SmartConnect Use Case:

D18 – Utility uses dynamic ratings to optimize transmission throughput

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Document History

Revision History

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Approvals

This document requires following approvals.

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Contents

1. Use Case Description

1.1 Use Case Title

Utility uses dynamic ratings to optimize transmission throughput.

1.2 Use Case Summary

This use case describes how dynamic rating of transmission lines and transformers can improve SCE's ability to optimize the power throughput of its transmission assets. Transmission lines are limited in their ability to transmit power by resistive heating. Increasing a line's loading will increase the conductor temperature, causing the line to sag through thermal expansion. Line sag can result in a violation of California Public Utility Commission clearance requirements, and in some cases it may cause permanent damage to the line. Heat also limits the operation of transformers. To protect these assets and comply with clearance requirements, utilities have historically relied upon static ratings to limit the throughput of these assets. In general, static ratings are designed conservatively to allow the asset to operate under most severe weather conditions (e.g. a hot summer day with no wind). This means that static ratings usually constrain these assets to operate beneath levels at which they can operate safely and reliably. Dynamic ratings take into account real-time weather conditions, in addition to other asset and system conditions, allowing transmission assets to increase power throughput without compromising safety or reliability. The business value of dynamic ratings includes improved system reliability, reduced costs, and increased renewables.

1.3 Use Case Detailed Narrative

One of the challenges shared by all electric utilities is maximizing the power throughput of transmission assets while also operating within a series of operational constraints. These constraints impose limits on the amount of power that can be carried through transmission lines, substation terminal equipment and transformers. Some limits are required by regulators, others are based on the physical characteristics of the equipment, while yet others are necessary to maintain system stability.

In terms of transmission lines, the first constraint is maintaining compliance with the California Public Utility Commission (CPUC) General Order No. 95 (GO 95) requirements on overhead electric line construction. GO 95 represents a series of requirements for the construction of overhead power lines. One of the GO 95 requirements is for lines to maintain a minimum height above the ground. Increasing the current on a transmission line can cause it to sag, risking violation of this height regulation. Line sag occurs when lines carry higher amounts of current continuously over time. Persistently higher currents heat up lines, causing them to stretch via thermal expansion.

If a transmission line is not at risk of violating height regulations, the next constraint relates to the line's physical characteristics. This constraint is referred to as a line's "thermal limit". If a line is loaded beyond the physical limitations of the conductor material, the line will anneal, causing irreversible changes to the conductor's physical properties. These physical changes increase the conductor's length and permanently increase sag. Transformers are similarly constrained by thermal limits in their ability to carry high current. This use case discusses how dynamic ratings can address both the GO 95 and thermal constraints on a real-time basis.

If a transmission line is not constrained by height restrictions or thermal limits (e.g. a theoretically perfect transmission line with zero resistance), the next constraint is to maintain system stability and to comply with the associated NERC / WECC reliability standards. One method of monitoring system stability is through phasor measurements (frequency, current, voltage, and phase angles). Phase angle differences and voltage stability need to be maintained across the electrical system in order to maintain system stability. Transmission lines (or transmission paths consisting of multiple lines) are thus constrained by the need to maintain this stability. Use cases D13 and D16 address the use of phasor measurements as a means of monitoring and maintaining system stability. Whereas thermal data facilitates the calculation of dynamic ratings, phasor data provides stability information. Dynamic ratings and phasor data complement each other by providing a more complete picture of the state of the network.

As discussed above, GO 95 restrictions and conductor thermal limitations constrain utilities' ability to transfer power over transmission lines. To operate within these two sets of constraints, utilities have traditionally used "static ratings" to limit power throughput on specific transmission assets. There are two types of ratings, normal ratings and emergency ratings. Normal ratings represent the maximum current, measured in amperes, that a line can carry during normal operating conditions. Emergency ratings represent the maximum current that can be carried during a contingency event (e.g. during an emergency), and are usually expressed as 15 minute, 30 minute, 1 hour and 4 hour emergency ratings. For example, a 15 minute emergency rating represents the current that can be maintained for at most 15 minutes. Emergency ratings are typically 10% to 20% higher than normal ratings. In general, static ratings are designed based on fixed weather assumptions. To ensure that an asset can operate under most weather conditions (e.g. a cool windy day as well as a hot summer day with no wind), static ratings are set conservatively so as to accommodate more severe weather conditions (e.g. high temperature, high solar radiation, low wind speed). These fixed assumptions generally allow the line to operate beneath its static rating around 98% of the time. However, this also means that static ratings usually constrain transmission lines to operate beneath levels at which they can operate safely and reliably.

Since static ratings rely on fixed weather assumptions, which ignore current weather and asset conditions, this imposes artificially tight constraints on the system. In restricting power throughput of transmission assets, static ratings can impair grid stability, restrict utilities' capacity utilization and operations flexibility, and can lead to higher energy costs. Dynamic ratings improve upon static ratings by considering current weather and asset conditions, prescribing real-time ratings that reflect the actual current-carrying capacity of the transmission assets. This has the potential to increase transmission capacity by up to 30%. One of the clearest applications of dynamic ratings is for transmission corridors for wind generation resources. Use of dynamic rating would increase the amount of wind energy that could be brought online during periods of high wind. The presence of wind tends to reduce line temperatures, causing dynamic line ratings to increase. Thus when winds increase, dynamic ratings on neighboring transmission lines would likewise increase, accommodating transmission of the wind power.

The benefits of deploying an effective dynamic line rating system are presented below. The ultimate realization of these benefits is contingent upon a utility overcoming a few known challenges associated with dynamic line rating technologies. Past SCE pilot projects demonstrated a lack of operating effectiveness in some dynamic rating technologies. Another challenge relates to identifying the critical spans that could benefit from dynamic rating. Finally, regulatory requirements would need to be consistent across the Independent System Operator (ISO) service territory such that operating parameters are consistently applied.

Scenario 1

This scenario describes the process of calculating dynamic line ratings to optimize transmission throughput. Dynamic line ratings are calculated by a Dynamic Line Rating System (DLRS) using a series of algorithms. These algorithms utilize asset and weather information obtained from DLRS sensors, substation sensors, and the Enterprise Asset Management System (EAMS). DLRS sensor information includes current weather (e.g. wind speed and direction, ambient temperature, conductor temperature, and solar radiation levels), line tension and line sag. Substation sensor information generally includes topology (e.g. switch and circuit breaker status), and levels of current flowing through certain devices. Substation information is important since a transmission line rating may actually be limited by the substation terminal equipment on the transmission path. Both the DLRS sensor and substation sensor data are delivered to DLRS via a Data Concentrator. EAMS information includes the nameplate conductor information (material and heat conductivity), and substation terminal equipment information (static ratings).

The dynamic line ratings consist of a normal rating and a series of 3 emergency ratings (15 minute, 30 minute, and one hour). After calculating this series of dynamic ratings, DLRS next compares them to the short term load forecast. The short term load forecast includes the current real-time load and a forecast for the next 6 hours. DLRS compares the lines ratings to the load forecast to determine whether to generate any alarms. DLRS will generate an alarm whenever the load forecast indicates that the load will exceed the normal dynamic rating over the 6 hour forecast period. Subsequent alarms will sound if the operator has not resolves the potential overload condition. For example, if a line has exceeded the 1 hour emergency rating for 55 minutes, an alarm would be generated to remind the operator. Initially, DLRS will also generate alarms based on the static ratings (in addition to the dynamic ratings), to build confidence in the EMS Operators that the DLRS is calculating dynamic ratings accurately.

DLRS alarms are delivered to the EMS Operator via a DLRS Visualization Screen on the EMS dashboard. Each alarm displays both the static and dynamic ratings, and indicates when the load is expected to exceed the rating. This information tells the EMS Operator how much time he has to react to the potential overload. The EMS Operator has the ability to override the dynamic ratings and revert to static rating.

In addition to comparing the dynamic ratings to the short term load forecast, DLRS also sends the dynamic ratings to the ISO and to the Contingency Analysis application. The ISO has sole responsibility for dispatching generation resources. Thus any tactics to mitigate potential overloads that involve dispatching generation would necessarily involve the ISO. The Contingency Analysis performs a series of hypothetical scenario analyses on the system, and generates alternative mitigation strategies for potential contingencies. If the Contingency Analysis application identifies a potential for overload of a dynamically rated line, it generates an alarm for the EMS Operator and sends alternative mitigation strategies. The EMS Operator then takes action to clear the alarm.

Scenario 2

This scenario describes the process of calculating dynamic ratings for substation transformers to optimize transmission throughput. Similar to Scenario 1, dynamic transformer ratings are calculated by a Dynamic Transformer Rating System (DTRS) using a series of algorithms. These algorithms utilize asset and weather information obtained from Dissolved Gas Analysis (DGA) devices, transformer sensors, substation sensors, and EAMS. DGA devices provide dissolved gas levels, moisture, and partial discharge information. Transformer sensors provide information about other transformer components beyond the tank and windings, such as bushings and Load Tap Changers. Substation sensors provide weather and transformer cooling system status information. DGA device data and substation sensor data are both delivered to DTRS via a Data Concentrator. EAMS information includes the transformer's static rating and other information, including heat run test data. Heat run test data enable the DTRS algorithms to evaluate a transformer's performance with respect to its factory heat test run performance. This allows the DTRS algorithms to identify transformer abnormalities.

The dynamic transformer ratings consist of a normal rating and a series of 3 emergency ratings (15 minute, 30 minute, and one hour). After calculating this series of dynamic ratings, DTRS next compares them to the short term load forecast. The short term load forecast includes the current real-time load and a forecast for the next 6 hours. DTRS compares the transformer ratings to the load forecast to determine whether to generate any alarms. DTRS will generate an alarm whenever the load forecast indicates that the load will exceed the normal dynamic rating over the 6 hour forecast period.

DTRS alarms are delivered to the EMS Operator via a DTRS Visualization Screen on the EMS dashboard. Each alarm displays both the static and dynamic ratings, and indicates when the load is expected to exceed the rating. This information tells the EMS Operator how much time he has to react to the potential overload. The EMS Operator has the ability to override the dynamic ratings and revert to static rating.

In addition to comparing the dynamic ratings to the short term load forecast, DTRS also sends the dynamic ratings to the ISO and to the Contingency Analysis application. As discussed in Scenario 1, any tactics to mitigate potential overloads that involve dispatching generation would necessarily involve the ISO. The Contingency Analysis performs a series of hypothetical scenario analyses on the system, and generates alternative mitigation strategies for potential contingencies. If the Contingency Analysis application identifies an overload for a dynamically rated transformer based on a potential outage, it generates an alarm for the EMS Operator and sends alternative mitigation strategies. The EMS Operator then takes action to clear the alarm.

Business Value

The benefits of performing dynamic rating of transmission lines include the following:

1. **Improved System Reliability**:
    a. Avoid Clearance Issues: Dynamic rating would allow EMS Operators to identify and take action to reduce load prior to lines sagging to critical levels.
    b. Peak Load: Dynamic rating would allow SCE to increase transmission throughput during peak demand periods.
    c. Reduced Outages: During N-1 or N-2 conditions, dynamic rating would reduce the risk of service interruptions by increasing transmission throughput on remaining lines. During these contingency events, having dynamic ratings that allow you to temporarily increase power throughput can give the EMS Operator more time to respond to an event. Likewise, if a transformer is in need of repair or replacement, SCE may be able to continue carrying load prior to the maintenance work (e.g. SCE avoids shedding load).
    d. Reduce Duration of Reliability Violations: Dynamic ratings provide the Contingency Analysis application with a wider variety of mitigation options, allowing SCE to avoid, or rapidly respond to, reliability violations.
2. **Reduced Costs**:
    a. Reduce Power Procurement Costs:
        i. Lower Cost Energy: To the extent dynamic ratings relieve transmission constraints, the real-time and forward energy markets will have a larger number of participants and potential bid stack options. The ISO would be able to optimize

generation dispatch based on the current spot price and other market considerations. This could include increasing dispatch of lower cost imported power.

ii. Dispatch Variable Generation: Dynamic ratings would allow a larger number of variable resources to come on line during brief periods based on available transmission capacity.

iii. Avoid RAS Activation: When RAS schemes trip generation, the cost of replacing that generation is more expensive than the tripped generation. Thus, reducing the use of RAS schemes would reduce the cost of replacing generation.

iv. Mitigation of Market Power: Increasing throughput within constrained or congested transmission corridors reduces the pricing power of participants.

v. Cost Effectiveness of Response to Reliability Violations: When reliability violations are detected, dynamic rating can provide more cost effective mitigation techniques. Since dynamic ratings increase the transmission capacity of a wide variety of lines, there are a greater number of available options to address instabilities or reliability violations.

b. Capital Efficiency:

i. Capacity Utilization: Dynamic rating allows SCE to maximize its use of transmission assets.

ii. Extend Asset Lives: To the extent older transformers are better monitored and maintained, and not simply replaced when they reach a certain age, these assets could remain in service longer.

iii. Temporary Overloads: Dynamic rating allows SCE to handle temporary overloads based on current asset and weather conditions.

iv. Rationalization of Capital Spending: Dynamic rating could allow SCE to better prioritize spending on capital equipment replacement by helping to identify assets most in need of upgrade or replacement.

v. Leverage Existing Netcomm Infrastructure: This use case does not prescribe a specific communications platform. However, to the extent that existing infrastructure such as the Netcomm radio system is used, SCE can leverage this infrastructure for purposes of economies of scope

vi. Postponement of Line Construction: Since dynamic line rating would allow higher transmission line throughput, this would allow generation to come online during the permitting and construction process. Likewise, this would allow SCE to defer construction or upgrading of transmission assets.

c. Operations Improvements:

i. Avoid Unnecessary Operator Actions: To the extent dynamic ratings increase equipment throughput limits, operators will take action less often.

ii. Avoid Clearance Violations: The DLRS Visualization Screen shall include the percentage sagged and the number of minutes until fully sagged. This information will provide advance warning of clearance violations giving the EMS Operator time to take corrective action.

iii. Penalty Reductions: To the extent SCE can reduce the number of reliability events, it would be subject to fewer reliability-based penalties.

iv. Avoid FERC Violations: If limits are exceeded, this must be self-reported to FERC. To the extent SCE can reduce the number of instances of exceeding limits through the use of dynamic ratings, reporting needs shall decrease.

v. Ice Monitoring: DLRS sensors would provide accurate ice monitoring capabilities, reducing the need to heat transmission lines. SCE has a small number of areas affected by ice (Big Creek, San Joaquin, and the High Sierras). However, this could be a more substantial benefit to other utilities that experience ice conditions.

3. **Increased Renewables**:

   a. Integration of Wind Power: Use of dynamic rating would increase the amount of wind energy that could be brought online during periods of high wind. The presence of wind tends to reduce line temperatures, causing dynamic line ratings to increase. Thus when winds increase, dynamic ratings on neighboring transmission lines would likewise increase, accommodating transmission of the wind power.

1.4 Business Rules and Assumptions

- Dynamic rating technology (e.g. tension and thermal monitors) is reliable, accurate, and consistent between opposite ends of critical spans.
- SCE can identify the critical spans.
- Contingencies that could affect the transmission path of a dynamically rated line or transformer are analyzed by the Contingency Analysis application, which would generate alarms independent of the Dynamic Line Rating System and Dynamic Transformer Rating System.
- Regulators allow operation of the transmission system based on dynamic ratings. This would be a change for WECC which currently requires the use of static ratings.
- Regulatory requirements are consistent across ISO service territory such that operating parameters are consistently applied.

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***
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 DLRS 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 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.
Data Concentrator	System	The Data Concentrator is a gateway to the Dynamic Line Rating System (DLRS). It receives and aggregates data from substation sensors and DLRS sensors. The Data Concentrator also performs a security role for the substation by providing access management. This is necessary for maintaining compliance with NERC standards on Critical Infrastructure Protection (CIP).
Dissolved Gas Analysis Device (DGA Device)	Device	A Dissolved Gas Analysis device monitors the condition of power transformers. The presence of dissolved gas can be an indication of imminent asset failure, or as an early warning for assets in need of repair.

Actor Name	Actor Type (person, device, system etc.)	Actor Description
Dynamic Line Rating System (DLRS)	System	The Dynamic Line Rating System (DLRS) is an application that receives sensor data from field devices, and runs the data against algorithms to calculate the dynamic line ratings. It calculates a normal rating and 3 emergency ratings (15 minute, 30 minute, and 1 hour). After calculating the dynamic line ratings, the DLRS compares the current loading against the ratings, and triggers alarms for lines that have exceeded their dynamic ratings.
DLRS Sensors	Device	DLRS sensors represent the sensors in the field that collect and transmit data to the DLRS. The specific data requirements are not defined within this use case, but would include things such as weather (wind speed and direction, temperature and solar radiation), tension and sag. In some cases sag would be provided directly by the DLRS sensors, while in other cases sag would be calculated by the DLRS algorithm.
DLRS Visualization Screen	Operator Screen	The DLRS Visualization Screen is a screen on the EMS Operators dashboard that includes the current dynamic line ratings and static line ratings. The screen includes the normal ratings and the 3 emergency ratings (15 minute, 30 minute, and 1 hour). This is the screen by which alarms are issued by DLRS to the EMS Operator. The screen enables the EMS Operator to override the dynamic ratings and revert to static ratings if there is a problem with the DLRS or communication systems.
Dynamic Transformer Rating System (DTRS)	System	The Dynamic Transformer Rating System (DTRS) is an application that receives sensor data from field devices, and runs the data against algorithms to calculate the dynamic transformer ratings. It calculates a normal rating and 3 emergency ratings (15 minute, 30 minute, and 1 hour). After calculating the dynamic transformer ratings, the DTRS compares the current loading against the ratings, and triggers alarms for transformers that have exceeded their dynamic ratings.
DTRS Visualization Screen	Operator Screen	The DTRS Visualization Screen is a screen on the EMS Operators dashboard that includes the current dynamic transformer ratings and static transformer ratings. The screen includes the normal ratings and the 3 emergency ratings (15 minute, 30 minute, and 1 hour). This is the screen by which alarms are issued by DTRS to the EMS Operator. The screen enables the EMS Operator to override the dynamic ratings and revert to static ratings if there is a problem with the DTRS or communication systems.
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, including the DLRS and DTRS Visualization Screens. They would receive the alarms from DLRS and DTRS and would 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, “nameplate” data, asset history, etc.
Equipment Diagnostic Processor (EDP)	System	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”. The system is generally used by the Asset Management Engineer to research condition-based monitoring related notifications. See use case D14 for further discussion of this actor’s role in condition-based maintenance.
Historian	System	The Historian is a common data repository for all the data generated by the various sensors and devices in this use case, including the DLRS sensors, DGA devices, substation sensors and transformer sensors. The Historian also stores the dynamic ratings generated by DLRS and DTRS.
Independent System Operator (ISO)	Organization	The Independent System Operator (ISO or Regional Transmission Organization) is responsible for the economic and reliable operation of the transmission grid. The ISO creates a functioning market for Energy, Capacity, and Ancillary Services. The ISO is responsible for compliance with federal and state rules and regulations.
Load Forecasting System	System	The Load Forecasting System generates a short term load forecast based on current load, and recent historical load change patterns. The historical data would likely cover the most recent week, and would also incorporate system topology and generation dispatch information. System topology information is important since changes to topology will impact the line loadings. The load forecast is transmitted to the DLRS for comparison against dynamic ratings to determine whether to issue alarms to the EMS Operator.

Actor Name	*Actor Type (person, device, system etc.)*	*Actor Description*
Substation Sensors	Device	Substation sensors measure and transmit information to the DLRS for purposes of calculating dynamic line ratings. Substation data includes the substation topology (e.g. switch and circuit breaker status). This information is important to the dynamic line ratings since substation terminal equipment can act as a bottleneck if the terminal equipment ratings are lower than the ratings of the lines connecting to the substation.
Transformer Sensors	Device	Transformer sensors measure and transmit information to the DTRS for purposes of calculating dynamic transformer ratings. These devices capture information related to transformer components other than the tank and windings. This could include bushings, Load Tap Changers, etc., and would vary by transformer.

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: Utility uses dynamic line ratings to optimize transmission throughput

This scenario describes the process of calculating dynamic line ratings to optimize transmission throughput. Dynamic line ratings are calculated by a Dynamic Line Rating System (DLRS) using a series of algorithms utilizing asset and weather information from field sensors and the Enterprise Asset Management System (EAMS). The dynamic line ratings consist of a normal rating and a series of 3 emergency ratings (15 minute, 30 minute, and one hour). After calculating this series of dynamic ratings, DLRS compares them to the short term load forecast. The short term load forecast includes the current real-time load and a forecast for the next 6 hours. DLRS compares the lines ratings to the load forecast to determine whether to generate any alarms. DLRS alarms are delivered to the EMS Operator via a DLRS Visualization Screen on the EMS dashboard. DLRS also sends the dynamic ratings to the ISO and to the Contingency Analysis application. The Contingency Analysis application performs a series of hypothetical scenario analyses on the system, and generates alternative mitigation strategies for potential contingencies. If the Contingency Analysis application identifies an overload for a dynamically rated line based on a potential outage, it generates an alarm for the EMS Operator and sends alternative mitigation strategies. The EMS Operator then takes action to clear the alarm.

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)*
SCE field sensors measure and transmit data to the Data Concentrator.	Dynamic Line Rating System Sensors & Substation Sensors		EMS Operator takes corrective action.

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	Dynamic Line Rating System (DLRS) Sensors and Substation Sensors	Sensors transmit data to Data Concentrator	
1.1	DLRS Sensors	DLRS Sensors transmit data to Data Concentrator.	DLRS Sensors are devices on the transmission equipment (lines, towers, etc.) that capture data for use by the DLRS. The specific data requirements are not completely defined within this use case, but would include things such as weather (wind speed, wind direction, conductor temperature, ambient temperature, and solar radiation levels), line tension and line sag. This use case does not prescribe a specific communication medium for transmitting data to the Data Concentrator. Options include SCE's existing Netcomm radio system, or a new cellular, satellite, or other terrestrial based system.

Step #	*Actor*	*Description of the Step*	*Additional Notes*
1.2	Substation Sensors	Substation Sensors transmit data to Data Concentrator.	Substation Sensor data is important for determining dynamic line ratings since the limitation for a transmission line may actually be based on the limitations of the substation terminal equipment. Substation data shall include topology (e.g. switch and circuit breaker status), and current levels flowing through specific devices. This information assists in calculating the limits on the substation terminal equipment.
2	Data Concentrator	Data Concentrator sends field sensor information to the Dynamic Line Rating System (DLRS).	The Data Concentrator receives data from multiple DLRS Sensors and Substation Sensors, and then forwards it to DLRS. DLRS is an application that runs algorithms to determine dynamic line ratings. DLRS would likely be one application within the Energy Management System.
3	DLRS	DLRS retrieves equipment information from the Enterprise Asset Management System (EAMS).	DLRS retrieves conductor (e.g. transmission line) and substation terminal equipment information from EAMS. Conductor information would include the conductor material and its heat conductivity. Terminal equipment information would include static ratings. Since static ratings of terminal equipment may be lower than the line ratings, this would represent a lower limit within the DLRS algorithms (i.e. it would be the bottleneck). Dynamic ratings would

Step #	*Actor*	*Description of the Step*	*Additional Notes*
			not be performed for terminal equipment since the static ratings are based on the physical properties of the equipment. These static ratings represent the maximum safe operating condition of the equipment (e.g. the equipment would be damaged if these limits are exceeded.)
4	DLRS	DLRS retrieves the short term load forecast from the Load Forecasting System (LFS).	DLRS retrieves the short term load forecast from the LFS so that in step 6 DLRS can compare the load to the dynamic ratings to determine whether it should generate any alarms. LFS generates forecasts based on data maintained in the Historian and current load information. In general, daily load curves follow a consistent cyclic pattern, with load rising throughout the morning, peaking at around 3 to 4 pm on a summer afternoon, and then declining. Naturally, this curve pattern experiences daily and seasonal variations, and is subject to other events and weather changes. Combining the load pattern with recent historical data could allow us to generate short term load forecasts. As an example, measuring the difference between the load at 10:00am yesterday and the load at 10:00am load today, could potentially allow us to forecast what the load will be at 11:00am, based on the load

Step #	Actor	Description of the Step	Additional Notes
			differential calculation and the recent historic daily load curve pattern. The historical data would likely cover the most recent week, and would also incorporate system topology. System topology information is important since changes to topology will impact the line loadings. Since historical line loading data may not be representative of current system topology and generation dispatch, one option is to input the load forecast into the State Estimator in study mode. The State Estimator could then perform a load flow analysis using the current system topology to determine the forecasted line loadings. Each short term load forecast will include the current real-time load as well as the forecast for the next 6 hours.
5	DLRS	DLRS calculates dynamic line ratings.	DLRS has multiple algorithms that calculate dynamic line ratings based on the information obtained in steps 2 & 3. The dynamic ratings shall be calculated based on the conductor type (conductor material and heat conductivity), current weather conditions, line tension, and line sag. The DLRS algorithms calculate a normal rating and a series of 3 emergency ratings (15 minute, 30 minute and 1 hour ratings). Normal ratings represent the current (measured in amperes) that the line

Step #	Actor	Description of the Step	Additional Notes
			can support during normal operation (e.g. no contingency events). Emergency ratings represent the current that the line can support during a contingency event. For example, during a contingency event the 15 minute emergency rating indicates the current that the line can support for the next 15 minutes. Emergency ratings generally allow 10% to 20% higher current levels than the normal rating. DLRS would perform this analysis once per minute.
6	DLRS	DLRS compares the line ratings to the line loading forecast.	DLRS compares the line ratings to the load forecast data (obtained in step 4) to determine whether to generate any alarms. There are alarms for each of the 4 ratings. DLRS will generate an alarm whenever the load forecast indicates that the load either currently exceeds or is projected to exceed any of the 4 ratings over the short-term load forecast period. Upon initial deployment of the dynamic rating capability, DLRS will generate an alarm when the load forecast exceeds either the dynamic or static ratings (whichever is lower). Continuing to generate alarms for static ratings will allow the EMS Operators (and other stakeholders) to develop confidence that the DLRS algorithms are calculating the dynamic ratings accurately. The

Step #	*Actor*	*Description of the Step*	*Additional Notes*
			continued alarming based on static ratings would likely be phased out over time.
6.1	DLRS	DLRS compares the dynamic line ratings to the line loading forecast.	DLRS compares the dynamic line ratings to the load forecast to determine whether to generate any alarms.
6.2	DLRS	DLRS compares the static line ratings to the line loading forecast.	DLRS compares the static line ratings to the load forecast to determine whether to generate any alarms.
7	DLRS	DLRS generates an alarm for the EMS Operator (if appropriate).	The alarm is delivered to the EMS Operator via a DLRS Visualization Screen on the EMS dashboard. DLRS generates an alarm when the load forecast exceeds the normal rating. Alarms shall also sound for the emergency ratings on a periodic basis as a reminder to the operator to resolve the potential overload condition. For example, if a line has exceeded the 1 hour emergency rating for 55 minutes, an alarm would be generated to remind the operator. The alarms would display both the dynamic rating and the static rating for each respective alarm. The alarm will also indicate when the load is expected to exceed the rating. This information will tell the EMS Operator how much time he has to react. For example, if a line carrying power into the LA basin is expected to exceed its rating in one hour, the EMS Operator would need to reduce

Step #	*Actor*	*Description of the Step*	*Additional Notes*
			the loading on the congested line, and have the ISO dispatch generation within the LA basin. If the EMS Operator is not able to react prior to exceeding the rating, his only alternative would be to drop load. The EMS Operator would be able to override the dynamic ratings and revert to the static ratings. This would be necessary in the event of DLRS or communications system malfunctions.
8	DLRS	DLRS sends dynamic ratings to the Independent System Operator (ISO)	Since generation dispatch decisions are the responsibility of the ISO, and since dynamic ratings can impact generation dispatch decisions, it is critical that SCE transmits the dynamic ratings to the ISO. The ISO could then use the dynamic ratings to operate the grid. SCE sends transmission data to the ISO via the Energy Communications Network (ECN), an Inter-Control Center Communications Protocol link. The dynamic ratings and real-time loading information would be added to the packet of data that is currently sent to the ISO through EMS. The DLRS would either be part of EMS, or it would need to be integrated with EMS to facilitate transmitting this information to the ISO.
9	DLRS	DLRS sends dynamic ratings to the Contingency Analysis	Contingency Analysis is an

Step #	*Actor*	*Description of the Step*	*Additional Notes*
		application.	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. Contingency Analysis currently performs analysis using static line ratings. However, once the dynamic rating capability is developed, static ratings would be replaced by dynamic ratings for purposes of its analyses. DLRS would likely send the dynamic ratings to the State Estimator prior to sending it to Contingency Analysis. However, this is a design feature that can be decided at a later date.
10	Contingency Analysis	The Contingency Analysis generates an alarm for the EMS Operator (if appropriate).	If the Contingency Analysis identifies a potential for overload on a dynamically rated line, it will generate an alarm for the EMS Operator.
11	Contingency Analysis	The Contingency Analysis calculates alternative mitigation strategies for potential contingencies.	See the Actors definition of Contingency Analysis for a discussion of how alternative mitigation strategies are calculated.
12	Contingency Analysis	The Contingency Analysis sends alternative mitigation strategies for potential contingencies to the EMS Operator (if appropriate).	The Contingency Analysis notifications are delivered to the EMS Operator via the EMS dashboard.

Step #	*Actor*	*Description of the Step*	*Additional Notes*
13	EMS Operator	The EMS Operator takes necessary action to clear the alarm.	The EMS Operator performs switching operations to adjust load to the maximum level at which reliability is maintained. This might involve taking the actions recommended by the Contingency Analysis application. The EMS Operator would be able to override the dynamic ratings and revert to the static ratings. This would be necessary in the event of DLRS or communications system malfunctions.
14	DLRS	DLRS sends raw measurements and ratings to the Historian.	
15	Historian	The Historian stores the raw measurements and ratings.	DLRS Sensor data is stored in the Historian for post-event analysis. The Historian would store the rating and sensor data as a trend curve. This information is stored in the Historian to facilitate checking the DLRS dynamic rating accuracy (and, if necessary, update the DLRS algorithms.)

3.2 Primary Scenario: Utility uses dynamic transformer ratings to optimize transmission throughput

This scenario describes the process of calculating dynamic ratings for transformers to optimize transmission throughput. Dynamic transformer ratings are calculated by a Dynamic Transformer Rating System (DTRS) using a series of algorithms utilizing asset and weather information from Dissolved Gas Analysis (DGA) devices, transformer sensors, substation sensors, and EAMS. The dynamic transformer ratings consist of a normal rating and a series of 3 emergency ratings (15 minute, 30 minute, and one hour). After calculating this series of dynamic ratings, DTRS next compares them to the short term load forecast. The short term load forecast includes the current real-time load and a forecast for the next 6 hours. DTRS compares the transformer ratings to the load forecast to determine whether to generate any alarms. DTRS alarms are delivered to the EMS Operator via a DTRS Visualization Screen on the EMS dashboard. DTRS also sends the dynamic ratings to the ISO and to the Contingency Analysis application. The Contingency Analysis application performs a series of hypothetical scenario analyses on the system, and generates alternative mitigation strategies for potential contingencies. If the Contingency Analysis application identifies an overload for a dynamically rated transformer based on a potential outage, it generates an alarm for the EMS Operator and sends alternative mitigation strategies. The EMS Operator then takes action to clear the alarm.

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)*
SCE field sensors measure and transmit data to the Data Concentrator.	Dissolved Gas Analysis Devices & Other Sensors		EMS Operator takes corrective action.

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	Dissolved Gas Analysis (DGA) Devices and Other Sensors	Devices transmit data to Data Concentrator	
1.1	DGA Device	DGA devices transmit data to Data Concentrator.	DGA devices are used as part of a condition-based maintenance program, and are discussed in more detail in use case D14. In this use case, DGA devices are leveraged to provide information to calculate dynamic transformer ratings. Use case D14 assumes DGA will be performed once per day, unless the condition of a particular asset warrants more frequent testing. This use case similarly assumes that DGA shall be performed once per day unless: (1) the transformer is operating above its static rating, or (2) the condition-based maintenance system prescribes a higher sampling frequency. If either of these conditions exists, the Equipment Diagnostic Processor (part of the condition-based monitoring architecture in D14 and D19) would

Step #	Actor	Description of the Step	Additional Notes
			determine a modified sampling rate and remotely reconfigure the DGA devices to perform sampling based on the new rate. DGA can be performed on a transformer at most once per hour.
1.2	Substation Sensors	Substation sensors transmit data to Data Concentrator.	Substation sensors shall provide additional data to assist in determining dynamic transformer ratings. The data requirements would include weather (wind speed, temperature, and solar radiation levels), and transformer cooling system status. There are likely to be other additional data requirements not identified in this use case.
1.3	Transformer Sensors	Transformer sensors transmit data to Data Concentrator.	Transformer sensors shall provide information about the condition of transformer components other than the tank and windings. This could include information about bushings, load tap changers, etc., depending on the specific transformer.
2	Data Concentrator	Data Concentrator sends information to the Dynamic Transformer Rating System (DTRS).	The Data Concentrator receives data from multiple DGA devices, substation sensors, and transformer sensors, and forwards it to the DTRS. Similar to the DLRS, the DTRS would likely be one application within the Energy Management System. The DTRS is an application that runs algorithms to determine the dynamic transformer ratings.

Step #	***Actor***	***Description of the Step***	***Additional Notes***
3	DTRS	DTRS retrieves equipment information from the Enterprise Asset Management System (EAMS).	DTRS retrieves the static rating and other transformer information, including heat run test data, from EAMS. A heat run is a one-time test performed at the factory prior to delivery to SCE. This is a benchmarking test of how the transformer performs at various temperatures. This test data would be one input into the dynamic transformer rating. This information would be used in conjunction with transformer loading and current DGA ambient gas level data (e.g. the gas levels that exist in the transformer oil when it is not overloaded). Ambient gas levels are an indication of the transformer's general health. If the transformer already has high ambient gas levels, then it should not be overloaded. In this case the dynamic rating would be the same as the static rating. However, if a transformer's ambient gas levels are normal, the transformer could be overloaded up to a secondary limit based on its physical properties (i.e. exceeding a certain temperature would damage the transformer core), while subsequent DGA results would serve as a break on this overloading. As a transformer goes into an overloaded situation (where the transformer is loaded beyond its recognized rating), DTRS would analyze the DGA gas levels and the other sensor information to identify

Step #	Actor	Description of the Step	Additional Notes
			whether the transformer is beginning to show signs of wear. As the transformer loading is increased, if DTRS detects that the transformer is producing increased amounts of gas or if it identifies other abnormalities, DTRS would instruct the transformer to reduce its loading to eliminate those abnormalities. In this case, the DGA data would serve as a break on further loading of the transformer. Part of the input to determining when the transformer is exhibiting abnormalities is the data from the factory heat run test.
4	DTRS	DTRS retrieves the short term load forecast from the Load Forecasting System (LFS).	DTRS retrieves the short term load forecast from the LFS so that in step 6 DTRS can compare the load to the dynamic ratings to determine whether it should generate any alarms. LFS generates forecasts based on data maintained in the Historian and current load information. In general, daily load curves follow a consistent cyclic pattern, with load rising throughout the morning, peaking at around 3 to 4 pm on a summer afternoon, and then declining. Naturally, this curve pattern experiences daily and seasonal variations, and is subject to other events and weather changes. Combining the load pattern with recent historical data could allow us to generate short term load forecasts.

Step #	*Actor*	*Description of the Step*	*Additional Notes*
			As an example, measuring the difference between the load at 10:00am yesterday and the load at 10:00am load today, could potentially allow us to forecast what the load will be at 11:00am, based on the load differential calculation and the recent historic daily load curve pattern. The historical data would likely cover the most recent week, and would also incorporate system topology. System topology information is important since changes to topology will impact the line loadings. Since historical line loading data may not be representative of current system topology and generation dispatch, one option is to input the load forecast into the State Estimator in study mode. The State Estimator could then perform a load flow analysis using the current system topology to determine the forecasted line loadings. Each short term load forecast will include the current real-time load as well as the forecast for the next 6 hours.
5	DTRS	DTRS calculates dynamic transformer ratings.	DTRS has multiple algorithms that calculate dynamic transformer ratings based on the information obtained in steps 2 & 3. The dynamic ratings shall consider multiple factors including dissolved gas, bubbling risks related to the presence of moisture, transformer

Step #	*Actor*	*Description of the Step*	*Additional Notes*
			temperature, rate of transformer temperature change, weather conditions, partial discharge level, transformer cooling system status, factory heat run test data, and the condition of other transformer components such as bushings and Load Tap Changers. Since DGA can be performed no more than once per hour, but the dynamic rating is performed once per minute, the dynamic rating algorithm should incorporate the lower periodicity of the DGA data as a conservative factor in the dynamic ratings. The DTRS algorithms calculate a normal rating and a series of 3 emergency ratings (15 minute, 30 minute and 1 hour ratings). Normal ratings represent the current (measured in amperes) that the transformer can support during normal operation (e.g. no contingency events). Emergency ratings represent the current that the transformer can support during a contingency event. For example, during an event the 15 minute emergency rating indicates the current that the transformer can support for the next 15 minutes. Emergency ratings generally allow 10% to 20% higher current levels than the normal rating. This analysis would be performed

Step #	*Actor*	*Description of the Step*	*Additional Notes*
			every 1 minute.
6	DTRS	DTRS compares the transformer ratings to the transformer loading forecast.	DTRS compares the transformer ratings to the load forecast data (obtained in step 4) to determine whether to generate any alarms. There are alarms for each of the 4 ratings. DTRS will generate an alarm whenever the load forecast indicates that the load either currently exceeds or is projected to exceed any of the 4 ratings over the short-term load forecast period. Upon initial deployment of the dynamic rating capability, DTRS will generate an alarm when the load forecast exceeds either the dynamic or static ratings (whichever is lower). Continuing to generate alarms for static ratings will allow the EMS Operators (and other stakeholders) to develop confidence that the dynamic rating algorithms are calculating the dynamic ratings accurately. The continued alarming based on static ratings would likely be phased out over time.
6.1	DTRS	DTRS compares the dynamic ratings to the transformer loading forecast.	DTRS compares the dynamic transformer ratings to the load forecast (obtained in step 5) to determine whether to generate any alarms.

Step #	*Actor*	*Description of the Step*	*Additional Notes*
6.2	DTRS	DTRS compares the static ratings to the transformer loading forecast.	DTRS compares the dynamic transformer ratings to the load forecast (obtained in step 5) to determine whether to generate any alarms.
7	DTRS	DTRS generates an alarm for the EMS Operator (if appropriate).	The alarm is delivered to the EMS Operator via a DTRS Visualization Screen on the EMS dashboard. DTRS generates an alarm when the load forecast exceeds the normal rating. Alarms shall also sound for the emergency ratings on a periodic basis as a reminder to the operator to resolve the potential overload condition. For example, if a line has exceeded the 1 hour emergency rating for 55 minutes, an alarm would be generated to remind the operator. The alarms would display both the dynamic rating and the static rating for each respective alarm. The alarm will also indicate when the load is expected to exceed the rating. This information will tell the EMS Operator how much time he has to react. For example, if a transformer associated with a line carrying power into the LA basin is expected to exceed its rating in one hour, the EMS Operator could dispatch generation within the LA-basin, and simultaneously reduce the loading on the congested transformer. If the EMS Operator is not able to react prior to exceeding the rating, his only alternative would be to drop load.

Step #	*Actor*	*Description of the Step*	*Additional Notes*
			The EMS Operator would be able to override the dynamic ratings and revert to the static ratings. This would be necessary in the event of DTRS or communications system malfunctions.
8	DTRS	DTRS sends dynamic ratings to the Independent System Operator (ISO)	Dynamic transformer rating information would only be sent for those transformers that are under the ISO's jurisdiction. SCE sends transmission data to the ISO via an Inter-Control Center Communications Protocol link, the Energy Communications Network (ECN). The dynamic ratings and real-time loading information would be added to the packet of data that is currently sent to the ISO through EMS. The DTRS would either be part of EMS, or it would need to be integrated with EMS to facilitate transmitting this information to the ISO.
9	DTRS	DTRS sends dynamic ratings to the Contingency Analysis application.	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 currently performs analysis using static transformer ratings. However, once dynamic rating capability is

Step #	*Actor*	*Description of the Step*	*Additional Notes*
			developed, the static ratings would be replaced by dynamic ratings for purposes of its analyses. DTRS would likely send the dynamic ratings to the State Estimator prior to sending it to Contingency Analysis. However, this is a design feature that can be decided at a later date.
10	Contingency Analysis	The Contingency Analysis application generates an alarm for the EMS Operator (if appropriate).	If the Contingency Analysis identifies a potential for overload on a dynamically rated transformer, it will generate an alarm for the EMS Operator.
11	Contingency Analysis	The Contingency Analysis application calculates alternative mitigation strategies for potential contingencies.	See the Actors definition of Contingency Analysis for a discussion of how alternative mitigation strategies are calculated.
12	Contingency Analysis	The Contingency Analysis application sends alternative mitigation strategies for potential contingencies to the EMS Operator (if appropriate).	The Contingency Analysis application notifications to the EMS Operator are delivered via the EMS dashboard.
13	EMS Operator	The EMS Operator takes necessary action to clear the alarm.	The EMS Operator performs switching operations to adjust load to the maximum level at which reliability is maintained. This might involve taking the actions recommended by the Contingency Analysis application. The EMS Operator would be able to override the dynamic ratings and revert to the static ratings. This would be necessary in the event of DTRS or communications system malfunctions.

Step #	***Actor***	***Description of the Step***	***Additional Notes***
14	DTRS	DTRS sends raw measurements and ratings to the Historian.	
15	Historian	The Historian stores the raw measurements and ratings.	DTRS sensor data is stored in the Historian for post event analysis. The Historian would store the rating and sensor data as a trend curve. This information is stored in the Historian to facilitate checking the DTRS dynamic rating accuracy and, if necessary, update the DTRS algorithms.

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	Dynamic Line Rating System (DLRS) sensors shall transmit data to the Data Concentrator.	1	1.1
2	DLRS sensors shall capture wind speed.	1	1.1
3	DLRS sensors shall capture wind direction (angle to the conductor).	1	1.1
4	DLRS sensors shall measure or calculate sag.	1	1.1
5	DLRS sensors shall measure or calculate conductor temperature.	1	1.1
6	DLRS sensors shall include solar radiation levels.	1	1.1
7	DLRS sensors shall include presence of precipitation (e.g. whether or not there is precipitation).	1	1.1
8	Dissolved Gas Analysis (DGA) devices shall transmit data to the Data Concentrator.	2	1.1
9	The Equipment Diagnostic Processor (EDP) shall be able to modify the DGA sampling rate.	2	1.1
10	Data Concentrators shall comply with NERC Critical Infrastructure Protection (CIP) requirements.	1	1.1 & 1.2
11	Substation sensors shall transmit substation topology data to the Data Concentrator (e.g. switch and circuit breaker status).	1	1.2
12	Substation sensors shall transmit weather information to the Data Concentrator.	1 & 2	1.2
13	Substation sensors shall transmit transformer cooling system status information to the Data Concentrator.	2	1.2

Req. ID	*Functional Requirements*	*Associated Scenario #* *(if applicable)*	*Associated Step #* *(if applicable)*
14	Transformer sensors shall transmit information about bushing condition to the Data Concentrator, if applicable.	2	1.3
15	Transformer sensors shall transmit information about Load Tap Changer (LTC) condition to the Data Concentrator, if applicable.	2	1.3
16	The Data Concentrator shall transmit DLRS sensor data to the DLRS.	1	2
17	The Data Concentrator shall transmit DGA device data to the DTRS.	2	2
18	The Data Concentrator shall transmit substation sensor data to the DLRS and DTRS.	1 & 2	2
19	The Data Concentrator shall transmit transformer sensor data to the DTRS.	2	2
20	The Enterprise Asset Management System (EAMS) shall make asset information available to DLRS and DTRS.	1 & 2	3
21	DLRS shall retrieve conductor material information from EAMS.	1	3
22	DLRS shall retrieve conductor heat conductivity information from EAMS.	1	3
23	DLRS and DTRS shall retrieve the static ratings of substation terminal equipment from EAMS.	1 & 2	3
24	DTRS shall retrieve transformer static ratings from EAMS.	2	3
25	DTRS shall retrieve transformer heat run test data from EAMS.	2	3
26	DLRS and DTRS shall retrieve the short term load forecast from the LFS.	1 & 2	4
27	LFS shall have access to real-time loading information.	1 & 2	4
28	LFS logarithms shall incorporate real-time loading information into the short term load forecast calculation.	1 & 2	4
29	LFS shall have access to historical load information from the Historian.	1 & 2	4
30	LFS algorithms shall incorporate recent historical load information into the short term load forecast calculation.	1 & 2	4
31	LFS shall have access to historical system topology information from the Historian.	1 & 2	4
32	LFS algorithms shall incorporate historical system topology information into the short term load forecast calculation.	1 & 2	4

Req. ID	*Functional Requirements*	*Associated Scenario #* *(if applicable)*	*Associated Step #* *(if applicable)*
33	LFS shall have access to historical generation dispatch information from the Historian.	1 & 2	4
34	LFS algorithms shall incorporate historical generation dispatch information into the short term load forecast calculation.	1 & 2	4
35	Each short term load forecast shall include the current real-time loading.	1 & 2	4
36	Each short term load forecast shall include the subsequent 6 hour period.	1 & 2	4
37	The DLRS and DTRS algorithms shall calculate a normal rating.	1 & 2	5
38	The DLRS and DTRS algorithms shall calculate a 15 minute emergency rating.	1 & 2	5
39	The DLRS and DTRS algorithms shall calculate a 30 minute emergency rating.	1 & 2	5
40	The DLRS and DTRS algorithms shall calculate a 1 hour emergency rating.	1 & 2	5
41	The DLRS and DTRS algorithms shall consider historical line data when calculating dynamic ratings.	1 & 2	5
42	The DLRS and DTRS algorithms shall consider current weather conditions when calculating dynamic line ratings.	1 & 2	5
43	The DLRS algorithms shall consider line tension when calculating dynamic line ratings.	1	5
44	The DLRS algorithms shall consider line sag when calculating dynamic line ratings.	1	5
45	The DLRS algorithms shall consider line characteristics (from EAMS) when calculating dynamic ratings.	1	5
46	The DLRS algorithms shall consider substation terminal equipment when calculating dynamic line ratings. For example, if the rating of the terminal equipment is lower than the line rating, then the lower rating of the terminal equipment shall be used as a lower limit by the DLRS algorithm.	1	5
47	The DTRS algorithms shall consider factory heat run test data when calculating dynamic transformer ratings.	2	5
48	The DTRS algorithms shall consider the presence of moisture when calculating dynamic transformer ratings.	2	5
49	The DTRS algorithms shall consider transformer temperature when calculating dynamic transformer ratings.	2	5

Req. ID	*Functional Requirements*	*Associated Scenario #* *(if applicable)*	*Associated Step #* *(if applicable)*
50	The DTRS algorithms shall consider rate of transformer temperature change when calculating dynamic transformer ratings.	2	5
51	The DTRS algorithms shall consider partial discharge information when calculating dynamic transformer ratings.	2	5
52	The DTRS algorithms shall consider transformer cooling system status when calculating dynamic transformer ratings.	2	5
53	The DTRS algorithms shall consider DGA data when calculating dynamic transformer ratings.	2	5
54	The DTRS algorithms shall consider the periodicity of DGA sample data as a conservative factor when calculating dynamic transformer ratings.	2	5
55	The DTRS algorithms shall consider the condition of bushings when calculating dynamic transformer ratings, if applicable.	2	5
56	The DTRS algorithms shall consider the condition of Load Tap Changers when calculating dynamic transformer ratings, if applicable.	2	5
57	DLRS and DTRS shall generate alarms based on the lowest rating (static or dynamic).	1 & 2	6
58	DLRS and DTRS shall compare short term load forecasts to dynamic ratings to determine whether to generate any alarms. This would be performed for each of the 4 ratings (normal, 15 minute, 30 minute and 1 hour).	1 & 2	6.1
59	DLRS and DTRS shall compare short term load forecasts to static ratings to determine whether to generate any alarms. This would be performed for each of the 4 ratings (normal, 15 minute, 30 minute and 1 hour).	1 & 2	6.2
60	DLRS and DTRS shall generate alarms when the short term load forecasts exceed the normal ratings.	1 & 2	7
61	Subsequent to alarming based on the normal rating, DLRS and DTRS shall generate periodic alarms when the short term load forecasts exceed the emergency ratings. This is to remind the operator to resolve the overload condition.	1 & 2	7
62	DLRS and DTRS shall be integrated with the EMS alarm system.	1 & 2	7
63	DLRS and DTRS alarms shall display the dynamic ratings to the EMS Operator via a DLRS (or DTRS) Visualization Screen on the EMS dashboard.	1 & 2	7

Req. ID	*Functional Requirements*	*Associated Scenario # (if applicable)*	*Associated Step # (if applicable)*
64	The DLRS and DTRS Visualization Screens shall display static ratings. This is to allow the EMS Operator to compare the two ratings (at least during the initial deployment).	1 & 2	7
65	The DLRS and DTRS Visualization Screens shall display dynamic ratings.	1 & 2	7
66	The DLRS and DTRS Visualization Screens shall display ratings in amperes for non-intertie lines.	1 & 2	7
67	The DLRS and DTRS Visualization Screens shall display ratings in MW for interties.	1 & 2	7
68	The DLRS and DTRS Visualization Screens shall display normal ratings.	1 & 2	7
69	The DLRS and DTRS Visualization Screens shall display 15 minute emergency ratings.	1 & 2	7
70	The DLRS and DTRS Visualization Screens shall display 30 minute emergency ratings.	1 & 2	7
71	The DLRS and DTRS Visualization Screens shall display 1 hour emergency ratings.	1 & 2	7
72	The DLRS and DTRS Visualization Screens shall display alarms for each rating.	1 & 2	7
73	The DLRS Visualization Screen shall display the percentage sagged.	1	7
74	The DLRS Visualization Screen shall display the estimated minutes until fully sagged.	1	7
75	DLRS and DTRS shall provide dynamic ratings to the Independent System Operator (ISO) via EMS.	1 & 2	8
76	DLRS and DTRS shall provide real-time loading information to the ISO via EMS.	1 & 2	8
77	DLRS and DTRS shall be integrated with the state estimation application.	1 & 2	9
78	DLRS and DTRS shall be integrated with the Contingency Analysis application.	1 & 2	9
79	DLRS and DTRS shall provide normal ratings to the Contingency Analysis application.	1 & 2	9
80	DLRS and DTRS shall provide 15 minute ratings to the Contingency Analysis application.	1 & 2	9
81	DLRS and DTRS shall provide 30 minute ratings to the Contingency Analysis application.	1 & 2	9
82	DLRS and DTRS shall provide 1 hour ratings to the Contingency Analysis application.	1 & 2	9
83	The Contingency Analysis application and DLRS and DTRS alarm functions shall both use the same dynamic rating information.	1 & 2	9

Req. ID	Functional Requirements	Associated Scenario # (if applicable)	Associated Step # (if applicable)
84	The Contingency Analysis application shall generate an alarm if there is potential for overload on a dynamically rated line or transformer.	1 & 2	10
85	The Contingency Analysis application shall calculate alternative mitigation strategies for potential contingencies.	1 & 2	11
86	The Contingency Analysis application shall send mitigation strategies to the EMS dashboard.	1 & 2	12
87	The EMS Operator shall be able to override the dynamic ratings and revert to static ratings. This is necessary in the event of failure of any DLRS applications or communications infrastructure.	1 & 2	13
88	DLRS and DTRS shall send ratings to the Historian. This is stored for future post-event analysis.	1 & 2	14
89	DLRS shall send the raw data received from the DLRS sensors to the Historian.	1	14
90	DTRS shall send the raw data received from the DGA devices to the Historian.	2	14
91	DLRS and DTRS shall send the raw data received from the substation sensors to the Historian.	1 & 2	14
92	DTRS shall send the raw data received from the transformer sensors to the Historian.	2	14
93	The Historian shall store the ratings information received from DLRS and DTRS on a time series basis.	1 & 2	15
94	The Historian shall store the raw data from the DLRS sensors on a time series basis.	1	15
95	The Historian shall store the raw data from the substation sensors on a time series basis.	1 & 2	15
96	The Historian shall store the raw data from the transformer sensors on a time series basis.	2	15
97	The Historian shall store rating data as a trend curve.	1 & 2	15
98	The Historian shall store sensor data as a trend curve.	1 & 2	15
99	DLRS and DTRS shall coordinate with the C-RAS Controller to accommodate changes in dynamic ratings. This would be necessary to avoid over or under tripping of generation and/or shedding of load by C-RAS.	1 & 2	All

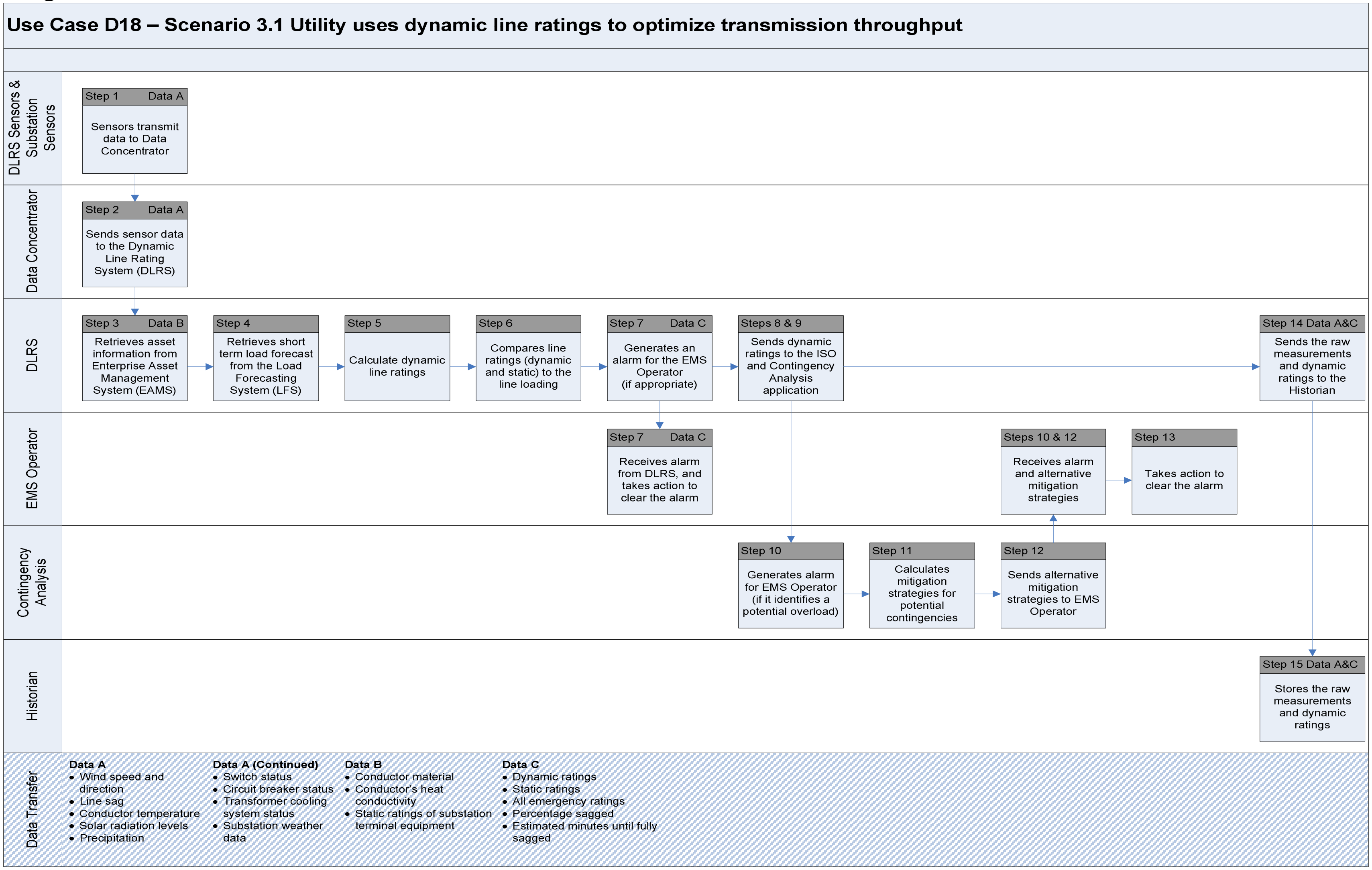
4.2 Non-functional Requirements

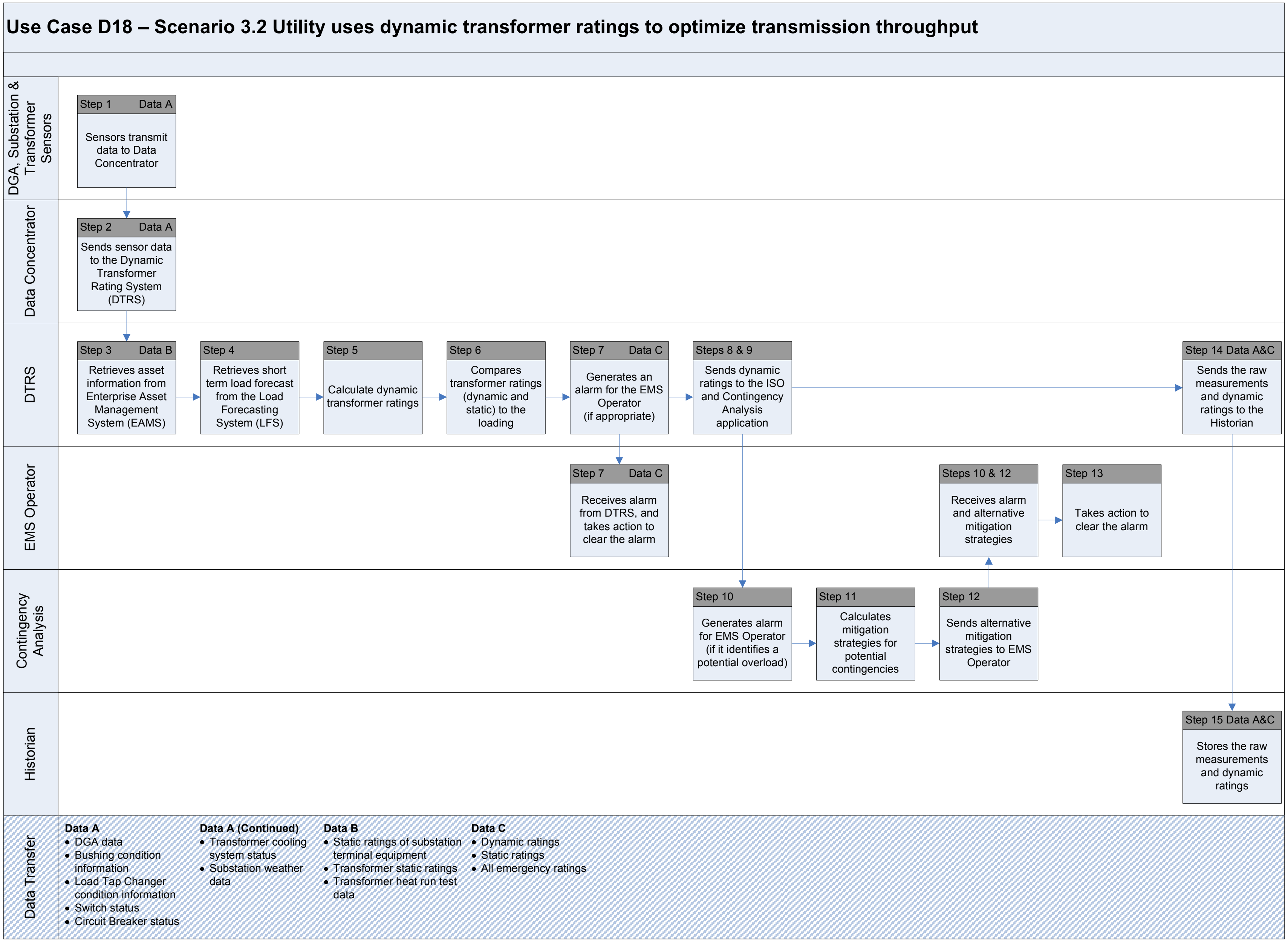
Req. ID	*Non-Functional Requirements*	*Associated Scenario # (if applicable)*	*Associated Step # (if applicable)*
1	Dynamic Line Rating System (DLRS) sensors shall transmit data to the Data Concentrator once per minute.	1	1.1
2	Dissolved Gas Analysis (DGA) devices shall transmit data to the Data Concentrator at least once per day.	2	1.1
3	DGA devices shall transmit data to the Data Concentrator once per hour if the transformer is operating above its static rating.	2	1.1
4	DGA devices shall transmit data to the Data Concentrator at the frequency prescribed by the Equipment Diagnostic Processor (EDP). See use case D14 for a discussion of EDP's role in condition-based maintenance.	2	1.1
5	Substation sensors shall transmit data to the Data Concentrator once per minute.	1 & 2	1.2
6	The Data Concentrator shall transmit data to the DLRS and Dynamic Transformer Rating System (DTRS) once per minute.	1 & 2	2
7	The Enterprise Asset Management System shall send equipment information to DLRS and DTRS on an event driven basis (whenever it changes).	1 & 2	3
8	The Load Forecasting System shall send short term load forecast to DLRS and DTRS once per minute.	1 & 2	4
9	DLRS and DTRS shall calculate dynamic ratings once per minute.	1 & 2	5
10	DLRS shall be able to calculate dynamic ratings for at least 400 transmission lines simultaneously.	1	5
11	DTRS shall be able to calculate dynamic ratings for at least 4,000 substation transformers simultaneously.	2	5
12	DLRS and DTRS shall compare the short term load forecast to the dynamic ratings once per minute.	1 & 2	6.1
13	DLRS and DTRS shall compare the short term load forecast to the static ratings once per	1 & 2	6.2

Req. ID	*Non-Functional Requirements*	*Associated Scenario #* *(if applicable)*	*Associated Step #* *(if applicable)*
	minute.		
14	There shall be no intentional delay in DLRS and DTRS generating an alarm on the DLRS and DTRS Visualization Screens.	1 & 2	7
15	DLRS and DTRS shall transmit dynamic ratings to the Independent System Operator (ISO) once per minute.	1 & 2	8
16	DLRS and DTRS shall transmit real-time loading information to the ISO once per minute.	1 & 2	8
17	DTRS shall only send the ISO dynamic transformer ratings for those transformers under the jurisdiction of the ISO.	2	8
18	DLRS and DTRS shall transmit dynamic ratings to the Contingency Analysis application once per minute.	1 & 2	9
19	There shall be no intentional delay in the Contingency Analysis application generating an alarm on the DLRS and DTRS Visualization Screens.	1 & 2	10
20	The Contingency Analysis application shall calculate alternative mitigation strategies once per minute.	1 & 2	11
21	The Contingency Analysis application shall send alternative mitigation strategies to the EMS Operator once per minute.	1 & 2	12
22	EMS Operator shall take action within 30 minutes of detecting a potential overload. Potential overload means that if there is a contingency event, the load will be overloaded. The 30 minute response time is a regulatory requirement for interconnections.	1 & 2	13
23	DLRS and DTRS shall send data to the Historian on a batch basis once per day.	1 & 2	14
24	The Historian shall save the raw data used for dynamic ratings in perpetuity.	1 & 2	15
25	Must meet Independent System Operator and California Energy Commission requirements on system-wide ratings consistency.	1 & 2	All
26	DLRS and DTRS components shall have reliability of 99.999%. This means that if you evaluate a line or transformer two times under identical conditions, the dynamic rating will be the same 99.999% of the time.	1 & 2	All
27	SCE shall use technologies capable of operating with small data packet sizes (satellite, Netcomm radio, cellular, etc.).	1 & 2	All

5. Use Case Models (optional)

5.1 Diagrams


Use Case D18 – Scenario 3.1 Utility uses dynamic line ratings to optimize transmission throughput
DLRS Sensors & Substation Sensors
Data Concentrator
DLRS
EMS Operator
Contingency Analysis
Historian
Data Transfer
Step 1 Data A
Sensors transmit data to Data Concentrator
Step 2 Data A
Sends sensor data to the Dynamic Line Rating System (DLRS)
Step 3 Data B
Retrieves asset information from Enterprise Asset Management System (EAMS)
Step 4
Retrieves short term load forecast from the Load Forecasting System (LFS)
Step 5
Calculate dynamic line ratings
Step 6
Compares line ratings (dynamic and static) to the line loading
Step 7 Data C
Generates an alarm for the EMS Operator (if appropriate)
Steps 8 & 9
Sends dynamic ratings to the ISO and Contingency Analysis application
Step 14 Data A&C
Sends the raw measurements and dynamic ratings to the Historian
Step 7 Data C
Receives alarm from DLRS, and takes action to clear the alarm
Steps 10 & 12
Receives alarm and alternative mitigation strategies
Step 13
Takes action to clear the alarm
Step 10
Generates alarm for EMS Operator (if it identifies a potential overload)
Step 11
Calculates mitigation strategies for potential contingencies
Step 12
Sends alternative mitigation strategies to EMS Operator
Step 15 Data A&C
Stores the raw measurements and dynamic ratings
Data A
• Wind speed and direction
• Line sag
• Conductor temperature
• Solar radiation levels
• Precipitation
Data A (Continued)
• Switch status
• Circuit breaker status
• Transformer cooling system status
• Substation weather data
Data B
• Conductor material
• Conductor's heat conductivity
• Static ratings of substation terminal equipment
Data C
• Dynamic ratings
• Static ratings
• All emergency ratings
• Percentage sagged
• Estimated minutes until fully sagged


Use Case D18 – Scenario 3.2 Utility uses dynamic transformer ratings to optimize transmission throughput
DGA, Substation & Transformer Sensors
Step 1 Data A
Sensors transmit data to Data Concentrator
Data Concentrator
Step 2 Data A
Sends sensor data to the Dynamic Transformer Rating System (DTRS)
DTRS
Step 3 Data B
Retrieves asset information from Enterprise Asset Management System (EAMS)
Step 4
Retrieves short term load forecast from the Load Forecasting System (LFS)
Step 5
Calculate dynamic transformer ratings
Step 6
Compares transformer ratings (dynamic and static) to the loading
Step 7 Data C
Generates an alarm for the EMS Operator (if appropriate)
Steps 8 & 9
Sends dynamic ratings to the ISO and Contingency Analysis application
Step 14 Data A&C
Sends the raw measurements and dynamic ratings to the Historian
EMS Operator
Step 7 Data C
Receives alarm from DTRS, and takes action to clear the alarm
Steps 10 & 12
Receives alarm and alternative mitigation strategies
Step 13
Takes action to clear the alarm
Contingency Analysis
Step 10
Generates alarm for EMS Operator (if it identifies a potential overload)
Step 11
Calculates mitigation strategies for potential contingencies
Step 12
Sends alternative mitigation strategies to EMS Operator
Historian
Step 15 Data A&C
Stores the raw measurements and dynamic ratings
Data Transfer
Data A
• DGA data
• Bushing condition information
• Load Tap Changer condition information
• Switch status
• Circuit Breaker status
Data A (Continued)
• Transformer cooling system status
• Substation weather data
Data B
• Static ratings of substation terminal equipment
• Transformer static ratings
• Transformer heat run test data
Data C
• Dynamic ratings
• Static ratings
• All emergency ratings

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.
1. Which line characteristics to use?
2. How to adjust protection settings based on Dynamic Line Rating System?
3. Independent System Operator (ISO) may wish to compare ratings to spot price, but not the utility.
4. Could use phasor data to estimate ratings until sensors deployed
5. Use LIDAR surveys to look at critical spans.
6. Should the technology be portable (i.e. move it to different sections of the line)?
7. Do we want to specify that there be no outage for installation?
8. Where is the tradeoff between line losses and additional capacity?
9. Overlap with ISO responsibilities of load balancing.
10. Need to define benefits better to justify work of determining critical spans.

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**
California Public Utility Commission (CPUC)	The CPUC is the regulatory body of the state of California that has decision-making authority over rates and regulations of public utilities. The CPUC regulates telecommunications, electric, natural gas, water, railroad, rail transit and passenger transportation companies. The commission is also charged with protecting consumers from fraud and promoting the health of California's economy.
Energy Communications Network (ECN)	The Energy Communications Network is a dedicated, shared, high-bandwidth, high-reliability communications network that enables communication between the utilities and the California ISO and amongst the California utilities.
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". The system is generally used by the Asset Management Engineer to research condition-based monitoring related notifications.
North American Electric Reliability Corporation (NERC)	The North American Electric Reliability Corporation is a non-governmental organization that develops and enforces reliability standards for bulk power systems.
Western Electricity Coordinating Council (WECC)	The Western Electricity Coordinating Council (WECC) is one of the eight regional reliability organizations 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.

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.