AFD Ep 421 Links and Notes - US Urban Electrification and Streetcars [Bill/Rachel] - Recording Apr 10, 2022

- Intro: This episode picks up where we left off [last week](#) at the end of the 1880s in our narrative on US electrification. The story of electrification of American cities from this point forward is inextricably tied up in the story of streetcar railways, which will be the main focus of today's episode, now that we've gotten most of the technical aspects covered last week. But first, before we explain why those stories are so closely linked, we need to cover one more technology point, briefly, which is the Current Wars of the late 1880s and early 1890s – something most people have probably at least vaguely heard about because of the battles between Edison (promoting Direct Current power) and Westinghouse (promoting Alternating Current power and aligned with Nicola Tesla, one of the pioneers of alternating current induction motors, as we discussed last week)
- [Bill] The Current Wars: DC vs AC https://en.wikipedia.org/wiki/War_of_the_currents
    - Direct Current, running in one direction, was weaker but efficient, which made it ideal for small applications like home lightbulbs, but it couldn't really deliver the kind of power loads or distribution distances that larger applications would require. The copper wire needed was much greater for DC for even the same short distances and copper prices were beginning to rise as the incipient explosive demand for copper wiring began to reach the mining industry. DC was however much less likely than early AC technology to cause dangerous situations in the home if people overloaded their circuits and so on.
    - Alternating Current, which shifts back and forth directionally, could be used for powering big things but also (if properly "stepped down" with "power transformers") smaller things as well, and it could provide strong power over longer distances, even if the wasted leakage losses along the way were (and remain to present day) quite high. Westinghouse acquired various AC power related patents and technologies from Germany and opened Westinghouse Electric in 1886. By 1888, Tesla's technologies were ready and Westinghouse (who had already opened 68 power plants to Edison's 121) continued deploying AC generators and wires, which at this point triggered the current war.
    - Edison and Westinghouse then battled it out in the public eye for a few years, mostly in New York State, with Edison arguing AC infrastructure was much more dangerous than DC and using all kinds of theatrics around executions of animals and human prisoners with AC Westinghouse equipment. But again, the limitations of DC technology at the time, especially for distance, simply ensured AC's victory anyway, especially as AC safety technology improved, both indoors and in the maze of initially poorly insulated outdoor distribution wiring. Ultimately Edison conceded defeat and by 1890 was already stepping back from day-to-day leadership to work on other things unrelated to power generation. His company began converting their power operations from DC to AC, notably via the 1892 merger of Edison Electric and AC-powered Thomson-Houston Electric Company into the General Electric Company (GE). (It's worth noting that JP Morgan and other financiers behind the merger actually ended up pushing the Edison team out almost entirely in favor of making Thomson-Houston the dominant half of the merger. Edison personally opposed the merger but was no longer in control anyway.) There was some further consolidation to get down to a basic duopoly of GE and Westinghouse, with patent-sharing arrangements also pushed through by Morgan. Some DC power plants actually continued operation through the 20th century in the US, but generally the standard was AC power after this point. There were several transitional technologies developed specifically to allow existing DC-based things to operate on the new AC grids until they could be

replaced. GE also quickly brought in AC experts to catch up on AC technology. GE and Westinghouse Electric soon had a joint contract for the Niagara Falls Hydroelectric project of 1893-1895. AC power from such sources was serving grid needs dozens of miles away.
https://en.wikipedia.org/wiki/Niagara_Falls#Hydroelectric_power

- Electrification by Streetcar (Load Factor Balancing)
    - On the last episode we talked about early power production without electricity grids, using horse labor or regular steam engines, and the transition to hydro power and very fast-spinning steam turbines. We also talked about the early spread of electric street lights and residential, commercial, or industrial interior lighting. But there was still one significant logistical and financial barrier to implementing the technology across wider, interconnected areas. And that finally brings us to the star of today's episode, electrification by streetcar for load factor balancing. Rachel will explain what all of that means and why it matters.
    - [Rachel] https://en.wikipedia.org/wiki/Electrification
        - *One of the biggest problems facing the early power companies was the hourly variable demand. When lighting was practically the only use of electricity, demand was high during the first hours before the workday and the evening hours when demand peaked.*[19] *As a consequence, most early electric companies did not provide daytime service, with two-thirds providing no daytime service in 1897.*[20]
        - *The ratio of the average load to the peak load of a central station is called the load factor.*[19] *For electric companies to increase profitability and lower rates, it was necessary to increase the load factor. The way this was eventually accomplished was through motor load.*[19] *Motors are used more during daytime and many run continuously. Electric street railways were ideal for load balancing. Many electric railways generated their own power and also sold power and operated distribution systems.*[1]
        - *The load factor adjusted upward by the turn of the 20th century—at Pearl Street the load factor increased from 19.3% in 1884 to 29.4% in 1908. By 1929, the load factor around the world was greater than 50%, mainly due to motor load.*
    - "The Time of the Trolley" by William D. Middleton (1967, Kalmbach Publishing), p. 6 & pp. 53-105, but especially pp. 53-73 because we're focusing on the electrification aspect more than trolleys broadly)
        - [Rachel] Urban electrification built the American city and led to the urbanization of the American populace: In 1831, when the first horsecar line ran down New York City's Bowery, only 1 in 12 Americans lived in cities, and NYC had only about 200,000 residents. Little more than a century later, 2 out of 3 Americans lived in cities, with over 100 cities surpassing 100,000 residents.
        - The battery era:
            - 1835 - Thomas Davenport built and exhibited a model railway run by an electromagnetic motor powered by a crude battery.
            - 1838 - Robert Davidson of Aberdeen, Scotland constructed a 7-ton electric locomotive powered by a 40-cell iron-zinc sulphuric acid battery. It made several successful trips, but was wrecked by steam-locomotive engineers and firemen who were out to destroy rivals in locomotive technology
            - 1847 - Prof Moses G. Farmer built an experimental electric locomotive that pulled a car that could carry 2 people on a 18-inch

wide track. His locomotive was powered by a 48-cell Grove nitric acid battery.
    - 1850 - Farmer, aided by Thomas Hall, built and exhibited an electric railway in Boston, which was the first to be powered by a stationary source, rather than on-car power.
    - 1851 - Prof. Charles G. Page designed and built a 16 h.p. battery-powered reciprocating motor that powered a locomotive. His locomotive was able to reach speeds of 19 mph on a trip between Washington and Bladensburg, Maryland. However, Page's pottery battery cells cracked when jolted, and by the end of the trip the battery was completely destroyed.
- The age of the dynamo and beyond:
    - 1867 - The age of the dynamo led to an improvement over fragile batteries. Farmer was the first man to successfully operate a dynamo-powered electric locomotive.
    - 1879 - Ernst Werner von Siemens, with J.G. Halske was the first to successfully operate a generator-powered electric railway in Berlin. His locomotive drew power from an electrified third rail, and was able to carry 18 passengers at a speed of 8 mph around an oval track that was ½ mile long
    - 1881 - Siemens opened the first commercial electric railway, consisting of a single car that could carry 26 passengers on a 1-½ mile track. A single motor mounted under the carbody and connected to the axles by wire cables powered the car. The motor drew power from the running rails.
    - 1883 - Siemens installed a 6-mile railway in Ireland that was the first powered by hydroelectric energy.
- Developments in electric traction in the US:
    - 1879 - Stephen D. Field developed plans for a railway that drew power from a third rail. In 1880-81, he constructed and ran an experimental railway in Stockbridge, Massachusetts. At the same time, Edison was experimenting with electric traction in Menlo Park. His designs took power from the running rails. Edison even made plans with Northern Pacific to electrify some of their lines, but NP's bankruptcy but the kibosh on those plans.
    - 1885 - Leo Daft opened the first commercial electric railway in Baltimore. His designs drew power from a third rail, but after several "unfortunate encounters" between street traffic and his third rail system, he erected an overhead power system. This early design used a crude pole to draw power from overhead lines. Daft constructed several more electric lines, but none of them as successful as his Baltimore line. He ultimately switched to a 2-wire overhead power collection system after several mishaps with third-rail systems. Daft used 4-wheel carriages called trollers that rode on the wires to collect power, but they had an unfortunate tendency to fall off the wires and crash into the roof of the car. These trollers got replaced by pole trolleys.
    - 1888 - The Bentley-Knight Company built a line in Allegheny, Pennsylvania that attempted to use an underground conduit system for current collection. They, too, ultimately had to switch to an overhead wire system.

    - 1888 - Frank J. Sprague's "wheelbarrow" motor mounting connected the motor's gearing directly to the car's axle, rather than using chain- or belt-drives to convey power from the motor to the axles. Sprague operated the Richmond system, which was the most successful system in the US, able to operate 40 cars at one time.
- By the end of 1889, there were no fewer than 154 electric street railway systems in the United States, and by the end of 1890, that number had grown to more than 200, over half of them equipped by Sprague's company.
- [Bill] [pp. 74-105] Between 1890 and 1902, according to the records of the US Department of Commerce & Labor, the total number of US streetcar track miles exploded from 1,262 to almost 22,000. This was the power of streetcar electrification, and with it came a broader grid electrification of most American cities. We've talked on previous episodes about the implications for American cities of the streetcar, especially during and beyond the 1890s, after electrification. On our postal service episode from August 2020, we talked about the growth in urban mail delivery before the advent of the telephone, with multiple pickups and deliveries per day, especially in business districts, and much of that was facilitated by streetcar, although not exclusively. On our "horse power" episode from August 2021, we talked about how streetcars significantly expanded the residential radius of the American city by allowing people to get quickly from home to work from much longer distances without having to walk or ride a horse or horse-cab. Both of these points are mentioned in the Middleton book at the start of the chapter by the same title as the book, "The Time of the Trolley." Some of the developments associated with streetcars begin of course in the horse-drawn era, but he emphasizes that most of the developments we associate with it happen extremely rapidly after the beginning of electrification because that dramatically lengthened the route potential and boosted the speed and volume by passenger weight. They were also much more cost-efficient to run. (Sometimes 60% less expensive per mile.) Streetcars also brought city-dwellers out to the growing suburbs to hundreds of (electrified!) amusement parks (owned by the companies), beach days, and even funerals in new cemeteries outside the crowding of city limits. Weekend rides even provided a new social activity for young couples in courtship. Parades and sight-seeing tours operated over the lines too. All of these served not just as extra trips to support the streetcar company's costs but also to promote and advertise to potential residents why they should move out to the suburbs permanently, in many cases because the same company that owned the streetcar was developing the real estate there. A $400 million streetcar industry in 1890 became a $2 billion industry by 1902. Ridership rose to 5 billion passenger trips, several times greater than steam railroad trips. "In 1880, less than 30 per cent of the population lived in urban areas; by the start of World War I fully half of the American population would be living in cities. [...] In 1880 there were only 20 U.S. cities that exceeded a population of 100,000; by 1910 there were 50." Some of the tail-end Gilded Age new money fortunes were made in electric streetcar railways. Initially, they were extremely profitable, and even if you invested in one of the loser companies, they would usually be acquired by a nearby

competitor for a good windfall anyway. Unfortunately, cities had a tendency to impose fairly extreme financial conditions or inflexible fare caps to grant permission to build new lines, which was fine in the early, most lucrative, days of streetcars, but which rendered many lines unprofitable long-term, or sometimes quite quickly. The capitalist mode of operating streetcars, with extensive fixed-capital assets and intense competitive pressure from redundant service, was not well-suited to preserving a level of service that might otherwise have been delivered, especially as some of these same companies just a few decades later began buying combustion-engine buses to get in on the interwar automotive transportation boom. Unsurprisingly, early 20th century left-wing and progressive reformers, particularly in the upper midwest, often called for municipal socialization of both the streetcar companies and the closely associated (if not co-owned) power and light utility companies, to get them out of private, for-profit control. Some cities also awarded contracts to streetcar companies to collect garbage or put out fires, with specialized equipment in both cases. And as noted earlier, special mail sorting and delivery cars existed, just like on regular railroads. Due to federal law, these operated even when local strikes were preventing operation of all other service on a streetcar company. All these kind of special uses tended to be abandoned fastest when motorized trucks arrived on the scene. That era spanned only about a quarter-century as a result. The peak year for the electric streetcar industry overall was 1917, about three decades in. By that point, there were over 1000 companies operating over 60,000 streetcars on 26,000 miles of track, not including electric interurban railroads and the emerging “rapid transit” sector. Americans were taking 11 billion trips per year, generating $600 million in operating revenues.

- See also: http://arsenalfordemocracy.com/2021/02/02/unlocked-feb-2-2021-early-us-rail-electrification-feat-justin-from-wtypp-arsenal-for-democracy-ep-347/
- http://arsenalfordemocracy.com/2021/08/08/aug-8-2021-horse-power-arsenal-for-democracy-ep-392/