GEOS 24705 / ENST 24705 / ENSC 21100
2018
Lecture 12

Electricity III
Split-ring commutator allows brushed DC motor
Force on a brushed DC motor
“Slip-ring” commutator produces / works with AC
Direct current (DC)

Proponent: Edison

Advantages:
- Understandable
- Available motors
- Charges batteries
- Available meters

Disadvantages
- Cannot transform voltage easily

Commercialization
- London 1882
- New York 1882 (both coal)

Also invented:
- Lightbulb (commercial)
- Phonograph
- Improved telegraph

Early DC generator, “long-legged Mary Anne”, 1884
Alternating current (AC)

Proponent: Tesla (former Edison engineer)

Advantages:
- Transforms voltage easily

Disadvantages
- No reliable motors available
- No battery charge

Commercialization
- Ames hydro: 1891
- Chicago coal: 1893
- Niagara hydro: 1895

Also invented:
- Induction AC motor
- Radio communication
- Wireless energy transmission
Edison vs. Tesla: “war of the currents”

DC

Edison’s company:
General Electric, founded 1890, now ranked (Forbes, 2009) the largest company in the world. Precursor: Edison Illuminating Co., 1880

Technical achievement:
First steam-powered electricity & electric utility, 1882, first U.S. transmission standard, multiple power plants (~1 mi. transmission) (for lighting only)

PR stunt: invented (AC) electric chair, attempted execution, 1890

AC

Tesla’s company:
Westinghouse Electric Company, founded 1886, now (after purchase of CBS) knows as CBS Corp. (sold power generation to Siemens, itself provider of first electric street lighting in 1881). Hired first woman electrical engineer in 1890s.

Technical achievement: long-distance transmission of hydropower at Niagara Falls to factories in Buffalo New York, 1895 (25Hz)

PR stunt: lit Chicago World’s Fair, 1893
Edison vs. Tesla at 1893 Chicago World’s Fair

Tesla’s system already had most characteristics of the modern electricity system in 1893.

World’s Fair + choice at Niagara 2 years later committed us to AC.

Comparatively little evolution after choice was made – standardization of frequencies.
By 1893 generators much larger than Edison’s first 1000 hp AC generators exhibited in Chicago World’s Fair
1893 Chicago World’s Fair lighting awed the U.S.

Image: Chicago History Museum/ Getty Images
1890: engineering decisions on Niagara Falls hydro: long-distance transmission, ~ 20 miles to Buffalo

motivated by beautification, early environmental activism – the “Free Niagara Movement” pushed to shift industry away from falls
How to transmit the power?
long-distance transmission, ~20 miles to Buffalo

1890 proposals received:

*Mechanical*
- Belts (steel cables on posts or pulleys)
- Compressed air
- High-pressure water

*Electrical*
- DC current (*transmit at up to 16,000 volts*)
- AC current (*transmit at 10,000 volts*)

*Westinghouse didn’t submit: waited for invitation to bid on project, bid submitted 1893, same year as World’s Fair, won contract*
Tesla’s system installed at Niagara Falls 1895-1897
Tesla’s AC system installed at Niagara Falls 1895-1897
First overhead power lines

11,000 volt lines (later upgraded to 22,000 V)
carrying power from Niagara to Buffalo, ~ 20 miles away

Notice: no automobiles yet. The first automobile company had started only 2 years before; by 1895 only ~10 total cars had been sold in the U.S.
Use of heat engines preceded electricity by > 100 years

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<td>1690 Papin concept of steam engine</td>
<td>1800 battery (Volta, Davy)</td>
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<td>1712 Newcomen reciprocating engine</td>
<td>1820 electricity &amp; magn. related (Oersted)</td>
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<td>1765 Watt’s improved engine</td>
<td>1825 Carnot calls steam engines the source of England’s strength</td>
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<td>1820’s invention of steam locomotive</td>
<td>1821 first motor (Faraday)</td>
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<td>1866 dynamo (Siemens)</td>
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<td>1870s dynamo used for arc furnaces</td>
<td>1880s lightbulb, first distribution (Edison)</td>
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<td>1884 steam turbine (Parsons)</td>
<td>1883 AC motor (Tesla)</td>
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<td>1893 Chicago World’s Fair electrified with Tesla’s AC power (25 Hz)</td>
<td>1895 transmission from Niagara Falls</td>
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<td>1920 Lenin calls to electrify Russia</td>
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Most lines are multiples of 3
Tesla’s transmission was “three-phase”

Note magnet is in rotor, not in stator
3-phase power transmission has advantages

Power ($\alpha V^2$) sums to a constant – no fluctuations in power transmitted

Voltages (and current) sum to 0 if perfectly balanced – no need for a return wire, which saves costs