Causes of California's Rotating Outages and A Resilient, Reliable Remedy: Geothermal Power

BY ANDREW J. VAN HORN

Andrew J. Van Horn is the Director of Applied Research at GreenFire Energy and can be contacted at andy.vanhorn@vhcenergy.com

Abstract

In August, a heat wave and prior decisions contributed to rotating outages in California. Future shortfalls can be avoided by modifying regulatory, market and grid processes and by adding reliable, carbon-free geothermal power plants.

What Happened on August 14th and 15th?

Who supplies and regulates California's electricity markets? California's electricity customers are served by a diverse generating portfolio that typically provides 70% of delivered MWh from in-state generators and 30% from out-of-state power resources. In 2019, 32% of in-state generation came from eligible renewable resources that include wind, solar, geothermal, small hydro and biomass. The grid balancing authority is the California Independent System Operator (CAISO), a non-profit, public benefit corporation. CAISO is responsible for managing about 80% of California's electricity demand and operates a competitive wholesale electricity market for its members, manages the high-voltage transmission system and provides a real-time energy imbalance market (EIM) across eight western states. CAISO is regulated by the Federal Energy Regulatory Commission (FERC), the National Electric Reliability Council (NERC), and the Western Energy Coordinating Council (WECC). At the state level the California Public Utilities Commission (CPUC) regulates the investor-owned utilities (IOUs) and sets reliability requirements and customer rates. Electric utilities regulated by the CPUC supply about 91% of the electricity demand served by CAISO. The California Energy Commission (CEC) carries out power plant licensing functions, funds innovative research and prepares forecasts of natural gas and electricity demands for system planning and policy analyses. The California Air Resources Board (CARB) administers California's successful economy-wide cap-and-trade program for greenhouse gases (GHG). Effective communication among these organizations is essential, and the development of better aligned capacity and reliability targets, procedures and coordinated policies is critical.

What happened In August 2020? California was burning with wildfires and the western U.S. baked during a six-day heat wave. High electricity demands taxed generation resources throughout the western United States. On Friday, August 14, CAISO reported a 750 MW unit was offline. At 2:56 pm the Blythe Energy Center, a 494 MW natural gas-fired generator generating at 475 MW, went down. Contingency resources were then dispatched.[1] Out-of-state imports were constrained, because that power was needed in other states and was not under firm contracts to California entities. To maintain load and resource balance, 800 MW of demand response resources were dispatched at 5:15 pm. At 6:36 pm CAISO reserves fell below the level required to meet minimum contingency reserve requirements, and a Stage 3 emergency was declared. Load-shedding of 500 MW was implemented. A further 500 MW of load was shed at 6:46 pm. By 7:56 pm electricity demands had decreased enough for CAISO to satisfy its load and contingency reserve obligations, and power began to be restored.[2] At 8:54 pm the emergency declaration was lifted.[3]

On Saturday, August 15, cloudy and smoky conditions across the state reduced solar generation, and breezes were erratic. At 4 pm wind generation increased rapidly, requiring other generators to back down quickly. But after 5 pm, about 1 GW of wind stopped blowing, requiring thermal power resources to ramp up quickly to meet loads, while power supplied by utility solar and behind-the-meter PV systems dropped. Figure 1 shows CAISO hourly generation on August 15 by renewable resources.

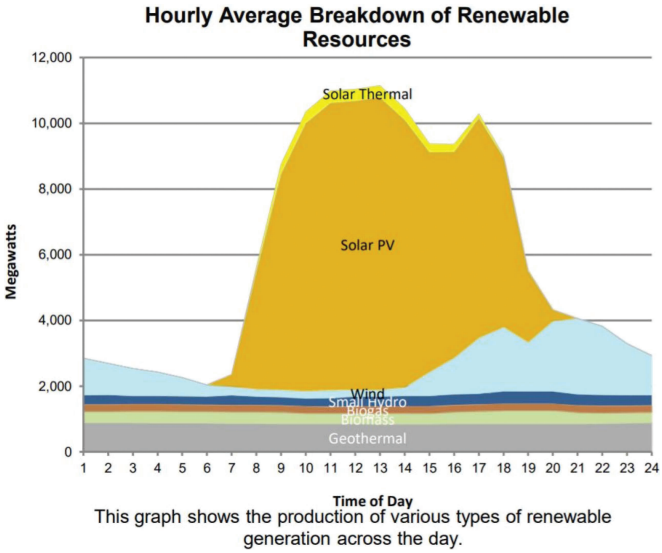

Figure 1. CAISO Hourly Average Renewable Generation on August 15, 2020. http://content.caiso.com/green/renewrpt/20200815_DailyRenewablesWatch.pdf

Between 5 and 6 pm, CAISO Area Control Error was -1,413 MW. At 6:13 pm, a 470 MW gas-fired generator ramped down from 394 MW to 146 MW, due to a scheduling mistake by PG&E. At that point CAISO didn't have enough committed capacity to ramp up to meet net load,[4] and couldn't access sufficient imports to avoid a Stage 2 alert. Stage 3 conditions followed. At 6:25 pm, 470 MW of load shedding/rotating outages were instituted.[5] Soon after, the wind ramped up, net load declined, and emergency assistance enabled load to be restored at 6:47 pm.

Because the 100+ degree Fahrenheit heat wave was forecast to continue, CAISO issued an Intent to Solicit and Procure Additional Capacity. CAISO reminded power purchasers not to under-schedule loads in the day-ahead market. Fortunately, better management of resources and "Flex-Alerts" calling for demand reductions avoided similar rotating outages in the following months.[6]

Contributing Causes

Why was California short of power and what changes should be considered? There are many factors that contributed to the August episodes. These include:

1. *Heat waves across the West that lasted for six days*. These increased loads and reduced California's ability to import out-of-state power. Rotating outages became necessary to avoid cascading, uncontrolled outages, when California generators unexpectedly went down, the sun was obscured by smoke, reducing solar generation, and the wind stopped blowing.
2. *A lack of diversity in grid resources added over the last decade.* Additions of wind and solar power plants combined with retirement of the San Onofre nuclear plant and reliance on aging natural gas plants mandated for retirement left California's grid with fewer than necessary dispatchable resources. Over-dependence on variable, non-dispatchable wind and solar power plants caused steep late afternoon/early evening ramp-ups in net load, added volatility to net loads, increased the complexity of grid operation, necessitated tariff and product changes, and reduced the diversity of proven resources. All these factors helped make the current grid more vulnerable to a variety of foreseeable conditions.
3. *The CPUC's misplaced emphasis on "least-cost, best-fit" metrics used to approve contracts and capacity additions.* Planning and decision-making has focused on near-term economic costs rather than long-term and lifecycle economic and environmental costs. Significant risks have been unexamined. Additions of proven flexible, baseload and energy storage resources are needed to avoid future risks[7] and to satisfy growing demand, e.g., from electric vehicles.

   How have capacity additions been analyzed and mandated? "The CPUC's reliability (termed resource adequacy [RA]) requirements are set based on the peak demand shown in the CEC's demand forecast, plus a planning reserve margin (PRM) of 15% [above the monthly load forecast]. The PRM is comprised of a 6% requirement to meet grid operating contingency reserves, as required by the WECC reliability rules, and a 9% contingency to account for unplanned plant outages and higher-than-average peak electricity demand."[8] The CPUC has mandated procurement of specific technologies deemed capable of meeting RA needs and California's Renewable Portfolio Standard (RPS) requirements. RA needs are determined using CEC demand forecasts that incorporate load reductions from forecasted demand response measures. Wind and solar resources are assigned Qualifying Capacity values to meet RPS and CAISO Net Qualifying Capacity (NQC) values to determine whether enough generation capacity has been contracted to meet local and system RA requirements. The methodology has overestimated capacity values for solar and wind. (Note that RA capacity values for stand-alone solar plants go down as more solar is added.)

   To date the CPUC and CEC have not fully considered lifecycle impacts, reliability needs under foreseeable stress conditions nor potential unintended consequences of intermittent solar and wind generation. California's aggregate energy supplies must be able to avoid a range of impacts of "high consequence" events and scenarios resulting from climate change, heat waves, fires and falling trees in forests, as well as less predictable events, like explosions in natural gas pipelines, gas storage field releases, earthquakes, cyber-attacks on the grid, terrorist acts, electro-magnetic pulses from the sun, and volcanic eruptions that affect global weather, which have obscured the sun for months. Such events have already occurred but could be more frequent and have greater consequences in the future.

   As a first step toward revising policies and practices, the CPUC, CEC and CAISO submitted a Preliminary Root Cause Analysis report to the Governor on October 6. CPUC President Marybel Batjer said, "The extreme heat storm in August was an extraordinary one-in-35-year event that, with climate change, is unfortunately becoming more common... We will absolutely adjust our planning, procurement, and market policies to meet these changing circumstances and ensure our energy future is clean, reliable, and affordable for all Californians." The report admits: "In transitioning to a reliable, clean and affordable resource mix, resource planning targets have not kept pace to lead to sufficient resources that can be relied upon to meet demand in the early evening hours. This makes balancing demand and supply more challenging. These challenges were amplified by the extreme heat storm."[9]

   In the October 14 webinar held by the Power Association of Northern California with discussants from the CPUC, CEC and CAISO, the CEC representative, Siva Gunda, aptly stated that California needs "least-regrets" generation capacity to be built today, so that we can meet our long-term needs.
4. *The slow implementation of a truly integrated western regional grid, of demand response measures and distributed energy resources*. These measures have technical and political hurdles to overcome and will take time to fully implement. The desirability of an integrated western grid and WECC-wide supply planning has been recognized since at least the 1980s. CAISO's Energy Imbalance Market is a recent step toward improved operations across eight states.

   Demand response measures are important, but measurement, verification, and cost-effectiveness issues remain. DER received a boost this September from landmark FERC Order 2222, which allows DER aggregators to compete in all organized regional wholesale electricity markets in the US. FERC's Order

should encourage innovation and enable competition to bring down consumer costs.[10]

5. *The failure to heed some of the key "lessons learned" from California's 2000-2001 electricity crisis and to penalize practices detrimental to the grid.* Twenty years ago, California experienced rolling blackouts/rotating outages during a period referred to as the California electricity crisis.[11] Market manipulation by firms such as Enron caused power shortages and rotating outages. One practice that contributed to power shortages in the real-time market was the chronic under-scheduling of generation resources in the day-ahead market. Under-scheduling by entities such as Southern California Edison violated FERC rules to schedule at least 95% of the next day's forecasted load in the day-ahead market. Eventually, chronic under-scheduling meant that sufficient generation was not procured to meet real-time demand; customers were curtailed.

   October's "Preliminary Root Cause Analysis" report shows that the current practice of under-scheduling contributed significantly to the August 14-15 outages: "Scheduling coordinators representing LSEs [Load Serving Entities] collectively under-scheduled their demand for energy by 3,386 MW and 3,434 MW below the actual peak demand for August 14 and 15, respectively… During the net demand peak time, the under-scheduling was 1,792 MW and 3,219 MW for August 14 and 15, respectively. The under-scheduling of load by scheduling coordinators [that reduced the day-ahead price] had the detrimental effect of not setting up the energy market appropriately to reflect the actual need on the system and subsequently signaling that more exports were ultimately supportable from internal resources. [Text added in brackets]"[12] Since the actual and net peak demands were 46,802 MW and 42,237 MW, respectively, on August 14 and 44,957 MW and 41,138 MW on August 15, under-scheduling distorted the market price and disrupted grid operations.
6. *Other interactions that contributed to the August 14-15 "perfect storm."* Additional areas of concern and actions to address other causes are described in the "Preliminary Root Cause Analysis" report. These actions include changes to the CAISO's Convergence Bidding process that "masked tight supply conditions" and enabled exports that should not have been scheduled, and changes to the CAISO's "residual unit commitment (RUC) process that provides additional reliability checks based on the CAISO's forecast of CAISO load after scheduling coordinators provide all of their schedules and bids for supply, demand, but excluding convergence bids."[13] The sheer complexity and interactions of these processes makes it quite difficult to stress-test grid operations in advance, particularly when good utility practices are not followed.

A Resilient Remedy Available Now: Geothermal Power

It is easy to forget that electric infrastructure is long-lived, capital intensive with lots of equipment beyond originally planned lives. The grid can't be entirely revamped in just a few years. One proposed panacea, expensive advanced battery storage, can't supply energy for longer than four hours and must be replaced and safely disposed of in about 10 years with significant adverse lifecycle environmental impacts. Like Northwest hydro generation, short-term and seasonal energy storage is energy-limited.

What if there were beneficial resources that would keep our lights on, when intermittent and energy-limited generators are not available? Fortunately, such a resource is already available, dependably supplying power during all California's outages. Figure 1 demonstrates that California's most dependable renewable resource is geothermal power. Geothermal energy uses Earth's abundant heat to generate around the clock, producing electric power and direct heat worldwide. In 2019, 15.4 GW of geothermal power operated in 27 countries. California is a world leader with 43 operating geothermal power plants with an installed capacity of 2.7 GW. However, it has been almost a decade since a new geothermal plant came online in California.

Geothermal energy can displace fossil fuels, charge a growing fleet of electric vehicles, balance the electric grid, and help countries around the world meet greenhouse gas reduction goals. Drilling costs are declining, and US contract prices for geothermal power are around $60-80/MWh. EIA estimates a total system levelized cost of $37.5/MWh for geothermal plants coming on-line in 2025.[14] Although this LCOE is higher than stand-alone solar and wind LCOEs, geothermal power provides several times more value over 8,760 hours than solar with batteries, because geothermal is 90-95% available, weather resilient and fuel-secure. It is estimated that 1 MW of geothermal with a much smaller footprint can economically displace 4-5 MW of solar with storage capacity.[15]

Recent advancements have made possible closed-loop geothermal (CLG) energy systems that can operate in a broader range of temperatures and rock compositions than conventional hydrothermal projects. CLG not only expands the potential supply of clean, carbon-free power, but does not require fracking and brings versatility by supplying both heat and power to new applications, such as hydrogen production, desalination, and lithium extraction.[16] CLG can also produce power from some unproductive geothermal and oil and gas wells.

Figure 2. GreenFire Energy's demonstration of a Closed-Loop Geothermal (CLG) energy system at the Coso, California geothermal power plant. September 2019.

CLG systems require the creation of a sealed well or multiple wells drilled into the subsurface hot rock strata. A sealed pipe (or pipes) enables a working fluid to continuously circulate and absorb heat to be delivered to downhole heat exchangers or the surface. CLG can go much deeper and hotter than conventional hydrothermal projects, so the potential energy resource is many times greater. Because it only extracts heat, CLG does not produce unwanted substances, does not require fracking and will not cause seismicity.

During 2019, GreenFire Energy tested a CLG system at the Coso, California geothermal power plant. This successful demonstration extracted heat from an existing unproductive well, separately testing water and supercritical carbon dioxide as working fluids to generate power.[17] CLG projects are now being initiated in Asia, Europe, and North America.

Today, carbon-free geothermal energy systems are poised to make significant contributions to global decarbonization and worldwide energy and environmental needs. When innovative geothermal technologies are further developed and deployed, cost-effective geothermal energy will increase employment in the clean energy sector, while enhancing the reliability, resilience, and security of supply in electricity grids around the world.

Footnotes

[1] California ISO, "Fact Sheet: Outage Report – Heat Wave of August 2020."

[2] California ISO, John Phipps, "Briefing on System Operations." Board of Governors Meeting, August 17, 2020.

[3] CAISO, News Release, "ISO Stage 3 Emergency declaration lifted; power restored statewide." August 14, 2020.

[4] "Net load" is the electric load that remains after non-dispatchable solar and wind generation is supplied. Net load is met by dispatchable power plants, e.g., natural gas, nuclear, geothermal, hydro, biomass, and combustion turbines. Studies in 2015 projected an afternoon ramp-up of 13,000 MW by 2020, but in early 2019 the ramp-up reached 15,600 MW due to increased additions of solar and wind. California's net load profile is called the "duck curve," and is typically met by aging, load-following natural gas-fired power plants.

[5] Ibid.

[6] Public Safety Power Shutoffs were carried out to reduce the risks of electrical equipment igniting wildfires in areas with high winds and extremely dry conditions.

[7] Sepulveda, N, et al., "The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation." Joule 2, 2403–2420, November 21, 2018.

[8] California ISO, California Public Utilities Commission, California Energy Commission. "Preliminary Root Cause Analysis Mid-August 2020 Heat Storm," October 6, 2020. Cover letter to the Governor and Executive Summary, pp 2-5.

[9] Ibid.

[10] "DERs are located on the distribution system, a distribution subsystem or behind a customer meter. They range from electric storage and intermittent generation to distributed generation, demand response, energy efficiency, thermal storage and electric vehicles and their charging equipment." FERC News Release: September 17, 2020. Docket No. RM18-9-000. Item No. E-1, Fact Sheet, Order 2222.

[11] Sweeney, J., "The California Electricity Crisis." (Stanford, California: Hoover Institution Press, 2002), 291 pages, ISBN 0-8179-2911-8 (hardcover).

[12] California ISO, California Public Utilities Commission, California Energy Commission, "Preliminary Root Cause Analysis Mid-August 2020 Heat Storm," October 6, 2020. Executive Summary, pp 12-14.

[13] Ibid.

[14] U.S. EIA, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2020," February 2020.

[15] Bartosz, A and Thomsen, P., "The Value of Geothermal in California," GRC Bulletin, Vol. 49, No. 3, June 2020: "...while geothermal is not the lowest cost resource on a levelized cost basis, it is by far the highest economic value in renewable resources that are operating in California and the surrounding region. Even as we see the contract prices for wind, solar PV, and lithium ion battery prices decline, geothermal's economic value over the life of long-term purchase agreements remains competitive as California and the region move to higher penetrations of renewable energy."

[16] Van Horn, A.J., et al., "New Opportunities and Applications for Closed-Loop Geothermal Energy Systems." Geothermal Resources Council Transactions, Vol 44, 2020, pp 1123-1143.

[17] GreenFire Energy, "Closed-Loop Geothermal Demonstration Project, California Energy Commission report, CEC-300-2020-007, June 2020.

IAEE
International Association for
ENERGY ECONOMICS