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ELECTRIC POWER GRID FUNDAMENTALS and CHANGES

NOVEMBER 7, 2018

ONSHORE ENERGY CONFERENCE

LONDON, ENGLAND

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Electric Power Grid - Fundamentals and Changes

This presentation will detail the inner workings of the electric power grid, presenting the path of the flow of an electron from the generation station to your home. This presentation will simultaneously be used to illustrate how the grid has dramatically changed in recent years, and how these changes will affect the energy market and insurance industry.

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National Academy of Engineering

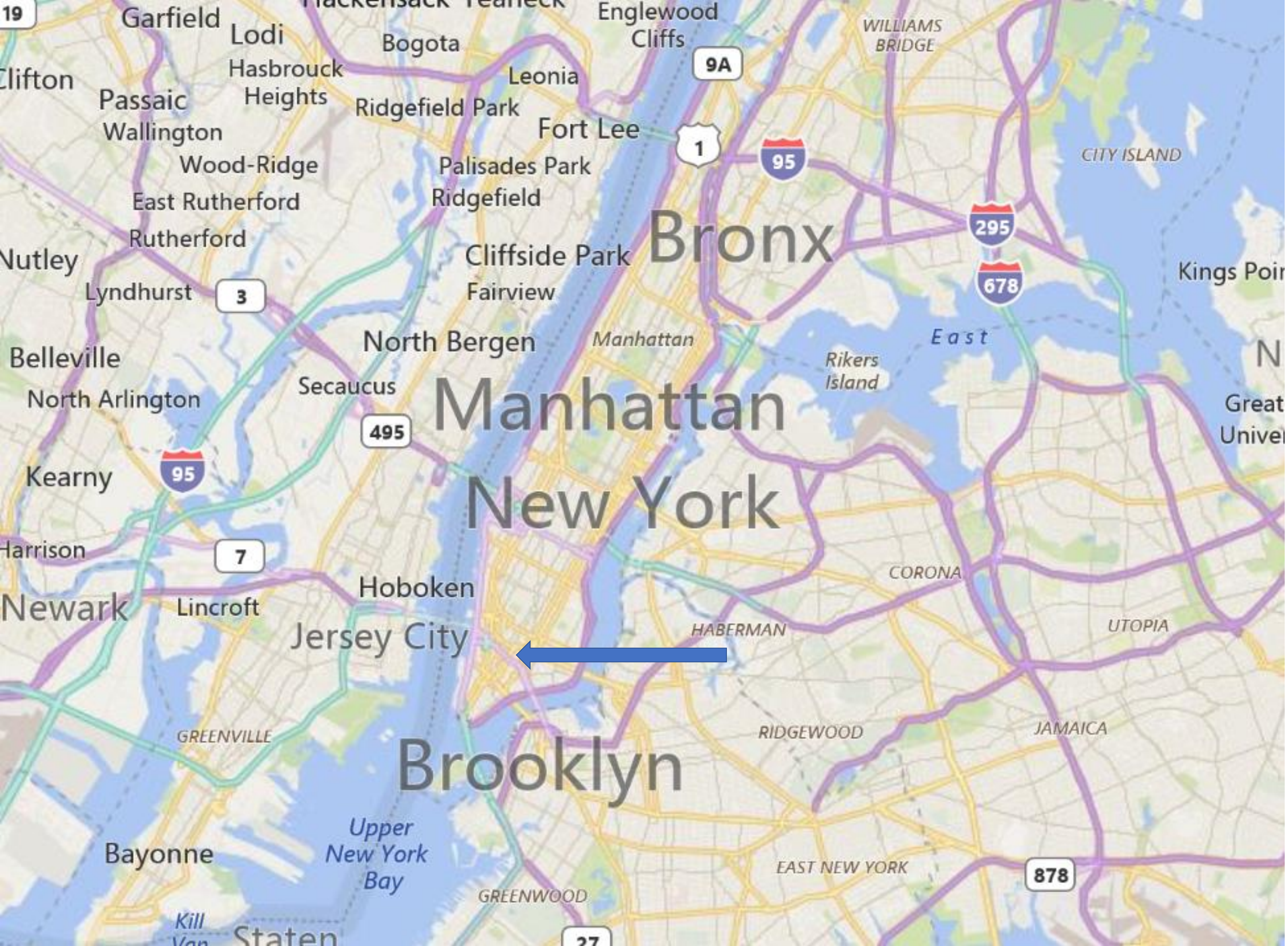
Top 20 Engineering Achievements of the 20th Century

The ranked list of the top 20 achievements in the 20th century was published as follows:[19][22]

1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials

ELECTRICITY PIONEERS

UNITED STATES
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
Ottawa
MAINE
OREGON
IDAHO
WYOMING
SOUTH DAKOTA
WISCONSIN
MICHIGAN
VT.
N.H.
N.Y.
MASS.
Gulf of Maine
IOWA
NEBRASKA
R.I.
NEVADA
UTAH
ILLINOIS
OHIO
PA
N.J.
MD.
INDIANA
WEST VIRGINIA
DELAWARE
COLORADO
KANSAS
MISSOURI
KENTUCKY
VIRGINIA
NEW YORK
CALIFORNIA
OKLAHOMA
TENNESSEE
NC
ARIZONA
NEW MEXICO
ARKANSAS
SC
ALABAMA
TEXAS
MISSISSIPPI
GEORGIA
LOUISIANA
FLORIDA
Nassau
Gulf of Mexico



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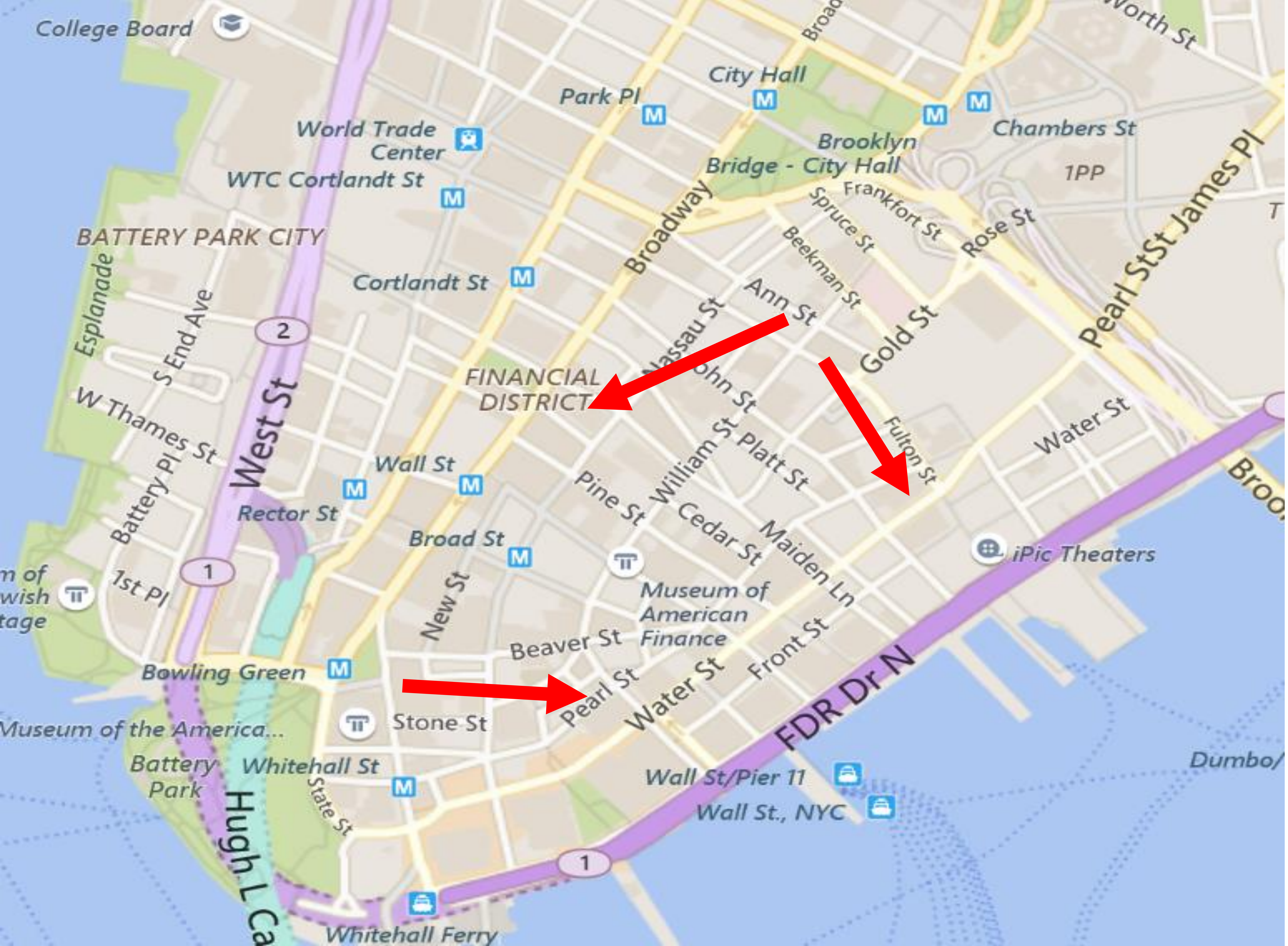
NEW YORK



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140 BROADWAY
25TH FLOOR
NEW YORK, NY 10005

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Thomas Edison

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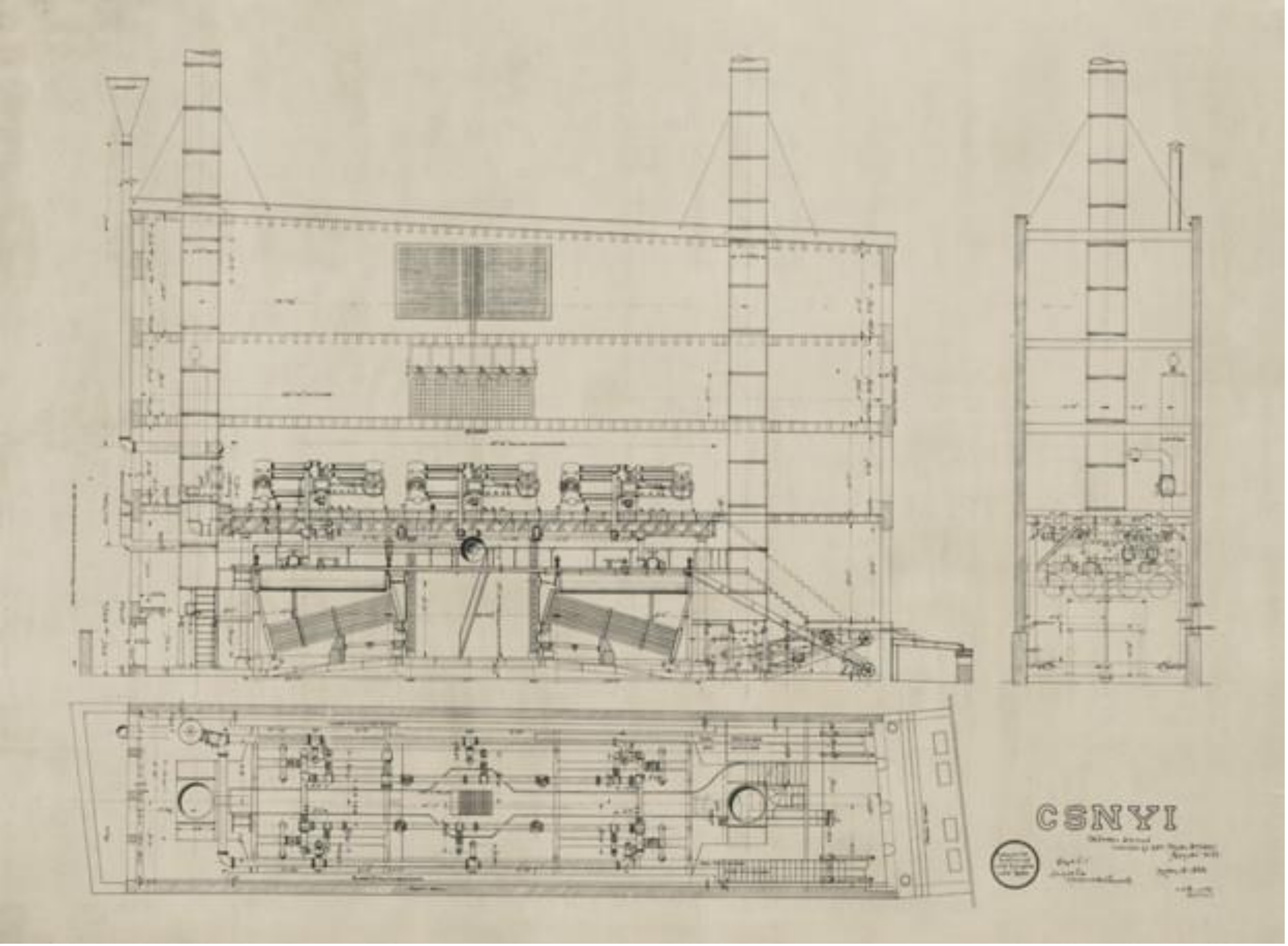
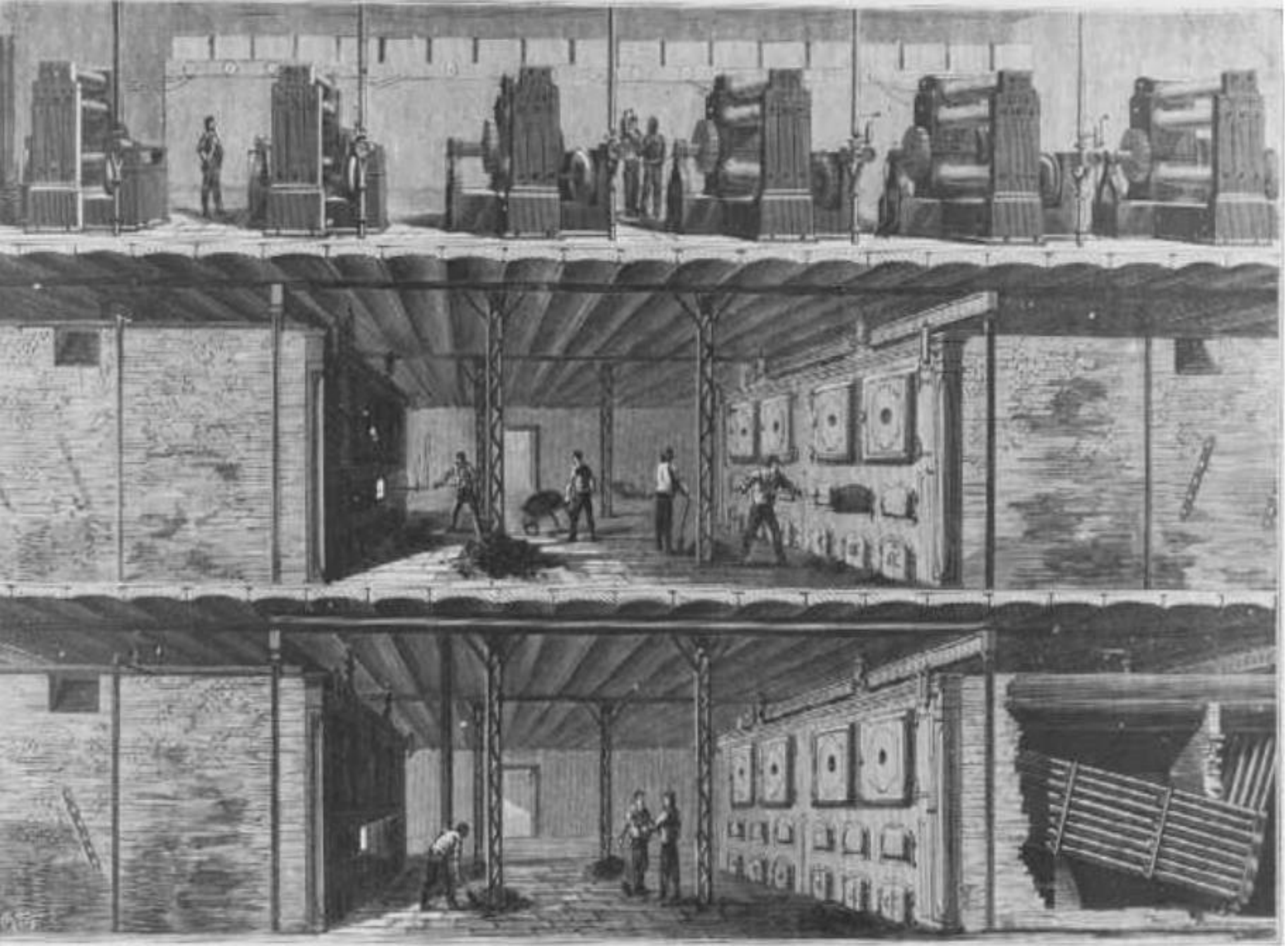
PEARL STREET STATION





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PEARL STREET STATION

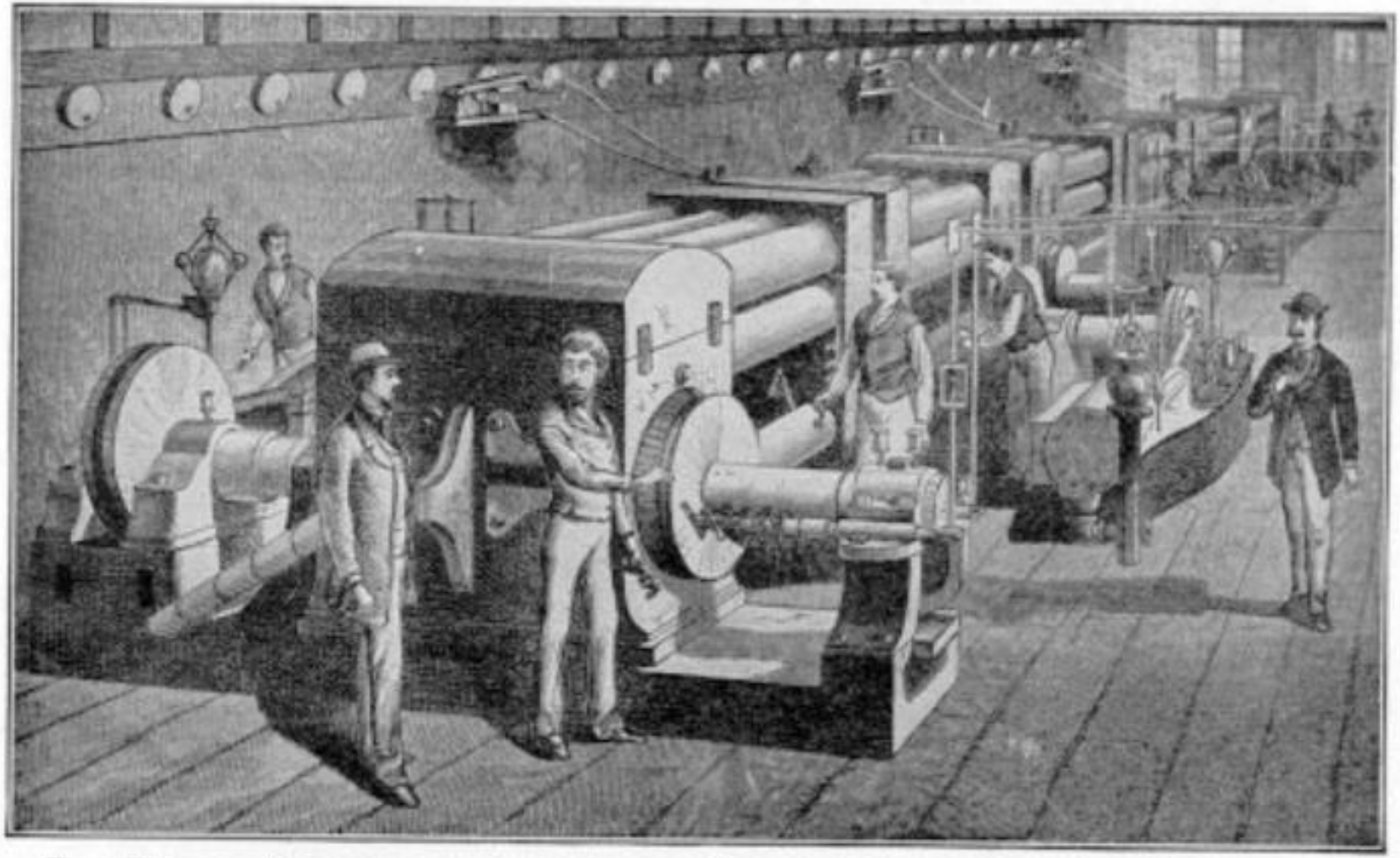
World's First
Central Station
Commercial Power Plant

World's First
Co-Gen Plant

Generated
Transmitted
Distributed

Electricity & Steam

PEARL STREET STATION



THE DYNAMO ROOM OF THE FIRST EDISON ELECTRIC LIGHTING STATION IN NEW YORK

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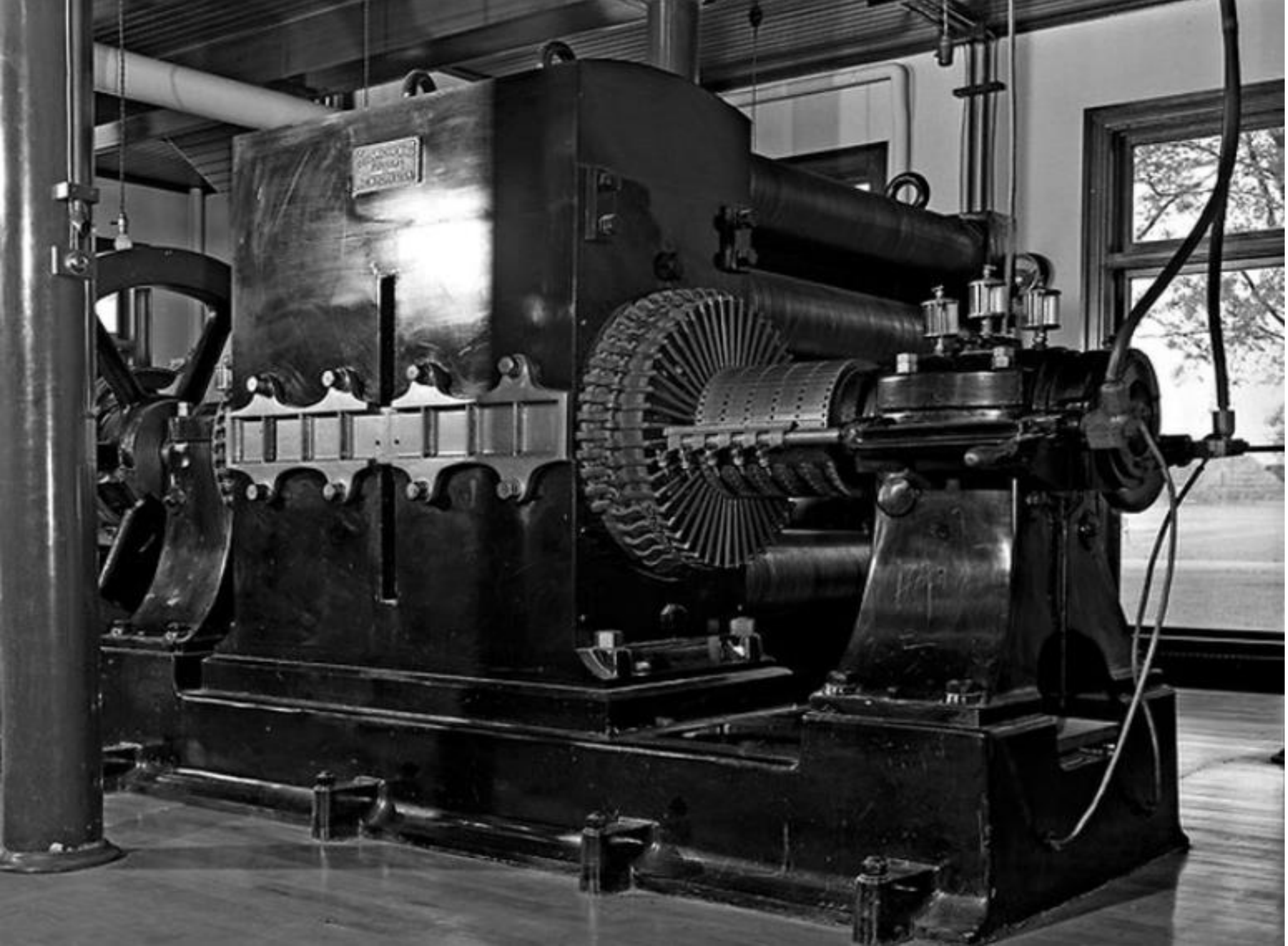
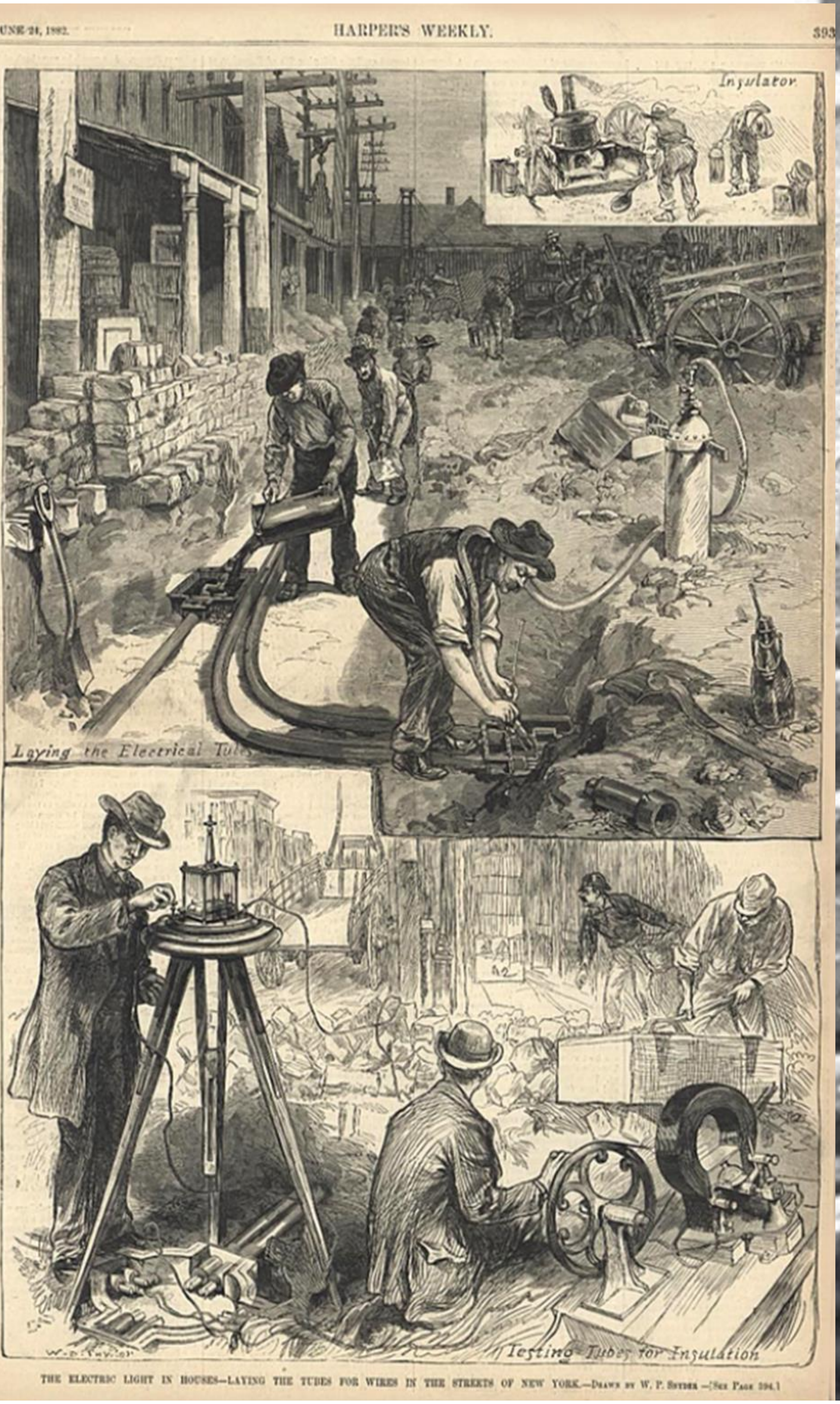


Edison Dynamo
“Jumbo”
100 Kw
1000 Bulbs
(If Lossless)



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Pearl Street
Pipe & Wire
Installation
(Last Cutover 2007)

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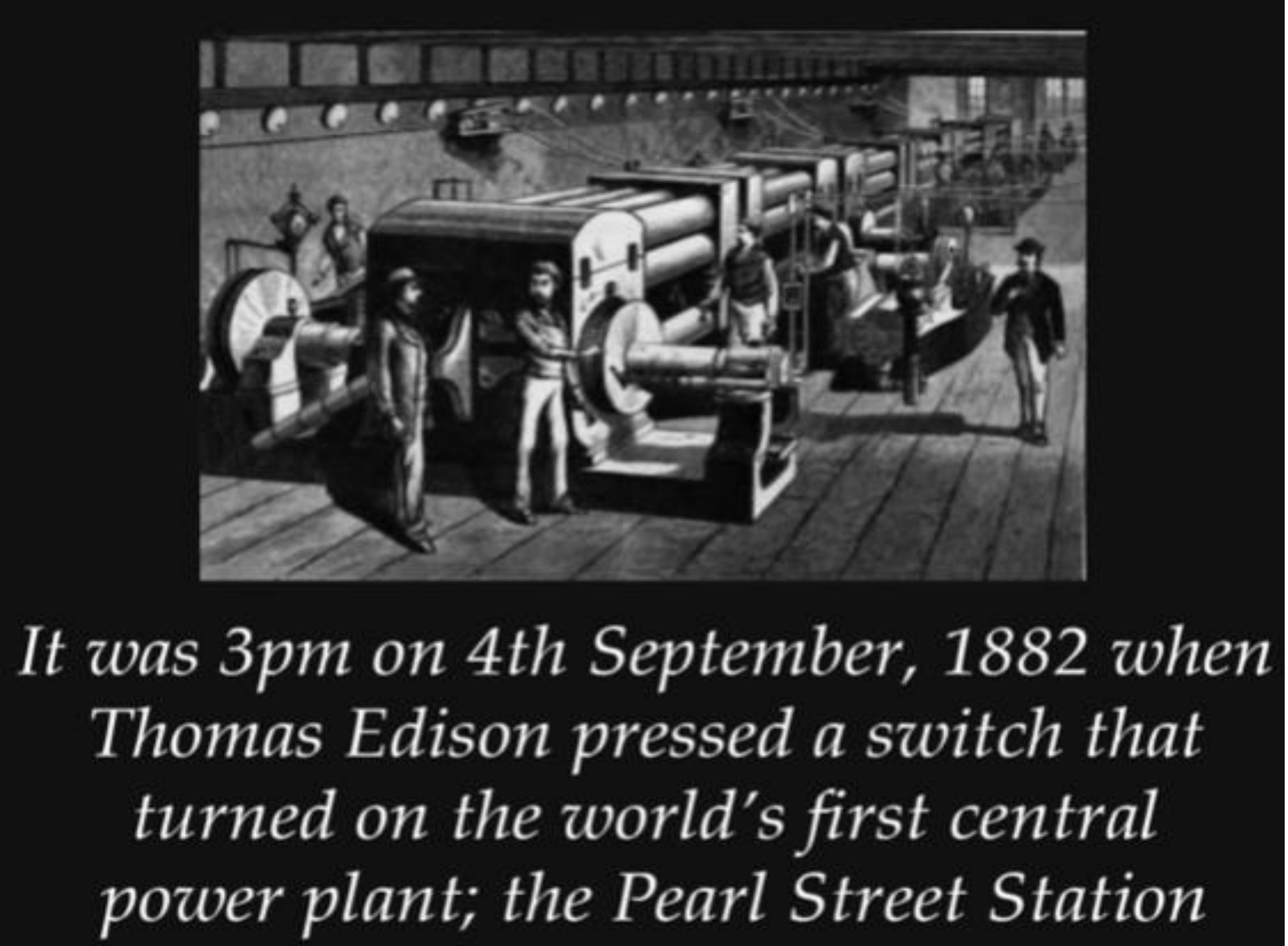

September 4, 1882

World First Generating Station

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September 4, 1882, that Edison switched on his Pearl Street generating station's electrical power distribution system, which provided 110 volts direct current (DC) to an initial load of 400 lamps at 85 customers. By 1884, pearl Street Station was serving 508 customers with 10,164 lamps. The station was built by the Edison Electric Illuminating, which was headed by Thomas Edison.

MEET THE NEW BOSS – AC POWER

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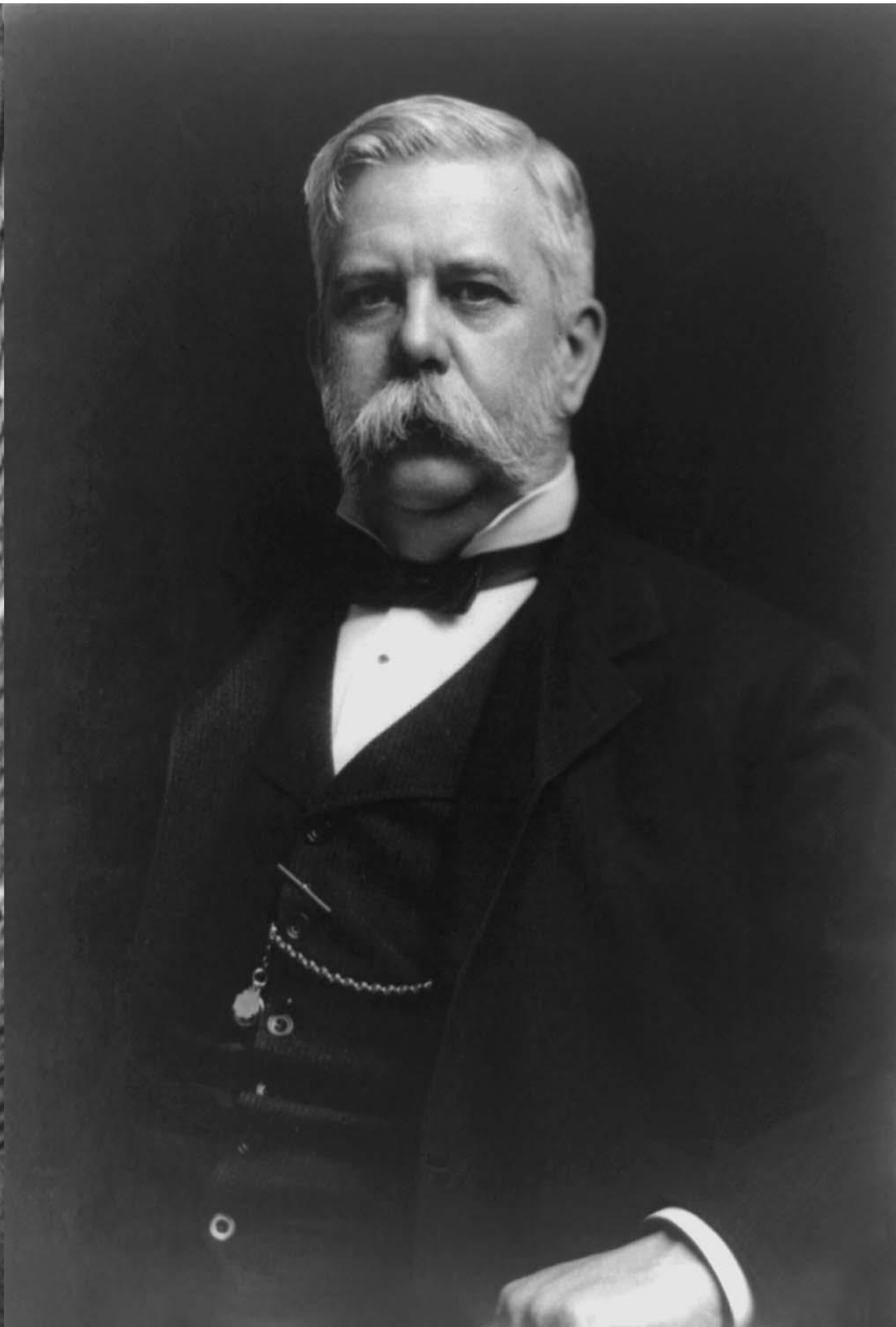
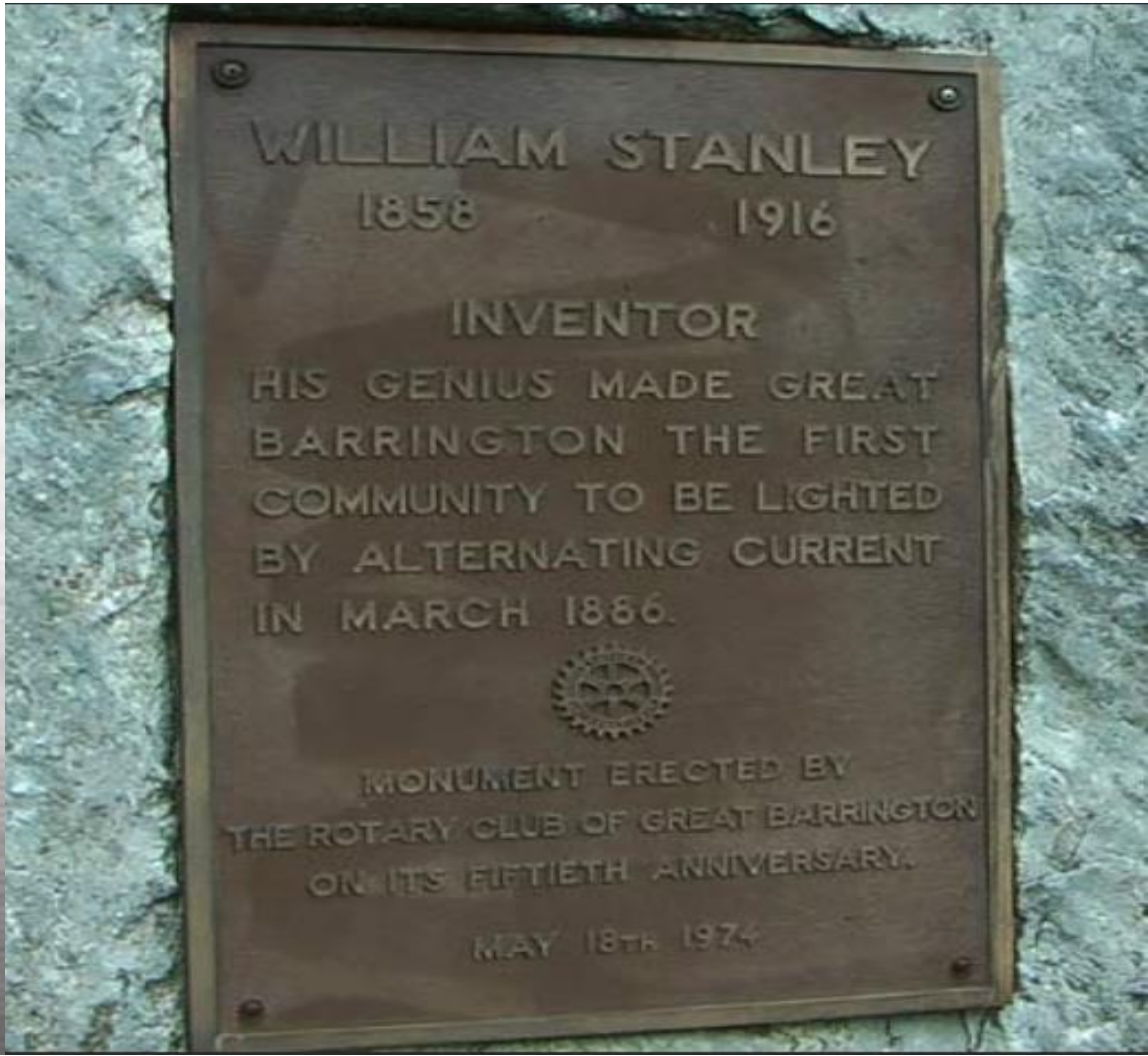


WILLIAM STANLEY




TRANSFORMATOR
OERLIKON.
www.EdisonTechCenter.org


ABB
EEP
ELECTRICAL ENGINEERING PORTAL

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Single Phase
1.1 MV
3,000 MVA


Alleys
P932 CEB
CY08 OXD


Allelys
Heavy Haulage
Allelys
Heavy Haulage
www.allelys.co.uk
STGO
MAN
T700 AHH
Allelys
Heavy Haulage
Allelys Heavy Haulage

A large generator passes under the George Washington Bridge as seen from Fort Lee, N.J., Tuesday, Aug. 8, 2017. A 130-foot-(40-meter)-tall steam generator built along the Hudson River outside Albany is on a barge heading south for a New Jersey power plant. (AP Photo/Seth Wenig)

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Steam Generator Heat Recovery

ADVANCED TESTING CAPABILITIES

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Transformer Electrical Testing

Dissolved Gas Analyzer on Rack

ADVANCED ELECTRICAL TESTING

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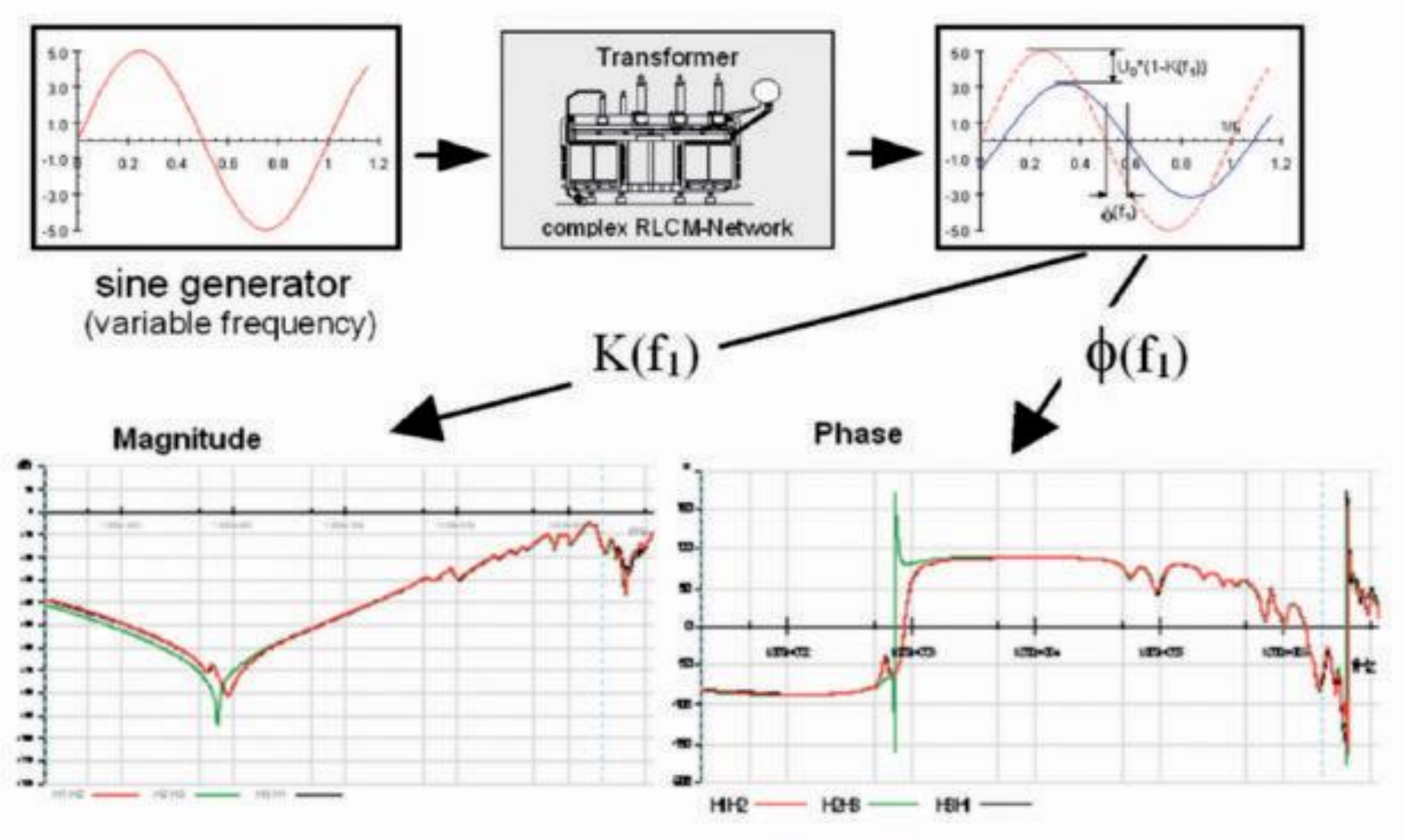

Sweep Frequency Response Analysis

HOW DOES THE ELECTRIC GRID WORK??

WHY DO SYSTEM VOLTAGES VARY SO MUCH?

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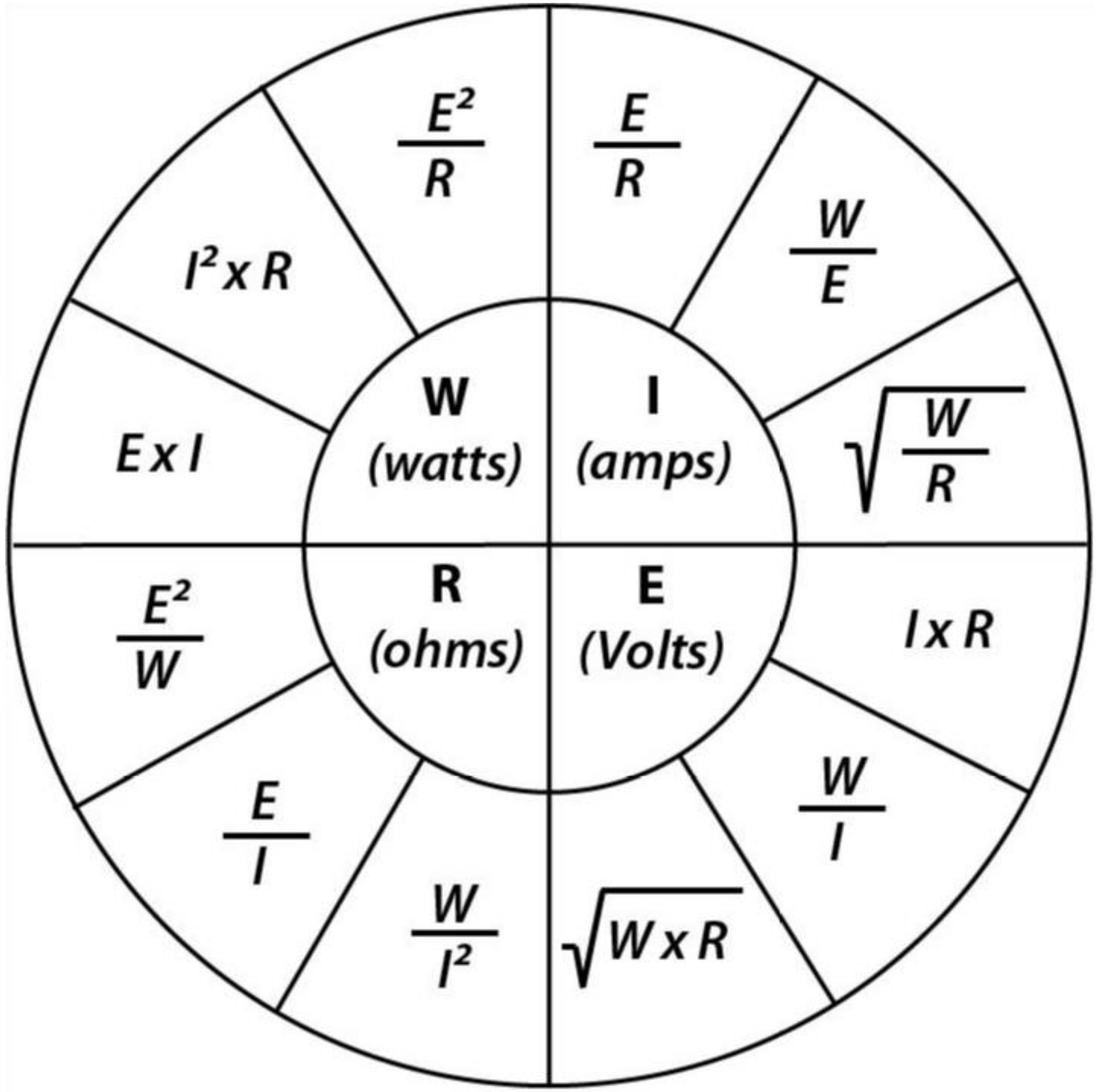
Why 120 VAC for Utilization Voltage?
Why Isn't it 12 VAC Used?
Why Not 1200 VAC?
Why Not 120 Kilo-Volts AC??
Why Not Generate at 765 KV?

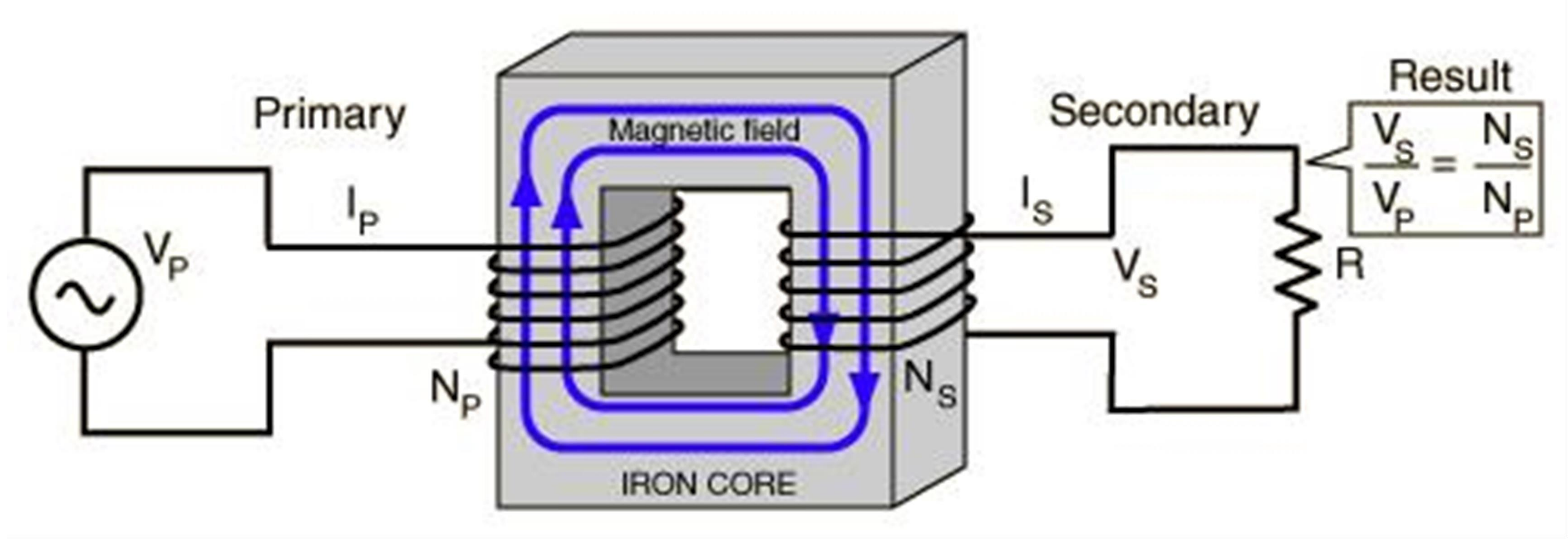
WHY DOES THE GRID UTILIZE LARGE TRANSMISSION TOWERS AND INSULATORS?

GOVERNED BY THE LAWS OF PHYSICS



OHM'S LAW

WHY DO WE HAVE TRANSFORMERS



BASIC ELECTRICAL TRANSFORMER REPRESENTATION

FIRST TRANSFORMERS
NECCESSITY IS THE MOTHER OF INVENTION

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THE PATH OF AN ELECTRON -
FROM GENERATOR TERMINALS TO YOUR HOME

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1000 MW NUCLEAR

22 KV Generation
345 KV Transmission

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Steam Turbine Generator

THE PATH OF AN ELECTRON -
FROM GENERATOR TERMINALS TO YOUR HOME

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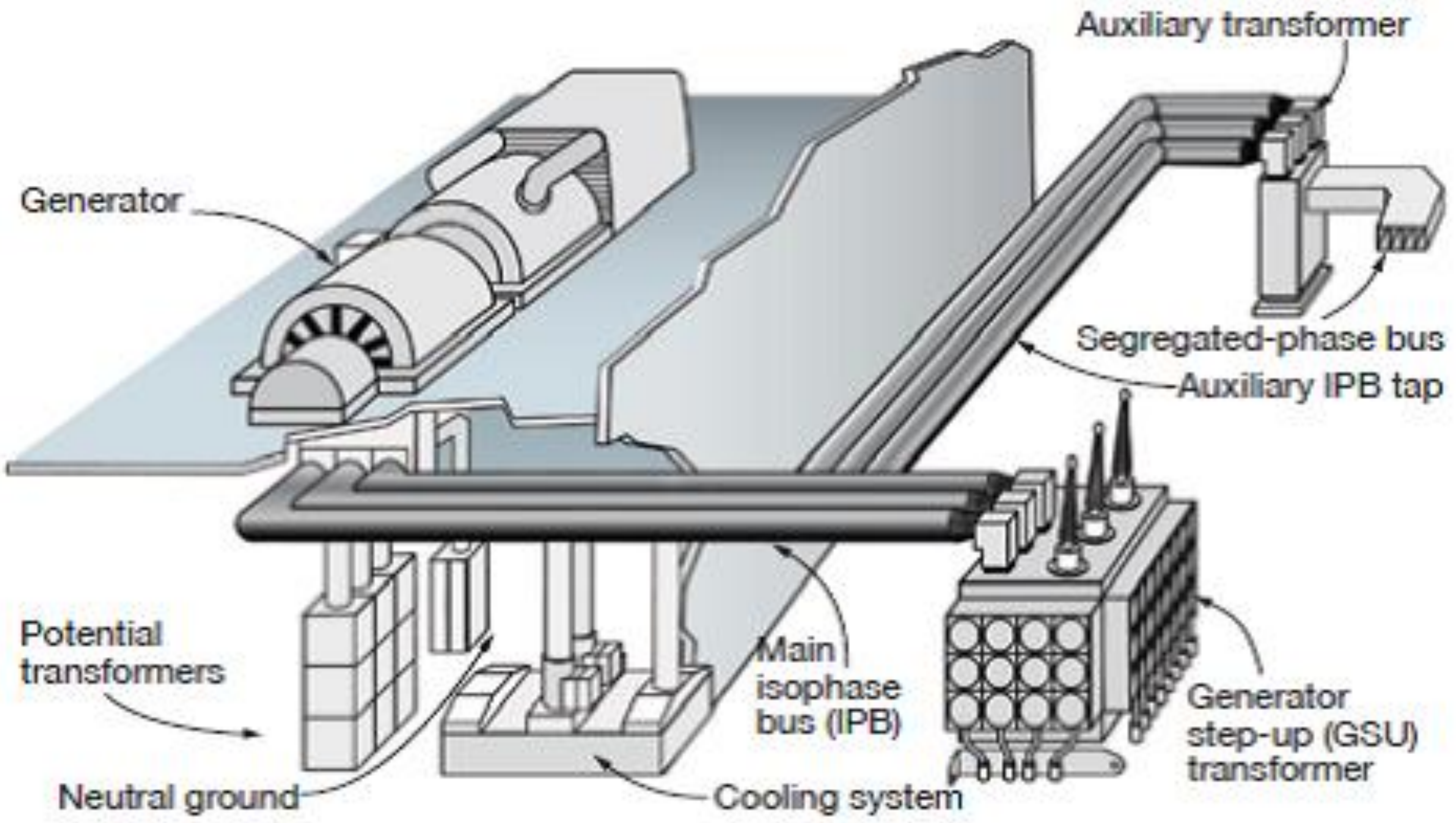

1. Electrical energy produced by the generator is moved via isophase bus to transformers that boost voltage for export to the grid or for in-plant use

1000 MW NUCLEAR

22 KV Generation
345 KV Transmission

THE PATH OF AN ELECTRON -
FROM GENERATOR TERMINALS TO YOUR HOME

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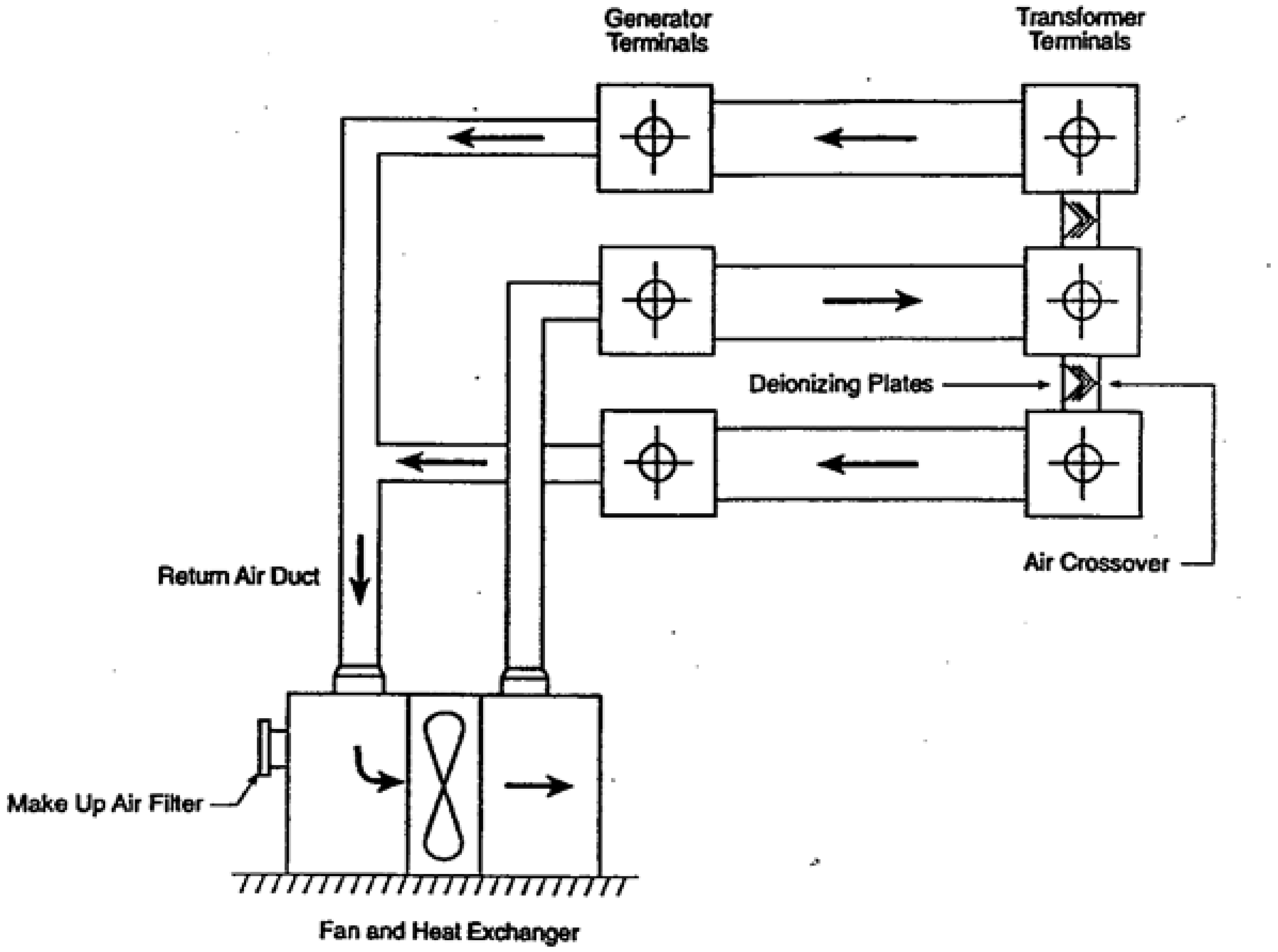
ISOPHASE BUS

22 KV - Generation
Air Cooled



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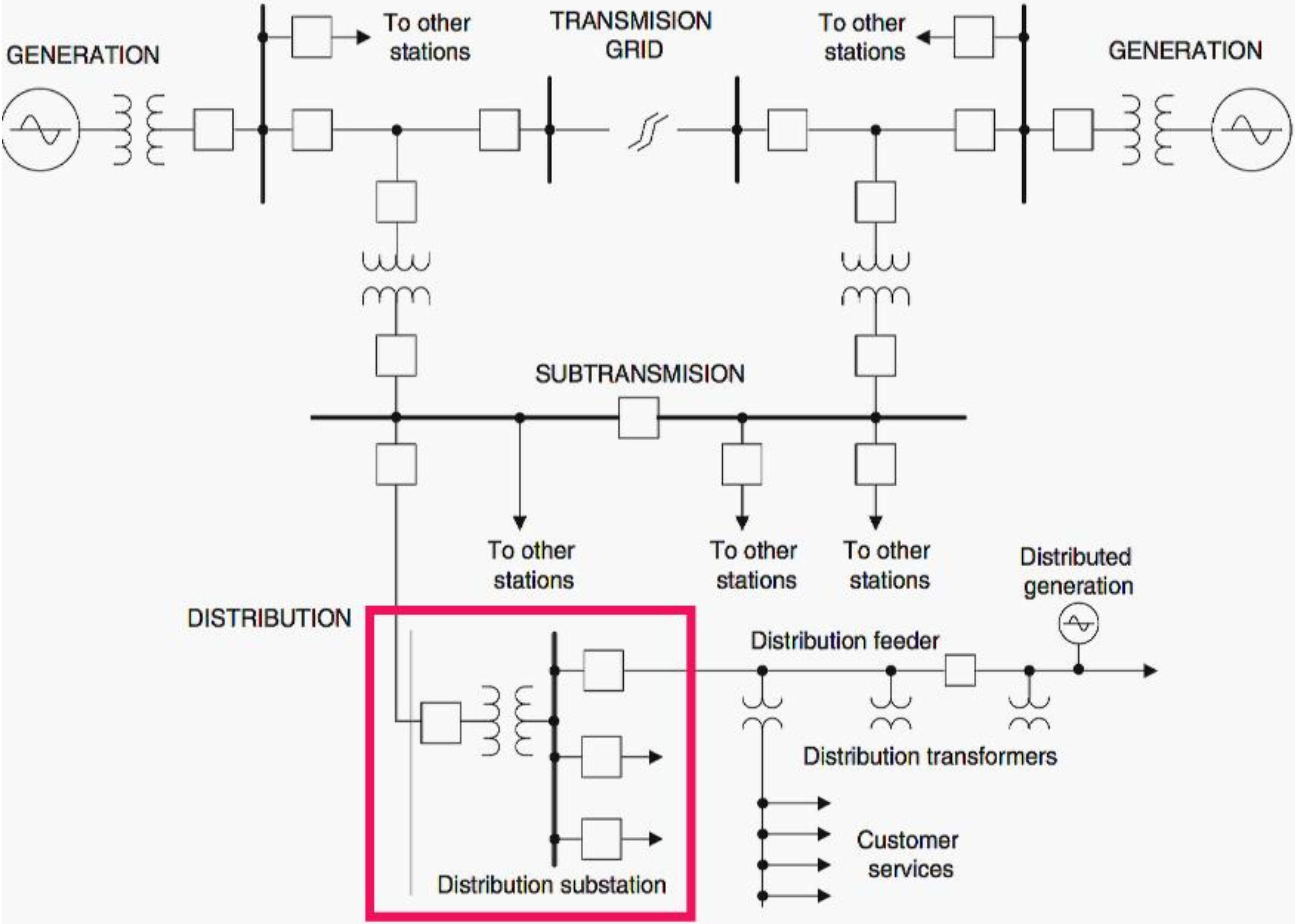
Typical System One-line Diagram



THE PATH OF AN ELECTRON - FROM GENERATOR TERMINALS TO YOUR HOME

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1000 MW NUCLEAR

22 KV - Generation
345 KV - Transmission

$$x = \frac{1000\ MVA}{(22\ KV)(\sqrt{3})} = 26{,}243\ A$$

This is the generator output power and current at the rated voltage of 22 KV

(Assume a loss-less system for the entire example)

THE PATH OF AN ELECTRON - FROM GENERATOR TERMINALS TO YOUR HOME

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1000 MW NUCLEAR

22 KV - Generation
345 KV - Transmission

The GSU is rated 22 KV/345 KV
Turns Ratio = 22:345 or 1:15.68

Voltage from Generator is STEPPED UP by a factor of 15.68X
So (22KV)(15.68) = 345 KV

P = E X I

Output current is lowered by a factor of 15.68

$$x = \frac{1000\ MVA}{(345\ KV)(\sqrt{3})} = 1673\text{ A}$$

Proof: $$x = \frac{26{,}243\ A}{15.68} = 1673\text{ A}$$

THE PATH OF AN ELECTRON - FROM GENERATOR TERMINALS TO YOUR HOME

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$$x = \frac{1000\ MVA}{(345\ KV)(\sqrt{3})} = 1673\ A$$

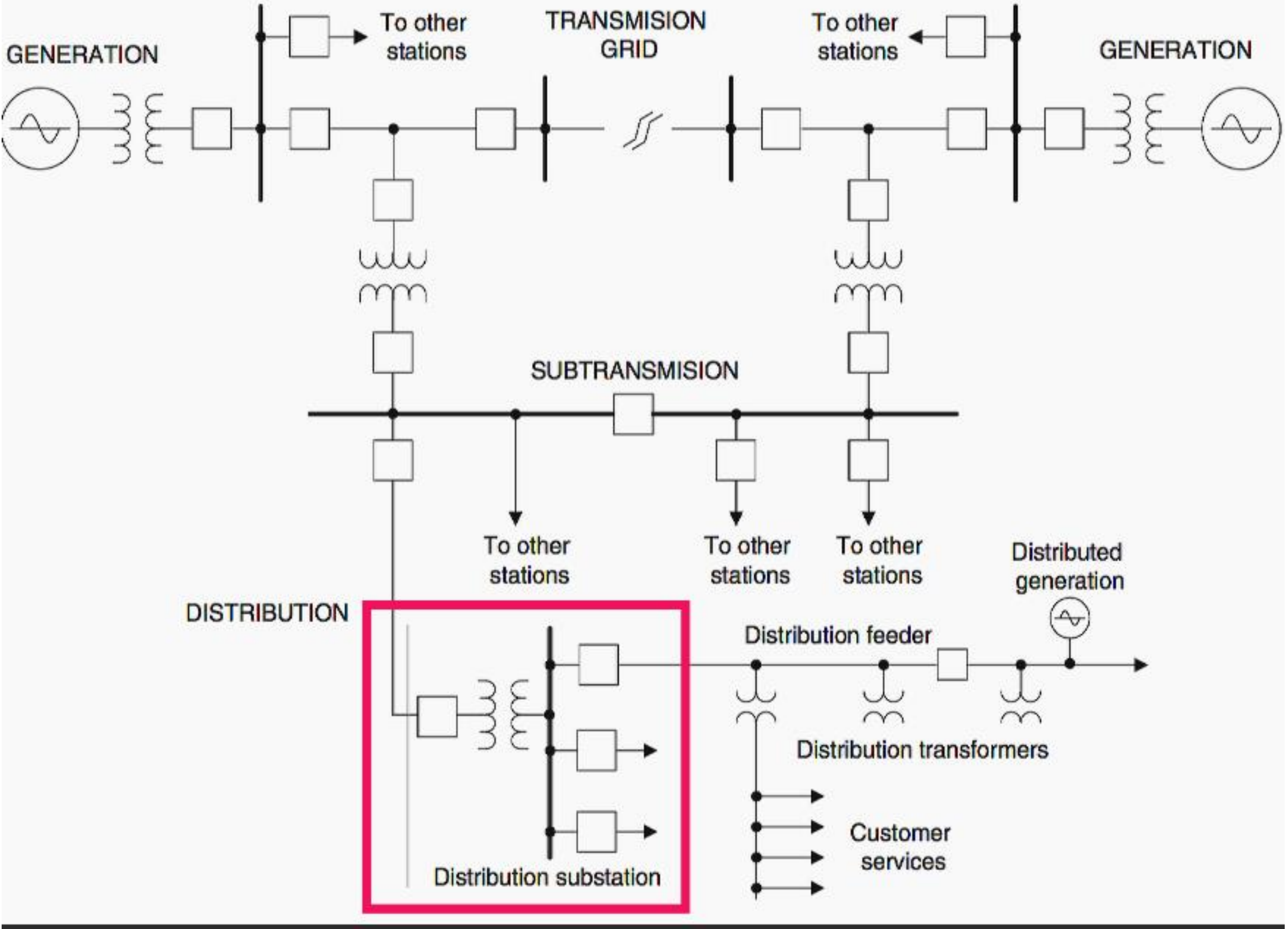
Represents a dramatic reduction in current, which ties directly to losses due to $P = I^2R$

Power flows into generating station substation and out to the transmission system on multiple transmission lines.

For our example, we will choose one transmission line at 200 MW and call it the A1 Line.

1000 MW NUCLEAR

22 KV - Generation
345 KV - Transmission



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Typical System One-line Diagram

THE PATH OF AN ELECTRON -
FROM GENERATOR TERMINALS TO YOUR HOME

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Current flows along the transmission system for X distance into bulk transmission substation

Transmission substation transformer is rated 345 KV/115 KV Auto, 200 MVA
Turns Ratio = 3:1

Voltage from transmission line is STEPPED DOWN by a factor of 3X
So (345KV)/(3) = 115 KV

1000 MVA GSU

22 KV - Generation
345 KV – Transmission

200 MVA AUTO
345KV/115KV

THE PATH OF AN ELECTRON -
FROM GENERATOR TERMINALS TO YOUR HOME

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Power flowing into the AutoTransformer (Transmission Substation) is 345 KV. The amperage is calculated as follows:

$$x = \frac{200\ MVA}{(345\ KV)(\sqrt{3})} = 335A$$

The AutoTransformer is 3:1 ratio, so the output voltage goes down to 115 KV, and the output current goes up:

(3X)(335 A) = 1005 A

Proof:

$$x = \frac{200\ MVA}{(115\ KV)(\sqrt{3})} = 1005A$$

1000 MVA GSU

22 KV - Generation
345 KV – Transmission

200 MVA AUTO
345KV/115KV

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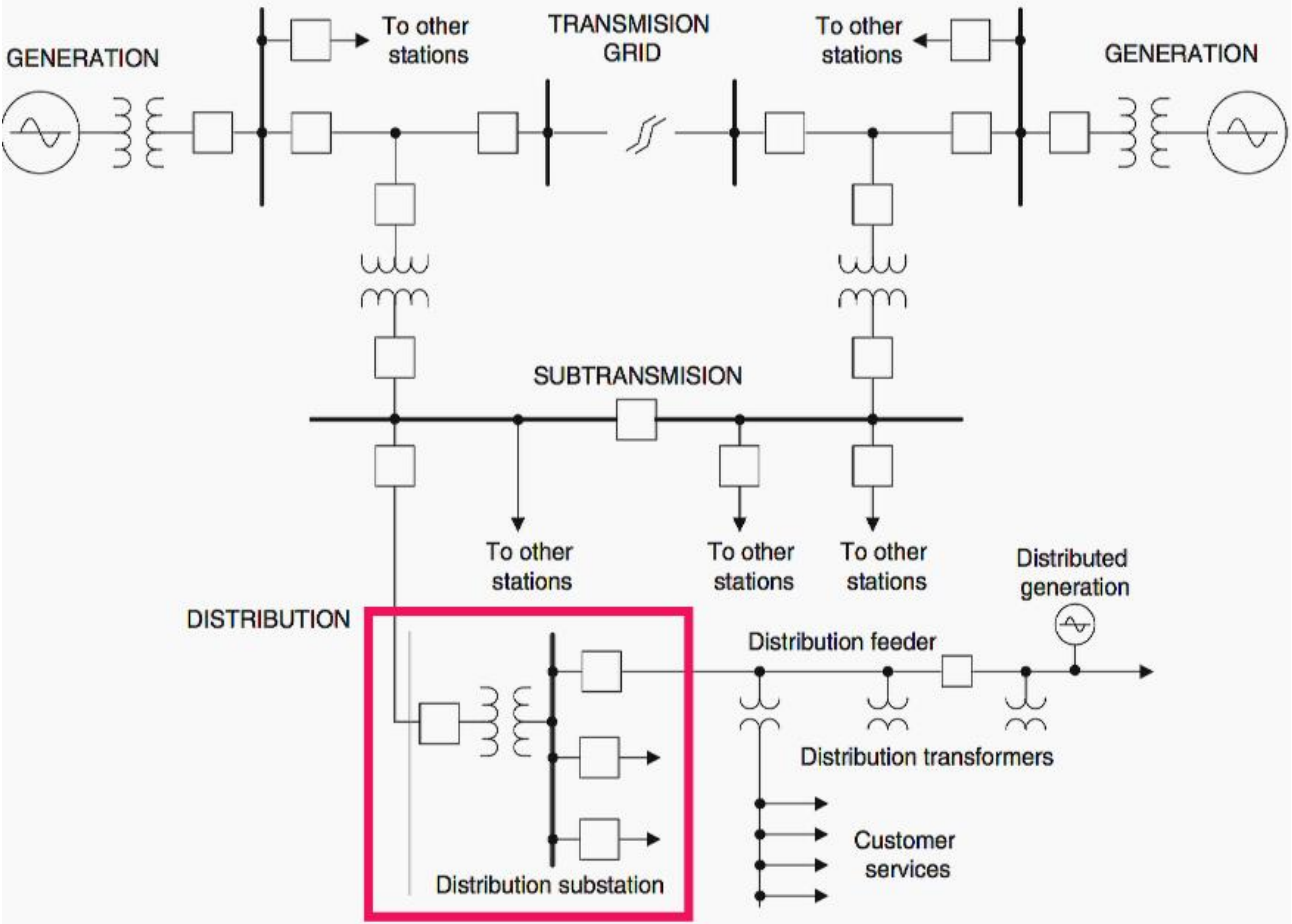
Typical System One-Line Diagram



We need to transmit power to several Distribution Substations located downstream of the Transmission Substation at 115 KV. We will send power on a sub-transmission line called the B2 line for 5 miles to a Distribution Substation that requires 40 MVA. The power flow is 40 MVA and the current is 200 A.

$$x = \frac{40\ MVA}{(115\ KV)(\sqrt{3})} = 200\text{A}$$

We will then step down the voltage to a more usable value as we draw nearer to the end user. The new Distribution Class voltage will be 13.8 KV AC. We will utilize a 40 MVA unit as stated above. Secondary current shall be as follows:

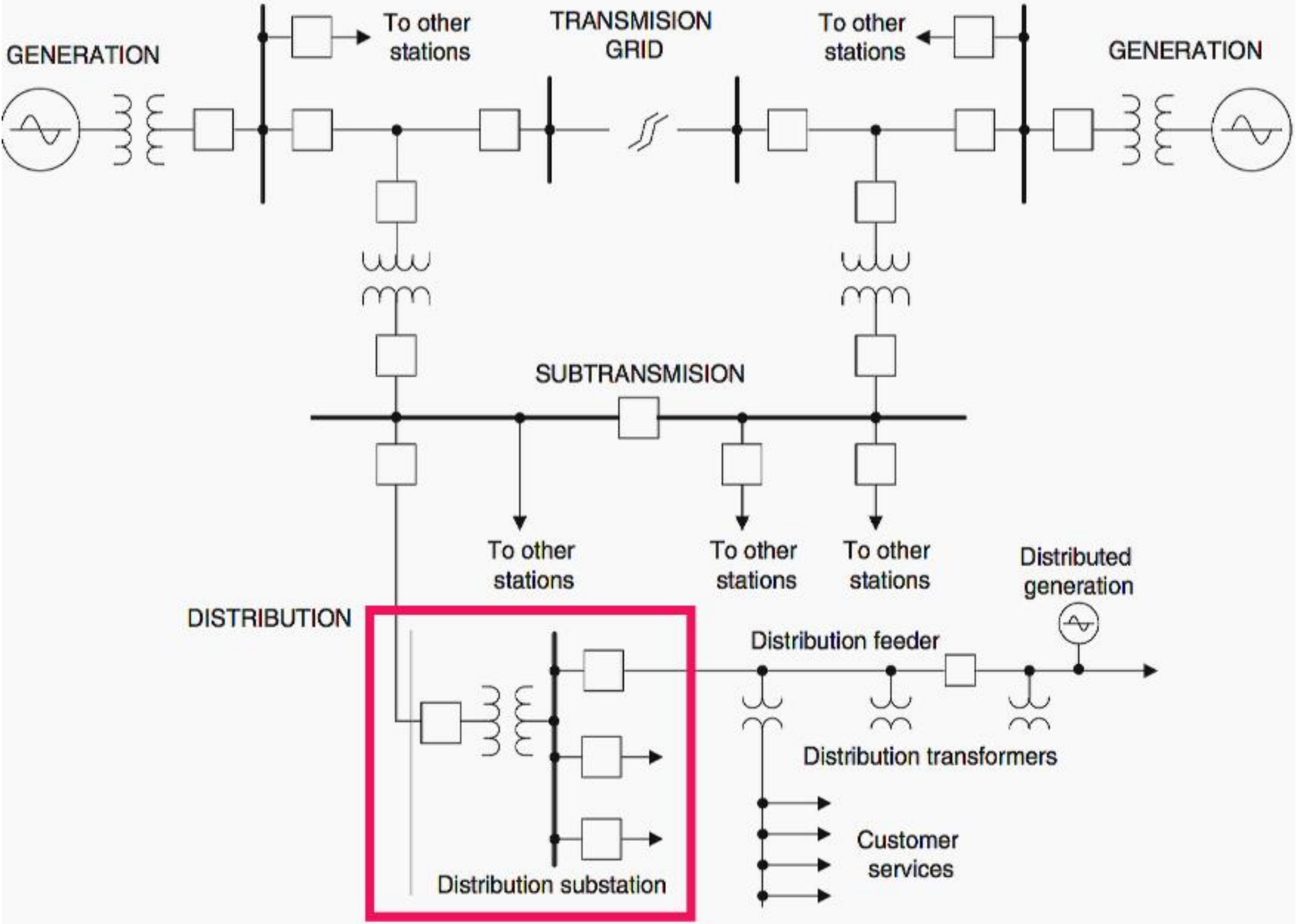
$$x = \frac{40\ MVA}{(13.8\ KV)(\sqrt{3})} = 1673\text{ A}$$

$$x = \frac{40\ MVA}{(13.8\ KV)(\sqrt{3})} = 1673\ \text{A}$$

We will then distribute the 40 MVA of electrical energy throughout the distribution system of a particular region of town. We have stepped-down the voltage to a more usable value of 13.8 KV AC. This energy is fed to numerous pad mount and pole-top distribution transformers.

We will choose one position in the switchgear for our use, and call this the C3 feeder. The power flows through this breaker position at 13.8 KV, travels underground to a telephone pole outside the distribution switchyard, and then rises up alongside the pole to a wooden cross arm. The power will continue to flow from pole to pole, as far as is needed. For our example we will state the C3 feeder travels one mile from the station, supplying power to various transformers at 13.8 KV. We will assume that this feeder position supplies a total of 5 MVA throughout a portion of the city. The current is calculated as follows:

$$\frac{5 \text{ MVA}}{(13.8 \text{ KV})(\sqrt{3})} = 209 \text{ A}$$



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Typical System One-Line Diagram

THE PATH OF AN ELECTRON -
FROM GENERATOR TERMINALS TO YOUR HOME

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Current flows along the distribution system for X distance until it reached the pad mount or pole-top transformer outside your home

Distribution transformer is rated
13.8 KV/7.96 KV – 120/240 VAC
25 KVA

Secondary service wires are tapped to your house to your 200 A Load Center. Outlets are wired from circuit breakers located within LC.

1000 MVA GSU

22 KV - Generation
345 KV – Transmission

200 MVA AUTO
345KV/115KV

40 MVA DISTRIBUTION
115 KV/13.8 KV

25 KVA DISTRIBUTION
7.97 KV - 120/240 VAC

ELECTRICAL GRID SYSTEM LOGIC

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Generate at 120 VAC = 10'X10' Aluminum conductor. Voltage would be zero before it left the driveway. Current at 1000 MW, 120 VAC, 1-Ø = 8.33 MEGA-AMPS!!

Generate at 345 KV or higher – Generator would be as big as an aircraft hanger - not practical.

Why not 345 KVAC at your house? – Your toaster would be as big as your garage.

<u>The answer is the transformer</u>

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New State Of
The Art
Relays & Controls

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NEW EQUIPMENT INTERFACE
STATE-OF-THE-ART
RELAYS & CONTROLS

SOPHISTICATED CHALLENGE

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5 MW Solar Farm
Walt Disney World

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London Square
Mile
Totally Renewable
By October 2018

The City of London, the historic “Square Mile” central district of London, will soon switch to clean energy in a big way. Starting in October 2018, the City of London will source 100 percent of its power needs from renewable energy sources by installing solar panels on local buildings, investing in larger solar and wind projects and purchasing clean energy from the grid. Though no longer a square mile, closer now to 1.12 square miles, the City of London is a major financial center within the city and the world. Its green energy transformation sends a clear message that London intends to take strong action against climate change.

WILDFIRES, ELECTRICAL UTILITIES, & INVERSE CONDEMNATION

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LOS ANGELES — Electrical equipment owned by Southern California Edison may have been "associated" with the start of the massive 2017 Thomas Fire that tore through California's central coast, company officials said Tuesday. Two people had died from the blaze.

In a Securities and Exchange Commission (SEC) filing Tuesday October 30, 2018 Edison "noted in that filing ... [the company] believes its electrical equipment was associated with an ignition near Koenigstein Road in Santa Paula," which was one of at least two origin points for the Thomas Fire.

Started in Dec. 2017, the Thomas Fire that raged across Ventura and Santa Barbara counties became the largest by acreage in state history, charring 282,000 acres, or 440 square miles — larger than the city of San Diego. More than 1,000 buildings were destroyed. A month later, heavy rains fell on hills left bare by the fire, unleashing mudslides that killed 21 and left two missing.

California ponders wildfire relief fund as PG&E seeks rate-case delay

Inverse condemnation in California allows you to sue the government if the government damaged your property.

US ELECTRICITY GENERATION BY FUEL SOURCE 2005-2017

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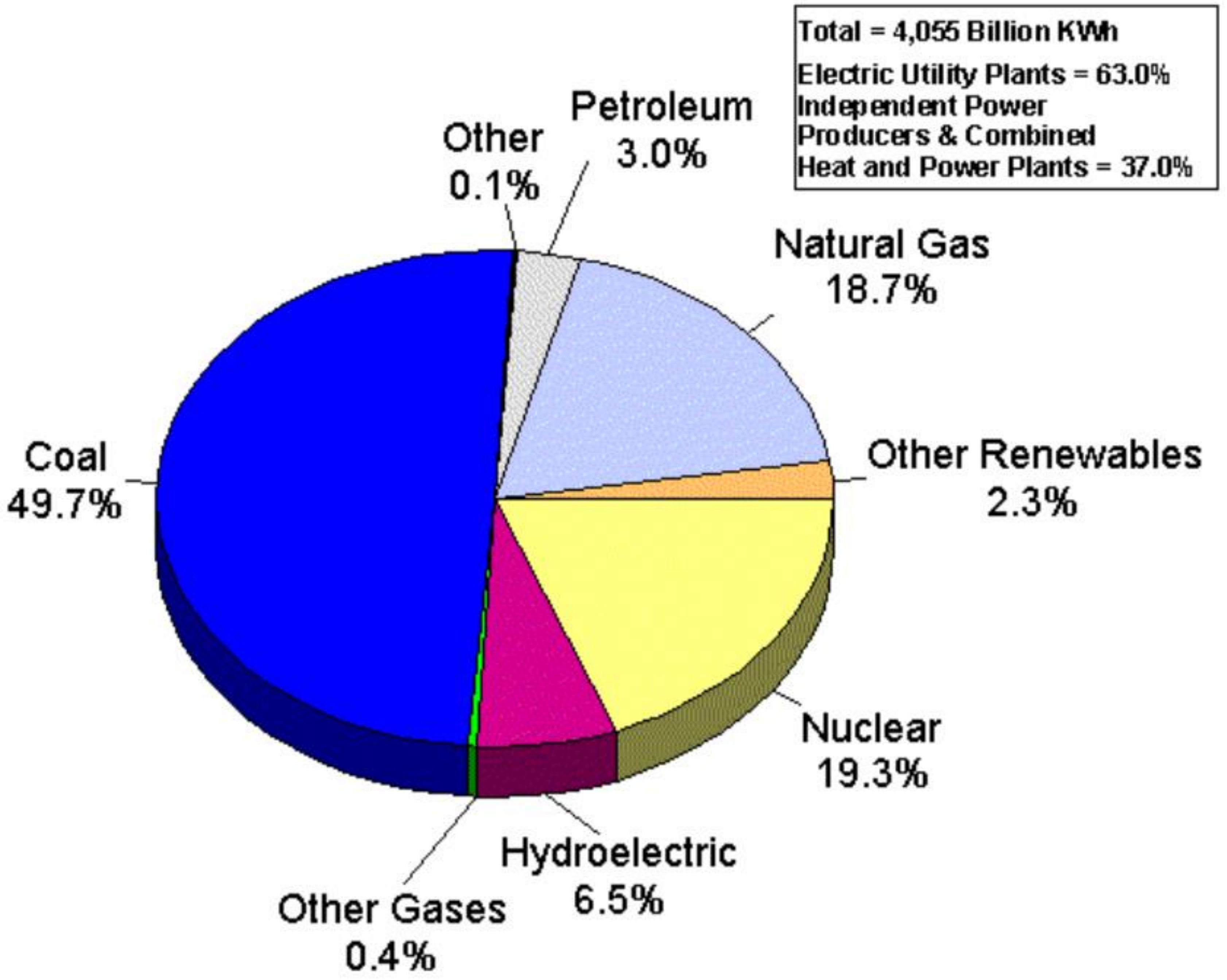
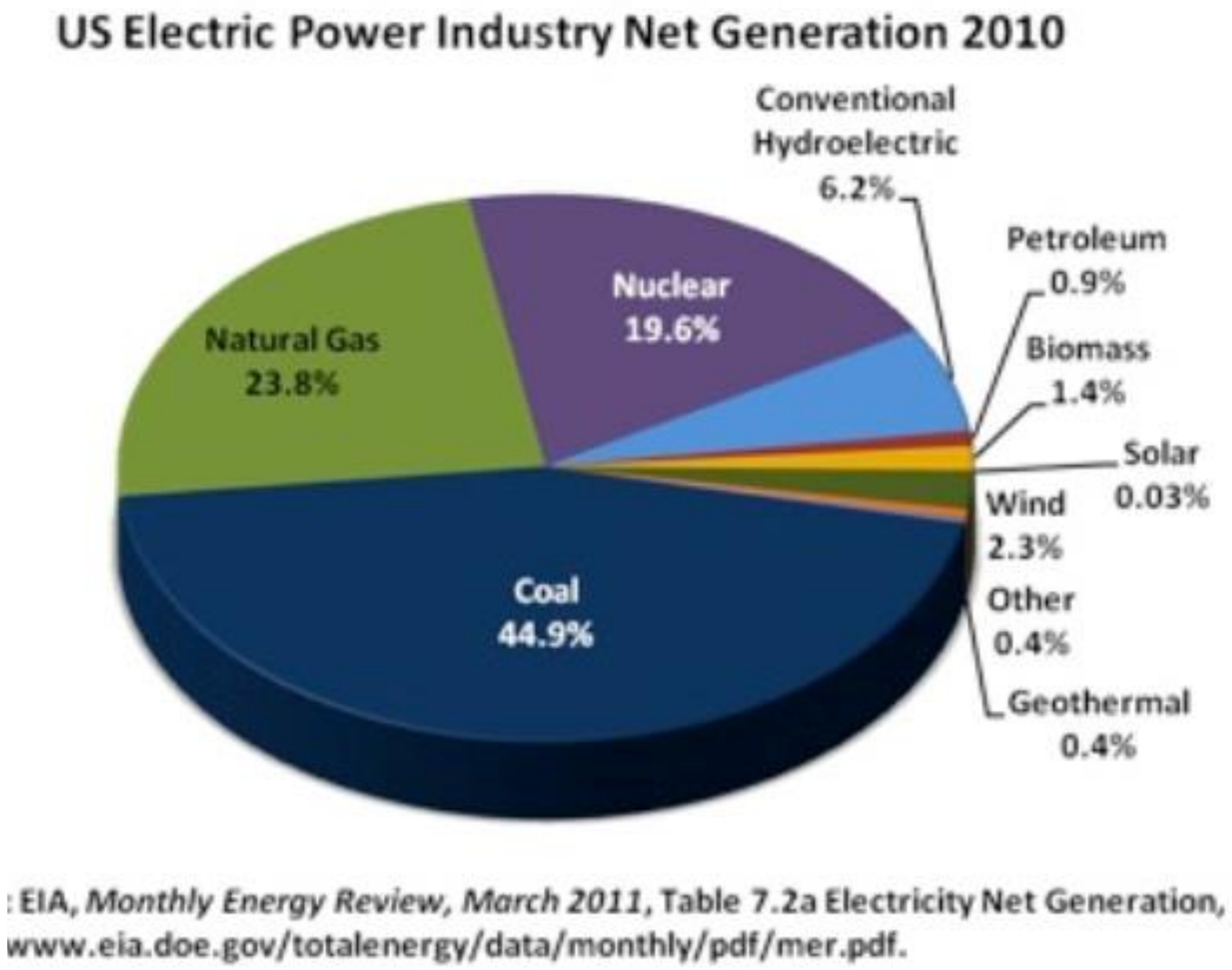
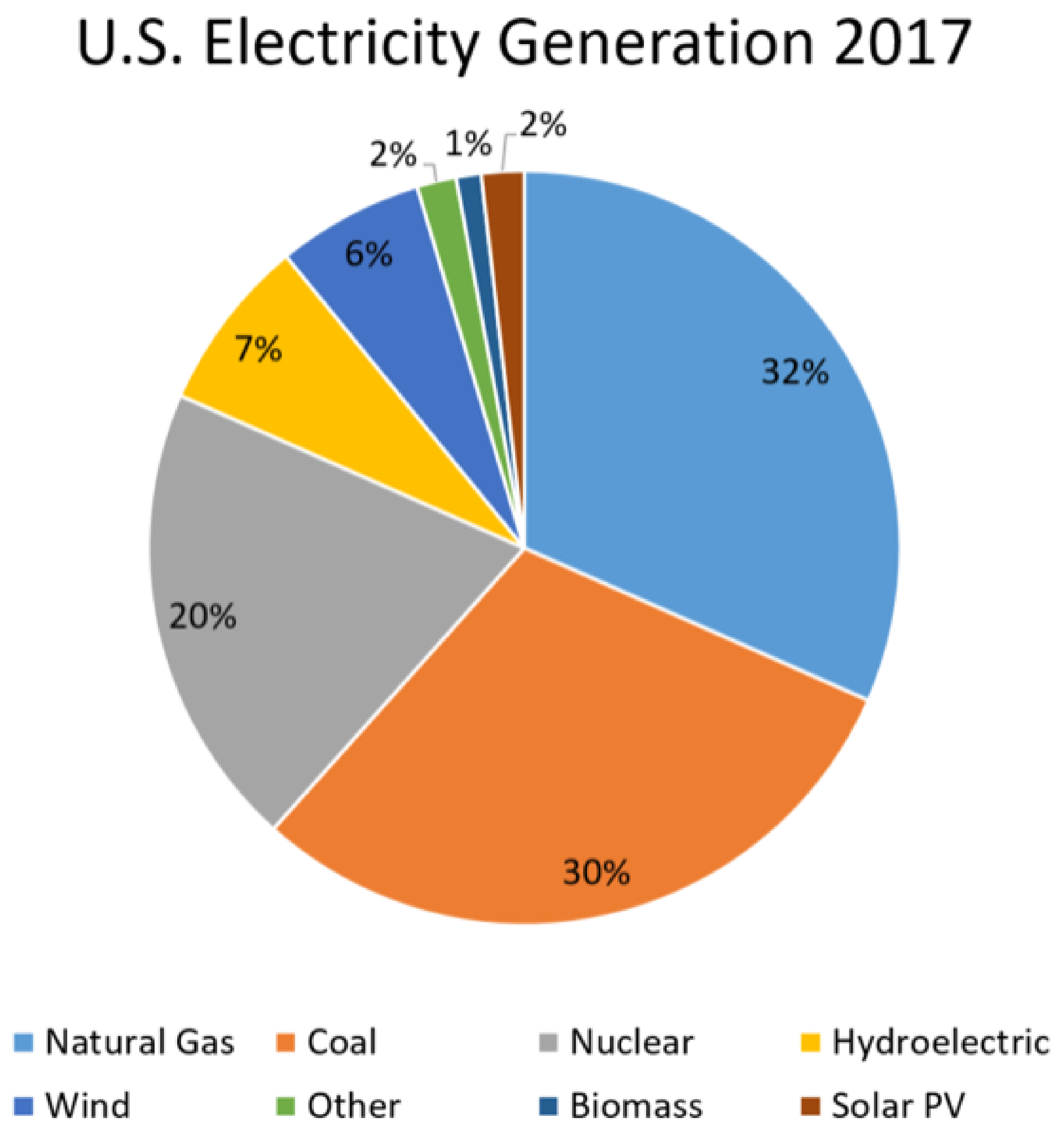


2005

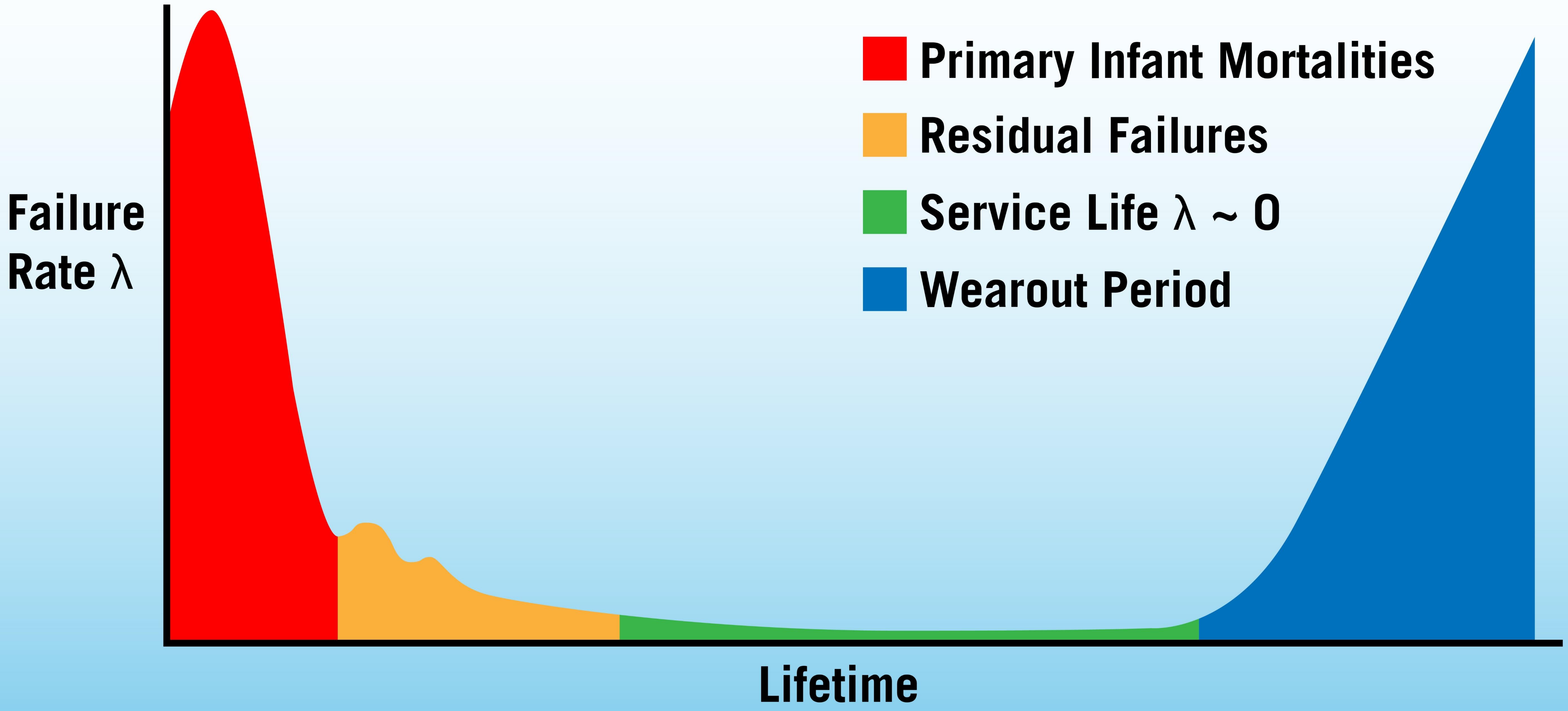


2010



2017

LARGE ELECTRICAL POWER APPARATUS

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CREDIT: ERIK BRIN
The pessimist complains about the wind; the
optimist expects it to change;

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RICHARD K LADROGA, P.E.
Director - Energy

140 Broadway
New York, NY 10005
212-532-2211 X1116 (W)
857-205-7333 (C)