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Pacific Intertie 3,100 megawatts, +/-500 kV DC, 1965 LADWP
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Planned Future HVDC Projects by 2020 in China
(The year means project in operation)

- Jinsha River | (Xiluodu, Xiangjiaba, Jingping & Xiaowan Dams, for 800kV UHVDC)
- Xiluodu - Shanghai
  800kV, 6400 MW, 1950km
  2011
- Xiluodu - Zhejiang
  800kV, 6400 MW, 1870km
  2015
- Jingping - East China
  600kV, 6400 MW, 2100km
  2012
- Xiluodu - Tibet
  600kV, 6400 MW, 1070km
  2014
- Xiluodu - Hubei (C.China)
  600kV, 6400 MW, 1700km
  2015
- Xiluodu - Yunnan (Bri-Bri Dam)
  600kV, 6400 MW, 2009
- Xiaowan Dam
  600kV, 6400 MW, 2009
- Yunnan - Guangdong
  800kV, 5000 MW, 1500km
  2009
- Beijing - Harbin
  800kV, 6400 MW, 2012
- Shanghai - Tianjin
  800kV, 6400 MW, 2015
- Tianjin - Shandong
  800kV, 6400 MW, 2015
- Xluluodu - Henan
  800kV, 6400 MW, 2015
- Xiluodu - Hunan
  800kV, 6400 MW, 2015
- Jinsha River II - East China
  800kV, 6400 MW, 2014
- Jingping - East China
  800kV, 6400 MW, 2012
- Jinping II - East China
  800kV, 6400 MW, 2019
- Jinping II - Fujian
  800kV, 6400 MW, 2018
- Nanxunhu-Guangdong
  800kV, 5000-6000 MW, 2015

Updated 2006-4-14, CNABB-PF50

ABB

Southeastern communities
Comment Set G0014, cont.
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South America: Potential Amazon River Projects

North Atlantic
1,800 MW
26,000 MW
20,000 MW

Low Xingu
Low Tocantins/Low Araguaia

Madeira
18,000 MW

Low Tapajós/Low Madeira
21,000 MW

High Tapajós/High Xingu
13,000 MW

South Africa: West Cor Line

Inga, the world's largest hydro power resource:

- > 5,000 MW run-of-river
- > 40,000 MW with dam

Inga station
Cuanza station
Angola
Namibia
Botswana
Zimbabwe
Pegasus station
South Africa
Omega Station

Proposed DC voltage level in both bipoles: 800 kV
Approx. 3000 km
Comment Set G0014, cont.
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+/− 800 kV 6400 MW DC converter station

Wall Bushing 800kV ABB
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Thyristors

- The valve voltage is not decisive for the thyristor. Will be handled by sufficient number of thyristor positions in series. Due to the well defined voltage grading each individual thyristor position has the same electrical stress in an 800 kV valve as in a 500 kV valve!

- The critical parameter for the thyristors is the short circuit current. This is given by the ratio between rated DC current and transformer reactance.
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<table>
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<tr>
<th>Project</th>
<th>Power Transmitted, MW</th>
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<th>Commissioned year</th>
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<th>Overload Current, A</th>
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<td>2000</td>
<td>4020</td>
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<tr>
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<td>2002</td>
<td>4020</td>
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<td>2003</td>
<td>3000</td>
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<td>2x100</td>
<td>336</td>
<td>2003</td>
<td>3920</td>
<td>-</td>
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<tr>
<td>Three Gorges-Guandong, China</td>
<td>3000</td>
<td>4176</td>
<td>2004</td>
<td>3000</td>
<td>3555 @20°C</td>
</tr>
<tr>
<td>Sylmar Replacement Pproject</td>
<td>3100</td>
<td>2016</td>
<td>2004</td>
<td>3190</td>
<td>3650 @20°C</td>
</tr>
</tbody>
</table>

One thyristor failed during commercial operation reported (Garabi 2002)

Composite support insulator +-800 kV DC, ABB
Comment Set G0014, cont.
California Botanical Habitat

Pylon foundation, Pacific Intertie 3,100 megawatts, 1965 LADWP
Ultra high voltage DC videos:

"800 kV UHVDC" (7 min)
Large 22 MB
"800 kV UHVDC" (7 min)
Small 7 MB

http://www.abb.com/cawp/qad02181/0ca04adc1b0b9c76c12570f3002eb4c7.aspx (Index of HVDC videos, which are available in high or low resolution for faster buffering)

http://www.prysmian.com/our-products/energy/power-transmission/high-voltage-systems.html (400 kV underground Madrid to Barajas Airport Prysmian cable and tunnel installation)
II. 7 high voltage (+/- 600 to 800 kV) high capacity (10,000 to 20,000 megawatt) underground DC routes, based on pairs of 3,000 to 5,000 megawatt cables, (in 1 to 4 trenches under each roadway, each 2 feet in width, up to 5 feet in depth, and separated by 10-12 feet.)

Underground power lines running east and west across San Diego County and along existing roads are expandable to at least 140,000 megawatts of underground UHVDC capacity, with approximately no environmental impacts and no property damages.
East to west highway routes from Imperial County to Western San Diego County

1. Highway S22 to 79 west to 74 into Orange County
2. Highway 78 west
3. Highway S2 to 76 west
4. Old Highway 80 west
5. Highway 94 + Southwest power line right-of-way to the east
6. Border road or Southwest power line right-of-way westerly
7. Unpaved roads east to west between border and Highway 2 in Mexico

High capacity underground DC cable considerations

1. Use the existing AC power network not for long distance transmission, DC can do that more efficiently with greater capacity, lower maintenance and negligible damages. AC’s advantage is for internal regional distribution, which is already substantially in place.

2. Where the roads may be narrow entering a desert region with high summer heat, such a Borrego Springs CA, a small water main may incidentally accompany a pair of underground cables, may also help increase capacity under high loads when the daytime temperature may exceed 110 F, even though DC cables operate cooler than AC power lines, and are designed to provide optimum performance at 70-90 degrees centigrade (158-194 F). Also a water line can help address desert water table depletion caused by aggressive agricultural practices. Naturally, thermodynamic modeling would have to verify efficiency, compared to increasing the copper cross-section vs. night dissipation.
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3. While underground cable capacities have increased from 150 kV to 300 kV to 600 kV and +/-800 kV, and underground spacing does not have an electrical effect, but does have a thermal influence that could also be taken into account during cable design. Four to five meter separations are in general sufficient to maintain the thermal influence at low values, i.e. a few degrees. Two 2 cable pairs could provide 6,000 to 10,000 megawatts operating at +/-500 to 800 kV. System examples including the Pacific Intertie which has increased voltages and capacity many years after construction, when needed, long after system reliability had been proven.

4. **Cables technologies:** Underground DC power lines with a minimum or 3,000 square millimeter copper cross-section and 6.2 inch outer diameter operating at: +/-300 kV (using XLPE, cross-linked polyethylene extruded cables), or +/-600 kV (using PPL, Paper Polypropylene Laminate), or +/-800 kV (using SCFF, Self Contained Fluid Filled).

5. Arguments that high voltage DC whether overhead or underground are exclusively cost effective for very long distance lines, may have been true decades earlier. However, runs as short as 20 miles have been effectively used, connecting New Jersey to Manhattan, and the cost of a 1.3 megawatt, 161 mile DC lines in the UK (BriNeC) has been $530,000,000 less costly than the proposed overhead AC Sunrise Powerlink.

6. Designing an underground power line which maximizes capacity and allows for upgrades, to double, triple or quadruple the initial capacity, means that a 50 foot wide roadway could 1st use one trench 2 feet in width to separate the first cable pair by 18 inches, which could provide between 3,000 and 5,000 megawatts at +/-600 to +/-800 kV, leaving room on the opposite side of the road for the second cable pair, plus room in the center for a third pair, and if there is adequate width for 2 trenches in the
middle, for a total of 4 trenches, 2 feet wide each, with a 10-12 foot separation between each trench, for a total capacity of 12,000 to 20,000 megawatts under a single county roadway, naturally depending on future requirements which can be incrementally increased.

7. While cable spool size may be determined by a delivery route which avoids any low bridges, with 6 inch cables, the expected lengths would be 500 to 600 meters, or 1640.4 to 1968.5, or .3728 miles per segment, or 268 segments and splices per 100 miles of cable, or 536.5 spools for + and - cables.

8. Using both sides of each road could provide adequate heat dissipation, or each cable could be placed in a separate trench separated by 10-12 feet, although an 8 inch separation between positive and negative DC cables is considered appropriate in a 1 foot wide trench that’s 5 feet in depth, however a .4 to .5 meter (18 inch separation) could assist heat dissipation in the desert or when operating at higher capacities. Deeper burial would not benefit night time heat dissipation during the summer months and could potentially reduce capacity, since the earth would act as an effective thermal insulator at greater depth.

9. Based on immediate need 2 cables can be installed on only one side of the highway providing from 3,000 to 5,000 megawatts of capacity, of which only 1,000 or 2,000 megawatts may to be implemented at first, which can later be expanded by simply upgrading the converter stations and later expanded by installing the second cable under the other side of the road, bringing the capacity up to 6,000 or 10,000 megawatts; leaving room for 1 or 2 additional expansions, with a total capacity of 12,000 to 20,000 megawatts under each road.

10. Naturally, underground barriers are installed such as poured concrete to inhibit accidental back-hoe damages, along with signs and phone numbers.

11. Water permeable concrete and pavers can be used to retain moisture from rain, which would assist with heat conduction, heat dissipation and solar heat reflection compared
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to black asphalt coatings. Further, such roadways when appropriately engineered for sub-pavement drainage will absorb rain water, not create puddles and not require storm drains. The paving systems have been designed for automated, rapid, low cost installation and eliminate the need for storm drains, providing a considerably more attractive road, with better traction, which is designed to carry fully loaded high-capacity tank trucks, at a lower cost than asphalt systems, and further can be disassembled and reassembled as needed for construction purposes, all with patented and licensed, high volume, low cost manufacturing facilities in Corona California. Further, such water permeable systems are becoming a requirement in San Diego County, which is an economic, environmental, safety and engineering advantage, particularly for underground power lines.

12. When someone is willing to sacrifice a functioning wilderness and ecosystem by placing an array of hot segging cables overhead in spite of studies showing a 70% increases in leukemia (based on only very limited EMF exposure levels), and is willing to disregard cancer deaths and oppose a vastly less damaging trench that’s only 5 feet deep, then the basis of the position appears to be a matter of dogma designed to perpetuate a fraud and the taking of lives. Which is not to say that the needless destruction of nature and property for personal profit is ultimately advantageous to anyone, nor even useful from the perspective of private gain; nevertheless we see these sorts of damaging actions repeatedly, as if they were the law. Naturally, a review process needs to accumulate, measure and summarize all damages caused by a Powerlink, based on the full restoration and the full cost of equivalent property replacement, including damages done to lives, not just commercially measured values, but fully equivalent values including equivalent habitat, unobstructed views, rare species, access, personal, local and urban facilities, energy generation capabilities, access, security, operating expenses and maintenance requirements, time to locate and acquire the equivalent sites, legal and collection expenses.

13. If a small portion of an underground power line needs to go from an existing highway, where it can be regularly watched and protected. Then that portion of off-road access
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needs to be carefully photographed and mapped, with the exact location and
orientation of each boulder identified, with accurate coordinates, so that the geology
and plant specimens impacted can be fully restored. The value of wilderness is not
what someone who wants to destroy it says it’s worth. It’s the full restoration and
replacement cost, the same as when anyone destroys a new Mercedes or a corporate
jet. Which incidentally are mass produced and far more easily replaced than
wilderness, that can take over 40 years of labor, materials and accumulated
knowledge to complete the restoration process at a cost of $25 to $75 per square
foot. Naturally a 1 square foot hole in a jet plane does not diminish its value by $75
or even $500. The entire jet plane has a negative value until the hole is completely
restored with skilled workmanship, which may mean that the loss may be in excess of
$50 million, until the hole or the demand for the obstruction is completely eliminated.
Of course serious and permanently enforced damages to a wilderness preserve are not
just damaged just where a collection of 500,000 volt cables pass overhead, the entire
palaeontological, research, facilities and recreational value of our properties is
overwhelmingly defeated, and require the full and complete restitution, based on
everything that has been lost, including the full and equivalent replacement value,
along with losses of time, expenses, legal and collection costs, plus interest (excluding
inflation), adjusted for the time of the full replacement, which incidentally can and
typically does take several decades of intensive effort to accommodate, and
undoubtedly will not be any bargain as population pressures increases and habitat is
lost, and could easily be well over 100 times more costly to either restore or replace,
given the lack of equivalent wilderness regions. Based on the often poorly measured
issue of inflation, homes that sold for $10,000 during the 1950’s were recently resold
for over $1 million, surprisingly not completely remodeled as anyone might expect, but
in their original ½ century old and poorly cared for condition, while better quality
homes in Bellaire have increased by over 300 times during that same period, which
naturally refers to the intentional economic mismanagement of this economy.

14. Why would the electric industry be expanding its dependency on imports, including
massive quantities of Liquefied Natural Gas (LNG) which does not offer a stable price
4. Comments and Responses on the RDEIR/ SDEIS

Comment Set G0014, cont.
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or supply, when the total national debt exceeds $90 trillion and when we have enormous quantities of renewable resources. Going deeper into debt to buy energy when we already have an abundance of energy resources doesn’t save money nor develop long-term profits.

15. Implementing lower cost, higher capacity, nondamaging solutions is an opportunity to reverse a long history of causing needless environmental and property damages. Fortunately, it also includes economic advantages for SDGE. Apparently, Europe, Australia, China, India and Brazil have all been able to evaluate the engineering advantages and implement higher capacity UHVDC and underground systems with very significant economic advantages. But we have to circumvent or violate our environmental laws and health laws because corporate executives can’t review the issues or consider change?

16. Thousands of people have pleaded with SDG&E to protect the San Diego County’s extraordinary wilderness regions, their homes, ranches and farms, with no reconsideration by SDGE of any lower cost underground alternatives that could reduce all these massive and needless damages.
Sunrise Powerlink Project
4. COMMENTS AND RESPONSES ON THE RDEI R/ SDEIS

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17. The integration of a fiber optic link above the underground power line can provide for immediate security alarms directly to the local sheriff, in addition to high definition video security cameras on each cable segment to provide for security monitoring, which is also available to the public, along with free wide area high-speed internet to all residents along the power line route, with the ability to rotate and zoom one camera on each visible segment, when not being used by SDGE or law enforcement.

18. With a more efficient grid that could save SDGE over $20 billion in expansion costs over several decades, as well as saving 100's of thousands of acres from environmental devastation, and saving many billions in property losses, there’s no doubt that SDGE could afford to reimburse everyone for the full replacement value of the property that was lost or was damaged along existing high power lines. Instead of the power industry spending 100's of millions of dollars trying to deny EMF and pollutant ionization, or proven associations with cancer, resources could be far better spent by providing funding for a local molecular biology institute to assist in studying cellular electron field interference, along with methods to defend against and reverse related cancers.

19. Restoration of environmental damages caused along existing power line routes can continue by researching advanced on-site propagation techniques based on rainfall for indigenous drought tolerant trees, along with nutrients, moisture retention, genetic strains and improvements to drought tolerance.

20. The public relation benefits for protecting the environment on a large scale, along with addressing the molecular biology of ion and field promoted cancers, while eliminating any significant need for eminent domain, and supporting sustainable electrical generation while resolving the huge electrical demand for plug-in hybrid vehicles, could incidentally result in a notable public relation benefits for Sempra Energy, as well as significantly increase SDGE’s delivery of electricity while providing support for the governor’s administration.
21. However, with identifiable nondamaging alternatives and cost estimates provided, SDG&E cannot later say they were unaware of the damages to the environment, damages to public and private property, the massive economic losses that would be inflicted, nor the cancer risks along the 150 mile route, based on large scale medical studies, because we provided SDG&E and the CPUC with hundreds of pages of documentation which they acknowledged receiving and reading, and we further personally offered to answer any questions that might exist, or respond to the accuracy or basis of any data, or the estimates which we have provided, also which has not occurred, and which we again offer on a cooperative, working basis, in order to help find a mutually beneficial solution, or initiate research to more thoroughly respond to any issue.

Many people at the May 12, 2008 CPUC hearing described their own successful home solar projects that have been operational for years, which also deliver unreimbursed excess power into the SDG&E grid.
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References:

5. http://www.undergroundpower.us
7. Next page, specifications for **+/-300 kV XLPE underground DC cable**, with a 3,000 square millimeter copper conductor, 155 mm (6.2 inch) diameter and 1,840 megawatts of capacity, with PPL and SCFF technology underground cable options to operate at +/-600 kV and +/-800 kV, with proportionally greater capacity (estimated at 3,680 megawatts, and 4900 megawatts).

Reel diameter, or local bridge height during transport are the more significant limiting factors to cable length and power line capacity or splice reduction, with a typical reel capacity of 600 meters (1,968.5 feet).
<table>
<thead>
<tr>
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Sea soil: Temperature 15 deg.C, Burial 1.0 metre, Thermal resistivity 1.0 K x W/m
Cable: Copper conductor, HVDC polymer insulation, Steel wire armour
Full-wave rectification, AC to DC

A full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output. Full-wave rectification converts both polarities of the input waveform to DC (direct current), and is more efficient. However, in a circuit with a non-center tapped transformer, four diodes are required instead of the one needed for half-wave rectification. (See semiconductors, diode). Four rectifiers arranged this way are called a diode bridge or bridge rectifier:

For single-phase AC, if the transformer is center-tapped, then two diodes back-to-back (i.e. anodes-to-anode or cathode-to-cathode) form a full-wave rectifier (in this case, the voltage is half of that for the non-tapped bridge circuit above, and the diagram voltages are not to scale).

Inverter (electrical), DC to AC

An inverter is an electrical or electro-mechanical device that converts direct current (DC) to alternating current (AC). The electrical inverter is in effect a high-power electronic oscillator. It is so named because early mechanical AC to DC converters were made to work in reverse, and thus were "inverted", to convert DC to AC. The inverter performs the opposite function of a rectifier. With HVDC power transmission, AC power is rectified and high voltage DC power is transmitted to another location. At the receiving location, an inverter in a static inverter plant converts the power back to AC.

http://en.wikipedia.org/wiki/Rectifier
Comment Set G0014, cont.
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The electromechanical version of the switching device includes two stationary contacts and a spring supported moving contact. The spring holds the movable contact against one of the stationary contacts and an electromagnet pulls the movable contact to the opposite stationary contact. The current in the electromagnet is interrupted by the action of the switch so that the switch continually switches rapidly back and forth. This type of electromechanical inverter switch, called a vibrator or buzzer, was once used in vacuum tube automobile radios. A similar mechanism has been used in door bells, buzzers and tattoo guns.

As they have become available, transistors and various other types of semiconductor switches have been incorporated into inverter circuit designs.

Square waveform with fundamental sine wave component, 3rd harmonic and 5th harmonic

Output waveforms

The switch in the simple inverter described above produces a square voltage waveform as opposed to the sinusoidal waveform that is the usual waveform of an AC power supply. Using Fourier analysis, periodic waveforms are represented as the sum of an infinite series of sine waves. The sine wave that has the same frequency as the original waveform is called the fundamental component. The other sine waves, called harmonics, that are included in the series have frequencies that are integral multiples of the fundamental frequency.

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Laying operation, Tubigo near Milan 2005, Prysmian extruded cross-linked polyethylene XLPE cable

380 kV cable, 1 x 2000 mm²:
1) CooperMilliken conductor, waterblocked; 2) semiconducting screen; 3) XLPE insulation; 4) semiconducting screen; 5) semiconducting waterswellable tapes; 6) Welded Aluminum Sheath; 7) PE outer sheath.

Cable has been design to comply with the required performances. Moreover, starting from 80% loading, it is capable to be overloaded at 180 % for 5 hours.