SmartConnect Use Case:

D15 – C-RAS system monitors grid system status and exerts control to maintain system stability and prevent overloads

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Document History

Revision History

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Approvals

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Contents

1. Use Case Description

1.1 Use Case Title

C-RAS system monitors grid system status and exerts control to maintain system stability and prevent overloads.

1.2 Use Case Summary

This use case describes how centralizing and coordinating Remedial Action Schemes (RAS) in a Centralized Remedial Action Scheme (C-RAS) architecture can improve SCE's ability to respond to contingencies in real-time to maintain system stability. RASs are used to detect abnormal grid conditions involving transmission line or transformer outages in congested transmission corridors, and to mitigate these conditions by taking pre-planned corrective actions. Corrective action can include generation runback or tripping, load shedding, or system configuration changes. Recent increases in the number of new RASs, limitations with existing RAS technology, and interactions between overlapping RASs has complicated SCE's ability to manage them. C-RAS addresses these limitations by offering a centralized platform that coordinates and optimizes the various RASs. C-RAS operates through a high-speed communications network, increasing the speed of SCE's response to an event. The business value of C-RAS includes improved system reliability, reduced costs, improved customer benefits and increased renewable energy.

1.3 Use Case Detailed Narrative

The electric utility industry has used Remedial Action Schemes (RAS) for several decades as a means of mitigating system problems including thermal overloads, post-transient voltage problems, and transient stability events. In general, they have been used to manage overloaded lines during transmission line and transformer outages. RASs operate by detecting abnormal grid conditions and initiating pre-planned corrective actions to restore grid stability. An example of an abnormal grid condition is a transmission corridor that exceeds its line flow limit while experiencing a concurrent line outage. A RAS would detect the condition and initiate corrective action to restore stability. Corrective action may include tripping generation, shedding load, or changing the system configuration to isolate the problem. Each RAS possesses unique arming and activation conditions. For example, all RAS will arm if line flows exceed predetermined thresholds. However, different RASs activate based on different factors, including line flow conditions, facility outages and thermal constraints. Each RAS requires a unique planning study to determine arming conditions and corrective action strategies. Corrective action strategies are pre-determined for a limited number of potential contingency scenarios. These strategies are summarized in "mitigation logic tables", and are programmed into the RAS logic controllers. RAS logic controllers are devices which are located in the substation most central to the RAS. These devices activate RASs based on the mitigation logic tables. If subsequent changes are made to the mitigation logic, personnel must travel to the substation to reprogram the device.

SCE currently has 18 RASs and is planning to implement an additional 50-70, depending upon the CAISO generation queue and load growth. New RASs are necessary to accommodate new generation resources awaiting interconnection with SCE's transmission system. The increase in RASs is related, at least in part, 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 either pay for redundant transmission, or they can allow the generation to "trip" during transmission outages. This form of tripping is performed through a RAS. RASs optimize use of available transmission capacity while operating at acceptable reliability levels. 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 need to connect remote renewable resources.

Increasing the number of RASs, limitations with existing RAS technology, and interactions between overlapping RASs have complicated SCE's ability to manage them effectively. Each new RAS requires purchasing and installing additional RAS logic processors, and installing redundant point-to-point communication circuits. Since this equipment is housed in substations, any update to the RAS logic processor requires traveling to the field to perform the reprogramming. As the number of overlapping RASs increases, this reprogramming has become more frequent.

Existing RAS technology has limited logic capabilities, lacks wide-area visibility of the system, and operates at slow speeds. The RAS logic processor is capable of responding to a maximum of 24 contingency scenarios. There are many permutations of contingency events, generation output levels and load levels, each of which deserves a unique mitigation strategy. This is not possible with the existing RAS logic processor technology. Additionally, each RAS operates in isolation of the other RASs, lacking knowledge of the broader system conditions. This can result in multiple RASs performing simultaneous and uncoordinated actions, tripping more generation than necessary. Finally, RASs typically require 12-15 cycles to detect, arm, and activate a mitigation strategy. This is not fast enough to facilitate automatic mitigation of widespread transient events on the system.

The limitations of the current RAS approach are compounded by the increasing level of interdependency between the various RASs[1]. As the number of RASs increases, instances in which multiple overlapping RASs arm and activate also increases. This overlap requires coordination such that the mitigation actions optimize the amount of dropped generation and load. The alternative is to allow activation of multiple independent RASs, resulting in over or under mitigation, potentially triggering a cascading loss of generation, load, and transmission lines.

The shortcomings of the existing RAS approach are resolved by consolidating the existing and new RASs into a Centralized Remedial Action Scheme (C-RAS) architecture. Under C-RAS, all RAS operations are consolidated into one centralized C-RAS Controller, eliminating the need for multiple RAS logic controllers at each substation. This also eliminates the need for personnel to travel to the substations for programming and maintenance. C-RAS allows the RASs to share wide-area system condition information, and to coordinate and optimize mitigation efforts within a

[1] The limitations associated with the current RAS approach, and the use of C-RAS to address these limitations is discussed in greater detail in SCE's 2009 General Rate Case Testimony (Volume 3, Part 5, Chapter 2).

single platform. It also accommodates an unlimited number of potential contingency events, eliminating the current RAS logic controller's limit of 24. Mitigation strategies could be calculated in real time, based on the contingency event, and current line flow and load. This fine-tuning of mitigation strategies would enable SCE to enact appropriate responses to contingency events, avoiding the under or over dropping of generation and load that exists under the current RAS approach.

C-RAS would utilize SCEnet, a telecommunications platform that currently provides rapid communications capabilities to SCE's larger substations. SCEnet would allow RASs to detect, arm and activate a mitigation strategy within 3 cycles, an improvement of approximately 80% over current RAS speeds. This would enable SCE to activate RAS strategies capable of mitigating widespread transient events.

Through C-RAS pilot studies, SCE has gained appreciation for a number of broader applications that could be enabled by C-RAS and other grid control systems. SCEnet's high-speed, broadband communications capabilities would be central to enabling these future capabilities. Merging this communications platform with a larger number of sensor devices would allow SCE to move from a "state estimation" approach to grid monitoring to a "state measurement" approach. The following is a partial list of future functionalities that could be enabled by C-RAS:

1. Real-Time Mitigation Calculation: The first generation C-RAS is expected to continue using Mitigation Logic Tables for determining mitigation strategies. This first generation will have a larger number of potential contingency scenarios than the existing RAS platform. However, it will still have a finite number of table-based scenarios. Future generations will substitute these tables with a contingency analysis capable of calculating mitigation strategies in real-time based on current conditions. Phasor measurement will likely be one component of the "state measurement" which will feed into this real-time contingency analysis.

2. Advanced Mitigation Strategies: Future versions of C-RAS should make dynamic decisions about which generation to trip on the basis of strategy efficacy, cost effectiveness, market pricing, and other justifiable factors.

3. Migrate from Mitigation to Modulation: Future versions of C-RAS should be able to modulate generation output rather than tripping an entire generator. Generation would be fed through a "governor", which would regulate the generation up or down according to system needs. This could spread the output loss among multiple generators, rather than tripping some of them.

4. Modulation via Energy Storage and Renewables: Rather than dropping load during a contingency event, SCE would prefer to dispatch energy storage, renewable resources or some other rapid-response resource. Similarly, SCE could turn on capacitor banks, or change the modes of SVCs and other FACTS devices to provide temporary system stability support.

5. Ability to Trigger Demand Response: Rather than dropping load during an event, C-RAS could be used to instigate a demand response event.

6. Grid Reconfiguration: Rather than separating a line during an event, C-RAS should be able to identify problem areas and reconfigure the grid to isolate the problem. This is performed by controlling switches to route line flow around trouble spots.

7. Coordination with other Utilities: There are approximately 5 major ties between the transmission networks of SCE and other utilities. C-RAS would provide visibility of how much load and line flow each tie is carrying. If one line is heavily loaded while others have spare capacity, it would be possible to share spinning reserves with the other utilities. In this case the impacted corridor would be able to shed less load.

8. Air Conditioner Control: AC stalling conditions can result in blackout conditions to entire regional transmission systems. Thus, a longer term vision is for C-RAS to be able to trip groups of air conditioners within 3 cycles (50 milliseconds). This capability, although ambitious in terms of the speed requirements for monitoring and control, would provide the electrical system with a valuable reliability safety net.

9. N-2 to N-6: NERC requires SCE to maintain grid reliability during the loss of a one (N-1) or two (N-2) transmission lines or transformers. However, with a move from "state estimation" to "state measurement", and with the ability to control grid assets with dynamic monitoring and control mechanisms, SCE should be capable of handling N-6 contingencies. For example, suppose SCE detects a simultaneous loss of 5 geographically distant grid components and surmises there is a widespread threat (e.g. a natural disaster or terrorist attack). SCE could immediately transition the grid from a high import condition (optimizing energy costs), to a low import condition (optimizing reliability), and ramp up generation in the LA basin. This would move the electric grid to a safe mode of operation, insulating itself from the problem, and allow it to achieve a higher reliability standard.

The use case scenario describes how C-RAS can be used to identify line outage conditions and activate mitigation strategies to maintain grid stability. The C-RAS process is initiated by relays which measure the grid condition by capturing line flows, loading levels, generation output, and the general grid condition (voltage, current, etc.). This data is transmitted to the C-RAS Controller, which evaluates the data to determine whether any Remedial Action Schemes (RAS) require arming. The C-RAS Controller performs this evaluation on a new data set every 100 milliseconds. Based on the current grid conditions and pre-defined arming logic, the C-RAS Controller may decide to arm one or more RASs. In general a C-RAS Controller will decide to arm a RAS if line flows exceed predetermined thresholds.

For example, suppose a hypothetical corridor has 3 separate transmission lines, each of which has a normal rating of 1,000MW and an emergency line rating of 1,200MW. These line ratings are based upon the lines' physical characteristics and represent their maximum potential carrying capacity. These limits are also referred to as thermal ratings[2]. SCE must always operate the transmission system such that it can maintain the safety and stability of the system after the loss of one or more grid assets (such as a transmission line). In the absence of a RAS, the corridor power flow limit is 2,400MW (i.e. the 3 lines in aggregate cannot carry more than 2,400MW). This effectively limits the 3 lines to 800MW each. If one of these 3 lines is lost, that line's 800MW would automatically shift to the two remaining lines. Thus, in this example, 400MW would shift to each of the two remaining lines, increasing their loading from 800MW to 1,200MW, the emergency rating.

A RAS would allow SCE to increase the corridor power flow limit from 2,400MW to 3,000MW. In this case, each line would now be able to carry 1,000MW, an amount equal to the normal line ratings. This is possible since a RAS would facilitate automatic system stability restoration following the loss of one of the 3 lines. For example, if each of the lines is carrying 1,000MW and one line is lost, the RAS would automatically trip generation or load such that the two remaining two lines would not exceed their 1,200MW emergency ratings. The load from the lost line would still shift to the remaining two lines, but the RAS would ensure that enough generation or load is tripped so that they are not overloaded. The net effect of having a RAS in place, in this example, is to increase the corridor power flow limit from 2,400MW (3 lines x 800MW per line), to 3,000MW (3 lines x 1,000MW per line). In terms of its operation, the RAS would be automatically armed if the line flows exceed 2,400MW, and it would subsequently activate by tripping generation or load upon the loss of one transmission line.

A RAS arms if the power flows within a corridor exceed the predetermined thresholds of a RAS developed for that specific corridor. Upon arming a RAS, the C-RAS Controller would notify the EMS Operator via the EMS dashboard. The message would indicate, based on the current conditions, the mitigation strategy to be activated if an outage occurs (based upon predetermined logic). For example, it would tell the EMS Operator that a specific substation and/or generation facility will be dropped. The EMS Operator would be capable of overriding the RAS arming.

If a RAS is armed and a relay subsequently detects a line outage, the relay transmits an outage signal to the C-RAS Controller which prepares to activate the RAS. The C-RAS Controller determines the amount of generation to be tripped and/or load to be shed based on the current grid conditions and the pre-determined Mitigation Logic Table. The C-RAS Controller then sends control commands to relays which activate the

[2] See use case D18 for a discussion of dynamic rating of transmission lines.

mitigation strategy. The EMS Operator is notified upon activation of the RAS. The EMS Operator would be capable of overriding the C-RAS Controller arming operation, but not its activation. By the time a line outage occurs the C-RAS Controller would have taken action prior to the EMS Operator having time to respond (the control action has a latency of less than 50 milliseconds). The EMS Operator would then attempt to resolve the event conditions through investigation and, ultimately, restore and re-dispatch the system. All event data would be stored by C-RAS in the C-RAS Historian and made available for future analysis.

Business Value

The benefits of using C-RAS to maintain system stability and prevent overloads include the following:

1. **Improved System Reliability**:
    a. Avoid Cascading Outages: C-RAS protects the electricity grid following the loss of one or more transmission lines within a transmission corridor, rebalancing the system to avoid cascading outages.
    b. Avoid Catastrophic Failures: To the extent SCE can maintain stability following the loss of one or more transmission lines, this would reduce the likelihood of catastrophic transmission asset failures.
    c. Rapid Restoration: If SCE's wide area network, SCEnet, can survive a blackout, SCE could rapidly restore the grid following a blackout condition.
    d. Improvements over Traditional Remedial Action Schemes (RAS):
        i. Speed of Configuration Changes: C-RAS would also increase SCE's speed of reacting to different situations that require changes to C-RAS logic and system configurations. These changes could be accomplished remotely from a central location.
        ii. Optimize Mitigation Quantities: Current RASs use Mitigation Logic Tables to determine mitigation strategies. However, these tables are based on ranges of 100MW, and they generally define mitigation strategies for worst case scenarios. Thus the prescribed mitigation strategies usually reduce load and/or generation by more than is necessary. In the future these tables will be substituted by real-time contingency analysis, which will calculate the mitigation strategy in real-time based on current conditions. This will optimize the mitigation strategy by avoiding over or under dropping of load and generation.
        iii. Manage RAS Interdependencies: Centralizing the RASs under C-RAS allows SCE to take action based on what is happening across the entire network, considering the interactions of the various RASs when making arming and activation decisions. This should avoid over shedding load and over tripping of generation.
        iv. System Stability via Modulation: In the future, C-RAS can move from a "mitigation" strategy in which load is shed, to a "modulation" strategy in which generation resources (including renewables) are rapidly dispatched to replace generation deficiencies caused by line outages.
        v. Increase Speed of RAS Arming and Activation: C-RAS would involve high speed, redundant communications, allowing RASs to detect, evaluate, arm, disarm, and activate mitigation strategies automatically within 50 milliseconds. To the extent SCE can increase the reaction speed, it can reduce the amount of load and generation that needs to be reduced.

vi. Safe Mode Operation: In the event of a widespread threat (e.g. a terrorist attack or other natural disaster), SCE could use C-RAS in conjunction with other forms of hierarchical grid control to transition from a high import condition (optimizing energy costs), to a low import condition (optimizing reliability). This would entail ramping up local generation within a very short time frame to insulate the grid from the threat. In this case SCE would expect to be able to maintain safe grid operation, despite the loss of a number of grid assets.

2. **Improved Customer Benefits**:
   a. Avoid Economic Loss: Avoidance of economic loss associated with blackouts that could result from grid instability.
   b. 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.
   c. Customer Satisfaction: Increased reliability would result in increased customer satisfaction.
   d. 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.
3. **Reduced Costs**:
   a. 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.
   b. Keep Economically Viable Generation Online: Eventually, C-RAS might be able to avoid tripping generation, or simply ramp down the output. Generation would be fed to a “governor” which would regulate the generators up or down.
   c. 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.
   d. Optimize Mitigation Mix: Calculating mitigation strategies in real-time allows C-RAS to evaluate the most economical generation to trip. This evaluation would consider both the current grid condition as well as energy market conditions.
   e. Import Nomogram Improvement: If SCE is able to respond more quickly to maintain stability during an event, it might be able to improve 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. Use of FACTS devices would allow SCE to maintain stability as it reduces local generation and brings in imported generation.
   f. Penalty Reduction: If out of compliance with WECC & NERC reliability requirements, a utility may be charged $1 million per occurrence per day. These penalties can be charged retroactively.
   g. Reduce Operating Costs: Coordination between C-RAS and the Predictive Grid Control System (PGCS) would allow SCE to operate the transmission system more efficiently, resulting in a reduction to operating expenses. (*See use case D13 for further discussion of the PGCS*).
   h. Capital Efficiency Improvement: Avoiding catastrophic grid events will extend the useful lives of SCE’s capital equipment.

i. Infrastructure Synergies: The underlying infrastructure to support C-RAS could be leveraged by multiple SCE initiatives. For example, SCEnet could serve as a platform for both C-RAS and the use of phasor measurement and FACTS devices described in use case D13. Likewise, IEC61850 GOOSE Data Packet capabilities could be utilized by both C-RAS and substation automation initiatives.

j. Defer Capital Investments: To the extent SCE can increase transmission line throughput, it can defer building new transmission lines.

k. FACTS Device Platform: Use case D13 describes how phasor data can be used to activate FACTS devices to maintain grid stability. This use of FACTS devices would benefit from having this SCEnet / C-RAS infrastructure. It could be the computation engine that determines how much SCE could load the system by changing FACTS modes, without compromising grid stability.

l. Increase Number of RASs: SCE currently has 18 RASs, and has a need for more than 50-70 additional RASs, depending upon the CAISO generation queue. Implementing new RASs is becoming increasingly challenging given the limited logic capabilities of the current logic controller, as well as the increasing interdependencies between the various RASs. Centralizing these schemes within a C-RAS architecture would allow SCE to increase the number and effectiveness of new RASs in a more cost effective manner.

m. Increase Number of Interconnections: To the extent SCE can increase the number of RASs, it can likewise increase the number of interconnections, allowing a greater number of economically viable generation resources to connect to the grid.

n. Regulatory Compliance: C-RAS would comply with WECC RAS redundancy criteria.

4. **Increase Renewable Energy**:

   a. Renewable Interconnections: To the extent SCE can increase transmission line throughput, it can move closer to meeting California's Renewables Portfolio Standard targets with the existing transmission infrastructure.

5. **Increase Demand Response**:

   a. Modulation via Demand Response: Rather than dropping load during an event, C-RAS could be used to instigate a demand response event to provide system stability support.

1.4 Business Rules and Assumptions

- Scope of C-RAS includes generating stations, high voltage transmission lines (500/230/115kV), and substation loads, potentially expanding to more granular load and distributed generation in the future.
- There is acceptance and participation of C-RAS among other utilities within WECC (only SCE has a C-RAS program today).
- The scenario in this use case assumes an outage must occur for the RAS to activate. However not all RASs have this requirement. Some are based solely on line loading levels.
- Relays used for C-RAS are dedicated solely to C-RAS and are not used for other EMS / SCADA purposes.
- Generation tripping events initiated by C-RAS do not violate any bilateral contracts with merchant generators or other CAISO rules.

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***
Centralized Remedial Action Scheme (C-RAS)	Set of systems and devices	Centralized Remedial Action Schemes (C-RAS) combine all RASs into a single, shared platform. This platform provides visualization of system-wide conditions (status of various RASs, general grid condition, generation outputs, etc) such that the calculation of real-time mitigation strategies allows C-RAS to optimize and coordinate the various RASs. C-RAS is faster than existing RASs since it communicates over a high speed, broadband wide area network. C-RAS also uses a logic processor that can handle a virtually unlimited number of contingency scenarios. Existing RAS logic processors are limited to 24.
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 RASs. In the future the C-RAS Controller will perform real-time contingency analysis and determine mitigation strategies based on the current condition.
C-RAS Historian	System	The C-RAS Historian is a data repository for all relay data related to grid condition, and any associated RAS arming and RAS activation events. The SCE C-RAS pilot currently uses OSISoft Pi Historian as the C-RAS Historian.
C-RAS Mitigation Logic Tables	Tables	The C-RAS mitigation logic tables list the prescribed mitigation strategies/actions for specific line outages. This table is developed by studies which determine the amounts of generation tripping and/or load shedding required to maintain grid stability following line outages. These mitigation actions are stored in the C-RAS Controller, which selects and executes one or more of the strategies during outage events.
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.

Actor Name	Actor Type (person, device, system etc.)	Actor Description
EMS Operator	Person	The EMS Operator monitors the EMS systems, and receives notifications from the C-RAS Controller when a RAS has been armed, disarmed or activated. The EMS Operator has the ability to disarm a RAS prior to activation.
Relay	Device	Relays are field devices that monitor grid conditions, including line flows, voltage and frequency; perform phasor measurement; detect line outages; transmit data to the C-RAS Controller; and perform mitigation functions (e.g. executing the C-RAS Controller commands by shedding load or tripping generation).
Remedial Action Scheme (RAS)	Process	A remedial action scheme (RAS) is a method of detecting grid congestion involving single (N-1) or double (N-2) transmission line or transformer outages, and taking remedial action. Remedial action may consist of generation tripping, load shedding or system reconfiguration. RASs are armed when the line flow on a particular transmission line exceeds a predetermined threshold. RASs are executed if, while they are armed, a subsequent triggering event takes place (such as the loss of a transmission line). Different RAS activate based on different triggers.

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: C-RAS system detects line outage and arms appropriate RAS

This scenario describes how Centralized Remedial Action Schemes (C-RAS) are used to identify abnormal grid conditions and activate mitigation strategies to maintain grid stability. The C-RAS process is initiated by relays which measure the grid condition by capturing "real power" line flows, load levels, generation output, and the general grid condition (voltage, current, etc.). This data is transmitted to the C-RAS Controller, which evaluates the data to determine whether any Remedial Action Schemes (RAS) require arming. The C-RAS Controller performs this evaluation on a new data set every 100 milliseconds, and will arm a RAS if line flows exceed predetermined thresholds. Upon arming a RAS, the C-RAS Controller notifies the EMS Operator via the EMS dashboard. The EMS Operator is able to disarm a RAS prior to its activation. Although there are several potential RAS activation triggers, in this use case scenario the RAS is activated by a line outage. Thus, if the RAS is armed and a relay subsequently detects a line outage, the relay transmits an outage signal to the C-RAS Controller which then prepares to activate the RAS. The C-RAS Controller determines the amount of generation to be tripped and/or load to be shed for the armed RAS, then sends control commands to relays which activate the mitigation strategy. The EMS Operator is notified upon activation of the RAS. By the time a line outage occurs the C-RAS Controller would have taken action prior to the EMS Operator having a chance to respond (the control action has a latency of less than 50 milliseconds). Thus, the EMS Operator would not be able to disarm the RAS activation. He would only be able to disarm the RAS arming. The EMS Operator would then attempt to resolve the event conditions through investigation and, ultimately, re-dispatching the system. All event data is stored by C-RAS in the C-RAS Historian and is available for future analysis.

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)*
A line outage occurs.	Relays	Planning studies have been performed for each RAS to determine arming levels and create "Mitigation Logic Tables". These tables identify mitigation strategies (e.g. load shedding and/or generation tripping levels)	The line is brought back online, and generation and load are restored.

		for a limited number of potential contingencies. **NOTE**: Future state of C-RAS eliminates pre-calculated tables. Rather, mitigation levels would be calculated in real-time based on current grid conditions.	

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	Relays	Relays monitor current electric grid conditions.	Relays monitor line flows, substation load levels, generating station outputs, the general grid condition (frequency, voltage, etc.), and line outage conditions. The relays monitor information that is similar to the information monitored by traditional EMS / SCADA systems. However, due to the faster speed requirements associated with C-RAS, these relays are assumed to be dedicated solely to C-RAS. At some point in the future these relays could potentially also be used for EMS / SCADA purposes, but only if this does not interfere with the C-RAS speed requirements.

Step #	*Actor*	*Description of the Step*	*Additional Notes*
2	Relays	Relays transmit electric grid condition data to C-RAS Controller.	Relays transmit data over SCEnet to C-RAS Controller. There is complete redundancy of C-RAS communications infrastructure, including the relays, switches, potential transformers and current transformers (PTCT), communication circuits, and C-RAS Controllers. The C-RAS Controller also archives all the grid condition data in the C-RAS Historian.
3	C-RAS Controller	C-RAS Controller determines that Remedial Action Scheme (RAS) arming is required.	Based on the current electric grid conditions and pre-defined arming logic, the C-RAS Controller determines that one or more RASs shall be armed. The act of receiving electric grid condition data and evaluating it with respect to the arming logic is performed every 100 milliseconds against a new data set. In general, the C-RAS Controller will decide to arm a RAS if line flows exceed predetermined thresholds. See the use case narrative on page 7 for an example of how a RAS is armed and activated. In the narrative example, a RAS is armed in the corridor power flow exceeds 2,400MW. The C-RAS Controller may determine that multiple RAS are required for a given situation. Due to the increasing number of generation facilities being brought online, there is also an increase in the number of required RAS. Since most of these generating facilities and RAS reside within SCE's 4 transmission

Step #	Actor	Description of the Step	Additional Notes
			corridors, these RAS often overlap. Thus, the C-RAS Controller needs to optimize the various RASs to avoid over or under tripping generation and/or shedding load.
3.1	C-RAS Controller	C-RAS Controller determines that RAS disarming is required.	Continuing with the example in the use case narrative, if the flow level drops below 2,400MW prior to a line outage, the C-RAS Controller would disarm the RAS. Again, this example uses a 2,400MW arming threshold for illustrative purposes only. The limits will vary for each RAS.
4	C-RAS Controller	C-RAS Controller arms the appropriate RAS.	As discussed in step 3, this may consist of more than one RAS.
4.1	C-RAS Controller	C-RAS Controller disarms the appropriate RAS.	If the flow level drops below 2,400MW prior to a line outage, the C-RAS Controller would disarm the RAS. This may consist of disarming more than one RAS.
5	C-RAS Controller	C-RAS Controller notifies EMS Operator of RAS arming.	The C-RAS Controller notifies the EMS Operator via the EMS dashboard that if a line outage event occurs, a RAS will be executed. For example, C-RAS would tell the operator that, given the current corridor conditions (load and generation levels), if a contingency occurs a specific substation will be dropped. It would also indicate the current amount of load being supported by this substation. The EMS Operator is capable of overriding the arming of a RAS. The C-RAS Controller would continue to update the EMS Operator as conditions change (e.g. as line flow and load levels

Step #	Actor	Description of the Step	Additional Notes
			change, the C-RAS Controller would notify the EMS Operator of the potential mitigation action vie the EMS dashboard).
5.1	C-RAS Controller	C-RAS Controller notifies EMS Operator of RAS disarming.	
6	C-RAS Controller	C-RAS Controller archives all event data in the C-RAS Historian.	The C-RAS Controller archives the relay data and RAS arming event in the C-RAS Historian.
7	Relay	Relay detects line outage.	There are a number of potential triggers that can activate RASs, one of which is a line outage.
8	Relay	Relay transmits outage signal to C-RAS Controller.	
9	C-RAS Controller	C-RAS Controller determines amount of load / generation to be dropped for the armed RAS (based on most recent sample of grid condition data).	Each RAS has a predefined Mitigation Logic Table which specifies, for given levels of line flow and load, which generation facilities need to be tripped (reducing generation), and/or which substation need to be shed (reducing load). In other words, each line flow and load level (typically defined in MW ranges), has a specific mitigation strategy under a given RAS. The C-RAS Controller uses this table to determine the mitigation strategy, based on the current line flow and load levels. Since the Mitigation Logic Tables are based on ranges, and they generally define mitigation strategies for a limited number of worst case scenarios, the prescribed mitigation strategies usually reduce load and/or generation by more than is necessary. The logic processor used for existing RAS allows a maximum of 24 different contingency scenarios. In the future these tables will

Step #	***Actor***	***Description of the Step***	***Additional Notes***
			be substituted by real-time contingency analysis, which will calculate the mitigation strategy in real-time based on current conditions. There is no limit to the number of scenarios that can be handled by these C-RAS logic processors. Phasor measurement would likely be one component of the "state measurement" that would feed into this real-time contingency analysis. In the future SCE will also coordinate RASs with signals to ramp up generation in the LA basin. This would help alleviate line flow restrictions in the impacted corridor. Another desired future functionality is to utilize energy storage resources, distributed energy resources (including renewables), and demand response resources during contingency events. Distributed energy and energy storage resources would be considered in the real-time C-RAS mitigation strategy calculation as a means of replacing generation that is tripped via the mitigation strategy. Demand response resources could be used in lieu of shedding substation load.
10	C-RAS Controller	The C-RAS Controller sends signals to load and/or generation relays to shed the desired load and/or trip the desired generation.	In the future, SCE will use C-RAS Controller to control capacitor banks to provide volt/VAR optimization. In the future, the C-RAS Controller will coordinate with the Predictive Grid Control System (PGCS) described in use case D13. PGCS facilitates the coordinated use of phasor measurement

Step #	*Actor*	*Description of the Step*	*Additional Notes*
			and FACTS devices to maintain grid stability during system events.
11	Relays	Relays shed load and/or trip generation.	
12	C-RAS Controller	The C-RAS Controller sends RAS activation notification to EMS Operator.	Following a line outage, the EMS Operator will receive a message via the EMS dashboard about the RAS activation. The message will state that the event just occurred, and it will indicate which lines were detected as out, and which generation was tripped and/or which substations were shed in response.
13	C-RAS Controller	C-RAS Controller archives all event data in the C-RAS Historian.	The C-RAS Controller archives the line outage and RAS execution event in the C-RAS Historian.
14	EMS Operator	The EMS Operator attempts to resolve the event conditions.	The EMS Operator has to re-dispatch the system to restore service to the substations.

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	Relays shall monitor line flows.	1	1
2	Relays shall monitor frequency.	1	1
3	Relays shall monitor line voltage.	1	1
4	Relays shall monitor substation load levels.	1	1
5	Relays shall monitor generating station output levels.	1	1
6	Relays shall transmit grid monitoring data to the C-RAS Controller.	1	2
7	The C-RAS Controller shall archive all grid monitoring data in the C-RAS Historian.	1	2
8	The C-RAS Controller shall contain pre-defined RAS arming logic.	1	3
9	The C-RAS Controller shall evaluate relay data with respect to predefined RAS arming logic to determine whether RAS arming is required.	1	3
10	The C-RAS Controller shall evaluate interactions between available RAS when deciding whether to arm a particular scheme.	1	3
11	The C-RAS Controller shall evaluate relay data with respect to predefined RAS arming logic to determine whether RAS disarming is required.	1	3.1
12	The C-RAS Controller shall evaluate interactions between armed RAS when deciding whether to disarm a particular scheme.	1	3.1
13	The C-RAS Controller shall arm the appropriate RAS (based on evaluation of relay data	1	4

Req. ID	Functional Requirements	Associated Scenario # (if applicable)	Associated Step # (if applicable)
	in step 3).		
14	The C-RAS Controller shall disarm the appropriate RAS (based on evaluation of relay data in step 3.1).	1	4.1
15	The C-RAS Controller shall notify the EMS Operator of the RAS arming via the Energy Management System (EMS) dashboard.	1	5
16	The C-RAS Controller shall notify the EMS Operator of condition changes via the EMS dashboard. For example, as line flow and load levels change, the C-RAS Controller would notify the EMS Operator of the revised potential mitigation action.	1	5
17	The EMS Operator notification shall include a summary of current corridor conditions (e.g. current load and generation levels).	1	5
18	The EMS Operator notification shall include a statement about the mitigation strategy that will be implemented if a line outage occurs (e.g. which substation would be dropped, and the current amount of load supported by that substation).	1	5
19	The EMS Operator shall be able to disarm RASs.	1	5
20	The C-RAS Controller shall notify the EMS Operator of the RAS disarming via the EMS dashboard.	1	5.1
21	The C-RAS Controller shall archive relay data in the C-RAS Historian. This is necessary so that SCE can perform post-mortem investigations.	1	6
22	The C-RAS Controller shall archive RAS arming actions in the C-RAS Historian.	1	6
23	Relays shall monitor for line outage conditions.	1	7
24	Relays shall transit line outage condition information to the C-RAS Controller.	1	8
25	The C-RAS Controller shall evaluate outage signals with respect to predefined RAS Mitigation Logic Tables to determine which generation facilities need to be tripped and/or which substations need to be shed, given the current line flow and load levels.	1	9
26	The C-RAS Controller shall calculate a mitigation strategy in real-time based on the most recent grid condition data sample. Once this functional requirement is satisfied, this mitigation strategy calculation will replace the Mitigation Logic Tables.	1	9

Req. ID	***Functional Requirements***	***Associated Scenario #*** ***(if applicable)***	***Associated Step #*** ***(if applicable)***
27	The C-RAS Controller mitigation strategies shall coordinate with generation facilities in the Los Angeles basin. For example, if generation is tripped in one of the 4 corridors outside the LA basin, the C-RAS Controller shall attempt to compensate for this lost generation by ramping up generation within the LA basin.	1	9
28	The C-RAS Controller mitigation strategy calculation shall consider energy storage resources. Energy storage shall be a means of replacing generation that must be tripped due to a line outage.	1	9
29	The C-RAS Controller mitigation strategy calculation shall consider distributed energy resources. Distributed energy resources (including renewables) shall be a means of replacing generation that must be tripped due to a line outage.	1	9
30	The C-RAS Controller mitigation strategy calculation shall consider demand response resources. Demand response resources shall be a means of reducing load in lieu of involuntary customer load shedding.	1	9
31	The C-RAS Controller shall be able to send mitigation strategy signals to relays.	1	10
32	The C-RAS Controller shall be able to send mitigation strategy signals to capacitor banks for volt/VAR optimization.	1	10
33	The C-RAS Controller shall coordinate with the Predictive Grid Control System (PGCS) described in use case D13.	1	10
34	The C-RAS Controller shall be able to send mitigation strategy signals to energy storage resources.	1	10
35	The C-RAS Controller shall be able to send mitigation strategy signals to distributed energy resources.	1	10
36	The C-RAS Controller shall be able to send mitigation strategy signals to demand response resources.	1	10
37	Relays shall be able to shed load.	1	11
38	Relays shall be able to trip generation.	1	11
39	Relays shall be able to ramp generation up and down	1	11

Req. ID	***Functional Requirements***	***Associated Scenario #*** ***(if applicable)***	***Associated Step #*** ***(if applicable)***
40	The C-RAS Controller shall notify the EMS Operator of the RAS execution via the EMS dashboard.	1	12
41	The EMS Operator notification shall indicate which lines were detected as out.	1	12
42	The EMS Operator notification shall indicate which generation was tripped.	1	12
43	The EMS Operator notification shall indicate which substations were shed.	1	12
44	The C-RAS Controller shall archive line outage information in the C-RAS Historian. This is necessary so that SCE can perform post-mortem investigations.	1	13
45	The C-RAS Controller shall archive RAS activation actions in the C-RAS Historian.	1	13
46	SCEnet shall remain on-line during a wide area blackout.	1	All

4.2 Non-functional Requirements

Req. ID	Non-Functional Requirements	Associated Scenario # (if applicable)	Associated Step # (if applicable)
1	C-RAS shall receive and evaluate relay data every 100 milliseconds. This includes evaluating relay data vis-à-vis arming conditions and mitigation level tables to determine whether RAS arming is required.	1	2
2	The messaging shall follow some interoperability and speed standards such as IEC61850.	1	2, 8, & 10
3	The messaging shall follow security standard IEC 62351 part 6.	1	2, 8, & 10
4	Each message shall be able to include 360 bytes.	1	2, 8, & 10
5	EMS alarms shall be delivered to the EMS Operator within a timeframe consistent with relevant IT performance standards (i.e. the messages do not need to delivered within a millisecond timeframe, but there shall be no intentional delay).	1	5, 5.1 & 12
6	C-RAS shall receive outage signals within 2 milliseconds of the outage condition.	1	8
7	There shall be less than 50 millisecond latency for the control operation (from line loss detection to delivery of the tripping signal to the mitigation relay).	1	11
8	C-RAS infrastructure shall include redundant relays.	1	All
9	C-RAS infrastructure shall include redundant potential transformers and current transformers (PTCT).	1	All
10	C-RAS infrastructure shall include a redundant C-RAS Controller.	1	All
11	C-RAS infrastructure shall include redundant routers.	1	All
12	C-RAS infrastructure shall include redundant switches.	1	All
13	The SCEnet communication network shall cover SCE's 4 main transmission corridors, extending to each 500kV and 230kV substation, and to each generating facility greater than 100MW.	1	All
14	SCEnet shall possess redundant communication circuits.	1	All

Req. ID	Non-Functional Requirements	Associated Scenario # (if applicable)	Associated Step # (if applicable)
15	C-RAS infrastructure shall support 90 remedial action schemes.	1	All

5. Use Case Models (optional)

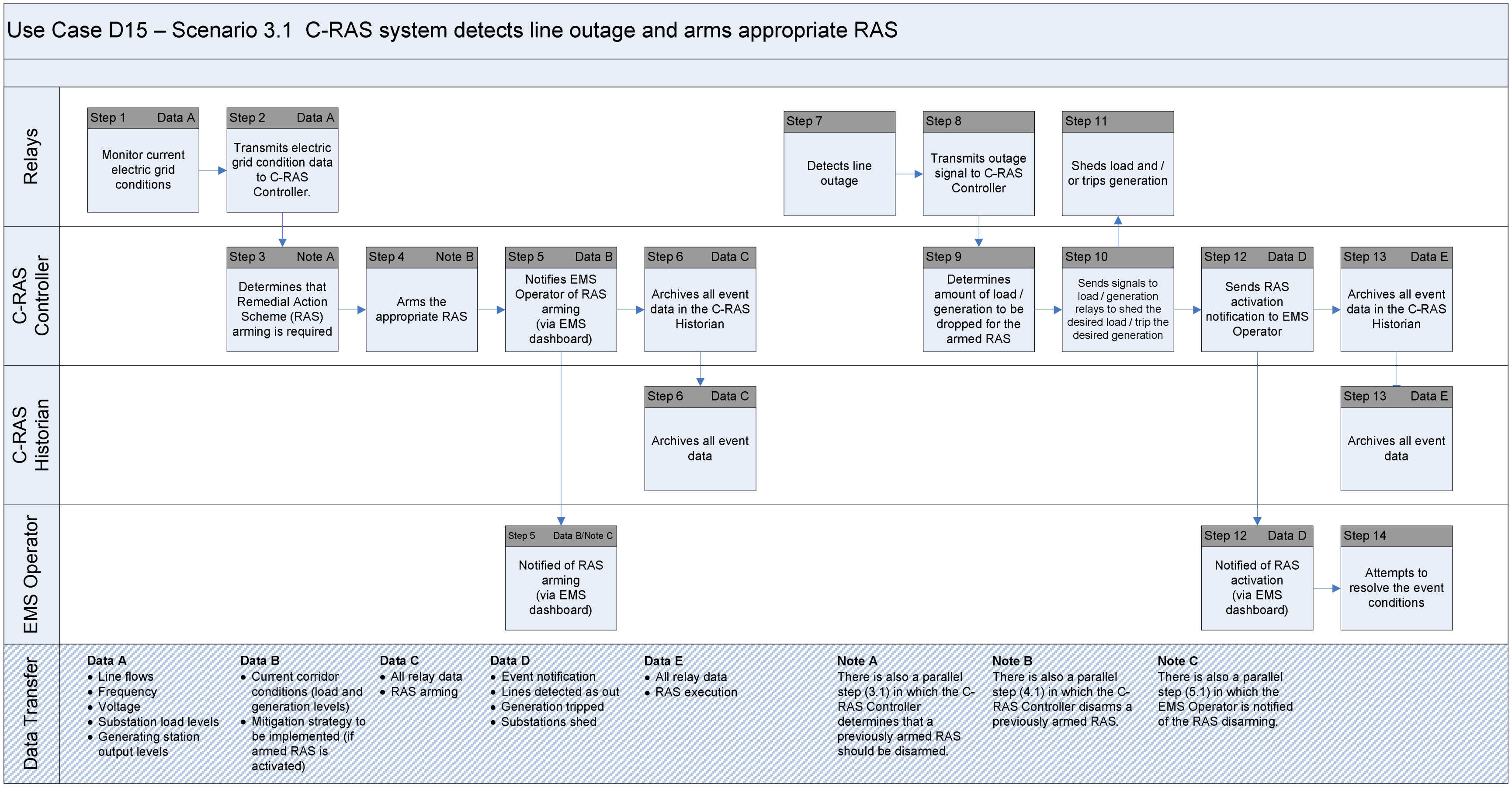
This section is used by the architecture team to detail information exchange, actor interactions and sequence diagrams

5.1 Information Exchange

For each scenario detail the information exchanged in each step

Scenario #	***Step #, Step Name***	***Information Producer***	***Information Receiver***	***Name of information exchanged***
#	*Name of the step for this scenario.*	*What actors are primarily responsible for Producing the information?*	*What actors are primarily responsible for Receiving the information?*	*Describe the information being exchanged*

5.2 Diagrams


Use Case D15 – Scenario 3.1 C-RAS system detects line outage and arms appropriate RAS
Relays
C-RAS Controller
C-RAS Historian
EMS Operator
Data Transfer
Step 1 Data A
Monitor current electric grid conditions
Step 2 Data A
Transmits electric grid condition data to C-RAS Controller.
Step 3 Note A
Determines that Remedial Action Scheme (RAS) arming is required
Step 4 Note B
Arms the appropriate RAS
Step 5 Data B
Notifies EMS Operator of RAS arming (via EMS dashboard)
Step 5 Data B/Note C
Notified of RAS arming (via EMS dashboard)
Step 6 Data C
Archives all event data in the C-RAS Historian
Step 6 Data C
Archives all event data
Step 7
Detects line outage
Step 8
Transmits outage signal to C-RAS Controller
Step 9
Determines amount of load / generation to be dropped for the armed RAS
Step 10
Sends signals to load / generation relays to shed the desired load / trip the desired generation
Step 11
Sheds load and / or trips generation
Step 12 Data D
Sends RAS activation notification to EMS Operator
Step 12 Data D
Notified of RAS activation (via EMS dashboard)
Step 13 Data E
Archives all event data in the C-RAS Historian
Step 13 Data E
Archives all event data
Step 14
Attempts to resolve the event conditions
Data A
• Line flows
• Frequency
• Voltage
• Substation load levels
• Generating station output levels
Data B
• Current corridor conditions (load and generation levels)
• Mitigation strategy to be implemented (if armed RAS is activated)
Data C
• All relay data
• RAS arming
Data D
• Event notification
• Lines detected as out
• Generation tripped
• Substations shed
Data E
• All relay data
• RAS execution
Note A
There is also a parallel step (3.1) in which the C-RAS Controller determines that a previously armed RAS should be disarmed.
Note B
There is also a parallel step (4.1) in which the C-RAS Controller disarms a previously armed RAS.
Note C
There is also a parallel step (5.1) in which the EMS Operator is notified of the RAS disarming.

6. 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.

7. 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**
SCEnet	SCEnet is SCE's fiber / microwave-based telecommunications platform that provides rapid communications capabilities to SCE's larger substations. SCEnet currently does not have redundancy. This would need to be extended to all generating stations and all substations to be able to shed load or trip generation. This has historically been used for administrative traffic (e-mail, internet access, etc). C-RAS will be the first project that turns SCEnet into an operating asset of the power grid.

8. References

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

9. Bibliography (optional)

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

1. 2009 SCE GRC Testimony on Centralized Remedial Action Scheme (Volume 3, Part 5, Chapter 2).