

Introduction to PowerWorld Simulator: Interface and Common Tools



I17: Time Step Simulation and Weather



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Time Step Simulation Essentials

Time Step Simulation



- It is often useful to assess how power system quantities vary hour by hour due to changes in load, generation, transmission line status, etc.
- The Time Step Simulation (TSS) allows you to
 - obtain power flow, OPF, and SCOPF solutions for a list of time points for which input (scenario) data has been specified
 - model actions that occur at specific times, as well as periodic actions
 - incorporate weather inputs and interact with weather models for renewable generation
 - incorporate GLC inputs

Time Step Simulation

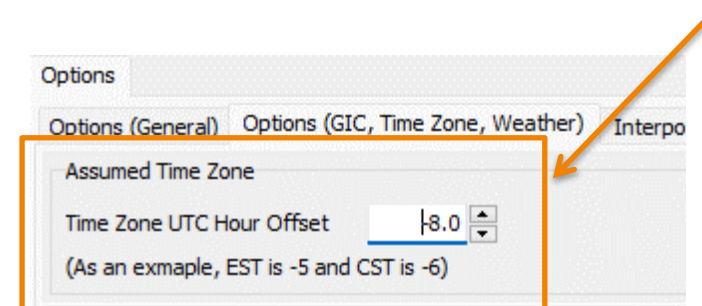


- In this section we'll learn how to:
 - Set up and maintain a list of time points
 - Specify time point input data
 - Specify scheduled input data
 - Customize the results we want to store from the solution
 - Apply weather data and renewable generation weather models
-  Open the ACTIVSg10kDC.pwb case. To access the Time Step Simulation Dialog, in Run Mode, go to Tools → Time Step Simulation.

Time Zone UTC Offset



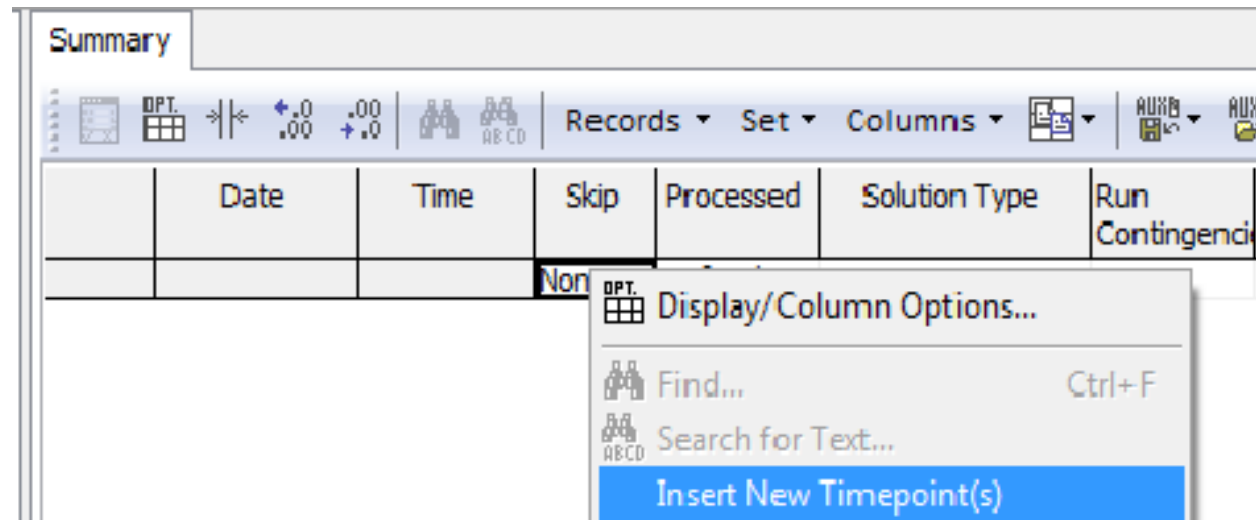
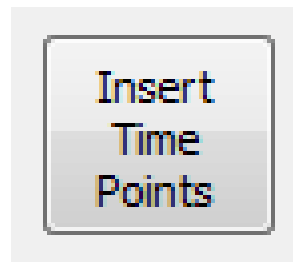
- First, we will establish a time zone for our input data and simulation
- This is important primarily for coordinating time series data from external sources, such as weather
- Go to Options → Options (GIC, Time Zone, Weather)
- Assume our hourly load aligns to Pacific Standard Time (UTC -8)
 - This field normally defaults to a value based on Windows system time
 - Value can be saved in a tsb or aux file
 - Changing the value after time series data are loaded is not recommended; it will shift any existing time points by the change



Inserting New Time Points



- Next we will define a list of time points we wish to simulate
- From the Summary page, right-click on the grid and select Insert New Timepoint(s), or press the Insert Time Points button



Inserting New Time Points



As an example, assume we want to simulate 24 hours, starting February 23, 2024 at 12:00 AM

New Timepoint Dialog

Manual Entry Fields

Start Date February 23, 2024

Start Time 12 : 00 : 00 AM

Milliseconds 0

Total Number of Timepoints to Enter 24

Time Zone for Above Date/Time

☒ Assumed Time Zone ☐ UTC

Time Zone UTC Offset (from Time Step Options page) -6.0

Interval for Additional Timepoints

Hours 1 Seconds 0

Minutes 0 Milliseconds 0

OK Cancel

Click to select the date from a calendar component

Number of time points that will be inserted

Specify interval between time points. Maximum resolution is 1 millisecond.

Inserting New Time Points



- After Inserting the Time Points, the Summary Tab looks like this:

Time Step Simulation

Starting Time: 2/23/2024 12:00:00 AM Do Run Reset Run Insert Time Points Save TSB File Clear Results Load Aux File Show Stored Solutions Playback Control Dialog

Ending Time: 2/23/2024 11:00:00 PM Do Single Point Do Previous Point Read TSB File Read PWW File Delete All Save to Aux View Stored Solutions Delete All Stored Solutions

☐ Run Time Backwards (End to Start)

Summary

Summary

	Date	Time	Skip	Processed	Solution Type	Run Contingencies	Solved	Store Result Solution	Has Stored Solution?	Initialize From Stored Solution	Enforce Generator Ramp Rates	Total MW Load	Total Mvar Load	Total MW Gen	Total Mvar Gen	Total Shun
1	2/23/2024	12:00:00 AM	☒	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
2	2/23/2024	1:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
3	2/23/2024	2:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
4	2/23/2024	3:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
5	2/23/2024	4:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
6	2/23/2024	5:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
7	2/23/2024	6:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
8	2/23/2024	7:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
9	2/23/2024	8:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
10	2/23/2024	9:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
11	2/23/2024	10:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
12	2/23/2024	11:00:00 AM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
13	2/23/2024	12:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
14	2/23/2024	1:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
15	2/23/2024	2:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
16	2/23/2024	3:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
17	2/23/2024	4:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
18	2/23/2024	5:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
19	2/23/2024	6:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
20	2/23/2024	7:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
21	2/23/2024	8:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
22	2/23/2024	9:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
23	2/23/2024	10:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	
24	2/23/2024	11:00:00 PM	☐	NO	Single Solution	NO	Not Started	NO	NO	YES	NO	0.0	0.0	0.00	0.00	

Last Result: Initialized Present Time ☒ Refresh All Displays Each Time Step Otherwise Update Display Every Specified Seconds 2.00

Close Help

Time Step Simulation Dialog



Can specify the simulation starting and ending date and time

Summary page contains list of time points

Simulation control buttons

Solution Type

Simulation progress

	Date	Time	Skip	Processed	Solution Type	Run Contin
1	5/18/2006	1:00:00 AM	NO	YES	Single Solution	NO
2	5/18/2006	2:00:00 AM	NO	YES	Single Solution	NO
3	5/18/2006	3:00:00 AM	NO	YES	Single Solution	NO
4	5/18/2006	4:00:00 AM	NO	YES	Single Solution	NO
5	5/18/2006	5:00:00 AM	NO	YES	Single Solution	NO
6	5/18/2006	6:00:00 AM	NO	YES	Single Solution	NO
7	5/18/2006	7:00:00 AM	NO	NO	Single Solution	NO
8	5/18/2006	8:00:00 AM	NO	NO	Single Solution	NO

Summary Page: Controlling Solution

- You can have the simulation skip or Pause after a Time Point
- The Time Point Solution Type can be:

- Single Solution: Same as the single solution button (usually standard power flow)
- Unconstrained OPF: OPF, but ignoring line and interface constraints
- OPF: Optimal Power Flow
- SCOPF: Security Constrained Optimal Power Flow, a contingency set must be defined
- GIC Only: apply GIC and associated transformer reactive power loss, but do not apply other time step inputs or solve power flow
- Apply Only (With Weather): apply the time step inputs, including weather if present, but do not solve power flow

Useful for fast
visualization of
time-varying
inputs

	Date	Time	Skip	Processed	Solution Type
1	2/23/2024	12:00:00 AM	NO	YES	Single Solution
2	2/23/2024	1:00:00 AM	NO	YES	Single Solution
3	2/23/2024	2:00:00 AM	YES	YES	Single Solution
4	2/23/2024	3:00:00 AM	Pause	YES	Single Solution

Last Result: 2/23/2024 3:00:00 AM Solved Correctly Paused Present Time

Summary Page:

More TimePoint Fields



- *Store Result Solution*: allows solution to be quickly restored or visualized after the run
- *Initialize From Stored Solution*: allows the state to be initialized from a prior result
- *Enforce Generator Ramp Rates*: for future use

Time Step Simulation Dialog

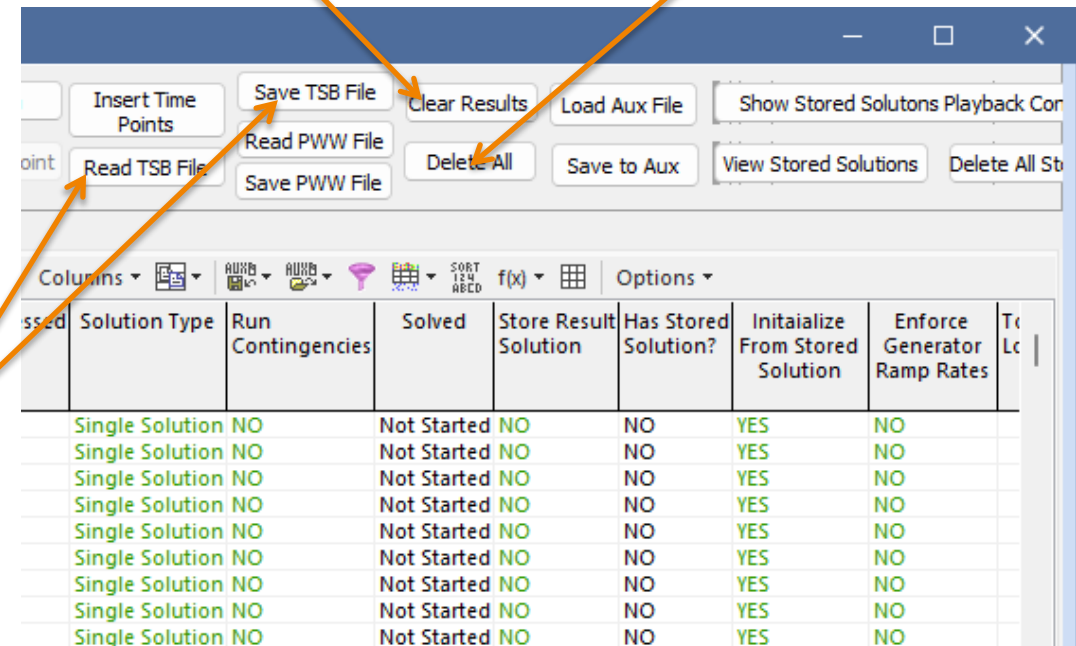


- The options, input data, results definition, and results of the Time Step Simulation can be saved in a Time Series Binary (*.TSB) file.
- They are NOT saved in the pwb file.

Just clear the results

Clear results, input and scheduled input data, and the list of time points

Read (load) or Save everything to .TSB file

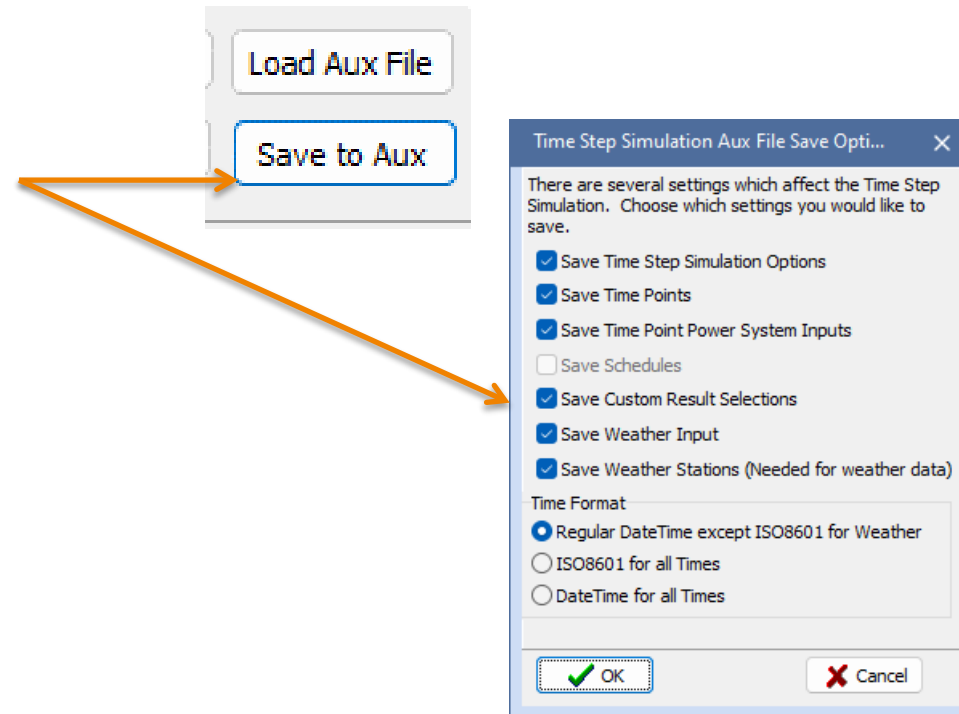


Time Step Simulation Dialog



- The input data and results definitions can also be stored in auxiliary files (*.aux)

Save to Aux brings
Option Dialog for
choosing which data
to save



Summary Page: Script Commands

- You can specify pre- and post script commands for each time point
- This allows you to perform almost every possible Simulator action before and after a time point is solved
- Uses may include setting unit commitment and bid curves, running contingency analysis, or saving particular sets of results

Total MW Gen	Pre Script Cmd	Post Script Cmd
0.00	LOADSCRIPT("GEN.AUX",GEN01)	LOADSCRIPT("GEN.AUX",GENRES01)
0.00	LOADSCRIPT("GEN.AUX",GEN02)	
0.00	LOADSCRIPT("GEN.AUX",GEN03)	
0.00	LOADSCRIPT("GEN.AUX",GEN04)	
0.00	LOADSCRIPT("GEN.AUX",GEN05)	LOADSCRIPT("GEN.AUX",CTGRUN)



Summary Page:

Script Command Tips



- It is a good idea to first test the script commands in script mode, to avoid potential syntax errors
- To edit the script command cell, double-click on the cell
 - You can copy/paste from the cells as usual
 - You can also copy/paste from excel or the clipboard.
- To delete a script command, double-click and hit the Delete or Backspace buttons
- To clear all the scripts commands in a column, right-click on the grid and select Set/Toggle/Columns → Set All Values To. Then just press OK without typing anything in the dialog.

Setting up Input Data



- Input data for each time point is specified in the Input pages for:
 - Load MW/Mvar
 - Generation MW/Max MW
 - Line Status
 - Area MW Load
 - Zone MW Load
 - Injection Group MW
 - Weather
- All these Input pages are matrix grids. This means that each row corresponds to a time point, and each column corresponds to the specific object for which data will be specified.
- Very detailed time-varying inputs may be specified on the Custom Inputs pages

Setting up Input Data

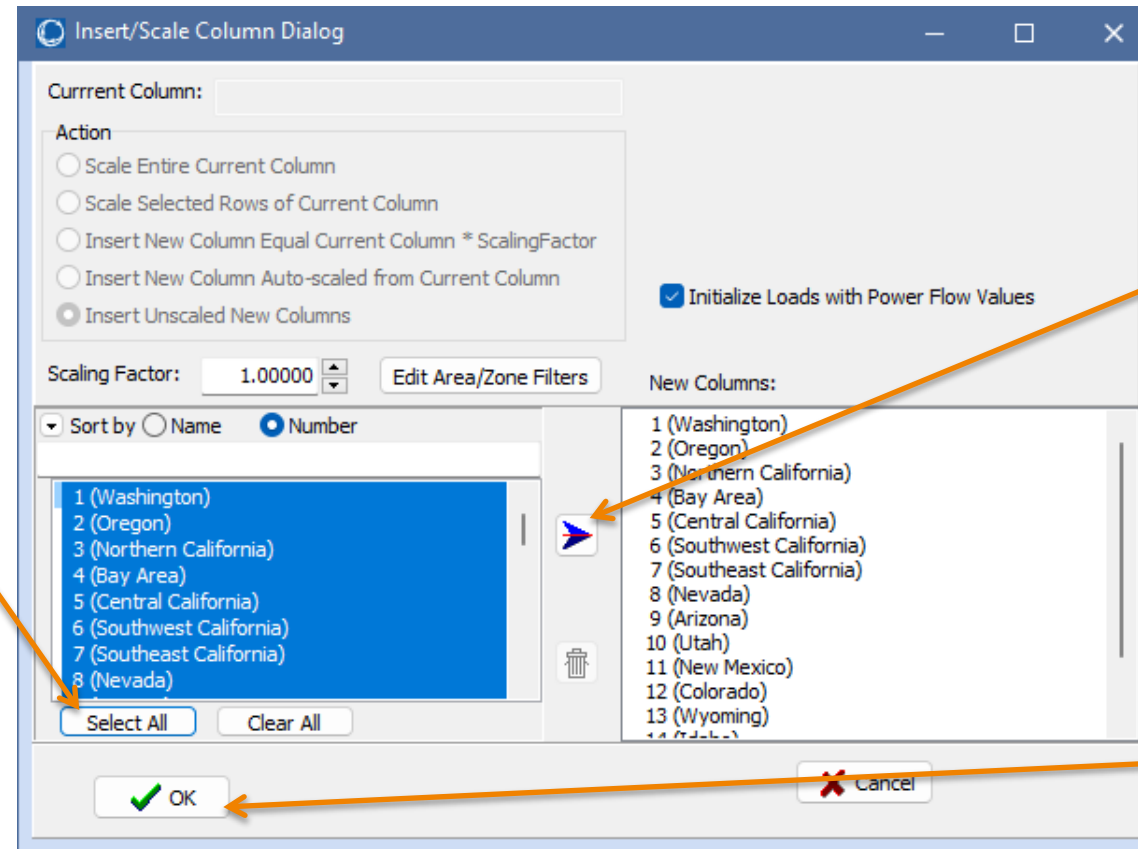


- Thus we need to explicitly tell Simulator which generators, loads, etc. will have input data
 - The objects that do not have input data (or scheduled input data) will keep the values from the reference case
- The matrix grids will have one column for the input data of each object
- Suppose that we want to specify Load by Area
 - In the **Input → Area Loads** page, right-click and select **Time Point Records → Insert/Scale Area Column(s)**

Hourly Area MW Load



1. *Select All areas*



2. Move them to
New Columns

3. Click *OK*

Hourly Area MW Load



Time Step Simulation

Starting Time: 2/23/2024 12:00:00 AM Do Run Reset Run Insert Time Points Save TSB File Clear Results Load Aux File Show Stored Solutions Playback Control Dialog

Ending Time: 2/23/2024 11:00:00 PM Do Single Point Do Previous Point Read TSB File Read PWW File Delete All Save to Aux View Stored Solutions Delete All Stored Solutions

☐ Run Time Backwards (End to Start)

Input

MW Loads Mvar Loads Gen Actual MW Gen Max MW Line Status Area Loads Zone Loads Injection Groups Weather Schedules Sched Subscriptions Time Step Actions Custom Inputs

	Date	Time	Total MW Load	Washington Load MW	Oregon Load MW	Northern California Load MW	Bay Area Load MW	Central California Load MW	Southwest California Load MW	Southeast California Load MW	Nevada Load MW	Arizona Load MW
1	2/23/2024	12:00:00 AM	0.00	16324.7	9537.9	6188.1	13497.0	6941.3	22365.6	18810.0	8127.4	15
2	2/23/2024	1:00:00 AM	0.00	16324.7	9537.9	6188.1	13497.0	6941.3	22365.6	18810.0	8127.4	15
3	2/23/2024	2:00:00 AM	0.00	16324.7	9537.9	6188.1	13497.0	6941.3	22365.6	18810.0	8127.4	15
4	2/23/2024	3:00:00 AM	0.00	16324.7	9537.9	6188.1	13497.0	6941.3	22365.6	18810.0	8127.4	15
5	2/23/2024	4:00:00 AM	0.00	16324.7	9537.9	6188.1	13497.0	6941.3	22365.6	18810.0	8127.4	15

In order to specify time point values, we can:

1. Adjust the values manually
2. Paste values from Excel (Copy the headers to Excel first)
3. Derive the values from another column
4. Scale the column values

Paste From Excel



- Open *TSS_SourceData.xlsx* and copy the contents of the “MW Loads” sheet to the clipboard.
 - Adjust the date and time columns to match the time points in Simulator
 - Paste into the Area Loads tab in Simulator

	A	B	C	D	E	F	G	H	I	J	K	L
1	Timepoint											
2	Date	Time	Washingt	Oregon Lc	Northern	Bay Area	Central Ca	Southwes	Southeast	Nevada Lc	Arizona Lc	Utah Lc
3	2/23/2024	12:00:00 AM	10110	5760	3847	9210	5135	16988	13879	5209	11810	421
4	2/23/2024	1:00:00 AM	9917	5653	3808	9147	5122	17048	13811	5143	11652	421
5	2/23/2024	2:00:00 AM	9854	5632	3788	9168	5190	17163	13918	5141	11520	414
6	2/23/2024	3:00:00 AM	10012	5826	3810	9197	5326	17351	14011	5225	11709	411
7	2/23/2024	4:00:00 AM	10280	6045	3903	9471	5524	18057	14324	5458	11978	421
8	2/23/2024	5:00:00 AM	10683	6458	4083	9771	6002	19447	14942	5817	13142	431
9	2/23/2024	6:00:00 AM	11144	6907	4326	10358	6601	21097	16144	6441	14743	464
10	2/23/2024	7:00:00 AM	11663	7308	4622	11032	6941	21996	16776	6731	15658	491
11	2/23/2024	8:00:00 AM	12217	7534	4912	11582	6867	22128	16788	6645	15474	521
12	2/23/2024	9:00:00 AM	12554	7531	5016	11636	6765	22111	16479	6467	15184	531

	Date	Time	Total MW Load	Washington Load MW	Oregon Load MW	Northern California Load MW	Bay Area Load MW	Central California Load MW	Southw Californ MW
1	2/23/2024	12:00:00 AM	0.00	10110.0	5760.0	3847.0	9210.0	5135.0	
2	2/23/2024	1:00:00 AM	0.00	9917.0	5653.0	3808.0	9147.0	5122.0	
3	2/23/2024	2:00:00 AM	0.00	9854.0	5632.0	3788.0	9168.0	5190.0	
4	2/23/2024	3:00:00 AM	0.00	10012.0	5826.0	3810.0	9197.0	5326.0	
5	2/23/2024	4:00:00 AM	0.00	10280.0	6045.0	3903.0	9471.0	5524.0	
6	2/23/2024	5:00:00 AM	0.00	10683.0	6458.0	4083.0	9771.0	6002.0	
7	2/23/2024	6:00:00 AM	0.00	11144.0	6907.0	4326.0	10358.0	6601.0	
8	2/23/2024	7:00:00 AM	0.00	11663.0	7308.0	4622.0	11032.0	6941.0	
9	2/23/2024	8:00:00 AM	0.00	12217.0	7534.0	4912.0	11582.0	6867.0	
10	2/23/2024	9:00:00 AM	0.00	12554.0	7531.0	5016.0	11636.0	6765.0	
11	2/23/2024	10:00:00 AM	0.00	12792.0	7411.0	5053.0	11374.0	6575.0	
12	2/23/2024	11:00:00 AM	0.00	12833.0	7202.0	4931.0	11075.0	6338.0	
13	2/23/2024	12:00:00 PM	0.00	12517.0	7035.0	4866.0	10820.0	6206.0	
14	2/23/2024	1:00:00 PM	0.00	12421.0	6873.0	4819.0	10558.0	6152.0	

NOTE: This step, by itself, can also insert timepoints and area columns. Those steps were done here separately for instructional value.



Another Method: Scaling



- Suppose we need to specify MW Load for Area Oregon, and know that it varies as 60% of Area Washington MW Load
 - First delete the just pasted column for Oregon Load MW (right-click, **Time Point records → Delete Area Column(s)**)
 - Right-click on column for Washington Load MW and select **Time Point records → Insert/Scale Area Column(s)**

Another Method: Scaling

Area Washington becomes
the current column

Area Oregon will be 60% of Area
Washington

Use the selector component to select
Area Oregon, whose values will be
derived from Area Washington.

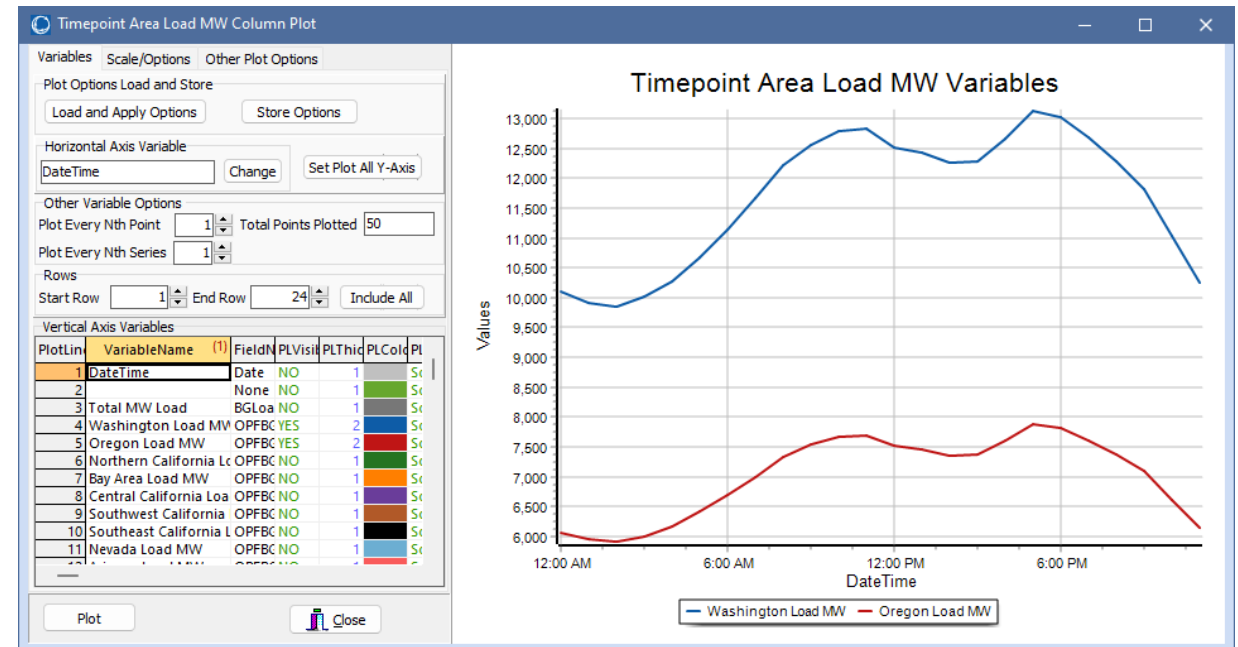
The screenshot shows the 'Insert/Scale Column Dialog' window. It has a title bar with a circular icon and standard window controls. The 'Current Column' field is set to 'Area 1 (Washington)'. Under the 'Action' section, the radio button for 'Insert New Column Equal Current Column * ScalingFactor' is selected. The 'Scaling Factor' is set to 0.60000. A checkbox for 'Initialize Loads with Power Flow Values' is checked. The 'Sort by' dropdown is set to 'Number'. A list of areas is shown: 1 (Washington), 2 (Oregon), 3 (Northern California), 4 (Bay Area), 5 (Central California), 6 (Southwest California), and 7 (Southeast California). '2 (Oregon)' is selected and highlighted in blue. An arrow points from the text 'Area Washington becomes the current column' to the 'Current Column' field. Another arrow points from 'Area Oregon will be 60% of Area Washington' to the 'Scaling Factor' field. A third arrow points from 'Use the selector component to select Area Oregon...' to the list of areas. The 'New Columns' field on the right shows '2 (Oregon)'. At the bottom are 'OK' and 'Cancel' buttons.

Setting up Input Data



- We can use the column plot to check our input data
- The plot column function of Case Information Displays becomes a plot versus date time when used from Time Step Simulation matrix grids

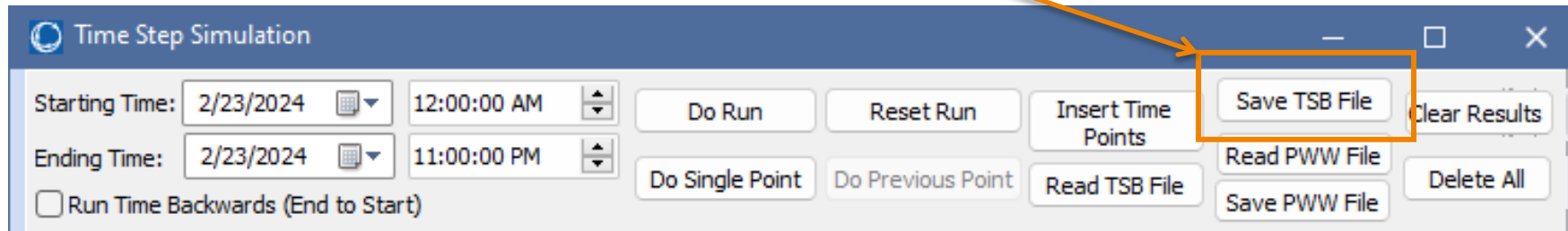
To plot a column, right-click on the column and select **Set/Toggle/Columns**
→ **Plot Column** from the Local Menu.
You can also drag the mouse across several columns to plot multiple columns. The Load MW for Areas Washington and Oregon looks like this.



Setting up Input Data



- As we have spent some time defining our input data, it is probably good to save the input data in the .TSB file.
- Press the **Save TSB File** button, and save the data as *Western10k.tsb*



What is Saved in the .TSB File?



- Because the amount of time information generated in the Time Step Simulation may be significant, a binary file is used to store it. This is called the Time Series Binary (.TSB) file.
- This file will save:
 - Input Data
 - Scheduled Input Data
 - Custom Inputs
 - Result Definitions
 - Results
 - Time Simulation Options (defined in the Options page)

Setting up Input Data



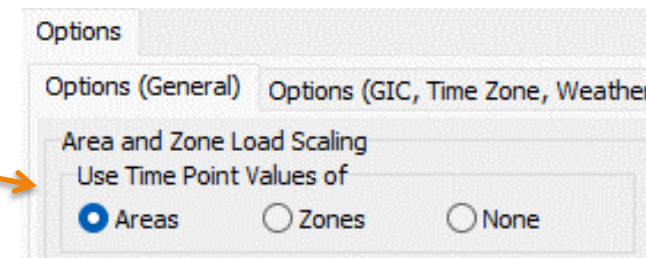
- In the same manner as we did for Area Load MW, hourly data for other quantities could be specified on other pages:
 - MW Loads
 - Mvar Loads

} For individual load objects

 - Gen Actual MW
 - Gen Max MW

} Sometimes useful for renewable resources;
Weather models can also be used

 - Line Status
 - Zone Loads
 - Injection Groups
- Recall that you can use the selector to create multiple columns at a time, and you can copy/paste the input data from Excel.
- Loads are scaled by Area OR by Zone;
go to **Options** → **Options (General)** to choose which is applied





Another Method: Schedules



- Besides time point input data, the Time Step Simulation allows you to specify scheduled data
- Scheduled data is used for data that more naturally spans multiple time points rather than being defined at each time point
 - Line statuses
 - Generator, load, capacitor and reactor statuses
 - MW levels of scheduled transactions
 - Number of capacitor/reactor blocks
 - Generator voltage set points
 - etc.
- Useful for periodic data that repeats daily or weekly



Specifying Scheduled Input Data



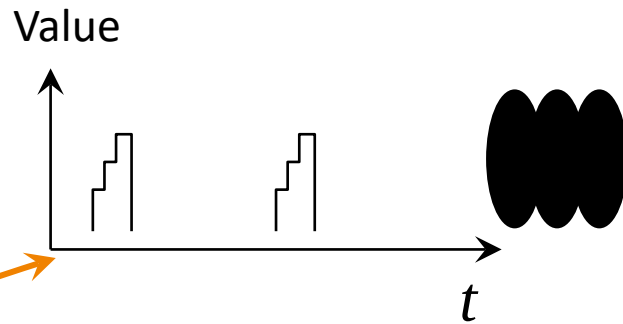
- Schedule input data requires a schedule and a schedule subscription
- The schedule defines how a quantity varies in time (just a shape). It is a list of time points together with Numeric or Yes/No values.
- By subscribing an object field (Line status, Gen MW, Transaction MW level, etc.) to a schedule, we can make this object field vary according to the shape of the schedule
- Schedules are implemented as sets of actions that are applied to the power flow case at the next available time point



Specifying Scheduled Input Data

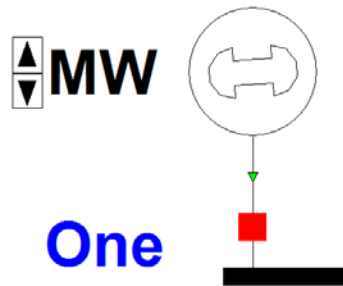


Schedule

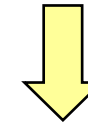
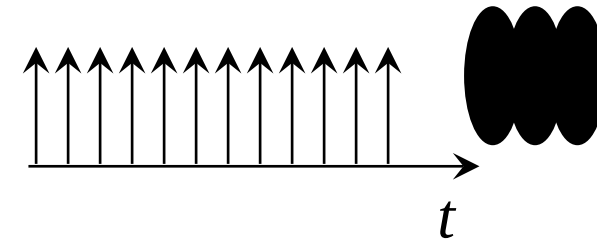


Subscription

Object Field



Time Point List



Gen MW





Defining a Schedule



- Schedules:
 - Can be Numeric, Yes/No, or Text
 - Can be made periodic by specifying them to repeat the shape with a certain period
 - Can have start and end validity dates (used normally for periodic schedules)
- To define a schedule, go to the Input → Schedules page, right-click on the grid, and select Insert New Schedule



Defining a Schedule



Schedule name must be unique

Identifies main characteristics of schedule

Settings for periodic Schedules

Date and Hour need not coincide with the date times of the list of time points (Summary page)

Shortcut buttons allow easy definition of the schedule date times

Date time and numeric values define the shape of the schedule

	Date	Hour	Numeric Value
1	Tuesday, 8/1/2006	12:00:00 AM	20.0000000
2	Tuesday, 8/1/2006	1:00:00 AM	30.0000000
3	Tuesday, 8/1/2006	2:00:00 AM	60.0000000
4	Tuesday, 8/1/2006	3:00:00 AM	40.0000000

Example Numeric Schedule

- Delete the default schedule points
- Copy the schedule from the spreadsheet “Load Schedule” in *TSS_SourceData.xlsx*
- Paste it into the Schedule Points grid in Simulator
- Give it a name e.g. “DailyLoadWinter”
- Set it to repeat daily

Schedule Dialog

Schedule Name: DailyLoadWinter Name Suffix: Num.PER.1d0h0m0s.N24

Periodic Schedule

☒ Repeat Every 1 Days 0 Hours 0 Minutes 0 Seconds

☒ Valid From Sat, Jan 01, 2000 12:00:00 AM

☐ Valid Until Tue, Dec 31, 2030 12:00:00 AM

Value Type

☒ Numeric

☐ Yes/No, Closed/Open

☐ Text

☐ Interpolate Values Between Time Points

☐ Apply Schedule Points as Events

Timepoint List

Add Point

Delete Point

	Date	Hour	Numeric Value
1	Friday, 2/23/2024	12:00:00 AM	0.6960000
2	Friday, 2/23/2024	1:00:00 AM	0.6900000
3	Friday, 2/23/2024	2:00:00 AM	0.6850000
4	Friday, 2/23/2024	3:00:00 AM	0.6950000
5	Friday, 2/23/2024	4:00:00 AM	0.7360000
6	Friday, 2/23/2024	5:00:00 AM	0.8180000
7	Friday, 2/23/2024	6:00:00 AM	0.9390000
8	Friday, 2/23/2024	7:00:00 AM	1.0000000
9	Friday, 2/23/2024	8:00:00 AM	0.9690000
10	Friday, 2/23/2024	9:00:00 AM	0.9310000
11	Friday, 2/23/2024	10:00:00 AM	0.8890000
12	Friday, 2/23/2024	11:00:00 AM	0.8540000
13	Friday, 2/23/2024	12:00:00 PM	0.8220000
14	Friday, 2/23/2024	1:00:00 PM	0.8010000
15	Friday, 2/23/2024	2:00:00 PM	0.7920000

OK Save Cancel



Defining a Schedule Subscription



- Most enterable fields from the following object types can subscribe to schedules: Generators, Loads, Line/transformers, Shunts, Areas, Transactions, and Zones
- Numeric fields subscribe to Numeric Schedules, Boolean fields subscribe to Yes/No schedules, and Custom Strings and Memo fields subscribe to Text schedules
- Suppose Northern California Load follows this pattern
 - Delete the Northern California Load MW column from the Area Loads (Time Point Records → Delete Area Column(s))
 - Go to the Input → Sched Subscriptions page, right-click on the grid, and select Insert New Subscription



Defining a Schedule Subscription



1. Select the object type: Gen, Load, Line/Xfrmr, Shunt, Area, Transaction or Zone

2. Select the particular object from the power flow case

3. Select the field that will subscribe to the schedule

4. Select the schedule the field will subscribe to

These values mean the MW loads in Area Northern California will scale from the Reference Case according to the values in the Schedule

The screenshot shows the 'Schedule Subscription Dialog' window. It contains the following fields and controls:

- Object Type:** A dropdown menu set to 'Area'. An orange arrow points to it from the first instruction.
- Object ID:** A dropdown menu set to '3 (Northern California)'. An orange arrow points to it from the second instruction.
- Field:** A dropdown menu set to 'Loads\Scale MW Value'. An orange arrow points to it from the third instruction.
- Schedule:** A dropdown menu set to 'DailyLoadWinter.Num.PER 1d0h0m0s.N24'. An orange arrow points to it from the fourth instruction.
- Active:** A checked checkbox.
- Time Shift:** A section with two radio buttons: 'Delay' (selected) and 'Advance'.
- Subscription Type:** A section with two radio buttons: 'Absolute (Use exact schedule values)' (selected) and 'Relative'. Below these are two input fields: 'Multiply schedule values times' (set to 1.0000) and 'Then shift resulting values by:' (set to 0.0000).
- Buttons:** 'OK', 'Save', and 'Cancel' at the bottom.

Annotations include orange arrows pointing from the instructions to the corresponding fields in the dialog. A yellow callout box on the right says 'Press to select multiple objects that subscribe to the same schedule' with an arrow pointing to the 'Select/View Objects' button. Another yellow callout box at the bottom right says 'When you select a field, this label changes telling whether the field is Numeric or Yes/No' with an arrow pointing to the 'Numeric' label.

Press to select multiple objects that subscribe to the same schedule

When you select a field, this label changes telling whether the field is Numeric or Yes/No

Defining a Schedule Subscription



Schedule actions can be applied with a specified time shift backward (delay) or forward (advance)

Leave the values 0 to avoid shift

Relative Subscription Type can modify the schedule values:
$$\text{Actual Value} = \text{Multiplier} * \text{Sched Value} + \text{Value Shift}$$

Schedule Subscription Dialog

Object Type: Area ☒ Active

Object ID: 3 (Northern California)

Field: Loads\Scale MW Value Numeric

Schedule: DailyLoadWinter.Num.PER.1d0h0m0s.N24

Time Shift

☒ Delay ☐ Advance

Days	Hours	Minutes	Seconds
0	0	0	0

Subscription Type

☒ Absolute (Use exact schedule values)

Multiply schedule values times	1.0000
Then shift resulting values by:	0.0000

Example: Yes/No, Closed/Open Schedule

- Suppose some lines and generators are not available in off-peak hours, between 11 pm and 6 am.
- First, create this schedule
 - Yes/No, Closed/Open
 - Repeat Every 1 Day
- Right click on a timepoint to Delete it or change the time (**SchedPoint Records → Change Time**)

Schedule Dialog

Schedule Name: AvailablePeakOnly Name Suffix: Y/N.PER.1d0h0m0s.N4

Periodic Schedule

Days Hours Minutes Seconds

☒ Repeat Every 1 0 0 0

☐ Valid From Sat, Jan 01, 2000 12:00:00 AM

☐ Valid Until Tue, Dec 31, 2030 12:00:00 AM

Value Type

☐ Numeric

☒ Yes/No, Closed/Open

☐ Text

Timepoint List

Add Point

Delete Point

Shift Datetime

Week Day Hour Minute Sec

☐ Interpolate Values Between Time Points

☐ Apply Schedule Points as Events

	Date	Hour	Yes/No Value
1	Tuesday, 2/27/2024	12:00:00 AM	NO
2	Tuesday, 2/27/2024	6:00:00 AM	YES
3	Tuesday, 2/27/2024	11:00:00 PM	NO

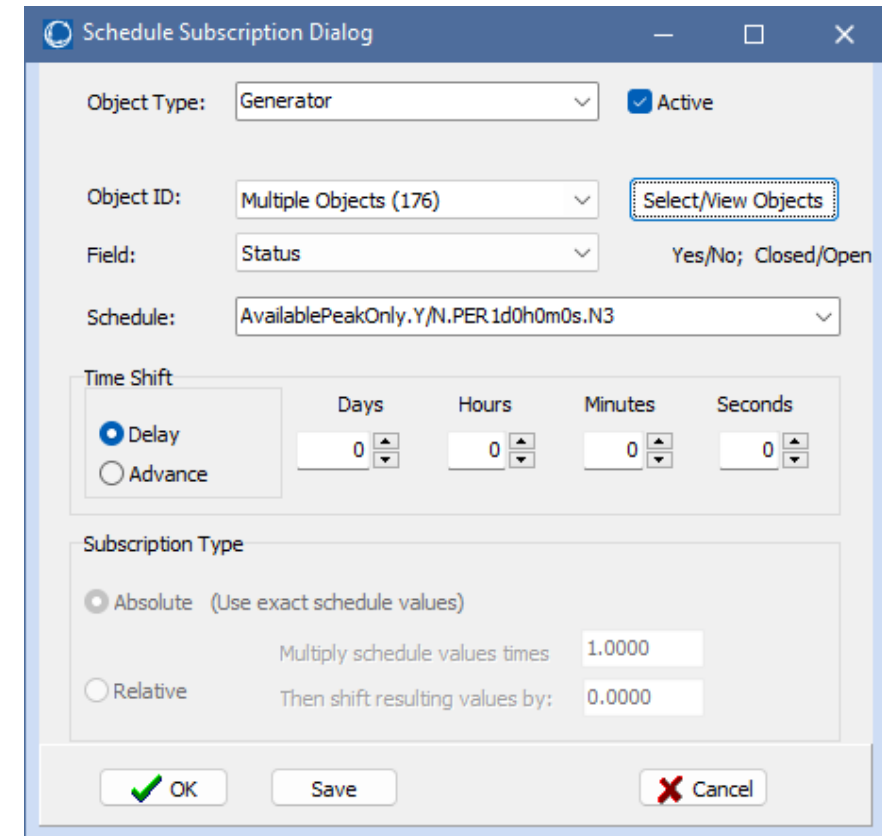
OK Save Cancel



Example: Yes/No, Closed/Open Schedule



- Subscribe Natural Gas Units under 20 MW to the schedule (Hint: apply a quick filter on Fuel Type starts with “NG” and MW Max < 20)
- Optionally subscribe a few lines to the schedule
- Could also use Excel to create new subscriptions using the established fields and pattern (NOTE: key and required fields must be included)



The screenshot shows the 'Schedule Subscription Dialog' window. It contains the following fields and options:

- Object Type:** Generator (dropdown menu)
- Active:** ☒ (checkbox)
- Object ID:** Multiple Objects (176) (dropdown menu)
- Select/View Objects:** (button)
- Field:** Status (dropdown menu)
- Yes/No; Closed/Open:** (text label)
- Schedule:** AvailablePeakOnly.Y/N.PER1d0h0m0s.N3 (dropdown menu)
- Time Shift:**
 - ☒ Delay (radio button)
 - ☐ Advance (radio button)
 - Days:** 0 (spin box)
 - Hours:** 0 (spin box)
 - Minutes:** 0 (spin box)
 - Seconds:** 0 (spin box)
- Subscription Type:**
 - ☒ Absolute (Use exact schedule values)
 - Multiply schedule values times:** 1.0000 (text box)
 - ☐ Relative
 - Then shift resulting values by:** 0.0000 (text box)
- Buttons:** OK (with green checkmark), Save, Cancel (with red X)



Schedule Subscriptions



- The advantage of schedules and schedule subscriptions is that power systems tend to have many quantities that follow a similar time pattern:
 - Bus loads of the same type
 - Different units of a power plant that are identically scheduled
 - A group of devices that are disconnected/reconnected at the same time. For instance, groups of capacitor or reactors.
- Using schedules, one avoids having to specify time point data for each field, which would be tedious and would require large quantities of memory

Setting Up Results



- During the time step simulation, Simulator obtains a PF/OPF/SCOPF solution for each time point.
- The amount of information that is generated may be significant since each time point can potentially contain the information of a solved PF, OPF, or SCOPF case.
 - For large systems, storing all these information may be limited by memory.
- Typically, you don't need to examine all the system quantities. The Time Step Simulation requires you to explicitly define which quantities you want to explore.

Setting Up Results



- Select the Results page:

Modify the Results Definitions

Results Display Options

Summary

- Input
- Results
- Areas
- Buses
- Generators
- Injection Groups
- Interfaces
- Lines
- Loads
- Owners
- Superareas
- Switched Shunts
- Transformers
- Zones
- Results: Constraints
- Options
- TSB Case Description

Input Results

Result Definitions

View/Modify Load Save

Group Results by

Identify Results by

Objects Fields Number Name Number + Name

Areas Buses Generators Injection Groups Interfaces Lines Loads Owners Superareas Switched Shunts Transformers Zones

	Date	Time	Skip
1	5/18/2006	1:00:00 AM	NO
2	5/18/2006	2:00:00 AM	NO
3	5/18/2006	3:00:00 AM	NO
4	5/18/2006	4:00:00 AM	NO
5	5/18/2006	5:00:00 AM	NO
6	5/18/2006	6:00:00 AM	NO
7	5/18/2006	7:00:00 AM	NO

Result pages

By default, no objects are shown

Setting Up Results



- Suppose we wish to track the output of certain generator classes via Injection Groups, the slack generation, Area MW Loads, and the total MW Load
- Load the aux file *InjectionGroups.aux* for injection group definitions
 - Solar (contains all solar generators)
 - Wind (contains all wind generators)
 - Thermal (contains all natural gas, coal, and nuclear generators)

Setting Up Results



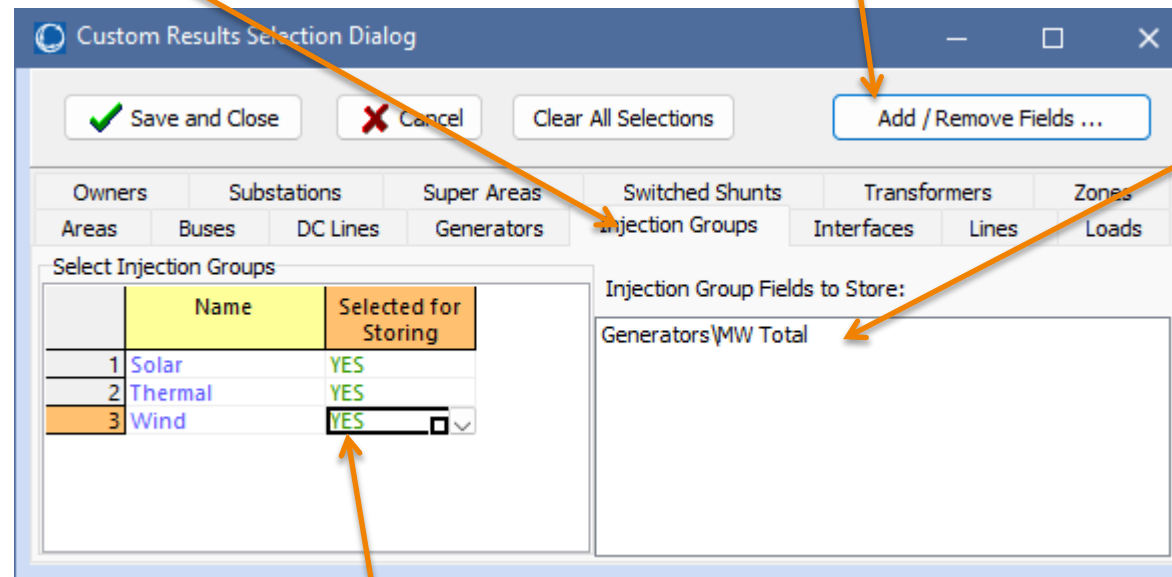
- Press the **View/Modify** Result Definitions button to tell Simulator the quantities you want to store
- You need to specify:
 - The type of object for which results must be saved (injection groups, super area, etc.)
 - The individual objects whose fields will be saved (Wind, Solar, Thermal)
 - The fields that will be saved for each type of objects (MW, Load MW)

Setting Up Results



Select the Injection Group page

Click Add/Remove Fields... to modify list of fields to store



For our example, assume we want to explore generation MW for all groups.

Save and Close the Result Definitions

Result Definitions are also saved in the .TSB file.

Set to YES the Injection Groups for which you want to store the fields (By default all are set to NO)

Setting Up Results



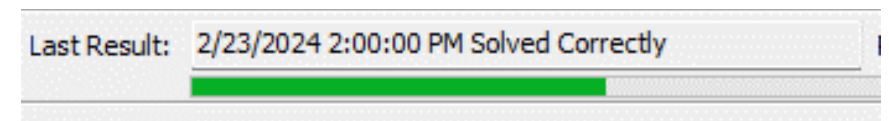
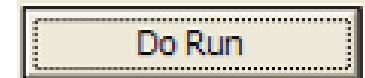
- Repeat for FullCase Super Area Loads\MW, all Areas Loads\MW, and Slack Bus (40845) Generators\MW
- Click the “Save and Close” button to return to the Results pages
- Results initially contain all zeros but will be populated after the simulation

Areas Buses Generators DC Lines Injection Groups Interfaces

Running the Simulation



- Now that we have set input data and specified which results we need to store, we can run the simulation
- Simulator will obtain a solution for each time point depending on the solution type
- In order to start the simulation, press the **Do Run** button
- During the simulation, you will see how the Last Result box and the Progress Bar are updated



Running the Simulation



- Simulator will do the following at each time point:
 - Look at the time point skip/pause flag and act accordingly
 - Run a pre-script command if it was specified
 - Apply time point and scheduled input data
 - Obtain the PF/OPF/SCOPF solution
 - Set the **Processed** flag in the Summary page
 - Update the Last Result and Progress Bar indicating the status of the solution
 - Write the results to the Result pages
 - Run a post-script command if it was specified

Exploring Results



- For our example, the Areas page of the Results shows Load MW
- Results can be grouped by objects or by fields
- Results can show object number, name, or both

Results

Result Definitions

View/Modify Load Save

Group Results by: ☒ Objects ☐ Fields

Identify Results by: ☐ Number ☐ Name ☒ Number + Name

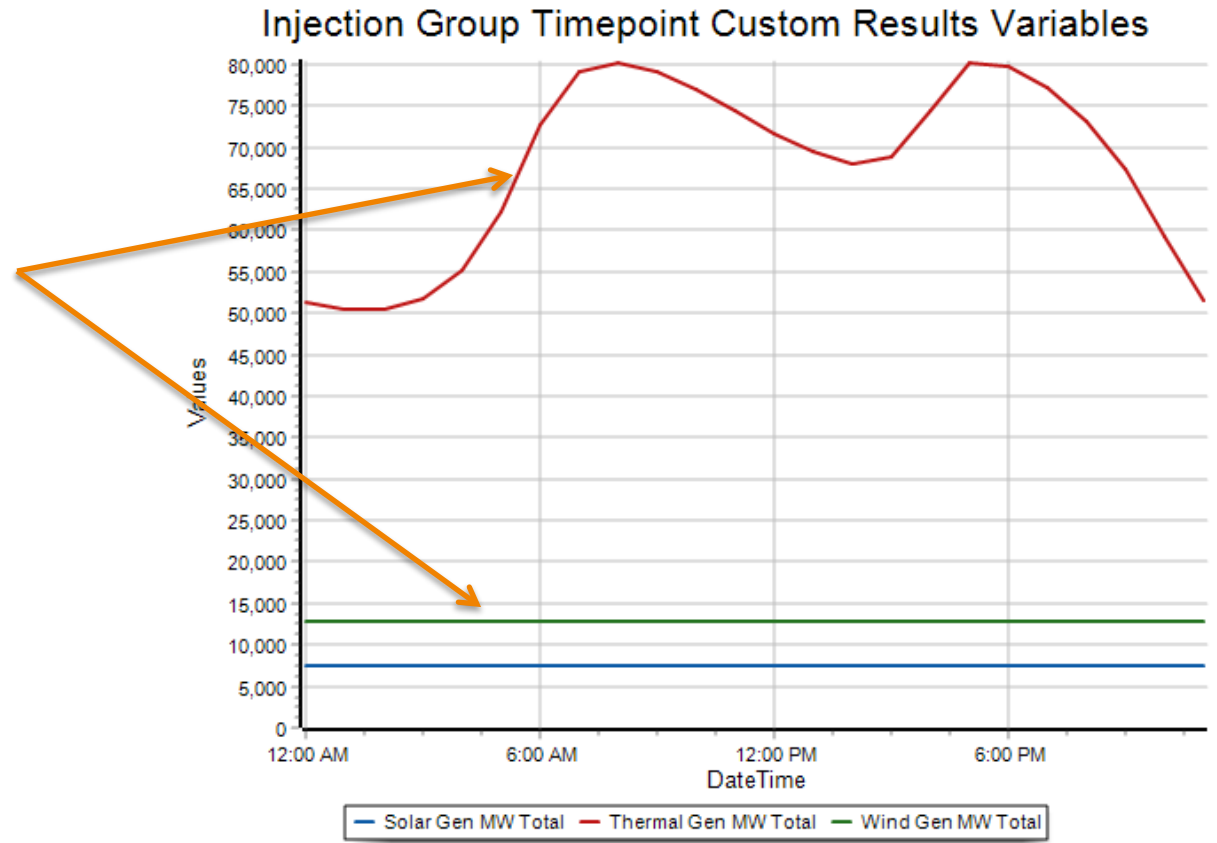
Areas Buses Generators DC Lines Injection Groups Interfaces Lines Loads Owners Substations Superareas Switched Shunts Transformers Zones

	Date	Time	Skip	1 (Washington) Load MW	2 (Oregon) Load MW	3 (Northern California) Load MW	4 (Bay Area) Load MW	5 (Central California) Load MW	6 (Southwest California) Load MW	7 (Southeast California) Load MW	8 (Nevada) Load MW	9 (Arizona) Load MW
1	2/23/2024	12:00:00 AM	NO	10289.59	6236.04	4306.91	9294.11	5188.15	17172.76	14023.74	5265.33	12020
2	2/23/2024	1:00:00 AM	NO	10093.17	6116.99	4269.79	9230.54	5175.01	17233.42	13955.02	5198.62	11859
3	2/23/2024	2:00:00 AM	NO	10029.04	6078.13	4238.84	9251.73	5243.71	17349.65	14063.15	5196.60	11725
4	2/23/2024	3:00:00 AM	NO	10189.86	6175.59	4300.73	9280.99	5381.12	17539.69	14157.10	5281.51	11917
5	2/23/2024	4:00:00 AM	NO	10462.62	6340.90	4554.44	9557.50	5581.16	18253.37	14473.36	5517.03	12191
6	2/23/2024	5:00:00 AM	NO	10872.77	6589.48	5061.87	9860.23	6064.11	19658.50	15097.81	5879.91	13376
7	2/23/2024	6:00:00 AM	NO	11341.97	6873.83	5810.62	10452.61	6669.32	21326.43	16312.35	6510.66	15005
8	2/23/2024	7:00:00 AM	NO	11870.18	7193.96	6188.10	11132.76	7012.83	22235.23	16950.94	6803.79	15937
9	2/23/2024	8:00:00 AM	NO	12434.00	7535.68	5996.27	11687.77	6938.07	22368.65	16963.05	6716.86	15750
10	2/23/2024	9:00:00 AM	NO	12777.01	7743.54	5761.12	11742.27	6835.01	22351.47	16650.84	6536.94	15454
11	2/23/2024	10:00:00 AM	NO	13019.25	7890.35	5501.22	11477.87	6643.04	22079.56	16334.59	6423.73	15005
12	2/23/2024	11:00:00 AM	NO	13060.96	7915.64	5284.63	11176.15	6403.59	21757.06	15954.66	6218.53	14615
13	2/23/2024	12:00:00 PM	NO	12739.34	7720.73	5086.62	10918.82	6270.22	21370.91	15546.45	6166.98	14311
14	2/23/2024	1:00:00 PM	NO	12641.64	7661.51	4956.67	10654.47	6215.67	20829.07	15166.52	6039.62	14130

Exploring Results



- We can also explore the results by obtaining a column plot. Here are the Injection Group Gen MWs.
- Note how the wind and solar are flat and the thermal generation tracks the load
 - This is because wind and solar units have AGC = NO
 - It is not realistic: solar should be zero at night!
 - We will next add weather models to dispatch the renewables



Save Progress



- Before continuing, let's save our work to the *Western10k.tsb* file (replace existing)
- We can also save results definitions and other settings to aux, so we could use them in another simulation; choose the "Save to Aux" button and file name *TSSSettings.aux*
- Choose what to Save
 - Options
 - Custom Results Selections

Time Step Simulation Aux File Save Opti...

There are several settings which affect the Time Step Simulation. Choose which settings you would like to save.

- ☒ Save Time Step Simulation Options
- ☐ Save Time Points
- ☐ Save Time Point Power System Inputs
- ☐ Save Schedules
- ☒ Save Custom Result Selections
- ☐ Save Weather Input
- ☐ Save Weather Stations (Needed for weather data)

Time Format

- ☒ Regular DateTime except ISO8601 for Weather
- ☐ ISO8601 for all Times
- ☐ DateTime for all Times

OK Cancel

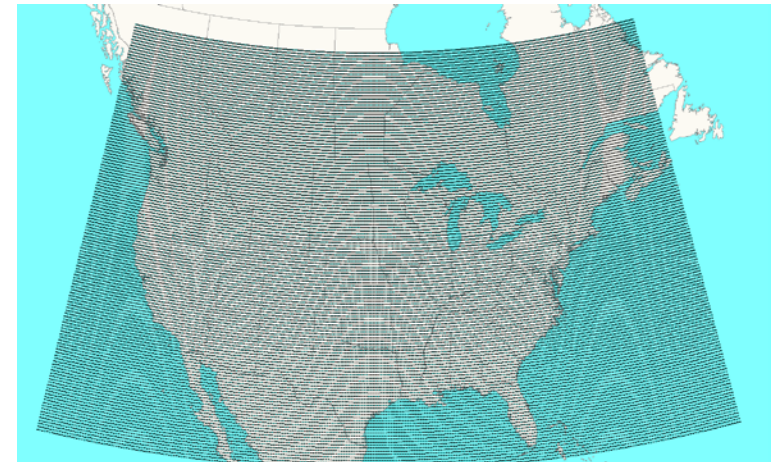


Weather Inputs and Models

Incorporating Weather



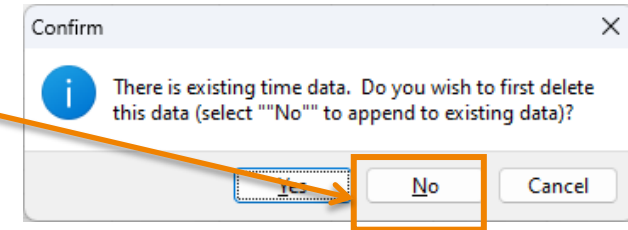
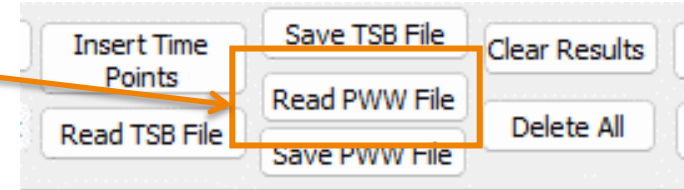
- The European Centre for Medium-Range Weather Forecasts (ECMWF) has global climate and weather data since 1940
 - Hourly time resolution on a 0.25 degree spatial grid
 - Includes 10m and 100m wind, and solar global horizontal irradiance and direct horizontal irradiance
 - ERA5 format; details at rmets.onlinelibrary.wiley.com/doi/10.1002/qj.3803
- PowerWorld formatted ERA5 data has *.pww extension
- North American data is available for download from Texas A&M University at <https://electricgrids.engr.tamu.edu/weather-data/>



Loading a Weather File



- Click **Read PWW File** and select *Western20240223.pww*
- Select “No” to append the weather to the time data already developed
- If a “Skip All Duplicates?” dialog appears, choose Yes
- The weather file contains extra time periods beyond our 24-hour range; we can delete these time points (right click → **Delete Entire Timepoint Record**)



Browsing Weather Data



- Weather data grids are found under the **Input** → **Weather** page

Available weather parameters

Each point on the grid is a “Weather Station”

Browse all parameters by Weather Station

	Date	Time	Datetime (UTC, ISO8601 Format)	Num Valid Wind Speed 100m	Save Timepoint in Aux or PWW File	Wind Speed 100m Average	Wind Speed 100m Minimum	Wind Speed 100m Maximum	+31.00-102.00/	+31.00-102.25/	+31.00-102.50/	+31.00-102.75/	+31.00-103.00/	+31.00-103.25/	+31.00-103.50/
1	2/23/2024	12:00:00 AM	2024-02-23T00:00:00Z	6789	YES	8.73	0	43	9.0	9.0	11.0	14.0	17.0	18.0	
2	2/23/2024	1:00:00 AM	2024-02-23T01:00:00Z	6789	YES	8.62	0	44	8.0	8.0	10.0	12.0	14.0	16.0	
3	2/23/2024	2:00:00 AM	2024-02-23T02:00:00Z	6789	YES	8.66	0	47	9.0	9.0	11.0	12.0	15.0	16.0	
4	2/23/2024	3:00:00 AM	2024-02-23T03:00:00Z	6789	YES	8.77	0	51	9.0	10.0	11.0	12.0	13.0	14.0	
5	2/23/2024	4:00:00 AM	2024-02-23T04:00:00Z	6789	YES	8.91	0	54	9.0	10.0	10.0	12.0	12.0	13.0	
6	2/23/2024	5:00:00 AM	2024-02-23T05:00:00Z	6789	YES	9.02	0	55	7.0	8.0	8.0	9.0	10.0	11.0	
7	2/23/2024	6:00:00 AM	2024-02-23T06:00:00Z	6789	YES	9.19	0	58	7.0	7.0	8.0	9.0	9.0	10.0	
8	2/23/2024	7:00:00 AM	2024-02-23T07:00:00Z	6789	YES	9.25	0	58	7.0	7.0	8.0	8.0	9.0	9.0	

Weather Units



- Can change displayed units for temperature, dew point, and wind speed on the **Options → Options (GIC, Time Zone, Weather)** page
- Many PWW files do not include solar radiation and use cloud cover percentage for solar inputs

Weather Data

☒ Save Weather Stations in TSB if there is Weather Data

TSB Weather Stations Load Option

☒ Replace Existing Weather Stations

☐ Merge with Existing Weather Stations

Temperature and Dew Point Units for Displays

☒ Fahrenheit (F) ☐ Celsius (C)

Wind Speed Units for Display

☒ Miles per hour (mph)

☐ Knots

☐ Meters per second (m/s)

☐ Km per hour (kmh)

Weather Input for Solar PV Calculation

☒ Use Solar Radiation Values If Available

☐ Only Use Cloud Coverage Percentage

Browsing Weather Data



- Additional weather file and data management is available from the **Tools Ribbon → Weather → Weather Models and Information**
- Weather Stations tab**

Weather Related Models and Information

Power Flow Weather (PFW) Models | **Weather Stations** | Weather (PWW) File Management | Weather (PWW) One Location

Weather Tools and Options

Power Flow Model Date and Time

Local Date and Time: 2/23/2024

Date and Time (UTC): 2024-02-23T08:00:00Z

Load Weather Obtained from Aviation.Gov (METARS)

☒ Update Case to METARS Time ☐ Delete All Existing Stations

☒ Add Unknown Stations

This data needs to be downloaded outside of Simulator from aviationweather.gov/data/cache/metars.cache.csv

Load Historical Weather from *.PWW Files

Historical Weather Directory:

G:\Scott\Support\Weather\

Desired Date and Hour (UTC): 2/23/2024 8

Reference Location

Location Latitude: 40.000

Location Longitude: -88.000

☒ Include Date and Time in Aux File

Reduce Number of Weather Stations and Measurements

Maximum Latitude: 37.00

West Side Longitude: -107.00 East Side Longitude: -93.00

Minimum Latitude: 25.50

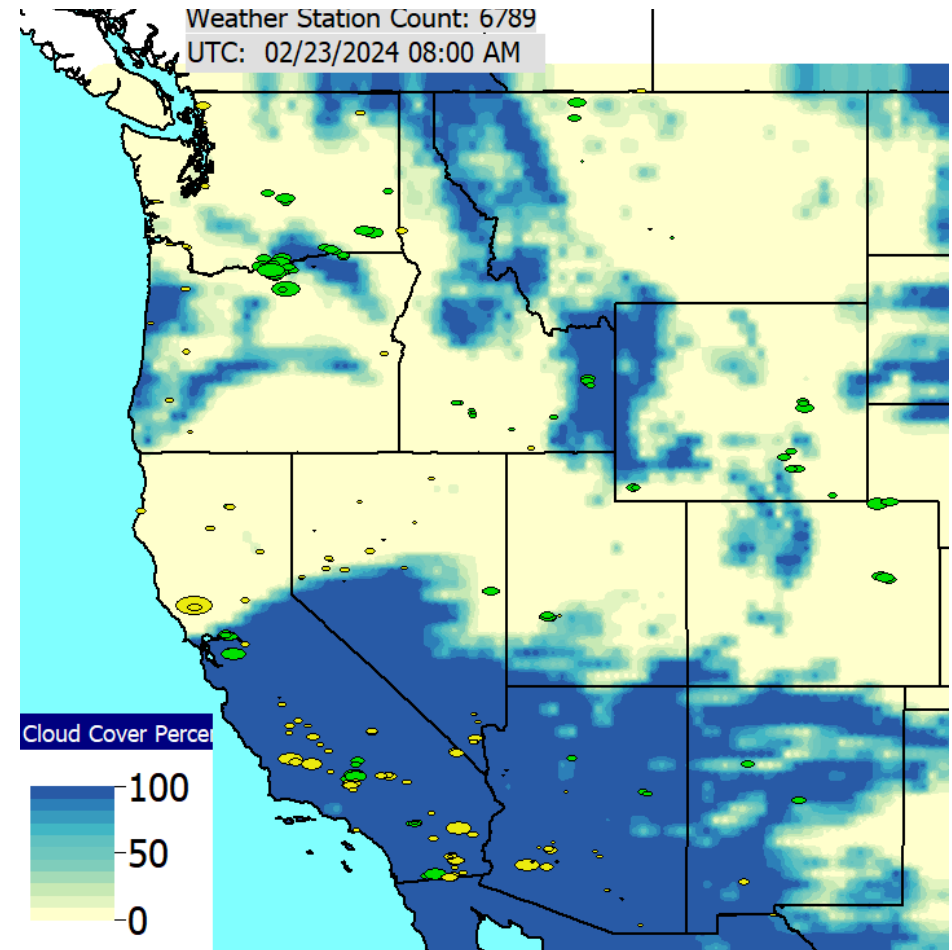
Total Weather Stations: 6789 Stations in Region: 525

	Name	Longitude	Latitude	ElevationFt	Enabled	Temp F	Temp C	Dew Point F	Dew Point C	Cloud Cover Percent	Wind Speed mph	Wind Speed 100m mph	Wind Direction	Global Horizontal Irradiance W/m^2	Direct Horizontal Irradiance W/m^2	Insolation Percent	Place_Name	Region
1	+31.00-102.00/	-102.000000	31.000000	2552	YES	50.0	10.0	33.0	0.6	59.0	4.0	9.0	70.0			0.0	TX	
2	+31.00-102.25/	-102.250000	31.000000	2612	YES	51.0	10.6	33.0	0.6	76.0	5.0	9.0	85.0			0.0	TX	
3	+31.00-102.50/	-102.500000	31.000000	2595	YES	51.0	10.6	33.0	0.6	64.0	7.0	11.0	85.0			0.0	TX	
4	+31.00-102.75/	-102.750000	31.000000	2687	YES	51.0	10.6	32.0	0.0	52.0	8.0	14.0	85.0			0.0	TX	
5	+31.00-103.00/	-103.000000	31.000000	2874	YES	51.0	10.6	31.0	-0.6	55.0	10.0	17.0	90.0			0.0	TX	

Visualizing Weather



- We can contour weather as “Spatial Data” on one-line diagrams
- The diagrams *NorthAmerica_CloudCoverPercent* and *NorthAmerica_Windmsec100m* are saved with such contour selections
- Activate the Saved View “western” in each diagram (Onelines Ribbon → **Save View** → **western**)



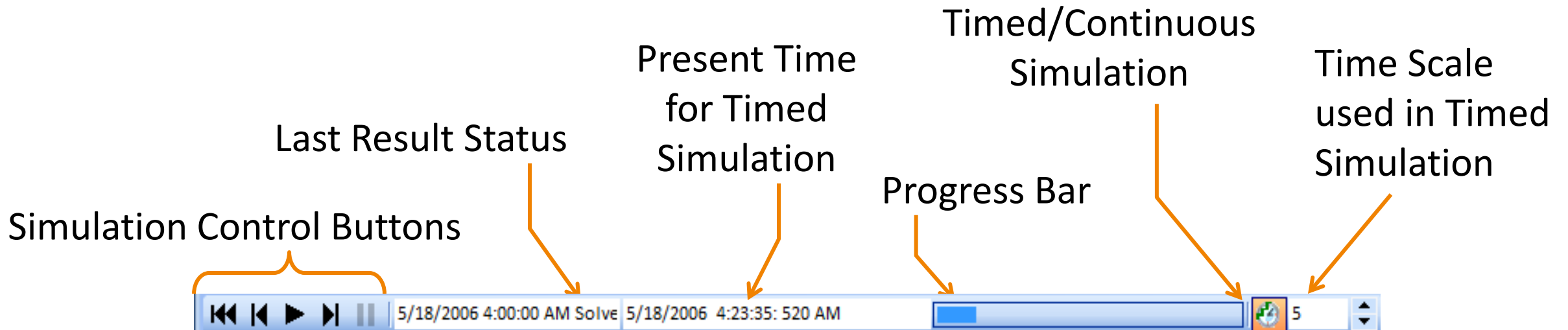
-



Time Step Simulation Toolbar

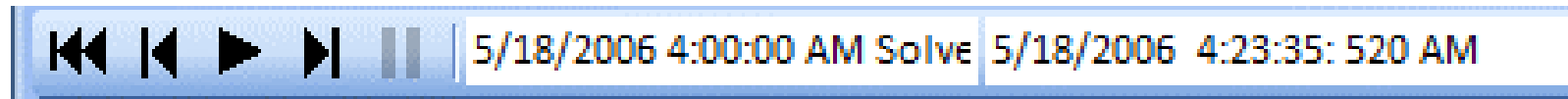


- The time step simulation toolbar is visible when the dialog is open and time points have been defined
- It allows you to control the simulation (continuous or timed), without using the time step simulation dialog





Time Step Simulation Toolbar



Reset the
Simulation

Solve the previous
Time Point

Play the Time Step Simulation in
either continuous or timed mode.

Pause a continuous or timed simulation

Solve the next Time Point

Adding Generator Weather Models



- Thus far, we have setup an hourly load schedule and imported weather data, but the weather and power flow models are not interacting
- We can add weather models (PFW models) to wind and solar generators to make their hourly maximum MW outputs dependent on wind speed and cloud cover percent, respectively
- Solar models can also modulate the maximum MW according to time of day, day of year, and geocoordinates

Assigning PFW Models



- The steps on the following slides describe a GUI process for assigning solar and wind weather models (PFW models)
 - You may have to use a similar process the first time assigning models to a specific case
 - Once assigned, you can store them in an aux file
 - You could also load them here from the file *ACTIVSg10kPFW.aux*
- Open the Generator case info display inside the “Weather Related Models and Information” dialog (**Tools Ribbon → Weather → Weather Models and Information → Power Flow Weather (PFW) Models → Generator PFW Models**)

Solar PFW Models



- Apply a Quick Filter on the Fuel Type Column for solar units (e.g. string starts with “SUN”)
- Show Dialog for one of the filtered units

Weather Related Models and Information

Power Flow Weather (PFW) Models | Weather Stations | Weather (PWW) File Management | Weather (PWW) One Location

Power Flow Weather (PFW) Model Options

Update PFW Weather Information and Set Inputs | Load PFW Model Aux File

Update PFW Weather Information; Apply to Power System | Save All PFW Models in Aux

Restore Design PFW Values | PFW Models Applied in Case: YES

Last Action: PFWModels Loaded from Aux File

Power Flow Model Date and Time

Local Date and Time: 2/23/2024 11:00:00 PM

Date and Time (UTC): 2024-02-24T07:00:00Z

Weather Station S

Number of Weather Stations: 3

Number With at Least One Solar Model: 4

Min Latitude: 3

Max Latitude: 4

PFW Model Summary | PFW Models All | Generator PFW Models (Filter:Quick)

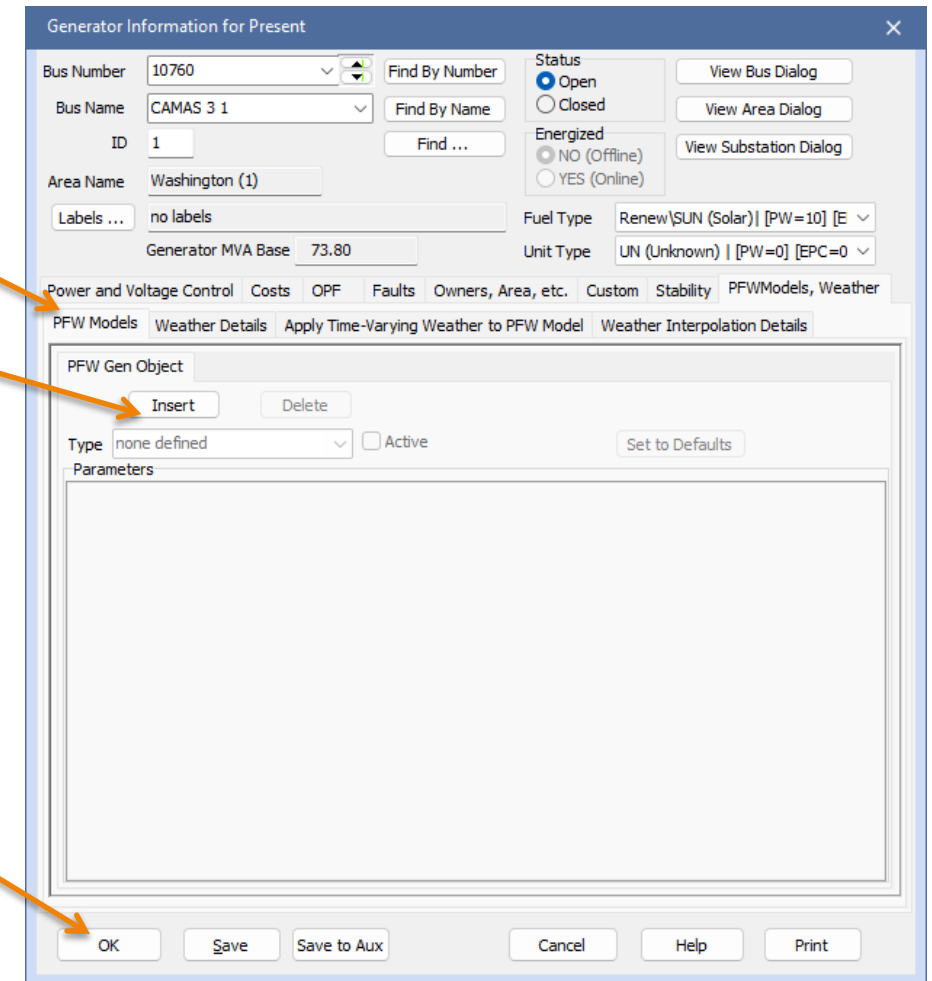
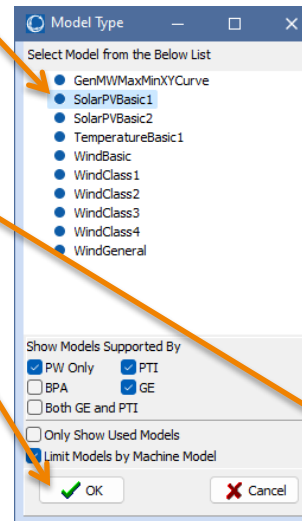
Records | Geo | Set | Columns | Options

	Number of Bus	Name of Bus	ID	Status	Gen MW	Min MW	Max MW	Fuel Type	PFW Model Count Active	PFW Model Count Inactive	Active PF
1	10760	CAMAS 3 1	1	Open	0.00	13.06	61.50	SUN (Solar)	0	0	
2	10776	MOUNT VERNO 1	1	Open	0.00	3.77	28.00	SUN (Solar)	0	0	
3	10776	MOUNT VERNO 2	2	Closed	14.32	6.15	20.00	SUN (Solar)	0	0	
4	10782	LONGVIEW 3 2	1	Closed	13.43	6.40	18.33	SUN (Solar)	0	0	
5	10782	LONGVIEW 3 2	2	Closed	14.65	7.37	18.33	SUN (Solar)	0	0	

Generator Dialog

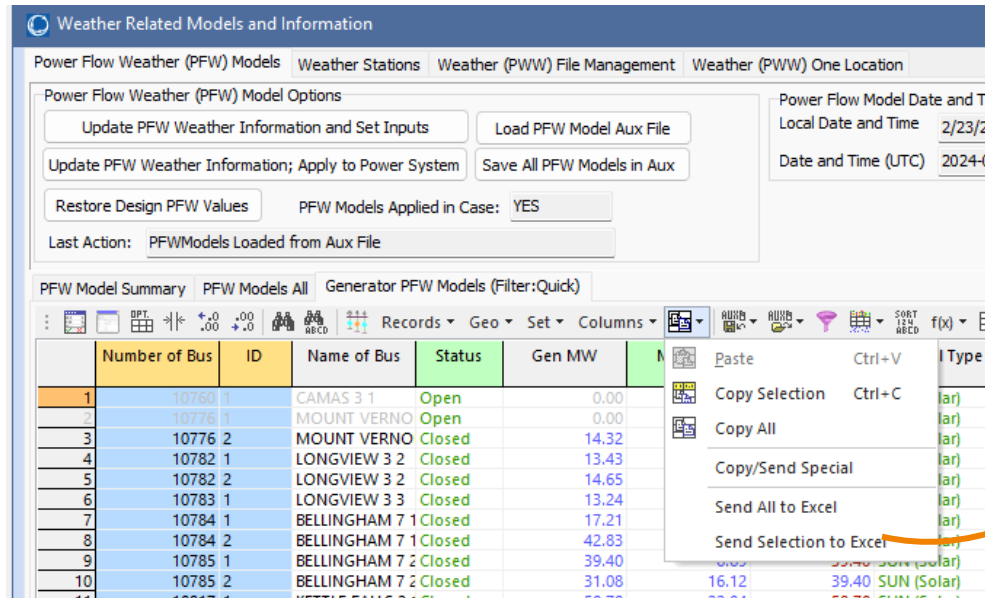


- Go to the **PFWModels**, **Weather** tab and click the **Insert** button
- Choose “SolarPVBasic1”, click **OK**, and **OK** again on the Generator dialog

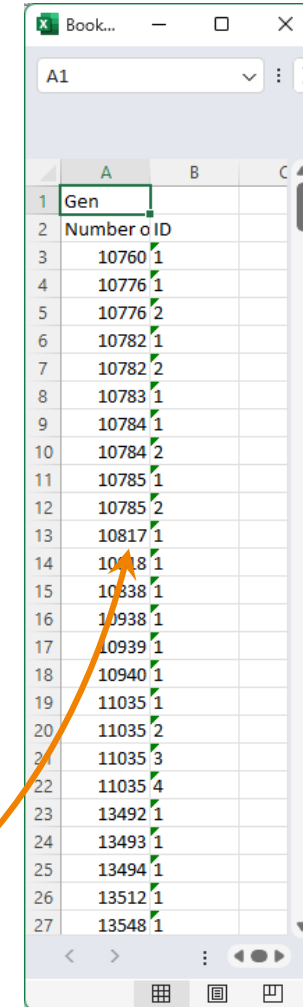


Copy the Models to all Solar Units

- Assume we want to assign “SolarPVBasic1” to all solar units
- Send the generator “Number of Bus” and “ID” columns to Excel (on the filtered list of solar units only)



	Number of Bus	ID	Name of Bus	Status	Gen MW	Type
1	10760	1	CAMAS 3 1	Open	0.00	
2	10776	1	MOUNT VERNO	Open	0.00	
3	10776	2	MOUNT VERNO	Closed	14.32	
4	10782	1	LONGVIEW 3 2	Closed	13.43	
5	10782	2	LONGVIEW 3 2	Closed	14.65	
6	10783	1	LONGVIEW 3 3	Closed	13.24	
7	10784	1	BELLINGHAM 7 1	Closed	17.21	
8	10784	2	BELLINGHAM 7 1	Closed	42.83	
9	10785	1	BELLINGHAM 7 2	Closed	39.40	
10	10785	2	BELLINGHAM 7 2	Closed	31.08	

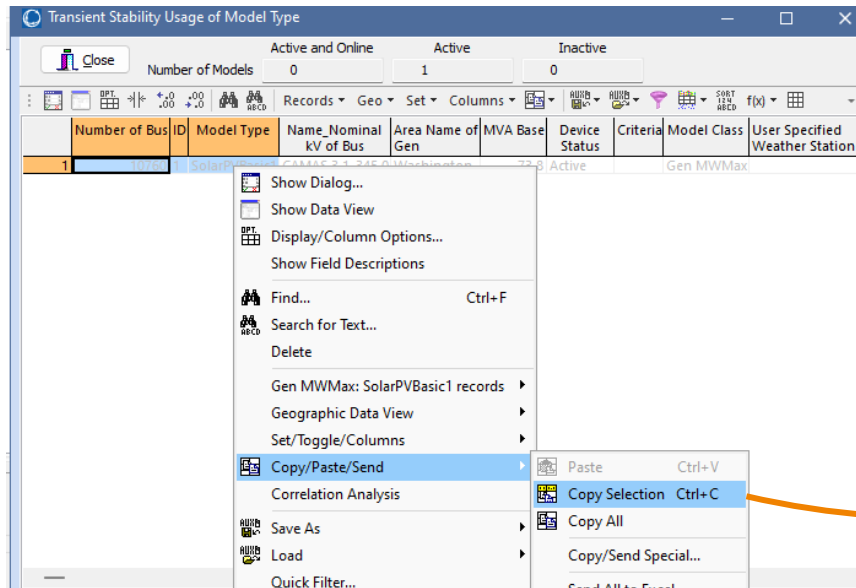


	Gen
1	Gen
2	Number of ID
3	10760 1
4	10776 1
5	10776 2
6	10782 1
7	10782 2
8	10783 1
9	10784 1
10	10784 2
11	10785 1
12	10785 2
13	10817 1
14	10818 1
15	10838 1
16	10938 1
17	10939 1
18	10940 1
19	11035 1
20	11035 2
21	11035 3
22	11035 4
23	13492 1
24	13493 1
25	13494 1
26	13512 1
27	13548 1

Copy the Models to all Solar Units



- Switch to the **PFW Model Summary** tab, and Show Dialog for the “SolarPVBasic1” Object Type
- Copy any field next to the list of Generators so the object type (GenMWMax_SolarPVBasic1) is copied

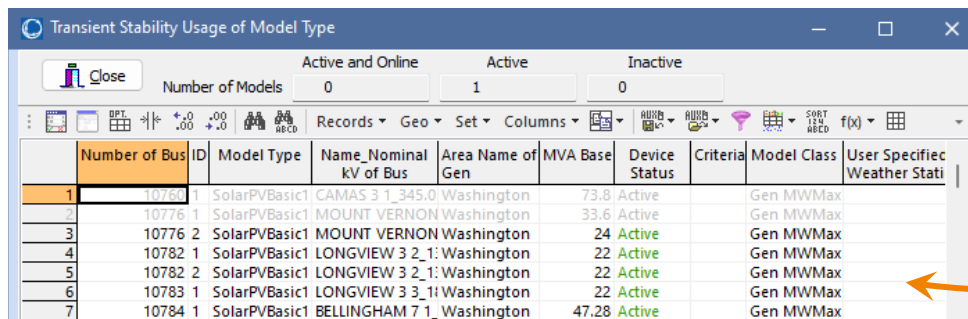


1	Gen			GenMWMax_SolarPVBasic1
2	Number o ID			Number o ID Model Type
3	10760	1		10760 1 SolarPVBasic1
4	10776	1		
5	10776	2		
6	10782	1		
7	10782	2		

Copy the Models to all Solar Units

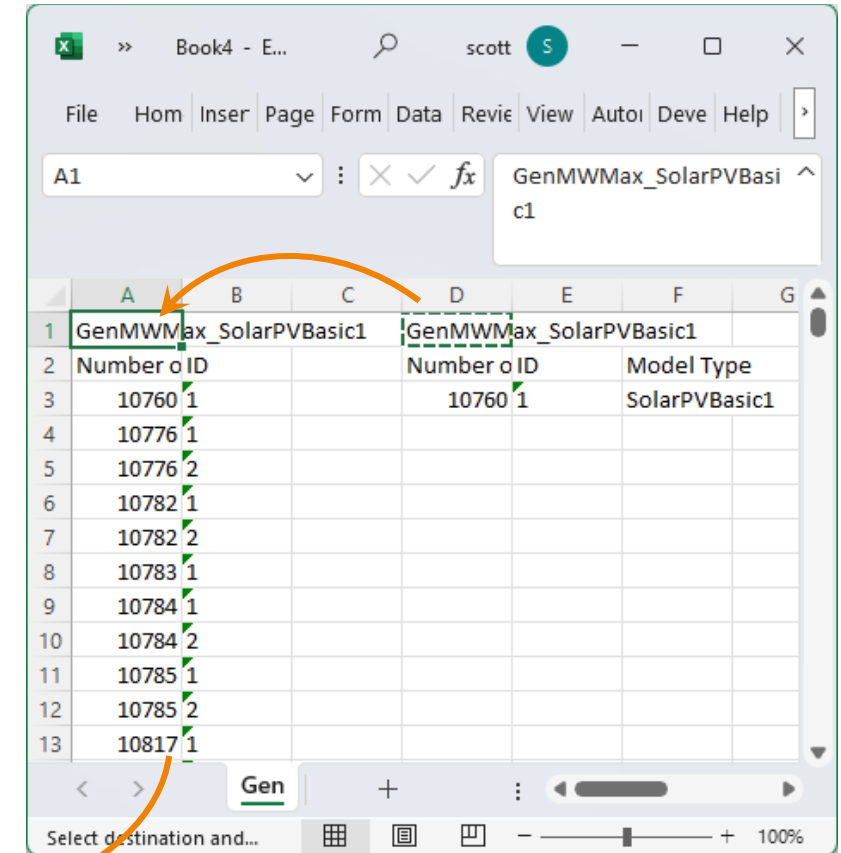


- Copy the “GenMWMax_SolarPVBasic1” object name over the object name of the solar generator list (D1 to A1 in the spreadsheet)
- Next, copy the whole list of “GenMWMax_SolarPVBasic1” records back into Simulator (columns A and B in the spreadsheet)



Transient Stability Usage of Model Type

Number of Bus	ID	Model Type	Name_Nominal kV of Bus	Area Name of Gen	MVA Base	Device Status	Criteria	Model Class	User Specified Weather Stati
1	10760	SolarPVBasic1	CAMAS 3 1_345.0	Washington	73.8	Active		Gen MWMax	
2	10776	SolarPVBasic1	MOUNT VERNON	Washington	33.6	Active		Gen MWMax	
3	10776	2	SolarPVBasic1	MOUNT VERNON	Washington	24	Active	Gen MWMax	
4	10782	1	SolarPVBasic1	LONGVIEW 3 2_1	Washington	22	Active	Gen MWMax	
5	10782	2	SolarPVBasic1	LONGVIEW 3 2_1	Washington	22	Active	Gen MWMax	
6	10783	1	SolarPVBasic1	LONGVIEW 3 3_1	Washington	22	Active	Gen MWMax	
7	10784	1	SolarPVBasic1	BELLINGHAM 7 1_	Washington	47.28	Active	Gen MWMax	



Book4 - E...

File Home Insert Page Layout Formulas Data Review View AutoTools Developer Help

A1 : X ✓ fx GenMWMax_SolarPVBasic1

	A	B	C	D	E	F	G
1	GenMWMax_SolarPVBasic1			GenMWMax_SolarPVBasic1			
2	Number o ID			Number o ID		Model Type	
3	10760	1		10760	1	SolarPVBasic1	
4	10776	1					
5	10776	2					
6	10782	1					
7	10782	2					
8	10783	1					
9	10784	1					
10	10784	2					
11	10785	1					
12	10785	2					
13	10817	1					

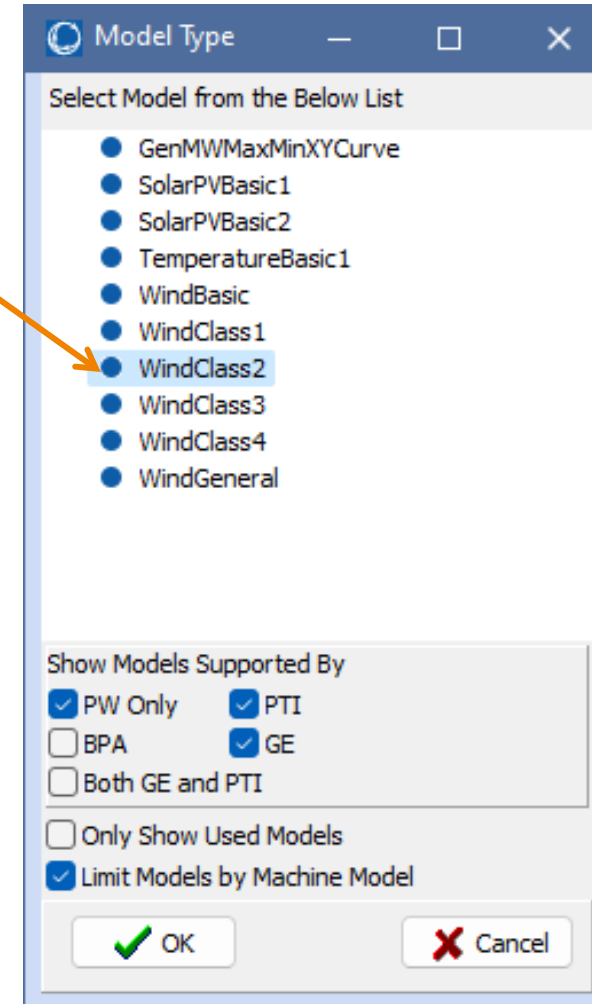
Gen

Select destination and...

Wind PFW Models

- Repeat the steps on the previous slides for Wind generators. For simplicity, assume all are Class 2
- PFW Model Summary should look like this

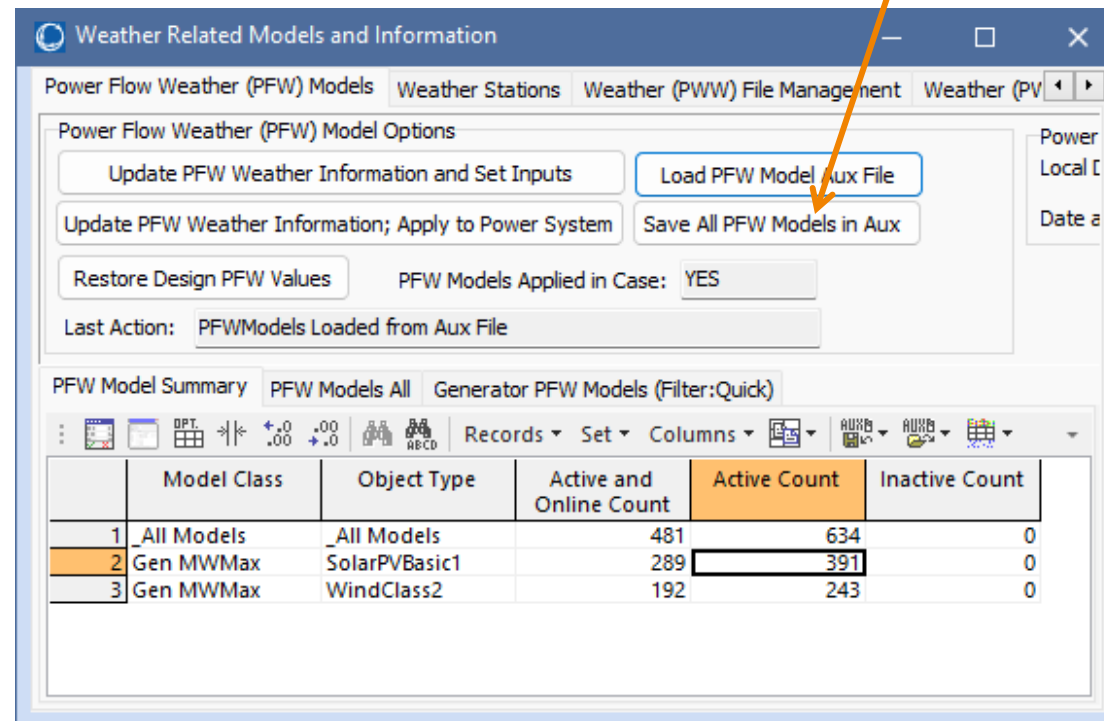
PFW Model Summary					
PFW Models All Generator PFW Models (Filter:Quick)					
	Model Class	Object Type	Active and Online Count	Active Count	Inactive Count
1	_All Models	_All Models	481	634	0
2	Gen MWMax	SolarPVBasic1	289	391	0
3	Gen MWMax	WindClass2	192	243	0



Saving PFW Models



- If you need to reload the models or use them in another case with the same set of generators, choose **Save All PFW Models in Aux**



Simulation with Weather



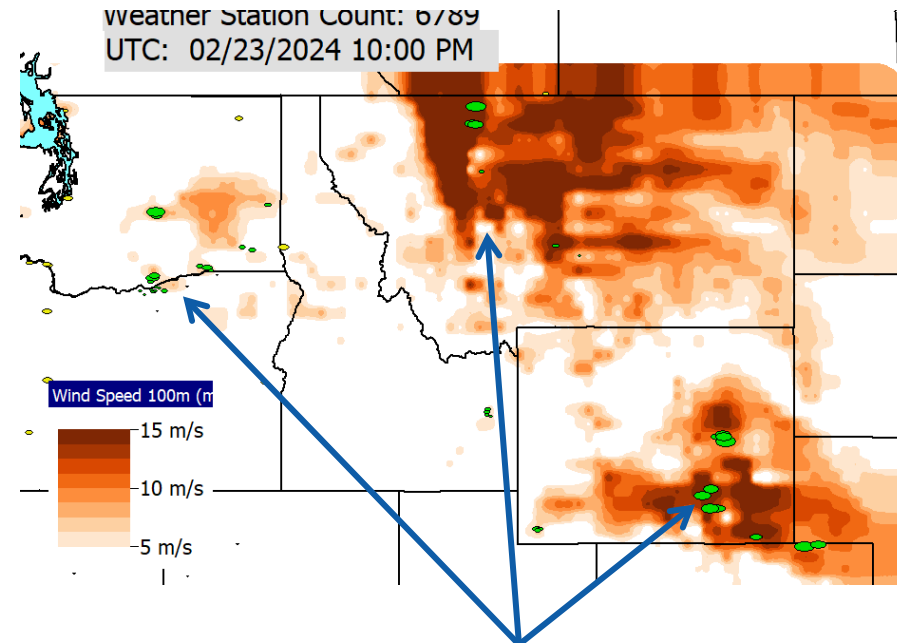
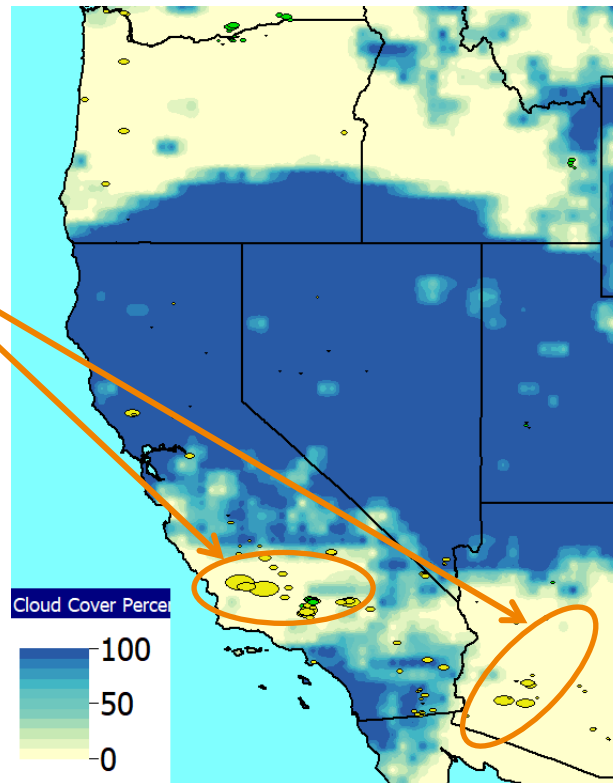
- Return to the Time Step Simulation and toggle all Solution Types back to “Single Solution”
- Restart the simulation (**Do Run**)
- Note that the weather one-line diagrams also feature Geographic Data View (GDV) substation objects
 - Yellow ovals represent substations with solar generation
 - Green ovals represent substations with wind generation
 - The size of the ovals is proportional to the MW output

Simulation with Weather



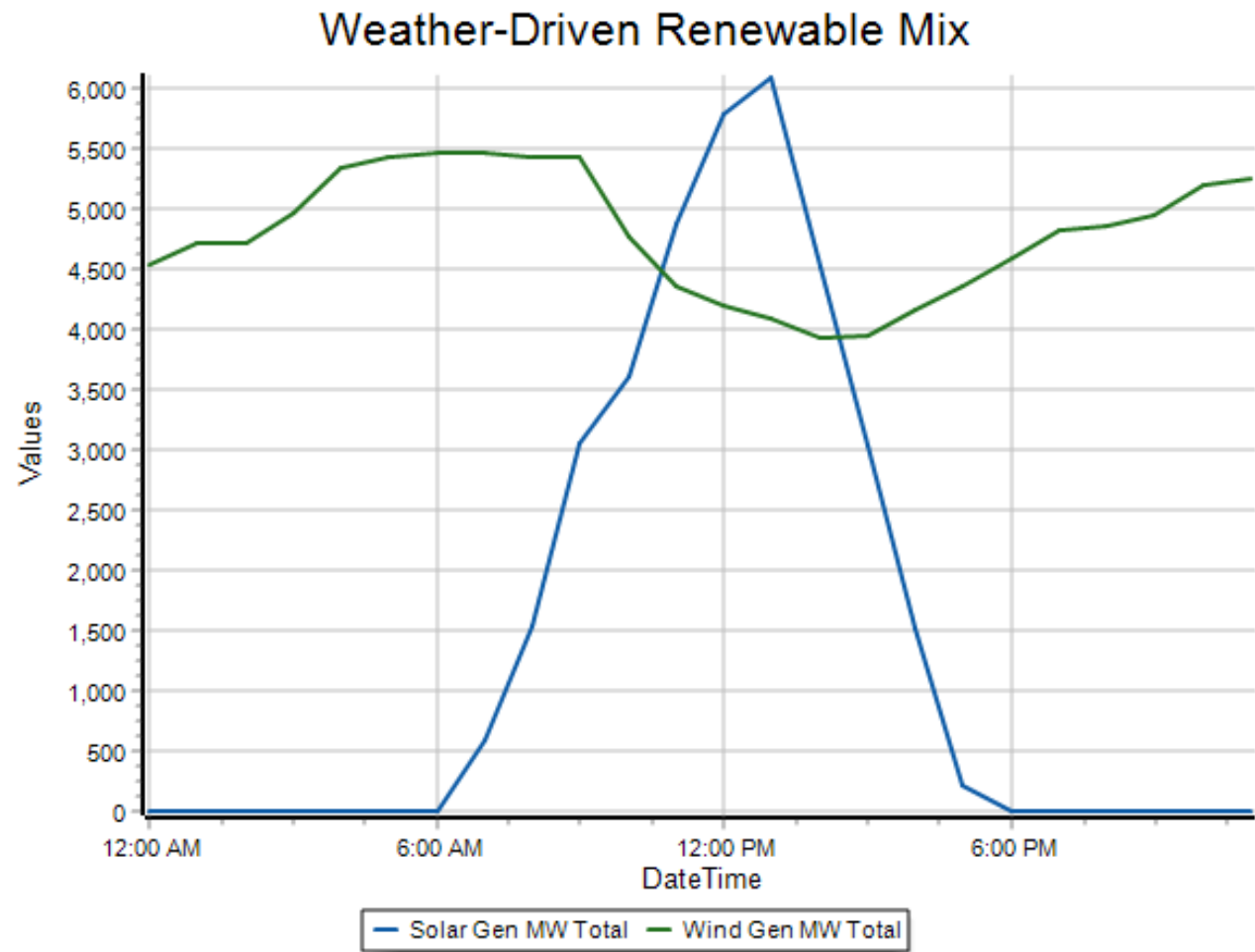
2pm Pacific Time (10pm UTC)

Note increased solar generation where cloud cover is lowest; no solar generation during night hours



Wind generation scales with local wind speed

Weather-Driven Renewable Mix





Other Time Step Features



Time Step Actions



- Special conditional actions may be modeled with time delays
- These are typically useful only for very detailed simulations with time steps on the order of several seconds or less, where the objective is to analyze switching behavior and resulting time-domain voltage profiles (e.g. wind farm operation)
- Time Step Actions are only considered for complete Time Step Runs (those started using **Do Run** button)
- Actions can be applied again, following the appropriate time delay, if model criteria is met
- Switched shunts and transformers may also incorporate switching delays (specified with individual shunt and transformer records)



Time Step Actions



- Example: Open a transmission line if it has been overloaded for at least 5 minutes

The screenshot displays the 'Time Step Simulation' software window. The 'Time Step Actions' tab is selected, showing a table of actions. The table has columns for 'Actions', 'Model Criteria', 'Status', 'Time Delay', and 'Comment'. A single action is listed: '1 OPEN Line One 138.0 (1) TO Two 138.0 (2) CKT 1' with the model criteria 'Line 1-2 Overloaded', status 'CHECK', and a time delay of '300'.

Actions	Model Criteria	Status	Time Delay	Comment
1 OPEN Line One 138.0 (1) TO Two 138.0 (2) CKT 1	Line 1-2 Overloaded	CHECK	300	



Time Step Actions



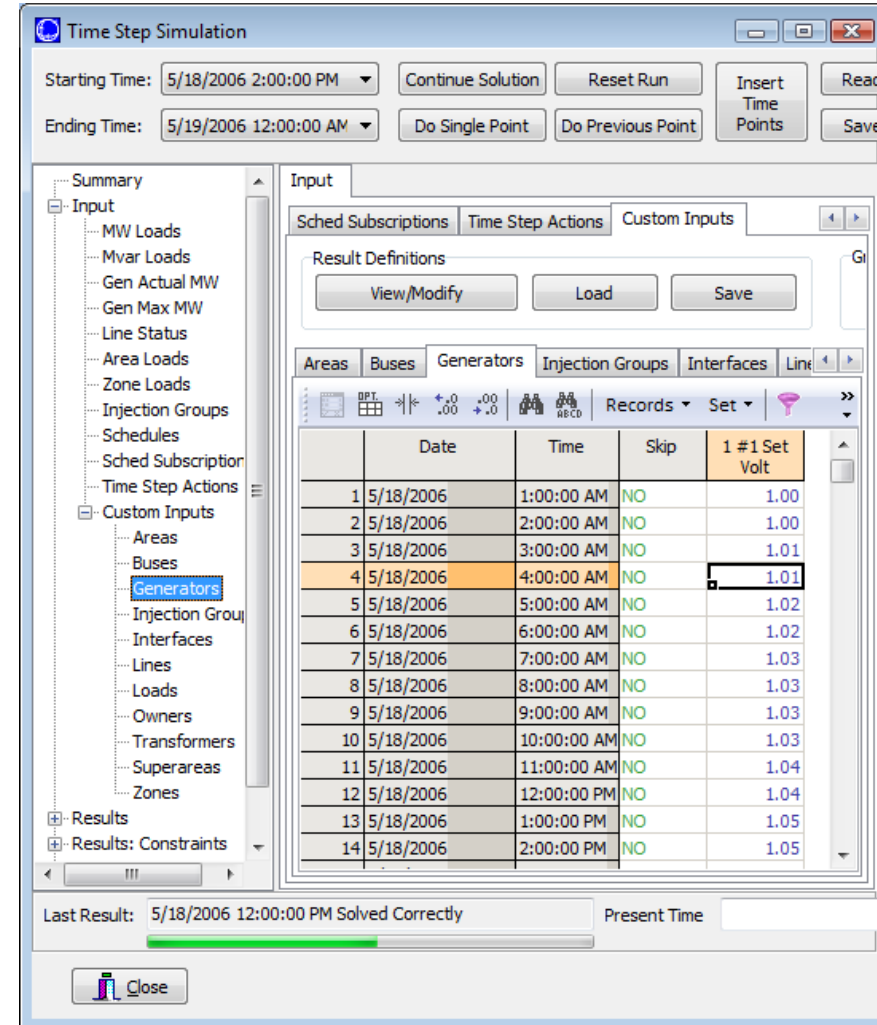
- Time Step Options for AVR transformer
- Typical application would be detailed time-domain voltage modeling of wind farm

The screenshot shows the 'Transformer Control Info' dialog box with the 'Time Step Options' tab selected. The 'Model Tap Delay in Time Step Simulation' checkbox is checked. A note states: 'Note: Regulation Minimum and Maximum specified with Common Options define the regulation range'. The 'Maximum Steps to Move' is set to 1. The 'First Move Delay' is 30 seconds for both 'Below (secs.)' and 'Above (secs.)'. The 'Next Move Delay' is 15 seconds for both. The 'Use Secondary Regulation Range' checkbox is unchecked. The 'Secondary Minimum' is 0.9900, 'Secondary Maximum' is 1.0000, and 'Secondary Max Steps to Move' is 1. The 'Sec. First Move Delay' is 15 seconds for both 'Below (secs.)' and 'Above (secs.)'. The 'Sec. Next Move Delay' is 10 seconds for both. At the bottom are 'OK', 'Cancel', and 'Help' buttons.

Parameter	Below (secs.)	Above (secs.)
Maximum Steps to Move	1	
First Move Delay	30	30
Next Move Delay	15	15
Secondary Minimum	0.9900	
Secondary Maximum	1.0000	
Secondary Max Steps to Move	1	
Sec. First Move Delay	15	15
Sec. Next Move Delay	10	10

Custom Inputs

- Custom inputs allow specification of more detailed parameters in the time domain for several object types
- Example: generator voltage setpoint





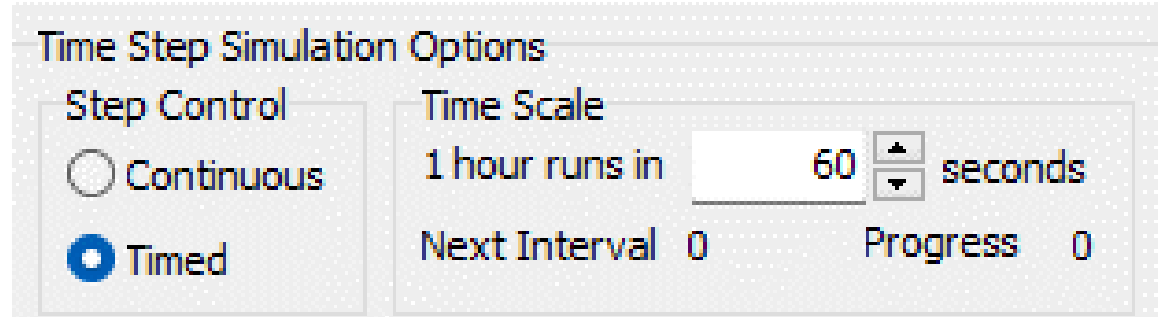
Continuous and Timed Simulations



- By default, when you hit the **Do Run** button, each time step is solved immediately after the previous one. This is called a *Continuous Simulation*.
- On the other hand, the Time Step Simulation can mimic a solution in actual time by specifying a time scale. This is called a *Timed Simulation*.
- The Timed Simulation allows you to visualize the solutions on oneline diagrams as a movie
 - You can see how time point and scheduled input data are applied and their effect on the system
 - You can also contour and animate

Continuous and Timed Simulations

- To set up a Timed Simulation go to the **Options → General** page and select *Timed* under **Time Step Simulation Options → Step Control**
- Set the **Time Scale**. A time scale of 60 means that the ACTUAL time delay between the solutions of two time points with date times 1:00 AM and 2:00 AM will be 60 seconds. Thus, if the 1:00 AM point is solved now, the 2:00 AM point will be solved 60 seconds later.



Time Step Simulation Options

Step Control

☐ Continuous

☒ Timed

Time Scale

1 hour runs in seconds

Next Interval 0 Progress 0



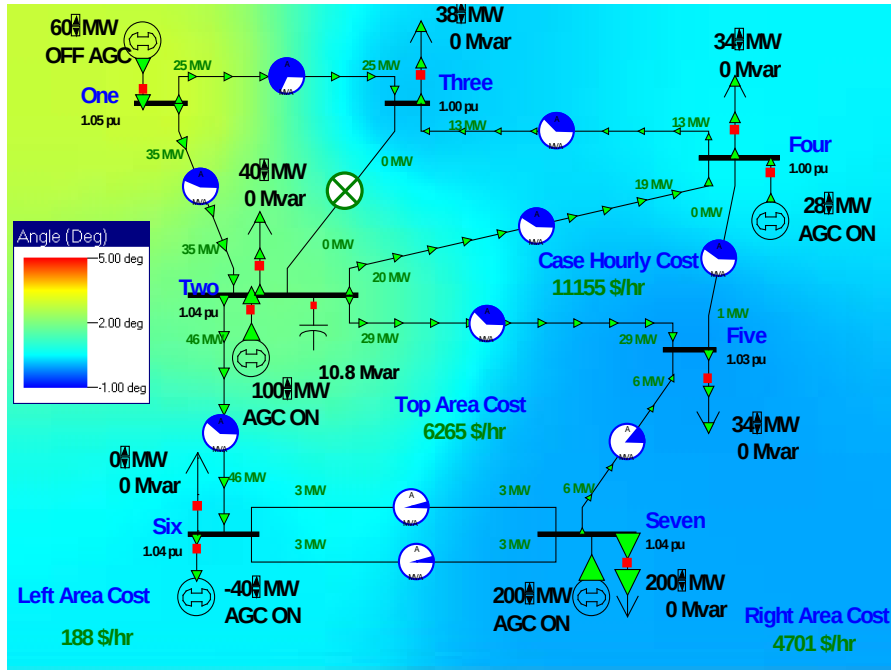
Timed Simulation Example



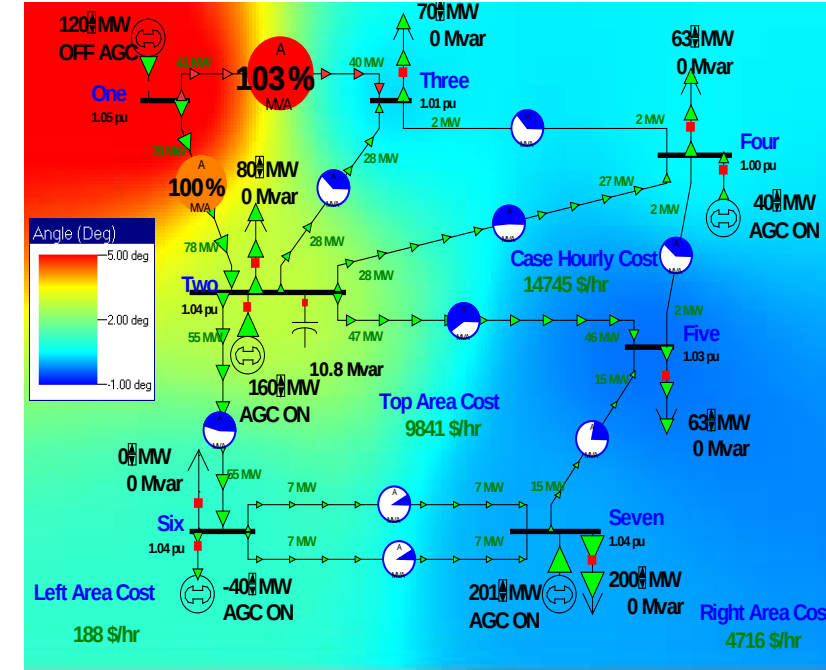
- Let us set the simulation to be **Step Control** = *Timed*, and set a **Time Scale** of 5 (1 hour runs in 5 seconds of actual time)
- Move the Time Step Simulation dialog so you can see the oneline, but still have access to the control buttons
- Run the simulation by clicking **Do Run**

Timed Simulation Example

System at 5 AM



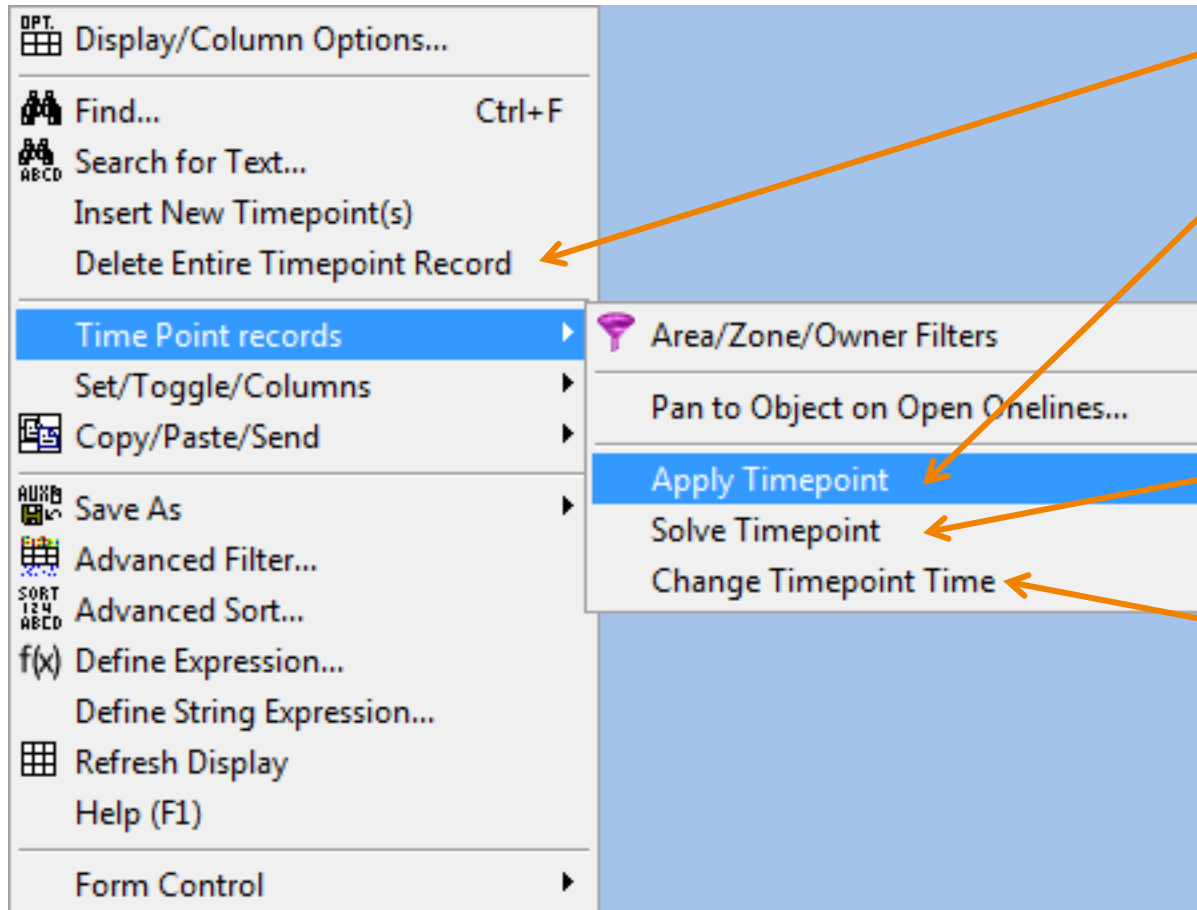
System at 2 PM



Note the status of transmission line 2-3, the values of generator 1 MW output, and how loads change at each time point. See how the line flows and angle contouring change (Note: Contouring should be set to continuously refresh).



Summary Page Local Menu



- Deletes the time point together with all the input data of that time point
- Applies the input data of the selected time point to the power system case (makes data available on the case information displays, oneline diagram, etc.). It does not apply scheduled input data.
- Solves the selected time point, by first applying both time point and schedule input data
- Brings up a dialog to change the date/time of a time point. It sorts the list afterwards.
- Paste (under Copy/Paste/Send) becomes enabled when the clipboard contains time step data in the correct format

Time Step Simulation Options



Options

Area and Zone Load Scaling

Use Time Point Values of

☒ Areas ☐ Zones ☐ None

Reactive Power Scaling

☒ Keep constant power factor ☐ Do not scale

Solution Options

☐ Pause if Power Flow Does Not Solve

☒ Enable Power Flow Area Interchange Control

☐ Turn generators off AGC when output changes

Pricing Options

☒ Solve Unconstrained Case

☐ Price Hydro Generation at Marginal Cost

☒ Reset Hydro Gen Price at End of Time Step

☒ Save Binding Constraints

When there is time point input data for area MW load and for individual load MW, always set to individual MW load value first. Then, if set to Areas, only areas are scaled. If set to Zones, only zones are scaled.

Important when changing Gen Actual MW and Injection Groups

OPF Pricing options

Saves binding constraint results in specific results matrix grid

Time Step Simulation Options



The screenshot shows the 'Time Step Simulation Options' dialog box. It has several sections: 'Step Control' with 'Continuous' and 'Timed' radio buttons; 'Time Scale' with a text box '1 hour runs in' containing '101' and 'seconds', and 'Next Interval' and 'Progress' both set to '0'; 'Step Type' with 'Apply and Solve' and 'Just Apply Data' radio buttons; a checkbox section with 'Apply Input Data' and 'Apply Schedule Data' both checked; 'Auto Load TSB File Options (saved in case pwb file)' with 'Automatically Load Default *.tsb File' and 'Automatically Set Default *.tsb File to Current *.tsb File' checked, and 'Automatically Run Simulation after Loading *.tsb' unchecked; a 'Default *.tsb File' text box with the path 'G:\Matt\projects\Support\12_11_09' and a browse button; and a checkbox 'Save the Default *.tsb File after Finishing the Run' which is unchecked. Orange arrows point from text annotations to specific controls: one to the 'Timed' radio button, one to the 'Apply and Solve' radio button, one to the 'Apply Input Data' and 'Apply Schedule Data' checkboxes, one to the 'Automatically Load Default *.tsb File' checkbox, and one to the 'Save the Default *.tsb File after Finishing the Run' checkbox.

Time Step Simulation allows you to either Apply and Solve or just Apply Data without solving

Sometimes you want to test only time point or schedule data

Loads the TSB automatically when the case is opened

When saving the TSB, set automatically the Default tsb to be the current tsb

Time Step Simulation Options



Options Page

A screenshot of a software interface titled 'Auto Contouring'. It contains a section labeled 'Action' with four radio button options: 'No Auto Contouring' (selected), 'Contour but Do Not Save', 'Save in File as Bitmap', and 'Save in File as JPEG'. Below this is a label 'Contour File Name Format:' followed by a text input field containing the string 'CONTOURmmddyyyyHRhh'.

The Time Step Simulation can contour online diagrams as the simulation takes place.

It can also save a list of the resulting images as Bitmaps or JPGs.

Time Step Simulation Options



Options Page

Result Storage Options

Storage Options

- ☒ Store results in memory
- ☐ Only store results in csv file
- ☐ Store in memory and csv file

CSV Object ID Options

- ☒ Primary key (number)
- ☐ Secondary key (name)
- ☐ Label

CSV File Identifier

CSV Output Path

The Time Step Simulation can save data directly to a CSV file. This is meant to enable the time step to store data from very long runs without running out of memory.

The file identifier is used to identify the run. Individual objects have files created for them.

For example, Year2010_areas.csv.



OPF and SCOPF Time Step Simulations



- Users of OPF and the SCOPF add-ons can obtain time point optimal power flow and security-constrained optimal solutions by specifying these solution types for one or more time points in the Summary page
 - Make sure you become familiar with Simulator OPF and SCOPF before running a Time Step Simulation with these options



OPF and SCOPF Time Step Simulations



Unconstrained OPF

- The Time Step Simulation will remove all the constraints that would normally act in the OPF and will optimize the system to find the minimum operating cost
- Simulator will change the set points of the specified controls (generators and phase shifters) to minimize the cost of all Areas and Super Areas set to OPF AGC control
- Besides the power flow solution options, the Unconstrained OPF simulation will take all the options that have been defined for a regular OPF solution. Most of these options are defined in **OPF Options and Results** Dialog under the **Add Ons** ribbon tab.



OPF and SCOPF Time Step Simulations



OPF

- The Time Step Simulation applies the time point and schedule input data and optimizes the control areas set to OPF to minimize cost while enforcing normal operation constraints
 - This includes: transmission line thermal limits, interface limits, generator control limits, and load control limits
- The OPF algorithm detects the controls that need to be moved, the constraints that are binding at the solution point, and the unenforceable constraints, i.e., constraints that cannot be enforced with the available controls



OPF and SCOPF Time Step Simulations



OPF

- Some of the quantities that are of interest in the solution of the OPF algorithm, are displayed in the Result: Constraints Pages:
 - Unconstrained Generator MW Output
 - Final generator MW Output
 - Change in Generator MW
 - Locational Marginal Prices: These are displayed in the Hourly Final Bus LMP Page. Average LMP prices and other LMP metrics are also available in the Results Page for Areas, Injection Groups, Super Areas, and Zones.
 - Binding Constraints as well as Marginal Cost of Limit Enforcement for lines and interfaces



OPF and SCOPF Time Step Simulations



SCOPF

- The SCOPF combines Simulator's OPF with Contingency Analysis to optimize a system for minimum cost while enforcing both normal operation and contingency constraints
- The solution of an SCOPF Time Step Simulation depends on the options that have been set up for the following tools:
 - Power Flow
 - Optimal Power Flow
 - Contingency Analysis
 - Security Constrained Optimal Power Flow
 - Time Domain OPF Options



OPF and SCOPF Time Step Simulations



SCOPF

- At each time point, the SCOPF Time Step Simulation does the following:
 - Applies the input data and scheduled actions
 - Solves a power flow
 - If specified, it solves an unconstrained OPF
 - Initializes the base case for the SCOPF by solving a power flow or an OPF
 - Solves the contingencies for the initialized system state
 - Solves the SCOPF optimization problem
 - Displays the results in the matrix grids



OPF and SCOPF Time Step Simulations



SCOPF

- The SCOPF often requires significant computer resources mostly because of the need to solve a large number of contingencies and to calculate their sensitivities
- The size of the problem also depends on the size of the system, number of constraints (monitored elements), and number of time points considered
- A mechanism to speed up the computation of the PF/OPF/SCOPF Time Step Simulation is to use DC solutions in some of the internal routines:
 - AC or DC power flow
 - AC or DC contingency analysis. This one will produce the larger time savings.
 - AC or DC SCOPF

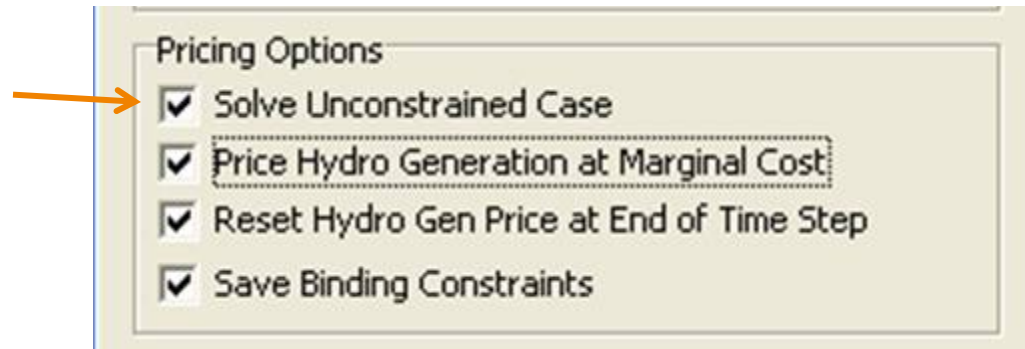


OPF Pricing Options



- Different applications of the OPF/SCOPF require special pricing options
- A method for congestion pricing consist of solving first the unconstrained case to determine unconstrained LMPs, and then solve the OPF or SCOPF. The difference between these two solutions correspond to the congestion cost or congestion component of the LMP for a given hour.

Check this option to solve an unconstrained OPF (equivalent to economic dispatch) before solving the OPF or SCOPF for each time point.

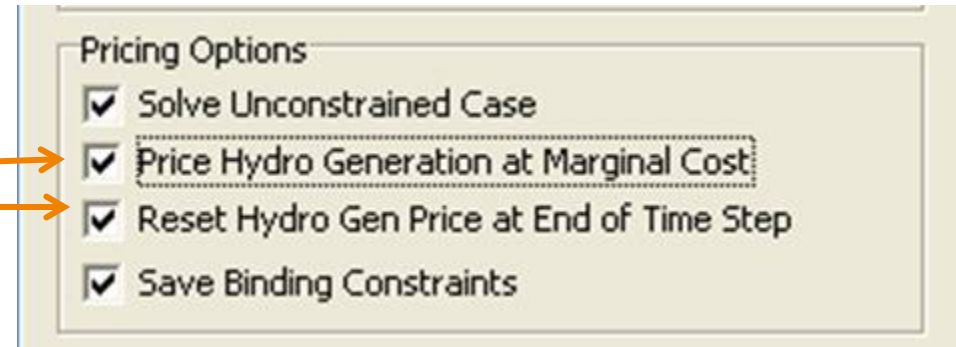




OPF Pricing Options



- It is also customary in LMP markets to price hydro generation at a cost equal to the unconstrained LMP
- Simulator will internally modify the cost curve of the hydro generation to match the unconstrained LMP obtained during the initial unconstrained simulation. It will then solve the constrained optimization problem using this cost for the hydro units.



Check this option to reset the cost curve of hydro generation to the original cost after each time step. Uncheck it to explore how Simulator changes the hydro cost to the unconstrained marginal price



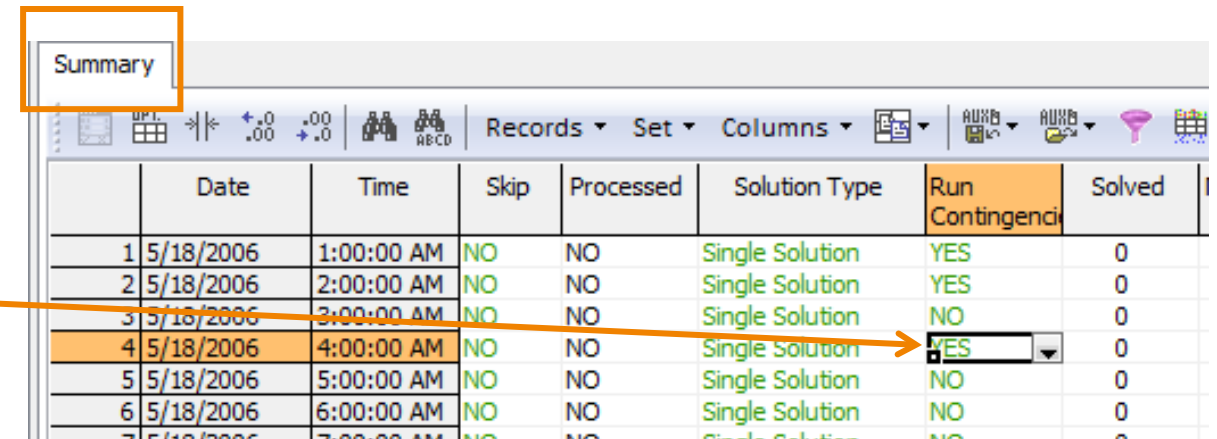
OPF Pricing Options



- OPF and SCOPF solutions with pricing options do the following for each time step:
 - Apply time point and schedule input data
 - if unconstrained then begin
 - Solve Unconstrained OPF
 - if price hydro then Hydro Cost = LMP
 - end
 - Solve OPF or SCOPF
 - if unconstrained and price hydro and reset then Reset Price
 - if Save then Save Binding Constraints

Time Step Simulation and Contingency Analysis

- Contingency analysis will take place as part of the SCOPF
 - Binding constraints will be saved in the Results: Constraints page.
- Sometimes summary information of contingency analysis is required without the SCOPF
 - For instance, the custom results for transmission lines allows saving the Aggregate MVA Overload and Max% Loading Contingency for each transmission element
- In order to run contingency analysis for a time point, set the corresponding “Run Contingencies” field to YES on the Summary page



	Date	Time	Skip	Processed	Solution Type	Run Contingencies	Solved
1	5/18/2006	1:00:00 AM	NO	NO	Single Solution	YES	0
2	5/18/2006	2:00:00 AM	NO	NO	Single Solution	YES	0
3	5/18/2006	3:00:00 AM	NO	NO	Single Solution	NO	0
4	5/18/2006	4:00:00 AM	NO	NO	Single Solution	YES	0
5	5/18/2006	5:00:00 AM	NO	NO	Single Solution	NO	0
6	5/18/2006	6:00:00 AM	NO	NO	Single Solution	NO	0

