OUTLINE

- Introduction
- Need for Asset Health Monitoring using Synchrophasors
- EPG’s iTAM Platform
- AEP Example – CCVT Failure Early Warning
- Use Cases
- Summary
ELECTRIC POWER GROUP (EPG) - INTRODUCTION

- Established in 2000 by an experienced team of electric utility executives
- EPG’s team includes internationally acknowledged industry experts in phasor technology
- EPG portfolio of Synchrophasor Applications are designed to deliver value to Transmission Companies and System Operators for Asset Monitoring, Event Notification, and Situational Awareness
- EPG provides synchrophasor solutions to over 30 Grid Operators and Transmission Utilities in North America, Middle East and India
EPG SYNCHROPHASOR SOLUTIONS

Phasor Data Management

Collection & Synchronization | Storage | Integration | Validation & Conditioning

*EPG PDC* | *Control Center PDC* | *PHASOR ARCHIVER* | *ICCP* | *IEC 104* | *DNP-3* |

Real-Time Analytics, Monitoring & Reports

*GridSmarts* | *eGENS* | *PhasorSmart* | *iTAM* |

Linear State Estimation

Enhanced Linear State Estimator

PhasorNXT Platform

Training

Phasor Simulator For Operator Training

Synchronphasor Training Courses

Edge Solutions

Big Data Analytics

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NEED FOR ASSET HEALTH MONITORING USING SYNCHROPHASORS

~ 60 Reported Failures between 1982-2004

*T. Yang, Applying Substation Linear State Estimator to Instrument Transformer Health Monitoring and Management: Roadmap, CIGRE 2016.
INTELLIGENT TRANSMISSION ASSET MONITOR – iTAM

PROACTIVELY DETECTING PRECURSORS OF SUBSTATION EQUIPMENT FAILURE TO TAKE PREVENTIVE ACTION
ITAM VALUE PROPOSITION

- Instrument Transformers such as PTs, CTs, and CCVTs are not monitored in substations
- Failures of PTs, CTs, and CCVTs have led to damage and/or explosions at substations, compromising personnel safety, affecting reliability, and causing outages
- The majority of failures in instrument transformers are electrical
- Electrical signatures can be analyzed using Synchrophasor data in real-time to identify anomalies and provide early warning.
- iTAM utilizes synchrophasor data and advanced analytics to monitor electrical signatures and issue alarms and alerts in real-time for timely operator action

*Improve Safety, Increase Reliability, Prevent Customer Outages, Reduce Cost*
iTAM – PLATFORM FOR ASSET MONITORING

- **Platform**: EPG developed iTAM to detect precursors to Equipment Failure
- **Data**: PMU (C37.118) and point-on-wave DFR data (COMTRADE)
- **Equipment**: Instrument Transformers (CT, PT, CCVT)
- **Methodology**: Advanced Data Driven Methods based on moving windows and dynamic thresholds, Substation Linear State Estimator – Model Based method
- **Flexible**: Central Location or in substations
- **Field Tested**: Deployed and validated at two AEP substations (138 kV & 765kV).
- **Visualization**: One Line Diagrams, Dashboards
- **Automated Alarm Notifications**
- **Filter Out False Alarms**: Designed to filter out false alarms by distinguishing instrument transformer failures from:
  - System Events (Line Trip, Generation Trip, Transients)
  - Bad Data (Dropouts, Time Errors, Communication Issues)
CCVT Failure Event - B Phase Voltage has anomalies/precursors before equipment failed

Can be detected 5 hours prior to failure, System is tuned to capture these failures and provide early warning
AEP EXAMPLES – CCVT FAILURE CAUSED 765KV LINE TRIP AND TRANSFORMER TRIP

Precursors Observed ~ 5 Hours Ahead

Precursors Observed ~ 5 Days Ahead

iTAM CAN DETECT DIFFERENT TYPES OF FAILURES

CCVT FAILURES THAT CAN BE DETECTED

<table>
<thead>
<tr>
<th>CCVT Failure type</th>
<th>Detected with physical inspection?</th>
<th>Detected by iTAM?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose fuse connections in CCVT safety switch</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Capacitor failure in high voltage stack of CCVT</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Capacitor failure in low voltage grounding stack</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Failure in voltage transformer and series reactor in CCVT</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Filter circuit failure and spark gaps</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Ferroresonance suppression circuit failure</td>
<td>✗</td>
<td>✔</td>
</tr>
</tbody>
</table>
# Types of Failures in CT’s and PT’s that Can Be Detected

<table>
<thead>
<tr>
<th>CT Failure type</th>
<th>Detected with physical inspection?</th>
<th>Detected by iTAM?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarity error</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Loose or corroded connections</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Open CT secondary</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Turn-to-turns shortage within same coil</td>
<td>❌</td>
<td>✓</td>
</tr>
<tr>
<td>Turn-to-ground shortage</td>
<td>❌</td>
<td>✓</td>
</tr>
<tr>
<td>Turn-to-turn shortage between different coils</td>
<td>❌</td>
<td>✓</td>
</tr>
<tr>
<td>Ratio setting error</td>
<td>❌</td>
<td>✓</td>
</tr>
<tr>
<td>Saturation of CT core and dielectric breakdown</td>
<td>❌</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PT Failure type</th>
<th>Detected with physical inspection?</th>
<th>Detected by iTAM?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blown Fuse</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Loose connections</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Primary winding issues</td>
<td>❌</td>
<td>✓</td>
</tr>
<tr>
<td>Secondary winding issues</td>
<td>❌</td>
<td>✓</td>
</tr>
</tbody>
</table>
NERC findings point to wiring issue in PT that triggered Interconnection Wide Oscillations.

Important to identify oscillations and locate source.

Also important to identify and address root-cause to prevent system wide impact.

Source: NERC, Oscillation Analysis Webinar, September 13, 2019
USE-CASE EXAMPLE

From NERC Lesson Learned Report

- NERC & NPCC Event Analysis Team Published a Report on April 14, 2020
- CCVT Failure Event caused a single-phase-to-ground fault
- CCVT had exhibited low, out-of-tolerance output prior to the event.
- Event caused communication equipment failure due to transient
- Primary and Back-up relay protection failed
- Fault continued for over 4 minutes causing significant damage

“Monitoring the output for “stair steps” can warn of developing failure”

https://www.nerc.com/pa/rrm/ea/Pages/Lessons-Learned.aspx
INSTRUMENT TRANSFORMER FAILURE EVENTS IN AUSTRALIA

- **March 3, 2017 – CCVT Failure**  
  - Explosive Failure of a CCVT in 275 kV Switchyard  
  - Caused series of faults and tripping of Busbar and generator  
  - Damage to generator disconnector  
  - Loss of 610 MW generation across 5 units  
  - CCVT was tested and physically/visually inspected 38 days before failure  

- **February 13, 2017 – CCVT Failure**  
  - Explosive Failure of a CCVT associated with 275kV line  
  - Caused single phase fault that developed into multiphase fault and tripping line  
  - Loss of 475 MW of load  

- **October 3, 2013 – CCVT Circuit Failure**  
  - Loose Fuse on secondary circuit of 330 kV line CCV  
  - Caused overvoltage and line outage  

- **November 20, 2015 – CT Failure**  
  - Explosive Failure of Current Transformer (CT) at 330 kV  
  - 330 kV Line Outage  
  - 125 MW customer load loss

*Source: AEMO Incident report, 10 March 2017  
Source: AEMO Incident report, 26 July 2017  
Source: AEMO Incident report, 16 December 2013  
Source: AEMO Incident report, August 2016*
EXAMPLES OF ITAM DETECTION CAPABILITIES
LOOSE CONNECTIONS, WINDING ISSUES, BLOWN FUSES, ETC.

Loose Fuse Connections in CCVT Safety Switch – OG&E
Switching Transients due to Ferroresonance
A - Phase CCVT Issue

References:
2) Bogdan Kasztanny and Ian Stevens, “Monitoring Ageing CCVTs – Practical Solutions with Modern Relays to Avoid Catastrophic Failures”, March 2007

Loose Connection at PT feeding the PMU – OG&E
Blown fuse on One Phase of PT – OG&E
Internal Primary Winding Issue - ATC
CVT Failure example from Dominion – PMU Data showed precursors 4 days before alarms from SCADA system
ONE LINE DIAGRAMS AND VISUALIZATION DISPLAYS

Alarms in real time displayed on one-line Diagrams

Analytics Screen
- Navigate between devices
- Navigate between time scales
- Dashboard with alarm history
- Trend charts with data, calculations, etc.

Alarm Indicator for each device monitored
REPORTING AND ALARMING – EMAIL NOTIFICATIONS

Sample email notification

Key Information:
- Substation effected
- Equipment alarming
- Faulty Phase
- Metric violated

Plot from Faulty equipment
SUMMARY

- iTAM – Synchrophasor Edge Solution for Asset Health Monitoring
- Complements Utility Asset Monitoring Systems
- Can be deployed at Individual Substations with alarms/results sent to other systems
- Designed to monitor instrument transformers (Current transformers, Voltage transformers, CCVT’s) that are critical to substation protection
- Detects precursors to failure and issues alarms and email notifications to Asset Managers to take pro-active action
- Substation equipment failures are costly – iTAM can prevent outages, reduce equipment replacement cost, promote safety
THANK YOU

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