Solutions for transmission network management
Spectrum Power™
Solutions for Transmission Network Management

Overview

Transmission Network Applications

Operator Training Simulator

Blackout Prevention

Summary
The Spectrum Power™ Transmission Network Applications (TNA) provide tools for the advanced monitoring, security assessment, and operational improvement of an electrical transmission network.

The Transmission Network Applications are used:
- to improve monitoring beyond SCADA
- to assess the consequences of switching actions before these are taken
- to assess the security in case of faults or outages
- to provide preventive/corrective measures against planned or existing events
- to optimize operations for costs or losses
Spectrum Power™ Transmission Network Applications

**Highlights**

- Field-proven application suite supporting utilities world-wide in ensuring the reliable and optimized operation of their transmission networks
- Focused on robustness and ease of use
- Focused on operational use – providing realistic, implementable measures
- Integrate the latest requirements in the network applications area, such as look-ahead security and situational awareness
- Configurable as a standalone system or integrated with Spectrum Power SCADA
Spectrum Power™
Transmission Network Applications

System Overview

Transmission Network Applications

- On-line
- Study
- Real time

Off-Line

Information Model Management

SCADA

External Systems (LF, COP, AGC, etc.)

One-lines

Tabulars

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Spectrum Power™
Transmission Network Applications

Operational Use – Overview

• **Real-time (State Estimator based)**
  Evaluate and manage real-time system conditions based on real-time measurements and data from SCADA, AGC, etc.

• **Study – Power Flow based**
  Analyze system conditions of interest (for example, next-day planned outages) off-line for a user-specified date and time. The base case can come from default data, a real-time snapshot, or from a save case.

• **Study – State Estimator based**
  Analyze system conditions typically related to real-time operations based on a real-time snapshot or from a save case in an off-line environment.
The Spectrum Power™ TNA suite consists of:

- State Estimator (SE)
- Network Parameter Adaptation (PA)
- Network Sensitivity (NS)
- Fault Calculation (FC)
- Security Analysis (SA)
- Security Analysis Look-Ahead (SL)
- Voltage Scheduler (VS)
- Security Dispatch (SD)
- Voltage Stability Analysis (VSA)

The following execution modes are supported:

- Manual on-demand execution of individual applications or the whole sequence of applications
- Triggered execution of the sequence, either periodically or by an event in the system (breaker operation…)

Operational Use – Real-Time
The Spectrum Power TNA suite consists of:

- Dispatcher Power Flow / Optimal Power Flow (DPF/OPF)
- Fault Calculation (FC)
- Security Analysis (SA)
- Voltage Stability Analysis (VSA)

The following execution modes are supported:

- Manual execution of individual applications
- Manual execution of an application sequence consisting of the DPF/OPF and SA applications
Operational Use – Study (SE based)

The SE based study mode is initialized from real-time or saved cases and includes the same set of applications that are used in real-time.
Operational Use – Study (SE based)
The Real-Time Sequence Control (RTSC) function provides control over the frequency and order of execution of the real-time applications. The RTSC can be triggered:

- periodically (for example, every 5 minutes)
- by a SCADA event (after a delay)
- by a user request

RTSC also supports:

- individual application execution
- enabling/disabling individual applications from executing in the real-time sequence
- controlling the frequency of execution for individual applications (for example, Network Sensitivity every 20 minutes)

The Real-Time Sequence Control function is available for real-time and the State Estimator based study.
The State Estimator provides the operator with the real-time state of the complete network, including identification of “bad” measurements (Anomalies) and operational limit violations for the reliable monitoring and control of the network. It also provides the base case for the other applications, such as Security Analysis.

Salient features of the State Estimator are:

- An orthogonal transformation algorithm, providing the capability to handle a wide range of measurement weights
- A measurement consistency check
- A Chi-Square test with normalized residual or a measurement compensation approach for identifying anomalies
- A single-pass solution of observable and unobservable areas in the network
Network Parameter Adaptation (PA)

PA uses State Estimator results to maintain a time dependent database of network data used to schedule bus loads, regulated voltages, and statuses of time dependent breakers. Exponential smoothing of the SE solution values is used to derive these data. Then, these data are used

- in the real-time execution to schedule loads and regulated bus voltages to be used by the State Estimator as pseudo-measurements or, configurable, if the measurement from SCADA is not available
- in study to schedule loads and regulated bus voltages for the user-specified study day-type and hour
Network Sensitivity (NS)

NS uses the State Estimator results to determine the network loss sensitivities against incremental changes of main company unit generation values and interchange values. These sensitivities are then:

- converted to real-time penalty factors for use by other applications (such as AGC) in real-time
- used to maintain a loss sensitivity database modeling 5 system load ranges and 5 net interchange ranges to be used by other applications in study mode. Exponential smoothing is used to derive the values in this database.

The update of the database is prevented in the case of detection of abnormal values.
Fault Calculation (FC)

FC calculates the fault current and fault current contributions for single faults and multiple faults (user selection). Fault rating violations at and near the fault are provided to the operator.

FC supports:
- Selection of fault type(s) and location(s) via the user interface
- Combining a fault with a single branch outage
- Modeling of fault impedance and fault-to-ground impedance
- Effects of mutually coupled lines
Determines the security of the network under specified contingencies (user-defined or n-1 criteria). Contingencies can be screened for security risks before being simulated in a power flow. Contingencies are ranked by the severity of the violations the contingencies cause.

SA supports:

- User-specified contingency and monitored equipment lists
- Single and multiple contingencies
- Automatic simulation of contingencies corresponding to the real-time violations
- Conditional contingencies
- Load transfer and generator reallocation
- Modeling of regulating controllers (LTC, …)
- Screening bypass
Security Analysis Look–Ahead (SL)

Provides the very same function as SA, but outages from COP are merged to the base case. Outages that are scheduled a configurable time window ahead of real time are included.

This function provides an early warning concerning the potential impact of scheduled outages on the network security. This provides time for operators to prepare preventive measures and/or to reschedule the outages.
VS determines the reactive voltage control settings (load tap changers, capacitor banks, etc.) towards eliminating or minimizing limit violations. In the absence of limit violations, VS determines these settings towards minimizing network losses.

VS is a subset of the Optimal Power Flow function for use in real-time to address specifically reactive power operating issues and improvements.
Security Dispatch (SD)

SD is used to eliminate or minimize network overloads through a number of optimal control actions such as generator re-dispatch. The set of overload constraints is automatically extended to include branch loading constraints corresponding to critically loaded branches (user specified critical loading factor).

SD can be executed in either of four modes:

- Constrained Economic Dispatch shift factors
- Closed-loop
- Open-loop
- Expanded controls

SD is a subset of Optimal Power Flow for use in real-time to address various active power operating issues and improvements.
Dispatch Power Flow (DPF)

DPF is used to evaluate the network state under various operating conditions such as tomorrow’s operating plan. It is used exclusively in study and typically in conjunction with other applications such as Security Analysis and Optimal Power Flow.

DPF solves (on user selection) using either the Fast Decoupled or Newton-Raphson algorithm. Some of the many features that DPF supports are:

- Continuous and discrete local controls (for example, generator MVAR output, LTC control)
- DC injections and branches
- Area interchange control
- Single/distributed slack, load slack and generation slack
Optimal Power Flow (OPF)

OPF is used to improve the system operation by recommending control adjustments to achieve either of the following optimization objectives:

- Security: active and reactive security optimization
- Cost: active cost and reactive security optimization
- Loss: Loss minimization
- Full: Cost optimization followed by loss minimization

Loss minimization is solved using Newton optimization. The other optimization modes use linear programming. Some of the many features supported by OPF are:

- Constraint and control priorities
- Constraint relaxation (long-to-medium/medium-to-short)
- Load shedding as a control
- Bus pair voltage / angle constraints
- Reactive reserve constraints
- etc.
Overview

The Spectrum Power Operator Training Simulator (OTS) suite provides a system for system operator trainees to perform generation and transmission dispatching functions in a simulation environment. The OTS is designed to permit training for multiple phases of system operation:

- Normal
- Emergency
- Restoration

The OTS system can be logically divided into several principle subsystems:

- Control Center Model (CCM)
- Power System Model (PSM)
- Educational Subsystem
Overview – Control Center Model (CCM)

The Control Center Model (CCM) includes a replica of the control functions in use in the EMS. Replication means that the features and UI of these functions in the EMS and OTS are identical as seen by the trainee at the console. The following functions are included in the OTS:

- Data Acquisition
- Data Processing
- Data Dissemination
- Supervisory Control
- Automatic Generation Control (AGC)
- Transmission Network Analysis (TNA) functions
- Historical Information System (HIS)
- Current Operating Plan (COP)

The EMS functions that have interaction with RTUs in the real-time environment are altered so that they interact with the Power System Model (PSM) in the OTS environment. They remain identical from the viewpoint of the Trainee.
### Functions – Control Center Model (CCM)

- Computer Network Management
- User Interface (one-line diagrams)
- SCADA Functions
  - Supervisory Control
  - Alarm Processing
- Automatic Generation Control (AGC)
  - LFC
  - ED
  - RM
- Real-Time TNA
  - Real Time Sequence Control
  - Model Update
  - State Estimator
- Study TNA (Power Flow)
- Historical Information Systems (HIS)
- Current Operating Plan (COP)
Overview – Power System Model (PSM)

The Power System Model (PSM) is a mathematical representation of the real-time electrical network. It calculates and sends realistic simulated electrical network analog and digital values to the SCADA model in the OTS environment on a 5-second periodicity.

The models of the PSM can be separated into two categories: static and dynamic.

- The **static solution** includes the simulation of transmission lines, transformers, relays, circuit breakers, etc. It includes models whose dynamics are too fast to be observed through the SCADA system data acquisition scans.

- The **dynamic solution** includes the simulation of boilers, turbines, nuclear units and the frequency response of the power system. The dynamic solution is accomplished using a numerical integration (trapezoidal method) with a time step of one second.
Overview – Power System Model (PSM)

- Load Model
- Protective Relay Model

**STATIC SOLUTION**
- Circuit Breaker Switching
- Network Topology Processing
- Bus Load Calculations
- Solve power flow on full system

**DYNAMIC SOLUTION**
- Island Load Calculations
- External AGC Model
- Advance Integration Time Step
- Frequency Model
- Power Plant Models
- Transformer Model
Models & Functions – Power System Model (PSM)

- Load/Feeder Model
- Power Plant Models, including:
  - Combined Cycle
  - Renewable Energy (Wind, Solar)
  - Battery Storage
- Multi-Island Frequency Model
- Transformer Model
- External AGC
- Protective Relay Models
  - Over/Under Voltage
  - Volts/Hz
  - Inverse Time Overcurrent
  - Over/Under Frequency
  - Over/Under Excitation
  - Synchro-check
- Automatic Reclosure
- Fast Acting Protection
Features – Control Center Model (CCM) / Power System Model (PSM)

- Simulation Fast/Slow
- Training Session Record/Playback
- Short Circuit Calculations for Fast Acting Relays
- Relay Alarms
- Generalized PSM to SCADA Mapping
Overview – Educational Subsystem

The Educational Subsystem provides a means for the Instructor to create and manage training scenarios. Instructor Displays provide the Instructor the capability to:

- Create base cases and events, which together form scenarios.
- Manage the flow of the training sessions - starting, stopping and taking snapshots as necessary.
- Evaluate the Trainee’s performance at the end of a training session.
### Spectrum Power™
Blackout prevention I

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<td>• Increasing exploitation of transmission systems – closer to stability limits</td>
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<td>• Integration of increasing shares of renewable energy resources in distribution grids</td>
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<td>• Identification of current system stability threats in real-time</td>
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<th>Siemens solutions</th>
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<tr>
<td>• SIGUARD® PDP software for visualization and analysis of PMU (Phasor Measuring Unit) data</td>
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<tr>
<td>• Supporting international standards for data input (IEEE C37.118) and output (IEC 60870-6 ICCP)</td>
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<td>• Limit monitoring for phase angles between selected power system busses</td>
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<td>• Modules for the detection and identification of potentially dangerous swings</td>
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<td>• Immediate detection of system islanding</td>
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<tr>
<td>• Calculation and display of Status Value for the power system</td>
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<td>• Geographical View (Google Earth based), Charts View, and Measurement List (CSV-Export, configurable)</td>
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<th>Customer benefits</th>
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<td>• Situational awareness of current system stability conditions</td>
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<td>• Identification of problem areas through After-the-fact analysis of past situations</td>
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<td>• Alarming of potentially dangerous situations</td>
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<td>• Capability to integrate with SCADA environment</td>
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SIGUARD® PDP
Wide area monitoring in transmission networks

Scenario – TSO – Detecting Potentially Dangerous Swings

Wide Area Monitoring
- Visualization and analysis of PMU (Phasor Measuring Unit) data collected from selected substations
- Identification of excessive phase angle spreads
- Secure detection of potentially dangerous swings
- Fast detection of network islanding

More generation connected at remote places
Sudden, strong events stimulate controller actions
Wide-area power transfers increase the risk of swings
SIGUARD PDP identifies and visualizes dangerous swings
Stored real-time data helps system planners determining remedial measures

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Challenges

- Find new ways to manage transmission systems already running close to stability limits
- Integrate increasing shares of renewable energy resources within distribution grids
- Identify current and upcoming threats to the system stability in real-time
- Determine viable remedial measures

Siemens solutions

- SIGUARD® DSA software provides automatic and intelligent dynamic security assessment to calculate the stability margin and validation of remedial actions in real-time
- Support international PSS/E standard for data interfacing
- Cover all possible stability phenomena: Voltage, Transient and Small Signal Stability
- Intelligent results analysis based on the experience of power system dynamics experts, and customizable to the specific needs and technologies of different power systems
- Short-term forecasts of loads, generation, and switching actions prepare for future scenarios, giving operators more time to analyze the situation and proposed remedial actions

Customer benefits

- Situational awareness of current and upcoming system stability conditions
- A range of ready-to-implement measures to prevent or, if needed, remedy dangerous situations
- Complete coverage of potential instability phenomena
- Intuitive user interface, specifically designed for control room purposes
- Potential integration with the SCADA environment
**Real-time Dynamic Stability Assessment**

- Simulate dynamic contingencies for current and forecasted situations
- Avoid large scale outages
- Make use of all transfer capacities
- Define and verify countermeasures

**Example: Germany**

2030: Generation far from load

- Voltage-Problems
- Power-Swings
- Contingency
- Nuclear plant retirement
- New fossil power plants
- Offshore-Windparks
Real-time Dynamic Stability Assessment

- Simulate dynamic contingencies for current and forecasted situations
- Avoid large scale outages
- Make use of all transfer capacities
- Define and verify countermeasures
- Visualization of actual and future status of the system security
- Validation of possible remedial actions & proposal of the successful

Actions required in 75 minutes!

Reason: Voltage problem

Possible actions
1. Re-dispatch ➔ Status: OK
2. Topology change ➔ Status: OK
3. Load shedding ➔ Status: not advised
Summary

- With Transmission Network Applications you have a **set of versatile load flow optimization tools in your hands** – seamlessly integrated in Spectrum Power™ SCADA/EMS for real-time use and operation planning.
- Transmission Network Applications is focused on **operational robustness and ease of use** - providing realistic, implementable measures.
- Transmission Network Applications help you to:
  - **Minimize network loads and losses** under given equipment constraints and load / generation patterns.
  - **Early detect system stability threats** and evaluation of potential countermeasures.
Summary

- With an Operator Training Simulator (OTS), it has become possible to **improve the quality of training** for power system Operators.
- Since Operators may be exposed to **simulated emergency and restorative conditions** on the OTS frequently and at will, as opposed to rarely and by chance on the job, the time required to train a new operator may be significantly shortened.
- Similarly, with an OTS it becomes possible to expose existing Operators to emergencies and restoration procedures as part of refresher training.
- With an OTS, it is possible to achieve and to maintain a **high level of operational readiness** among power system Operators.
Successfully implemented – today.

Thank you.