

Oracle Utilities Network Management System

Advanced Distribution Management System
Implementation Guide

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Oracle Utilities Network Management System Advanced Distribution Management System
Implementation Guide, Release 2.5.0.2.0

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Contents

Chapter 1

Introduction	1-1
Glossary.....	1-1

Chapter 2

OMS Modules	2-1
Data Model	2-1
SCADA Adapters	2-1
Trouble Management & Events	2-2
Web Switching	2-2

Chapter 3

ADMS Modeling	3-1
Sources of Data	3-1
Default Data	3-2
Data Categories.....	3-2
Sources	3-2
Loads.....	3-3
Load Profile Data	3-3
Transformers (and Voltage Regulators)	3-4
Capacitors (and Reactors)	3-6
Distributed Energy Resources (DERs).....	3-6
Distributed Energy Resource Profiles.....	3-7
Switches and Fuses	3-8
Conductors	3-9
Split Model	3-10
Phasing Information	3-11
Nominal Voltages.....	3-11
DER and Weather Zone Forecasts	3-12
Weather Zones.....	3-12
Large Scale Utility DERs	3-13
Demand Response Groups	3-13
Seasonal and Temperature Based Limits.....	3-14
Seasonal Based Limits	3-14
Temperature Based Limits	3-14

Chapter 4

ADMS Applications Overview	4-1
Configuration	4-2
Configuration Assistant.....	4-2
Event Management Rules	4-2

Chapter 5

Power Flow & Feeder Load Management (FLM)	5-1
Power Flow and Other Applications	5-1
Viewer	5-1
Web Switching	5-2
Feeder Load Management	5-2
Power Flow Mode (PF Mode)	5-3
FLM Mode	5-3
Performance	5-4
FLM Island Statistics Window	5-4
Sanity Checking	5-7
Solution Details	5-7
Conductor Mismatch Tool	5-8
Data Requirements	5-9
Model	5-9
SCADA	5-9

Chapter 6

Fault Location, Isolation and Service Restoration (FLISR)	6-1
Configuration	6-2
Power Flow Mode (PF Mode)	6-2
FLISR Mode	6-2
Performance	6-3
Data Requirements	6-4
Model	6-4
SCADA	6-4

Chapter 7

Fault Location Analysis (FLA)	7-1
Configuration	7-1
Performance	7-1
Data Requirements	7-2
Model	7-2
SCADA	7-2

Chapter 8

Optimization (formerly VVO)	8-1
Configuration	8-2
Feeder Type	8-2
Optimization Mode	8-3
Optimization Objective	8-3
Performance	8-4
Data Requirements	8-4
Model	8-4
SCADA	8-5
Bellwether Meters	8-5

Chapter 9

Suggested Switching	9-1
Configuration	9-1
Performance	9-1
Data Requirements	9-2

Model	9-2
SCADA	9-2

Chapter 1

Introduction

This guide provides an overview to implementing the Advanced Distribution Management System (ADMS) modules of Oracle Utilities Network Management System (NMS).

This is intended to be a high-level overview that will allow implementers to make decisions about data requirements, order of deployment, application scope and training requirements. It is intended to be a "quick start" guide; more detailed information is presented in the "DMS Fundamentals" and "DMS Configuration" training courses offered by Oracle Utilities.

Glossary

Wherever possible this guide uses terms that are standard across the industry. Inevitably regional and national differences exist. This section describes terms as used throughout this document:

Connected kVA: An unbalanced 3-phase solution of the current flows on a radial feeder. Sometimes known as the "Ladder Solution". The load flow is determined by simply summing up all downstream loads.

Distribution Xfmr: The location where primary voltages are dropped to secondary voltages. Sometimes referred to as service xfmr.

Electrical Island: A subset of the network model of devices & feeders that are electrically connected. These islands can be energized (if they contain a source object) or de-energized. Most frequently, network models are divided into islands that contain whole substations with no interconnections. This term shouldn't be confused with the expression Islanded, which typically refers to a section of network isolated from the main supply and sustained by distributed generation.

Equivalent Source: Start of energization for an island. In ADMS applications they encapsulate the entire upstream network as a single Thevenin source.

Load: The part of the network model where customer load is accounted for in Load Flow analysis. Depending on the extent of the network that is being modeled in NMS this could any number of locations. Typical locations include: Distribution Xfmr, LV feeder Head, Customer Meter or a virtual device used to aggregate load.

Load flow: A generic term for determining the flow of power in a network. This can be Powerflow, kVA Solution or Connected kVA.

kVA Solution: An unbalanced 3-phase solution of the current flows in an island. The solution does not consider losses and voltages are therefore nominal throughout the solution.

Operator: A user of the NMS system. The actual role might be dispatchers, controllers, planners, and so on.

Powerflow: A rigorous unbalanced 3-phase solution of the voltages and current flows in an island.

Power Xfmr: Any transformer in the Transmission, Sub-Transmission or Distribution parts of the network that does not have LV voltages on the secondary winding.

Chapter 2

OMS Modules

This chapter provides an overview of the Outage Management System (OMS) modules that are used to varying extents by Distribution Management System (DMS) applications.

Data Model

Oracle Utilities Network Management System shares a common model between the OMS and DMS modules. If a customer decides to implement DMS functionality they will need to layer engineering attributes (for example, impedances, voltage, ratings, and so on.) onto the existing OMS connectivity model such that a power flow analysis can be conducted. If desired the engineering attributes can be pulled from 3rd party data such as GIS, planning system, and so on. Since the model is common between the OMS and DMS modules there are no requirements to implement a synchronization process between these two systems.

Module specific data requirements are discussed in later sections.

SCADA Adapters

SCADA adapters are responsible for bringing real-time data from the field into the NMS system. The DMS modules benefit from (and sometimes require) this data. In particular, they will leverage:

- Device status (Open, Closed)
- Fault Indicators
- Recloser Lockout Status
- Voltage
- Current (Amps)
- Active Power
- Reactive Power
- Fault Currents

In addition some modules will need to be able to control field devices. In particular:

- Device Status (Open / Close, On/Off)
- Recloser Lockout Suppress
- Tap Positions
- Set Point values - voltage or power output targets
- Demand Scan

A number of product adapters are offered which support industry standard protocols, such as: MultiSpeak and ICCP.

Projects can also implement the Oracle Generic SCADA adapter (RDBMS based) or custom adapters to suit specialized needs as required.

Whilst called "SCADA Adapters" there is no particular requirement for them to be interfaces to SCADA systems. Virtually any reasonable real-time data gathering/field control system can be integrated via an appropriate adapter.

Trouble Management & Events

The DMS applications will create events that can be seen in the regular Operator Workspace applications, such as Work Agenda and Event Details.

Operators that are familiar with the OMS applications will be immediately comfortable as DMS modules are added. Filters can be created to route DMS related events to operators with specific roles.

Events that can be created by DMS applications include:

FLISR Event: Created when an unsolicited outage (with lockout) is reported by SCADA. FLISR attempts to find a way to isolate the fault and restore service via SCADA controllable sectionalizers.

Fault Event (FLA): Created when a device reports a momentary or sustained outage as a result of a field fault (fault current reported). FLA attempts to predict the location of the event based on reported fault currents.

Optimization Event: Created when an optimization opportunity has been detected. The Optimization module makes suggestions to perform Loss Minimization, Power Factor Correction, Conservation Voltage Reduction or Overload Relief optimizations.

DER Event: Created when a problem is forecasted or detected for a Distributed Energy Resource. The scenarios include: Current or future overload of the device's capacity/rating, Current or future expiration of the device's fuel supply. Typically these events are generated for only utility and commercial scale DERs where fuel and generation capacity are known, behind the meter DER units are not monitored to the same extent.

Web Switching

Whenever a DMS application needs to perform switching in the field it does so by creating a switch plan in Web Switching. Depending on the mode of operation, these plans might require operators to authorize and execute field device changes (open/close, tap raise/lower, capbank on/off, and so on).

DMS modules that can create switch plans include: FLISR, Load Shedding and Optimization.

Chapter 3

ADMS Modeling

The section provides a high-level description of the Advanced Distribution Management System (ADMS) modeling requirements. It is intended to help implementers understand the type of information required and allow them to determine where in their organizations they might look to source this data.

More detailed information can be found in the following documents:

- ADMS Modeling Requirements
- NMS Configuration Guide
- OPAL Powerflow Engineering Data Workbook
- OPAL Model Workbook

Sources of Data

All ADMS applications read their data from the NMS model, therefore the ADMS specific data must be brought into the model. Typically this is done through the NMS model build process.

The model build process is configured using the same "NMS Distribution Model" Workbook that implementers are already familiar with. There are tabs in the Model Workbook that cover DMS related data, for example: pf_dist_gens, pf_xfmrs and the sources for each data element can be configured and/or defaulted.

In addition, there is a "Powerflow Engineering Data" workbook. This workbook can be used as a source of data and is intended for data which has to be managed by the NMS support team because there is no easily accessible source of the data. Ideally all data would be sourced from well managed sources within the organization and there would be no need to use the Powerflow Workbook. However, in practice some data can be hard to obtain, or update automatically and, therefore, the Powerflow Workbook gives a convenient way to manually manage this data.

In general, it is not intended that the Powerflow workbook be the source of default data. Wherever possible, defaults should be provided in the Model workbook; the Powerflow workbook is used to manage known instances of data. Typically, logic is added in the model workbook to look for data in the following order on a device by device or even an attribute by attribute basis:

1. Check if GIS data exists for a device/attribute
2. Check if Powerflow Workbook data exists for a device/attribute
3. Use a hard coded default value

Default Data

ADMS applications consume significantly more data elements than Outage Management System (OMS) applications. Providing all the data can be a significant effort with varying degrees of return on the effort necessary. However not all data is required by each application. In some cases, the presence of data will improve the functionality or predictions. In some cases, sufficient accuracy can be provided by defaulting data.

There are two broad approaches that can be taken to determining defaults:

1. **Reasonable Values:** Providing reasonable values for data will allow the application to run and provided reasonably accurate analysis. For example for a 1000 kVA Xfmr, it might be reasonable to default Leakage Reactance to 4%. For most applications, this is non-critical value and 4% represents a reasonable estimate.
2. **Unreasonable Values:** Some data elements are more critical and require a precise value to render any analysis as useful. In this situation, it might be best to supply a completely unreasonable value for the defaults so that the validation checks performed in DMS applications will immediately alert administrators or operators to a missing piece of data. For example it might be critical to generate overload warnings for a Power Xfmr in a substation, if the device is missing its ratings value then it would be good to set it to an unreasonable default (for example, 1kVA) so that violations are always reported and the users can see the device has unreasonable data.

Data Categories

The ADMS applications use the following data categories. Full details can be found in the Modeling Workbook and the "DMS Modeling Requirements" document.

Sources

Location:	pf_sources table
Required for:	Providing source energization into the model
Used by:	All ADMS modules to determine energization sources
Notes:	Generally default data is acceptable though FLA accuracy is dependent on getting impedances correct.

Loads

Location:	pf_loads table; ultimately used in the pf_loads_profile_view, which combines the loads with their load profile data. The pf_loads_profile_view table is a near replica of the pf_loads table with the exception of the profile_id column. If no data exists for a device in the pf_loads_profile_override the profile_id data will come from the pf_loads table but as soon a device is populated with a value in the pf_loads_profile_override table the profile_id data will come from that table instead. Please see the Load Profile Data section below for more information.
Required for:	Modeling the point of consumption of energy
Used by:	All ADMS modules to determine where power is utilized
Usage:	Aside from SCADA measurements, the flow of power around the network is determined by the expected load size at each point of consumption. Therefore accurate load data is particularly important for Load Flow accuracy. Additional the mixture of Constant Power, Constant Current and Constant Impedance load is important in optimization applications for determining optimal configurations.

Load Profile Data

Location:	pf_load_interval_data: Contains default, customer class, and/or device specific load profiles. Data within this table can come from the Power Flow Engineering Data workbook and/or the NMS Profile Adapter. Typically default profiles and customer class profiles will be defined in the Power Flow Engineering Data workbook and imported into this table. These records will have a default indicator set within the table. The Profile Adapter can also be setup to write to this table with device specific profiles. The adapter will not touch any profiles that are marked as a default. pf_loads_profile_override: This table is only written to by the NMS Profile Adapter and is used to mark which profiles have been loaded by the adapter and are device specific. This is used to override the value in profile_id within table pf_loads. For example, a load may initially be configured with a profile_id of "Residential" but once the adapter loads a specific profile for the device a value will be placed in table pf_loads_profile_override of "T10520". Once this takes place the view pf_loads_profile_view which is a combination of pf_loads and pf_loads_profile_override will pick up the fact a specific profile is available and the profile_id column will be populated with data from pf_loads_profile_override instead of pf_loads. pf_loads_profile_samples: This table is only written to by the NMS Profile Adapter and is used to track how many times different day type/hour/temperature combinations have been sampled. The frequency at which certain data points have been sampled is used in the averaging algorithm by the adapter.
Required for:	Modeling the changes in load consumption over time and temperature
Used by:	All ADMS applications to improve the accuracy of power flow. Particularly important for applications where future forecasts are required, these are: Feeder Load Management, FLISR, Suggested Switching and Optimization

Notes:	<p>Load profile data is used to model how load changes over time. A single load profile represents the change in load levels over a 24-hour period. Multiple profiles may be associated with a single load to represent different load behavior for different types of day (for example, weekday, weekend) and for different temperatures (for example, 80°F - 90°F, 90°F - 100°F). The use of load profile data improves the accuracy of the DMS applications by providing more realistic loading scenarios for the current or predicted analysis time period. For example, profiles are used to verify switch plans, determine suggested switching recommendations, and generate daily and seasonal peak limit alarms.</p> <p>The Oracle Utilities Network Management System supports a variety of sources of load profile data such as load class profiles or individual transformer profiles. Once processed, all profile data is placed in the pf_load_interval_data table. For load class profiles, the profile_id column in the pf_loads table can be set to point to the appropriate data in the pf_load_interval_data table. For transformer specific profiles, the adapter will populate a table pf_loads_profile_override; this table will be used to specify which transformers have specific profiles as opposed to just load class profiles. Anything defined in the pf_loads_profile_override table will override the profile_id field in the pf_loads table.</p> <p>Please see the "Modeling Loads" section in Chapter 8 of the <i>Oracle Utilities Network Management System Configuration Guide</i> for more information.</p>
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Transformers (and Voltage Regulators)

Location:	pf_xfmrs, pf_xfmrs_tanks table, pf_xfmr_limits for seasonal, temperature, and dynamic ratings.
Required for:	Modeling the locations where voltage is changed and/or regulated
Used by:	<p>All ADMS applications to determine accurate voltage levels across the network Feeder Load management and FLISR to generate overload and voltage violations.</p> <p>Optimization to determine regulation parameters for optimal network configuration.</p>

Notes:

Some data (for example, regulation parameters) can be defaulted if voltage accuracy is not critically important.

FLA requires accurate impedance information to correctly determine fault currents

- As of NMS v2.4+, projects will not be required to populating indicators specifying if grounds or neutrals are present on the primary and secondary windings. This information will be inferred from the transformer winding type specified for each device. The various winding types supported and details about the grounding information can be found in the Power Flow Engineering Data workbook.
- As of NMS v2.5+, two new transformer winding types have been made available for unique cases. A Zigzag winding has been added which is a single winding transformer that can be used as a grounding bank to create a grounding point on delta configured circuits. The second new type is a Scott winding that takes 3 phases at 120Degree rotation and converts to 2 phases with 90Degree rotation.
- The following configuration will be needed if transformers operate at a different voltage level than the system base. The primary and secondary ratios will need to be adjusted for the voltage the transformer outputs at the neutral tap position. The voltages configured for the unit should be based on what the voltages base that should be used for displaying results.

For example, if a transformer had voltages levels from 138kV to 13.8kV on network at a 13.2kV system base, the primary ratio would be set to 1, the secondary ratio set to 1.04, the primary voltage would be set to 138kV, and the secondary voltage set to 13.2kV. If the device is auto regulating, the voltage target would then be set in P.U. based on a 13.2kV system base. With this scenario, the transferrer would output 13.8kV assuming no load and a 138kV input at the neutral LTC position. The power flow details would indicate this in the balloon as 1.04P.U. based on a 13.2kV system base.

Capacitors (and Reactors)

Location:	pf_capacitors table
Required for:	Power flow, in particular to determine reactive power flow
Used by:	All DMS applications to determine accurate load flow. Optimization to determine regulation parameters for optimal network configuration.
Notes:	Capacitors have significant impact on power flow. The reactive flow around the network affects current magnitude, voltage and power factor. Some data (for example, regulation parameters) can be defaulted if voltage accuracy is not critically important. Capacitors must be modeled shunted off the feeder. The device should either be directly connected to the feeder or with a handful of devices to create a simple path between the device and feeder (for example, conductors and switch). If things like bypasses or junctions exist between the capacitor and feeder the NMS tracing during PFSservice startup may not be able to properly identify the monitored device for regulation.

Distributed Energy Resources (DERs)

Location:	pf_dist_gen table
Required for:	Power flow, in particular to determine real power flow as impacted by distributed generation
Used by:	All ADMS applications to determine accurate load flow. FLISR to determine phantom load during restoration.
Notes:	DERs have significant impact on power flow. The real power flow around the network affects current magnitude, voltage and power factor. DER has the effect of masking load. If the DER supply is suddenly removed (for example, IEEE1547 disconnection rules) the network will suddenly have to cope with significant extra load. Some data (for example, regulation parameters) can be defaulted if voltage accuracy is not critically important.

Distributed Energy Resource Profiles

Location:	<p>pf_load_interval_data: Contains generation output curves for the configured DER within the model. The curves can be configured for a combination of DER type and/or device specific profiles. For example a PV panel could have multiple profiles to represent various output levels of cloud cover density. A diesel generator however may have various profiles to show percentage output.</p> <p>pf_weather_zone_forecast: Contains the DER forecast for the weather affected DERs. This table will contain a key to the profile that should be used for the day and hour. For example it may specify to use the cloudy profile from 9am-12pm for the PV panels for a particular weather zone, then use from the partly cloudy profile from 12pm-3pm, and finally use the sunny profile from 3pm-6pm. The forecast data configured identifies the pieces of each profile configured in pf_load_interval_data to use for the specified date and time.</p> <p>pf_der_forecast: Contains the DER forecast for non-weather affected DERs that have their own forecast schedule. For example it would be common to see utility scale batteries and gas based generators within this table. Similar to the pf_weather_zone_forecast table this contains profile keys that map to which piece of the profile to use the specified date time.</p> <p>pf_demand_response_forecast: Contains the demand response (DR) forecast for the various DR groups that have been configured within NMS. Similar to the pf_weather_zone_forecast table this contains profile keys that map to which piece of the profile to use the specified date time.</p>
Required for:	Modeling the change in DER generation for different fuel types and varying weather conditions. For example a PV panel could have multiple profiles to represent various output levels of cloud cover density. A diesel generator however may have various profiles to represent percentage output.
Used by:	All ADMS applications to improve the accuracy of power flow. Particularly important for applications where future forecasts are required; specifically, Feeder Load Management, FLISR, Suggested Switching, and Optimization.
Notes:	<p>Each DER is mapped to a particular fuel type (for example, Solar, Wind, Gas, and so on) and unique profiles can be provided to define how a particular fuel type behaves for varying conditions. For example solar profiles could be built for different degrees of cloudiness ranging from clear to cloudy that can be used to simulate how solar DERs behave. A customer also has the ability to also configure the weather zone that each DER belongs to and a forecast can be provided to each zone. For example it's partly cloudy, wind 10-15mph, 70F in the mountain zone but in the coastal zone it's sunny, wind 0-5mph, 80F. A customer has the ability to configure as few or as many weather zones as needed and can build DER profiles for varying conditions as well.</p> <p>Oracle NMS provides a productized profile adapter that is capable of creating solar profiles based on the time of year and location of the utility. The curves generated by the adapter reflect a normalized output and within the power flow analysis are applied against the device specific kW output. The number of PV profiles generated to represent various levels of cloud density is configurable based on the customers' business requirements.</p>

Switches and Fuses

Required for:	Generation of violations, Network Protection
Used by:	All ADMS applications that check violations. This includes: Feeder Load Management, FLISR, Suggested Switching and Optimization. Also used by topology processor for modelling Network Protector operations
Notes:	<p>Predicting and reporting on violations is a core advantage of a DMS system. Having accurate ratings and protection settings will allow the applications to generate meaningful violations.</p> <p>Data can be defaulted to reasonable values. Alternatively, they can be modeled as "Zero Impedance" devices to stop violation checking.</p> <p>It should be noted that for protective devices that open to clear faults such as breakers, reclosers, and fuses the minimum pickup current should be used. For example a breaker may be rated for 2000Amps but the relay is configured to trip at values greater than 600Amps, in this situation a value of 600Amps should be configured for the devices normal, emergency short term, and emergency long term ratings.</p> <p>For non-protective devices, the max continuous current rating of the device should be used which would represent the maximum amount of the current the device could handle before failing. If desired, a separate emergency short term and long term limit could also be provided for non-protective devices. These values would represent a limit that could be sustained for a short duration of time (for example, 2-4 hours for short term and 24 hours for long term).</p> <p>Within NMS, capability exists to dynamically determine if protection reach issues exist on feeders. This occurs when the fault current on portions of a feeder are lower than the minimum pickup settings configured for the relay. In this situation the fault current would not be seen as fault current and the device would not open to clear the fault. This can occur when feeders are switched abnormally and the length extended by picking up portions of adjacent feeders. To take advantage of this functionality customers will need to configure the minimum pickup current for ground faults and for phase to phase faults for protective devices. For non-protective devices or if this is not desired functionality the values can be left null.</p> <p>NMS has the ability to model Network Protection trip/reclose operations. Network Protectors are modelled as switches using optional columns in the pf_switches table.</p>

Conductors

Location:	wire_size column of network_components table, pf_line_catalog
Required for:	Accurate determination of voltage in load flow applications, and the effects on short circuit currents.
Used by:	All ADMS applications that check violations. This includes: Feeder Load Management, FLISR, Suggested Switching and Optimization. Applications where voltage change is important: Optimization Applications where impedances are important: FLA, Protection Reach
Notes:	Conductor data has significant impact on most DMS applications. Losses introduced by conductor impedances affect voltages throughout the network. Accurate conductor impedance data is critical for these applications. Impedance data can be provided directly. It can also be calculated (by the Powerflow Engineering workbook) from construction data using Carson's modified equations.

Split Model

Performance of Load Flow algorithms are (to varying degrees) dependent on the amount of network that has to be solved. Typically the minimum unit is the electrical islands - all objects that are currently electrically connected to each other without open switches.

To limit the performance impact of the power flow engine, customers that model transmission and sub transmission should consider using model splits. These introduce artificial breaks between sections of the network. At these locations a "virtual load" is introduced on the high side and a "virtual source" is introduced on the low side. For outage management, energization state of the "virtual load" is translated into on/off status for the "virtual source". Similarly for load flow applications, the calculated power flow at the "virtual source" is propagated across as the dynamic load on the "virtual load".

All the NMS applications support seamless integration across model splits.

The advantage of model splits is that they localize the extent of network that needs to be resolved and significantly speed up the applications. The disadvantage is that there is some loss of accuracy in the Load Flow solutions. However, with practical considerations these inaccuracies should be insignificant.

Whilst model splits can be placed at any location, it is recommended that they are placed at the high side of the power transformers in the substations. The reason for selecting this location is:

1. These transformers usually have Load Tap Changing functionality - that way the voltage at the low side bus can be accurately modeled and is somewhat independent of the upstream losses and voltage drops. It often has the benefit of being telemetered and can actually improve power flow accuracy on the distribution feeders.
2. Optimization applications will still be able to consider the LTC as part of the island encompassing the downstream feeders where optimization objects are typically targeted. If the split were below the transformer then it would not form part of the island being optimized.
3. The short-circuit impedances for bus faults are usually well known and readily obtainable from the planning systems. These will be translated into the impedances for the "virtual sources" at the split.

Phasing Information

Phasing information within the DMS data model is extremely important to solution accuracy, the more the accurate the phasing information the more accurate the power flow solution will be. If accurate phasing information cannot be provided there will be limitations with certain DMS functionality. For example while using Fault Location Analysis if per phase fault currents are being received at the breaker the algorithm may not trace down the correct single phase lateral if the phasing has been defaulted. Let's say a fault occurs on a "A" phase lateral in the field but in the NMS the lateral has been defaulted to phase "B" this candidate location will not be flagged. To default phasing information there are several options that could be used.

1. Create a balanced 3 phase model in which all devices are simply defaulted to 3 phase and the load split across each phase evenly. This scenario would provide reasonable results down the feeder backbone but the lateral taps off the feeder would generally show incorrect current flow since in the field it would be a single phase device but NMS would have it modeled as a 3 phase device and the current would be spread across three phases rather than all on a single phase.
2. Create a program that analyzes the feeder and tries to estimate the phasing. This program would need to look at the total load served on the feeder and then distribute it evenly such that a single phase is not overloaded. If phasing was known for a portion of the feeder the load in the known area should first be summed and then the unknown loading distributed accordingly to maintain balance.

Nominal Voltages

To help with data accuracy related to nominal voltages within the NMS model an iterative approach is used to set the data used by PFService for the power flow analysis. It is expected customers will populate the NETWORK_COMPONENTS.VOLTAGE column with as accurate data as possible from the GIS, this data will be used at PFService startup to establish a starting point for the nominal voltages. After the initial load of the device attributes PFService begins a process of refining the nominal voltage data by tracing from key devices using the "As built" topology model. Since voltages are configured at Equivalent Source objects and Power Transformers PFService can use these voltages to cross reference the voltages that were set in the NETWORK_COMPONENTS table to check for mismatches. For example if the source voltage is 138kV PFService knows that everything between that point and the downstream Power Transformer needs to be 138kV, once the tracing hits a downstream transformer it checks to see what the secondary side nominal voltage is for the transformer. If the secondary side voltage was determined to be 12.47kV it then understands that everything downstream of the transformer should be 12.47kV until another transformer is reached or the end of the network is reached. During this process PFService checks the voltage for each device that was read from NETWORK_COMPONENTS against what was found during the tracing and adjusts accordingly in PFService memory. If PFService Model debug is enabled an associated message will also be placed in the PFService log file to alert an admin that an incorrect voltage was found in the NETWORK_COMPONENTS table and should be changed. It is critical that customers ensure an accurate voltage is configured for Equivalent Sources and Power Transformers that get populated in tables PF_SOURCES and PF_XFMRS respectively. The limitation of this processing is the tracing does not currently refine areas that are nominally de-energized or set as construction pending, so care must be taken to ensure the NETWORK_COMPONENTS table is populated with accurate voltage data. The voltage data populated within the NETWORK_COMPONENTS table should always be in terms of "Line to Line" voltage even if the object is single phase, all PFService model tables have this same requirement (for example, PF_SOURCES, PF_XFMRS, and so on).

DER and Weather Zone Forecasts

A utility has the ability to provide forecast data for various types of DER resources that are present within the electrical network. The NMS categorizes DERs into the following forecasts categories:

- Weather Affected DERs
- Utility Scale DERs
- Demand Response Groups

The following sections will describe how to configure them, and provide the required forecast data.

Weather Zones

A utility has the ability to configure different weather zones within the NMS data model such that different distributed generation profiles can be used within each of the different zones to characterize the real-time and forecasted generation output. For example, if the "coastal" zone is cloudy, a user could set the forecast for PV to use a cloudy profile in the coastal zone, but all other zones would use the clear profile. The weather zone configuration is also used by loads to adjust load profiles as temperature changes. DERs technology types (for example, PV, Wind, and so on) that are mapped to weather zones should be weather affected DERs only. For example, a large utility scale diesel generator would not be mapped to a weather zone since its forecast and output is independent of weather conditions.

If a utility wishes to configure weather zone functionality, data needs to exist that maps each distributed generation and load resource in the NMS data model to one of the applicable zones. The preferable location for this data would be the GIS, but, if needed, the data could be placed in the customer specific Power Flow Engineering Data workbook. This data needs to be brought across during the model build into the ZONE columns of the PF_DIST_GEN and PF_LOADS tables. The value populated will need to map to a configured zone in the PF_WEATHER_ZONE table.

Once Weather Zones have been configured, the utility has the ability to provide a forecast for each zone that forecasts how the DER resources for each power source will behave for the current day plus the next six days. This forecast should also include a temperature forecast for each applicable zone; this will be used to adjust load profiles as temperature changes.

During implementation, a utility needs to determine how they would like to use the weather zone forecast functionality.

- They could have an administrator use the Weather Zone Forecast tool to set the generation profile daily for each zone and power source. The power flow solutions will then use the profiles that have been set for the day in the real-time solutions and forecasts.
- For more advanced forecasting, they could use an external interface (for example, weather feed) to populate the PF_WEATHER_ZONE_FORECAST table for each hour of the day with what generation profile to use. This would allow for more granular refinement of the power flow solutions. In this scenario the utility would not use the Weather Zone Forecast tool to set the weather forecasts.
- Alternatively, they could provide direct scaling factors to use for each hour instead of what profile to use for each hour; the input method can be configured with the distGenDefault SRS rule.

Whichever method is used, the entire forecast for each zone must be provided with the same method (profiles or scaling factor) for each power source.

Temperature forecasts can be provided for US customers using a product adapter that interfaces to a weather data server. Alternatively, an implementer could build a custom adapter that would provide temperature forecasts on a zone basis from an alternate resource such as utility specific forecasts (see the Oracle Utilities Network Management System Adapters Guide for more information).

Large Scale Utility DERs

Large scale utility DERs are categorized as units that are large in scale and unaffected by weather. An example would be a diesel generator or large battery that has an output that is unaffected by weather. For these units, the forecast is provided for each individual unit and they are not aggregated together like DERs within weather zones. It may be entirely plausible to have two large batteries in close proximity to each other but their forecasts could be drastically different.

If a utility wishes to categorize a DER resource as being outside of a weather zone the ZONE field within the PF_DIST_GEN database table should be configured within the alias of the unit. The preferable location for this data would be the GIS, but if needed the data could be entered in the utility's Power Flow Engineering Data workbook. This data will need to be brought across during the model build. A corresponding power source also needs to be configured for the unit (for example, Diesel, Gas, Battery, and so on).

Once the large scale DERs have been configured, the utility has the ability to provide a forecast for each unit that forecasts the output for the current day plus the next six days. It is expected that an external system would be used to populate the forecasts for these units and the data is stored in the PF_DER_FORECAST database table. Within this table a key corresponding to a distributed generation profile can be provided (for example, on, off, peak shave, and so on). Alternatively, a utility could provide direct scaling factors to use for each hour instead of what profile to use for each hour, the input method can be configured with the distGenDefault SRS rule. With either method the entire forecast for all units must be provided with the same method (profiles or scaling factor) for each power source. The NMS has a DERMS adapter product that is capable of taking a CSV or RDBMS based forecast from an external system for use by the NMS (see the Oracle Utilities Network Management System Adapters Guide for more information).

Demand Response Groups

A utility has the ability to configure different demand response groups (DR groups) within the NMS data model such that different DR profiles can be used within each of the different groups to characterize the real-time and forecasted DR scenarios. For example, the ability to simulate a DR group dropping load for 2 hours during a peak load day.

If a utility wishes to configure demand response group functionality, data would need to exist that maps each DR resource in the NMS data model to one of the applicable demand response groups. The preferable location for this data would be the GIS, but, if needed, the data could be placed the utility's Power Flow Engineering Data workbook. This data will need to be brought across during the model build into the ZONE column of the PF_DIST_GEN table. The value populated will need to map to a configured zone in the PF_DEMAND_RESPONSE_GROUPS table.

Once the demand response groups have been configured, the utility has the ability to provide a forecast for each demand response group that forecasts the output for the current day plus the next six days. It is expected that an external system would be used to populate the forecasts for these units and the data is stored with NMS DB table PF_DEMAND_RESPONSE_FORECAST. This table can have a key corresponding to a distributed generation profile (for example, on, off, and so on). Alternatively, a utility could provide direct scaling factors to use for each hour instead of what profile to use for each hour; the input method can be configured with the distGenDefault SRS Rule. With either method, the entire forecast for all units must be provided with the same method (profiles

or scaling factor) for each power source. The NMS has a DERMS adapter product that is capable of taking a CSV or RDBMS based forecast from an external system for use by the NMS (see the *Oracle Utilities Network Management System Adapters Guide* for more information).

Seasonal and Temperature Based Limits

The power flow analysis can be configured to work with seasonal or temperature based limits when specifying ratings for power transformers and conductors. For these types of devices, the upper limit that the device can be pushed to is heavily dependent on the ambient air temperature (in general, these devices can be pushed harder when the temperature is cooler since natural cooling can occur). Both the seasonal and temperature based approaches represent a mechanism to specify what the ambient air temperature is doing — with the temperature based approach providing much more possibility for granularity. Both approaches are global in nature so a project cannot specify one type of configuration for one area of the model and another approach for another area. Any ratings provided for switches will have the standard concept of normal, short term emergency, and long term emergency limits.

Note: This configuration can be changed in the **USE_TEMP_LIMITS** SRS rule. Setting the rule to **yes** enables temperature based limits; setting the rule to **no** enables seasonal based limits. Depending on the configuration of this rule, various user interface elements will change to show the corresponding options.

Seasonal Based Limits

For seasonal based limits, projects will pre-configure a set of date ranges that define seasons applicable to the geographic region. The quantity of seasons and dates associated with each season is configurable so, for example, if only two seasons were needed, a project could set up **Winter** and **Summer** seasons. When providing limit data to use for conductors and power transformers, values need be provided for each season in the Power Flow Engineering Data work. In the real-time power flow analysis, the date for which the solution is conducted will determine which set of seasonal limits is used; so, for example, if the date of December 12th falls in the **Winter** season, all seasonal limits associated to **Winter** would be utilized in the analysis. While running power flow analysis in study mode, users have the option to choose whichever season they wish to use for *what if* analysis.

One of the shortcomings of the seasonal method is when there are areas in the network that experience different weather conditions, For example, some areas might be experiencing weather typical of summer while others areas are experiencing weather typical of fall; in this scenario, the analysis would use the season that includes the date despite the different conditions.

Temperature Based Limits

For temperature based limits, transformers and conductors can be grouped to the same set of *Weather Zones* that are used for driving Distributed Energy Resource forecasts. Each of these weather zones will have a temperature forecast that is provided via a real-time weather feed. Predefined limits will be provided in the Power Flow Engineering Data workbook for various temperature bands and the weather forecast will drive which of these is applied for the real-time loading and future forecasts. So, for example, the configuration may be set up such that conductors and transformers will have a limit defined for each 20°F range of temperature. The limit used for each power flow solution will be based on the forecast temperature for the date and time the solution is for and weather zone the device is in. Therefore, while looking at forecast power flow solutions for a device, it may be

possible to see the upper limit changing as the temperature changes throughout the day. This is the one big differentiator between seasonal based limits and temperature based limits; with the temperature based limits, the limit used has the possibility to change hour by hour as temperature changes; in contrast, with a seasonal limit, the same limit will be used for a larger date range.

Note: For SCADA telemetered power transformers, it is possible to configure a temperature value for the device. In this situation, the analysis will use the SCADA provided temperature instead of the forecast temperature for the weather zone the device is a part of for choosing the limit in the real-time solution. For all forecast solutions, the weather feed temperature will still be used for choosing the limit.

For configuration information, see the **Seasonal and Temperature Limits** section in the *Oracle Utilities Network Management System Configuration Guide*.

Chapter 4

ADMS Applications Overview

The following is a brief overview of the applications that are considered as part of the ADMS functionality in the Oracle Utilities Network Management System. A full description of each application is given in the following sections.

Power Flow:

The Power Flow application is the core of the ADMS functionality, most other ADMS applications depend on the Power Flow module.

This module calculates the voltages at every bus in the system and from that derives the current flows along with the real and reactive load flows. When analyzing the real-time model, it can incorporate data from SCADA to scale the loads appropriately. It will also utilize historical load profiles (if present) to refine the results.

Feeder Load Management (FLM):

The FLM application is intended to provide a system wide overview of the current loading conditions on the network and optionally future loading scenarios.

Fault Location, Isolation and Service Restoration (FLISR):

The FLISR application is for finding ways to restore power to customers that have been unexpectedly de-energized, typically due to a fault. It is triggered by a breaker lockout and it seeks to identify the faulted section. Through the use of SCADA controllable switches, it will formulate a plan to isolate the faulted section and restore service to customers above and below the faulted section where possible.

Fault Location Analysis (FLA):

The FLA application predicts the location of faults using fault currents reported from the relay of the tripped device. It uses short-circuit analysis to determine the probable fault locations that may exist on a feeder.

Optimization:

The Optimization application continuously monitors the distribution system looking for opportunities to optimize performance to meet pre-configured objectives.

Suggested Switching (SS):

The SS application runs only in Study Mode and is used to create planned switch sheets that allow certain operations to be performed with minimum customer interruptions whilst preventing other issues like ratings or voltage violations.

Configuration

Configuration Assistant

The Configuration Assistant tool provides a Feeder Management tab for configuring various aspects of the ADMS applications. This screen should be used to make configuration changes that need to be applied on a feeder-by-feeder basis, such as turning certain applications on or off on a single feeder.

The Feeder Management tab is populated by data obtained from the FEEDERS table. This is a model managed table. The configuration data in this table is initialized by model build when the feeder is first created (so it should be populated with reasonable defaults), but it is not updated on subsequent model builds. Changes to the feeder configuration persist across model builds even if the feeder is altered by the incremental patch.

The feeder-by-feeder configuration of ADMS functionality is intended to satisfy two requirements:

1. The applications can be turned on as the data for the respective feeders is sourced and validated. Once confident the information is accurate, administrators can activate the application on those feeders.
2. It may not always be necessary to run all applications, on all feeders with the same degree of accuracy and/or updates. For example a feeder that is run close to limits might require frequent, accurate solutions and forecasts, whereas a feeder that seldom has issues might be disabled for solutions all together.

The details of how each option impacts a module are discussed in more detail in later sections.

Event Management Rules

The Configuration Assistant tool provides an Event Management Rules tab for configuring various aspects of the ADMS applications. These rules are known as SRS rules in older versions of OUNMS.

These rules configure "global" parameters; these parameters apply to the applications every time they run irrespective of which feeder is being analyzed. The rules are too numerous to enumerate in this guide, and are typically covered in workshops. It is recommended that the implementer bring up the full set of ADMS Event Management Rules in Configuration Assistant, which are grouped by ADMS application, and review with the customer.

Chapter 5

Power Flow & Feeder Load Management (FLM)

The core of the ADMS applications is the Power Flow application. Virtually all other ADMS applications require a power flow solution to be performed in order to perform their analysis.

On the real-time network, it can be configured to operate cyclically or on-demand on a feeder-by-feeder basis. It can also be used in Study Mode to analyze load flows in any configuration the operators wish to examine.

Power Flow and Other Applications

Power Flow is tightly integrated into the following applications that typical OMS installations use:

Viewer

Power Flow results for any device can be observed by clicking on the device and bringing up the Device Details Balloon. If cyclical solutions are available the results are displayed immediately. If an on-demand solution is required, a small delay will occur whilst the analysis is completed.

Once the network under observation has a power flow solution various features in the viewer enable. In particular conductor "glow" will give a visual heat map of problematic areas.

If the "Show Flow Direction" option is enabled, arrows appear on the conductors to indicate the flow direction of real power.

Additionally, the view can be changed to show Currents, Voltages and Loading. In these modes the conductor coloring indicates the load or current flow as a percentage of rating or level of deviation from nominal voltage.

Look Ahead

Power Flow results for an operator action can be viewed in the Look Ahead tool before committing to the operation. The results will show the making/breaking current for the operation, and the voltage angle differences (where relevant).

Additionally, any violations impacted by the operation can be viewed. The results will indicate if the operation is going to add or remove violations, or indeed make them better or worse.

If distributed energy resources are configured in the model, they will also display in the Lookahead if they are in the path of the operation. Indication is given if distributed energy resources are upstream or downstream of the device being operated.

Web Switching

Power Flow analysis is integrated into web switching. When a planned switch sheet has been created, the operator can (at the click of a button) run a Power Flow analysis on that sheet.

The analysis will show any violations that are created or removed by the steps and the projected load flows on the impacted feeders.

Feeder Load Management

The Feeder Load Management (FLM) application is intended to provide a system wide overview of the current loading conditions on the network and optionally future loading scenarios. The FLM Summary tool can be viewed as a "Work Agenda" for ADMS; it can allow the operators to quickly identify current or future problems. It has 3 views of feeder status:

- **Earliest Alarms:** Displays feeders that are either currently in an alarm state or predicted to enter an alarm state within the forecast window.
- **Worst Alarms:** Displays the worst current or forecasted alarm (if any) for each feeder.
- **Present Loads:** Displays the current state of each feeder. This is the only view that shows feeders not in an alarm state.

Alarms on a feeder are triggered by warnings or violations of the following types:

- Ratings overload
- Voltages out of range
- Backfeeding
- Distributed generation alerts
- Protection issues.

Note on licensing: The PowerFlow license incorporates both real-time and study mode power flow analysis and includes real-time Feeder Load Management analysis. The Feeder Load Management license leverages PowerFlow, but also incorporates load forecasting and is dependent on load profile data.

Configuration

As mentioned previously the Power Flow and FLM applications are configured through the Configuration Assistant **Feeder Management** tab.

Power Flow Mode (PF Mode)

The PF Mode configures the type of Load Flow analysis performed for a feeder or island. When feeders in the same island have different modes the least accurate mode is used for the whole island - that is kVA Mode. The choices are:

Power Flow Mode: The Load Flow analysis will run a full power flow solution and utilize the full set of engineering attributes. This includes load profiles, generation profiles, equipment ratings, and the impedance model. This will calculate voltage, loading, and losses at all points on the electrical island. Power Flow Mode will provide the most accurate power flow results. Power Flow Mode is mandatory for FLA and VVO. The full set of violations can be detected using Power Flow Mode including overloads, voltage violations and protection reach (NMS 2.3+). Power Flow Mode will have the highest impact on performance.

kVA Mode: The power flow solution is solved ignoring impedance attributes. Load profiles, generation profiles, and equipment loading ratings are still utilized in kVA mode. Overload conditions can still be detected. In kVA mode the Power Flow engine typically solves in a single iteration so it has less CPU performance impact than Power Flow Mode. Utilizing this mode introduces some limitations (for each electrical island configured with one or more feeders configured in kVA mode):

- Voltage violations cannot be detected.
- VVO not available because voltage drop and line losses are not calculated.
- FLA not available because impedance data is needed to predict fault locations.

kVA mode should be utilized if the utility does not have good impedance data, or if they want to limit the performance impact of the full Power Flow engine for one or more electrical islands.

The full power flow model can provide solutions both on-demand and cyclically. The on-demand solution is performed in Study Mode and on feeders where automatic solutions are disabled.

Cyclical solutions are performed on the real-time network for feeders that are configured for automatic solutions; typically on a 15 to 30 minute cycle unless there is a topology change. Topology (switch) changes trigger a near immediate parent island resolve.

FLM Mode

The FLM Mode configures the type of Feeder Load Management solutions that are generated. There are 3 choices:

Disabled: In this situation no automatic solutions are generated for this feeder. To see real time solutions the feeder must be selected in the viewer and will be solved on demand (when the user asks for power flow information via the balloon tool).

Real-Time: In this situation the feeder is resolved periodically and weighted with SCADA data (where available) to better determine current loading conditions. The rate at which solves are performed can be selected at a global level by setting the CYCLE_TIME rule in the "Power Flow" rule-set. By default this is set to 15 minutes.

All feeders enabled for Real-Time or Forecasting (see below) are periodically re-solved at this rate. If only one feeder in an island is enabled, the whole island still needs to be solved, but only the enabled feeder is displayed in the results.

Forecasting: FLM forecasting is performed hourly (at the top of the hour) and produces hourly forecast for the next 24 hours and daily peak forecasts for the next 6 days. The loads used in these forecasts are derived by scaling load profile data with current SCADA loading information.

Load profile data is mandatory for Forecasting.

Performance

Over all the ADMS applications, Feeder Load Management probably puts the most burden on the system. Large models with both cyclical solutions and full forecasting can keep the PowerFlow sub-system (PFService) very busy, so consideration needs to be given to the scope and desirability of FLM solutions. In particular the implementer should address the following questions:

1. Are forecasts required for each feeder or island? For areas where excess load is unlikely it might be appropriate to configure those feeders for simply "Real-Time" solutions or disable from FLM altogether.
2. Are full Power Flow solutions required for each feeder or island? For areas where voltage violations are not sufficiently likely and/or optimizations won't be performed it might be appropriate to configure those areas for kVA solutions, which are significantly faster than full Power Flow.
3. Is the FLM cycle time set appropriately - is the 15 minute default too fast or slow?
4. For areas where optimizations are being performed, what frequency of optimization calculations are required? Can the feeders be configured for hourly optimizations or do they require more frequent analysis?

FLM Island Statistics Window

Statistics pertaining to the performance of real-time power flow and FLM solutions are available through the FLM Islands Statistics window, which is accessed by selecting **FLM Islands Stats...** from the Web Workspace **Tools** menu. By default, this option is only available for **Administration** or **Trainer** user types.

The tool is a visualization of the FLM_ISLANDS database table. The table is updated every time the periodic FLM solution runs; with the default product configuration, this is every 900 seconds (15 minutes). Various information about the performance of the solution is written to that table.

An *island* is defined to be all network fed from the same (set of) energization sources. For most customers, this is typically a substation and its distribution feeders. If the model is split, islands start at the location of the split.

The tool is useful in getting a high-level summary on the performance of the power flow engine for real-time solves and allows application support staff to identify areas of the model that are having difficulty solving.

The columns shown by default on the page are:

Column Name	Description
Island Name	The name of the island as determined by one of the energization sources and the corresponding entry in the data model FEEDERS table.
Status	The status of the power flow solution. These match the values reported in FLM. Typically, this can be one of: Solved, Suspect SCADA, Model error, Failed.
Updated	The time the last information was written for this island.
Solve Time	The time take to perform the state estimation, power flow solution, and SCADA load allocation.
Supply Connections	Report how many energization source nodes feeder the island.
Feeders	How many FID or MID nodes are present in the model. This is broadly related to the number of distribution feeders plus power transformers. The exact location of each of these nodes is determined during model design and project implementation.
Buses	Number of connection points in the island. Each device (Transformer, switch, conductor, and so on) has a connection point at each end.
Powerflow Iterations	Number of iterations of the power flow engine to converge on a solution.
State Estimator Iterations	Number of iterations of the state estimator (capacitor status, network protector status, and/or regulating DERs) to converge on a solution.
SCADA Iterations	Number of iterations of the SCADA load allocation engine to converge on a solution.
Total Iterations	Sum of the previous three columns.
Voltage Violations	Number of voltage violations (Low or High) detected by the power flow.
Flow Violations	Number of thermal violations detected by the power flow.
Transformers	Number of transformers in the islands. This figure typically excludes service transformers as they tend to be modeled as load points for the power flow. If, however, the load and DER behind the xfmr is dis-aggregated then the service transformers do get included in this count. This is implementation dependent and typically depends on the level of behind the meter DER penetration there is in a service territory.
Shunts	Number of shunted devices (capacitors, SVCs, or reactors) in the island.
Switches	Number of switchable devices (typically breakers, reclosers, load-break switches, non-load break switches, and fuses).
Distributed Generators	Number of DER units (primary and behind the meter) that are in the island.

Columns available but hidden by default include:

Column Name	Description
kW Gen Phase A B C	Per phase real power generation in the island.
kVAr Gen Phase A B C	Per phase reactive power generation in the island (excludes Caps, SVC, and Reactors).
kW Load Phase A B C	Per phase real power load in the island.
kVAr Load Phase A B C	Per phase reactive power load in the island.
kW Cap Phase A B C	Per phase real power support in the island (from Caps, SVC, and Reactors). Almost always zero.
kVAr Cap Phase A B C	Per phase reactive power support in the island (from Caps, SVC, and Reactors).
kW Loss Phase A B C	Per phase technical real power loss in the island (typically from conductors).
kVAr Loss Phase A B C	Per phase technical reactive power loss in the island (typically from conductors).
kW Xfmr Loss Phase A B C	Per phase technical real power loss in the island from transformers (excludes service transformers modeled as loads).
kVAr Xfmr Loss Phase A B C	Per phase technical reactive power loss in the island from transformers (excludes service transformers modeled as loads).
SRC Class	The class handle of one of the energization sources feeding the island.
SRC Index	The index handle of one of the energization sources feeding the island.

The statistics table supports all standard table functionality for the NMS user interface, including filtering, automatic filtering, column selection, column locking, copying, and printing.

You can select a row and navigate to the island in the Viewer by clicking the **Viewer Focus** button () in the toolbar.

The rows have the following context menu options:

- **Auto Filter:** Activates auto filtering based on the selected cell.
- **Show Errors and Statistics...:** Opens the FLM Feeder Errors, Warnings, and Details window, which displays detailed information about model data errors and warnings. The FLM Feeder Errors, Warnings, and Details window also provides a deep dive into the solution details and information about the areas of the model where convergence is taking a long time.

Model Validation

Sanity Checking

Model validation performs a basic level of sanity checking on the data attributes provided in the NMS model. After the model has been loaded each device is validated to determine if it has reasonable data. These checks are performed on a device by device basis without consideration of the context. Therefore model validation will catch things like a device's rating might be outside all reasonable limits (for example, a transformer has a negative rating), but it won't catch that a 1/0 Conductor has been used where you'd expect to see a 336 kCM device.

Validation failures are categorized as: Errors or Warnings. Power flow will not be attempted on islands containing errors; these will be reported as "Model Errors" in the FLM Summary window.

Details about model validation checks can be obtained in two ways.

1. They are presented in the Feeder Load Management GUI for the feeder where they are reported. They can be navigated to by right clicking on the feeder and selecting **Show Errors and Statistics** and then looking under the **Show Errors and Statistics** tab. As feeders are part of an island, it only takes a single device error in the whole island to block a solution. In this scenario it is necessary to inspect all the feeders in an island to determine the error location.
2. The errors can also be reported in the log file for PFService. To do this the MODEL debug facility should be activated on that service. To activate at start up add the following to the command line of PFService as specified in system.dat:

```
-debug MODEL 1
```

To activate the debug on a running instance of PFService use a high-level command:

```
Action any.PFService debug MODEL 1
```

Solution Details

Not all issues can be caught by sanity checking or are appropriate given the context of the device in the surrounding network. Some errors (for example, inappropriately sized capacitors or incorrect voltage angles on sources) will introduce errors that ultimately cause the Power Flow solution to fail. These types of failures will be reported as "Solution Failed" or "Inconclusive Solution" in the FLM tools.

These types of issues are somewhat harder to debug. To start with the details can be viewed by right clicking on the feeder and selecting "Show Errors and Statistics" and then looking under the "Solution Details" tab. This will give hints as to where the power flow engine is having difficulty converging on a solution.

Another approach it to use Study Mode analysis to try to locate the problem. By incrementally isolating sections of the network it is possible to narrow down the faulted device. Start off by removing everything below the energization sources and verify a solution can be obtained. Afterwards add in chunks of the network until the solution starts erroring again, this will help identify problematic regions and devices.

Upstream Impedance Trace

The Upstream Impedance Trace is an optional tool (which we recommend you configure) allows a user to generate an impedance report for a section of electrical network adhoc. The report shows the individual device impedances along the selected section of network and helps to identify potential data issues. A user clicks a point on the network where they would like to start the report and the tool then traces upstream to the source finding all impedance contributing devices along the trace path. This tool helps to identify sections of network where impedance may be defaulted or incorrectly attributed leading to incorrect power flow results such as inaccurate FLA predictions.

Conductor Mismatch Tool

The Conductor Mismatch Tool can be invoked by an admin type user and runs in the background. It attempts to find sections of network where conductor impedances look incorrect. For example if a circuit backbone was primarily large conductors and in the middle there was a very small conductor (for example, 556ACSR to 2/0 AL), this would most likely be representative of a data error in the attribution of conductor sizing. These potential data issues are placed in a report which can then be reviewed by an admin type user or displayed in the NMS user interface.

Data Requirements

Model

The amount of model data required depends on the solution engine that is being utilized.

Power Flow kVA: Minimum data requirements. Device ratings, nominal voltages, Xfmr voltage levels and service transformer sizes are sufficient.

Power Flow: Full data requirements. Defaulting is acceptable but will affect accuracy of results. In addition to the items listed for kVA mode, conductor catalogs are required to produce accurate voltage solutions.

SCADA

SCADA is optional for Power Flow and FLM, though the following will be utilized in present:

- Device Status (Open/Closed)
- Bus voltages at or near the equivalent source locations
- Real-time load conditions. Various permutations are supported. The following is order of preference:
 - Per-phase real and reactive power flow
 - Per-phase current flow. Voltage and power factor optional
 - 3-phase average or total real and reactive power flow
 - 3-phase average or total current flow. Voltage and power factor optional

Chapter 6

Fault Location, Isolation and Service Restoration (FLISR)

The Fault Location, Isolation and Service Restoration (FLISR) application is for finding ways to restore power to customers that have been unexpectedly de-energized, typically due to a fault. It is triggered by a breaker lockout and it seeks to identify the faulted section. Through the use of SCADA controllable switches it will formulate a plan to isolate the faulted section and restore service to customers above and below the faulted section where possible.

At a high level FLISR will:

1. Use the Recloser Lockout signal from SCADA to determine a genuine lockout has occurred
2. Use Fault Indication signals from devices along the feeder to identify the faulted section
3. Run a Power Flow analysis with the pre-trip load conditions to determine the state of the feeder pre-fault.
4. Identify all possible restoration scenarios
5. Run Power Flow solutions on all potential pickup feeders to determine their current state, available capacity and near-term future capacity.
6. Evaluate every restore scenario by using further Power Flow solutions to determine the effects of restoration operations. It will consider not only current network conditions, but also the affects of DER that are presently on the faulted section and future load conditions.
7. Select the best option that considers:
 - a. Violations that will occur
 - b. Conditions that might block restoration for safety reasons (tags, grounds, crews, and so on)
 - c. Feeders that are fed from the same substation transformers.
 - d. Feeders that have Co-gen or DER presence
 - e. Feeders that will have most capacity after the restoration sequence has been executed.

Configuration

As mentioned previously the FLISR application is configured through the Feeder Management tab of the Configuration Assistant tool. The options that affect it are:

Power Flow Mode (PF Mode)

The PF Mode configures the type of Load Flow analysis performed for a feeder or island. When feeders in the same island have different modes the least accurate mode is used for the whole islands - that is kVA Mode. The choices are:

FLISR Mode

FLISR can be run in one of three modes, which is configurable on a per-feeder basis from the Feeder Management tab. The modes are:

Disabled: FLISR will not run on this feeder. This is useful for feeders where data or field infrastructure requirements have not been met.

Manual: FLISR will produce solutions on this feeder but not automatically execute them. The solutions must be reviewed by an operator first. This is useful for building confidence in the solution.

Automatic: FLISR will automatically execute the best solution it can find for a feeder, provided no blocking conditions (including violations) are detected. The solutions can be reviewed by an operator after execution.

Restore Only: FLISR can use the feeder as a restore feeder to pickup load from an adjacent faulted feeder, but it will not attempt to find isolation/restore solutions for faults on this feeder.

Performance

FLISR has to perform several Load Flow solutions in order to evaluate the scenarios under consideration. As FLISR events typically happen sporadically the effects on overall system performance tend to be negligible. However the time taken to find a solution for a particular FLISR event may be longer than desired in some situations (for example some regulatory situations mandate a minimum time to ensure restored customers only experience a momentary outage). In particular there are two aspects that can impact how long FLISR can take to generate a solution that need to be considered:

Forecast Hours: FLISR looks out into the future to predict load so that it will not create plans that whilst immediately viable might have issues in a few hours. How far out FLISR looks is configurable from 0 to 24 hours.

FLISR Solution Engine: For some organizations it is necessary for FLISR to execute extremely quickly. In some parts of the world regulators provide financial incentives to restore outages within 60 seconds. To accommodate this FLISR can be configured to run in "Connected kVA" mode.

FLISR's "Connected kVA" mode is not the same as "Power Flow kVA" mode. It has certain advantages and disadvantages:

1. It will only run on radial feeders, therefore substation conditions (for example, Xfmr Overloads) may not be detected
2. It will assume nominal voltage on the feeder and will not detect voltage violation conditions
3. As it only analyzes single feeders it is considerably faster
4. As it uses the "Ladder Method" it can only support feeders that are truly radial. Feeders that are meshed or contain loops cannot be solved.
5. FLISR "Connected kVA" does not require a Power Flow license and can be implemented as a first ADMS application with significantly less data requirements.

Data Requirements

Model

The amount of model data required depends on the solution engine that is being utilized.

Connected kVA: Minimum data requirements. Device ratings, nominal voltages and service transformer sizes are sufficient.

kVA: Minimum data requirements. Device ratings, nominal voltages, Xfmr voltage levels and service transformer sizes are sufficient.

Power Flow: Full data requirements.

Future Forecasting: If future forecasting is enabled (for any solution engine type) then load profile data is required.

SCADA

FLISR requires the following from SCADA:

- Device status.
- Lockout Status (Optional). If not available it will run on time delays and device status signals.
- Fault Indications.
- Real-time load measurements.
- Pre-trip load measurements (Optional). If not available FLISR will utilize rudimentary history of the load.
- Outbound controls for device status and recloser lockout.

Chapter 7

Fault Location Analysis (FLA)

The Fault Location Analysis (FLA) application is used to predict the location of faults using fault currents reported from the relay of the tripped device. It uses short-circuit analysis to determine probable fault locations.

At a high level FLA will:

1. Use the Fault Indicator signal from SCADA to determine a fault has occurred. This can be a fault that triggers a lockout or just a momentary.
2. Gather the fault currents from the reporting relay and determine the impedance seen downstream - this includes the conductor impedances and the fault impedance.
3. Use Fault Indicators to refine the search to portions of the network downstream of devices signaling a fault.
4. Run a short-circuit analysis at the reporting relay's location to determine a baseline impedance and fault current.
5. Traverse down the network from the reporting relay summing conductor impedances until one or more locations are found that match the fault impedance determined in step 2.

Configuration

As mentioned previously the FLA application is configured through the Feeder Management tab of the Configuration Assistant tool. Through this tab FLA can be enabled or disabled on a feeder.

Performance

FLA has negligible impact on overall system performance because FLA results are not particularly time critical and the analysis is performed within a low-priority thread.

Data Requirements

Model

FLA only requires impedance data to accurately determine fault currents. In particular this should be provided on equivalent sources, transformers and conductors.

Due to its minimal data requirements, FLA is also a good choice as a first ADMS application to be implemented.

SCADA

FLA requires the following data from SCADA:

- Device Status (Optional)
- Fault Indicators
- Fault Currents

Chapter 8

Optimization (formerly VVO)

The Optimization application continuously monitors the distribution system looking for opportunities to optimize network performance to meet pre-configured objectives.

Optimizations are evaluated for the primary distribution feeders and substation LTC transformers. The optimizations will consider the tap positions, regulation settings and or operating bandwidths of:

- Substation Load Tap Changing (LTC) Transformers
- Voltage regulators
- Capacitors (cab banks)
- Dispatchable DERs (such as batteries)

The analysis is performed on the group of devices from the Substation LTC and all downstream distribution feeders. The intent being that often the most benefit can be derived from setting the regulation targets at the LTC.

The optimization strategies available are:

Loss Minimization: Will attempt to reduce technical losses on the feeder through both power factor correction and voltage adjustments.

Power Factor Correction: Will attempt to adjust reactive power flow such that the feeder head Power Factor is as close to unity as possible. Will only operate reactive devices: Capacitors and Reactors.

Conservation Voltage Reduction (CVR): Will attempt to reduce voltage along the feeder whilst avoiding low voltage violations. The objective being to minimize real power consumption especially in constant impedances and constant current loads.

Overload Relief: Will attempt to reduce voltage or flow violations along the feeder by dispatch real or reactive power from DERs.

The optimization application can run in both real-time and in study mode:

In real-time the application is configured to determine how frequently to run on each optimization group and whether to produce automatic on manual plans. As these plans are intended to achieve immediate benefits from optimization, they will only consider devices that can be controlled via SCADA.

In study mode the application can make optimization recommendations on any network status the operator cares to investigate. Additionally the operator can choose to include manually switched devices in the analysis.

Configuration

As mentioned previously the optimization application is configured through the Feeder Management tab of the Configuration Assistant tool. The configuration only impacts how optimization is run on the real-time network. For Study mode optimization analysis, the options are selected via the wizard that the operator uses to conduct the analysis.

The options that affect real-time optimization are:

Feeder Type

This option confirms the role played by a feeder in the network. It is probable that this can be detected correctly at model build time and therefore should not be alterable in the tool. However for various reasons (primarily the way the GIS model works) it is not always possible to correctly identify the role at model build time and manual configuration is necessary.

The feeder type option does not directly affect the functionality of the optimization engine. It does however control which other parameters and options are available for optimization configuration. The options available are:

Sub Transmission: The feeder is part of the sub-transmission network.

Sub Transmission Xfmr: The "feeder" is a transformer in sub-transmission network. Downstream feeders are considered to be sub-transmission and therefore not directly serving load.

Primary: The feeder is part of the distribution network and feeds load. It is therefore a good candidate for optimization.

Primary Xfmr: The "feeder" is a transformer in a substation and its immediate downstream feeders are considered Primary feeders. Typically the optimization engine will expect these devices to have LTCs that are auto or manually regulating and these devices are typically the location where the bulk of optimizations are achieved.

Secondary: The Low Voltage part of the distribution network. Typically not modeled by North American utilities. In other regions these are modeled due to the prevalence of switchable devices in the secondary network.

Secondary Xfmr: The "feeder" is the transformer between the Primary and Secondary networks. Often referred to as the distribution xfmr.

None: The feeder's role in the network is unclear.

Optimization Mode

This option configures how and when a optimization is performed.

For feeders that have been configured with a type of "Primary Xfmr" the following options are available:

Automatic (Slow Cycle): The feeder will be optimized after hourly FLM forecasts have been completed; this means in practice that optimization will be performed once per hour. If an optimization opportunity is identified a switch plan will be created and automatically executed.

Automatic (Fast Cycle): The feeder will be optimized after cyclical FLM analysis has been completed; this means in practice that optimization will be performed once every 15 minutes (or whatever cycle time FLM is configured for). If an optimization opportunity is identified a switch plan will be created and automatically executed.

Manual (Slow Cycle): As with the automatic option, the feeder will be optimized after hourly FLM forecasts have been completed; this means in practice that optimization will be performed once per hour. If an optimization opportunity is identified a report is generated which must be reviewed by the operator before a switch plan can be created and executed.

Manual (Fast Cycle): As with the automatic option, the feeder will be optimized after cyclical FLM analysis has been completed; this means in practice that optimization will (by default) be performed once every 15 minutes. If an optimization opportunity is identified a report is generated which must be reviewed by the operator before a switch plan can be created and executed.

Disable: The feeder will not be optimized.

For feeders that have been configured with a type of "Primary" the following options are available:

Enable: The regulating devices on a feeder will be considered when determining an optimization opportunity for the upstream "Primary Xfmr".

Disable: The regulating devices on a feeder will not be considered when determining an optimization opportunity for the upstream "Primary Xfmr".

For all other "Feeder Types" it is not possible to set the Optimization Mode.

Optimization Objective

This option configures which objective should be used when performing the analysis. The following options are available:

- **Loss Minimization**
- **Power Factor Correction**
- **Conservation Voltage Reduction (CVR)**
- **Overload Relief**

Performance

Real-time has the potential to be a large drain on system resources; particularly CPU load consumed by PFService. As with many of the ADMS applications its usage and scope should be the result of careful consideration.

Obviously fast-cycle optimization will run the most frequently, potentially 4 times per hour using the default 15 minute cycle times. This analysis is performed on the real-time state of the network. This mode should probably be constrained to the areas of the network which are most sensitive to Volt/Var issues.

Slow-cycle optimization has the benefit of using the forecasted feeder loads provided by FLM to produce optimizations that achieve the best result over a number of hours. This means in practice that the best plan might not be used in the short term because it will either produce violations in the long term or will need to be backed off. The trade-off of course is that this mode is less stressful on the NMS system and more importantly, performs less field operations thus potentially extending field device life expectancy.

Data Requirements

Model

The optimization application is the most sensitive to data requirements. To achieve accurate optimization results the best quality data is required. This includes:

Regulating Parameters: The application needs to know the regulating abilities of all the controllable devices: Substation LTCs, Voltage Regulators, Capacitors and Reactors.

Full information including regulation ranges, number of taps, bandwidths, setpoints and so on.

Transformer Impedances: In order to calculate losses correctly an accurate model of the Substation Xfmrs is required.

Conductor Catalogs: Similarly conductor material and construction methods impact losses as power flows through the conductors.

Load Models: How individual loads respond to changes in voltage will affect most of the optimization strategies. An accurate understanding of the relative amount of Constant Power, Constant Current and Constant Impedance is required.

SCADA

SCADA is essential for real-time optimization to function correctly. The optimizer needs to have an accurate understanding of the current network state and what options are available to make adjustments. The required inputs are:

- Device Status (Open/Closed) or On / Off
- Regulation targets
- Tap positions
- Voltages
- Bandwidths (if variable)

Some method of adjusting the device's behavior is necessary. Therefore each device needs to have at least some combination of the following NMS outbound controls:

- Device Status
- Tap Position (Up/Down or set)
- Regulation target
- On / Off thresholds
- Bandwidth

Bellwether Meters

The Volt/Var optimization engine can leverage bellwether meters to provide feedback that allows the ADMS to gauge how effective the previously executed adjustments have been and whether more or less aggressive action is required to achieve the desired optimization objective.

The term bellwether is used to indicate that the ADMS does not need comprehensive voltage measurements at all points along a feeder for IVVC/CVR to work. Good results can be achieved with a small number of meters. So for example, if AMI data is available at every customer meter, the ADMS would only want to consume a small fraction of those meters on a fast (near real-time) channel.

Additionally, the term "Meter" is used in a generic sense of any device capable of measuring voltage. It doesn't have to be an AMI meter on a customer's premise. It can be voltage measurements on the primary circuit located near (or at) a capacitor bank for example.

For the purpose of guiding and directing Volt/Var optimizations, the ADMS only leverages voltage measurements. Other measurements (for example, Amps, kW or kVAR) can be used to sure up the powerflow / state estimation calculations. Typically these types of measurements are most suitable gathered from devices on the primary feeder (for example, reclosers). To date it has been impractical and cost prohibitive to gather loading measurements, in near real-time from all customer meters. It is also questionable whether this exercise would yield significant operational benefit over existing methods to estimate load from recloser data.

A summary of what can be measured and it's effects on various ADMS functionality is given below:

1. For IVVC the only measurement that is processed is voltage. That is used as feedback into the CVR module. It is used to confirm (or refute) that expected changes have occurred and to set limit constraints if the change in voltage is more (or less) than the expected change from the power flow solutions. Essentially it used to refine the

expected behavior as determined by the model, with the actual behavior seen in the field.

2. As mentioned above the ADMS can utilize a voltage measurement anywhere along the feeder. That includes:
 - a. Primary voltage measurements at any existing location where there are measurements. For example a pole-top RTU at a recloser; at this location we might already be monitoring things like: Recloser open/close status, recloser mode (Auto-reclose or switch only mode), fault targets, current flow). The ADMS can utilize primary side voltages from this location too.
 - b. Secondary voltage measurements either at a service transformer or at a meter. For example the ADMS could consume voltage measurements from an AMI system if they can be obtained in near real-time. If the ADMS is to use measurements at secondary locations, then the model needs to have some basic understanding about the configuration of the secondary network at that location. If the secondary network is not modeled then at the very least an estimate is needed of the percentage voltage drop from the service xfmr to the meter location.
3. Where present, measurements would need update within the frequency at which CVR calculations are run. The ADMS optimization objects are configurable (on a substation transformer basis) to run in Fast mode and Slow mode. Slow mode means once and hour at the top of the hour. Fast mode means on the back of FLM cycles, which are typically expected to be once every 15 minutes (but can be configured differently).

In this situation, suppose there is a set of CVR feeders in fast mode. CVR will run every 15 minutes. Measurement data from the bellwether meters needs to be produced and consumed faster than that. It is recommend that at least two updates between CVR cycles, to confirm that adjustments have had expected results. If CVR is being run on 15 minute cycles it is recommended that bellwether data would be configured on 5 minute cycles.

4. Size and locating of metering:
 - a. Anecdotal evidence from utilities suggests around 10 measurement points along a feeder provides a good trade-off between expense and accuracy.
 - b. Measurements located at controllable devices (Substation LTC buses, cap banks and regulators) would be a significant benefit.
 - c. Measurements at locations identified to be the weakest (lowest) / strongest (highest) voltage levels.

Chapter 9

Suggested Switching

The Suggested Switching (SS) application runs only in Study Mode and is used to create planned switch sheets that allow certain operations to be performed with minimum customer interruptions whilst preventing other issues like ratings or voltage violations.

There is no automatic mode to SS. All switch plans created are "planned" and must go through normal authorization and scheduling procedures.

The scenarios available are:

Isolate Only: Isolate a device (or group of devices) in the most efficient way. Currently open devices that would re-energize the device if closed are tagged.

Isolate And Restore: Isolate a device (or group of devices) in the most efficient way and wherever possible re-energize "downstream" customers through tie switches. Currently open devices that would re-energize the device if closed are tagged.

Isolate: Restore energization to a device in the most efficient way, ensuring no violations occur if at all possible.

Feeder Unloading: Reduce load on a feeder head by transferring the smallest section of the feeder to an adjacent feeder without creating violations if possible.

Substation Switching: Open a feeder head breaker or isolate a transformer in a substation. All downstream load is transferred to adjacent buses, feeders or substations without incurring violations if possible.

Configuration

As SS is a study mode only application, there is no real-time feeder-by-feeder configuration required. All options are addressed on the wizard that the operator uses to set up the analysis.

Performance

As SS is a study mode application it is only run on demand by users. Its impact on performance will be dependent on the frequency of its use. As every step in the plan needs to be validated, it is possible large plans can require several Power Flow solutions to be performed.

The application is designed to be put in the background if necessary. It runs in a low priority thread and the operator can let it complete by itself whilst attending to other tasks.

Data Requirements

Model

The data requirements for SS are similar to regular power flow. The primary objective of SS is to perform switching without incurring violations, therefore the more accurate the model, the better the analysis.

- **kVA:** Minimum data requirements. Device ratings, nominal voltages, Xfmr voltage levels and service transformer sizes are sufficient.
- **Power Flow:** Full data requirements. Defaulting is acceptable but will affect accuracy of results. In addition to the items listed for kVA mode, conductor catalogs are required to produce accurate voltage solutions.

At a minimum therefore projects should provide: Device ratings, nominal voltages, Xfmr voltage levels, service transformer sizes and conductor catalogs.

Device regulation parameters, load profiles and load models will provide better analysis.

SCADA

SCADA is optional for SS. If SS knows that a device is SCADA switchable, it can refine plans to only use those devices if desired.