UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Grid Resilience in Regional Transmission Organizations and Independent System Operators	**)** **)** **)**	**Docket No. AD18-7-000**

COMMENTS OF THE CALIFORNIA INDEPENDENT SYSTEM OPERATOR CORPORATION IN RESPONSE TO THE COMMISSION'S REQUEST FOR COMMENTS ABOUT SYSTEM RESILIENCY AND THREATS TO RESILIENCE

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The California Independent System Operator Corporation (CAISO) hereby submits its responses to questions posed by the Commission in its January 8, 2018 *Order Terminating Rulemaking Proceeding, Initiating New Proceeding, and Establishing Additional Procedures* (Resilience Order).

In considering the resilience of the bulk power system, the Commission should take a holistic approach that also considers the unique circumstances and conditions facing each region. Although some threats potentially can affect all regions, individual regions also face distinct threats to resilience. The CAISO footprint faces natural threats primarily from earthquakes, drought, and fires, not hurricanes or extreme cold conditions like other regions. The CAISO also has a different resource mix than other regions. There are no baseload coal resources in the CAISO balancing authority area, and the one remaining nuclear unit is scheduled to retire in 2024. Where other regions are experiencing an influx of natural gas-fired resources, such resources are declining in number in the CAISO footprint. Although the CAISO will need gas fired resources to provide vital reliability services for the foreseeable future, the CAISO system is changing at a rapid pace to one where renewable and other non-carbon emitting

resources, both grid connected and behind-the-meter, will serve much of the load and, ultimately, be called upon to provide a significant portion of needed reliability services. These and other circumstances create a distinct planning and operational landscape for the CAISO bulk power system.

I. HOW TO DEFINE RESILIENCE

The Commission seeks comments regarding its understanding of resilience, which is:

> The ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event.

The Commission also asks for comments on whether any of the terms used in the definition require further elaboration to ensure a common understanding (*e.g.*, identifying the particular types of disruptive events).

CAISO Response

Although it is not possible or practical to guard against every possible combination and magnitude of future events or conditions, planning, procurement, coordination, reliability, market enhancements, and other efforts in the CAISO balancing authority area have produced a robust and diverse infrastructure and "set of tools" that have helped the CAISO to remain reliable and resilient in the face of significant threats such as the restricted operations at the Aliso Canyon Natural Gas Storage Facility (Aliso Canyon), the unexpected closure of the San Onofre Nuclear Generating Station (SONGS), severe droughts and fires, and the recent solar eclipse.

The CAISO proactively considers and addresses the specific reliability and resilience-related challenges it faces on many fronts and through many tools at its

disposal. These include, but are not limited to:

- complying with national and regional reliability standards;
- planning a robust transmission system to meet applicable reliability criteria, including CAISO-specific planning standards (that go beyond the national standards);
- a resource adequacy program that, besides system and local capacity requirements, includes flexible capacity requirements designed to respond to and address changing conditions on the CAISO's system;
- effective backstop procurement mechanisms;
- special studies regarding current, emerging, and anticipated conditions and challenges;
- a robust transmission maintenance program;
- effective coordination with state authorities, transmission and generation owners, and other third-parties, including other balancing authority areas and gas-service providers;
- flexibility to respond to events;
- targeted market and non-market mechanisms, including a flexible ramping product and the energy imbalance market (EIM); and
- effective incident command, business continuity, system restoration, and cyber security programs.[1]

There can be significant differences among regions for purposes of assessing and achieving resilience. The needs, circumstances, and conditions that exist in each region are unique and can vary significantly, as regions face different risks, threats, and operational challenges and have vastly different resource mixes and load curves, fuel supply options, and environmental requirements. Resilience must account for regional differences, and entities in each region must have the flexibility to determine what capabilities are needed to maintain reliability and resiliency based on the specific

[1] In its responses to the questions posed in the Resilience Order, the CAISO describes in detail the resilience-related issues in its region and its efforts, processes, programs, and mechanisms to consider and address resilience.

circumstances in their region. The CAISO's experience highlights the need to consider the unique characteristics of each region in addressing resilience.

The Commission should also recognize that any risks to the resilience of the electric system are not limited to Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs); they can affect all jurisdictional entities and all regions. Further, although ISOs and RTOs have a functional role in addressing resiliency, other entities, too, have roles. Ensuring resilience potentially requires the involvement and actions of a host of entities other than ISO's and RTOs -- transmission and generation owners, fuel suppliers and transporters, federal agencies, reliability organizations, states, consumer groups, environmental groups, and other stakeholders.

The CAISO notes that the concept of "resilience" presented in the Resilience Order is general and somewhat vague. It includes no clear objective criteria, metrics, or standards to evaluate whether the existing grid is resilient. Similarly, it does not (1) instruct entities on the specific steps they should take to achieve the desired level of resilience or (2) specify any compliance obligations entities have to ensure the grid remains resilient. Resilience cannot be broad-brushed.

Moreover, nowhere does the proposed definition of resilience contemplate the undertaking of any type of cost-benefit analysis, prudence assessment, or the ability of entities to finance any extensive resilience efforts. Considering the potentially substantial costs that could be associated with mitigations to improve resilience, these are necessary considerations in determining how much and what type of resilience is appropriate.

As defined, resilience appears to be related to reliability and not a wholly distinct

concept. Many reliability standards address, in some manner, acceptable bulk electric system performance, and the system's ability to withstand or recover from disruptive events including the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event. Complying with these standards, and any local reliability standards that individual ISOs and RTOs have, achieve many of the general objectives reflected in the proposed definition of resilience. For example, the North American Electric Reliability Corporation (NERC) Reliability Standard TPL-001-4 defines what types of disruptive events, including extreme events, the system must withstand (or is allowed not to withstand) with or without losing non-consequential load and interruption of firm transmission services. The term "ability to anticipate and absorb" contained in the resilience definition can be interpreted as addressing similar issues.

Further, the NERC glossary defines "contingency" as "the unexpected failure or outage of a system component, such as a generator, transmission line, circuit breaker, switch or other electrical element." Under the reliability standards, ISOs/RTOs plan for contingencies. The Resilience Order uses the broad term "disruptive events," which can encompass an infinite number of occurrences that can affect the grid. Disruptive events can cause a contingency to occur on the grid. The NERC reliability standards define acceptable system performance in response to those contingencies. It is unclear whether the Commission intends that ISOs/RTOs must separately plan for both contingencies and disruptive events, or whether the two are interwoven. In addressing resilience, the Commission should be clear to avoid any confusion. In addition, if the Commission intends that entities mitigate for specific disruptive events, it must be mindful that although grid operators study, assess, plan, and approve mitigation for

disruptive events, they cannot prevent many such events (*e.g.*, earthquakes, hurricanes, fires, and drought) from occurring and cannot limit the scope and duration of the events themselves.

The Resilience Order does not address any potential overlap between resilience and reliability, clearly articulate the differences between the two, state why a new, wholly separate concept is needed, or indicate what specific requirements a resilient system must meet. These are necessary steps if the Commission is to distinguish resilience from reliability and establish objective resilience standards and guidelines that are separate and distinct from reliability standards. The Commission should eliminate any source of potential confusion or conflict between the two concepts.

II. HOW RTO/ISOs ASSESS THREATS TO RESILIENCE

The Commission seeks comment on how each RTO/ISO evaluates the resilience of its system. The Commission directs RTOs/ISOs to address questions on this issue and, as needed, to highlight any unique resilience challenges that exist in their respective regions.

Question (a): What are the primary risks to resilience in your region from both naturally occurring and man-made threats? How do you identify them? Are they short-, mid-, or long-term challenges?

Response to Question (a):

A. Primary Risks to Resilience in the CAISO Balancing Authority Area

The primary naturally occurring risks to resilience in the CAISO region are earthquakes, drought, and changing weather conditions. Earthquakes are an ever-present risk. Although devastating earthquakes have not been frequent, they have occurred in the CAISO balancing authority area footprint, and can occur without notice.

Droughts are not uncommon in the CAISO balancing authority area, but their occurrence is irregular. They can last for a year or several years. The CAISO considers the resilience risks from earthquakes and drought to be mid-to-long-term challenges because they are infrequent or occur irregularly, but when they occur, can significantly affect the power system.

Changing weather conditions (*e.g.*, cloud cover, solar eclipse, wind conditions, heat waves) are mainly a short-term challenge because they can affect the availability of certain resources on any given day. The CAISO balancing authority area typically does not experience widespread, severe cold periods that other regions face. Although weather conditions typically pose short-term operational challenges, they can present longer term planning challenges to ensure there is sufficient infrastructure and resources with the right attributes available to maintain reliability when whether-dependent resources are not available. Inclement weather conditions can also cause events such as mudslides that can pose near-term threats to resilience in specific local areas.

Fires have become a common occurrence in the CAISO balancing authority area. Fires can result from natural causes and acts of man – both deliberate and accidental. Their affects are typically short-term; although, they can create potentially hazardous conditions (*e.g.*, land deterioration) that that can be aggravated by other events and potentially can last beyond the short-term. The CAISO notes that last year California experienced its worst wildfire ever that resulted in significant property destruction, and recently the state faced oppressive drought conditions. These events had significant cost impacts on the state but caused no significant outages on the bulk

electric system.

Depending on their specific nature and scope, other events or emerging circumstances can present short-term, mid-term, or long-term threats to resilience. Examples include unexpected outages, closures of key facilities (*e.g.*, the San Onofre Nuclear Generating Station and the Aliso Canyon Gas Storage Facility), potential early retirements of resources needed to maintain reliability, loss of fuel supply, and a rapidly changing resource mix.

Besides accidents, manmade threats include those that are committed intending to inflict harm on the power grid such as destructing power grid facilities and cyber-attacks. Information security incidents that threaten the confidentiality, integrity, and availability of CAISO's systems or information may include, but are not limited to, losing grid visibility, losing energy market systems, data disclosure, changing control variables, losing access to critical operational systems, accessing employee data, or causing financial loss or manipulation. Man-made threats can occur at any time and without notice. Their effects on the grid are unpredictable. Larger events could have consequences that are mid-term in nature.

Cyber-security risks are a priority concern for the CAISO. The CAISO is acutely aware of cyber-security risks and attentive to efforts to identify and address them. As discussed further below and in its response to Question II (c), the CAISO has business units, processes, and protocols dedicated to identifying and addressing cyber-security threats, and it actively coordinates with expert third-parties to identify, assess, and prevent them.

B. How the CAISO Identifies Risks to Resilience

The CAISO identifies risks to resilience in its balancing authority area through a comprehensive and coordinated effort that involves numerous planning, monitoring, special study, coordination, and forecasting activities. The CAISO generally utilizes two approaches to identify resilience risks. The first, more programmatic approach entails conducting transmission system analysis of both conventional and extreme events, and then focusing on areas of particular concern where the consequences may fall within the range of acceptable performance under the various NERC and Western Electric Coordinating Council (WECC) planning standards, but the CAISO views them as potentially unacceptable due to their severity. The CAISO then examines in more depth the potential risks an extreme event could trigger and assesses the need for mitigation. The second approach, which is more case-specific and responsive to particular issues or conditions, is to consider a particular risk in a geographic area or system wide, and then examine potential impacts. Below, the CAISO briefly describes these efforts.

As an initial matter, the CAISO seeks to understand the nature of the risks to which the system is exposed. The CAISO actively monitors and assesses the potential occurrence of the events known to occur in California that can affect resilience. The CAISO is not the expert on many of these matters (*e.g.*, earthquakes). As such, it regularly communicates and coordinates with others entities, including neighboring balancing authorities and knowledgeable third parties having responsibilities (and specific knowledge) in these areas, to identify risks and assess their potential impact. The CAISO communicates with experts at the US Geological Survey regarding earthquake risks, and with weather agencies regarding potential El Nino, La Nina, and

other weather-related matters. The CAISO communicates and coordinates with the California Department of Forestry and Fire Protection regularly to identify consider expected fire dangers as California's fire season approaches and during the season itself. The CAISO has participated in a drought task force with other entities in the state. The CAISO also runs simulations and drills based on significant events such as earthquakes.

The CAISO assesses the impact of the loss of service of portions of the grid, regardless of what event or risk cause the outage, through its annual transmission planning process. This process enables the CAISO to identify risks to system reliability and resilience.[2] The CAISO identifies and plans for Contingencies[3] and other potential reliability problems over a 10-year horizon in the annual transmission planning process. In addition, the CAISO conducts an Extreme Event analysis under NERC Reliability Standard TPL-001-4. For example, the CAISO assessed the potential impacts of a significant seismic event on electric system reliability in the San Francisco Peninsula. The CAISO discusses this study in further in its response to Question II (b).

In the transmission planning process, the CAISO also conducts special studies to identify and assess the risks of emerging or anticipated issues or conditions and "get out in front of" any potential emerging issues and challenges. In the 2016-2017 and 2017-2018 planning cycles, the CAISO has been assessing the system reliability risks

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[2] A link to the transmission planning page of the CAISO's website is available at: http://www.caiso.com/planning/Pages/TransmissionPlanning/Default.aspx

The page provides access to the CAISO's annual transmission plans and special transmission planning studies referenced in this document.

[3] The NERC glossary defines "Contingency" as "the unexpected failure of outage of a system component, such as a generator transmission line, circuit breaker, switch, or other electrical element,"

resulting from potential retirements of gas-fired resources, beyond those that are known. In addition, the CAISO conducted sensitivities of the potential risk to system reliability if similarly situated generators retire more-or-less simultaneously. The study focused on two aspects of reliability: local areas of the grid where retirements could create reliability issues or negatively affect grid operations; and retirements that may unduly compromise systems reliability requirements such as load following, operating reserves, and regulating reserves. The studies showed potential shortfalls in load following and reserves, with capacity insufficiencies in the early evening after sunset, based on 1,000-2,000 MW of retirements in the latest sensitivity analyses. The CAISO discusses its efforts to mitigate these shortfalls in response to Question II (e) *infra*.

In the 2015-2016, 2016-2017, and 2017-2018 transmission planning processes, the CAISO conducted and reported on gas-electric coordination transmission planning studies for southern and northern California, to among other things, gather information about the gas system and supply network to gas-fired power plants, investigate plausible conditions that could cause gas curtailment to power plants potentially reducing electric generation, and perform studies to identify any adverse impacts on electric system reliability.[4] In the two most recent planning processes, the CAISO reported on the reliability of the southern California system under various gas curtailment scenarios with the Aliso Canyon gas storage outage.

In addition, in the 2014-2015, 2015-2016, 2016-2017, and 2017-2018 transmission planning processes, the CAISO conducted frequency response studies to

[4] The WECC is currently undertaking a Gas-Electric Interface Study for the Western Interconnection. This is a cross-sector study that is assessing the adequacy security, and risks associated with natural gas infrastructure and its ability to meet the needs of the Bulk Electricity System.

identify issues in managing system dispatch and maintaining reliable service, in particular frequency response performance, across a range of operating conditions as the result of conventional resources being displaced by variable energy resources.[5] Although these efforts are ongoing, the initial steps the CAISO has taken have positioned it to evolve and enhance this analysis in the future.

Besides identifying risks through special studies in the transmission planning process, the CAISO also conducts special studies outside of that process to identify proactively risks from anticipated changes on the system.[6] The CAISO has conducted numerous renewables integration and other studies to identify potential operational risks associated with the expected, extensive change in resource mix on the system, in particular increasing numbers of variable energy resources displacing conventional resources. These studies identified several emerging conditions requiring specific resource operational capabilities to address —steep ramps, oversupply risk, and decreased frequency response.

The CAISO also identifies resilience risks (and the extent of such risks) following actual unexpected events. Two examples are the unexpected closure of the San Onofre Nuclear Generating Station (SONGS) following an outage and the limited operation of the Aliso Canyon Natural Gas Storage Facility following a leak that

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[5] The CAISO has also conducted other frequency response assessments. These include (1) deterministic evaluations of the system based on low-frequency events within the CAISO to make sure it can meet if portion of the Interconnection Frequency Response Obligation, (2) studies with renewable resource penetrations at 50 percent, and (3) studies to assess the impact of high levels of distributed energy resources from a frequency response standpoint. These studies support the CAISO's efforts to ensure it can meet its share of the IFRO under future expected conditions.

[6] The Reports and Bulletins page of the CAISO website provides access to many of the studies referenced in this document, including renewables integration studies and seasonal assessments. http://www.caiso.com/planning/Pages/ReportsBulletins/Default.aspx

occurred at that facility in 2016. The SONGS and Aliso Canyon situations are examples of incidents that initially presented short-term risks that eventually became longer-term risks. CAISO provides detail on actions taken in response to the closure to the SONGS facility and to the limited operations of Aliso Canyon in its response to Question II (r).

Losing SONGS constituted an extreme event that the CAISO had considered in the past, albeit under the expectations that any outage would be temporary and the unit would return to service. The unexpected retirement of SONGS resulted not only in short-term risks, but also in mid- and long-term risks. The CAISO's efforts to identify the specific risks from the event (and mitigation measures) corresponded with the periods of the various risks.[7] The CAISO followed established operating and planning processes and procedures, and coordinated with its Participating Transmission Owners, California Energy Commission, California Public Utilities Commission, California Governor's office, and the state water and air resources boards to first assess the situation, identify the short-term risks and needs, and identify short-term solutions that could meet the immediate summer load requirement.[8] The CAISO worked and coordinated with the Governor's Task Force, which prepared the *"Preliminary Reliability Plan for LA Basin and San Diego."*[9] Then, through its transmission planning process and continued coordination efforts with the entities mentioned above, the CAISO assessed longer-term

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[7] The CAISO discusses its efforts to address the SONGS closure in detail in its response to Question II (r).

[8] Short-term measures included, *inter alia*, the CAISO working with generation owners and the local utility companies to convert recently retired generating units to synchronous condensers for voltage support in the impacted local capacity requirement areas or to defer retirement of several peaking units located within the impacted local area.

[9] The plan is available at: http://www.energy.ca.gov/2013_energypolicy/documents/2013-09-09_workshop/2013-08-30_prelim_plan.pdf

needs knowing that Southern California Edison Company would retire the nuclear unit from service.

The CAISO identified risks resulting from the limited operation of the Aliso Canyon storage facility following a leak at the facility in a similar manner.[10] To identify near-term risks (and mitigation measures), the CAISO collaborated with state agencies, the Los Angeles Department of Water and Power, and Southern California Gas Company in technical assessments to identify the respective risks to natural gas and electric reliability. As the problem persisted beyond the initial summer season, the CAISO continued its coordination and assessment efforts, which identified additional risks (and mitigation measures). The CAISO performed subsequent summer and winter seasonal assessments to evaluate the ongoing risks posed by Aliso Canyon's limited operation. The CAISO identified mitigation measures to reduce the impacts of the event, maintain reliability, and enhance its ability to address similar events in the future. Given the potential long-term ramifications of the limited operability of Aliso Canyon, the CAISO considered the situation in its transmission planning process special study of gas-electric coordination in southern California.

The CAISO also identifies resilience-related risks in the various seasonal assessments it conducts. Resilience risks identified in these studies are typically associated with the seasonal supply and demand outlook, hydro conditions, snowpack for run-of-river hydro during the early summer operating season, rain, reservoir capacity levels, and natural gas supplies. These studies focus on conditions and potential risks

[10] The CAISO discusses its efforts to address the Aliso Canyon situation in detail in its response to Question II (r).

for the upcoming season, and they rely primarily on expected conditions and historical data. These assessments thus focus more on identifying and preparing for near-term and seasonal risks, rather than planning for or identifying longer-term or emerging risks.

The CAISO performs a Summer Loads and Resources Assessment (Summer Assessments) for the CAISO balancing authority area annually that considers the upcoming supply and demand outlook using a stochastic production simulation modeling approach based on readily available data from the CAISO's energy management system and other databases. The CAISO works with state agencies, generation and transmission owners, load serving entities, and other balancing authorities through NERC, WECC, and the CAISO's established planning and operational processes to formulate the summer forecast and identify any issues regarding upcoming operating conditions. The assessment considers the supply and demand conditions across the entire CAISO balancing authority area as well as the geographically different northern and southern California areas. The CAISO has used complex production simulation tools and data to develop a robust probabilistic approach to assess the supply and demand outlook on an hourly basis. In particular, the CAISO assesses hydro conditions, and monitors snowpack, rain, and reservoir capacity levels. The CAISO also coordinates with WECC and natural gas providers to identity potential issues that might affect the grid and electric service. The Summer Assessment also considers the impact of specific events on the upcoming season (*e.g.,* the limited operability of the Aliso Canyon storage facility and SONGS outage).

The CAISO also performs operations assessments for the summer and winter operating seasons. These assessments consider, *inter alia*, the impact of outages and

new additions on the system.[11] For operations, in anticipating and preparing for the upcoming summer and winter operating seasons, it is crucial to consider gas and water supply needs and the impact of outages, new additions, and retirements on the system. Resilience risks associated with operations are considered short-term in nature because they depend on the existing or expected conditions of the grid.

The CAISO identifies immediate-term risks through monitoring, communication with third-parties, daily and intra-day assessments, and forecasting efforts.

Annually, the CAISO conducts flexible capacity assessments and local capacity requirement (LCR) studies to determine system flexible capacity needs and capacity needs in local capacity areas, respectively, for the upcoming year and informational studies looking out five years. Every other year the CAISO performs informational studies looking out ten years. The studies looking out one year help determine annual resource adequacy requirements for load serving entities that correspond to the CAISO's expected capacity and operational needs for the upcoming year. The CAISO also conducts studies and assessments to determine whether changing conditions on the system require changes to the method(s) in which resource adequacy requirements are determined. The CAISO is studying whether the existing methodologies for determining system needs in shoulder months and flexible capacity needs are producing gaps and are not in alignment with the CAISO's operational needs. The CAISO discusses this in detail in its response to Question III (d).

Man-made threats are typically unpredictable. The CAISO complies with cyber-

[11] The CAISO also hosts annual pre-summer coordination preparedness training events where operations representatives from entities across the western interconnection come together to consider and discuss summer operating issues that they may face during the upcoming summer operating season.

security standards, and maintains an infrastructure that automatically monitors CAISO facilities and systems identifies, visualizes, and resolves threats and vulnerabilities. The CAISO actively coordinates and communicates with state and federal agencies, transmission and generation owners, and other third parties to stay abreast of, and share information regarding, and identify potential threats.

The CAISO's information security program is designed to prevent, detect, and respond to cyber events and to maintain the confidentiality, integrity, and availability of CAISO grid and market systems. Besides incorporating prevention and protection mechanisms, the CAISO has implemented attack detection tools and procedures to allow us to react to and recover from cyber events.

In recent years, the largest cyber-attack vector is associated with social engineering. In response, the CAISO has implemented mitigating controls focused on limiting exposure to such risks: increased user awareness; email protections; end-point protections; user, application, and network behavior analysis; and anomaly detection. The CAISO has implemented a mature and comprehensive phishing awareness program, highlighted by regular phishing tests and education. Results from phishing campaigns are tracked and reported, allowing for required training. Besides implementing a comprehensive user awareness program surrounding phishing/social engineering, the CAISO has also implemented strong technical controls.

Question (b): How do you assess the impact and likelihood of resilience risks?

Response to Question (b):

In addition to considering the discussion below, the Commission should refer to the CAISO's response to Question I (a). Most of the same activities the CAISO

undertakes to identify resilience risks also assess to varying degrees the impact and likelihood of such risks. These efforts include: (1) transmission planning reliability assessments under the NERC Reliability Standards and CAISO Planning Standards; (2) special studies of particular conditions or emerging issues performed within and/or outside of the transmission planning process; (3) seasonal assessments; (4) post-event assessments; (5) monitoring, forecasting, security, operational and other assessments; (6) resource-adequacy-related studies; and (7) coordination with third-parties. The CAISO will not repeat its entire prior discussion here, but certain points warrant mention here.

The approaches the CAISO takes to assess the impact and likelihood of resilience risks vary depending upon the particular circumstances and requirements. The CAISO generally follows the two approaches described in its response to Question I (a).

Risks to resilience such as earthquakes, drought, and fires are known to occur in the CAISO Balancing Authority Area, but their specific occurrence and impact cannot be pinpointed with a high accuracy far in advance of the occurrence itself. However, the CAISO can assess the relative likelihood of a particular risk or extreme event and focus on mitigation in higher risk areas. In the CAISO's view, undertaking a holistic "bottoms up" assessments of the system to identify potentially problematic areas of the grid and then identify appropriate mitigation measures is important. It is less important to attempt to predict with unreasonable expectations of accuracy the occurrence and impact of a specific future event.

In general, the CAISO looks to the NERC Reliability Standards for guidance on

how to formulate study assumptions for an assessment. Providing a detailed discussion of the NERC Reliability standards is unnecessary, but the CAISO notes that NERC Reliability Standard TPL-001-4 requires the CAISO and other system planners to study the effects of Extreme Events (Category D) on the system; however, the standard does not require that mitigation solutions be implemented for the Extreme Events. Information from these studies, however, provides valuable information regarding the impact to the grid if an extreme event were to occur that results in losing facilities.

Besides considering this information, the CAISO considers other factors in assessing potential risks. The CAISO conducts studies based on specific conditions, circumstances, and emerging challenges in its balancing authority area. Below, the CAISO provides two examples that it did not discuss in its response to Question I (a).

The first example is the CAISO's extreme event reliability study of the San Francisco Peninsula.[12] In the CAISO's 2012-2013 transmission planning process, the CAISO initiated an assessment of the reliability need of the San Francisco Peninsula, to address further the reliability concern in supply to the downtown San Francisco area due to an extreme event as defined by the reliability standards. The reliability standards require the CAISO to assess the impacts of extreme events; however, they do not mandate that the consequences be mitigated. Rather, the need for mitigations is left to the responsible planning entity based on its specific circumstances. The reliability assessment focused on whether the specific risks and circumstances regarding the San Francisco Peninsula warrant mitigation measures beyond the minimum measures

[12] The CAISO notes that the specific San Francisco Peninsula extreme event studies are non-public. As such, the CAISO only provides information available from its approved transmission plans.

prescribed by mandatory reliability standards.

The CAISO's analysis concluded that due to the nature of the risks, the existing supplies to the peninsula, and the characteristics of the transmission system within the peninsula, an additional supply source would not materially reduce load loss or reduce restoration times if a major earthquake event occurs. Rather, the CAISO, working with the local utility as the local load serving entity and transmission owner of the local transmission facilities identified several measures (hardening and reinforcements) to harden and improve the survivability of the facilities and enhance resilience in the region. [13]

The second example involves an assessment of drought conditions in a local area of the grid. In the 2016-2017 transmission planning process, the CAISO included a scenario with 330 MW of Big Creek Area generation to represent low hydro drought conditions in the area. The results on the CAISO's study showed a P1 (N-1) contingency would cause low shed of 170 MW with low hydro conditions. The CAISO approved the Big Creek Corridor Rating Project to address the P1 load shed during low hydro conditions.

[13] As discussed in its response to Question II (i), the CAISO adopted a specific standard in the CAISO Planning Standards that requires the CAISO to undertake a more extensive examination of reliability risks in the San Francisco Peninsula. The Standard permits the CAISO to identify and approve reliability solutions to mitigate the risk of extreme events in this area of the grid beyond what the NERC Standards require. *See* Section 7.1 of CAISO Planning Standards. Section 7 of the CAISO Planning Standards permits the CAISO to consider other areas of the system under such standard on a case-by-case basis.

Question (c): Please explain how you identify and plan for risks associated with high-impact, low-frequency events (e.g., physical and cyber-attacks, accidents, extended fuel supply disruptions, or extreme weather events). Please discuss the challenges you face in trying to assess the impact and likelihood of high-impact, low-frequency risks. In addition, please describe what additional information, if any, would be helpful in assessing the impact and likelihood of such risks.

Response to Question (c):

A. CAISO Efforts to Identify and Plan for High-Impact, Low-Frequency Events

Besides the discussion below, the Commission should also refer to the CAISO's responses to Questions II (a) and II (b). The CAISO employs many of the same study and assessment activities described above to identify and plan for risks associated with high-impact, low frequency events. The CAISO seeks not to repeat its previous discussion here.

The CAISO identifies and plans for risks associated with physical and cyber-attacks, fuel supply disruptions, extreme weather events, and other reliability threats through established processes, procedures, and protocols that are an integral part of the CAISO's overall business practices. Both in and outside of the transmission planning process, the CAISO undertakes several activities to identify and plan for high-impact, low frequency events.

A key component of this effort is the Extreme Event analysis the CAISO conducts under NERC Reliability Standard TPL-001-4. As part of its annual reliability assessment studies and in accordance with Requirements R3.5 and R4.5 of NERC Standard TPL-001-4, the CAISO performs a deterministic assessment of high-impact,

low-frequency events listed in the Extreme Events portion of Table 1 of the standard.[14] As discussed in the CAISO's response to Question II (b), the CAISO relied on this type of analysis, and other considerations, to plan for high-impact, low probability events in the San Francisco Peninsula. Section 7 of the CAISO Planning Standards permits the CAISO to consider similar actions in other portions of the system on a case-by-case basis.

As described in its responses to Questions II (a) and (b), the CAISO also conducts special studies to identify and plan for future risks associated with specific conditions and emerging issues/conditions. These studies enable the CAISO to "get out ahead of" potentially significant issues and challenges. In addition, as described in its response to Question I (a), the CAISO regularly communicates and coordinates with knowledgeable third parties regarding potential significant threats.

Post-event assessments, such as those undertaken in connection with the SONGS and Aliso Canyon events, also help the CAISO plan for potential unexpected high-impact, low frequency events. In addition, under NERC Reliability Standard EOP-005-2, the CAISO has an approved restoration plan and Black Start program if one or more areas of the Bulk Electric System experience a widespread outage.

The CAISO also plans for and manages risks through its Incident Command and response program. The Incident Command team brainstorms risks and potential events, develops scenarios, and conducts exercises and drills to plan for risks and assess potential impacts. Scenarios vary. The CAISO also plans and prepares for

[14] The CAISO describes the specific TPL-001-4 Extreme Event criteria in its response to Question II (g).

risks associated with high-impact, low frequency events under Operating Procedure 4110, System Operations Emergency Preparation, Notifications and Reporting,[15] and its Business Continuity Policy.

Under Operating Procedure 4110, the CAISO assesses and prepares for potential adverse operating conditions including, but not limited to, wildfires, earthquakes, flooding, tsunamis, and geomagnetic disturbances that might threaten elements of the BES. The CAISO reports Significant Events that occur within its BAA that may be of interest and/or require action by state agencies. Operating Procedure 4110 defines Significant Events as any condition that threatens or causes harm to life, property, or resources within the CAISO BAA or causes interest and/or remedial action by the CAISO, state agencies, public safety agencies, or other select organizations. Participating Transmission Owners, Utility Distribution Companies, Scheduling Coordinators on behalf of Participating Generators and Metered Subsystems report Significant Events that threaten grid reliability or might result in peril to life, property, or grid resources within the CAISO balancing authority area.

Another element of the CAISO's risk mitigation effort is identifying all reasonably foreseeable risks, assessing the potential impact of those risks, and developing effective mitigation strategies and plans. The activities to identify, quantify, and mitigate risk are collectively known as the Business Continuity Management System; these protocols involve, *inter alia,* planning, emergency response, incident management, and recovery. They inform how the CAISO can mitigate, prepare for, respond to, and recover from disruptive incidents. They also specify the basic measures CAISO

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[15] Operating Procedure 4110: http://www.caiso.com/Documents/4110.pdf.

personnel and core business units must implement, including rigorous and comprehensive strategies that systematically address risk mitigation, incident management, crisis communications, departmental recovery, and information technology recovery. These strategies consider people, facilities, equipment, information assets, and supplier and vendor dependencies.

Regarding cyber-attacks, the CAISO has an information security program that is designed to prevent, detect, and respond to cyber events to maintain the confidentiality, integrity, and availability of the CAISO grid and market systems.[16] The CAISO actively and regularly evaluates cyber security risks at the corporate level. The CAISO also utilizes a well-organized incident management process and engages with multiple local, state, and federal organizations (*e.g.*, NERC, WECC, Department of Justice, Department of Homeland Security, Department of Energy, Federal Bureau of Investigation, California Governor's Office of Emergency Services, Industrial Control System Cyber Energy Response Team, and Electricity (Sector) Information Sharing and Analysis Center).

The CAISO also is an active participant in biennial GridEx exercises, which provide an opportunity for utilities to demonstrate how they would respond to and recover from simulated coordinated cyber and physical threats and incidents, strengthen their crisis communications relationships, and provide input for lessons learned. The first exercise took place in 2011, and the most recent one was in 2017. To prepare for and mitigate against threatening events, the CAISO also communicates and coordinates with other transmission and generation companies and other ISOs to

[16] The CAISO also discusses its cyber-security efforts in its response to Question I (a).

share and exchange information regarding security threats information, best practices, and tools.

The CAISO collaborates with Participating Transmission Owners in performing risk assessment studies (deterministic) under NERC CIP-014 Physical Security Standard to identify critical substations and their associated primary control centers that, if damaged because of a physical attack, could cause instability, uncontrolled separation, or cascading. Participating Transmission Owners then respond appropriately to secure physically these substations under the standard.

The recent solar eclipse is an example of how the CAISO prepared for a specific low frequency, but potentially high-impact, event. The CAISO discusses its preparations and planning for the solar eclipse in the next section of its response to this question.

B. The CAISO's Efforts Regarding the Recent Solar Eclipse

Solar resources account for approximately 14 percent of the CAISO's resource mix. Leading up to the solar eclipse, the CAISO undertook numerous reliability-related tasks. It conducted market simulation using different inputs to analyze regulation requirements and to capture intra-hour solar ramp. Regarding Regulation procurement, the CAISO analyzed the increased Regulation need going into the eclipse, and downward need coming out of the eclipse. The CAISO positioned large hydro units for rapid response to account for potentially losing solar resources and their ultimate return. The CAISO instructed variable energy resources to follow their Dispatch Optimization Target for the duration of the eclipse. For EIM participants, there was a consistent policy for external transfers during the eclipse and an accounting for the eclipse in

variable energy resource adjustments made to the solar output forecasts to account for the shading of photo-voltaic (PV) resources during the event. The CAISO conducted training for Operations personnel using both tabletop and simulation exercises. There also was a guide for on-shift crew, and ongoing coordination with the Southern California Gas Company.

In addition, the CAISO's forecast service providers produced forecasts accounting for the solar eclipse that automatically fed through the CAISO's daily processes. The aggregate forecast for large scale solar was available through OASIS on the CAISO's website. Market mechanisms and processes used in connection with the solar eclipse included: reserves procurement; flexi-ramp product usage; special operating procedures; using EIM transfer capability; internal market simulation; determining gas supply needs; internal market simulation; interaction with scheduling coordinators; coordination with WECC, market participants, and the CAISO's reliability coordinator Peak RC; issuing flex alerts for voluntary conservation; pre-curtailment of renewables and ramp rate limitations on the return of renewable resources to provide for more gradual ramping; manual operator intervention as needed; and the Day +2 conference bridge to discuss CAISO plans and expectations with transmission operators and market participants prior to event.

The CAISO also planned for potential additional challenges in real-time that did not arise in the day-ahead market simulation. This effort included assessing hourly compared to five-minute averages, voltage stability, the need for additional Regulation due to five-minute granularity, the effect of the California Public Utilities Commission's "Give the Sun a Break Day" campaign, the effects of the marine layer on load forecasts,

and the load forecast trends of EIM entities with behind-the-meter solar.

Responding to the last component of Question (c), the CAISO is not aware of additional information requirements at this time.

Question (d): Should each RTO/ISO be required to identify resilience needs by assessing its portfolio of resources against contingencies that could result in the loss or unavailability of key infrastructure and systems? For example, should RTOs/ISOs identify as a resilience threat the potential for multiple outages that are correlated with each other, such as if a group of generators share a common mode of failure (e.g., , a correlated generator outage event, such as a wide-scale disruption to fuel supply that could result in outages of a greater number of generating facilities)? The RTOs/ISOs should also discuss resilience threats other than through a correlated outage approach. Do RTOs/ISOs currently consider these types of possibilities, and if so, how is this information used?

Response to Question (d):

The CAISO does not presently see the need for an additional "requirement." As discussed above, existing reliability standards already call for consideration of extreme events, and although guidance on potential risks that may not have been elevated to the same level of consideration across all ISOs and RTOs may be helpful, that guidance can be accommodated within existing reliability frameworks.

The CAISO agrees that assessing reasonable common mode impacts on its key infrastructure and systems is appropriate and, in fact, is a common component of prudent utility practice in reliability planning. As such, creating a new risk-based analysis requirement would likely be overly prescriptive, difficult to clearly define, and likely duplicate existing reliability standards given the wide range of varying specific risks different ISOs and RTOs face.

The CAISO, in its response to Question I --How to Define Resilience -- explains that planning, procurement, coordination, reliability, and other efforts in the CAISO balancing authority area have produced a robust and diverse infrastructure and "set of

tools" that have helped the CAISO to remain reliable and resilient in the face of significant threats such as the restricted operations at the Aliso Canyon Natural Gas Storage Facility (Aliso Canyon), the unexpected closure of the San Onofre Nuclear Generating Station (SONGS), severe droughts and fires, and the solar eclipse. The CAISO proactively considers and addresses a broad range of reliability and resilience-related challenges it faces and through many tools at its disposal. Prudent planning contemplates that all credible threats be considered to assess the impact on and reliability of the grid, including correlated generator constraints resulting from common mode impacts such as limitations on gas supply facilities into an area. The CAISO notes that it attentively considered the particular example posed regarding common mode failures of gas supply through broader gas-electric coordination studies and studies focused on Aliso Canyon in particular. The CAISO describes such efforts response to Questions II (a), (e), and (r).

The CAISO also considers resilience threats that are not correlated through a common point of failure in CAISO planning processes, either in assessing extreme events occurring or as separate and special considerations. An example of the former includes considering the risk of fires and related smoke contamination on insulators affecting equipment on common transmission corridors or corridors in some proximity. Separate and special considerations are generally driven by the CAISO's recognition of an emerging issue, such as the risk posed by widespread use of specific equipment that may be subject to unanticipated failure or mode of operation. The analysis performed by the CAISO to assess the risk of unintended loss of inverter-based solar generation due to faults on the high voltage transmission system is one example of this latter

situation.[17]

Identifying these resiliency risks, either common mode failures or otherwise, typically takes place through exploratory analysis and industry and stakeholder input in the CAISO's transmission planning processes, or through the CAISO's review of emerging issues identified through actual system operation and monitoring (*e.g.*, the inverter tripping issues for certain reasons that could not reasonably be ascertained through traditional modeling and system analysis practices).

Question (e): Identify any studies that have been conducted, are currently in progress, or are planned to be performed in the future to identify the ability of the bulk power system to withstand a high-impact, low-frequency event (e.g., physical and cyber-attacks, accidents, extended fuel supply disruptions, or extreme weather events). Please describe whether any such studies are conducted as part of a periodic review process or conducted on an as-needed basis.

Response to Question (e):

In its responses to questions II (a) and (b), the CAISO has provided information on what it believes are primary risks to resiliency in its region and how it identifies and studies resilience risks and their potential impacts on the interconnected network. In its response to question (c), the CAISO discussed how it identifies and plans for risks associated with high-impact, low frequency events. The CAISO plans for and manages risks associated with physical and cyber-attacks, fuel supply disruptions, and extreme weather events through established processes, procedures, and protocols that are an integral part of the CAISO's overall business practices. These practices include standalone planning and operating studies focusing on particular issues or needs, reliability studies conducted as part of the CAISO's transmission planning process, and

[17] *See* the CAISO's response to Question II (r).

additional special studies undertaken in the annual transmission planning process to assess issues that may need to be incorporated into routine reliability analysis going forward. The CAISO conducts studies and assessments regarding potential high-impact, low frequency events both on a regular basis (*e.g.,* cyber-security, transmission planning for applicable reliability criteria, including extreme event studies and assessments under the CAISO Planning Standards, resource adequacy, seasonal assessments) and on an as-needed basis due to specific events or emerging issues (*e.g.*, SONGS, Aliso Canyon, drought, renewables integration). The CAISO regularly communicates and coordinates with various state agencies and other knowledgeable parties regarding potential high-impact, low frequency events.

The CAISO transmission plan documents reliability studies performed by the CAISO during the annual transmission planning process that assess resilience risk. In the transmission planning process the CAISO evaluates system performance under NERC reliability standards and CAISO Planning Standards to identify the need for any necessary mitigation measures to address reliability issues. These are typically focused on particular areas of concern. An example referred to earlier is the San Francisco Extreme Event reliability assessment, which the CAISO discusses in detail in its response to Question II (b). The CAISO planning Standards permit the CAISO to undertake similar examinations of other parts of the system on a case-by-case basis.

In addition, during the transmission planning process (and elsewhere), the CAISO considers emerging issues and trends such as the changing makeup of the generation fleet and conducts special studies based on the specified circumstances and conditions in its balancing authority area. Examples of prior special studies addressing

emerging issues include:[18]

Aliso Canyon

The CAISO has provided more detail regarding its assessment of the Aliso Canyon situation in response to Questions II (a) and (r). In the last two transmission planning cycles, the CAISO has also evaluated gas-electric coordination issues in southern California accounting for the Aliso Canyon situation.

Risks of Early Retirement of Gas Fleet

The significant amount of new renewable generation capacity being added to the CAISO grid is putting economic pressure on the existing gas-fired generation fleet, especially for those generators unable to obtain resource adequacy contracts. Further, the bulk of the grid-connected renewable generation developed to date has been "deliverable", *e.g.*, capable of providing capacity towards the state's resource adequacy program, making the availability of resource adequacy compensation for the existing gas-fired generation fleet even more uncertain. Compensation for providing flexibility services can also be uncertain, with the gas-fired generation fleet facing competition from other sources.

As generation owners independently assessed market conditions and their own particular circumstances, the CAISO, too, has performed a preliminary analysis of potential risks to system reliability if generators that are economically similar retire more or less simultaneously. This analysis has focused on two aspects of reliability:

[18] The CAISO's response to Question I (a) includes a link to the CAISO's transmission planning web page. From there, reviewers can access recent transmission plans and review the special studies the CAISO has undertaken.

- Are there localized areas of the transmission system where the retirement of a number of similarly situated generators would create reliability issues or other negative impacts on the operation of the transmission system? and,

- Are system-wide reliability requirements, *e.g.*, load following, operating reserves and regulating reserve levels, unduly compromised?

To study the second aspect regarding system-wide reliability, the CAISO relied upon Energy Exemplar's PLEXOS production simulation package and approach, which is consistent with the methodologies the CAISO previously has employed. The CAISO first undertook the study in the 2016-2017 transmission planning process. That process identified the need for additional sensitivity studies, which the CAISO conducted in the 2017-2018 transmission planning process and documented in the CAISO's transmission plan.

The studies showed potential shortfalls in load-following and reserves, with capacity insufficiencies occurring in the early evening after sunset, based on 1,000-2,000 MW of retirements in the latest sensitivity analyses. This is a concern to the CAISO. To address this risk, the CAISO is (1) supporting multi-year resource adequacy (RA) requirements for local capacity resources, (2) pursuing changes to the risk-of-retirement provisions of it Capacity Procurement Mechanism, (3) proposing more stringent resource adequacy requirements in shoulder months, (4) assessing revisions to the flexible resource adequacy capacity framework to better align it with expected conditions, (5) utilizing its backstop procurement mechanisms to procure resources needed for reliability that have not received an RA contract, and (6) conducting further studies to identify resources needed for reliability.

Gas-Electric Reliability Coordination

In the past several planning cycles, the CAISO has conducted gas-electric

coordination transmission planning studies for southern and northern California. The purpose of these studies has been, among other things, to gather information about the gas system and supply network to gas-fired power plants, investigate conditions that could result in gas curtailment to power plants potentially reducing electric generation, and perform studies to identify any adverse impacts on electric system reliability in both the short-term and the long-term.[19] In the two most recent planning processes, the CAISO assessed the reliability of the southern California system under various gas curtailment scenarios with the Aliso Canyon gas storage outage.

Frequency Response Evaluations

The CAISO has conducted frequency response studies in recent planning cycles to identify issues regarding frequency response performance in light of the changing resource mix in the CAISO balancing authority area as the result of conventional resources being displaced by variable energy resources. The materially different operating characteristics of variable energy resources necessitates a broad range of issues in managing system dispatch and maintaining reliable service across a broad range of operating conditions. The concerns raised by these studies highlight the need for flexible ramping generation and adequate frequency response to maintain the capability to respond to unplanned contingencies as the percentage of variable energy resource generation online increases. These study efforts are still ongoing, and the initial studies the CAISO has conducted have laid the groundwork for enhanced analysis in the future.

[19] The WECC is currently undertaking a Gas-Electric Interface Study for the Western Interconnection. This is a cross-sector study that is assessing the adequacy security, and risks associated with natural gas infrastructure and its ability to meet the needs of the Bulk Electricity System.

In the annual transmission planning process, the CAISO also conducts special reliability studies. These studies have included reliability requirements for resource adequacy capacity, local capacity requirements, and various local capacity requirements sensitivity studies, locational effectiveness factors for local capacity resources, resource adequacy import capability, and reviews existing System Protection Schemes. In recent years, the CAISO has also performed numerous studies to assess the impact of the changing resource mix on the system. These include renewables integration studies, studies regarding the use of renewable resources to operate the grid reliably, and the benefits of bulk storage.

Finally, the CAISO continually evaluates cyber security and performs yearly exercises, including cyber security penetration tests and information security maturity evaluations.

Question (f): In these studies, what specific events and contingencies are selected, modeled, and assessed? How are these events and contingencies selected?

Response to Question (f):

The CAISO selects events and contingencies for its studies and assessments primarily for the following reasons: (1) compliance with NERC and WECC reliability standards; (2) compliance with CAISO Planning Standards that go beyond NERC's transmission planning; (3) events and contingencies known to occur in the CAISO balancing authority area (*e.g.*, earthquakes, drought, and fires); (4) emerging, and/or anticipated issues and conditions that the CAISO expects to face in future years (*e.g.*, the increasing number of variable energy resources on the system, renewables integration needs, risk-of-retirement of resources needed for reliability, and frequency response challenges); (5) unexpected events (*e.g.*, Aliso Canyon, SONGS closure);

(6)trends or changing conditions (*e.g.*, potential changes to local and flexible capacity requirements); (7) seasonal assessments that consider conditions affecting the upcoming season; and (8) special circumstances (*e.g.*, the San Francisco Peninsula study).

The CAISO selects the events and contingencies it studies primarily based on compliance requirements, urgency, magnitude of the impact, the need to determine how a specific event or circumstance might affect the CAISO, and the existence of any special circumstances.

Question (g): What criteria (e.g., load loss (MW)), duration of load loss, vulnerability of generator outages, duration of generator outages, etc.) are used in these studies to determine if the bulk power system will reasonably be able to withstand a high-impact, low-frequency event? Are the studies based on probabilistic analyses or deterministic analyses?

Response to Question (g):

The CAISO predominately performs studies using deterministic analysis approach in that it assumes an event such as an earthquake or fire will occur, resulting in contingencies on the grid that impact system performance. The CAISO performs a deterministic assessment of high-impact, low-frequency events in the Extreme Events portion of Table 1 of the standard. The CAISO studies them through deterministic analysis to determine mitigation options in accordance with Requirements R3.5 and R4.5 of NERC Standard TPL-001-4 and the CAISO Planning Standards. The extreme events considered in TPL-001-4 for steady state assessment include:

1. Loss of a single generator, Transmission Circuit, single pole of a DC Line, shunt device, or transformer forced out of service followed by another single generator, Transmission Circuit, single pole of a different DC Line, shunt device, or transformer forced out of service prior to System adjustments.

2. Local area events affecting the Transmission System such as:

a. Loss of a tower line with three or more circuits.

b. Loss of all Transmission lines on a common Right-of-Way.

c. Loss of a switching station or substation (loss of one voltage level plus transformers).

d. Loss of all generating units at a generating station.

e. Loss of a large Load or major Load center.

3. Wide area events affecting the Transmission System based on System topology such as:

   a. Loss of two generating stations resulting from conditions such as:

      i. Loss of a large gas pipeline into a region or multiple regions that have significant gas-fired generation.

      ii. Loss of the use of a large body of water as the cooling source for generation.

      iii. Wildfires.

      iv. Severe weather, *e.g.*, hurricanes, tornadoes, etc.

      v. A successful cyber attack.

      vi. Shutdown of a nuclear power plant(s) and related facilities for a day or more for common causes such as problems with similarly designed plants.

   b. Other events based upon operating experience that may wide area disturbances.

Requirements R3.5 and R4.5 of NERC Standard TPL-001-4 provide:

R3.5.

Those extreme events in Table 1 that are expected to produce more severe System impacts shall be identified and a list created of those events to be evaluated in Requirement R3, Part 3.2. The rationale for those Contingencies selected for evaluation shall be available as supporting information. If the analysis concludes there is Cascading caused by the occurrence of extreme events, an evaluation of possible actions designed to reduce the likelihood or mitigate the consequences and adverse impacts of the event(s) shall be conducted.

R4.5.

Those extreme events in Table 1 that are expected to produce more severe System impacts shall be identified and a list created of those events to be evaluated in Requirement R4, Part 4.2. The rationale for those Contingencies selected for evaluation shall be available as supporting information. If the analysis concludes there is Cascading caused by the occurrence of extreme events, an evaluation of possible actions designed to reduce the likelihood or mitigate the consequences of the event(s) shall be conducted.

In evaluating the need to mitigate the impacts of extreme events, the CAISO considers the possible risk of cascading outages or system instability that could impact the system more broadly than the local areas where the event occurred, even if loss of load within the local area would occur. The CAISO Planning Standards identify the following characteristics that warrant a higher level of mitigation for extreme events in the San Francisco Peninsula:

- Meeting the CAISO's criteria for being a high density urban load area;
- The specifics of the geographic and system configuration;
- The potential risks of outages including seismic, third party action and collocated facilities; and
- Consideration of restoration times.

To date, the San Francisco Peninsula is the only area the CAISO has identified as requiring a more conservative mitigation standard based on these considerations.

In its role as a Planning Coordinator, the CAISO also collaborates with Participating Transmission Owners in performing risk assessment studies (deterministic) under NERC CIP-014 Physical Security Standard to identify critical substations and their associated primary control centers that, if damaged because of a physical attack, could cause instability, uncontrolled separation, or cascading. Participating Transmission Owners then respond appropriately to secure these substations physically under the standard. The CAISO uses a 1000 MW load loss

criteria for the CIP-014 analysis. The load loss does not include consequential load loss or load dropped by a remedial action scheme. The disruptive event simulated in Reliability Standard CIP-014 risk assessment studies is the entire loss of each substation and all associated transformation, protection, control and communication equipment, and all transmission lines and generators that are connected to the substation.

The CAISO also performs deterministic studies of generation and transmission facilities to identify those facilities that should have a Medium Impact Rating under NERC CIP-002 Cyber Security Standard. The CAISO uses the same load loss criteria for these studies as CIP-014 studies.

In the planning context, the CAISO does not perform probabilistic analysis except as described in the CAISO's planning standards for "Planning for High Density Urban Load Area Standard", "Extreme Event Reliability Standard" and "Background behind Planning for New Transmission versus Involuntary Load Interruption Standard". The CAISO discusses these standards in detail in its responses to Questions II (i) and (l). In its Summer Assessments, the CAISO has conducted both deterministic and probabilistic analyses.

Question (h): Do any studies that you have conducted indicate whether the bulk power system is able to reasonably withstand a high-impact, low frequency event? If so, please describe any actions you have taken or are planning as mitigation, and whether additional actions are needed.

Response to Question (h):

The term "reasonably withstand" is not defined, and therefore it is difficult to respond to this question with precision because what constitutes "reasonably

withstanding a high impact, low frequency event" is open to interpretation. Nevertheless, the CAISO has conducted studies of specific conditions that have occurred or are emerging on the CAISO bulk electric system and has adopted certain mitigation measures. Responses to Questions II (a)-(g) provide detail on these measures. The CAISO complies with the requirements set forth in the NERC Reliability Standards and the CAISO Planning Standards, which provide clear guidance regarding system performance requirements and when mitigation solutions are needed.

As discussed in detail in response to Question II (b), an example of such studies and mitigation actions taken was the CAISO's San Francisco Peninsula extreme event study. The CAISO concluded that due unique characteristics and nature of the risks in the San Francisco Peninsula area the existing supplies to the peninsula, and the characteristics of the transmission system within the peninsula, additional supply would not materially mitigate service interruption or improve restoration following a major seismic event. The CAISO identified several system hardening and reinforcement measures on the peninsula that the participating transmission owner could take.

Other examples include the mitigation measures the CAISO ordered based on its assessments of drought conditions in the Big Creek area and the SONGS outage. These assessments are discussed in response to Questions II (b) and (r), respectively. Another example is the study the CAISO conducted under NERC Reliability Standard CIP-014 that resulted in physical facility enhancements. The CAISO discussed this effort in its response to Question II (g).

Not all risks needing mitigation require transmission infrastructure upgrades and improvements. The CAISO has mitigated other identified risks through study and

assessment with “tools” such as tariff amendments, new market products, backstop procurement, conservation efforts, gas-electric coordination, or changes in the resource adequacy program. As discussed in the CAISO’s response to Question II (r), the Aliso Canyon assessments identified mitigation measures such as tariff changes, enhanced gas-electric coordination efforts, and conservation efforts. The SONGS assessments discussed in response to Question II (r) identified mitigation measures such as CAISO backstop procurement and conservation efforts besides infrastructure improvements. Renewables integration studies described in response to Question I (a) identified the need for a flexible ramping product and modifications to the resource adequacy program to implement a flexible capacity requirement. A black start and recovery plan assessment discussed in response to Question III (c) identified the need for a black start tariff amendment and additional procurement in the PG&E service area. Frequency response studies discussed in response to Question I (a) supported a frequency response tariff amendment.[20].

Question (i): How do you determine whether the threats from severe disturbances, such as those from low probability, high impact events require mitigation? Please describe any approaches or criteria you currently use or otherwise believe are useful in determining whether certain threats require mitigation.

Response to Question (i):

In the first instance, the CAISO determines whether threats from severe disturbances require mitigation through transmission and operational planning studies. Under the transmission planning provisions of its Commission-approved tariff, the

[20] *Id.*

CAISO may approve transmission solutions (or non-transmission alternatives) required to ensure System Reliability consistent with all Applicable Reliability Criteria and CAISO Planning Standards.[21]

The CAISO Planning Standards allow the CAISO to plan to a higher standard than NERC Reliability Standard TPL-001-4 for high population density urban load areas. Section 6 of the CAISO Planning Standards, entitled *Planning for High Density Urban Load Area Standard,* includes Section 6.1 --Local Area Planning, which states:

> A local area is characterized by relatively small geographical size, with limited transmission import capability and most often with scarce resources that usually can be procured at somewhat higher prices than system resources. The local areas are planned to meet the minimum performance established in mandatory standards or other historically established requirements, but tend to have little additional flexibility beyond the planned-for requirements taking into account both local generation and transmission capacity. Increased reliance on load shedding to meet these needs would run counter to historical and current practices, resulting in general deterioration of service levels.
>
> For local area long-term planning, the ISO does not allow non-consequential load dropping in high density urban load areas in lieu of expanding transmission or local resource adequacy capability to mitigate NERC TPL-001-4 standard P1-P7 contingencies and impacts on the 115 kV or higher voltage systems.
>
> - In the near-term planning, where allowed by NERC standards, load dropping, including high-density urban load, may be used to bridge the gap between real-time operations and the time when system reinforcements are built.
>
> - In considering if load shedding, where allowed by NERC standards, is a viable mitigation in either the near-term, or the long-term for local areas that would not call upon high density urban load, case-by-case assessments need be considered. Assessments should take in consideration, but not limited to, risk assessment of the outage(s) that would activate the SPS including common right of way, common structure, history of

[21] CAISO tariff section 24.4.6.2.

> fires, history of lightening, common substations, restoration time, coordination among parties required to operate pertinent part of the transmission system, number of resources in the area, number of customers impacted by the outage, outage history for resources in the area, retirement impacts, and outage data for the local area due to unrelated events.

For local area long-term planning, the CAISO does not allow non-consequential load dropping in high-density urban load areas in lieu of expanding transmission or local resource capability to mitigate NERC TPL-001-4 standard P1-P7 contingencies and impacts on the 115 kV or higher voltage systems. A High Density Urban Load Area is defined for the purposes of the standard as an Urbanized Area, as defined by the US Census Bureau, with a population over one million persons.

Section 7 of the CAISO Planning Standards, entitled *Extreme Event Reliability Standard*, states:

> The requirements of NERC TPL-001-4 require Extreme Event contingencies to be assessed; however, the standard does not require mitigation plans to be developed for these Extreme Events. The ISO has identified in Section 7.1 below that the San Francisco Peninsula are has unique characteristics requiring consideration of corrective action plans to mitigate the risk of extreme events. Other areas of the system may also be considered on a case-by-case basis as part of the transmission planning assessments.

Section 7.1 of the CAISO Planning Standards sets forth the *San Francisco Peninsula –Extreme Event Reliability Standard*:

> The [CA]ISO has determined through its Extreme Events assessments conducted as part of the annual transmission planning process, that there are unique characteristics of the San Francisco Peninsula that require consideration for mitigation as follows:
>
> - high density urban load area,
> - geographic and system configuration,
> - potential risks of outages including seismic, third party action and collocating facilities; and

- challenging restoration times.

The higher standards reflected in the CAISO Planning Standards have allowed the CAISO system to retain more local generation in key locations than would otherwise have been possible, thus supporting grid resilience. In addition, as discussed in the CAISO's response to Question II (b), the CAISO Planning Standards enabled the CAISO to approve extreme event mitigation measures in the San Francisco Peninsula.

The CAISO also performs studies to assess whether specific events that have occurred (*e.g.*, Aliso Canyon, SONGS), current or anticipated conditions (*e.g.*, drought), or emerging circumstances or issues (*e.g.*, changing resource mix), require mitigation.

Besides complying with tariff and applicable reliability criteria described above,[22] the CAISO considers other factors in determining whether a specific threat or issue requires mitigation. The need for mitigation depends in large part on the nature and scope of the specific threat. Factors the CAISO might consider include, but are not limited to, the following: (1) potential loss of load and the magnitude and duration of such loss; (2) potential damage to facilities; (3) the expected duration of the problem; (4) the scope of potential reliability or operational problems; (5) how effective any mitigation efforts might be; (6) the costs versus the benefits of mitigation; (7) the likelihood of the risk; (8) the potential for multiple threats that could aggravate conditions; and (9) any special circumstances. As stated in the CAISO's response to Question II (h), mitigation measures can take many forms and do not contemplate just infrastructure

[22] The CAISO also identifies threats associated with physical and cyber security of bulk electric system facilities and identifies mitigation according to the criteria and methodology defined in the NERC CIP Standards (*e.g.*, CIP-014 and CIP-002). *See* response to Question II(g) regarding the CAISO's role in complying with the two CIP standards.

improvements.

Question (j): How do you evaluate whether further steps are needed to ensure that the system is capable of withstanding or reducing the magnitude of these high-impact, low frequency events?

Response to Question (j):

Besides the discussion below, the Commission should refer to the CAISO's responses to Questions II (h) and (i).

In determining whether to undertake additional study work beyond what is required by applicable reliability criteria to assess threats to the bulk power system, the CAISO considers several factors such as economic, reliability, security, social, and environmental impacts of threats to the bulk power system. As an initial step, the CAISO applies the deterministic NERC reliability standards, WECC regional criteria, the CAISO Planning Standards, and local capacity criteria to evaluate whether further steps are needed to ensure that the system can withstand or reduce the magnitude of impacts of events at different points on the grid. The CAISO often finds in its reliability assessments that additional study is required, particularly if there is some uncertainty about the results, more information is required, or system dynamics are not settled. As noted in responses to prior questions, the CAISO Planning Standards include requirements applicable to uniquely situated areas, such as the San Francisco Peninsula, that provide for mitigating the impacts of more extreme, lower frequency events such as those that cause loss of an entire transmission substation, generating station, or three or more transmission lines in the same corridor. The CAISO Planning Standards allow the CAISO to consider applying these standards as appropriate, across the grid on a case-by-case basis.

As indicated above, the CAISO generally applies the aforementioned standards and criteria assuming normal operating conditions as a starting point. If the CAISO identifies circumstances that affect that starting assumption, such as a drought, potential closure of a nuclear power station, or natural gas shortage due to closure of a major gas storage facility, the CAISO applies the planning standards and criteria with the expected abnormal operating condition as a starting assumption to identify appropriate corrective actions. The CAISO considered drought conditions in approving mitigation measures in the Big Creek area.[23]

Many planning and operational studies the CAISO undertakes result in subsequent study efforts. The CAISO's special studies regarding gas-electric coordination, frequency response, and risk of retirement have spanned multiple planning cycles. Similarly, the CAISO has conducted numerous renewables integration studies since the enactment of renewable portfolio standards in California. Often initial studies identify emerging issues or potential risks that require further study to fully assess their impacts. The CAISO generally determines whether further steps are necessary considering the factors enumerated in its responses to Questions II (f) and (i). In addition, further steps may be required if the CAISO finds that it needs more information or information over a longer term, or more analysis, to fully study and understand a potential risk or challenge it has identified. In addition, changing conditions can necessitate multiple study efforts, including running sensitivity studies in addition to base case studies.

The CAISO's local capacity criteria ensure there is sufficient local capacity to

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[23] *See* the CAISO's response to Question II (b).

prevent voltage instability if an extreme contingency occurs involving overlapping loss of a single system element such as a transmission line or a generator followed by two transmission lines on the same structures. When CAISO studies show any of these standards or criteria are not met, the CAISO develops solutions to address the criteria requirements.

Through its established planning process, the CAISO confers with other entities with functional role regarding the overall reliability and resilience of the bulk power system, including transmission and generator owners, state authorities, neighboring balancing authorities, its reliability coordinator, and WECC.

Question (k): What attributes of the bulk power system contribute to resilience? How do you evaluate whether specific components of the bulk power system contribute to system resilience? What component-level characteristic, such as useful life or emergency ratings, support resilience at the system level?

Response to Question (k):

The CAISO responds to question (k) in the context of the portion of the bulk power system, it operates.

All attributes of the bulk power system contribute to system resilience, and the CAISO plans the system to maximize its utilization while meeting the applicable reliability standards. The bulk power system comprises facilities and control systems necessary for operating an interconnected electric energy transmission network and associated resources to maintain transmission system reliability. The attributes of the bulk power system include the condition and technical capabilities of facilities and control systems, and the software and personnel employed to operate them. In this response, the CAISO briefly discusses how the attributes of these elements of the grid contribute to system resilience and provides some examples of the processes the

CAISO employs to evaluate whether these attributes are effectively contributing to system resilience.

The performance of the bulk power system transmission assets and their associated attributes that contribute to bulk power system resilience are measured by how the corresponding equipment responds to both dynamic and steady state system changes. The location of static var compensators, synchronous condensers, and STATCOM's on the bulk power system, coupled with their capabilities and operating points, can lead to increased bulk power system dynamic voltage stability margins. Effective use of equipment emergency ratings and placing of static power apparatus can increase steady state thermal and overload limits of transmission facilities, maximizing system utilization.

Regarding transmission facilities, the bulk power system includes a network of substations, overhead and underground transmission lines, transformers, flow control elements, reactive devices and high voltage direct current facilities. The design of each of these physical elements directly affects the resilience of the system. Radial transmission lines with tapped connections have lower initial costs and reduced complexity, but eventually they result in higher outage rates and lower reliability. Networked systems have higher levels of complexity and cost, but they lead to fewer interruptions and quicker restoration of service. In addition, although overhead transmission construction is less costly and can be restored more quickly, underground transmission is less likely to be forced out of service.

Other considerations in system design include the location and redundancy of control center operations. The CAISO maintains two separate, fully functional system

control centers to ensure seamless electric system operations. This helps eliminate a common mode of failure that could significantly limit the reliability and resilience of the bulk power system.

Generation attributes that contribute to resiliency include the ability of generating sources to respond to system changes, whether planned or unplanned. Sources that can be automatically re-dispatched through Automatic Generation Control signals provide for tighter control of frequency and intertie flows. Generation source inertia, the ability to supply reactive power, power system stabilizer design and high speed generator exciter controls are some of attributes that can provide the bulk power system with higher levels of dynamic stability, while the specific ramp rates, equipment overload, and emergency affect shorter term steady state operating conditions. The attributes and benefits to resilience that can be achieved by the active management of transmission and generation assets also depend upon a robust, high speed and highly reliable SCADA system. The control system attributes that contribute to the bulk power system's resiliency include the speed of the system, the level of deployment within the bulk power system, degrees of automation, and system security and redundancy.

A. The CAISO Employs Different Processes To Evaluate How Different Attributes of the Bulk Power System Contribute to System Resilience

1. CAISO Maintenance Program

Electrical system operations depend on the availability and proper operation of equipment. Electrical assets require regular maintenance in order to continue to operate properly over their useful life. Without proper maintenance, transmission equipment will limit the ability of the bulk power system to operate as designed. Under the authority granted by the Commission and consistent with California Public Utilities

Code Section 348[24], the CAISO has adopted maintenance and inspection standards for electric transmission facilities under its operational control.

These standards are one example of a means by which the CAISO evaluates how various physical attributes of the bulk power system contribute to system resilience. The standards, incorporated into the CAISO's Transmission Control Agreement with its Participating Transmission Owners, ensure that Participating Transmission Owners maintain their transmission assets under CAISO operational control through six complementary elements:

(1) Participating Transmission Owner Filed Maintenance Practices
(2) Annual Maintenance Reviews
(3) Transmission Line Availability Measures
(4) Standardized Maintenance Reporting System
(5) Transmission Maintenance Coordination Committee
(6) Review for Cause

a. PTO Filed Maintenance Practices

Section 14.1 of the CAISO Tariff and Appendix C of the CAISO Transmission Control Agreement, establish the requirements for the Participating Transmission Owners' filed maintenance practices. Each Participating Transmission Owner must provide detailed maintenance practices for the three classes of equipment: Overhead Transmission Line Circuits; Underground Transmission Lines; and Electrical Substations. These practices must be performance-based and/or prescriptive and

24 California Public Utilities Code §348, reads in part: "The Independent System Operator shall adopt inspection, maintenance, repair, and replacement standards for the transmission facilities under its control. The standards, which shall be performance or prescriptive standards, or both, as appropriate, for each substantial type of transmission equipment or facility, shall provide for high quality, safe, and reliable service. In adopting its standards, the Independent System Operator shall consider: cost, local geography and weather, applicable codes, national electric industry practices, sound engineering judgment, and experience."

provide for high quality, safe, and reliable service. They must consider costs, local geography and weather, applicable reliability criteria, national electric industry practice, sound engineering judgement, and experience. The filed maintenance practices must also include a schedule for any time-based maintenance activities and a description of all condition based metrics used to initiate any performance-based activities. The filed maintenance practices must describe maintenance, repair, and replacement activities including the processes and procedures used to trigger and track these activities. Finally, , the filed maintenance practices describe the Participating Transmission Owner's repair/replacement capability for 500kV and 230kV transmission facilities such as structures, cable, conductor, circuit breakers, power transformers and major reactive components. Details of the specific equipment classes are included below.

For the specific transmission line circuits and substations under CAISO's operation control, each Participating Transmission Owner's filed maintenance practices must describe the maintenance activities for the various attributes below:

Overhead Transmission Lines:

(1) Patrols and inspections, scheduled and unscheduled
(2) Conductor and shield wire
(3) Disconnect/ pole top switches
(4) Structure Grounds
(5) Guys/anchors
(6) Insulators
(7) Rights of way
(8) Structures/foundations
(9) Vegetation Management

Underground Transmission Lines:

(1) Patrols and inspections, scheduled and unscheduled

(2) Cable/Cable Systems
(3) Cathodic Protection
(4) Fluid Pumping Facilities
(5) Terminations
(6) Arrestors
(7) Rights of way
(8) Splices
(9) Structures/vaults/manholes
(10) Vegetation Management

Electrical Substations:

(1) Inspections, scheduled and unscheduled
(2) Battery systems
(3) Circuit breakers
(4) Direct Current Transmission Components
(5) Disconnect Switches
(6) Perimeter fences and grounds
(7) Station grounds
(8) Insulator/bushings/arrestors
(9) Reactive power components
(10) Protective relay systems
(11) Station service equipment
(12) Structures/Foundations
(13) Transformers/Regulators
(14) Vegetation Management

In addition, Participating Transmission Owner filed maintenance practices include specific information identifying replacement equipment and activities within the respective Participating Transmission Owner's area. Detailed requirements for preparing, submitting, and amending Participating Transmission Owner maintenance

practices are set forth in the CAISO's Transmission Maintenance Procedure No. 7.[25]

After the CAISO receives maintenance practices from a Participating Transmission Owner, CAISO staff reviews and adopt the associated filed maintenance practices. Over time, Participating Transmission Owners may choose to revise their filed maintenance practices, or the CAISO may request the Participating Transmission Owners to revise them. Whether revisions are recommended by a Participating Transmission Owner or the CAISO, these modifications to filed maintenance practices can be based on omissions discovered during the CAISO's annual maintenance reviews, changes to applicable reliability criteria, adding new classes of equipment to a Participating Transmission Owner's transmission assets, statistical analysis, and/or migration from time based maintenance activities to a condition based methodology. The CAISO must adopt proposed changes to a Participating Transmission Owner's filed maintenance practices prior to implementation by the Participating Transmission Owner.

b. Annual Maintenance Reviews

The CAISO performs an annual review of each of Participating Transmission Owner's maintenance program. This review determines if the Participating Transmission Owners are following their filed maintenance practices adopted by the CAISO and to verify inspection and maintenance performance. CAISO maintenance review methodology and scope are documented in CAISO Transmission Maintenance Procedure 4, 'ISO Maintenance Review'.[26] Field reviews entail CAISO staff visiting each selected site and verifying the physical condition of the transmission facilities,

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25 *See* http://www.caiso.com/Documents/Procedure7-Preparing_Submitting_andAmendingMaintenancePractices.pdf

26 *See* http://www.caiso.com/Documents/Procedure4-ISOMaintenanceReview.pdf

including transmission lines, rights-of-way, stations, and associated equipment.

The CAISO randomly selects, by voltage classification, up to ten percent (10%) of a Participating Transmission Owner's Transmission Facilities to review. The voltage classification for each station is determined by its highest voltage. If the total number of Stations under CAISO operational control in a given voltage class is less than ten (10), the CAISO will select at least one (1) station per voltage class.

The review of the selected facilities comprises two distinct tasks: (1) a detailed records review; and (2) a field review. These reviews encompass the CAISO controlled equipment identified in the associated filed Participating Transmission Owner maintenance practices. The CAISO staff that conducts the maintenance reviews are subject matter experts in the design and maintenance of substation facilities, transmission line facilities, and system protection, and are qualified to carry out the maintenance reviews.

The records review takes place on the first day of the CAISO maintenance review. It includes an exhaustive review of all the maintenance records including field inspections, notifications, scheduled and emergency repair or maintenance activities and any other corrective actions taken to restore or maintain the functional capabilities of the failed or malfunctioning transmission equipment at the selected sites. CAISO staff analyzes the data to confirm that the Participating Transmission Owner is following its filed maintenance practices. Deviations from these filed maintenance practices are noted and included in the annual maintenance review report.

The substation review is comprehensive and includes a review of all equipment and related systems identified in the Participating Transmission Owner's filed

maintenance practices. Among other tasks, the CAISO opens and inspects equipment cabinets, checks compressors and hydraulic pumps, confirms nitrogen supplies and blankets, records outstanding alarms, notes oil and/or hydraulic leaks, examines battery fluid levels and plate conditions, and scrutinizes protective relaying and associated communication systems for targets, alarms, and valid calibration labels. Transmission line inspections include a comprehensive visual review of transmission line hardware, conductors, shield wires, insulators, vegetation management, and structures and foundations. The CAISO performs transmission line hardware and tower/structure reviews are performed via ground level and/or helicopter. At the conclusion of the field maintenance reviews, CAISO staff document their review in a maintenance review report, including any deviations from the maintenance practices, and make recommendations for corrections or modifications to the corresponding Participating Transmission Owner's existing filed maintenance practices to improve member maintenance programs. After issuing the final maintenance review report, the CAISO follows up with each Participating Transmission Owner to confirm that the outstanding maintenance tasks identified in the report have been or are being addressed.

c. Transmission Line Availability Measures

CAISO controlled grid reliability is a function of a complex set of variables including, the accessibility of alternative paths to serve load, generator unit availability, load forecasting and resource planning, speed, coordination, and sophistication of protection systems, and the availability of transmission line circuits owned by the Participating Transmission Owners. Availability measures are a principal determinant of the effectiveness of each Participating Transmission Owner's maintenance effort. The

availability performance monitoring system is one of the CAISO's core maintenance functions. By measuring transmission line availability year-over-year, the CAISO can monitor the effectiveness of Participating Transmission Owner's ongoing maintenance. Availability is a function of several variables, including transmission facility maintenance, initial design, extreme exposure, capital improvements, and improvements in restoration practices. The CAISO considers these factors when assessing availability measures and maintenance effectiveness.

Many techniques can monitor maintenance effectiveness; however, techniques that do not account for random variations in processes have severe limitations. To account for random/chance variations while monitoring for shifts and trends, control charts have been widely accepted and used. Control charts are statistically based graphs that illustrate both the expected range of performance based on historical data and discrete measures of recent performance. The relative positions of these discrete measures of recent and longer-term performance and their relationship to the expected range of performance are used to gauge Participating Transmission Owner maintenance effectiveness.

Early in each calendar year, CAISO staff works with each Participating Transmission Owner to classify its prior year's outage information logged by the CAISO in its outage management system. Once the CAISO validates this data, the CAISO uses it to create specific availability control charts by voltage class (*i.e.,* 500kV, 230kV, 115kV and 69kV classes). These charts provide historical year-over-year trends for transmission line availability, outage duration, and proportion of the system experiencing outages. The three types of control charts for each Participating

Transmission Owner and Voltage Class are: annual average forced outage frequency; annual average accumulated forced outage duration; and the annual proportion of transmission line circuits that have not experienced any forced outages. These three control charts assist the CAISO and Participating Transmission Owners in assessing the maintenance effectiveness of each Voltage Class over time.

The CAISO and Participating Transmission Owners review control charts annually based on four separate statistical tests to evaluate Availability Measures performance and determine if further action is necessary. The CAISO has selected these four tests to identify exceptional performance in an individual calendar year, shifts in longer-term performance, and trends in longer-term performance. Test 1 detects a short-term change in the average level while Tests 2 and 4 detect long-term changes. Test 1 detects an exceptional year in performance, positive or negative. Test 2 seeks to identify any shift up or down in averages; whereas, Test 4 detects a continuously increasing or decreasing trend in average values. Test 3 assesses changes in performance during a three-year period. If none of these tests indicates that a change has occurred, the CAISO will consider performance stable and consistent with past performance. If one or more of these tests indicates a change, the CAISO will consider availability performance as having either improved or degraded relative to the performance defined by the control chart. After the CAISO completes the analysis, each Participating Transmission Owner submits an annual report to the CAISO describing its availability measures performance. Further details of the Availability Measures can be found in Appendix C of the Transmission Control Agreement.

d. Standardized Maintenance Reporting System

The standardized maintenance reporting system requires Participating Transmission Owners to submit annually their planned and actual maintenance activities to the CAISO. The standardized maintenance reporting system allows the CAISO to monitor and analyze the annual maintenance activities of each Participating Transmission Owner. The activities reported in the standardized maintenance reporting system reports include all scheduled substation and transmission line maintenance tasks. The standardized maintenance reporting system reports include an accounting of the quantity of specific equipment classes under CAISO control and the number of forced maintenance activities per classification. Each Participating Transmission Owner submits the previous calendar year's actual maintenance activities and the current year's planned maintenance activities in March of each year.

The CAISO reviews and analyzes the standardized maintenance reporting system reports, and then the CAISO and Participating Transmission Owner discuss and resolve any concerns that the CAISO may have with unexpected changes in reported annual maintenance activities. The CAISO also maintains historical standardized maintenance reporting system data, which allows the CAISO to correlate any changes in the annual Participating Transmission Owner maintenance activities with changes with the Availability Measures discussed earlier. CAISO engineers can monitor and assess planned and forced outage trends.

e. Transmission Maintenance Coordination Committee

In October of 1997, the Commission directed the CAISO Board of Governors to create a Transmission Maintenance Coordination Committee to perform the duties set

forth in Appendix C of the Transmission Control Agreement. In compliance with the directive, the Board created an advisory committee entitled the Maintenance Coordination Committee, commonly referred to as the Transmission Maintenance Coordination Committee. Since its establishment, the Transmission Maintenance Coordination Committee has reported directly to the Board in its advisory role. In May 2011, the Board directed CAISO Management to file a request with Commission to allow the Transmission Maintenance Coordination Committee to report directly to CAISO Management. On October 18, 2011, the Commission issued an order approving the request.[27]

The Transmission Maintenance Coordination Committee comprises one member representing each Participating Transmission Owner with transmission facilities subject to the CAISO transmission maintenance standards, two members representing organizations representing labor interests, five members representing other organizations, and the CAISO vice president responsible for transmission maintenance, or his or her designee, who serves as the Chair of the Transmission Maintenance Coordination Committee. Each member must meet certain qualifications to be appointed. The Transmission Maintenance Coordination Committee meets quarterly to discuss maintenance trends, lessons learned, and alternative maintenance methodologies and to provide any modifications to the CAISO maintenance standards as necessary or appropriate. The committee provides a valuable forum for the discussion of bulk power system maintenance concerns and processes. Topics discussed include lessons learned from grid events and outages, industry news,

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[27] *See* Letter Order dated October 18, 2011 in Commission docket ER11-4340

maintenance best practices, and pending regulatory standards and/or requirements.

f. Review for Cause

A Review for Cause determines whether maintenance is a contributing factor in a specific area of concern, such as a major system outage or event. If the CAISO has a specific concern, CAISO staff will communicate their concerns in writing to the Participating Transmission Owner. A specific area of concern will typically determine the scope of the review for cause and may include a review of the maintenance records, verification of maintenance, and/or a visual inspection of the transmission facilities. Areas of concern may include: availability measures performance due to maintenance activities or unknown causes; SMRS reports indicating numerous deficiencies; significant non-compliance with maintenance practices; deficient maintenance records; or/and ongoing CAISO investigation into a system disturbance. In addition, the CAISO may opt to inspect a Participating Transmission Owner's transmission facilities to verify maintenance performance as reported by the Participating Transmission Owner. The CAISO's Review for Cause procedures are included as part of CAISO Maintenance Procedure 4 – CAISO Maintenance Review.[28]

B. Planning Studies

The CAISO performs numerous planning studies to support continued, reliable operation of the transmission system. These efforts also support grid resilience. The planning studies help to ensure that the bulk power system can provide electrical service while maintaining the required reserves to account for unplanned events. These include studies and reports to confirm system resource adequacy in known or

28 *See* http://www.caiso.com/Documents/Procedure4-ISOMaintenanceReview.pdf

anticipated system conditions. The CAISO includes seven basic elements to ensure system resource adequacy:

(1) A procedure for forecasting system conditions relating to Demand;
(2) A default Reserve Margin and default counting rules for resources;
(3) A deliverability analysis including a determination of local area capacity requirements;
(4) Defined criteria for determining eligible resources and the amount of capacity able to satisfy the Reserve Margin;
(5) Load Serving Entity plans identifying how each load serving entity meets its resource adequacy requirements;
(6) Defined rules under which resources identified in plans are made available to the CAISO to balance supply and demand; and
(7) A compliance program that ensures Load Serving Entities comply with resource adequacy programs.

These elements, establish the basis for forecast, reserve margins, and local and flexible capacity requirements to satisfy Reliability Criteria and ensure that the system can reliably operate for the expected system conditions. The CAISO has also developed CAISO Planning Standards providing for specific higher performance criteria within its balancing authority area to address higher population density area electrical service reliability.

The CAISO performs specific scenario planning studies to confirm stable and reliable bulk power transmission service under many system scenarios. These studies have included:

(1) Gas and electric system coordination studies
(2) Flexible capacity studies
(3) Seasonal system studies
(4) On and off peak deliverability studies
(5) Integration of renewable resource studies

C. Real-Time Visibility and Monitoring

Another example of a process the CAISO uses to assess the attributes that contribute to bulk power system resilience is the CAISO's Energy Management System, a computer system that primarily supports the reliability-related CAISO functions and provides needed inputs to the CAISO Market Operation Systems continuously.

To facilitate the real time monitoring and operation of the CAISO Balancing Authority Area, the Energy Management System requires a model of the physical power system network and real-time information on the status of power system components represented in the model. The network model and real-time data support applications that determine the operational state of the system. The CAISO also uses the network model for real time operations and off-line steady state studies to analyze the impact that single event (N-1) and critical multiple event (N-2) contingencies have on the power system and to develop plans to mitigate the impact of such outages if they occur.

The CAISO uses the Energy Management System detailed physical network model in the state estimator and other reliability applications, which run on the CAISO's Energy Management System, used for Real-Time operations and for monitoring grid reliability. The Energy Management System model includes representation of the interconnected power system of the CAISO Controlled Grid and certain parts of the WECC region.

D. Established Operating Procedures

For bulk power system facilities where there is not sufficient visibility to ensure the accuracy required for congestion management, the market software will not enforce the constraints. In these cases, operators will examine all available information,

including State Estimator solutions and telemetry, to operate the system. Under such circumstances, operators will follow CAISO operating procedures. CAISO operating procedures define constraints other than thermal limits of individual network branches, and state the conditions in which the constraints are valid, including variation by season, time of day, temperature, wind speed, existence of outages, and market time horizon.

CAISO Operating Procedure 1210 provides a process through which on any given day the CAISO staff reviews the results of power flow analyses run for the next Trading Day (within the Day Ahead Market process), for one day past the next Trading Day (D+2), and for two days out past the next Trading day (D+3). This process allows the CAISO to validate the market model, including any changes to topology or ratings due to planned or forced outages, and to evaluate the feasibility and reliability implications of market commitments and schedules.

E. Maintaining a Common Data Base for Determining System Ratings and Limits

At the inception of the CAISO, each Participating Transmission Owner placed under the CAISO's Operational Control, the transmission lines and associated facilities forming part of the transmission network it owns or to which it has Entitlements. Under Section 4.2 of the Transmission Control Agreement, the CAISO created the Transmission Register to ensure it can reflect attributes of bulk power system facilities that contribute to resilience.

Coordinated equipment emergency ratings lead to better communications and a common understanding of the Bulk Electric System operating limits during unplanned events or system outages. The CAISO coordinates emergency ratings within its balancing authority via the Transmission Register, which serves as a central database

to ensure that operators within the CAISO balancing authority area make decisions based on the same information.

The Transmission Register is a secure web-enabled database used by the CAISO and external users to capture specific transmission asset information. The Transmission Register catalogs equipment ratings, operational control dates, historical changes, asset owners, maintenance organizations, whether or not the equipment is under CAISO control. The CAISO uses the information in the Transmission Register as the official data for transmission assets. Many CAISO programs use Transmission Register data, including the Outage Management System, Scheduling and Logging Programs, Power Systems Load Flow analysis, Emergency Management System, and the Full Network Model. The Participating Transmission Owner's operation group uses the database in concert with CAISO Operations Engineering to manage real time operations and study future system conditions, including analyzing all potential scheduled and forced transmission outages (NERC standards TPL1-7). A common database ensures that all operators are using the same ratings and not over-taxing the system.

F. Operations Studies

Among the processes the CAISO employs to assess whether attributes of the bulk power system will contribute to resilience are outage studies and day ahead studies to ensure the system can operate within its limits regardless of the planned configuration. Based on these studies, the CAISO seeks to ensure it can generate a feasible market solution that respects the constraints on the system. If a proposed outage cannot be accomplished within the reliability limits, the CAISO will not authorize

the outage. In addition, the CAISO evaluates all contingencies identified in NERC standards and operates Real Time Contingency Analysis software in order to constantly monitor and plan for contingencies.

G. Black Start Planning

The CAISO also maintains a system restoration plan approved by its reliability coordinator to recover from system outages. As required by NERC Reliability Standard EOP-005-2 R6, this plan verifies "through analysis of actual events, steady state and dynamic simulations, or testing that its restoration plan accomplishes its intended function" on a five year cycle. Restoration plans are specifically developed by local regions based on their stated restoration priorities and are approved by the CAISO and the Reliability Coordinator. Restoration analysis is completed in concert with or with approval of the CAISO and includes the associated Black Start Resource identified cranking paths.

The CAISO has developed a System Restoration Plan Study and Verification Process that is documented in CAISO operating procedure 4600, which is non-public. The CAISO reviews system restoration plans annually. It re-studies cranking paths when permanent changes impact the associated transmission operator's local restoration plan or at least once every five years, whichever comes first. Over the past few years, supplemental restoration system analysis performed by the CAISO determined that the anticipated restoration times for certain high population density areas were not consistent. The CAISO is in the process of procuring additional black start resources to support consistent restoration times, and the Commission approved

tariff revisions to facilitate this process in 2017.[29] The resources the CAISO selected will reduce the anticipated system outage restoration time for these areas. Outage restoration time is directly correlated to system resiliency because it is a measure of time the system is not operational. When evaluating Black Start Resources to include in the CAISO restoration plan, the CAISO evaluated multiple and selected resources based on several selection criteria critical to system wide resiliency and restoration, including geographical and electrical diversity. The CAISO considered these factors to ensure that the loss or failure of a single Black Start Resource would not unduly delay system recovery and the restoration of electrical service.

Question (l): If applicable, how do you determine the quantity and type of bulk power system physical asset attributes needed to support resilience? Please include, if applicable, what engineering and design requirements, and equipment standards you currently have in place to support resilience? Are those engineering and design requirements designed to address high-impact, low-frequency events? Do these requirements change by location or other factors?

Response to Question (l):

The CAISO works with its participating transmission owners and other stakeholders, including state and local authorities, to ensure those elements of the bulk power system under its operational control have the attributes necessary to support resilience. As part of these efforts, the CAISO has identified requirements regarding engineering and design of the bulk power system and engages in a programmatic approach to assess whether equipment is maintained consistent with applicable standards. This approach includes studying the capability of the bulk power system to

[29] *California Independent System Operator Corporation,* 161 FERC ¶ 61,116 (2017). The tariff amendment is discussed in greater detail in the CAISO's response to Question III (c).

withstand certain contingencies and working with other entities with a functional role to protect the resilience of the bulk power system. Below, the CAISO provides examples of its approaches to determining the bulk power system physical asset attributes needed to support resilience, including resilience during high impact, low frequency events.

A. CAISO Planning Standards

The CAISO tariff authorizes the CAISO to establish planning guidelines and standards beyond those established by NERC and WECC to ensure the secure and reliable operation of the CAISO controlled grid.[30] The CAISO Planning Standards do not duplicate the NERC and WECC reliability standards; rather, they complement them where it is in the best interests of the security and reliability of the CAISO controlled grid. The CAISO Planning Standards identify whether the CAISO should adopt specific criteria that are more stringent than the NERC/WECC reliability standards and WECC Regional Criteria.

The CAISO Planning Standards specify when it is necessary to upgrade the transmission system from a radial to a looped configuration or to eliminate load dropping otherwise permitted by NERC/WECC reliability standards through transmission infrastructure improvements. The CAISO Planning Standards specify: (1) no single contingency (TPL-001-4 P1) should cause the loss of over 250 MW of load, (2) all single substations of 100 MW or more should be served through a looped system with at least two transmission lines "closed in" during normal operation, (3) existing

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[30] *See generally* CAISO tariff section 24.2 and Appendix A of CAISO tariff, Master Definition Supplement.

radial loads with back-tie(s) should have their back-up tie(s) sized at a minimum of 50% of the yearly peak load or to accommodate the load 80% of the hours in a year, whichever is more constraining, (4) the NERC Bulk Electric System definition applies to all transmission facilities under CAISO control, (5) extreme event mitigation plans, including a separate San Francisco Peninsula Extreme Event Reliability Standard,(6) any turbine element of a combustion turbine must meet NERC Reliability Standard TPL-001-4 (P1) for single contingencies, (7) a high density urban load area planning standard, (8) specific nuclear unit standards, and (9) a voltage standard. These are discussed in greater detail below.

1. No single contingency (TPL-001-4 P1) may cause loss of over 250 MW of load.

The CAISO intended this standard to coordinate CAISO planning standards with the WECC requirement that all transmission outages of at least 300 MW or more be directly reported to WECC. The CAISO intends that no single contingency (TPL-001-4 P1) should trigger a loss of 300 MW or more of load. The CAISO chose the 250 MW level recognizing that differences between the load forecast and actual real time load can be higher sometimes than the forecast and to allow time for transmission projects to become operational because some require five-six years of planning and permitting with inherent delays. The CAISO intends to cap the radial and/or consequential loss of load allowed under NERC standard TPL001-4 single contingencies (P1).

2. All single substations of 100 MW or more should be served through a looped system with at least two transmission lines "closed in" during normal operation.

This standard promotes consistency between the Participating Transmission Owners' substation designs. The CAISO does not intend to disallow substations with

load below 100 MW from having looped connections; however, the CAISO's intends that all substations with peak load above 100 MW must be connected through a looped configuration to the grid.

3. Existing radial loads with back-tie(s) (drop and automatic or manual pickup schemes) should have their back-up tie(s) sized at a minimum of 50% of the yearly peak load or to accommodate the load 80% of the hours in a year (based on actual load shape for the area), whichever is more stringent.

This standard ensures that the system is maintained at the level that existed prior to electrical restructuring in California. As load grows, existing back-ties radial loads (or remaining feed after a single contingency for looped substations) may not be able to pick up the entire load; therefore, the reliability to customers connected to the system may deteriorate. The CAISO's intent was to require Participating Transmission Owners to maintain a minimum level of back-up tie capability.

4. NERC Bulk Electric System definition applied to all transmission facilities under ISO control.

The CAISO Planning Standards also apply NERC Transmission Planning standards and the approved WECC Regional Criteria to facilities with voltages levels less than 100 kV, which might not otherwise be not otherwise covered under the NERC Bulk Electric System standards. The NERC Bulk Electric System definition applies to all transmission facilities turned over to the CAISO's operational control regardless of voltage level.

5. Extreme event mitigation plans.

NERC TPL-001-4 requires assessing Extreme Event contingencies; however, the standard does not require developing mitigation plans for these Extreme Events. However, the CAISO determined that the San Francisco Peninsula area has unique

characteristics requiring consideration of corrective action plans to mitigate the risk of extreme events. Section 7.1 of the CAISO Planning Standards sets forth a specific San Francisco Peninsula Extreme Event Reliability Standard. The CAISO may also consider other areas on a case-by-case basis as a part of the transmission planning assessments.

Section 7.1 states:

> The ISO has determined through its Extreme Event assessments, conducted as part of the annual transmission planning process, that there are unique characteristics of the San Francisco Peninsula area requiring consideration for mitigation as follows:
>
> - high density urban local area,
> - geographic and system configuration
> - potential risk of outages including seismic, third party action and collocating facilities, and
> - challenging restoration times.

The unique characteristics of the San Francisco Peninsula form a credible basis for considering for approval corrective action plans to mitigate the risk of outages that are beyond the application of extreme events in the reliability standards to the rest of the ISO controlled grid. The ISO will consider the overall impact of the mitigation on the identified risk and the associate benefits that the mitigation provides to the San Francisco Peninsula area.

6. Any turbine element of a combustion turbine must meet NERC TPL-001-4 (P1) for single contingencies.

The CAISO Planning Standards further support resilience by treating an outage of any turbine element of a combustion turbine be a single outage of the entire plant and therefore must meet the same performance level as the NERC TPL-001-4 standard

P1. Thus, the CAISO has determined that, a combined cycle module should be treated as a single contingency. In making this determination, the CAISO reviewed the actual operating experience to date with similar (but not identical) combined cycle units currently in operation in California. The CAISO's determination was based in large part on the performance history of new combined cycle units and its experience with such units. The number of combined cycle facility forced outages that have occurred does not support a double contingency categorization for combined cycle module units in general. The CAISO notes that that all of the combined cycle units that are online today are treated as single contingencies.

7. Planning for high density urban load area standard

For local area long-term planning, the CAISO does not allow non-consequential load dropping in high density urban load areas in lieu of expanding transmission or local resource capability to mitigate NERC TPL-001-4 standard P1-P7 contingencies and impacts on the 115 kV or higher voltage systems. A local area is characterized by relatively small geographical size, limited transmission import capability, and often with limited resources.[31] Local areas typically meet the minimum performance established in mandatory standards or other historically established requirements, but typically have little additional flexibility beyond the planned-for requirements considering both local generation and transmission capacity. Increased reliance on load shedding to meet these needs would run counter to historical and current practices and could cause general deterioration of service levels.

[31] A “local area” for purposes of this Planning Standard is not necessarily the same as a Local Capacity Area as defined in the CAISO Tariff.

8. Specific nuclear unit standards

The CAISO Planning standards include criteria pertaining to the Diablo Canyon Power Plant), as specified in the NUC-001 Nuclear Plant Interface Requirements (NPIRs) for Diablo Canyon Power Plant, and Appendix E of the Transmission Control Agreement to ensure safe operation and shutdown of the nuclear power plant. The criteria include requirements regarding offsite power including number of circuits, capacity, capability, availability, inspection and testing, grid stability, shared structures, systems and components, single failure, station blackout, maintenance and communication.

9. Voltage standard

The voltage standard provides the standards and limits used within the CAISO controlled grid regarding voltage and voltage deviation under normal conditions and/or following contingencies. All buses within the CAISO controlled grid that cannot meet the requirements specified the standard will require further investigation. The CAISO may grant exceptions to the voltage standard and document them through stakeholder process.

B. CAISO Reliability and Technical Studies

Besides the CAISO Planning Standards, the CAISO performs certain reliability studies to identify solutions needed to ensure system reliability and hence resilience. The CAISO performs these reliability studies using the following analyses; although, the CAISO may use other types of analyses occasionally to ensure that planning objectives are met:

Power Flow Analysis

Studies focusing on equipment thermal loadings and voltage magnitudes in the system at a specific study scenario.

Stability Analysis

Assessments of system responses during the transient period after disturbances or small signal stability of the system under various scenarios.

Voltage Stability Analysis

Analysis of reactive power sufficiency to ensure reliable system operations under different system conditions and disturbances. Power flow and stability are primary technical studies in the reliability assessment.

The CAISO performs technical studies annually to ensure that all transmission facilities in the CAISO balancing authority area can be operated in a manner consistent with the conditions identified in the planning standards. These technical studies address near-term needs (up to five years) and long-term needs (six through ten years or more) under various stress conditions (*e.g.*, summer peak, off-peak). Where system performance criteria is not met, the CAISO will propose mitigation plans to address the identified system performance issues and consider alternative mitigation plan proposals submitted through the request window by Participating Transmission Owners and other interested parties.

Participating Transmission Owners, also perform reliability assessments, with the CAISO's partnership, in connection with their roles as NERC transmission planners. Based on resource considerations, technical expertise, and the roles of Participating Transmission Owners as NERC transmission planners, the CAISO can assign technical

studies or portions of technical studies to project sponsors or the Participating Transmission Owners to perform. Similarly, the CAISO may seek the voluntary commitment of other market participants to perform technical studies or portions thereof. Unless otherwise justified to the CAISO and documented in the study plan, all studies performed by a Participating Transmission Owner (s) or other market participants must be completed in accordance with CAISO-established planning methodologies and assumptions documented in the Study Plan developed by the CAISO.

C. CAISO Maintenance Standards and Procedures

A well maintained transmission system not only should be able to withstand high impact, low frequency events, it also should be able to rapidly recover from such events. The CAISO has adopted maintenance and inspection standards for electric transmission facilities under its operational control. The CAISO discussed its Transmission Maintenance Standards and Procedures program in its response to Question II (k) and refers the Commission to that discussion.

Question (m): To what extent do you consider whether specific challenges to resilience, such as extreme weather, drought, and physical or cyber threats, affect various generation technologies differently? If applicable, please explain how the different generation technologies used in your system perform in the face of these challenges.

Response to Question (m):

The CAISO system has remained resilient even in the face of significant drought, extreme fires, losing SONGS, a solar eclipse, weather impacts on generation resources,

and the limited operability of Aliso Canyon.[32] Among other measures, a robust transmission system, diverse resource mix, targeted tariff provisions and market products, conservation efforts, effective coordination, and proactive planning and identification of needs have supported these results.

However, specific conditions can affect different generation technologies differently, and there are certain natural events that can affect a portion of the fleet. In particular, different weather conditions can affect thermal resource capacity, wind/solar production, and load levels in the region. Although the CAISO balancing authority area does not face the extreme cold weather conditions faced in other regions, it can face drought conditions that affect hydroelectric resource availability and can also affect thermal resources that are not once-through-cooling resources. Periods of prolonged high temperatures can impact load levels and thermal resource capacity. Cloud cover and evening conditions can affect solar output, and wind production is dependent on favorable wind conditions. The CAISO considers these factors when developing assumptions for its planning and special studies, seasonal assessments and joint efforts with third-parties.

Forecasting is particularly important for resources whose output is weather-dependent. Factors pertaining to forecasting and weather-related impacts on generation are briefly summarized below:

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[32] The CAISO further discusses its efforts in response to the solar eclipse in its response to Question II (c) and its efforts regarding Aliso Canyon and SONGS in its response to Question II (r).

SOLAR Resources (large scale and behind the meter)

Extreme Heat:

Temperature Forecast is an input to solar forecasting outcomes as it can affect panel efficiency.

Drought:

Soiling Effects on Solar Generators -- effect included in forecast for behind-the-meter and large scale

Cloud Cover:

The CAISO works closely with the research community to continuously improve the numerical weather prediction models in relation to cloud cover forecasting and ability for the energy industry to obtain irradiance forecast information, such as Global Horizontal Irradiance[33] in addition to the current numerical weather prediction variable downward shortwave radiation flux.

The CAISO is also involved in ongoing research work with probabilistic forecasting (uncertainty forecasting) using the ensemble forecasts within the Numerical Weather Prediction Models to develop forecast bands to help deal with uncertainty within different weather features as they move through.

CAISO forecasting works closely with the operations team to address ramps and uncertainties within the forecast that can create differences from the forecast to what is seen during real time operations.

Wind Resources:

Prediction and communication of cut out wind events when wind speeds are

[33] Defined as total solar radiation: the sum of direct and diffuse radiation.

extremely high.

Forecasting closely works with operations team to address ramps and uncertainties within the forecast from the empirical number created.

Regarding wind speed and direction impact, the CAISO works closely with the research community to continuously improve the numerical weather prediction models output in relation to wind forecasting. The CAISO's coordination efforts in the past assisted with getting 10 meter wind speed and direction output directly from the numerical weather prediction models to assist with renewable forecasting. In more recent years, the CAISO has worked on adding more instruments to areas of heavily concentrated wind resources to see what additional accuracy gains can be made. A lot of this work was done through Department of Energy and California's Electric Program Investment Charge Program[34]funded projects, in which the CAISO participated and provided technical support.

The CAISO also is involved in ongoing research work with probabilistic forecasting (uncertainty forecasting).

All Generation Technologies (including Load from Forecasting Side):

The CAISO coordinates with meteorologists throughout the state regularly to work through some of the more difficult forecast situations and collaborate thoughts. These include meteorologists with the three investor owned utilities and the National Weather Service. The CAISO coordinates with natural gas companies on risks that could create more strain on the natural gas operations.

Earthquakes can affect any type of generation technology within an earthquake

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[34] *See* http://www.energy.ca.gov/contracts/epic.html

zone. Similarly, fires affecting specific transmission lines can affect all generation-types connected to such line.

With increasing numbers of resources on its system affected by weather conditions, the CAISO has undertaken numerous renewables integration studies and frequency response studies to determine the actions, products, and resource attributes required to effectively integrate such resources and reliably operate the system. In addition, the CAISO has undertaken special studies to assess the benefits of adding bulk storage as the amount of variable energy resources on the grid increases.

The CAISO balancing authority area can also face drought conditions that reduce that available capacity of hydroelectric generation.[35] Accordingly the CAISO regularly monitors water conditions both statewide and in local areas and appropriately plans for and operates around such conditions. Approximately 13.9 percent (9756 MW) of the generating capacity in the CAISO balancing authority area is hydroelectric generation. As described in annual Summer Assessments, the CAISO assesses and prepares for varying hydro conditions both system wide and locally. The CAISO operated reliability when recently faced with drought conditions through a mix of transmission upgrades and new transmission facilities, new renewables generation resources, imports, and moderate load growth. The CAISO also determines the Net Qualifying Capacity of resources for resource adequacy purposes. For the most recent drought, the CAISO applied derates to the total hydro Net Qualifying Capacity, thus ensuring that sufficient offsetting capacity would be available to maintain reliability.

Cyber security affects different technologies differently. The main challenge is to

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[35] Droughts can also cause dry conditions that increase the risk of wildfires.

protect all equipment at the level to prevent attacks exposing any security vulnerabilities. The CAISO does not own or maintain field equipment; it is the transmission and generation's owner's responsibility to perform this job. Transmission and generator owners also must comply with security standard adopted by NERC. All systems require continuous monitoring and updating of all software elements. Beyond this, CAISO has additional tools to monitor in real time and prevent/minimize the effect on these vulnerabilities.

Finally, the CAISO has access to numerous, diverse sources of natural supply. In addition, the resource mix is changing with the rapid influx of new resources that are not fuel supply dependent. There are several natural gas pipelines that serve gas powered generators in the CAISO balancing authority area, including Pacific Gas and Electric, Southern California Gas, San Diego Gas and Electric, Kern River Gas Transmission, Mojave Pipeline, and Southwest Gas, and their share of the load is relatively balanced. Further, a number of generators have the ability connect to multiple pipelines, and the natural gas pipelines, themselves, are interconnected to allow for gas intertie sales and facilitate gas deliveries when there are unexpected pipeline outages. There are several gas-storage facilities in the footprint of the CAISO balancing authority area. The pipeline serving California follow several different paths. They access different supply basins spanning the western United States and Canada including the Permian Basin, Anadarko Basin, San Juan Basin, Rocky Mountain Basin, and the Western Canada Sedimentary Basin with delivery through multiple major pipelines including El Paso and Transwestern pipelines in the south with delivery at Needles and Topock, the Ruby and Kern River pipelines accessing natural gas from the Rockies

area, and the Trans-Northwest, Northwest, and Sunstone pipelines in the North West area of the CAISO balancing authority area.

Supply sources serving electric generation should be considered in any resilience assessment. Depending on the specific circumstances in a region, there may be merit in considering wide-scale disruption to fuel-supply. In other regions, it may make less sense, and more targeted studies and mitigation efforts may be more appropriate. As noted above in its response to Questions II (a) and (e), in recent transmission planning cycles, the CAISO has studied short-term and longer-term gas-electric coordination issues in southern and northern California.

Also, over the last ten years, the CAISO has worked closely with gas suppliers to coordinate information exchanges to manage information on facility outages, maintenance windows, and construction time frames, among other issues. Essentially, the CAISO has been considering the resiliency of gas supply sources, and their potential impact on multiple generation resources, as a normal matter of reliability planning. The robust coordination efforts during the Aliso Canyon situation demonstrate the benefits and importance of effective gas-electric coordination.

Question (n): To what extent are the challenges to the resilience of the bulk power system associated with the transmission system or distribution systems, rather than electric generation, and what could be done to further protect the transmission system from these challenges?

Response to Question (n):

The California grid typically does not face many of the extreme events that other regions face (*e.g.*, tornadoes, hurricanes, severely cold weather).

Earthquakes and fires can affect transmission, distribution, and generation depending on where the event occurs. However, hardening of transmission and

distribution facilities can make them fairly resilient to earthquakes. As the CAISO discussed in its response to Question II (b), the CAISO recommended facility hardening based on its special studies assessing extreme event risks on the San Francisco Peninsula. Beyond a certain level, however, further hardening is not a reasonable strategy, and the focus shifts to enhancing restoration planning.

During seasons with fire risk, the CAISO coordinates closely with Cal Fire, the US Forest Service, and other agencies. Before a contingency occurs, the CAISO de-energizes lines. Having a robust transmission system allows the CAISO to re-dispatch generation as necessary. Locational diversity of transmission and generation is important as is the ability to accommodate flows in multiple directions. Quick start, load following, and ramping capabilities of generation resources are important as the number of variable energy resources on the system grows. As discussed in the CAISO's responses to Questions III (b) and (d), load serving entities have resource adequacy flexible capacity requirements, and the CAISO has implemented a flexible ramping product to effectively address operational issues on a rapidly changing grid. The CAISO is currently assessing further changes to the flexible capacity framework.

Question (o): Over what time horizon should the resilience assessments discussed above be conducted, and how frequently should RTOs/ISOs conduct such an analysis? How could these studies inform planning or operations?

Response to Question (o):

Depending on the specific matter being assessed, the CAISO conducts reliability resilience assessments in real-time, hourly, daily, seasonally, annually, as needed. The CAISO regularly and constantly monitors and assesses reliability and resilience risks. All of these efforts inform operations and/or planning to some extent. The frequency of

ISO/RTO studies depends on the specific circumstances addressed. The CAISO does not believe more frequent studies over different time horizons are necessary. Below, the CAISO provides some examples of study horizons and frequency.

The CAISO conducts an annual transmission planning process that looks out over a 10-year planning horizon. The 10-year time frame provides a reasonable opportunity for transmission needs and mitigations to be identified, approved, and implemented. The annual transmission planning process typically includes several special studies assessing emerging and anticipated issues. These special studies are not required under the CAISO tariff or by NERC reliability standards. They are discretionary studies and analyses that provide insight into emerging issues and help the CAISO and industry better prepare for future planning cycles.[36] Outside of the transmission planning process, the CAISO conducts studies on an as-needed basis (*e.g.,* renewables integration studies in response to the changing resource mix on the system). These types of studies can inform both planning and operations. They can also serve as the basis for further studies, stakeholder initiatives culminating in tariff amendments, or other subsequent efforts.

The CAISO conducts Summer Assessments before each summer peak season and seasonal operations assessments for the winter and summer seasons. These typically inform operations, as opposed to long-term planning, because they focus on near-term conditions for upcoming season.

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[36] A review of the CAISO's annual transmission plans show the special studies the CAISO has conducted in the transmission planning process. The CAISO has provided a link to its transmission planning process webpage in its response to Question I (a).

Question (p): How do you coordinate with other RTOs/ISOs, Planning Coordinators, and other relevant stakeholders to identify potential resilience threats and mitigation needs?

Response to Question (p):

The CAISO interacts and coordinates with numerous entities on matters affecting resilience. The CAISO has discussed several coordination efforts in prior responses. Many entities (*e.g.*, the Participating Transmission Owners, Generator Operators, state authorities, and regulatory agencies) have their own programs, processes, requirements, and activities that support grid resilience. In these responses, the CAISO does not seek to identify or discuss the resilience-related efforts of these other entities. The CAISO is focusing on its efforts regarding resilience. Other entities with more specific knowledge can describe their specific resilience-related activities in their comments submitted 30 days after the CAISO submits its responses. The CAISO discusses its coordination efforts below.

The CAISO coordinates with the California Public Utilities Commission and local regulatory authorities regarding resource adequacy requirements and input assumptions – including renewable and conventional resource assumptions in transmission planning activities. The California Public Utilities Commission oversees the Integrated Resource Plan process that looks out 20 years and is updated every two years.[37] As stated in the CAISO's response to Question III (d), the Integrated Resource Plan provides resource portfolios for the CAISO to analyze in its annual transmission

[37] The Integrated Resource Plan process is discussed in greater detail in the CAISO's responses to questions III (b) and (d).

planning process.[38] The CAISO conducts local capacity and flexible capacity studies annually, and they inform resource adequacy requirements for the upcoming resource adequacy year.

The CAISO coordinates with transmission owners on numerous matters pertaining to transmission planning, transmission maintenance, and the overall reliability of the transmission grid. The CAISO interacts with generators for its maintenance outage program, exceptionally dispatching non-resource adequacy capacity to maintain reliability, ancillary services testing, and other matters pertinent to maintaining reliability on the system.

The CAISO regularly coordinates with weather agencies and agencies with information regarding potentially disrupting events (*e.g.*, CalFire, US Geological Survey).

As discussed in greater detail in its response to Question II (r), the CAISO worked closely with utilities, regulators, and other agencies to consider and address the risks and potential impacts of the Aliso Canyon situation and the potential impact to grid reliability. The CAISO staff participated on an assessment team with staff from the California Public Utilities Commission, California Energy Commission, and the Los Angeles Department of Water and Power to develop a risk assessment technical report and an action plan to mitigate the impacts of the event.

The CAISO Regional Operations Policy and Analytics group provides full time support to Gas-Electric Coordination for the CAISO balancing authority area. The

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[38] Previously, such portfolios were developed through the California Public Utilities Commission's biennial Long-Term Procurement Plan proceedings.

CAISO has non-disclosure agreements with the natural gas transmission providers of California allowing us to share information specific to natural gas transmission, electric generation, and bulk electric system operations both in the planning horizon and real-time operations timeframe. The open communication with the gas pipeline operators allows the CAISO to develop operational visibility tools and reports for both natural gas and electric dispatch operators and planners. The CAISO issues daily gas reports and gas burn reports. The CAISO reviews outages on both the electric and gas systems for potential impact to the other system and makes adjustments as necessary to eliminate operational impacts to either system. Gas limitations and curtailments are coordinated through operating procedures 4120, 4120b, and 4120c to ensure both systems remain reliable. Further, the CAISO incorporates the gas system limitations in the winter and summer assessment studies completed for each season every year to identify and mitigate risks. Finally, CAISO continuously works with each of the gas pipeline companies to conduct cross training regarding gas and electric system operations and to identify opportunities to improve the joint gas electric coordinating activities.

The CAISO engages with all stakeholders regarding transmission planning and market enhancement initiatives. The CAISO coordinates with neighboring balancing authority areas regarding regional and interregional transmission planning and the Energy Imbalance Market. For example, the CAISO has a Coordinated Transmission Agreement with the Bonneville Power Administration.

The CAISO coordinates with both its reliability coordinator Peak RC and with WECC on reliability-related issues, including gas electric coordination reliability issues.

The CAISO participates in a monthly Gas Electric Coordination and Common

Operational Issues conference call between MISO, PJM, ISO New England, and ISO New York.

The CAISO's gas and electric coordination group actively participates in extreme event planning and exercises annually , working with California natural gas transmission providers, neighboring utilities, and state and federal emergency service agencies. The CAISO also trains natural gas operations personnel on its electric grid restoration and recovery process so both systems may benefit from the CAISO's emergency operations policies.

The CAISO is an active contributor in the Pacific Northwest Utilities Coordinating Committee, Power and Natural Gas Task Force group addressing matters such as western region gas electric coordination and bulk electric system issues.

The CAISO works with state and federal agencies in the planning and implementation of system restoration and recovery drills and training. The CAISO played a leading role in 2017 drills with Pacific Gas and Electric Cyber Security, Southern California Edison Earthquake Drill, So Cal Catastrophic Earthquake Plan, Critical Lifelines Planning Workgroup, and the UC Berkeley Assessing Extreme Weather-Related Infrastructure Vulnerability and Resilience Options.

The CAISO actively participated in the 2016 Vigilant Guard San Andreas 7.0M Earthquake Exercise representing the bulk electric system. The CAISO coordinated in real-time operations with the California National Guard, Nevada National Guard, US Air Force, California Office of Emergency Services, Federal Emergency Management Agency, Homeland Security and California Earthquake Clearing House.

The CAISO was involved in California's 2017 Black Sky Exercise representing

the bulk electric system and discussing the interdependency of California's electric grid and natural gas transmission supplying California and the western states.

The CAISO is an active member of California Utilities Emergency Association and chairs the Energy Committee.

In 2017, the CAISO Regional Operations Policy and Analytics group hosted the first Bulk Electric System and Natural Gas Transmission Infrastructure workshop. This training was focused on providing the US Air Force and National Guard Intelligence Analysts a good understanding of power grid and natural gas transmission operations and the ability to recognize infrastructure specific equipment and facilities of the bulk electric system. The technologies these analysts employ to identify problems help the CAISO assess system conditions during state emergencies and natural disasters. They played a huge role in providing timely information on infrastructure conditions during the firestorms of 2017/2018.

The CAISO has participated with other domestic and international ISOs and RTOs on matters pertaining to grid reliability, security, and resilience. For example, the Regional Operations Policy and Analytics group represents the CAISO on the Electric Gas Task Force and the Emerging Technology Task Force under the Operating Committee of the ISO/RTO Council of North America and led the GO15, Strong Grid Committee 2 task force activities, in which representatives from nineteen ISO/RTO entities around the world worked together to develop reports identifying best practices and operational challenges facing the electric utility industry.

The CAISO has a representative on NERC's Reliability Issues Steering Committee. Among other things, this steering committee identifies key risks to the

reliable operation of the bulk power system and provides recommendations to mitigate those risks.

As discussed in the CAISO's responses to Questions II (a) and (c), the CAISO routinely coordinates with numerous entities regarding cyber security matters.

Question (q): Are there obstacles to obtaining the information necessary to assess threats to resilience? Is there a role for the Commission in addressing those obstacles?

Response to Question (q):

Forecasting Distributed Energy Resources effects on actual load consumption present forecasting, operational, and market challenges for the CAISO. The CAISO's objective is to accurately predict the short term load forecast conditions so it can commit sufficient capacity at least cost to ensure the safe and reliable operation of the grid.

The challenge today is that most Distributed Energy Resources "self-dispatch" as load modifiers, altering the overall load shape. However, the CAISO has no visibility into, cannot track, and does not know exact rooftop solar numbers. This can make load forecasting difficult. Without accurate load forecasts, the CAISO and distribution operators have less certainty whether sufficient resources are available and committed to serve load and maintain system stability. This uncertainty can lead to inefficient dispatch and potential reliability concerns.

It may not be necessary for the CAISO to have complete transparency regarding every individual distributed resource, but effective load forecasting requires sufficient, well placed facilities to upscale the actual generation appropriately for forecasting and operational awareness by technology type.

The picture below represents information being transferred within one day of trade date. Such granularity would assist with load forecasting now; but in the future

there likely will be a need for more real time transfers of data.

	Supply Resource DER (SRDER) (Distribution resources, including DR bid into the market)	Load Modifying DER (LMDER) (Distribution resources, including DR, that are outside of our market. This includes behind the meter resources)
Load Forecast	Need for gross and net load forecast with components broken out: Actual Load = Gross Load – SRDER - LMDER.	
Visibility (Load Forecast)	Within 3 days of trade date, provide aggregated 5 minute load impact (Ex Post) for each day. (SC Metered entities provide metered data at T+48B)	On a monthly basis provide the installed capacity broken by technology. On a daily basis provide next day hourly (Ex Ante) forecasted output for each PNode broken by technology type (i.e. solar, DR, Storage). Within 3 days of trade date, provide actual 5minute load impact (Ex Post) in aggregate for each day. If estimated numbers are provided, true up due XX days.

Question (r): Have you performed after-the-fact analyses of any high-impact, low-frequency events experienced in the past on your system? If so, please describe any recommendations in your analyses and whether they have or have not been implemented.

Response to Question (r):

The electric utility industry has well established protocols for investigating large consequential events. Such events are rare, but when they occur, significant resources are devoted to study the event. Whenever significant impact events occur that can impact the CAISO controlled grid, the CAISO leads and/or actively participates in event analysis. Examples of high impact, low frequency events in which the CAISO performed or participated in an after-the-fact analyses include the September 8, 2011 system disturbance in the Pacific Southwest that resulted in a cascading outage, the early retirement of the San Onofre Nuclear Generating Station in 2013, the Aliso Canyon Gas Storage Field leak beginning in October 2015, and the solar inverter

dropout event in August 2016. These examples are not exhaustive, but explain the scope of analysis and activities that the CAISO may engage in as part of a review of a high-impact, low-frequency events affecting the CAISO system. The CAISO describes each of the events below along with the recommendations that were implemented and/or steps the CAISO pursued. The CAISO also explains its process for reviewing low level events that have the potential to have a great impact if left unmitigated.

A. September 8, 2011 Event

On the afternoon of September 8, 2011, an 11-minute system disturbance occurred in the Pacific Southwest, leading to cascading outages and leaving approximately 2.7 million customers without power. The outages affected parts of Arizona, Southern California, and Baja California, Mexico. All of the San Diego area lost power, with nearly one-and-a-half million customers losing power, some for up to 12 hours.

Pursuant to a settlement agreement,[39] the CAISO undertook the following reliability enhancements:

a. Enhance the full network model for its day-ahead application, including a fully looped representation of the entire Western Interconnection. Upon completion of the full network model enhancement, CAISO shall provide Enforcement and NERC staff with the results of its day-ahead, current-day, and real-time analysis. The improved model should:
   i. reduce compensating injections associated with loop flows,
   ii. enable expanded flow-based and contract-based congestion management and energy balancing WECC-wide both in day-ahead and real-time,
   iii. explicitly model high voltage direct current links, and
   iv. enable better outage and day-ahead analysis.

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[39] *California Independent System Operator Corporation,* 149 FERC ¶61,189 (2014).

b. Enhance and expand its real-time contingency analysis (RTCA) to account for the external model changes so that operators are aware of the impact of any external contingencies to CAISO's transmission operations as well as the impact on external transmission systems of contingencies on CAISO's system, and expand the RTCA user interface to allow for better operator situational awareness with alarms, sorting, and historical capability.

c. Enhance its Energy Management System (EMS) and Supervisory Control and Data Acquisition systems by adding detailed network models for IID, NV Energy, APS/Yuma, Western Area Power Administration Lower Colorado and Sierra Nevada regions, Los Angeles Department of Water and Power, Sacramento Municipal Utility District, Modesto Irrigation District and Turlock Irrigation District.

d. Implement the Contingency Modeling Enhancement Project to ensure that the CAISO market procures the appropriate resources that have the correct characteristics to ensure the ability to recover from a contingency and be ready for the next N-1 contingency as soon as possible but no longer than 30 minutes.

e. Commit to continue working with the RC and other TOPs on the RC's efforts to establish a mandatory periodic design review process for key Remedial Action Schemes (RASs) within the Pacific Southwest region and eventually for the entire Western Interconnection.

The CAISO has completed all of these activities except (d). In the first half of 2018, the CAISO will file a tariff amendment with the Commission to implement the Contingency Modeling Enhancements project. The enhancements can help maintain reliability and avoid cascading outages in the region.

B. SONGS Retirement

In the first quarter of 2012, while the San Onofre Nuclear Generating Station (SONGS) was on outage, the risk that the outage might last longer than expected and carry into the summer season became apparent. SONGS never returned to service and was permanently retired on June 7, 2013. Serving Southern California for over four decades, SONGS provided energy to nearly 1.5 million residents.

Without SONGS, San Diego and Los Angeles reliability was a risk under heavy load conditions. The CAISO and local utilities were challenged to replace the lost

electricity in the area with other sources. Working with several parties, including state energy, air quality, and emergency management agencies, public utilities, and generation owners, the CAISO explored both near-term and long-term solutions to address the situation. The CAISO relied on a mix of clean resources, new synchronous condensers, energy efficiency, energy storage, and consumer demand response, to complement natural-gas-fired power sources. The CAISO authorized new transmission upgrades and equipment, and other measures, to deliver additional power into the communities affected by the retirement of SONGS.

The CAISO took several steps in 2012 to address potential near-term impacts of the outage. The CAISO procured non-resource adequacy resources in the region under its Capacity Procurement Mechanism. Other key components of the near-term plan included conservation efforts, demand response, accelerating completion of the Barre-Ellis transmission projects and ensuring the Sunrise transmission project remained on schedule, returning the Huntington Beach Units 3 and 4 to service, and restricting maintenance outages. Conservation and demand response efforts included fully funding the Flex Alert program (that provides for paid and unpaid radio and TV conservation appeals),[40] implementing an extensive program of conservation education, fully utilizing demand response, and seeking additional military and public agency demand response. The CAISO also hosted weekly coordination calls to assess the upcoming week.

Recognizing there was a need for voltage support, the CAISO worked with the owner of Huntington Beach Units 3 and 4 to convert the units into synchronous

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[40] The CAISO describes the Flex Alert program in its response to Question III (c).

condenser units. The CAISO and the resource owner negotiated the terms of a Reliability Must Run Agreement for the Huntington Beach Units 3 and 4 synchronous condensers, which the resource owner filed with the Commission on November 9, 2012. The CAISO took this particular action to address the short-term need for voltage support bridging the gap until permanent synchronous condenser facilities throughout the Southern California Edison and San Diego Gas & Electric transmission systems could be constructed. The last of these facilities is nearing completion, and the Reliability Must Run Agreement for the Huntington Beach Unit 3 and 4 resources terminated at the end of 2017.[41]

In the 2013-2014 transmission planning process, a key focus was reliability needs in Southern California – the LA Basin and San Diego in particular – because of the retirement of SONGS, coupled with the impacts of potential retirements of gas-fired units in the regions. The CAISO worked with state agency staff to develop a preliminary draft plan that focused on achieving reliability, while transitioning to a cleaner grid.

In the 2013-2014 Transmission Plan, the CAISO adopted a least regrets transmission solutions approach, while recognizing the need for future flexibility.

The CAISO identified and authorized three projects in the 2013-2014 Transmission Plan: the Mesa Loop-in Project; Imperial Valley Flow Controller; and an additional 450-700 Mvar of Dynamic Reactive Support in the area.

The Mesa Loop-in Project expanded Southern California Electric's existing Mesa 230/66/16 kV Substation to include 500 kV service. The project involved building a new

[41] Details regarding the Huntington Beach Reliability Must Run Agreement are included in the November 9, 2012 filing in docket ER13-351-000.

500/230/66 kV substation on the property of the existing substation. This would allow Southern California Electric to bring a new 500 kV service into its metropolitan load center, delivering power from Tehachapi wind resources area or resources in the Pacific Gas & Electric service territory or the Northwest via the 500kV bulk transmission network. Also, the project would help reinforce the bulk transmission system and improve voltage performance.

The Imperial Valley Flow Controller was 800 MVA, and the CAISO concluded that it could be a back-to-back high-voltage, direct current convertor or phase shifting transformer at or near the Imperial Valley Substation on the 230 kV circuit to Comisión Federal de Electricidad's La Rosita substation. Both options would allow loop flow through CFE's system under the critical overlapping Category C3 (N-1-1) contingency to provide resources from the Imperial Valley to San Diego Gas & Electric's system to help mitigate voltage instability concern under post-transient conditions.

In evaluating the effectiveness of the Mesa Loop-in and the Imperial Valley Flow Controller, the CAISO identified a need for additional dynamic reactive support at the future SONGS Mesa substation or electrically equivalent location in the vicinity. The CAISO recommended installing two synchronous condensers totaling 450 MVAr at the San Luis Rey substation.

As stated in the approved Transmission Plan, the CAISO recommended these solutions that "optimiz[ed] existing transmission" as mitigation that would maintain reliability and materially reduce local capacity requirements without adding new transmission rights-of-way. The CAISO concluded that this provided the best use of existing transmission lines and transmission rights-of-way, minimizing risk about

permitting and timing of permitting.

The CAISO did not drop any load as a result of the unexpected long-term outage and then eventual retirement of SONGS. Several factors contributed to this: broad and effective backstop procurement mechanisms that enabled the CAISO to procure capacity that was not under a resource adequacy contract and that allowed the CAISO to procure resources for voltage support (not energy); effective coordination with transmission and generation owners and state agencies; a robust existing transmission system and the ability to identify and approve transmission solutions that could be completed sooner without significant permitting challenges; and effective conservation programs.

C. Aliso Canyon Gas Storage Field

A major natural gas leak occurred at the Aliso Canyon Natural Gas Storage Facility on October 23, 2015 and lasted until February 2016. The incident caused the California Public Utilities Commission to issue an order directing the operator of the facility -- Southern California Gas Company -- to draw down the field to 15 billion cubic feet. After the leak was stopped, there was a moratorium on injections into the underground reservoir until a comprehensive safety review of the facility was completed. This safety review required that all 114 wells in the facility either be thoroughly tested for safe operation or removed from operation and isolated from the underground reservoir. For an extended period, withdrawal capability was limited to amounts necessary to maintain energy reliability.

To address the loss of this critical resource, a team comprising the Staff of the California Public Utilities Commission, California Energy Commission, the CAISO,

Southern California Gas Company, and the Los Angeles Department of Water and Power formed to identify potential risks and mitigation measures and address potential electric reliability concerns for the upcoming summer in the Los Angeles Basin and throughout Southern California. Technical experts from the team performed an Aliso Canyon risk assessment and documented their findings in an Aliso Canyon Risk Assessment Technical Report. The report identified seventeen gas-fired power plants totaling 9,500 MW located in the CAISO and Los Angeles Department of Water and Power balancing authority areas as being most directly affected by Aliso Canyon's reduced capabilities. The Technical Report found that if no gas could be withdrawn from Aliso Canyon during the summer months, there was a significant risk of up to sixteen days of natural gas curtailments, which could interrupt service and affect millions of electric customers during as many as fourteen summer days.[42]

The staff of the California Public Utilities Commission, California Energy Commission, the CAISO, Southern California Gas Company, and the Los Angeles Department of Water and Power also prepared an Aliso Canyon Action Plan to Preserve Gas and Electric Reliability for the Los Angeles Basin.[43] The Action Plan proposed eighteen specific measures to reduce the possibility of electric service interruption during the summer of 2016. The mitigation measures by category were:

Prudent Alison Canyon Use

- Utilize the 15 Bcf currently stored at the field to prevent summer electricity

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[42] The Technical Assessment is available at: http://www.energy.ca.gov/2016_energypolicy/documents/2016-04-08_joint_agency_workshop/Aliso_Canyon_Risk_Assessment_Technical_Report.pdf

[43] The report is available at: http://www.energy.ca.gov/2016_energypolicy/documents/2016-04-08_joint_agency_workshop/Aliso_Canyon_Action_Plan_to_Preserve_Gas_and_Electric_Reliability_for_the_Los_Angeles_Basin.pdf

interruptions, later approved for a higher operating level – 23 Bcf.

- Efficiently complete the required safety review of the field to allow safe use

Tariff Changes

- Implement tighter gas balancing rules
- Modify the operational flow order rule
- All operational flow orders sooner in the gas day
- Provide market information to generators before Cycle 1 gas scheduling
- Require CAISO generators to show gas lined up before bidding into day-ahead electric market

Operational Coordination

- Increase electric and gas operational coordination, including through CAISO tariff changes
- Establish more specific gas allocation among electric generators in advance of curtailment
- Determine if any gas maintenance tasks can be safely deferred

Los Angeles Department of Water and Power Operational Flexibility

- Curtail physical gas hedging
- Stop economic dispatch
- Curtail block energy and capacity sales

Reduce Natural Gas and Electricity Use

- Use new and existing programs asking customers to reduce natural gas and electricity usage
- Expand gas and electric efficiency programs targeted at low income customers
- Expand demand response programs that target air conditioning and large commercial use
- Focus and re-prioritize existing energy efficiency towards projects with potential to impact usage during the upcoming summer and winter
- Re-prioritize spending in existing solar thermal program to fund project installable by the summer and by the end of 2017.

On May 9, 2019, in docket number ER16-1649, the CAISO filed tariff amendments proposing market mechanisms and other tools, including measures

recommended by the Task Force, to mitigate the risks to gas and electric reliability to avoid electric service interruptions to the extent possible. The tariff amendments were designed to ensure the CAISO's dispatches are better coordinated with the constrained gas system and minimize to the extent possible the impact of further challenges to gas and electric system reliability for the summer. The CAISO intended the measures to ensure that limitations of the constrained gas system are reflected in CAISO market processes. The CAISO proposed the measures summarized below on an interim basis, until November 30, 2016:

(1) To increase access to potentially useful market information prior to the CAISO day-ahead market, the CAISO proposed to provide scheduling coordinators, for informational purposes only, advisory commitment schedules produced in the residual unit commitment process conducted on a two-day-ahead basis and based on available bids and forecasts of system conditions. The advisory schedules were not financially or physically binding, but were intended to assist scheduling coordinators with gas procurement decisions and gas nominations processes.

(2) Use timelier and more accurate gas commodity prices for commitment costs bid caps, default energy bids, and generated bids in the day-ahead market. This method would reflect prevailing gas prices, in contrast to the CAISO's then-current day-ahead gas price index, which used prices published the day before the market run. The revised process enabled the day-ahead market to better capture gas price variability that may occur because of summer constraints, resulting in day-ahead schedules that are better aligned with actual gas system conditions.

(3) Increase the gas commodity price used to calculate commitment costs and default energy bids for generators served by the affected gas systems by an amount necessary to ensure that the cost-minimizing market-clearing process considers the impact of gas system limitations in dispatching these generators, (*e.g.*, the need to limit the dispatch of these generators for local rather than system-wide needs). This change was designed to help mitigate against the real-time market dispatching generators that are affected by the absence of available gas from Aliso Canyon and ensure that the CAISO dispatches do not further aggravate existing gas system constraints.

(4) Allow a resource to rebid its resource commitment costs in the CAISO real-time market if the resource was not committed in the day-ahead market and the resource had not already started up and is within its minimum run time range.[44] This change was intended to alleviate pressures on the gas and electric system by ensuring that generators' costs in the CAISO real-time market appropriately reflect real-time gas constraints when conditions on the gas system change.

(5) Ensure that the CAISO's short-term unit commitment process does not commit resources in real-time that were not committed in the day-ahead and does not automatically resubmit bids into the real-time market. In addition to preventing the commitment of resources that have not bid into the real-time market and that have no obligation to do so, this tariff change avoided exposing resources to any unplanned real-time gas procurement variability resulting from real-time commitments.

(6) Include a new constraint in the CAISO markets that the CAISO operators can use to better ensure that dispatches are consistent with observed gas system limitations and avoid further stressing the gas system, which could in turn adversely impact electric grid reliability. This additional operational tool enabled the CAISO market clearing process to limit the maximum amount of generation dispatched in a given area of the CAISO balancing authority area if burning more gas might risk jeopardizing gas and electric system reliability. Similarly, the CAISO could use the constraint to ensure that a minimum amount of generation is dispatched in a given area if necessary to avoid further stressing the gas system and assure reliability on the electric grid. This constraint allowed CAISO operators to minimize variations between day-ahead and real-time gas usage if such variations have the potential to undermine gas and electric system reliability.

(7) Expand the CAISO's authority to reserve internal transfer capability by adjusting transmission constraints on the system and releasing such internal transfer capability as needed. Using this operational tool in the market clearing process helped ensure that it dispatches or commits resources from other areas of the grid as necessary to ensure that resources in the southern California region are deployed in a manner that recognizes gas system limitations. In conjunction with authority to reserve internal transfer capability, the CAISO also requested authority to adjust the network model used in releasing monthly congestion revenue rights to ensure that the CAISO does not release rights that would not be

[44] The CAISO developed this specific proposal before the issues created by the Aliso Canyon storage facility arose. However, this flexibility was also helpful in ensuring that if a generator faced higher costs in the real-time than it did in the day-ahead, it could reflect those higher costs in its bids and allow the CAISO real-time market to consider those costs.

sufficiently funded by congestion revenues collected in the day-ahead market.

(8) Authorize the CAISO to suspend convergence bidding if the CAISO determines it is adversely affecting market efficiency. This authority was necessary so that virtual bidding would not undermine the measures taken by the CAISO to ensure that schedules and dispatches reflect actual physical conditions. This authority was also necessary to ensure, during the summer months when the system is constrained, that virtual bidding does adversely affect market outcomes that unfairly transfer revenue from one group of market participants to another.

(9) Add tariff provisions allowing scheduling coordinators to seek after-the-fact cost recovery from the Commission in a section 205 filing, to the extent they are otherwise unable to recover their costs through the CAISO's cost-recovery mechanisms.

The Commission approved the proposed tariff revisions on June 1, 2016.[45] Besides these measures, the CAISO increased its operational coordination with Southern California Gas Company and Los Angeles Department of Water and Power to increase awareness of changing operational conditions and be ready to act appropriately to mitigate risks to gas and electric reliability. The CAISO also collaborated with Peak RC and WECC to ensure the transfer capability is maximized to the extent possible during periods of electric supply challenges brought on by gas curtailments. The CAISO's actions to prepare for summer 2016 are described in the CAISO's 2016 Summer Assessment.[46]

Since the Aliso Canyon event, the CAISO has continued to collaborate with the inter-agency task force entities. The staff of the participating entities prepared an Aliso

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[45] *California Independent System Operator Corporation*, 155 FERC ¶ 61,224 (2016).

[46] The 2016 summer assessment is available at: http://www.caiso.com/Documents/2016SummerAssessment.pdf

Canyon Winter Risk Assessment Technical Report (Winter Assessment), published on August 22, 2016.[47] The analysis showed that gas-fired electric generation could be susceptible to gas curtailments without Aliso Canyon under certain conditions. Although electric load is generally lower in the winter than in the summer, the availability of electric generation supply may be reduced in winter due to the commitment of fewer generators on-line and outages for scheduled maintenance. The members of the inter-agency task force, except for Southern California Gas Company, also prepared an Aliso Canyon Gas & Electric Reliability Winter Action Plan (Winter Action Plan), published on August 22, 2016.[48] In addition to the mitigation measures for the summer referenced above, the Winter Action Plan identified ten new measures to help reduce the possibility of gas curtailments large enough to cause electricity service interruptions during the winter. These measures were:

- Southern California Gas Company establishing a gas demand response program
- Further efforts by Southern California Gas Company to establish a gas conservation messaging campaign
- Continuing a set of tighter gas balancing rules for non-core customers
- Establishing gas balancing rules applicable to Southern California Gas Company core customers
- Southern California Gas Company submitting reports to the California Public Utilities Commission describing rapid process in restoring pipeline service during maintenance outages
- Exploring the feasibility of purchasing liquefied natural gas for delivery into the San Diego Gas & Electric system
- Exploring what if anything natural gas producers can do to increase deliveries into the Southern California Gas Company system
- The California Public Utilities Commission updating a protocol that it will apply if

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47 The winter assessment is available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=212904

48 The winter action plan is available at : https://efiling.energy.ca.gov/getdocument.aspx?tn=212903

and when some of the gas currently stored is withdrawn

- The California Energy Commission monitoring refinery gas use and operations and the California Attorney General monitoring gasoline prices for potential price manipulations
- The CAISO using a maximum limit on electric generator gas burns in advance of very cold days.

In October 2016, the CAISO filed a tariff amendment in docket number ER17-110 to maintain in effect for an additional twelve months, until November 30, 2017, with some modifications,[49] certain measures the Commission previously approved to address the Aliso Canyon situation.[50] The CAISO proposed to discontinue tariff provisions that were no longer needed to manage reliability: (1) tariff provisions regarding the CAISO's authority to reserve internal transfer capability; and (2) tariff provisions permitting the CAISO to adjust its monthly congestion revenue rights auction and allocation process. The Commission accepted the tariff revisions, subject to condition, effective November 30, 2016, for a period of twelve months.[51]

The CAISO and inter-agency task force continued to monitor and study the Aliso Canyon situation in 2017. On November 28, 2017, the staff of the California Public Utilities Commission, California Energy Commission, the CAISO, and the Los Angeles Department of Water and Power issued the Aliso Canyon Risk Assessment Technical Report 2017-2018 Supplement.[52] The assessment concluded that the region faced new

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[49] The CAISO proposed to augment the after-the-fact cost recovery measure accepted by the Commission in the June 1 Order to permit resources to seek after-the-fact recovery of incremental fuel costs related to generated bids of and all types of default energy bid (*i.e.*, not just default bids under the variable cost option).

[50] The transmittal letter for the filing summarized the need for tariff revisions and the findings in the Winter Assessment and the Winter Action Plan. Transmittal Letter at 15-18.

[51] *California Independent System Operator Corporation,* 157 FERC ¶ 61,151 (2016).

[52] The Risk Assessment Technical Report is available at : http://docketpublic.energy.ca.gov/PublicDocuments/17-IEPR-

challenges and greater uncertainty compared to the prior winter, in particular because three natural gas transmission pipelines Southern California Gas Company relies on to serve its customers were out of operation. The assessment also noted that necessary maintenance on electricity transmission lines to reduce reliability risks would begin February 1, 2018. The assessment stated that combining these factors with unexpected but possible events or extreme cold could cause insufficient gas supplies being available to meet demand. The largest identified risk to the system was not from a single day with high gas demand, but instead from multiple days of higher demand. The assessment indicated that all of the mitigation measures implemented previously would remain in place and suggested some potential additional measures for consideration: delaying Los Angeles Department of Water and Power's transmission upgrade work until February; using more gas from Aliso Canyon than the prior winter; increased conservation and deployment of more smart thermostats; emergency moratorium on new gas hook-ups in Los Angeles county; shift electric gas generation to facilities located outside of the Southern California Gas Company system to reduce its gas use in December; bring liquefied natural gas to the Otay Mesa generating unit if it cannot acquire pipeline capacity; and monitor and communicate constantly, including to the public.

Given continued concerns with Aliso Canyon, the CAISO filed a tariff amendment on September 29, 2017 in docket number ER17-2568, to extend three of the existing mitigation measures – the day-ahead market gas index, adjustments to commitment

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11/TN221863_20171128T103411_Aliso_Canyon_Winter_Risk_Assesment_Technical_Report_201718_Supp.pdf

cost caps and default energy bids, and after-the-fact fuel cost recovery -- for an additional twelve months and adopt the other four existing measures – maximum gas constraint, competitive path assessment, virtual bidding suspension, and pre-day ahead information – permanently. The Commission accepted the CAISO proposal to extend temporarily certain provisions, but rejected the proposal to extend permanently the remaining provisions. [53] The CAISO subsequently filed a tariff amendment requesting that the Commission approve re-implementing the four measures it had rejected on an interim basis, through November 30, 2018. The Commission accepted the tariff amendment via letter order issued on December 15, 2017 in docket number ER18-375.[54]

The CAISO did not have to curtail any load as a result of the limited availability of the Aliso Canyon storage facility. The successful handling of the Aliso Canyon situation shows the importance of addressing events that can threaten reliability and resilience in a multi-pronged, multi-dimensional effort. The CAISO was able to maintain electric reliability in large part due to strong, effective, and prompt gas and electric coordination and inter-agency coordination. In addition, other measures on both the natural gas side and the electric side supported reliable operations. These included key market design and tariff changes, conservation, a robust transmission system to support generation redispatch, sufficient fuel supply and generation options, public communication, and prudent gas and electric operations.

As discussed further in the CAISO's response to Question III (e), one of the

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53 *California Independent System Operator Corporation,* 161 FERC ¶ 61,232 (2017).

54 *See* https://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=14777739

lessons the CAISO learned in response to the Aliso Canyon event is the value of the maximum gas constraint that the Commission approved on an interim basis, but rejected on a broader, more permanent basis. The maximum gas constraint allows the CAISO to include a nomogram in the day ahead and real-time markets to limit the maximum gas burn by generators within a specified area. This feature helps ensure the market dispatch of electric generation needed to support the bulk power system without exacerbating reliability issues on a gas pipeline system. As a result, the constraint promotes resilience for both the gas system and the bulk power system.

D. Solar Inverter Dropout Events

The Blue Cut Fire was a system disturbance that occurred in Southern California. On August 16, 2016, at 10:36 a.m. Pacific, the Blue Cut fire began in the Cajon Pass, just east of Interstate 15. The fire quickly moved toward an important transmission corridor with three 500kV lines owned by Southern California Edison and two 287kV lines owned by the Los Angeles Department of Water and Power. By the end of the day, the Southern California Edison transmission system experienced thirteen 500kV line faults, and the Los Angeles Department of Water and Power system experienced two 287kV faults because of the fire. Four events resulted in losing a significant amount of solar photovoltaic generation. All faults were cleared rapidly per design (less than four cycles total clearing time), but significant blocks of generation were lost. Generation should not disconnect from service during the routine clearing of transmission line faults, unless of course the fault is on the generation tie itself. The most significant event related to the solar photovoltaic generation loss occurred at 11:45 a.m. Pacific and resulted in losing nearly 1,200 MW. There were no solar photovoltaic

facilities de-energized as a direct consequence of the fault event; rather, the facilities ceased producing electricity as a response to the fault on the system.

The CAISO joined with Southern California Edison to investigate the occurrence. The initial results showed that the vast majority of the generation was solar photovoltaic. Further investigation showed that some generation returned within seconds; whereas, other generation took several minutes to return, and some generation never returned. The CAISO and Southern California Edison approached WECC and NERC and asked for assistance in the investigation.

A NERC/WECC joint task force assembled to analyze the disturbance, and the task force prepared a report prepared a report titled, *1200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report*. Besides analyzing the disturbance, the task force sought to determine the causes, and develop key findings and recommendations, to ensure that similar occurrences are mitigated throughout the North American Bulk Electric System.[55] The report had two key findings and recommendations:

(1) Key Finding: Inverters that trip instantaneously based on near instantaneous frequency measurements are susceptible to erroneous tripping during transients generated by faults on the power system.

Recommendations**:** Inverter manufacturers that experienced this type of tripping during the Blue Cut fire event have recommended changes to their inverter settings to avoid this erroneous tripping. Such change will add a time delay to inverter frequency tripping that will allow the inverter to "ride through" the transient/distorted waveform period without tripping. Solar development owners and operators involved in this event are

[55] The task force included members from NERC, WECC, the Commission, affected registered entities involved in the event, industry subject matter experts in the area of inverter-based resources, and inverter manufacturer representatives. The task force gathered data and information about the event from the affected registered entities involved in the disturbance, and this was instrumental to the successful and timely completion of this analysis. The CAISO participated in the task force to develop recommendations and monitor the progress and results.

working with their inverter manufacturers, the CAISO, and Southern California Edison Company to develop a corrective action plan for implementation of changes to inverter parameters.

(2) Key Finding**:** The majority of currently installed inverters are configured to momentarily cease current injection for voltages above 1.1 per unit or below 0.9 per unit. During the Blue Cut fire event, some inverters that went into momentary cessation mode returned to pre-disturbance levels at a slow ramp rate.

Recommendations**:** Inverters that momentarily cease output for voltages outside their continuous operating range should be configured to restore output with a delay no greater than five seconds. NERC should review PRC-024-2 to determine if it needs to be revised to indicate that momentary cessation of inverter connected resources is not allowed within the no-trip area of the voltage curves.

The report also provided the following additional recommendations:

(1) A NERC alert should be issued to the NERC registered Generator Owners (GOs) and Generator Operators (GOPs) to ensure they are aware of the recommended changes to inverter settings and alert them of the risk of unintended loss of resources. This alert should include a recommendation for Balancing Authorities and Reliability Coordinators to assess the reliability risk of solar PV momentary cessation and take appropriate measures. NERC should review Reliability Standard PRC-024-2 to determine if it needs to be revised to add clarity that outside the frequency curves is a “may-trip” area (if needed to protect equipment) and not a must-trip area and to determine if there should be a required delay for the lowest levels of frequency to ensure transient/distorted waveform ride through.

(2) In-depth analysis of momentary cessation with higher penetrations of inverter connected resources is needed to determine if that should be allowed for voltages less than 0.9 per unit or greater than 1.1 per unit. More detailed benchmarking studies and analysis should be performed by the Electric Reliability Organization Enterprise and affected Balancing Authorities to determine the extent to which these potential resource loss events caused by momentary cessation or tripping could pose a reliability risk. NERC should communicate findings and recommendations in this area to the industry, regulators, and other venues.

(3) With the proliferation of solar development in all interconnections across North America, the results of this disturbance analysis needs to be widely communicated to the industry highlighting the present potential for widespread solar resource loss during transmission faults on the BPS.

> The NERC alert, along with further study and outreach, will assist the industry in taking steps to resolve this issue and ensure interconnection reliability.

NERC also issued a formal advisory to all registered generator owners based on the recommendation of the Inverter based Resource Performance Task Force. A modeling notification to all registered generator owners has also been issued. The Inverter based Resource Performance Task Force continues to meet and plans to issue guidelines for the performance of inverter based generation at the end of 2018. The CAISO has been and remains a very active participant in the Inverter based Resource Performance Task Force.

D. Low Level Event Analysis

During the course of any year, there are a large number of Low Level Events that occur on the bulk power system. Low Level Events, by definition, do not result in any consequential loss of load and do not violate any of the NERC established reliability metrics. However, they do provide an opportunity to gain insight into potential vulnerabilities in processes and systems, and identify ways to improve performance. Addressing these weaknesses can reduce the likelihood of a future large event.

Understanding the causes of Low Level Events is necessary to avoid the recurrence of the events and to enhance system reliability. Root Cause Analysis provides a tool for gaining detailed insights into the causes of process or technology failure with particular attention to the identifying faults in process design, training, procedures, and policies which must be improved to prevent repetition of events.

CAISO Operations has established a method to provide a quantitative snapshot of system reliability and Low Level Events on a daily basis with a set of daily metrics

that provide a measure of reliability performance and help identify Low Level Events. When a trend is established over time based on the recent Low Level Events analysis, Operations engages in a more detailed look into one of the Low Level Events to gain a better insight and provide recommendations. The goal of the Low Level Events analysis and Root Cause Analysis is to reduce or eliminate risk of significant impact events caused by areas within the control of the CAISO.

Question (s): Please provide any other information that you believe the Commission would find helpful in its evaluation of the resilience of the RTO/ISO systems.

Response to Question (s):

The CAISO has attempted to provide all information pertinent to an evaluation of resilience in its responses to other questions. In its response to Question III (e) *infra,* the CAISO identifies some additional modifications and requirements that would better enable it to be more resilient.

III. HOW RTOs/ISOs MITIGATE THREATS TO RESILIENCE

The Commission states in the Resilience Order that once an ISO/RTO identifies a particular need or threat to resilience, there should be various ways to mitigate such risk. The Commission seeks comment on how ISOs and RTOs evaluate options to mitigate any risks to grid resilience. The Commission directs ISOs and RTOs to answer five questions on this topic. The CAISO responds to the Commission's questions on this topic below.

Question (a): Describe any existing operational policies or procedures you have in place to address specific identified threats to bulk power system resilience within your region. Identify each resilience threat (e.g., the potential for correlated generator outage events) and any operational policies and procedures to address the threat. Describe how these policies or procedures were developed in order to ensure their effectiveness in mitigating the identified risks and also describe any historical circumstances where you implemented these policies or procedures.

Response to Question (a):

The CAISO has several operating procedures that address the types of matters identified in the question.[56] The CAISO briefly summarizes the procedures below. The CAISO developed several of them to comply with NERC Reliability Standards. Others the CAISO developed because it identified specific scenarios that required more guidance for operators and/or external parties.

Operating Procedure Number	Procedure Name	Description of how this procedure addresses Resilience Threat
4100	System Operations Emergency Plan	**Disruptive System Event mitigation/recovery:** This procedure provides a detailed plan to mitigate operating emergencies. Also, it includes the details of the coordinated plan within the Reliability Coordinator area. This procedure fulfills requirements specified by NERC Standard EOP-011-1, which must be included in an Emergency Operating Plan. This fulfills the NERC Reliability Standard EOP-011-1 requirements in an overarching plan, while minimizing duplication between procedure documents. In accordance with the Coordinated Functional Registration (CFR) agreements that the CAISO has with several TOPs in its area, the Transmission Entities (TEs) (PGAE, SCE, SDG&E, TBC and VEA) and the CAISO will each

[56] Public operating procedures are available on the CAISO's website at: http://www.caiso.com/rules/Pages/OperatingProcedures/Default.aspx.

Operating Procedure Number	Procedure Name	Description of how this procedure addresses Resilience Threat
		develop and maintain the NERC EOP-011-1 requirements in their respective plans.
4110	Operations Emergency Preparation Notifications and Reporting	**Disruptive System Event mitigation/recovery:** This procedure defines the actions performed by the CAISO and other entities to prepare for and report natural disasters, major outages, damage or destruction of BES equipment, and other Significant Events that affect the reliability of the grid. It directs CAISO System Operator actions to manage Significant Events in accordance with CAISO Emergency Procedures and as otherwise necessary and appropriate for the prevailing conditions.
4120	Natural Gas Coordination	**Disruptive System Event mitigation/recovery:** This procedure pertains to coordination with the applicable Natural Gas Transmission Pipeline System Operator concerning gas limitations imposed on generation resources that occur in Real Time, to ensure both gas and electric reliability to the extent possible. This procedure outlines the steps taken when there is a natural gas reduction or insufficiency in a region, requiring curtailment of multiple generator resources consistent with the gas company's tariff as interpreted by the gas company.
4120C	SoCalGas Service Area Limitations or Outages	
4130	Geomagnetic Disturbance Operating Plan	**Disruptive System Event mitigation/recovery:** To mitigate the effects of geomagnetic disturbance (GMD) events through planning and coordination with Transmission Operators (TOPs), Adjacent Balancing Authorities (BAs), and the Reliability Coordinator (RC), the CAISO maintains a Geomagnetic Disturbance (GMD) Operating Plan,

Operating Procedure Number	Procedure Name	Description of how this procedure addresses Resilience Threat
		coordinates the process for reviewing TOP GMD procedures within the RC area, and proactively disseminates forecasted and current space weather information to BAs and TOPs as identified in the RC's Plan.
4410	Emergency Assistance	**Disruptive System Event mitigation/recovery:** The plan ensures reliable operation of the CAISO Controlled Grid and Balancing Authority Area. Coordinates emergency and wheeling assistance with other Balancing Authorities (BAs). The CAISO, through agreements with other Balancing Authority Areas (BAAs), may take actions during System Emergencies regarding emergency assistance whether receiving or providing emergency assistance. The CAISO will not shed firm Load to provide emergency assistance to other Balancing Authorities. This procedure applies to Balancing Authorities that may provide or receive emergency assistance or wheeling assistance to/from the CAISO. Emergency assistance may be available from the CAISO for Balancing Authorities within the WECC Interconnection that are signatories to contractual agreements with the CAISO (*e.g.*, Interconnected Control Area Operating Agreements, (ICAOA), or Adjacent Balancing Authority Operating Agreements (ABAOA) Service Schedule 13), or that have entered into a verbal contract with the CAISO by requesting such assistance in Real-Time.
4420	System Emergency	**Disruptive System Event mitigation/recovery:** This procedure outlines the steps that the CAISO may take to prevent a System Emergency and to stabilize the system if a System Emergency occur. A System Emergency can consist of a Transmission Emergency or a Staged Emergency, and may be sudden or progressive in nature. To prevent a System Emergency, and to maintain system reliability, the CAISO may issue a

Operating Procedure Number	Procedure Name	Description of how this procedure addresses Resilience Threat
		restricted maintenance operations, alert, or warning notice. This procedure directs timely and appropriate Real-Time actions necessary to ensure reliable operation of the CAISO Controlled Grid and Balancing Authority Area.
4510	Load Management Programs	**Disruptive System Event mitigation/recovery:** This procedure describes and provides actions for Under Frequency Load Shedding (UFLS) and Load management programs. It initiates implementation of Load management programs and response and restoration of load following a UFLS event. The CAISO System Operators hold authority, as delegated by the Executive Officers of the CAISO, to take or direct timely and appropriate Real-Time actions necessary to ensure reliable operation of the CAISO Controlled Grid, up to and including shedding of firm Load to prevent or alleviate system operating limit or interconnection reliability operating limit violations. These actions may be performed without obtaining approval from higher-level personnel within the CAISO.
4600	ISO System Restoration Plan	**Disruptive System Event mitigation/recovery:** This procedure documents the verification process of the CAISO Restoration Plan and to provide evidence, through steady state and dynamic simulations, that the CAISO would accomplish its intended function. The CAISO performs this verification process comply with the requirements outlined in the North American Electric Reliability Corporation (NERC) Reliability Standard EOP-005-2 R6. This procedure includes study and verification activities to ensure that plans, procedures, and resources are available to restore the electric

Operating Procedure Number	Procedure Name	Description of how this procedure addresses Resilience Threat
		system to a normal condition in the event of a partial or total shut down of the system. This procedure briefly includes study methodology and assumptions and study results from PG&E, SCE and SDG&E and potential cranking path information.
4610	System Restoration	**Disruptive System Event mitigation/recovery:** This procedure establishes priorities, and provides strategies and guidelines for restoring the CAISO Transmission Operator area if a partial or total system shutdown occurs. It serves as a directive to Participating Transmission Owners (PTOs), Transmission Operators within the CAISO's Balancing Authority Area, Utility Distribution Companies (UDCs), Metered Subsystems (MSSs), and Participating Generators (PGs) by coordinating restoration activities directed by the CAISO and the Peak Reliability Coordinator.
4710	Loss of Control Center	**Disruptive System Event mitigation/recovery:** This procedure outlines the plan of action for the CAISO to continue reliable operations of the grid in if one of the CAISO Control Centers becomes inoperable or uninhabitable. It gives the method to evaluate whether transfer of operations from one Control Center to the alternate control center is needed and directs System Operators accordingly. The procedure ensures that all required notifications are made and that risk to the Bulk Electric System is mitigated from losing Control Center functionality. If one of the CAISO Control Centers becomes inoperable, the CAISO will continue to operate the grid by transferring operations to the alternate Control Center. The primary Control Center for the CAISO is located in Folsom, California while the secondary is located in Lincoln, California (EOP-008-1 R1.1). Both Control Centers are fully functional, are staffed by

Operating Procedure Number	Procedure Name	Description of how this procedure addresses Resilience Threat
		NERC Certified System Operators and can both reliably operate the CAISO Balancing Area (EOP-008-1 R4). Transfer of operations to the alternate Control Center will typically take place within minutes but no more than two hours (EOP-008-1 R1.5).
1330	Day-Ahead Exceptional Dispatch	**Disruptive System Event mitigation/Resource Dispatch Flexibility:** During emergency operations or when the CAISO cannot maintain System Reliability by using resources available to the CAISO market, the CAISO is authorized by the CAISO Tariff to arrange Exceptional Dispatch (ED) for Energy transactions with Scheduling Coordinators and non-Scheduling Coordinators. This may include, but is not limited to, forced shutdowns or forced Start-Ups of Generation, Dynamic System Resources, Condition 2 RMR Generating Units, and Participating Load. The CAISO may also enter into agreed upon transactions with Interchange Resources (Imports and Exports).
1710	Day-Ahead Market Suspension and Intervention	**Disruptive System Event mitigation/Resource Dispatch Flexibility:** The CAISO intervenes in the operation of the Day-Ahead Market (DAM) if it determines that such intervention is necessary to correct the Day-Ahead Market inputs to better align with Real-Time conditions. These interventions may occur on a Balancing Authority Area-wide basis regarding islanded portions of the Balancing Authority Area. The CAISO does not intervene or suspend the operation of the Day-Ahead Market unless there has been a total or major collapse of all or part of the CAISO Controlled Grid and the CAISO is restoring it or if the CAISO anticipates that it will not publish day-ahead market results.
2330	Real-Time Exceptional Dispatch	**Disruptive System Event mitigation/Resource Dispatch Flexibility:**

Operating Procedure Number	Procedure Name	Description of how this procedure addresses Resilience Threat
		The CAISO will strive to use Exceptional Dispatch only as necessary. During emergency operations or when the CAISO cannot maintain System Reliability by using resources available to the CAISO market, and the CAISO Tariff authorizes the CAISO to arrange ED for Energy transactions with Scheduling Coordinators and non-Scheduling Coordinators. This may include, but is not limited to, forced Shut-Downs or forced Start-Ups of Generation, Dynamic System Resources, Condition 2 RMR Generating Units, and Participating Load. The ISO may also transact with Interchange Resources (Imports and Exports).

Question (b): How do existing market-based mechanisms (e.g., capacity markets, scarcity pricing, or ancillary services) currently address these risks and support resilience?

Response to Question (b):

As discussed elsewhere in these comments, there are numerous mechanisms in the CAISO region that support resilience. These range from integrated resource planning efforts to day-ahead and real-time market mechanisms that work together to address reliability risks and support resilience over different timeframes. The CAISO's response to the third set of questions posed in the Resilience Order focuses primarily on its tools that can address resilience, as opposed to the separate and distinct tools and mechanisms that others (*e.g.*, transmission owners, distribution owners, generation owners) may have to address resilience.

The CAISO does not operate a centralized capacity market for the procurement of capacity. Instead, the resource adequacy program ensures that load-serving entities procure sufficient resource capacity on an annual and monthly basis to meet local, system, and flexible capacity needs. Resource adequacy resources have must-offer

obligations to offer their capacity into to the CAISO's day-ahead and real-time markets. Resource adequacy is the underlying foundation for ensuring there are sufficient resources with sufficient attributes and capabilities for the CAISO to call upon to operate the grid reliably. The bi-lateral resource adequacy arrangements are supposed to ensure that resources are sufficiently compensated to be available to the CAISO for market and operational commitment and dispatch. In determining resource adequacy requirements, the CAISO performs annual assessments of requirements in local capacity areas and for flexible capacity, as well as conducting system deliverability and maximum import capability assessments that determine the net qualifying capacity of a resource. The CAISO describes the resource adequacy program in greater detail in its response to Question III (d).

If there is a deficiency in resource adequacy resources, or resource adequacy resources cannot meet the reliability needs of the system, the CAISO has several mechanism that it can use to ensure sufficient resource capability exists to operate the system reliably: (1) the Capacity Procurement Mechanism; (2) Reliability Must Run Agreements; and (3) Exceptional Dispatch. The CAISO describes these and other product procurement mechanisms in greater detail in its response to Question III (d).

The Integrated Resource Planning process overseen by the California Public Utilities Commission guides long-term procurement of new resources. Integrated Resource Planning is a new process in its first cycle. The intent of the Integrated Resource Planning is to identify the resource portfolio mix that meets the state's policy objectives. An Integrated Resource Planning simulation also tests whether the ultimate plan is operable because it meets the targeted loss load probability. The plan is

supposed to consider the effective load carrying capability of preferred variable resources like wind and solar. The CAISO contributed to the current Integrated Resource Planning with comments on the need to consider the impacts on the plan of the premature retirement of conventional resources due to their earning insufficient revenues in the markets, rather than assuming there will be no economic retirement beyond the planned retirement of once-through-cooled resources and the Diablo Canyon Nuclear Power Plant. The CAISO discusses the Integrated Resource Planning in its response to Question III (d).

In the CAISO planning horizon, the CAISO conducts transmission planning studies and performs analysis to determine the risk and impact of the economic curtailment of resources. These studies help guide where and how much local and system risk exists in the planning horizon. The CAISO discusses its transmission planning process generally in response to Question III (d) and discusses specific aspects of it in several other responses.

The CAISO continually looks to enhance its market-based mechanisms to ensure the market structure evolves with the changing resource mix to maintain a resilient electric grid. The CAISO is working on several enhancements that it will file with the Commission this year to improve the market's ability to schedule and dispatch resources in a manner that ensures a resilient and secure grid.[57]

Below, the CAISO discusses its current market mechanisms that address risks

[57] The CAISO is preparing filings on contingency modeling enhancements, generator and remedial action scheme modeling, commitment cost and default energy bid enhancements, and a suite of day-ahead market enhancements to better align resource schedules with real-time operational needs and better position resources to meet real-time supply and load uncertainty.

and support resilience below.

A. The Day-Ahead and Real-Time Markets

The CAISO's day-ahead market comprises three processes: (1) market power mitigation, (2) integrated forward market integrated forward market; and (3) residual unit commitment. The market power mitigation determines whether a resource has local market power and then mitigates energy bids when such market power could be exercised. If the CAISO mitigates a resource, it replaces the resource's bid with its cost-based default energy bid, which will then be used in the integrated forward market. The integrated forward market co-optimizes energy and ancillary service based on bid-in supply, subject to mitigation, and bid-in demand.

The CAISO then runs the residual unit commitment process to determine whether it must commit additional capacity to meet the next day's forecasted load. The CAISO performs the residual unit commitment process immediately after the integrated forward market has run and the CAISO has established feasible and final schedules in the integrated forward market. A residual unit commitment process is necessary if the total amount of load scheduled in the integrated forward market does not meet the CAISO's load forecast. The residual unit commitment is essentially a market-based reliability backstop that allows the CAISO to meet its reliability requirements and serve load. The residual unit commitment process compensates non-resource adequacy capacity it commits to ensure that capacity is available in the real-time.

The resource adequacy process described above complements the integrated forward market and residual unit commitment process in that resource adequacy resources must offer their resource adequacy capacity into the integrated forward

market and residual unit commitment process consistent with applicable must offer obligations depending on the resource type. Because resource adequacy resources have contracts for their capacity, resource adequacy resources must bid their capacity into residual unit commitment at $0 for their availability; whereas, non-resource adequacy resources can offer their capacity at a price up to $250/MW. The residual unit commitment process compensates resources needed in cases when resource adequacy capacity cannot meet the system needs.

The real-time market commits additional capacity, dispatches resources to meet forecasted demand at 15-minute and 5-minute dispatch intervals, procures additional ancillary services if needed, and procures hourly energy across the interties. If energy or ancillary services become scarce, there are pricing mechanism that allow prices to reflect scarcity conditions. In addition, the CAISO has incorporated a flexible ramping product, described below, to the real-time market to ensure that resources are positioned and capable of meeting ramping speed needed to balance supply and demand on a 5-minute basis. This ramping capability can also show scarcity in cases where sufficient ramp speed is tight.[58]

B. Flexible Ramping Product

A particular challenge facing the CAISO is that the generation mix in its balancing authority area is changing rapidly as more variable energy resources come on-line and conventional resources retire. The change in fleet make-up presents significant

[58] In addition to the mechanisms discussed above, the CAISO has implemented additional temporary market measures to address reliability concerns that arose out of the Aliso Canyon gas limitations in Southern California. These measures, described in the CAISO's response to Question II (r) include providing advisory information two days in advance of the operating day, adding an additional gas constraint if needed, and introducing market bidding flexibility on start-up and minimum load costs to help reduce gas burdens on southern California when the CAISO determines that conditions warrant it.

operational challenges. Not only must the CAISO focus on meeting peak load, but it now must also ensure sufficient ramping capability, both upwards and downwards, is available over relatively short periods to meet the sudden swings caused by variable energy resources. The CAISO's experience in operating the markets has shown that the fleet of resources committed in the fifteen-minute real-time unit commitment process to provide energy rarely provides sufficient flexible ramping capability in the five-minute real-time dispatch to meet the actual changes in net load that occur over every successive five-minute period. When there is a lack of such resources, the CAISO may have to (1) relax the non-priced constraints such as power balance or transmission constraints, which triggers scarcity pricing as described further below, or (2) dispatch units out of economic sequence or that are not in the market, which imposes additional costs on the system that are borne through uplift, and result in prices that do not reflect marginal costs. These challenges will only increase as California progresses toward a 50 percent Renewal Portfolio Standard requirement and beyond.

To address these issues, the CAISO has modified, and continues to consider modifications to both its resource adequacy requirements and its market rules to incentivize investment in enhanced resource dispatch flexibility and not incent resources that are inflexible or, when dispatched, contribute to the need for additional downward dispatch flexibility. As discussed in its response to Question III (d) *infra*, there are resource adequacy flexible capacity requirements to ensure that load serving entities procure sufficient flexible capacity that must be economically bid into the CAISO markets. This helps flexible resources receive resource adequacy capacity payments to provide the operational attributes needed to maintain reliable grid operations with higher

levels of renewable resource penetration.

On the market side, the CAISO developed, and the Commission approved, the flexible ramping product, which the CAISO implemented on November 1, 2016.[59] The flexible ramping product functionality allows the CAISO to ensure its dispatches and price signals are better aligned with meeting the system flexibility requirements.

The flexible ramping product procures and compensates resources for providing ramping capability for both the forecasted movement of net load, which is the gross load forecast less the wind and solar output, and uncertainty in the forecasted net load. The flexible ramping product procures ramping capability for the forecasted net load ramp, between the financially-binding interval and the subsequent advisory interval. Ramping of load, dispatchable resources, non-dispatchable resources, and interties can create both a demand for ramp and a supply for ramp. The CAISO charges demand or supply resources that increase the need for ramping capability between intervals and compensates those that decrease the need for ramping capability between intervals, based on the flexible ramping product price. Settling ramping capability directly between demand and supply resources that consume ramping capability and those that provide ramping capability helps manage the ramping need by incentivizing load serving entities to have a portfolio of both dispatchable and non-dispatchable resources that can follow their load profile.

Besides procuring ramping capability for the change in forecasted net load, the flexible ramping product procures an additional amount of ramping capability to cover uncertainty in the forecasted net load. Absent a flexible ramping product requirement,

59 *California Independent System Operator Corporation*, 156 FERC ¶ 61,226 (2016).

the market will solve only for expected load and system conditions. This limits the ability of the real-time dispatch to meet changes in system conditions between the fifteen-minute market and five-minute real-time dispatch, and between subsequent market runs of the five-minute dispatch. The flexible ramping product addresses this forecasted net load uncertainty by procuring ramping capability in addition to that needed to meet the forecasted movement between intervals. It will only do this if the expected benefits of this additional ramping capability exceed its costs. The CAISO determines this trade-off by calculating the probability of a power balance violation due to a deficiency in imbalance energy and the associated costs to the market and comparing this to the costs to procure ramping capability.

Unlike forecasted movement between intervals, there cannot be a direct settlement between those supply and demand resources requiring ramping capability and those providing ramping capability to cover uncertainty in the forecasted net load because the market may not need to use, and consequently attribute to a specific load or supply resource, the flexible ramping capability procured to cover uncertainty. The market will allocate the costs of the ramping capability it procures to cover uncertainty based on a load's or a supply resource's contribution to this uncertainty. It will do this by evaluating each demand or supply resource's contribution to this uncertainty first daily and then recalculate those amounts for each month.

The CAISO pays and charges resources a flexible ramping price equal to the shadow price of the uncertainty requirement for the applicable constraint, which equals the marginal cost of procuring the flexible ramping product. The CAISO settles forecasted movement awards, which is the ramping capability reserved through the

multi-interval optimization process, at the ramping price it determines from uncertainty awards. The CAISO compensates each resource and intertie schedule for movement in the direction of total system movement in each market at the same price that is calculated for the uncertainty requirement.

The flexible ramping product is distinct from capacity products such as ancillary services. Ancillary services in the CAISO market are "standby" unloaded capacity available to meet net system demand deviations from assumed levels in the same trading interval. The unloaded capacity represents energy withheld from the market and not routinely available for dispatch. The CAISO deploys through automated generation control energy from regulation services after the real-tie dispatch through automatic generation control. The CAISO dispatches operating reserves through the real-time contingency dispatch only after a defined contingency event occurs.

C. Ancillary Services

The CAISO procures four types of ancillary services through its markets: regulation up; regulation down; spinning reserve; and non-spinning reserve.[60] The CAISO establishes minimum procurement requirements for these ancillary services to meet applicable reliability standards, but it may establish more stringent criteria for procuring ancillary services or procure additional ancillary services as conditions

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[60] *See generally* CAISO tariff section 8.1 *et seq.* The CAISO does not have an auction market for voltage support or black start services. Spinning reserves are that portion of unloaded synchronized resource capacity that is immediately responsive to frequency and that is capable of being loaded in 10 minutes, and is capacity that is capable of running for at least 30 minutes from the time it reached its award capacity. Non-spinning reserve is that portion of resource capacity that is capable of being synchronized and ramping to a specified load in 10 minutes (or that is capable of being interrupted in 10 minutes) and that is capable of running (or being interrupted) for at least 30 minutes from the time it reaches its award capacity. Regulation is service provided upward or downward that can match on a real-time basis demand and resources consistent with NERC and WECC criteria.

warrant.[61] Scheduling Coordinators submit bids and submissions to self-provide ancillary services from resources that meet the technical certification requirements. The CAISO attempts to procure 100 percent of its ancillary services in the day-ahead market based on the CAISO's day-ahead demand forecast net of self-provided ancillary services.[62]

The CAISO has established two ancillary service regions within its balancing authority area. These regions are (1) the CAISO expanded system region, which includes the CAISO balancing authority and its intertie scheduling points with adjacent balancing authorities; and (2) the CAISO system region that does not include interties scheduling points with adjacent balancing authority areas. Within these regions, the CAISO has established eight ancillary service sub-regions.[63] These sub-regions nest within the system and expanded system regions, the CAISO can establish maximum or minimum procurement requirements for ancillary services in individual regions and sub-regions. These constraints ensure the CAISO's market has access to adequate ancillary services, and the market sets the price for ancillary services based on these constraints.

The CAISO may only establish new ancillary service regions and sub-regions after first conducting a stakeholder process, and then obtaining Commission authorization.[64] The CAISO will consider adjusting the boundaries of the existing

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61 *See* CAISO tariff sections 8.2.3, 8.2.3.1, and 8.2.3.2.

62 *See* CAISO tariff section 8.3.1.

63 CAISO tariff, section 8.3.3. *See also* CAISO Business Practice Manual for Market Operations at 74-78.

64 CAISO tariff, section 8.3.3.4.

ancillary service regions or creating a new ancillary service region through a stakeholder process if two conditions are met: (a) there is a persistent difficulty in obtaining an appropriate distribution of ancillary services using market procurement mechanisms; and (b) adjusting the boundaries of the existing ancillary service regions or creating a new ancillary service region would reduce the persistent difficulty in obtaining an appropriate distribution of ancillary services using market procurement mechanisms.[65] The CAISO market pays a marginal clearing price for ancillary service obligations based on the market value of the Scheduling Coordinator's accepted self-provided ancillary services.

Since implementing its nodal market design in 2009, the CAISO has attempted to improve the efficiency of ancillary services procurement. At the end of 2009, the CAISO started using a regulation forecasting procurement tool that adjusts the procurement requirements for regulation in the day-ahead market throughout the operating day based on anticipated demand levels and as potential changes in generator and intertie schedules. In 2011, the CAISO introduced an enhancement in its procurement of ancillary services that recognizes resources' operational ramp rates. This feature provides greater assurance that ancillary services awarded to a resource will be deliverable in real-time. As part of its efforts to improve efficiency of ancillary services markets, the CAISO also identified a gap in how the CAISO market systems settle ancillary services capacity that the CAISO disqualifies prior to the real-time market.

After the close of the day-ahead market, the CAISO analyzes ancillary services awards and submissions to self-provide ancillary services to ensure that resources can

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65 *Id.*

provide the service in real-time given changes in system conditions or resource operating capabilities. If the CAISO determines that a day-ahead award or submission to self-provide ancillary services is not available prior to real-time, the CAISO disqualifies the capacity to permit the CAISO's market systems to procure replacement ancillary services to meet ancillary service requirements. The CAISO also has payment rescission rules that apply to ancillary services if the capacity is unavailable, not dispatchable, or not delivered.[66]

The CAISO's ancillary services procurement promotes grid reliability both system-wide and in specific areas of the system. It is flexible enough to allow the CAISO to address changing load forecasts and system conditions.

D. Scarcity Pricing

The CAISO has tariff provisions implementing scarcity pricing for energy and ancillary services.[67] If there is scarcity of energy or ancillary service bids, *i.e.*, not enough supply bids to meet bid-in demand or ancillary services procurement targets based on CAISO forecast of CAISO demand, the CAISO has scarcity pricing mechanisms that allow the price for energy and supply of energy to rise to levels established by scarcity parameters for constraint relaxation.[68]

In any fifteen-minute interval of the Fifteen Minute Market, the CAISO co-

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66 *See* CAISO tariff sections 8.10.8 *et seq.*

67 The CAISO tariff includes pricing provisions to address shortages of energy and ancillary services, including the use of scarcity reserve demand curves for ancillary services and the triggering of price caps for energy with regard to scheduling and pricing parameters. *See* CAISO tariff sections 27.1.2 and 27.4.3.

68 Refer to Section 27.4.3 of the CAISO Tariff and section 6.6.5 of the Market Operations Business Practice Manual (https://bpmcm.caiso.com/BPM%20Document%20Library/Market%20Operations/BPM_for_Market%20Operations_V55_redline.pdf)

optimizes the procurement of energy or ancillary services based on submitted supply bids and the forecast of demand and its ancillary services requirements. In any given interval, if effective supply bids cannot clear forecasted demand, scarcity pricing will trigger indicating a shortage of supply for that applicable interval. Similarly, if ancillary services bids cannot meet the ancillary services procurement target, ancillary services scarcity pricing will trigger for that interval. Triggering shortage pricing for shortages resulting from insufficiency of resources ensures that any shortage pricing accurately reflects system conditions, as opposed to creating prices based on a modeling error or some other artificial reason. In the integrated forward market, the CAISO co-optimizes energy and ancillary services based on bid-in demand and ancillary services procurement targets. If bid-in supply cannot meet all self-scheduled demand, self-scheduled demand is reduced to where the available supply is sufficient to clear the market, and the CAISO triggers scarcity pricing where all the cleared, self-scheduled Demand is deemed willing to pay the maximum energy bid price that can be submitted (*i.e.*, the bid cap).

The CAISO employs a system of parameters and rules to set energy scarcity prices when there supply bids cannot clear the market without relaxing a specific modeled non-priced constraint.[69] The rules and parameters ensure the CAISO market optimization run yields a feasible solution utilizing all reasonably effective resources when the market has run out of reasonably effective bids to relieve a particular constraint. When a constraint is relaxed, the software will trigger a price signal, which

[69] These parameters and rules are reflected in Section 27.4.3 of the CAISO tariff, with further details contained in Section 6.6.5 of the CAISO Business Practice Manual for Market Operations.

usually is the maximum bid price suppliers can submit (*i.e.*, the bid cap), and dispatch resources that are reasonably effective in relieving the constraint. Because these constraints are not themselves priced, the CAISO must assign a price to instruct the software to prioritize which constraint is relaxed first in if there are competing constraints and what will be the cost of the solution based on the relaxation. The bid cap is the appropriate price for such relaxations because it signals appropriately an insufficiency of effective resource bids to yield a solution that is feasible within the constraints the CAISO must honor.

The non-priced constraints the market systems must honor and could relax comprise (1) transmission constraints, which reflect the topology of the system and include contingencies and nomograms the CAISO must implement, (2) supply and demand self-schedules, (3) a power balance constraint to reflect sufficient system supply to meet system demand. To respond to the unanticipated gas shortages with the limited use of the Aliso Canyon facility, the CAISO also developed a supply-based constraint that moves the gas burn away from affected gas regions.

The parameters are designed to: (1) implement Commission-approved scheduling priorities, including the emphasis on utilizing economic bids as far as possible before adjusting self-schedules; (2) utilize all reasonably effective solutions before relaxing the constraints based on the high constraint relaxation parameters; (3) ensure that high scheduling parameters necessary to implement those priorities do not unduly impact settlement prices, while allowing prices to reflect the underlying circumstances that led to the adjustment of one or more non-priced quantities; (4) support the fundamental CAISO objective to create feasible and operationally prudent

schedules and dispatch instructions; and (5) honor the least-cost solution principle by ensuring that the market optimization does not pursue unnecessarily expensive re-dispatch solutions when a non-priced quantity can be adjusted at lower cost to the system.

Consistent with these requirements, the constraint relaxation parameters allow the market solutions and associated prices to rise to scarcity level, while the market solutions assess both system power balance, normal and contingency transmission constraints. This allows the market runs to clear and provide a reliable market solution within system capability assessed in every market interval in the day-ahead and real-time markets. This allows the CAISO to address identifiable system contingencies through the market solution and allow seamless operations if a contingency occurs. Without such mechanisms, the CAISO must rely on manual dispatches to address infeasibilities. These mechanisms enable the market software to respond to constrained system conditions efficiently and effectively with reasonable solutions, including committing additional resources, dispatching resources, and identifying participating demand response that are needed to reliably operate the grid. In addition, high prices arising because of scarcity or constraint relaxation conditions can inform operators that additional measures beyond those the market can provide may be needed in the operational timeframe or in the longer procurement and planning horizons.

In the operational timeframe, operators can also exceptionally dispatch resources to mitigate constraints that unresolved due to scarcity, which will trigger a capacity

procurement mechanism[70] designation and payment if the exceptionally dispatched capacity is not subject to a resource adequacy must-offer obligation. In the procurement and planning horizon, scarcity events may highlight areas of the system that require additional procurement or planning solutions if they are expected to sustain and are not temporary in nature to planned or unplanned events. Such deficiencies can be cured with the procurement of additional capacity through the Capacity Procurement Mechanism process.

The CAISO market systems contain scarcity demand curves prices[71] for deficiencies in bid in ancillary services, when the CAISO may require additional commitment of resources. The CAISO targets procuring 100% of its ancillary service requirements in the day-ahead market. The amount of ancillary services the CAISO procures in the integrated forward market is based on the CAISO's forecast of CAISO demand and the forecasted intertie schedules in the real time market for the Operating Hour net of self-provided ancillary services. The ancillary services pricing allows market prices for ancillary services to rise automatically, potentially beyond any bid cap, when there is a shortage of supply in the market. Scarcity pricing enhances short-term and long-term market efficiency and reliability by stimulating demand response, attracting additional supply, creating incentives for generation availability during peak load periods, and promoting long-term contracting for energy and ancillary services.

The ancillary services scarcity pricing is triggered by insufficient supply to meet

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[70] Details regarding the Capacity Procurement Mechanism program are provided in the CAISO's response to Question III (c).

[71] Refer to Section 4.4.1.1 of the Market Operations Business Practice Manual https://bpmcm.caiso.com/BPM%20Document%20Library/Market%20Operations/BPM_for_Market%20Operations_V55_redline.pdf

the minimum ancillary service requirements, as defined in the tariff. As illustrated in the table below, which is contained in tariff section 27.1.2.3, the ancillary services scarcity prices are based on a joint scarcity reserve demand curve for the three upward reserves (regulation up, spinning, and non-spinning) and a scarcity reserve demand curve for regulation down. The administratively determined demand curve values are tied to the energy maximum bid price.

Reserve	**Scarcity Demand Curve Value ($/MWh)**					
	Percent of Energy Max Bid Price		**Max Energy Bid Price = $750/MWh**		**Max Energy Bid Price = $1000/MWh**	
	Expanded System Region	**System Region & Sub-Region**	**Expanded System Region**	**System Region and Sub-Region**	**Expanded System Region**	**System Region and Sub-Region**
Regulatio	20	20	$1	$1	$2	$200
Spinning	10	10	$7	$7	$1	$100
Non-Shortage > 210 Shortage > 70 & MW ≤ 70 MW	70 60 50 %	70 60 50 %	$5 $4 $3 75	$5 $4 $3 75	$7 $6 $5 00	$700 $600 $500
Upward	**100**	**10**	**$75**	**$7**	**$10**	**$1000**
Regulatio Shortage MW > 32 & Shortage ≤ 32 MW	70 60 50 %	70 60 50 %	$5 $4 $3 75	$5 $4 50 $375	$7 $6 $5 00	$700 $600 $500

E. Other Mechanisms for Dealing with Scarce Conditions

Besides the scarcity pricing mechanisms discussed above, the CAISO has other mechanisms to deal with scarcity conditions. Within a 15-minute interval in which the CAISO clears energy and ancillary services, the CAISO can deploy operating reserves to address a contingency, or deploy regulation to continuously balance supply and demand. The CAISO operators may activate operating reserves identified as contingency only either on a resource specific-basis or for all such resources through a

market tool incorporated in the five-minute clearing processes called the Real-Time Contingency Dispatch. When the operators activate “Contingency Only” reserves in Real-Time Contingency Dispatch, the original energy bids associated with the resources providing operating reserves will be used for the clearing the market in the real-time dispatch. The Real-Time Contingency Dispatch uses a security constrained dispatch to produce an optimized set of binding dispatch instructions. Resources must respond to Real-Time Contingency Dispatch dispatch instructions as soon as possible. The CAISO may also manually deploy reserves through mechanisms other than the co-optimization function of the market. The CAISO only deploys contingency-only reserves if there is a real-time occurrence of an unplanned outage, a contingency, or an imminent or actual system emergency. The CAISO does not deploy contingency-only reserves based on whether sufficient supply bids meet the demand and operating reserves requirements.

The CAISO establishes requirements for operating reserves heading into each operating hour. These requirements must, at a minimum, satisfy WECC reliability standard BAL-002-WECC-2 — Contingency Reserve. In the event of a contingency, the CAISO may dispatch energy from these operating reserves. Once the CAISO dispatches the reserves, the WECC reliability standard allows the CAISO sixty minutes to fully recover its operating reserves. The CAISO, however, seeks to fully recover the operating reserves needed to meet its hourly requirements before that time frame. When the CAISO seeks to replace contingency reserves that it has dispatched through real-time procurement and cannot obtain sufficient capacity, the CAISO market triggers scarcity pricing. The fifteen minute market in the next interval will attempt to procure the requisite operating reserves requirement and, if there are insufficient ancillary services

bids to serve those requirements, ancillary services scarcity pricing will trigger. Similarly, if there are insufficient energy bids to cover the demand, energy shortage pricing will trigger. During each interval in which the resources were deployed, the system was not actually short of supply bids when the operating reserves for that interval were procured. The availability of operating reserves to meet the contingency and address the issue means the system was not short of the reserves it procured to serve that process. Also, once the CAISO deploys the reserves, if the market allows for full recovery of the required reserves, the contingency event itself will not trigger scarcity pricing for ancillary services because there is no actual shortage of operating reserves, unless there are insufficient resources to meet operational needs for operating reserves in the next applicable market interval.

Similarly, the CAISO procures and deploys regulation to match supply and demand on a real-time basis consistent with NERC and WECC reliability standards,[72] but any deployment of regulation alone does not indicate a shortage. As the CAISO explained in its technical bulletin on using regulation, the CAISO:

> procures Regulation for many reasons including load following, frequency response, demand forecast inaccuracies, and market imbalance inaccuracies that occur between one Real Time Dispatch (RTD) period to the next. Through Automatic Generation Control, the ISO uses Regulation to balance all deviations continuously while the RTD corrects the 5 minute Energy imbalances.[73]

The CAISO continuously dispatches regulation to match supply with demand because actual real-time conditions vary within the five-minute dispatch interval for energy. A shortage exists only when there are insufficient resources to meet

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[72] *See* CAISO tariff appendix A, definition of "Regulation".

[73] Technical bulletin, *AS Procurement –Regulation,* p.3 (Dec. 30, 2009).

operational needs for regulation in the next applicable market interval. In any given market interval, if a shortage is observed, shortage pricing will trigger within that interval, and the CAISO does not wait for the shortage to materialize beyond that interval before triggering shortage pricing. The CAISO does not have escalating prices based on the magnitude of the shortage events being priced.

Question (c): Are there other generation or transmission services that support resilience? If yes, please describe the service, how it supports resilience, and how it is procured.

Response to Question (c):

The CAISO has several other mechanisms to support reliability and resilience that are not discussed in response to questions III (b) and (d). These include Reliability Must Run Agreements; Capacity Procurement Mechanism designations; Exceptional Dispatch; Frequency Response and Transferred Frequency Response; and Black Start. The CAISO discusses these mechanisms below.

A. Capacity Procurement Mechanism

The Capacity Procurement Mechanism, as set forth in Section 43A of the CAISO tariff, serves as a "backstop mechanism" to allow the CAISO "to procure capacity to address a deficiency or supplement resource adequacy procurement by load serving entities, as needed, to maintain grid reliability."[74] Capacity Procurement Mechanism resources are essentially treated as resource adequacy resources and are subject to a must offer obligation. The Capacity Procurement Mechanism supplements the resource adequacy program (which is discussed in the CAISO's response to question III (d)),

[74] *California Independent System Operator Corporation*, 153 FERC ¶ 61,001, at P 2 (2015).

rather than supplanting or interfering with it. The Capacity Procurement Mechanism option is available under certain specified circumstances in Section 43A of the tariff:[75]

(1). Insufficient Local Capacity Area Resources in an annual or monthly Resource Adequacy (RA) Plan;[76]

(2) Collective deficiency in Local Capacity Area Resources;[77]

(3) Insufficient Resource Adequacy Resources in an LSE's annual or monthly Resource Adequacy Plan;[78]

(4) A CPM Significant Event;[79]

(5) A reliability or operational need for an Exceptional Dispatch CPM;[80]

(6) Resources at risk of retirement within the current RA Compliance Year (because it is uneconomic for them to continue operating without an RA contract or some other form of capacity payment) that will be needed for reliability by the end of the calendar year following the current RA Compliance Year; [81]and

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[75] CAISO tariff section 9.3.1.3.2.5 also provides that the CAISO can procure backstop capacity under the Capacity Procurement Mechanism if a Scheduling Coordinator for a load serving entity does not provide sufficient operationally available resource adequacy capacity to meet a substitution requirement identified by the CAISO, and the resource does not reschedule or cancel the outage after the supply plan is submitted.

[76] CAISO tariff sections 43A.2.1.1 and 43A.2.1.2, respectively.

[77] CAISO tariff section 43A.2.2. A collective deficiency occurs when the local capacity resources procured by load serving entities and reflected in their annual RA showings fail to ensure compliance in one or more local capacity areas with the Local Capacity Technical Study provided in tariff section 40,3,1,1, even if no there is no deficiency in the amount of local capacity area resources procured by load serving entities. In other words, no load serving entity may be deficient in procuring local capacity resources, but the specific resources that have been procured are insufficient to meet reliability in certain local areas. This can occur because the Resource Adequacy program only requires load serving entities to procure their allocated quantity of local capacity resources within a Transmission Access Charge (TAC) Area. The Resource Adequacy program does not require them to procure a pro rata share of resources in each local capacity area within a TAC Area.

[78] CAISO tariff section 43A.2.3.

[79] CAISO tariff sections 43A.2.4. As defined in Appendix A of the CAISO tariff, a Capacity Procurement Mechanism Significant Event is a "substantial event or a combination of events determined by the CAISO to either result in a material difference from what was assumed in the resource adequacy program for purposes of determining the Resource Adequacy Capacity requirements, or produce a material change in system conditions or in CAISO Controlled Grid operations, that causes, or threatens to cause a failure to meet Reliability Criteria absent the use of a non-Resource Adequacy Resource(s) on a prospective basis.

[80] CAISO tariff sections 43A.2.5.

[81] CAISO tariff section 43A.2.6. Risk-of-retirement Capacity Procurement Mechanism complements Reliability Must Run, which are discussed *infra*. The CAISO can procure resources through a Reliability

(7) A cumulative deficiency in the total Flexible RA Capacity included in the annual or monthly Flexible RA Capacity Plans, or in a Flexible Capacity Category in the monthly Flexible RA Capacity Plans.[82]

Resources designated under the Capacity Procurement Mechanism are compensated based on bids into a competitive solicitation process with a soft offer cap, or they can cost-justify a higher rate by making a filing with the Commission based on Schedule F of the *pro forma* Reliability Must Run Agreement as contained in Appendix G of the CAISO tariff.[83] The latter option allows Capacity Procurement Mechanism resources to recover their annual fixed cost of service, including but not limited to capital costs, return on equity, cost of debt, and fixed operations and maintenance (O&M) costs.

The Capacity Procurement Mechanism supports CAISO resilience both on a short-term and a long-term basis. The risk-of-retirement mechanism allows the CAISO to retain resources that will be needed for reliability by the end of the calendar year in which it will be designated as a Capacity Procurement Mechanism resource. Risk-of-Retirement serves as "bridge" until the year the unit is needed for reliability. This mechanism enables the CAISO to retain resources that are needed for future reliability but cannot obtain a resource adequacy contract. The other types of Capacity Procurement Mechanism enable the CAISO to procure non-resource adequacy resources that are needed for reliability.

Must Run Agreement if they are needed for reliability during the current year or the upcoming resource adequacy. Risk-of-Retirement Capacity Procurement Mechanism resources are those that are not needed for reliability until the following year. Thus, neither the CAISO nor resource owners can pick and choose between Reliability Must Run and Risk-of-Retirement Capacity Procurement Mechanism. They are not interchangeable.

82 CAISO tariff section 43A.2.7.

83 *Id.* at P 29.

B. Reliability Must Run

The CAISO generally relies on resource adequacy programs as supplemented by the Capacity Procurement Mechanism to secure resources needed for system reliability. Sometimes the CAISO may also rely on its authority to enter into Reliability Must Run contracts. Governed by Section 41 of the CAISO tariff, these contracts are geared towards reliability on a local level.[84] The CAISO performs Local Capacity Technical Studies under tariff section 40.3.1 and other technical studies as necessary to ensure compliance with applicable reliability criteria. The CAISO will then determine what units it requires to be Reliability Must Run units. Acceptance of a Reliability Must Run designation is mandatory.[85] Reliability Must Run agreements allow a generator to recover up to all of its fixed costs, as well as the costs associated with planned and unplanned capital expenditures and repairs that occur during the term of the Agreement[86] The CAISO awards these contracts to local generators on a one-year basis.[87] These contracts ensure that generators bound by the contracts can provide their output to the CAISO to meet local reliability needs.[88]

Reliability Must Run contracts permit an owner of a generator unit to select from one of two conditions of how its unit will operate when the CAISO dispatches it to

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[84] In particular, the CAISO can procure Reliability Must Run units under Section 41 to meet Load demand in constrained areas and provide voltage or black start required to meet local capacity needs.

[85] CAISO tariff section 41.2.

[86] A Commission-approved *pro forma* Reliability Must Run contract is set forth in Appendix G to the CAISO tariff.

[87] *Cal. Indep. Sys. Operator Corp.*, 116 FERC ¶ 61,274, at P 408 (2006) ("CAISO MRTU order"), *order on reh'g*, 119 FERC ¶ 61,076, *order on reh'g*, 120 FERC ¶ 61,023 (2007), *reh'g denied*, 124 FERC ¶ 61,094 (2008), *aff'd, Sacramento Mun. Util. Dist. v. FERC*, 616 F.3d 520 (D.C. Cir. 2010).

[88] CAISO MRTU Order at P 408.

address local reliability needs.[89] If the reliability Must Run unit owner chooses Condition 1, it is compensated a certain percentage of its annual fixed costs while still participating in CAISO markets and retaining all revenues.[90] Alternatively, if the Reliability Must Run unit owner chooses Condition 2, it is paid 100 percent of the unit's fixed costs.[91] However, a Reliability Must Run unit owner under Condition 2 may not engage in CAISO market transactions, unless the CAISO issues a relevant dispatch notice.[92] When the CAISO dispatches the Condition 2 Reliability Must Run unit for reliability purposes, the owner of the generator unit must bid all of its capacity at formula-based prices.[93]

The Reliability Must Run mechanism promotes current and upcoming-year reliability by allowing the CAISO to procure a needed resource has no resource adequacy contract.

C. Exceptional Dispatch

If the CAISO does not have sufficient capacity in the day-ahead or in real-time to address reliability needs, the CAISO can rely on its Exceptional Dispatch mechanism to commit or dispatch resources that are out-of-merit order or that did not submit market bids. Exceptional Dispatch supports efforts to maintain short-term reliability and resilience.

Specifically, under tariff section 34.11.1, the CAISO can manually exceptionally

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89 *Id.* (footnote omitted).

90 *Id.*

91 *Id.*

92 *Id.*

93 *Id.*

dispatch resources "in addition to or instead of resources with a Day-Ahead Schedule dispatched by the RTM [real-time market] optimization software during a System Emergency, or to prevent an imminent System Emergency or a situation that threatens System Reliability and cannot be addressed by the Real Time Market optimization and system modeling."[94] Tariff section 34.11.2 also authorizes the CAISO to issue manual Exceptional Dispatches for resources in addition to or instead of resources with Day-Ahead Schedules or dispatched by the Real Time Market optimization software, among other things to mitigate for over generation, provide for voltage support, prevent a Market Disruption or minimize the effect of a Market Disruption Capacity, or address transmission-related modeling limitations in the full network model. Capacity that the CAISO exceptionally dispatches that is not under a resource adequacy contract is entitled to a one-month or two-month Capacity Procurement Mechanism designation -- and an accompanying Capacity Procurement Mechanism capacity payment -- depending on whether the resource is meeting a system need or a non-system need, respectively.[95]

D. Frequency Response

Having sufficient frequency response in the interconnection is important to prevent disturbance events from cascading into an under-frequency load shedding event. To meet the interconnection requirements all balancing authority areas, including the CAISO, must meet their frequency response obligations. The CAISO determines if it has sufficient frequency response. If it does not, the CAISO will seek to

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94 CAISO tariff section 34.11.1.

95 CAISO tariff section 43A.3.6.

transfer frequency response responsibility via an annual request for offering process approved by the Commission. The CAISO discusses transferred frequency response in the next section.

E. Transferred Frequency Response And Other Measures to Address Deteriorating Performance During Frequency Disturbance Events

On April 29, 2016, the CAISO filed tariff revisions in docket number ER16-1483 addressing its compliance with NERC Reliability Standard BAL-003-1.1—Frequency Response and Frequency Bias Setting. In its filing, the CAISO noted that in recent years it has experienced deteriorating frequency response performance and that its assessment revealed that if the new standard had been in effect previously, the CAISO would have been out-of-compliance. The proposed tariff provisions (1) enhanced market rules regarding the primary frequency response capabilities of generators with governor controls, and (2) authorized the CAISO to procure transferred frequency response from other balancing authorities in the Western Interconnection.

Regarding the former, the CAISO proposed that participating generators with governor controls be required to: (1) set the governor droop for each generating unit with governor controls no higher than four percent droop for combustion turbines and five percent droop for other technology types; (2) use a deadband no larger than 0.036 Hz; and (3) not inhibit primary frequency response except under certain operational constraints such as ambient temperature limitations, outages of mechanical equipment, or regulatory considerations.

Transferred frequency response is a compliance instrument and does not involve the provision or exchange of physical services. Transferred frequency response is reported on applicable NERC/WECC compliance forms and applied consistently to each

reported frequency disturbance event. On these forms, the balancing authority selling transferred frequency response decreases its performance by the amount it has transferred to the receiving balancing authority, and the receiving balancing authority increases its performance by the same amount. The CAISO procures transferred frequency response before a compliance year, and can adjust its reported performance to all reportable frequency response events that occur during the compliance year. Transferred frequency response may reflect an aggregate amount from multiple contracts. Any reported Transferred frequency response cannot exceed the frequency response performance that the delivering balancing authority has produced, as reflected in its annual frequency response measure.

The Commission approved the tariff revisions on September 16, 2016.[96] Subsequently the CAISO procured transferred frequency response from several entities under Transferred Frequency Response Agreements approved by the Commission.[97]

F. Black Start

Black Start is the procedure by which a generating unit self-starts without an external source of electricity, thereby restoring a source of power to the CAISO Balancing Authority Area following system or local area blackouts. Black Start resources are essential to restart other generation and to restore power to the grid if an outage occurs. The CAISO tariff requires Black Start units to have several attributes, including the ability to start without external aid from the grid, make a minimum number

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96 *California Independent System Operator Corporation,* 156 FERC ¶61,182 (2016).

97 *See, e.g., California Independent System Operator Corporation,* 158 FERC ¶ 61,053 (2016) (Letter order approving a Transferred Frequency Response Agreement between the CAISO and the Bonneville Power Administration).

of starts, operate in stand-alone and parallel modes, have start-up load pickup capability, produce and absorb reactive power, and have necessary communication/control equipment.

In Order No. 749, the Commission approved NERC Reliability Standard EOP-005-2 that requires transmission operators to have a system restoration plan approved by the reliability coordinator. In response to Order No. 749, the CAISO revised its tariff to align its process for determining its Black Start needs and to develop a system restoration plan consistent with the requirements of Reliability Standard EOP-005-2.[98] The CAISO developed its system restoration plan in consultation with participating transmission owners.[99] The CAISO also amended its existing Black Start agreements to incorporate testing requirements under Reliability Standard EOP-005-2.

In 2016, as part of its effort to review the system restoration plan, the CAISO determined that additional Black Start capability was needed in the San Francisco Bay Area. The CAISO initiated a stakeholder process to examine the appropriate method for allocating the costs of such incremental Black Start capability and to describe the process for Black Start capability procurement. At the time of this initiative, the CAISO had procured Black Start service either through Reliability Must Run agreements or interim Black Start agreements. On August 3, 2017, the CAISO filed tariff revisions in docket number ER17-2237 to: (1) reorganize and consolidate provisions related to Black Start capability; (2) establish provisions related to technical requirements and performance tests; (3) remove Black Start related provisions that were outdated and

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98 *See California Independent System Operator Corporation,* Docket No. ER13-699-000 (February 13, 2013) (delegated letter order).

99 CAISO tariff section 8.2.3.4.

inapplicable; and (4) designate the costs of procured incremental Black Start capability as reliability services costs under the CAISO tariff and allocate such costs to the participating transmission owner in whose service territory the Black Start resources are located. The CAISO also proposed tariff changes to reflect its current operating procedures and reliability requirements. The Commission approved the tariff amendments on October 30, 2017.[100] To secure the additional Black Start capacity, the CAISO started a process to contract with participating generators on a cost-of-service basis.

The aforementioned mechanisms collectively provide the CAISO with important and effective tools to ensure that the CAISO can procure any resource it needs to maintain the reliability of the CAISO balancing authority area, including resources at risk of premature retirement. These mechanisms allow the CAISO to meet immediate-term needs and needs up to two years out that other resources cannot meet. As such, they also contribute to system resilience. The Commission has also found that each of these mechanisms provides for just and reasonable compensation to resources.

Question (d): How do existing operating procedures, reliability standards (e.g., N-1 NERC TPL contingencies), and RTO/ISO planning processes (e.g., resource adequacy programs or regional transmission planning) currently consider and address resilience?

Response to Question (d):

The CAISO's response to question III (a) discusses resilience-related operating procedures. CAISO responses to numerous questions discuss specific aspects of the CAISO's transmission planning process and special studies the CAISO has performed

[100] *California Independent System Operator Corporation,* 161 FERC ¶ 61,116 (2017).

as part of prior transmission planning process.[101] Prior responses also identify NERC reliability standards and the CAISO Planning Standards that consider and address resilience.[102] The CAISO will not repeat that discussion here. This particular response will provide a general overview of its transmission planning process and describe the resource adequacy program and other state procurement mechanisms.

A. Transmission Planning Process

A core CAISO responsibility is to identify and plan the development of solutions to meet the future needs of the CAISO controlled grid. Fulfilling this responsibility includes conducting an annual transmission planning process that culminates in a CAISO Board of Governors (Board) approved, comprehensive transmission plan. The plan identifies needed transmission solutions and authorizes cost recovery through CAISO transmission rates, subject to regulatory approval. The plan also identifies non-transmission solutions that will be pursued in other venues to avoid building additional transmission facilities. The steps and requirements of the CAISO's transmission planning process are set forth in section 24 of the CAISO tariff.[103]

In recent transmission planning cycles, the CAISO has prepared the plan in the larger context of supporting important energy and environmental policies and assisting the transition to a cleaner, lower emission future while maintaining reliability through a resilient electric system. The transition to a generation fleet with significantly increased

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101 *See, e.g.,* the CAISO's responses to Questions II (a), (b),(e), (g), (h), (i) and (r).

102 *See, e.g.,* the CAISO's responses to Questions II (b), (g), (h), (i), and (l).

103 A link to the transmission planning page of the CAISO's website is available at: http://www.caiso.com/planning/Pages/TransmissionPlanning/Default.aspx. The page provides access to the CAISO's annual transmission plans and special transmission planning studies referred to in this document.

renewables penetration and “duck curve” issues,[104] combined with increasing variability in net sales patterns due to behind-the-meter generation and other load-modifying behaviors, not only drive the ramping needs and flexible generation requirements within the electricity market, but are having an even more pronounced impact on the transmission grid as flow patterns change – and change frequently through each day – from traditional patterns. Because these other changes, including growth in behind the meter generation, have been occurring more rapidly than originally anticipated only a few short years ago, the CAISO has needed to revisit both the techniques relied upon to assess system needs and certain previously planned projects.

Within this context, the transmission plan’s primary purpose is to identify – based on the best information when plan was prepared – needed transmission facilities based upon three main categories of transmission solutions: reliability, public policy, and economic needs. A transmission plan may also identify any transmission solutions needed to maintain the feasibility of long-term congestion revenue rights, provide a funding mechanism for location-constrained location constrained resource interconnection facilities, or provide for merchant transmission projects. In recommending solutions for identified needs, the CAISO considers an array of considerations.

The CAISO identifies needed reliability solutions to ensure transmission system performance complies with all NERC standards and WECC regional criteria, and the

[104] The increase in variable energy resources on the system has led to different operating conditions. Net load curves illustrate such impacts. Net load is the difference between forecasted load and expected electricity production from variable energy resources. In certain times of the year, these curves produce a “belly” appearance in the mid-afternoon that quickly ramps up to an arch similar to the neck of a duck.

CAISO Planning Standards (which are CAISO-specific standards above and beyond the NERC standards). The reliability studies necessary to ensure such compliance comprise a foundational element of the transmission planning process. CAISO staff assess comprehensively the CAISO controlled grid to verify compliance with applicable reliability standards. The CAISO performs this analysis across a 10-year planning horizon and modeled summer on-peak and off-peak system conditions. The CAISO assesses transmission facilities ranging in voltage from 60 kV to 500 kV. The CAISO also identifies plans to mitigate observed concerns including upgrading transmission infrastructure, implementing new operating procedures, installing automatic special protection schemes, and identifying the potential for conventional and non-conventional resources to meet these needs.

Planning assumptions and scenarios are developed through an annual coordination process among the CAISO, California Public Utilities Commission, and California Energy Commission. The alignment effort involves three core infrastructure planning processes: long-term energy demand forecasts produced by the California Energy Commission as part of its integrated energy policy report; biennial integrated resource plan proceedings conducted by the California Public Utilities Commission (that have replaced the California Public Utilities Commission's long-term procurement plan proceedings), and the CAISO's annual transmission planning process. As part of this process, the California Public Utilities Commission feeds its renewable portfolio standard generation portfolios into the transmission planning process, and the CAISO vets them with stakeholders in that process. The CAISO's policy-driven transmission framework enables the CAISO to identify and approve transmission facilities that will

allow system users to comply with state and federal policy requirements.

Since implementing the current transmission planning process in 2010, the CAISO has considered and placed a great deal of emphasis on assessing non-transmission alternatives, both conventional generation and preferred resources such as energy efficiency, demand response, renewable generating resources, and energy storage programs. Although the CAISO cannot specifically approve non-transmission alternatives as projects or elements in the comprehensive transmission plan, it can identify them as the preferred mitigation solutions in the same manner that it can opt to pursue operational solutions in lieu of transmission upgrades. Further, load modifying preferred resource assumptions incorporated into the load forecasts adopted through state energy agency activities provide an additional opportunity for preferred resources to address transmission needs.

The transmission plan documents CAISO analyses, results, and mitigation plans. Public policy-driven transmission solutions are those needed to enable the grid infrastructure to support state and federal directives. In recent transmission planning cycles, the focus of public policy analysis has been predominantly on planning to ensure achievement of California's renewable energy goals and achieving the 33 percent renewables portfolio standard by 2020 as set out in state law. Efforts to establish state policy direction for resource planning to achieve the longer term renewable energy goal of 50 percent by 2030 are underway, and the CAISO anticipates that, at the earliest, direction will be incorporated into the 2018-2019 planning cycle.

Economic-driven solutions are those that provide net economic benefits to consumers as determined by CAISO studies, which include a production simulation

analysis. Typical economic benefits include reductions in congestion costs and transmission line losses and access to lower cost resources for the supply of energy and capacity. As renewable generation continues to be added to the grid, with the inevitable economic pressure on other existing resources, economic benefits must also consider cost effective mitigations of renewable integration challenges. In preparation of future industry discussions on these issues, the CAISO has updated the documentation of its current economic study methodologies[105] and anticipates needing to undertake other methodology enhancements to consider more nuanced and complex economic analyses in the future.

Besides undertaking the aforementioned analyses required by the tariff, the CAISO regularly undertakes several "special studies" in the transmission planning process. The CAISO has identified some of its special studies that address resilience in its responses to Questions II (a) and (e).[106] The special studies are not required under the CAISO tariff but are discretionary analyses to provide insight into emerging issues and help the CAISO and industry better prepare for future planning cycles. Special study efforts in in the 2017-2018 planning process focused on:

- Continuing frequency response study efforts through improved modeling;
- Continuing the analysis of large scale storage benefits with further sensitivities;
- Further refinement of the necessary characteristics for slow response resources in local capacity areas;
- Continuing the analysis of the risks of early economic retirement of gas fleet;
- Gas/electric reliability coordination in southern and northern California;
- Further analysis supporting 50 Percent Renewable Generation and Interregional

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105 "Transmission Economic Assessment Methodology (TEAM)," November 2, 2017, http://www.caiso.com/Documents/TransmissionEconomicAssessmentMethodology-Nov2_2017.pdf.

106 *See, e.g.,* the CAISO's response to Questions II (a), (e).

Coordination activities, focusing on interregional transmission project analysis

B. Integrated Resource Plans

On February 8, 2018, the California Public Utilities Commission adopted a decision articulating the integrated resource plan filing requirements for jurisdictional load serving entities.[107] The integrated resource plan process is the "umbrella" planning proceeding to consider all of the California Public Utilities Commission's electric procurement policies and programs to meet state greenhouse gas reduction goals and while ensuring safe, reliable, and cost-effective electricity supply. The recent Decision implements legislation added to the California Public Utilities Code to "[i]dentify a diverse and balanced portfolio of resources needed to ensure a reliable electricity supply that provides optimal integration of renewable energy in a cost-effective manner."[108] In addition, each load serving entity plan must "[e]nsure system and local reliability."[109] The integrated resource plan process, which involves a two-year planning cycle, is coordinated with other state agencies and provides both a reliability-based and public policy-based portfolio to the CAISO's transmission planning process. The integrated resource plan is the vehicle for load serving entities proposing actual procurement of additional resources to meet the planning requirements adopted in the Decision. At the end of each two-year cycle, the California Public Utilities Commission will authorize procurement, where appropriate, that is necessary within the next one-three years to meet targets and needs identified in the integrated resource plan

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107 California Public Utilities Commission, *Decision Setting Requirements for Load Serving Entities Filing Integrated Resource Plans*, Decision 18-02-018, February 8, 2018.

108 California Public Utilities Code 454.51(a).

109 California Public Utilities Code 454.52(a)(1)(E).

process.

C. Resource Adequacy Requirements

Since 2006, the CAISO and local regulatory authorities within its balancing authority area, chiefly the California Public Utilities Commission, have jointly administered the resource adequacy program. The resource adequacy program serves two stated objectives:

(1) Provide sufficient resource adequacy capacity to the CAISO when and where needed to support the safe and reliable real-time operation of the CAISO grid; and

(2) Provide incentives for the siting and construction of new resources needed for future reliability.

The resource adequacy program requires that load serving entities procure capacity to meet their forecasted load plus a reserve margin (*i.e.*, System resource adequacy), local area capacity requirements, and flexible resource adequacy requirements. System resource adequacy requirements are currently based on a 1-in-2 peak load forecast for each month of the year. The California Public Utilities Commission and local regulatory authorities determine the reserve margin applicable to their jurisdictional load serving entities. If they set no reserve margin, a 15 percent default reserve margin applies.

Load serving entities under the California Public Utilities Commission's jurisdiction must procure at least 90 percent of their system resource adequacy requirement for the five summer months in compliance with a year-ahead forward commitment obligation. If their load is in any of the CAISO-defined local capacity regions, they must procure 100 percent of their local capacity need for the entire year in the year-ahead timeframe. California Public Utilities Commission jurisdictional load

serving entities must procure 100 percent of the capacity needed to meet their resource adequacy requirement—their total forecast load for each month plus a planning reserve margin of 15 percent—in compliance with a month-ahead forward commitment obligation. California Public Utilities Commission-jurisdictional load serving entities must demonstrate that they have procured the required resource adequacy capacity by submitting an annual resource adequacy plan and monthly resource adequacy plans. Similarly, non-California Public Utilities Commission load serving entities must submit annual and monthly resource adequacy plans to the CAISO demonstrating procurement of the system resource adequacy requirements their respective local regulatory authorities establish and their allocated share of local capacity. In their annual and monthly resource adequacy plans, load serving entities must also show their procurement of 90 percent and 100 percent, respectively, of their flexible capacity requirements.

Each year the CAISO's role in the resource adequacy process begins with publishing the Locational Capacity Technical Study and the Deliverability Study. The Locational Capacity Technical Study determines the minimum capacity needed in each identified transmission constrained "load pocket" or local capacity area to ensure reliable grid operations. Annual and monthly local capacity requirements are based on a 1-in-10 load forecast. In performing the Local Capacity Technical Study, the CAISO applies methods for resolving contingencies considered appropriate for the performance level that corresponds to a particular studied contingency as provided in NERC Reliability Standards TPL-001-0, TPL-002-0, TPL-003-0, and TPL-004-0, as augmented by the CAISO Reliability Criteria. Under tariff section 40.3.1.1, CAISO Reliability

Criteria include:

(1) Time Allowed for Manual Readjustment: This is the amount of time required for the Operator to take all actions necessary to prepare the system for the next Contingency. This time should not be more than thirty (30) minutes.
(2) No voltage collapse or dynamic instability shall be allowed for a Contingency in Category D --extreme event (any B1-4 system readjusted (Common Mode) L-2).

Under tariff section 40.3.1.2, the Local Capacity Technical Study assesses these Contingencies:

NERC/WECC Performance Level A –No Contingencies

NERC/WECC Performance Level B—Loss of a single element

Generator (G-1_
Transmission Circuit (L-1)
Transformer (T-1)
Single Pole (dc) Line
G-1 system readjusted L-1

NERC/WECC Performance Level C – Loss of two or more elements

L-1 system realignment G-1
G-1 system readjusted T-1 or T-1 system readjusted G-1
L-1 system readjusted T-1 or T-1 system readjusted L-1
G-1 system readjusted G-1
L-1 system readjusted L-1
Bipolar (dc) line
Two circuits (Common Mode) G-2
WECC-S3. Two generators (Common Mode) G-2

D—Extreme Event—loss of two or more elements

Any B1-4 system readjusted (Common Mode) L-2

Based on the results of the Local Capacity Technical Study, the CAISO allocates responsibility for local capacity resource resources to scheduling coordinators for load

serving entities generally based on load serving entity load share within each Transmission Access Charge Area. Load serving entities are not required to procure local capacity area resources to satisfy capacity requirements for each local capacity area identified in the technical study. Rather, the requirement is only that they procure their allocated quantity of local capacity resources within the Transmission Access Charge Area. If a load serving entity is deficient in procuring sufficient resources to meet its annual or monthly local capacity obligations, the CAISO may fill the deficiency by procuring backstop capacity under its Capacity Procurement Mechanism. If there is a collective deficiency in local capacity after all load serving entities have submitted their final resource adequacy showings, the CAISO may fill the collective deficiency by procuring Capacity Procurement Mechanism capacity.

In 2014, the Commission accepted the CAISO's proposal to establish flexible resource adequacy capacity requirements for load serving entities and to enable the CAISO, under its Capacity Procurement Mechanism, to procure backstop flexible resource adequacy capacity if there is a cumulative deficiency of flexible resource adequacy capacity.[110] Prior to this tariff amendment, there were no flexible capacity requirements for load serving entities. The Commission-approved filing also established must offer obligations for resources providing flexible resource adequacy capacity. The CAISO sought flexible resource adequacy capacity obligations to maintain reliability in the face of the increasing variability and unpredictability arising from the expected increased quantities of variable energy resources and distributed energy resources. Also, flexible resource adequacy capacity requirements recognized

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[110] *California Independent System Operator Corporation*, 149 FERC ¶ 61,042 (2014).

that once-through-cooling requirements would reduce the number of existing resources that are available to provide the flexibility necessary to manage the increased variability and maintain day-to-day reliability. CAISO studies showed that to reliably operate the grid with this heightened variability and uncertainty, the CAISO had an increased need for resources that can ramp up and down quickly and start and shut down potentially multiple time per day, *i.e.,* flexible capacity. As with certain other resource adequacy requirements, the CAISO developed flexible capacity requirements under its tariff in parallel with California Public Utilities Commission proceedings on the same topic.[111]

The flexible resource adequacy capacity requirements are set forth in Section 40.10 *et seq*. of the tariff. To establish flexible resource adequacy requirements, the CAISO, in the year-ahead timeframe, conducts a study to determine its system-wide flexible capacity needs for each month of the next calendar year. The CAISO determines flexible capacity needs each month by assessing the largest monthly three-hour net load ramps. The flexible capacity need has three components: (1) the largest system three-hour net load ramp each month; (2) the higher of the most severe single contingency or 3.5 percent of forecasted peak load monthly; and (3) a forecast adjustment (upward or downward).

There are three types of flexible capacity: (1) base ramping flexibility;[112] (2) peak ramping flexibility;[113] and (3) super-peak ramping flexibility.[114] Resources providing flexible resource adequacy capacity are subject to the must offer obligation according to

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111 *Id.* at P 2.

112 CAISO tariff section 40.10.3.2.

113 CAISO tariff section 40.10.3.3.

114 CAISO tariff section 40.10.3.4.

their designated flexible capacity category and must submit economic bids for such capacity. Resources providing baseload ramping flexibility must submit economic bids for energy and ancillary services into the CAISO market for the 17-hour period 5:a.m. to 10:00 p.m. every day.[115] Resources providing peak ramping flexibility must submit economic bids for a five-hour period each day, as determined by the CAISO as part of the annual flexible capacity needs assessment, using the net-load ramping forecast.[116] Super-peak ramping flexibility resources have the same five-hour period obligation to submit economic bids as peak flexibility resources, but they are only required to respond to five dispatches per month, and they are only required to submit economic bids on non-holiday weekdays.[117]

The CAISO allocates a proportionate share of the total flexible capacity needs to each local regulatory authority based on its load serving entities' average contribution to the components of the five highest daily maximum three-hour net load ramps on the system. Each local regulatory authority then determines how to allocate that overall need to each of its jurisdictional load serving entities.

Under the CAISO tariff, local regulatory authorities' capacity determines in the first instance the qualifying capacity[118] of resources providing resource adequacy capacity. Tariff section 40.8 specifies default qualifying capacity criteria if local regulatory authorities fail to adopt such criteria and provide them to the CAISO.

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115 CAISO tariff section 40.10.6.1 (a).

116 CAISO tariff section 40.10.6.1 (b).

117 CAISO tariff section 40.10.6.1 (c)

118 Qualifying capacity is the maximum amount of capacity a resource can have for RA purposes, and is subject to reduction based on provisions for determining net qualifying capacity in section 40.4 of the CAISO tariff.

However, the CAISO determines the Net Qualifying Capacity of resources, which is the amount of capacity that can count toward resource adequacy purposes. Net Qualifying Capacity accounts for potential reductions from a resource's qualifying capacity based on testing and deliverability. The CAISO conducts a Deliverability Study establishing the deliverability of generation in the CAISO balancing authority area and the total import capability for each import path allocated to each load serving entity. The CAISO uses the information in these studies and generator data to compile the annual Net Qualifying Capacity Report and Effective Flexible Capacity Report, which lists the net qualifying and effective flexible capacity, respectively, of all participating generators and other generating units that have requested to be eligible to participate in the resource adequacy program for the coming resource adequacy compliance year. [119]

Load serving entities use the Net Qualifying Capacity Report and the Effective Flexible Capacity Report to identify resources from which they can procure resource adequacy capacity to satisfy their resource adequacy obligations. In the year-ahead and month-ahead timeframes, scheduling coordinators for load serving entities must provide resource adequacy plans to the CAISO demonstrating that they have met their resource adequacy requirements for that reporting period. Scheduling coordinators for resource adequacy resources also submit year-ahead and monthly supply plans to the CAISO that verify their commitment to provide the listed resource adequacy capacity. The CAISO cross-validates the resource adequacy plans and supply plans to ensure that load serving entities are meeting their resource adequacy requirements. If a discrepancy between plans, the CAISO advises the scheduling coordinators and the

[119] CAISO tariff section 40.4 *et seq*.

local regulatory authority to resolve the issue.

The CAISO notes that it is currently supporting several changes to the resource adequacy program.

First, in the ongoing California Public Utilities Commission resource adequacy proceeding in Rulemaking 17-09-020, the CAISO has asked the California Public Utilities Commission to consider adopting more conservative load forecasts during shoulder months for resource adequacy planning purposes.[120] System resource adequacy requirements are currently based on the California Energy Commission's 1-in-2 monthly load forecast, plus a 15 percent reserve margin. The CAISO's recommendation is based on its experience with a Stage 1 Emergency on May 3, 2017 and further studies. The event occurred in part because of an unseasonably early and extreme heat wave and the fact that demand remained high during and after sunset, but as solar production declined, thermal resources could not come on-line at the same rate. The CAISO depleted its operating reserves faster than expected. This event highlighted that months such as May can experience wide temperature ranges that lead to a significant difference in peak demand during different days of the month. The CAISO noted that using a 1-in-2 load forecast for all months by definition overlooks the potential and actual occurrence of extreme variability in temperatures that can occur in a given month. May and June numbers provided by the CAISO show that 1-in-5 and 1-in-10 peak demand can be materially higher than 1-in-2 peak demand during those months. The CAISO's preliminary comparative analysis indicated that May and June

[120] CAISO Resource Adequacy Proposals, California Public Utilities Commission docket number. R.17-09-020, Feb, 16, 2018 (February 18 Resource Adequacy Filing).

experience variability greater than July. This variability is largely driven by the increasing temperatures experienced as the season changes from spring to summer, followed by stabilizing at warmer summer temperatures. The larger variability in demand above 1-in-2 peak levels results in a smaller portions of the 15 percent planning reserve being available for resource outages or other operational issues occurring in those months. The CAISO believes that monthly resource adequacy procurement should be based on a demand forecast, plus reserve margin, that ensures sufficient resource adequacy capacity is procured given the specific characteristics of the month (particularly shoulder months) to ensure reliable grid operations during that month.

Second, the CAISO is also conducting a stakeholder process -- its Flexible Resource Adequacy Capacity and Must-Offer Obligation (FRACMOO 2) initiative --to consider revising the flexible capacity framework. The CAISO submitted its current proposed revised framework with its February 16 resource adequacy filing in the California Public Utilities Commission's ongoing resource adequacy proceeding. The CAISO indicated its intent to continue developing and refining the framework in the CAISO stakeholder process and to coordinate with the California Public Utilities Commission in its resource adequacy proceeding to seek adoption of a final framework in Track 2 of the proceeding. The CAISO believes there are fundamental gaps in the existing framework and, to close those gaps, there needs to be a new framework that better captures both the CAISO's operational needs and the predictability (or unpredictability) of ramping needs. To successfully align procurement with operational needs, the flexible resource adequacy program must enable the CAISO to meet

anticipated ramping uncertainty within the time-scales of the real-time market. Based on its studies thus far, the CAISO has determined that the most efficient way to address unanticipated uncertainty appears to be to develop rules and products tied to two types of ramping needs: (1) predictable ramping needs*, i.e.*, those that are known or reasonable foreseeable; and (2) unpredictable ramping needs, *i.e.*, those caused by load following and forecast error. To address these needs, the CAISO is considering developing three products as part of a new flexible capacity framework: (1) a five-minute flexible resource; (2) a 15-minute flexible resource; and (3) a day-ahead shaping resource. The CAISO continues to study these issues and will seek to develop a record in the resource adequacy proceeding.

Third, the CAISO supports multi-year resource adequacy requirements for local capacity. In the ongoing California Public Utilities Commission resource adequacy proceeding, the CAISO has supported a California Public Utilities Commission Energy Division proposal to require load serving entities to procure 100 percent of their local capacity requirements two years forward, and 80 percent of their local requirements for the subsequent three years. This will help address risk-of-retirement issues and enable resources that are needed to maintain local reliability to undertake necessary capital maintenance projects.

D. Resource Adequacy Related Requirements

1. The Replacement Rule

In 2006, the California Public Utilities Commission implemented the “replacement requirement” for its jurisdictional load serving entities. Under this rule, California Public Utilities Commission -jurisdictional load serving entities had to meet their resource

adequacy requirements with resource adequacy capacity that would not be on an extended scheduled maintenance outage during a resource adequacy compliance month.[121] The replacement rule required that if a load serving entity's resource adequacy plan included a resource scheduled for more than a *de minimus* outage, then the load serving entity had to procure replacement resource adequacy capacity for the capacity on outage.

In a 2011 decision, the California Public Utilities Commission terminated the replacement requirement effective for the 2013 resource adequacy compliance year.[122] Absent the California Public Utilities Commission's replacement rule, California Public Utilities Commission -jurisdictional load serving entities would have been able to fully count resource adequacy capacity from a resource scheduled to be on outage for the entire month. To fill this gap, in 2012 the CAISO proposed its own replacement requirement,[123] which the Commission accepted.[124]

Under the CAISO replacement requirement tariff provisions,[125] the CAISO can approve resource maintenance outages from resources providing resource adequacy capacity through the outage management process if the resources provide substitute capacity. If resources do not provide substitute capacity, they can take their outages during off-peak hours or upon short notice if the outage will not detrimentally impact the

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121 *Opinion on Remaining Phase 1 Issues*, Cal. Pub. Util. Comm'n, D.06-07-031 (July 20, 2006).

122 *Decision Adopting Local Procurement Obligations for 2012 and Further Refining the Resource Adequacy Program*, Cal. Pub. Util. Comm'n, D.11-06-022 (June 23, 2011).

123 *California Independent System Operator Corporation*, Transmittal Letter, FERC Docket No. ER12-2669-000 (Sept. 20, 2012).

124 *California Independent System Operator Corporation*, 141 FERC ¶ 61,135 (2012).

125 CAISO tariff section 9.3.1.3.1.

efficient use and reliable operation of the grid. The replacement rule ensures sufficient capacity will be operationally available to operate the grid reliably and meet the load obligations of the load serving entities, while minimizing CAISO procurement of capacity through its backstop procurement mechanisms.

2. Resource Adequacy Availability Incentive Mechanism

The CAISO also implemented a resource adequacy availability incentive mechanism to help ensure resource adequacy resources remain available to meet demand.[126] In contrast to being a "pay-for-performance" program intended to incentivize compliance with dispatch instructions, the resource adequacy availability incentive mechanism incentivizes resource adequacy resources to comply with their must-offer obligations.[127] This helps ensure not only that a resource is running, but that it is also complying with its must offer obligation to submit economic bids and/or self-schedules to the CAISO's markets.[128] The resource adequacy availability incentive mechanism provisions are contained in Section 40.9 of the CAISO tariff.

Under resource adequacy availability incentive mechanism, the CAISO assesses charges (called non-availability charges) and makes payments (called availability incentive payments) based on a resource's availability each month. Specifically, resource adequacy availability incentive mechanism evaluates resources' availability based on the extent to which resources providing resource adequacy capacity meet their must offer obligations in the assessment hours applicable to generic capacity

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126 *California Independent System Operator Corporation*, 153 FERC ¶ 61,002, at P 15 (2015).

127 *Id.*

128 *Id.* at P 29.

(system and local), flexible capacity, and overlapping capacity (MW of capacity that count as both).

Resource adequacy availability incentive mechanism became financially binding on April 1, 2017. After determining that the approved formula was producing less-than-optimal and potentially problematic results, the CAISO evaluated changes to the resource adequacy availability incentive mechanism formula that would promote the primary objectives of resource adequacy availability incentive mechanism -- ensuring that resource adequacy resources comply with their must offer obligations and are available to maintain system reliability when needed or provide substitute capacity when they are not available. On January 29, 2018, CAISO filed a tariff amendment in docket number ER18-728 to revise the resource adequacy availability incentive mechanism formula. The CAISO has asked the Commission to accept the new tariff provisions effective April 1, 2018, with financially binding resource adequacy availability incentive mechanism charges and payments under the new availability methodology starting with the June 1, 2018 trading day.

Other Existing Mechanisms That Can Address Resilience

Besides the processes, programs, standards, rules, and market mechanisms described above, a robust transmission system, state energy efficiency mandates, access to imports from neighboring balancing authority areas, increasing storage levels, increasing distribution-side resources, demand response, and the Flex Alert program[129] can also help maintain a reliable and resilient system.

[129] The Flex Alert program is a voluntary energy conservation program that alerts and advises consumers about how and when to conserve energy. It is an important tool for the CAISO during periods of high demand or other stressed conditions to maintain system reliability.

Among other things, California has adopted a renewable portfolio standards that requires load-serving entities to procure 50 percent of their energy requirements from eligible renewable resources by 2030.[130] This target will likely increase in the future. Increasing renewable portfolio standards requirements will significantly increase the number of variable energy resources on the system and provides opportunities for renewable resource to obtain compensation under long-term power purchase agreements entered into with load serving entities. The California Public Utilities Commission has also adopted storage procurement targets (over 1800 MW for different types of storage) for its jurisdictional load serving entities, which provide compensation opportunities for storage resources. The CAISO is actively involved in studies assessing the use of renewables to balance and reliably operate the grid and considering the benefits of bulk storage on the grid.

Question (e): Are there any market-based constructs, operating procedures, NERC reliability standards, or planning processes that should be modified to better address resilience? If so, please describe the potential modifications.

Response to Question (e):

The CAISO is transitioning to a grid where a significant portion of the supply and services necessary to meet load and maintain reliability will be provided by variable energy resources. Effectively and efficiently integrating renewable resources, maintaining grid reliability and resilience, and addressing other challenges in a rapidly changing environment will require new/improved tools, market mechanisms, procurement standards and processes, and enhanced interregional and cross-sector

130 *See* CAISO, *FAST FACTS*, at 1 (2016), available at https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

coordination. The CAISO requests that the Commission carefully consider any future proposals and modifications to promote reliability and resilience on the CAISO system. The CAISO identifies below some areas where potential modifications are appropriate.

A. Resource Adequacy

As discussed in its response to Question III (d), the CAISO supports modifications to existing system, local, and flexible resource adequacy capacity requirements. Specifically, the CAISO supports adopting (1) multi-year procurement requirements for local area capacity (2) a revised flexible resource adequacy capacity framework to address gaps in the current framework and better align flexible capacity procurement with the CAISO's operational needs in view of changing grid conditions, and (3) using a 1-in-5 year forecast rather than a 1-in-2 year forecast to determine system resource adequacy requirements in shoulder months given the significant variability of demand in such months. These reforms are being considered in the California Public Utilities Commission's ongoing resource adequacy proceeding[131] A robust resource adequacy program is an integral component of a reliable and resilient system. Modifications can ensure that the grid remains resilient in the future and the resources the CAISO needs to maintain reliability and resilience are available to it.

B. Upcoming Market Enhancements

The CAISO is contemplating several market enhancements that can support system resilience.

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131 *See* Order Instituting Rulemaking to Oversee the Resource Adequacy Program, Consider Program Refinements, and Establish Local and Flexible Procurement Obligations for the 2019 and 2020 Compliance Years, California Public Utilities Commission docket number R.17-09-020 (Sept. 28, 2017), available at http://www.cpuc.ca.gov/proceedings/.

First, the CAISO proposes to implement Contingency Modeling Enhancements functionality to explicitly model and price the corrective capacity needed to return electrical flows to within normal limits within a specified timeframe following a transmission contingency. The enhancements will enable the market models to efficiently calculate the required amounts and locations of corrective capacity and represent the value of that capacity through a locational marginal capacity price. Explicitly modeling corrective capacity in the day-ahead and real-time markets will, among other things, ensure that the CAISO balancing authority area is optimally positioned if a contingency occurs. The CAISO intends to file a tariff amendment to implement Contingency Modeling Enhancements in the second quarter of 2018.

Second, in the Commitment Costs and Default Energy Bid Enhancements initiative the CAISO has evaluated market rules regarding supplier; bidding flexibility. The CAISO intends to file the Commitment Costs and Default Energy Bid Enhancements tariff amendments with the Commission in the second quarter of 2018. Among other changes, the CAISO will make permanent use of the next day gas commodity price from the Intercontinental Exchange price published the morning of the day-ahead process in the day-ahead market. This will ensure the CAISO calculates reference levels for mitigated resources that can accurately reflect gas-fired unit cost expectations. The amendments will also allow suppliers to request adjustments from their reference levels in day-ahead or real-time if a fundamental driver has changed such that it drives their cost expectations away from the reference level used on a routine basis. This will ensure that adjustments reasonably reflect suppliers' cost expectations. The tariff amendments will better allow suppliers to bid prices that reflect

cost expectations and business needs, particularly during stressed system conditions. By increasing the accuracy of reference level calculations, the CAISO can better: (1) support integration of renewable resources by improving its valuation of resources under uncompetitive conditions in a manner that will incent flexible resources participation during times of tight fuel supply; (2) account for costs of flexible resources (gas and non-gas fired) to reduce risk of insufficient cost recovery; and (3) encourage participation of non-resource adequacy and energy imbalance market resources.

Third, the CAISO has recently initiated a stakeholder process to consider day-ahead market enhancements. The purpose of the initiative is to improve grid reliability and efficiency of the CAISO's day-ahead market. The day-ahead market enhancements will better positon the system to accommodate net load variability. At this initial stage, the CAISO is proposing enhancements to change the day-ahead market from hourly to 15-minute granularity, combine the integrated forward market and residual unit commitment processes, and procure imbalance reserve that will have a must offer obligation to submit economic bids for the real-time market. Fifteen-minute scheduling granularity will ensure the day-ahead market commits resources with sufficient ramping capability by modeling ramping that more closely aligns with real-time conditions. With day-ahead 15-minute schedules, the real-time market must dispatch resources to address uncertainty in the day-ahead forecasts that materialize in the real-time market. Adding a new day-ahead imbalance reserve product will ensure there are sufficient real-time supply bids. Finally, optimizing the integrated forward market and residual unit commitment increases efficiency and allows CAISO market systems to optimize bid-in demand and net load forecast simultaneously.

C. Maximum Gas Constraint

As discussed in the CAISO's response to Question II (r), and the Commission accepted, a maximum gas constraint in southern California as an interim tool to mitigate the potential problems caused by the unexpected leak at the Aliso Canyon gas storage facility. This measure enables the CAISO to enforce a constraint that limits the maximum gas burn in the Southern California Gas Company and San Diego Gas & Electric Company gas regions to (1) better ensure that market dispatches are consistent with observed gas system limitations; (2) reflect these restrictions on market clearing prices, and (3) avoid further stressing the gas system, which could adversely affect electric grid reliability.

In September 2017, in docket number ER17-2568, the CAISO proposed to adopt this measure permanently and apply it to the entire market footprint. The Commission rejected the CAISO's proposal, and subsequently issued an order approving continued use of the maximum gas constraint in southern California on an interim basis through November 30, 2019.

The CAISO believes that implementing the maximum gas constraint permanently and throughout its entire footprint would be an important mechanism to promote grid reliability and resilience. Gas constraints are a better tool than Exceptional Dispatches for limiting the gas burn when gas systems are experiencing constraints than are manual exceptional dispatches, which the CAISO must rely on absent the ability to use such a constraint. Lessons the CAISO learned by applying the maximum gas constraint in southern California show that the tool can effectively be applied in other areas the CAISO operates markets to ensure the market systems produce a gas dispatch solution

that considers gas system constraints and does not aggravate them or cause a system reliability issue.

A maximum gas constraint will permit CAISO operators to enforce in the day-ahead and real-time markets constraints to limit the dispatch of generators in affected areas to a maximum gas usage if there is a limitation on the maximum amount of gas used. The constraint also limits CAISO market dispatch of affected generators in the real-time market to a maximum gas usage if there is a limitation that relates to differences between gas scheduled with the gas company and gas consumed during the operating day due to gas system imbalance limitations. The CAISO considers the maximum gas constraint to be a necessary measure to ensure the reliable operation of the electric grid within the bounds imposed on the CAISO by the operation of the natural gas system.

If known and identifiable constraints are on the natural gas system, over-dispatching resources in gas-constrained regions can negatively affect pipeline conditions, exacerbating existing gas system limitations. This could lead to significant outages or curtailments of gas-fired generating resources, thus threatening the reliability of the electric system. If the gas system experiences limitations affecting specific regions of the CAISO grid, and the CAISO market systems cannot capture those limitations through market constraints, the market could clear generation based on submitted bids and system conditions that do not account for gas-system limitations. This might occur in the real-time market even if of generators on the affected systems reflect tightened gas balancing requirements. Such dispatches could aggravate already constrained gas system conditions compromising gas reliability and resulting in gas

curtailments because gas generators cannot access gas needed to serve the electric grid reliably. If this occurs and electric generators cannot access gas to serve load and power cannot be delivered into the local area, electric curtailments will also be likely.

A maximum gas constraint would allow the CAISO to respond to gas system conditions proactively as they develop, better ensuring that market dispatches reflect actual system conditions. It is critical for both gas and electric system reliability that the CAISO have authority to be proactive and act before such occurrences to ensure the dispatch reflects the conditions on the natural gas system to the maximum extent possible.

D. Applying Protection and Control Reliability Standards to Inverter-Based Resources

Finally, the CAISO believes that NERC should clarify the applicability of the requirements of protection and control reliability standards to inverter based resources.

As discussed above, in 2016 and 2017, the CAISO experienced several disturbance events in which significant amounts of solar PV based generation ceased generating following the normal high speed clearing of high voltage (230 kV and 500 kV) transmission lines. The generation lost varied from a low of 62 MW to a high of 1178 MW. The CAISO and Southern California Edison approached WECC and NERC to initiate and facilitate an investigation. After investigation, NERC issued a report of its findings in June 2017.[132]

The report indicates, *inter alia*, that there is confusion pertaining to the applicability of NERC Standard PRC-024 to inverter-based resources. Inverter-based

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[132] The report is available at: http://www.nerc.com/news/Headlines%20DL/Inverter%20060817.pdf

resources differ significantly from conventional synchronous-based generation. Characteristics such as momentary cessation is unique to inverter-based resources. Neither Standard PRC-024 nor any other NERC Standard appear to expressly address this phenomenon.

NERC convened a task force after the report was issued in June 2017, and the task force is in the process of developing *guidelines* for non-synchronous generation. The CAISO is actively participating in this effort, and believes there should be a reliability standard clearly governing the performance of inverters used in asynchronous plants interconnected to the bulk electric system to provide essential reliability services such as frequency control, voltage control, and having the capability to acknowledge and respond to a dispatch signal from the system operator at a predefined ramp rate. As more non-synchronous resources interconnect to the bulk power system, it becomes more imperative that a national reliability standard be developed to provide uniform requirements for inverter-based resources, thus ensuring more consistent and reliable operation.

IV. CONCLUSION

The CAISO appreciates having the opportunity to inform the Commission's resilience efforts and requests that the Commission consider its responses addressing resilience. In developing any resilience strategy, the Commission must be mindful of regional differences, the need for regional flexibility, and the resilience efforts already being undertaken in the various regions.

Respectfully submitted,

By: *<u>/s/ Anthony J. Ivancovich</u>*

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CERTIFICATE OF SERVICE

I hereby certify that I have this day served the foregoing document upon each party listed on the official service list for this proceeding, in accordance with the requirements of Rule 2010 of the Commission's Rules of Practice and Procedure (18 C.F.R. § 385.2010 (2013)).

Dated at Folsom on this 9th day of March, 2018.

/s/ Anna Pascuzzo

Anna Pascuzzo