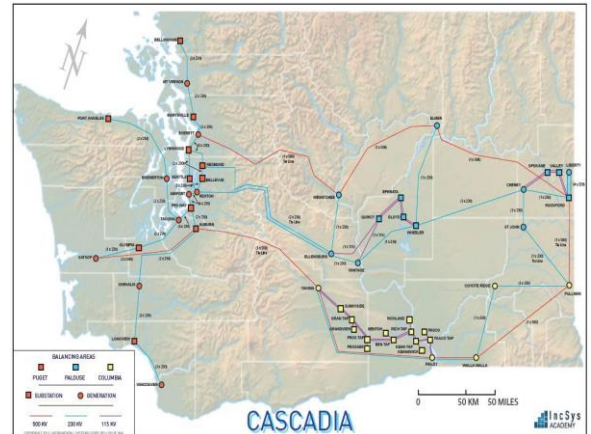


# Phase Shifter Operation

This is a computer-based training module which contains a blend of video lecture and simulation to instruct students on the design, operation, and functions of Phase Shifters. Students learn how phase shifters can control MW flow in AC networks. Then students operate a phase shifter in hypothetical power system to observe the effects of different tap settings. Students also use the phase shifter to remove an IROL violation during a simulated loss of transmission line contingency. The Instructor presents a lecture on phase shifters construction and use and the students review how power flows on transmission lines. The instructor will provide examples of network conditions with a phase shifting transformer as it controls the angle of the sending bus. The instructor also reviews the phase shifter tap settings and how they are operated. Students will perform a simulated exercise on a hypothetical power system where they record MW flows around a major loop in the network, operate a phase shifting transformer, and record the changes in the system as they review the simplified power flow equation in order to predict the changes in looped MW flow when setting the tap positions of the phase shifting transformer. Students will perform another simulated exercise on a hypothetical power system where they play the role as the Transmission Operator while responding to transmission line MVA System Operating Limit violations. They will review NERC standard TOP-001-4 and the system operating limits of the equipment on the hypothetical system and use the SCADA interface and contingency analysis program to monitor for System Operating Limits and Interconnection Operating Reliability Limits. They will also operate the phase shifting transformer to remove IROL violations.



## Cascadia 4080 Course Objectives

### Phase Shifter Operation

COURSE CE HOURS		
OT	STD	SIM
2	1	1.5

#### Lecture Objectives:

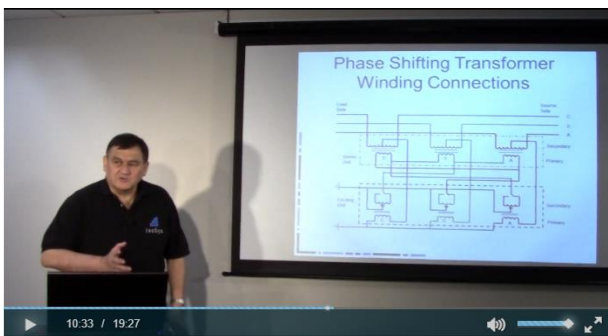
- Select the best uses of a phase shifting transformers while operating a transmission network.
- Recall the design of a phase shifting transformer.
- Describe how phase shifters control MW flows on AC networks.
- State the typical tap range of a phase shifting transformer and how tap position can induce loop flow on an AC network.
- Describe the responsibilities of a Transmission Operator in when monitoring and using a phase shifting transformer.

#### Simulation Exercise #1 Objective

- Estimate the changes in Cascadia system major 500 and 230 kV loop flow as the phase shifting transformer is moved from 0 to the +16 setting and 0 to the -16 setting using the Cascadia Electrical Distance Diagram.
- Operate the Pullman PST at 0, +16 and -16 tap settings and record flows throughout the Cascadia 500 and 230 kV loop.
- Explain why flows at various points differ from an average estimated loop flow.
- Observe the mental model of a minor loop flow.
- Observe the mental model of flow being diverted to path that is parallel to the main loop.

#### Simulation Exercise #2 Objectives:

- Respond to a double circuit 230 kV outage in the Puget system.
- Record the SOL violations with thermal overloads beyond the emergency rating of the Airport – Renton 1 & 2 lines.
- Run Contingency Analysis. Document the IROL violation due to loss of one of the remaining Airport – Renton lines causing voltage collapse.
- Apply a Phase Shifter at a station in the East side of the Cascadia systems to mitigate the SOL violation in the West side of the Cascadia System.
- Run Contingency Analysis to show that this control action also alleviates the IROL violation.
- Observe how PSTs can provide non cost adjustments to rapidly alleviate a SOL and an IROL violation.



### Phase Shifting Transformer Winding Connections



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