

Transmission Efficiency Initiative: Host Demonstration Project

Voltage Control Optimization to Help Reduce Transmission Losses



Substation Control

Project Scope

As part of EPRI's Transmission Efficiency Initiative, Southern Company is evaluating a possible demonstration of voltage control optimization to help reduce transmission losses.

Southern Company will provide historical, real-time power flow cases and operations expertise to support EPRI in assessing potential incremental benefits of more frequent optimization of voltage schedules. Potential gains in voltage support could be compared with gains achieved through simpler, less costly, static voltage control approaches.

Technology Description

Voltages affect the flow of reactive power in the grid. Changes in the flows of reactive power have a strong influence on system losses. Thus, adjusting voltages can have a significant effect on losses. Also, appropriate management and control of reactive power in the grid allows maximization of the amount of real power that can be transferred across congested transmission lines. Otherwise, reactive power (more than necessary) flows in the grid consuming transmission and generation capacity, hence limiting the system's ability to move real power.

- 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.

Southern Company and, in general, almost all North American grid operators, control transmission voltages and reactive powers principally in a decentralized fashion at the power plant/substation level. In the control center, transmission system operators provide the generator operators with hourly voltage schedules to maintain at high-side generator interconnecting transmission bus and switch transmission banks of shunt capacitors or reactors. The transmission operators' manual control actions are coordinated with automatic reactive power control actions such as automatic voltage (or VAR flow) controlled distribution and transmission capacitors, the action of on-load tap controllers and flexible ac transmission system controllers.

Southern Company performs off-line optimal power flow studies to develop system voltage schedules for different system load conditions. Voltage profile targets are then communicated to generators for them to set voltage control objectives for their units. Studies have shown that 52 MW of loss reduction can be achieved by optimizing voltage across the network as compared to a flat voltage profile. Benefits of an optimized voltage profile include higher dynamic and static reserves, higher voltage stability margin, and lower line and transformer loadings.

Southern Company conducts voltage schedule analysis through off-line studies on a regular basis. However, because system operation conditions continually change, voltage profiles determined in the off-line studies might not necessarily represent optimal conditions for all the possible operating states. One alternative for adapting voltage control objectives to the ever-changing operating conditions is to implement a hierarchical, dynamic voltage control system. This would be a centralized control system, installed in the grid control center, that determines optimal voltage across the grid and automatically and remotely adjusts the setpoints of the primary voltage controllers. Such a technology is being applied by system operators in Asia and Europe, but it has not been applied yet on the North American grids. The incremental benefits of a continuous optimization approach versus a static approach have not been assessed.

Another alternative would be to enhance the existing voltage scheduling process by performing near-real-time optimal power flow simulations and using the results to send updated voltage setpoints to on-line generators. In that way, optimal voltage profile would more closely follow variations in system operating conditions. One shortcoming of this alternative is that it increases coordination with generators. Thus, the benefits of increasing the frequency of voltage setpoint updates must be contrasted against the higher costs, complexity, and operating challenges of real-time optimization.

Expected Benefits

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

- Lower real and reactive losses
- Lower CO₂ 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**
- Operating challenges to follow and control voltage target updates

Project Plan

- Southern Company will support EPRI with operating data and expertise to assess the enhanced voltage scheduling potential.
- 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 framework of the Green Transmission Initiative.

The schedule of the project tasks is proposed as follows:

1. Southern Company will work with EPRI to identify appropriate historical, real-time power flow cases for postmortem optimal power flow analysis by EPRI.
2. Southern Company will provide EPRI with target voltage schedules for the provided power flow cases.
3. Southern Company will provide EPRI with a list of the known transmission and generation bus voltage level constraints.
4. EPRI will analyze the historical, real-time power flow cases to quantify any additional real or reactive power efficiencies. EPRI might potentially quantify the extended voltage stability margins through a more optimized voltage schedule, taking into account potential device accuracies and the action of existing reactive, automated controls. If applicable, EPRI will ensure that secure operating states for N-1 conditions are maintained.
5. Final project report, date to be determined.

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