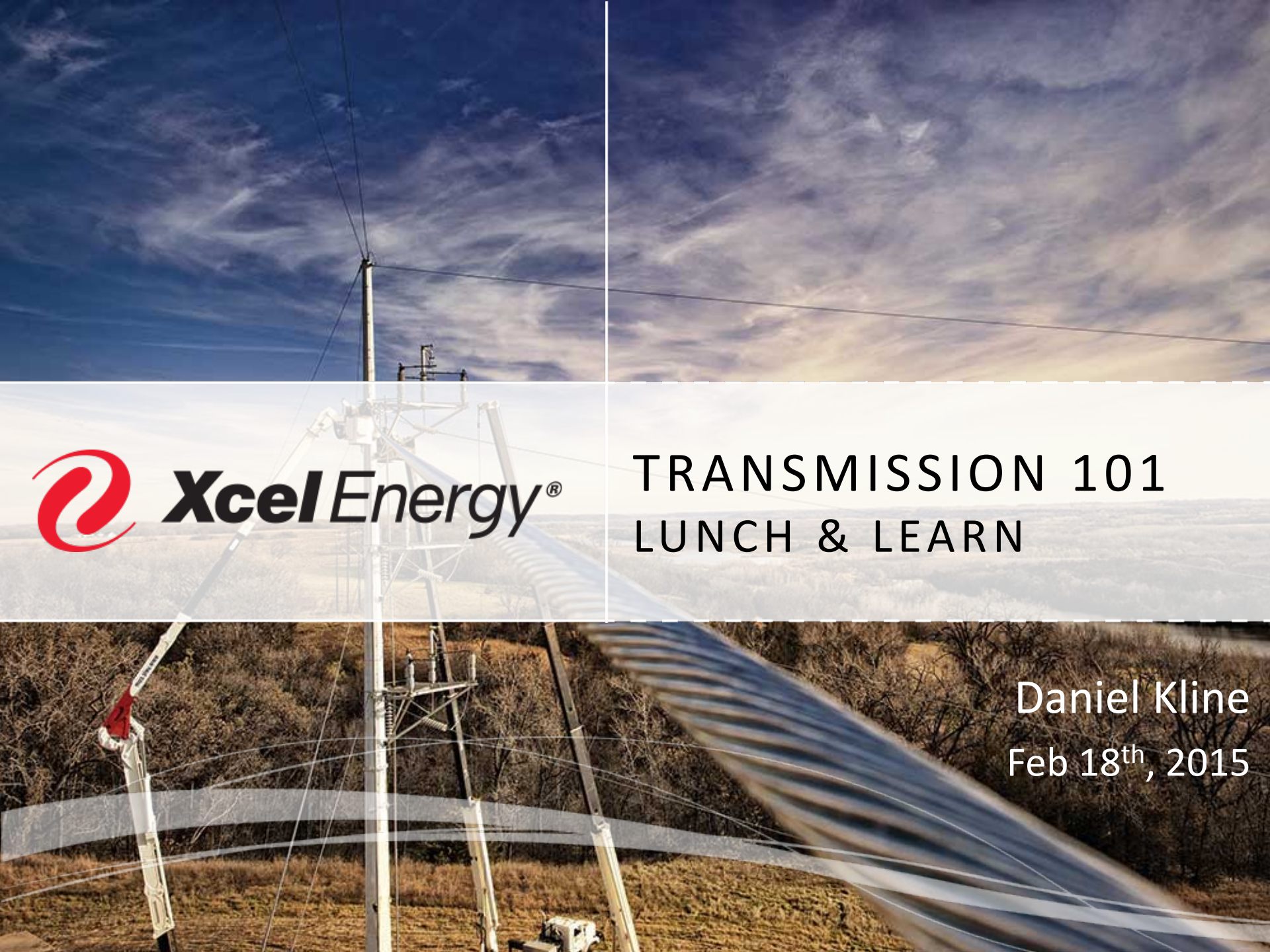


Xcel Energy®

TRANSMISSION 101
LUNCH & LEARN

Daniel Kline

Feb 18th, 2015

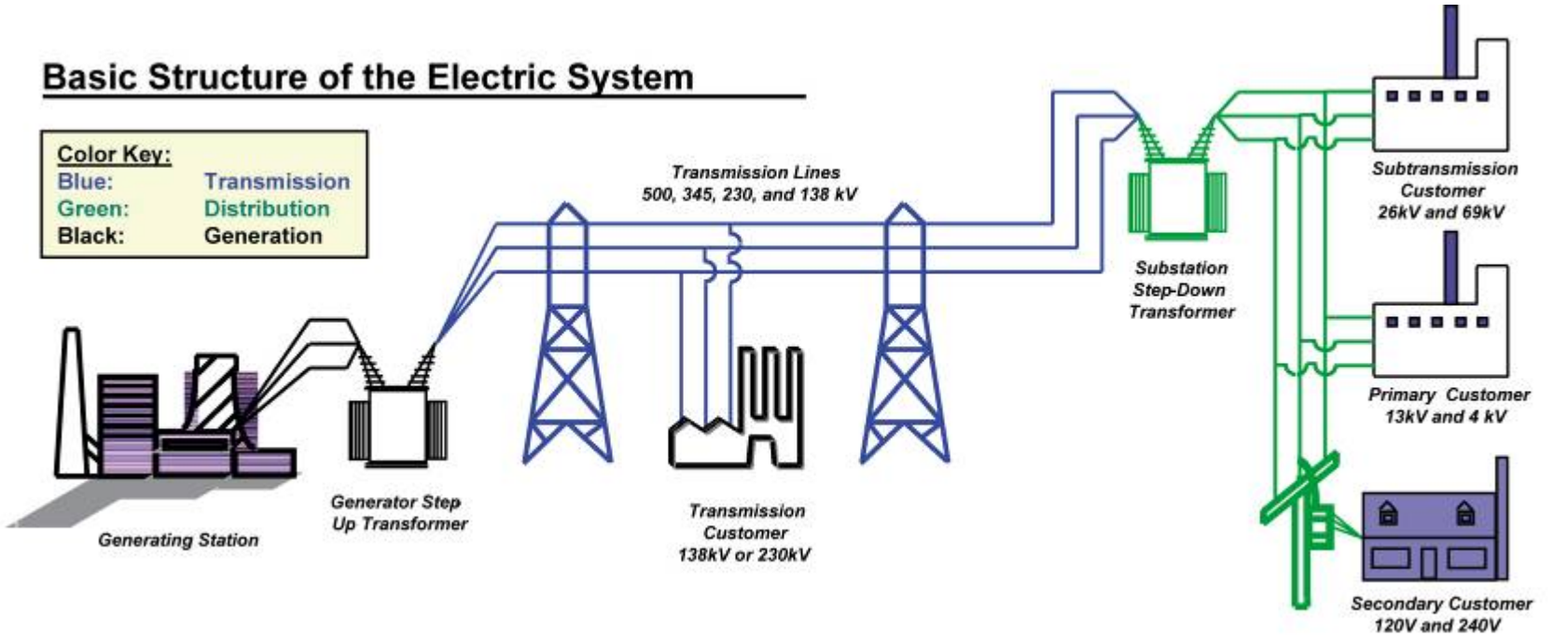
AMERICA'S TRANSMISSION SYSTEM

"Greatest engineering achievement of the 20th century[1]"

[1]National Academy of Engineering

COMPONENTS OF THE ELECTRICAL SYSTEM

COMPONENTS OF THE GRID



Source: www.nerc.com

- The “grid” can be broken down into four main components: Generation, Transmission, Distribution, and Load Customers

COMPONENTS OF THE GRID:
GENERATION


Source: haskellcorp.com, Matanuska reciprocating engines


Source: upwindsolutions.com, Fire Island

Source: adn.com, Bradley Lake Hydro


Source: adn.com, Healy Coal Plant

- Creates electric energy
- Fueled by various sources of energy (fossil fuels, wind, hydro, etc.)

COMPONENTS OF THE GRID:
TRANSMISSION

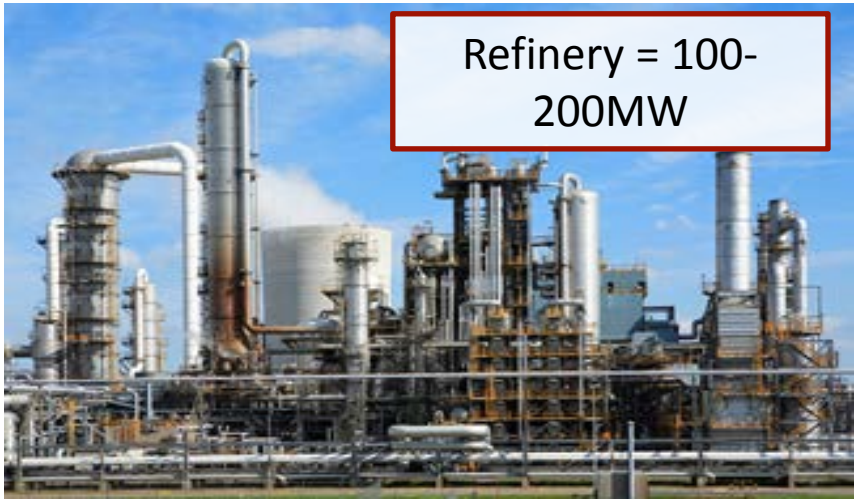
Source: TD World, Quartz Creek

- Higher voltage wires are used to move power relatively long distances from generators to load with lower losses
- Networked (looped) transmission systems are used to enhance reliability by linking many different generators and loads
- Transmission allows the dispatch of generation over a wider geographic area for both economic and reliability purposes

COMPONENTS OF THE GRID:
DISTRIBUTION

- Primary purpose is to serve loads (customers) -*your house is connected to a distribution system*
- Generally radial (non-networked) in nature
- Not used for interstate commerce or long distance power delivery

COMPONENTS OF THE GRID:
LOAD



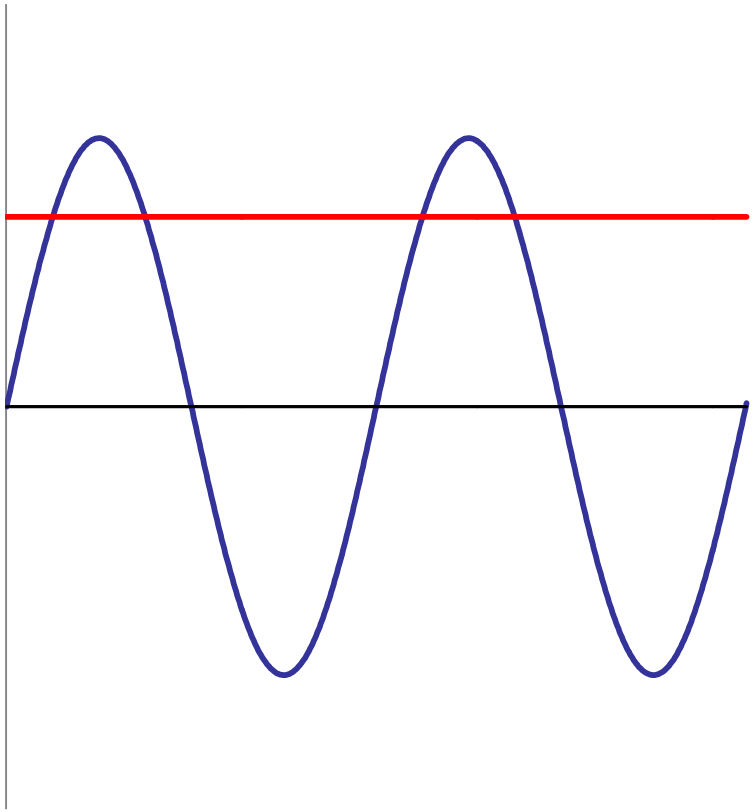
TECHNICAL OVERVIEW

TECHNICAL OVERVIEW
DEFINITIONS

VOLTAGE	▪ Electrical “pressure” is measured in volts ▪ For power systems we typically measure in 1000’s of volts or kilovolts (kV)
CURRENT	▪ Movement of charge (electrons) through a conductor ▪ Measured in Amperes (A)
FREQUENCY	▪ Measured in Hertz (Hz) ▪ North America is 60 Hz, while majority of countries use 50Hz
POWER	▪ Rate at which electricity does work ▪ Measured in watts or more typically kilowatts (kW) or megawatts (MW)
ENERGY	▪ Amount of work that can be done by electricity ▪ Measured in kilowatt-hours (kWh) or megawatt-hours (MWh)

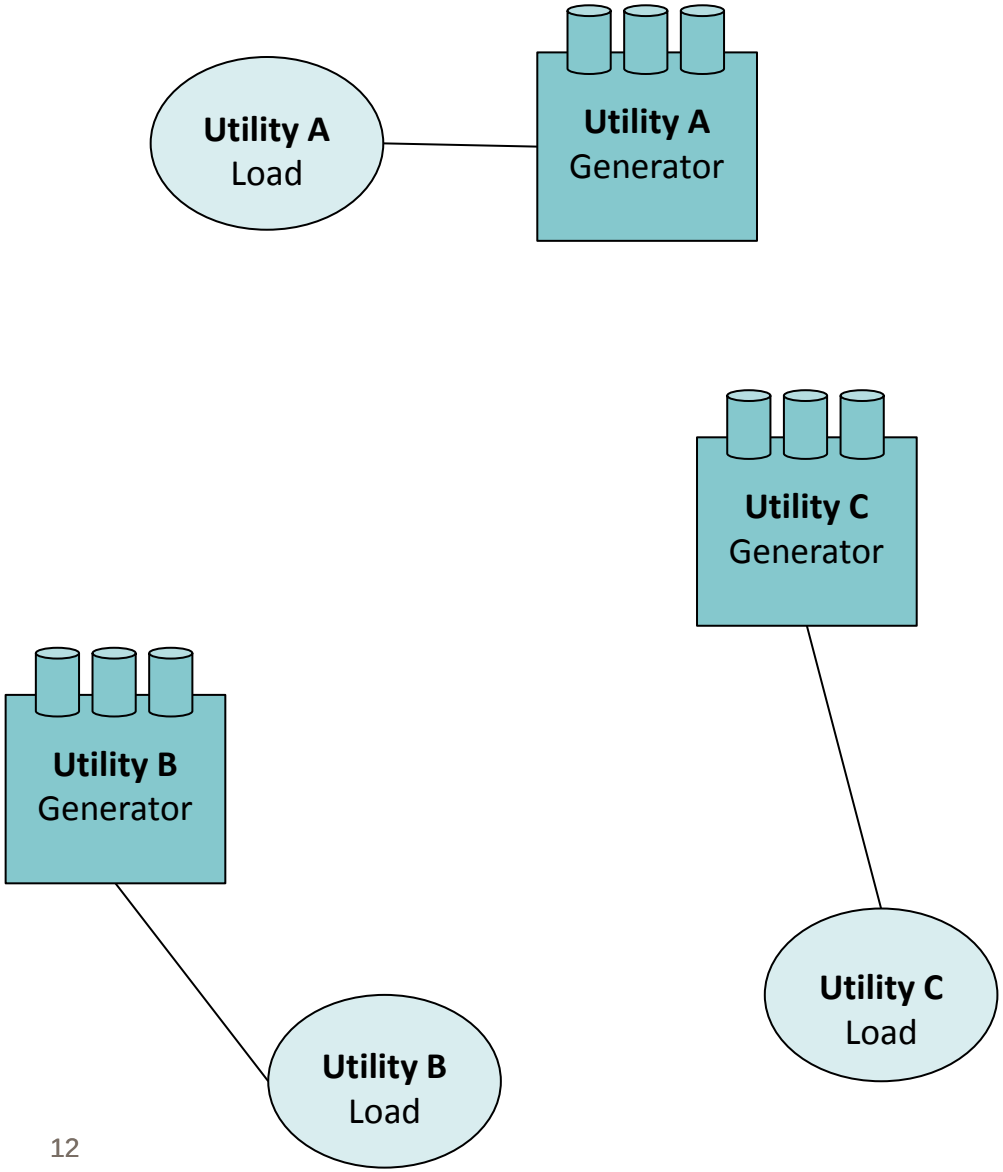
TECHNICAL OVERVIEW
ALTERNATING VS. DIRECT CURRENT

- Alternating Current (AC)
  - Magnitude of current and voltage varies with time
  - Most of grid is AC
- Direct Current (DC)
  - Magnitude of current and voltage is constant
  - Applications of high voltage direct current (HVDC) exists in U.S. and elsewhere



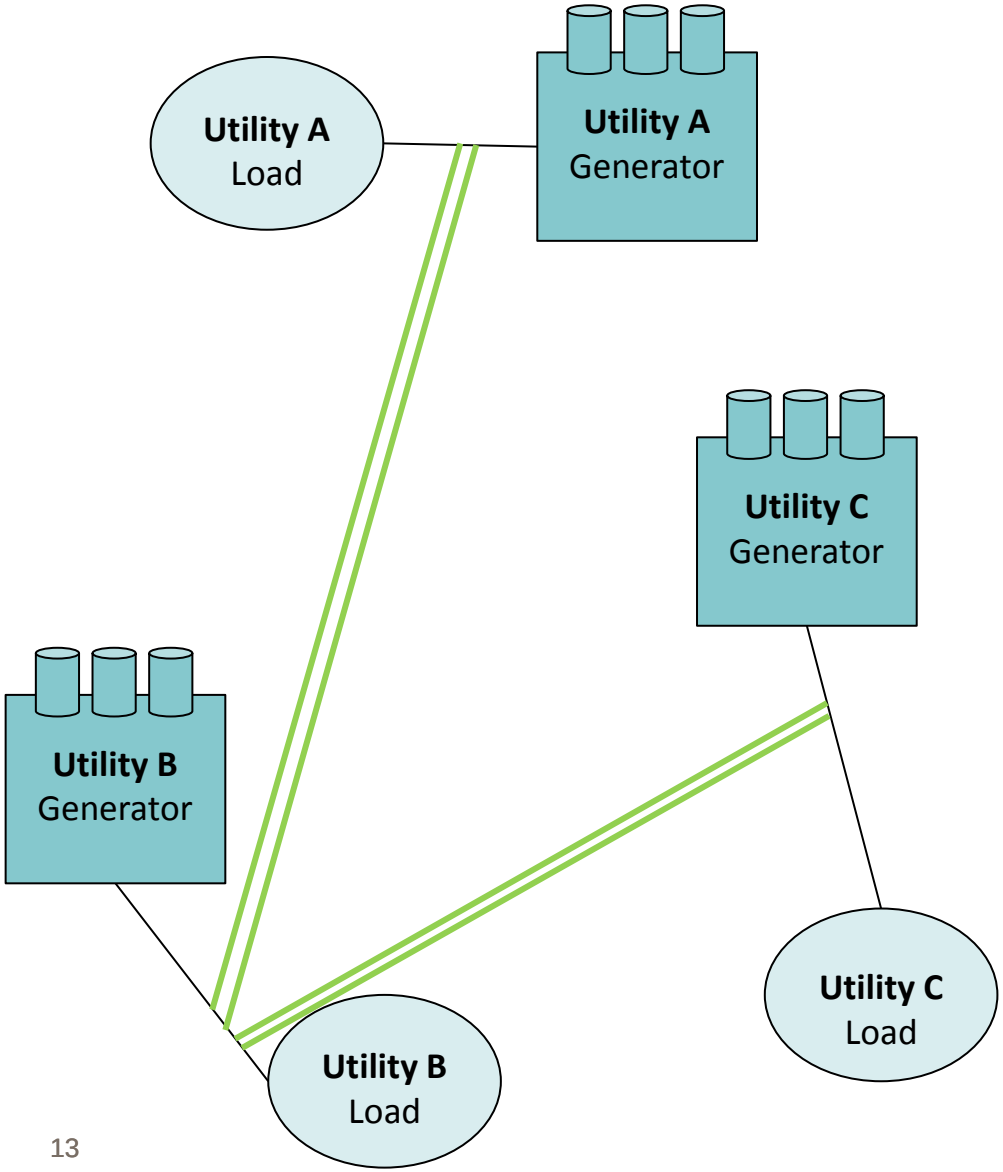
BENEFITS OF A UNIFIED TRANSMISSION SYSTEM

NON-REGIONAL TRANSMISSION
LIMITATIONS TO LOCAL SYSTEMS



- Must build generation near loads
- Limited fuel diversity
- Typically required to install smaller, less efficient generation
- Results in significantly higher costs to rural areas
- Results in over capacity of generation (no economies of scale)

REGIONAL TRANSMISSION
BENEFITS OF A REGIONAL SYSTEM



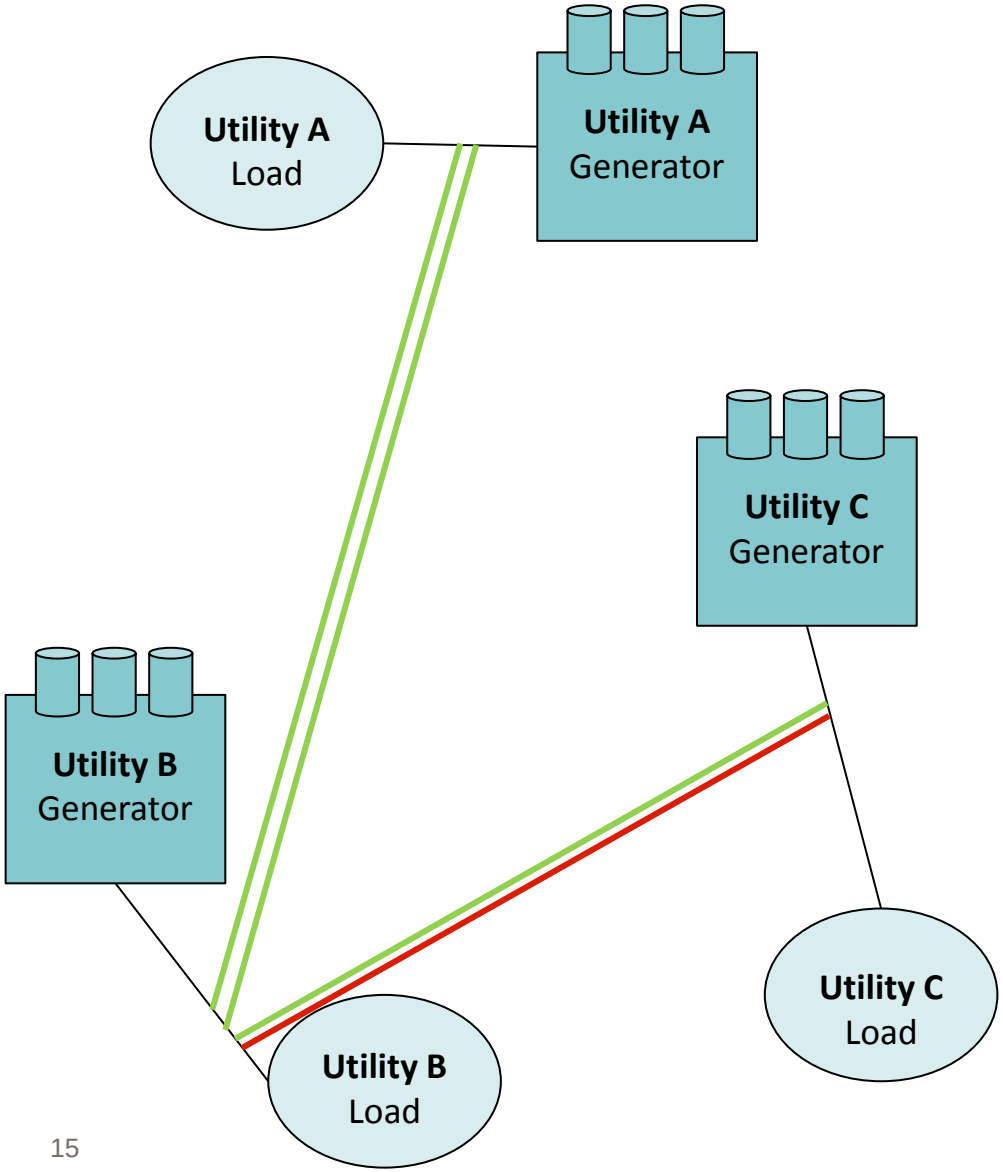
- Generation can be built in areas removed from the loads
- Larger and more efficient generators can be built
- Ability to send power to remote areas with lower losses
- More loads can be served more reliably and economically from the unified grid

AFFORDABLE & RELIABLE ELECTRICITY
DRIVERS OF ECONOMIC GROWTH

Lower electricity prices and reliability drive economic growth…

…which regional transmission and economic dispatch of generation can facilitate.

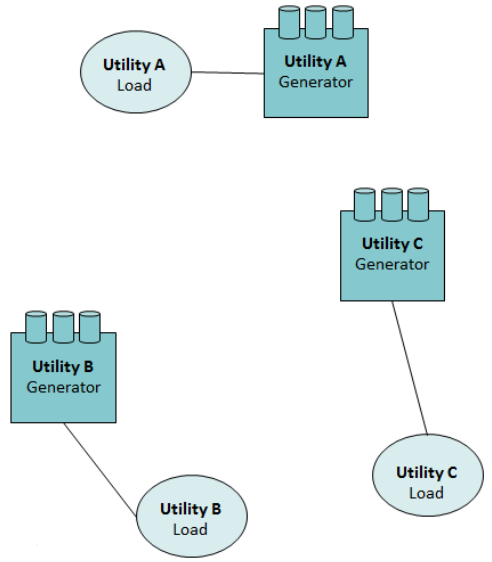
HOW TO IMPROVE RELIABILITY
REGIONAL PLANNING



- Regional planning takes into account the use of transmission to enable each utility to serve the other utilities load, even with the loss of one transmission element (N-1 capable)

TRANSMISSION ENABLES COST SAVINGS
BASIC ECONOMIC DISPATCH EXAMPLE

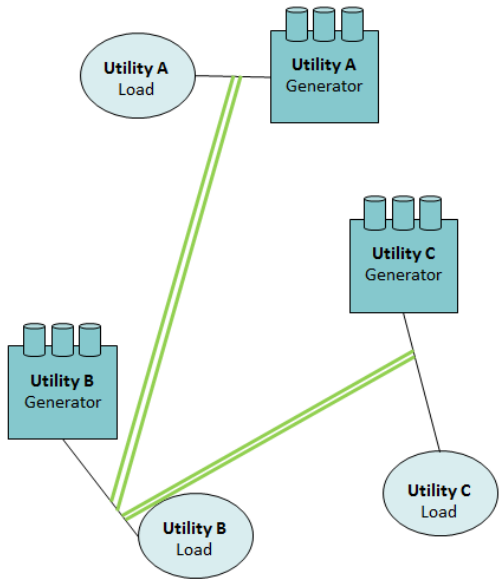
Without Economic Dispatch



	Customer Load	Generation Capacity	Dispatched Generation	$/MW	Total $
Utility A	20 MW	25 MW	20 MW	$90	**$1,800**
Utility B	10 MW	15 MW	10 MW	$70	**$700**
Utility C	10 MW	30 MW	10 MW	$60	**$600**
Total	**40 MW**	**70 MW**	**40 MW**		**$3,100**

Each utility and their customers have access to only their generation

With Economic Dispatch



	Customer Load	Generation MW	Dispatched Generation	$/MW	Total $
Utility A	20 MW	25 MW		$90	**$0**
Utility B	10 MW	15 MW	10 MW	$70	**$700**
Utility C	10 MW	30 MW	30 MW	$60	**$1,800**
Total	**40 MW**	**70 MW**	**40 MW**		**$2,500**

Each utility and their customers have access to the lowest cost generation

THANK YOU

Xcel Energy®

RESPONSIBLE BY NATURE®