PowerWorld Simulator's Security-Constrained Optimal Power Flow (SCOPF)

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The SCOPF Explained

The SCOPF is a PowerWorld Simulator add-on that performs an optimal dispatch subject to transmission constraints under normal and contingency conditions. It is a very powerful tool, but misunderstanding about what it does can produce confusion and misleading results. Some confusion may result from a myriad of similar sounding terms used in the power industry and research literature. The key is using the software to accurately formulate the problem you wish to solve.

Let's start by defining what Optimal Power Flow (OPF) means in PowerWorld Simulator. The OPF determines the optimal dispatch, subject to transmission constraints. Optimal usually means least cost (or most economical), but may also mean minimum control change. This is the objective function and may be set on Simulator's OPF Options and Results dialog. Simulator also provides options to enable or disable different classes of controls, such as generators, loads, and area interchange, and options to enforce or ignore certain constraints, such as transmission line and interface ratings. This functionality is sometimes also described in literature as Security-Constrained Economic Dispatch or SCED.

Simulator's Security-Constrained OPF, or SCOPF, adds contingencies. Specifically, it adds the contingencies defined in Simulator's Contingency Analysis tool. The SCOPF will seek a single dispatch that does not cause any overloads in the base case, nor any overloads during any of the contingencies. It is important to understand that it solves for a single dispatch, and not a separate dispatch for each contingency.

SCOPF Challenges

We occasionally receive inquiries from customers who attempt to solve an SCOPF with a large, comprehensive set of contingencies, such as all N-1 outages over an entire control area or ISO. The problem is that power systems are often intentionally operated in such a way that some contingencies may cause overloads, but those overloads are mitigated with Special Protection Schemes or SPS. (Note that these may be called Remedial Action Schemes or RAS in some circles, but we will henceforth use only SPS for simplicity.) An SPS often defines a modification to the dispatch for one contingency or group of contingencies.

When the SCOPF is used with a large list of contingencies and no modeling or incomplete modeling of SPS, it almost always results in a large number of unenforceable constraints. Often, a dispatch that mitigates some contingent overloads exacerbates others. Simulator handles unenforceable constraints with penalty functions and is very good at finding a solution to the optimization problem. However, the solution is unlikely to resemble the way the power system is actually operated. The problem is over-constrained, thus the resulting optimal cost may be unrealistically high and the locational marginal prices (LMPs) may be severely distorted.

There may still be value in performing an SCOPF simulation with a large set of contingencies and no SPS. It may help identify the most severe contingencies that require SPS, but it probably provides little insight to behavior of an actual power market.

Alternative Approaches for Market Analysis

If you are primarily interested in understanding how a power market would behave, a few alternative approaches are likely to improve the analysis:

1. Add explicit modeling of SPS to contingency definitions.
2. Use Modeling Exceptions.
3. Use the basic OPF tool (not the SCOPF) with flowgates.

We'll next examine some details of each approach.

1. **Add explicit modeling of SPS to contingency definitions**. SPS actions may be modeled by simply defining them as additional contingency actions. SPS actions may also be conditional, in that they occur only under specific circumstances. Simulator can model conditional SPS with Model Criteria. This approach may require a lot of data and specific SPS actions may vary with loading conditions, time of day, season, or other temporal variables.
2. **Use Modeling Exceptions**. Simulator's contingency analysis allows exclusion or inclusion of specific pairs of contingencies and monitored elements. You can use this to simply ignore contingent overloads that are known to be mitigated with SPS. A possible pitfall of ignoring constraints this way is that the limits effectively become infinite. For example, a specific SPS may alleviate 100 MVA of overload on a path, but if you ignore that path completely, there is a chance that the optimal dispatch would overload it more than 100 MVA.
3. **Use the basic OPF tool (not the SCOPF) with flowgates**. Simulator can model contingency flowgates as interfaces. A typical flowgate involves the monitoring of one transmission element for loss of (flo) another. Advantages of this approach are speed and simplicity. It may also be the best choice to replicate how real power markets enforce contingent constraints. A possible challenge is that the set of enforced flowgates may change over time. For example, analyzing a 2015 scenario with 2011 flowgates may overlook some vulnerabilities of the future system. In this case, contingency analysis and the SCOPF may be needed to help identify new flowgates that are not yet defined.

If the objective is to understand behavior of present-day markets, the third approach provides a very good balance between modeling detail and simplicity.