Solutions for distribution network management
Outage Management (OM)

The Outage Management is a **core application** of Spectrum Power™ Advanced Distribution Management System (ADMS) providing the following functions:

- Outage Management
- Trouble Call Management
- Crew Management
- Storm Management
- Mobile Outage Management
Outage Management (OM)

Provides a collection of functions, tools and procedures for an operator or dispatcher to manage

- **Unplanned Outages** - fast and easy detection, location, isolation, repair and restoration of faults which occur unexpectedly on the utility electric network

- **Planned Works** - facilitate the preparation and resolution of planned network changes
Typical causes for faults are incidents like storm, snow, falling trees or accidents.

Leading to indications processed by Outage Management:

- Trouble calls from customers
- Power supply interruption indication by smart meters
- Telemetered status change indications from switches
- Manual switch operation updates
Planned Work

- Planned Works are usually prepared by a planning engineer in the back-office and executed on a scheduled time and date by the operator.
- Planned Works summarizes all activities for maintenance of network elements and changes of the network configuration.
  - Feasibility
  - switch plan definition
  - notification of affected customers
  - timely execution scheduling
Outage Management (OM)

- **Fuzzy calls** - maintenance and verification tasks of incoming trouble events that cannot be automatically mapped to a network asset (e.g. street light disturbance)

- **Storm Mode** - during certain peak conditions (e.g. extreme weather conditions) as plenty of outages occur the operator needs guidance and focusing on most important events

- **Prediction Module** and **Rules Engine** - provides evaluation of trouble calls from different sources and is able to build the relation to the network assets
Outage Management provides the ability to handle calls that can not directly be linked to a customer or other sort of premise e.g. a street light dropped out at a certain street.

These kind of calls are grouped under the rubric fuzzy calls and can be displayed on the Geo Spatial Display.

The operator can assign a service crew or group them to other outage events, service points / transformers.
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Outage Management

Prediction Engine

- Trouble tickets are generated by external or internal interfaces.
- The Prediction Engine evaluates incoming trouble calls from different sources in order to identify the related outage location.
- Trouble events are assigned to a service point or to an existing outage record.
- Engineering of prediction rules.

![Diagram showing the flow of prediction engine]
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Outage Management – Outage Prediction (simplified)

110 kV

Substation

T1
Substation Transformer

CB1

T2
Substation Transformer

CB2

20 kV

Substation

FT1

CB3

S1

T3
T4
F1

10

6

Field crews verifies the outage & operator changes outage status.

Single customer call

Confirmed Local Service Outage

10 6

2

7 3

F1
Several customer calls

Confirmed Transformer Outage

Field crew verifies the outage & operator updates switch position
Several customer calls

Confirmed outage at protective device

Field crew verifies the outage & operator updates switch position

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Fuzzy Call: a call that does not refer to a specific customer installation e.g. 'fallen tree hits overhead line' → Fuzzy Call

Fuzzy calls come in → fuzzy outages are created

Field crew identifies the reason of the fault e.g. protection tripped → an outage is created

... or: operator identifies an already existing outage the calls are related to

Operator assigns the fuzzy calls to the outage.
Storm Mode

- During extreme weather conditions / storm events the control system responds adequately and provides the ability to **handle the very large number of trouble calls** from customers or by smart meters
- With a dedicated **Storm Mode User Interface** operators can easily redefine distributed storm areas using the system’s listing of various storm mode events and types
- By activating the storm mode the Outage Prediction Engine will change the rule settings appropriate to guide the operator in the **fast and optimized restoration activities**
Outage Management implies a wide range of supporting functions:

- Customer call back registering
- Web based user interface
- System reliability indices
- Standard reporting tool
- Export to Excel
- Standardized SOA interface to external applications
Outage Management builds a relationship between network information and customer information

- Analysis of trouble calls
- Graphical displays of trouble calls
- Filtering of affected customers
- Archiving of taken measures
- Creation of work orders
- Dispatching crews
- Comprehensive outage details
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OM User Interface

- Summary of all outages
- Summary of currently outaged equipment
- Summary of Trouble Call Events
- Summary of affected customers (incl. priority customers and life support customers)
- Summary of crews
- Summary of Grid impact (e.g. lost kW)
- Display for individual outages (Unplanned outage, Planned work, Fuzzy call)
- Creation of new outages
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Trouble Call Management

- Provides convenient access to information necessary for tracking trouble calls
- Assists the operator in answering and recording customer telephone calls (which indicate loss of supply and other problems in the field)
- Supports searching for customers and address/cross streets
- TCM works closely with Outage Management (OM) for outage identification, tracking and resolution
Crew Management

- Assigning and tracking work schedules for utility field crews
- Crew Composition
  Assignment of people and equipment to the crew
- Overview of current and planned tasks by crew
- Crew Tracking
  Support of crew and truck location
- Outage Management Interface
  Assignment of crews to outages
Mobile Outage Management

• The Mobile OM gives local field crews the mobility and flexibility to handle tasks efficiently.
• Crews receive tasks from the operator and forward task progress information to the operator via mobile device.
• Manage tasks and send status updates
• Update crew position data
• Display Google maps and use navigation functionality
• User administration
• Offline mode / synchronization capability
Outage Management Reports

- Performance Indices report providing supply interruption information according IEEE definition.
- Outage Management reports containing outage summary overviews as well as detailed information on individual outage reports.
- Reports can be viewed and saved in different file formats (e.g. Pdf, Excel, Word, etc.)
Outage Management Dashboard

- Dashboards contain concentrated information e.g. comprehensive outage summaries, trouble level information, performance indication values.

- Allowing management and OM operating personal to gain a fast overview on the current outage situation.
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Seamless interaction to handle outages fast and efficiently

Handle trouble calls
Review outage details
Manage crews
Isolate and restore faults
Analyze values
Create and execute switching procedures
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Outage Management

Integration with MDM

- Out-of-service notifications (last gasp) - Meter events are mapped to customers and/or distribution substation – visualization on map using coordinates – processing with OM outage prediction
- Back-to-service notifications (first breath)
- ADMS operator or application pings specific meters to verify power outage - visualize “no power” status on map
- ADMS operator or application pings specific meters to verify power after service restoration
- Storm Mode / Outage notification from OM to MDM for intelligent filtering of messages
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Distribution Network Applications

Overview
Outage Management
Fault Management
Distribution Network Analysis
Summary
Spectrum Power™
Fault Location

Fault Location (FLOC)

• Handles outage faults (i.e. short-circuit faults) and non-outage faults (i.e. earth faults)
• Triggered on state change of fault indicators and feeder CB’s unexpected tripping
• Fast localization of faulty section
• Designed to determine the smallest possible faulted section based on available real-time information
• Essential to restore supply fast and to as many customers as possible
• Uses remote metered and manually updated information such as:
  • Protective devices’ tripping (CB’s, re-closers, etc.)
  • Status of fault passing indicators
  • Status of earth fault relays
  • Fault information from impedance fault relays
Fault Isolation and Service Restoration (FISR)

Once the faulty segment has been identified (e.g. by fault location module):
- Fault Isolation and Service Restoration module identifies the best way to isolate the faulty segment
- Fault Isolation and Service Restoration module identifies the best way to restore power to all related non-faulty segments

- Minimizes the outage time for the affected customers
- Establishes the series of required switching operations
- Used also for outage planning (equipment isolation for planned maintenance)
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**Fault Location / Fault Isolation and Service Restoration – Use Case**

**Fault Location locates fault**
- Fault Location gets triggered by a circuit breaker trip
- Fault Location determines the faulted area based on all available information
  - status of fault passing indicators
  - Status of earth fault relays
- Fault information (impedance) from fault relays

**Run Fault Isolation and Service Restoration**
- Faulted area (affected equipment) is automatically forwarded from Fault Location to Fault Isolation and Service Restoration
- User manually starts Fault Isolation and Service Restoration
  - Select Isolation and immediate restoration
  - Specify if the calculation shall include power flow validation

**Forward solution to Switching Procedure Management and execute**
- Fault Isolation and Service Restoration proposes switching actions to isolate the faulted area and restore power to as much affected customer as possible
- User may review the proposed changes/optimization
- The switching actions are forwarded as switching procedure to SPM (Switching Procedure Management)
- The switching actions are executed with SPM
Distribution System State Estimator

- Distribution System State Estimator estimates loads (active and reactive power) based on existing measurements using weighting factors for measurements and loads
- Distribution System State Estimator calculates voltages for all busbars, flows through lines and transformers (active and reactive power and currents) and active and reactive power losses
- Distribution System State Estimator is used to assess the real-time operating conditions of the distribution network and monitor for overloads and/or voltage limit violations
- Solves for both, balanced representation of the network (i.e. positive sequence only) and for three phase unsymmetrical representation of the network
- Operation from and Visualization in the one-lines
- Executes periodically, on event and on demand

✓ Used to identify gross measurement errors and measurement inconsistencies
✓ Provides an improved load model via Short Term Load Scheduler
✓ Provides a reliable basis for optimal network operation
**Distribution System State Estimator**

- Continuously calculates network
- Checks for violations
- User analyzes violations

**User analyzes violations**

- Distribution System State Estimator runs cyclically / triggered by topology changes
- Distribution System State Estimator calculates voltages, active and reactive power, etc. based on available measurement and the load schedules
- Checks for overloads and voltage limit violations
- Detected violations are reported as alarm
- The violated equipments are highlighted in the single line diagrams with defined color
- User may navigate from the violation alarms to the single line diagram to locate the violated equipment
- User may request detailed Distribution System State Estimator results via query from the single line diagram

**Bus violations**

<table>
<thead>
<tr>
<th>Name</th>
<th>Violation type</th>
<th>Voltage solved [p.u.]</th>
<th>Limit [p.u.]</th>
<th>Violation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>/Net-E/Net_Companies/EU-51/EU-51/11 kV/BB_11_1</td>
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<tr>
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<td>Long</td>
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</tr>
</tbody>
</table>
Distribution System Power Flow

• Distribution System Power Flow calculates voltages for all busbars, flows through lines and transformers (active and reactive power and currents) and active and reactive power losses
• Distribution System Power Flow checks for equipment overloads and violation of voltage limits
• Distribution System Power Flow is used to study electric power distribution networks under various loading conditions and configurations
• Distribution System Power Flow is used to support planned and unplanned outage switching procedures
• Solves for both, balanced representation of the network (i.e. positive sequence only) and for three phase unsymmetrical representation of the network
• Operation from and Visualization in the one-lines

✓ Used to study “what if” scenarios
✓ Used to support operator’s training together with other applications
### Spectrum Power™
Distribution System Power Flow – Use Case “Validate Switching Procedure”

<table>
<thead>
<tr>
<th>Switching procedure is executed in a study</th>
<th>Distribution System Power Flow checks for violations</th>
<th>User analyzes violations</th>
</tr>
</thead>
<tbody>
<tr>
<td>- A switching procedure is executed in a study, i.e. based on a save case</td>
<td>- Distribution System Power Flow checks for overloads and voltage limit violations</td>
<td>- User may view violations and navigate to the single line diagram to locate the violated equipment</td>
</tr>
<tr>
<td>- Distribution System Power Flow runs on the resulting topology and calculates voltage, active and reactive power, etc.</td>
<td>- Detected violations are reported in the violation list</td>
<td>- User may request detailed Distribution System State Estimator results via query from the single line diagram</td>
</tr>
<tr>
<td></td>
<td>- The violated equipments are highlighted in the single line diagrams with defined color</td>
<td></td>
</tr>
</tbody>
</table>
Short Term Load Scheduler maintains load schedules that provide the load data for power flow calculations.

Input Data:
- Initial nominal loads and typified static load curves.
- Load values provided by Advanced Meter Infrastructure (AMI)
- Results of the Distribution System State Estimator

Processing:
- Recursively calculates a short term load schedule as an exponentially smoothed aggregation of values of the past as well new load values and measurement data.

Results:
- Maintains an adapted data base of load schedules (e.g. 7 days / 15 minutes interval)
- Provides schedule of the loads for a specified day on a quarter hourly basis
Short Circuit Calculation

- Short Circuit Calculation calculates currents that are results of a short circuit due to a fault or an incorrect connection in an electric network. It calculates:
  - **Maximum short-circuit current** which determines the rating of electrical equipment.
  - **Minimum short-circuit current** as basis for the protection sensitivity checking or fuse selection.
  - **Fault current** calculation at selected location.
  - **Earth fault current** for ungrounded networks.
- Short Circuit Calculation provides 2 calculation modes
  - **Single calculation** for selected location and specified type of short circuit for manual check of equipment.
  - Calculation in **screening** mode for multiple short circuit locations and simulated faults for continuous monitoring of the network.
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Short Circuit Calculation – Fault Types

- **3-phase short circuits** without ground connection (L-L-L)
- 3-phase short circuits with ground connection (L-L-L-G)

- **2-phase faults** without ground connection (L-L)
- 2-phase faults with ground connection (L-L-G)

- **1-phase to earth** (L-G) – 1-phase-to-ground fault or zero sequence capacitance current.
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Short Circuit Calculation – Screening Mode / Single Mode

**Screening Mode**

Continuous evaluation of short circuit effect via automatic execution
- cyclic – fault calculation for entire network
- triggered by topology change – for respective network area

Calculations and checks
- Calculates (maximum) short circuit currents at busbars
- Breaking capability check: *Is the breaking capability of the breakers/fuses sufficient?*
- Protection sensitivity check: *Are the relay protection settings for breakers/fuses OK?*
- Earth fault current check: *Are the earth fault currents for the busbars within the specified limits?*

**Single Mode**

Evaluate selected fault current via manual execution
- Simulate short circuit for selected equipment, selected type of short circuit, type of calculation, ...

Calculations and checks
- Short circuit currents at short circuit location and on all lines, transformers of the related network
- Voltages at short circuit location and on all busbars of the related network
- Circuit breakers where short circuit current exceeds the breaking capability
- Circuit breakers where short circuit current is below the value that triggers the circuit breaker
- Ground fault current and violations at the fault location
Optimal Volt/Var Control

• The Optimal Volt/Var Control application provides distribution network optimization, typically loss minimization, using voltage and VAr controls, i.e. respectively Load Tap Changers/Line Voltage Regulators and Regulating Capacitors.

• This optimization consists in minimizing an objective function that is user selectable as one or any combination of the following sub-objective functions:
  
  • **Minimize losses**
  • **Minimize active power consumption**
  • **Minimize reactive power consumption**

• The optimization is subject to the network constraints, i.e. the load flow equations and the operational, e.g. voltage, transformer, etc. limits.
Optimal Volt/Var Control

- Optimal Volt/Var Control is executed periodically and upon events in the real-time context and on user request in the study context.

- Execution in 2 distinct modes:
  - **Open loop** - In this mode all settings are stored in SPM for implementation
  - **Closed loop** - In this mode all settings are automatically implemented via SCADA (using exclusively remotely controllable devices)
Optimal Volt/Var Control

- The Optimal Volt/Var Control application maintains the operational limits, e.g. voltage, transformer, etc. while minimizing an objective function that is user selectable as one or any combination of the following sub-objective functions:
  - Minimize losses
  - Minimize active power consumption
  - Minimize reactive power consumption
- The Optimal Volt/Var Control application provides distribution network optimization, using voltage, VAr or watt controls, i.e. respectively Load Tap Changers/Line Voltage Regulators and Regulating Capacitors, Batteries and Flexible Loads; thus it provides interfaces to new technologies like Demand Response Management Systems.
- In this use case the Optimal Volt/Var Control application preferably executes in Closed Loop mode.
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Optimal Volt/Var Control – Use Case “Voltage stabilization”

**DSSE detects violations**

- Network is monitored continuously by Distribution System State Estimator
- Voltage violations are indicated in single line diagram and reported as alarm

**Run VVC**

- **Manual start**
  - User selects violated equipment, defines objective and other settings and starts Optimal Volt/Var Control

- **Automatic start**
  - Distribution System State Estimator violations trigger Optimal Volt/Var Control, which runs with preconfigured settings

**Forward solution to SPM and execute**

- Optimal Volt/Var Control proposes switching actions for volt / var controls to improve the voltage profile
- User may review the proposed changes/optimization
- The switching actions are forwarded as switching procedure to Switching Procedure Management
- The switching actions are executed with Switching Procedure Management
Optimal Feeder Reconfiguration

- Optimal Feeder Reconfiguration determines the optimal radial distribution network configuration, means the specification of the normally open switches, accounting for equipment loading limits, voltage limit, and feeder losses. The user may select any combination of the following individual objectives:
  - Minimize violations
  - Minimize active power losses on feeders
  - Load balancing among supply substation transformers
- Optimal Feeder Reconfiguration is particularly effective in Large Area Restoration (LAR). LAR determines the restoration plan for supplying large parts of the distribution network, which are de-energized after a fault occurrence or maintenance work.
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**Optimal Feeder Reconfiguration – Use Case “Reduce violations”**

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**Distribution System State Estimator** detects violations

- Network is monitored continuously by Distribution System State Estimator
- Violations are indicated in single line diagram and reported as alarm

**Run Optimal Feeder Reconfiguration**

**Manual start**
- User selects violated part, defines objective and other settings and starts Optimal Feeder Reconfiguration

**Automatic start**
- Distribution System State Estimator violations trigger Optimal Feeder Reconfiguration. OFR runs with preconfigured settings

**Forward solution to Switching Procedure Management and execute**

- Optimal Feeder Reconfiguration proposes switching actions to reconfigure feeder
- User may review the proposed changes/optimization
- The switching actions are forwarded as switching procedure to Switching Procedure Management
- The switching actions are executed with Switching Procedure Management

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### Line violations

<table>
<thead>
<tr>
<th>Name</th>
<th>Violation type</th>
<th>I from [A]</th>
<th>Limit [A]</th>
<th>Violation [%]</th>
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</thead>
<tbody>
<tr>
<td>Net-E Infra Companies/EU-SI/SIPO/33/20 kV/UNO1_SIPE Short</td>
<td>Stall</td>
<td>644.40</td>
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<td>345.00</td>
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### Switching proposal

<table>
<thead>
<tr>
<th>Order</th>
<th>Step</th>
<th>Switch name</th>
<th>Action</th>
<th>Type</th>
<th>Power losses [kW]</th>
<th>Transformer imbalance [%]</th>
<th>Overload [A]</th>
<th>Effect [%]</th>
<th>Temporary</th>
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<tr>
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<td>1</td>
<td>Net-E Infra Companies/EU-SI/SIPO/33/10008_SIPE</td>
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<td>3</td>
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<td>0.00</td>
<td>0.09</td>
<td>0.09</td>
<td>YES</td>
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</tbody>
</table>
Benefits for the Distribution Utilities from Distribution Network Analysis

- Improve the dispatchers’ ability to observe the distribution grid during normal, abnormal, and emergency conditions
- Consistent management of planned (maintenance) and unplanned (disturbance) outages
- Improve quality of service and customer relations by responding to service interruptions more rapidly
- Reduce operating costs by optimal use of field crews, improved power system efficiency and reduced technical losses
- Reduce outage times and lost revenues
- Improve the personnel safety
- Comprehensive overview of outages and planned works
- Interfaces to external systems
Thank you.

Successfully implemented — today.