From: Cherry, Brian K
Sent: 11/16/2012 8:50:49 AM
To: Sandoval, Catherine J.K. (catherine.sandoval@cpuc.ca.gov) (catherine.sandoval@cpuc.ca.gov)
Cc:
Bcc:
Subject: FW: IEEE Spectrum - San Francisco's Secret DC Grid

Thought you'd enjoy this after our conversation at NARUC about AC vs DC.

From: owner-Newsflash-Real-Time@pge.com [mailto:owner-Newsflash-Real-Time@pge.com] **On Behalf Of** News Flash
Sent: Friday, November 16, 2012 8:46 AM
To: Newsflash-Real-Time
Subject: IEEE Spectrum - San Francisco's Secret DC Grid

IEEE Spectrum magazine published a story about how PG&E converted the DC power distribution grid while still providing service for its customers with historic elevators in San Francisco.

San Francisco's Secret DC Grid

The last direct-current power lines are being dismantled just as DC distribution seems headed for a comeback

By Peter Fairley

IEEE Spectrum, November 2012

Nikola Tesla's alternating current may have "won" the War of Currents at the end of the 19th Century, but the defeated incumbent—direct-current distribution, aggressively championed by Thomas Edison—endured. As historian of technology Thomas P. Hughes observed in his influential essay on the evolution of large technological systems, the War of Currents ended "not with victor and vanquished, but with the invention of devices making possible the interconnection of the two systems." Remnants of DC power distribution kept performing their assigned tasks for decades as the AC grid thickened around them.

In fact, a few live on to this day. One of the best examples is in San Francisco, where 250-volt DC power still flows through underground and overhead cables across the city. These DC lines peacefully coexist with their AC counterparts; you can see this mix of currents straddling utility poles in the city's South of Market district. DC's perseverance in that neighborhood seems fitting, for it was just a few blocks away that the tiny California Electric Light Co.—a forebear to California's dominant **Pacific Gas and Electric (PG&E)**—became the first power company in the United States, and possibly the world, to supply electricity to multiple customers from a central generating station. It was in September 1879—a full three years before Edison turned on his famous Pearl Street generating station in New York City—that California Electric began burning coal, raising steam, and driving dynamos in a wooden shack at the corner of Fourth and Market streets to feed current to its customers' electric lights.

While DC continues to race through San Francisco power lines at nearly the speed of light, it does so anonymously. You'll find no reference to DC power distribution in PG&E's annual reports or on its websites. Even some utility engineers are unaware of its existence, which raises a curious question: Why is the inheritor of this legacy, the mighty and sophisticated PG&E, still bothering with DC distribution 133 years later?

DC endures in San Francisco because more than 900 of PG&E's customers still need it. Most of the utility's customers transitioned to AC lightbulbs and appliances easily enough as competing power distributors coalesced within PG&E and harmonized their equipment around AC. But for some of these building owners, however, elevators were a problem.

DC-driven winding-drum elevators—the leading design until the 1930s—use a DC motor in the basement that winds and unwinds the elevator's steel cable on a steel drum, thus lifting and lowering the car from pulleys atop the elevator shaft. DC drive was the only way to go at the time for a speedy elevator, because only DC could deliver variable-speed operation for smooth starts and stops.

The DC motors were also energy efficient, capable of something that has only recently become possible with modern elevator designs: regenerating power when the elevator descends.

However, safety was a weak point. If a winding drum's control system fails, its motor can drive the elevator through the roof, according to San Francisco–based elevator consultant Richard Blaska. As a result, says Blaska, new installation of winding-drum elevators was banned in the 1940s and 1950s in favor of traction elevators, whose cable will simply slip and hold the car at the top floor if the control system fails. Traction elevators can be engineered for either AC or DC operation.

Existing DC winding-drum elevators, however, have stubbornly resisted exile to the scrap heap, in no small part with support from local elevator repair firms such as Erik Bleyle's. Bleyle Elevator makes replacement parts, rebuilds DC motors, and designs custom circuits to sustain these machines from a bygone era. Bleyle admits that repairs can be pricey, especially hand-rewinding a DC motor, which can run between US $30 000 and $40 000. But he says even a refurbished motor looks cheap compared with the $500 000 cost of replacing the elevator, not to mention the months of involuntary stair climbing during the upgrade.

"Usually people just go for the motor," says Bleyle.

For most of the past century, PG&E has supplied San Francisco's DC elevators via a citywide DC grid. While its origins are obscure, this DC grid likely came together organically as neighboring—and, in some cases, competing—utilities absorbed one another and wiring coalesced into one great citywide circuit.

"Some of the pieces of the DC grid were actually part of the very first original systems," says Tom Cannon, PG&E's principal engineer for electric asset strategy in San Francisco.

By the mid-20th century, large rectifiers installed at two downtown substations supplied the current, pushing 250-V DC onto a rectangular loop of 3.6-centimeter-diameter cable. Local lines branched off this loop in a meshed pattern that, much like the meshed communications networks that form the Internet, provided redundant paths for power to flow around cable breaks and blown fuses.

Operating the meshed grid came with unique challenges, thanks to DC's oddball status as the 20th century wore on. For example, stray current from DC lines would wind up flowing down the core of copper neutrals in the AC distribution grid, invisibly corroding them from the inside out. "It would look fine, but strike it with a hammer and it would shatter," says **Steve Austin, PG&E's first line supervisor for electric operation, maintenance, and construction**, and the million-dollar man when it comes to keeping DC power flowing. The DC grid was also always difficult to troubleshoot because faults are hard to localize on a single large circuit—a challenge that **Austin** says is compounded by the scant support this forgotten technology gets from equipment vendors. **Austin** adapted a circa-1990 AC/DC hammer drill to create his own diagnostic tool for so-called phantom voltage—tiny dribbles of DC flowing across blown fuses that can hoodwink unsuspecting "troublemen" and their trusty voltmeters. **Austin** knows he's found a phantom when he clips his modified Black & Decker Macho III hammer drill onto a circuit, pulls its trigger, and gets a whimper instead of a roar.

As the citywide DC network aged, cables failed and phantoms multiplied, making maintenance costly and threatening both reliability and safety. The final straw came in 2009, when a 1920s-era DC cable overheated at a splice junction under the intersection of Polk and O'Farrell streets, melting the seals on a neighboring AC switch and igniting the oil within it. The grid was blind to the ensuing crisis below San Francisco's Tenderloin district until the blaze blew off a manhole cover and shot flames 9 meters into the air.

"When you had a failure out there like a fire in a manhole, the DC grid saw it as a load and just kept on pumping power at it," says **Austin**. The Tenderloin fire provided fuel for critics of PG&E's maintenance record and prompted the utility to accelerate and complete an ongoing redesign of its DC supply system. PG&E finished the job and shut down its two old rectifiers at the end of 2010.

PG&E upgraded San Francisco's DC supply system with a back-to-the-future redesign. Austin explained the islands to *IEEE Spectrum* schematically in an impromptu drawing on an underground equipment box in the South of Market district. The company broke up the DC network into islands serving 7 to 10 customers each by deliberately introducing breaks in the network mesh. At first glance, the resulting 171 power islands resemble the short-range DC grids of the 19th century. But instead of steam-driven dynamos, today's neighborhood-scale circuits get their DC power from the AC grid. Each is equipped with a rectifier plugged into the local AC distribution system.

This islanding solution safely retained older DC lines, even paper- and lead-wrapped cables from the early 1900s, by requiring them to carry less current. It also improved power quality by providing a means of regulating delivered voltage—a recurring challenge for the citywide network. And islanding accelerated troubleshooting by isolating line faults within a handful of city blocks.

In a subsurface chamber under the sidewalk along Second Street in the South of Market district, electricity entering from the AC distribution grid at 12 000 volts AC is transformed and converted to deliver 240-V AC and 250-V AC power to the surrounding city blocks. To produce DC power, a transformer [the small beige box] first drops the AC to 175 V, which then feeds the 50-kilowatt rectifier [the larger black box] to make 250-V DC. Cables exiting through a conduit in the wall to the right of the rectification equipment distribute the DC power to the area's island of six customers on three city blocks.

DC endured through the 20th century in many cities, but it is losing ground in the 21st century. With the exception of a few holdouts, such as San Francisco, AC-minded cities are finally clearing away lingering DC lines. Consolidated Edison in New York cut off its last DC customer in 2007, for example, and DC's days are numbered in Chicago—the home of the of the 1893 World's Fair, which was triumphantly powered by Tesla and Westinghouse's AC system.

This is not, of course, the end of DC power. It will endure within the bowels of these cities' oldest buildings, as DC customers install their own rectifiers to supply their ancient elevators.

Could holdouts such as San Francisco ultimately have the last laugh? The spread of both DC generators (such as photovoltaic panels) and DC loads (such as cellphones, flat-panel televisions, LED lights, and even electric cars) is inspiring a small but growing niche for DC microgrids that link the two together. If such building-wide circuits grow into neighborhood grids and, ultimately, meld together to form citywide DC grids, this circuit of electrical history will finally be closed.

PG&E's distribution chiefs in San Francisco aren't counting on it. Then again, stranger things have happened.

Photo caption:

Steve Austin is the go to guy for problems with the DC grid. He lugs a drill around as a test instrument.

Photo link:

http://spectrum.ieee.org/img/10WSanFranDCgridf3-1352492025049.jpg

Photo credit:

Peter Fairley

Photo caption

PG&E's Steve Austin draws out a DC circuit map.

Photo link:

http://spectrum.ieee.org/img/10WSanFranDCgridf5-1352491138273.jpg

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