Superconductor based Power Distribution

Vinod, Joydeep, Biplob, Anita and Atul

Indian Institute of Science Education and Research Mohali

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Overview of the Talk

Current Scenario

Superconductor Description

- Properties
- YBCO Wires [pictures follow]
  - Manufacturing of YBCO
  - Manufacture of Tape
  - Manufacture of Wire
- Cooling
  - Running Temperature (70 K)
  - What happens when cooling fails — How the design helps
  - Types of Losses
    - Resistance (Joint losses)
    - AC loss (magnetic losses)

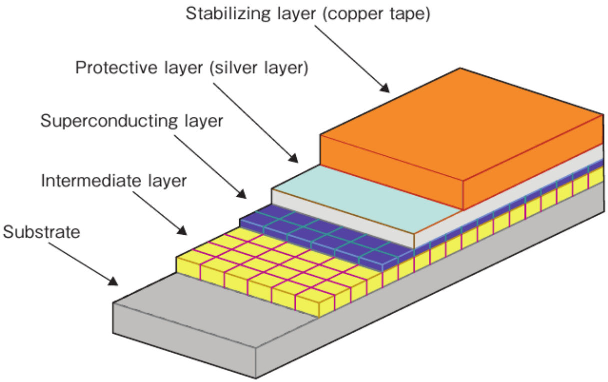

Figure : Structure of YBCO tape

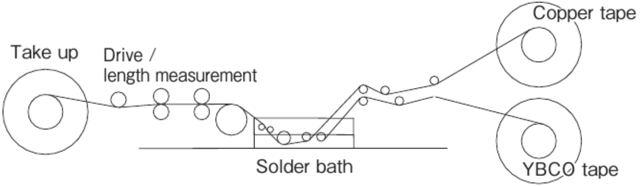

Figure : Laminating machine for copper-composite YBCO tape

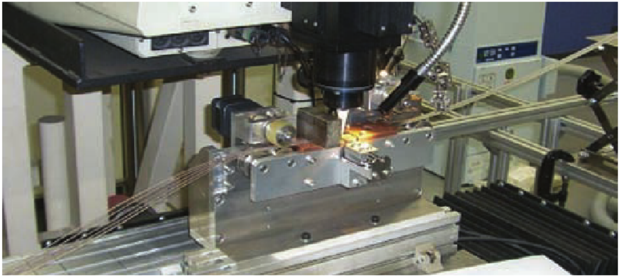

Figure : Laser cutting machine for YBCO tapes

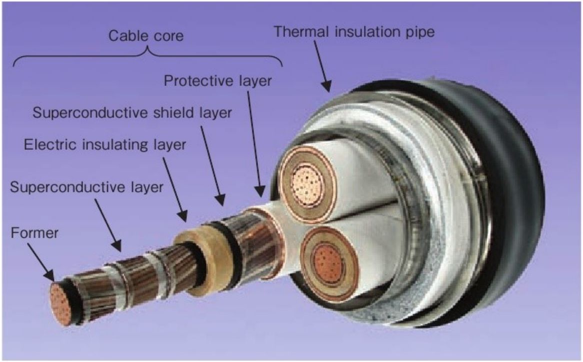

Figure : HTS power cable

AC DC

Losses

- Efficiency
  - AC has both ohmic and AC loss (200 kW/km) [AC loss is dominant]
  - DC has only ohmic (20 kW/km)
- Number of wires
  - For 3 phase AC, 4 wires required
  - For DC, only 2 are required

Status Quo

- Power Generation [wikipedia page]
- Power Rate   2.5 Rs / kWh
- Type of transmission — High voltage AC (500 KV), aluminium [550KV, 2500 mm^2, AC resistance 0.0168 ohm/km, reactance 0.199 ohm/km, max continuous current 1 kA]

Smart Grid

Consider some state x, which has a power consumption of y MW and generates the same. If the generation fails, then power can be tapped from nearby states.
It can distribute excess energy produced to the states that need it.
Power plants can now be placed without too many contrainsts on geographical locations.
Further, power can be sold to nearby countries, should the generation exceed the demand.
Power intensive projects can be setup without worrying about the location.

- General advantage, if something fails, backup
- Easy distribution, to avoid wastes
- Location of powerplants
- Power can be sold
- Ease the setup of energy intensive projects

Model for losses in Status Quo

- State to state, connection
- Voltage: 500 KV
- Aluminium Wires [specified earlier]
- Number of wires, using max current rating
- Price per unit (KWh) [sepcified earlier]
- Power stations assumed in the capital

Proposed Model

- State to state, connection
- Voltages: 900 KV [Standard for scope for future development]
  Current capability: 70,000 A — max used: 36,111 A
- Calculations [will follow]
- Time for recovery
- Transformers for stepping up and stepping down 900 KV
- Distance from ground and distance between two wires
- Along highway
- Power station assumed in the capital

Algorithm/Formulae

Not considered

- Aluminium Wire laying cost
- Cooling cost (including maintenance)
- Islands
- AC/DC conversion losses

Discharge issues have been taken into account.
The main idea has been summarized in the following equation.

The Cost Equation

$$At = L_c^s + A^s t \qquad (1)$$

where A is the power loss in the current system, in Rupees per unit time,
L_c^s is the cost of installing the superconductor grid in Rupees, and A^s is the running cost of the superconductor grid in Rupees, which has been assumed to be zero in accordance with the said assumptions.

Laying Cost of Superconductor L_c^s

\$: rate per unit distance (in Rupees, per meter, per 70,000A)
l: Total Distance

$$L_c^s = 2\$l \tag{2}$$

Running Cost estimate of a similar conductor grid A

$$A = \sum_j (i_j^2 R_j) C_{\mathrm{Rs/t}}^{\mathrm{Watt}} \tag{3}$$

where $C_{\mathrm{Rs/t}}^{\mathrm{Watt}}$ is the conversion factor from Watt to Rs per unit time, the index j counts uniquely, the connection between two cities, while the other variables have been defined as follows.

Running Cost estimate of a similar conductor grid A

Joule heating is given by $i_j^2 R_j t$, where i_j is the total current and R_j the effective resistance of the wires joining the two cities.
Given two cities
$S_j \to l \equiv$ Distance between them
$S_j \to p \equiv$ Max(Power produced by States)
Thus,
$i_j = \frac{S_j \to p}{V}$, where V is the AC Voltage
Further, $\#_{wires} = \lceil \frac{S_j \to p}{i_w V} \rceil$, where i_w is the maximum current the wire can withstrand.
And finally, we have $R_j = \frac{R_w}{\#_{wires}} S_j \to l$, where R_w is the resistance of the wire per unit length.

Calculations and Results

[Redirect to the excel sheet]

Summary of the result

From our estimates, installation cost of the superconductor grid would be recovered within 36.5 years, considering the current losses.

Phase 1

Mini Test in IISER Mohali

- 10 m superconductor cable test.
- Wire cost $ 4,000

Phase 2

Test in IISER Mohali

- 500 m superconductor cable test.
- Wire cost $ 200,000

Phase 3

Convincing the national funding agencies to accept the country wide grid's proposal

References

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Thank you