Unravelling

Complexities of AC & DC Currents in Pipeline Integrity

To be presented by Gabriel Gonzales and Ian Kinnear on July 30, 2024, this document has been created to be a summary of the presentation which is to take place with Materials Performance (MP). We aim to explore the complexities associated with alternating current (AC) and direct current (DC) in the context of pipeline integrity, specifically, corrosion. It covers increasing electricity demands, investment trends, and the impact of extreme weather on utilities.

The first half of 2024 saw a 5% increase in electricity generation compared to 2023 due to hotter summers and higher commercial demand. The second half of 2024 is expected to see a 2% growth in electricity generation(EIA Energy). Natural gas accounted for 39% of electricity generation in 2023, but this is expected to decrease to 37% in 2024 as increased LNG demand from Europe drives new investments in gas infrastructure (AEM Tradeshows - The Utility Expo). Renewable energy is alsoon the rise, with a planned increase of 30% in solar capacity (31 GW) and 5% in wind capacity (7 GW) in 2024. Wind and solar are projected to account for 18% of total electricity generation in 2024(Deloitte United States) (EIA Energy).

In **2023,** U.S. utility-scale electricity generation totaled 4178 billion kWh, with fossil fuels making up 60% of this amount. Natural gas was the largest contributor among fossil fuels at 43.1%, followed by coal at 16.2% and petroleum at 0.4%. Nuclear energy accounted for 18.6%, while renewables made up 21.4%, with wind contributing 10.2%, hydropower 5.7%,and solar 3.9% (U.S. Energy Information Administration).

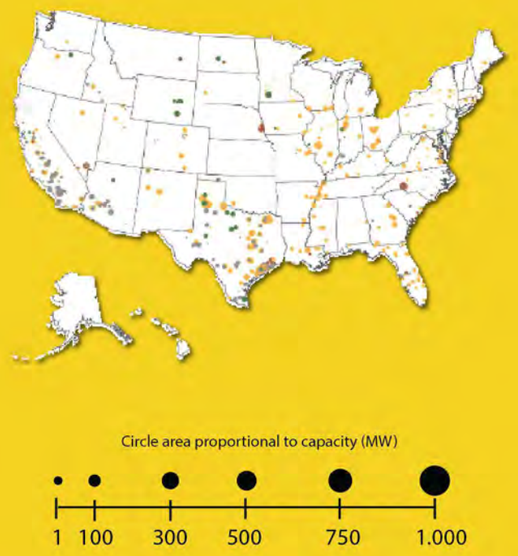
Investment in infrastructure is crucial to meet the growing electricity demand and ensure grid resilience. In 2023, large energy utilities spent nearly $171 billion on infrastructure, with expectations for further increases in 2024. These investments are aimed at addressing growing demand, grid modernization, and resilience against severe weather (Deloitte United States). The residential sector consumed 12.30 quadrillion Btu in 2022, while the commercial sector used 9.58 quadrillion Btu (EIA Energy).

Energy source	Billion kWh	Share of total
Total all sources	4,178	
Fossil fuels (total)	2,505	**60.00%**
Natural gas	1,802	43.10%
Coal	675	16.20%
Petroleum (total)	16	0.40%
Petroleum liquids	12	0.30%
Petroleum coke	5	0.10%
Other gases	11	0.30%
Nuclear	775	**18.60%**
Renewables (total)	894	**21.40%**
Wind	425	10.20%
Hydropower	240	5.70%
Solar (total)	165	3.90%
Photovoltaic	162	3.90%
Solar thermal	3	0.10%
Biomass (total)	47	1.10%
Wood	31	0.80%
Landfill gas	8	0.20%
Municipal solid waste (biogenic)	6	0.10%
Other biomass waste	2	0.10%
Geothermal	16	0.40%
Pumped storage hydropower	-6	**-0.10%**
Other sources	10	**0.20%**

Data source-U.S. Energy Information Administration, Electric Power Monthly, February 2024; preliminary data

Looking ahead, the utility industry is expected to see significant growth in electricity demand driven by the electrification of transportation, buildings, and industrial sectors. Load growth projections suggest up to an 80% increase by 2045 in high electric vehicle (EV) adoption areas (Southern California Edison) (Deloitte United States). Utility-scale solar installations are expected to double by 2024, and grid-scale battery storage capacity is projected to reach 32 GW (Deloitte United States) (Guide to Next 2024).

Record-high capital expenditures for grid modernization and resilience are anticipated, supported by significant funding from the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA) (Deloitte United States) (EY US). Technological advancements, including the integration of AI and digital solutions, will play a key role in enhancing grid stability and efficiency.

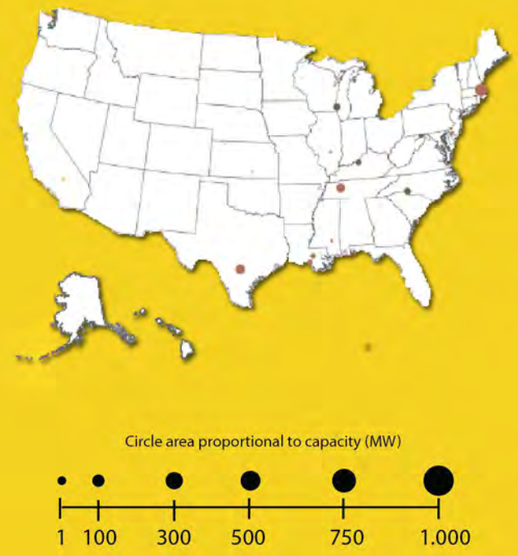


Wind
Solar
Natural Gas
Coal
Nuclear
Conventional hydroelectric
Other

Circle area proportional to capacity (MW)

1 100 300 500 750 1.000

Sources-US. Energy Information Administration. Form EIA-860. 'Annual Electric Generator Report and Form EIA-860M, 'Monthy Update to the Annual Electric Generator Steport.



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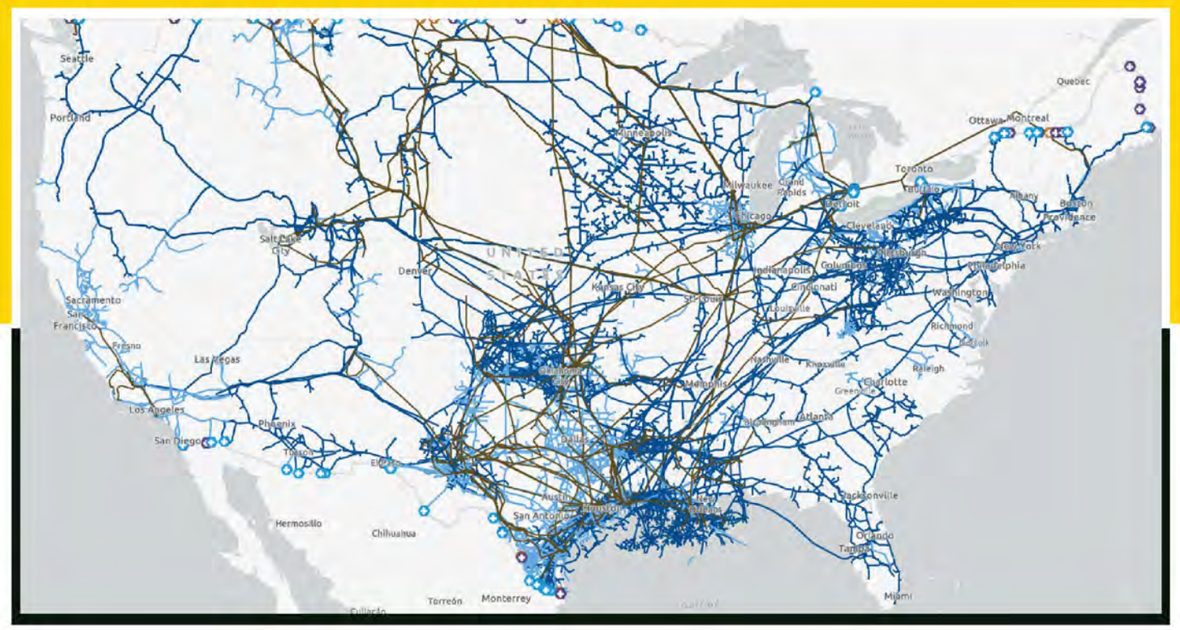
Extreme weather events pose significant challenges to utility infrastructure, leading to increased investments in resilience measures to mitigate the impacts of hurricanes, wildfires, and heatwaves (GAO) (Federal Energy Regulatory Commission). **A growing trend towards burying power lines helps protect against storm damage and enhances reliability by reducing the vulnerability of overhead lines to weather-related disruptions** (Digital Services Firm | West Monroe). Modernizing the grid to handle renewable energy variability and improve resilience involves deploying advanced technologies such as smart grids and utility-scale batteries.

Electricity transfer and distribution in the USA involve high voltage transmission lines (HVTLs) that carry electricity over long distances at voltages from 115 kV to 765 kV. Step-up transformers increase voltage for efficient long-distance transmission, while substations step down voltage from HVTLs to 4 kV - 33 kV for local distribution. Distribution lines carry medium voltage electricity to local areas, and distribution transformers further reduce voltage to 120V-480V for end-users. Smart grids enhance efficiency and reliability, integrating renewable energy sources (U.S. Energy Information Administration) (pv magazine USA).

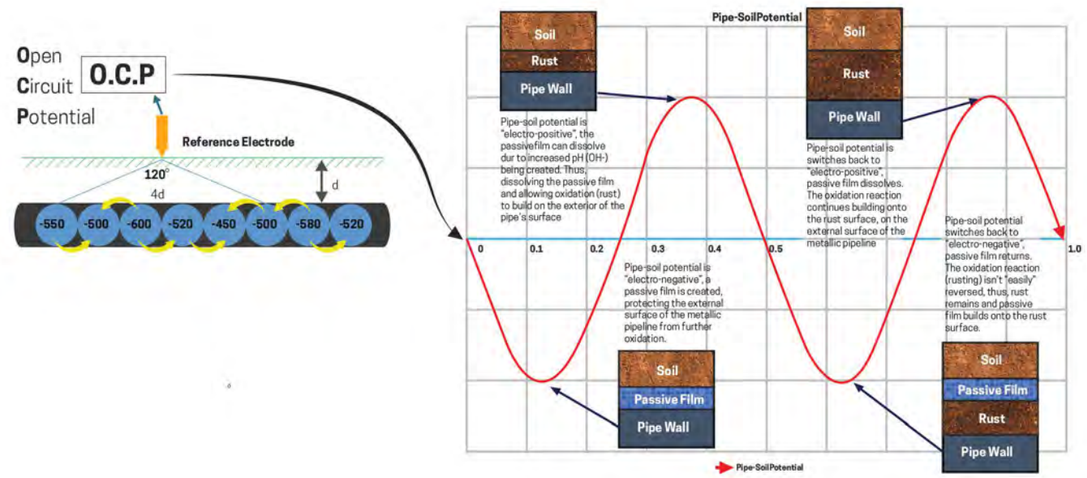
Gas and crude oil transfer and distribution in the USA rely on pipelines for high-pressure transport to processing facilities and distribution centers. Liquefied natural gas (LNG) is cooled for long-distance transport, especially where pipelines are not feasible. Rail and trucks are used for shorter distances or where pipelines are unavailable. Gas processing plants remove contaminants and prepare gas for pipeline transport, while storage facilities manage supply and demand fluctuations. Local distribution companies deliver gas to consumers through lower-pressure pipelines (U.S. Energy Information Administration) (ARPA-E).

The concern that is being presented is that, while grid modernization is in full effect, do we understand enough about buried assets, or better yet, are we gathering effectively monitoring to affectively prevent AC induced corrosion or similar, specifically, metallic pipelines, to determine if there will be any detriment to having electrical utilities buried, next to/near metallic pipelines?

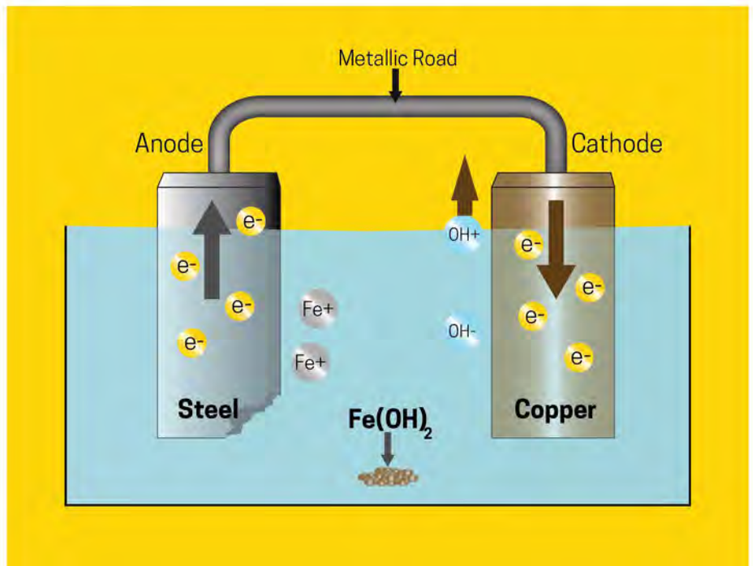


Cathodic protection for buried metallic pipelines involves DC cathodic protection, where anodes (sacrificial or impressed current) provide electrons to the cathode (pipeline) to inhibit anodic reactions that cause metal loss. The continuous flow of electrons from anode to cathode maintains a stable environment, preventing the formation of corrosive compounds and creating an alkaline environment at the cathode (Peabody A.W. & Bianchetti R.A., 2017) (Von Baeckmann W., Schwenk W., & Prinz W., 1997) (National Association of Corrosion Engineers).

AC induced corrosion occurs when buried pipelines running parallel to high voltage AC power lines experience induced AC due to electromagnetic fields. AC current causes the pipeline to periodically become anodic and cathodic, leading to localized corrosion. The alternating nature of AC leads to the generation of both hydroxide and hydrogen ions, causing pH fluctuations and destabilizing the protective environment created by DC cathodic protection (Peabody A.W. & Bianchetti R.A., 2017) (Von Baeckmann W., Schwenk W., & Prinz W., 1997) (Scully J.R., 1999).



The Basic Corrosion Cell



isosmart

An All-in-One Remote Asset Integrity Monitoring System

- One simple solution for monitoring your pipeline remotely

All readings are instantly logged and communicated to a user web portal, notifying the user of all events

- **Instant alerts for any type of event:**
  - Loss of isolation
  - Polarization on pipeline no longer providing enough protection
  - Loss of critical bond
  - AC current density past threshold
- **Track trends over time**
- **Create reports for compliance submission**
- **Peace of mind for having reliable data all in one location**
- **Understanding that your systems are performing as intended**
- **Provide continuous data instead of a yearly data point**

The first portion fop the presenation is aimed to highlight the growing demand for electrical utilities and the need for assetss being more resinient wo extreame weather. With anticipation that, eventually, all HVTL will be burried. This posses the concern of corrossion on burrie, metalic, pipelines. Specifically against AC Induced Corrossion.

Iso-Smart is being marketed as an "all-in-one" solution and, more importantyl, aims to be an all encompessing echosystem. So, can you afford to not know what's "on" your burried, metallic, pipeline?

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