SmartConnect Use Case:

D16 – Utility uses phasor data for grid operation, control and analysis

May 5, 2009

Document History

Revision History

Revision Number	Revision Date	Revised / Reviewed By	Summary of Changes	Changes marked
(#)	(yymmdd)	(Name)	(Describe change)	(Y/N)
0.1	090224	Kevin Clampitt	Initial draft from workshop on November 20, 2008	N
0.2	090423	Kevin Clampitt	Second draft	N
0.3	090506	Kevin Clampitt	Third draft	N

Approvals

This document requires following approvals.

Name	Title
Bryan Lambird	Project Manager, Planning & Policy Support
Thomas Botello	Manager, Grid Control Management
Anthony Johnson	Engineer, Engineering Advancement

Contents

1. Use Case Description

1.1 Use Case Title

Utility uses phasor data for grid operation, control and analysis.

1.2 Use Case Summary

This use case describes how the use of phasor measurement data could enable SCE to maintain system stability following a system event. SCE currently uses phasor data to evaluate system conditions on a post-mortem basis, following an event. This use case describes the use of phasor data to trigger alarms and provide recommendations for system operator control actions within seconds of a system event. This capability would reduce the likelihood of an event causing widespread catastrophic grid instability.

Phasor data measures the physical characteristics of voltage and current waveforms, including phase angle magnitude and frequency oscillation. If SCE's Phasor Analysis Application identifies abnormal conditions, it would generate an alarm in EMS and prompt the Contingency Analysis application to calculate recommended actions for the system operator. The system operator would then receive the recommended actions from the Contingency Analysis and take appropriate remedial action. This use of phasor data represents one method within a portfolio of tools to combat system instability, and should be considered within a broader context of intelligent grid control. Other methods of maintaining grid stability that do not utilize phasor data include Centralized Remedial Action Schemes (discussed in use case D15), and other tools that optimize for various system variables such as transmission capacity loss, volt/VAR control, distributed generation dispatch, and renewable resource penetration levels. The benefits of using phasor data for real-time grid monitoring and control include increased system reliability, reduced costs, and increased customer benefits.

1.3 Use Case Detailed Narrative

Recent years have witnessed an increasing number of "reliability events" in major cities, and in entire geographic regions, demonstrating the vulnerability of electricity transmission systems to widespread and prolonged outages. The 2003 Eastern Interconnection blackout that affected the northeastern U.S. and parts of Canada, and the 2006 blackouts in Europe are two recent examples. There is general agreement that deregulation, growing electricity demand, and a changing mix of generation resources are placing the electricity grid under increased stress, contributing to the rise in reliability events.

In California, one source of system stress relates to deregulation of the wholesale electricity market. Prior to deregulation in 1997, SCE planned, built and operated generation, transmission and distribution infrastructure in an integrated manner. Service reliability was one objective of this integrated framework, causing SCE to construct a network of transmission lines for use during outages and periods of instability. For example, during transmission line outages, backup lines would allow SCE to maintain service. Following deregulation, Independent Power Producers (IPP) are able to locate generation resources in areas without backup transmission. SCE provides interconnection of these new resources to its transmission system, and the IPPs pay for this service. IPPs may opt to pay for redundant transmission, or they can allow the generation to "trip" during transmission outages. This form of tripping is performed through Centralized Remedial Action Schemes (discussed in use case D15). Due to the high cost of transmission capacity most IPPs opt to allow generation curtailment rather than build the transmission redundancy. Available transmission capacity has not kept pace with needed transmission capacity for additional reasons, including growth in electricity demand, a "not in my backyard" political environment which delays construction approvals, and the prioritized need to connect remote renewable resources. These factors are causing the grid to operate in a manner different than was intended during its construction. This results in system stress, which will increasingly threaten grid stability unless efforts are made to mitigate it.

Traditional SCADA systems provide system operators with information that is critical to monitoring the real time status and health of the electrical grid. These traditional monitoring systems offer an "x-ray view" of the grid. Phasor data, on the other hand, provide system operators an "MRI-like view" of the system. This perspective allows system operators to observe stresses between various points on the system, and other emerging abnormalities invisible to traditional monitoring systems. Phasor monitoring could identify deterioration in synchronism between different systems (between SCE's service territory and the Pacific Northwest, for example), and low voltage or VAR conditions. Moreover, phasor monitoring could identify when the electrical system has greater margin than otherwise indicated by traditional monitoring systems. In this context, phasor measurements can be compared to a speedometer. Driving a car without a speedometer could cause someone to drive at around 50mph, well below the 65 mph speed limit, to avoid speeding violations. Driving with a speedometer, on the other hand, allows you to drive at the 65mph speed limit. Likewise, phasor monitoring allows system operators to run the electrical system closer to its limits while maintaining system stability.

Phasor monitoring extends a system operator's vision beyond what is provided by traditional monitoring capabilities. This vision is extended in terms of both the type of information monitored and the geographic scope of the monitoring. Ultimately, phasor monitoring allows system operators to take prescriptive measures to maintain stability during system disturbances, and also to prevent problems in other systems from migrating into SCE's service territory (e.g. a system overload in the Pacific Northwest).

This use case discusses the use of phasor data as a means of maintaining system stability following a destabilizing event (both within and outside SCE's service territory). This represents one among a number of tools to combat system instability, and should be considered within the broader context of an intelligent grid control system. Related tools include Centralized Remedial Action Schemes (C-RAS), and applications, systems and devices that optimize different system variables such as transmission capacity losses, volt/VAR control, distributed generation dispatch, and renewable resource penetration levels. Phasor measurement data is currently used by SCE on a post-mortem basis to understand the cause of system disturbances[1]. This use case describes how phasor measurement data can be used to (1) increase situational awareness of the system; and (2) recommend system operator control operations to maintain system stability during a system disturbance. Although not addressed in this use case, a longer term goal is to utilize phasor data as an input into a control system that takes certain corrective action automatically (e.g. without system operator intervention).

[1] For additional information on SCE's existing applications that use phasor measurement to evaluate system disturbances, including Power System Outlook and SCE SMART, a brief introduction is provided by the Southern California Edison Backgrounder, Edison's Smarter Transmission Grid.

Scenario 1

This scenario describes the process of using phasor measurement data to trigger EMS[2] alarms and calculate recommended control actions for the system operator. The process begins with the collection of phasor data by Phasor Measurement Units (PMUs) following a system disturbance. PMUs located at the ends of each critical transmission node capture time-stamped phasor data throughout SCE's service territory. In addition, PMUs throughout the entire CAISO / WECC region also capture phasor data for the respective utility service territories. The CAISO / WECC data is shared with SCE on a reciprocal basis to facilitate the common goal of monitoring and maintaining wide-area system stability. Upon capture, the PMUs transmit the phasor measurement data to SCE's Phasor Data Concentrator (PDC). CAISO / WECC phasor data is transmitted to a separate dedicated SCE PDC. The PDC then forwards the data to the Historian and the Phasor Analysis Application.

The Phasor Analysis Application (PAA) is an EMS application that performs a series of analyses of the phasor data. The primary analysis includes comparing the data to various phasor parameters to determine whether to generate any alarms. The PAA may generate one or more of the following seven alarms:

1. Phase angle excursion
2. Phase angle rate of change
3. Insufficient oscillation damping
4. Insufficient rate of oscillation damping
5. Low voltage
6. Low reactive power
7. Lost communication with PMU or PDC

The PAA also analyzes phasor data to refine transmission line stability ratings. This would be particularly useful for lines involving interchanges that carry imported bulk power over long distances. The PAA is also used to calculate line impedance. Accurate impedance information is critical to the fault location identification process. This process is described in more detail in use case D20.

When an alarm is generated, the PAA also sends a Condition Change Notification to the Contingency Analysis. The Contingency Analysis is an application that, on a pre-contingency event basis, performs a series of hypothetical scenario analyses on the system. For each scenario, the Contingency Analysis also generates alternative mitigation strategies. Contingency Analysis performs this analysis on a periodic basis, or when prompted by a change in network topology. The Condition Change Notification would similarly prompt the Contingency Analysis to perform a "demand run" system analysis. The Contingency Analysis then provides corrective action recommendations to the system operator. For example, if there is an overloaded line, as indicated by an increased separation of the phase angles beyond the threshold limit, the Contingency Analysis might recommend that the system operator reconfigure the system to route power around the overloaded line. Alternatively, the recommendation could be to dispatch more generation, reduce generation, reduce load (potentially through demand response), or transfer load to a substation with less stress.

---

[2] The Phasor Analysis Application could be part of EMS, or it could potentially reside on a dedicated situational awareness system.

Depending on the recommended action, the system operator could be the EMS Operator, the CAISO Reliability Coordinator, or the equivalent person at another Regional Transmission Organization within WECC. In general, actions that involve increasing or decreasing generation must be performed by CAISO. SCE would take actions necessary to protect its grid assets.

Scenario 2

This scenario describes some of the ways in which phasor data can be used to analyze system disturbances on a post-mortem basis. Following scenario 1, the phasor data is available for viewing in the Historian by multiple groups of personnel, including the Situational Awareness and Analysis Center, and other system planning engineers. In general, this data is analyzed post-mortem to learn from system events. This analysis assists SCE in determining the cause of system disturbances, validating and/or refining Contingency Analysis algorithms, validating system models, system planning efforts, EMS Operator training simulations, validating and/or refining C-RAS Controller algorithms, and managing voltage and reactive power.

Business Value

The benefits of using phasor data for grid operation, control and analysis include the following:

1. **Improved System Reliability**:
    a. Avoid Catastrophic Failures: Phasor measurement units alert SCE to impending system instability, allowing the system operator to take corrective action to avoid system failure.
    b. Reduce Imported Risk: Monitoring system stability problems outside SCE’s service territory could allow the system operator to take action prior to the problem migrating into SCE’s service territory.
    c. Modulate Remedial Action Schemes: Phasor measurements could be used to optimize the remedial actions taken by remedial action schemes based on actual current system conditions. For example, if rather than tripping 2,000MW of generation, real-time phasor monitoring might indicate that a lesser amount is required, or perhaps no tripping is required. Remedial action schemes are based on studies which generalize for worst case scenarios and in some cases can result in over tripping.
    d. Avoid Service Interruptions: Improved power quality and system reliability would result in avoided service interruptions. Service interruptions and blackouts have large societal costs, including losses in productivity, and risks to public health and safety.
    e. Avoid Blackouts: Real-time wide area monitoring and situational awareness would allow system operators to identify system instability and take remedial action to avoid blackout conditions.
    f. Islanding Support: Distributed phasor monitoring and coordinated control actions could facilitate islanding as a means of maintaining reliability for certain customer groups.
    g. Fault Location: To the extent phasor data is used to generate more accurate impedance information, this could improve the fault location identification process (which would lead to reduced outage durations). See use case D20 for more discussion of this concept.

2. **Reduced Costs**:
    a. Reduce Dependence on Remedial Action Schemes: SCE might be able to reduce its dependence on severe remedial action schemes by implementing more appropriate control. Designing, testing and maintaining remedial action schemes can be expensive, so any reduction in dependence on these programs would reduce operations expense.
    b. Improve Capacity Utilization: An improvement in its ability to restore stability during an event would allow SCE to increase transmission capacity utilization. It would operate with a reduced risk of system failure.
    c. Penalty Reduction: If out of compliance with WECC and NERC reliability requirements, a utility may be charged $1 million per occurrence per day. These penalties can be charged retroactively.
    d. Dynamic Ratings & Operating Parameters: Phasor measurement data could facilitate dynamic rating of transmission lines. It could also assist with studies to refine operating parameters. Both of these developments could potentially increase system throughput.
    e. Reactive Power Management: Centralized monitoring of reactive power would improve operations efficiencies in managing reactive power.
    f. Keep Economically Viable Generation Online: SCE would be able to keep economically viable, and other must-take/must-run, generation online and avoid tripping due to system instability if it is better able to monitor and maintain stability.
    g. Congestion Management: SCE's ability to maintain system stability will allow it to better manage congestion by increasing transmission throughput with a reduced risk of system failure.
    h. Import Nomogram Improvement: If SCE is able to respond more quickly to maintain stability during an event, it might be able to increase the level of imported generation allowed by the import nomogram. This would allow SCE to economize its energy procurement by replacing some amount of higher cost local generation with lower cost imported generation.
    i. NERC Reporting Compliance: Phasor measurement data could assist SCE in maintaining compliance with NERC reporting requirements for system events.
    j. Reduce Operating Costs: Improved monitoring and control capabilities would allow SCE to operate the transmission system more efficiently, resulting in a reduction to operating expenses.
    k. Capital Efficiency Improvement: Avoiding catastrophic grid events will extend the useful lives of SCE's capital equipment.
    l. System Planning Improvement: Historical phasor measurement data can inform engineers in system planning efforts.
3. **Increased Customer Benefits**:
    a. Customer Satisfaction: Increased reliability would result in increased customer satisfaction.
    b. Avoid Collateral Damage: A reduction in catastrophic failures reduces potential collateral damage. Collateral damage includes customer interruption and economic loss, declines in customer satisfaction, loss of capital assets, loss of revenue, and loss of productivity during service restoration periods.
    c. Avoid Economic Loss: Avoidance of economic loss associated with blackouts that could result from grid instability.

4. **Increased Renewables**:
   a. Intermittency Management: Phasor monitoring could improve the overall intelligent grid monitoring and control needed to mitigate additional stress associated with an increased renewables portfolio.

1.4 Business Rules and Assumptions

- Network Model (i.e. topology) information is fed into State Estimator.
- Need to re-examine assumptions around limit setting and investigate dynamic limits to get additional value out of phasor information.
- Other roles and responsibilities regarding coordination with CAISO and other WECC entities needs to be clarified before full implementation of scenarios included in this use case.

2. Actors

Describe the primary and secondary actors involved in the use case. This might include all the people (their job), systems, databases, organizations, and devices involved in or affected by the Function (e.g. operators, system administrators, customer, end users, service personnel, executives, meter, real-time database, ISO, power system). Actors listed for this use case should be copied from the global actors list to ensure consistency across all use cases.

Actor Name	***Actor Type (person, device, system etc.)***	***Actor Description***
California Independent System Operator (CAISO)	Organization	The California Independent System Operator (ISO or Regional Transmission Organization) is responsible for the economic and reliable operation of the transmission grid in SCE's service territory. The CAISO creates a functioning market for Energy, Capacity, and Ancillary Services. The CAISO is responsible for compliance with federal and state rules and regulations. The Independent System Operator, or California Independent System Operator, is the regional transmission system operator. The regional transmission system, regional grid, is operated independently of the suppliers and load aggregators by the ISO. The ISO is sort of like the "traffic cop" charged with balancing the electricity and the flow on the grid.
Contingency Analysis (CA)	Application	The Contingency Analysis (CA) is an Energy Management System (EMS) application that, on a pre-contingency event basis, performs a series of hypothetical scenario analyses on the system. It also generates alternative mitigation strategies for each of the hypothetical scenarios. To perform its analysis, CA first receives the current state of every bus on the system from the State Estimator. Using this information as its baseline, the CA then performs a series of analyses whereby it takes different equipment out of service (e.g. a line or transformer), and observes how the system adjusts. For each scenario, CA also determines whether the system adjustment would violate any of the line ratings. For each scenario, the CA also evaluates each line to determine the available current-carrying capacity that could be used if there is a contingency event. For example, suppose there are three parallel lines, Line A, Line B and Line C. Line A begins operating above its line rating and causes EMS to generate an alarm. Meanwhile, Line B and Line C are both operating beneath their line ratings. The CA would evaluate how much capacity is available on Lines B and C based on the current dynamic ratings and current system loading conditions. It would then inform the EMS Operator how much capacity is available on Lines B and C, in

Actor Name	Actor Type (person, device, system etc.)	Actor Description
		case he needs to shift load from Line A to Lines B and C. CA runs this series of hypothetical analyses approximately once every 15 minutes, or upon demand.
C-RAS Controller	System	The C-RAS Controller is the hardware (and associated software) that stores the Remedial Action Scheme (RAS) arming and mitigation logic tables, receives data from relays related to current grid conditions (including outage conditions), and performs the logical processing associated with arming and executing RAS schemes. In the future the C-RAS Controller will perform real-time contingency analysis and determine mitigation strategies based on the current condition.
Energy Management System (EMS)	System	The Energy Management System is a system of tools used by system operators to monitor, control, and optimize the performance of the transmission system. The monitor and control functions are performed through the SCADA network. Optimization is performed through various EMS applications.
EMS Operator	Person	The EMS Operator monitors the EMS systems. They would receive the EMS alarms generated by the Phasor Analysis Application and could be responsible for initiating resolution of the alarm (e.g. by reconfiguring the grid, moving load, etc.).
Enterprise Asset Management System (EAMS)	System	This represents the module of the Enterprise Resource Planning system concerned with storing and updating information regarding utility assets. This keeps track of every asset in the enterprise including all trouble reports, installation information, manufacturer, information gathered by field personnel, etc. This is used to establish baselines on individual assets and classes of assets, and to track these assets to compare against the baselines. This system also contains a suite of analysis tools, decision support functions, dashboard, etc.
Historian	System	The Historian is a common data repository for all operational and non-operational data. In this use case, the Historian receives a complete set of phasor data from each Phasor Measurement Unit, generates a dead-banded set of this data, saves the dead-banded phasor data, and forwards it to the State Estimator.

Actor Name	Actor Type (person, device, system etc.)	Actor Description
Phasor Analysis Application (PAA)	Application	The PAA is an application that analyzes phasor measurement data and alerts system operators to abnormal grid conditions. The PAA receives phasor measurement data (voltage, current and frequency) from SCE phasor measurement units, and from CAISO / WECC. The PAA uses this phasor data to calculate phase angles, real power and reactive power. The PAA then activates alarms for abnormal conditions within SCE's service territory as well as those within the CAISO / WECC territories. The PAA would likely be an application within the Energy Management System. The concept of phasor analysis is a subset of a broader class of systems referred to in the industry as Wide Area Management Systems (WAMS). WAMS also includes SCADA systems and other real-time monitoring equipment.
Phasor Data Concentrator (PDC)	Device	This is a device that collects and aggregates phasor data from multiple Phasor Measurement Units (PMU) and relays the data to the Phasor Analysis Application. There would be multiple PDCs throughout SCE's service territory.
Phasor Measurement Unit (PMU)	Device	Phasor Measurement Units (PMU) are devices capable of measuring voltage and current sinusoidal waveforms on transmission lines, and transmitting the data to the utility for monitoring and control purposes. The data consists of voltage and current measurements (real and imaginary) and frequency. The data is accurately time-stamped to IEEE standards, and is capable of being transmitted to the Phasor Analysis Application within 100 milliseconds.
State Estimator	Application	The State Estimator is an application within EMS that estimates the current state of the electrical system based on SCADA measurements at various points on the system, and other known system parameters.
Situational Awareness and Analysis Center (SAAC)	Organization	The Situational Awareness and Analysis Center (SAAC) is the location at which engineers perform post-event analysis of the collected phasor data. At SCE today, this group monitors phasor measurements in real-time, and studies phasor technology for purposes of applying it to other situational awareness and control processes.
System Operator	Person	In this use case, the System Operator refers to the operator responsible for taking action to maintain grid stability during a system event. Depending on the specific circumstances and the required action, the System Operator may be the EMS Operator, the CAISO Reliability Coordinator, or the Reliability Coordinator at other Regional Transmission Organizations within WECC. In general, CAISO is responsible for all generation dispatch actions within the CAISO region. The EMS Operator is responsible for shifting or reducing load.

Actor Name	Actor Type (person, device, system etc.)	Actor Description
Western Electricity Coordinating Council (WECC)	Organization	The Western Electricity Coordinating Council (WECC) is one of eight regional councils of NERC. WECC is responsible for coordinating and promoting electric system reliability in its territory, which includes the 14 western US states, the Canadian provinces of Alberta and British Columbia, and northern Baja California, Mexico.

3. Step by Step analysis of each Scenario

Describe steps that implement the scenario. The first scenario should be classified as either a "Primary" Scenario or an "Alternate" Scenario by starting the title of the scenario with either the work "Primary" or "Alternate". A scenario that successfully completes without exception or relying heavily on steps from another scenario should be classified as Primary; all other scenarios should be classified as "Alternate". If there is more than one scenario (set of steps) that is relevant, make a copy of the following section (all of 3.1, including 3.1.1 and tables) and fill out the additional scenarios.

3.1 Primary Scenario: EMS uses phasor monitoring data to provide decision-support to the system operator for corrective action.

This scenario describes the process of using phasor monitoring data to identify system disturbances, generate EMS alarms, and provide decision support to system operators. Phasor measurements are captured by multiple Phasor Measurement Units both within SCE's service territory, and within the CAISO / WECC regions. This data is accumulated and transmitted by Phasor Data Concentrators to SCE's Historian and Phasor Analysis Application (PAA), an application within EMS. The PAA analyzes the phasor measurement data to determine whether any operating parameters have been violated. If there are violations, the PAA generates an alarm and sends a Condition Change Notification to the Contingency Analysis. The Contingency Analysis then performs a demand run analysis and generates recommended control actions for the system operator. The system operator then takes action to maintain or restore system stability. Depending upon the recommended control action, the system operator may either be the EMS Operator, the CAISO Reliability Coordinator, or the equivalent person at another Regional Transmission Organization within WECC.

Triggering Event	***Primary Actor***	***Pre-Condition***	***Post-Condition***
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
An event occurs on a transmission line.	Phasor Analysis Application	Multiple Phasor Measurement Units are installed throughout the CAISO / WECC territory.	System Operator takes action based on Contingency Analysis recommendations.

3.1.1 Steps for this scenario

Describe the normal sequence of events that is required to complete the scenario.

Step #	*Actor*	*Description of the Step*	*Additional Notes*
#	*What actor, either primary or secondary is responsible for the activity in this step?*	*Describe the actions that take place in this step. The step should be described in active, present tense.*	*Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column.*
1	Phasor Measurement Unit (PMU)	Phasor Measurement Unit measures phasor data.	SCE has approximately 20 PMUs in its service territory. This use case assumes deployment of multiple PMUs throughout SCE's transmission system, between critical nodes. The PMU data includes voltage and current measurements (real and imaginary), as well as frequency calculations. The PMU data is accurately time-stamped to IEEE standards.
2	PMU	PMU transmits phasor data to Phasor Data Concentrator (PDC).	SCE has multiple PDCs in its service territory, each of which receives phasor data from multiple PMUs. PMU data is transmitted through a Phasor Data Network which facilitates communication between the individual Phasor Measurement Units and Phasor Data Concentrators.

Step #	*Actor*	*Description of the Step*	*Additional Notes*
3	CAISO / WECC	CAISO / WECC transmit phasor data to PDC.	CAISO / WECC transmits the phasor data to an SCE PDC. This PDC is separate from the one identified in step 2, and is dedicated to receiving non SCE-generated phasor data. The CAISO / WECC phasor data includes the same data elements as the SCE phasor data. This additional phasor data is necessary to facilitate SCE monitoring of wide-area system conditions (e.g. to identify events occurring beyond inter-ties with other utility service territories.) The communication interface between SCE and CAISO / WECC needs to comply with NASPInet requirements. Eventually, NASPInet will represent a national database for the collection of phasor data.
4	PDC	The PDCs receive the phasor data.	The PDCs receive phasor data from SCE PMUs and from CAISO / WECC. CAISO / WECC would have collected this phasor data from other PMUs within the CAISO / WECC territories.
5	PDC	The PDCs transmit phasor data to other users.	
5.1	PDC	The PDCs transmit all phasor data to the Historian.	The PDCs transmit the phasor data from SCE PMUs and from CAISO / WECC.
5.2	PDC	The PDCs transmit all phasor data to the Phasor Analysis Application (PAA).	The PDCs transmit the phasor data from SCE PMUs and from CAISO / WECC.
5.3	PDC	The PDCs transmit the SCE phasor data to CAISO / WECC.	SCE transmits phasor data to CAISO / WECC to facilitate wide-area monitoring and control. This reciprocal trading of phasor data between SCE and CAISO / WECC provides complementary wide area monitoring of system conditions. During an event, SCE would make contact with

Step #	Actor	Description of the Step	Additional Notes
			CAISO / WECC, likely by telephone, to confirm that each party is aware of the event. This communication would also coordinate the corrective actions necessary for each respective party.
6	Historian	The Historian "dead-bands" the phasor data.	A "dead-band" is a range over which a measurement is considered stable, and thus no record of the measurement needs to be maintained. "Dead-banding" refers to the process of eliminating the measurements within the dead-band range. The Historian dead-bands the PMU data obtained from the PDC in step 5.1 prior to transmitting it to the State Estimator. The dead-band settings shall be such that the State Estimator is able to provide an accurate system topology. If dead-banding the data limits this capability, the dead-band settings can be reduced to zero (e.g. no dead-band).
7	Historian	The Historian saves the dead-banded phasor data.	
8	Historian	The Historian transmits the dead-banded phasor data to the State Estimator.	Phasor data allows the State Estimator to create a more refined estimate of the system state. Phasor data also enables the State Estimator to perform other "what if" scenarios on the system topology. These scenarios are to be used by Contingency Analysis in step 12 after the Phasor Analysis Application triggers an alarm.

Step #	Actor	Description of the Step	Additional Notes
9	PAA	The PAA analyzes the phasor data to determine whether to generate any alarms.	The PAA generates a series of alarms by comparing the phasor measurements to a series of phasor parameters (e.g. phase angle excursions, inadequate oscillation damping, low voltage or reactive power, etc.). The PAA is assumed to be aware of the health of the PMU and PDC communications network such that the analysis algorithms will incorporate the unavailability of any PMU data. One potential use of phasor data is to refine transmission line stability ratings (particularly those involving interchanges that carry imported bulk power over long distances). The PAA could perform this stability rating refinement. Use case D20 discusses the use of phasor data in calculating accurate impedance information. Having accurate impedance information is critical to the fault location identification process. The PAA could also perform this function.
10	PAA	The PAA generates an alarm.	PAA alarms appear on the EMS Operator dashboard. Upon receiving the alarm, the EMS Operator contacts either the CAISO Reliability Coordinator or the equivalent person at one of the other Regional Transmission Organizations within WECC. This is to verify that they are aware of the condition, and to coordinate remedial action.
10.1	PAA	The PAA generates an EMS alarm for a phase angle excursion.	Phase angle differences exist between various locations on an interconnected system. Generally speaking, the greater

Step #	***Actor***	***Description of the Step***	***Additional Notes***
			the phase angle difference, the greater the amount of power transfer. As phase angle differences increase, however, the grid becomes less tolerant of system disturbances. Phase angle differences exceeding threshold limits can lead to loss of synchronism (e.g. regional system separation), which could result in blackout conditions. Consequently, if there is growth in the phase angle difference following a system disturbance, this will influence the decision to take corrective action. A phase angle excursion represents growth in the phase angle difference beyond a certain tolerance.
10.2	PAA	The PAA generates an EMS alarm for phase angle rate of change.	If the difference in phase angles between two PMUs changes too rapidly this will generate an alarm. For example, if the phase angle difference increases from 40 degrees to 60 degrees within 3 seconds, this would generate an alarm.
10.3	PAA	The PAA generates an EMS alarm for insufficient frequency oscillation damping.	There are multiple PMUs that monitor oscillation over transmission paths. If the PAA identifies that oscillation has not been adequately damped following an event, PAA will generate an alarm. The operator would have 5 minutes in which to respond to these situations.
10.4	PAA	The PAA generates an EMS alarm for insufficient rate of oscillation damping.	
10.5	PAA	The PAA generates an EMS alarm for low voltage.	
10.6	PAA	The PAA generates an EMS alarm for low reactive power.	
10.7	PAA	The PAA generates an alarm in the Equipment Diagnostic Processor if it detects that a PMU or PDC has lost	The Equipment Diagnostic Processor is an EAMS application utilized in condition-based maintenance. See use case D19 for

Step #	Actor	Description of the Step	Additional Notes
		communication.	further discussion of condition-based maintenance.
11	PAA	The PAA sends a Condition Change Notification to the Contingency Analysis.	The Contingency Analysis is an application that, on a pre-contingency event basis, performs a series of hypothetical scenario analyses on the system. It also generates alternative mitigation strategies for each of the hypothetical scenarios. The Contingency Analysis performs this analysis on a periodic basis, or when prompted by a network topology change. The Condition Change Notification would have a similar effect in terms of prompting Contingency Analysis to perform an ad hoc system analysis.
12	Contingency Analysis	The Contingency Analysis performs a demand run to calculate recommended System Operator actions.	Upon receipt of a Condition Change Notification from PAA, the Contingency Analysis will automatically perform a demand run (e.g. an ad hoc system analysis). To perform its analysis, the Contingency Analysis first obtains the current system topology from the State Estimator. The Contingency Analysis will provide corrective action recommendations to resolve the problems identified in each PAA alarm. For example, suppose there is an overloaded line and the phase angle separation increases beyond the threshold limit. The Contingency Analysis might calculate a recommendation that allows the system operator to dispatch around the overloaded line. The recommendation could also be to dispatch more generation, in an effort to reduce the phase angle

Step #	*Actor*	*Description of the Step*	*Additional Notes*
			separation. Other recommendations could include reducing generation, reducing load (potentially through demand response), or transferring load to a different substation with less stress. In doing this, Contingency Analysis would utilize output from the State Estimator. The most likely recommendation would be to reduce imports. The only way to reduce the stress between two electrical systems is to reduce the power flow between them. Another potential recommendation might be to change the mode of a static VAR compensator. These devices have the capability of changing their mode of operation on "voltage stabilization" to "power system stabilization". This might allow the system operator to maintain imports. See use case D13 for a discussion of this potential capability. As discussed above, depending upon the circumstances and the recommended action, the System Operator could be the EMS Operator, or the Reliability Coordinator of CAISO or another Regional Transmission Organization within WECC. Operations that involve the dispatching or dropping of generation would be performed by CAISO.
13	Contingency Analysis	The Contingency Analysis transmits recommended actions to the System Operator.	The System Operator represents either the EMS Operator or the CAISO System Operator, depending on the required action. The EMS Operator would telephone the CAISO / WECC Reliability Coordinator to confirm receipt and coordinate action. In this use case scenario, the CAISO would

Step #	Actor	Description of the Step	Additional Notes
			already have SCE's phasor data and should be aware of the problem. However, the EMS Operator would call CAISO to verify that they are aware of the disturbance, and to coordinate remedial action steps.
14	Contingency Analysis	The Contingency Analysis transmits recommended actions to the Historian.	This is necessary for engineers to validate and refine the Contingency Analysis algorithms that calculate remedial control actions (in scenario 2).
15	Historian	The Historian saves the Contingency Analysis' recommended actions.	
16	System Operator	System Operator takes appropriate remedial action.	

3.2 Primary Scenario: Engineering uses phasor monitoring data to analyze system disturbances on a post-mortem basis.

This scenario describes some of the ways in which phasor data can be used to analyze system disturbances on a post-mortem basis. Following scenario 1, the phasor data is available for viewing in the Historian by multiple groups of personnel, including the Situational Awareness and Analysis Center, and other system planning engineers. In general, this data is analyzed post-mortem to learn from system events. This analysis assists SCE in determining the cause of system disturbances, validating and/or refining Contingency Analysis algorithms, validating system models, system planning efforts, EMS Operator training simulations, validating and/or refining C-RAS Controller algorithms, and managing voltage and reactive power.

Triggering Event	***Primary Actor***	***Pre-Condition***	***Post-Condition***
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
An event occurs on a transmission line.	Situational Awareness and Analysis Center (SAAC) and Planning Engineers	Multiple Phasor Measurement Units are installed throughout the CAISO / WECC territory.	SCE analyzes and learns from phasor data, improving monitoring and control processes, and informing system planning efforts.

3.2.1 Steps for this scenario

Describe the normal sequence of events that is required to complete the scenario.

Step #	Actor	Description of the Step	Additional Notes
#	*What actor, either primary or secondary is responsible for the activity in this step?*	*Describe the actions that take place in this step. The step should be described in active, present tense.*	*Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column.*
1	Various	Engineers use phasor measurement data to analyze system disturbances on a post-mortem basis.	This scenario assumes that the steps associated with scenario 1 have been completed, and, on a post-mortem basis, SCE engineers analyze the phasor data. This analysis serves several purposes, but the overarching goal is to learn from history to improve monitoring and control operations, and to improve system planning efforts.
1.1	Situational Awareness and Analysis Center (SAAC)	Situational Awareness and Analysis Center engineers analyze phasor data to determine the cause of a system event.	
1.2	SAAC	SAAC engineers validate the Contingency Analysis algorithms responsible for determining System Operator remedial actions.	In scenario 1, the Contingency Analysis generates recommended actions for the System Operator in step 12. This particular scenario 2 step involves a SAAC engineer reviewing these recommendations to determine whether any adjustments are necessary for the Contingency Analysis algorithms.

Step #	*Actor*	*Description of the Step*	*Additional Notes*
1.3	SAAC	SAAC engineers review phasor data to identify potential system studies for purposes of revising stability ratings and operating parameters.	
1.4	Planning Engineer	Planning Engineers analyze phasor data to inform system planning efforts.	This would be performed by Transmission Planning engineers.
1.5	Planning Engineer	Planning Engineers analyze phasor data to validate models and establish operating parameters.	This would be performed by Transmission Planning engineers.
1.6	EMS Operator	EMS Operators participate in training simulations based upon phasor measurements from historical system events.	
1.7	C-RAS Controller	The C-RAS Controller incorporates phasor data into the remedial action scheme control.	The intent of this step is to use phasor measurement data to optimize the operation of remedial action schemes, minimizing the amount of load and/or generation to be shed, while still maintaining system stability. See use case D15 for further discussion of remedial action schemes. This capability would require significant additional research and development efforts.
1.8	Planning Engineer	System engineers use phasor data to manage system voltage and reactive power on a non real-time basis.	Voltage and current are captured by Phasor Measurement Units, and reactive power is calculated by the Phasor Analysis Application using this data. Voltage and reactive power allows engineers to identify areas where voltage is high or low. Low voltage generally indicates a deficit of reactive power. In this case an engineer would identify capital infrastructure improvements to mitigate the situation and issue temporary instructions to operating entities to increase reactive power output from generators.

Step #	***Actor***	***Description of the Step***	***Additional Notes***
1.9	EMS Operator and Planning Engineer	System engineers use phasor data to validate readiness for a “black start”.	Phasors can be used to synchronize an “islanded” group of generation facilities with the wider transmission grid prior to a “black start”.

4. Requirements

Detail the Functional, Non-functional and Business Requirements generated from the workshop in the tables below. If applicable list the associated use case scenario and step.

4.1 Functional Requirements

Req. ID	*Functional Requirements*	*Associated Scenario #* *(if applicable)*	*Associated Step #* *(if applicable)*
1	Phasor Measurement Units (PMUs) shall measure voltage (real and imaginary).	1	1
2	PMUs shall measure current (real and imaginary).	1	1
3	PMUs shall calculate frequency from the voltage measurements.	1	1
4	PMU data shall be time-stamped.	1	1
5	PMUs shall transmit phasor measurement data to a Phasor Data Concentrator (PDC).	1	2
6	CAISO / WECC shall transmit phasor measurement data to a dedicated SCE PDC.	1	3
7	PDC shall receive phasor data from SCE PMUs.	1	4
8	PDC shall receive phasor data from CAISO / WECC.	1	4
9	PDC shall transmit all SCE and CAISO / WECC phasor data to the Historian.	1	5.1
10	PDC shall transmit all SCE and CAISO / WECC phasor data to the Phasor Analysis Application (PAA).	1	5.2
11	PDC shall transmit SCE phasor data to CAISO / WECC.	1	5.3
12	The Historian shall dead-band the phasor data.	1	6
13	Dead-band thresholds shall be configurable to optimize the amount of data retained by the Historian.	1	6
14	The Historian shall save the dead-banded phasor data.	1	7
15	The Historian shall transmit the dead-banded phasor data to the State Estimator.	1	8

Req. ID	*Functional Requirements*	*Associated Scenario #* *(if applicable)*	*Associated Step #* *(if applicable)*
16	The Phasor Analysis Application (PAA) shall calculate phase angles from voltage measurements (real and imaginary).	1	9
17	The PAA shall calculate real power.	1	9
18	The PAA shall calculate reactive power.	1	9
19	The PAA shall analyze the phasor data to determine whether to generate any alarms.	1	9
20	The PAA shall be aware of the health of the PMU and PDC network.	1	9
21	The PAA shall incorporate the health of the PMU network in its analysis (i.e. if a PMU is not transmitting data, the PAA will account for this in its analysis.)	1	9
22	The PAA shall refine transmission line stability ratings.	1	9
23	The PAA shall transmit refined stability ratings to the Enterprise Asset Management System (EAMS).	1	9
24	The PAA shall calculate line impedance.	1	9
25	The PAA shall transmit line impedance calculations to EAMS.	1	9
26	The PAA alarm triggering thresholds shall be configurable.	1	10.1 thru 10.7
27	The PAA alarm triggering thresholds shall be individually configurable for each analysis node.	1	10.1 thru 10.7
28	The PAA alarm triggering thresholds shall be individually configurable for each alarm type.	1	10.1 thru 10.7
29	The PAA shall generate an EMS alarm for phase angle excursions.	1	10.1
30	The PAA shall generate an EMS alarm for phase angle rates of change.	1	10.2
31	The PAA shall generate an EMS alarm for insufficient oscillation damping.	1	10.3
32	The PAA shall generate an EMS alarm for insufficient rate of oscillation damping.	1	10.4
33	The PAA shall generate an EMS alarm for low voltage.	1	10.5
34	The PAA shall generate an EMS alarm for low reactive power.	1	10.6
35	The PAA shall generate an alarm in the Equipment Diagnostic Processor if it detects that a PMU or PDC has lost communication.	1	10.7

Req. ID	*Functional Requirements*	*Associated Scenario #* *(if applicable)*	*Associated Step #* *(if applicable)*
36	The PAA shall send a Condition Change Notification to the Contingency Analysis when an EMS alarm is generated.	1	11
37	The Contingency Analysis shall perform a demand run upon receiving a Condition Change Notification.	1	12
38	The Contingency Analysis shall calculate recommended System Operator actions.	1	12
39	The Contingency Analysis shall identify stressed nodes. This is important in terms of allowing the Contingency Analysis to identify un-stressed nodes to which it can transfer load as a recommended action.	1	12
40	The Contingency Analysis shall transmit recommended actions to the EMS Operator.	1	13
41	The Contingency Analysis shall transmit recommended actions to CAISO.	1	13
42	The Contingency Analysis shall be able to transmit recommended actions to the appropriate Regional Transmission Organization within WECC (as appropriate).	1	13
43	The Contingency Analysis shall transmit recommended actions to the Historian.	1	14
44	The Historian shall save the Contingency Analysis' recommended actions.	1	15
45	Historical phasor data and Contingency Analysis recommendations shall be available for post-event analysis.	2	All
46	Phasor data and Contingency Analysis recommended actions shall be accessible to relevant personnel via the Historian.	2	All
47	The PAA shall support queries for system planning and operational adjustment activities.	2	All
48	The Historian shall have adjustable reporting capabilities.	2	All
49	The Contingency Analysis algorithms shall be accessible to SAAC engineers for analysis and validation.	2	1.2 & 1.3
50	The C-RAS Controller shall be able to incorporate phasor data into the remedial action scheme mitigation logic mechanism.	2	1.7

4.2 Non-functional Requirements

Req. ID	*Non-Functional Requirements*	*Associated Scenario #* *(if applicable)*	*Associated Step #* *(if applicable)*
1	Phasor Measurement Units (PMU) shall provide 30 data points per second (1 data point for every other cycle).	1	1
2	PMUs time-stamping of phasor data shall comply with IEEE time-stamping standards.	1	1
3	There shall be at least one PMU at both ends of each critical transmission node.	1	1
4	The Phasor Data Concentrators (PDC) shall conform to the Tennessee Valley Authority (TVA) specifications.	1	2, 3, 4 & 5
5	The PDCs shall conform to the ePDC specifications.	1	2, 3, 4 & 5
6	Phasor data communication interfaces shall meet NASPInet interface requirements	1	2, 3 & 5.3
7	The SCE PMU phasor data and the CAISO / WECC phasor data shall be in the same format.	1	3
8	The PDC messages shall comply with IEEE standard C37.118.	1	5
9	The Phasor Analysis Application (PAA) shall receive phasor data within 100 milliseconds of it being recorded by the PMUs.	1	5.2
10	The Historian shall retain phasor data associated with a contingency event in perpetuity.	1 & 2	Scenario 1: 7 Scenario 2: All
11	The Historian shall retain all phasor data at full resolution (30 measurements per second) for 60 days.	1 & 2	Scenario 1: 7 Scenario 2: All
12	The Historian shall save all phasor data not associated with a contingency event in perpetuity in a "down sampled" format of one measurement per second. For example, rather than saving 30 measurements per second (the rate at which PMUs capture phasor measurements), they would be saved at one sample per second.	1 & 2	Scenario 1: 7 Scenario 2: All
13	The Historian shall provide dead-banded phasor data to the State Estimator once per second, if there is any. Under normal conditions data will not surpass dead-band thresholds. The intent of	1	8

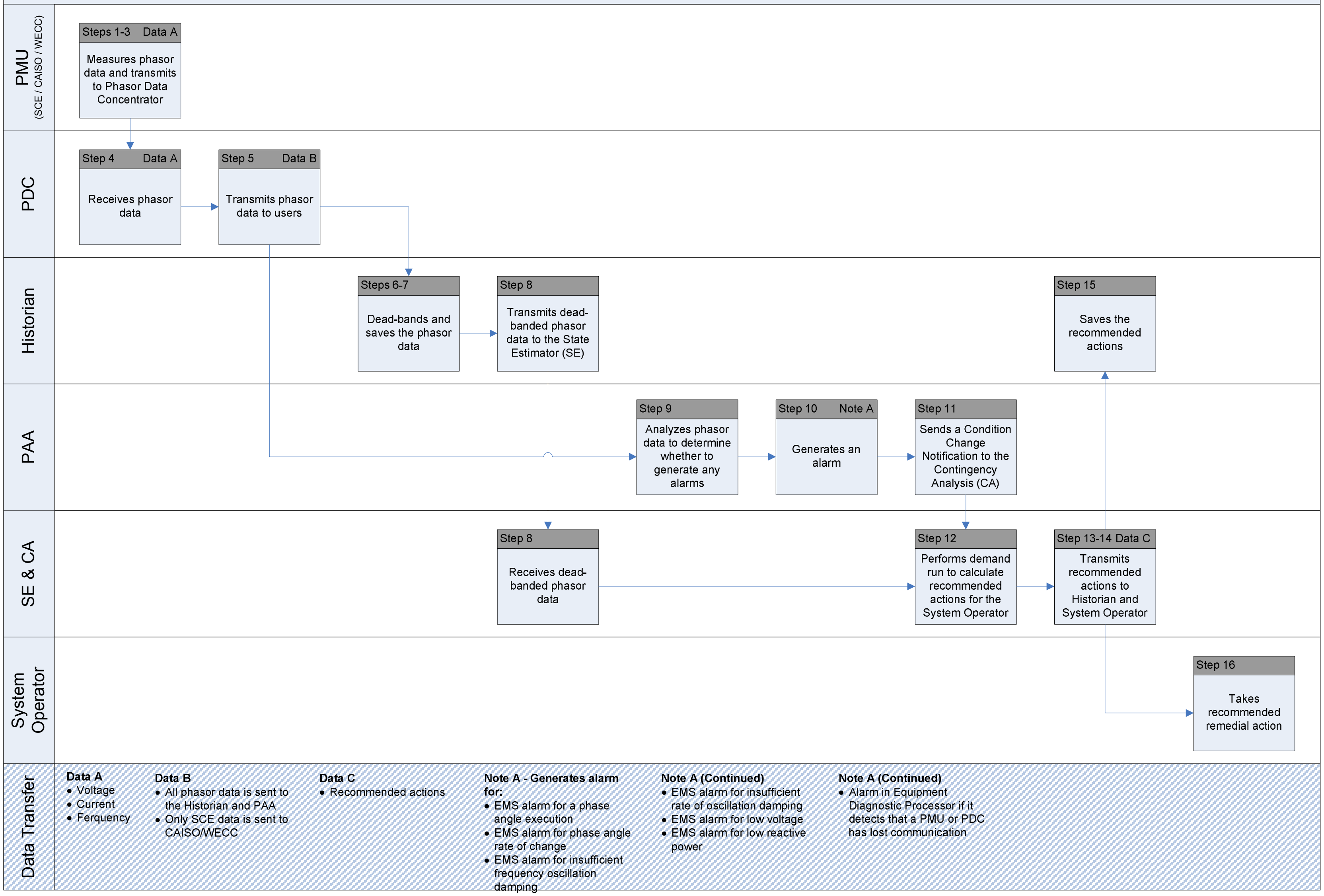
Req. ID	*Non-Functional Requirements*	*Associated Scenario #* (if applicable)	*Associated Step #* (if applicable)
	this requirement is to provide data at a rate appropriate for the State Estimator's calculations.		
14	The PAA shall generate an EMS alarm for phase angle excursions greater than threshold limits.	1	10.1
15	The PAA shall generate an EMS alarm if damping is less than 5%.	1	10.3
16	The Contingency Analysis shall transmit recommended actions to the System Operator within 2 seconds of an alarm.	1	14
17	The Historian shall retain all Contingency Analysis recommended actions in perpetuity.	1 & 2	Scenario 1: 15 Scenario 2: All
18	EMS Operator training courses shall be certified such that the EMS Operators are in compliance with NERC certification credits.	1	16

5. Use Case Models (optional)

This section is used by the architecture team to detail information exchange, actor interactions and sequence diagrams

5.1 Diagrams

Use Case D16 – Scenario 3.1 EMS uses phasor monitoring data to provide decision-support to the system operator for corrective action.



Use Case Issues

Capture any issues with the use case. Specifically, these are issues that are not resolved and help the use case reader understand the constraints or unresolved factors that have an impact of the use case scenarios and their realization.

Issue
Describe the issue as well as any potential impacts to the use case.
1. How to have a person on shift dedicated to addressing system issues identified through Remedial Action Schemes and phasor data? This is particularly important during off hours.
2. How to make engineering staff available to operations on a regular basis?
3. How to ensure the system model is maintained in only one place (since it is shared between the Phasor Analysis Application and State Estimator)?

6. Glossary

Insert the terms and definitions relevant to this use case. Please ensure that any glossary item added to this list should be included in the global glossary to ensure consistency between use cases.

Glossary	
Term	**Definition**
Black Start	A "black start" is the process of starting up a generation resource without relying on grid power from an off-site source (e.g. from a source beyond the facility's circuit breaker connecting it to the transmission grid).
Equipment Diagnostic Processor (EDP)	The Equipment Diagnostic Processor is an application within EAMS that evaluates current asset condition data with respect to historical baseline data and, based on a series of factors, provides diagnoses and identifies probable "bad actors". See use case D19 for more discussion of this application.
North American SynchroPhasor Initiative (NASPI)	NASPI is a group of 20 utility, consulting, academic, government, vendor and other leaders working to advance the adoption of synchrophasor technology.
NASPInet	NASPInet, under the auspices of NASPI, shall be a nationwide system for handling phasor data. The communication interface specifications are currently due for completion on April 27, 2009.

7. References

Reference any prior work (intellectual property of companies or individuals) used in the preparation of this use case

8. Bibliography (optional)

Provide a list of related reading, standards, etc. that the use case reader may find helpful.

Southern California Edison, Southern California Edison Backgrounder, Edison's Smarter Transmission Grid. (http://www.sce.com/NR/rdonlyres/70273B28-8752-419A-A974-069A87AB87C2/0/SCEBackgroundersmarttransOct07.pdf)