Electric Power Group

iTAM

intelligent Transmission Asset Monitor

*i*TAM

Introduction

Utilities have made significant investments in substation and transmission assets. Substations are critical for reliable operation of power systems and serving customer loads. Substation assets, such as transformers, circuit breakers, instrument transformers (Current Transformers (CT), Potential Transformers (PT), Coupling Capacitor Voltage Transformers (CCVT)) and Intelligent Electronic Devices (Relays, PMUs, DFRs), must operate properly for power system operations, grid reliability, and personnel safety. Failure of these assets could cause forced outages, personnel safety issues, switchyard equipment damage, power system reliability issues, etc. PMU data from PTs, CTs, CCVTs, etc., can be used to monitor equipment signatures and identify anomalies that are precursors of potential equipment failure. Early warning, and timely intervention to repair or replace equipment before catastrophic failure will promote safety, reduce costs and prevent outages.

The iTAM Platform is designed to detect equipment malfunction and precursors to equipment failure and alert operators in time to take corrective action.

IIntelligent Transmission Asset Monitor (*i*TAM) addresses this critical utility need to monitor substation equipment health by monitoring equipment failure signatures and patterns in real time using synchrophasor data to identify operating anomalies for diagnostics and timely corrective action for proper operation of substation equipment*. iTAM* Platform uses advanced analytic methods to detect equipment malfunction and precursors to equipment failure. By monitoring signal signature anomalies *i*TAM can detect potential equipment malfunction and alert utility personnel in real-time to diagnose the malfunction and take appropriate actions to prevent equipment failure, customer outages and injury. It will also help avoid relay system mis-operation, equipment damage, forced outages, and safety hazards, and support calibration of Instrument Transformers (IT) & Intelligent Electronic Devices (IED).

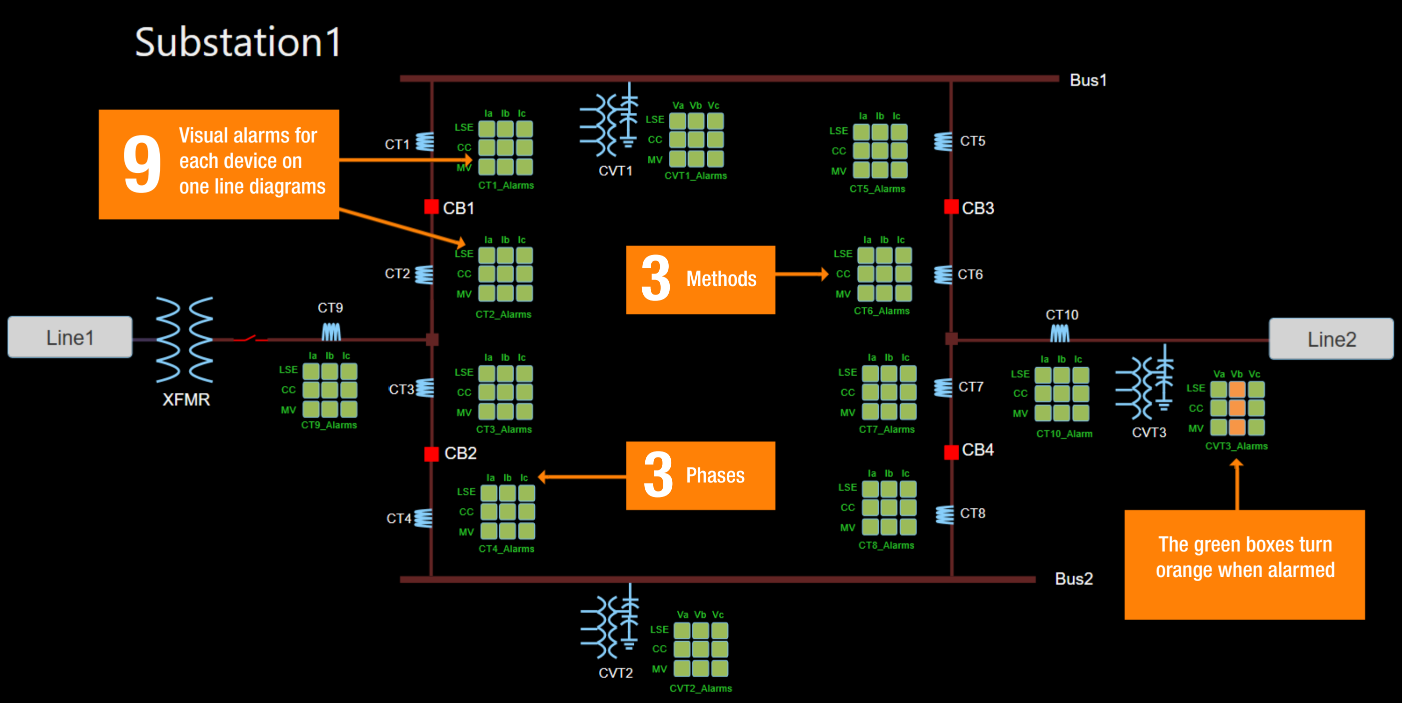
*i*TAM provides unprecedented visibility into the status and health of secondary equipment, especially CTs, PTs and CCVTs, by using high-resolution (30 samples per second and above for 60 Hz systems and 25 samples per second and above for 50 Hz systems) synchrophasor data to monitor signatures and data patterns to identify anomalies. It enables utilities to use synchrophasors as a complement to existing asset health monitoring tools.

Detection of **Failure Signals**

*i*TAM can analyze equipment signatures and alert relevant personnel to facilitate pre-emptive checking, repairs and other actions to prevent potential catastrophic failures. iTAM offers the following capability to detect transmission equipment failure in substations and alert operators via alarms:

- Monitoring of all ***three*** phases of each equipment
- Failure detection using ***three*** different methods - one model based on two data-driven methods
- Alarm panel with ***nine*** alarms for each equipment - each of 3 phases with 3 methods
- Alarms visualized in real time on one-line diagrams, alarm panels and on dashboard that included alarm history

The model-based method uses Substation Linear State Estimation (SLSE) and compares the SLSE estimated data to the measured PMU data. This method ignores system events such as line faults and tripped breakers and only detects local events/anomalous data that may indicate equipment malfunction. The data driven methods rely on statistical comparison of previous data in a time window to the latest data. When the latest data has an error and falls outside of what is expected given its history, an alarm will be triggered. The data driven methods cannot by themselves differentiate between system events that affect all the measuring devices, such as line faults and tripped breakers, and local events/anomalous data that effect very few measuring devices and may indicate hardware failure. Therefore, additional logic has been implemented to avoid alarming on system events.



Architecture and **Data Flow**

*i*TAM can receive input data from PMUs or devices that support COMTRADE data, such as DFRs; and sends alarms when it detects a failure signature of an instrument transformer (PT, CT, CCVT). COMTRADE input is converted to phasor data before it is sent to *i*TAM for further processing. PMU data flows through DataNXT for conditioning before it is sent to the *i*TAM engine. *i*TAM is both an application and an application host. *i*TAM runs all the calculations for the data driven algorithms for anomaly detection. It hosts 4 applications: InfluxDB database, Grafana visualization platform, SLSE Engine, and DNP3 Module. The applications can be run locally at the substation(s) or from a centralized location such as the control center. Alarms can be sent to the EMS via industry standard protocols, such as DNP3. *i*TAM functions as follows. *i*TAM receives data from DataNXT and the data is stored in InfluxDB. *i*TAM hosts the SLSE that takes data from Influx DB, runs its calculations and sends them to InfluxDB. Separately, *i*TAM runs the data driven algorithms Control Chart and Moving Variance and adds the results to InfluxDB. Once all operations are performed on the data and the results are stored in InfluxDB, the results are displayed in Grafana. Alarms can be displayed in Grafana or on the One-Lines diagram. Flags and alarms can be sent to EMS using DNP3 Module.

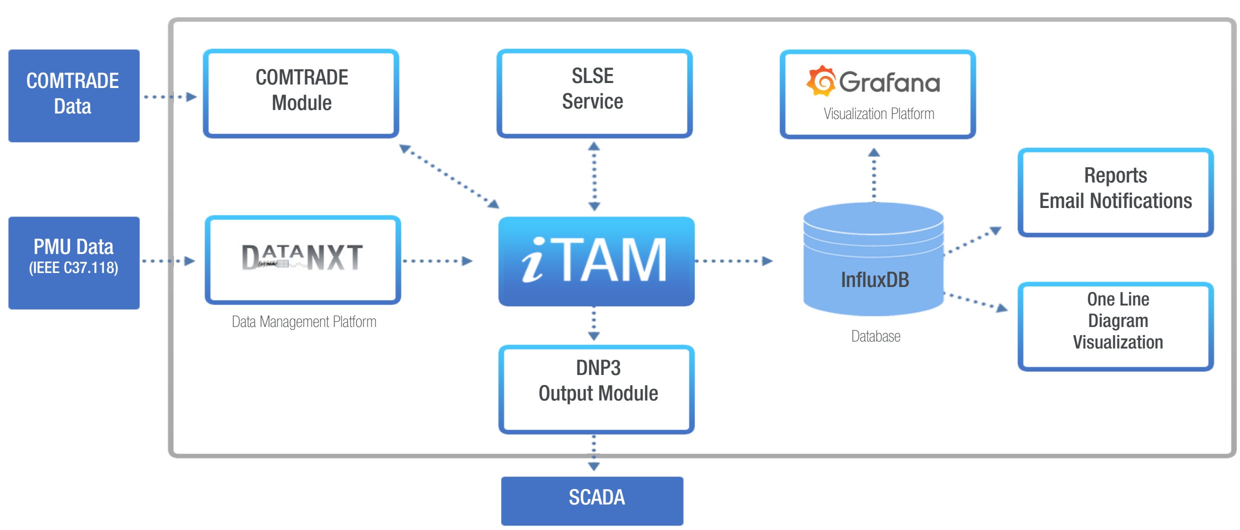
Details of the *i*TAM applications are as follows:

1. **Database:** InfluxDB is the database where the field measured data and the calculated results are stored. InfluxDB works in the back-end and is not directly configurable by the end user. InfluxDB is installed and configured automatically by *i*TAM installation package.
2. **Visualization Platform:** Grafana directly displays data from InfluxDB database. Grafana can also perform many calculations to the data before it is displayed in order to improve visualization.

   a. *Alarms can be displayed directly on the One-Line diagram.*
   b. *Alarms can be displayed in alarm panel on Grafana. Grafana can directly display any data from influxDB database can be customized to the user's requirements including alarm history dashboards, trend charts, raw and calculated data, etc. Grafana can also perform many calculations to the data before it is displayed in order to improve visualization.*

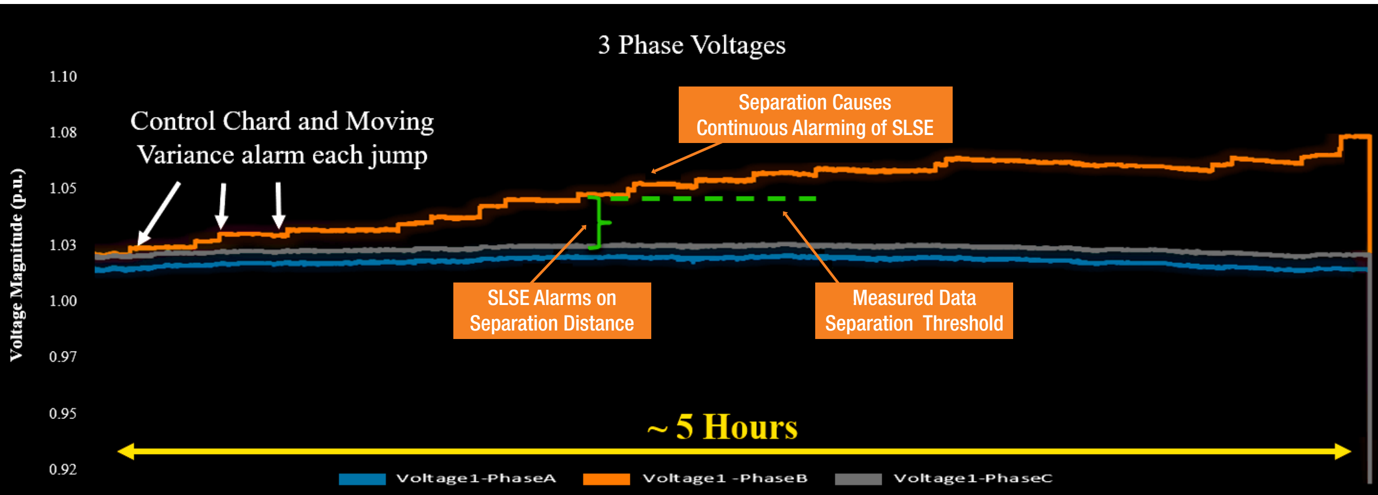
3. **Data driven methods:** Data driven methods include Control Chart and Moving Variance algorithms. The data driven methods rely on statistical comparison of old data to new data. When a new data has an error and falls outside of what is expected given its history, the data point will be alarmed.
4. **SLSE Engine:** *i*TAM controls the SLSE Engine that is installed separately. SLSE is a model-based method utilizing three phase Substation Linear State Estimator (SLSE) for monitoring and diagnostics of substation equipment anomaly signatures and patterns.
5. **DNP3 Module:** DNP3 interface is a built-in function of *intelligent* Transmission Asset Monitor (*i*TAM). When enabled, *i*TAM will work as a single or multiple DNP3 slave(s) and TCP servers. It will respond to DNP3 master or masters to poll. *i*TAM supports multiple DNP3 slaves when needed so that multiple DNP3 masters can poll data.
6. **Reports:** When an equipment anomaly is detected, detailed reports are generated and sent out via email.

Data Flow



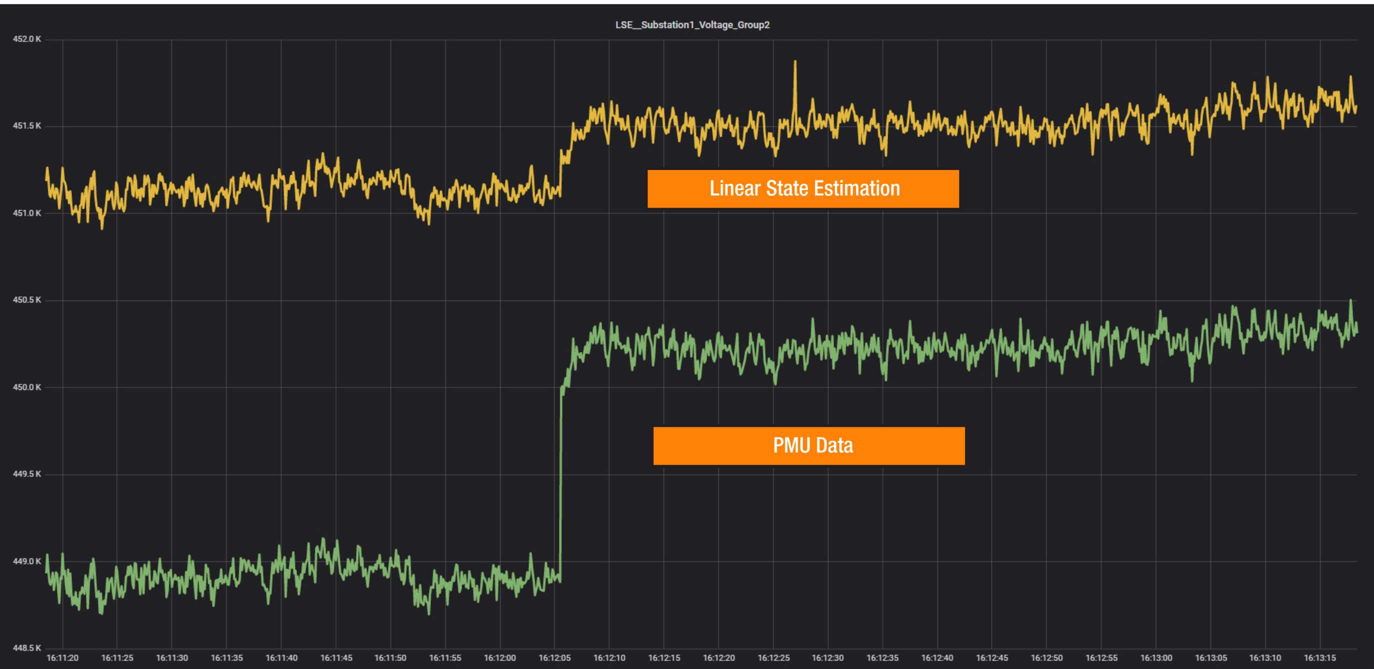
CCVT **Failure Detection**

*i*TAM has been validated for a CCVT failure event shown below. Failure of capacitor stacks in the CCVT triggered alarms as early as 5 hours before the device was disconnected. The data driven methods and the Substation Linear State Estimation (SLSE) methods both detected the CCVT failure. The SLSE alarms when the separation between calculated and measured data surpass a threshold. The data driven methods treat each jump in voltage as a sperate event and alarm each event separately.



Model Based **Method**

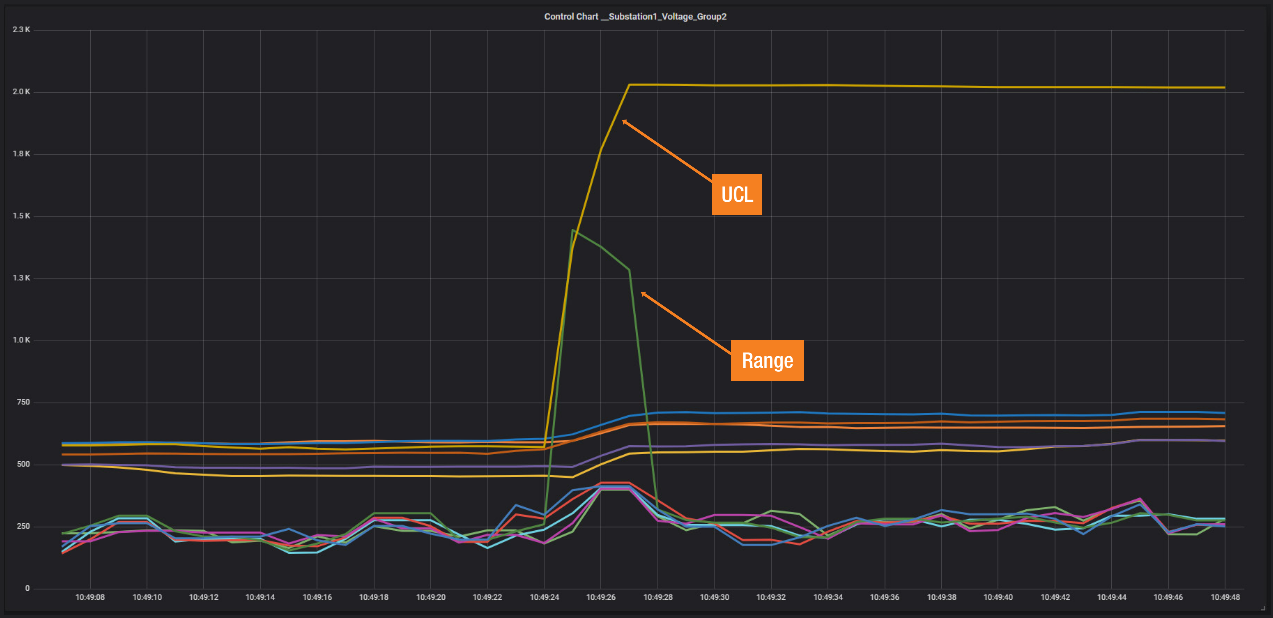
A model-based method utilizing three phase Substation Linear State Estimator (SLSE) is used for monitoring and diagnostics of substation equipment health. The SLSE leverages synchrophasor data and three phase linear state estimation technology using substation topology and measurement mapping information to estimate breaker status and to formulate a weighted least square problem. The solution of the SLSE is then used to compare the estimated data with the measured data. An anomaly is detected if the measured data is statistically different from the model-based estimation. The SLSE successfully differentiates between system events and local anomalies, only flagging for the latter ones as local anomalies indicate signs of problems with substation secondary equipment such as PTs, CTs, and CCVTs.



Data Driven **Methods**

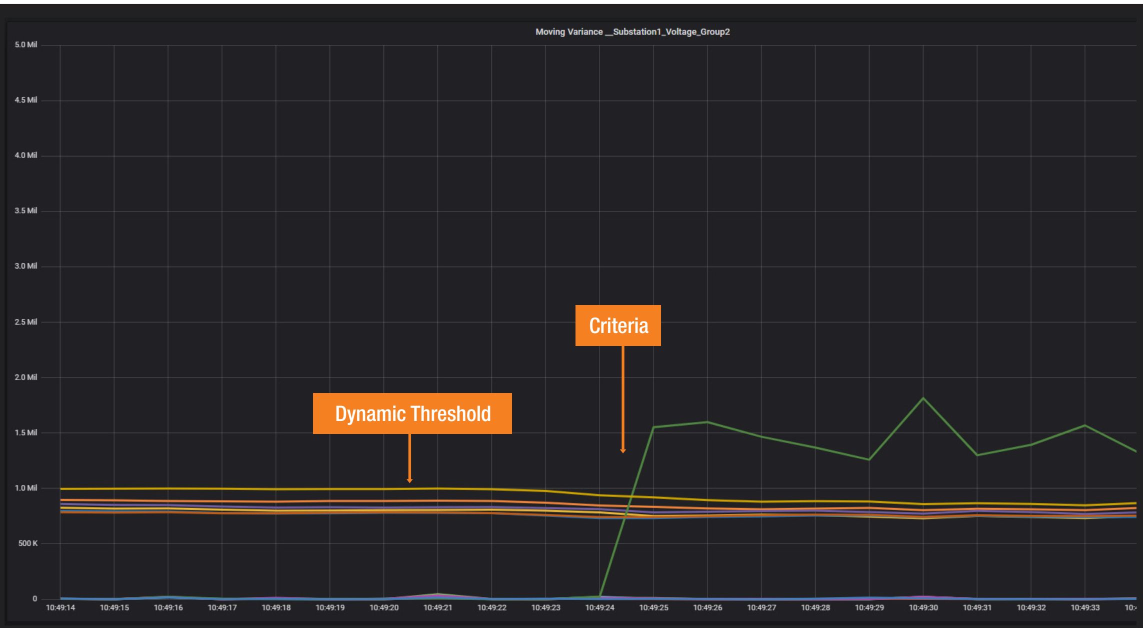
Control Chart

The control chart uses the R Chart method. This method divides the time window into sub windows. For each sub window the Range of the sub window is calculated by subtracting minimum from maximum of the sub window. Then a mean central line is calculated for the Range window. The upper control limit (UCL) is calculated using a user-defined multiple of the standard deviation. Data is flagged based on comparison between the change of the Range and the UCL. In the figure, the CCVT failure is detected when the Range rises above the UCL.



Moving Variance

A Dynamic Threshold is calculated by multiplying a user configurable scaling factor by the moving variance. The criteria are created by taking each new data point and centering and squaring it. The Criteria is the compared to the Dynamic Threshold. In the figure, the CCVT failure is detected when the Criteria rises above the Threshold.



Features and **Functionalities**

Overall

- Three phase Substation Linear State Estimator (SLSE) to detects measurement issues – precursor to asset failure
- Two data driven methods to detect data anomalies - precursor to asset failure
- Customizable displays/dashboards of data and results
- Visual alignment of 3 algorithms across 3 phases for cross validation of alarms
- Alarm display on one-line diagram
- DNP3 output to SCADA
- Input PMU or Point on Wave data

Web-Based Visualization

- Visualize and query data
- Panels - *Graphs/Trends, Gauge, Bar Charts, Logs, Single Statistics Dial/Panel, Tables, Heatmaps, Alert List, Dashboard List, Text Panels*
- User defined Dashboards - *Variables, Annotations, Folders, Playlist, Search, Sharing, Synchronized Time Range, Export & Import*
- Aggregators – *Count, Distinct, Integral, Mean, Median, Mode, Sum*
- Selectors - *Bottom, First, Last, Max, Min, Percentile, Top*
- Transformations – *Derivative, Spread, Non-negative derivative, Difference, Moving average, Cumulative sum, Standard deviation, Elapsed (periodic value)*
- Customizable Dashboards
- Alerting on various metrics – *Frequency, Voltage, Current, Real and Reactive Power, Composite Metrics, User-Defined Calculations*
- Email reporting and notification

System Requirements

Operating System:	64 bit Microsoft Windows 10
Processor Speed:	2.8 GHz or higher
Processor Cores:	Intel Processors (4 cores total or greater)
Memory:	8 Gigabytes or greater
I/O Ports:	1 Network Interface Card (NIC) supporting 1 Gbps
Hard Disk Storage:	100 GB Minimum

Substation Deployment can be on a PC or a hardened PC

About **EPG**

Electric Power Group (EPG) was established on June 24, 1999 and began operations in 2000. EPG is led by technical, management, and executive level personnel with extensive utility power systems experience in planning, operations, transmission, protection with specialization in use of synchrophasor technologies and advanced applications for analytics, real-time operations and grid monitoring technologies. EPG's research in the use of synchrophasor measurements led to the development of the first of its kind wide-area real-time performance monitoring system for electric grids, referred to as Real Time Dynamics Monitoring System (RTDMS®); the first prototype was installed at California ISO in 2003. EPG's RTDMS® application for Wide Area Situational Awareness and other synchrophasor applications are in use at many of the leading ISOs and utilities in North America for real time and off-line analytics as well as real time wide area situational awareness and monitoring in control centers. EPG applications using SCADA data are installed at North American Electric Reliability Corporation (NERC) for reliability monitoring.

EPG is a leading provider of synchrophasor technology solutions with more than 32 customers in USA, Canada, Middle East, India and Dominican Republic. EPG specializes in working with transmission companies, utilities and ISOs in the areas of power systems planning, analysis, reliability technologies, control center operations, research and development, and development and implementation of synchrophasor technology applications. EPG has been working with synchrophasor technology since 2001 and has extensive first-hand knowledge and experience with addressing the challenges that ISOs and utilities face in making use of synchrophasor applications by operators, reliability coordinators, operating engineers, and planners.

EPG experience covers all components of synchrophasor technology networks and use of synchrophasor technology data for reliability management including – data collection, synchronization, data validation and conditioning, data archiving, linear state estimation, real-time streaming to applications, real-time monitoring and offline analysis applications for use in control room, engineering environments, substations, universities and technology centers.

EPG WAMS and Substation Applications

PHASOR DATA MANAGEMENT

Collection and Synchronization

eSPDC
Substation PDC

ePDC
Control Center PDC

Storage

PHASOR ARCHIVER

Integration

ICCP

DNP-3

Validation and Conditioning

DATA NXT

Algorithms / Models

GRID RESILIENCY

PhasorNxt

TRAINING

PSOT

Phasor Simulator
for Operator Training

Synchrophasor
Training Courses

REAL-TIME ANALYTICS, MONITORING, NOTIFICATIONS & REPORTS

PHASOR RTDMS®
Analytics and Monitoring

eGENS
enhanced
Grid Events
Notification System

gs
GridSmarts
Reports

OFFLINE ANALYTICS PLATFORM

Phasor Grid
Dynamics Analyzer

ePDE
Phasor Data Extractor

AUTOMATED Event Miner
Big Data Analytics

LINEAR STATE ESTIMATION

eLSE
enhanced Linear State Estimation

GRID PERFORMANCE

GRID PERFORMANCE
ASSESSMENT SERVICE

SUBSTATION APPLICATIONS

iTAM
Intelligent
Transmission Alert
Monitor

eGENS
enhanced
Grid Events
Notification System

GMV
Generator Model
Validation

PhasorSmart
WAMS Package for Substations

for further information on all EPG products and services please visit us at www.electricpowergroup.com

Electric Power Group
251 South Lake Avenue, Suite 300
Pasadena, CA 91101 USA
Tel: (626) 685-2015
www.electricpowergroup.com
contact@electricpowergroup.com