Oracle Utilities
Distributed Grid Management

User's Guide

Release 2.0.0.1

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Oracle Utilities Distributed Grid Management User's Guide, Release 2.0.0.1

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Contents

Preface

This guide provides an overview of Oracle Utilities Distributed Grid Management system functionality and details for using the client application to manage a distributed microgrid area.

Audience

This document is intended for all Oracle Utilities Distributed Grid Management users.

Related Documents

For more information, see the following documents in the Oracle Utilities Distributed Grid Management, Release 2.0.0.1, documentation set:

- *Oracle Utilities Distributed Grid Management Release Notes*
- *Oracle Utilities Distributed Grid Management Quick Install Guide*
- *Oracle Utilities Distributed Grid Management Installation and Configuration Guide*

Conventions

The following text conventions are used in this document:

Convention	Meaning
boldface	Boldface type indicates graphical user interface elements associated with an action, or terms defined in text or the glossary.
italic	Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.
`monospace`	Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.

Chapter 1

Overview

This chapter provides an overview of Oracle Utilities Distributed Grid Management. Topics include:

- **About Oracle Utilities Distributed Grid Management**
- **Understanding the Manager**

About Oracle Utilities Distributed Grid Management

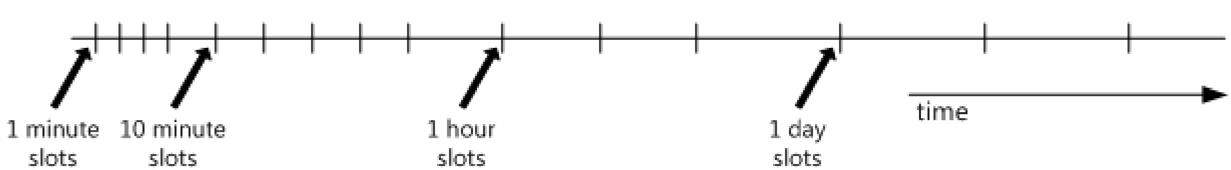
Oracle Utilities Distributed Grid Management allows optimal control of a microgrid or a small section of a larger distribution grid. Oracle Utilities Distributed Grid Management has two primary components:

- **The Manager**: The Manager is the server component, which contains the business logic for the calculations and optimizations that it communicates to external systems and grid devices via project specific adapters.
- **The Viewer**: The Viewer, which is a rich client that runs on a PC, provides the user interface for operator analysis and system interaction through the Manager.

While Viewer interaction is the primary focus of this guide, the remainder of this chapter provides an overview of key Manager concepts needed to effectively use the Viewer.

Understanding the Manager

The Manager maintains a timeline that represents the current time through the forecast period (for example, the following seven days). The timeline timeslots are unequally spaced, as shown in the diagram below:



In this example, there are ten 1-minute timeslots for the next ten minutes, then five 10-minute timeslots for the next hour, twenty-three 1-hour timeslots for the next day, and then six 1-day timeslots. Each timeslot is a separate snapshot of the system state for which analysis is performed. See the *Oracle Utilities Distributed Grid Management Installation and Configuration Guide* for information on configuring timeslots.

The Manager performs **load forecasting**, **load flow analysis**, and **alert reporting** for each timeslot. The optimization algorithms (**switch reconfiguration**, **volt/VAr analysis**, and **distributed energy resource (DER) scheduling**), are performed for timeslots that are at least 30 minutes and up to 24 hours ahead (configurable).

The optimization may result in device action commands, such as switching actions or capacitor and tap changes. These commands are scheduled and executed depending upon the **System Operating Mode** and **Device Control Mode**.

The Manager also accepts commands from users to schedule the operation of network devices. These commands are sent out through an appropriate interface at the required time.

Understanding the System Operating Mode

Oracle Utilities Distributed Grid Management has two system operating modes: *Automatic* and *Manual*.

- In **Automatic Mode**, the scheduled device commands are sent out without any user interaction. This allows for close-loop control of the microgrid.
- In **Manual Mode**, no command is sent out without the user's permission. An authorized user must approve each command. If a user does not approve a scheduled command within one minute following the scheduled device action time, the command times out; this is applicable even to manually scheduled commands.

Understanding the Device Control Mode

Individual grid devices may have the following control modes:

- **Manual**: The device is controlled by the operator through the Viewer. In Manual Mode, optimization engine does not consider the device for optimization. The manual control mode is applicable to generators, capacitors, switches, transformers, and regulator taps.
- **Automatic**: In Automatic Mode, the device is controlled by the Manager and is evaluated for optimization. The optimization algorithms can generate and schedule commands for the devices. The automatic control mode is applicable to capacitors, switches, transformers, and regulator taps.
- **Local**: When a device is in local control mode, it is controlled by its own controller. For example, transformer taps may be controlled by an on-load tap changer to maintain the bus voltage locally. The local control mode is applicable to capacitors, transformers, and regulators that have their own internal controllers.

Chapter 2

Using the Viewer

This chapter describes how to use the Oracle Utilities Distributed Grid Management Viewer (the Viewer) to evaluate and control a microgrid. Topics include:

- **Logging In**
- **Understanding the Viewer**
- **Using the Network Map**
- **Understanding the Power Balance Graph**
- **Using the Detailed Device Graphs**
- **Understanding Scheduling Information**
- **Understanding Voltage Optimization**
- **Using the Generator Schedule Tool**
- **Understanding Automatic Generation Scheduling**

Logging In

The following steps describe the process for starting the Viewer. Note that the Manager must be running on the server for you to login.

The Viewer is launched using a file named `ViewerLaunch.cmd`, which is installed with the Viewer application files.

> **Note:** The installation instructions recommend placing a shortcut to `ViewerLaunch` file on your desktop; if the shortcut is missing or is deleted, the file is located in the `C:\Oracle\DGM\microgrid\viewer\dist\` folder.

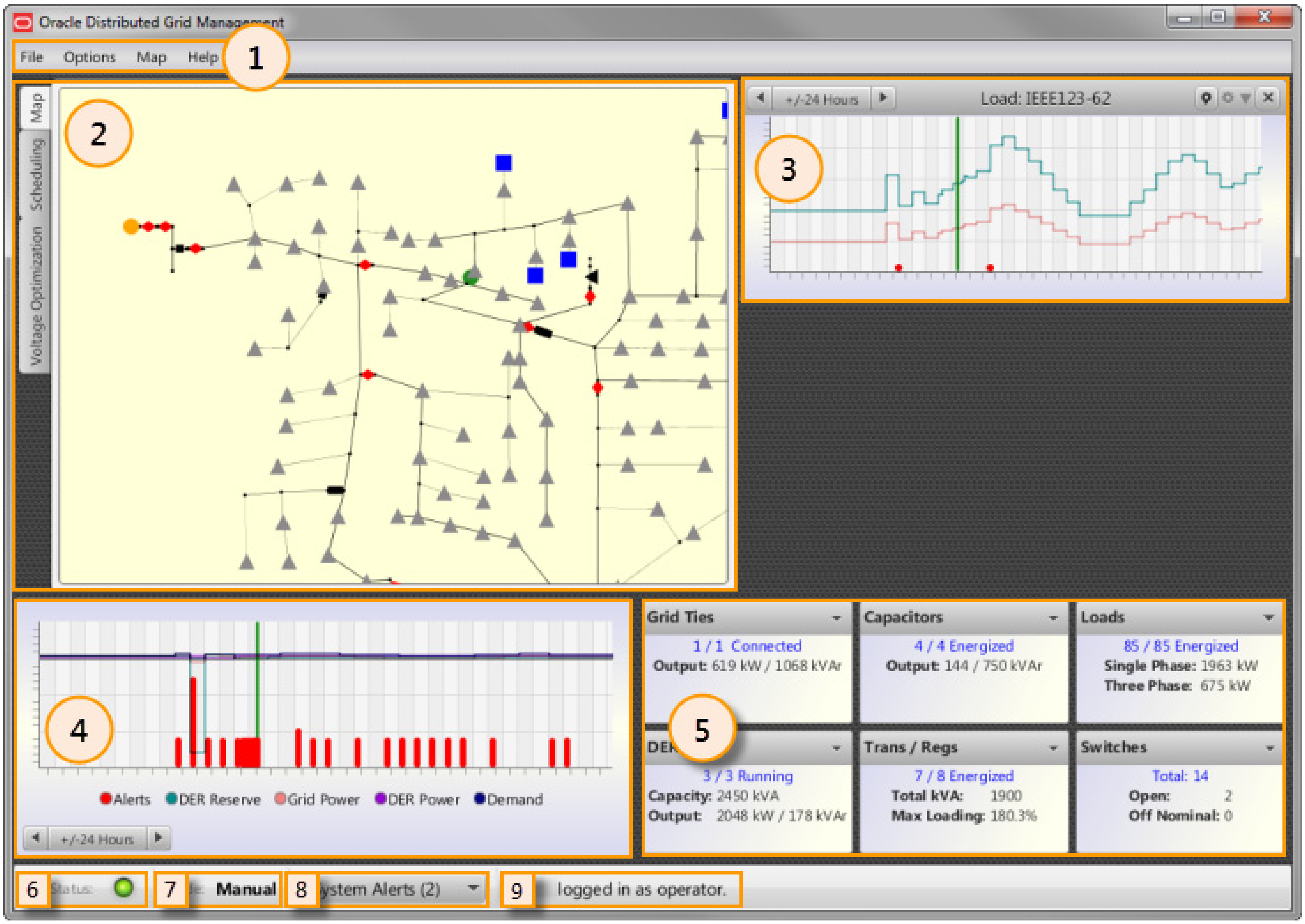
1. Double-click the **ViewerLaunch** shortcut to start the Oracle Utilities Distributed Grid Management client processes. The Distributed Grid Management Login window opens.
2. Enter your username and password.

   Note: Your system administrator will provide your username and password. You will also be granted one of two access levels:

   - **Operator:** An Operator can perform actions, such as device control, and change the system operating mode.
   - **View Only:** A View Only user can only view information about the system.
3. Click **Login.** The Login window closes and the Viewer window opens.

Understanding the Viewer

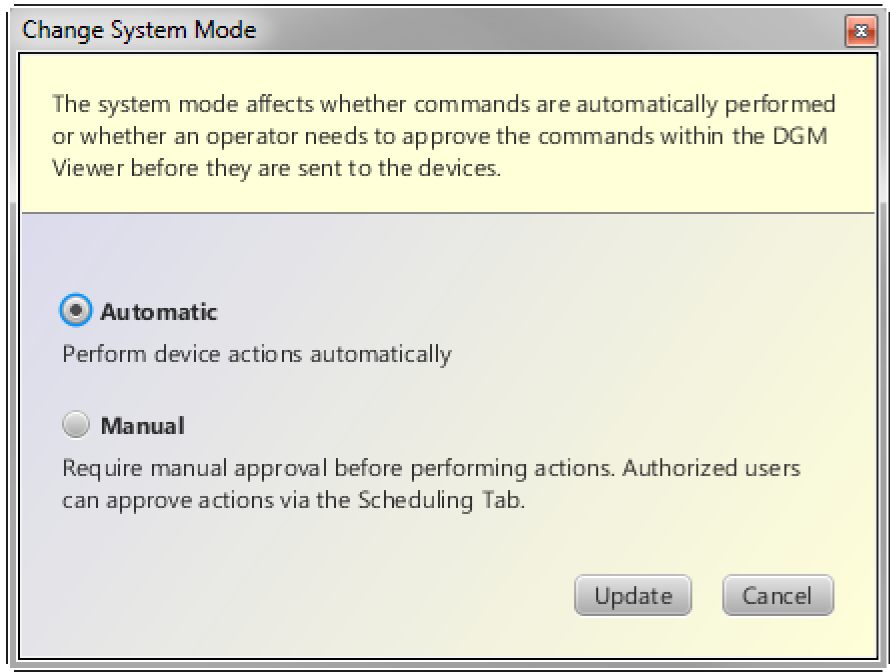
The Viewer window is comprised of several functional areas, as illustrated below:



The functional areas are containers for the following functionality:

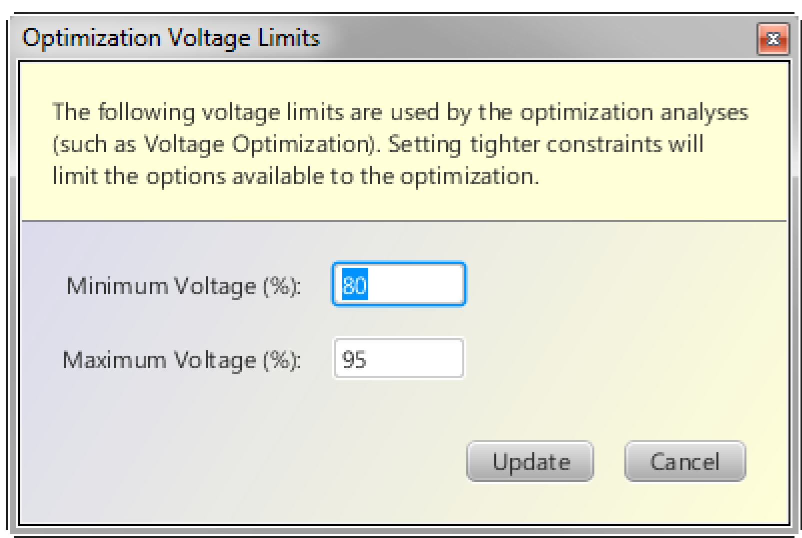
1. Menus
   - **File:** The **File** menu allows you to:
     - **Logout:** Closes the Viewer window, logs you out of the system, and opens the Login window for a subsequent login.
     - **Exit:** Closes the Viewer window and logs you out of the system.

- **Options:** The **Options** menu provides the following
  - **System Mode...:** Opens the Change System Mode dialog box, which allows an administrator to change the **System Mode** between **Manual** and **Automatic** settings.



The System Mode determines whether device actions are automatically performed or whether they require operator approval (on the Scheduling tab) before they are sent to devices.

  - **Voltage Limits...:** Opens the Optimization Voltage Limits dialog box from which an administrator can select the allowable voltage limits to use for voltage optimization. The analysis will attempt to maintain voltages throughout the system within these limits; setting tighter constraints will tend to limit the options available to the optimization.



  - **Generator Schedule...:** Opens the Set Generator Schedule dialog box. See **Using the Generator Schedule Tool** on page 2-26 for details.

- **Map:** The **Map** menu provides options for the Map view:
    - **Show Map Controls:** toggles the map pan/zoom controller on or off.
    - **Reset Map View:** returns the map to the default view.
    - **Show Flow Direction:** sub-menu provides options to show or hide arrows on conductors that illustrate power flow direction. The sub-menu provides the following options:
        - **Real Power:** show flow directional arrows based on real power values.
        - **Reactive Power:** show flow directional arrows based on reactive power values.
        - **None:** if checked, hide flow directional arrows.
- **Help:** The **Help** menu provides information about the Oracle Utilities Distributed Grid Management installation.

2. Tabbed Views provide access to the three primary information panes:
    - **Map:** The **Map** tab shows the network map. See **Using the Network Map** on page 2-5 for details.
    - **Scheduling:** The **Scheduling** tab shows scheduled commands for network devices. See **Understanding Scheduling Information** on page 2-23 for details.
    - **Voltage Optimization:** The **Voltage Optimization** tab shows the results of the Voltage Optimization analysis, including Volt/VAr optimization and switching optimization. See **Understanding Voltage Optimization** on page 2-25 for details.
3. **Detailed Device Graphs:** The detailed device graphs display information about a device that was double-clicked in the Map or selected from the aggregate device panels. See **Using the Detailed Device Graphs** on page 2-17.
4. **Power Balance Graph:** The Power Balance Graph . See **Understanding the Power Balance Graph** on page 2-13 for details.
5. **Aggregate Device Panel:** provides overview information for devices by category. Each box provides an options menu that allows you to open detailed device information for a selected device.

The Status Bar. The bottom section of the Viewer window provides a status bar with information about system status, operating mode, system alerts, and user login information.

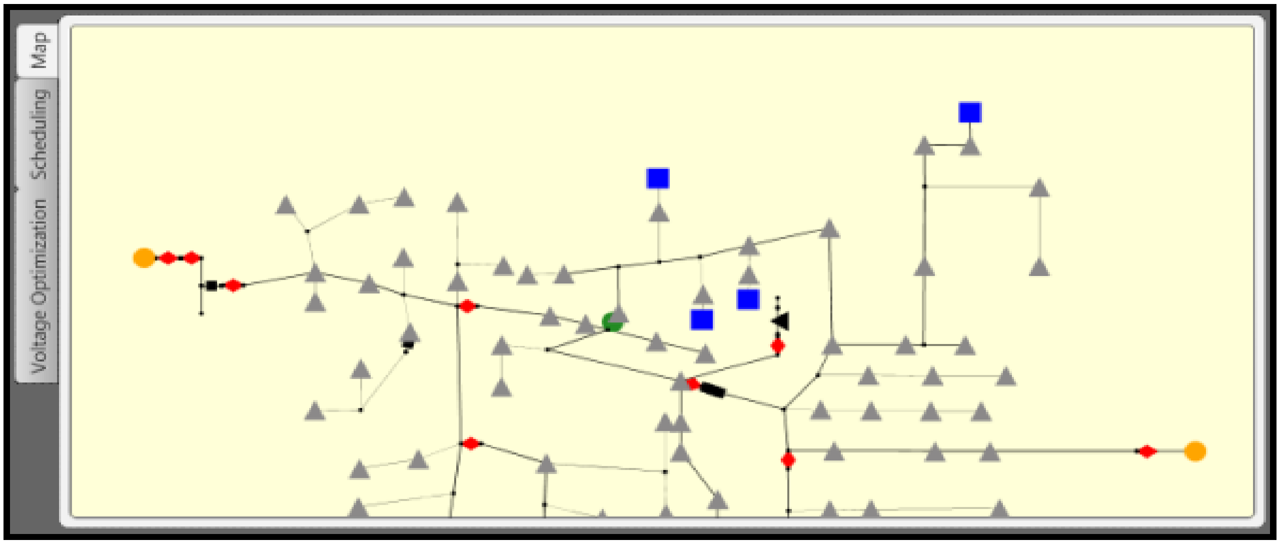
6. **Status:** The status indicator provides a system connection indicator and hover tip information for last data refresh from the Manager.
    - **Green Circle ( ):** the Manager is available and communicating with the Viewer.
    - **Red Circle ( ):** the Viewer is not communicating with the Manager.
7. **Mode:** The system operating mode, Automatic or Manual. See
8. **System Alerts**: Displays the number of System Alerts for the current time and a drop-down list with alerts grouped by time and device type. See **Using the System Alerts List** on page 2-15 for details.
9. User Information: The area to the right of the System Alerts list displays the username and user type as plain text. When you hover over the text with the mouse, a tooltip is displayed that shows your last login date and time.

Viewer Data Refresh

The Viewer polls the Manager periodically to get new data. This is known as the refresh period and is configurable by the administrator. Because of this refresh period, there may be a short delay between when a user action is performed and when the results of that action are reflected on the Viewer display.

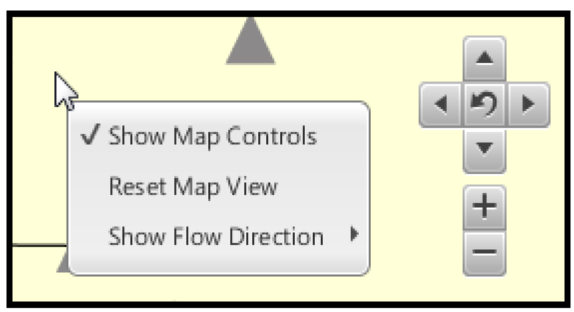
Using the Network Map

The network map is a single-line geospatial map of the electrical network that displays static and dynamic data for all devices.



Map Controls

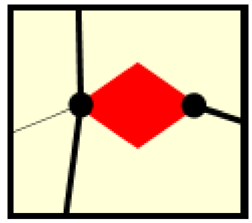
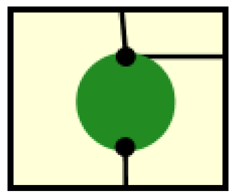
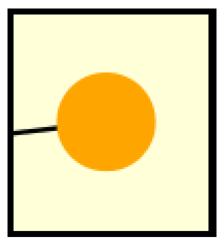
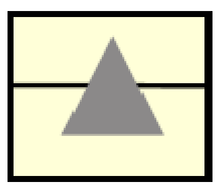
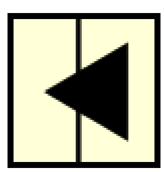
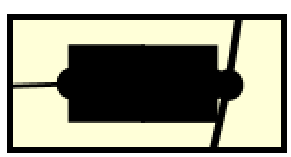
The map supports zooming and panning with controls accessed by right-clicking the map area and selecting **Show Map Controls** from the context menu.

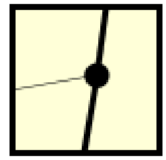
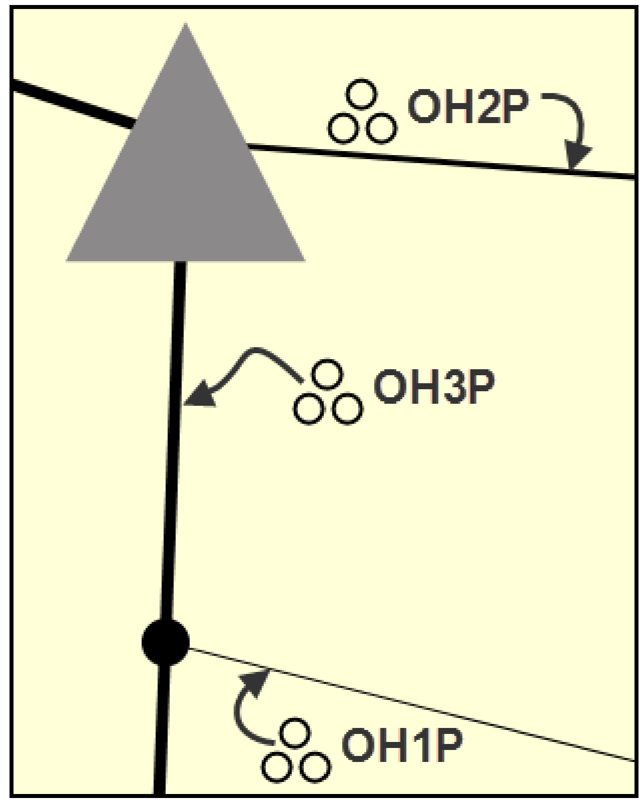


Alternatively, panning is supported by "grabbing" the map with the mouse (left-click and hold) and then dragging the map in a desired direction; zooming is supported using a mouse scroll-wheel.

Symbology

The default map uses following notation for devices:

Device Type	Symbol
Switch (closed)	
Switch (open)	
Generator	
Load	
Transformer (step-down)	
Regulator	

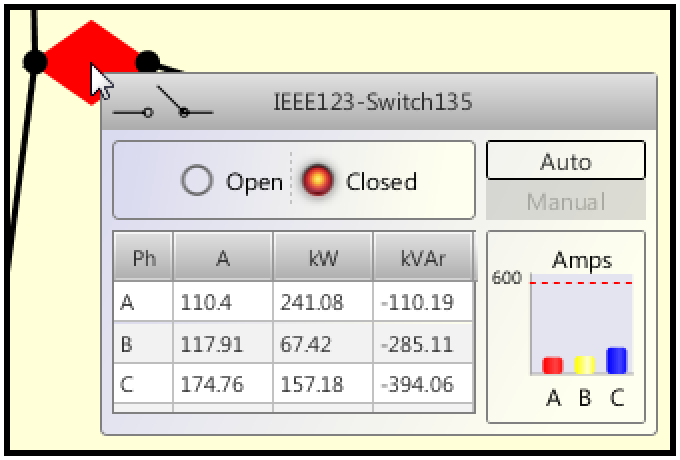
Device Type	Symbol
Node	
Conductors (Overhead) As shown in the illustration, the number of phases on the conductor determines the line thickness. The thinnest line is a single phase (1P), while the thickest line is a three phase (3P), and the two phase (2P) line thickness is of intermediate thickness.	

Object Information

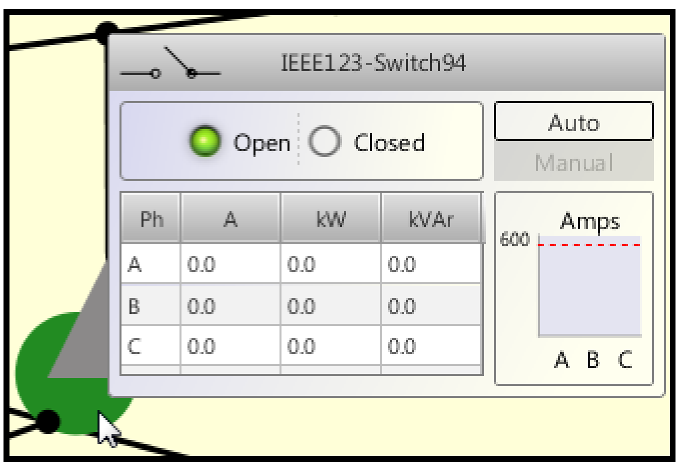
When the mouse pointer is close to a device or line, a tooltip window appears showing relevant information for the device, node, or line. The information displayed includes device ratings, real time voltages, currents, and power flows for the object.

> **Note:** If you double-click a device symbol, the symbol detailed device graph will open. See **Using the Detailed Device Graphs** on page 2-17 for more information.

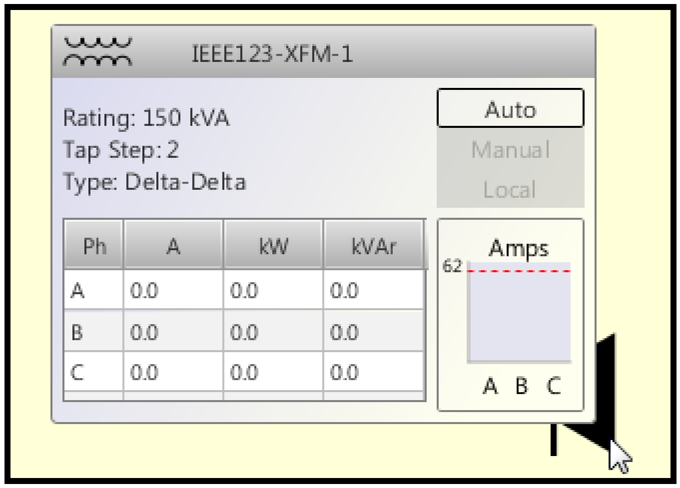
- **Example**: Closed Switch



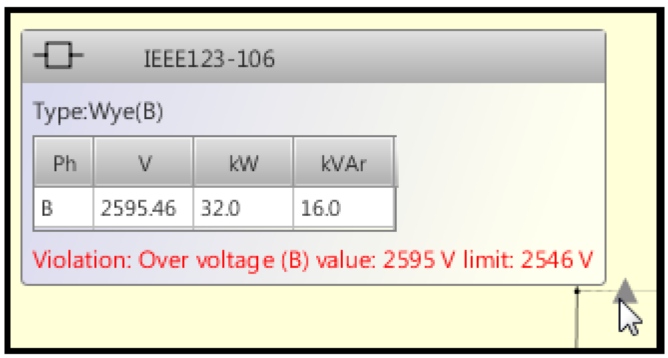
- **Example**: Open Switch



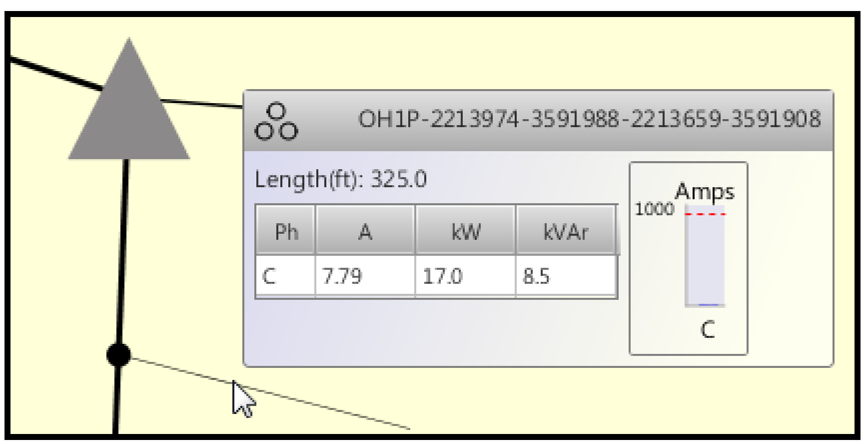
- **Example**: Transformer



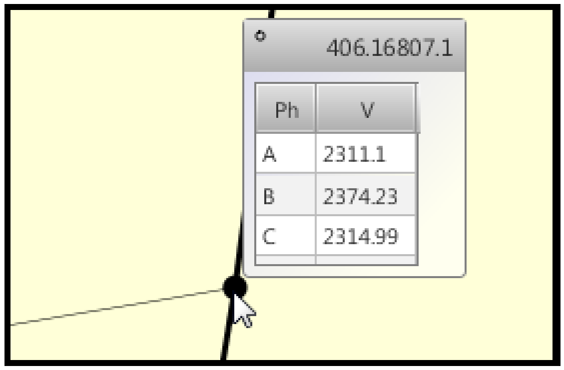
- **Example**: Load



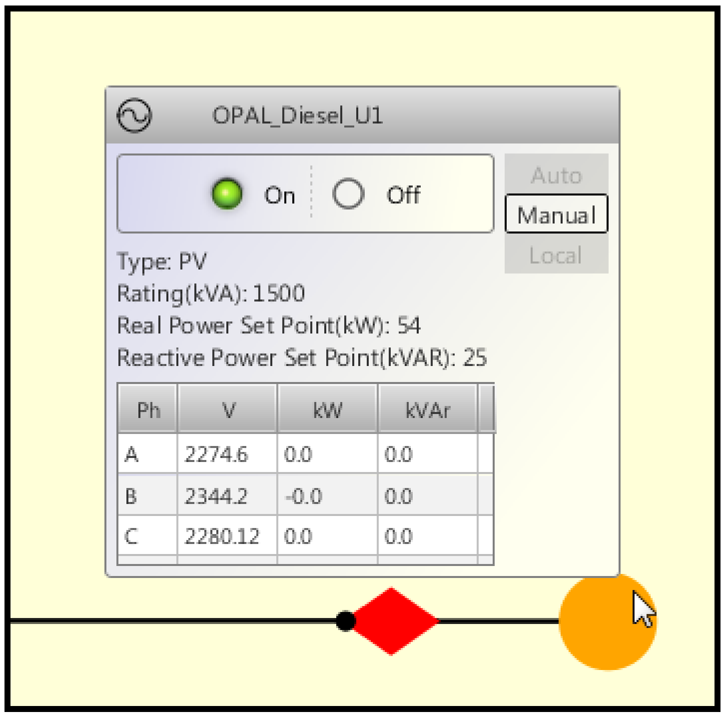
- **Example**: Conductor - Overhead, Single Phase



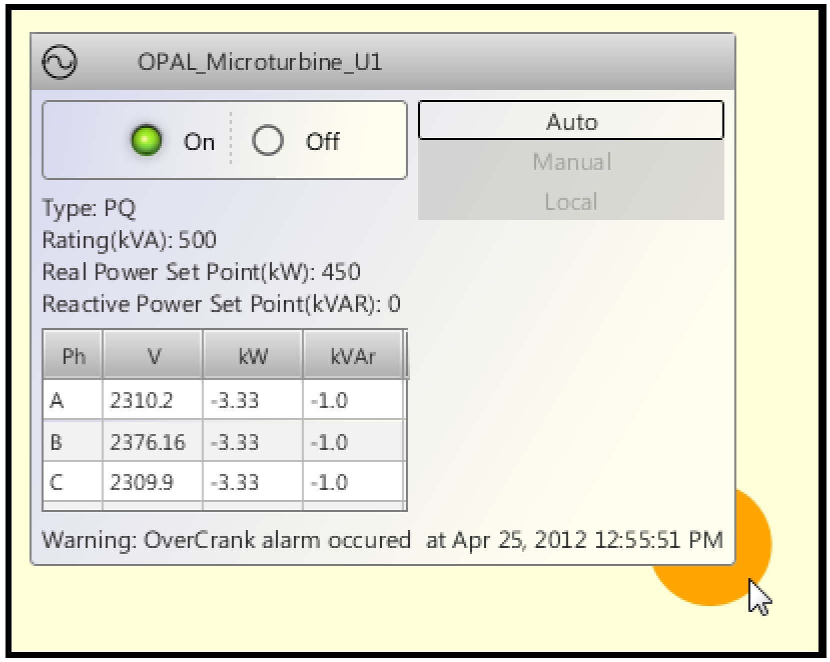
- **Example:** Node



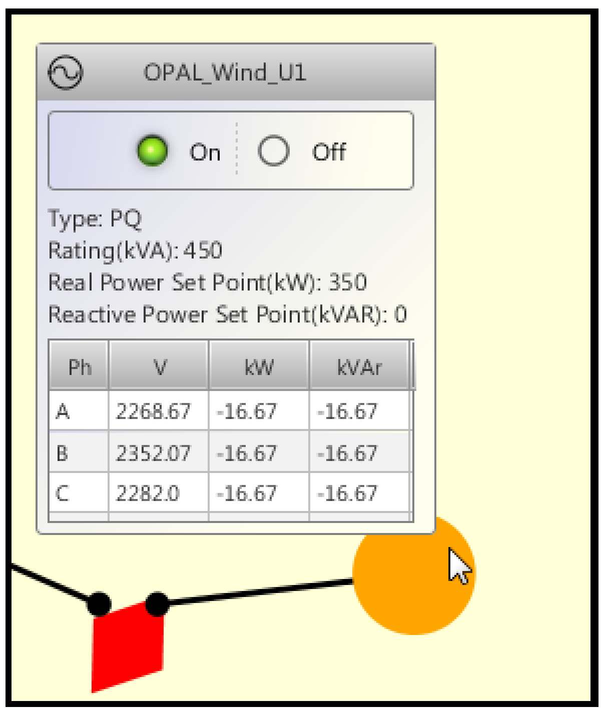
- **Example:** Generator (Diesel)



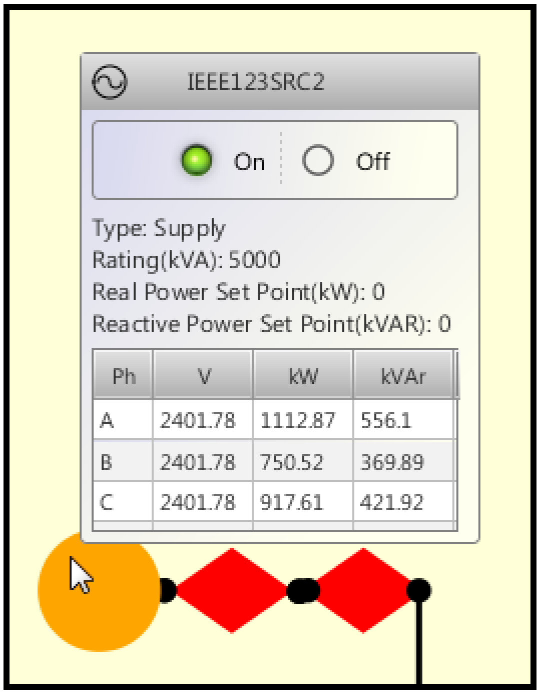
- **Example:** Generator (Microturbine)



- **Example:** Generator (Wind)



- **Example:** Generator (Supply/Feeder)



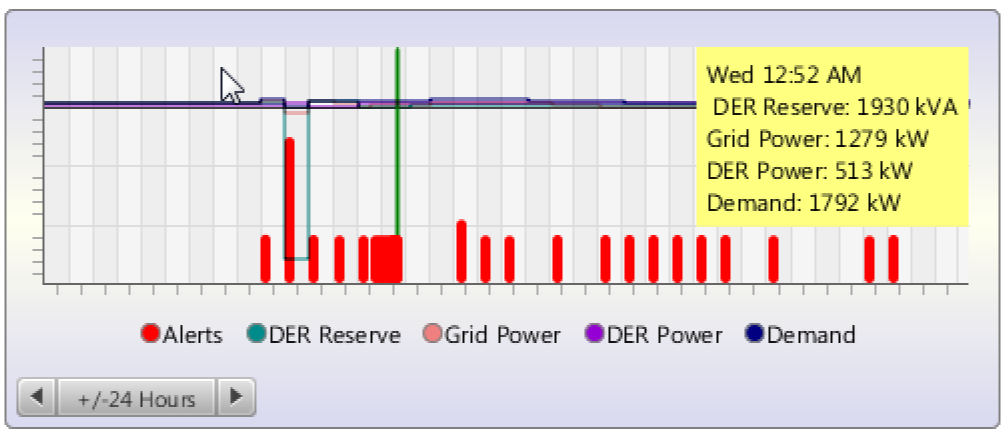
Understanding the Power Balance Graph

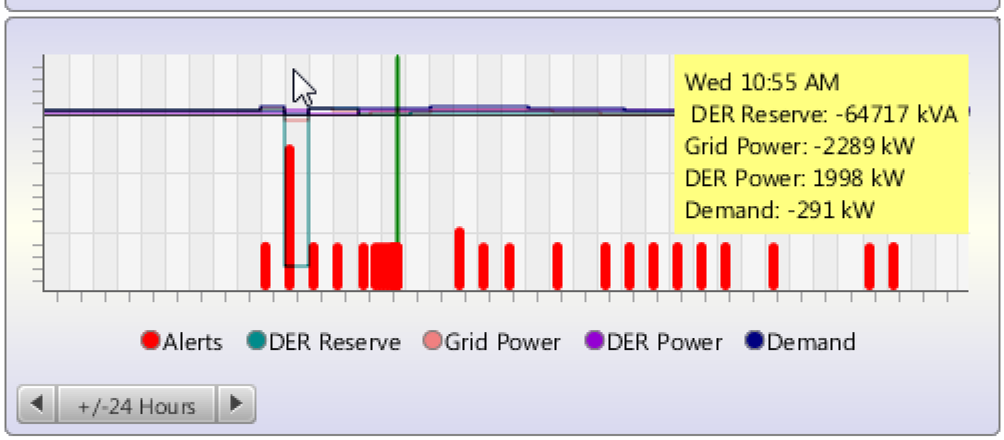
The **Power Balance Graph** displays a forecast of the grid power balance. The power balance components are:

- **Grid Power:** supply power
- **DER Power:** power from Distributed Energy Resources (DERs)
- **DER Reserve:** available generation capacity of DERs
- **Demand:** system demand

The value of each power balance component is plotted individually over time (the x-axis).

As you hover your mouse over the graph, data for the time interval is displayed as a tooltip.



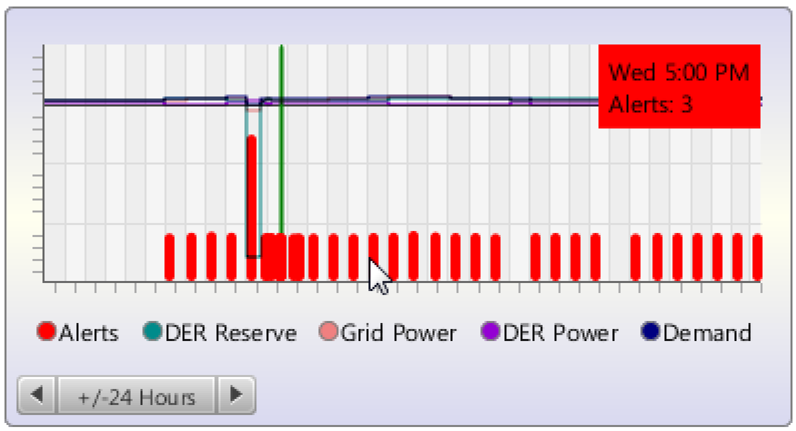


Time Scale

The time scale can be changed from minutes to hours to days using the time scale control, which is located in the lower left corner of the Power Balance Graph pane. Click the ◀ button to decrease the time scale; click the ▶ button to increase the time scale. Smaller time scales, such as 10 minutes or 60 minutes, show forecasts for the near future, while longer time scales, such as 24 hours or 7 days, show longer term data. These forecasts are an estimate of the system state in the future. Oracle Utilities Distributed Grid Management continuously refines its predictions as new data is available.

Alerts

Alerts are represented on the Power Balance Graph as red columns. As you hover over an alert column, a tooltip is displayed that shows the number of alerts for that time period.



Using the System Alerts List

Oracle Utilities Distributed Grid Management generates alerts to inform you of system conditions that violate allowable limits. The System Alerts List gives an overview of all alerts for the current system and for each future forecast period.

> **Note:** Alerts are also displayed in map tooltips, detailed device chart tooltips, and the Power Balance Graph.

Alerts include:

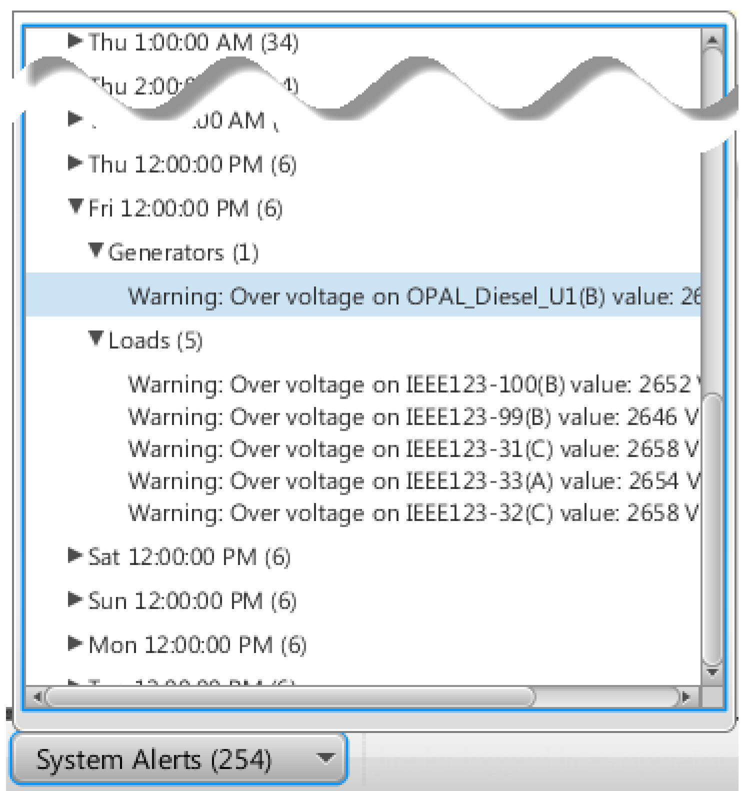
- Over voltage conditions
- Under voltage conditions
- Overloading of devices
- Excessive voltage imbalance.
- Generator-specific adverse conditions, such as over-cranking on a microturbine

Viewing Alerts in the System Alerts List

To view the list, do the following:

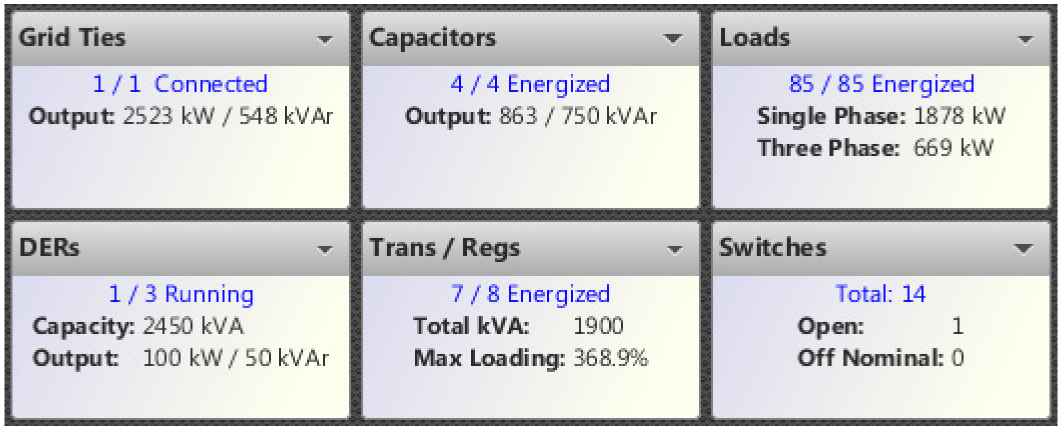
1. Click the System Alerts button. The list will expand to show time intervals with alert conditions.
2. Double-click a listed time to expand the data. (Alternatively, you may click the arrow to expand the list.)

As you drill down, you can read the specific warnings.

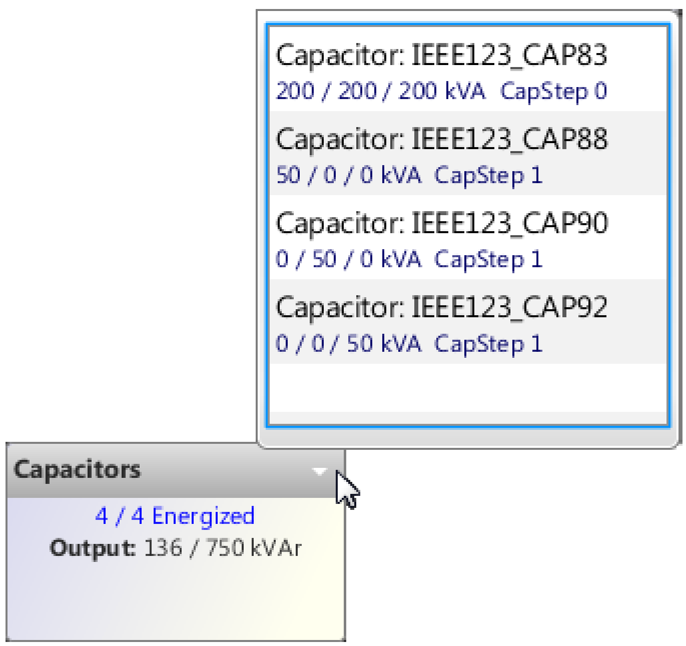


Using the Aggregated Device Information

The aggregated device information panes are located on the right bottom section of the Viewer main display. These panes give device information grouped by device types.



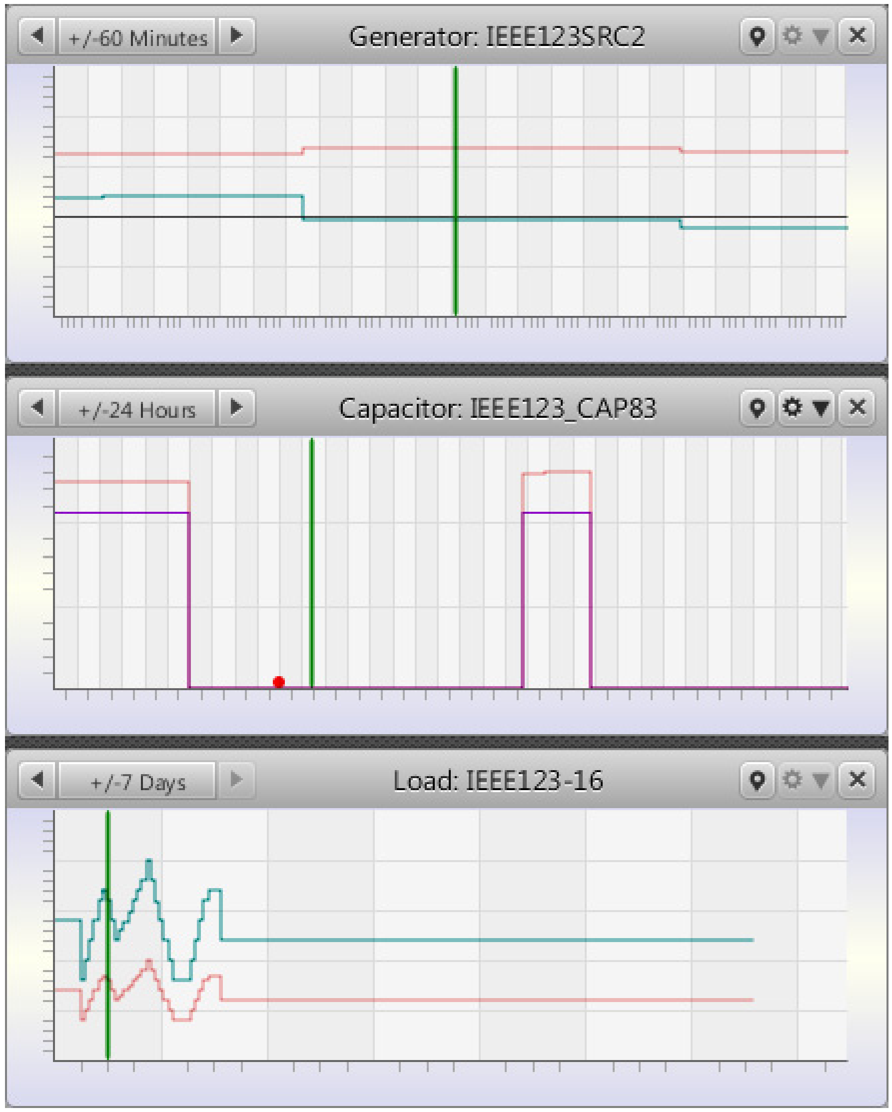
They also provide access to the list of devices that belong to the particular type. The device list is opened by clicking the  button.



When you select a device in the list, a detailed device graph window opens. See **Using the Detailed Device Graphs** on page 2-17 for more information.

Using the Detailed Device Graphs

The detailed device graph shows output or status of devices over a selected period of time.



Device Graph Controls

Time Scale

The time scale indicator shows the currently selected time scale and provides control buttons to decrease or increase the displayed time.

The default time scale values are:

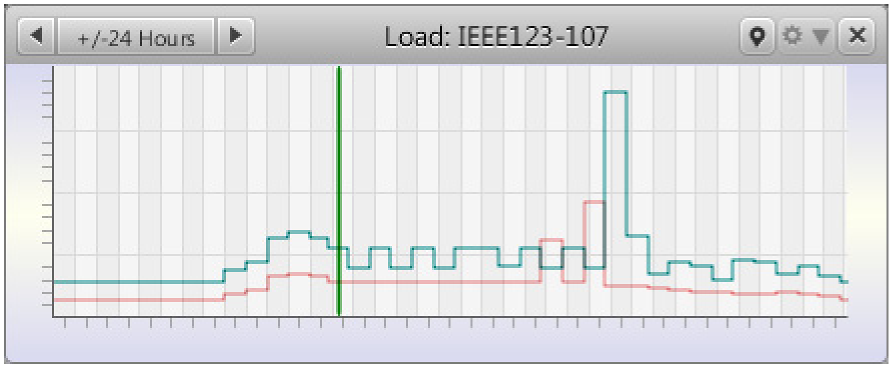
- +/- 10 Minutes
- +/- 60 Minutes
- +/- 24 Hours
- +/- 7 Days

The time scale can be decreased by clicking the  button and increased by clicking the  button.

Focus

The Focus button ( ) allows you to center the device in the Viewer Map. The following example demonstrates the steps to focus the map.

1. Select a device from an aggregate device panel.



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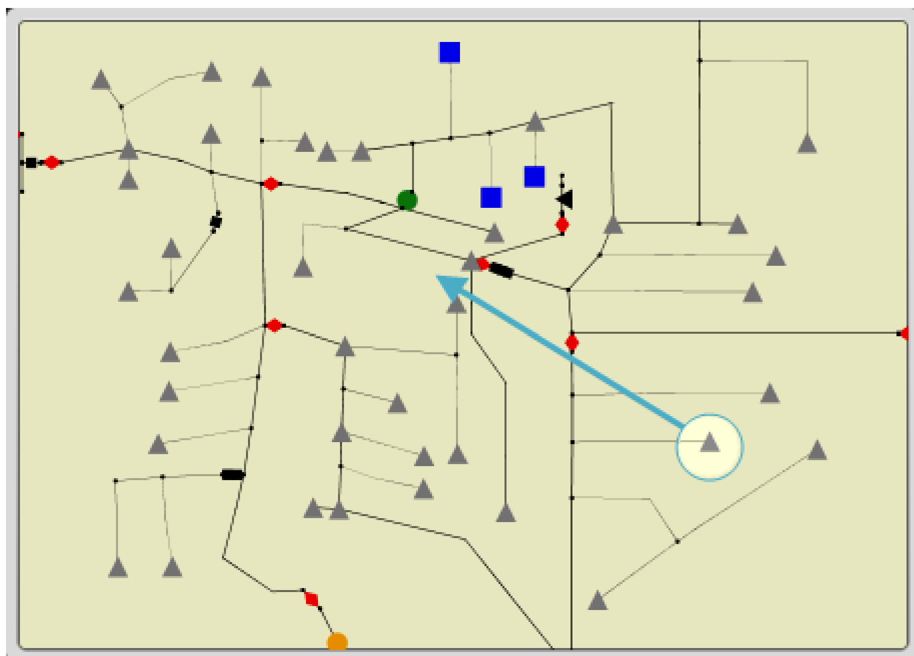
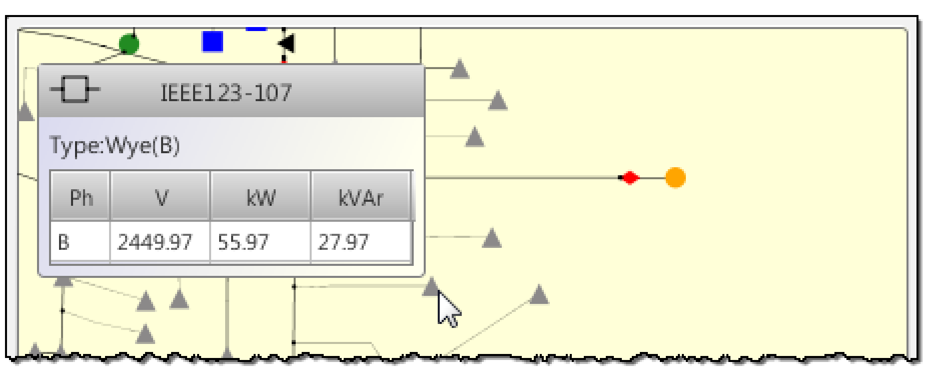
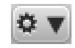
2. Click to focus on the device. The map will redraw from this initial view (device highlighted in the lower right quadrant):

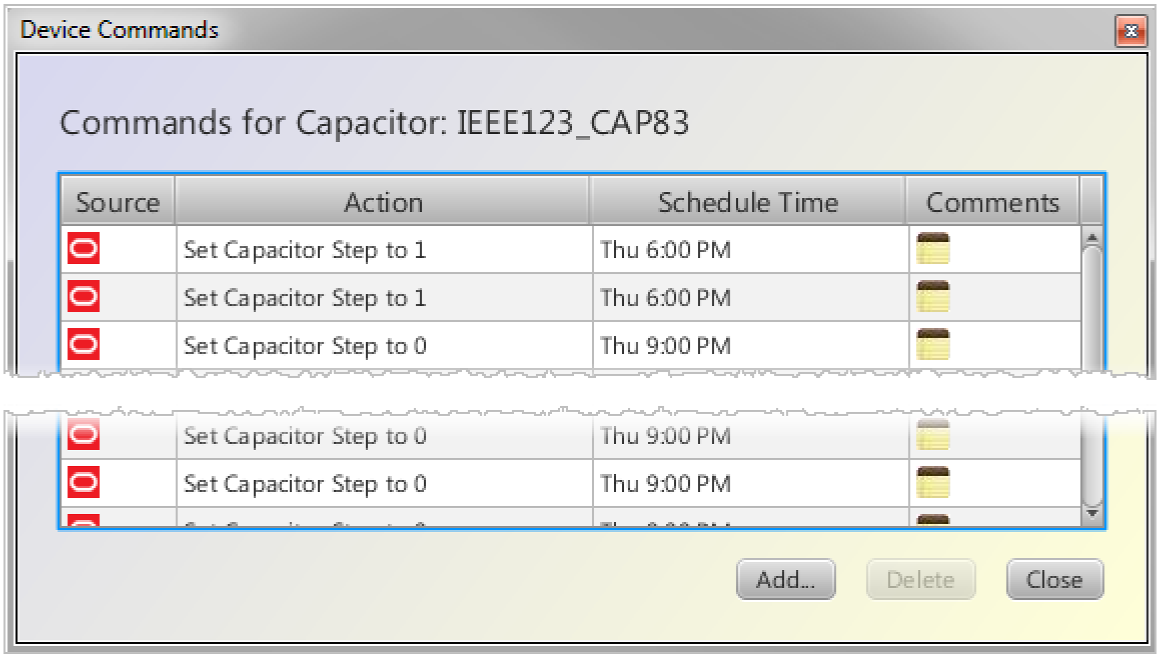


to the final where the device is centered in the drawing area:



Device Commands

The device command dialog, opened by clicking the  button shows the scheduled actions for that device and also provides the option to **Add** or **Delete** an action, if you have privileges to operate devices.



New Device Commands

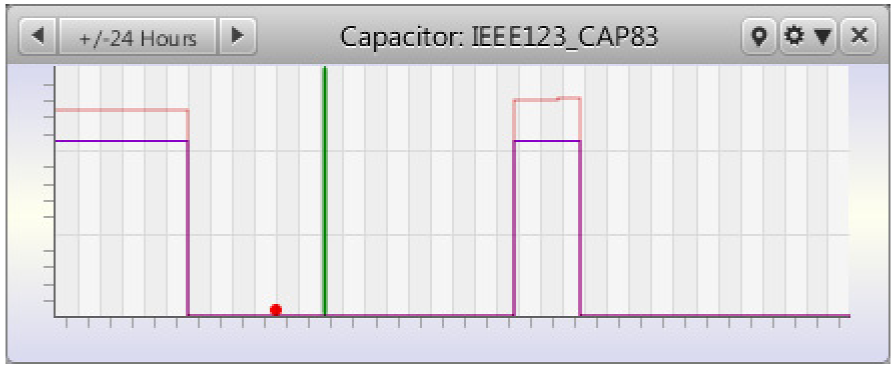
The New Device Commands dialog can be accessed from the device commands dialog by clicking **Add**. The New Device Commands dialog allows you to perform an action on a device immediately or schedule it for a future time. Each device supports certain types of control actions. For example, a switch can be opened or closed, while a tap can have its setting changed.

You can also change the control mode of a device (see **Understanding the Device Control Mode** on page 1-2). The following table lists the available control modes and control actions for each device type

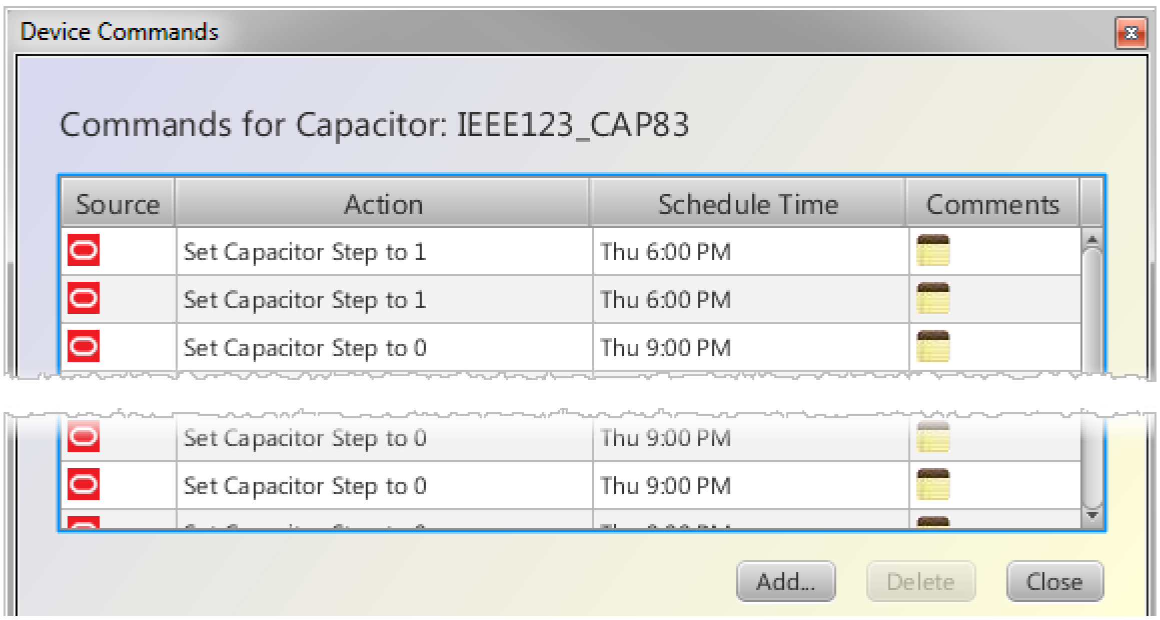
Device Type	Control Modes	Control Actions
Switch	Automatic, Manual	Open, Close
Capacitor	Automatic, Manual, Local	Set capacitor step
Transformers/Regulators (taps)	Automatic, Manual, Local	Set tap setting
Generator	Automatic, Manual, Local	Set generator output

Example: Set Capacitor Step

1. Click the **Device Commands** button:

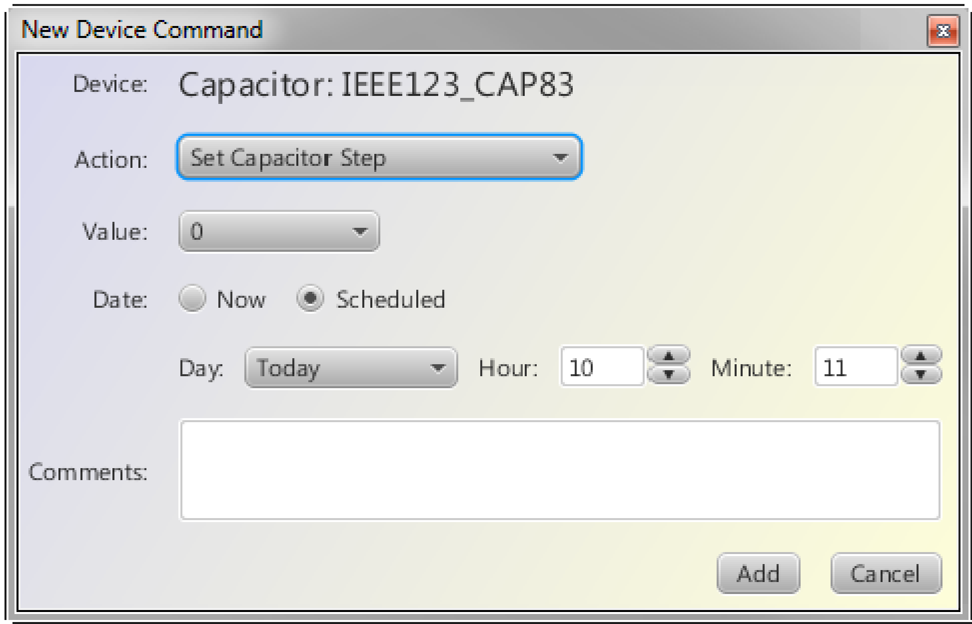


2. The **Device Commands** dialog opens.

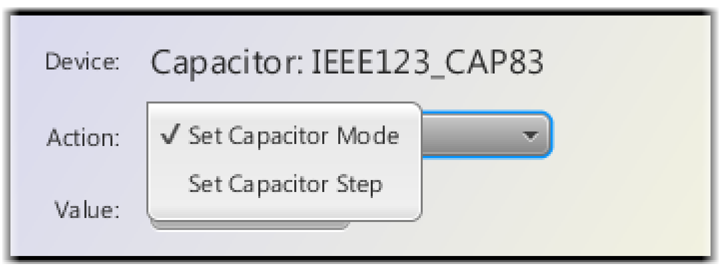


3. Click **Add...**

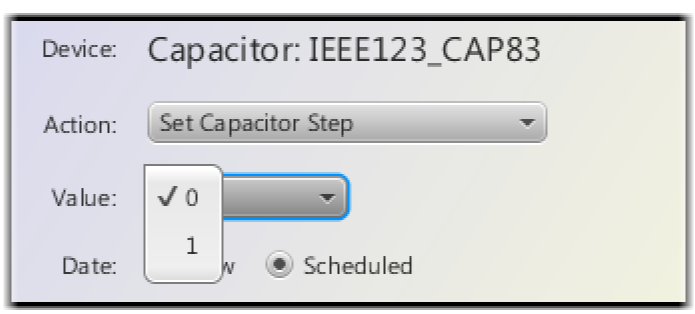
The **New Device Command** dialog opens.



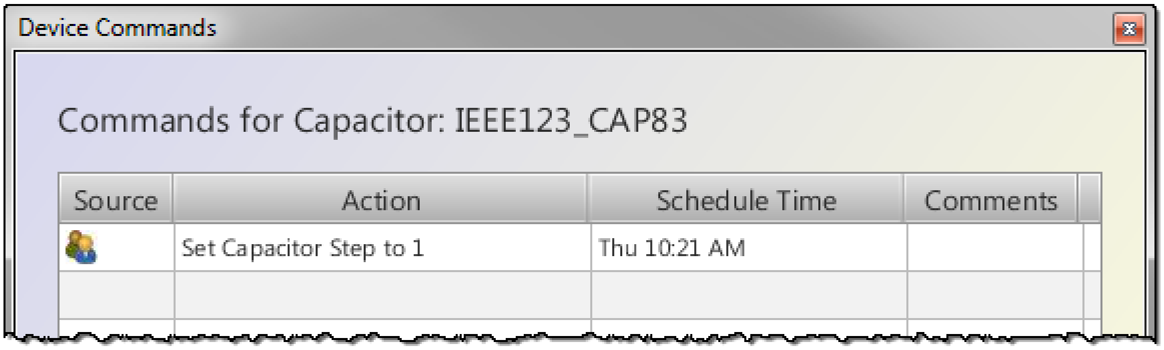
The **Action** menu provides two options for this capacitor:



4. Select Set Capacitor Step.
5. Select the Step Value..

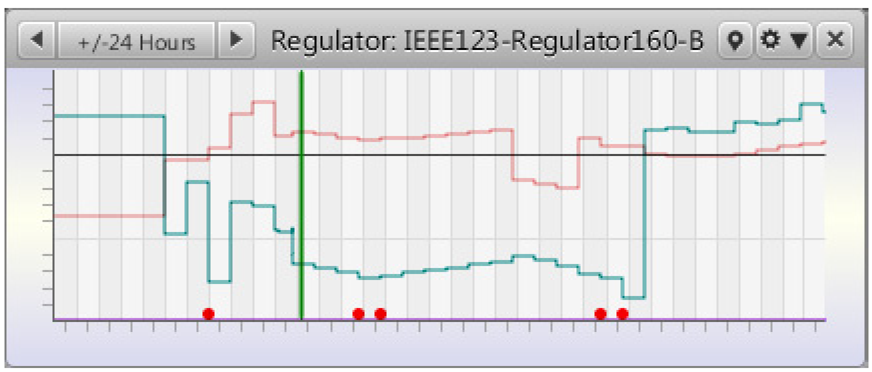


6. Click **Add.** The **Device Commands** window is populated with the new command:

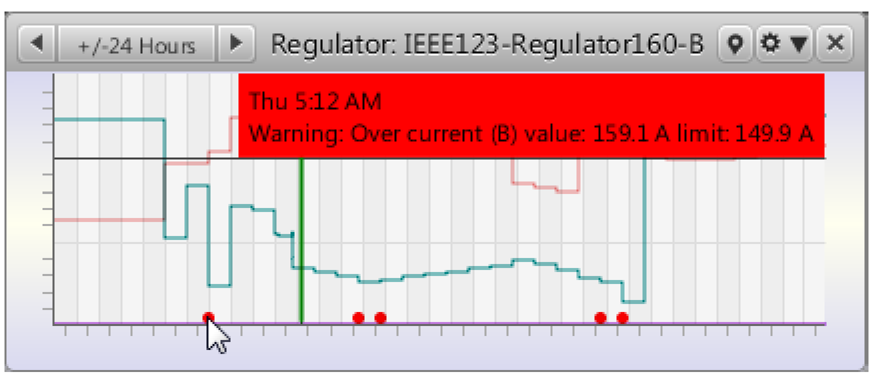


Alerts

Alerts are represented by red circles above the timeline.

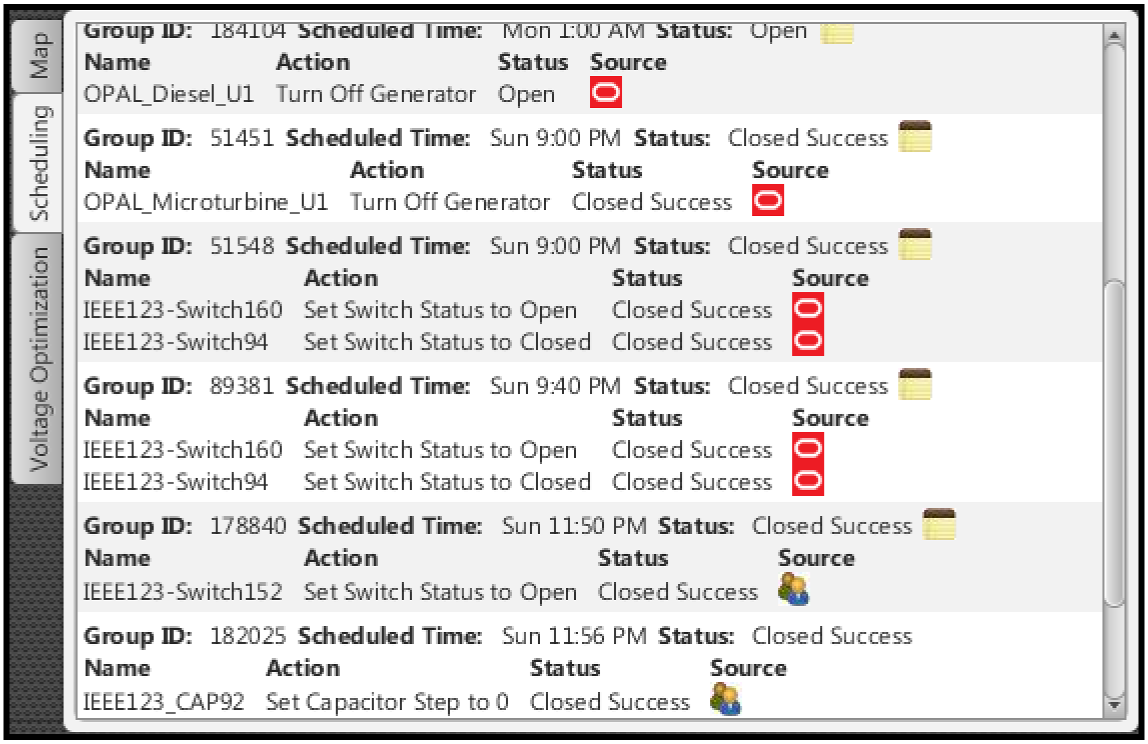


If you hover over a red dot, hover text will display the warnings at that point in time:



Understanding Scheduling Information

The device command schedule display can be accessed by selecting the Scheduling tab, as shown in figure below.

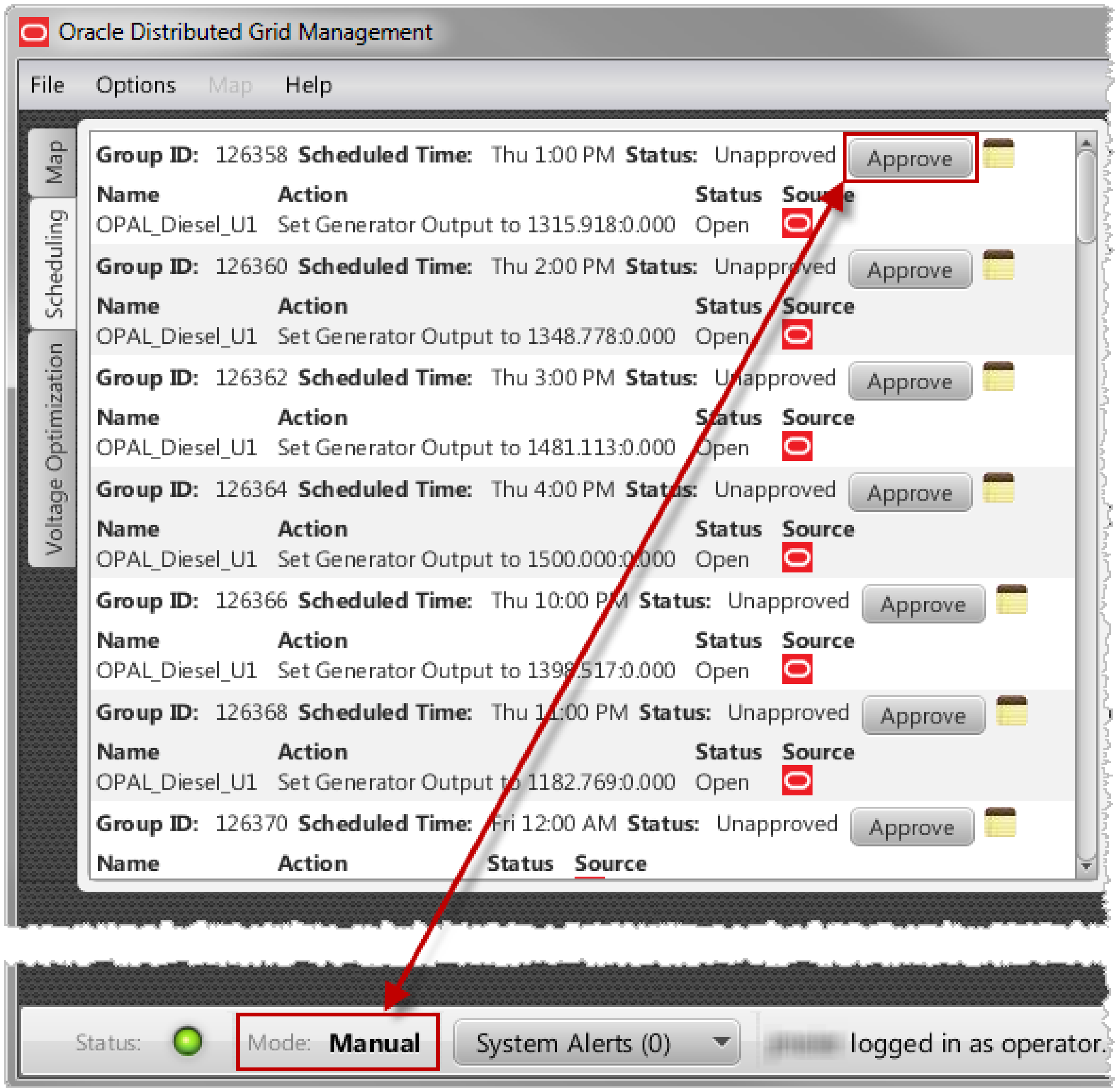


The scheduling screen shows the scheduled device actions as scheduled command sequences. A command sequence is sequence of one or more commands that must be performed in the order of their sequence. If a command in a command sequence fails, a predefined *undo* action is performed on the successfully executed commands.

Commands have following *command statuses*:

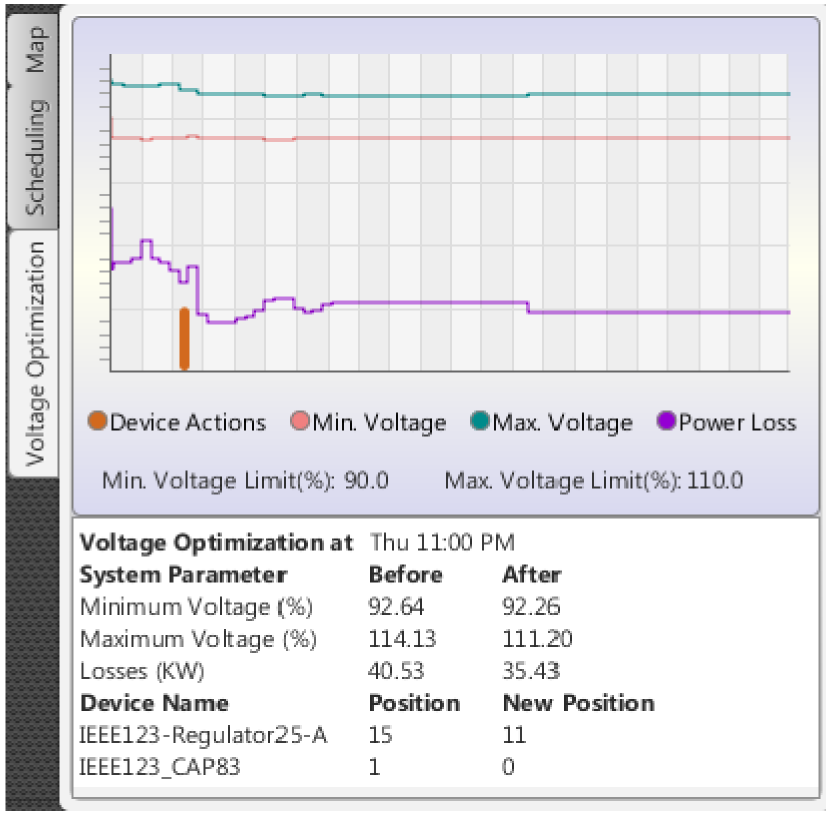
- **Open**: a command is *Open* when it is scheduled and waiting to be executed
- **Pending**: once a command is sent out, it becomes *Pending* until it is executed.
- **Closed Success**: once a command is executed successfully it becomes *Closed Success*
- **Closed Fail**: if a command fails, it is *Closed Fail*
- **Closed Time Out**: if a command is in the pending state, and no response is received for a predefined time period, it becomes *Closed Time Out*

In manual mode, the scheduling screen allows the operator to approve or unapprove the commands in *Open* state; only approved commands are sent out..



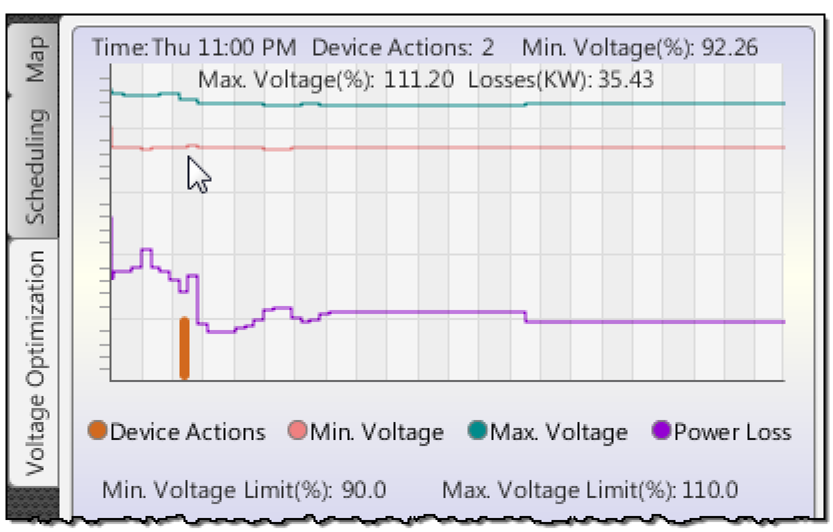
Understanding Voltage Optimization

The **Voltage Optimization** tab shows the results of the Voltage Optimization analysis, including Volt/VAr optimization and switching optimization. It assists in understanding which automatic device actions the optimization is scheduling and how these actions affect the system voltages and losses.



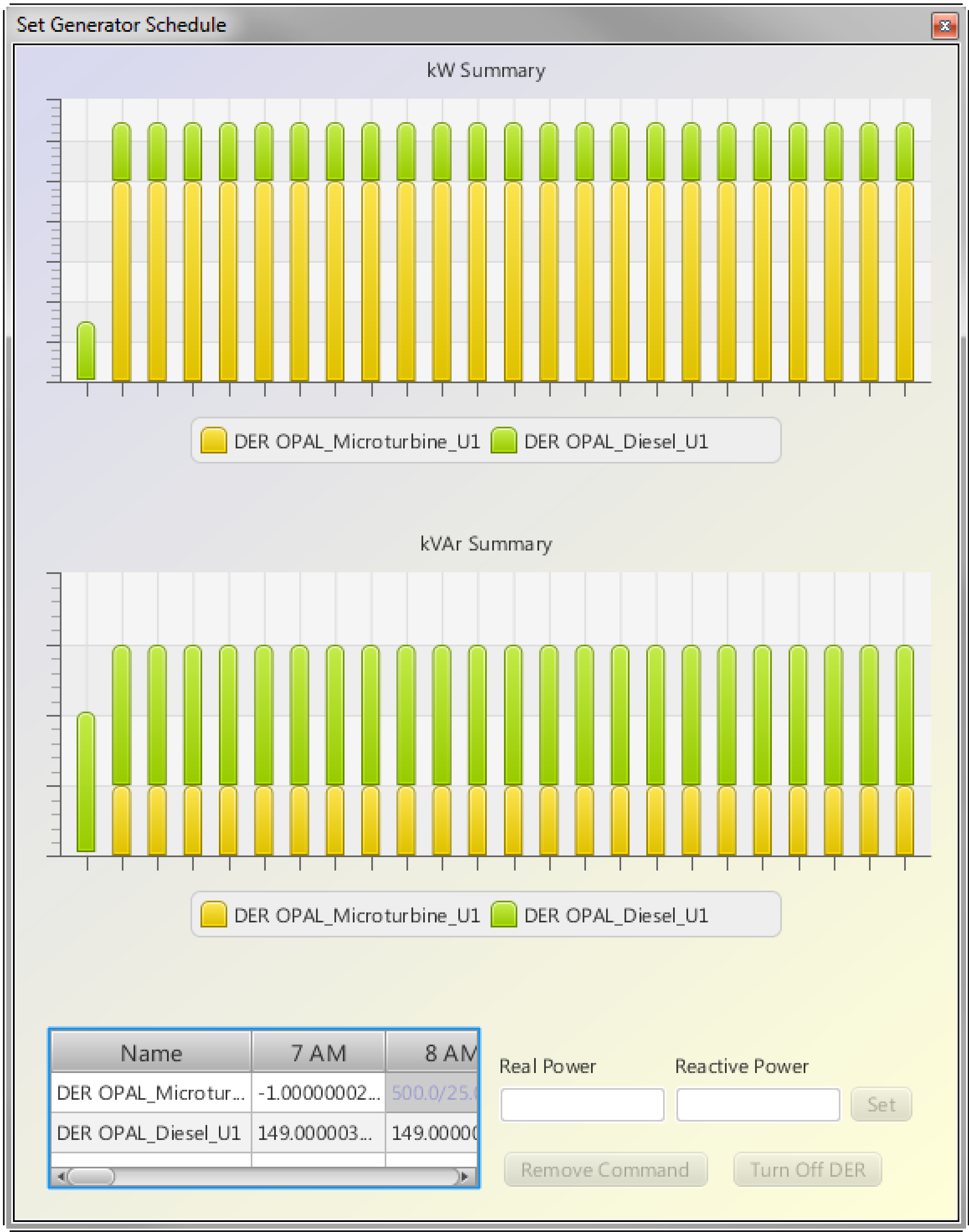
The graph on the top half of the tab shows future forecasts for the system including losses voltages and the number of scheduled actions due to the optimization. The tabular information on the bottom of the tab shows similar information in tabular form, including detailed information about the scheduled device actions and any reduction in losses due to those actions.

As you hover your mouse over the graph, the interval time, device actions, minimum and maximum voltages, and losses are displayed at the top of the graph.

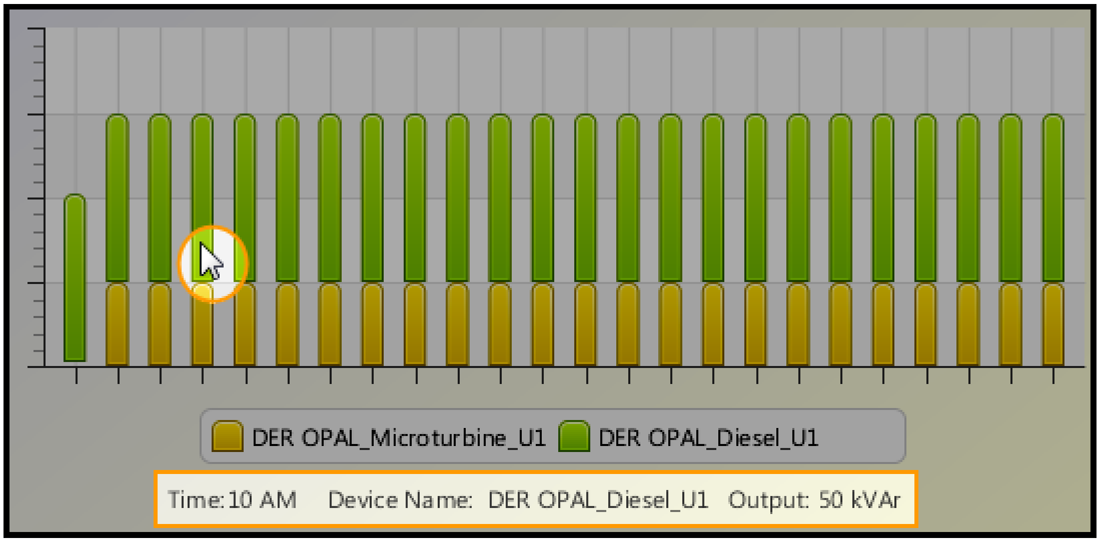


Using the Generator Schedule Tool

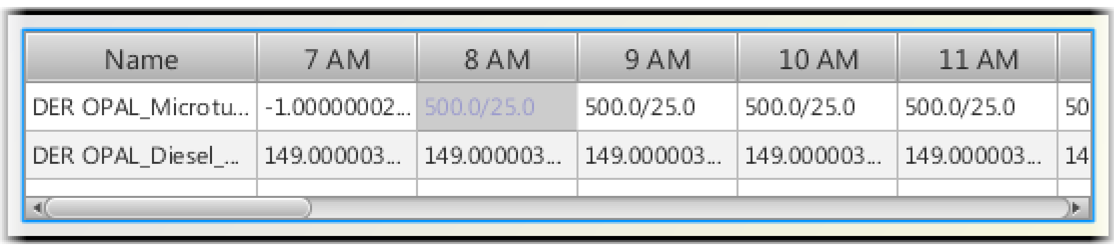
The Set Generator Schedule dialog provides a way to conveniently schedule the full set of controllable DER devices using manual commands. It shows the kW and kVAr output of each DER over the scheduling period, which is configurable.



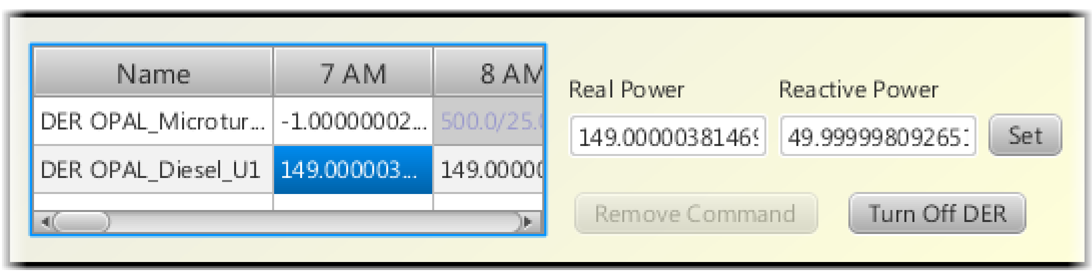
The kW or kVAr values are displayed as hover text when you hover over either graph.



The tabular section of the dialog shows values for each hour.



When you click a cell, the real and reactive power set points are populated in the Real Power and Reactive Power fields (to the right).



This allows you to:

- Enter a new setpoint for the selected hour
- Remove a command.

Changes are then reflected in the graphs.

The functionality in the Set Generator Schedule dialog is equivalent to opening the **Add Command** dialog for a DER and entering manual commands for the device.

Understanding Automatic Generation Scheduling

The Oracle Utilities Distributed Grid Management automatic generation scheduling (AGS) function schedules the controllable DERs to provide energy most economically.

The automatic generation scheduling considers the operating limits, cost curves for the DERs, the system load demand, and determines most economical operating plan for the configured dispatch horizon using Particle Swarm Optimization (PSO) algorithm.

Particle Swarm Algorithm

Particle swarm optimization (PSO) is a population based stochastic optimization technique inspired by natural social behavior bird flocking or fish schooling etc.

In PSO, the system is initialized with number of randomly generated particles. This collection of particles is known as a “swarm”. Each particle in the swarm keeps track of its coordinates in the problem space which are associated with the best solution it has achieved so far. This is called the “local best”. The swarm as a whole also keeps track of the best solution achieved so far. This is called the “global best”. Each particle “learns” from its local best and the global best and moves accordingly. After each position change the fitness is evaluated and new local bests and the global best is determined. After number of such iterations, the global best is presented as the solution.

The particle swarm optimization can be summed up in following two equations:

[1]: $V_t = \omega V_{t-1} + \rho 1 rand()(gbest - X_{t-1}) + \rho 2 rand($

Where:

V_t = new velocity

ω = inertia constant

V_{t-} = earlier calculated velocity

$\rho 1$ = learning constant 1

$rand()$ = random number

$gbest$ = global best

$\rho 2$ = learning constant 2

$pbest$ = local best

X_{t-1} = position of the particle

[2]: $\sum_{i=1}^{N} P_{it} U_{it} = D_{it}$

Where:

X_t = new position

V_t = velocity calculated in (1) above

X_{t-1} = earlier calculated position

PSO configuration parameters

Following PSO parameters are configured in the Oracle Utilities Distributed Grid Management configuration file:

- Population: Number of particles in a swarm. This parameter typically does not need to be changed.
- Velocity limit: This is the limit on the velocity described above. This parameter can be changed to best suite the problem. The thumb rule is that the minimum value should be equal to the largest minimum operating limit of a resource. It can be increased from that point to obtain best solution. Setting this value to zero will result in dynamic velocity limits that are calculated as the difference between maximum operating limit and minimum operating limit.
- Inertia constant: This parameter should be kept close to 1.0. It can be varied from 1.2 to 0.8
- Inertia constant low limit: this parameter should be kept close to 0.5. It can be varied from 0.6 to 0.4, To disable the variation of the inertia (which usually does not give better results), this may be set to the same value as that of the inertia constant
- Learning constant 1: The learning constants should be set such that the learning constant 1 and learning constant 2 add up to between 3.0 and 4.0 and the learning constant 1, should be greater than learning constant 2.
- Learning constant 2: The learning constants should be set such that the learning constant 1 and learning constant 2 add up to between 3.0 and 4.0 and the learning constant 1, should be greater than learning constant 2.
- Number of iterations: Number of iterations needed depend upon the size of the problem. For more number of time intervals, more number of iterations is needed. Generally about 30000 iterations for 24 intervals work well, while about 60000 iterations for 48 intervals work well.
- Initial penalty factor: This parameter is used to calculate penalties for the constraint violations, and this typically does not need to change
- MUT/MDT penalty: The minimum up time or minimum down time violation penalty should be about 70 to 80% of the total production cost in one interval. This is an approximate value that can be rounded up.
- Heuristic step size: The generation scheduling uses conventional merit order method to fine tune its results to some extent. This parameter represents the adjustment in output that will be performed at a time. This value can be large (for example, 25) if all resources have segmented cost function. If some of the resources have quadratic cost function, the step size should be smaller (range of the largest unit / number of heuristic iterations).
- Number of maximum heuristics iterations: default value is usually good enough, and does not need to change.

The Unit Commitment Problem

The unit commitment problem for the generation scheduling is formulated as follows –

The objective of the unit commitment problem is the minimization of the total production costs over the scheduling horizon. Therefore the objective function is expressed as the sum of fuel and start-up costs of the DER. For N DERs the total production cost for the dispatch horizon can be expressed mathematically as:

[3]: $TPC_{NT} = \sum_{t=1}^{T}\sum_{i=1}^{N}\left[F_{it}(P_{it}) + ST_i(1 - U_{i(t-1)})\right]U_{it}$

Where:

TPC_{NT} = Total production cost for N DERs for T time intervals

P_{it} = Power output of DER *i* in time interval t

$F_{it}(P_{it})$ = Cost function expressed as function of the power output of DER *i* in time interval t

ST_i = Startup Cost for DER *i*

$U_{i(t-1)}$ = Status of DER *i* in time interval t-1

U_{it} = Status of DER *i* in time interval t

Constraints

The objective of the optimization is to minimize subject to following constraints:

- **Power balance constraint**

  [4]: $\sum_{i=1}^{N} P_{it}U_{it} = D_{it}$

  Where:

  D_{it} = Total load demand for the microgrid area

- **DER limit constraint**

  [5]: $P_{itmin} \leq P_{it} \leq P_{itmax}$

  Where:

  P_{itmin} = minimum operating limit for DER *i*

  P_{itmax} = maximum operating limit for DER *i*

- **Minimum up time constraint**

  Minimum up time constraint states that once online, a unit must stay online for specified time period before it can be turned off again.

  [6]: $X_i^{on}(t) \geq MU_i$

  Where:

  $X_i^{on}(t)$ = time in ON status for DER *i* in time interval t

MU_i = Minimum up time for the DER *i*

- **Minimum down time constraint**

  The minimum down time constraint states that, once offline, a unit must stay offline for specified time period before it can be brought back online again.

  [7] : $X_i^{off}(t) \geq MD_i$

  Where:

  $X_i^{off}(t)$ = time in OFF status for DER *i* in time interval t

  MD_i = Minimum down time for DER *i*

As seen above the automatic generation scheduling function considers following constraints:

- System load balance (losses are ignored)
- Resource limit constraint
- Minimum up time constraint
- Minimum down time constraint

Cost Functions

The automatic generation scheduling supports two types of cost functions a) quadratic cost function, b) linearized segmented cost function. These cost functions are described below.

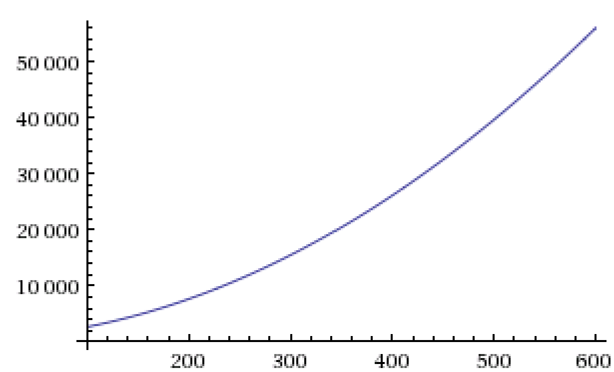
Quadratic Cost Function

Quadratic cost function is stated as:

$$aP^2 + bP + c$$

Where: a, b, and c are constants ant the constant c represents no load cost of the unit. P is the power output of the unit.

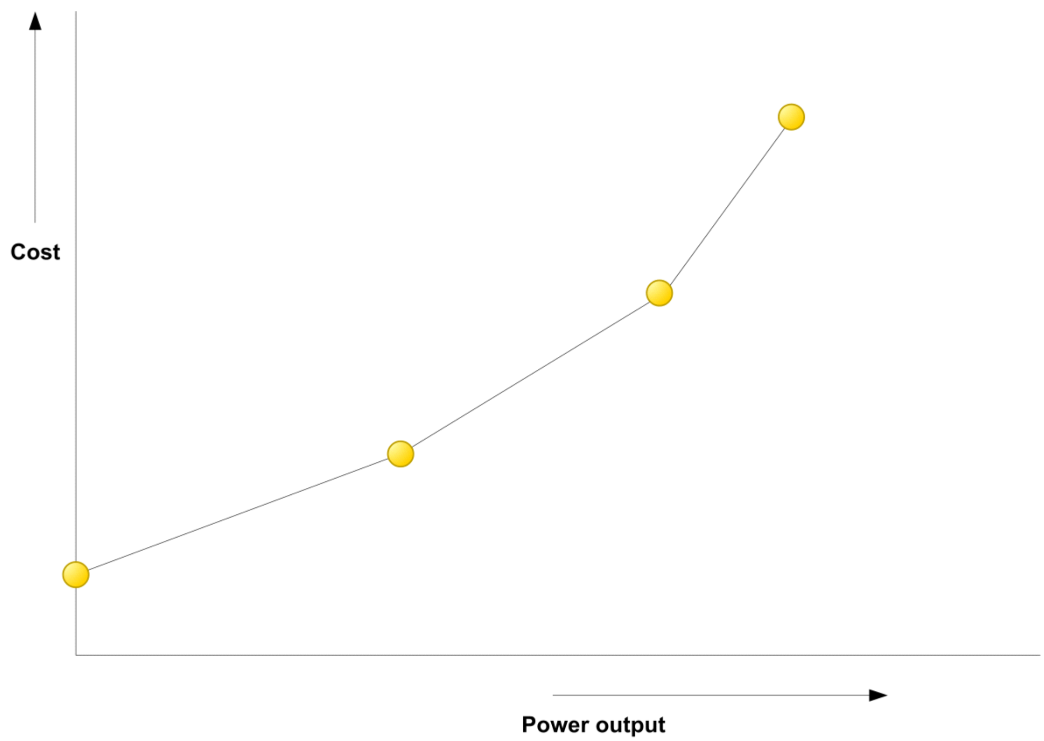
Example of quadratic cost function:



Linearized Segmented Cost Function

The quadratic cost curve is often approximated as a number of linearized segments, and in most cases just one linear segment. This curve can be specified as number of pairs of cost and output points of the curve.

The following figure shows one illustration of linearized segmented cost function.



Automatic Generation Scheduling Data Requirements

The automatic generation scheduling requires engineering data for the DERs in addition to the network model provided via the xml model file. The engineering data for the automatic generation scheduling is specified in the Engineering Workbook for Oracle Utilities Distributed Grid Management. You must specify following data in the engineering workbook for generation scheduling.

- External name of resource: This must match the external identifier from the XML model file.
- Physical (flag): Whether the resource maps directly to the resource in the network model
- Minimum operating limit
- Maximum operating limit
- Minimum economic limit
- Maximum economic limit
- Startup time
- Minimum up time
- Minimum down time
- Cost function type
- Startup cost
- Default cost curve

Dynamic Cost Functions

Generation scheduling allows for the dynamic cost functions. It means that the user can specify different cost functions for different time periods. The dynamic cost functions are provided in a comma separated value (csv) file by specifying following attributes for each cost function.

- External resource name: This must match the one provided in the engineering workbook
- Start and end time in format “mm/dd/yyyy HH24:mm”
- Cost function type (“SEGMENTED”, or “QUADRATIC”)
- Cost function data

The dynamic cost functions override the default cost function provided in the engineering workbook for the corresponding time periods.

Participating and Non-Participating Resources

The automatic generation scheduling considers the resources that are in automatic mode throughout the dispatch horizon as the participating resource. Only the participating resources are scheduled by the automatic generation scheduling.

Other than the manual generation resources, the non controllable resources other than the grid tie point are considered non-participating resources. The grid-tie however when present is always considered a participating resource although no control commands are generated for it.

The automatic generation scheduling considers the expected generation output from non-participating resources from the generation forecast for the renewable resources or from the current condition and manual commands for the resources in manual control mode, but it does not schedule non-participating resource.

Load Balance Requirement Determination

The load balance requirement for each time interval is determined as follows:

Load balance requirement = load prediction – forecast generation – manual generation.

The load prediction takes into account the load scaling performed by the load flow functionality based on the measured values received from SCADA, for the time intervals it is available. If the load flow results are not available for a time interval, the load forecast is obtained from the load curves provided.

The forecast generation from the uncontrollable renewable resources is obtained from the generation forecast curves for such resources.

The manual generation is calculated from the current generator condition and the manually scheduled commands during the current time through the end of dispatch horizon.

Cycle Time for the Automatic Execution of Generation Scheduling

The cycle time for automatic generation scheduling is configured in the Oracle Utilities Distributed Grid Management configuration file. The valid cycle time for automatic generation scheduling are 1 minute, 5 minutes, 10 minutes, 15 minutes, 20 minutes, 30 minutes, and 60 minutes.

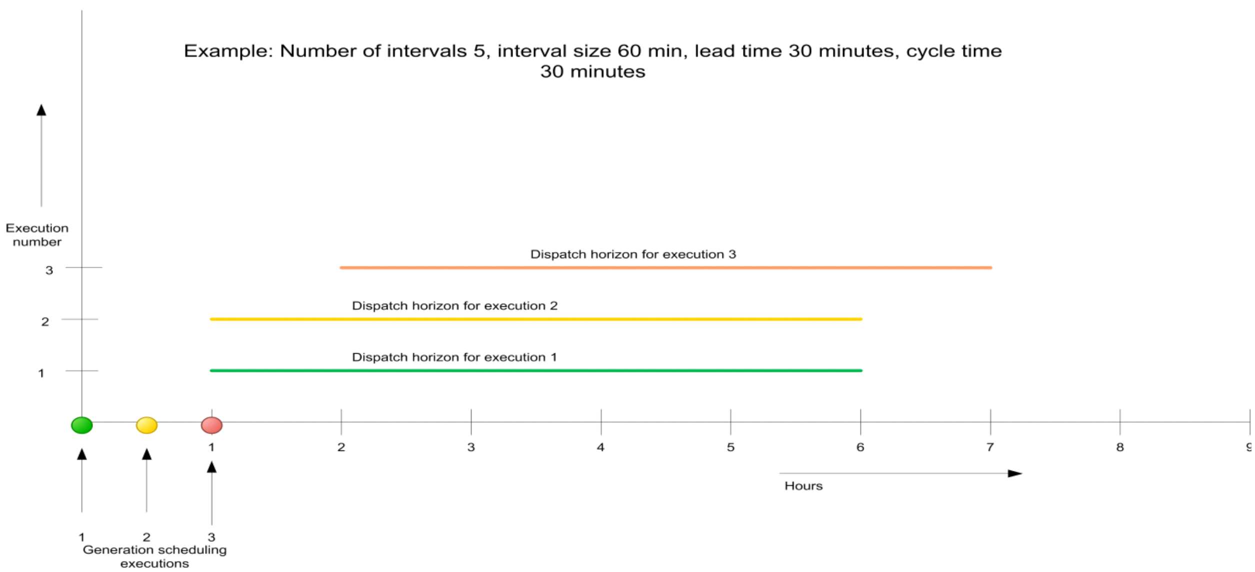
The execution of the generation scheduling is synchronized with clock; for example, if cycle time is 15 minutes, the generation scheduling will execute at 00, 15, 30, and 45 minutes in the hour.

Dispatch Horizon and Time Intervals for Automatic Generation Scheduling

The dispatch horizon is determined by configured number of time intervals, duration of the time interval, and the lead time. These parameters are configured in the DGM configuration file.

The valid time interval sizes are 5 minutes, 10 minutes, 15 minutes, 30 minutes and 60 minutes. The time intervals are also clock synchronized; for example, 15 minute time interval will start either at 00, 15, 30 or 45 minutes into the hour, while 60 minute interval will start only at the top of the hour.

The “lead time” parameter ensures that there is enough time between execution time and start of the dispatch horizon. The lead time should consider the longest amount of time that will take to execute a decision made by the generation scheduling.; for example, if startup time for a generator is 20 minutes, and the communication time is 5 minutes, then it will be appropriate to set the lead time to 30 minutes (add 5 minutes to allow for the execution of the generation scheduling). This ensures that the start of the dispatch horizon will always be minimum 30 minutes away from the execution time. If the cycle time is 60 minutes, then this will result in the dispatch horizon starting at h+1 hour for generation scheduling executions until 30 minutes into the hour, and after that the dispatch horizon will start at h+2. This is illustrated in following diagram.



Automatic Generation Scheduling Control Commands Generation

The generation scheduling output from the PSO algorithm is further processed to generate control commands for the physical controllable resources.

All earlier auto generated commands during the dispatch horizon are removed before creating new commands for the dispatch horizon.

A control command for a resource is generated if status of the resource is changed from previous time interval or initial condition or the output of the resource is changed more than a threshold.

The generation scheduling does not schedule the reactive power for the resources, but it tries to maintain the power factor at the initial condition if the resource is currently online. The generated command consists of the scheduled active power output as well as the reactive power output to maintain the power factor at initial condition.

The generated control commands are passed on to the Command Sequence processor for further processing.

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