Security Factor Calculation

In the various GB charging consultations and England and Wales charging review National Grid has provide explanations of how the Security Factor, for use in the DCLF Transport & Tariff model, is derived. A summary is repeated here along with a detailed description.

Summary

This security factor is derived using a Secured DCLF (SECULF) programme which calculates the marginal cost for each node taking into account the requirement to be secure against circuit outages.

This Secured DCLF programme is a separate self-contained application that uses the same network and nodal data as the DCLF transport model. The network analysis is carried out without expansion factors i.e. the base network data is used with the physical circuit lengths unexpanded. In the same way as the DCLF transport model produces a marginal cost for each node for the intact system, the Secured DCLF programme additionally calculates the marginal cost for each node taking into account the requirement to be secure against a set of contingencies. The programme does this by identifying the worst contingencies in terms of maximum flows for each circuit. The secure and intact marginal costs are compared on a nodal basis and a "least squares fit" employed to derive the GB security factor.

Detailed SECULF methodology & Security Factor Calculation

The input to the SECULF programme is the nodal generation and demand data plus network line data taken from the same input file as used in the simple DCLF transport model. Additionally a slack (reference) node and a contingency dataset are required.

SECULF first validates the input data for consistency i.e. to ensure that each node is included in the network data and connected to at least one other node. The contingency dataset is also checked to make sure that all contingencies are in the network. For the load flow analysis SECULF first scales generation to match demand. The base case is solved and the resulting circuit flows are stored as initial values. The flow data stored consists of the magnitude of the flow, the flow direction and the contingency number (which is zero for the intact flows).

SECULF uses the same standard DC theory as the simple DCLF Transport model to solve the power flow on a circuit. SECULF also calculates both the intact and secured nodal marginal costs in a similar way to the simple DCLF by assessing the nodal sensitivities. However, it considers the 'cost' (MW flow) from each individual circuit in turn which helps to simplify the secured nodal marginal cost calculation.

For the secured analysis SECULF uses a more efficient algorithm based on maximum circuit flows. It solves a load flow for each contingency in turn and the resulting flows are compared to the maximum flows from previous contingencies. If the magnitude of the flow in a circuit is greater than the previous maximum for that circuit, the maximum flow data (magnitude of flow, flow direction and contingency) for that circuit is updated.

Once a load flow has been done for all contingencies, a load flow is repeated for each circuit for the contingency that caused the maximum flow in that circuit.

Therefore the SECULF network cost algorithms for intact and secured cases may be written as;

$$C_b = \sum_j L_j \left| flow_{j,0} \right|$$

$$C_s = \sum_j L_j \, \underset{ctg}{Max} \left\{ \left| flow_{j,ctg} \right| \right\}$$

where

L_j is the length of line j

$flow_{j,ctg}$ is the flow in line j in contingency ctg, contingency zero is the null contingency with no lines out that gives the intact network.

SECULF carries out nodal sensitivities by differentiating the cost algorithm by the nodal injection power. The intact and secured nodal marginal costs are then given by;

$$\frac{\partial C_b}{\partial P_i} = \sum_j L_j \frac{\partial \left| flow_{j,0} \right|}{\partial P_i}$$

$$\frac{\partial C_s}{\partial P_i} = \sum_j L_j \frac{\partial}{\partial P_i} \left(\underset{ctg}{Max} \left\{ \left| flow_{j,ctg} \right| \right\} \right)$$

where

P_i is the nodal injection for node i, this is given by the difference between the nodal generation and demand ($G_i - D_i$).

Or in other words the secured nodal sensitivities are the sum of the node line sensitivities that cause the maximum flow.

The SECULF output file includes both intact and secured nodal marginal costs, which are imported into an Excel spreadsheet. The intact and secured costs are then plotted on a (scatter plot) graph. A trend line is produced by Excel to give the relationship between the intact and secured costs. The trend line is calculated using the least squares method to derive the best-fit linear relationship and the resulting gradient displayed in the formula of the trend line is the security factor.

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