OPTIMAL TECHNOLOGIES

AEMPFAST

Case Study: Optimum Placement of DG Units and Capacitors for Large Municipality Transmission System Using AEMPFAST™

Using AEMPFAST P and Q indexes, utilities can optimally place capacitors and distributed generators, thus significantly improving their load serving and import capabilities.

Challenge

A large municipal utility that serves a metropolitan area of over a million people asked Optimal to demonstrate how AEMPFAST could significantly improve the load serving and import capability of its system. Specifically, AEMPFAST's objectives were as follows:

- To evaluate all cases and Critical Contingencies to determine the effect of additional DG and capacitance resources on the system's load serving and import capabilities
- To determine the optimum locations and size for placement of additional distributed generation (DG) and capacitors within the system
- To optimize the system voltage profile to reduce system voltage variations
- To develop a new planning tool for measuring and verifying the correctness and effectiveness of DG and capacitor placements relative to the load serving and import capability of the system.

Optimal was supplied with several High Load Power Factor and Low Load Power Factor planning cases for the years 2005, 2006, 2007, and 2008. The utility (hereafter referred to as the "test system") also specified 13 critical system contingencies that included 7 single (N-1) and 6 double (N-2) contingencies. All of the standard control devices, such as generator reactive power and voltage settings, Tap Changers Under Load Controls (TCULs), and SVDs were assumed active during the optimization.

Solution

Optimal addressed the DG and capacitor optimization steps separately, using AEMPFAST's unique active and reactive power Resource Sensitivity Indices (RSIs). AEMPFAST RSIs indicate mathematically the active and reactive power resource sensitivity at every bus in the system under a given set of system resources, operating rules, and constraints. RSIs show the change in objective function value resulting from changes in resources (such as generation and capacitance) and the corresponding resource stress condition at every bus.

Over the period of time covered by the study, AEMPFAST repeatedly demonstrated the following results for the test system under evaluation:

1. **Additional DG, optimally placed, increases system load serving and import capability at optimized locations in the test system.** Optimal

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AEMPFAST RSIs indicate mathematically the active and reactive power resource sensitivity at every bus in the system under a given set of system resources, operating rules, and constraints.

performed iterative DG optimization on planning cases and contingencies using AEMPFAST RSIs to measure the system's active power (P RSIs). For each AEMPFAST run, P RSIs were sorted (ranked) according to their values.

In the test system, a DG unit was placed at the location with the highest P RSI stress value, then the case was run again, and another DG unit was added at the most stressed bus. This procedure was repeated until additional identified increments of DG offered negligible system improvements. AEMPFAST achieved some impressive results:

- The addition of 145 MW DG (approximately 4.15% of the total system load) with limited reactive power capability to the High Load Power Factor case increased load serving capability by 150 to 180 MW (4.3% to 5.7% of total load). The import capability increased by 5 to 65 MW (0 to 3% of import capability).
- The addition of 158 MW DG (approx. 4.51% of the total load) with limited reactive power capability to the Low Load Power Factor case increased the load serving capability by 200 MW to 230 MW (5.5% to 7.8%). Significantly, the import capability increased by 182 MW to 311 MW (9.9% to as much as 17.67% of import capability).

A limited amount of reactive power capability was also assumed for the DG units, thus providing the system both active and reactive power benefits from added DG units. This is justified because most modern DG units support reactive power generation either using small scale controllable capacitors or prime-mover field controls

2. **Additional capacitance, optimally placed, increases system load serving and import capability at optimized locations in the test system.** Optimal performed iterative capacitor optimization on planning cases and contingencies using AEMPFAST RSIs to measure the system's reactive power (Q RSIs). The Q RSIs (like the P RSIs described above) were generated as a programmed by-product of AEMPFAST's optimization function as applied to each study year and case. As with DG, capacitance was selectively added at vulnerable locations until no additional increments were required to improve system capacity; specifically:

   - The addition of 175 MVAR of capacitors to the transmission system for the High Load Power Factor cases increased the load serving capability by 16.7 MW to 66.7 MW (0.5% to 2.12% of the load). The import capability increased by 30 MW to 90 MW (1.5% to 4.55% of the import capability).
   - The addition of 300 MVAR of capacitors to the Low Load Power Factor cases increased the load serving capability by 135 MW to 250 MW (3.85% to 8.49% of the total load). Significantly, the import capability increased by 240 MW to 300 MW (13.09% to as much as 16.96% of the import capability).

   In the test system, new capacitors were placed only at system transmission-level 115kV and 230 kV buses. A maximum limit of 50 MVAR of added

capacitors per bus was assumed, and a capacitor unit size of 25 MVAR was used.

Once an optimal set of capacitor additions was determined for each year and each case, the lists were combined using the priority locations for each year and case, to arrive at a single set of capacitor locations that would optimize the test system over all the study years.

3. **Reliability of the AEMPFAST Nomogram tool.** Optimal constructed a "Minimum Generation Nomogram" for use as a benchmark measure of present test system performance. Over time, the effects of additional distributed generation and capacitors that AEMPFAST identified and optimized were plotted with the nomogram tool.

   The nomogram plot results from a sequence of algorithmic steps that identify the minimum system generation that is required to reliably meet the system load at that point. The nomogram shows the maximum import capability of the test system under various base case and contingency conditions as the difference between the minimum system generation level and the load level at any given time.

   More precisely, AEMPFAST starts with the peak load, and with each run, reduces the load for the test case by fixed amounts. With each load reduction, system generation levels are further reduced until any additional reduction in generation would provoke a security violation (e.g., a line flow violation or a voltage collapse violation under base case or contingency conditions).

Benefits

Using AEMPFAST P and Q indexes, utilities can optimally place capacitors and distributed generators, thus significantly improving their load serving and import capabilities. With unparalleled speed and accuracy, AEMPFAST provides a fast way to generate load serving capability nomograms and significant additional system benefits.

About Optimal

Optimal Technologies™ develops technologies and applications that enable power utilities, businesses, and consumers to optimize their electric networks and energy use. The Optimal SmartGrid product suite includes AEMPFAST™, which is supply-side electric power grid optimization and analysis software, and SUREFAST™, a demand-side energy management and home automation system. The company's mission is to ensure a more intelligent, reliable, efficient, and environmentally-responsible electric power grid by offering unique technologies, products, and services with the potential to create unprecedented industry, economic, environmental, and consumer benefits. The privately-held company is financed by Goldman Sachs International.