

PHASOR SIMULATION FOR OPERATOR TRAINING (PSOT)



DOE Grant Award DE-OE0000702

NASPI Presentation

**Neeraj Nayak – Electric Power Group, LLC
October 20, 2016**

PSOT Project Participants

- **Southern California Edison (SCE)** – Cost Share Participant
 - Project Manager – Jun Wen/Armando Salazar
- **Electric Reliability Council of Texas (ERCOT)** - Cost Share Participant
 - Project Manager - Bill Blevins
- **Electric Power Group, LLC** – Prime Contractor and Cost Share Participant
 - Project Manager - Jim Dyer
- **Powertech Labs Inc.** – Added to Project for Real Time Simulations with TSAT/ePMU
 - Project Manager - Lei Wang

Topics to be discussed...

- PSOT Need and Background
- What is PSOT?
- PSOT Use Case Examples
- Training Methods
- PSOT Status and Next Steps for Training
- Web-based Synchrophasor Training for Operators and Engineers

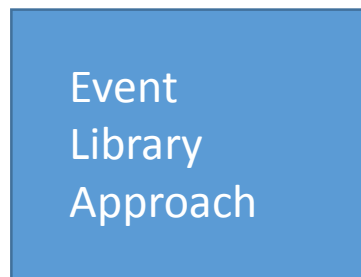
PSOT Need and Background

- Need for Operator Training identified by DOE and industry
- DOE issued an FOA in 2014 - EPG PSOT Project Selected for Funding with SCE and ERCOT as Cost Share Partners
- Project Objectives - Research, design, develop and demonstrate a pre-commercial phasor-based training simulator to train power system operators on the use of synchrophasor technology
- Project Completed – PSOT Demonstrated and Implemented at SCE and ERCOT
- PSOT has progressed beyond original DOE Funded Project Scope

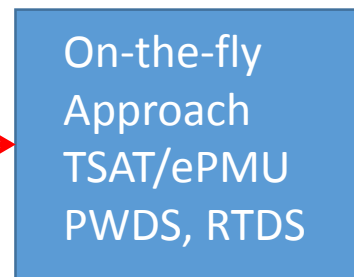
DOE Funded Project

SCE, ERCOT – Implementation

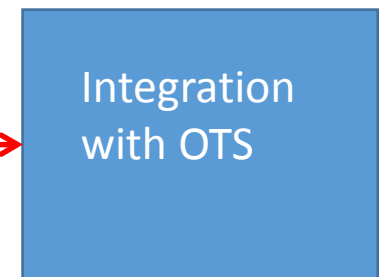
Planned



Software
Technology
Advancement



Participants
desire to Run
OTS & PSOT in
parallel



Simulation Time:
15-20 minutes

**< 5 seconds,
less wait time**

**Designed
Completed**

What is PSOT?

- A **Phasor-based training simulator** to train power system operators on the use of synchrophasor technology
- PSOT can be used for training using two approaches
 - Event Library – Simulated or Recorded Events
 - On-the-Fly Simulations
- PSOT Components Include:
 - Industry Standard Power System Simulation Tools including - PSLF, PSS/E, TSAT/ePMU for Off-Line; and TSAT/ePMU, Power World Dynamics Studio, RTDS, ePhasorSim for On-the Fly Simulations
 - Event Streamer and Library Manager
 - RTDMS for Visualization
- PSOT is now available commercially with a library of 10 events which can be expanded

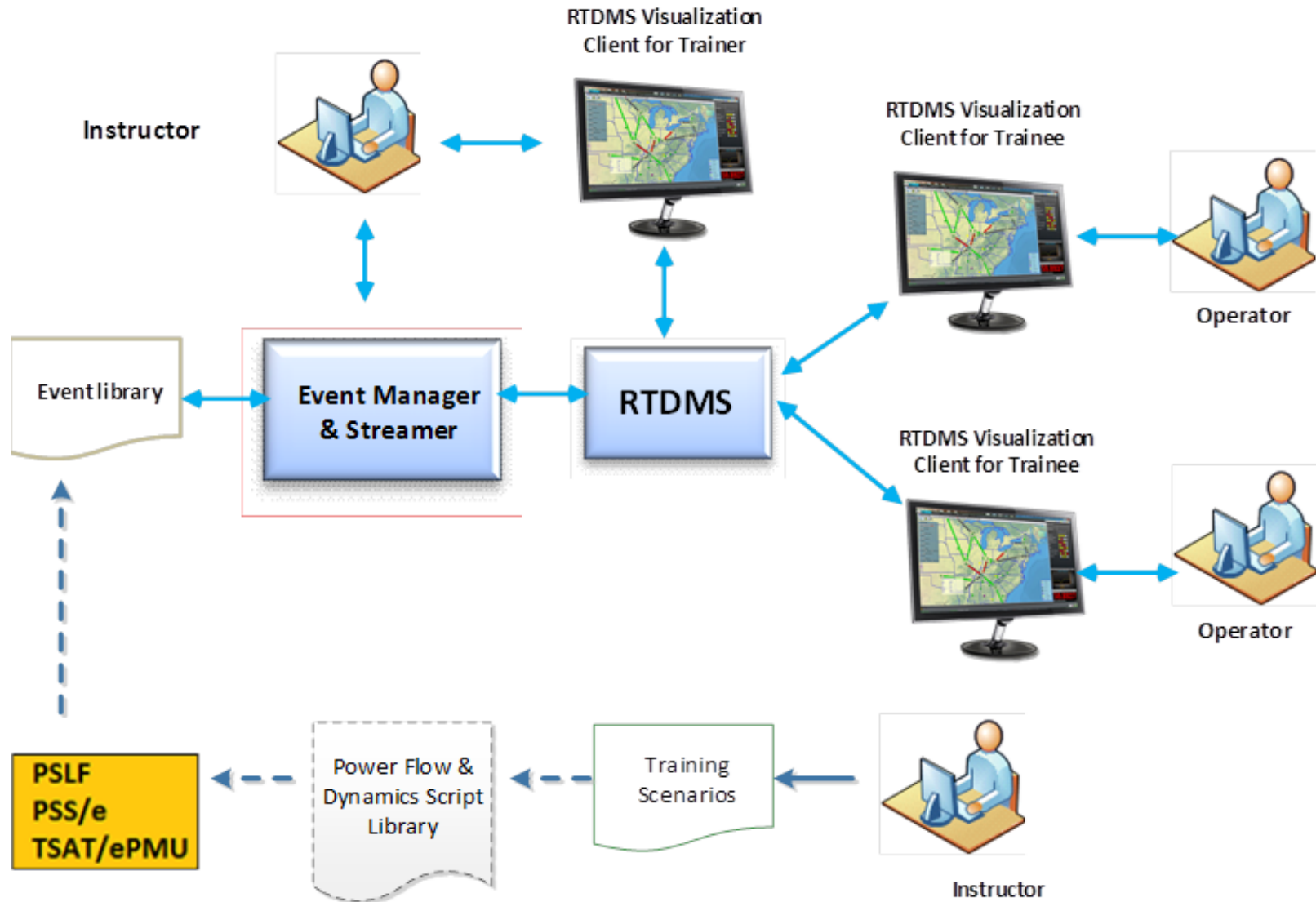
PSOT Use Case Examples

- Operator Training – Event Library and On-the-fly
- Validate Alarm Threshold Settings for Use in real time operations – NYISO
- Outage Planning – Simulate and Validate Maintenance Plans - SCE
- Test and Validate New Algorithms and Linear State Estimator
- Validate real-time actions prior to implementation

Starter Library - 10 Training Events with Corrective Actions

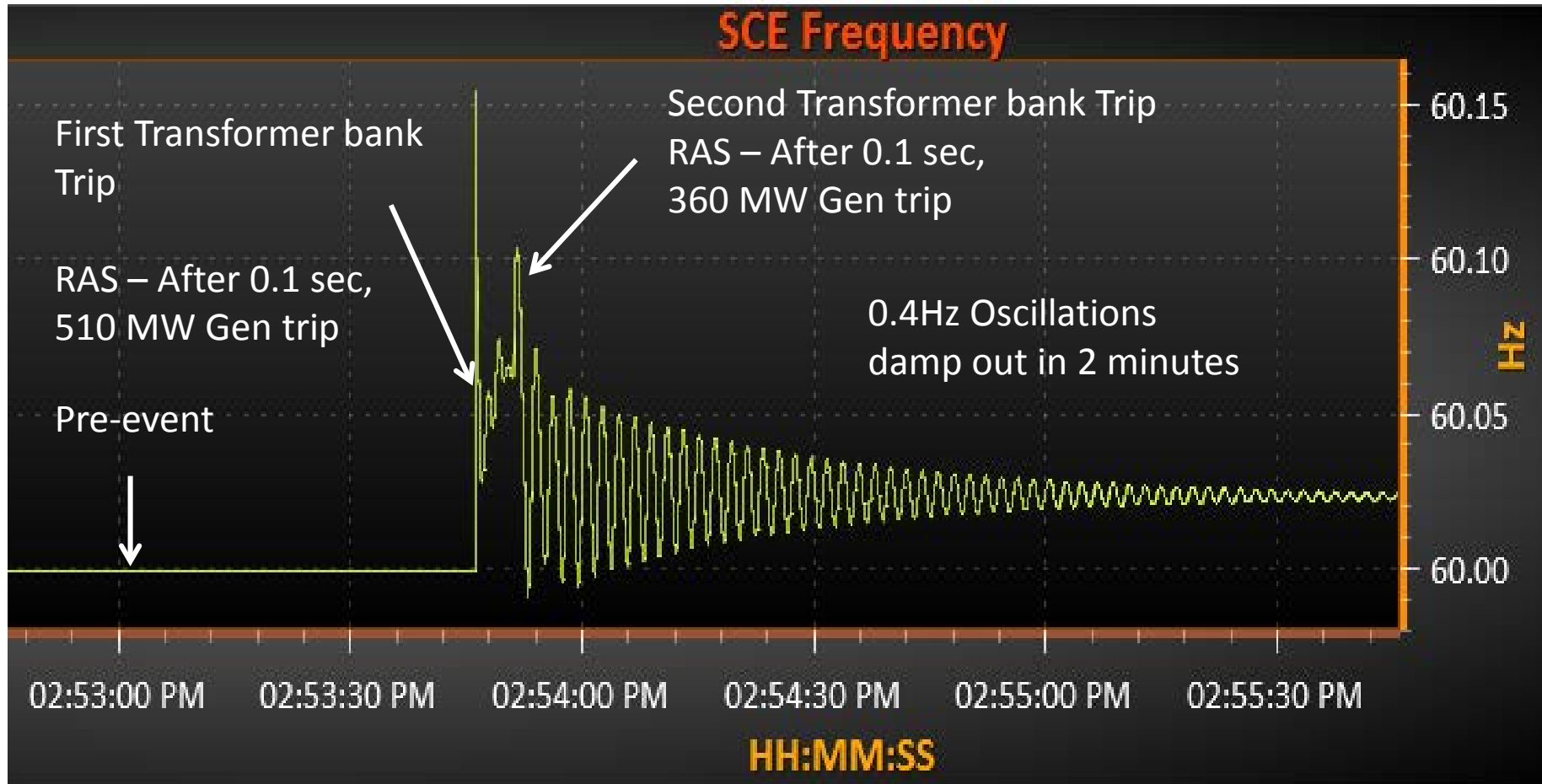
| Training Event | Event Detection: Alarms | Event Diagnostics | System Violations | Corrective Actions |
|--|---|--|---|---|
| System Separation | Islanding popup notification, Over Frequency/Voltage in island | Fault+ Line Trip | Islanding, Over Frequencies/Voltages in island | Generation Trip, SVC Switch in |
| Loss of 2 parallel 500 kV lines | High Phase Angle Differences, High Power Flow | Fault + Line Trip | Line Overload, Phase Angle Differences Increase | 1550 MW Load Drop |
| Loss of 3 parallel 500 kV lines | High Phase Angle Differences, High Power Flows, Low Voltages | Fault + Line Trip | Low Voltages, Line Overloads, Phase Angle Differences Increase | 2625 MW Load Drop |
| Loss of 2 parallel 500 kV lines and generation drop | High Phase Angle Difference, High Power Flow | Fault + Line Trip | Line Overloads, Phase Angle Difference Increases | 800 MW Generation Trip |
| Loss of Double circuit 345kV lines | Phase angle difference Alarm | Fault + Line Trips | Phase Angle Difference Increases | 1. Reduce 900MW Wind Generation 2. Reclose Relayed Lines |
| Loss of 2 500/230 kV Transformer Banks | High Phase Angle Difference, Low Damping Oscillations | Fault + Transformer Trip | Low Damping oscillations, Phase Angle Difference Increases | 870 MW Generation Trip |
| Compound Event - Loss of 3 units and Loss of two 345 kV Lines | Phase angle difference Alarm & Instability Alert Popup | Generation + Line Trips | Frequency drops, Phase Angle Difference Increases | 1. Drop 700MW Load 2. Reclose Relayed Lines and Restore Dropped Load |
| Wind Farm Oscillations | Low Damping Alarm and Popup, High Rate of Change Alarms in Frequency, Voltage, Phase angle difference Alert | Oscillations Near Wind Power Plant | Low Damping < 1%, High Rate of Change in Frequency, Voltage and Phase Angle Difference | 1. Curtail Wind Output below 40MW to reduce magnitude of Oscillations 2. Restore correct Control Settings & Increase Wind Output |
| Hydro Unit Oscillations | Low Damping Alarm and Popup, High Rate of Change Alarms in Frequency, Current, Phase angle difference Alert | Oscillations near Hydro Power plant | Low Damping < 1%, High Rate of Change in Frequency, Current & Phase Angle Difference | 1. Curtail Hydro Unit Output to reduce magnitude of Oscillations 2. Restore correct Control Card & Increase Hydro Unit Output |
| N-3 & Wind Ramp Event | Phase angle difference Alarm, Low Frequency Alarm | Line Trips + Generation Trip + Wind Power Ramp | Frequency Drop, Phase Angle Difference increases significantly, Wind power output increases greatly | Curtail Wind Output |

Event Library Method - Flow Diagram



Event Library Method - Example

- Loss of two 500/230 kV Transformer Banks in SCE's High Desert Region



On-the-fly Method - Flow Diagram

RTDMS Visualization
Client for Trainer

RTDMS Visualization
Client for Trainee



Operator



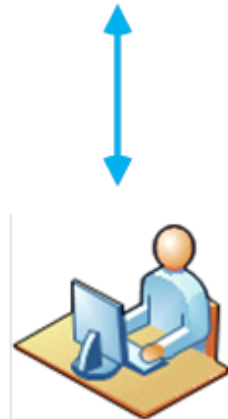
IEEE 37.118



RTDMS Visualization
Client for Trainee



Operator



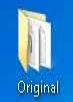
Instructor

Training
Scenarios

On-the-fly Method - Example

N-5 Event with Generator Trip, Line Trip, Load Drop, Restoration

| | Time | Sequence | Status / Actions |
|----|----------------|--|--|
| 1. | 0-40 s | Pre-Event | System Frequency at 60Hz |
| 2. | 40 s | N-3 Units Trip | Loss of 650 MW of Generation |
| 3. | 100 s | Double 345 kV line fault (3-phase) | |
| 4. | After 5 cycles | Fault Cleared | N-4 & 5 Events - Both 345 kV Lines Relay |
| 5. | 120 s | Drop 700 MW of Load | Corrective action taken |
| 6. | 140 s | Reclose Relayed Lines | System stable |
| 7. | 160 s | Restore 700 MW of Load | System recovers |



TSAT

File View Auto Help

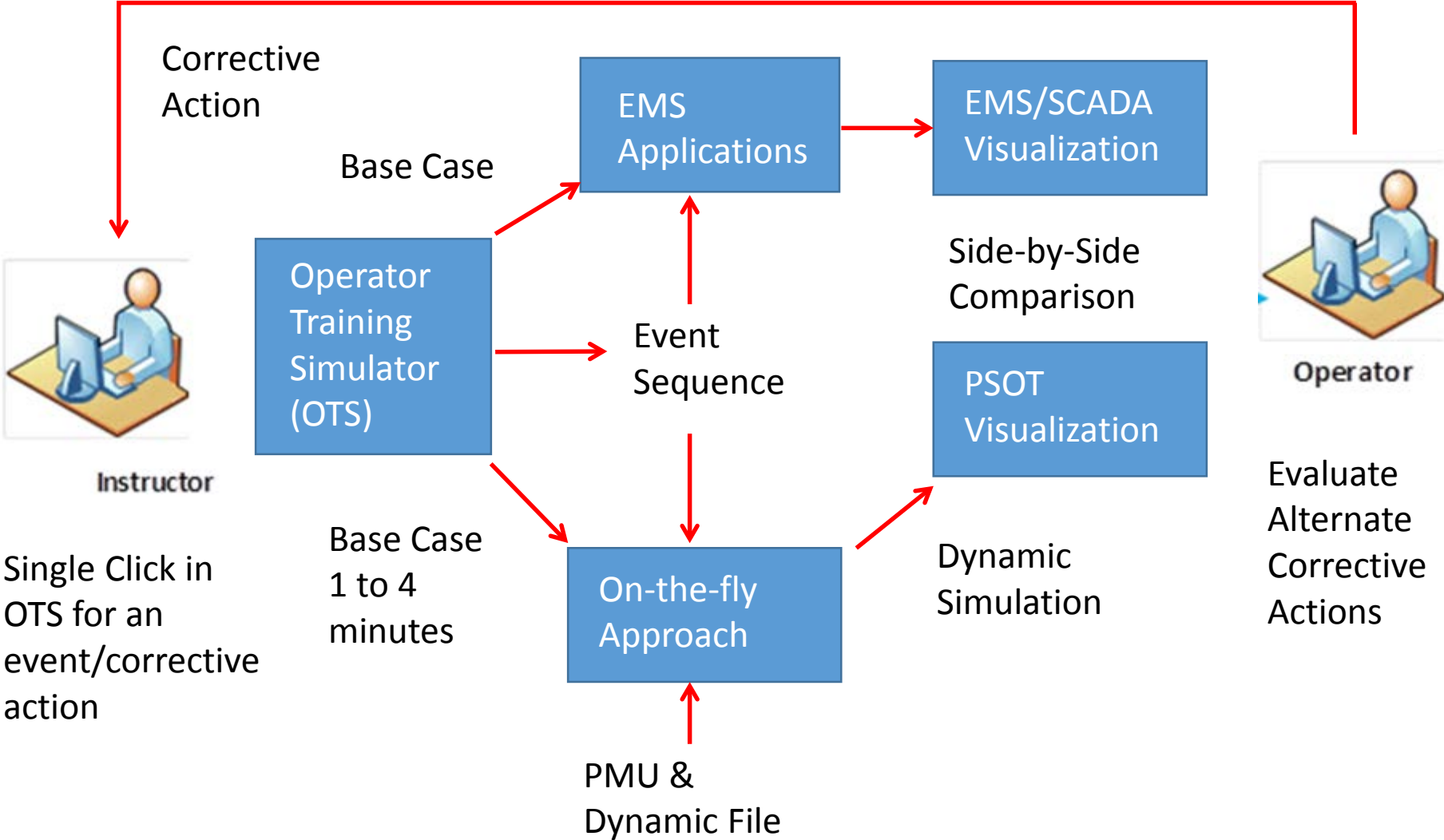
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Ready

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PSOT Integration with OTS - Planned



PSOT - Status and Additional Technologies for Training

- PSOT Developed, Demonstrated, Integrated and Implemented at SCE and ERCOT – Adopted by Training Departments
- State of the Art Advanced from Initial Event Library Concept to Real Time On-The-Fly approach
- PSOT Use Cases Expanding
 - Operator Training – Event Library and On-the-fly
 - Validate Alarm Threshold Settings for Use in real time operations – NYISO
 - Outage Planning – Simulate and Validate Maintenance Plans - SCE
 - Test and Validate New Algorithms and Linear State Estimator
 - Validate real-time actions prior to implementation
- PSOT Now Commercially Available with 10 Library Events
- Additional Technologies
 - Web-based Synchrophasor Training Portal Developed for Operator Training
 - Integration with OTS Planned

Introduction to Synchrophasors Course Available on EPG's Training Portal

- Foundational Course On Phasor Technology with 5 Sessions
 1. Synchrophasor Fundamentals - **Ken Martin**
 2. Synchrophasor Metrics – Use in Real Time Operations – **Wayne Schmus**
 3. Phase Angle Differences – How can they used in Operations? - **Jim Dyer**
 4. Grid Event Signatures – Use to detect and diagnose grid events - **Prashant Palayam**
 5. Power System Oscillations – Types, Causes and Monitoring - **Kevin Chen**
- Each session is 1 hour - Video based, includes on-line quizzes, access via internet
- Flexible (24x7), reduces training costs
- Designed for Operators, Engineers, Planners, Trainers, Field Personnel
- Additional Courses in Development



Introduction to Synchrophasors and EPG_116487_Online_Introduction_to_Synchrophasors is recognized by the North American Electric Reliability Corporation as an approved learning activity for which 5.00 NERC CEHs can be awarded, and Electric Power Group adheres to CE Program Criteria.

Thank You & Any Questions?



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