ELECTRIC POWER RESEARCH INSTITUTE

conEdison

Transmission Efficiency Initiative: Host Demonstration Project

Evaluation of the Use of Power Flow Controllers to Improve Transmission System Utilization and Energy Efficiency

Phase shifter transformer

- Evaluate the Con Edison PARs and transformers to determine opportunities for improved system utilization and efficiency.
- Monitor before and after energy losses and utilization and document the results.
- Benefits include reduced energy losses, enhanced system utilization, and reduced carbon footprint.

In an ac electric grid, power flow is determined by the relative impedances of the various paths and interconnections within the grid and the constantly changing values of generation and the loads. This can result in large imbalances in which the paths with the smallest impedance carry the largest part of the load. Grid congestion, loop flows, and bottlenecks impede the efficient movement of power, reducing system reliability, efficiency, and utilization. Both real and reactive power flow control hardware can be used to optimize system utilization and efficiency. Power flow patterns can be controlled in a way to operate the grid closer to an optimal or desirable condition by forcing power onto paths that provide benefits for loss reduction, contingency response, or economic dispatch.

The Con Edison in-city transmission system consists of both 138- and 345-kV areas that are tied together. Both areas have varying levels of generation and load, and the real and reactive flows between them are regulated by phase angle regulators (PARs) and transformers, respectively. Transformers that bridge two active transmission areas (such as 138- and 345-kV) can move reactive power between these areas while adjusting voltage.

A PAR is a type of transformer that is designed to control power flow through the path in which it is located. Its basic function is to vary the effective phase displacement between its input voltage and the output voltage, thus controlling the amount of active power that can flow in the line. The phase shift is obtained by extracting the line-to-ground voltage of one phase and injecting a portion of it in series with another phase. This is accomplished by using two transformers: the series transformer and the regulating (or magnetizing) transformer, which is connected in shunt. Controlling phase-shift on a transmission system affects primarily the flow of active power. The angle of a PAR is normally adjusted by on-load tap-changing devices.

Ideally, the settings of PARs and transformers to balance power flow and achieve minimum-loss operation could be continually adjusted as the power system progresses through the daily load cycle. An optimal load flow that minimizes losses and is combined with a state estimator could apply ongoing settings changes. However, frequent operation of tap changers would produce excessive wear and tear of the mechanical components, and the time and attention required of the operators would become burdensome. An automatic process could be implemented to overcome that problem, with caveats for monitoring potential contingency violations.

Con Edison has vast experience with the use of PARs. The company has 21 PARs installed across a relatively small but densely loaded transmission system. Five PARs are used to regulate power flow on ties from adjacent utilities, and 16 PARs are used to balance real power flows between the 345-, 138-, and 69-kV portions of the internal transmission system. An additional 15 transformers are used to balance reactive power flows on the same paths between these areas.

Project Scope

As part of EPRI's Transmission Efficiency Initiative, ConEdison is evaluating a possible demonstration project for more effective and organized utilization of PARs and transformers to improve transmission efficiency. This project has the following main goals:

- Document ConEdison's experience with the use of PARs and transformers to evaluate the benefit of the technology in improving system performance and utilization.
- Evaluate potential opportunities to improve the use of PARs and transformers to increase utilization of the transmission network and reduce losses, including enhancement of operating and control strategies with both the current system and future installations.

Expected Benefits

One or more of the following benefits might be realized through the application of this technology:

- Increase utilization of the ConEdison transmission system.
- Reduce transmission losses by reducing loop flows and diverting power flow to a higher voltage path when possible.
- Reduce carbon footprint by reducing losses and facilitating greater dispatch of more efficient units.

Approach for Measurement and Validation

A key objective of EPRI's Transmission Efficiency Initiative is to verify and validate the "actual" benefits realized by the application of the identified technology using a consistent measurement and verification methodology that will be developed as part of EPRI's transmission efficiency research portfolio.

The detailed methodology of M&V will be developed during the course of the project using the following general approach:

- Demand, energy, and CO_2 savings will be determined based on transmission load flow studies and measurements before and after the implementation of the technology (new control approach or new hardware or both).
- System utilization improvement will be assessed by considering generation dispatch, congestion costs, line loading, and other metrics that will be defined.
- A life cycle carbon footprint methodology will be developed for this case.

Project Approach

Phase 1: Feasibility and Scoping Study

1. Con Edison will provide transmission system data and information about the physical and operational characteristics of the PARs installed in the system, as well as the information needed to quantify the impact on lifecycle carbon footprint, increased utilization of transmission system, and impact on system losses, according to the M&V approach defined by EPRI.
2. Document Con Edison's experience with the utilization of PARs and other transmission system controls and to assess the benefits for system performance improvement, including utilization and transmission losses.
3. Identify opportunities to use PARs and other transmission system controls to further improve system efficiency and utilization.
4. Assess benefits, costs and implementation considerations of the most promising project opportunities. Project type can range from improvements of operating and control procedures to the installation of new devices.

Phase 2: Engineering Design, Implementation, and Verification. Based on the results of Phase 1, one or more projects will be selected for implementation. The main activities of this phase will be the following:

1. Detailed engineering analysis and design
2. Implementation (new procedures and purchase, installation, and commissioning of new hardware).
3. Monitor active and reactive power flows, transmission related losses, generation dispatch and margins for 12 months.
4. Determine savings and changes in system utilization using the EPRI demonstration protocol.
5. Final project report. The non-proprietary results of the project will be published within the framework of the Green Transmission Initiative.

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