SCDC Cables

Pitfalls and Potential

(or vice versa)

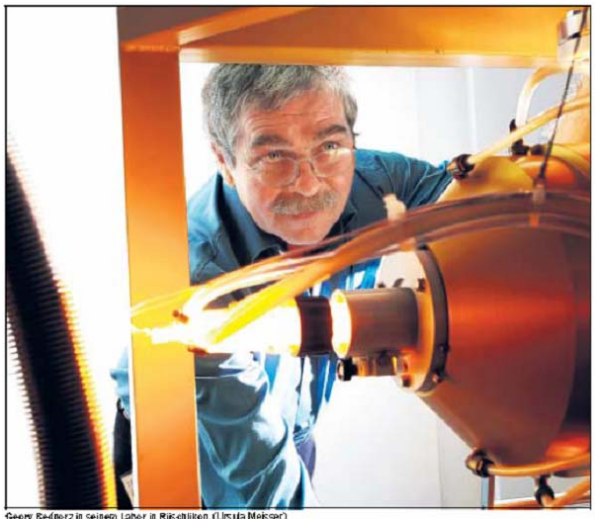
Paul M. Grant
W2AGZ Technologies

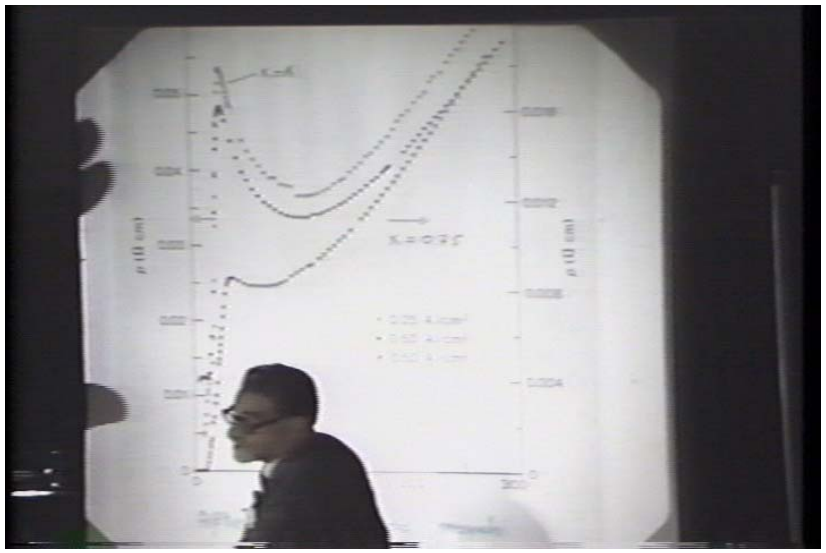
http://www.w2agz.com/doe-wdw07.htm

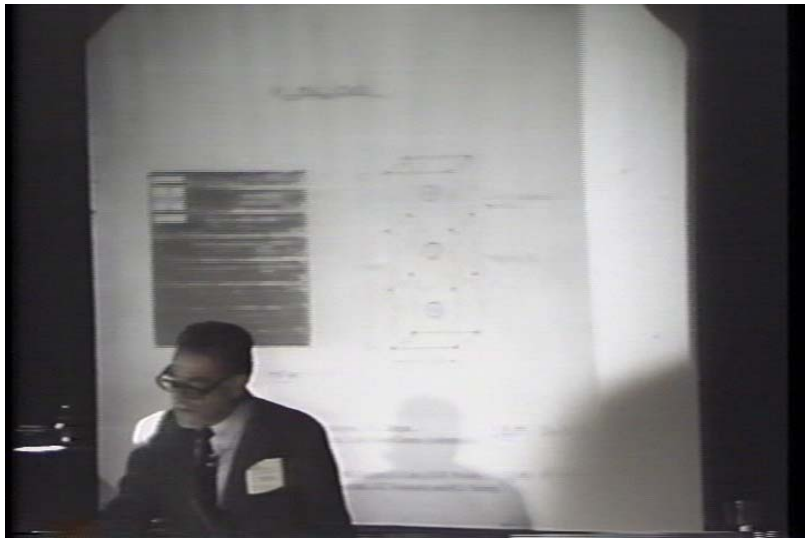
DOE Wire Development Workshop, Panama City, FL 17 January 2006

"Be There or Be Square"

20th Anny of Woodstock, APS Denver, 5 March 2007







HTSC SCDC Cable Anthology

A Proposal for DC Superconducting Power Transmission Line

2006

Satarou Yamaguchi, Makoto Hamabe, Atsushi Sasaki, Isamu Yamamoto, Fawakinwa Tosin, Keiju Matsui, Masayuki Yukimoto, Eiji Mizuno, Kimio Yamada, Atsuo Iiyoshi, Akira Ninomiya, Haruhiko Okumura, Tsutomu Hoshino, Nagato Yanagi, Joel Schultz, Yasuhide Ishiguro, Kuniaki Kawamura

Feasibility of Electric Power Transmission by DC Superconducting Cables

2005

P. Chowdhuri, Fellow, IEEE, C. Pallem, Student Member, IEEE, J.A. Demko and M.J. Gouge

A dc transmission cable prototype using high-temperature superconductors

1996

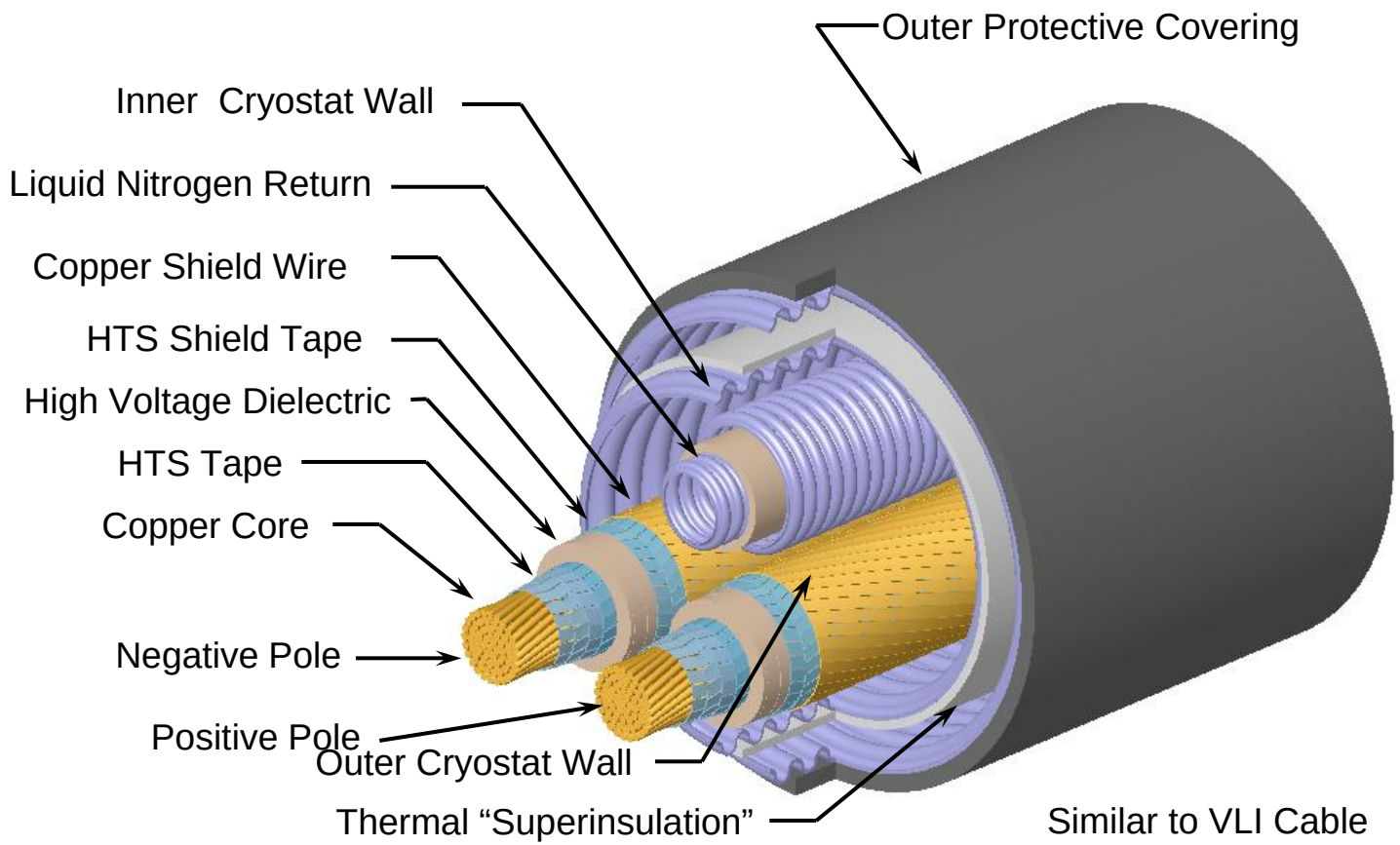
T P Beales†, C M Friend†, W Segir‡, E Ferrero‡, F Vivaldi§ and L Ottonello§

A Techno-Economic Design Study of High-Temperature Superconducting Power Transmission Cables

1994

S. P. Ashworth, P. Metra, R. J. Slaughter

Typical DC Cable (Ground Return) Cross Section



Courtesy: Mike McCarthy, AMSC

SCDC CableTechnology Pitfalls & Potential

- Pitfalls
  - None (except possibly wire cost)
  - Caveat
    - Needs demonstration at high current (> 10 kA)
- Potential
  - High
    - No other way to deliver massive amounts of electricity in a small eco-friendly package
  - Caveat
    - Alternative may be parallel conventional HVDC cables "corridor-ed" via directional drilling

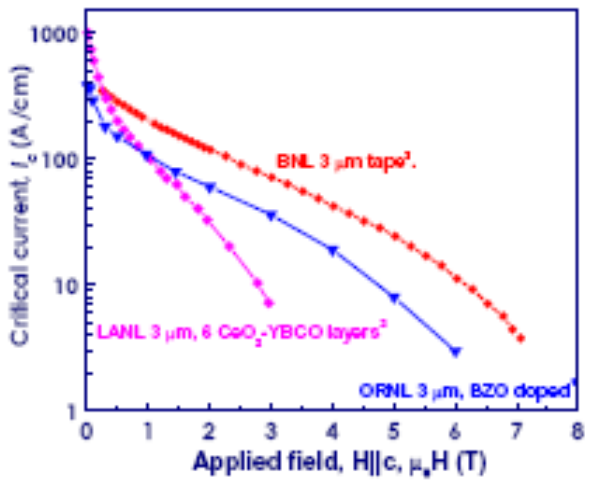
"Best of Show, PR 2006"

Performance of 3 μm films on AMSC tape in liquid nitrogen.

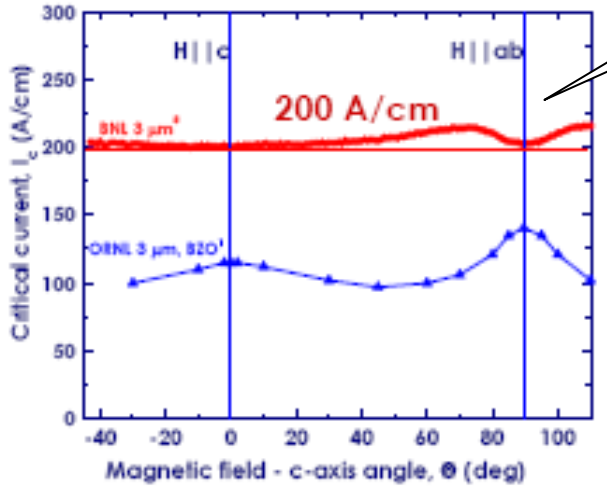
BROOKHAVEN NATIONAL LABORATORY

DOE Peer Review 200

WOW!



1 Tesla field



[1]PLD deposited YBCO with BZO columnar structures, S. Kang, et al. *Science*, 311, p. 1911 (2006).
[2]X. Jia, S. R. Foltyn, P. N. Arendt, and J. F. Smith, *Appl. Phys. Lett.*, 80, p. 1601, (2002).
[3]Transport J_c measurement by L. Civale and B. Maiorov, LANL.

✓ BNL 3 μm sample exhibited very strong isotropic pinning, which was combined with high T_c.

7

SCDC Cable Applications Pitfalls & Potential

- Pitfalls
  - Is there a "commercial" market? (SOS)
    - IOUs…investment in very high capacity transmission unlikely…too many other alternatives (e.g., FACTS, HVDC)
    - Merchant Transmission…maybe, but MT in the US seems at a standstill.
    - B2B's and inter-RTO connections don't need huge "bandwidth" for stabilization and isolation
    - SCDC cables not mentioned in the NCI Report
- Potential
  - Energy efficiency and other "public interest" long term investment
  - Caveat
    - Highly dependent on volatile political and social whims and agendas

EMPIRE CONNECTION

Specifications

2-1000 MW HVDC Bipolar Circuits

- Circuit 1: 130 miles, Greene County → Bronx County
- Circuit 2: 140 miles, Albany County → New York County
- Each Circuit: +/- 500 kV, 1000 A Bipolar (2 cables ea.)

Financials

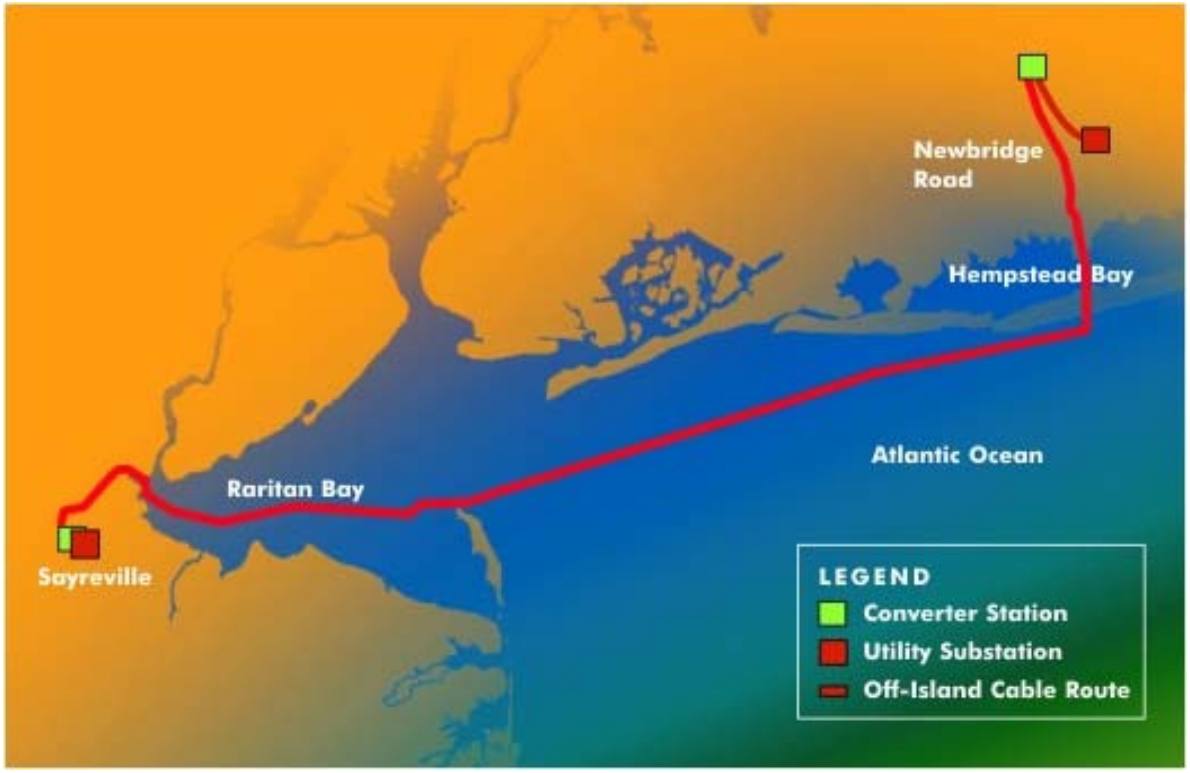
$750 M ($400 M "VC", $350 M "Futures")

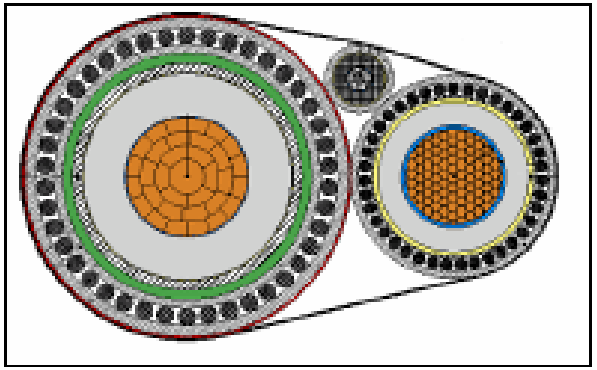
Loan Payment (4%, 40 yrs, 750 M$) =	35 M$/yr
Labor, Overhead, Maintenance =	5 M$/yr
Tariff =	0.5 ¢/kWh
Profit (NOI) @ 50% Capacity =	4 M$/yr
Profit (NOI) @ Full Capacity =	48 M$/yr

Why didn't it go forward?

Wire C/P = 100 $/kA×m
HTSC Cost = $87 M

NEPTUNE
Regional Transmission System™





HVDC Cable Cross-Section

Pirelli (Prysmian) Energy Cables

$190 M

Sayerville, NJ → Levittown LI, NY

- 600 MW (+/- 250 kV, 1200 A)
- 65 miles (105 km)
- $400 M
- 2007

Financials

40 yrs @ 4%:	$ 20M
LOM:	1 M
NOI (100%):	5 M

T 77 K	C/P $/kA×m	Cost ($M)
Cu	7	1.8
HTSC	100	25.1

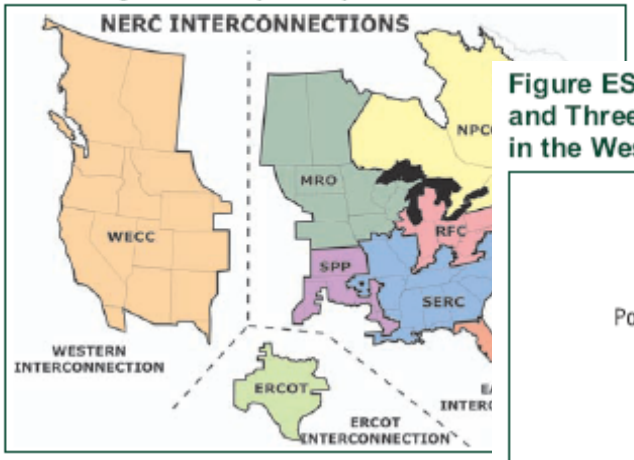
B2B, Lamar, Colorado

Customer:	Xcel Energy
Location:	Lamar / Colorado / USA
Power Rating:	210 MW continuous
AC Systems	230 kV AC 60 Hz (West Lamar / Colorado), 345 kV AC 60 Hz (East Finney / Kansas)
DC Voltage	63,6kV
Type of Thyristor:	Direct-light-triggered 8kV

7 B2B's in US, 4 between ERCOT and the World, all < 500 MW. Is HTSC really needed?

National Electric Transmission Congestion Study

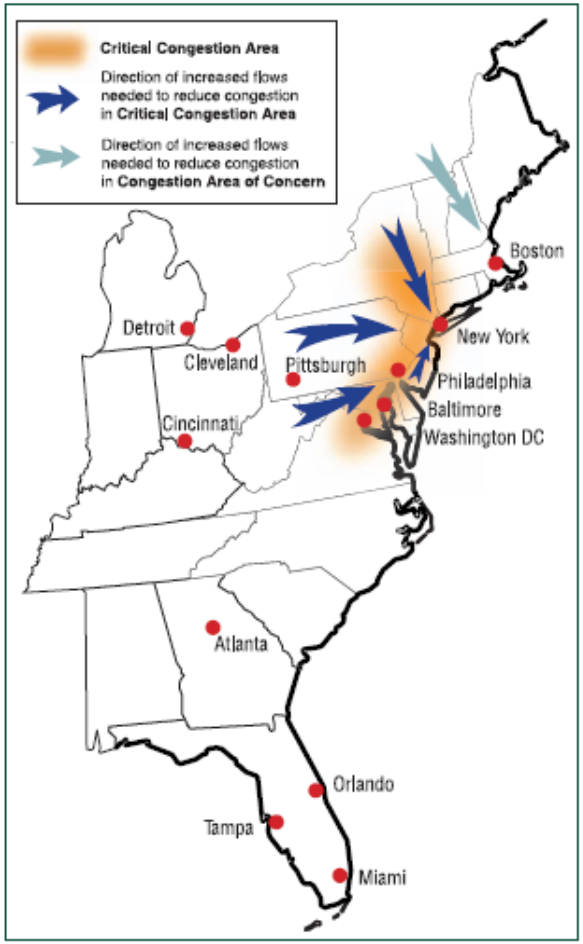
Figure ES-1. Map of North American Electric Reliability Council (NERC) Interconnections



Source: NERC, 2006.

Figure ES-3. One Critical Congestion Area and Three Congestion Areas of Concern in the Western Interconnection

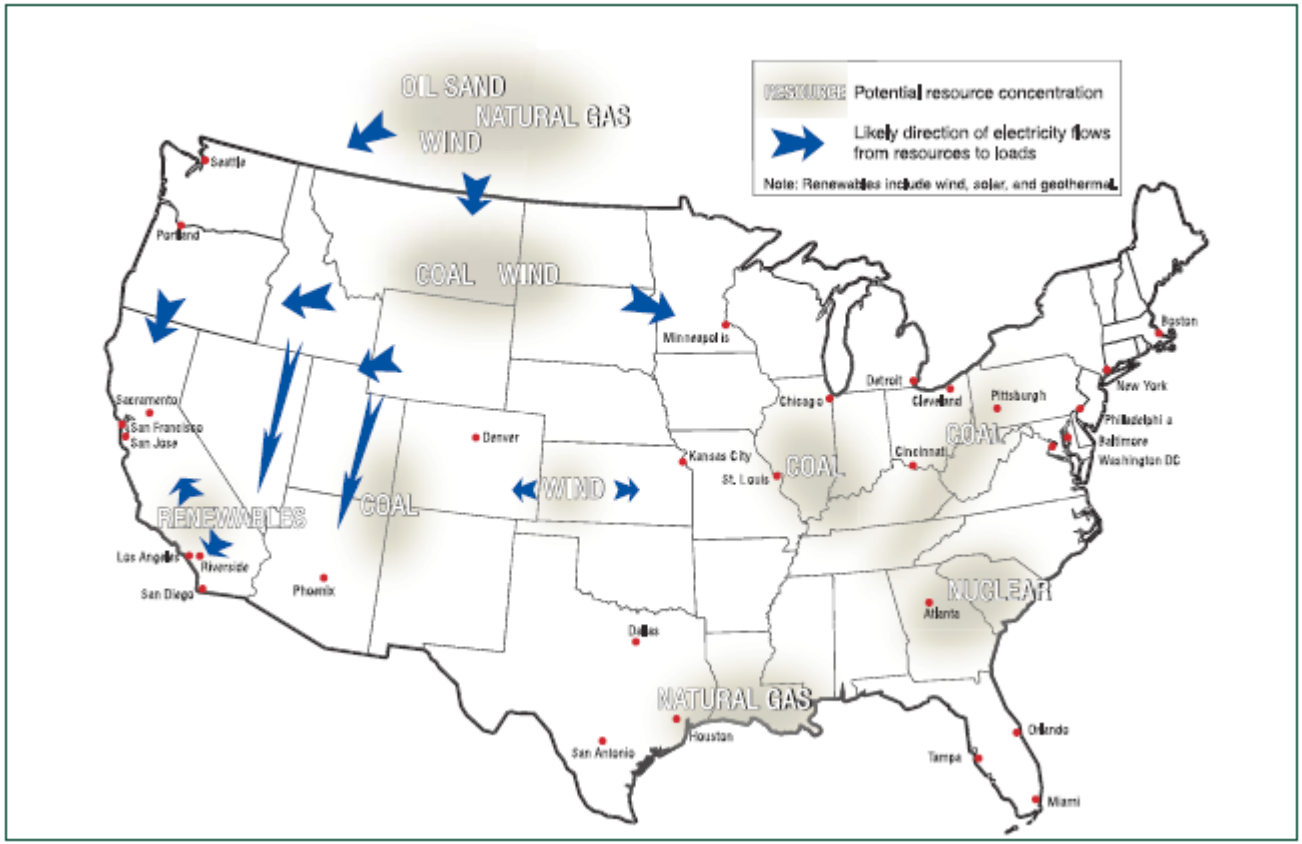
Figure ES-2. Critical Congestion Area and Congestion Area of Concern in the Eastern Interconnection



The HTSC community did not participate in this study!

Future Challenges

Figure ES-4. Conditional Constraint Areas



Recommendations to DOE-OE

Commission a review of the NETC Study by the HTSC community (Forrestal, companies, nat labs) to assess potential (and pitfalls!) for deployment of high capacity SCDC cables (and ac) in relief of present and future transmission constraints.

HVDC Pacific InterTie

Customer:	Bonneville Power Administration
Location:	The Dalles, Oregon/USA
Power Rating:	2000 MW
AC systems:	230 kV, 60 Hz
DC Voltage:	± 500 kV DC
Type of thyristor:	8kV LTT

- Authorized by JFK in 1961
- Specs
  - 841 miles
  - 2 GW
  - 500 kV bipolar
  - 2 kA (4 cm diameter Al)

Customer:	Los Angeles Department of Water and Power, California, USA
Location:	Sylmar Converter Station East, Los Angeles
Configuration:	Bipole
Power Rating:	550 (825) MW
AC systems:	230 kV, 60 Hz
DC Voltage:	± 500 kV DC
Thyristor:	8 kV
Number of thyristors:	936

U.S. Electricity Production/Loss Summary

	TkWh	% in T&D Loss and In-Plant Use	Revenue @ $0.10/kWh (B$)	No. of 500 MW Power Plant Equivalents	Capital Cost @ $800/kW (B$)
Total	3.24		324	740	296
T&D Losses	0.28	8%	28	63	25
In-Plant Used	0.15	5%	15	35	14

From 1997 DOE PR

Superconductivity and Efficiency

	1994	2014 @ 2%/yr	2014 Plants Saved 0.2% Penetration 4× Efficiency
Total	**740**	**360**	
T&D Losses	**63**	**31**	**11**
In-House Use	**35**	**17**	**6**

From 1997 DOE PR

National Ticket 20??

Prez

SecEn

Veep