Lost in Transmission

Power Loss in Transmission Lines

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Abstract

Energy supply and stability are important topics in modern society. In order to address both of these needs, we have investigated methods of improving electrical transmission. Transmission lines inherently lose part of the energy that flows through them. We analyzed the possibility of improving our current electrical grid by utilizing direct current (DC) as opposed to the traditional alternating current (AC) to mitigate power lost in an economical way. By comparing cost and energy loss figures, we were able to determine if switching systems would be beneficial and then calculate the payback period for the investment.

Background

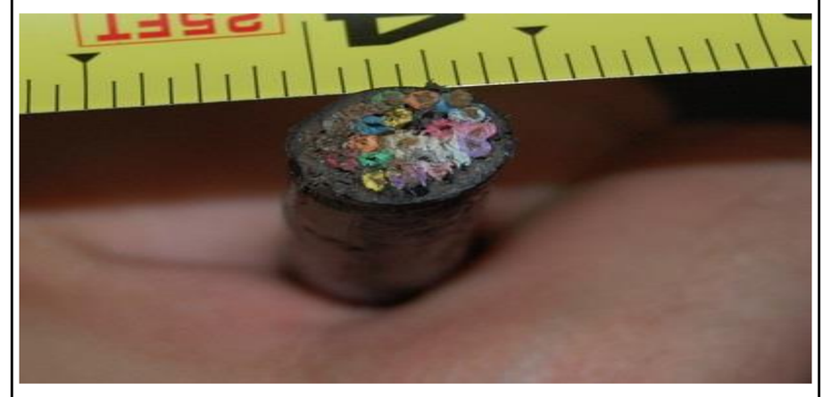
- When electricity flows through a wire, energy is always lost.
- Some of the phenomena that cause this are:
  - Resistance (Ohm's Law)
  - Corona effect
  - Skin effect (AC only)

"The overall effect of power losses on the system is a reduction in the quantity of power available to the consumers."

U.S. Energy Data (2014)	
Net energy generation	4,093,606 (1000 MWh)
Energy sold to ultimate customers	3,764,700 (1000 MWh)
Average price of electricity	10.44 (cents/kWh)
Lost energy	328,906 (1000 MWh)
Lost money	≈34,337,758,530 (USD)

Early Stages

Wire Composition



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DC transmission

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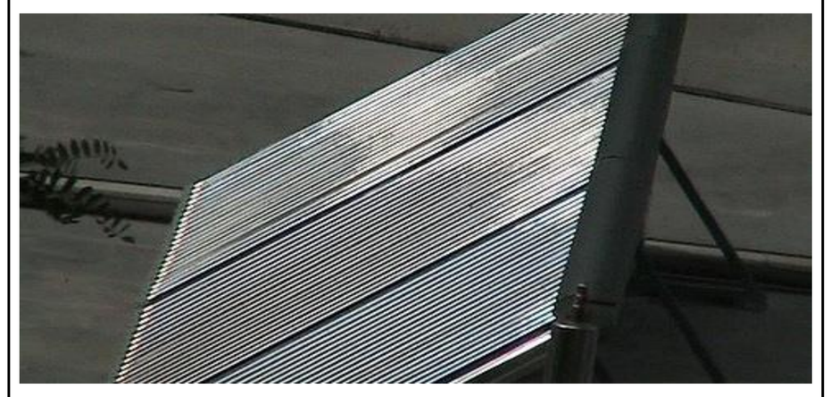
Decentralized Power Generation



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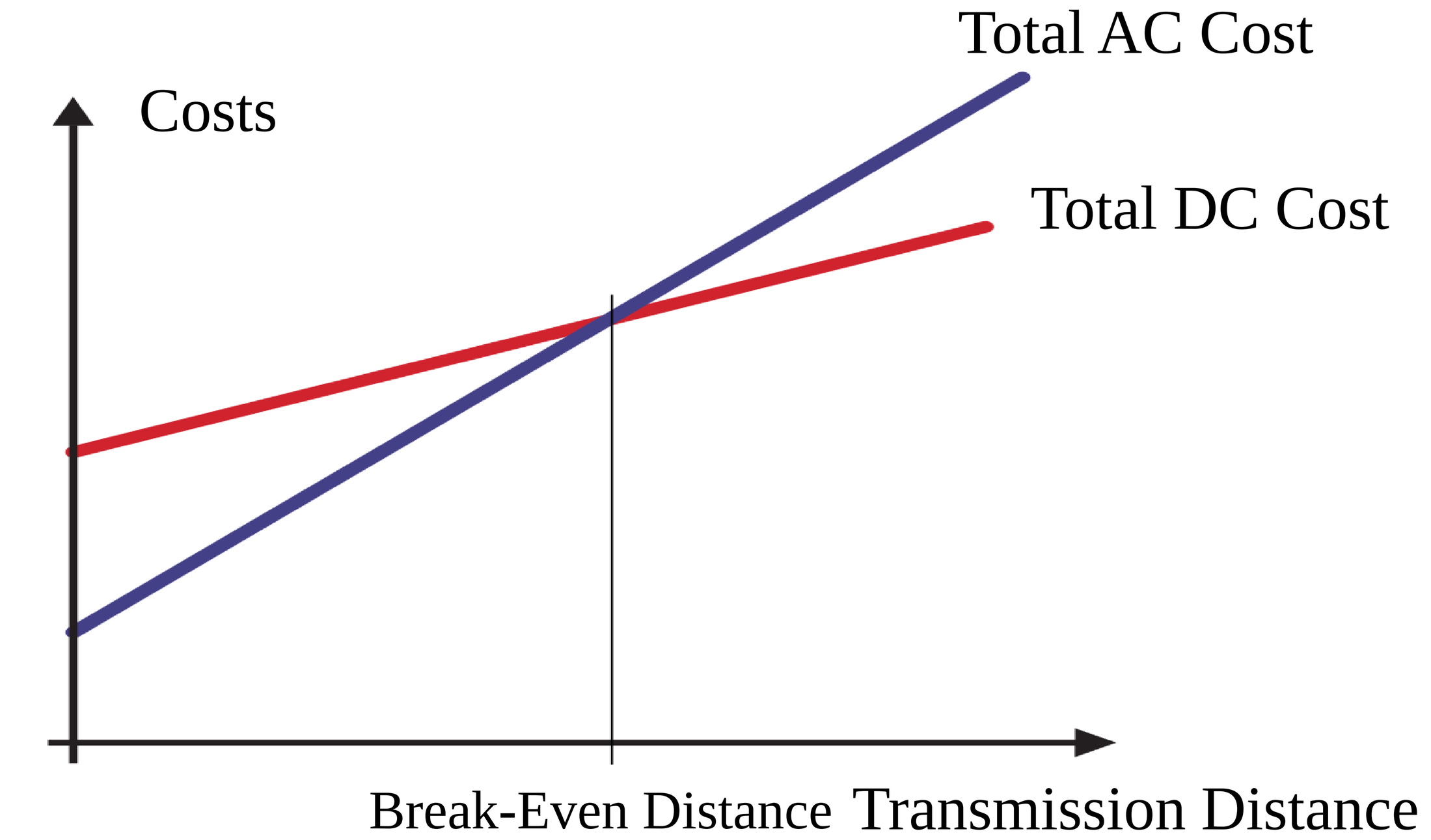
DC Transmission

Pros	Cons
Lower energy loss per unit distance.	HVDC converters are expensive.
Higher line capacity.	Requires better circuit breakers.
Lower cost of cables.	DC to DC transformers are only experimental.

Data and Analysis

Line	Itaipu	Rihand-Delhi	Garabi	Leyte-Luzon	Gotland
Annual savings DC vs. AC	172.8 MUSD	41.15 MUSD	30.18 MUSD	12.07 MUSD	1.372 MUSD

Cost Comparison



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- DC has a higher initial cost as a result of the necessary HVDC converters, but past the break-even distance, DC costs less than AC.
- The cables for DC transmission lines cost less per mile, so the overall costs for the two options intersect at a certain distance (called the break-even distance).
- The break-even distance varies; anywhere from 600-800 kilometers for above ground lines.

Associated Costs (estimated)	
HVDC converter stations	250 (million USD)
AC substations	80 (million USD)
Price of transmission lines	250 (thousand USD)

Results and Conclusions

- DC loses less power than AC.
- HVDC is best suited for long distance, high voltage lines.
- Large initial costs of DC eventually break even with AC due to lower transmission line costs.
- Over the lifespan of the line energy and subsequently money are saved.
- HVDC technology should be integrated into the grid more in the future as new lines are established.

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