Time Step Simulation

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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.
- It also allows you to model actions that occur at specific times, as well as periodic actions.

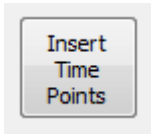
Time Step Simulation

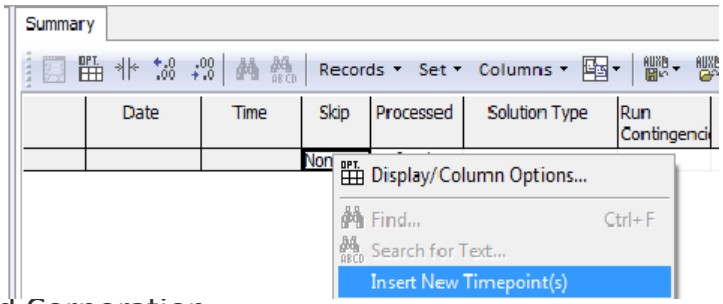
- In this section we'll learn how to:
  - Set up and maintain a list of time points
  - Specify time point input data
  - Specify scheduled input data
  - Customize the results we want to store from the solution
  - Run "continuous" and "timed" simulations

- Open the B7flat.PWB case. To access the Time Step Simulation Dialog, in Run Mode, go to the **Tools** ribbon tab and select → **Time Step Simulation**.

Inserting New Time Points

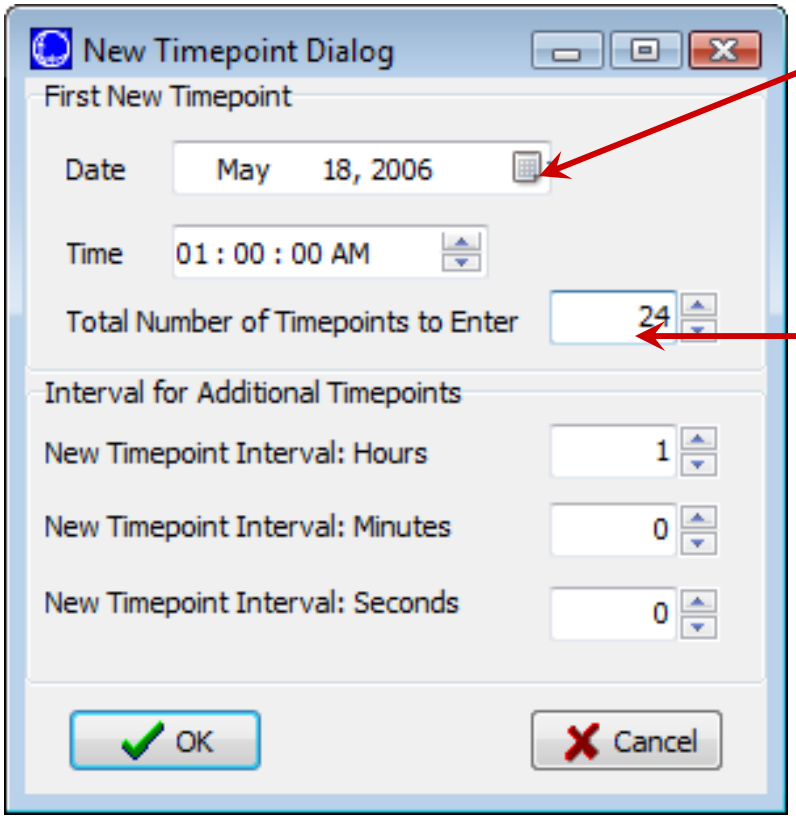
- The first step in setting up a Time Step Simulation is to define a list of time points.
  - This is a list of points in time for which Simulator will obtain solutions.
- In the Time Step Simulation dialog, right-click on the grid and select **Insert New Timepoint(s)**, or press the **Insert Time Points** button.





Inserting New Time Points

As an example, assume we want to simulate 24 hours, starting on May 18, 2006 at 1:00 AM



Click to select the date from a calendar component

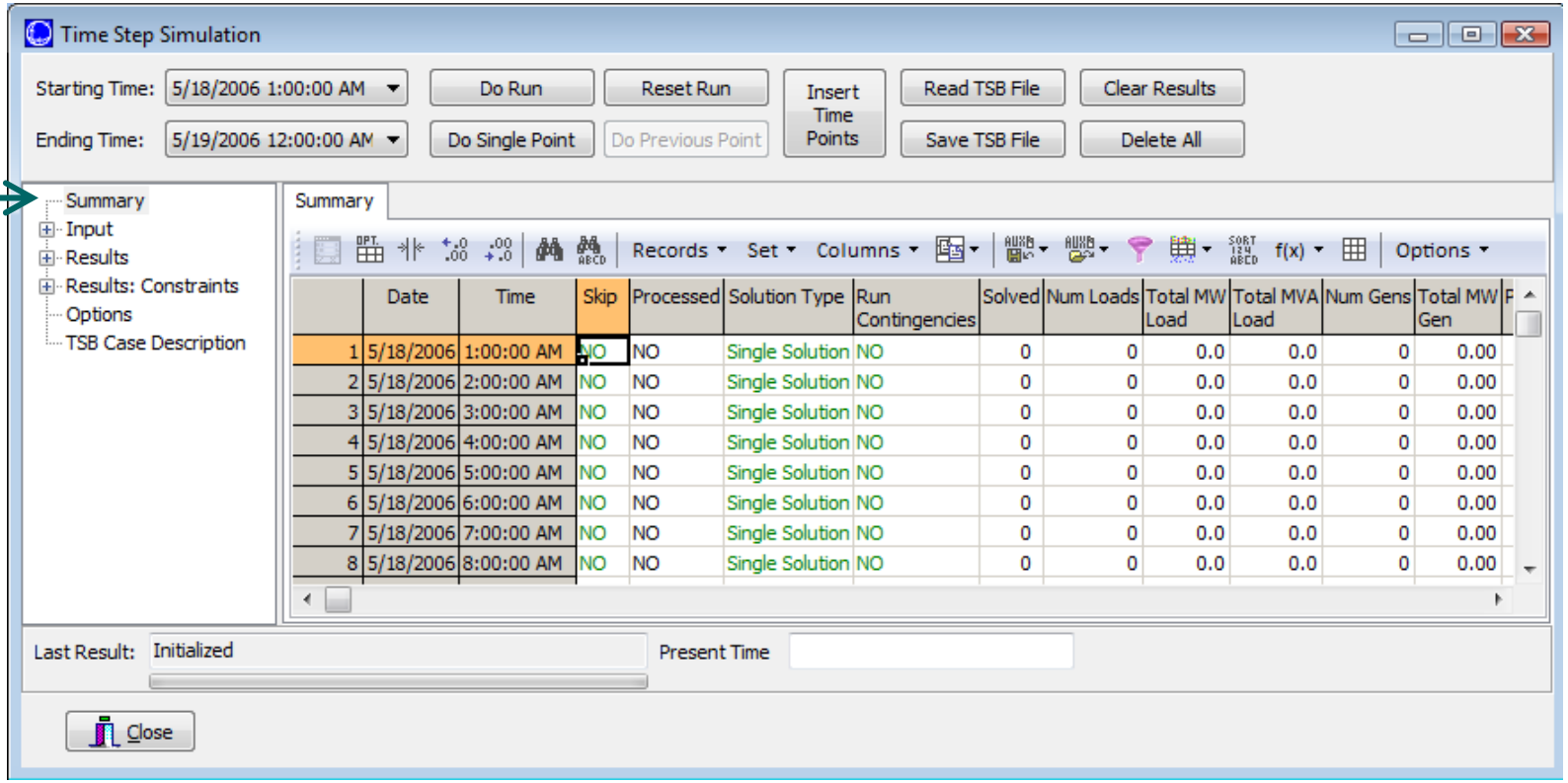
Number of time points that will be inserted

Specify the interval between time points. Maximum resolution is 1 second.

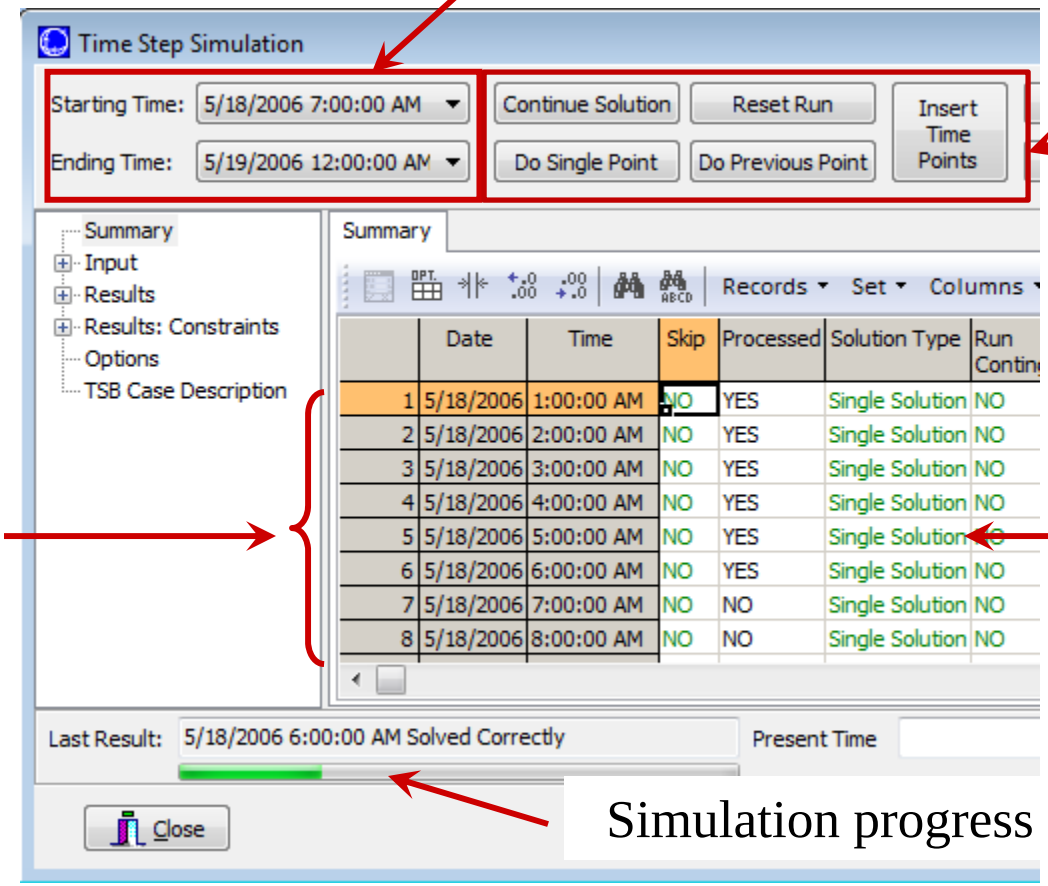
Inserting New Time Points

- After Inserting the Time Points, the Time Step Simulation dialog looks like this:

By default dialog shows the Summary page



Time Step Simulation Dialog



Can specify the simulation starting and ending date and time

Simulation control buttons

Summary page contains list of time points just inserted

Solution Type

Simulation progress

Summary Page: Controlling Solution

During the simulation you can skip a Time Point or you can pause at a Time Point

	Date	Time	Skip	Processed	Solution Type
1	5/18/2006	1:00:00 AM	NO	NO	Single Solution
2	5/18/2006	2:00:00 AM	NO	NO	Single Solution

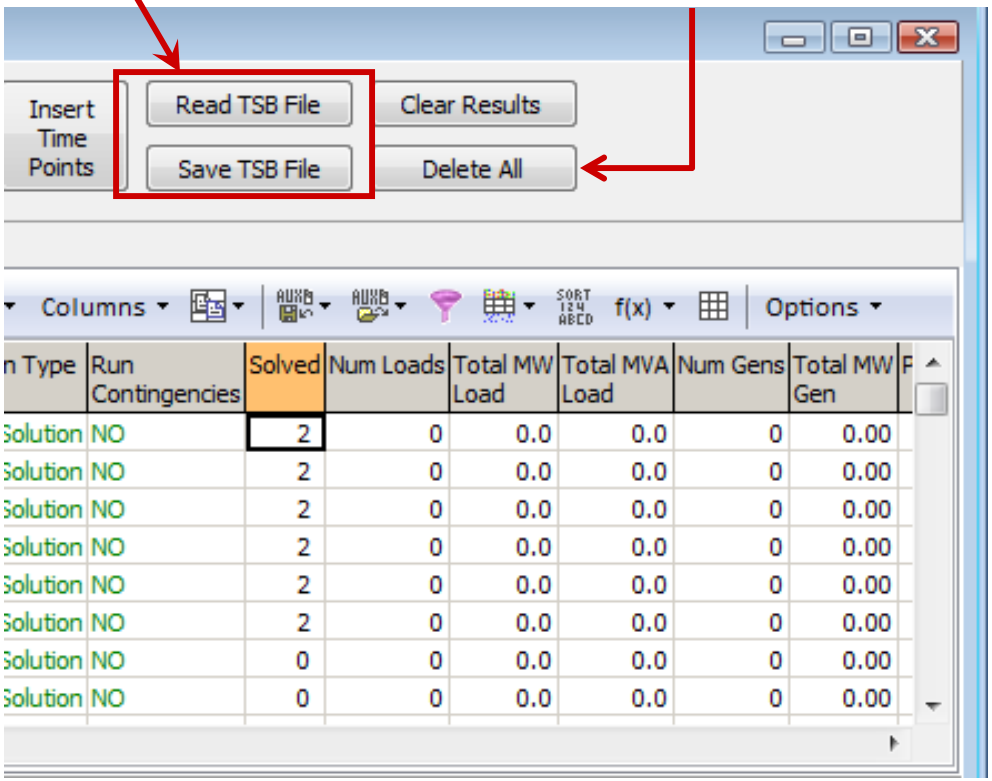
- The Time Point Solution Type can be:
  - *Single Solution*: Same as hitting the single solution button, but would act on the corresponding time point.
  - *Unconstrained OPF*
  - Optimal Power Flow (*OPF*)
  - Security Constrained Optimal Power Flow (*SCOPF*)
- Different time points can have different solution types

Time Step Simulation Dialog

The input data and the results of the Time Step Simulation can be saved in a Time Series Binary (*.TSB) file. (Time Step Actions saved in .PWB)

.TSB file Control

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



n Type	Run Contingencies	Solved	Num Loads	Total MW Load	Total MVA Load	Num Gens	Total MW Gen
Solution	NO	2	0	0.0	0.0	0	0.00
Solution	NO	2	0	0.0	0.0	0	0.00
Solution	NO	2	0	0.0	0.0	0	0.00
Solution	NO	2	0	0.0	0.0	0	0.00
Solution	NO	2	0	0.0	0.0	0	0.00
Solution	NO	2	0	0.0	0.0	0	0.00
Solution	NO	0	0	0.0	0.0	0	0.00
Solution	NO	0	0	0.0	0.0	0	0.00

Summary Page: Script Commands

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)

- 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.
- Typical actions are running contingency analysis or saving particular set of results.

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
- 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

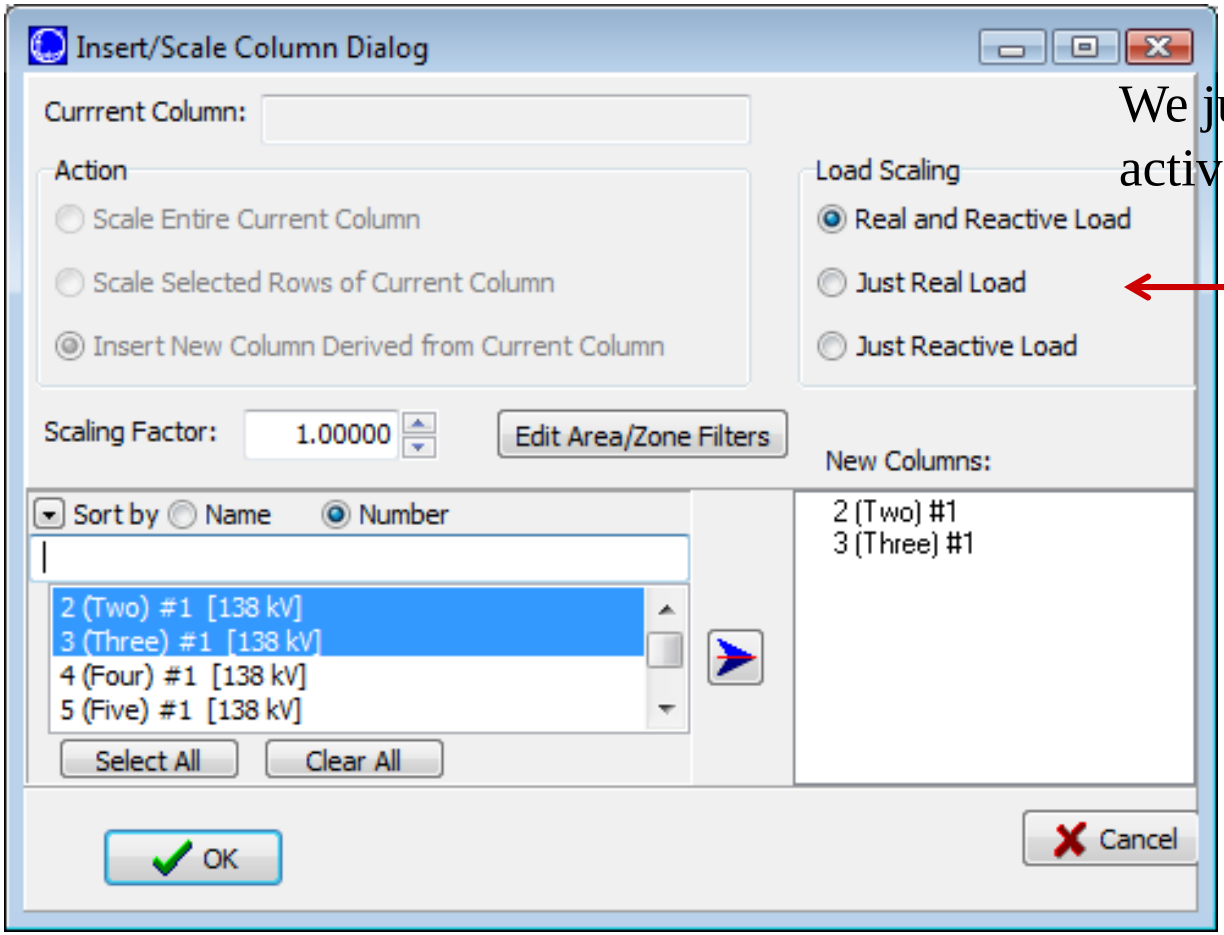
Setting up Input Data

- 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 case.
- The matrix grids will have one column for the input data of each object.
- In the B7flat.pwb case, suppose that we want to specify Load MW data for Loads 2 and 3.
  - In the Input page → MW Loads page, right-click and select **Time Point records → Insert/Scale Load Column(s)**

Setting up Input Data

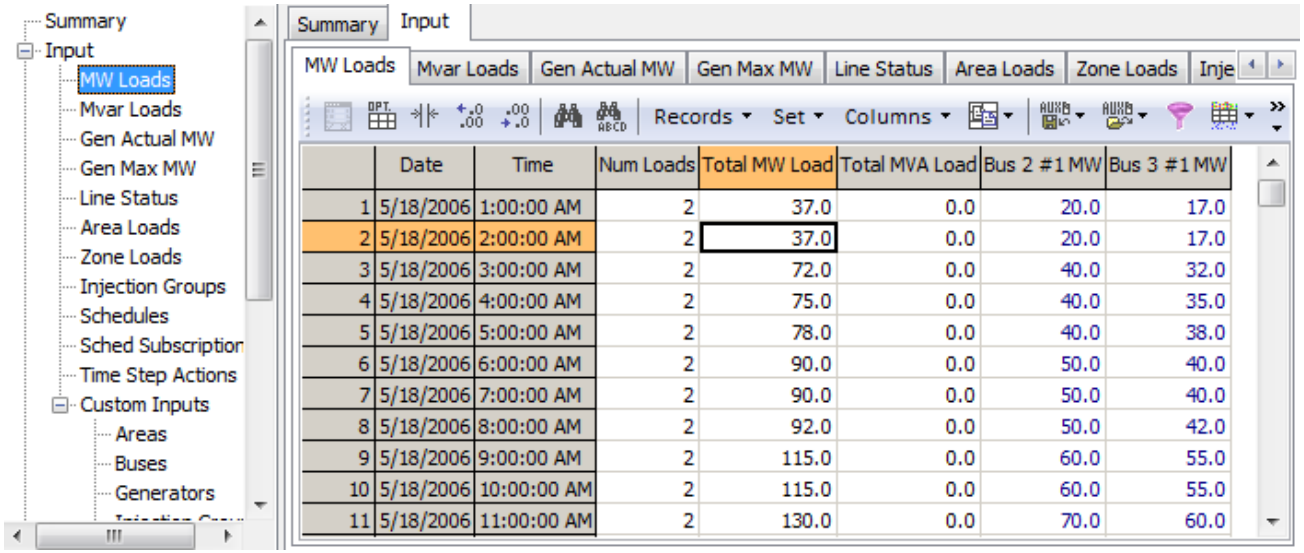
By default, we just want to insert new columns

Use the selector component to select Loads 2 and 3 at the same time.



We just need active load

Setting up Input Data



	Date	Time	Num Loads	Total MW Load	Total MVA Load	Bus 2 #1 MW	Bus 3 #1 MW
1	5/18/2006	1:00:00 AM	2	37.0	0.0	20.0	17.0
2	5/18/2006	2:00:00 AM	2	37.0	0.0	20.0	17.0
3	5/18/2006	3:00:00 AM	2	72.0	0.0	40.0	32.0
4	5/18/2006	4:00:00 AM	2	75.0	0.0	40.0	35.0
5	5/18/2006	5:00:00 AM	2	78.0	0.0	40.0	38.0
6	5/18/2006	6:00:00 AM	2	90.0	0.0	50.0	40.0
7	5/18/2006	7:00:00 AM	2	90.0	0.0	50.0	40.0
8	5/18/2006	8:00:00 AM	2	92.0	0.0	50.0	42.0
9	5/18/2006	9:00:00 AM	2	115.0	0.0	60.0	55.0
10	5/18/2006	10:00:00 AM	2	115.0	0.0	60.0	55.0
11	5/18/2006	11:00:00 AM	2	130.0	0.0	70.0	60.0

The columns will contain zeros by default. Those will need to be filled with correct data.

In order to specify time point values, we can:

1. Enter the values manually (as shown in the Figure)
2. Paste values from Excel (Copy the headers to Excel first).
3. Derive the values from another column.
4. Scale the column values.

Setting up Input Data

Example:

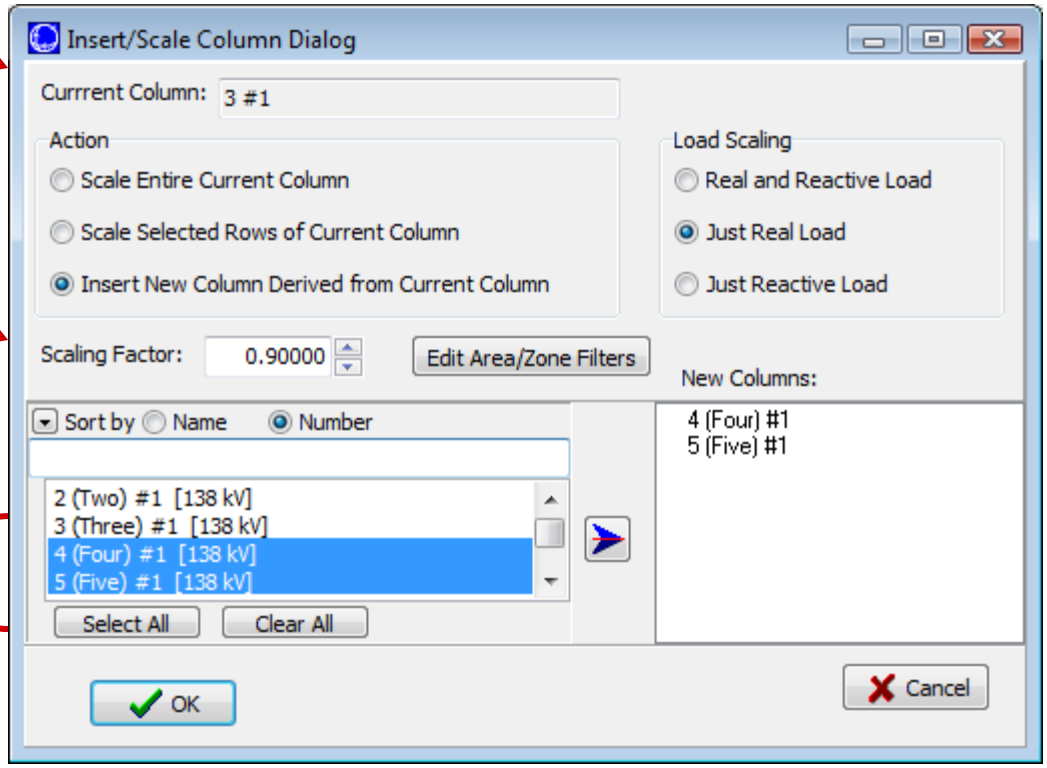
- We have specified some values for Loads 2 and 3 (as shown in the previous slide).
- Suppose we also need to specify input data for Loads 4 and 5, and know that those vary as Load 3, but are 90% of it.
  - We can derive the values for Loads 4 and 5 from Load 3.
- Right-click on column for Load 3 and select **Time Point records → Insert/Scale Load Column(s)**.
  - Column 3 will now be the Current Column

Setting up Input Data

Column 3 becomes the current column

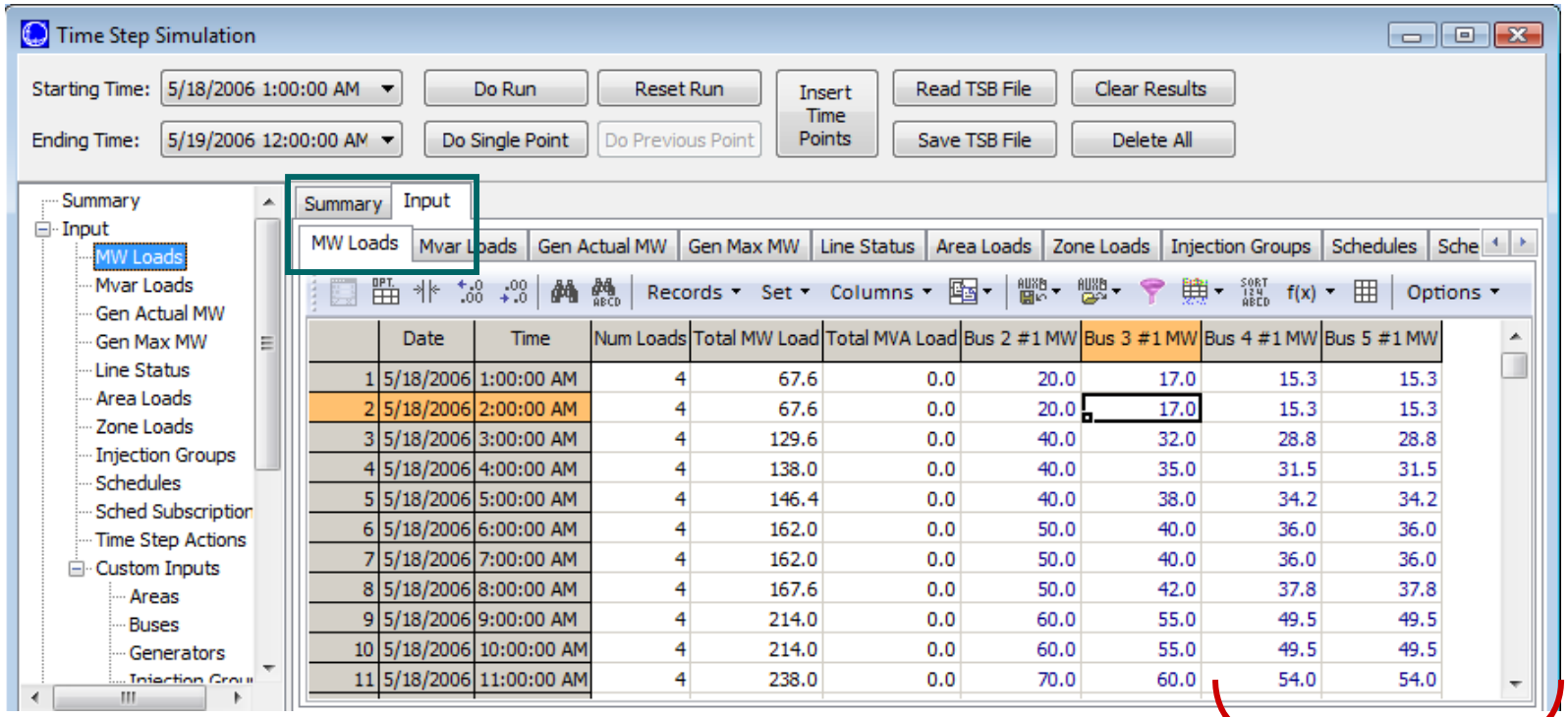
Loads 4 and 5 will be 90% of Load 3

Use the selector component to select Loads 4 and 5, whose values will be derived from Load 3.



Setting up Input Data

- The Input Load MW page now looks like this:



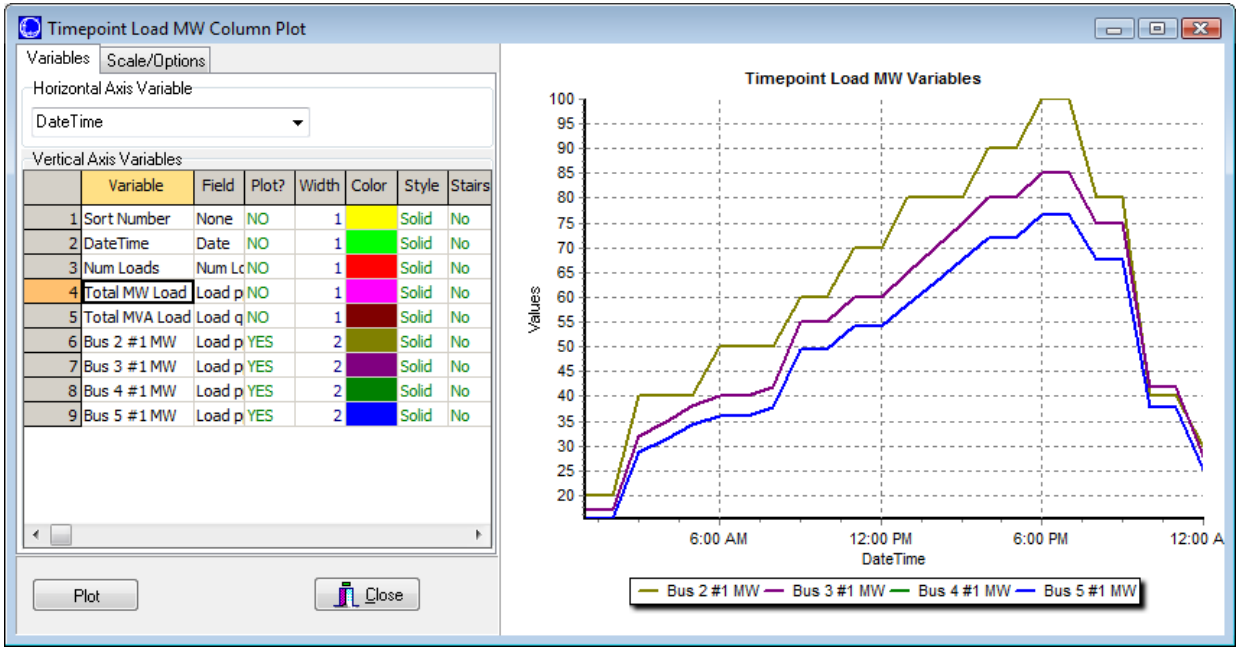
	Date	Time	Num Loads	Total MW Load	Total MVA Load	Bus 2 #1 MW	Bus 3 #1 MW	Bus 4 #1 MW	Bus 5 #1 MW
1	5/18/2006	1:00:00 AM	4	67.6	0.0	20.0	17.0	15.3	15.3
2	5/18/2006	2:00:00 AM	4	67.6	0.0	20.0	17.0	15.3	15.3
3	5/18/2006	3:00:00 AM	4	129.6	0.0	40.0	32.0	28.8	28.8
4	5/18/2006	4:00:00 AM	4	138.0	0.0	40.0	35.0	31.5	31.5
5	5/18/2006	5:00:00 AM	4	146.4	0.0	40.0	38.0	34.2	34.2
6	5/18/2006	6:00:00 AM	4	162.0	0.0	50.0	40.0	36.0	36.0
7	5/18/2006	7:00:00 AM	4	162.0	0.0	50.0	40.0	36.0	36.0
8	5/18/2006	8:00:00 AM	4	167.6	0.0	50.0	42.0	37.8	37.8
9	5/18/2006	9:00:00 AM	4	214.0	0.0	60.0	55.0	49.5	49.5
10	5/18/2006	10:00:00 AM	4	214.0	0.0	60.0	55.0	49.5	49.5
11	5/18/2006	11:00:00 AM	4	238.0	0.0	70.0	60.0	54.0	54.0

Columns derived as 90% of Load 3

Setting up Input Data

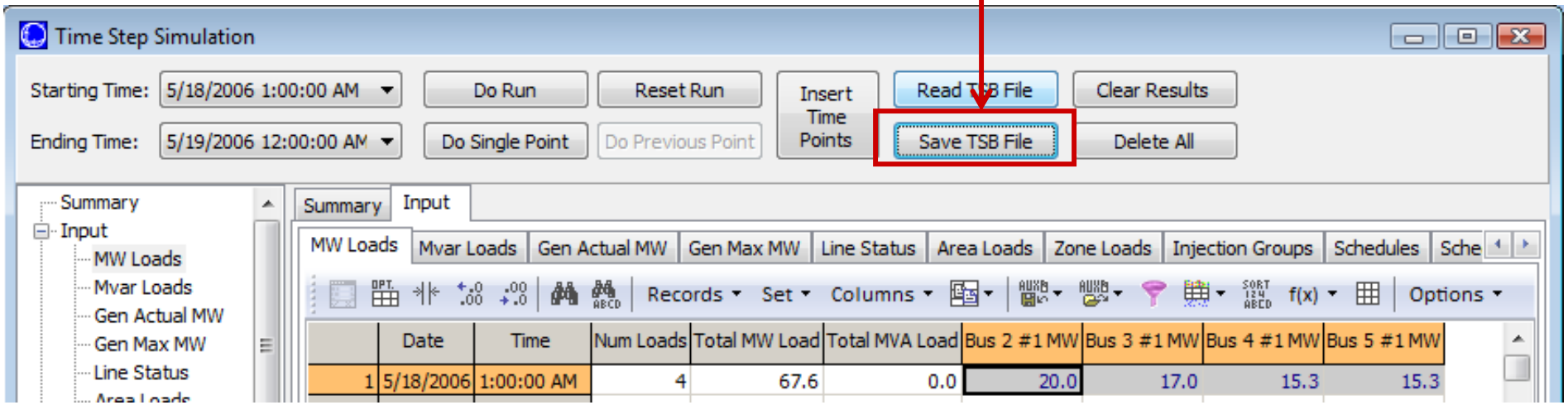
- We can use the column plot to check our input data.
- The plot column function of Case Information Displays becomes a plot versus date time when used from Time Step Simulation matrix grids.

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 Loads 2-5 looks like this.



Setting up Input Data

- Since 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 B7TSS.TSB



Setting up Input Data

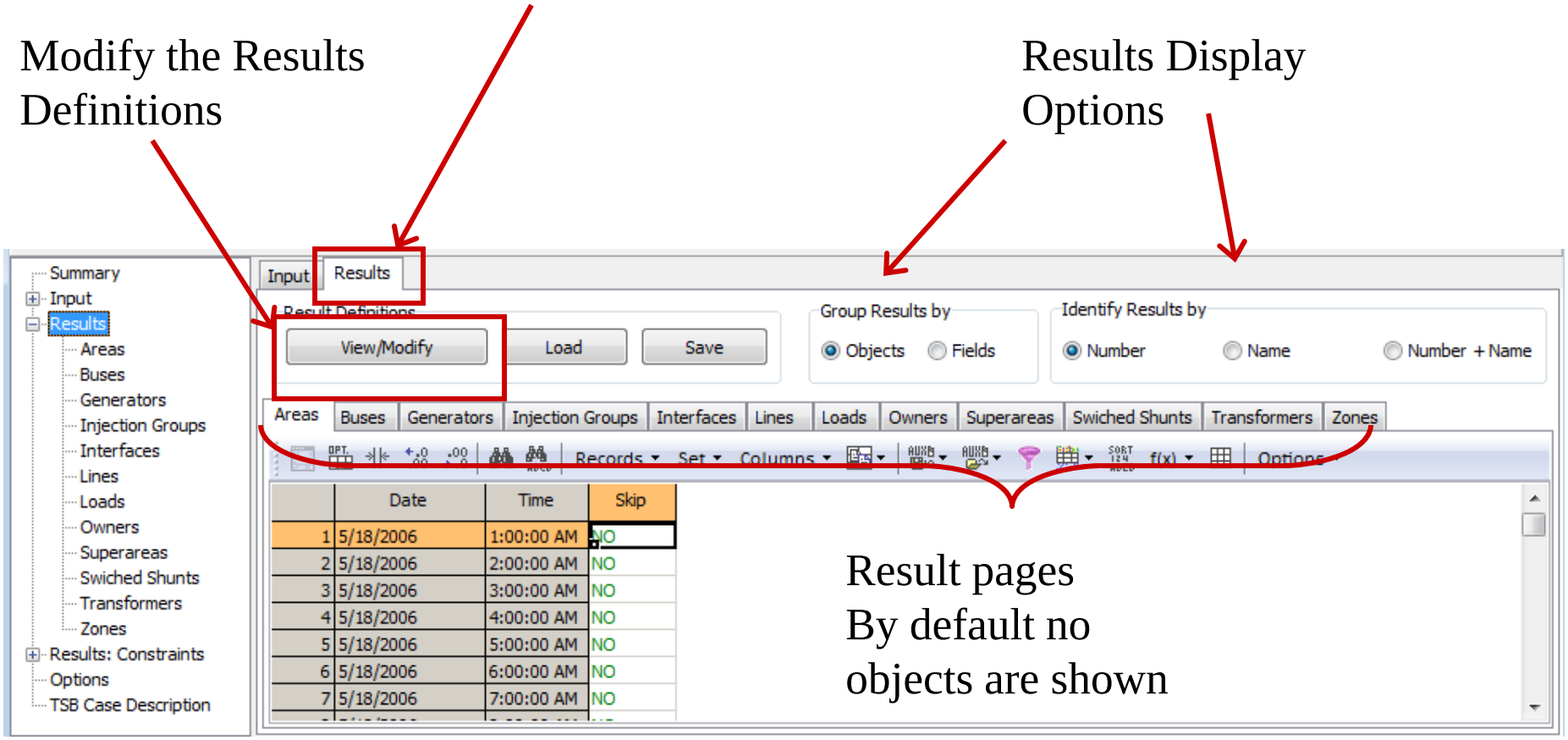
- In the same manner as we did for load MW, hourly data for other quantities would be specified in the corresponding pages:
  - Mvar Loads
  - Gen Actual MW
  - Gen Max MW
  - Line Status
  - Area Loads
  - Zone Loads
  - Injection Groups
- Recall that you can use the selector to create multiple columns at a time, and you can copy/ paste the input data from Excel.

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:



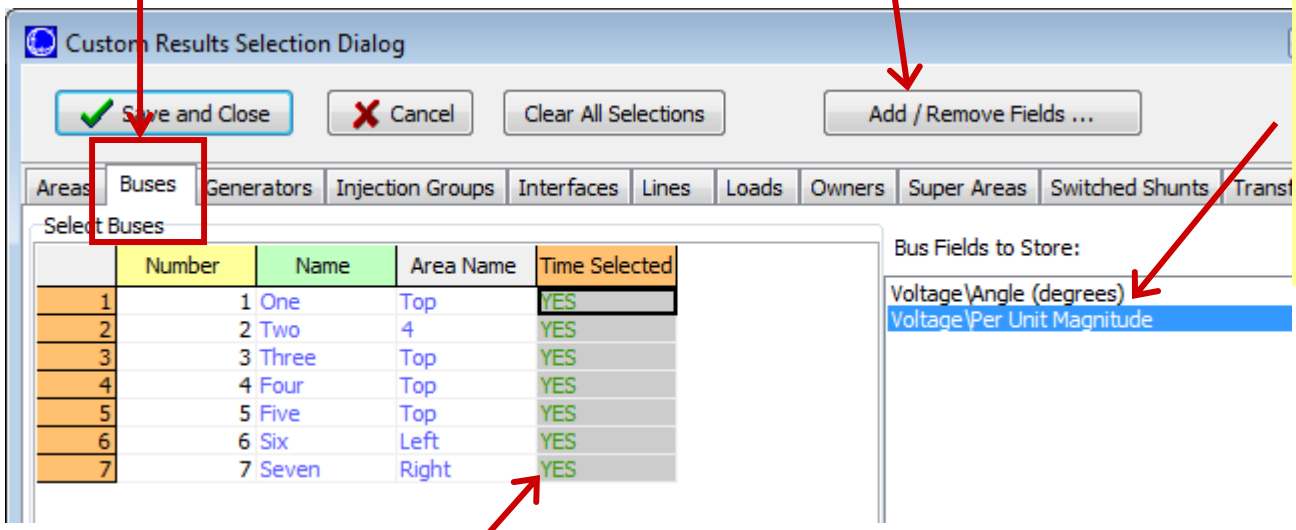
Setting Up Results

- Press the **View/Modify** Result Definitions button to tell Simulator the quantities you want to store.
- You will need to specify:
  - The type of object for which results must be saved (buses, generators, etc.)
  - The individual objects whose fields will be saved (Bus 1, Bus 2, etc.)
  - The fields that will be saved for each type of objects (Bus pu volt, etc.)

Setting Up Results

Select the Buses page

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



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

For our example, assume we want to explore per unit voltage and angle for all the buses.

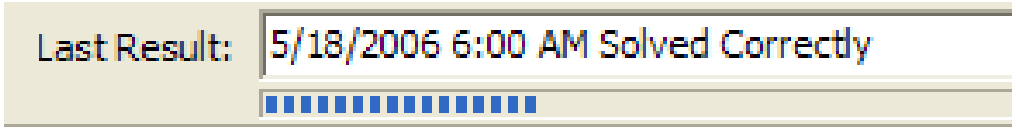
Save and Close the Result Definitions

Result Definitions are also saved in the .TSB file.

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.

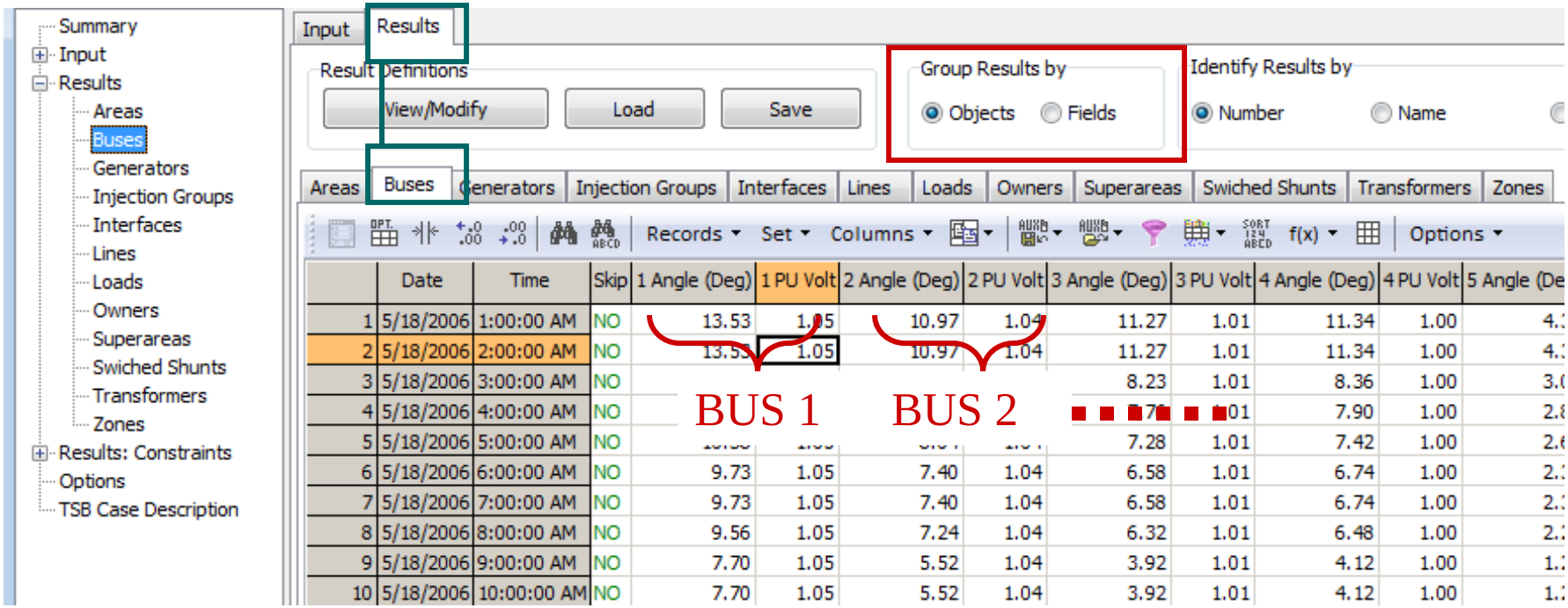


Running the Simulation

- 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.
    - We'll learn how to set scheduled input data later on.
  - 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

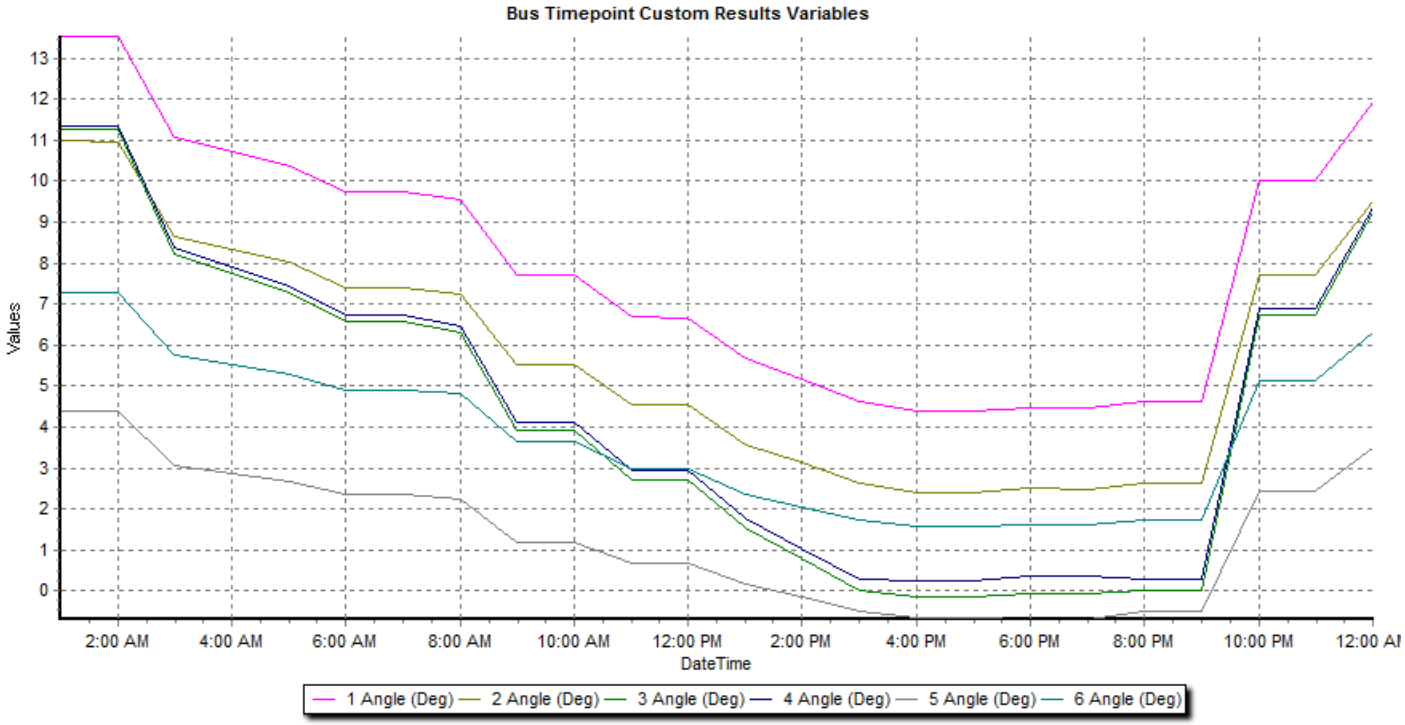
- For our example, the Buses page of the Results shows bus voltages and angles.
- The results can be grouped by objects or by fields.



	Date	Time	Skip	1 Angle (Deg)	1 PU Volt	2 Angle (Deg)	2 PU Volt	3 Angle (Deg)	3 PU Volt	4 Angle (Deg)	4 PU Volt	5 Angle (De
1	5/18/2006	1:00:00 AM	NO	13.53	1.05	10.97	1.04	11.27	1.01	11.34	1.00	4.
2	5/18/2006	2:00:00 AM	NO	13.53	1.05	10.97	1.04	11.27	1.01	11.34	1.00	4.
3	5/18/2006	3:00:00 AM	NO					8.23	1.01	8.36	1.00	3.
4	5/18/2006	4:00:00 AM	NO					7.[illegible]	1.01	7.90	1.00	2.
5	5/18/2006	5:00:00 AM	NO					7.28	1.01	7.42	1.00	2.
6	5/18/2006	6:00:00 AM	NO	9.73	1.05	7.40	1.04	6.58	1.01	6.74	1.00	2.
7	5/18/2006	7:00:00 AM	NO	9.73	1.05	7.40	1.04	6.58	1.01	6.74	1.00	2.
8	5/18/2006	8:00:00 AM	NO	9.56	1.05	7.24	1.04	6.32	1.01	6.48	1.00	2.
9	5/18/2006	9:00:00 AM	NO	7.70	1.05	5.52	1.04	3.92	1.01	4.12	1.00	1.
10	5/18/2006	10:00:00 AM	NO	7.70	1.05	5.52	1.04	3.92	1.01	4.12	1.00	1.

Exploring Results

- We can also explore the results by obtaining a column plot. This is how the bus angles look in our example.



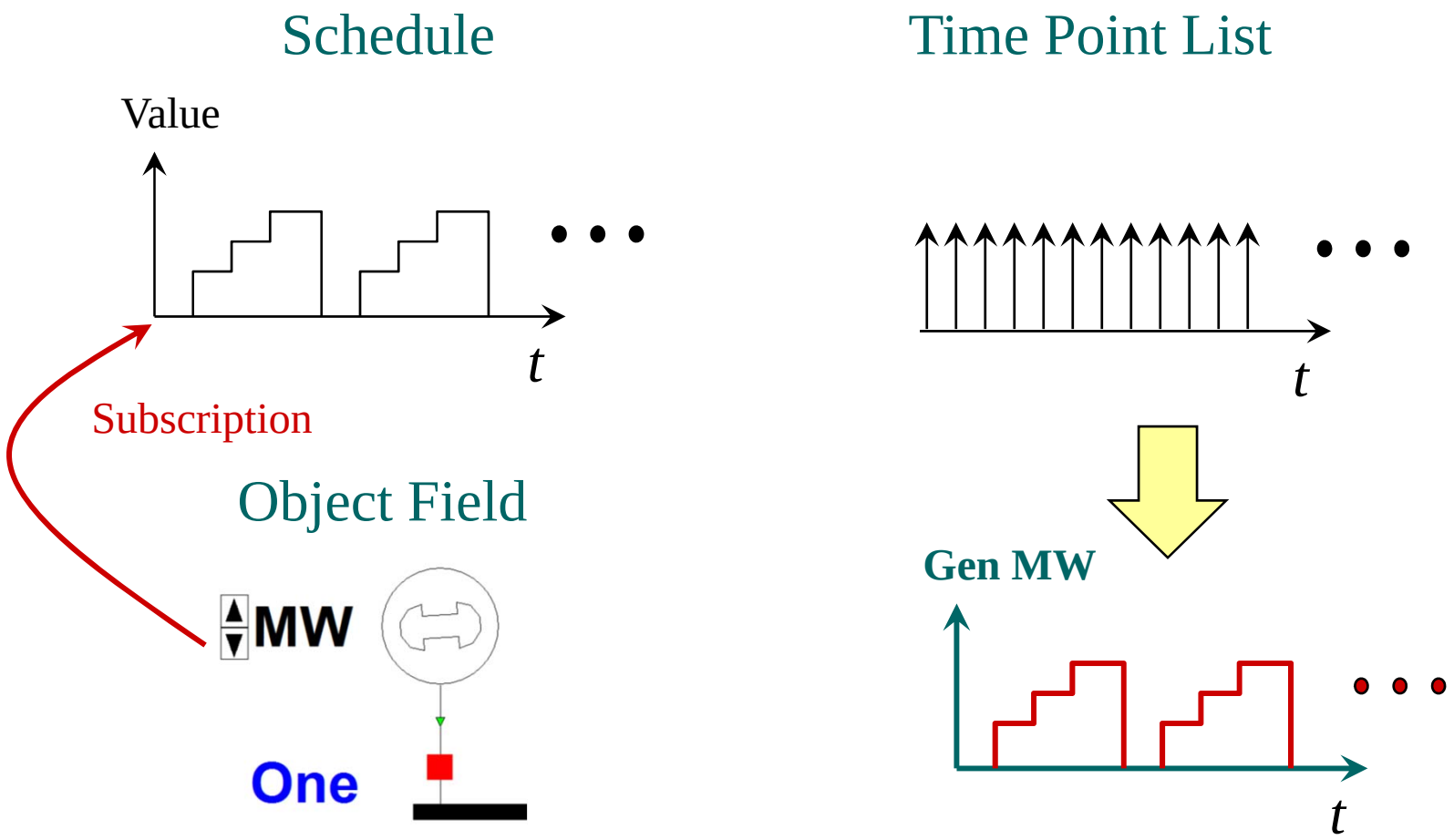
Specifying Scheduled Input Data

- 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.

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



Defining a Schedule

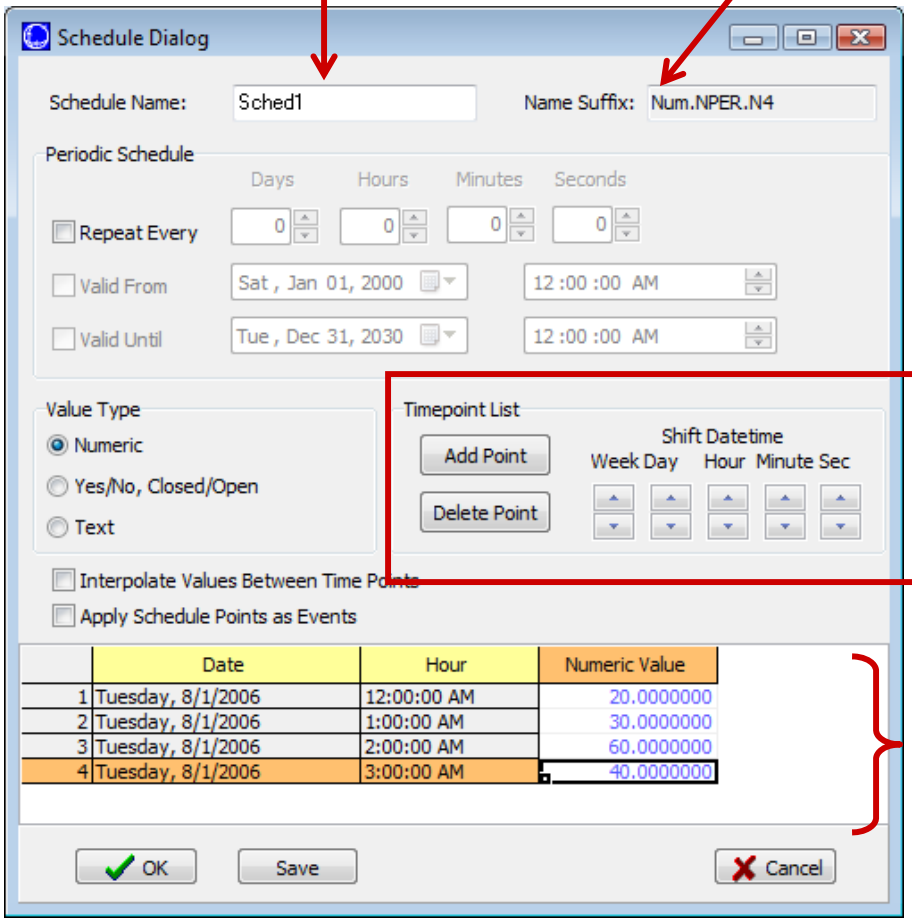
- Schedules:
  - Are Numeric, Yes/No, or Text
  - Can be made periodic by specifying them to repeat the shape with a certain period.
  - Can have start and end validity dates (used normally for periodic schedules).
- To define a schedule go to the Input page → Schedules page, right-click on the grid,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

Defining a Schedule

Schedule name must be unique

Identifies main characteristics of schedule

Settings for periodic Schedules



Shortcut buttons allow easy definition of the schedule date times

Date times don't need to coincide with the date times of the list of time points (Summary page)

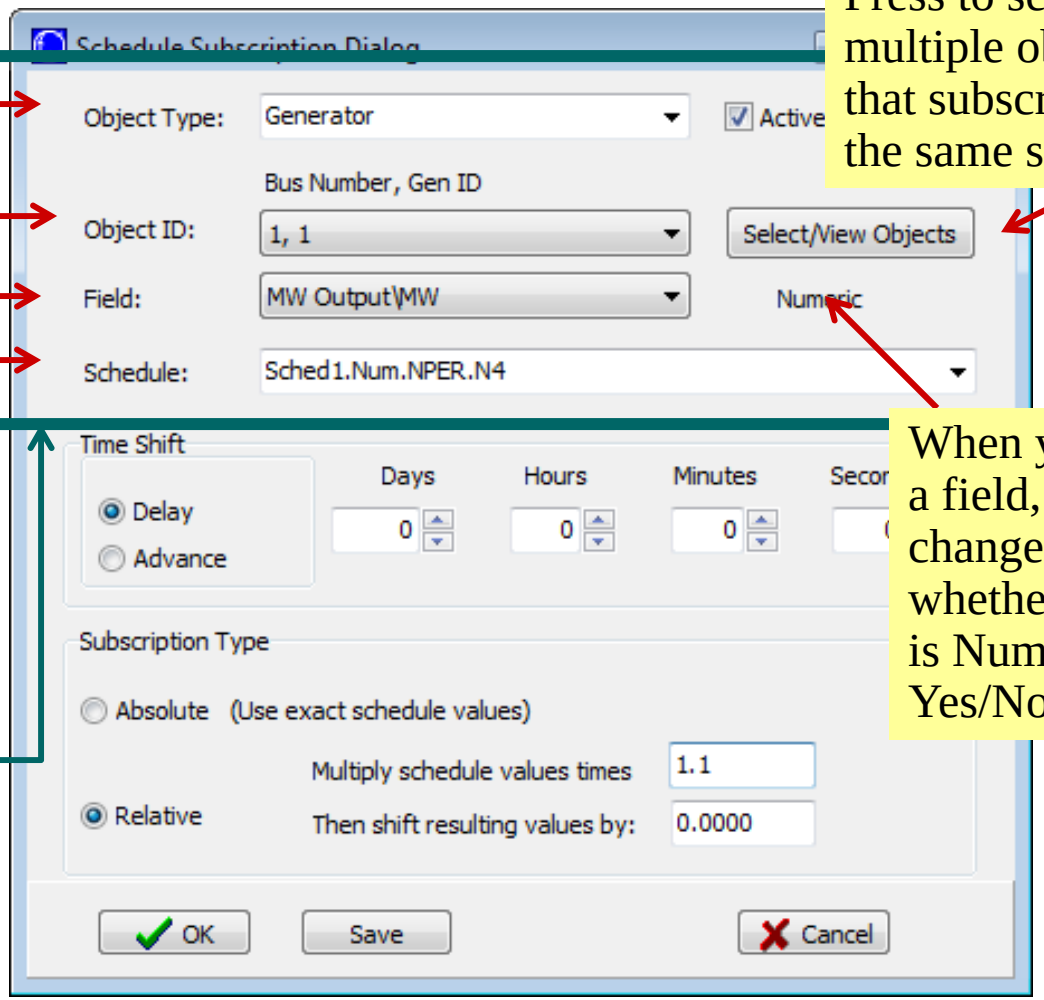
Date time and numeric values define the shape of the schedule

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.
- To define a schedule subscription, go to the Input page → 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.



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

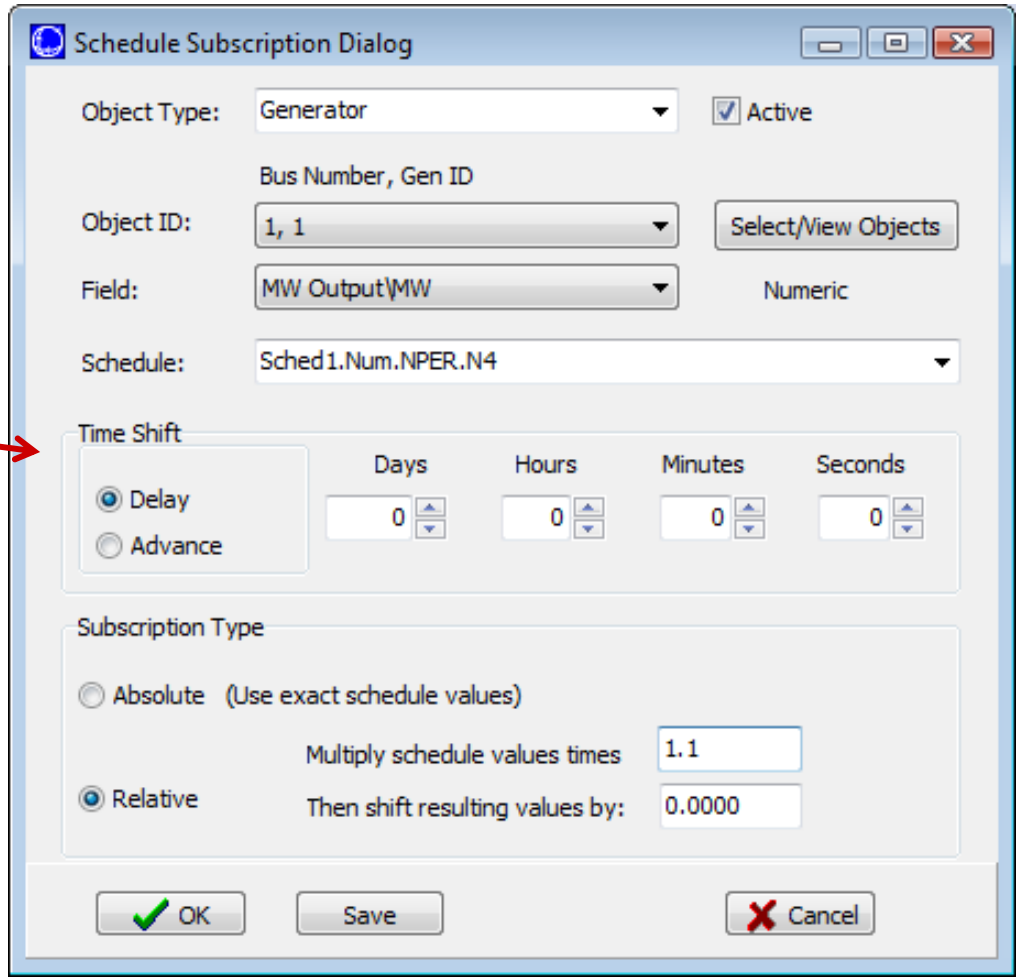
For instance, this means that the Gen MW output of Generator 1 at bus 1 will follow the shape of Schedule 1.

Defining a Schedule Subscription

Schedule actions are applied with the specified delay

Subscriptions to numeric schedules can modify the schedule values:

*Actual Value = Multiplier *Sched Value + Value Shift*



Example: Scheduled Input Data

- In the B7Flat.pwb case, the following input data is known for Gen 1 and line 2 to 3. The generator values occur every day.

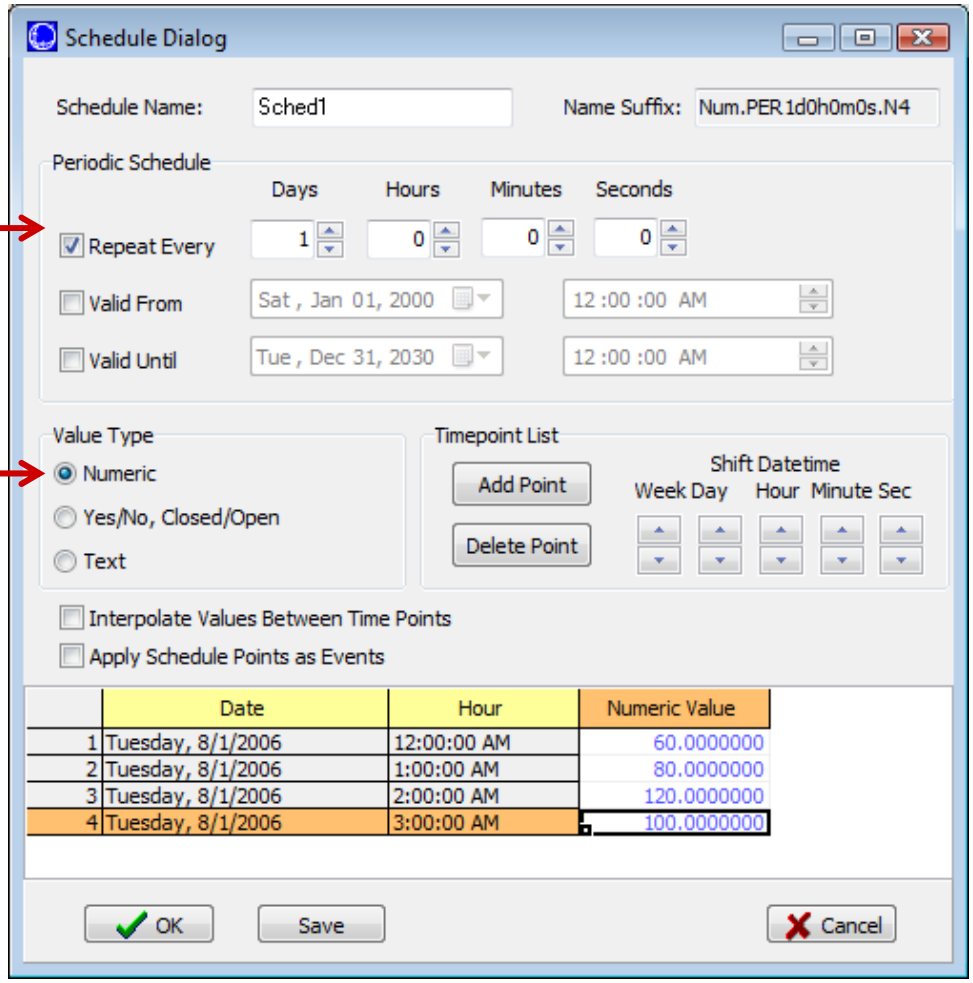
Hour	Gen 1MW
1:00 AM	60 MW
7:00 AM	80 MW
1:00 PM	120 MW
7:00 PM	100 MW

Hour	Line 2-3 Status
4:00 AM	Open
2:00 PM	Closed

- We want to create the schedules and schedules subscriptions needed to model these varying quantities.

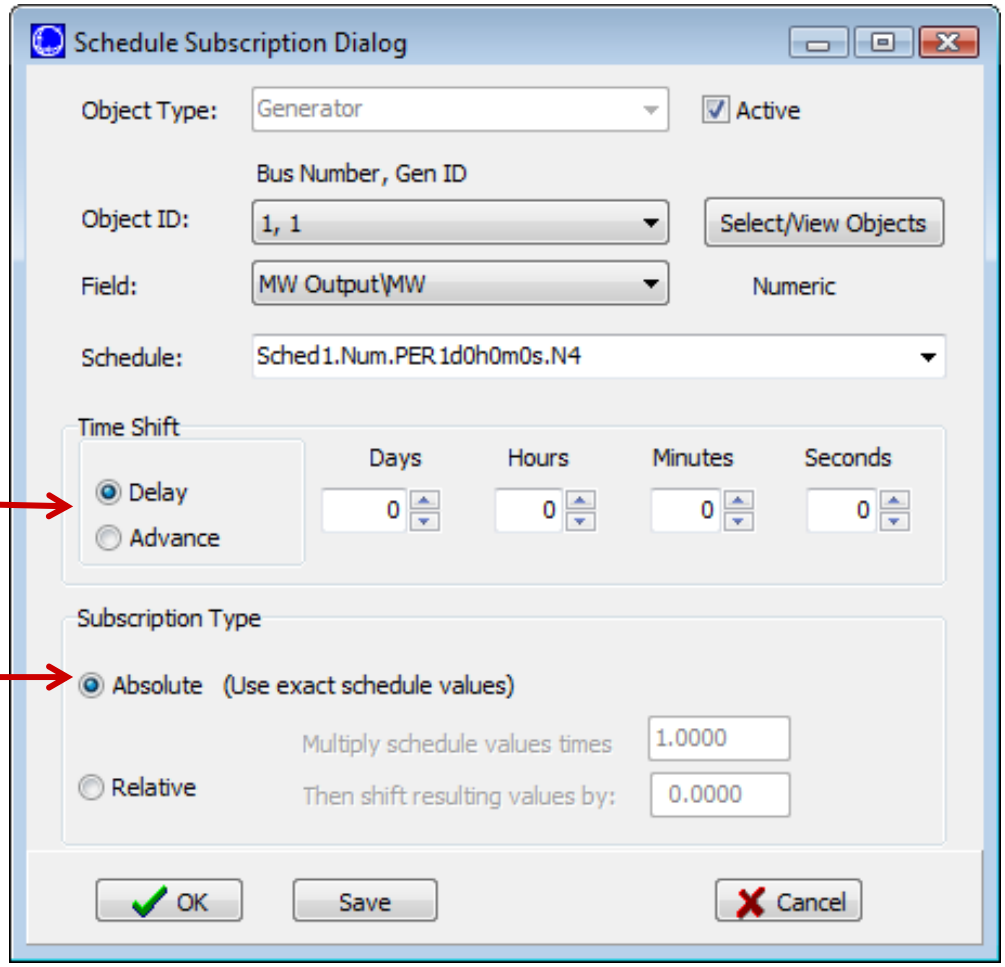
Example: Schedules

- For the generator, we create a periodic schedule with period = 1 day.
- The schedule is numeric.
- The schedule has 4 time points.

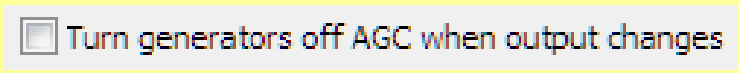


Example: Schedule Subscriptions

- Then we subscribe the Gen MW output filed of generator 1, ID 1 to Sched1.
- There is no delay
- The field takes the exact values of the numeric schedule.

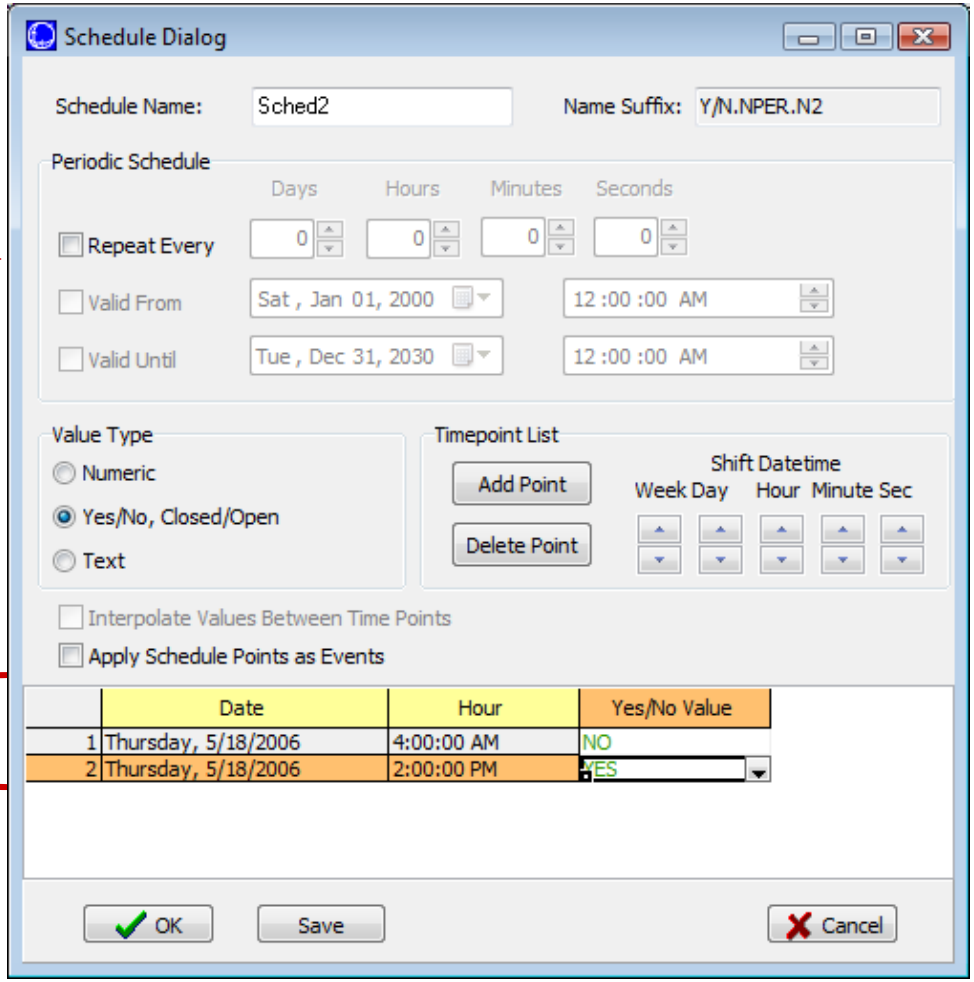


Note: Gen1 needs to be Off-AGC in order to keep the scheduled MW output. Manually set or use option



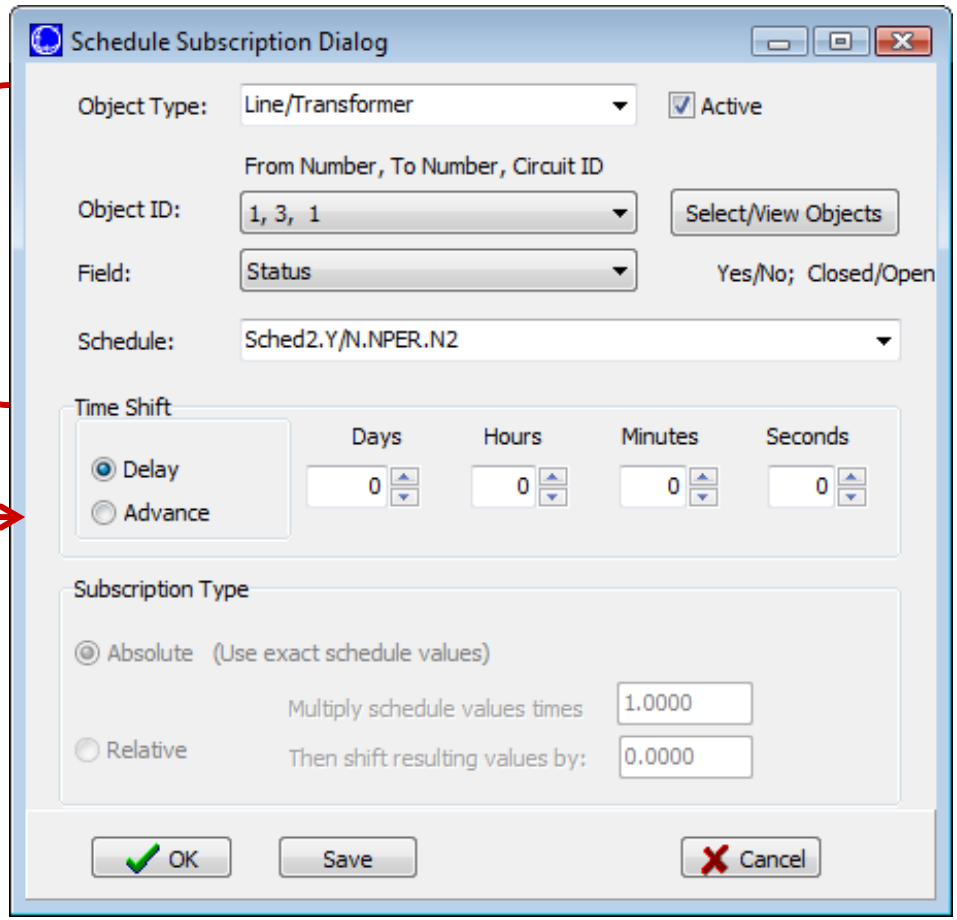
Example: Schedules

- For the transmission line, we create a non-periodic schedule
- The schedule type is Yes/No.
- The schedule has 2 time points. Line will open at 4 AM and will close at 2 PM.



Example: Schedule Subscriptions

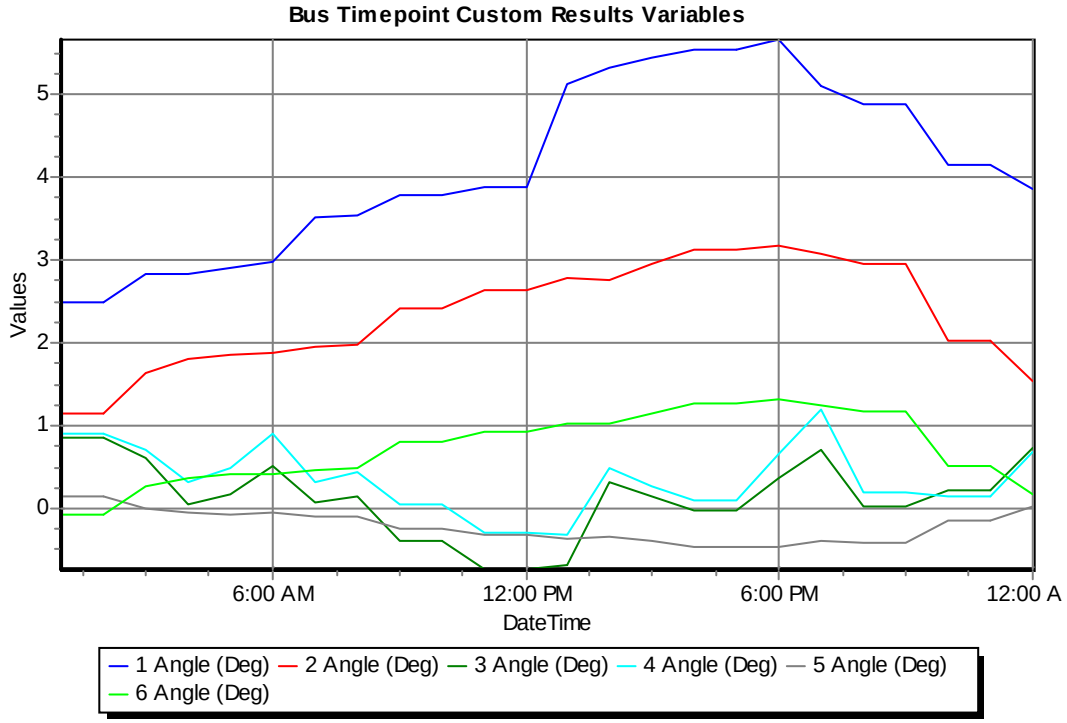
- Then we subscribe the Status of Transmission Line 2 to 3, circuit 1 to Sched2.
- There is no delay



Let us go ahead and rerun the Time Step Simulation.

Example: Schedule Subscriptions

- By exploring the results, we can see how bus angles changed due to load variations, the generator schedule and the outage of the transmission line.



Schedule Subscriptions

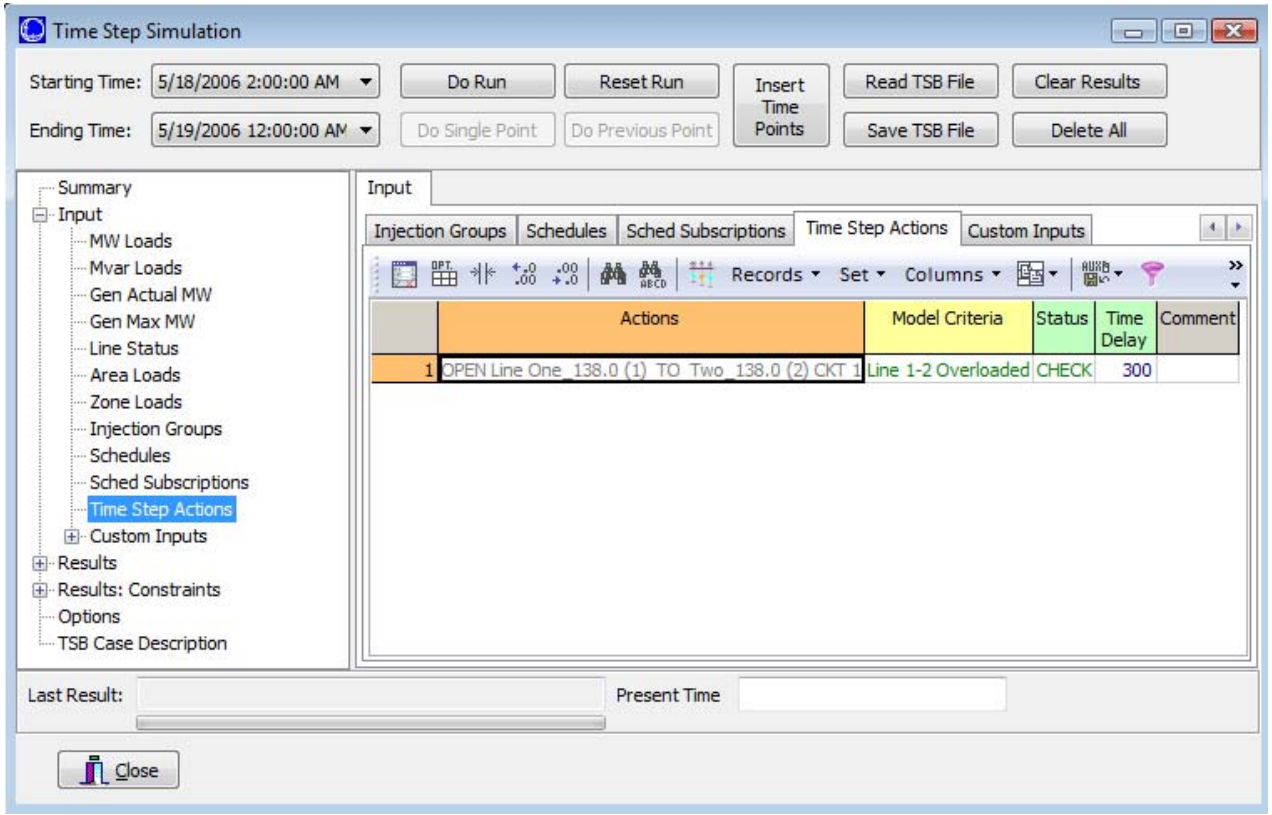
- The advantage of schedules and schedule subscriptions is that power systems tend to have many quantities that follow a similar time pattern:
  - Bus loads of the same type
  - Different units of a power plant that are identically scheduled
  - A group of devices that are disconnected/reconnected at 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.

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)

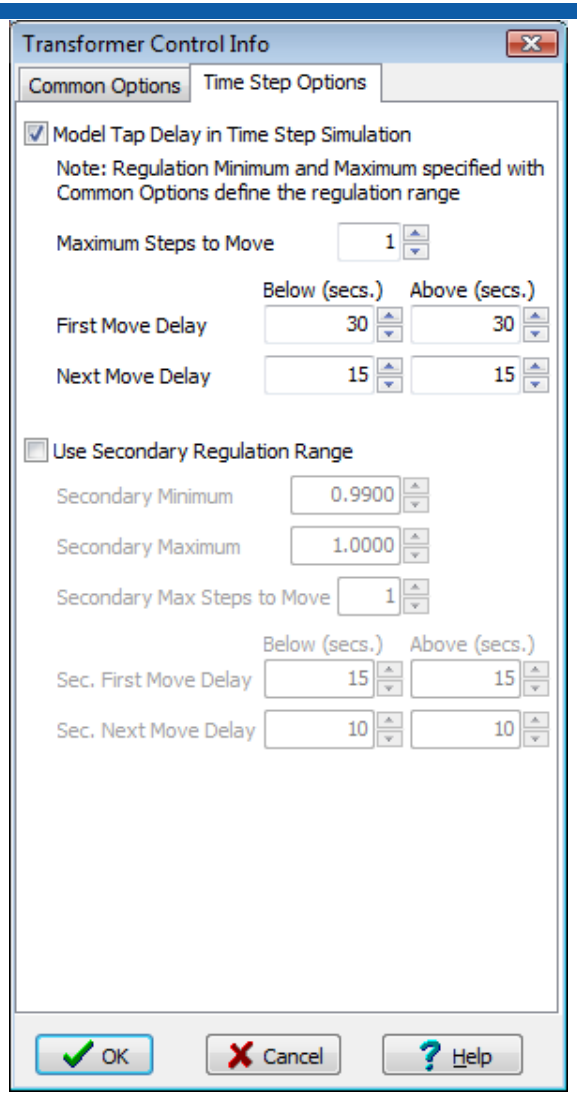
Time Step Actions

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



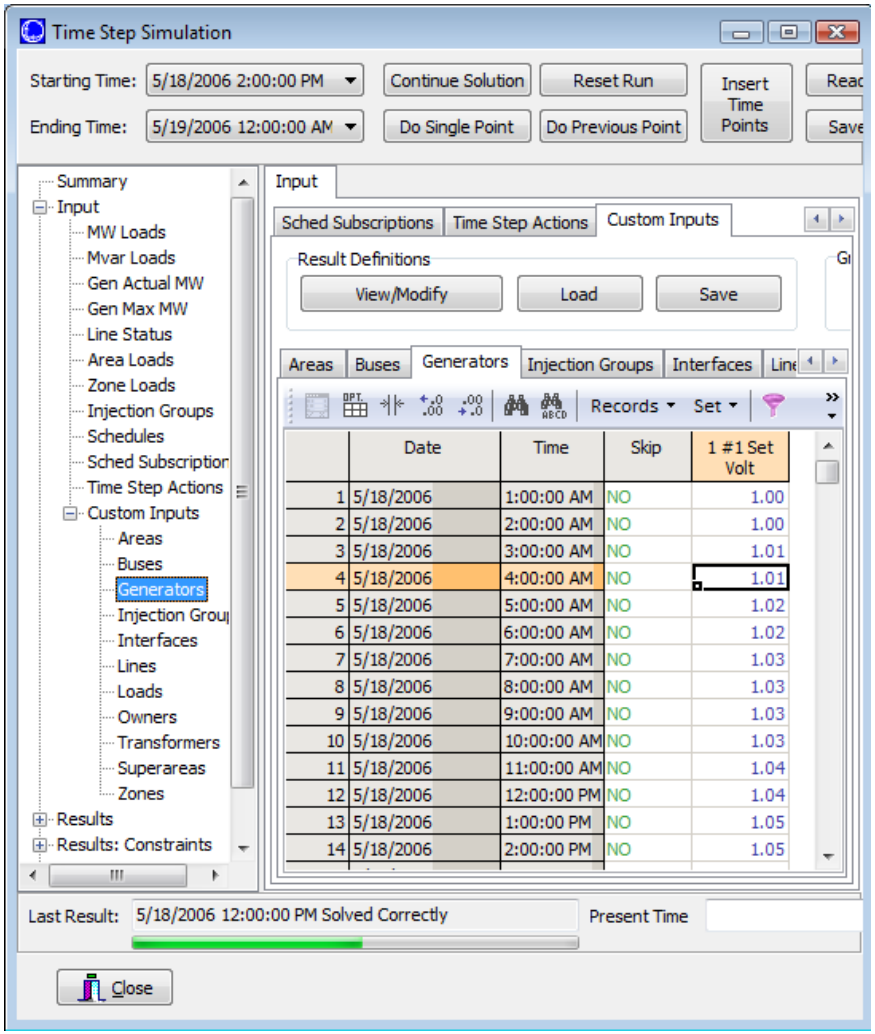
Time Step Actions

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



Custom Inputs

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



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)

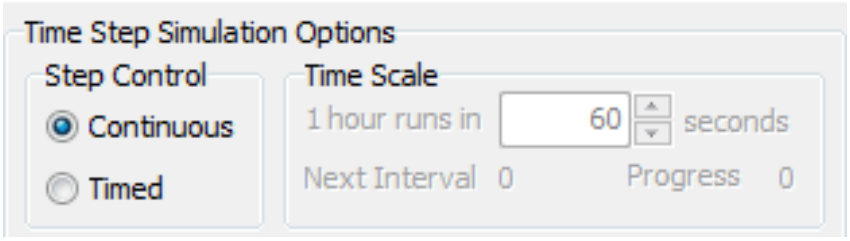
Continuous and Timed Simulations

- 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 page and select *Timed*, in the **Time Step Simulation Options** under **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.



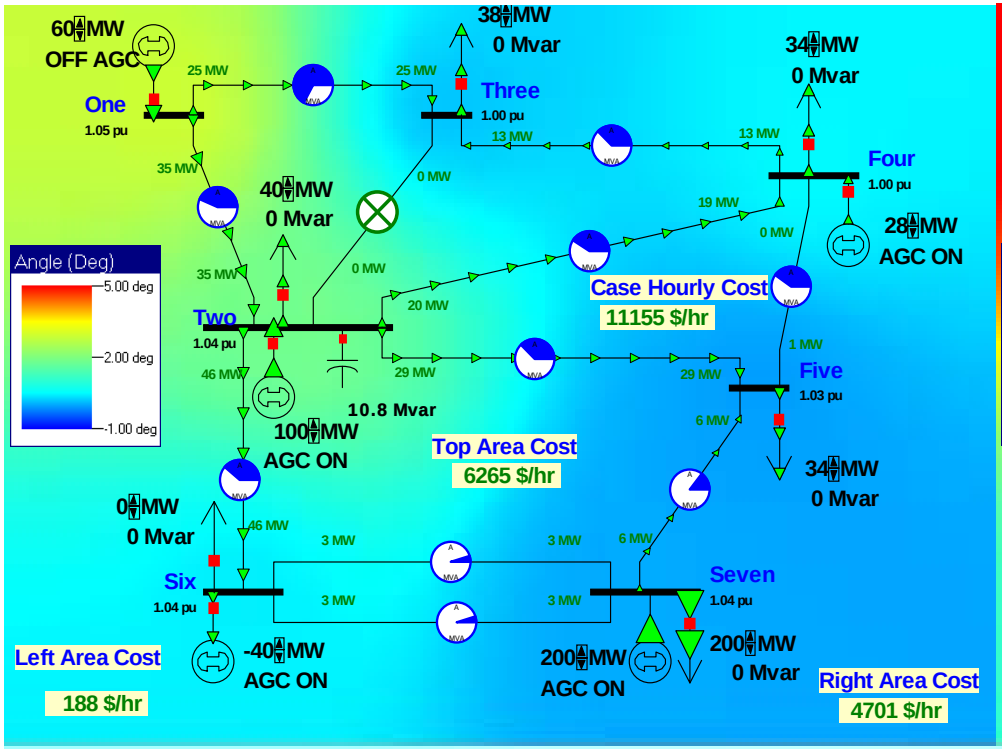
Continuous and Timed Simulations

Example

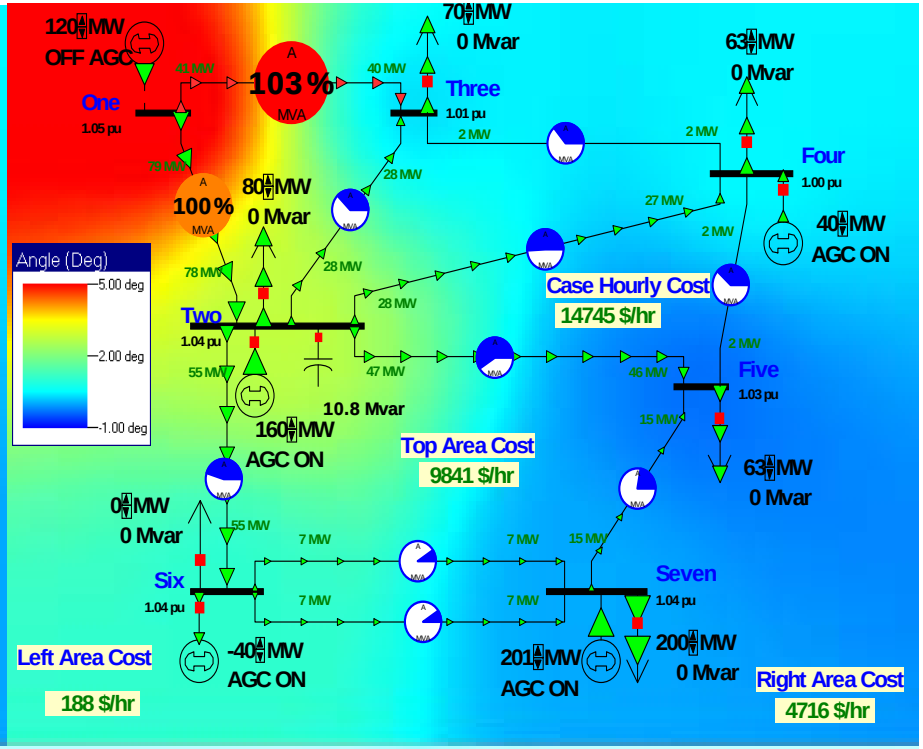
- Let us set the simulation to be **Step Control** = *Timed*, and set a **Time Scale** of 5 (1 hour runs in 5 seconds of actual time).
- Move the Time Step Simulation dialog so you can see the oneline, but still have access to the control buttons.
- Run the simulation by clicking **Do Run**

Continuous and Timed Simulations

System at 5 AM



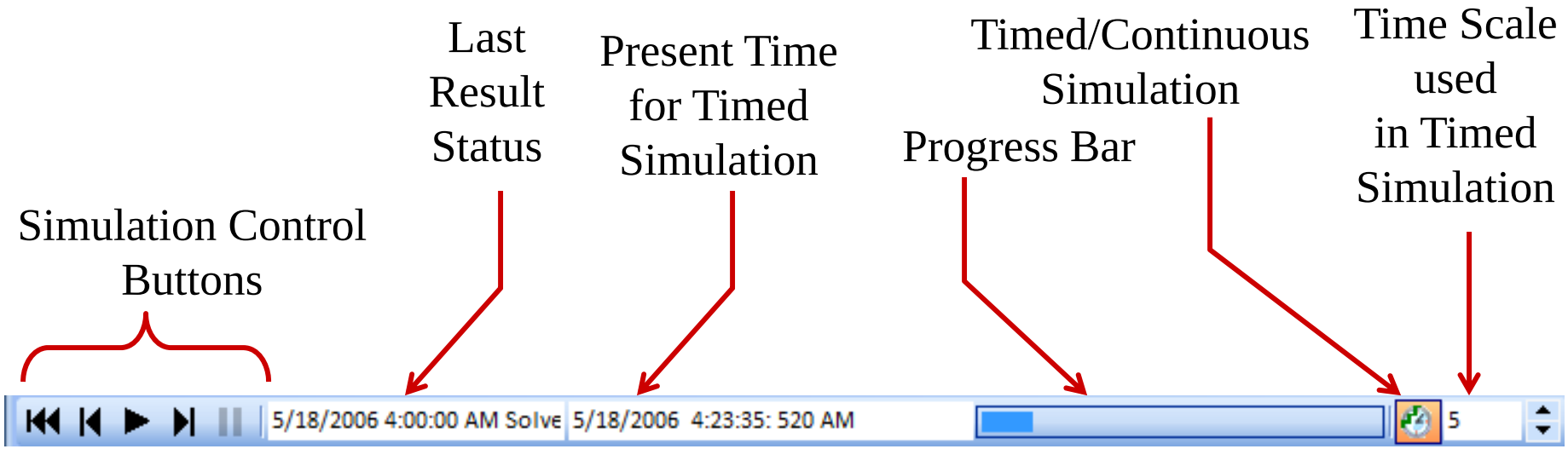
System at 2 PM



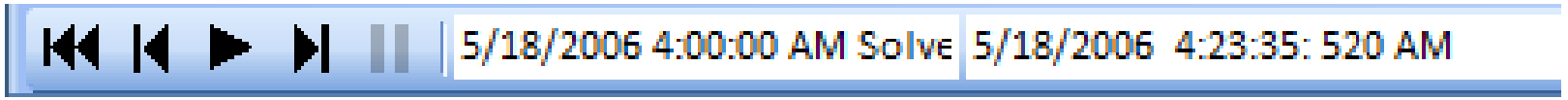
Note the status of transmission line 2-3, the values of generator 1 MW output and how loads change at each time point. See how the line flows and angle contouring change (Note: Contouring should be set to continuously refresh).

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

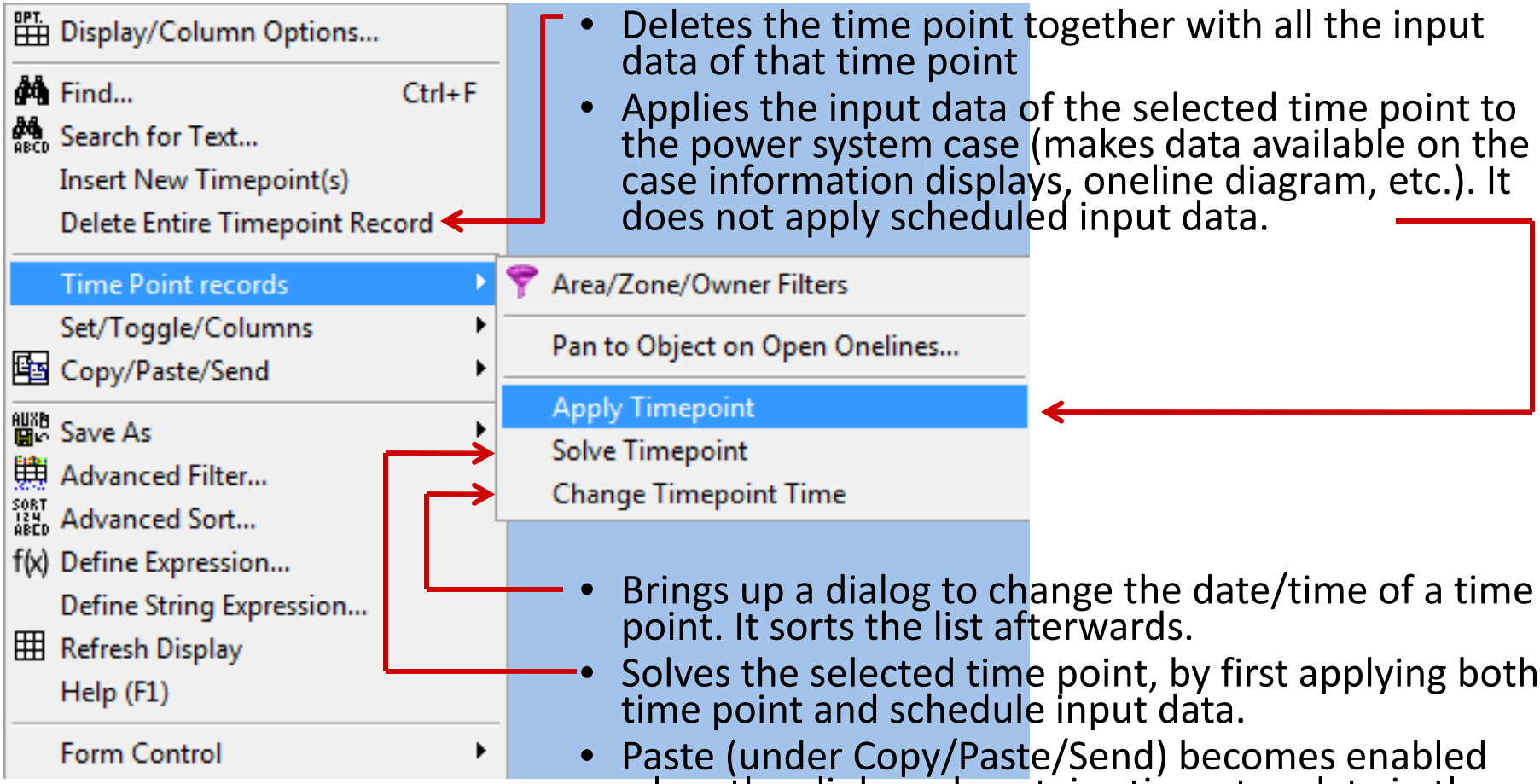
Solve the previous Time Point

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

Solve the next Time Point

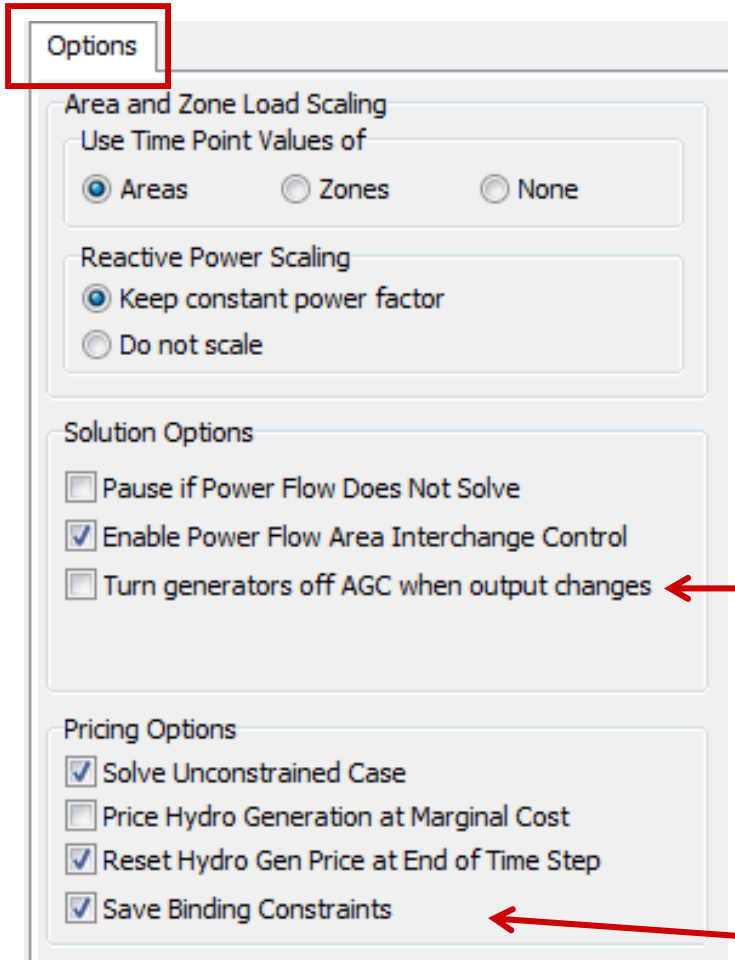
Pause a continuous or timed simulation

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.
- Brings up a dialog to change the date/time of a time point. It sorts the list afterwards.
- Solves the selected time point, by first applying both time point and schedule input data.
- Paste (under Copy/Paste/Send) becomes enabled when the clipboard contains time step data in the correct format.

Time Step Simulation Options



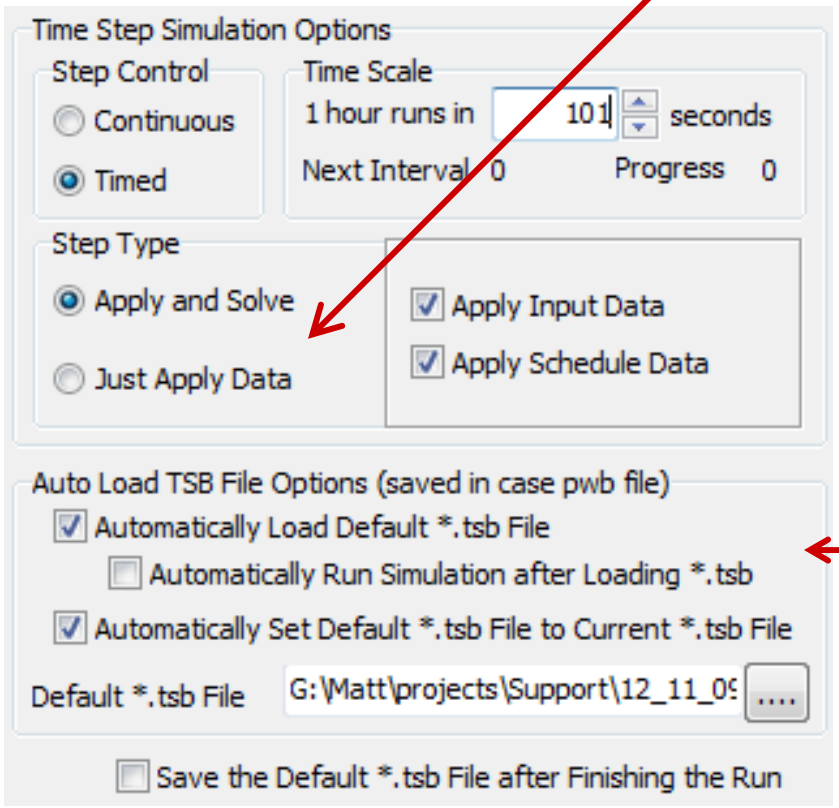
When there is time point input data for area MW load and for individual load MW, always set to individual MW load value first. Then, if set to Areas, only areas are scaled. If set to Zones, only zones are scaled.

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



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

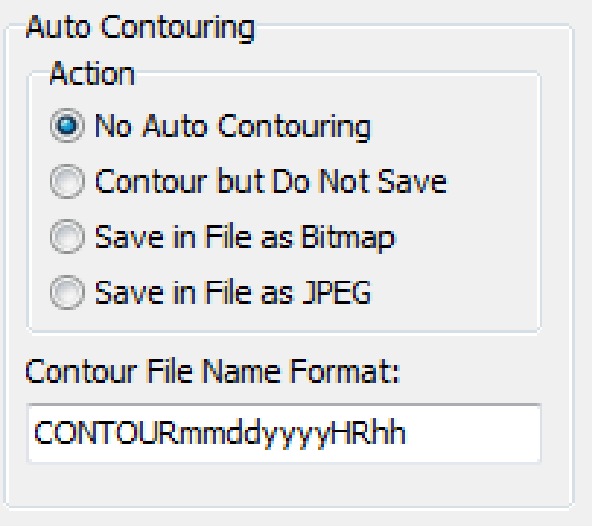
Sometimes you want to test only time point or schedule data

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

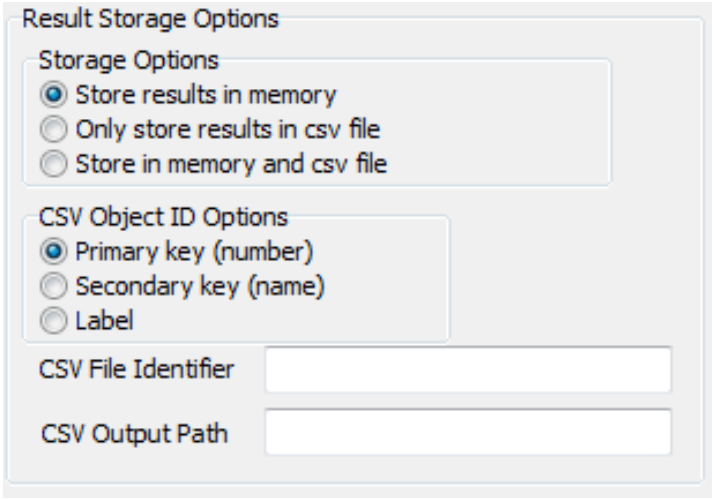
Options Page



The Time Step Simulation can contour oneline 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



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

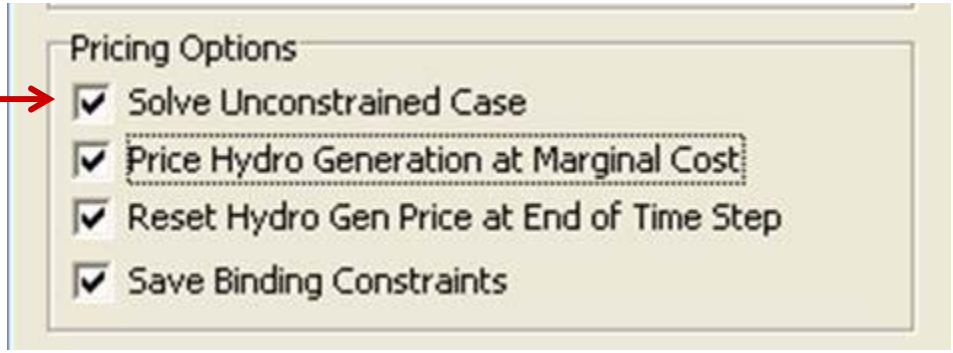
SCOPF

- 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

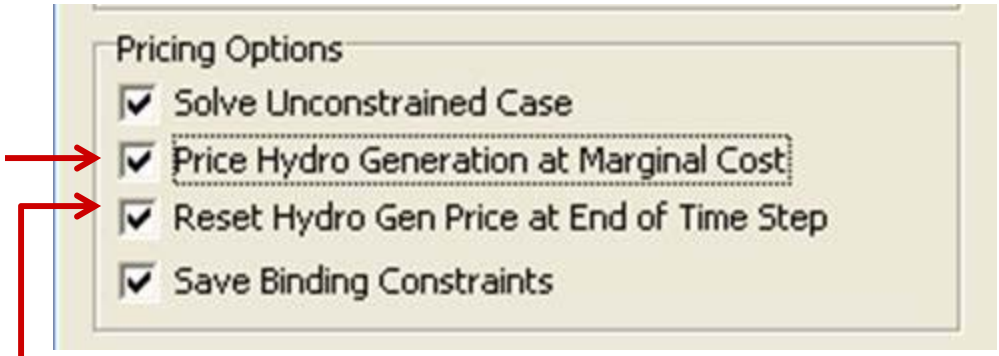
- Different applications of the OPF/SCOPF require special pricing options.
- A method for congestion pricing consist of solving first the unconstrained case to determine unconstrained LMPs, and then solve the OPF or SCOPF. The difference between these two solutions correspond to the congestion cost or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



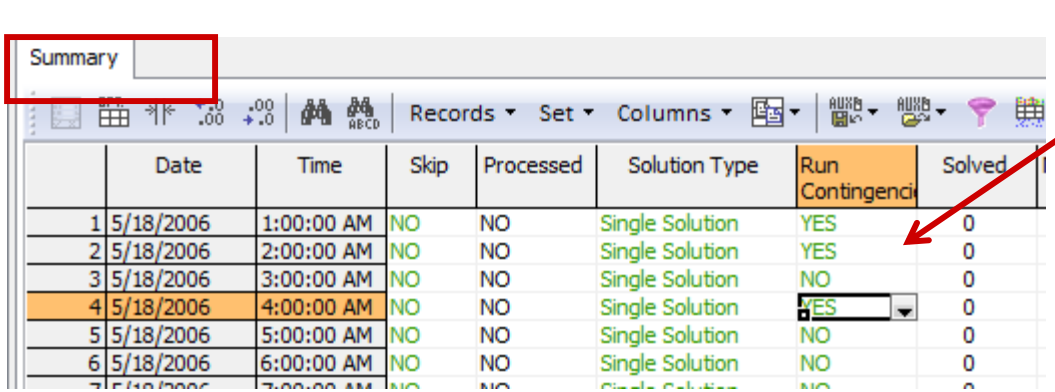
- Check this option to reset the cost curve of hydro generation to the original cost after each time step.
- Uncheck this option to explore how Simulator changes the hydro cost to the unconstrained marginal price.

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 field to YES in the Summary page.



	Date	Time	Skip	Processed	Solution Type	Run Contingenci	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

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