Weather-Dependent Branch MVA Limits

Jamie Weber
Director of Software Development

WECC User's Group Meeting
October 2022

PowerWorld Corporation

Temperature-Dependent MVA Limits

- Users are asking for an ability to specify a temperature dependence with Branch MVA limits
  - Some of this is driven by requests from NERC
- These new features give you this ability
  - Adds several new objects
  - Adds lots of new input data for you to gather!
- Expanded to Weather more generically
- Expanded to expose features for weather-dependent Generator MWMax and MWMin

© 2022 PowerWorld Corporation

Specification of Weather-Dependent Limits

- New Objects
  - WeatherMeasurement
  - XYCurve
  - XYCurvePoint
- Fields with existing objects
  - Substation
    - WeatherMeasurement
  - Branch
    - WeatherMeasurement
    - TemperatureLimitNormalName, TemperatureLimitNormalUse
    - TemperatureLimitCTGName , TemperatureLimitCTGUse
  - Generator
    - WeatherMeasurement
    - WeatherMWMaxName, WeatherMWMaxUse, WeatherMWMaxField
    - WeatherMWMinName, WeatherMWMinUse, WeatherMWMinField

© 2022 PowerWorld Corporation

WeatherMeasurement

- Name: string is our key field
- What does it represent
  - A location at which weather measurements specified
    - Typically include latitude and longitude information
  - Could be a recording station
  - Could be output of some special weather forecast software a utility has
  - Could be a National Oceanic and Atmospheric Administration (NOAA) measurement location
  - Might be as simple as the airports in the area

© 2022 PowerWorld Corporation

Weather Measurement Fields

- Initial design was temperature only

Field	Type	Description
`Name`	String (KEY field)	name of the measurement. This is the unique identifier (Key Field) for the weather measurement
`Enabled`	boolean	Set to YES to indicate that the measurement should be used. When this is set to NO, all numeric fields for the measurement will be disabled and no limit calculations can be based on this measurement.
`TempF` `TempC`	single float	Temperature in Fahrenheit or Celsius. We only store a single value internally and so the final one read will be kept. An entry of blank means there is not a valid value for this quantity.
`Longitude`	double float	Longitude Coordinate. An entry of blank may be given in which case there is not a valid value for this quantity.
`Latitude`	double float	Latitude Coordinate. An entry of blank may be given in which case there is not a valid value for this quantity.
`ObservationTime`	string	This is the date time of when the latest observations were recorded. It is optional and when blank indicates no time is known.

© 2022 PowerWorld Corporation

More Fields added

- Original purpose for this feature was only for Branch MVA limits
  - We have only seen users that have temperature-dependent MVA limits, so initial design only supported Temperature measurements
  - Dr. Thomas Overbye is always pushing the research envelope
    - Added more information for Weather Measurements
    - Added support for having weather-dependent generator MWMax and generator MWMin as well
      - Thinking is WindSpeed → Generator MW Max for a wind plant
      - Thinking "InsolationPercent" → Generator MW Max for solar farm

© 2022 PowerWorld Corporation

More WeatherMeasurement Input Values

Field	Type	Description
`ElevationM` `ElevationFt`	double float	Elevation of measurement in meters or feet. We only store a single value internally and so the final one read will be kept. An entry of blank means there is not a valid value for this quantity.
`DewPointF` `DewPointC`	single float	DewPoint in Fahrenheit or Celsius. We only store a single value internally and so the final one read will be kept. An entry of blank means there is not a valid value for this quantity.
`CloudCoverPerc`	single float	Cloud Cover Percentage (between 0 and 100). An entry of blank means there is not a valid value for this quantity.

`WindSpeedmph`
`WindSpeedKnots`
`WindSpeedMsec`
`WindSpeedkmph`
	single float	Wind Speed in miles per hour, knots, meters per second, or kilometers per hour. We only store a single value internally and so the final one read will be kept. An entry of blank means there is not a valid value for this quantity.

`WindDirection`	single float	Wind Direction in degrees. (90 = From East; 180 = From South; 270 = From West; 360 = From North. Only show 0 if wind speed also 0.) An entry of blank means there is not a valid value for this quantity.

© 2022 PowerWorld Corporation

More WeatherMeasurement Identifying Information

- Tom Overbye found public sources of information on weather included these

Field	Type	Description
ICAO	String	This is 4-character code assigned by the International Civil Aviation Administration. The last 3 digits are often the airport code.
GHCN	String	Global Historical Climatology Network identifier
WMO	Integer	This is 5-digit numeric code to identify a weather station assigned by the World Meteorological Organization
CountryCode	String	Two character country code; e.g., US, CA, etc.
Region	String	For the US and Canada this is the two character state or providence code
Subregion	String	County name for some US states
PlaceName	String	Extra identifier in various weather resources
StationName	String	Extra identifier in various weather resources

© 2022 PowerWorld Corporation

Calculated Fields of WeatherMeasurement

- The following fields depend on the time of day and the latitude and longitude
  - Solar related values depend on location of the sun

Field	Type	Description
SolarElevation	single float	Sun Elevation (Deg). Depends on the time of day and the Latitude and Longitude of the measurement
SolarAzimuth	single float	Sun Azimuth in compass degrees with zero due north, 90 due east, 180 due south and 270 due west. This depends on the time of day, latitude and longitude.
AtmosphericTransmittance	single float	Atmospheric transmittance with 1 for the sun directly overhead, and lower values as the sun goes through more of the atmosphere. This depends on the time of day, latitude and longitude.
InsolationPercent	single float	Estimate insolation Percent. (100-CloudCoverPerc)*AtmosphericTransmittance

© 2022 PowerWorld Corporation

XYCurve and XYCurvePoint

- Need a structure for entering a generic XYCurve
  - Represents **one** input – **one** output lookup function
- Object has 3 fields and then a list of XYCurvePoints

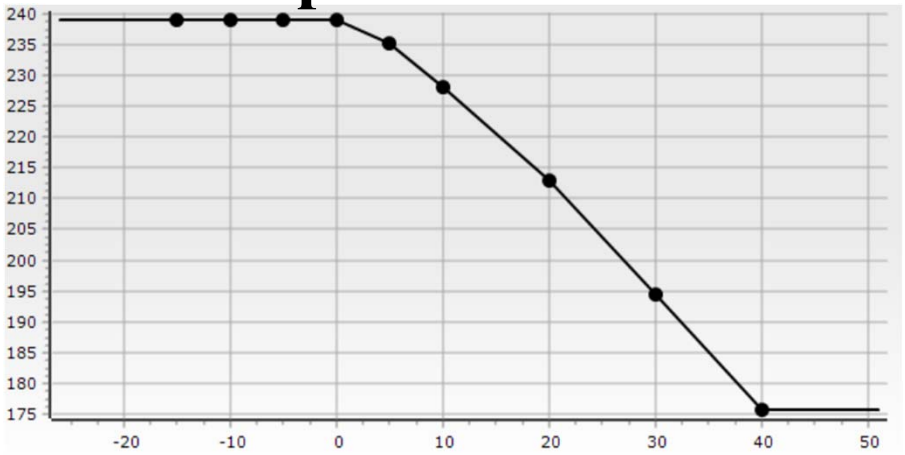
Field	Type	Description
`Name`	String (KEY field)	Name of the curve
`Information`	String	Informational string about equipment that results in this curve being used. It is possible that one device in the power system model will have multiple curves associated with it. For example: a line may also have current transformer associated with it that has a different lower rating than the line.

`IntermediateType`	Discrete Options
	`AtOrAbove`
	`AtOrBelow`
	`Closest`
	`Interpolate`
		Specifies how to handle any lookup when the temperature falls between X values.
		`AtOrAbove` means the limits are at or above the specified temperature
		`AtOrBelow` means the limits are at or below the specified temperature
		`Closest` means use the limit based on the closest temperature
		`Interpolate` means we will linearly interpolate between points

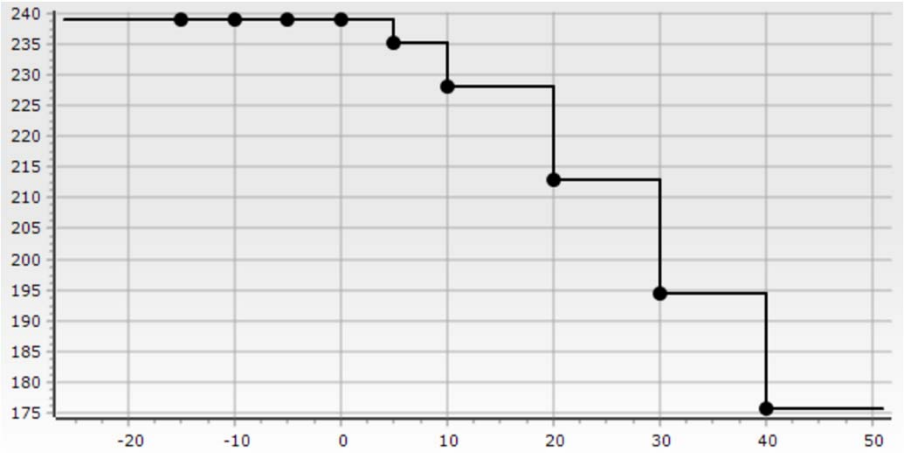
© 2022 PowerWorld Corporation

IntermediateType

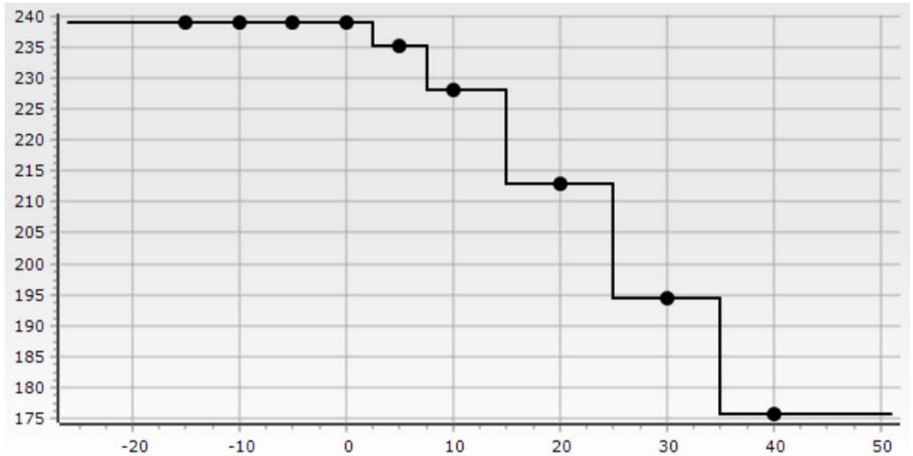
Interpolate



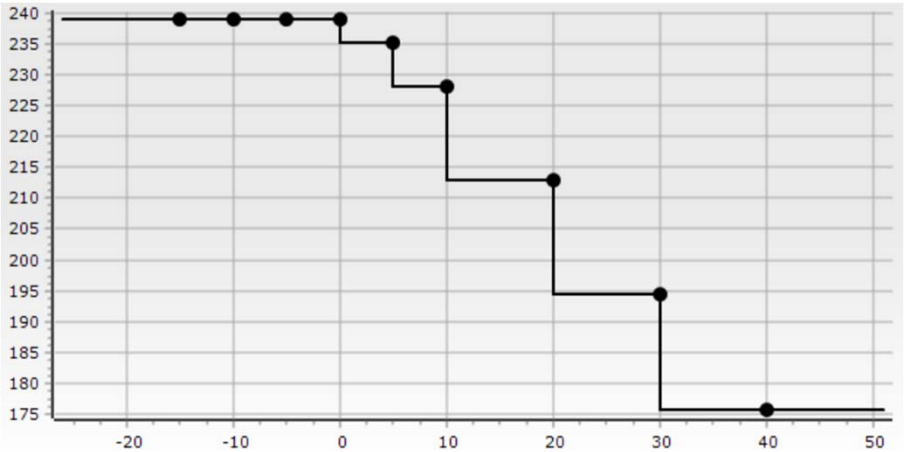
AtOrAbove



Closest



AtOrBelow



© 2022 PowerWorld Corporation

XYCurvePoint

- Belongs to an XYCurve (Name)
- Has an X, Y value and some informational values about the point (we will discuss Info shortly)

Field	Type	Description
Name	String (KEY field)	Name of the XYCurve to which this point belongs
X	single float (KEY field)	Single float storing temperature (tolerance would be 0.01. Thus 10.223 and 10.218 are both considered to be 10.22 degrees). The unit of this field will depend on what object is using the curve, so the curve itself does not know the units. This is assumed to be Celsius for temperature dependent curves.
Info1..Info5	String	Informational strings about device that results in this value being used. There may be processing done outside of PowerWorld that creates a curve where each point in the curve represents a different piece of equipment. This may be done instead of defining a separate curve for each piece of equipment
Y	Single float	Limit at this temperature. The unit will depend on what object is using this curve, so the curve itself does not know the units. This is assumed to be MVA for temperature dependent rating curves.

© 2022 PowerWorld Corporation

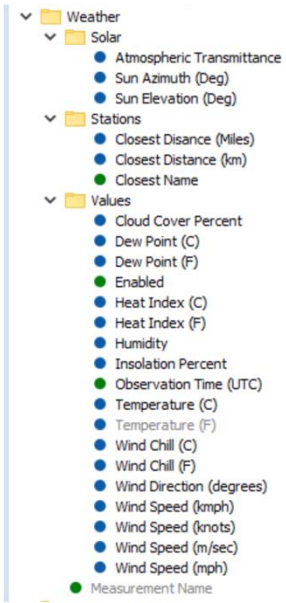
Substation Weather-Related Fields

- Each substation can be assigned to a WeatherMeasurement object directly

Field	Type	Description
WeatherMeasurement	String	Name of WeatherMeasurement that is assigned to the substation. Branch and Generator objects will then use this information if they are not assigned to their own WeatherMeasurement

- Substation then has a bunch of fields that do lookups based on the assigned WeatherMeasurement

WM_CloudCoverPerc	WM_InsolationPerc	WM_Enabled
WM_DewPointC	WM_ObservationTime	WM_HeatIndexC
WM_DewPointF	WM_TempC	WM_HeatIndexF
WM_Enabled	WM_TempF	WM_Humidity
WM_HeatIndexC	WM_CloudCoverPerc	WM_InsolationPerc
WM_HeatIndexF	WM_DewPointC	WM_ObservationTime
WM_Humidity	WM_DewPointF	



© 2022 PowerWorld Corporation

Branch
Weather-Related Fields

- Specify WeatherMeasurement (if empty, get from substation)
- Specify a *list of* XYCurves to use (NormalName and CTGName)
- Specify if this should be done (NormalUse, CTGUse)
- *X-value for lookup is always by temperature in Celsius*

Field	Type	Description
`WeatherMeasurement`	String	Optionally specify the name of WeatherMeasurement from which this Branch gets its temperature. If this is not specified, the measurement to use will be determined from the largest of the measurements at the from and to bus substations.
`TemperatureLimitNormalUse`	String	YES or NO. Specify YES to use the TemperatureLimitNormal values
`TemperatureLimitCTGUse`	String	YES or NO. Specify YES to use the TemperatureLimitCTG values
`TemperatureLimitNormalName`	String	A comma-delimited list of names of XYCurves that will impact this Branch. Multiple curves are allowed because there may be multiple devices that impact the limit of this branch. For example, a Current Transformer (CT) may be on a particular branch that imposes a different limit on the line as compared to the conductor limit. The limit that is calculated by PowerWorld Simulator will be the minimum limit across all these curves. **The x value of the curves is assumed to be temperature in Celsius.**
`TemperatureLimitCTGName`	String	A comma-delimited list of names of XYCurves that will impact this Branch during a contingency. Multiple curves are allowed because there may be multiple devices that impact the limit of this branch. For example, a Current Transformer (CT) may be on a particular branch that imposes a different limit on the line as compared to the conductor limit. The limit that is calculated by PowerWorld Simulator will be the minimum limit across all these curves. **The x value of the curves is assumed to be temperature in Celsius.**

© 2022 PowerWorld Corporation

Generator Weather-Related Fields

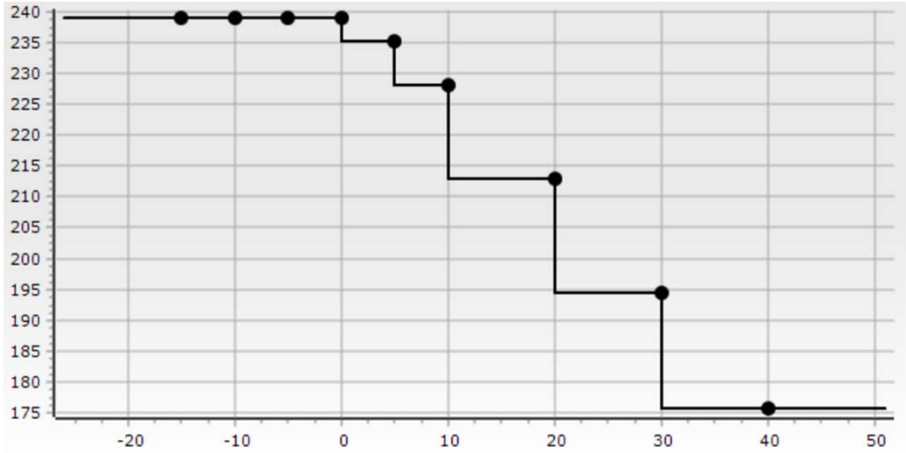
- Specify WeatherMeasurement (if empty, get from substation)
- Specify a *list of* XYCurves to use for MWMax (and MWMin)
- Specify if this should be done (MWMaxUse, MWMinUse)
- Specify what the x-axis lookup variable is such as Wind, Temp, etc.

Field	Type	Description
`WeatherMeasurement`	String	Optionally specify the name of WeatherMeasurement from which this generator gets its weather value. If this is not specified, it will be determined from the generator's substation.
`WeatherMWMaxUse` `(also WeatherMWMinUse)`	String	YES or NO. Specify YES to use the WeatherMWMax values
`WeatherMWMaxField` `(also WeatherMWMin)`	String	Field indicating what X value is represented in the XYCurves and which weather measurement value should be used to determine the MWMax limit. Options are: TempF, TempC, DewPointF, DewPointC, CloudCoverPerc, WindSpeedmph, WindDirection, WindSpeedKnots, WindSpeedMsec, WindSpeedkmph, and InsolationPerc.
`WeatherMWMax` `(also WeatherMWMin)`	String	A comma-delimited list of names of XYCurves that will impact the MWMax of this generator. Multiple curves are allowed because there may be multiple devices that impact the limit of this generator. The limit that is used by PowerWorld Simulator will be the minimum limit across all these curves.

© 2022 PowerWorld Corporation

Purpose of XYCurve Design

- Design was built around what users have for temperature-dependent MVA limit information
- Simplest case: a lookup function for a conductor of **MVA limit** vs. **Temperature in Celsius**
  - This would a single curve for the conductor that might look something like the following



© 2022 PowerWorld Corporation

Why can Multiple XYCurves be assigned to One Branch?

- Transmission line may have multiple devices that constrain the MVA flow on the transmission line
  - A planning model may not include breakers or disconnects
    - Full topology model could be used to include Disconnect and Breaker limits, but the EMS often does not populate limits for these
  - Current Transformer (CT) could also limit the flow on a branch
    - The CT is not going to be modeled even in a full EMS system model
- Potential: you may have many different devices that limit the MVA on a transmission line
  - Conductor, CT, Disconnects, Breakers, etc.
  - All devices may have different temperature-dependent MVA limits
  - PowerWorld lets you assign multiple XYCurves to a branch
  - PowerWorld lookup will do lookup on all XYCurves and return the minimum MVA

© 2022 PowerWorld Corporation

Alternate Representation for XYCurve with multiple devices

- Sometimes a user may combine the multiple set of temp-dependent curves into a single curve
  - Trace of the 3 curves and choose the minimum Y value at all X values

XYCurve	-15C	-10C	-5C	0C	5C	10C	20C	30C
Conductor	240	240	240	230	220	210	190	170
CT	205	210	280	290	280	270	250	220
Disconnect	320	310	300	280	250	220	200	160

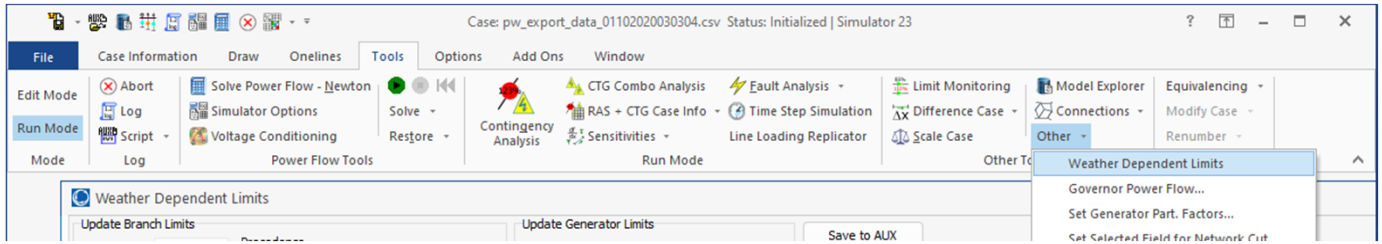
  - Instead of having 3 curves, combine into a single curve and use the "Info1" field for each XYCurve to provide information about limiting device

XYCurve	-15C	-10C	-5C	0C	5C	10C	20C	30C
Combined	205	210	240	230	220	210	190	160
Combined	CT	CT	Conductor	Conductor	Conductor	Conductor	Conductor	Disconnect

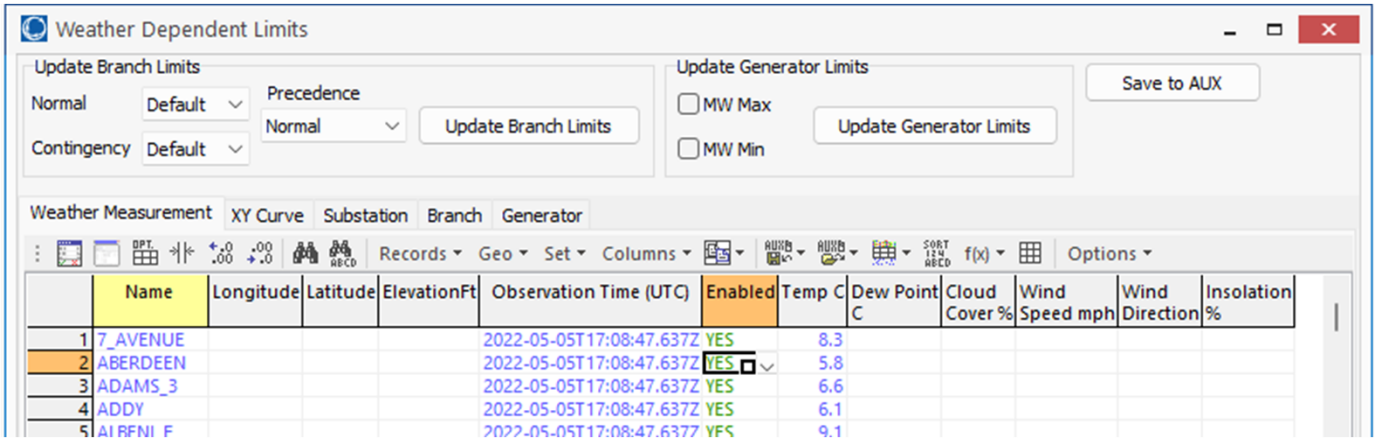
© 2022 PowerWorld Corporation

User Interface for Weather Dependent Limits

- Tools Tab, Other → Weather Dependent Limits



- Opens the Weather Dependent Limits Dialog



© 2022 PowerWorld Corporation

Fields on Branch

- **Weather Meas Temp**: Looks up the temperature for the branch and shows it
- TemperatureLimitNormal
  - Takes the **Weather Meas Temp** value and looks up the MVA limit based on the list of *Limit XY Curves*
    - If no curves, then blank
    - If 1 curve, returns lookup for that curve
    - If *multiple* curves, returns the *minimum* value
- TemperatureLimitCTG
  - Same thing, but does it for the *CTG Limit XY Curves*

© 2022 PowerWorld Corporation

Using Temperature Dependent Limits

- Users could use the TemperatureLimitNormal or TemperatureLimitCTG field in their own scripts
- PowerWorld Simulator has a built-in **Update Branch Limits** button
  - Click **Update Branch Limits** will copy any valid (non-blank) weather-dependent MVA limit *and overwrite* whatever the presently Normal Limit and Contingency Limit is for each branch
  - This all depends on the Limit Monitoring settings, so it can get complicated

© 2022 PowerWorld Corporation

Script Commands for Performing of Weather Limit Updates

```
TemperatureLimitsBranchUpdate(RatingSetPrecedence,
NormalRatingSet, CTGRatingSet);
```

- RatingSetPrecedence
  - Optional (NORMAL if not specified)
  - Either Normal or CTG. Specify which RatingSet is copied (if both NormalRatingSet and CTGRatingSet are the same)
- NormalRatingSet
  - Optional parameter (Default if not specified)
  - Default: will use the Limit Monitoring Settings to determine the active RatingSet and overwrite it
  - No: will not use temperature dependent normal rating
  - A, B, C, … M, N, O: Will overwrite the specified rating set
- ContingencyRating Set
  - Same as NormalRatingSet, but for the Contingency Ratings set

© 2022 PowerWorld Corporation

Expected Use of Temperature Dependent Limits

- Branches have 15 limits in PowerWorld (A,B,…O)
- When making extensive use of temperature-dependent limits, we expect
  - All Limit Monitoring Settings for branches with temperature-dependent limits will be configured to use the same Rating Set
    - Limit A = Normal (or maybe Limit M, 13th limit)
    - Limit B = Contingency (or maybe Limit N, 14th limit)
  - They can then just copy the temperature dependent limits right into A and B (or M and N)

© 2022 PowerWorld Corporation

Our Recommendation

- Choose Season Limits consistently (for example)
  - D, E, F = Spring Seasonal Limits
  - G, H, I = Summer Seasonal Limits
  - J, K, L = Fall Seasonal Limits
  - M, N, O = Winter Seasonal Limits
- Configure Limit Monitoring Settings to use remaining “unused” 3 limits
  - A = Normal Limit
  - B = Contingency Limit
- When it is Summer, do the following
  - Push Summer Seasonal Limits into active limits
    - Copy Limit G and H and overwrite A and B

```
SetData(Branch, [LimitMVAA,LimitMVAB],
                ["@LimitMVAG","@LimitMVAH"],
                "FilterNameforMyBranches");
```

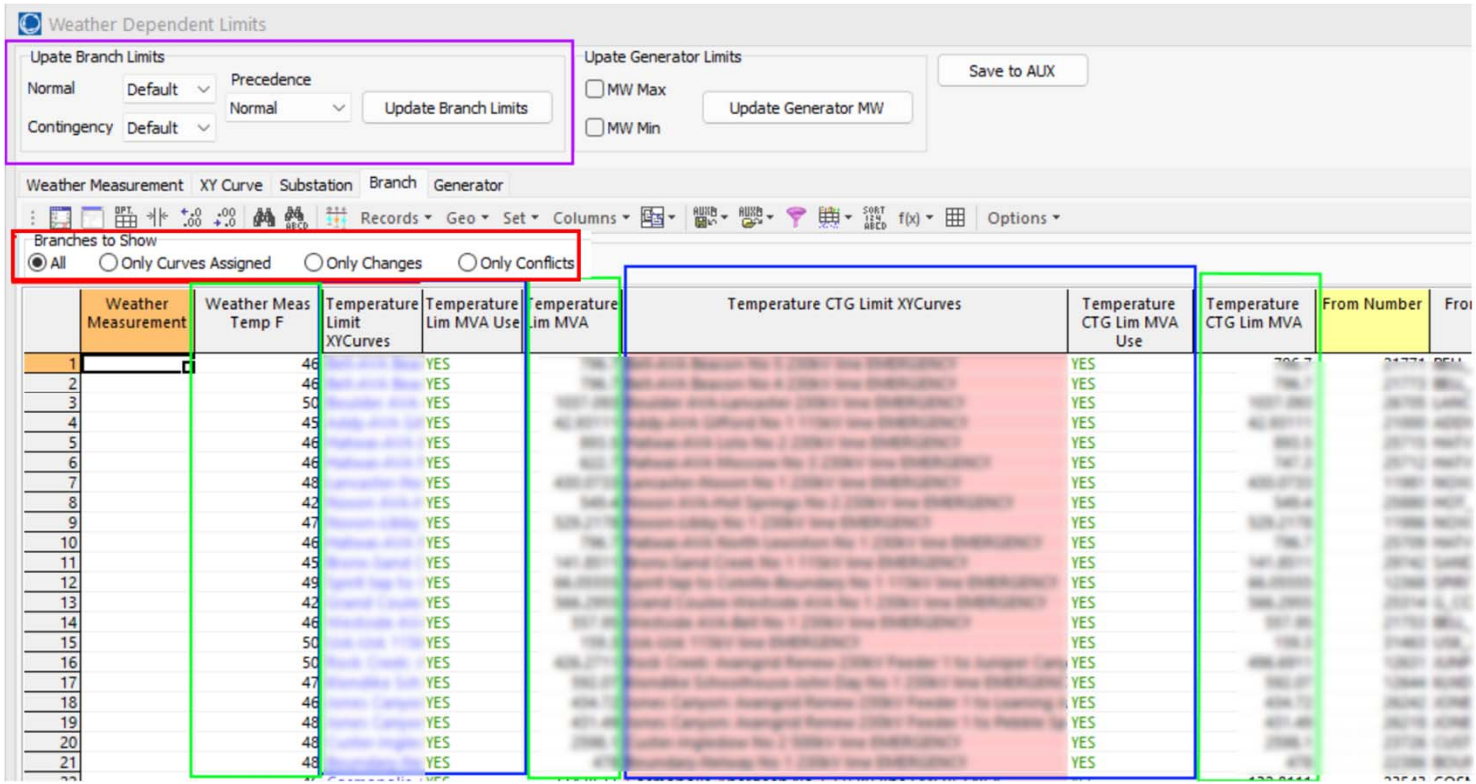
  - Copy Temperature Dependent Limits into active limits

```
SetData(Branch, [LimitMVAA,LimitMVAB],
                ["@TemperatureLimitNormal","@TemperatureLimitCTG"],
                "FilterNameforMyBranches");
```

© 2022 PowerWorld Corporation

Temperature Dependent Line Limits User Interface

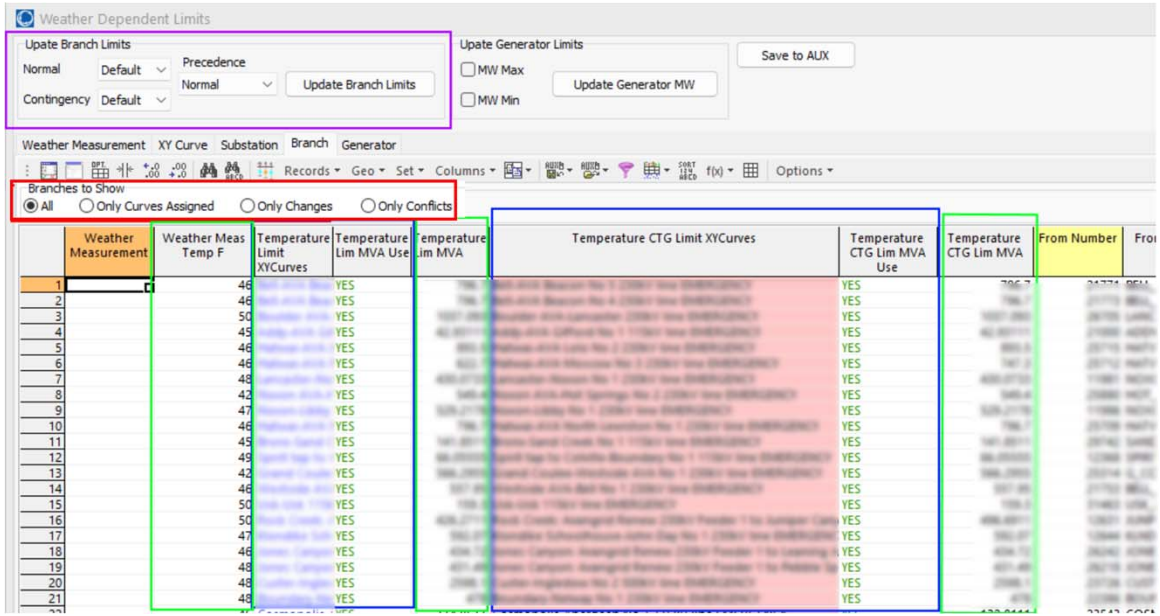
- **Red Box**: Quick filtering of the branches shown table
  - **Only Curves Assigned**: Branches have XYCurves assigned and InUse (blue boxes)
  - **Only Changes**: Branches that will update limits based on purple box options
  - **Only Conflicts**: Branches that have a conflict with either the Normal or CTG curve based on the options in the purple box
  - **All**: All branches



© 2022 PowerWorld Corporation

Update Branch Limits (Purple Box)

- Specify which Limits to overwrite:
  - Normal = Default means overwrite based on Limit Monitoring Settings. Otherwise specify: A, B, C, … M, N, O
  - Contingency (same as for Normal)
  - Precedence
    - Possible that Normal and Contingency are the same Rating Set (both are A)
    - Precedence says which one is applied second (and thus overwrites the first one)



© 2022 PowerWorld Corporation

Conclusion

- Users studying near real-time with good weather forecasts can use this in Version 23
- Anyone can start using it to do additional studies for there system
  - What if the temperature is 110 degrees?
    - We are in Phoenix!
  - How about 20 degree weather in a Southern State?

© 2022 PowerWorld Corporation