ELECTRIC POWER RESEARCH INSTITUTE

Transmission Efficiency Initiative: Host Demonstration Project

Voltage Control Optimization to Improve Transmission System Efficiency

Control System

- Demonstrate the benefits of voltage profile optimization.
- Implement an enhanced voltage scheduling process that allows adapting the optimal voltage profile to the changing operating conditions.
- Increase the voltage stability and system reliability.
- Reduce losses by minimizing loop currents and keeping a low voltage profile.

Project Scope

As part of EPRI's Transmission Efficiency Initiative, the Tennessee Valley Authority (TVA) is evaluating a possible demonstration of its new voltage scheduling methodology, which is intended to maximize MVAR reserves and reduce transmission losses. The demonstration project is the continuation and completion of the program for optimal voltage scheduling already initiated by TVA. The scope of this project includes the following:

- Completion of a field survey on transformer tap settings and other voltage control equipment.
- Analysis of conditions and requirements to implement the voltage optimization software in on-line mode.
- Determination of the optimal frequency of voltage scheduling (how often the optimization program must be run and voltage setpoints updated). By increasing the rate of voltage setpoint updates, the optimal voltage profile more closely follows the variation in system operating conditions, thus maximizing the benefits of coordinated voltage control. On the other hand, it increases coordination with generators and substation operator. Thus, the benefits of increasing the frequency of voltage setpoint update must be contrasted with the hurdle and cost of higher coordination and communication burden.

Technology Description

Voltages affect the flow of reactive power in the grid, which in turn has a strong influence on system losses and congestion. Thus, voltage control is an effective method for reducing losses and increasing transmission capacity. Therefore, managing voltage reduces resistive losses and minimizes reactive power flow on the grid, which allows operators to maximize the amount of real power that can be transferred across congested transmission lines. Indeed, reactive power flows in the grid consume transmission and generation capacity, thus limiting a system's ability to move real power. Reactive power flows must, therefore, be minimized.

TVA, as in general almost all North American grid operators, controls transmission voltages and reactive powers mainly in a decentralized fashion at the power plant/substation level. In the control center, system operators manually dispatch the reactive powers of generating units, schedule the high-side voltages of power plants, switch the banks of shunt capacitors or reactors, and change the voltage setpoints of on-load tap controllers and flexible ac transmission system controllers.

TVA has identified the need for an analytical, engineering-based assessment of the voltage schedule in its transmission system and has initiated a program in that direction. The program is intended to improve the voltage profile and the use of the reactive power sources through a coordinated voltage schedule. The goal is to analytically set the TVA transmission system voltage profile so that the desired reactive power reserves are met through the following controls: generator voltage setpoints, bulk transformer tap settings, capacitor and reactor switching, smoothly controlled compensators, and optimal placement of new VAR sources.

Initial studies conducted by TVA demonstrate that an optimized voltage profile in which the main objective is to maximize MVAR reserves allow increased generator reserves of almost 35% over the peak system base case. Study results also show that, even though reduction of losses was not the ultimate optimization objective, substantive real and reactive losses (10 MW of loss reduction over 486.0 MW total losses in the pre-optimized operating state). It was found that, in some cases, losses might increase because as local reserves are kept higher, more reactive power must be transferred from remote locations. Thus, in some cases maximizing local MVAR reserve and reducing losses may be conflicting objectives.

TVA recently initiated the implementation process of this new voltage schedule program. Although the optimization studies have been conducted on several cases, hedging the solution, further analysis is required to assess the feasibility of the proposed voltage scheduling process for real-time voltage optimization.

The proposed voltage scheduling is basically an open-loop voltage control, in which the setpoints of voltage controls are determined through centralized optimization software and then communicated to generators or substation operators to locally adjust their corresponding voltage control devices. It is not envisaged to install a higher-level, centralized voltage control system that remotely commands local voltage control devices installed at power plants or substations.

Expected Benefits

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

- Lower real and reactive losses
- Lower CO_2 emissions and fuel savings
- Higher voltage stability margin
- Better use of reactive power resources
- Lower line and transformer loadings

Challenges and Limitations

- Increased complexity of coordination between system operator and generators.
- Difficulty to follow and control voltage target updates.

Project Plan

- TVA will work with EPRI to develop the enhanced voltage scheduling methodology.
- TVA will complete a field survey on the conditions of voltage control devices installed in the network.
- TVA will apply the developed methodology in testing mode in its power system.
- EPRI will apply the demonstration and loss reduction verification protocol developed as part of the initiative to document the impact on loss reduction and utilization improvements.
- The non-proprietary results of the project will be published within the frame work of the Green Transmission Initiative.

The schedule of the project tasks is as follows:

1. Evaluate conditions and requirements for on-line implementation.
2. Determine the optimal frequency of voltage schedule update.
3. Evaluate impact on system losses, reliability, and utilization, using off-line simulation.
4. Implement the new scheme in testing mode, September 2010.
5. Monitor active and reactive power flows, losses, and generation dispatch and margins for 12 months, completing in September 2011, and document the results using the EPRI demonstration protocol.
6. Final project report, December 2011.

Product ID: April 2010

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com