FEASIBILITY OF ELECTRIC POWER TRANSPORT BY DC SUPERCONDUCTING CABLES IN TENNESSEE

P. Chowdhuri
Center for Electric Power
Tennessee Technological University
Cookeville, TN 38505

2003 Annual Peer Review Meeting
Superconductivity for Electric Systems
U.S. Department of Energy
Washington, D.C.
24 July 2003

Advantages of a DC Superconducting Cable (DC SPTL)

- No hysteresis, eddy-current and dielectric losses
- No stability limit in power transfer
- No charging current to limit power transfer of a DC SPTL
- No external magnetic field from a coaxial DC SPTL
- Short circuit current can be limited to less than 2 p.u.
- No dc circuit breaker is needed
- Two DC SPTL in bipolar mode are equivalent to six AC SPTL

The only disadvantage is the cost of the converters

Program Objectives

To study the feasibility of dc superconducting cables, emphasizing the following:

- **Preliminary cable design for monopolar/bipolar operation**
- **Compatible converters at the cable terminals**
- **Analysis of:**
  (a) short-circuit current,
  (b) harmonic losses,
  (c) transient overvoltages
  (d) reactive power compensation,
- **Future course of action**

One distribution site and one transmission site in Tennessee were proposed for the study

Project Schedule

<table>
<tr><th rowspan="2">Task</th><th colspan="6">Months</th></tr>
<tr><th>3</th><th>6</th><th>9</th><th>12</th><th>15</th><th>18</th></tr>
<tr><td>I</td><td>3 months</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>II</td><td></td><td colspan="4">12 months</td><td></td></tr>
<tr><td>III</td><td></td><td></td><td></td><td></td><td></td><td>3 months</td></tr>
</table>

Task I: Selection of (i) two power transport sites and (ii) dc superconducting cables
Task II: Analysis of technical feasibility and preliminary economic evaluation
Task III: Recommendation of future plan and final report

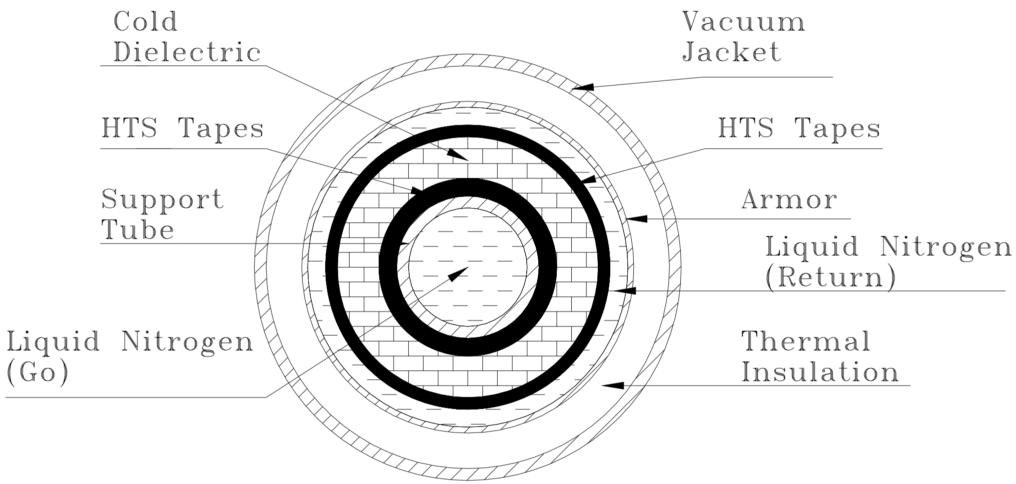
Progress To Date

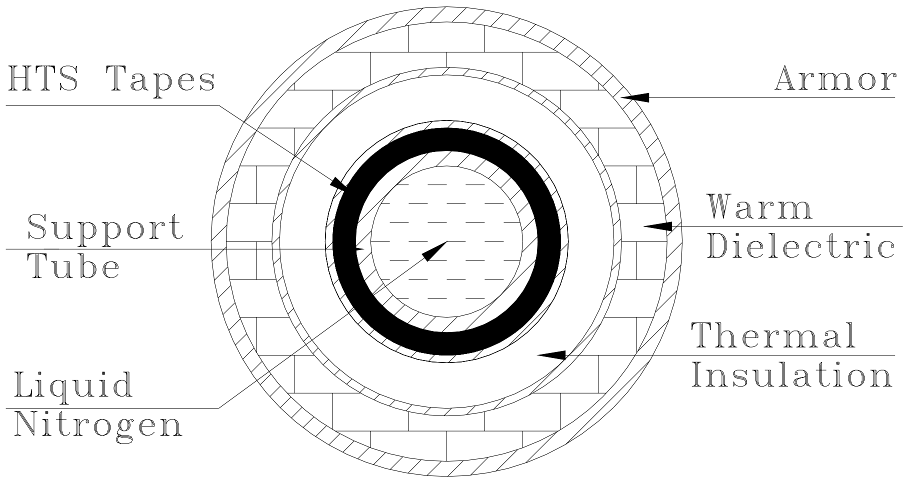
Site Specifications

Site	Line Length km	Rated Power GW	Desired DC Voltage
TVA #1	580	6	+/- 300 kV, 10 kA bipolar
TVA #2	95	3	300 kV, 10 kA monopolar
TVA # 3	161	3 to 6	300 kV, monopolar @ 3 GW +/- 300 kV, bipolar @ 6 GW
NES	0.61	0.5	100 kV, 5 kA monopolar

Progress To Date

Task I: Cables

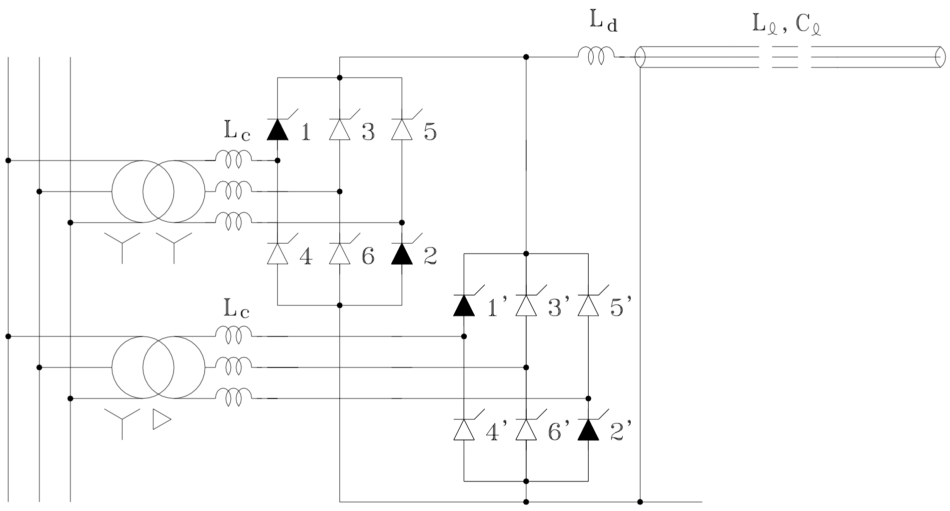




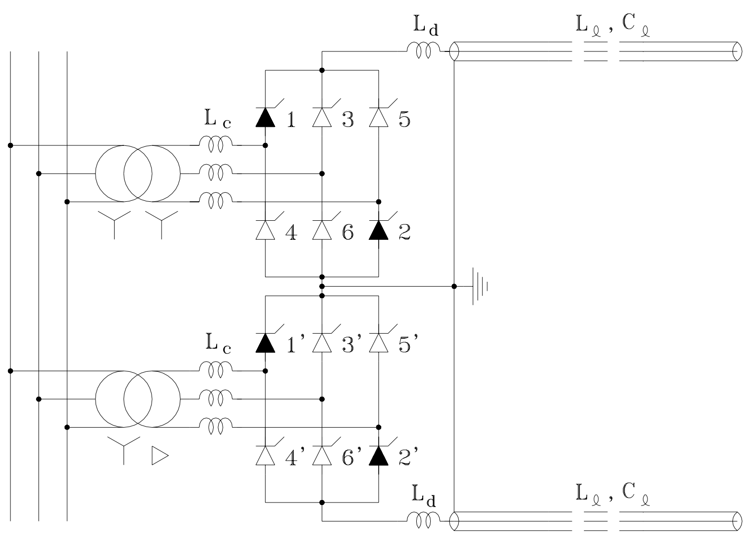
Progress To Date

Possible Converter Connections

Twelve–Pulse Parallel–Connected Converter

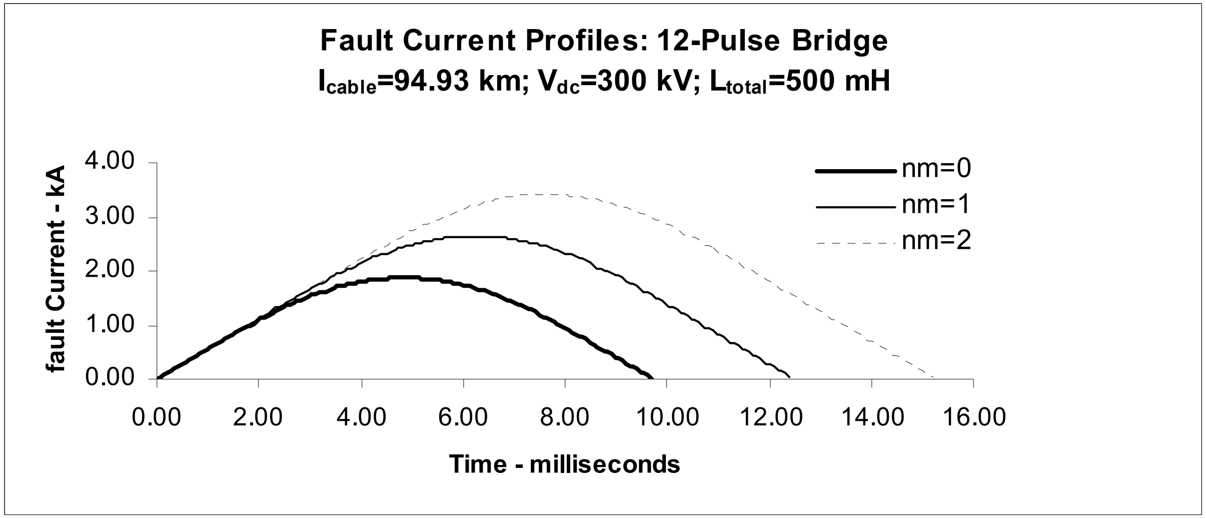


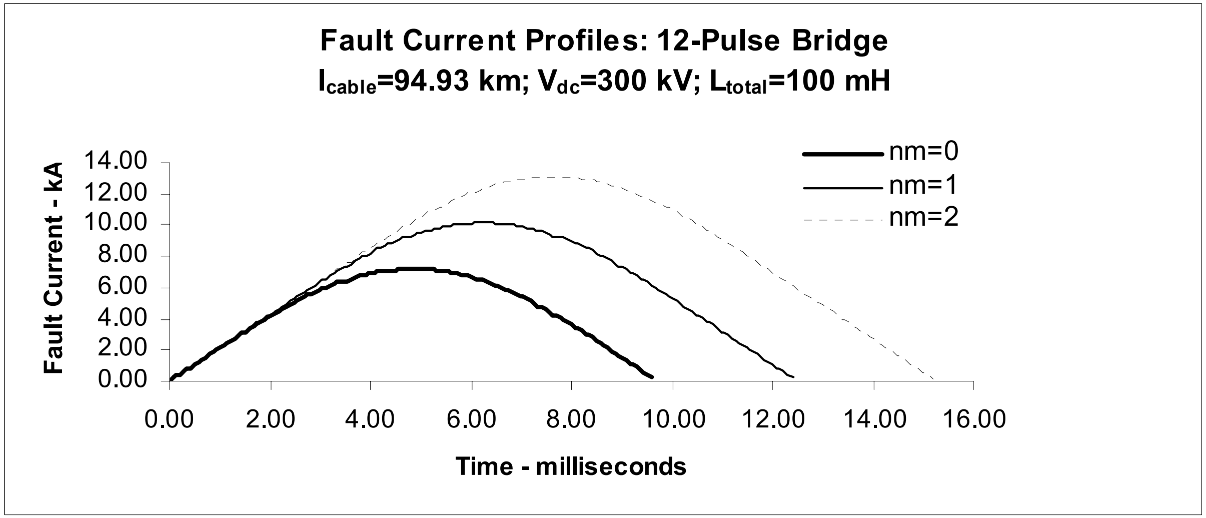
Twelve–Pulse Bi–Polar Converter



Progress To Date

Task II: Analysis – Fault Current





Progress To Date

Task II: Analysis – Fault and Harmonic Currents
TVA Sites

Rated Power=3 GW; V_{dc}=300 kV
12-pulse operation; No. of misfires=1

Site	Terminal Inductance H	Discharge Current		Fault Current		Max. Harmonic Current A
		Amplitude kA	Duration ms	Amplitude kA	Duration ms	
1	0.5	11.06	6.69	2.32	12.5	33.82
	0.1	11.06	6.69	6.59	12.5	169.10
2	0.5	11.06	1.10	2.64	12.5	29.58
	0.1	11.06	1.10	10.14	12.5	147.90
3	0.5	11.06	1.86	2.59	12.5	18.98
	0.1	11.06	1.86	9.45	12.5	94.89

Progress To Date

Task II: Analysis – Fault and Harmonic Currents
NES Site

Rated Power = 500 MW
12-pulse operation; No. of misfires=1

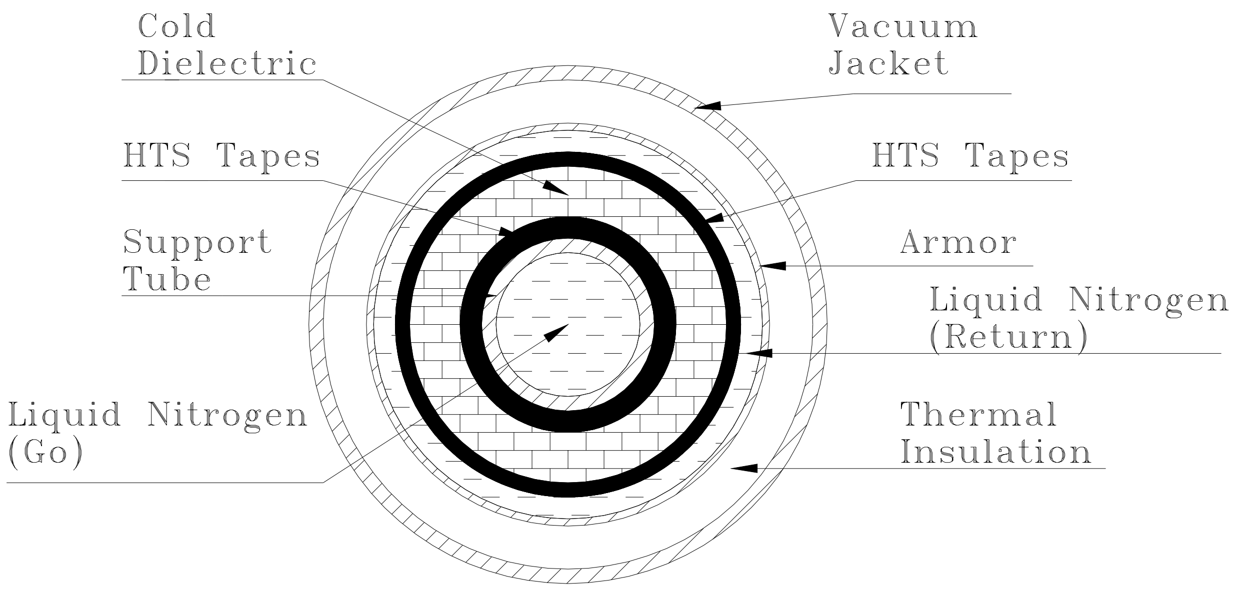
DC Voltage kV	Terminal Inductance H	Discharge Current		Fault Current		Max. Harmonic Current A
		Amplitude kA	Duration ms	Amplitude kA	Duration ms	
50	0.5	11.06	5.57	0.48	12.5	1.60
	0.1	11.06	5.57	2.38	12.5	8.01
100	0.5	11.06	5.57	0.95	12.5	3.20
	0.1	11.06	5.57	4.77	12.5	16.01

Progress To Date

Task II: Analysis – Transient Overvoltages

Paths of Entry of Transient Overvoltages:

- **Innermost conductor (HTS) via converter**
- **Outermost conductor (cryogenic envelope) from lightning strike to earth**



Progress To Date

Task II: Analysis – Transient Overvoltages

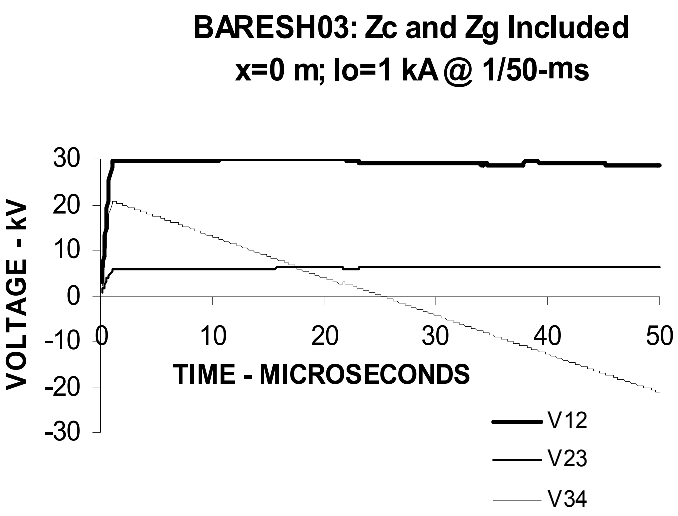
Analytical Techniques:

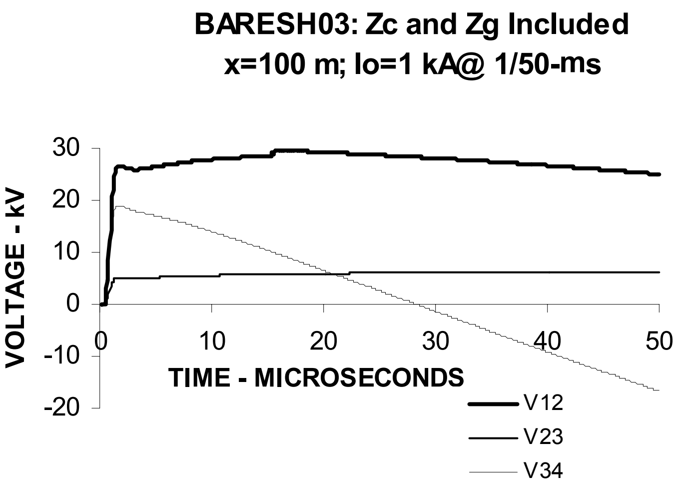
- **Image method to compute cable parameters, L's and C's**
- **Time-domain conductor internal impedance, Z_c**
- **Time-domain earth-return impedance, Z_g**

Progress To Date

Task II: Transient Overvoltages

Rated Power = 3 GW; V_{dc} = 300 kV





Tasks To Be Completed

- Transient Overvoltages
  (i) Cable terminal impedances
  (ii) Alternate paths of entry
  (iii) Outermost conductor insulated

- Economic Evaluation

Tentative Recommendations For Future Plan

- **Dielectric at Cryogenic Temperatures**
  - (i) DC breakdown
  - (ii) Impulse breakdown
  - (iii) Polarity reversal
  - (iv) Stress cone (cable joint) design
  - (v) Bushing (terminal) design

- **Behavior of Power Semiconductor Devices at Cryogenic Temperatures**
  - (i) Steady-state current rating
  - (ii) Steady-state forward/reverse voltage ratings
  - (iii) di/dt and dV/dt ratings
  - (iv) Turn-on/off characteristics
  - (v) Transient voltage rating

Acknowledgments

- Collaboration with Oak Ridge National Laboratory is gratefully acknowledged
- Advice and help from Los Alamos National Laboratory are also gratefully acknowledged