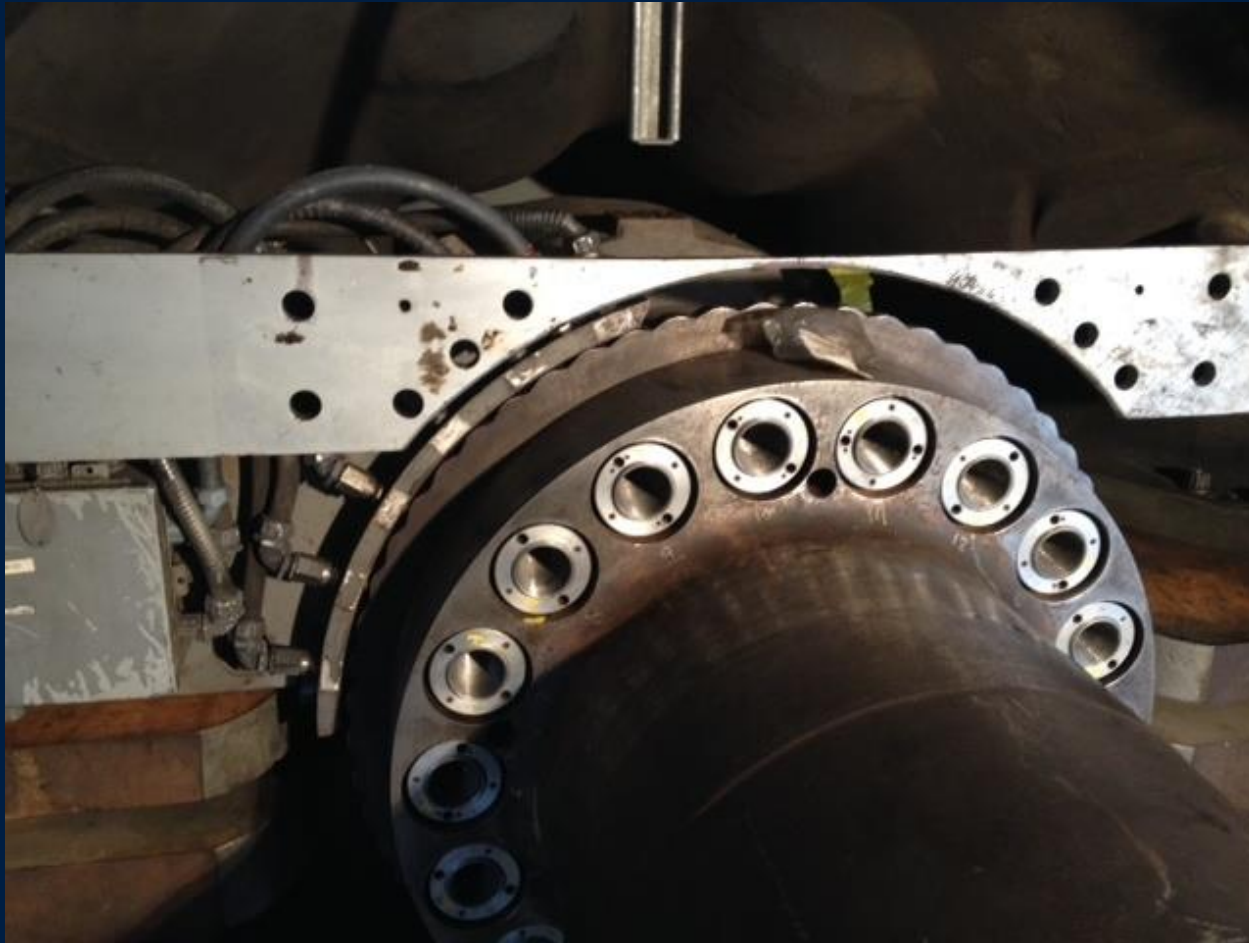
# Instrumenting for Mechanical Signals

## Rotor Speed and Angle

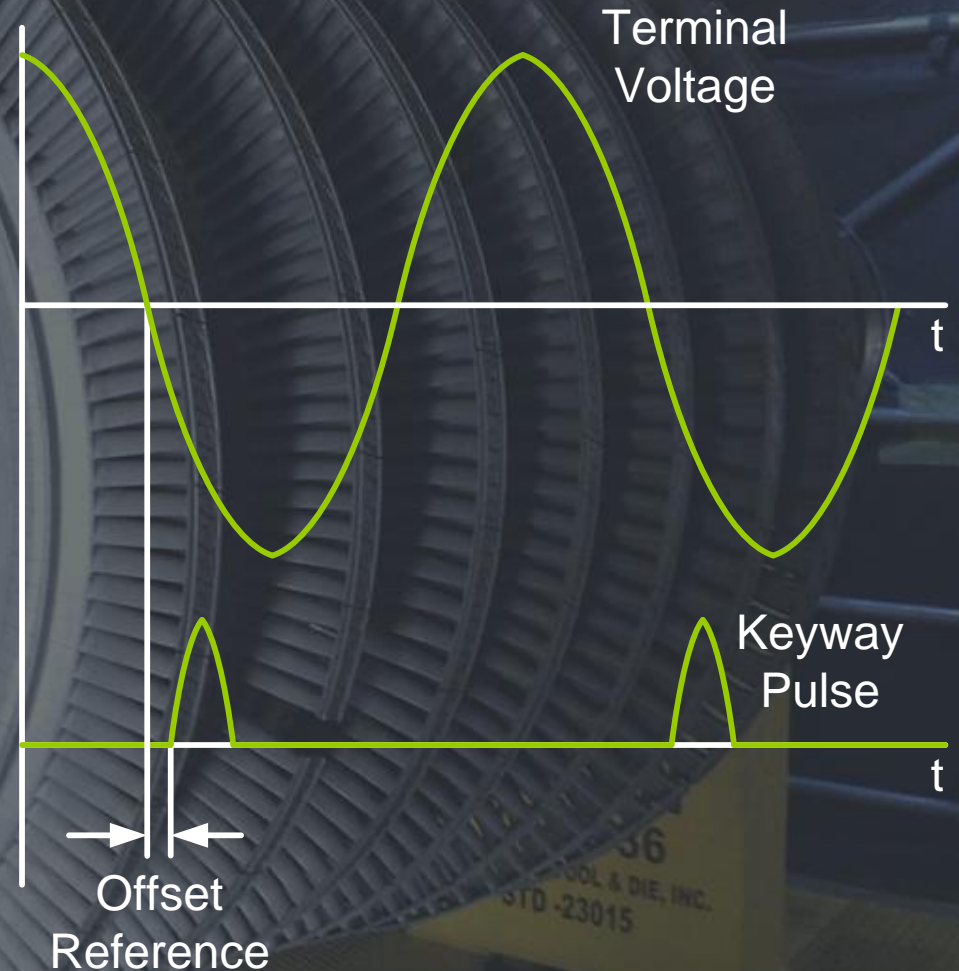
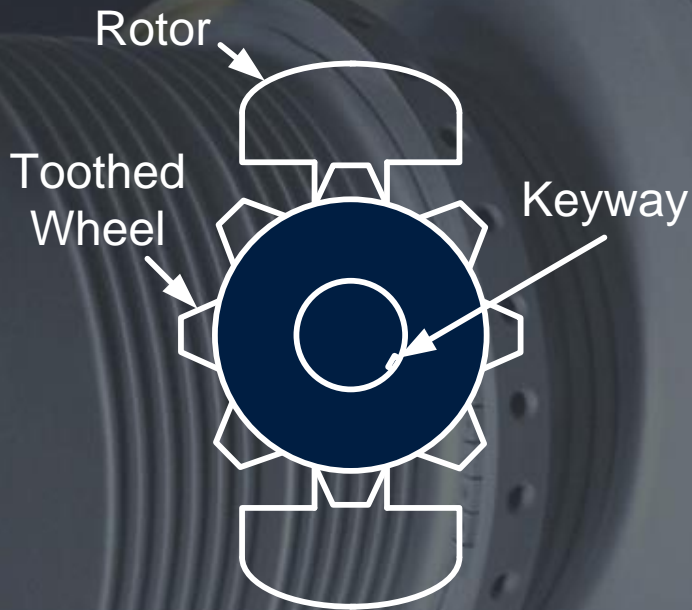




# Exactly What Are We Instrumenting?



# Combining Electrical and Mechanical Data

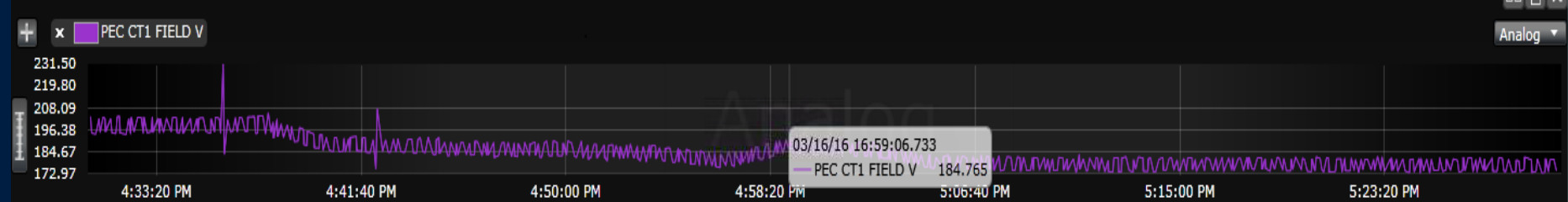


# PMU Data

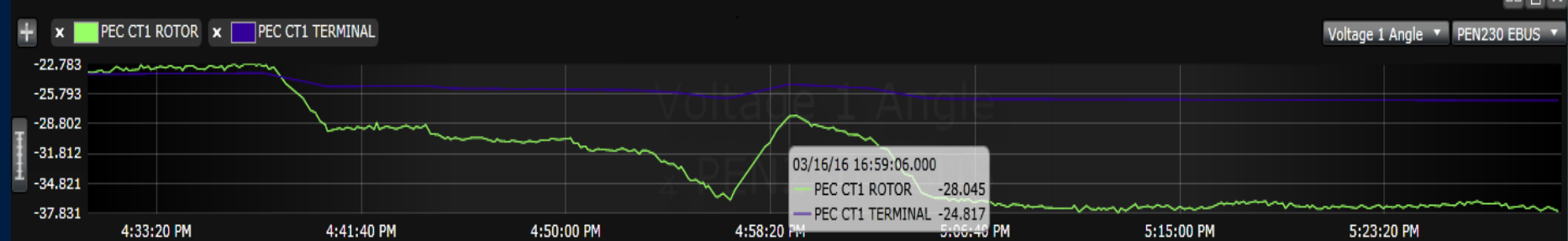
Standard Chart



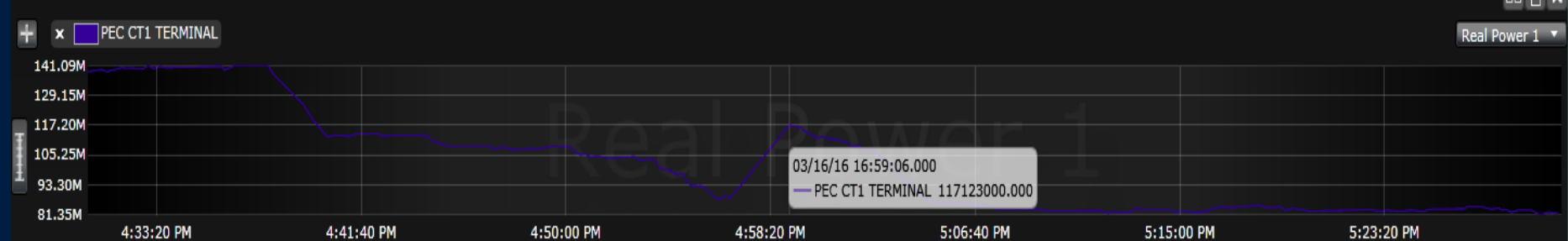
Standard Chart



Standard Chart

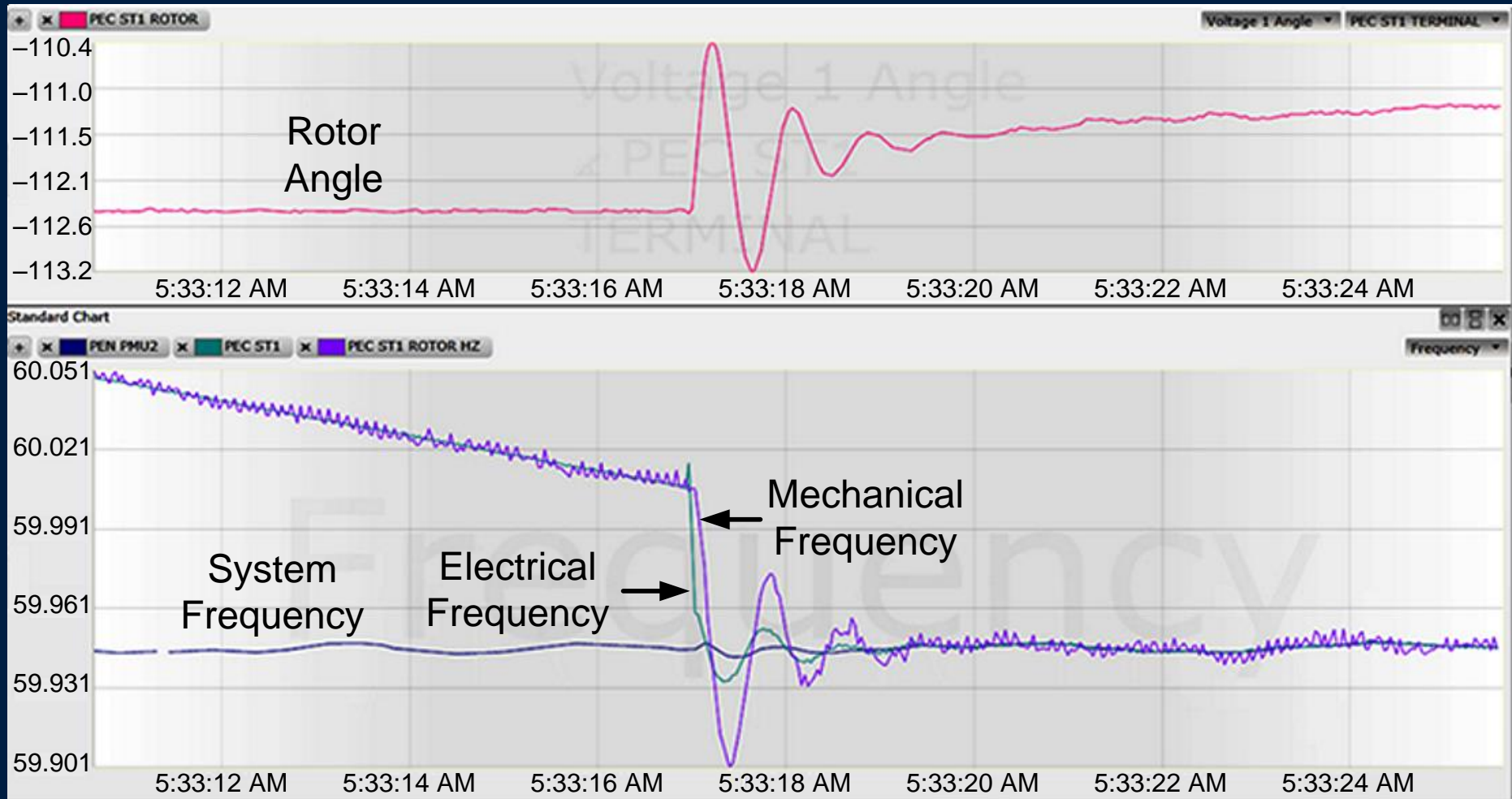


Standard Chart

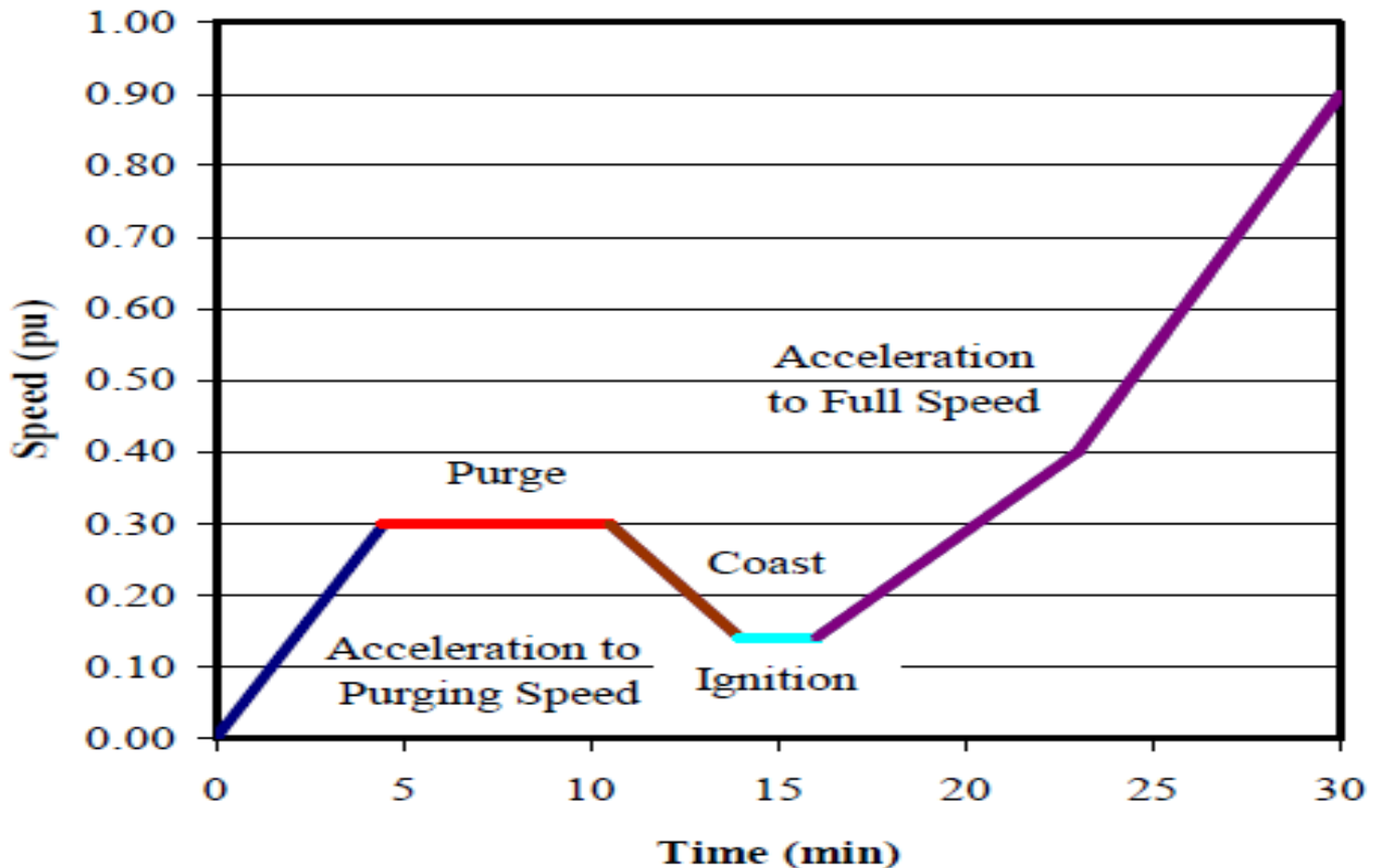




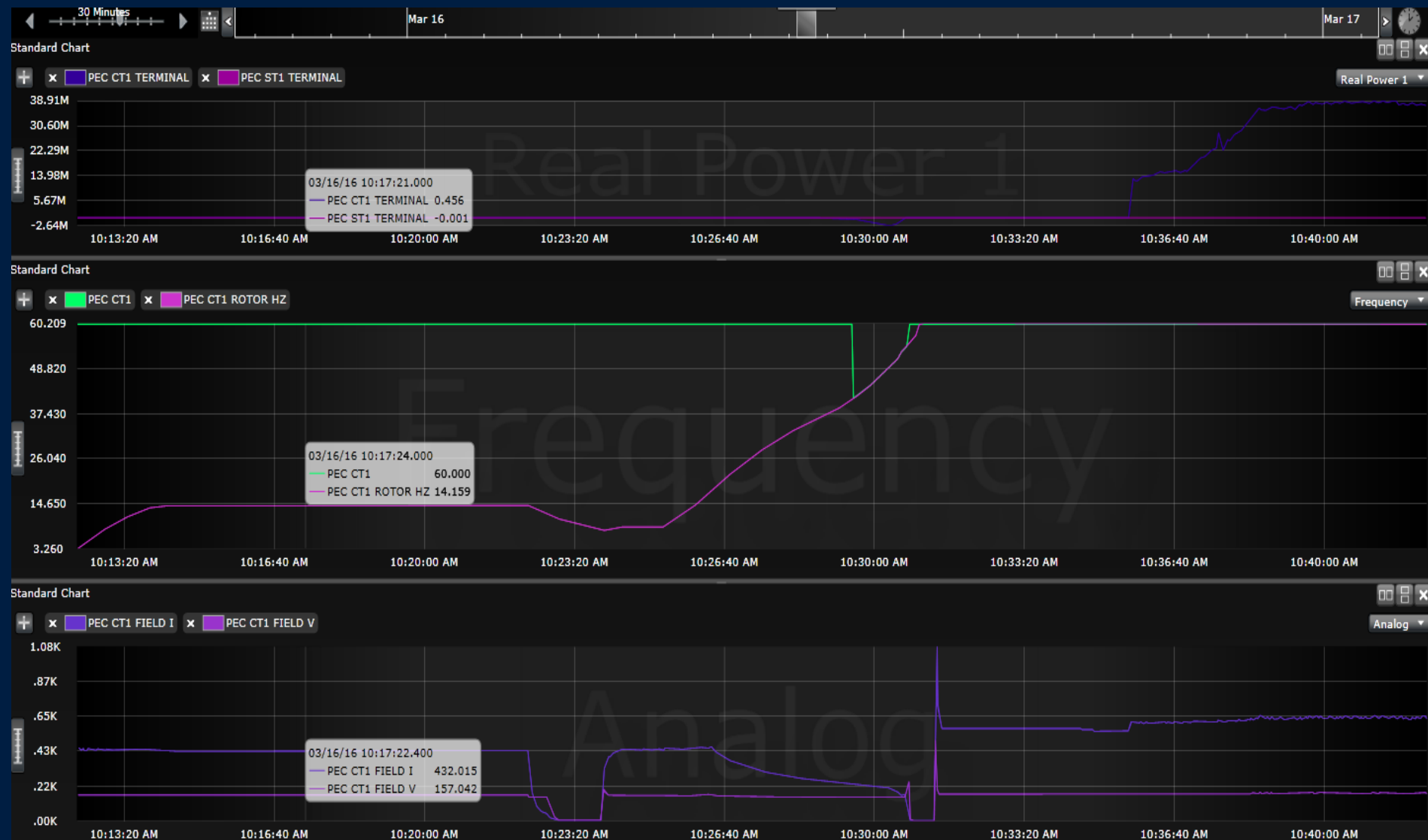
# Watching 20 Tons of Metal Get Tossed Around – A Synchronization Story



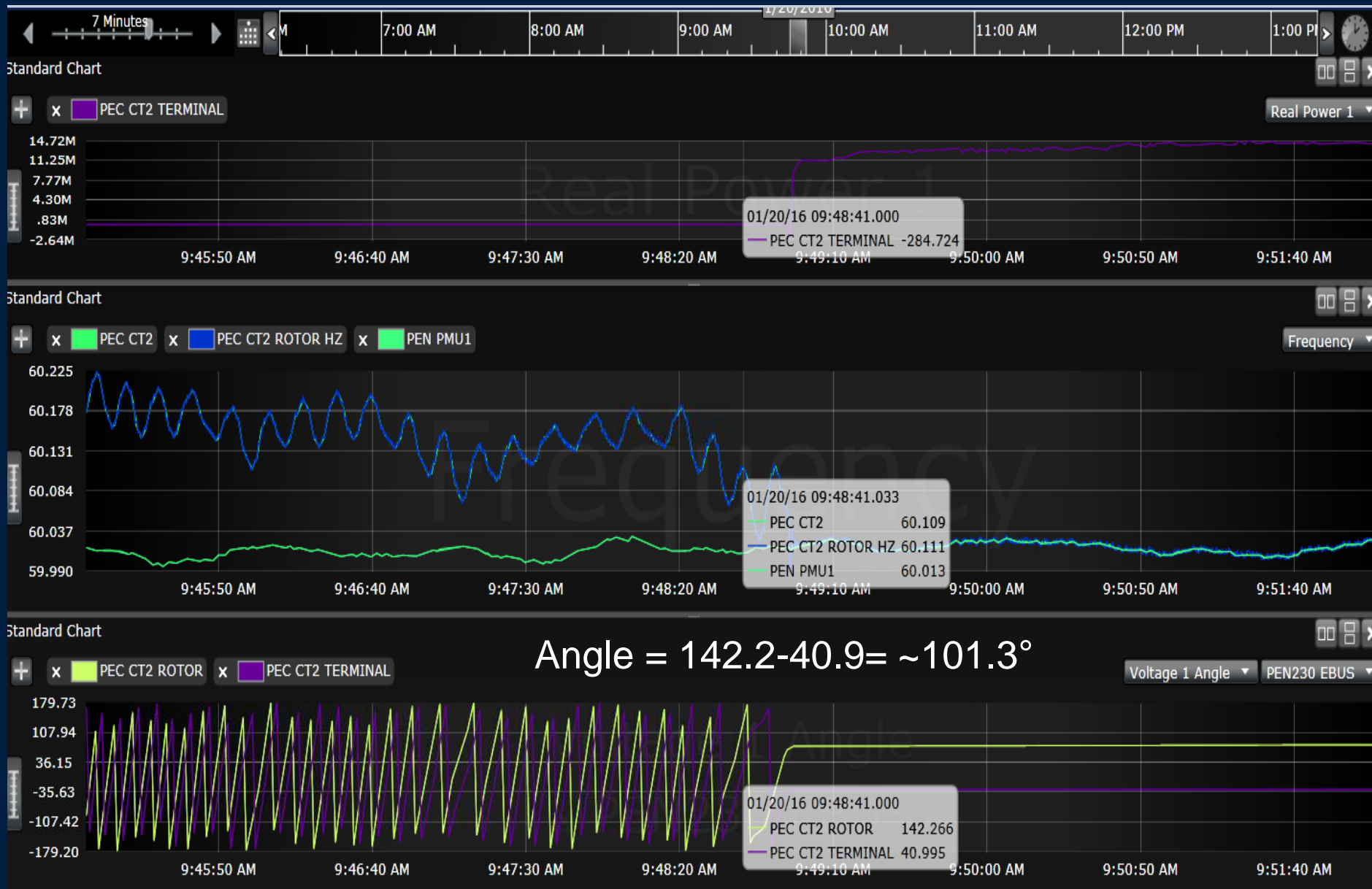
# Standard Start Load-Commutated Inverter



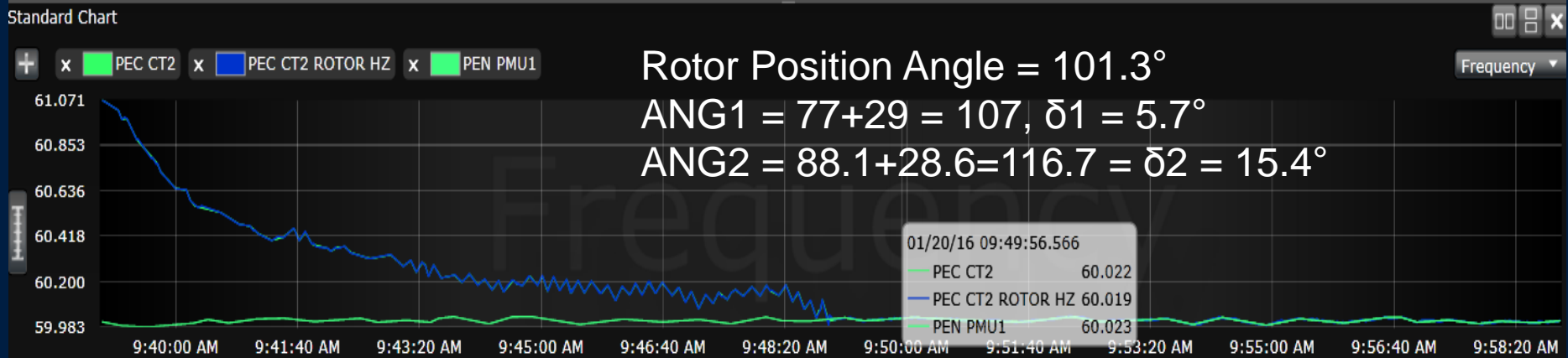
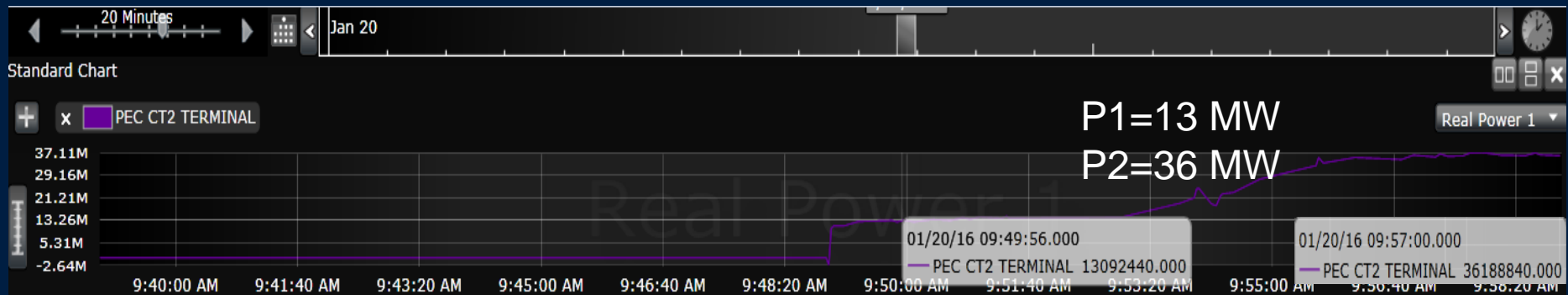
# Starting a Machine With a Load-Commutated Inverter



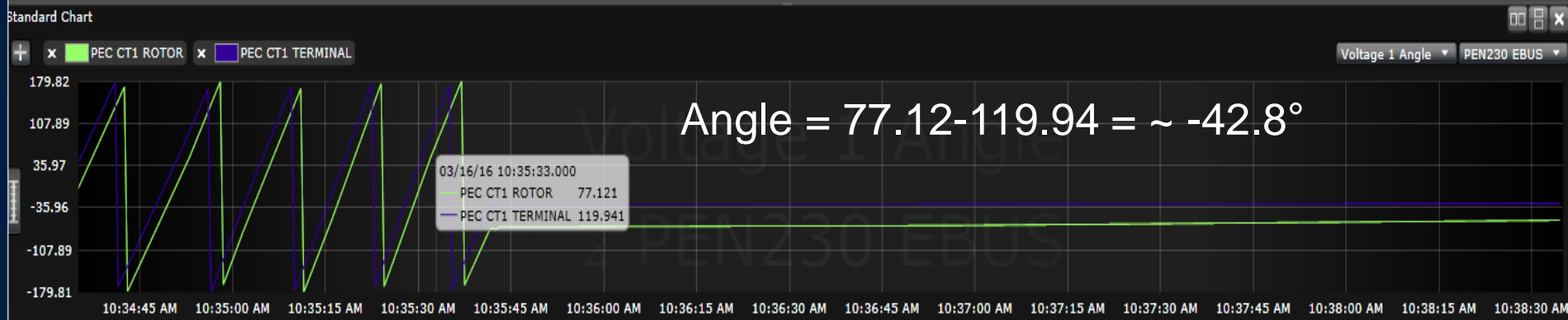
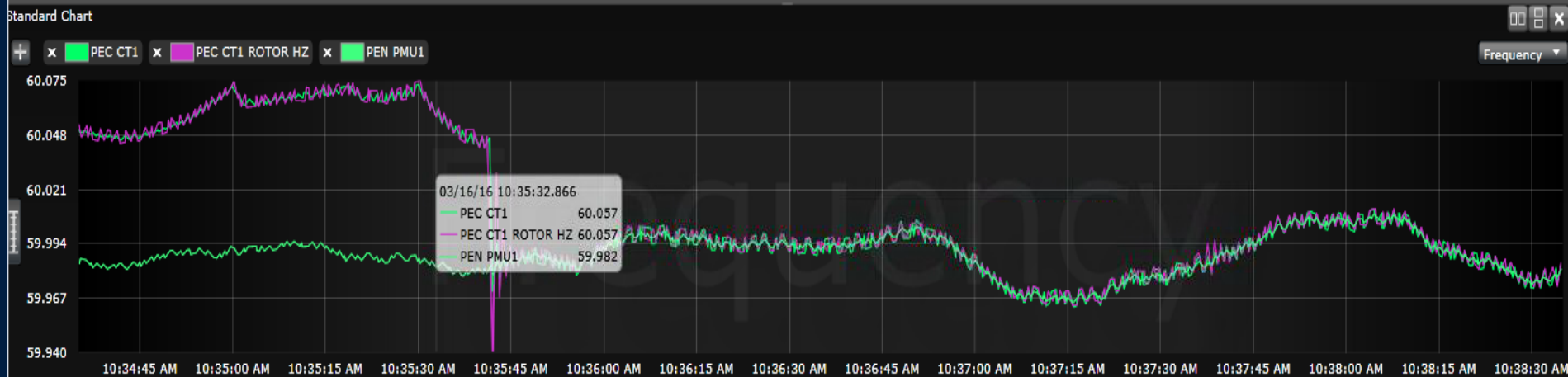
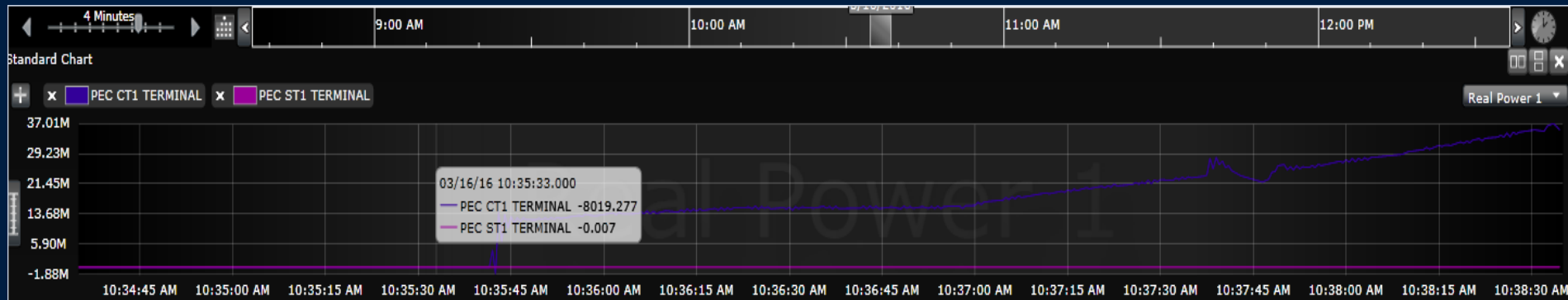
# CT2 Startup



# CT2 Loading

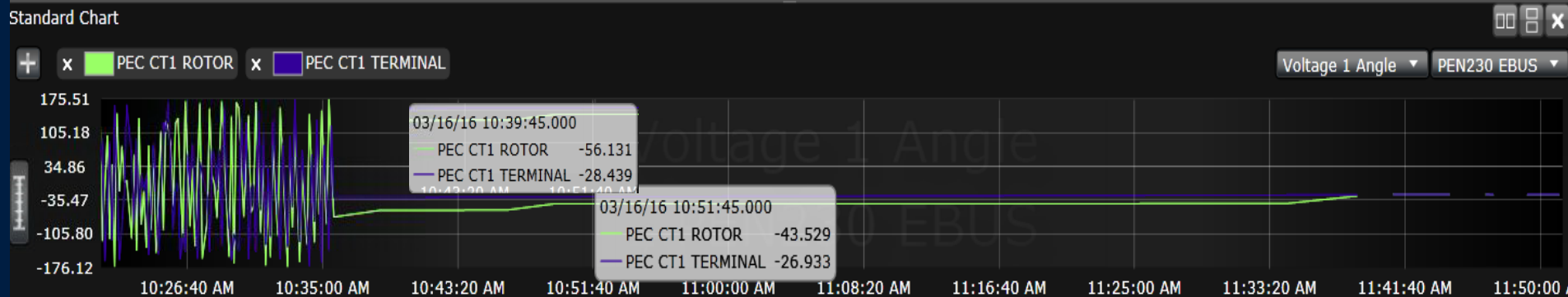
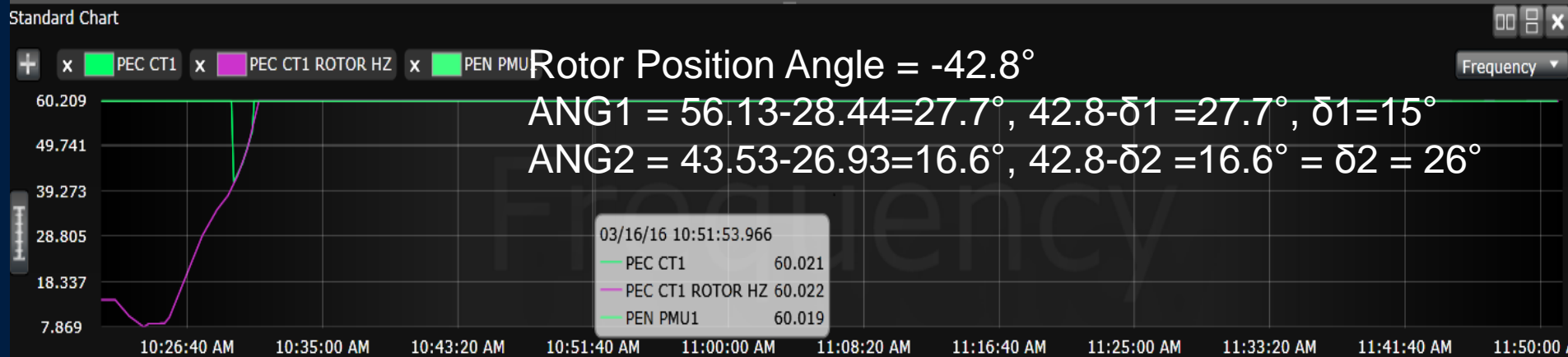
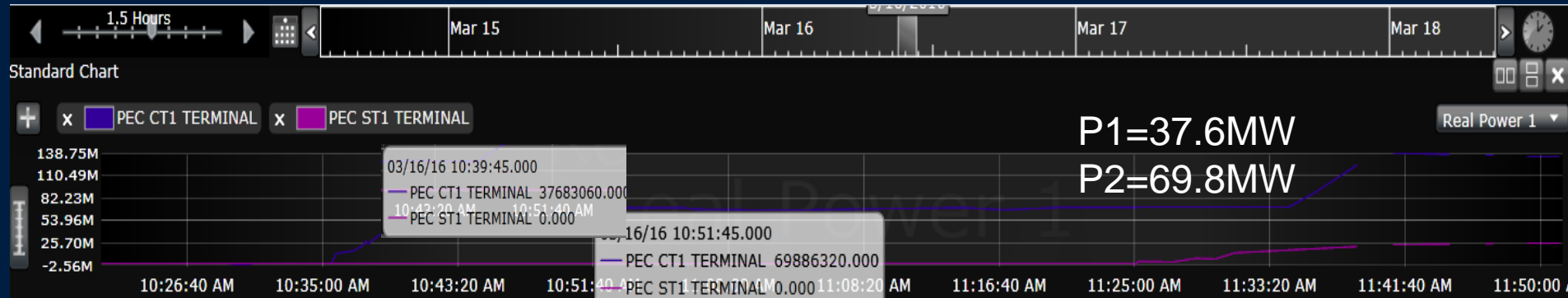


# CT1 Startup





# CT1 Loading



# Building on Forward Progress

- Continue monitoring and data validation
  - Field current, voltage
  - Rotor angle (1 & 60 pulse)
- Model validation
- NERC MOD verification
- Estimating generator parameters
- Real time condition assessment

**Questions?**