SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL℠ Company

Catalina Island Final Grid Stability Study

(09/29/2023)

I. Executive Summary

As part of its multi-year effort to modernize its aging Pebbly Beach Generating Station (PBGS) on Santa Catalina Island (Catalina), Southern California Edison (SCE) commissioned a comprehensive grid stability study to identify feasible renewable generation options that, if implemented, would enable SCE to continue to provide safe, reliable, clean, and affordable electric power to its customers on Catalina. This report summarizes the results of the analyses conducted by SCE and two consultants, POWER Engineers (POWER) and Mitsubishi Electric Power Products Inc. (MEPPI), of the viability of 22 generation scenarios. The key findings are:[1]

- A minimum of three U.S. EPA Tier 4 Final-certified (T4F) diesel generators must be present to provide resource adequacy, allow for planned maintenance activities, and supply sufficient system inertia to maintain grid stability during routine generation-to-load imbalances and unplanned outages.
- SCE must retain existing diesel generators to serve as backup units to ensure resource adequacy during planned maintenance activities overlapping with unplanned contingency events.
- The maximum annual amount of propane available for PBGS power generation (after allocation for gas utility service) will be limited to 400,000 gallons because of fire suppression regulations and with the assumption that the existing microturbines will have been replaced with a different propane technology. The current maximum amount that can be used is approximately 250,000 gallons annually[2] because of the physical and operating conditions of the aging microturbines as well as the need to cap inverter-based generation for grid stability concerns. Fire- and safety-related objections raised by the City of Avalon Fire Chief prevent increasing the amount of propane storage by using the fourth PBGS tank.[3]

[1] This report relates only to generation resource adequacy and grid stability. SCE will provide emissions estimates separately.

[2] PBGS used approximately 268,000 gallons of propane for power production in 2022. It is important to note that 200,000 gallons is more representative of typical annual propane consumption for power production because the PBGS NaS battery is generally dispatched in favor of the microturbines because it is a zero-emission resource. The amount of propane consumed in 2022 was higher because the PBGS battery was out of service for a large portion of the year, thereby allowing for the increased use of the propane-based microturbines. Achieving the target of 250,000 gallons of propane annually is largely dependent on the installation of the T4F diesel generators because their greater operating range allows for increased propane use.

[3] Letter from City of Avalon Fire Chief to SCE (09/06/2023) (attached as Exhibit K).

- If found to be feasible and commercially available in the future, propane-fueled inverter-based resources[4] could potentially supply up to approximately 14 percent of annual energy production.
- Only two of the 22 scenarios provide sufficient generation and appear to be feasible from a grid stability perspective.
- Inverter-based resources must meet or exceed requirements identified in IEEE Standard 1547-2018 and Hawaiian Electric Company's Source Requirements Document (Version 2.0) for frequency ride-through requirements[5] as well as be able to accommodate rate-of-change-of frequency (RoCoF) settings of equal to or greater than 4.1 Hz per second.
- Should solar generation be made available at the Middle Ranch site, it may be able to contribute significantly to annual energy production (particularly when paired with energy storage) reducing fossil fuel use.

This study provides critical guidance on generation scenarios SCE may be able to implement to minimize emissions and maximize renewable energy generation on Catalina. Once information becomes available regarding proposals from the Clean Energy RFO and if SCE's recommended ride-through and RoCoF requirements can be met, it may be possible to increase Catalina renewable generation up to nearly 30 percent annually and approximately 70 percent instantaneously.[6]

II. Background

Catalina is located 26 miles off the coast of Southern California. SCE's PBGS is the sole provider of electricity, water, and gas utility services for more than 4,100 residents and over one million annual tourists. Reliable electrical service is the backbone of the utility infrastructure required to provide reliable electric service promoting the safety and well-being of the residents on the island. Catalina is a unique area within SCE's electrical service territory. The island is

---

[4] The term "inverter-based resources" refers to generation resources that produce direct current (DC) and consequently require a device called an "inverter" to convert that output to the alternating current (AC) used by the U.S. grid. National Renewable Energy Laboratory (NREL), Inertia and the Power Grid: A Guide Without the Spin (05/2020) ("NREL 2020"), at p. v (available at https://www.nrel.gov/docs/fy20osti/73856.pdf); *see also* NREL, An Introduction To Inverter-Based Resources on the Bulk Power System (06/2023) (available at https://www.nerc.com/pa/Documents/2023_NERC_Guide_Inverter-Based-Resources.pdf).

[5] SCE Catalina Island Planning Criteria and Guidelines (09/2023), at pp. 4-5 (attached as Exhibit D).

[6] "Instantaneously" means that the renewable generation in total has the potential to meet 70 percent on a moment-by-moment basis and should not be confused with the annual total energy production (GWh) of 30 percent. In reference to nearly 30 percent annual renewable power production, refer to Exhibit H, Table 1, Scenario No. 4b, "Solar PV" (p. 5). In reference to the approximately 70 percent instantaneous renewable production, refer to Exhibit J, Table 3.2-2 (p. 3-6). In this bookend example of maximum renewable generation during maximum loading conditions, the sum of the renewable power production delivered to the Catalina grid from the Middle Ranch solar, USC microgrid, and Catalina Airport solar facilities is 4,350 kW. When this value is divided by the peak island load of roughly 6,000 kW, the result is 72 percent.

isolated from SCE's mainland grid and all utility services must be provided from infrastructure located on the island.

Rules implemented by the South Coast Air Quality Management District (SCAQMD) require SCE to replace the aging diesel engines at the PBGS. As part of its investigation of generation alternatives, SCE commissioned a grid stability study to determine how much renewable generation can be implemented on Catalina while maintaining a reliable and safe grid. Upgrading an existing and operational electrical system, while maintaining service to all customers, can be far more challenging than building a new system and transferring service over to it. When considering potential system scenarios, it is essential to comprehensively evaluate them to determine their feasibility in meeting the stated objectives. Part of this evaluation includes performing a series of electrical system modeling studies (i.e., grid stability studies). The consequences of the failure to evaluate these studies, or of taking shortcuts in performing them, could include the eventual construction of a project that ends up being unreliable, unsafe, or infeasible to operate in the manner necessary to meet the stated objectives.

A. Grid Stability Fundamentals

1. The Importance of Inertia

The electrical grid is a network of interconnected generation sources (such as power plants), transmission and distribution lines, and the customers who receive the generation (and often can provide their own). The North American grid is composed of four separate smaller grids known as "interconnections."[7] The generation sources within an interconnection all rotate at the same frequency, a concept called "synchronous generation." This produces inertia, or the tendency of an object in motion to remain in motion.[8] System inertia is necessary to mitigate system instability and potential system collapse (i.e., blackouts) during instances of generation-to-load mismatches which result from the loss of generation, loss of load, or sudden increases in load. Operators can rely on the energy from the spinning generators' inertia to compensate temporarily for lost generation, which affords them time to increase generation elsewhere. The amount of inertia available also depends on the grid's size. The greater the number of connected generators there are, the more inertia is produced. This provides the grid operator with more time to respond to instability events.

2. Frequency

The U.S. electrical grid uses alternating current, which means that as electric current flows from generation sources to customers, it changes direction rapidly. The term "frequency" refers to the rate of this change. For the U.S. grid, the default frequency is 60 Hertz (Hz).[9] In order to maintain a functioning grid, operators must ensure that its frequency stays as constant as possible; deviations too far below or above 60 Hz cause disruptions. In most of the mainland U.S., when grid frequency drops below 59.5 Hz, actions known as "frequency control" are taken to restore it

---

[7] NREL 2020, at pp. 2-3. Three interconnections are in the United States (Eastern, Western, and ERCOT (Texas); the fourth, Quebec, is in Canada.

[8] *Id*. at p. 2.

[9] *Id*.

to 60 Hz, such as forced load shedding (i.e., disconnecting customers) (known as an underfrequency load-shedding event, or UFLS).[10] Similarly, when grid frequency jumps above 60.5 Hz, the operator must shut down some generation to compensate.[11] In either scenario, if the required actions do not occur in time, widespread outages could result, as illustrated below:

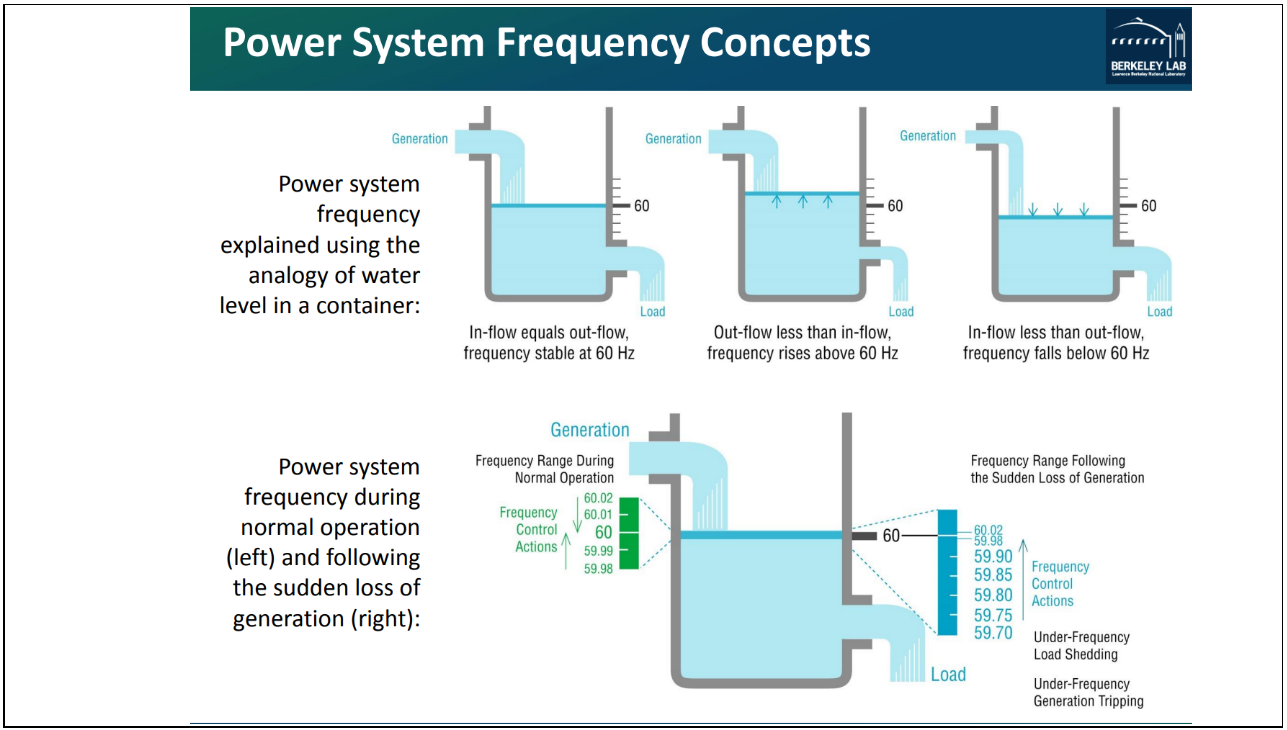


Figure 1 *(Source: Lawrence Berkeley National Laboratory)*[12]

a) Frequency Stability: RoCoF

The term "frequency stability" refers to the electrical system's ability to maintain an almost constant frequency under normal conditions and to quickly recover from any imbalances.[13] System operators use the rate of change of frequency (RoCoF) of generation resources as a means of evaluating frequency stability. Factors that affect RoCoF include the amount of inertia in a system, how quickly generation equipment can respond to a contingency event (e.g., an unplanned outage of a generation resource), the magnitude of the response, and the size of the contingency.[14] Each

---

[10] International Renewable Energy Agency, Transforming Small-Island Power Systems (2018), §§ 1.3 (available at Transforming small-island power systems (irena.org)).

[11] NREL 2020 at p. 4.

[12] Lawrence Berkeley National Laboratory, BNL's Frequency Response Study for FERC (available at https://www.energy.gov/sites/prod/files/2018/07/f53/2.1.1%20Frequency%20Response%20Panel%20-%20Eto%2C%20LBNL_1.pdf).

[13] *Id*. at p. 2.

[14] North American Electric Reliability Corporation (NERC), Fast Frequency Response Concepts and Bulk Power System Reliability Needs (03/2020), at p. iv (available at https://www.nerc.com/comm/PC/InverterBased%20Resource%20Performance%20Task%20Force%20IRPT/Fast_Frequency_Response_Concepts_and_BPS_Reliability_Needs_White_Paper.pdf).

of these characteristics were included in the system modeling performed in the grid stability studies.

b) Primary Frequency Response

The term "primary frequency response" (PFR) refers to a system's ability to react or respond to a change in system frequency.[15] A form of "cruise control," it can be accomplished mechanically inside a power plant via control devices that can speed up or slow down individual generators as needed.[16] The following figure illustrates a system recovering from a contingency event:

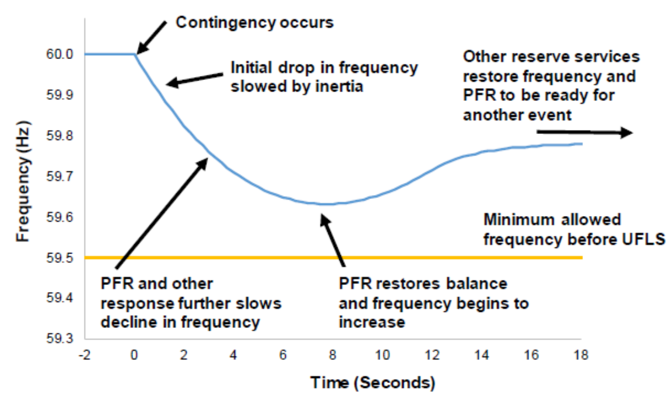


Figure 4. A successful recovery from a contingency event

Figure 2 *(Source: NREL)*[17]

The X axis of the graph depicts the passage of time in seconds and the Y axis depicts the change in frequency. The orange line represents the minimum frequency threshold to avoid UFLS. Before the contingency event occurs, frequency is stable at 60 Hz. At zero seconds, the contingency event occurs and frequency begins to drop; after eight seconds, it reaches a nadir of approximately 59.6 Hz. During the first eight seconds of the contingency event, PFR (i.e., inertia provided by the remaining generators) slows the decline in frequency, avoiding the threshold that would trigger UFLS. At this point, the system operators engage other reserve services to restore balance and increase frequency back towards 60 Hz.

---

[15] NERC Glossary of Terms (available at https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf).

[16] NREL 2020 at p. 5.

[17] *Id*. at p. 7.

The following factors contribute to frequency stability:

Factor	Impact of Greater Amount[a]
Generator inertia	Slows down frequency decline
Load inertia and load damping	Slows down frequency decline
Contingency size	Increases frequency decline
Underfrequency limits (UFLS settings)	Lower UFLS settings provides more time for overall response
Frequency response speed	Responds faster to a decline in frequency
[a] Assumes no other factors change	

Figure 3 *(Source: NREL)*[18]

The first factor listed in Figure 4, generator inertia, is described above (section II.A.1.). The second factor, load inertia/load damping, results from the tendency of some motors to continue spinning even after the electricity supply is terminated. This reduces load, which in turn reduces the frequency decline that otherwise is inevitable after loss of generation. The third factor is contingency size; the larger the contingency, the faster the frequency drops. The fourth factor relates to the relevant underfrequency limit in a particular system, which is the point at which circuit breakers will initiate load shedding. In Figure 3 above, the UFLS limit is set at 59.5 Hz. Reducing that limit even slightly allows the system operator more time to respond to a contingency and try to keep the frequency level from dipping below the UFLS limit. The final factor, frequency response speed, is the rate at which remaining online generation can temporarily increase its output to arrest the decline in frequency while other generation resources can be brought online to compensate for the contingency.

B. Electrical System Planning

1. *Resource Adequacy*

When assembling a generation resource portfolio, it is essential to ensure that enough power is available constantly to meet demand. The term "resource adequacy" refers to the evaluation of available resources that includes regularly planned generator maintenance downtime and accounts for contingency events where a generation resource is unexpectedly offline.[19] This is especially important in an isolated grid like Catalina. Studies are performed to evaluate the adequacy of generation to meet load requirements during all hours of the year for both planned and unplanned outages of generation units. Outages of generation units can occur simultaneously or overlap (e.g., one unit can be offline for planned maintenance and then a concurrent unplanned outage of an additional unit occurs)."[20]

---

[18] *Id*.

[19] NERC defines "adequacy" as "The ability of the electric system to supply the aggregate electrical demand and energy requirements of the end-use customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements." NERC Glossary of Terms, *supra* note 15. *See also* California Independent System Operator, Resource Adequacy: The Need for Sufficient Energy Supplies (available at https://www.caiso.com/Documents/Resource-Adequacy-Fact-Sheet.pdf).

[20] SCE Catalina Island Planning Criteria and Guidelines (09/2023), at pp. 4-5 (attached as Exhibit D).

SCE's planning criteria account for the required redundancy of generating units, which is expressed as follows: the letter N represents the number of online and operational generating units required to meet load requirements at any given time. The redundancy is expressed by adding numbers to N. For example, in an N+1 scenario, there is enough generation to cover demand when the largest generation unit is offline. In an N+2 scenario, there is enough generation to cover demand when the two largest generation units are offline.

2. Operating Reserve

The term "operating reserve" refers to surplus operating capacity that can instantly respond to a sudden increase in electric load or a sudden decrease in generation output. Operating reserve provides a safety margin that helps ensure reliable electricity supply despite variability in the electric load and renewable power supply. In the context of this document, the term "operating reserve" is used to reflect both the reserve of online synchronous generators (i.e., diesel generators) as well as that of any frequency-responsive inverter-based resources (e.g., grid-following energy storage).[21]

C. System Protection

SCE monitors and manages grid stability by using protection devices that sense, control, and isolate problems. Sensing devices (e.g., voltage transformers and current transformers) monitor electrical system parameters such as voltage, current, and frequency. Control devices (e.g., relays) receive input from the sensing devices and based on the programmed settings, act when a parameter is exceeded by sending a signal to a sectionalizing device. When a sectionalizing device (e.g., circuit breaker) receives a signal, it opens or closes depending on the intended operation. Coordinated protection from generation to the end-of-line of the distribution circuits is essential to minimize power system disruptions and to quickly de-energize electrical facilities for public safety during fault conditions.

D. Special Considerations

1. Island Systems

SCE developed unique standards for Catalina due to its isolation from the mainland grid.[22] Unlike the mainland, on Catalina a single generator or single load feeder can amount to approximately 40 percent of the total load connected to the system. The operation, protection, and control of the Catalina Island power system must recognize that events such as the tripping offline of a generator or a load feeder will commonly cause more severe deviations in voltage and frequency than are seen in large, interconnected mainland power systems. Of particular concern for islanded power systems is maintaining frequency stability following relatively large steps in generation and load (e.g., loss of a generator, loss of a load feeder, or the startup of large motors/load blocks). To maintain frequency stability, the power system needs sufficient primary

[21] *Id*. at p. 5.

[22] *Id*. at p. 3.

frequency response to arrest the deviation in frequency before the widespread loss of generation or load can occur.[23]

2. *Inverter-Based Resources*

Unlike synchronous generators, alternative energy sources such as wind, solar photovoltaic (solar PV), and battery storage lack inherent inertia. Known as "inverter-based resources," their use in large quantities can cause inertia to decline, as illustrated below:

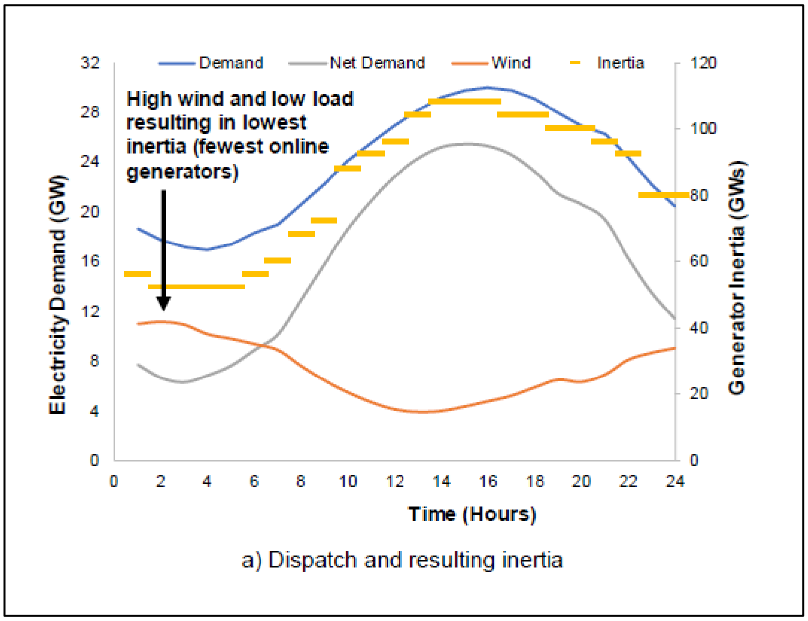


Figure 4 *(Source: NREL)*[24]

System operators mitigate this tendency by using newer electronic-based PFR mechanisms; if customers voluntarily agree to forced load-shedding to compensate for the lower inertia generated by inverter-based alternative energy sources, the system operator can use electronic sensors to accomplish this quickly. This practice is known as "load response." Reducing UFLS settings can buy more time for system operators to find alternative generation to compensate during contingency events, as described above (section II.A.2.b.).[25] For the purposes of the system stability studies described below (section III), any new inverter-based resources located at PBGS were assumed to be grid-forming.[26]

[23] *Id*. at pp. 7-8.

[24] *Id*. at p. 20.

[25] *Id.* at pp. 26-27.

[26] Grid-forming inverters can operate independently of the main electrical grid and can provide voltage and frequency support to the grid. *See* https://energycentral.com/c/iu/grid-forming-vs-grid-following.

III. SCE's Grid Stability Study Process

To perform the grid stability studies (also described as system stability studies), SCE contracted with POWER and MEPPI due to their experience working with islanded power systems and performing grid stability studies. The studies are extensive and include evaluating generation dispatch, resource adequacy, protection, and system stability. Various industry-accepted software programs were used to model the electrical distribution system (e.g., the distribution circuits) and the potential generation scenarios including resources within PBGS as well as those that may be considered elsewhere on Catalina.

A. Summary of Studies

1. July 2022: SCE PBGS Action Plan

SCE's initial efforts to evaluate grid stability focused on its current practice of limiting inverter-based generation (from the microturbines and battery) to the greater of approximately 30 percent of total generation output or up to the amount of operating reserve of the online diesel units.[27] This limit is necessary because the microturbines' protection relays (which detect electric fault events by measuring RoCoF) are set at 1 Hz per second. This means that if the relays detect a frequency change at a rate greater than 1 Hz per second, they will force the microturbines to cease generating as a self-protection mechanism. Such frequency changes can be caused by sudden spikes in load (such as when a large motor load starts up at the Catalina rock quarry). SCE's July 2022 report affirmed the appropriateness of the 30 percent limit on inverter-based resources at PBGS because the microturbines' protection settings could not be adjusted without violating the Underwriters Laboratories (UL) 1741 standard.

2. September 2022: Initial System Stability Study

In its next study, SCE evaluated possible ways to increase the 30 percent limit on inverter-based resources by testing different forms of grid-stability mitigation.[28] The analysis concluded that frequency stability was not linked to the amount of microturbine generation, but rather to the amount of inertia on the system (provided by the diesel generators).[29] SCE evaluated whether improved controls on the microturbines would increase grid stability and concluded they would not.

[27] SCE, Pebbly Beach Alternatives Study: Revised Final Action Plan (07/14/2022), at 16-17 (attached as Exhibit A).

[28] SCE & POWER Engineers, Pebbly Beach Generating Station: System Stability Study (09/30/2022) (attached as Exhibit C).

[29] *Id*. at p. 15.

3. September 2023: Final System Stability Study

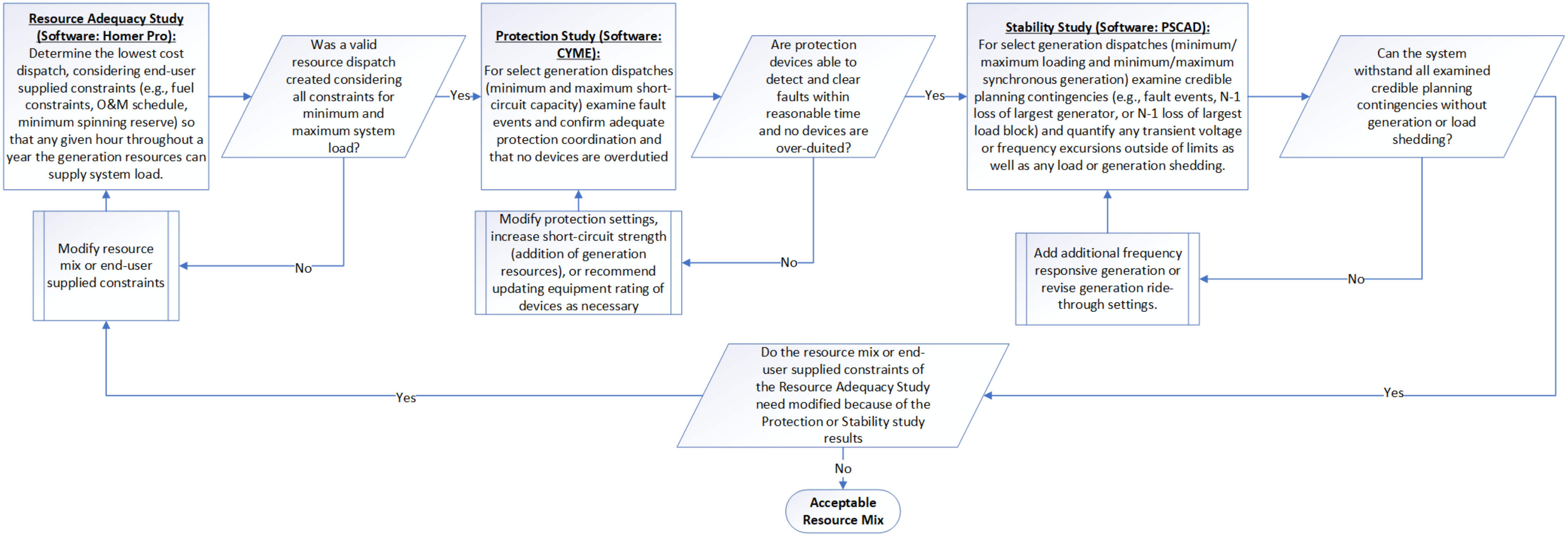
In 2023, SCE worked with POWER and MEPPI on a comprehensive, multiphase study of the feasibility of future generation scenarios and their resulting impact on grid stability.[30] The software program HOMER Pro was used to model generation resource dispatch on an hourly time-series basis. This program models generation output to meet electrical demand to determine resource adequacy and fuel consumption, factoring in required maintenance times and contingency events that take generation resources offline. Another software program, CYME, was used to evaluate distribution circuitry for load flow and protection coordination. Load flow and short-circuit studies were performed at selected instantaneous moments in time to reflect various system stress conditions. The results demonstrate how various proposed generation scenarios would affect the existing distribution circuitry and whether upgrades would be required. Finally, the software program PSCAD was used to evaluate the proposed generation scenarios to determine impacts on the system stability during contingency events (e.g., unplanned outages of either a generation resource or a distribution load). These studies were performed at selected instantaneous moments in time to reflect various system stress conditions.

The evaluation process was iterative and includes a feedback loop, which allows refinements in the parameters if a scenario fails to meet one or more input constraints (e.g., fuel consumption, protection, stability, etc.). The initial phase of the grid stability studies evaluated proposed generation scenarios using HOMER Pro to screen out any scenarios that cannot meet resource adequacy. For those scenarios initially determined feasible through the HOMER Pro analysis, PSCAD was then used to study system stability only within PBGS (i.e., within the plant and excluding contingency events occurring on the distribution circuits).

Scenarios identified as being feasible were then assessed through CYME. This phase of the study evaluated the performance of the protection devices both at PBGS and along the distribution circuitry. Through the CYME assessments, any areas of concern were identified (e.g., if inadequate short-circuit current adversely affected the ability to detect and isolate fault conditions or miscoordination between protection devices). At this point, scenarios with areas of concern were evaluated to determine whether refinements were possible (e.g., modifying the generation resource mix to provide more short-circuit current, adjusting the relay settings of protection devices, or replacing protection devices). In the case of modifying the generation resource mix, this included reassessing the scenario within HOMER Pro and adjusting the dispatch. Once adjustments were made, and if the scenarios successfully passed the HOMER Pro analysis again, the scenarios followed a similar path of study as before and were reevaluated with CYME to determine if original issues had been remedied. Scenarios determined to be feasible through the aforementioned analyses were again studied using PSCAD, but this time assessing contingency events occurring on the distribution circuitry using an island-wide model of the electrical system (i.e., both PBGS and distribution circuitry). The study process can be depicted visually as follows:

---

[30] The study built on an April 2023 report by SCE and POWER that evaluated two scenarios: (A) three T4F units, Units 7, 12, and 14 as backup only, the existing PBGS battery, and the existing microturbines; and (B) two T4F units, Units 7, 12, and 14 as backup only, and one 2.097 MW prime-rated propane reciprocating generator. The report concluded that Scenario A was feasible but not recommended due to lack of redundancy and that Scenario B was infeasible. SCE & POWER, PBGS Technical Assessment: Configurations A and B Report (04/28/2023) (see Exhibit B, Letter from SCE to SCAQMD (attaching the report as Exhibit C).


Resource Adequacy Study (Software: Homer Pro):
Determine the lowest cost dispatch, considering end-user supplied constraints (e.g., fuel constraints, O&M schedule, minimum spinning reserve) so that any given hour throughout a year the generation resources can supply system load.
Was a valid resource dispatch created considering all constraints for minimum and maximum system load?
Yes
No
Modify resource mix or end-user supplied constraints
Protection Study (Software: CYME):
For select generation dispatches (minimum and maximum short-circuit capacity) examine fault events and confirm adequate protection coordination and that no devices are overdutied
Are protection devices able to detect and clear faults within reasonable time and no devices are over-duited?
Yes
No
Modify protection settings, increase short-circuit strength (addition of generation resources), or recommend updating equipment rating of devices as necessary
Stability Study (Software: PSCAD):
For select generation dispatches (minimum/maximum loading and minimum/maximum synchronous generation) examine credible planning contingencies (e.g., fault events, N-1 loss of largest generator, or N-1 loss of largest load block) and quantify any transient voltage or frequency excursions outside of limits as well as any load or generation shedding.
Can the system withstand all examined credible planning contingencies without generation or load shedding?
No
Add additional frequency responsive generation or revise generation ride-through settings.
Yes
Do the resource mix or end-user supplied constraints of the Resource Adequacy Study need modified because of the Protection or Stability study results
Yes
No
Acceptable Resource Mix

B. September 29, 2023 System Stability Final Study Results

1. *HOMER Pro Analysis*

a) Explanation

HOMER Pro evaluates system resource adequacy; in other words, whether a configuration provides sufficient generation supply to meet electrical demand. As an example, when a generation scenario successfully passes the HOMER Pro stage, the program produces a table displaying the relative share of generation that each element of the scenario provided along with the number of gallons of fuel consumed by each fuel type as shown below:

SCENARIO 3			
DG Unit 7	106,442.42	Diesel	3.82%
DG Unit 12	10,159.78	Diesel	0.37%
DG Unit 14	65,499.46	Diesel	2.35%
T4F Unit A	451,745.98	Diesel	18.90%
T4F Unit B	908,039.62	Diesel	41.70%
T4F Unit C	426,766.30	Diesel	18.80%
Linear Generator	399,999.86	Propane	14.10%

Figure 5: *HOMER Pro Result for Scenario 3 (Source: Exhibit H)*

In contrast, when a scenario cannot provide sufficient generation, HOMER Pro produces an error message as shown below:

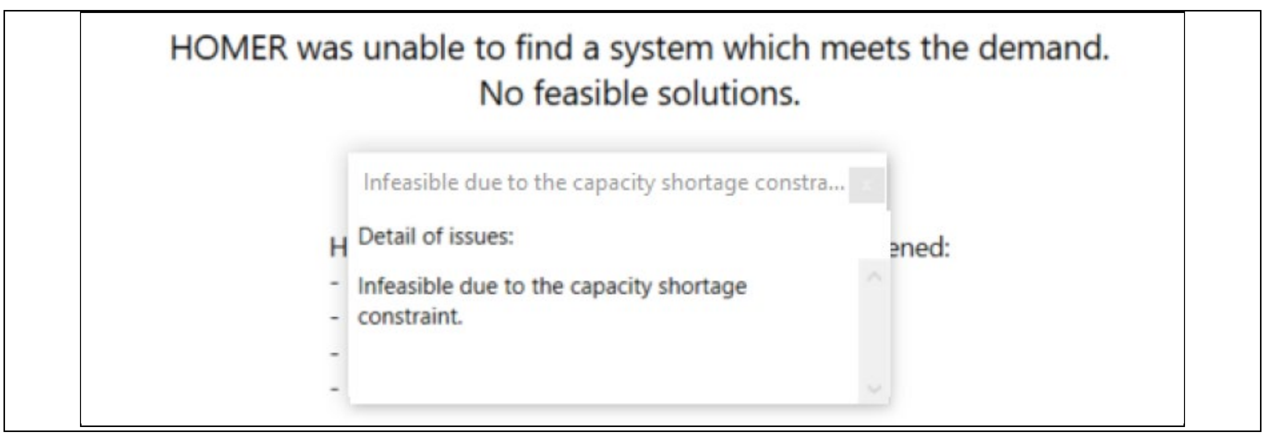


Figure 6: *HOMER Pro Result for SCAQMD Scenario 1 (Source: Exhibit F)*

b) SCE Scenarios

SCE identified 20 different scenarios that included a mix of T4F diesel generators, solar, battery storage, and propane technology.[31] Each scenario listed below included the following elements:

- Three T4F diesel generators; and
- Retain Units 7, 12, and 14 as backup generation.

POWER included numerous assumptions when performing the HOMER Pro analyses, the most important of which are:

- Load demand forecasted data for 2026 reflecting a peak of 6 MW and approximately 31 GWh annual loading;
- One T4F diesel unit receiving one three-month-long maintenance outage;
- Two T4F diesel units each receiving one month-long maintenance outage; and
- One biweekly planned maintenance activity per T4F diesel unit with 10 hours of downtime.

(1) Scenarios Evaluated Using HOMER Pro

Eight scenarios were considered in the HOMER Pro evaluation. The following chart provides a high-level summary of the differences between the scenarios (a detailed version is included in Exhibit H):

[31] Detailed explanations of the scenarios are provided in Exhibits F (the SCAQMD's scenarios) and G (SCE's scenarios).

#	Details	Outcome
1	• Retain existing battery at PBGS • One 2.097 MW prime-rated propane reciprocating generator (with 400,000-gallon annual supply)	Completed HOMER but excluded from further analysis
2	• Retain existing battery at PBGS • One 2.097 MW prime-rated propane reciprocating generator (with 400,000-gallon annual supply) • Solar farm (no battery)	Modified and rerun as No. 2(a)
2a	• Retain existing battery at PBGS • One 2.097 MW prime-rated propane reciprocating generator (with 400,000-gallon annual supply) • Solar farm with battery	Modified and rerun as No. 2(b)
2b	• Upgrade battery at PBGS • One 2.097 MW prime-rated propane reciprocating generator (with 400,000-gallon annual supply) • Solar farm with battery	Completed HOMER but excluded from further analysis
3	• Retain existing battery at PBGS • Five 250 kW propane linear generators (with 400,000-gallon annual supply)	Completed HOMER and advanced to PSCAD & CYME analysis
4	• Retain existing battery at PBGS • Five 250 kW propane linear generators (with 400,000-gallon annual supply) • Solar farm (no battery)	Modified and rerun as No. 4(a)
4a	• Retain existing battery at PBGS • Five 250 kW propane linear generators (with 400,000-gallon annual supply) • Solar farm with battery	Modified and rerun as No. 4(b)
4b	• Upgrade battery at PBGS • Five 250 kW propane linear generators (with 400,000-gallon annual supply) • Solar farm with battery	Completed HOMER and advanced to PSCAD & CYME analysis

Although Scenario Nos. 1 and 2(b) passed HOMER Pro analysis, they were not carried forward to the stability and protection study stage. One of SCE's overarching priorities is to maximize the use of near-zero emission and zero-emission technologies while meeting our obligation to provide safe, reliable, and affordable utility services to customers. As a result, higher priority was given to the propane-fueled technology that provided the greatest potential to maximize propane fuel use while also providing the greatest operational flexibility in generation dispatch. The key consideration associated with the selection of propane linear generators for further grid stability modeling is that the propane reciprocating generator would have an operating range of between 75 and 100 percent of its prime output rating of 2.097 MW (where this is the derated value due to propane fuel use). This equates to an operating range of 1.573 MW to 2.097 MW and leads to many instances where the minimum loading of the propane reciprocating generator would be greater than the needed capacity and therefore would not be dispatched. This would hamstring SCE's ability to maximize the use of propane. In contrast, with respect to the propane linear generators, the smaller unit size and consequential ability to dispatch any number of units results in a much greater and more flexible operating range (between the minimum output of a single unit up through the maximum output of 1.25 MW) that would allow operators to bring the linear generators online as needed in smaller increments. While these grid stability studies included linear generators in the models for evaluation, it is noted that this technology (specifically the 250 kW grid-forming model) is nascent and still evolving. Currently, none have been permitted for use by SCAQMD and none have been commercially deployed.

Of the scenarios that passed the HOMER Pro analysis stage, only two provided sufficient generation and maximized propane use to warrant PSCAD and CYME modeling (grid stability and protection studies). Both scenarios share the following elements:

- Three T4F generators (replacing existing Units 8, 10, and 15);
- Retain Units 7, 12, and 14 as backup generation;[32] and
- Five 250 kW propane linear generators (with 400,000-gallon annual supply).

The remaining elements of the two successful scenarios differ as follows:

The remaining elements of the two successful scenarios differ as follows: **Scenario 3**	**Scenario 4(b)**
• Retain existing battery at PBGS	• Upgrade existing battery at PBGS • Solar farm with battery

Scenario Nos. 3 and 4(b) were carried forward for PSCAD/CYME analysis.

(2) Scenarios Eliminated Without HOMER Pro Analysis

After an initial screening, 12 scenarios were removed from further consideration because they were found to be infeasible. Of the 12 scenarios, eight scenarios[33] were removed because they included a quantity of annual propane use that SCE learned would be impossible to accommodate because the City of Avalon Fire Chief stated that use of the fourth storage tank at PBGS would not be allowed for public safety/fire-suppression reasons. Four other scenarios were removed because one included a propane reciprocating engine (dismissed in favor of the greater operational flexibility of the propane linear generators) and the other three either had no solar farm or a solar farm but without paired energy storage. This allowed POWER and MEPPI to then focus on completing the two newly proposed HOMER Pro scenarios imposed by the SCAQMD Hearing Board[34] by the August 29, 2023 deadline, as well as analysis of Scenario 3 and 4(b) by the September 29, 2023 extended deadline.

[32] Units 7, 12, and 14 each have distinct power production output values that, when coupled with their operating ranges, allow PBGS operators flexibility to dispatch the units when needed. SCE recommends retaining all three units to optimize dispatch to meet electrical demand and minimize emissions from operation of the backup units.

[33] Scenarios 5, 6, 7, 8, 13, 14, 15, and 16.

[34] SCAQMD Hearing Board, Order of Abatement (07/25/2023), Condition No. 4 (p. 11).

#	Details	Outcome
5	• Retain existing battery at PBGS • One 2.097 MW prime-rated propane reciprocating generator (with 750,000-gallon annual supply)	Eliminated
6	• Retain existing battery at PBGS • One 2.097 MW prime-rated propane reciprocating generator (with 750,000-gallon annual supply) • Solar farm (no battery)	Eliminated
7	• Retain existing battery at PBGS • Five 250 kW propane linear generators (with 750,000-gallon annual supply)	Eliminated
8	• Retain existing battery at PBGS • Five 250 kW propane linear generators (with 750,000-gallon annual supply) • Solar farm (no battery)	Eliminated
9	• Upgrade battery at PBGS • One 2.097 MW prime-rated propane reciprocating generator (with 400,000-gallon annual supply)	Eliminated
10	• Upgrade battery at PBGS • One 2.097 MW prime-rated propane reciprocating generator (with 400,000-gallon annual supply) • Solar farm (no battery)	Eliminated
11	• Upgrade battery at PBGS • Five 250 kW propane linear generators (with 400,000-gallon annual supply)	Eliminated
12	• Upgrade battery at PBGS • Five 250 kW propane linear generators (with 400,000-gallon annual supply) • Solar farm (no battery)	Eliminated
13	• Upgrade battery at PBGS • One 2.097 MW prime-rated propane reciprocating generator (with 750,000-gallon annual supply)	Eliminated
14	• Upgrade battery at PBGS • One 2.097 MW prime-rated propane reciprocating generator (with 750,000-gallon annual supply) • Solar farm (no battery)	Eliminated
15	• Upgrade battery at PBGS • Five 250 kW propane linear generators (with 750,000-gallon annual supply)	Eliminated
16	• Upgrade battery at PBGS • Five 250 kW propane linear generators (with 750,000-gallon annual supply) • Solar farm (no battery)	Eliminated

2. SCAQMD-Proposed Scenarios

SCE evaluated two additional scenarios proposed by the SCAQMD staff. Both scenarios share the following assumptions:

- 10% minimum charge on the existing battery system (NaS BESS);
- Load demand forecasted data for 2026 reflecting a peak of 6 megawatts (MW) and approximately 31 gigawatt-hours (GWh) annual loading;
- Existing NaS BESS modeled as 1 MW/7 megawatt-hours (MWh) with a round-trip efficiency of 85%;
- Annual consumption of 500,000 gallons of diesel;
- Annual consumption of 2.1 million gallons of propane; and
- No minimum spinning reserve requirement.

SCAQMD Scenario 1 contains the following elements:

- Utility-scale renewable PV system (30% of annual load);
- Three U.S. EPA Tier 4 Final-certified (T4F) diesel generators (1.825 MW each);
- Existing NaS BESS;
- Five new BESS (1 MW each); and
- Propane near-zero-emission (NZE) technology with a combined rating of at least 2.25 MW (65% of annual load).

SCAQMD Scenario 2 contains the following elements:

- Utility-scale renewable PV system (30% of annual load);
- Three T4F diesel generators (1.825 MW each);
- Existing NaS BESS;
- Five new BESS (1 MW each); and Propane NZE technology with a combined rating of at least 2 MW (50% of annual load).

POWER included the following additional assumptions:

- One T4F diesel unit receiving one three-month-long maintenance outage;
- Two T4F diesel units each receiving one month-long maintenance outage; and
- One biweekly planned maintenance activity per T4F diesel unit with 10 hours of downtime.

The BESS was modeled in aggregate as a 6 MW/27 MWh system (i.e., the existing PBGS NaS BESS at 1 MW/7 MWh plus a renewable solar PV system paired with a BESS at 5 MW/20

MWh). After the parameters for SCAQMD Scenario 1 were entered into HOMER Pro, the program provided the output message shown below:

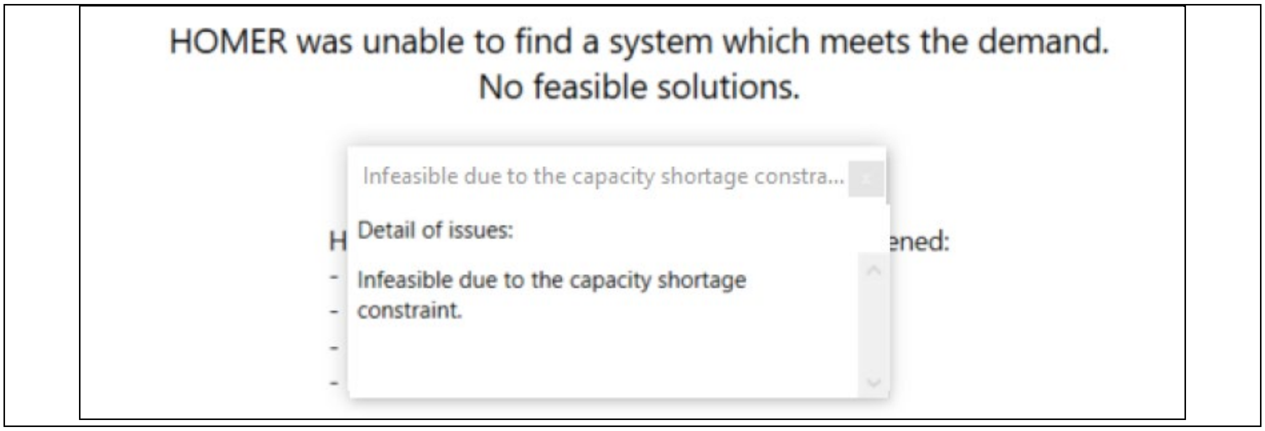


Figure 7: *HOMER Pro Output for SCAQMD Scenario 1 (Source: Exhibit F)*

The HOMER Pro results depicted in Figure 8 indicate that SCAQMD Scenario 1 is infeasible because it fails to provide sufficient capacity to meet all electrical demand at all hours throughout the year. SCAQMD Scenario 2 differs from SCAQMD Scenario 1 by a 250 kW reduction in the generating capacity of the propane NZE technology. Because SCAQMD Scenario 2 provides less generation output capacity than Scenario 1, it also fails to meet demand. Simply put, neither proposed SCAQMD Scenario can meet Catalina's electrical demand requirements at every hour throughout the year.

In order to determine whether the failure to pass the HOMER Pro analysis was due to the propane fuel availability parameters identified in the SCAQMD's proposed scenarios, POWER revised the model to allow the consumption of an unlimited amount of propane before rerunning the first scenario. Again, the outcome was reported as infeasible. SCAQMD Scenario 2 had the same result (failure) because, as mentioned above, it provides less generation output capacity than SCAQMD Scenario 1. Even when all constraints on fuel consumption parameters for both propane and diesel are removed (allowing unlimited consumption), neither scenario would provide the necessary generation resource adequacy to ensure sufficient power supply to meet the requirements of Catalina's customers. This indicates the failure of these two scenarios is due to the lack of generation output capacity rather than fuel availability.

The purpose of modeling generation scenarios using software such as HOMER Pro is to determine whether they will meet the resource adequacy requirements of the electrical system being studied (e.g., Catalina). When an analysis produces a result that demonstrates a scenario is cannot supply the amount of generation required, the consequences (should such a scenario be implemented) can include the following at every instance when a deficiency is identified:

- Required forced load shedding of customer demand to reduce consumption to within the limits of the generation resource mix contemplated; or
- System instability resulting in system collapse (i.e., island blackout) if the aforementioned load shedding does not occur or does not occur quickly enough.

The results from the HOMER Pro analysis of SCAQMD Scenario 1 identified more than 1,000 instances where it was unable to supply the amount of generation required to meet customer demand. The analysis was performed on an hourly basis throughout the year (i.e., all 8,760 hours in one year); the number of instances in which there was insufficient power to supply Catalina customers equates to over 10 percent of the time annually. SCAQMD Scenario 2, which has 250 kW less generation capacity than SCAQMD Scenario 1, is expected to cause even more instances where the system would be unable to supply the amount of generation required to meet customer demand.

The HOMER Pro program evaluates system resource adequacy only and does not reflect system stability issues that may result from insufficient system inertia. System stability was analyzed in the next phase of the study (using software designed for evaluating stability and protection) for those scenarios that pass the HOMER Pro stage. Therefore, only if either scenario above passed the HOMER Pro stage would a PSCAD/CYME system stability and protection analysis be appropriate. Because they failed, no further analysis was conducted of these two scenarios.

C. Conclusions from the HOMER Pro Analysis

Two scenarios advanced to the system stability and protection study phase: Nos. 3 and 4(b). Each scenario requires the installation of three new T4F units as well as keeping Units 7, 12, and 14 as backup generators.

D. Stability & Protection Studies

POWER and MEPPI conducted separate PSCAD analyses of SCE Scenarios Nos. 3 and 4(b). MEPPI also investigated whether under either scenario, and under bookend system dispatches,[35] the Catalina grid could withstand credible planning contingencies without frequency excursions outside the system's operating limits or that triggered significant shedding of generation or load. MEPPI also confirmed that under bookend system dispatches, Catalina's existing protection scheme can adequately detect and clear fault events while remaining within the protective devices' short-circuit rating.

1. POWER: PSCAD Stability Study

To evaluate system stability, POWER measured the RoCoF on the grid from consistent disturbances under different generation dispatches for SCE Scenario Nos. 3 and 4(b). POWER reached four conclusions:

- Having more Tier 4 Final (T4F) units online and powering the system leads to increased system stability.
- The stability benefits of the T4F units are based upon the number of units online regardless of loading levels.

[35] The term "bookend" means that MEPPI studied the minimum and maximum loading and minimum and maximum synchronous generation.

- An inverter-based resource responds more quickly to system disturbances to improve RoCoF than the governor response of a synchronous generator, although the extent is reduced by BESS state-of-charge constraints and limits to fault current contribution.
- Linear generators showed similar improvement in RoCoF to that of adding a second T4F diesel generator. Constraints on propane linear generators include insufficient fuel storage and the lack of proven commercial performance.[36]

Based on the RoCoF levels observed, POWER recommended that SCE operate two T4F generators at all times to maintain sufficient frequency stability. This means that installing a third T4F generator is necessary so that it is available when either of the other two are offline for maintenance or experience an outage. As soon as one of the two T4F generators in operation becomes unavailable, SCE must start up the third T4F unit immediately to prevent load-shedding and/or to maintain system stability. In recognition that each T4F must undergo regular maintenance, during which time it is unavailable for operation, POWER recommends that SCE retain backup diesel generation to replace the unavailable T4F generator.

2. MEPPI: Stability & Protective Device Coordination Studies

MEPPI's study evaluated whether the Catalina grid could successfully handle SCE Scenario Nos. 3 and 4(b) while avoiding any frequency excursions that either exceed the system's limits or would trigger load-shedding.[37] MEPPI analyzed the scenarios' performance when one generating unit (T4F or linear generator) was unavailable due to an outage. MEPPI concluded that two T4F diesel generators must be in operation at all times to provide sufficient inertia and frequency responsive operating reserves. MEPPI also found that custom voltage and frequency ride-through requirements were necessary to avoid unintentional shedding of generation or load during such an outage.[38] The RoCoF exceeded the IEEE Standard 1547-2018 Category III requirement (of 3 Hz) and the frequency nadir dropped below the IEEE Standard 1547-2018 Category III minimum (of 57 Hz). Consequently, SCE will need to incorporate these limits into its frequency ride-through requirements.[39] MEPPI also confirmed that under bookend system dispatches, Catalina's existing protection scheme can adequately detect and clear fault events while remaining within the protective devices' short-circuit rating.

---

[36] POWER Engineers, Southern California Edison: Pebbly Beach Generating Station PSCAD Stability Study at p. 1 (09/27/2023) (attached as Exhibit I).

[37] MEPPI's work was limited by the lack of as-built models for the Cummins TF4 generators and future Middle Ranch solar farm and thus relied on a set of generic, reasonable assumptions.

[38] MEPPI, Southern California Edison: Stability and Protection Device Studies – Catalina (09/2023) (attached as Exhibit J).

[39] *Id*. at p. 3-10, pp. 3-13 to 3-14.

IV. Conclusion

With the conclusion of the HOMER Pro, PSCAD, and CYME evaluations, SCE has completed its comprehensive grid stability study and identified feasible generation scenarios that, if implemented, would enable SCE to continue to provide safe, reliable, clean, and affordable electric power to Catalina. The two feasible scenarios that passed the generation resource adequacy, system stability, and protection reviews both include three T4F generators (replacing existing Units 8, 10, and 15); retaining Units 7, 12, and 14 as backup generation; and five 250 kW grid-following propane linear generators[40] (with a 400,000-gallon annual supply). The two scenarios differ in that one would retain the existing PBGS battery (No. 3), while the other includes an upgraded PBGS battery and a solar farm at Middle Ranch paired with energy storage (No. 4(b)).

Upon SCE's receipt of additional information from Cummins relevant to the governor and excitation models of the T4F diesel units, refinements will be made to the CYME and PSCAD studies to identify whether any upgrades to protection devices and/or settings changes may be required. These anticipated refinements are not expected to change the results of the HOMER Pro, PSCAD, and CYME evaluations. The study confirmed the need to install three new T4F diesel generators and to retain three existing diesel units (Units 7, 12, and 14) as backup generators for use only when the new T4F generators are unavailable due to planned or unplanned outages.

SCE will incorporate the study conclusions into the ride-through requirements for future inverter-based resources such as the proposed Middle Ranch solar farm. Additionally, any proposed generation resources that would interconnect to the distribution system outside of PBGS would require power flow studies to determine any necessary distribution system upgrades to accommodate the interconnection(s), as well as stability studies to determine any grid impacts. Finally, SCE will continue to monitor the development and deployment of linear generators (and other grid-forming, propane-fueled inverter-based resources) to see whether the technology matures to the point where it has been demonstrated, in practice, that its use is feasible for power generation and complies with future emissions limits that may be imposed.

[40] Although the two scenarios were identified as being feasible, both included 250 kW grid-forming linear generators. This is evolving technology; to SCE's knowledge, none have been either permitted for use by SCAQMD or commercially deployed.

Exhibits

A. SCE, PBGS Action Plan (07/14/2022)

B. Letter from SCE to SCAQMD (04/28/2023), Exhibit C: PBGS Technical Assessment: Configurations A and B Report

C. SCE and POWER Engineers, System Stability Study (09/30/2022)

D. SCE, Catalina Island Planning Criteria and Guidelines (09/2023)

E. SCE, Grid Stability Study Explanation (08/08/2023)

F. Letter from SCE to SCAQMD (08/30/2023)

G. SCE, Grid Stability Scenarios (9/06/2023)

H. POWER Engineers, Southern California Edison: Pebbly Beach Generating Station Combined HOMER Pro Memos (09/28/2023)

I. POWER Engineers, Southern California Edison: Pebbly Beach Generating Station PSCAD Stability Study (09/28/2023)

J. Mitsubishi Electric Power Products Inc. (MEPPI), Southern California Edison: Stability and Protection Device Studies – Catalina (09/2023)

K. Letter from City of Avalon Fire Chief to SCE (09/06/2023)