Electric Utility 101 Series (3 of 5)

Electric Utility 101: Substations

March 30, 2017
2 – 3:30 p.m. Eastern

Instructor:

Wallace Barron
President
Barron & Associates,
Corporate Solutions, LLC
Atlanta, GA
WallaceBarronLLC@aol.com
Upcoming Webinars on Electric Utility Basics

• Electric Utility 101: Transmission April 13
• Electric Utility 101: Distribution May 11

All webinars take place from 2 – 3:30 p.m., Eastern time

Previous webinars:
• Communicating the Public Power Advantage Feb. 16
• Electric Utility 101: Generation March 9

Past webinars can be purchased from the APPA Product Store or by contacting Matt Konjoian at: Mkonjoian@PublicPower.org; 202/467-2926.
About the Instructor

- Wallace Barron
  - Began in the electric utility industry in 1970
  - Was a Vice President at Florida Power Corp
  - Has done consulting for two decades
  - Has worked with the public power sector for about two decades
  - WallaceBarronLLC@aol.com
The Electric Power System

[Diagram of the Electric Power System showing various components like electric power plant, step-up transformer, major industrial user, transformer, electric train, industrial user, AC/DC converter, distribution substation, underground vault transformer, small industrial user, distribution transformer, street lights and traffic signals, small business user, and residential user.]
Substations in the Power Grid

• In this webinar we will discuss how substations control the flow of electricity and modify the voltage
• The various major types of substations will be covered
• The role of substations in maintaining a reliable energy supply will be explored
Substations and Demand

• Electric utilities are unique, relative to other utilities, such as gas, telephone and water.
• Unlike the other types of utilities, we must generate and supply the energy in real time, exactly when the load demands it.
• We must have facilities such as substations already built and in place to meet the forecasted demand.
Substations

- Many varieties and types of substations
- They are built to supply the system load
- Substations connect major links in the power supply chain
- They can be owned by your company or a variety of power wholesale providers
- They always exist adjacent to large power plants and connect the generator to the transmission grid
Substation Designs

• They are designed to maximize reliability and functionality while minimizing cost

• The location and placement must consider many factors
  - Central to the load serving area
  - Land area with expansion capability and buffer zones
  - Environmental factors such as noise, looks, drainage, etc
Indirect Substation Benefits

• Reduction of greenhouse gas emissions through reduction of system loss and more efficient operations
• Improved customer satisfaction through higher reliability and reduced outages
• More efficient utilization of scarce highly skilled personnel
Substations at Power Plants
The Electric Power System

Generation Substations

• They are the first nodes in the grid and:
  o Connect the generators or power plants to the transmission grid
    ▪ These substations associated with power plants are sometimes called switchyards
    ▪ They also provide a critical off site power source back to the generators for reliability and restart
    ▪ They are step-up substations and are often the only substation on the system with step-up transformers
Generation Substations

- The important switching function performed in these and all substations involve:
  - Disconnecting transmission lines or other components from the energized system for planned maintenance
  - Automatically switching for equipment protection in case of faults
  - System stability and reliability measures.
  - Supervisory control and data acquisition
Step-Up Substations

• Connect a large power plant to the grid.
• They convert the electric power (energy) coming out of the generating plant from low voltage/high current to high voltage/low current to reduce losses in the transmission lines.
• This is loss reduction is discussed in detail in the transmission webinar next month.
Generation to Transmission Substations

• **Utilize Step-up Transformers**
  
  • The primary windings (low voltage side) have less turns than the secondary windings (high voltage side)
  
  • This is the type of transformer used in the substation outside the power plant to convert the voltage coming out of the power plant (typically 12Kv to 30Kv) to transmission voltage levels (115Kv to 800Kv) while maintaining the same power transfer levels
Step-Up Transformer Drawing

• A transformer has
  o Iron core (ferromagnetic)
  o Coils of wire around the core energized by the input voltage and current are called the primary windings
  o Secondary windings are the output side of the transformer

• Power can flow either way so the same transformer can act as a step-up or step-down device

Substation Transformer

Transformers with cooling fans
Power Plants Substations
Hoover Dam
Step-Up Substation Issues

• All substations are expensive to build
• Generation step-up substations must be cleaned periodically due to plant pollution on insulators and equipment
• They are a critical link between the power plant and the rest of the electrical system
  o Unlike the other system components, an outage of the step-up substation will force the power plant off line
The Electric Power System
Transmission Substations

• They are also nodes in the power grid and:
  o Connect the high voltage transmission lines to other high voltage lines or to the lower voltage transmission grid to transfer bulk power across the grid
  o They can contain breakers for isolating transmission lines of the same voltage
  o These are sometimes called system substations
System Substations

• They often enable the large bulk cross country transmission lines to be transformed into lower voltage transmission lines of smaller size which can run along city streets and into the load centers

• They contain devices for monitoring, voltage control, power factor correction, or phase shifting transformers to control power flow between adjacent systems
Transmission Substations

- They are almost always AC substations operating at 60 Hz in the USA
  - With the dramatic development of power electronics in the past decades a special type of substation has evolved
  - These substations convert AC to DC to energize DC transmission lines
  - The power electronic substations also provide flexible AC transmission systems (FACTS)
  - We will discuss these DC lines in more detail in the transmission webinar next month
The Electric Power System
Distribution Substations

• They are also nodes in the power grid and:
  o Connect the transmission grid to the distribution grid
    ▪ These are usually called distribution substations
    ▪ They are where the distribution systems take their wholesale service
    ▪ They are the billing points for the wholesale & retail power purchase exchange
    ▪ They represent an important link in the energy supply chain which reaches from the generator to the customer’s meter
Distribution Substations

• They are sometimes loop fed, meaning that they are fed from two different transmission lines which increases reliability
• Like all substations, they can contain a large variety of equipment including rigid Buss work, switches, breakers, transformers, voltage regulators and SCADA equipment
• Their output typically ranges from 2kV to 35kV
• They can be basic, complex or unique
Dual Feed Distribution Substation
Unique Distribution Substations

A distribution substation in Ontario is disguised as a house, complete with a driveway, front walk and a mown lawn and shrubs in the front yard. A warning notice can be clearly seen on the "front door".

Communities are wanting the substations to not be intrusive and look pretty. The phrase “beatification of substations” is used.
Mobile Substations

Source: Eaton's Cooper Power Systems
Distribution Substation

www.ceg-engineers.com/
Components of a Power System

• In this section we will discuss how step-down substations convert high voltage power to lower voltage power
• We will discuss why step-down substations are needed
• The issues relating to substations will be covered
Step-Down Substations

115 Kv to 12 Kv Transformer

Source: Rickey Peterson 2012
Voltage Step-Down Transformer

- Step down transformer having more windings on the primary (input) side than the secondary (output) side.
- All transformers are bilateral devices meaning that power can flow either way in the device.
Voltage Step-Down Substations

• Step-down in voltage
  o The secondary has fewer turns than the primary and reduces the voltage to a lower level
  o Converts transmission voltage levels to distribution voltage levels (Typically between 12Kv to 14Kv )

• Types of substations
  o Transmission to sub-transmission
  o Sub-transmission to distribution
  o Ones which supply traction systems
Voltage Step-Down Substations

Types of Substations

• Transmission to sub-transmission
  o Connects higher voltage transmission lines (338 Kv to 500 Kv) to lower voltage transmission lines (230 Kv to 115 Kv)

• Sub-transmission to distribution
  o Connects lower voltage transmission lines to the distribution system
Step Down Substation
Substations Components

115 KV disconnects and sulfur hexafluoride, SF6 Breakers

Source: Rickey Peterson 2012
Disconnects Opened Under Load

• http://youtu.be/vqgNrj6oEdc
Substations SCADA

SCADA voltage monitoring systems with 3 Potential Transformers for all 3 phases

Source: Rickey Peterson 2012
Substations
Low Voltage Side

12 KV breakers also called reclosers

Source: Rickey Peterson 2012
Other Substation Functions

• They also act as a collection point for distributed generation such as wind farms or solar arrays to connect them to the transmission grid
• They can supply light rail power (MARTA)
• Substations enable critical Supervisory Control and Data Acquisition (SCADA) functions
Substations

• The SCADA system collects near real-time data from many points in a substation, and sends that data to the energy control centers around the country

• The data can be:
  o Demand (kW or MW)
  o Energy (kWh or MWH or VARS)
  o Voltage
  o Status of equipment (Everything from temperature of transformers to breaker operations)
Substations

• The SCADA system enables control of equipment in a substation, by the energy control centers in that service area

• The remote operations include such functions as:
  o Breakers or reclosers (trip & close)
  o Control of tap changing transformers for voltage control
  o Capacitor bank switching for voltage and VAR control
Substations & SCADA

• SCADA at the generation, substation and transmission levels have been active and sophisticated for decades.

• These SCADA systems are the technology (hardware and software) the electric utilities use to cost minimize and control power flow on the systems.

• SCADA is a solid foundation for future “smart grid” enhancements
Smart Grid

- Smart grid is an umbrella term that covers modernization and increased functionality of substations and the transmission and distribution grids
- Distributed automatic control at substations are one element of the smart grid
- The smart grid will eventually span from the generators through the supply system components to the customer’s meter and beyond
Smart Grid

Smart Grid applications, include:

• Integrated Voltage and VAR Control (IVVC)
• Fault Detection Isolation and Restoration (FDIR) in Distribution Automation (DA)
• Advanced Metering Infrastructure (AMI), as well as the Demand Response (DR), increase operational functionality for distribution substations and feeders
• Predictive operational control - AI
Substations Issues

- Distribution substations must be located near load centers
- They play a critical role in reliability
- Cost is a factor in location and type
- The “look” of the substation is becoming a major factor in the design
- NIMBY – Not In My Back Yard
AC/DC & DC/AC Conversion Substations

• AC to DC and DC to AC substations are associated with Direct Current transmission lines and also frequency conversion substations
• These static inverter substations are expensive to build and maintain
• We will discuss DC transmission lines and inverters in the next webinar
World Voltage & Frequency

- 220-240V/50Hz
- 220-240V/60Hz
- 100-127V/60Hz
- 100-127V/50Hz

Japan
Japan's utility frequencies are 50 Hz and 60 Hz.
USA Frequency

• The power supply frequency in the US was not always at 60 Cycles per second (60 Hz)
• As late as the mid 1940’s Southern Cal Edison was completing the transition of its system from 50 Hz to 60 Hz
• The original Niagara Falls generators were built to produce 25 Hz power and converted to 60 Hz in the late 1950’s
In Summary

• Substations are critical links (nodes) in the electric supply chain
• There are many types of substations connecting a variety of energy sources
• Different types interconnect the grid at the transmission and distribution levels
• The smart grid will impact the substation technology in the future
Substations

• In the future substations will have the ability to control power flow along specific transmission lines
• They will be even more automated in ways that integrate with the smart grid at the Generation, Transmission and Distribution levels
• They are, and will always be, a critical link in the electric energy supply chain
Upcoming APPA Events

Webinars

Key Financial Targets for Financial Decision Makers
(Part of a 6-webinar series on Public Utility Governance)
April 6  2 – 3:30 p.m. ET

Determining Revenue Requirements for Your Utility
(Part of a 6-webinar series on accounting and finance)
April 11  2 – 3:30 p.m. ET

Electric Utility 101: Transmission
(Part of a 5-webinar series based on the electric utility industry)
April 13  2 – 3:30 p.m. ET

Strategic Planning for Long-Term Effectiveness
(Part of a 6-webinar series on Public Utility Governance)
May 2  2 – 3:30 p.m. ET

Development of Cash Reserve Policies
(Part of a 6-webinar series on accounting and finance)
May 4  2 – 3:30 p.m. ET

Electric Utility 101: Distribution
(Part of a 5-webinar series based on the electric utility industry)
May 11  2 – 3:30 p.m. ET

Conferences and In-depth Courses

Spring Education Institute
May 15-19  Minneapolis, Minn.

Featuring 17 in-depth courses on the following topics:
- Accounting & Finance
- Cost of Service & Retail Rate Design
- Energy Efficiency Management Certificate Program (5 courses)
- Underground Distribution Systems
- Public Power Manager Certificate Program (3 courses)

Public Power Lineworkers Rodeo
May 15-16  Sacramento, Calif.

Engineering & Operations Conference
May 7-10  San Antonio, Texas

Featuring four pre-conference seminars:
- How to Develop a Physical Security Plan for Your Utility
- Overview and Practical Applications of the 2017 Safety Manual

Visit www.APPAAcademy.org, for more information
THANK YOU

*Please fill out the webinar survey*

Wallace Barron
Email: WallaceBarronLLC@aol.com