SuperGrid As SuperTie

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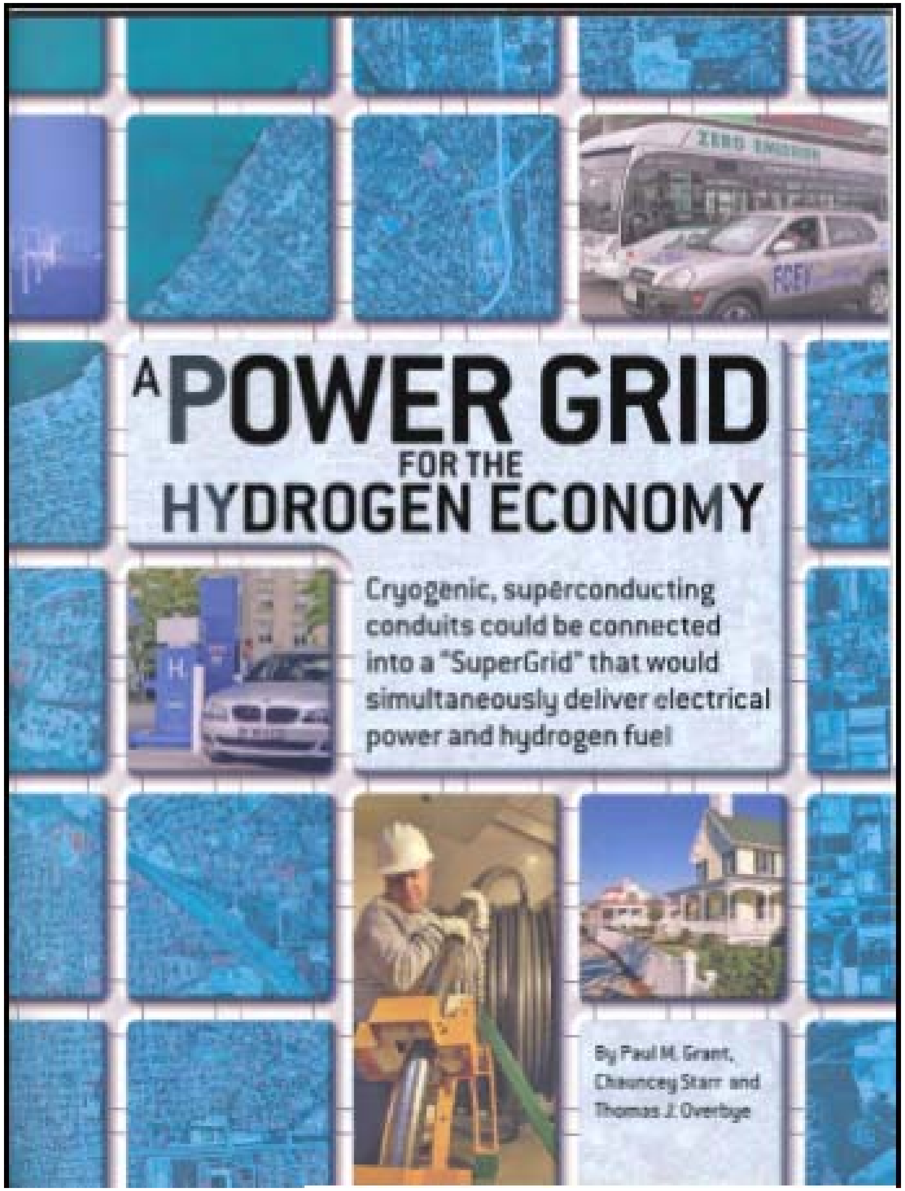

Superconducting Lines for the Transmission of Large Amounts of Power over Great Distances

Garwin-Matisoo Revisited 40 Years Later!

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Oral Session: Power Cable – 1
Applied Superconductivity Conference 2006
10:30 AM, Monday 28 August 2006
Seattle, WA

Superconducting Lines for the Transmission of Large Amounts of Electrical Power over Great Distances

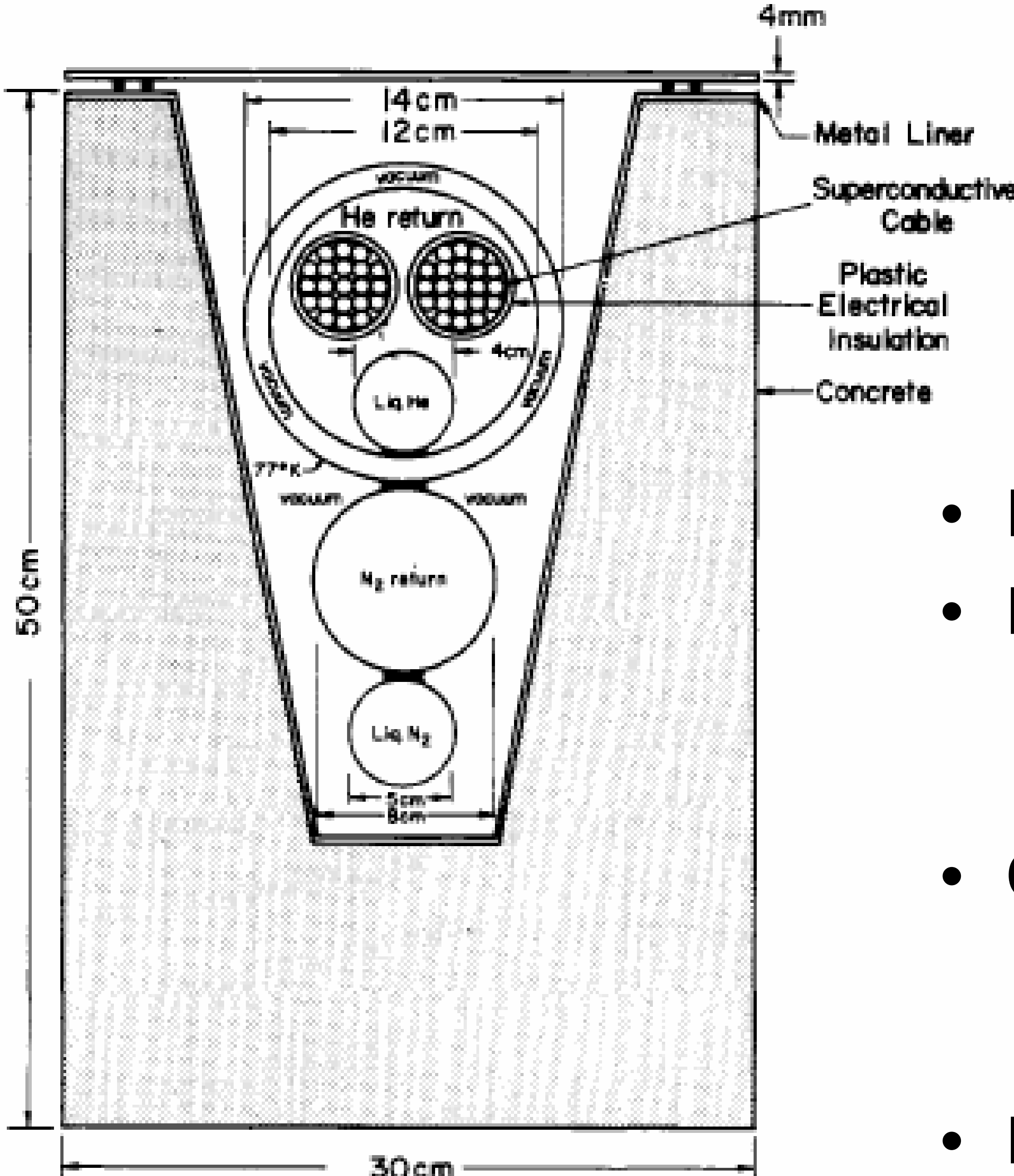
R. L. GARWIN AND J. MATISOO

Submitted 24 June 1966

PROCEEDINGS OF THE IEEE, VOL. 55, NO. 4, APRIL 1967

Rationale: Huge growth in generation and consumption in the 1950s; cost of transportation of coal; necessity to locate coal and nuke plants far from load centers.

Furthermore, the utilities have recently become aware of the advantages of power pooling. By tying together formerly independent power systems they can save in reserve capacity (particularly if the systems are in different regions of the country), because peak loads, for example, occur at different times of day, or in different seasons. To take advantage of these possible economies, facilities must exist for the transmission of very large blocks of electrical energy over long distances at reasonable cost.



Specs

- LHe cooled
- Nb_3Sn (T_C = 18 K)
  - J_C = 200 kA/cm^2
  - H* = 10 T
- Capacity = 100 GW
  - +/- 100 kV dc
  - 500 kA
- Length = 1000 km

G-M Engineering Economy
- Yesterday & Today -

Wire Cost is 68% of Total

VARIOUS COMPONENT COSTS OF A 1000 KM, NB-SN CABLE IN 1966 AND NOW

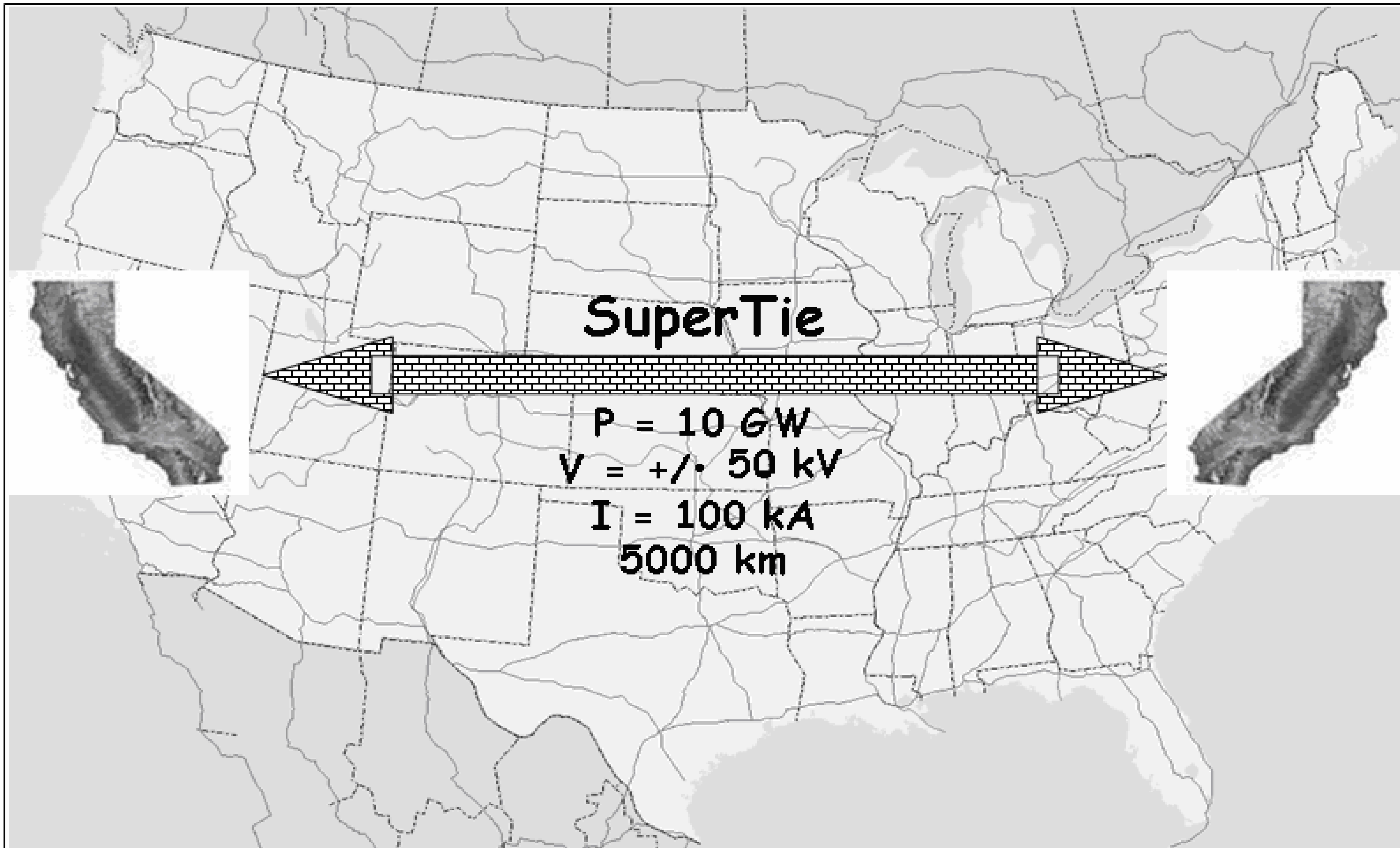
Item	Description/Quantity	1966 Cost (M$)	2006 Cost (M$)*
Superconductor	10^4 Tons Nb_3Sn	550	3405
Line Refrigeration	0.5 M$ for 1 kW LHe station every 20 km	25	155
End-Station Refrigeration	10 kW each	5	31
Vacuum Pumps	$500 per station (2000)	1	6
Fabricated Metal	$1/lb, linear line weight = 100 gm/cm	20	124
Concrete	[illegible]/yd^3 for a total volume of 0.5 yd^2 times 1000 km	5	31
ac/dc Converters	Thyristors at $1/kW	200	1238
Total:		806	4990

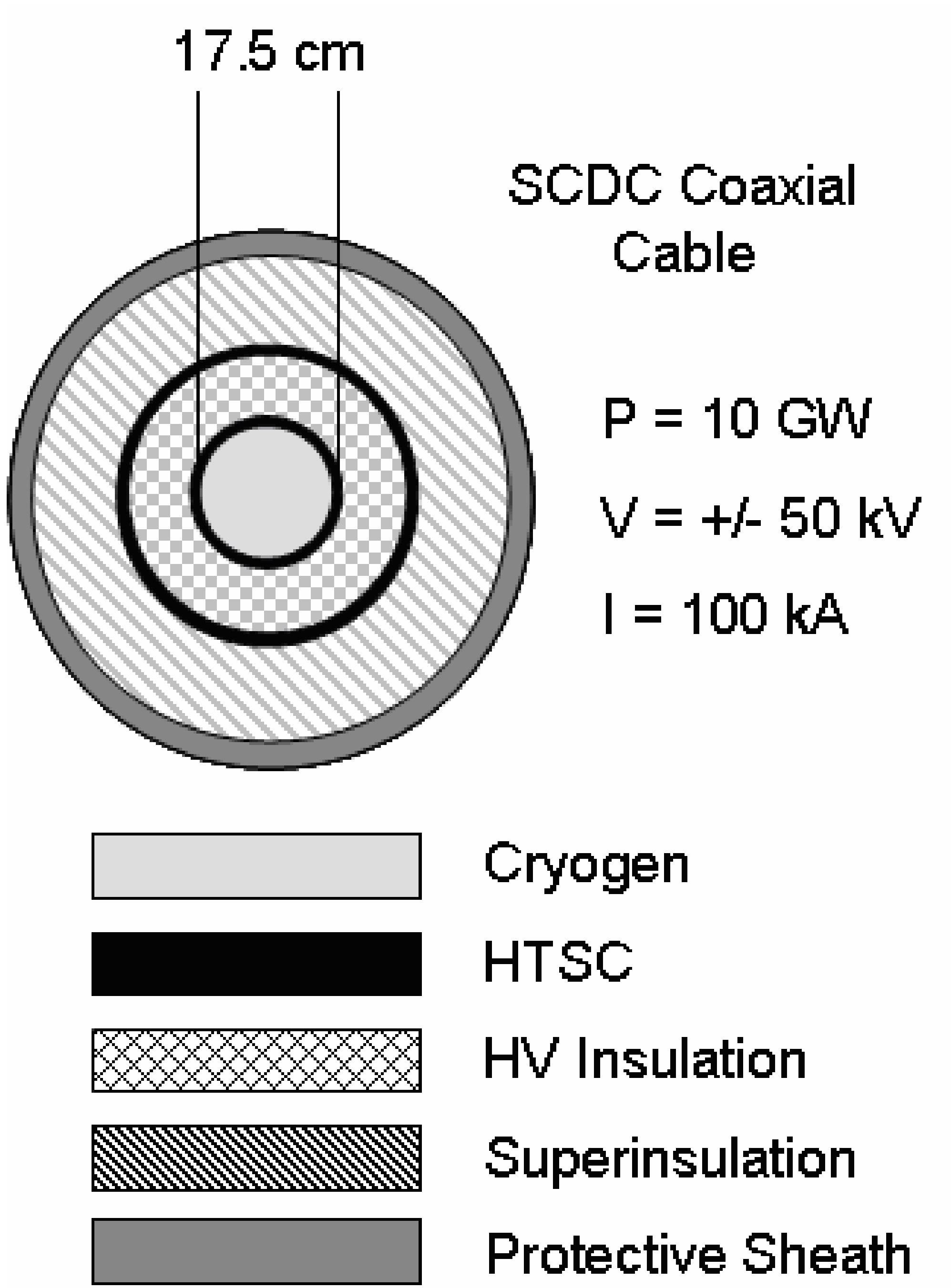
Unrealistic !

*CPI Factor = 6.19

~ 500 M$/10 GW/1000 km

“Two Californias”



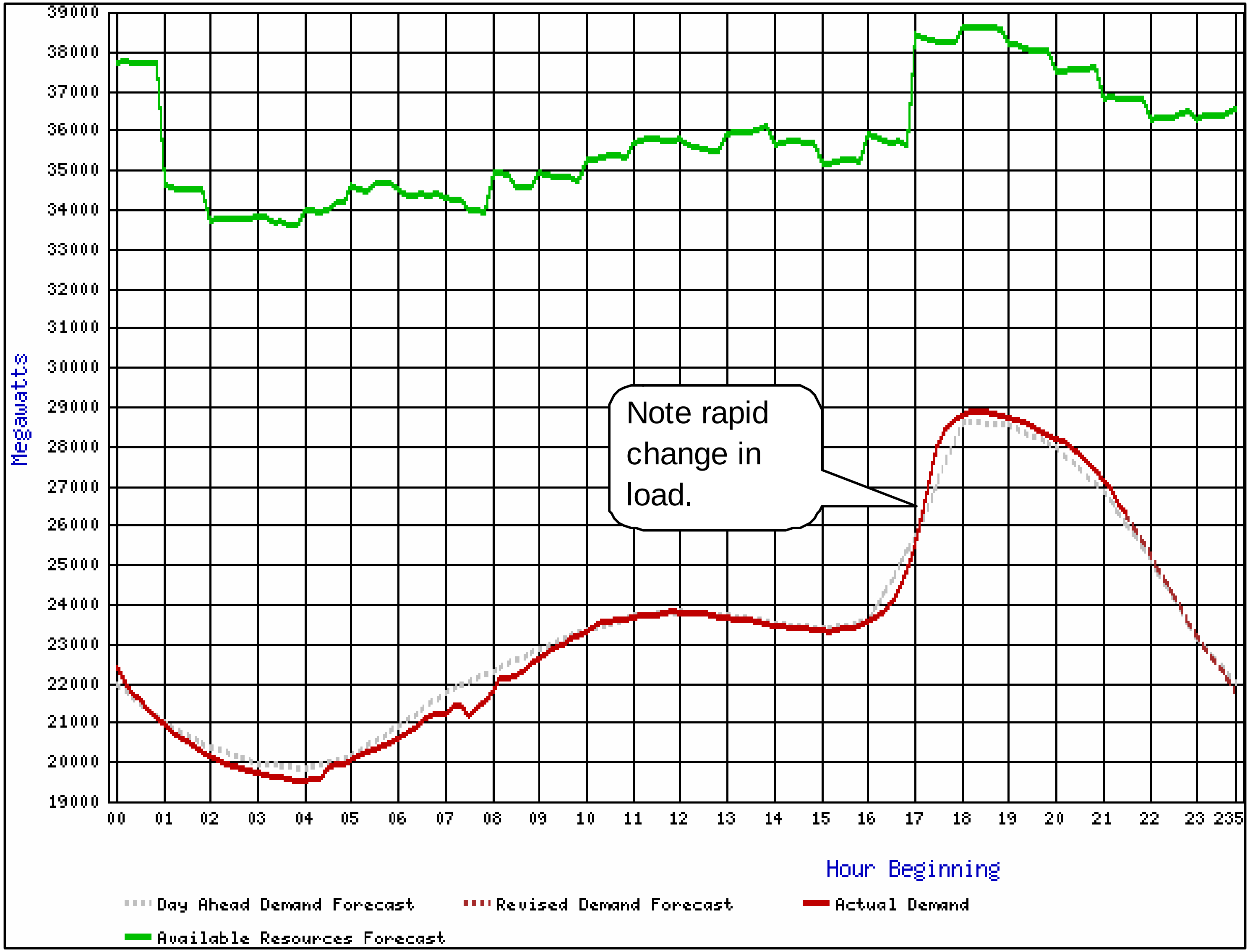

17.5 cm
SCDC Coaxial Cable
P = 10 GW
V = +/- 50 kV
I = 100 kA
Cryogen
HTSC
HV Insulation
Superinsulation
Protective Sheath

SCDC SUPERTIE CABLE DESIGN AND PERFORMANCE PARAMETERS

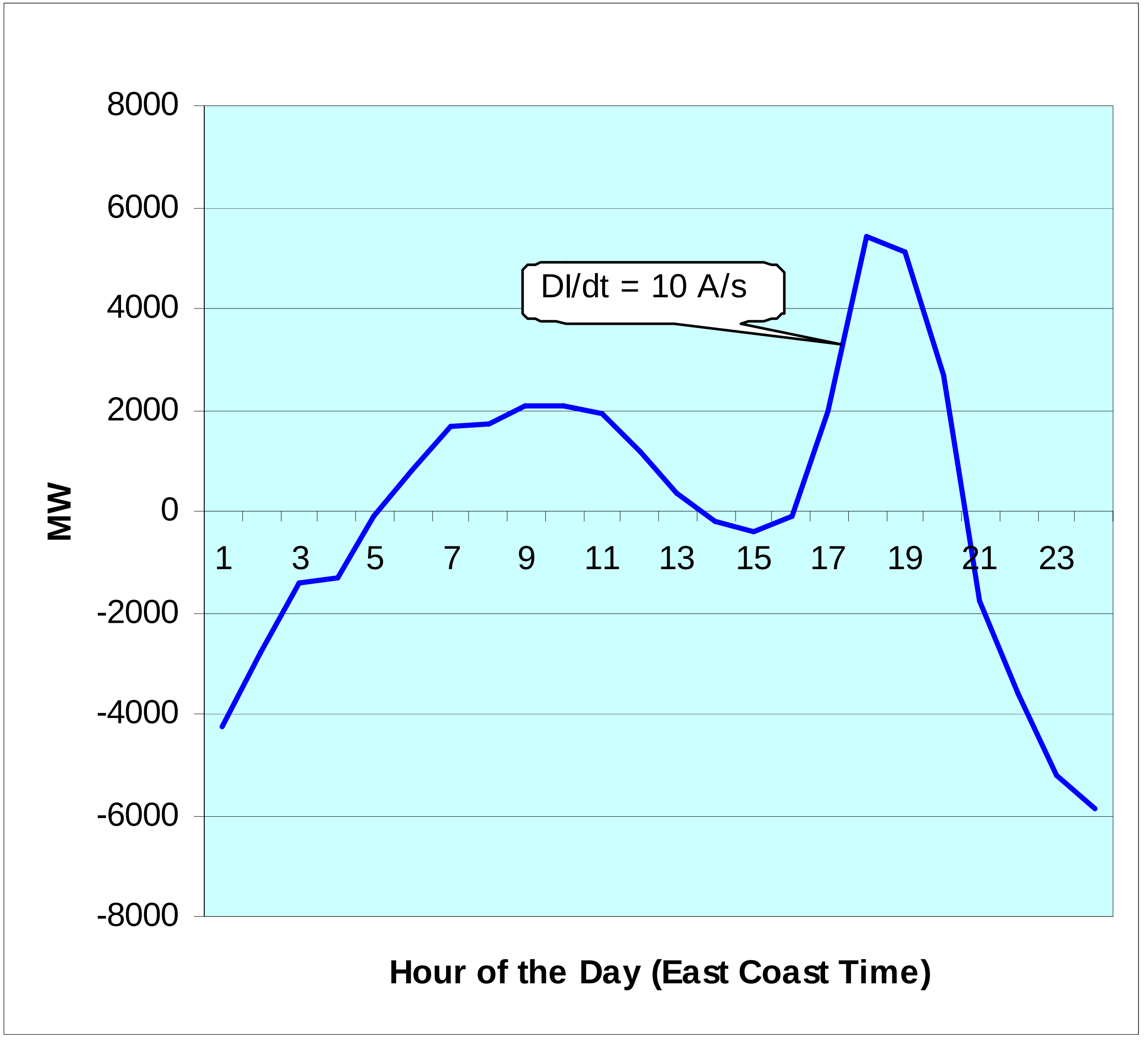
Item	Value/Quantity	Units
HTSC Tape Parameters (77 K, 0.3 T)		
- Critical Current Density, J_C	15,000	A/cm^2
- Tape Critical Current, I_C	150	A/tape
- Cost/Performance	50	$/(kA×m)
- Width	0.4	cm
- Thickness	0.025	cm
- Single Tape Length	800	m
- Integration "wasteage"	5	%
- Joint Resistance	0.92	mW
- I^2R Dissipation per Joint	0.8	mW/m
SuperTie SCDC Cable Parameters and Performance		
- Overall Length	5000	km
- Number of Conductors*	2	1 per pole
- Conductor Annular Radius	8.75	
- Maximum Power	10	
- dc Voltage	50	
- dc Amperage	100	kA
- Field at Conductor Surface	0.23	T
- Conductor X-Section Area	6.62	cm^2
- # HTSC Tapes/X-Section	667	
- Total Tape Length/Pole	3,475,600	km per Conductor-Pole
- Total # Joints per Pole	4,345,000	
- Power Lost in Joints/Pole	4.0	kW
- HTSC Tape Cost per Pole	26.3	B$

~ 10,000 M$/10 GW/1000 km
(20× G-M !)

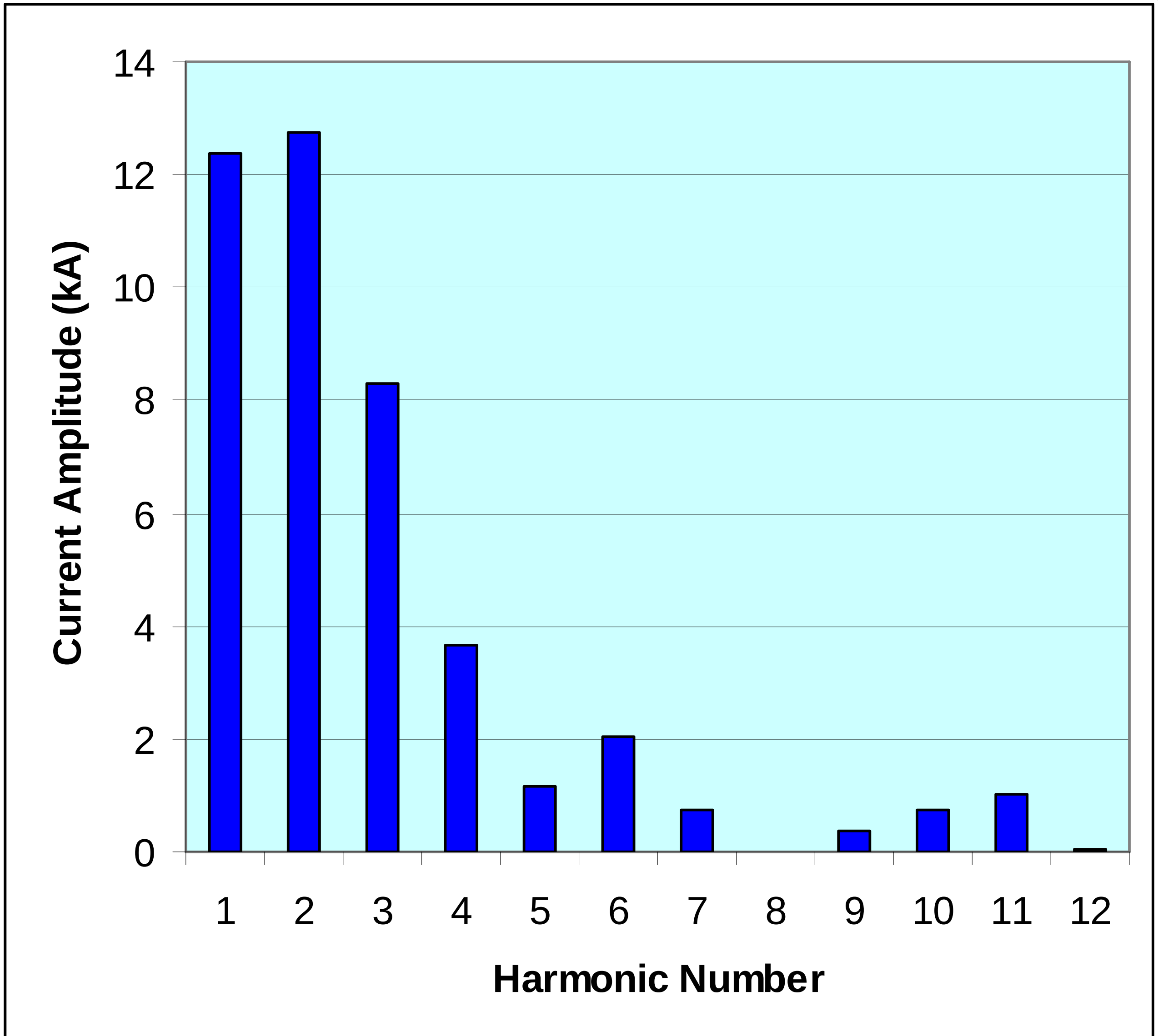
Hotel California, 8 January 2006



“Twin Californias”



Current Harmonics for "Twin Californias" Diurnal Trading



“Twin California” Trading Losses

Harmonic, n	I_n (kA)	f (μHz)	W_H (kW/5000 km)
1	12.4	11.6	1.8
2	12.8	23.2	3.8
3	8.31	34.7	2.4
4	3.67	46.3	6.2
		Total	8.7

No Problem!

“Sanity Check”

- Worst Case: Assume a “toleration loss” no larger than 1 W/m, then the entire SuperTie could be reversed in only 2 hours.
- The “fastest” change would be ~ 10 A/s between 5 and 6 PM EST. Compare with 1% ripple on 100 kA at the 6^{th} harmonic of 60 Hz which is 720,000 A/s!

5000 km SuperTie Economics

Base Assumption: C/P “Gen X” = $50/kA×m

Cost of Electricity ($/kWh)	Line Losses in Conventional Transmission (%)	Annual Value of Losses on 10 GW Transmission Line @ 50% Capacity (M$)	Additional Capital Costs for HTSC and Refrigeration (M$)	FRB Discount Rate (%)	Period for ROI (Years)
0.05	5 %	110	52,574	5.5 %	62

“Deregulated Electricity” will <u>not</u> underwrite this ROI, only a “public interest” investment analogous to the Interstate Highway system makes sense

Possible SuperTie Enablers

- Active public policy driving energy efficiency
- Carbon tax
- Tariff revenue from IPPs accruing from massive diurnal/inter-RTO power transactions
- Unique Value-added Not Possible with other/alternate cable technologies

Hydrogen !