The Evolution of American Electric Power: Past, Present & Future

UT Energy Week | February 19, 2015

Calvin Crowder
President
Electric Transmission Texas, LLC

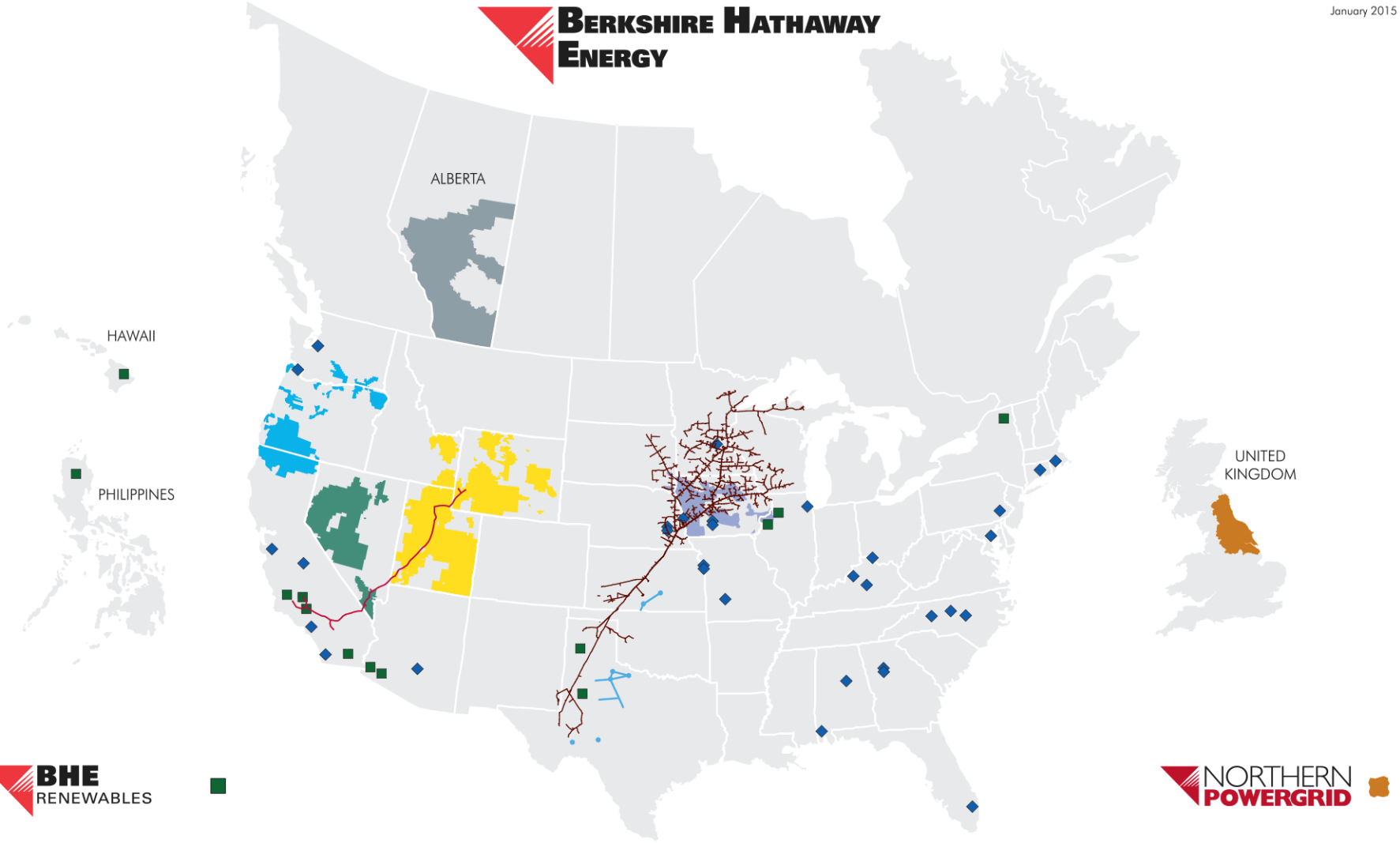
Electric Transmission Texas

- **Formed in 2007, ETT is a joint venture between subsidiaries of American Electric Power (NYSE: AEP) and Berkshire Hathaway Energy Company**
- **Operating in the ERCOT region of Texas**
- **Over $2 billion in assets**

ETT℠
Electric Transmission Texas

Berkshire Hathaway Energy

January 2015



BHE RENEWABLES

PACIFICORP

PACIFIC POWER

ROCKY MOUNTAIN POWER

PACIFICORP ENERGY

NVEnergy

MidAmerican ENERGY

BHE PIPELINE GROUP

Northern Natural Gas

Kern River GAS TRANSMISSION COMPANY

ALTALINK

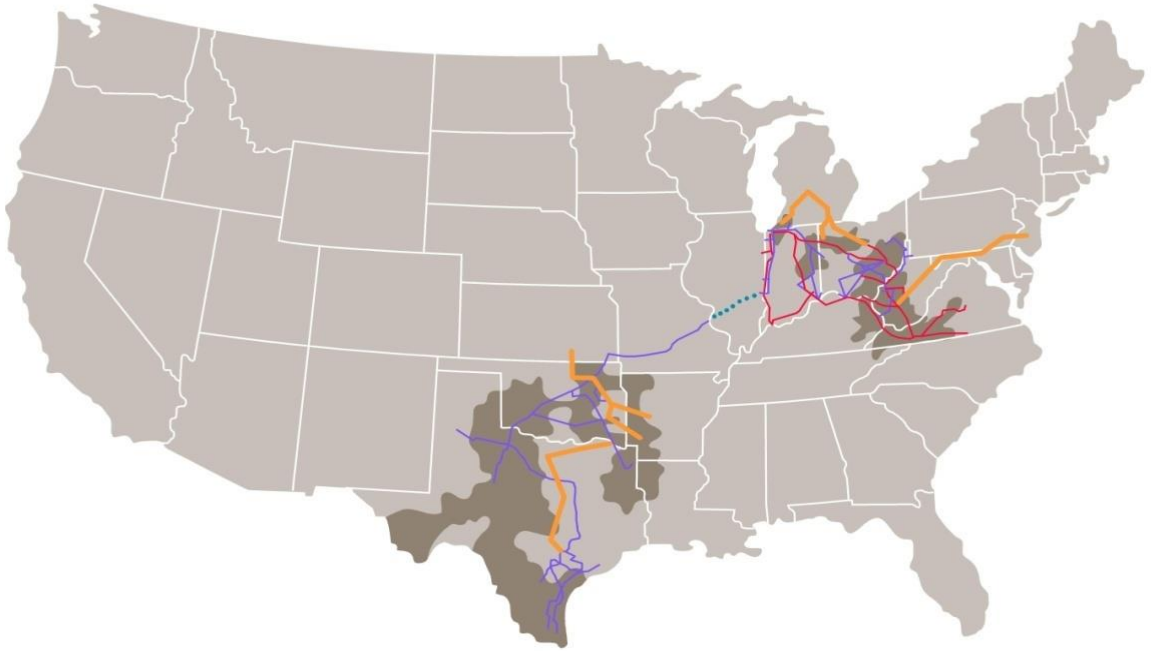
BHE U.S. TRANSMISSION

NORTHERN POWERGRID

HomeServices of America, Inc. A Berkshire Hathaway Affiliate

Real Estate Operating Companies

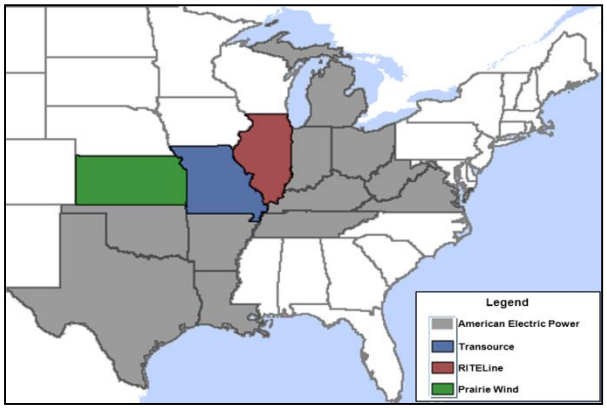
American Electric Power



- AEP utility operations serves 5 million customers in seven operating companies serving a total of 11 states and 3 RTOs
- Nearly 38,000 megawatts of Generation
- 40,000 miles of transmission, with 2,100 miles of 765-kV lines (the largest transmission system in the country)
  - AEP celebrates its 110th anniversary in 2016

AEP Transmission

- **AEP owns the largest transmission system in the United States, delivering electricity to more than five million customers**
  - Service territory covers approximately 200,000 square miles in 11 states
    - Over 97,000 square miles in Texas
  - More than 40,000 circuit miles of transmission lines, including over 2,100 circuit miles of 765-kV transmission
    - More 765-kV than all other U.S. utilities combined



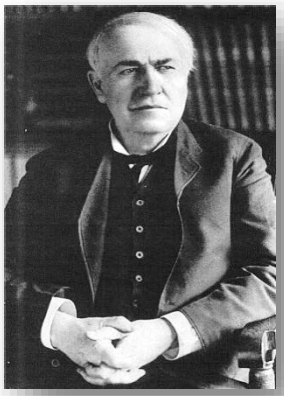
- **AEP Transmission is an advocate of efficient transmission systems and technological innovation**
- **Leadership in emerging markets, project development and technology**

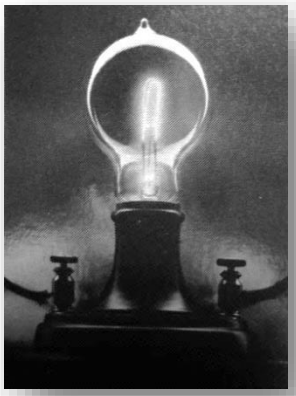
AEP Transmission manages a robust portfolio of transmission assets and investments. Newly established transmission-only entities provide greater transparency to investors and allow AEP to aggregate transmission growth.

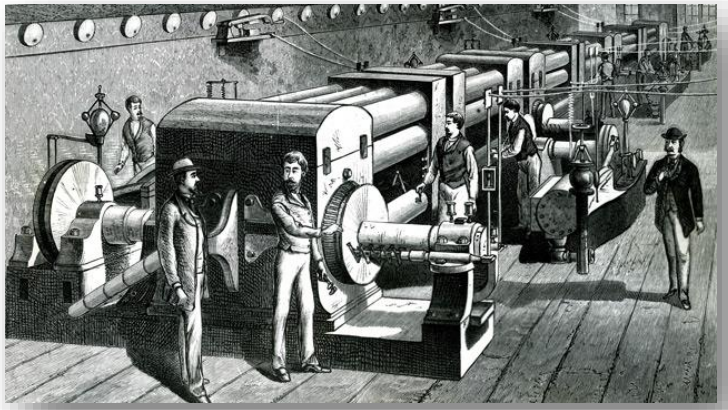
RITELine Transmission
TRANSOURCE
Pioneer TRANSMISSION
Prairie Wind Transmission
A joint venture between Westar Energy and ETA
ETT Electric Transmission Texas

In the Beginning

The Early Years



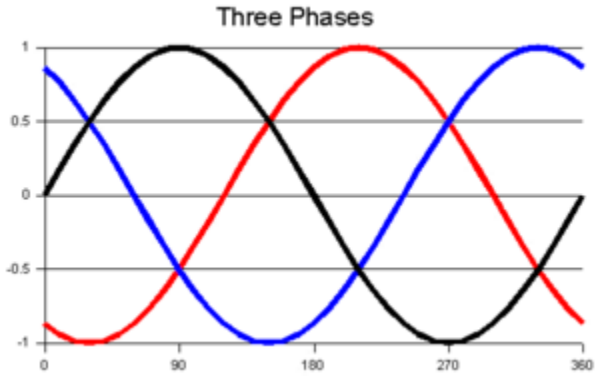


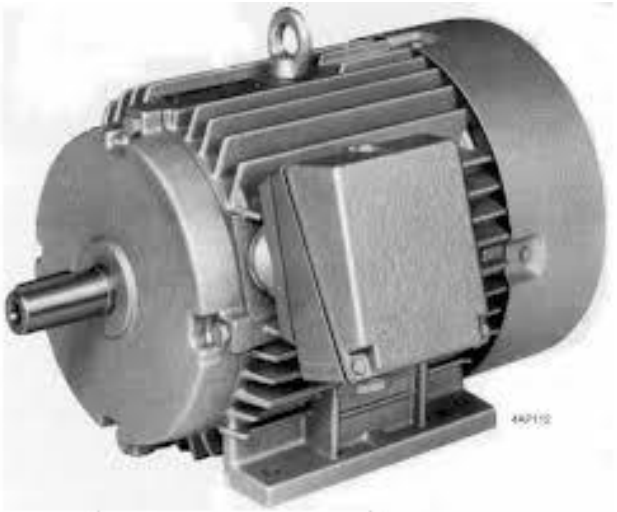


- ***1879*** – Thomas Edison creates first reliable electric incandescent lamp

- ***Sept 4, 1882*** – Edison's Pearl Street in New York City, the first full-scale central station for generating and distributing electric power, begins operation

The Age of Electrification





THE CURRENT WAR

THE TALE OF AN EARLY TECH RIVALRY

DC

DIRECT CURRENT

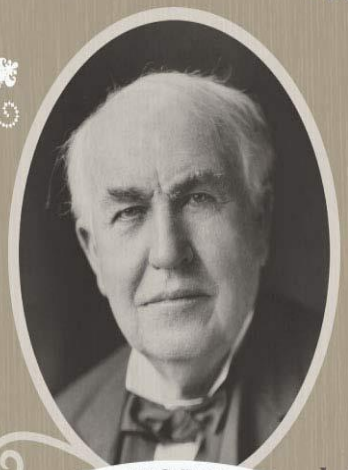
The flow of electricity is in one direction only. The system operates at the same voltage level throughout and is not as efficient for high-voltage, long distance transmission.

Direct current runs through:

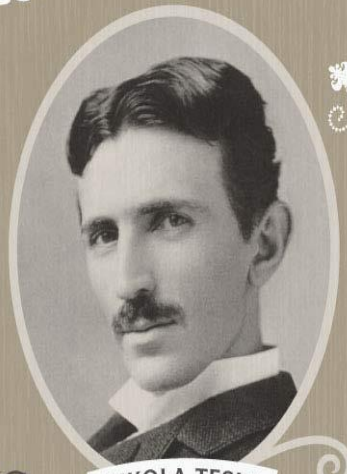
Battery-Powered Devices | Fuel and Solar Cells | Light Emitting Diodes

"[TESLA'S] IDEAS ARE SPLENDID, BUT THEY ARE UTTERLY IMPRACTICAL."

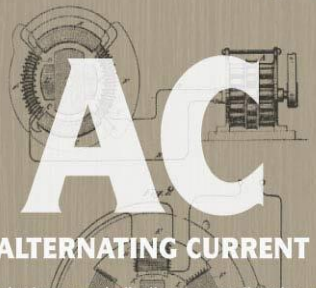
- THOMAS EDISON



THOMAS EDISON VS. NIKOLA TESLA



You would have never found two geniuses so spiteful of each other beyond turn-of-the-century inventors Nikola Tesla and Thomas Edison. They worked together—and hated each other. Let's compare their life, achievements, and embittered battles.



AC

ALTERNATING CURRENT

Electric charge periodically reverses direction and is transmitted to customers by a transformer that could handle much higher voltages.

Alternating current runs through:

Car Motors | Radio Signals | Appliances

"IF EDISON HAD A NEEDLE TO FIND IN A HAYSTACK, HE WOULD PROCEED AT ONCE... UNTIL HE FOUND THE OBJECT OF HIS SEARCH. I WAS A SORRY WITNESS OF SUCH DOINGS, KNOWING THAT A LITTLE THEORY AND CALCULATION WOULD HAVE SAVED HIM 90 PERCENT OF HIS LABOR."

- NIKOLA TESLA

LATE BLOOMER

Thomas Edison, the youngest in his family, didn't learn to talk until he was almost 4 years old.

1847	BORN	1858
Milan, Ohio	BIRTHPLACE	Smiljan, Croatia
Wizard of Menlo Park	NICKNAME	Wizard of the West
Home-schooled and self-taught	EDUCATION	Studied math, physics, and mechanics at The Polytechnic Institute at Gratz
"Genius is one percent inspiration and ninety nine percent perspiration." -Thomas Edison	FORTE	Mass communication and business; Electromagnetism and electromechanical engineering
	METHOD	Trial and error; Getting inspired and seeing the invention in his mind in detail before fully constructing it
DC (Direct Current)	WAR OF CURRENTS: ELECTRICAL TRANSMISSION IDEA	AC (Alternating Current)
Incandescent light bulb; phonograph; cement making technology; motion picture camera; DC motors and electric power	NOTABLE INVENTIONS	Tesla coil - resonant transformer circuit; radio transmitter; fluorescent light; AC motors and electric power generation system
1,093	NUMBER OF US PATENTS	112
0	NUMBER OF NOBEL PRIZES WON	0
1	NUMBER OF ELEPHANTS ELECTROCUTED	0
1931—Passed away peacefully in his New Jersey home, surrounded by friends and family	DEATH	1943—Died lonely and in debt in Room 3327 at the New Yorker Hotel

WAR OF CURRENTS OFFICIALLY SETTLED

In 2007, Con Edison ended 125 years of direct current electricity service that began when Thomas Edison opened his power station in 1882. It changed to only provide alternating current.

FALLING OUT

Edison promised Tesla a generous reward if he could smooth out his direct current system. The young engineer took on the assignment and ended up saving Edison more than $100,000 (millions of dollars by today's standards). When Tesla asked for his rightful compensation, Edison declined to pay him. Tesla resigned shortly after, and the elder inventor spent the rest of his life campaigning to discredit his counterpart.

EDISON FRIES AN ELEPHANT

In order to prove the dangers of Tesla's alternating current, Thomas Edison staged a highly publicized electrocution of the three-ton elephant known as "Topsy." She died instantly after being shocked with a 6,600-volt AC charge.

NOBEL PRIZE CONTROVERSY

In 1915, both Edison and Tesla were to receive Nobel Prizes for their strides in physics, but ultimately, neither won. It is rumored to have been caused by their animosity towards each other and refusal to share the coveted award.

SOURCES: CHENEY, MARGARET. "TESLA: MAN OUT OF TIME" | UTH, ROBERT. "TESLA: MASTER OF LIGHTNING." | THOMASEDISON.COM | PBS.ORG | WEB.MIT.EDU | WIRED.COM

A COLLABORATION BETWEEN GOOD AND COLUMN FIVE

Financing Electrification


No. CS 13289

—18— OF ONE SHARE
200THS

SCRIP CERTIFICATE FOR A FRACTION OF ONE SHARE OF COMMON STOCK OF

INSULL UTILITY INVESTMENTS, INC.

AN ILLINOIS CORPORATION

THIS CERTIFIES that the BEARER of this scrip certificate

—EIGHTEEN—

INSULL UTILITY INVESTMENTS, INC.

INSULL UTILITY INVESTMENTS, INC.

Dated JUL 15 1930

By Samuel Insull Jr. PRESIDENT

Samuel Insull used the Holding Company structure to leverage assets and build an empire in the US Midwest

American Gas & Electric

PRESENT THIS BILL WHEN MAKING SETTLEMENT. WE DO NOT MAKE DUPLICATE BILLS.

OFFICE HOURS, 8:30 A. M. TO 5:00 P. M.
BOTH TELEPHONES
Canton, Ohio 1906
M Fred Oiler
FOLIO 59-12 308 ... Ave
To THE CANTON LIGHT, HEAT & POWER CO., Dr.

Balance due as per bills rendered
For electricity consumed from ... to
Arc Lights, from ... to ... @
Kilo Watt Hours consumed 28 @ 11 c per K. W. Hour 3.08
Power @ c
If paid on or before the 10th inst. we will allow a discount of $ .61 2.47
Present index of meter 5080
Received payment for the Company
Presented Paid 12-10-06

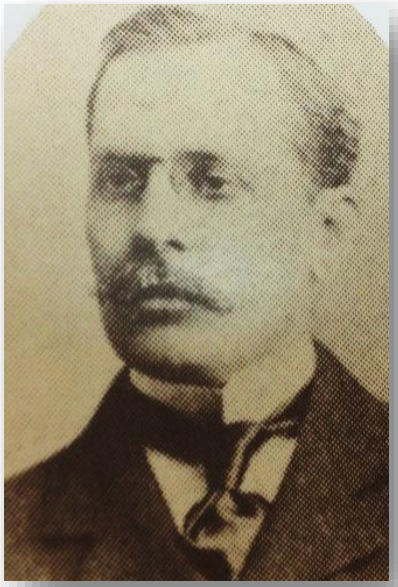
ALL BILLS MUST BE PAID AT THE OFFICE, 320 NORTH MARKET STREET.

Typical line crew in South Bend, Indiana, 1910.

- ***Sept 13, 1882*** – Wheeling, West Virginia became the first city in what is now the AEP System to enjoy electric lights.
- ***1911*** – The company had a power plant in Muncie and another in Marion. It seemed natural to George Tidd, AG&E's general manager at the time, that reliability could be improved by having each plant support the other. Many experts thought that would never work. Tidd built the 33,000-volt line across 30 miles of Hoosier farmland, and the interconnected power system was under way.

The Cactus Patch

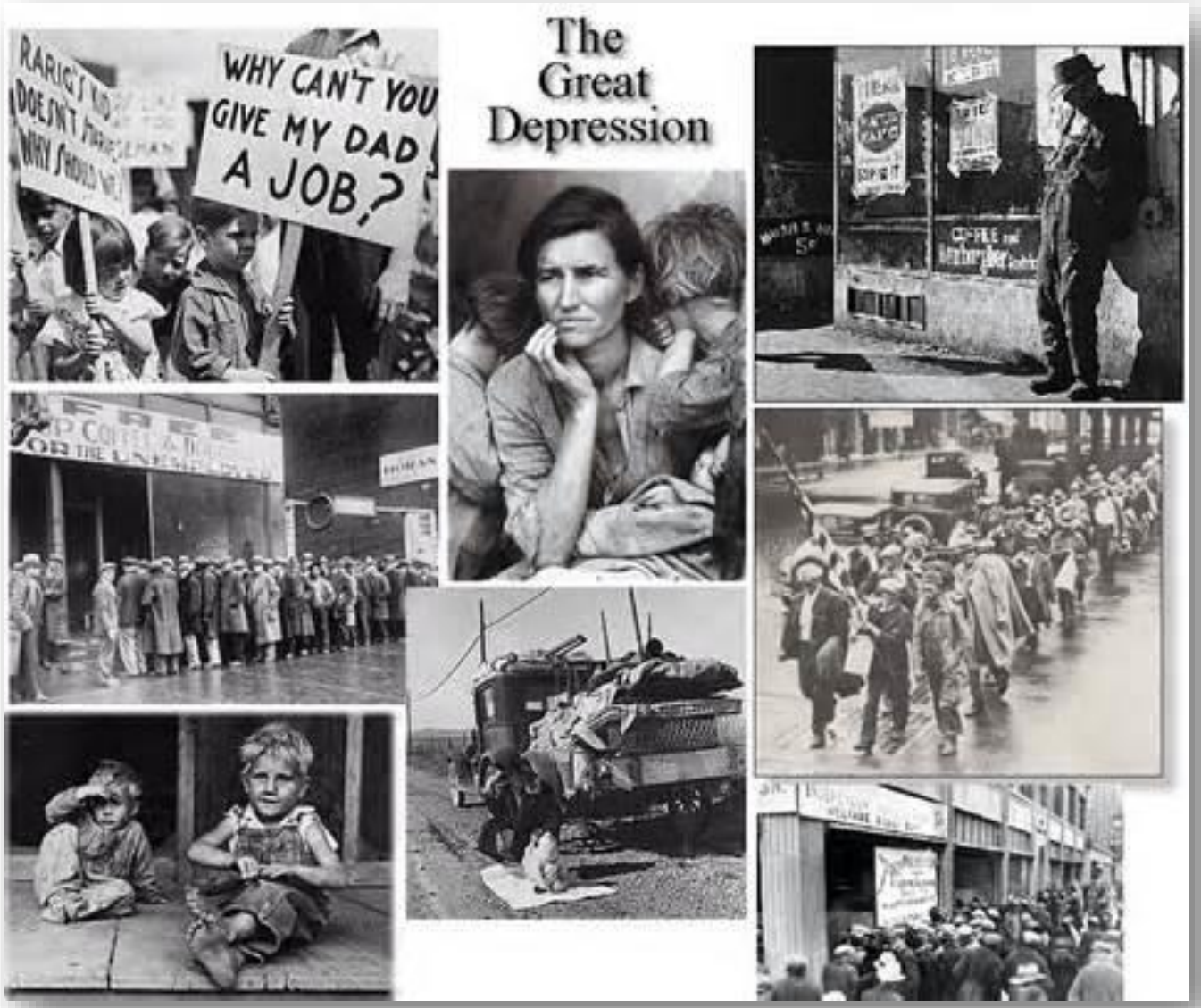
- ***1912*** **– Samuel Insull, president of Commonwealth Edison in Chicago and a former secretary to Thomas Edison, created Middle West Utilities Company.**
- ***1925*** **– Insull created Central and South West Corporation as a subsidiary of Middle West Utilities. Nicknamed the "Cactus Patch," Central and South West had 5 operating company subsidiaries:**
  - American Public Service
  - Public Service Company of Oklahoma
  - Chickasha Gas and Electric
  - Central Power and Light
  - Southwestern Gas and Electric



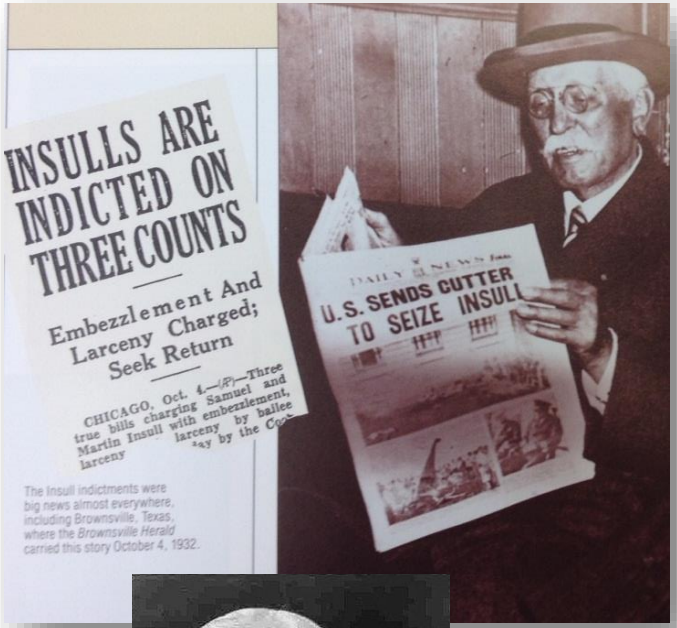
Delivering Value to Customers

- **Unlike the northern and eastern United States, where streetcars were apt to be the first major application of electric power, ice was the ticket to success in the sizzling Southwest.**
  - CSW produced nearly a half million tons of ice, and nearly 25 percent of the company's gross revenues came from the sale of ice.

1929 Stock Market Crash



Public Utility Holding Company Act of 1935



- ***1935*** **– Congress enacted the Public Utility Holding Company Act of 1935, following a seven-year inquiry by the Federal Trade Commission into the practices of the electric utility industry.**

Progress in Power

Although fragmented by federal legislation, the electric utility industry had major technological advancements. Among AEP "Firsts" were:

- **1917 First major mine-mouth power plant, Windsor Plant in West Virginia, and long-distance transmission to load center**
- **1929 First use of automatic frequency and tie-line load control**
- **1935 First ultra-high-speed (one cycle or 1/60th of a second), high-voltage reclosing circuit breaker (138,000 volts)**
- **1948 First aerial inspection of transmission line**
- **1951 First electronic line relay**
- **1953 First EHV transmission line (energized at 330,000 volts), between Sporn and Kanawha River stations in West Virginia**
- **1953 First hot-line maintenance of EHV line**
- **1958 First 345,000-volt interconnection, AEP System and Commonwealth Edison**
- **1960 First large-scale use of helicopters in transmission line construction**
- **1961 First bare-hand maintenance of EHV line**
- **1966 First use of laser beam to monitor transmission line**

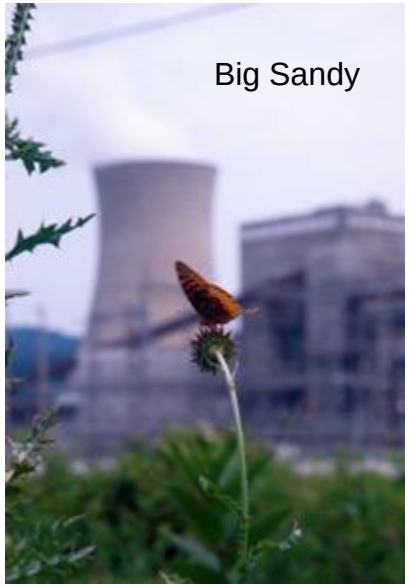
First 765kV Transmission Line

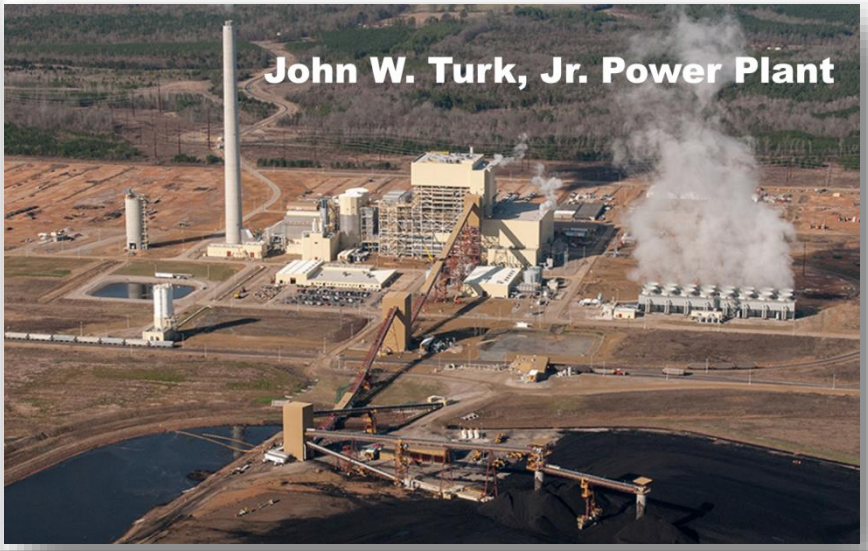
1969 **– AEP completed the world's first 765,000-volt transmission line, a 68-mile line from the Baker Substation adjacent to Kentucky Power's Big Sandy Plant to Ohio Power's Don Marquis Substation near Piketon, Ohio.**

It was the first leg in what today is a network of 765-kV lines extending for more than 2,000 miles. The highest-voltage line in operation until that point was a 735,000-volt line in Canada. One 765,000-volt line can carry as much power as five 345,000-volt lines or as many as thirty 138,000-volt lines.

AEP Generation

AEP completed its first 800,000-kilowatt generating unit at Kentucky Power's Big Sandy Plant. It would be the first in a series of five such units installed on the AEP System in the period from 1969 to 1972.

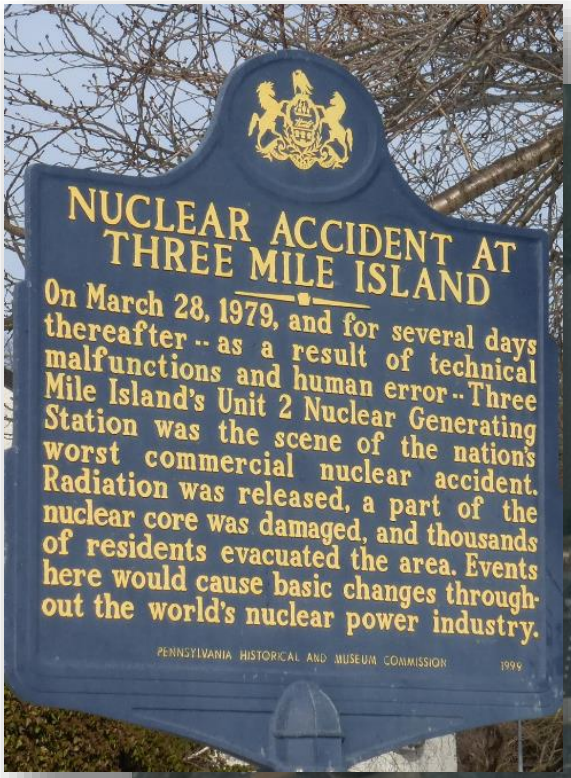




Turk, a 600MW unit located in Fulton AR, began commercial operation in 2012. It was the first U.S. ultra-supercritical generating unit, generating electricity more efficiently at higher temperature. This requires less coal and produces fewer emissions.

Industry Restructuring

Three Mile Island & Its Impacts



CSW & AEP Nuclear Involvement

The South Texas Project
(later sold during transition to deregulation)

Cook Nuclear Plant

Retail Competition in ERCOT

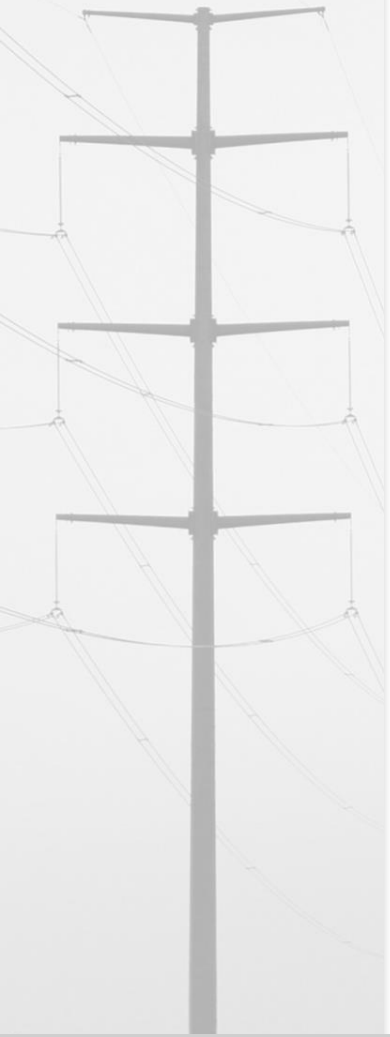
2002 – Integrated utilities like Central Power and Light and West Texas Utilities into power generation, energy delivery and retail companies.

With passage of the electricity restructuring legislation in 1999, the retail market was deregulated in 2001.

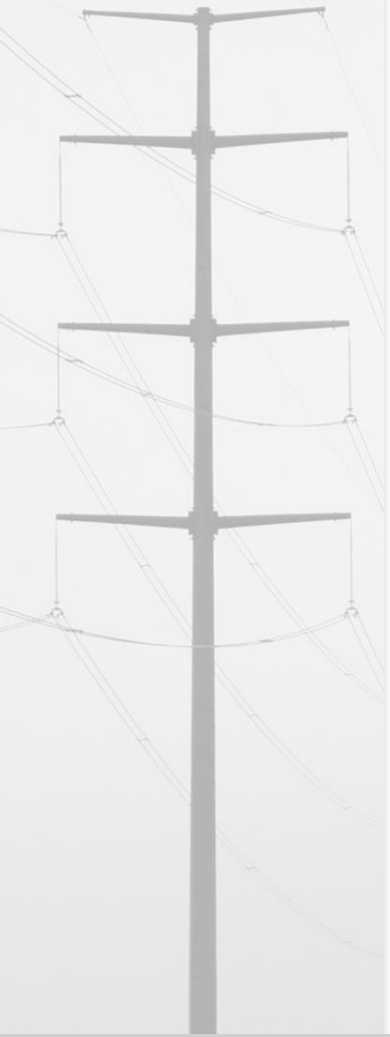
Pre-Retail Competition Electric Service Providers:

CPL | WTU

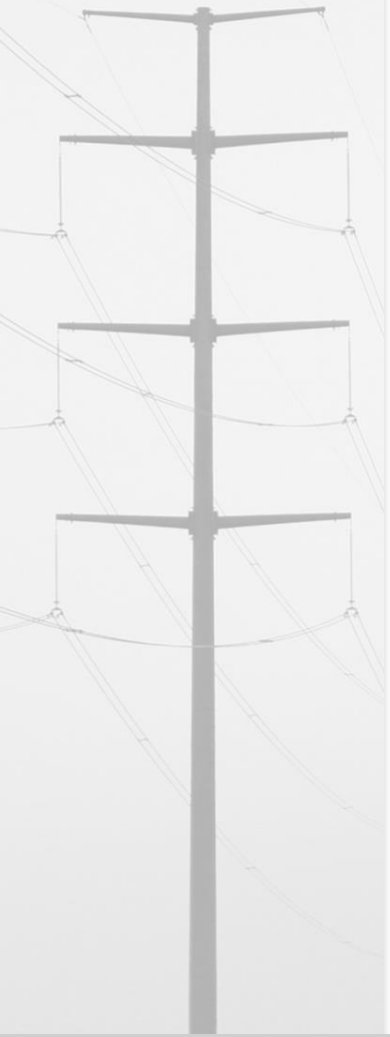
Retail Electric Providers (REPs) in this area today:



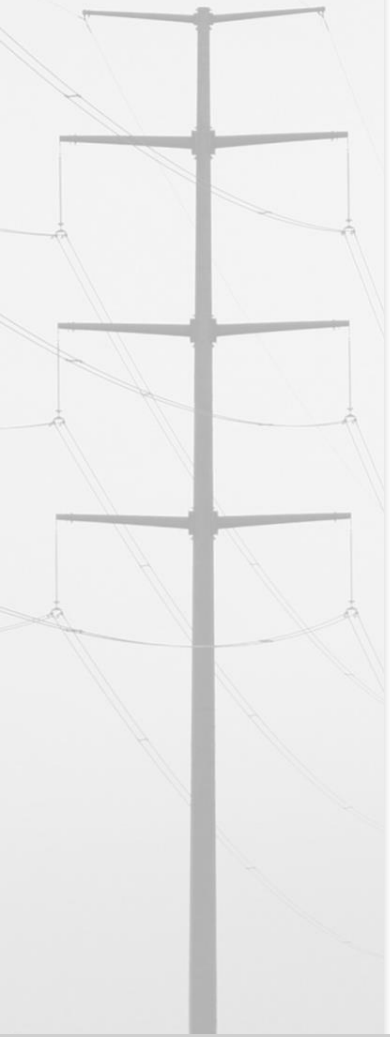
Retail Electric Providers - Option I	
10041	4CHANGE *
10041	4CHANGE ENERGY *
10041	4CHANGE ENERGY COMPANY
10129	ACCEL ENERGY *
10078	ACCENT ENERGY *
10078	ACCENT ENERGY TEXAS LP
10014	AES NEWENERGY *
10074	ALLIANCE POWER COMPANY LLC
10179	ALLTEX POWER & LIGHT *
10117	AMBIT *
10117	AMBIT ENERGY *
10117	AMBIT TEXAS LLC
10147	AMERICAN L&P CO
10147	AMERICAN LIGHT & POWER *
10147	AMERICAN LP *
10224	AMERICAN POWERNET MANAGEMENT LP
10147	AMERICAN XP *
10076	AMERIPOWER LLC
10081	AMIGO ENERGY *
10049	ANDELER CORPORATION
10049	ANDELER POWER *
10049	ANDELER RETAIL *
10105	AP COMMERCIAL *
10105	AP GAS & ELECTRIC (TX) LLC
10074	APC ELECTRIC *
10105	APG&E *
10105	APG&E ENERGY SOLUTIONS *
10211	APOLLO POWER & LIGHT LLC *
10004	ASSURANCE ENERGY *
10227	AXON POWER & GAS LLC
10206	BEYOND POWER *
10222	BOSE POWER & ELECTRIC *
10222	BOSE POWER & ELECTRIC CLEARING HOUSE *
10162	BOUNCE ENERGY INC
10038	BP ENERGY COMPANY
10211	BREEZE ENERGY LLC *
10211	BREEZE LLC
10211	BREEZE POWER LLC *
10129	BRIGHTSTAR POWER *
10140	BRILLIANT ENERGY LLC
10137	BROOKLET ENERGY DISTRIBUTION LLC
10098	CHAMPION ENERGY INDUSTRIAL SERVICES *
10098	CHAMPION ENERGY INDUSTRIAL SERVICES I *
10098	CHAMPION ENERGY INDUSTRIAL SERVICES II *
10098	CHAMPION ENERGY INDUSTRIAL SERVICES III *
10098	CHAMPION ENERGY SERVICES LLC
10034	CIRRO ENERGY *
10034	CIRRO GROUP *
10034	CIRRO GROUP INC
10129	CLEARVIEW ELECTRIC INC
10129	CLEARVIEW ENERGY *
10177	COMPASSION ENERGY *
10112	CON ED SOLUTIONS *
10112	CON ED SOLUTIONS 1 *
10112	CON ED SOLUTIONS 2 *



10112	CON EDISON SOLUTIONS *
10037	CONOCOPHILLIPS COMPANY
10179	CONSERVICE ENERGY *
10112	CONSOLIDATED EDISON SOLUTIONS INC
10014	CONSTELLATION NEWENERGY INC
10025	CORAL POWER LLC *
10025	CORAL POWER SOLUTIONS *
10174	COST PLUS ENERGY *
10023	CPL *
10011	CPL BUSINESS *
10023	CPL RETAIL ENERGY *
10023	CPL RETAIL ENERGY LP
10040	DIRECT ENERGY *
10011	DIRECT ENERGY BUSINESS LLC
10040	DIRECT ENERGY BUSINESS SERVICES *
10040	DIRECT ENERGY LP
10040	DIRECT ENERGY MULTI-FAMILY *
10161	DISCOUNT POWER *
10078	DYNOWATT *
10078	DYNOWATT POWERED BY ACCENT ENERGY *
10064	EAGLE ENERGY *
10153	EDF ENERGY SERVICES LLC
10201	ENCOA *
10220	ENERGY ME *
10220	ENERGY ME MIDWEST LLC
10172	ENERGY PLUS HOLDINGS LLC
10221	ENERTRADE ELECTRIC LLC
10197	ENTRUST ENERGY INC
10205	EPIQ ENERGY *
10178	EVERYTHING ENERGY *
10178	EVERYTHING ENERGY LLC
10011	EXPERT ENERGY *
10008	FIRST CHOICE POWER *
10008	FIRST CHOICE POWER POLR *
10008	FIRST CHOICE POWER SPECIAL PURPOSE LP
10169	FRONTIER UTILITIES *
10169	FRONTIER UTILITIES LLC
10081	FULCRUM RETAIL ENERGY LLC
10214	GALT POWER TEXAS LLC
10053	GDF SUEZ ENERGY RESOURCES NA INC
10204	GDF SUEZ RETAIL ENERGY SOLUTIONS LLC
10147	GENERAL LIGHT & POWER INC *
10147	GENERAL POWER & LIGHT *
10027	GEXA CORP *
10027	GEXA ENERGY *
10027	GEXA ENERGY CORP *
10027	GEXA ENERGY LP
10027	GEXA ENERGY.COM *
10123	GLACIAL ENERGY OF TEXAS INC
10130	GOAL ENERGY *
10110	GREEN FIELDS ELECTRICITY *
10009	GREEN MOUNTAIN ENERGY COMPANY
10053	GSERNA POLR *
10060	HINO ELECTRIC POWER COMPANY
10092	HUDSON ENERGY SERVICES LLC
10078	IGS ENERGY *
10179	ILUMINAR ENERGY LLC
10178	INDEPENDENCE ENERGY *



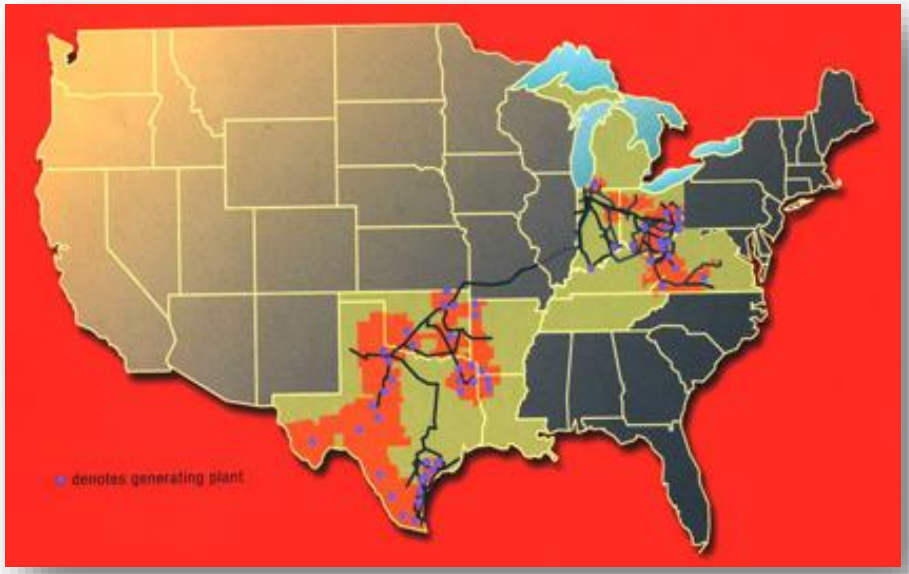
10196	INFINITE ELECTRIC LLC
10196	INFINITE ENERGY *
10223	INFUSE ENERGY LLC
10212	IRON ENERGY LLC
10222	JADE ENERGY LLC
10052	JUST ENERGY *
10052	JUST ENERGY RGV *
10052	JUST ENERGY TEXAS LP
10212	KONA ENERGY *
10132	LIBERTY POWER DELAWARE LLC
10131	LIBERTY POWER HOLDINGS LLC
10118	LPT LLC
10118	LPT SP LLC *
10217	MANSFIELD POWER & GAS LLC
10141	MEGA ENERGY LP
10159	MIDAMERICAN ENERGY COMPANY
10174	MP2 ENERGY TEXAS LLC
10021	MUTUAL ENERGY *
10021	MUTUAL ENERGY SPP *
10021	MUTUAL ENERGY SWEPCO LP
10166X	NEC RETAIL *
10040	NEW LEAF ENERGY *
10014	NEWENERGY *
10122	NEXTERA RETAIL OF TEXAS LP
10017	NOBLE AMERICAS ENERGY SOLUTIONS LLC
10161	NOORUDDIN INVESTMENTS LLC
10207	NORTH AMERICAN POWER AND GAS LLC
10126	NOVA ELECTRIC CO *
10172	NRG ENERGY PLUS *
10166X	NUECES ELECTRIC COOPERATIVE (DISTRIBUTION SERVICE PROVIDER) *
10166X	NUECES ELECTRIC COOPERATIVE RETAIL DIVISION
10077	ONPAC ENERGY *
10218	ORIGEN ENERGY LLC
10170	OUR ENERGY LLC
10110	PAGA MENOS *
10110	PAYLESS POWER *
10077	PEGASUS ALLIANCE CORPORATION
10177	PENNYWISE *
10177	PENNYWISE POWER *
10087	PENSTAR POWER LLC
10087	PENSTAR POWER LLC 1 *
10064	PILOT ENERGY *
10070	PILOT POWER GROUP INC
10219	PIONEER ENERGY *
10219	PIONEER POWER LLC
10211	PLAID ENERGY LLC *
10211	PLAID POWER LLC *
10157	POTENTIA ENERGY LLC
10161	POWER EXPRESS *
10064	POWER HOUSE ENERGY *
10179	PREMIUM POWER & LIGHT *
10216	PRO POWER PROVIDERS LLC
10205	PRONTO POWER *
10007	RELIANT *
10007	RELIANT ENERGY *
10007	RELIANT ENERGY BUSINESS SERVICES *
10007	RELIANT ENERGY RETAIL SERVICES LLC



10169	RODEO ENERGY *
10053	SERNA POLR *
10104	SG&E *
10025	SHELL ENERGY NORTH AMERICA (US) LP (SENA)
10221	SHYNE ENERGY *
10051	SMART PREPAID ELECTRIC *
10089	SMARTPAY POWER *
10169	SOL ENERGY *
10206	SOURCE *
10206	SOURCE POWER & GAS LLC
10206	SOURCE POWER & GAS LLC RES *
10206	SOURCE POWER & GAS LLC RT *
10126	SOUTHWEST POWER & LIGHT *
10046	SPARK ENERGY LLC
10089	STAR ELECTRICITY INC
10089	STARTEX POWER *
10202	STAT ENERGY *
10104	STREAM ENERGY *
10104	STREAM SPE LTD
10205	SUMMER ENERGY LLC
10021	SWEPCO RETAIL ENERGY *
10051	TARA ENERGY *
10051	TARA ENERGY LLC
10081	TARA ENERGY RESOURCES *
10081	TARA POWER *
10201	TERM ENERGY *
10201	TERM POWER & GAS LLC (TERM)
10065	TEXAS RETAIL ENERGY LLC
10126	TEXPO ENERGY *
10126	TEXPO POWER LP
10204	THINK ENERGY *
10064	TRIEAGLE ENERGY LP
10064	TRIEAGLE ENERGY SERVICES *
10130	TRUSMART ENERGY *
10130	TRUSMART ENERGY LLC
10130	TRUVALUE ENERGY *
10004	TXU ENERGY *
10004	TXU ENERGY RETAIL *
10004	TXU ENERGY RETAIL COMPANY LLC
10110	UNO ENERGY *
10052	US ENERGY SAVINGS CORP *
10177	US RETAILERS LLC
10210	V247 POWER CORPORATION
10199	VETERAN ENERGY LLC
10226	VOLT ELECTRICITY PROVIDER LP
10202	WOLVERINE ALTERNATIVE INVESTMENTS LLC
10022	WTU *
10011	WTU BUSINESS *
10022	WTU RETAIL ENERGY *
10022	WTU RETAIL ENERGY LP
10203	XOOM ENERGY TEXAS LLC
10126	YEP *
10110	YOUNG ENERGY LLC
10077	YPAYS MORE *
10105	ZIP ENERGY *
10212	ZONE ENERGY *

CSW and AEP Merger

- ***1997*** **– On December 22, AEP and Central and South West announced an agreement under which AEP would acquire CSW in a stock-for-stock transaction. In their announcement, AEP and CSW said the combined company would have 4.7 million customers, 38,000 megawatts of generating capacity and yearly energy sales of $11 billion.**



Recent Technological Advances

Eagle Pass HVDC Tie

The Eagle Pass High Voltage Direct Current tie links the AEP transmission system with the Mexican transmission system owned and operated by CFE.

The 36-megawatt tie, the first back-to-back HVDC with a black start bypass breaker interconnecting AEP Texas and Mexico transmission grids, allows energy exchange to occur across the existing 138-kilovolt tie-line between Piedras Negras and Eagle Pass.

Laredo Variable Frequency Transformer

ETT owns a 100 megawatt variable frequency transformer (VFT) that allows reliable power transfer between ERCOT and CFE in Mexico. The VFT is a controllable, bidirectional transmission device that allows power transfer between two networks that might not be synchronized.

VFT technology provides an innovative alternative to back-to-back high voltage direct current converters by allowing customers to control power between two asynchronous grids with less risk than with conventional technologies.

Presidio NaS Battery

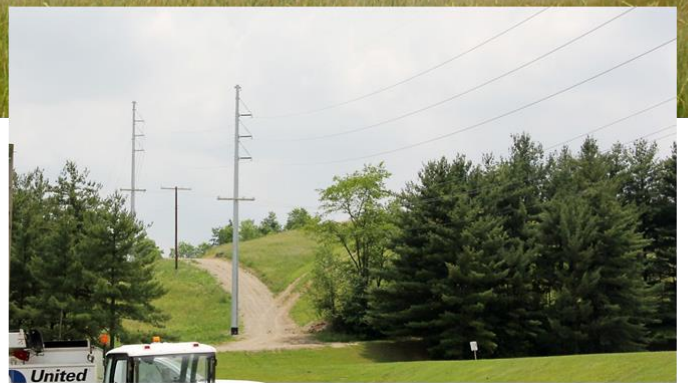
Drop In Control Module

- Standardizes control room configuration
- Reduces installation and construction time
- Provides increased versatility; pre-built to accommodate 138 kV, 345 kV and 765 kV

Skid Station

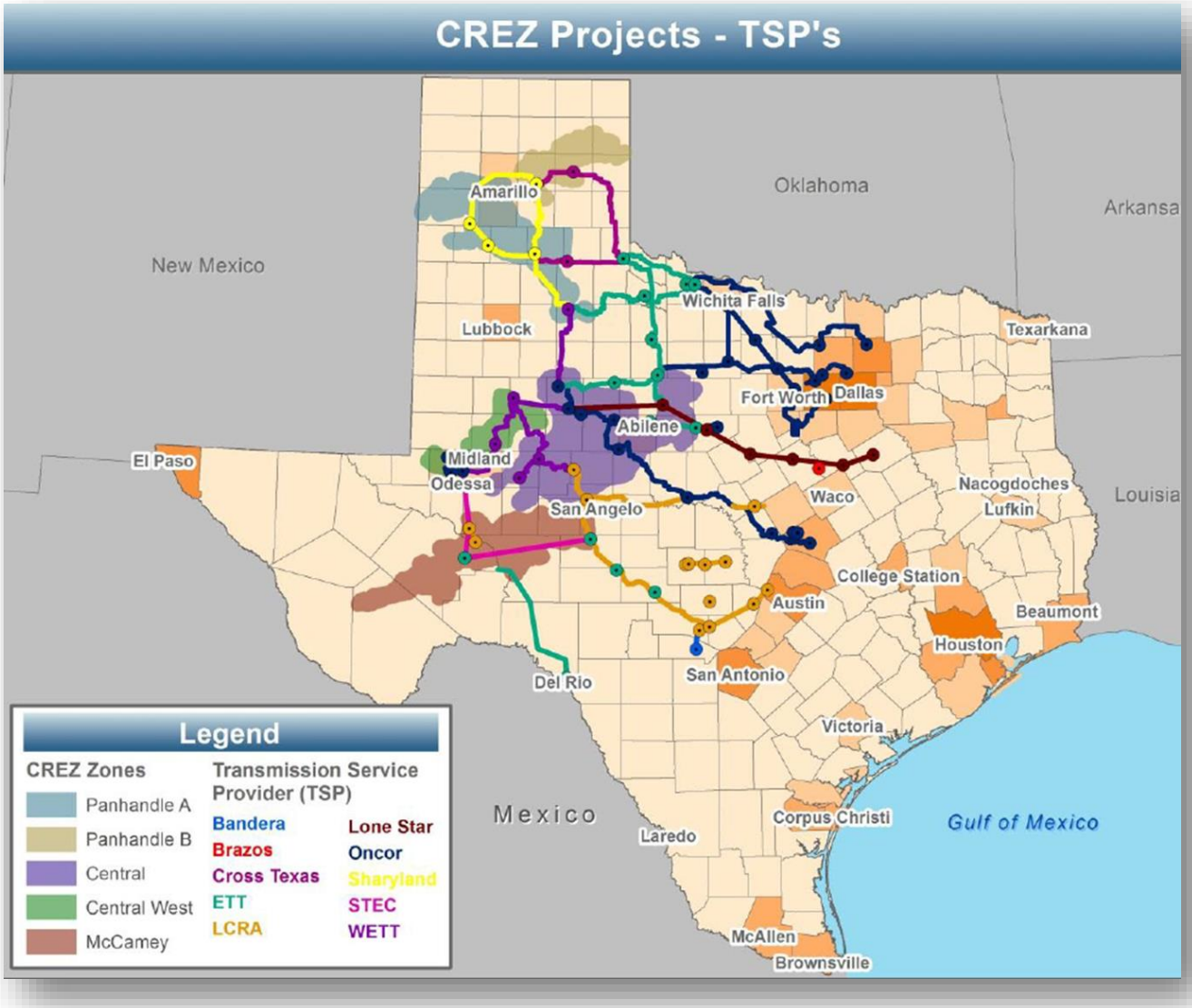
- Reduces construction time to 4-6 weeks
- Portable and readily deployed
- Transferable to other locations as needed

Scio, Ohio
Skid Station Example

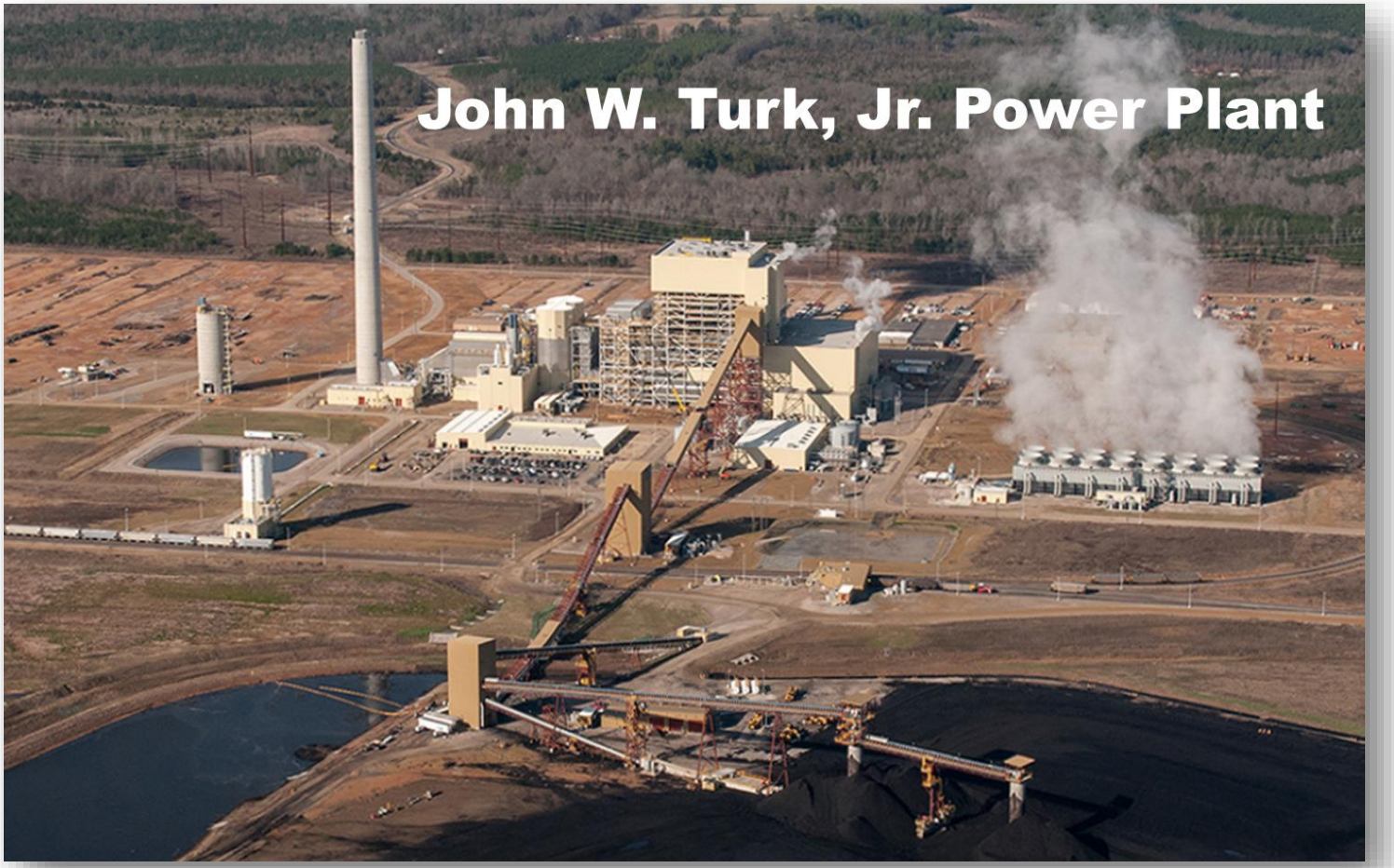


Station in a Box

CREZ Projects Assigned By the PUCT

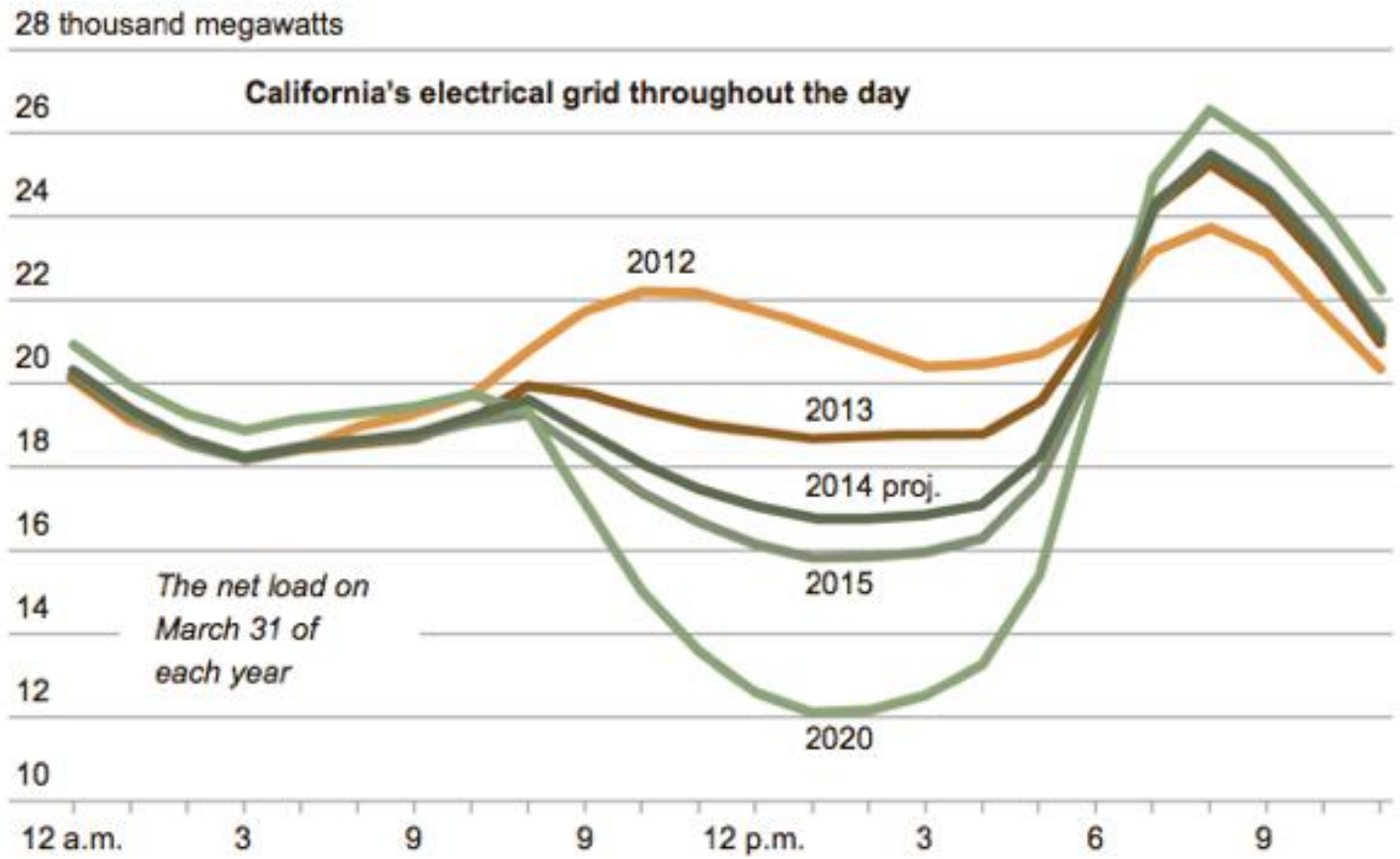


Edison Series Capacitors


John W. Turk, Jr. Power Plant

Future Challenges and Opportunities

Solar Challenge is Growing

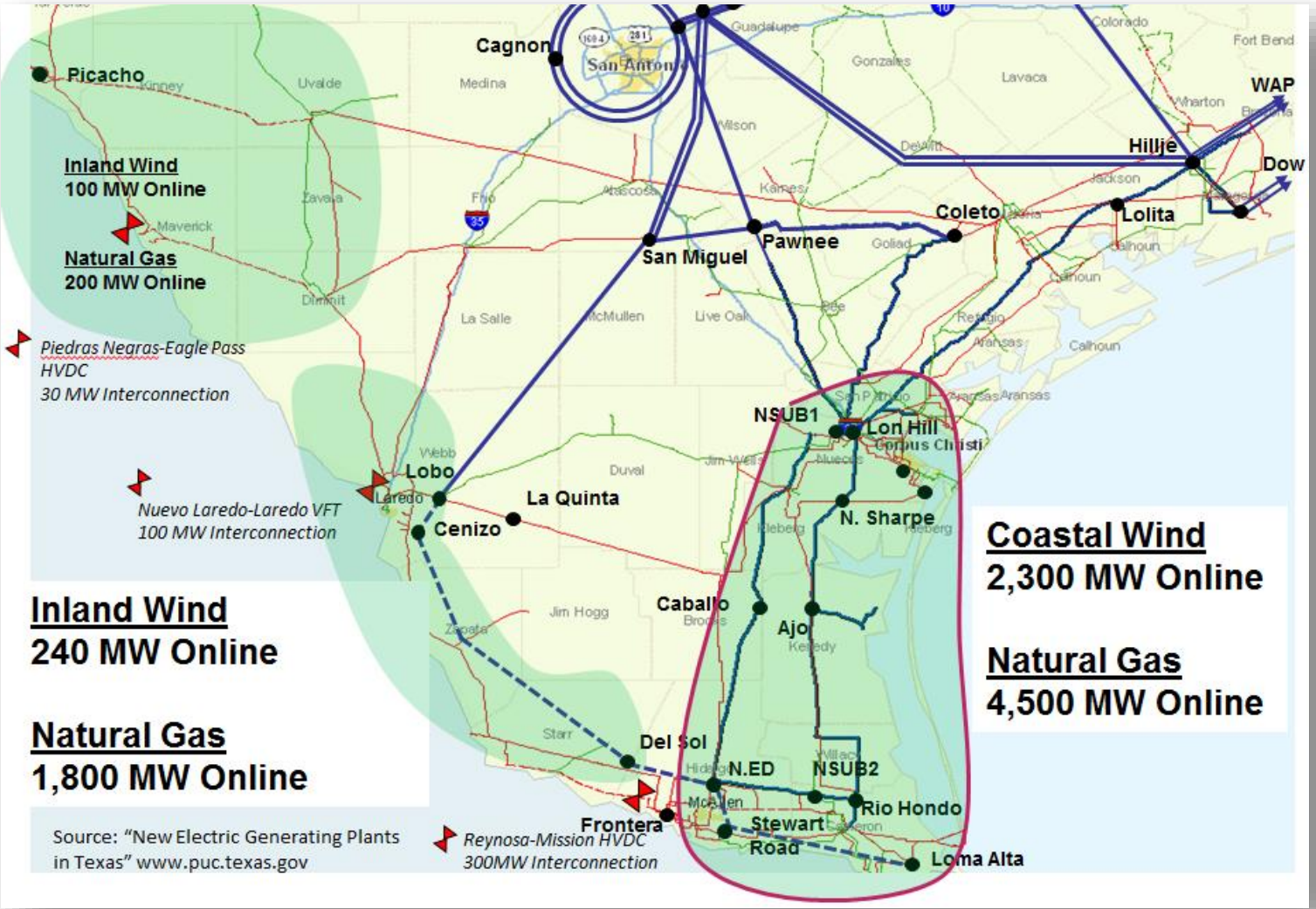


Source: CalISO

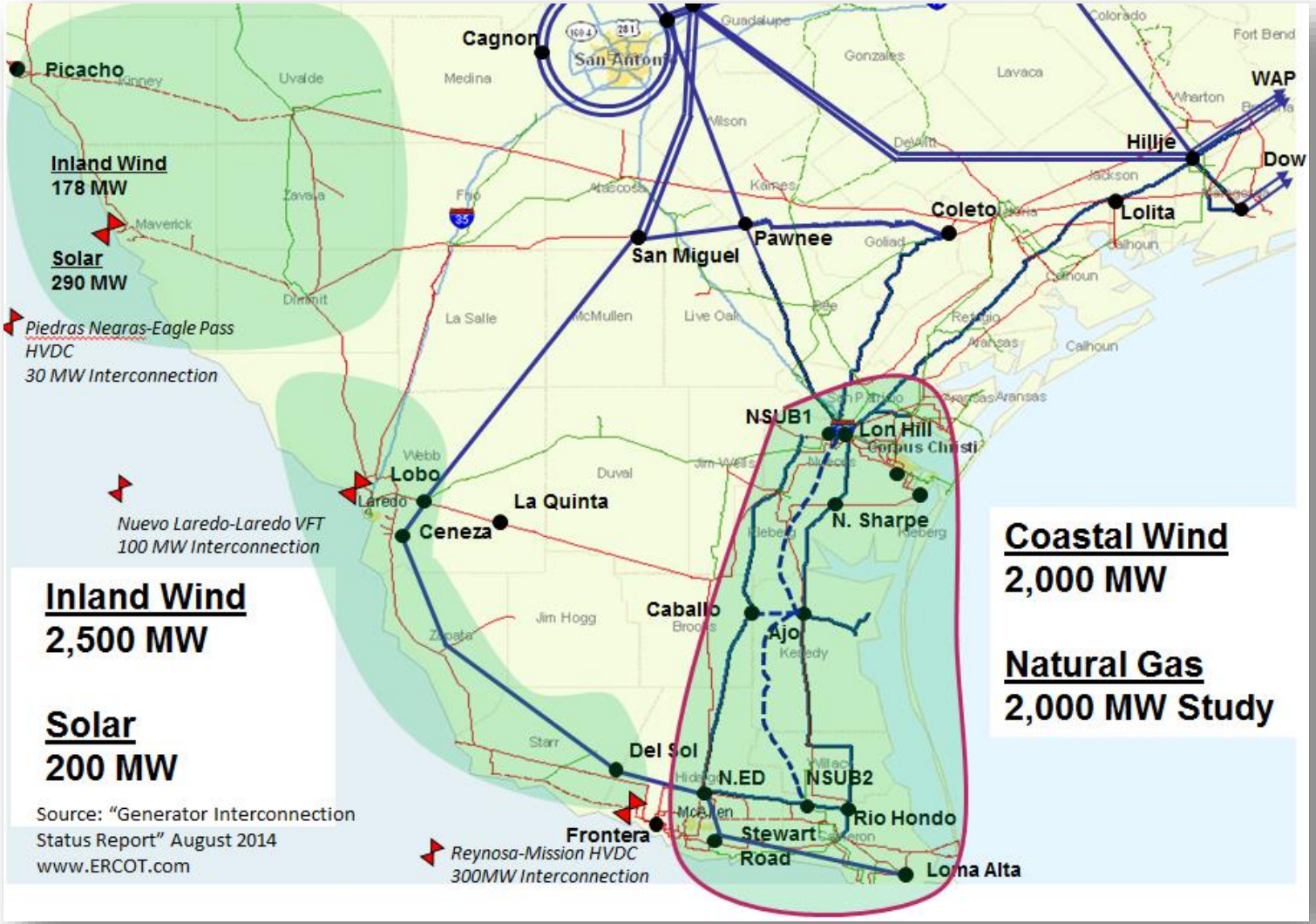
Elon Musk is designing a Tesla battery to power your home

By John McDuling | February 19, 2015

Coastal Wind & Rio Grande Valley
Installed Capacity



Coastal Wind & Rio Grande Valley
Future Capacity Under Construction & Study

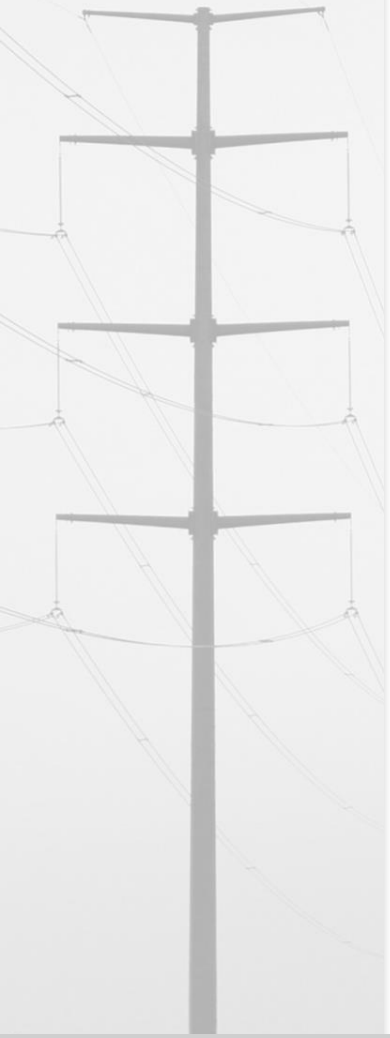


Beauty with Brawn: BOLD

In 2014, construction crews began drilling foundations for a 21-mile double circuit 345/138-kilovolt (kV) transmission line running between Sorenson and Robison stations near Fort Wayne, Indiana (in the existing Fort Wayne-Marion 138-kV corridor). While most of the ground beneath the stations is suitable for conventional construction of 25-foot-deep concrete piers, the high water table and loose gravel soil (call glacial till) just north of Sorenson Station, proved unstable and required an unconventional solution.

The Bold [Breakthrough Overhead Line Design] structures compared to the conventional 345-kV double-circuit design arranged on an eight-armed,150-foot tower, the proposed compact line configuration is suspended from a crescent-shaped cross arm, balanced on a 100-foot tubular steel pole. Its power delivery capacity can exceed a typical 345-kV line up to 60 percent; and potentially surpass the capacity of a 500-kV line. The structures are 50-feet shorter than the conventional eight-armed tower (left). It promises to make greater use of rights-of-way, be more efficient and more acceptable to the public.

Steady as She Goes, Executing on Plan through Rough or Calm Waters



Questions?