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**Additional Comments of Edward G. Cazalet on the behalf of NGK Insulators and
MegaWatt Storage Farms**

Additional submitted attachment is included below.

Additional Comments of Edward G. Cazalet on the behalf of NGK Insulators and MegaWatt Storage Farms, Inc.

On the behalf of NGK Insulators and MegaWatt Storage Farms, on Friday November 20th, 2015, I attended and testified at the “Joint California Energy Commission (CEC) and California Public Utilities Commission (CPUC) Long-Term Procurement Plan Workshop on Bulk Energy Storage - Docket 15-MISC-05.”

The focus workshop was on “Bulk” storage, which was defined as large, long-duration storage, especially pumped storage (PS) and compressed air energy storage (CAES). However, I and several other speakers emphasized that chemical batteries also can competitively provide “Bulk” storage with shorter lead-times and more flexible locational deployment and right sizing.

CPUC Commissioner Peterman in her opening remarks mentioned sodium sulfur batteries as an alternative bulk storage technology. In these opening remarks she expressed interest in further information on the “longer term roadmap and cost projections for sodium sulfur batteries.

History of the sodium sulfur battery

The sodium sulfur battery was invented in the United States in the 1960s, followed by various trials in the US, Europe and Japan. The development of the battery was for electric automobiles and electric grid energy storage systems.

In 1984, NGK started the development of a Beta Alumina ceramic electrolyte utilizing its expertise of fine ceramic technologies, jointly with Tokyo Electric Power Company (TEPCO). In 1989, NGK applied this to the development of NAS (sodium sulfur) battery cell.. TEPCO’s goal was a more easily deployed and more economic alternative to pumped storage. The development resulted in first deployments of the NAS battery for a substation in 1995 and full

commercialization of NAS in 2002. NAS is now the most-used and proven large-scale battery technology in the world with 3 GWH of capacity deployed at over 190 projects.

<https://www.ngk.co.jp/nas/why/history.html>

In 2008, NGK expanded its manufacturing capacity to about 1 GWH per year of sodium sulfur battery production - this was the first Gigafactory built entirely for grid-scale storage.

Development roadmap for the sodium sulfur battery

NGK has continued to develop the sodium sulfur battery system to reduce costs and improve performance. It now delivers the system in 20-foot ocean containers that can be deployed rapidly. NGK is currently completing construction of the world's largest battery 300 MWH (50 MW for 6 hours) using about 250 such containers, deployed in about 6 months.

<http://www.ngk.co.jp/english/news/2015/0622.html>.

NGK, with the support of the Government of Japan, has carried out the containerization and the manufacturing automation to reduce costs. Sodium sulfur batteries use abundant low cost raw materials. The cost reduction roadmap for sodium sulfur will achieve 23,000 yen per kWh (\$190 per kWh at current exchange rates) by 2020.

<http://www.bloomberg.com/news/articles/2013-09-02/sumitomo-ngk-picked-for-project-to-cut-energy-storage-costs>.

In my remarks at the workshop I mentioned that PG&E has deployed 42 MWh (6 MW) of sodium sulfur batteries at two sites: San Jose and Vaca-Dixon. These batteries are the subject of a CEC, PG&E and EPRI study and report that describes the technology and many tests of the two installations of sodium sulfur batteries.

<http://www.energy.ca.gov/2015publications/CEC-500-2015-060/CEC-500-2015-060.pdf>.

Warranty and safety of the sodium sulfur battery

CEC Chairman Weisenmiller asked if the warranty on the PG&E battery was eliminated because of a fire incident. As detailed in the CEC report, a sodium sulfur battery experienced a fire when one battery cell failed and burned and caused adjacent cells in the system to also burn, before self-extinguishing. There were no injuries and damage was limited to a portion of a battery. The spreading of the fire to adjacent cells was due to a rare combination of events and was unexpected. NGK redesigned the modules by adding additional internal barriers and other safety mechanisms. The incident and the subsequent investigation and safety enhancements are also described at <http://www.ngk.co.jp/english/news/2012/0607.html>.

The incident represents a fire risk (prior to new safety mechanisms) of about 1 in 1000 MW-years of operation (0.1%/year). This is equal to or better than transformers, which have a fire risk of 0.1%/year, according to one source¹ and of 0.6%/year according to another².

As part of its strong commitment to safety, on its own initiative, NGK decided to replace all battery modules in the US including PG&E's, with new safety-enhanced modules. This was done even though many of these systems (including PG&E's) were out of warranty. The worldwide expense of these safety enhancements to NGK was about \$600 million. This voluntary decision demonstrates NGK's outstanding commitment to its customers and to the safety of their systems.

Both Chairman Weisenmiller and Commissioner Peterman asked about NAS warranties. NGK delivered the batteries to

¹

http://static.mimaterials.com/midel/documents/sales/Guide_for_Transformer_Fire_Safety_Practices.pdf

² 730 per year of 110,000 = 0.6%, http://gnedenko-forum.org/Journal/2011/012011/RTA_1_2011-07.pdf

PG&E in 2009 with a standard 2-year warranty. As mentioned above NGK replaced the battery modules in 2012 at its expense, even though the warranty had expired.

For new batteries, NGK currently offers a standard two-year warranty with purchase. NGK also offers an optional extended warranty of up to 13 years with proper maintenance for a total warranty of 15 years on new batteries.

California sodium sulfur battery current performance

Commissioner Weisenmiller asked for any information on the performance of the PG&E sodium sulfur batteries since the completion of the CEC study. To NGK's knowledge the batteries are performing as designed. We suggest contacting PG&E for details.

Commissioner Peterman asked about another sodium sulfur battery at Catalina Island. I said there was a 7 MWh (1 MW) sodium sulfur battery on Catalina owned by SCE. To NGK's knowledge the Catalina battery is performing as designed. We suggest contacting SCE for details.

Other references

Below are links to two recent articles I recently coauthored that provide further context for "bulk" long-duration storage.

<https://www.greentechmedia.com/articles/read/Deploying-Storage-Now-That-Its-Become-Mission-Critical>

<http://www.fortnightly.com/fortnightly/2015/12/solar-high-noon?authkey=183ac419607be82652f38bd7aacf7e8af68419442e77de3ca7f89e374fadc697>.