Bulk Electric System Reliability

Reliability is a measure of the ability of the power system to deliver electricity to all points of utilization within accepted standards and in the amount desired. Reliability can be defined in two ways:

- **Adequacy** is the ability of the electric systems to supply the aggregate electrical demand and energy requirements of their customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.
- **Security** is concerned with the ability of the electric systems to withstand sudden disturbances, such as electric short circuits or unanticipated loss of system elements.

Power system adequacy is often assessed using the power flow solutions of PSS™E, while security is typically assessed using the dynamic simulation or PV analysis functions. Reliability of a power system can be analyzed either on a deterministic or probabilistic basis. The newly added features in the PSS™E power flow analysis engine provide program users with a comprehensive tool to evaluate the steady state problems encountered in large or small power systems.

**Features for Deterministic Reliability Assessment**

Automatic AC Contingency Computation and Multi-Level AC Contingency Computation (ACCC/MACCC) can be used to perform deterministic reliability assessment. Automatic contingency analysis can analyze user specified and automatically selected single and multiple contingencies within one run, categorizing and storing results for easy post-processing. User specified and automatically generated contingencies can be tested individually or combined with each other as overlapping outages of up to three levels (N-3). The contingency enumeration process is based on the use of several built-in contingency ranking schemes which provide tremendous savings in computation effort by avoiding the explicit evaluation of contingencies that are not likely to affect system reliability. Three types of contingency rankers are offered by PSS™E: ranking of single machine outages and single branch outages according to their respective impact on thermal loadings, and ranking of single branch outages according to voltage depression impact.

Figure 1 shows an example of a 2-level contingency analysis in which user Specified Outages (S) and machine (U) and branch (B) outages from the rankers are chosen for N-1 testing, while combinations of single machine and single branch outages from the rankers are chosen for N-2 testing.

![Figure 1 – Example of 2-Level Contingency Analysis](image.png)
Automatic contingency analysis also features generation dispatch, non-divergent power flow solution algorithm, tripping simulation and corrective actions. Figure 2 outlines the computational procedures in a contingency analysis.

![Figure 2 - Computational Procedures in a Contingency Analysis](image)

Generation dispatch allows users to simulate system response to power imbalances caused by contingencies. PSS®E provides several options by which generation dispatch may be performed: according to machine inertial response, governor action, spinning reserve and generation capability. These provide a more realistic representation of system response than the traditional approach of using the system swing generator to accommodate power imbalances. Figure 3 shows allowable dispatch modes in contingency analysis.

Non-divergent power flow solution can provide meaningful information regarding the state of the power system during severe contingencies that will typically result in a diverged power flow solution. Using this built-in algorithm in the contingency analysis process, the user can detect the portion of the power system that is experiencing severe reactive deficiency or voltage collapse.

![Dispatch mode](image)

Figure 3 - Allowable Dispatch Modes
Tripping simulation can be designed to disconnect or connect a generator or a circuit, or drop or transfer a load in response to a pre-specified criterion, such as a condition of low bus voltage or excessive branch flow, or according to the service status of a particular branch or machine. Within the automatic contingency analysis process, tripping simulation will be automatically performed and a new load flow solution obtained whenever trip sequences are triggered by a contingency. The tripping option can be applied to model special protection schemes (SPS) or simulate cascading outages in severely overloaded conditions.

Corrective action function can be applied to simulate operator actions, such as the re-dispatch of generation, curtailment of load and adjustment of phase-shifting transformers. This translates system-based reliability measures, such as the location and magnitude of branch overloads and bus voltage violations, to customer-impact indices in terms of the potential amount of service interruptions.

Post-Processing Functions in PSS™E

System problems found in a contingency analysis may include: branch flow overload, change in line loading, low and high bus voltage, network islanding and loss of load. PSS™E provides several functions to post process results for reporting.

- Single Accc run report function provides seven types of reports in either spreadsheet or non-spreadsheet format.
- Multiple Accc runs report function compares up to 9 contingency runs.
- Python programs allow users to extract data stored in contingency result files to create their own reports.
- ACCCBrowser is a stand-alone application that presents results in spreadsheet format.

Features for Probabilistic Reliability Assessment

Probabilistic reliability assessment will be provided in PSS™E-31. Probabilistic transmission reliability incorporates the impact of frequency and average duration of equipment outages on system reliability assessment. Bulk reliability measures are obtained relative to various system problems, including branch overloads, load interruptions, voltage limit violations, and voltage collapse conditions. These indices provide a better indication of power system reliability by taking into consideration the relative likelihood of different contingencies that may occur.

Figure 4 is a sample probabilistic reliability assessment report showing different levels of load lost in the system and the associated statistics.

<table>
<thead>
<tr>
<th>LOAD CURTAILMENTS</th>
<th>FREQ.</th>
<th>DURATION</th>
<th>PROB.</th>
<th>POWER INT.</th>
<th>ENG CURT</th>
<th>NO. OF CONT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENTIRE SYSTEM</td>
<td>0.8652</td>
<td>12.6</td>
<td>0.0012</td>
<td>90.6</td>
<td>632.5</td>
<td>822</td>
</tr>
<tr>
<td>0.0 --100.0</td>
<td>0.4331</td>
<td>12.4</td>
<td>0.0006</td>
<td>98.1</td>
<td>456.1</td>
<td>481</td>
</tr>
<tr>
<td>100.0 --200.0</td>
<td>0.5050</td>
<td>31.8</td>
<td>0.0018</td>
<td>180.1</td>
<td>1132.3</td>
<td>778</td>
</tr>
<tr>
<td>200.0 --300.0</td>
<td>0.0549</td>
<td>10.2</td>
<td>0.0001</td>
<td>135.1</td>
<td>2.6</td>
<td>63</td>
</tr>
</tbody>
</table>

CONTINGENCY LEGEND:

- **12_789**: OPEN LINE FROM BUS 4105 [MAINSUB 138.00] TO BUS 2110 [EAST-TIE 138.00] CKT 1
- **BREAKER_FAIL**: trip branch from BUS 1341 to BUS 1701 CIRCUIT 1
- **EAST_WEST**: trip branch from BUS 1061 to BUS 10619 CIRCUIT 1
Transfer Capability Analyses
The basic contingency analysis process can be extended to assess the steady state power transfer capabilities in a power system. Transmission transfer analysis investigates the ability of the electric system to move power from one region to another. Capability of transmission system to support power transfers is a measure of interconnected transmission system reliability. The PSS™E functions for transfer capability study include the transmission interchange limits calculation (TLTG) and interchange limits with two opposing systems (POLY). These solution engines are based on a linear power flow model, allowing users to process thousands of contingencies in an instant.

The user may also apply the full AC power flow solution engine to compute transfer limits using the PV analysis feature. The program can automatically run a series of power flow solutions under normal and contingency conditions and determine the maximum transfer level that can be achieved before voltage collapse. Another solution engine within PSS™E, for QV analysis, determines the amount of reactive compensation needed to maintain voltage stability.

The many added features in PSS™E have greatly enhanced the capabilities of the transmission planning engineers for analyzing the increasingly complex power systems that we have today.

For further reading on the subject of reliability in this issue of the Siemens PTI eNewsletter, please see the article titled Reliability Rules by Ramón Nadira and Carlos A. Dortolina.

\[1 \text{ North American Electric Reliability Council, Glossary of Terms Task Force, August 1996.}\]