LSE for Synchrophasor Data Quality – Implementation and Performance at BPA

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Outline

- **WECC Synchrophasor Data Validation and Conditioning Application (SDVCA)**
  - Project Overview
  - Modeless Validation and Conditioning
  - Model-based Conditioning - LSE
- **EPG Enhanced Linear State Estimator (eLSE)**
  - Enhancements
  - eLSE Model Builder
  - Historical Data Testing
- **BPA Field Testing and Results**
  - BPA Testing Environment
  - Live Data Testing with ICCP Integration
- **Lesson Learned and Future Work**

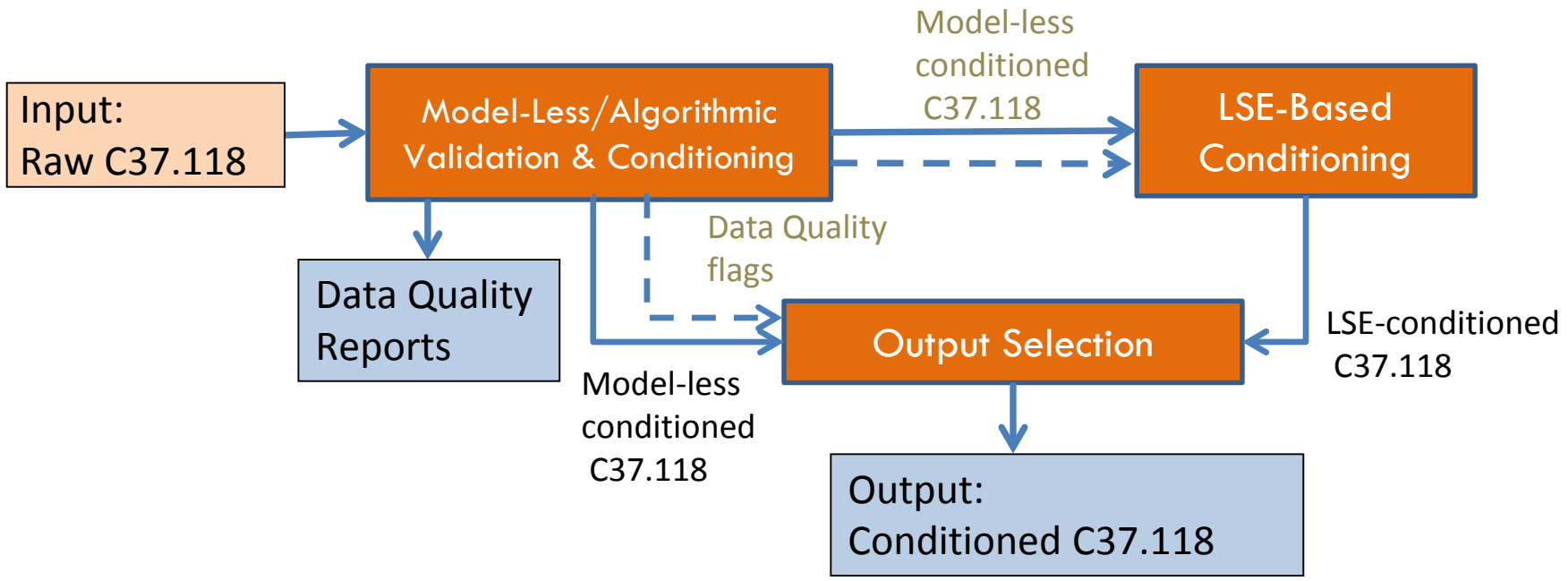
SDVCA Overview

- **Objective is to develop a validation and conditioning application of PMU data for WECC utilities**
- **Specified to include validation & conditioning using:**
  - Modeless algorithms
  - Model Based Linear State Estimator (LSE)
- **Modeless approach uses the algorithms developed under a DOE sponsored project**
  - EPG was the contractor for this project
- **Model based approach uses the LSE**
  - Enhanced VT/Dominion LSE code
- **Test and demonstration at BPA**
  - Test site arranged by WECC
  - Historical data testing using archived data
  - Real-time data testing using a live data feed

Modeless & LSE-Based Data Validation and Conditioning

Algorithms = Detect and Flag Bad Data

Linear State Estimator = Replace Bad Data with Validated Model Based Values



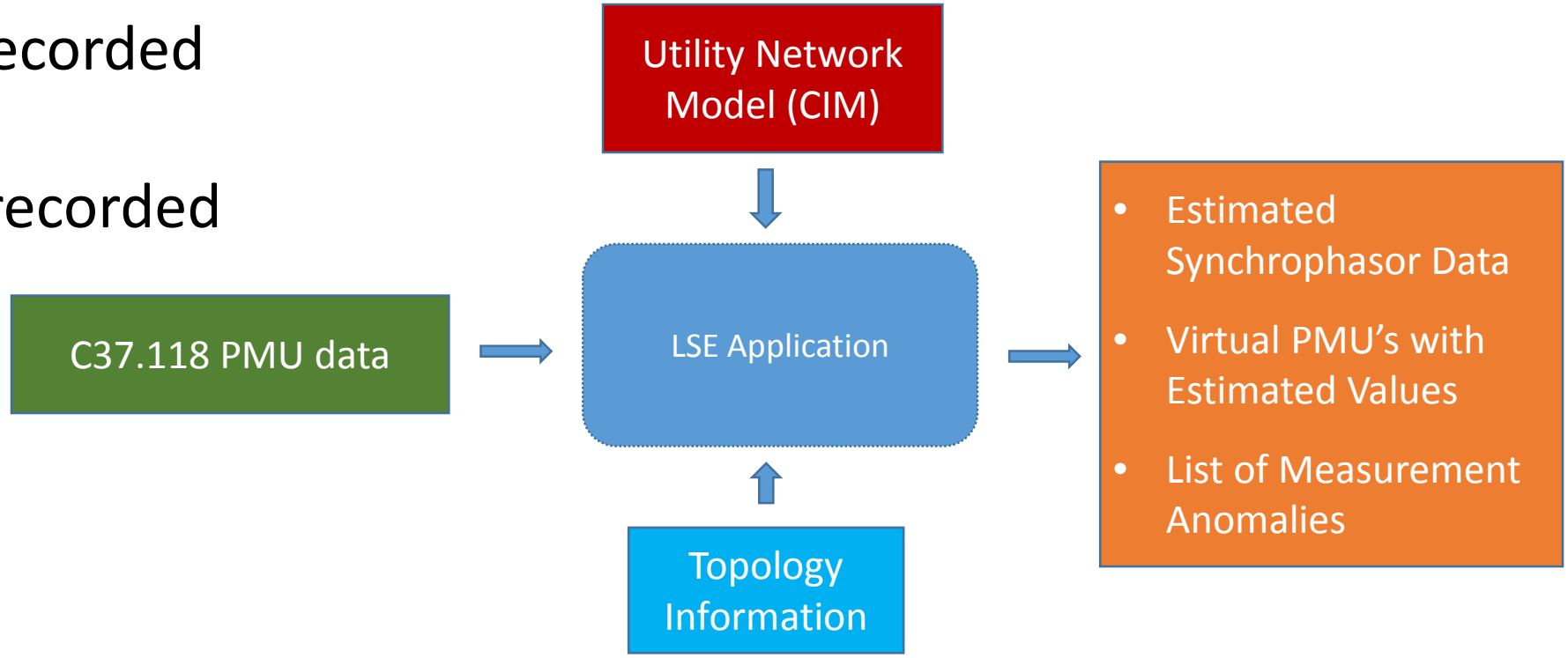
Modeless Validation and Conditioning

- Modeless Error Detection
  - Communication problems (format, CRC, etc. errors)
  - Problems in measurement (37.118 flags)
  - Timing errors and anomalies
  - Severe measurement anomalies (out of range values)
  - Measurement mismatch (topology comparisons)

- Modeless Conditioning
  - Flags bad or suspect values
  - Replace with user set value (NaN, last good, set number)

Model Based Conditioning – LSE

- Network Model (CIM format)
  - Converted into LSE format model
- PMU Data
  - Real-time or recorded
- Topology Info
  - From EMS or recorded



EPG´s *e*LSE and Major Enhancements

- EPG started with this open source code and developed a production grade *e*LSE that incorporates enhancements to operate on complex systems such as the WECC/BPA system
- Seven major enhancements
  - Bad data detection and identification module
  - Series Capacitor
  - Shunt capacitor/reactor
  - Split bus
  - Naming convention
  - Bypass breaker modeled in line
  - Breaker status interface to accept Inter-Control Center Communications Protocol (ICCP)

eLSE Network Model Builder – Four Major Components

- Automatic CIM parsing engine
  - > Parse the CIM model and convert it to LSE model
- Mapping File Creation
  - > Mapping PMU signals to LSE model
- Signal mapping engine
  - > Read the mapping file and automatically map PMU signal to the LSE model
- GUI of network model builder
  - > Edit network model, eg add or remove lines, breakers
  - > Update models

Field Testing on BPA System

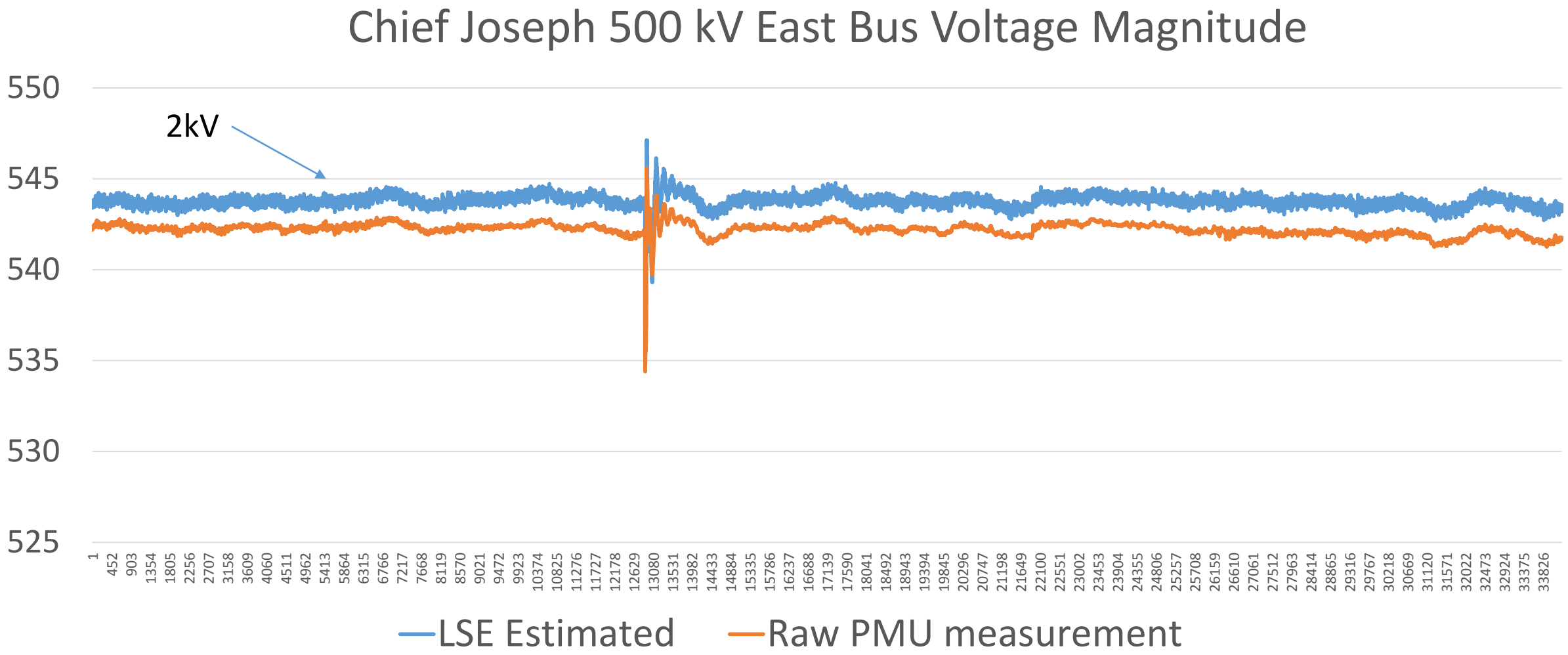
65 Observable Substations with PMUs at 37 Substations

- Validated for BPA's entire 500 kV and portion of 230 kV system
- System reduced to PMU visible area
  - 37 Substations with PMU installed
  - 220 phasor measurements
  - 65 observable substations
- Run properly at 60 frames per second
- Testing with historical and live PMU data

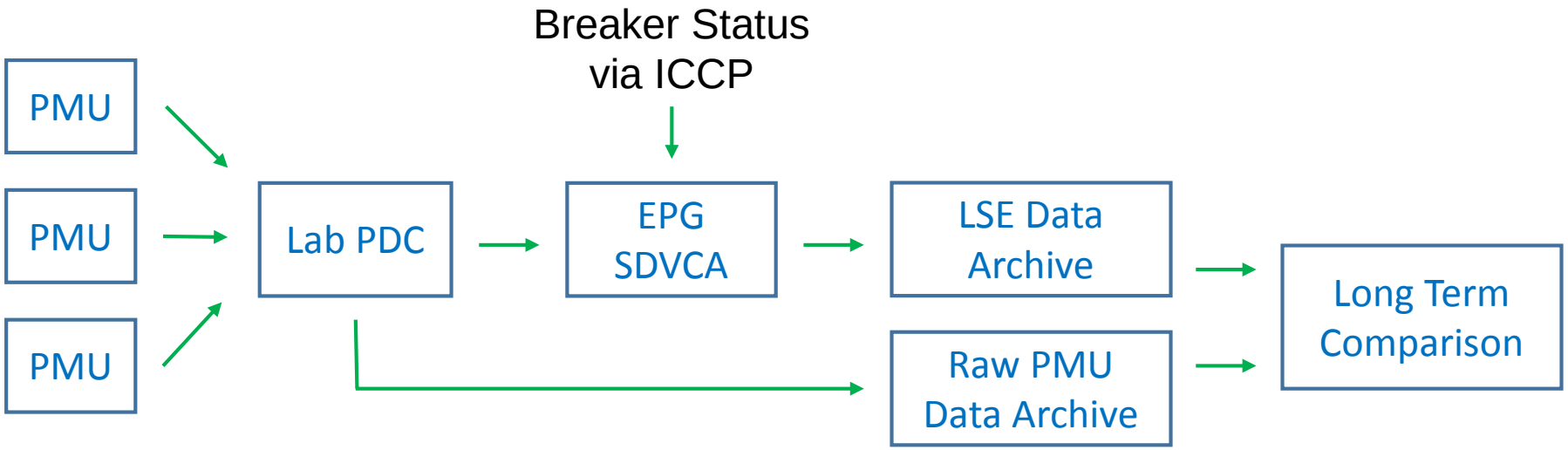
Elements	Number
Substations	65
Lines	96
Line Segments	126
Transformers	129
Nodes	3091
Breakers	849
Switches	2357
Series Capacitors	18
Shunt Capacitors	112
Observable buses	78

Historical Event Testing Results

- Chief Joseph Brake event



BPA Testing Environment

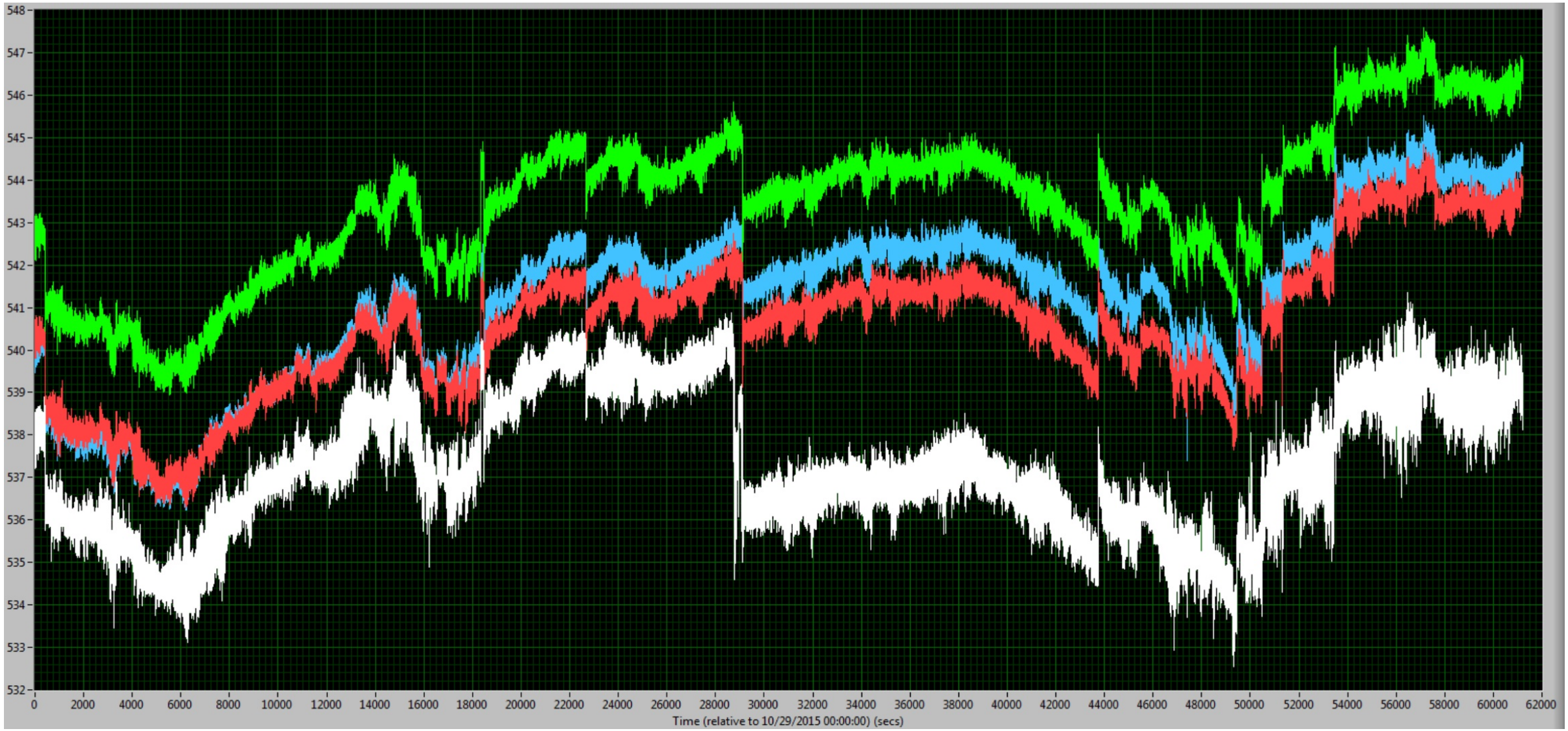


- SDVCA replaces measured values with state estimates
- Estimates stored in temporary LSE Data Archive
- Estimate compared to raw signal for reasonability

Live Data Testing Result - 17 hours

With Real-Time ICCP Update

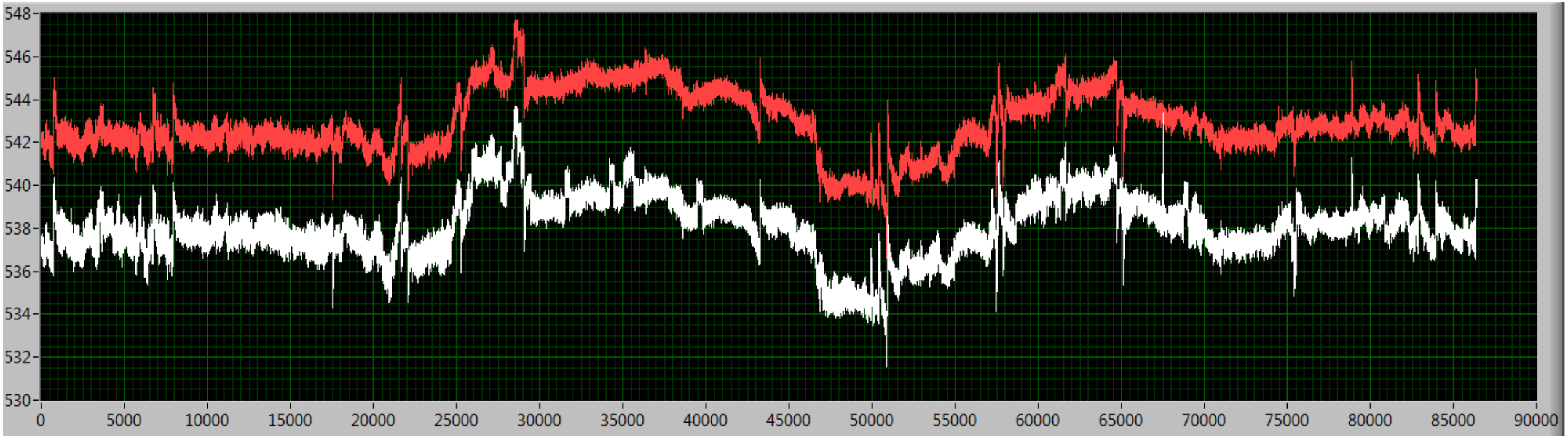
White: SDVCA Red: Phase A Blue: Phase B Green: Phase C



Recent Live Data Testing Result - 24 hours

With Real-Time ICCP Update

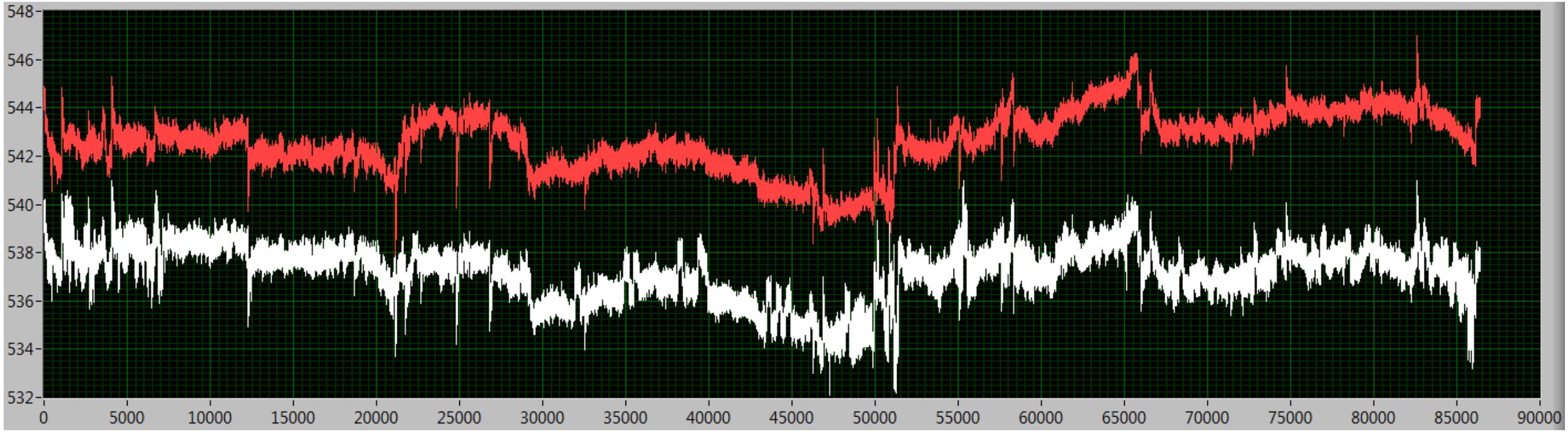
White: SDVCA
Red: Raw



Recent Live Data Testing Result – another 24 hours

With Real-Time ICCP Update

White: SDVCA
Red: Raw



Lessons Learned

- Standard CIM Model
  - > “Common” information model, NOT common, customization required
- Network parameters
  - > Critical for LSE estimated results
- Good redundancy of measurements
  - > Help detect bad data and give better estimated results
- PMU digitals for breaker status, instead of using ICCP
  - > No time skew issue if using PMU digitals

Future Work

- Continue long term testing
- Automate comparison of estimate vs. raw data
  - > Flag large differences, trace to issues in field
- Pursue issues with network model parameters
  - > Update models as necessary
- Test applications using conditioned data
- Investigate use of LSE in operational environment

Thank You - Questions?

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