Bellevue Comprehensive Plan Update **January 2007**
Electrical System Basics & Planning Considerations White Paper

Puget Sound Energy has prepared this white paper to introduce common terms, facilities and concepts used in discussing the planning, construction, operation and maintenance of our electrical utility transmission and distribution systems. Questions about this material can be directed to PSE's Community Services Department.

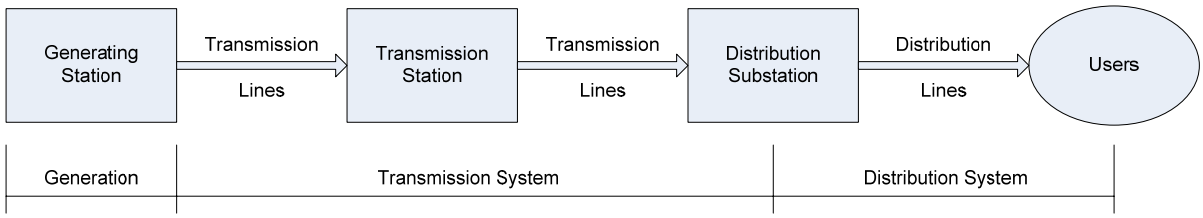
Common Terms

A glossary of common electric utility system terms appears at the end of the document.

Overview

Electric power is produced and delivered to users by means of an integrated system of generation, transmission and distribution facilities. Once generated, power must be transported nearly instantaneously, often over great distances, to end users. A conceptual electric power system is shown in Figure 1.

Figure 1 – Power System Overview



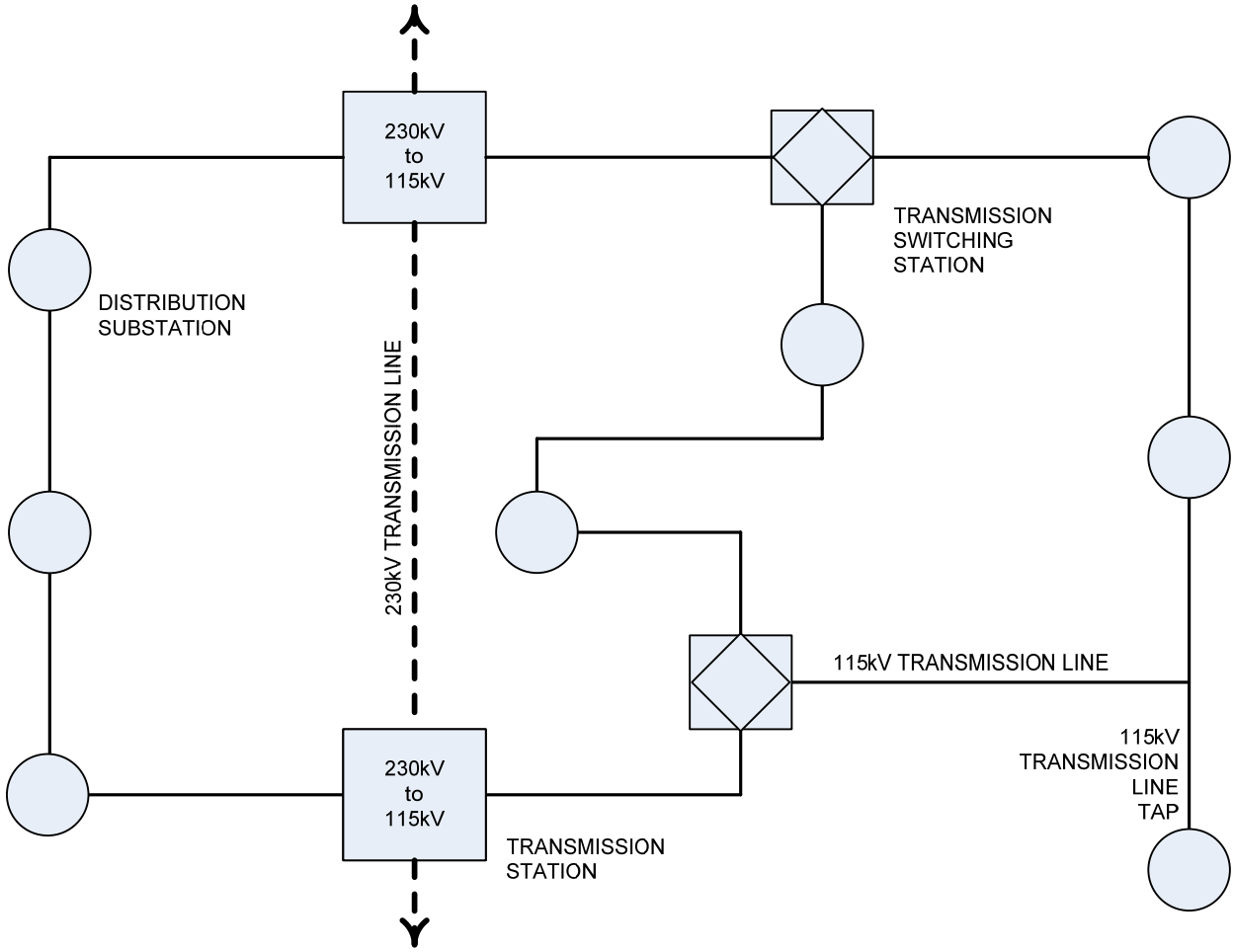
Transmission System

A conceptual transmission system diagram (simplified) is shown in Figure 2.

Once generated, electric power is transported in bulk throughout a region over the transmission system to areas where it is used. The amount of power that can be moved over the transmission system – its capacity – is largely a function of 1) the transmission system operating voltage and 2) the transmission lines conductor size and/or number of conductors. Generally speaking, for a given conductor size, increased voltage allows more current (more power) to be transported over greater distances. Larger conductors and/or increased numbers of conductors also allow more power to be transported. Over time the transmission system must be upgraded, expanded and reconfigured to ensure enough power can be reliably moved to where it is needed.

The transmission system in the greater Puget Sound region is an interconnected system of transmission facilities owned and operated by the Bonneville Power Authority, Puget Sound Energy, Snohomish Public Utility District, Seattle City Light, Tacoma Power and others. This integrated transmission system operates at voltages of between 55,000 volts (55kV) to 500,000 volts (500 kV). PSE has transmission lines that operate at 230kV and below, with most operating at 115kV.Most of PSE's transmission system is constructed and operated in a 'looped' configuration in which multiple

Figure 2 – Conceptual Transmission System Diagram



transmission lines are interconnected at stations to provide operational flexibility. In many cases this configuration allows power flow to be rerouted and maintained in the event of a fault in one part of the system because there are multiple transmission paths to stations. However, some transmission lines are not looped, but are radial 'tap' lines which have only a single source of power. Stations which receive power from tap lines do not have redundant power supply paths. Tap lines also do not contribute to the overall capacity of the transmission system since they do not interconnect with other parts of the transmission system at both ends. Overall transmission system capacity and reliability can be increased by closing the loop at the end of tap lines.

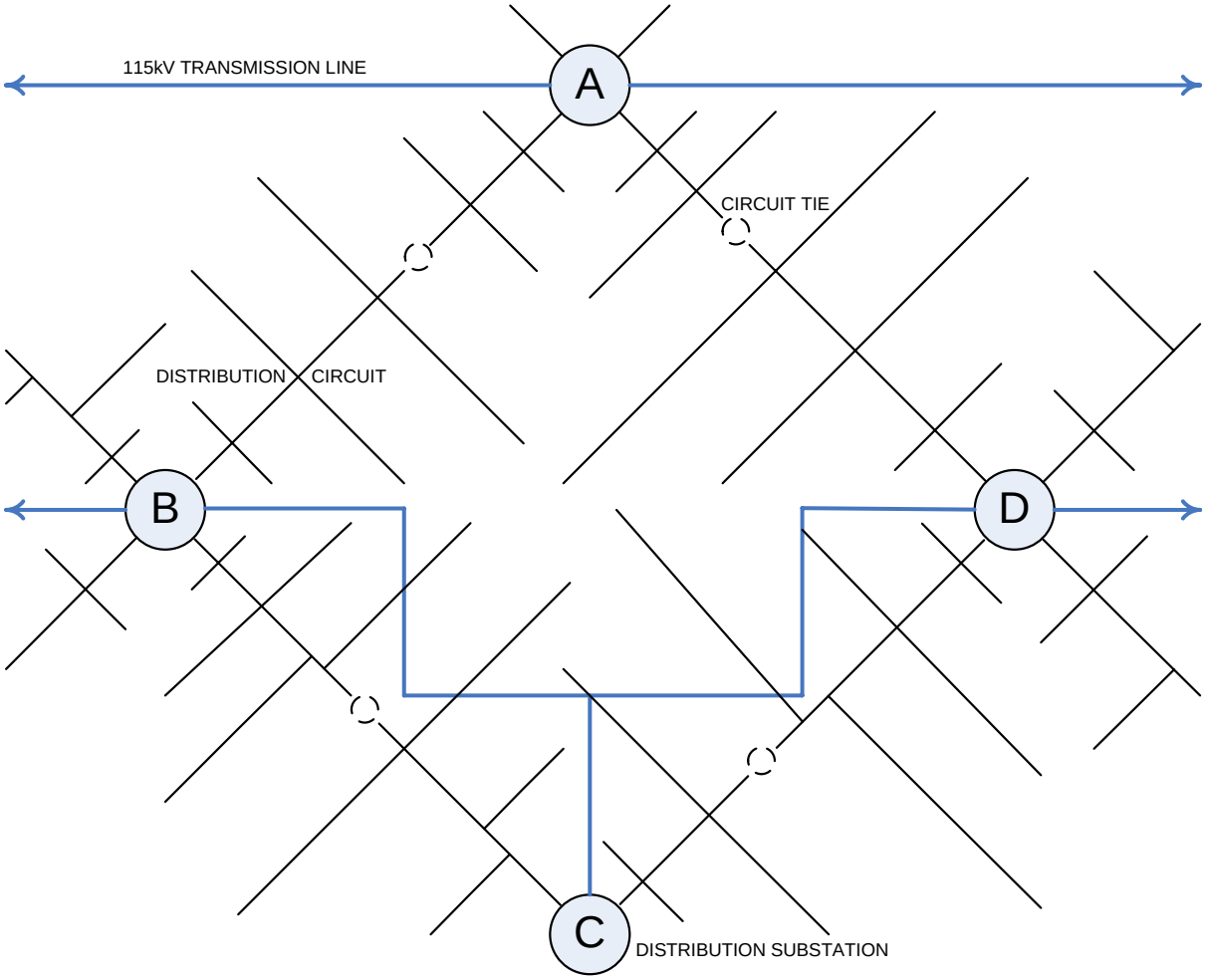
Distribution System

A conceptual distribution system diagram (simplified) is shown in Figure 3.

Distribution substations take power from the transmission system, reduce the power voltage and then distribute the power into the surrounding area through a system of

distribution lines. The capacity of the distribution system is largely a function of 1) the distribution system operating voltage, 2) the distribution lines conductor size and

Figure 3 – Conceptual Distribution System Diagram



3) customer distance from the substation. Most of PSE's distribution system operates at 12,500 volts (12.5kV) and below. Transformers connected to the distribution lines further reduce power voltage for delivery to customers which are connected to the distribution system by service lines.

Distribution substation location is largely a function of electric load density (the amount of load in a given geographic area). Substation capacity must be located in proximity to the load. Generally speaking, areas of lower load density can have fewer substations arranged somewhat farther apart, while areas having higher load density will typically require more substations spaced somewhat closer together. Alternatively, fewer substations having greater capacity may be used to serve such areas.

In addition to substation capacity, load allocation along distribution circuits plays a determining role. Areas having lower load density may be served by single geographically expansive circuits, whereas areas having higher load density will

typically be served by shorter multiple distribution circuits. Distance as measured along the distribution circuit is also a factor which relates to power quality and system stability.

As electric loads increase and load distributions and densities change, the distribution system must be reconfigured and/or enhanced to the meet the changing service needs. Existing load may be transferred to alternative circuits to accommodate additional load and existing and/or new circuits may be extended into areas of load growth. When load growth is projected to exceed existing distribution substation or distribution circuit capacity in an area, one or both parts of the distribution system must be addressed.

System Capacity and Reliability

As electric load increase with time, additional capacity must be added to the transmission and distribution systems. Capacity is generally added in increments. For example, most distribution substation transformers used by PSE are rated capacity of 25 MVA (megavolt-amperes). PSE has chosen this size transformer as a balance of load carrying capacity and customer service reliability (managing the number of customers potentially impacted by equipment failure). As load served by a given transformer approaches the rated capacity of the transformer, assuming capacity is not available from another existing transformer, the next transformer (the next 25 MVA increment of capacity) must be added. This may mean adding a transformer at an existing station or building a new substation. Similarly, as aggregate load served from a given transmission line approaches the capacity of the line, a new piece of transmission line may need to be built even though the load it may serve only a fraction of the line's capacity when it first enters service.

In addition to having enough capacity located where needed to serve customer load, the transmission and distribution systems must have additional capacity and flexibility to provide reliable customer service. In general this means system design and operation must allow for system maintenance and unplanned system events while avoiding or minimizing service interruptions to customers. The primary means to achieve this flexibility is to plan and build systems in terms of location, capacity and configuration so that parts of these systems can be used to substitute for other parts when the need arises or, when this is not possible, to limit the impact to customers resulting from temporary impairment or interruption of system operation.

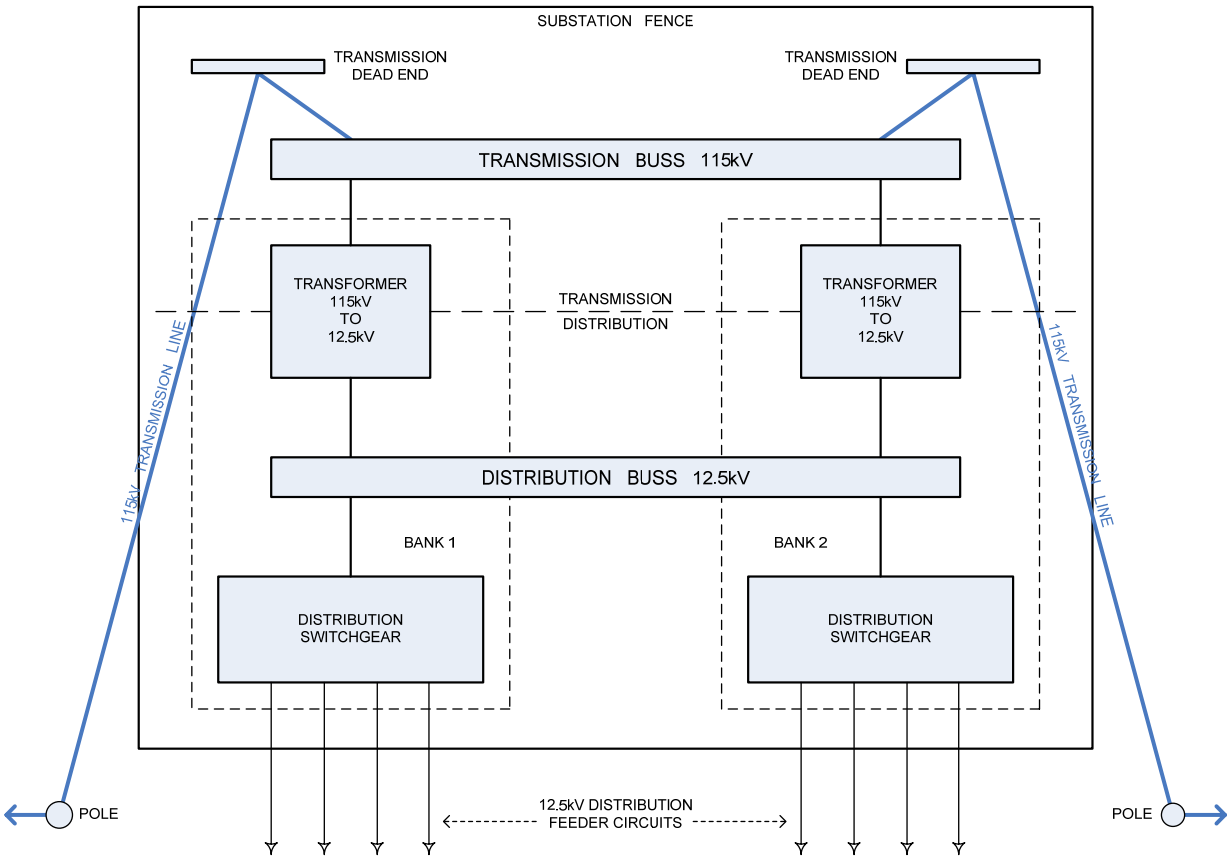
For example, aggregate load served by distribution substations connected to a given transmission line is managed and kept below the capacity of the transmission line to provide a measure of transmission system reserve capacity. Similarly, distribution circuits are configured so that in most cases there is reserve capacity available to temporarily substitute for other circuits in the event this becomes necessary. Increasing loads and changes in load distribution often require installation of the next increment of system capacity to ensure adequate reserve capacity is available to the system as a whole.

Limited portions of our systems do not posses flexibility as described above. For example, distribution substations which are served by a radial transmission line tap have only a single transmission source available to them. A fault in a transmission line tap results in loss of power to connected substations (and the customers served from

them) until the fault is corrected or the distribution circuits served from such substations can be switched to alternative substations. PSE manages customer service reliability at such substations by eliminating or reducing potential threats to transmission line and substation operations, such as vegetation and bird/animal contacts and vehicle-pole accidents. However, as load served from such substations increases and/or loads increase on the transmission system to which such transmission line taps are connected, new segments of transmission line may be needed to loop the transmission system and provide two paths of service to each substation and additional transmission system capacity.

Substation Capacity Improvements – Expansion and New Development

Figure 4 – Conceptual Distribution Substation Diagram



Many existing PSE distribution substations are already built to accommodate installation of planned capacity additions. When originally constructed, the fenced yards at many distribution substations were sized and built containing the physical space needed for both the first transformer bank and the future installation a second transformer bank to provide the ultimate planned substation capacity. However, some older substations were not so constructed and must be physically expanded to provide adequate space for installation of additional capacity. Alternatively, a new facility might be built to provide the needed additional capacity.

System Facilities Serving Bellevue

Within Bellevue, PSE transmission lines operate at 115kV and Seattle City Light transmission lines operate at 230kV (SCL lines pass through but do not serve Bellevue). In the future, PSE expects that parts of PSE's transmission system in Bellevue will need to operate at 230kV. PSE distribution lines in Bellevue operate at 12.5kV and below.

Most of the sixteen PSE distribution substations serving Bellevue are fed by looped transmission lines. The Factoria, Interlaken, Lake Hills, Phantom Lake and Somerset distribution substations are served from transmission line taps. PSE plans to add new sections of transmission lines to these substations in the future.

Planned capacity improvements (installation of a second transmission bank) at the Bridle Trails, Center, College, Lake Hills, Midlakes, Northrup, Phantom Lake, Somerset and South Bellevue distribution substations will not require physical expansion of these existing substations.

A few existing distribution substations in Bellevue would need to be physically expanded – or completely rebuilt – to provide future needed substation capacity. The Factoria substation would need to be completely rebuilt using an expanded footprint to accommodate installation of a second transformer bank. At Clyde Hill and Lochleven substations, expansion would be needed to accommodate future addition of second and/or third transformer banks and transmission line switching capability. The North Bellevue and Center distribution substations may need to be expanded to accommodate installation of future third transformer banks. Expansion of the Lakeside transmission switching station is planned to accommodate future installation of 230kV to 115kV transformation. With the exception of the North Bellevue distribution substation, PSE owns the land necessary for station expansions.

PSE has identified areas within Bellevue in which, if current development projections hold, new distribution substations would be needed to serve the associated electric load. PSE does not own and has not identified potential sites for these future facilities.

Additionally, projected development and load growth is expected to result in the need to reconfigure portions of the existing transmission system in Bellevue which would require development of new transmission switching stations (which could also include distribution substation functionality). PSE owns a site for the proposed Westminster transmission switching station, but does not own sites for a second proposed switching station.

Glossary of Common Terms

Bank/Transformer Bank – At a distribution substation a distribution transformer, together with associated distribution circuit breakers (typically four), buss and equipment. Substations are often described by the number of banks present, such as single banked (one such collection) or double banked (two collections). Most PSE distribution substations are built with the physical space to be double banked.

Breaker/Circuit Breaker – A device which connects parts of transmission systems or distribution systems and provides automatic disconnection in the event of an abnormal operating condition, such as a electrical fault or overload.

Buss – Rigid conductors (such as bars or pipes) and their supports connecting equipment such as breakers, switches and transformers within a substation.

Conductor – A medium though which electric current flows or voltage is present. In an electric utility system conductor typically refers to the wires and cables used to connect elements of the system together.

Current – The flow of electricity (electrons) through an electrical system and a measure (in amperes or amps) of how much electricity (power) is flowing through an electrical system, analogous to the flow rate (in gallons per second) in a water piping system.

Distribution Circuit – A collection of interconnected distribution lines having a common distribution breaker. Distribution circuits in PSE's distribution system have rated capacities of about 600 amps.

Distribution Circuit Tie – A physical location at which two different distribution circuits can be interconnected. Distribution circuits normally operate independently, but can be connected (tied together) when necessary. For example, if the power supply for one circuit is unavailable, the circuit may be tied to another circuit and supplied with power from the alternative source.

Distribution Feeder – Highest capacity distribution lines which serve as the backbone of the distribution system and individual distribution circuits.

Distribution Line – An assemblage of conductors and supporting poles and underground cables that move power from the distribution substations out into the surrounding area to serve customers.

Distribution Substation – A facility at which power is taken from a transmission line, reduced in voltage and sent out through distribution circuits to serve customers in a local area.

Distribution System – An interconnected system of distribution substations, distribution lines, switches and transformers used to distribute power customers. Distribution systems typically serve local areas and are roughly analogous to a roadway system of arterials and residential streets.

Generator – A facility or equipment that produces (generates) electricity. In the Pacific Northwest, most electric power is generated by burning fuel (coal, gas, oil), running water (rivers/dams) and wind.

Lateral/Tap – A line branching from another line without connection to another line at the far end.

Load/Electric Load – The amount of electricity or power being used in an electrical system, measured in kilowatts (1,000 watts) abbreviated kW and megawatts (1,000,000 watts) abbreviated MW. In an electric utility system, an alternative measure of megavolt-amperes, abbreviated MVA, is used which measures both the power used doing work (active power) and power used to facilitate the doing of work (reactive power).

Load Density – A term referring to the amount and distribution of load within a geographic area. Generally speaking, as the amount of electric load increases within a given geographic area, the load density in that area increases.

Looped System – A system of lines arranged to provide the capability for service from more than one power source.

Service Line – A conductor connecting a customer to the distribution system.

Switch – A device which connects and disconnects segments of lines, cables or circuits. Switches allow changes in system configuration as needs may arise.

Transformer – A device that changes (either up or down) the voltage of power flowing through it. Large transformers are used in distribution substations to provide power to distribution circuits. Smaller transformers are located throughout distribution circuits on poles, in boxes on the ground or in vaults below ground to serve customers.

Transmission Line – An assemblage of conductors and supporting structures (typically poles or towers). Transmission lines link generators to transmission switching stations and transmission stations. Except for submarine cable crossings under water bodies and one short trail section, PSE transmission lines use overhead configurations.

Transmission Station – A facility at which transmission system voltage is decreased or increased using one or more transformers. For the context of this paper, transmission stations reduce transmission system voltage and connect to lower voltage transmission lines used to move power to distribution substations.

Transmission Switching Station – A facility at which multiple transmission lines interconnect through using a system of busses and breakers. Switching stations provide the ability to change the configuration of the transmission system as operational needs may require.

Transmission System – An interconnected system of transmission lines, transmission substations and transmission switching stations which moves large bulk amounts of electrical power from generating sources to locations where power is used. Transmission systems typically serve large regions and are roughly analogous to the interstate and state highway systems.

Voltage – A measure (in volts) of operating capacity in an electrical system, analogous to pressure (in pounds per square inch) in a water piping system. The typical measurement used in electric utility systems is kilovolts (1,000 volts) abbreviated kV.