

New GDV Functionality for Summary Objects and Line Summary Objects



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Overview



- Over the last year lots of new geographic data view (GDV) functionality had been added to PowerWorld
 - This includes being able to auto insert (and anchor) lines to bus and substation GDVs, and interfaces to area and zone GDVs; GDVs also now work with difference flows
 - Other changes include GDV support for more objects including contingencies, RASs and DC lines
 - GDVs now have more local menu objects, including quick links to bus view displays
- This slide set provides a review of GDVs and then focuses on the more recent GDV Summary Objects and GDV Line Summary objects

Slides Example Systems

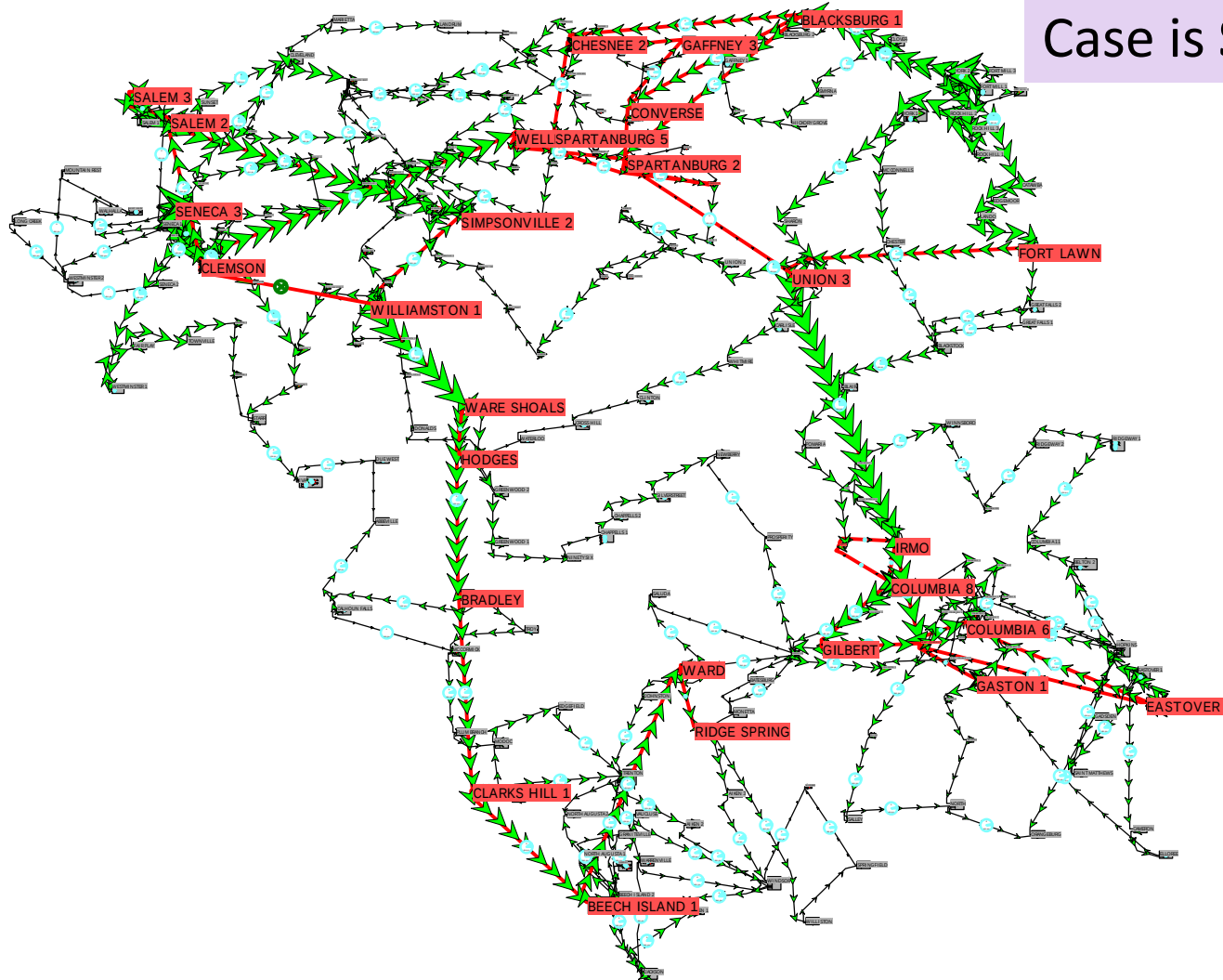


- The results presented in these slides are demonstrated on four example systems, all of which are synthetic, and hence contain no CEL and are fully public
 - **Bus37**: A 37 bus grid with a generic geographic location (arbitrarily placed in Texas)
 - **SC500**: A 500 bus system in South Carolina
 - **Texas7K**: A 6770 bus grid on the ERCOT footprint
 - **US82K**: An 82K grid covering the contiguous US with three interconnect corresponding to the US parts of the EI, WECC and ERCOT footprints

SC500 Oneline



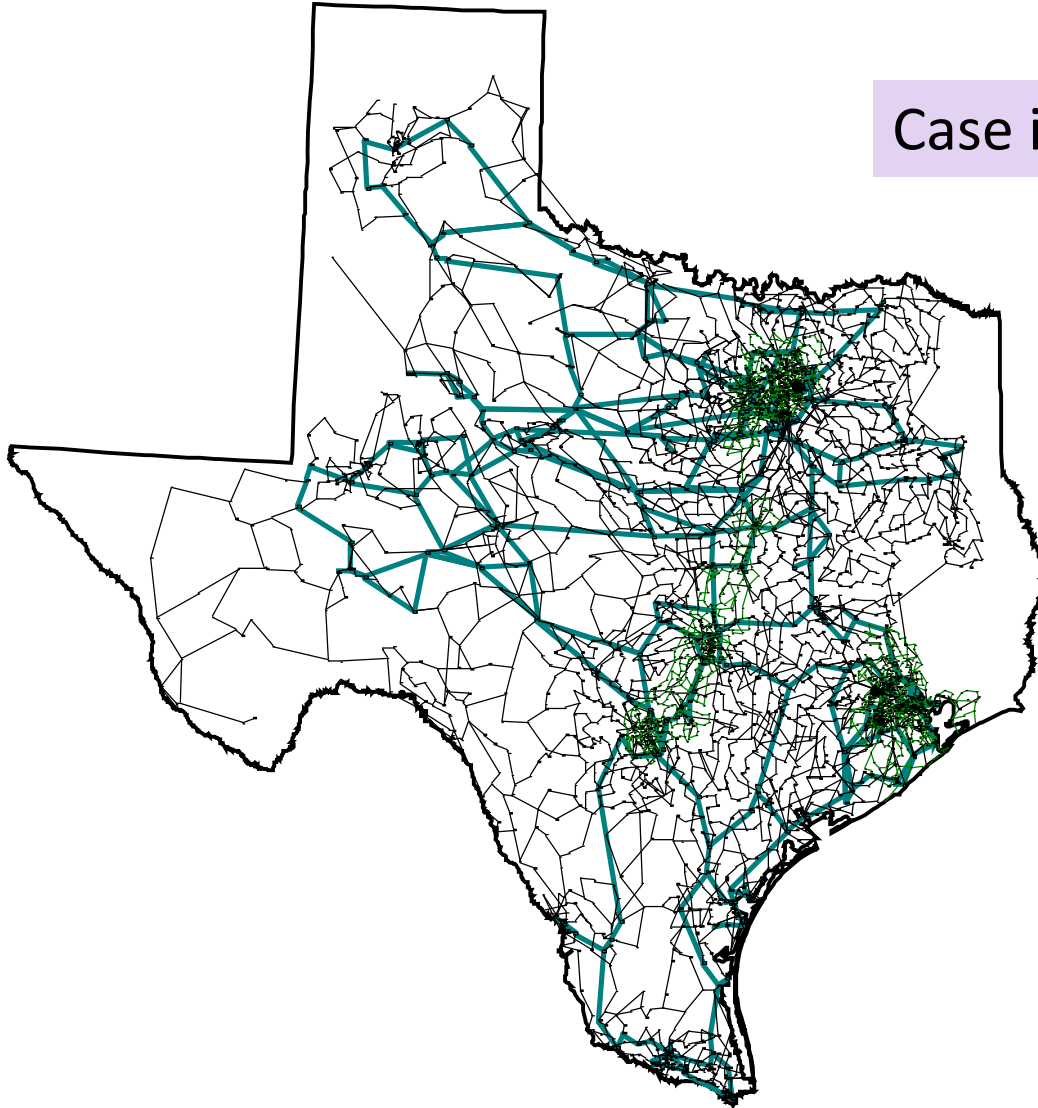
Case is SC500_Oneline



Texas7K Oneline



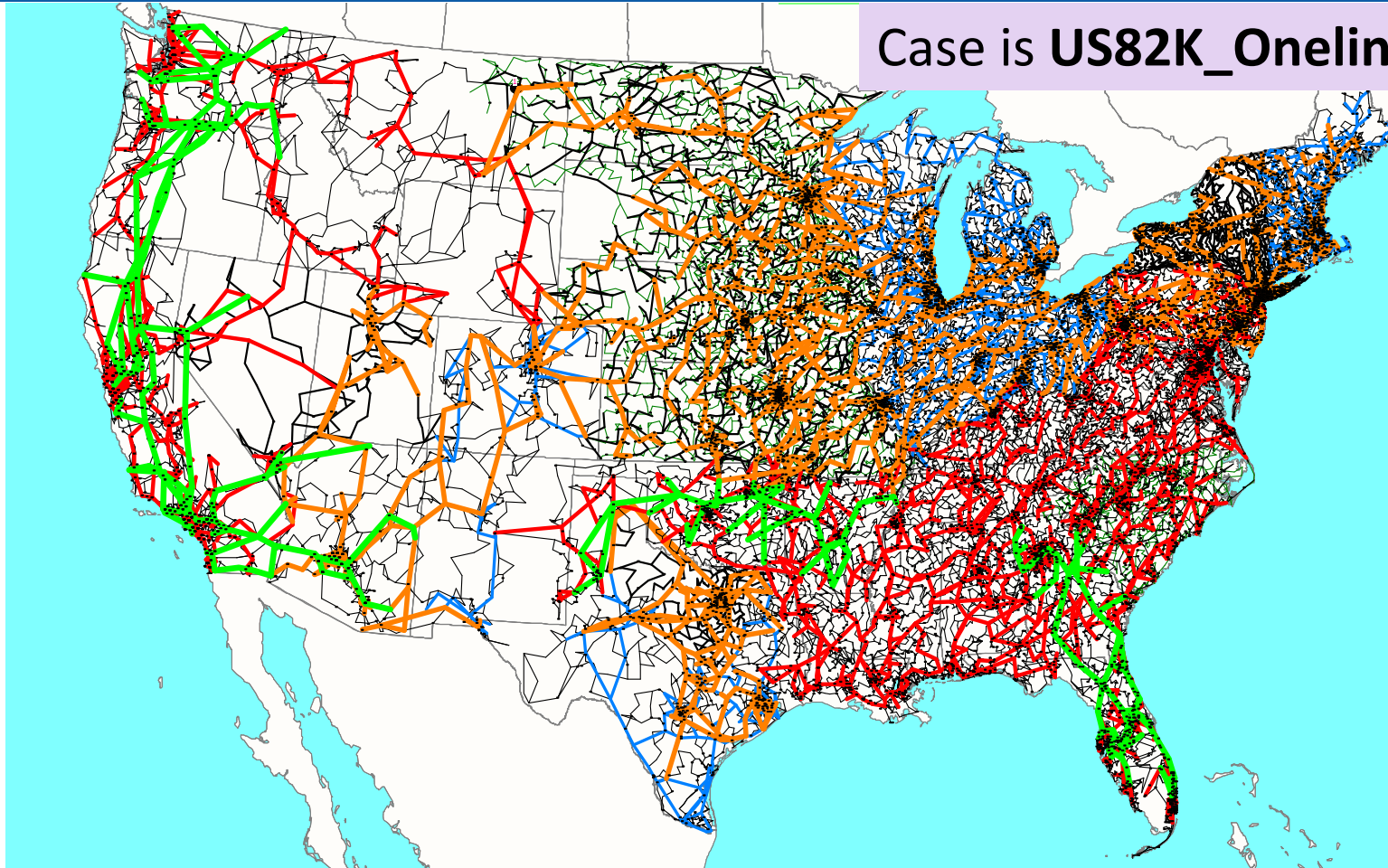
Case is **Texas7K_Oneline**



US82K Oneline



Case is **US82K_Oneline**



GDV History and Overview



- The GDV concept arose about 13 years back as a way to auto-create online displays using geographic information embedded in power system models
- GDVs can be created from Model Explorer displays by right-clicking and selecting **Geographic Data View** and then either **Geographic Data View** to create a display of the selected objects or **Select Column, then Geographic Data View** for all the objects
 - As always, filters can limit the column objects

GDV History and Overview, cont.



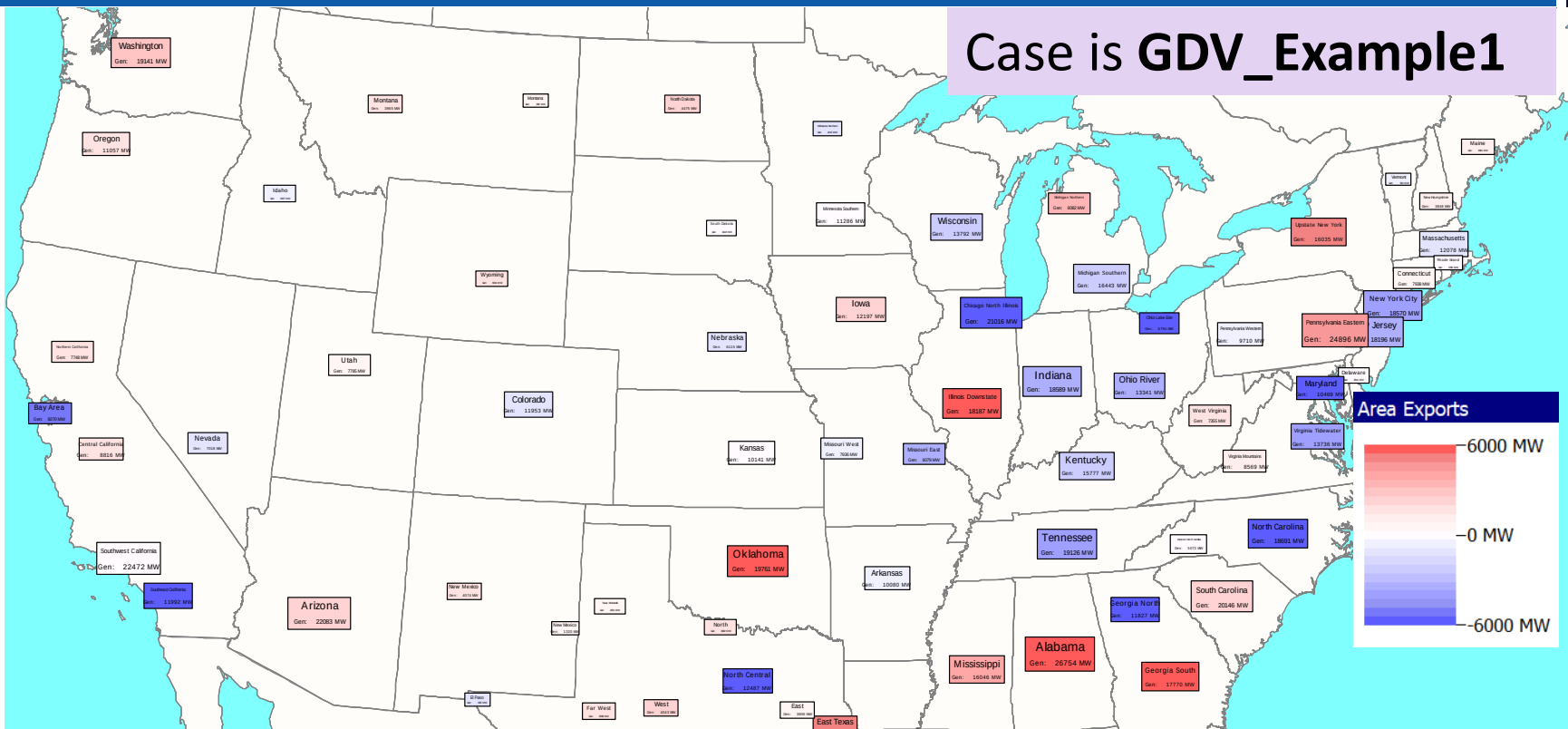
- Once defined, the GDVs are grouped based on an associated GDV Style
- The GDV Style is then used to customize their appearance on the displays
- The GDVs themselves are ultimately display objects that can be saved in a pwd or axd file
 - The requirement is that they also be saved with the definition for their style
- Like other *.pws, the GDVs can be used with multiple power systems

GDVs and Geography



- The GDVs are meant to leverage the growing amount of geographic information that is embedded in power system models
- Geographic information, at least at the substation level, is now widely available
 - This was due in part because of the need for this information for geomagnetic disturbance studies
 - With the rapid development of synthetic electric grids geographic information is now widely available

GDV Example 1



This is a classic GDV display in which the location of each GDV (shown as an area here) is derived from its elements. The size is proportional to generation, color depends on its exports. Each GDV is linked, allowing access to its Area Dialog.

GDV Example 1 Customizations



Geographic Data View Style Options

Object and Field Display Option Sets

Style Name:

Object Type:

General Display Options | Fields and Attributes | Display Attributes | Linked Objects | Line Summary Objects | Pseudo-Geographic Mosaic Display | Pruning | Au

Attribute	Default for Attribute	Use	Field Lookup
Line Thickness	1	☐	Area Num Find...
Line Thickness Summary Object Data Type		Style Default	
Line Color	Black Change	☐	Area Num Find...
Line Color Summary Object Data Type		Style Default	
Fill Color	☒ Use Fill Cyan Change	☒	Interchange\Actual Find...
Fill Color Summary Object Data Type		Style Default	
☒ Use Auto Width of Objects		☐ Scale Size, Not Total Area	
Total Area	Width 944.332	☒	Generators\MW Find...
Size to Width Ratio 0.500		☒	Kite Shape Only Find...
Area Summary Object Data Type		Style Default	
Rotation Angle	0.0 (Degrees)	☐	Area Num Find...
Rotation Angle Summary Object Data Type		Style Default	
Rotation Rate	0.0 (Hz)	☐	Area Num Find...
Rotation Rate Summary Object Data Type		Style Default	

Area Value Lookup

Field Set Metrics

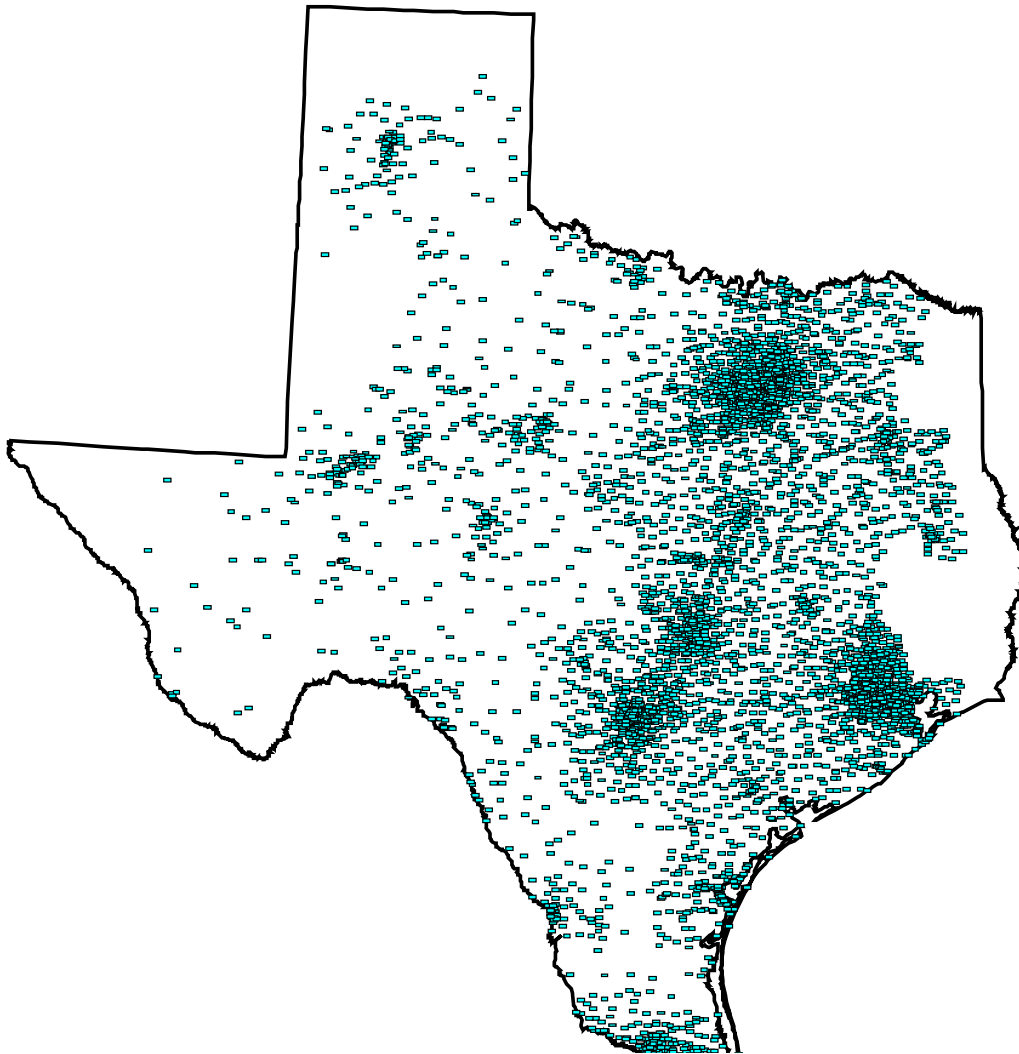
Min	523.57	Median	18318.69
Max	36113.82	Average	10990.42

Value Map Options

☐ Use Absolute Value

Input Value	Characteristic Value
0.00	50000
30000.00	500000

GDV Example 2a



For the Texas 7K grid the image shows the 4900 substation GDVs without dynamic formatting.

Case is **GDV_Example2a**

GDV Example 2b

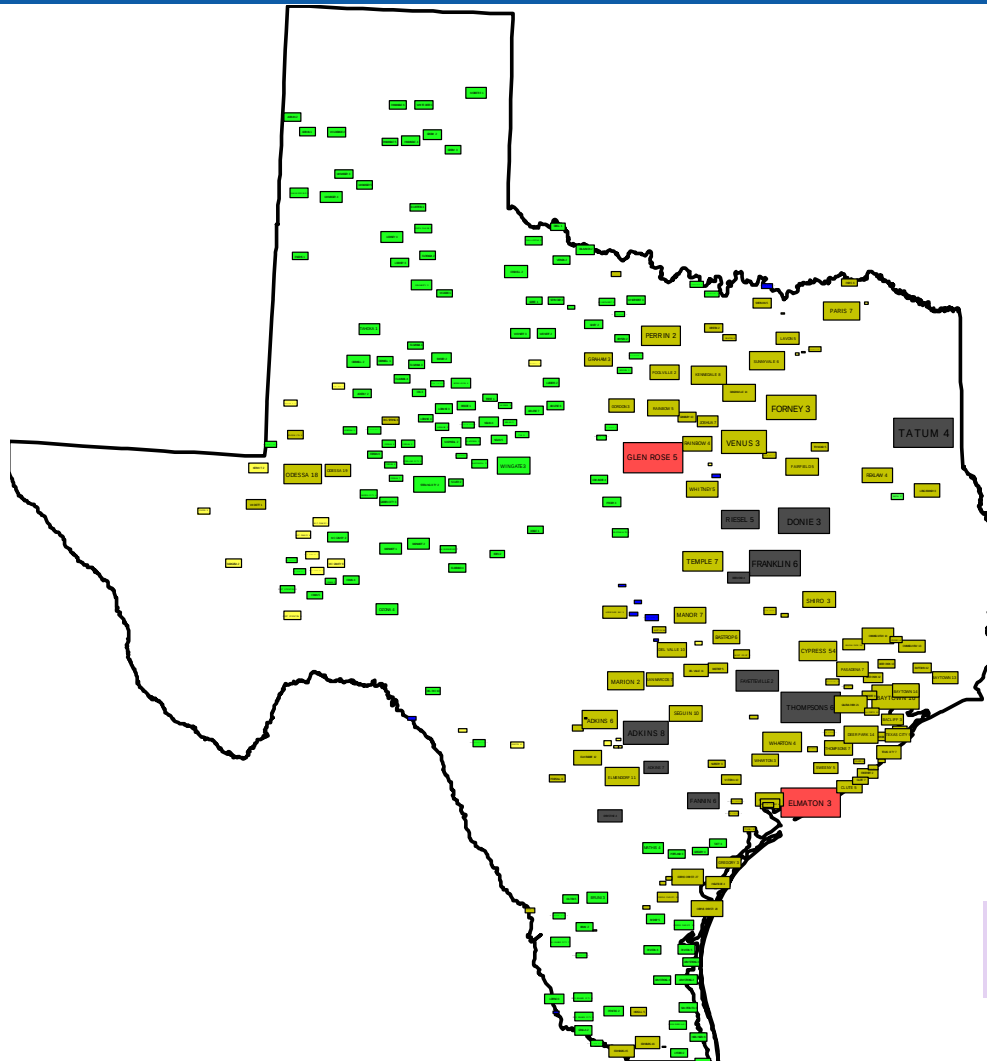


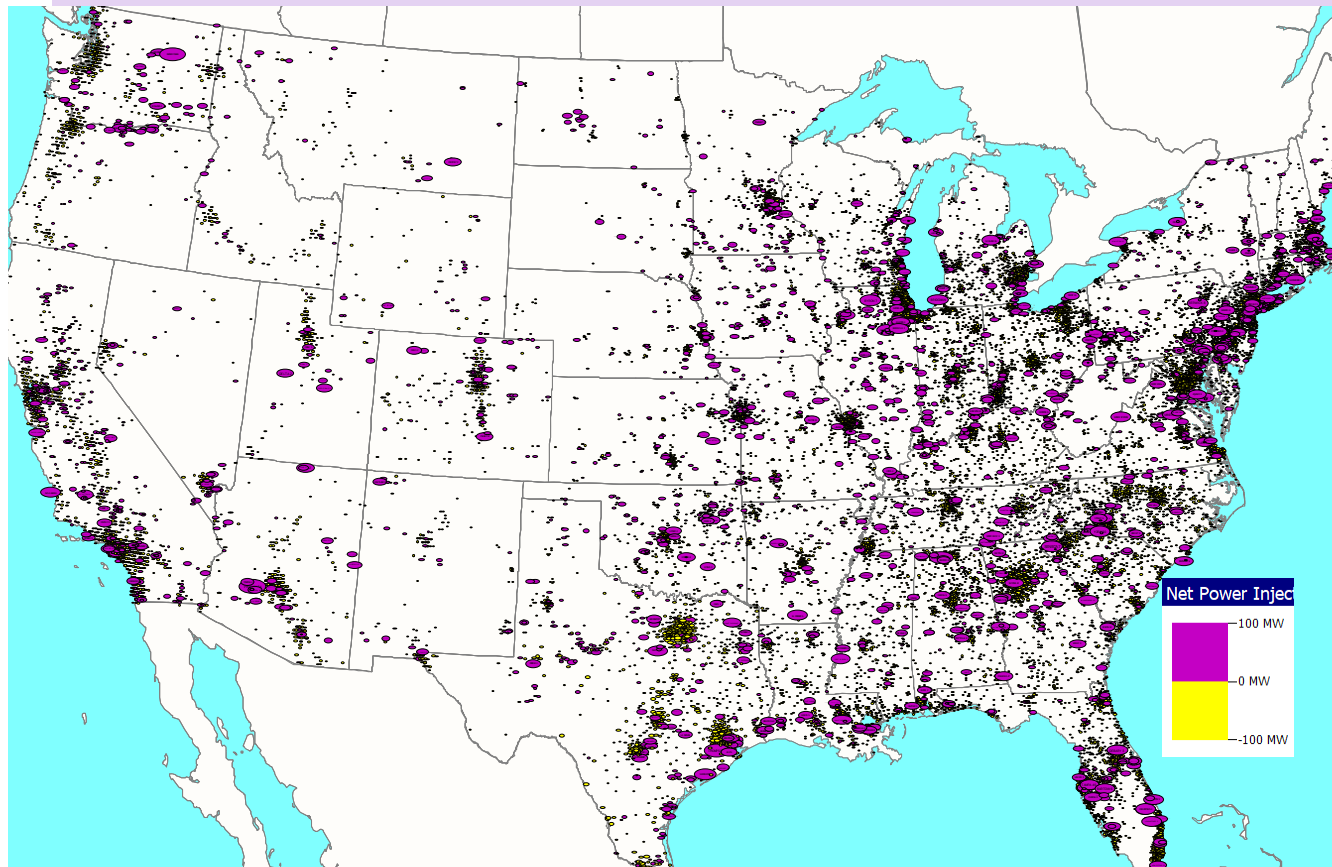
Image shows the substation GDVs sized by generation (MW), with color based on the fuel type (red: nuclear, black: coal, brown: natural gas, green: wind, yellow: solar).

Case is **GDV_Example2b**

GDV Example 3: 40K Substation GDVs

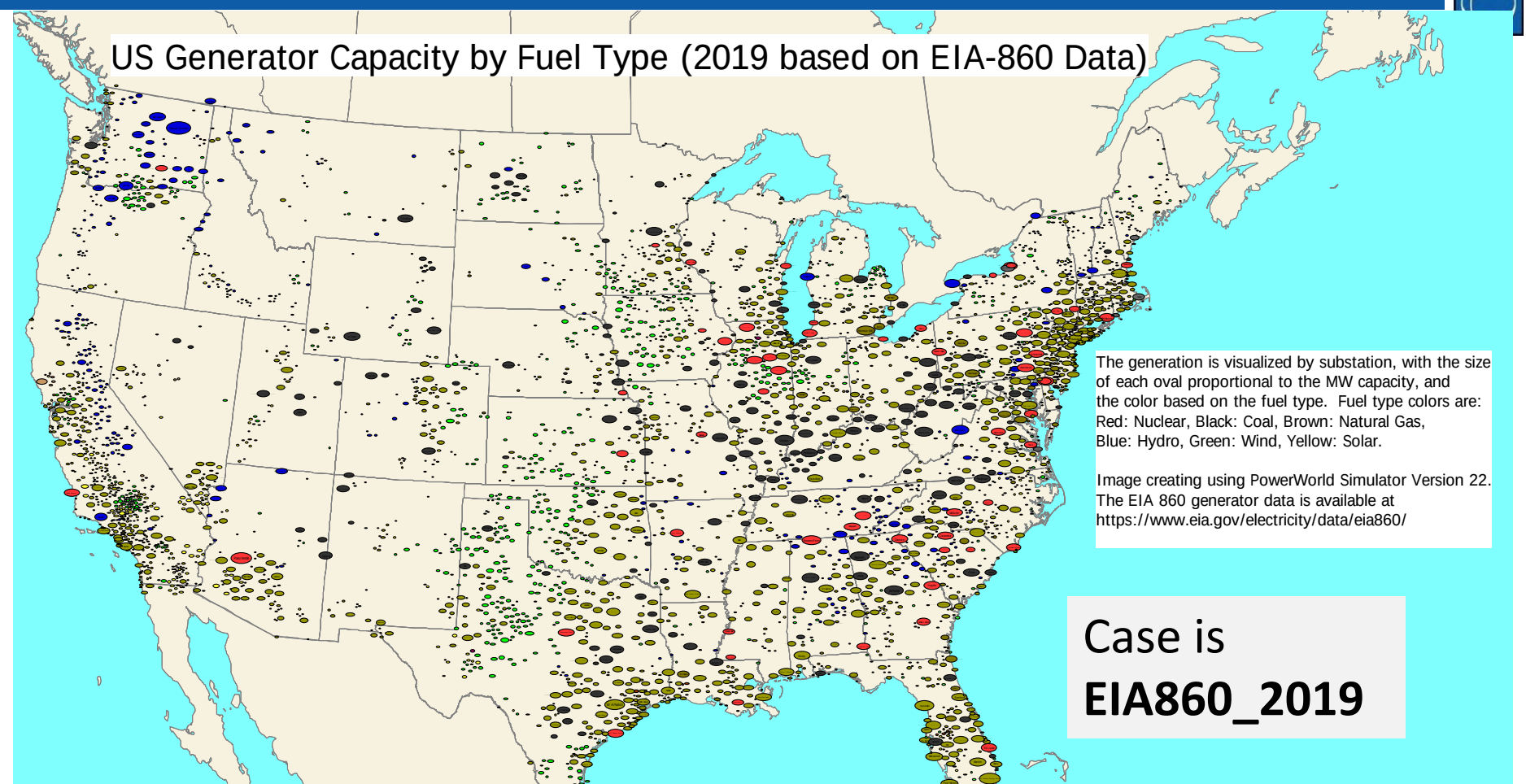


Each GDV is linked, the GDVs can easily be customized, and the display can be saved like a regular pwd online (generation substations are magenta, load substations are yellow)



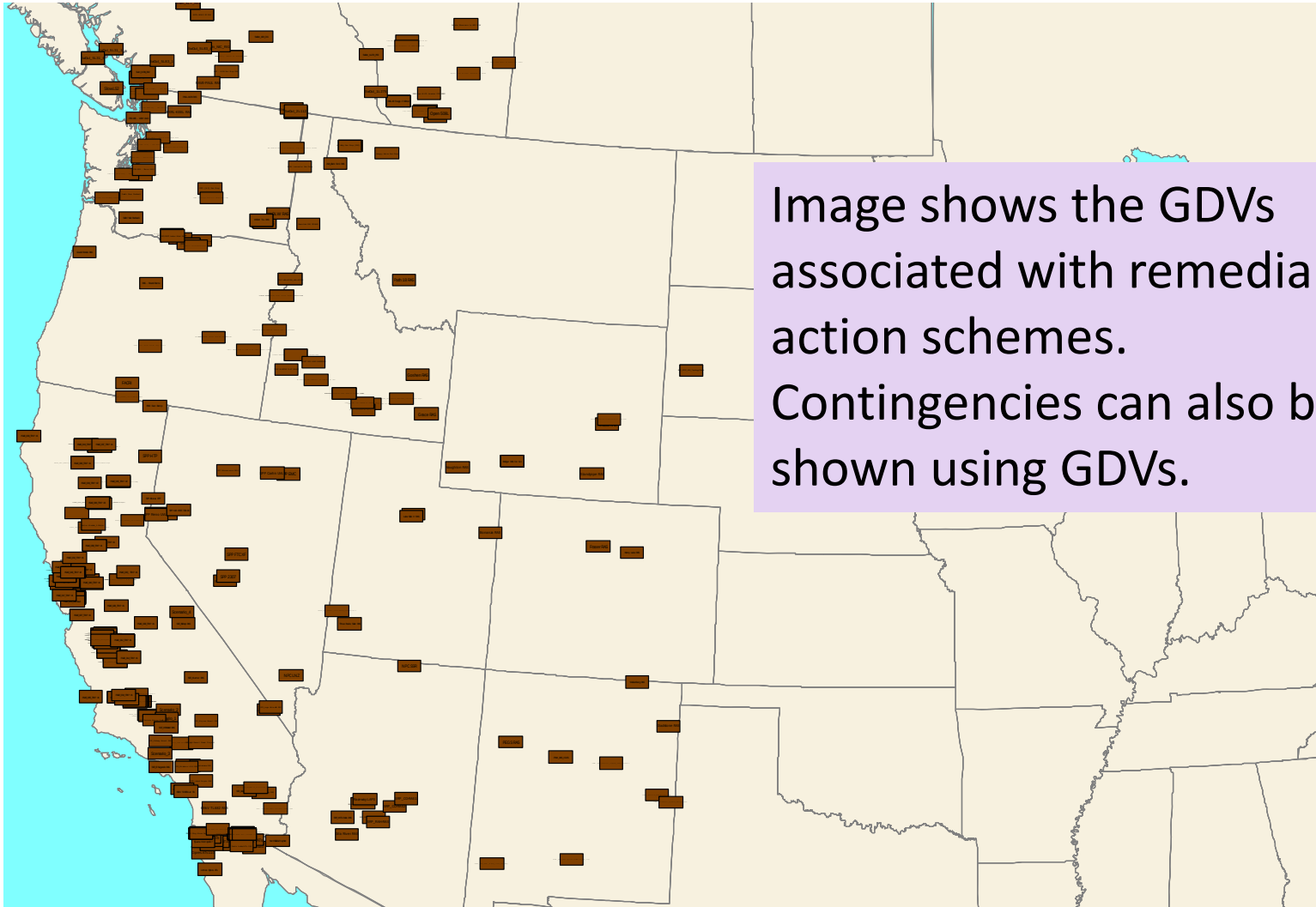
Case is
GDV_Example3

GDV Example 4



This image was created by using the EIA 860 data to setup the substations and generators. A simple power system was created by adding one bus per substation; fuel types were shown using the Integer A 16 Color mapping. Data provided for 11,800 substations with 22,700 gens.

GDV Example 5



Creating GDVs



- There are two main ways to create GDVS
 - As previously noted, from the Model Explorer displays. This approach can be quite fast, allowing for very customized GDVs.
 - From axd files
- When creating from an axd, to automatically set the location just set the SOX and SOY fields to zero.
- GDVs can both be created as needed (display on demand) or used in a more traditional sense

GDV Example:

Switched Shunt Information



- Assume the desire is to know the status and voltage information about the switched shunts in the 7K system
- To create the GDV
 - Open the case, in the Model Explorer selected **Network, Switched Shunts**
 - There are 634 of them
 - Right click and select **Geographic Data View, Select Column then Geographic Data View**
 - If desired filtering could be used to limit the number
 - The selected column can be used to set the initial field
 - This displays the **Geographic Data View Dialog**

Case is
Texas7K_SShuntGDV

Geographic Data View Customization Dialog



The first step is to select a map; usually I just use a North American one I've pre-built (**NorthAmerica_BlankLight.pwd**)

Select a Style and text to show

Geographic Data View Customization Dialog

Select Online for Geographic Data Addition

Open Onelines with Map Projections

Browse to Open an Existing One-line... Create an Empty Online Create Online with Geographic Borders

Note, the use of geographic data views requires both that the online have a map projection and that the objects have geographic coordinates. Map projections are added to one-lines using the Online Display Options, Geography/Coordinate page.

Object and Field Display Option Sets

Style Name Shunt_SSNMVR Change Linked Style Rename Style Create New Style

Object Type Shunt Load Styles from Auxiliary Save All Styles to Auxiliary

General Display Options Fields and Attributes Display Attributes Linked Objects Line Summary Objects Pseudo-Geographic Mosaic Display Pruning Auto Layout

Style

☒ Rectangle ☐ Kite ☐ Rounded Rectangle ☐ Arrows ☐ Oval ☐ Line Segment ☐ Triangle

Selection Options

☐ Can Be Selected

Line Thickness 1

Line Color

Animation Control

☐ Enable Animation

Interval (Milli-seconds) 101

☒ Use GDV Objects on Contours

GDV Summary Object Options

Object Type to Insert

☒ Individual Object GDVs ☐ Summary Objects by Lat/Long ☐ Summary Objects by Custom Int 1

Grid Count, X (Longitude) 20

Grid Count, Y (Latitude) 20

Object Center

☒ Grid Cell ☐ Object Avg.

Default Data Type

☒ Sum ☐ Avg. Abs. Values ☐ Maximum ☐ Abs. Value Sum ☐ Minimum ☐ Max Abs with Sign ☐ Average ☐ Min. Abs, No Zero ☐ Count

GDV Line Flow Summary Objects (GLSOs)

☐ Automatically Include Line Flow Summary Objects

☒ Insert Planar GLSOs GLSO Count 0

Show Line Flow Summary Options and List Dialog

Update GDV Summary Objects Update GLSOs Delete All GLSOs

First Line Second Line Third Line

Relative Line Size 1.0

☐ Prefix ID with Object Type Set Font...

Text to Show

☒ Name ☐ None ☐ Number ☐ Field Value ☐ Name (Number) ☐ Sparkline ☐ Number (Name)

Suffix Text Prefix Text

Add Geographic Data View Objects to Online and Close Dialog Save Style Changes Cancel Help

Geographic Data View Customization Dialog



Many different customizations are possible

Geographic Data View Style Options

Object and Field Display Option Sets

Style Name: Shunt_SSNMVR Change Linked Style Rename Style

Object Type: Shunt View Different Style Load Styles from Auxiliary Save All Styles to Auxiliary

General Display Options | Fields and Attributes | Display Attributes | Linked Objects | Line Summary Objects | Pseudo-Geographic Mosaic Display | Pruning | Au

Attribute	Default for Attribute	Use	Field Lookup
Line Thickness	4	☐	Mvar\Mvar (nominal) Find...
Line Thickness Summary Object Data Type		Style Default	
Line Color	Change	☒	Online (Integer) Find...
Line Color Summary Object Data Type		Style Default	
Fill Color	☒ Change	☒	Voltage\Per Unit Ma Find...
Fill Color Summary Object Data Type		Style Default	
☒ Use Auto Width of Objects		☐ Scale Size, Not Total Area	
Total Area	Width: 103.484	☒	Mvar\Mvar (nominal) Find...
Size to Width Ratio: 0.500		☐ Kite Shape Only Find...	
Area Summary Object Data Type		Style Default	
Rotation Angle	0.0 (Degrees)	☐	Mvar\Mvar (nominal) Find...
Rotation Angle Summary Object Data Type		Style Default	
Rotation Rate	0.0 (Hz)	☐	Mvar\Mvar (nominal) Find...
Rotation Rate Summary Object Data Type		Style Default	

Fill Color Lookup

Field Set Metrics

Min: 1.0189 Median: 1.0556

Max: 1.0922 Average: 1.0389

Color Map

Discrete 21 Red/Blue

☐ Reverse Color Map Colors

☐ Use Discrete Color Map

Darker Normal Lighter

☐ Use absolute value ☐ Ignore Zero Values

Maximum: 1.05

Break High: 304.59

Nominal: 1.00

Break Low: 65.18

Minimum: 0.95

Set Breakpoints from Metrics

Add New Color Map

☐ Draw Color Key

Color Key Title: Voltage

Color Key Units: PU

Decimal Points: 2 Scalar 1.000

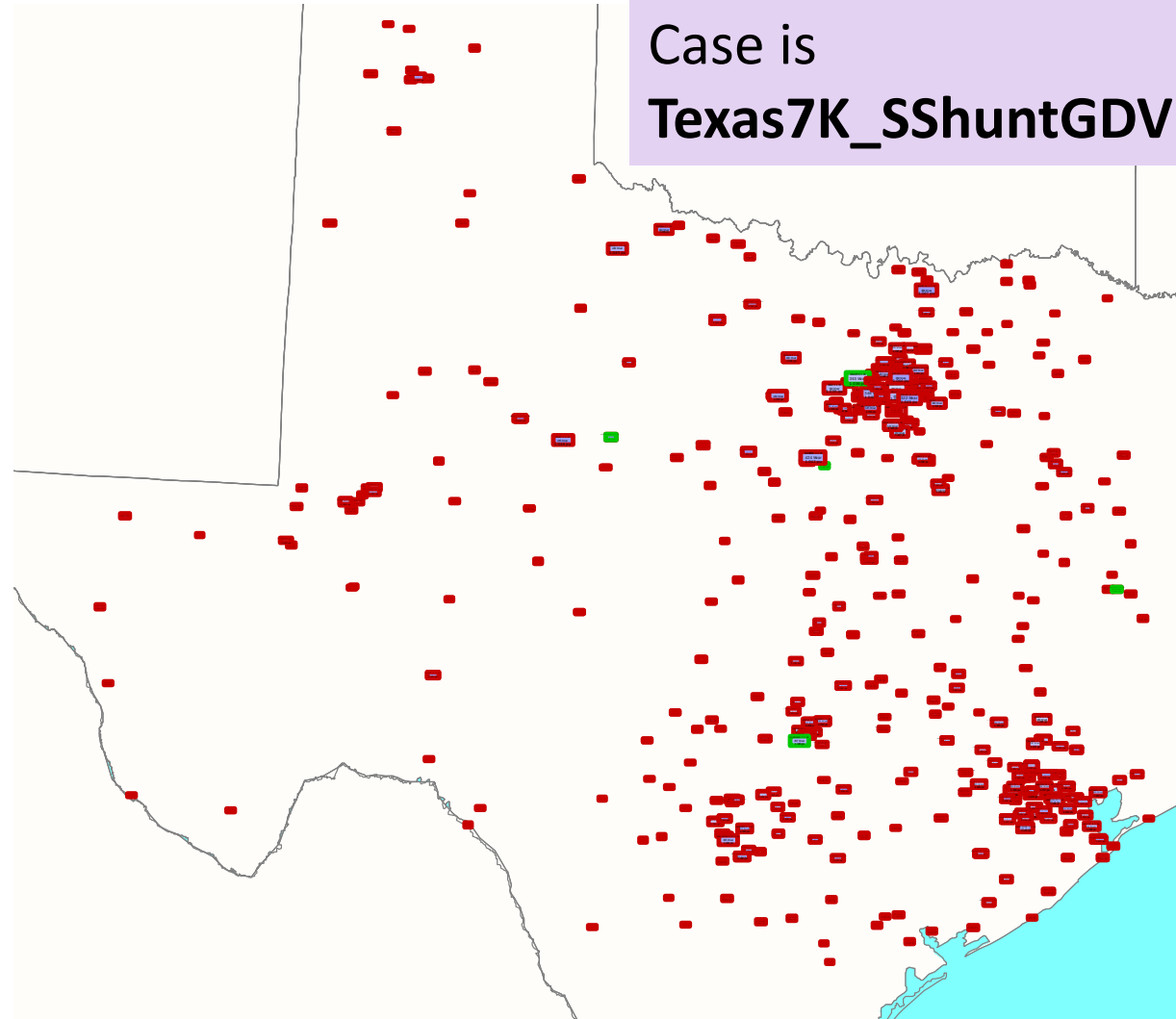
OK Save Style Changes Cancel Help

GDV Visualization



All the GDVs are linked to provide quick access either to the object's dialog, bus information, or the GDV Customization Dialog

Case is
Texas7K_SShuntGDV





Addressing GDV Overlap



- An obvious problem with trying to show lots of GDVs on a display is overlap. There are four approaches for addressing this
 - Manually move the objects, then store the *.pwd. This works if there are not too many or there is a desire to have a particular layout
 - Use the Pseudo-Geographic Mosaic Display (PGMD) functionality (covered next)
 - Use a force-based layout
 - Use GDV summary objects

Pseudo-Geographic Mosaic Displays



- The idea of a PGMD is to maximize screen space, trading off geographic accuracy
- The PGMDs are meant to be temporary
- A paper covering this is on my website (overbye.engr.tamu.edu/publications/) in 2019, paper 3

Wide-Area Electric Grid Visualization Using Pseudo-Geographic Mosaic Displays

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Abstract—This paper introduces a new technique for wide-area visualization of information about electric power grids known as a pseudo-geographic mosaic displays (PGMDs). The PGMD approach uses dynamically created geographic data view (GDV) objects to show information about the attributes of different electric grid objects, and then arranges them on the screen to maximize the used display space. The paper presents the PGMD algorithm and then discusses design approaches to maximize their usability. Results are presented for several large-scale electric grids.

Index Terms—power grid visualization, wide-area transmission visualization, interactive control, mosaic displays, treemaps

I. INTRODUCTION

The design and operation of large-scale electric grids requires the use of models with many thousands of buses, and results in the creation of large amounts of data. Electric power system visualization helps the human users make sense of all this information. Over the last several decades good progress has been made in this area. For example, about twenty

an operator in a control center or an engineer doing a study, with the pertinent information about the state of the electric grid without excessive extraneous clutter. Techniques that have been utilized on such displays include the use of color contours for data such as bus voltage magnitudes [1], [2] and locational marginal prices [3], the use of dynamically sized system elements such as pie charts to indicate transmission line loading [4] (taking advantage of preattentive processing [5, pp.152-161]), and for some applications animated transmission flows [6]. The use of interactive 3D for power system visualization was presented in [7], though it is not currently widely used. Animation of time-varying power system information is discussed in [8] and [9], [10] presents some approaches for showing electric grid structure, while [11] and [12] show some approaches for showing electric grid dynamics information.

Usually wide-area electric grid information is conveyed using either a geographic or a pseudo-geographic approach, often utilizing a power system one-line diagram. In the geo-

Pseudo-Geographic Mosaic Displays



- To show the PGMD, right click on any GDV and then select **View Geographic Data View Options**, then select the **Pseudo-Geographic Mosaic Display** tab, then click on **Apply or Update Mosaic View**

General Display Options | Fields and Attributes | Display Attributes | Linked Objects | Line Summary Objects | **Pseudo-Geographic Mosaic Display** | Pruning | Au

Layout

Display Rows to Columns Ratio: 3.0

Left/Right Margin (Percent): 2.0

Top/Bottom Margin (Percent): 2.0

Image Display Center and Extent

Image Center Options

☒ Design Time Screen Center

☐ GDV Object Center

☐ Custom Center

☐ Always Screen Center

Current GDV X Center: 20591.000

Current GDV Y Center: 11454.678

Custom X Center: 20847.999

Custom Y Center: 12356.593

Image Extent on Screen at Design

☒ Screen ☐ GDV Area

☒ Allow Image to be Zoomed

Placement Sort Y Bias: 0.00

Metric Area Value Full Screen Scaling

Full Screen Area Based on:

☒ Current Metric Value ☐ Custom Base Metric Value

Current Metric Value: 628658.950

Custom Metric Value: 634000.000

Set Custom to Scale Display (Ratio of Full): 0.9916

Transition Animation

Total Animation Time (Seconds): 3.0

Total Animation Frames: 15

Maximum Transition Percent (0-100): 100.0

☐ Save Transition Images as JPEGs

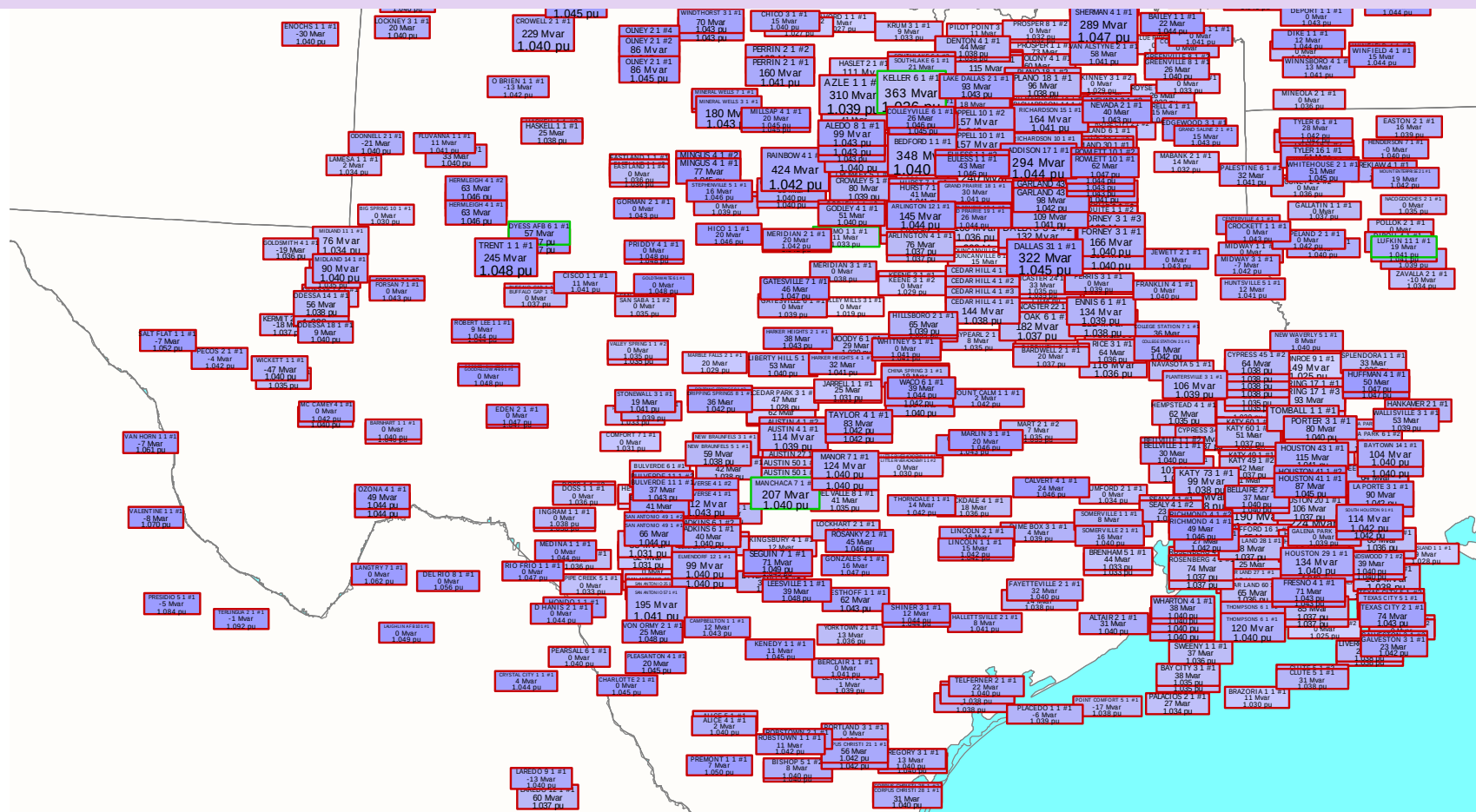
JPEG Quality (1-100): 50

Base Image Name: GDVTransition

Buttons: Apply or Update Mosaic View, Restore From Mosaic View

Example uses case
Texas7K_SShuntGDV

The PGMD method moves the objects to fill the entire display; this image shows them partially transitioned.



[illegible]

GDV Force-Based Layout



- There is now functionality to apply a force-based layout algorithm to the GDVs
 - This can be used with any GDV display
- This algorithm could be better optimized from a computational perspective, but it does work fairly well even with larger number of GDVs
- This functionality will be introduced by an example using the 634 switched shunt display from the 7000 bus system
- On the **Geographic Data View Options** select the **Auto Layout Tab**

Auto Layout Page



- The layout uses a Coulomb force to push the GDVs apart, with each GDV anchored to its starting (Base) value using a linear spring force
- The **Layout Options** allow customization of these force values
- Select **Do Layout** to do the layout
- Base values stay the same until changed by **Set Present XY to Values to Base**

Geographic Data View Style Options

Object and Field Display Option Sets
 Style Name:
 Object Type:

Fields and Attributes | Display Attributes | Linked Objects | Line Summary Objects | Pseudo-Geographic Mosaic Display | Pruning | **Auto Layout**

Layout Options

Relative Attraction Force to Starting Point:
 Relative Starting Point Sticking Force:
 Relative Expulsion Force:
 Change Per Iteration Scalar:
 Maximum Iterations:
 Distance Change Tolerance:

Options to Limit Number of Neighbors

☐ None (include all)
☒ Limit by Maximum Object Size * Multiplier
☐ Treat Multiplier as Radius

Number of Neighbors Multiplier:
 Maximum number of neighbors:
 Update Display Every N Iterations:

Forbidden Regions (e.g., water)

☐ Use Forbidden Region Based on Color
 Forbidden Region Color 1:
 Forbidden Region Color 2:
 Region Size Multiplier:
 Region Resolution Multiplier:

Layout Results

Number Moveable Objects: Average Object Neighbors: Total Change X:
 Number Nonmoveable Objects: Total Iterations: Total Change Y:
 Solution Time Seconds:
 Percent Forbidden:

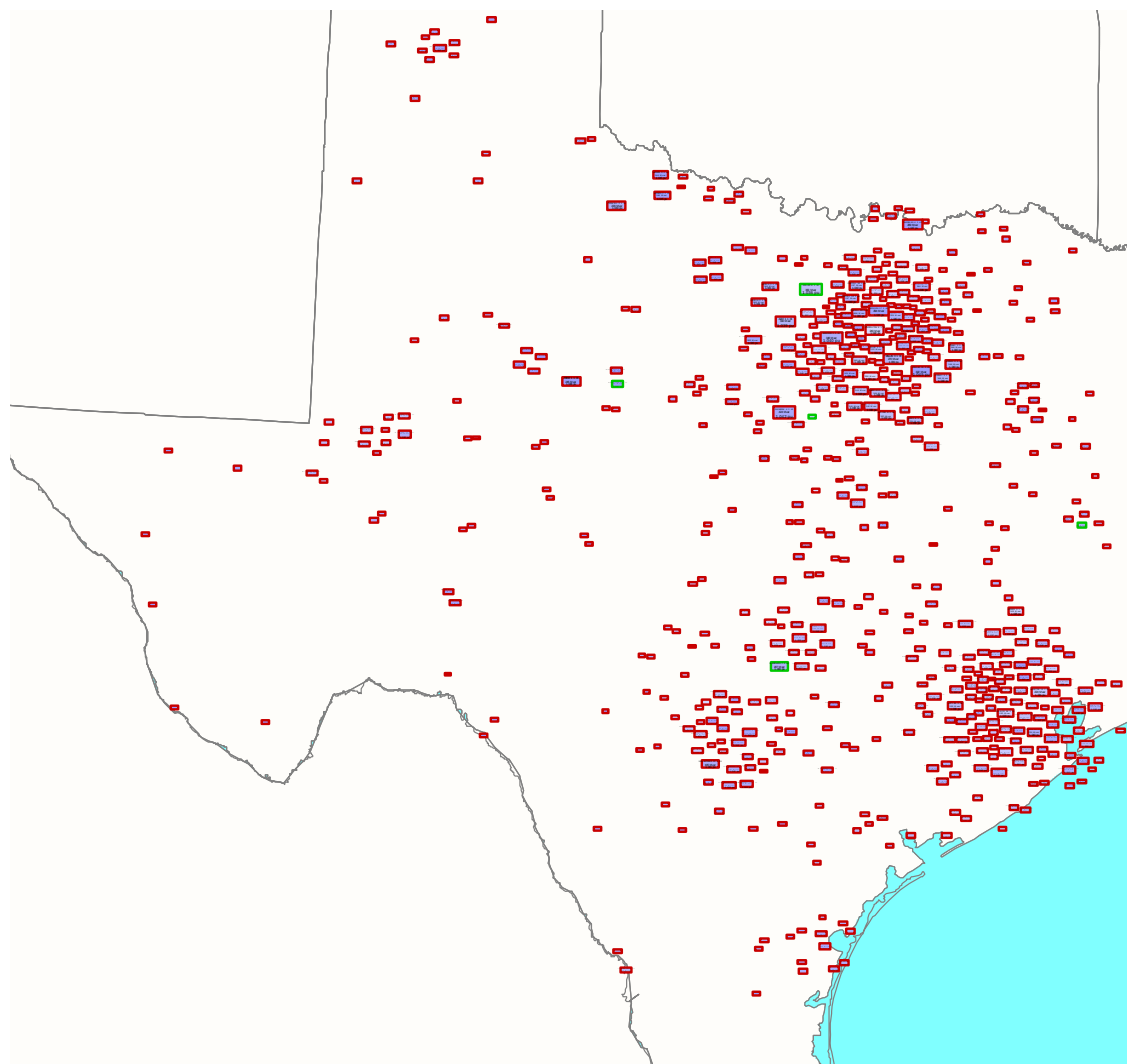
	Number of Bus	ID	Online (Integer)	PU Volt of Bus	Nominal Mvar	Name_Nominal kV of Bus	Hidden	Fixed	Moveable	Base X	Base Y
1	210221	1	1	1.02	0.00	VALLEY MILLS	NO	NO	YES	20536.3954	11719.
2	170234	1	1	1.02	0.00	BLUE RIDGE 3	NO	NO	YES	21036.1916	12646.
3	120203	1	1	1.02	13.70	HELOTES 3 1	NO	NO	YES	20062.2932	10715.
4	120203	2	1	1.02	0.00	HELOTES 3 1	NO	NO	YES	20062.2932	10715.
5	130066	3	1	1.02	0.00	DUNCANVILL	NO	NO	YES	20804.2716	12321.
6	130066	1	1	1.02	207.90	DUNCANVILL	NO	NO	YES	20804.2716	12321.
7	130066	4	1	1.02	0.00	DUNCANVILL	NO	NO	YES	20804.2716	12321.
8	130066	2	1	1.02	15.40	DUNCANVILL	NO	NO	YES	20804.2716	12321.
9	130164	1	1	1.02	240.00	CARROLLTON	NO	NO	YES	20804.5805	12415.

Layout Example

No Boundary Enforcement



Image shows the result of applying the algorithm with the default values. The original GDV positions can be quickly restored by selecting **Restore to Base Values**. If the new values are acceptable select **Set Present XY to Values to Base**.



Layout Results and Boundary Enforcement



Style Options

Option Sets
MVR

Change Linked Style Rename Style

View Different Style Load Styles from Auxiliary Save All Styles to Auxiliary

Display Attributes Linked Objects Line Summary Objects Pseudo-Geographic Mosaic Display Pruning Auto Layout

Distance to Starting Point 1.00

Stiffness Force 1.00

Radius 1.00

Radius 0.200

Radius 1000

Radius 0.100

Options to Limit Number of Neighbors

☐ None (include all)

☒ Limit by Maximum Object Size * Multiplier

☐ Treat Multiplier as Radius

Number of Neighbors Multiplier 6.00

Maximum number of neighbors 100

Update Display Every N Iterations 200

Forbidden Regions (e.g., water)

☒ Use Forbidden Region Based on Color

Forbidden Region Color 1

Forbidden Region Color 2

Region Size Multiplier 1.00

Region Resolution Multiplier 1.00

Statistics

Average Object Neighbors

Total Change X

Solution Time Seconds

Objects

Total Iterations

Total Change Y

Percent Forbidden

Set Present XY Values to Base

Do Layout

ID	Online (Integer)	PU Volt of Bus	Nominal Mvar	Name_Nomin kV of Bus	Hidden	Fixed	Moveable	Base X	Base Y
	1	1.02	0.00	VALLEY MILLS	NO	NO	YES	20536.3954	11719.805
	1	1.02	0.00	BLUE RIDGE 3	NO	NO	YES	21036.1916	12646.805
	1	1.02	13.70	HELOTES 3 1	NO	NO	YES	20062.2932	10715.805
	1	1.02	0.00	HELOTES 3 1	NO	NO	YES	20062.2932	10715.805
	1	1.02	0.00	DUNCANVILL	NO	NO	YES	20804.2716	12321.805
	1	1.02	207.90	DUNCANVILL	NO	NO	YES	20804.2716	12321.805
	1	1.02	0.00	DUNCANVILL	NO	NO	YES	20804.2716	12321.805
	1	1.02	15.40	DUNCANVILL	NO	NO	YES	20804.2716	12321.805

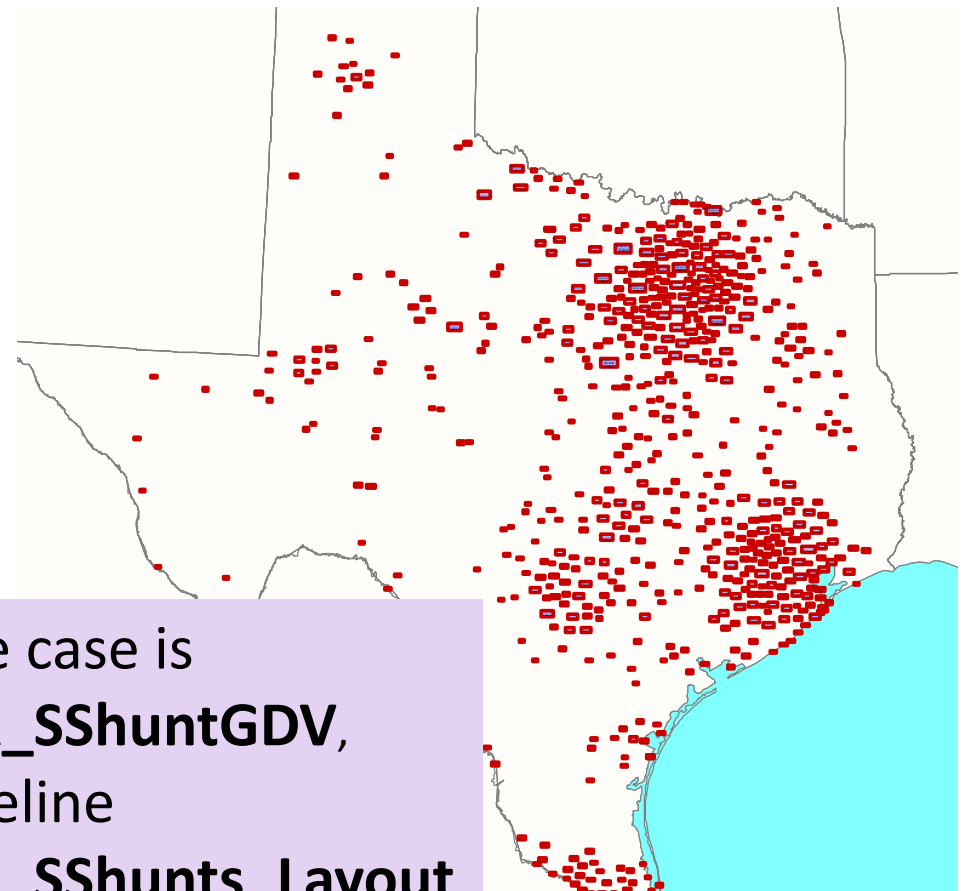
Simple boundary enforcement is implemented by preventing the GDVs to moving to screen locations with certain colors (a maximum of two colors can be enforced). This then prevents the movement of GDVs to locations with that background color.

To work correctly the entire image show be displayed

Auto Layout Page with Boundary Enforcement



- Here are the results with boundary enforcement; the relative expulsion force (Coulomb) was also increased to 2
- Note the layout took longer and actually hit a max iteration limit
 - For more iterations just again select **Do Layout**



Example case is
Texas7K_SShuntGDV,
with online
Texas7K_SShunts_Layout

GDV Layout Dialog



- Individual GDVs can also be easily fixed and hence not included in the layout; right click on the entries in the stringgrid to see the regular object dialog.

Geographic Data View Style Options

Object and Field Display Option Sets

Style Name: Substation_SubName1 Change Linked Style Rename Style

Object Type: Substation View Different Style Load Styles from Auxiliary Save All Styles to Auxiliary

General Display Options | Fields and Attributes | Display Attributes | Linked Objects | Pseudo-Geographic Mosaic Display | Pruning | Auto Layout

Layout Options

Relative Attraction Force to Starting Point: 1.00

Relative Starting Point Stickness Force: 1.00

Relative Expulsion Force: 4.00

Change Per Iteration Scalar: 0.200

Maximum Iterations: 1000

Distance Change Tolerance: 0.100

Options to Limit Number of Neighbors

☐ None (include all)

☒ Limit by Maximum Object Size * Multiplier

☐ Treat Multiplier as Radius

Number of Neighbors Multiplier: 6.00

Maximum number of neighbors: 100

Update Display Every N Iterations: 200

Forbidden Regions (e.g., water)

☒ Use Forbidden Region Based on Color

Forbidden Region Color 1:

Forbidden Region Color 2:

Region Size Multiplier: 1.00

Region Resolution Multiplier: 1.00

Layout Results

Number Moveable Objects: Average Object Neighbors: Total Change X: Solution Time Seconds:

Number Nonmoveable Objects: Total Iterations: Total Change Y: Percent Forbidden:

Reset to Base Values Present XY Values to Base Do Layout

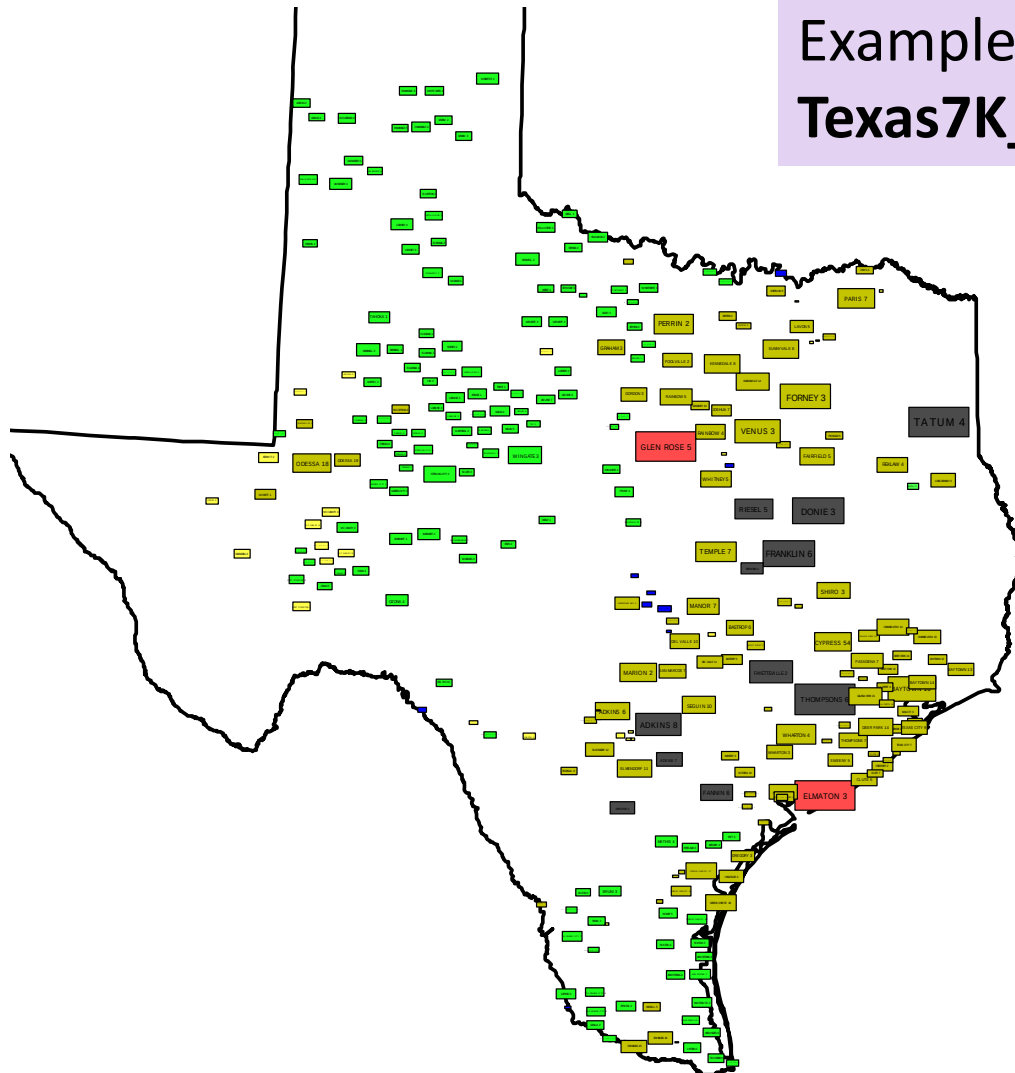
	Sub Num	Sub Name	Area Num	Fixed	Moveable	Base X	Base Y	X	Y	Change
1	1105	THOMPSONS	7	NO	YES	21335.5040	10601.0830	21198.6577	10391.2279	-13
2	968	WADSWORTH	7	NO	YES	21160.3232	10231.7185	21168.7391	10160.0939	
3	1229	MOUNT PLEA	8	NO	YES	21564.6395	12536.7571	21773.2449	12540.4453	20
4	858	ELMENDORF	6	NO	YES	20170.1804	10484.1594	20242.8401	10243.3324	7
5	1110	CHANNELVIEW	7	NO	YES	21555.0827	10781.4497	21899.9332	10668.2551	34
6	1143	ALVIN	7	NO	YES	21523.5387	10571.5774	21457.9286	10377.5313	-6
7	359	BROWNSVILLE	4	NO	YES	20522.0396	8688.8668	20522.0396	8688.8668	
8	794	SAN ANTONIO	6	NO	YES	20188.0077	10576.1978	20304.9781	10433.1033	11
9	984	LAPORTE	7	NO	YES	21575.7738	10733.7948	21654.0218	10723.5093	7

OK Save Style Changes Cancel Help

GDV Example: Generator Fuel Types



Example case is
Texas7K_Sub_GenMWFuelType



This example uses color to show the primary generator fuel type at each substation; the display uses the **Primary Generic Fuel Type Integer** field type (which goes from 1 to 16), with the IntegerA 16 Color mapping, that is set to match the fuel types.

Grouped Display Objects



- In the development of PowerWorld an early design decision was to separate the power system from its displays
 - This gave rise to the separate *.pwb and *.pwr files
- While this might seem obvious now, at the time, when PowerWorld cases were defined graphically and setup for educational purposes, the need for separate files wasn't as obvious
 - Having the displays separate did help to drive a lot of subsequent PowerWorld developments

Grouped Power System Objects



- Currently power system elements are grouped at the power system level and stored in the pwb files
 - Substations, areas, zones, superareas, owners, etc.
- GDV Summary Objects (GSOs) and GDV Line Summary Objects (GLSOs) provide a way to group objects at the *.pwd (display) level
 - With this approach multiple displays can be created with different summary groups

The Need for Summary Objects



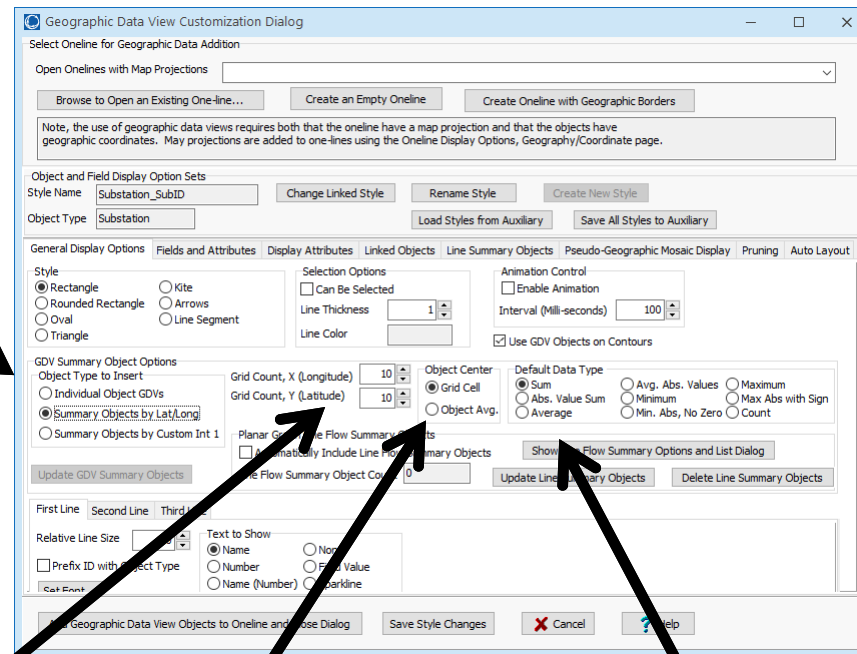
- The previous GDV displays are useful but for some purposes there are just too many individual GDVs to understand overall patterns
- A solution is to auto group the objects when the display is created.
- One way is to group them geographically using a xy grid; other more customized approaches are also available with the axds.
- The size of the grid is selected when the GDV display is created

Creating GDV Summary Objects (GSOs)



- Select the objects as normal, then on the **GDV Customization Dialog** set the **Summary Object Options**

- Currently they can be setup either by latitude and longitude, by the Custom Integer 1 field, or by axds
- Set the initial grid size



Object
center

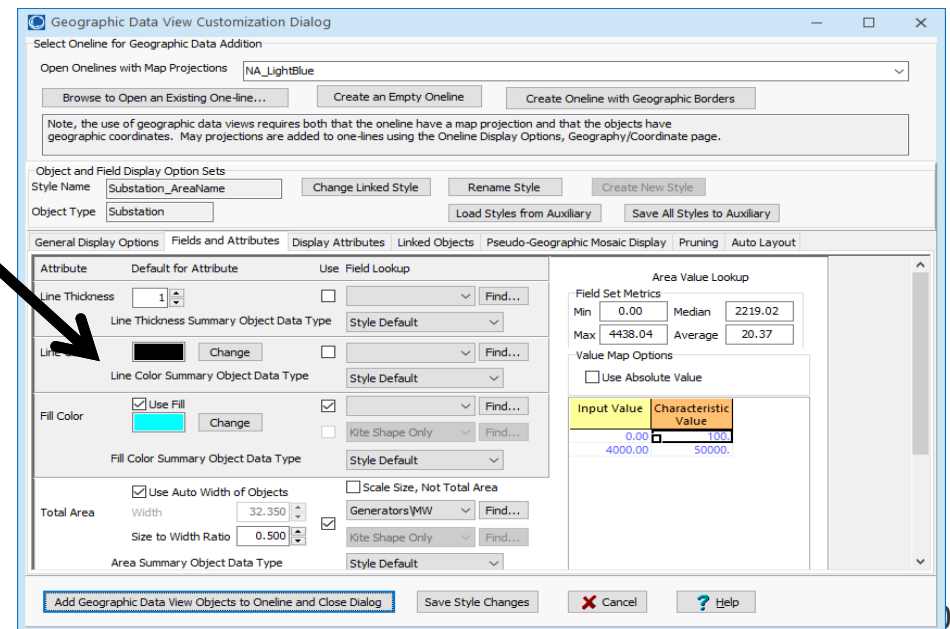
Default summary
object data type

Creating GSOs

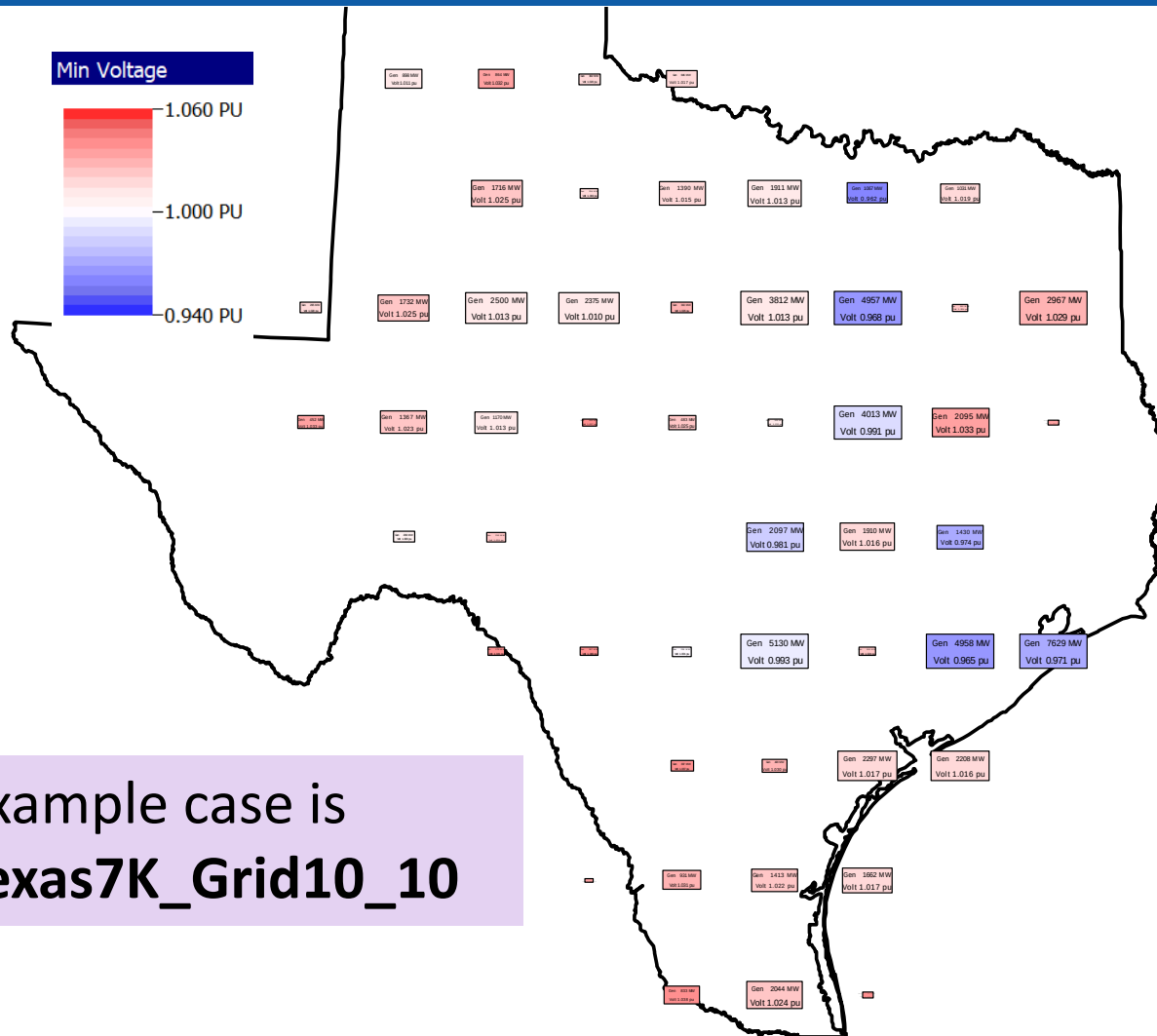


- Each GSO will summarize all the objects in its group (e.g., a geographic region)
- The display attributes are selected as for regular GDVs, with a key difference being the need to select how the field value is calculated for the GSO

– Supported values include sum, abs sum, average, minimum, maximum



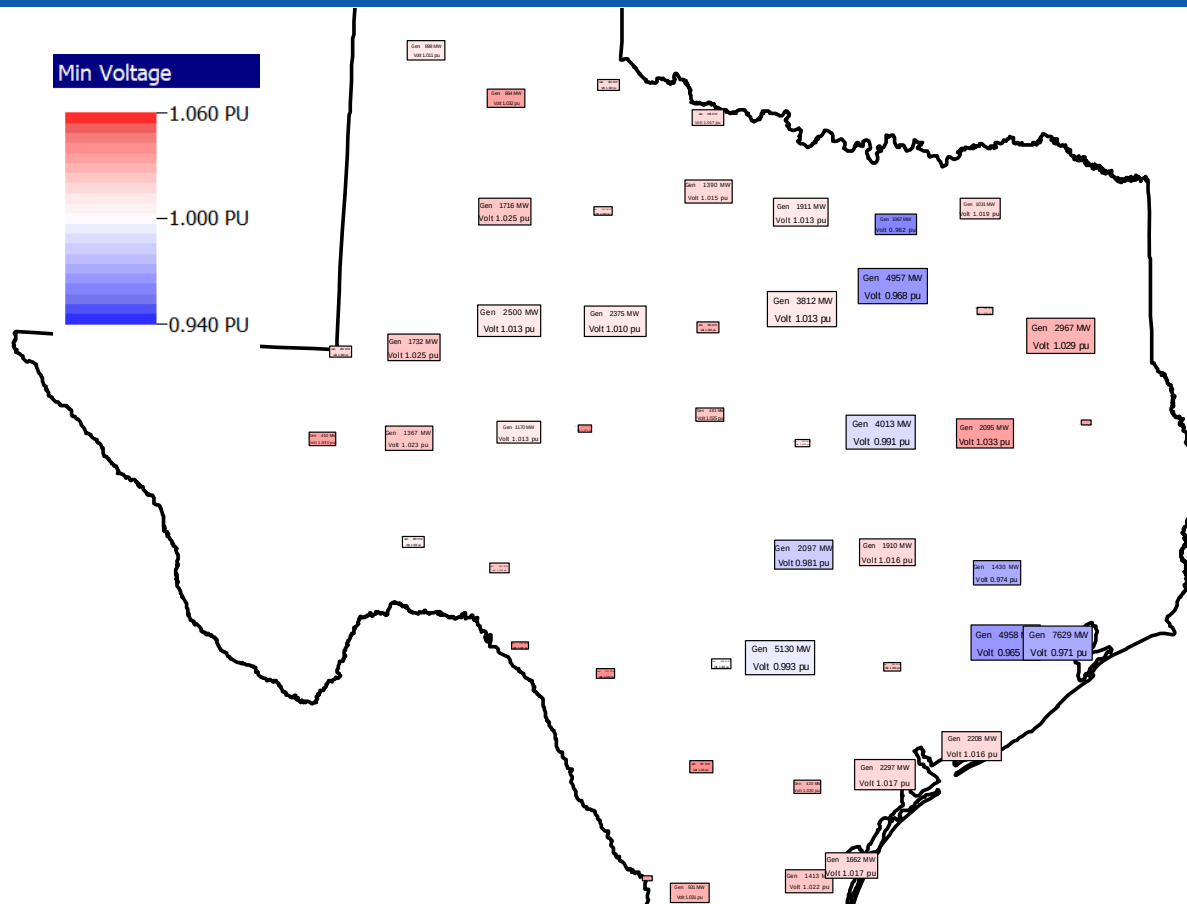
Texas 7K, 10 by 10 Grid



Example case is
Texas7K_Grid10_10

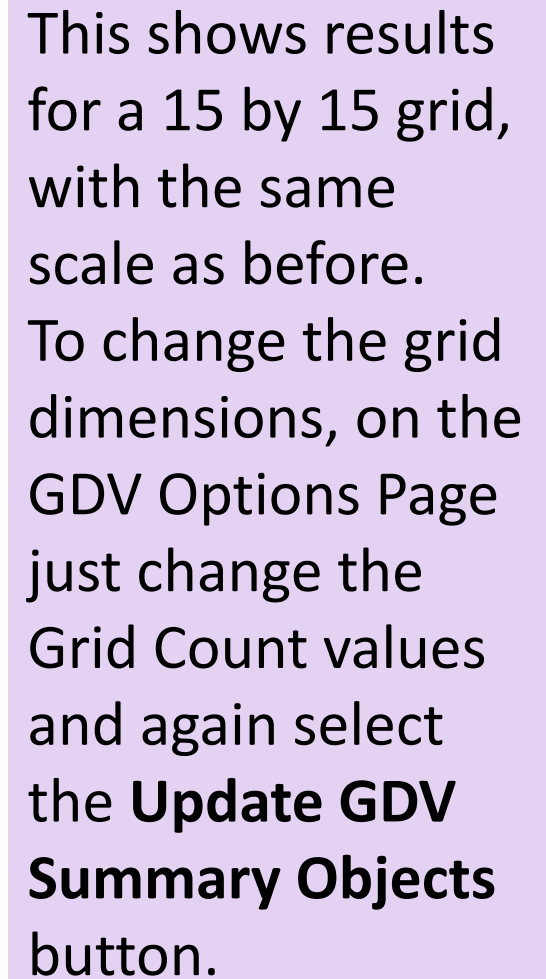
This is a 10 by 10 latitude/longitude grid with the GSO center based on the grid point. The disadvantage of this is some objects are outside the border. The size is generation, the color is the minimum voltage.

Texas 7K, 10 by 10 Grid



This is the same grid, except the GSO center is based on the average of all its elements. This approach is often preferred.

To create this display, load the **Texas7K_Grid10_10** case, then on the **GDV Style Options** change **Object Center** to Object Avg. and select **Update GDV Summary Objects**.



GDV Summary Object Dialog



- All the GSOs are linked and have an associated dialog that provides details on all its elements; in the string grid all the objects are also linked.

GDV Summary Object Dialog

Number: 109
 Name: GDV Summary 109
 Number Objects: 533
 Center Latitude: 32.86554
 Center Longitude: -96.77046
 Grid Coordinate Longitude: 11
 Grid Coordinate Latitude: 10
 Linked Object Type: Substation

Attribute Field Values (blank if not used)

	Field Name	Field Value	Type		Field Name	Field Value	Type
Area	Gen MW	3178.3699	Sum	Line Color	Area Num	2665.0000	Sum
Area 2	Area Num	2665.0000	Sum	Line Thickness	Area Num	2665.0000	Sum
Fill Color	PU Volt (min)	0.9619	Minimum	Rotation Angle	Area Num	2665.0000	Sum
Fill Color 2		0.0000		Rotation Rate	Area Num	2665.0000	Sum

	Linked Object ID	Latitude	Longitude	Type	Type Integer	Attribute Area Value	Attribute Area2 Value	Attribute FillColor Value	Attribute FillColor2 Value
1	Substation '1310'	32.6938	-96.6457	Nonline	0	0.0000	5.0000	1.0215	0.0000
2	Substation '1311'	32.6973	-96.5881	Nonline	0	0.0000	5.0000	1.0242	0.0000
3	Substation '1312'	32.6116	-96.6815	Nonline	0	0.0000	5.0000	1.0143	0.0000
4	Substation '1313'	32.6488	-96.5542	Nonline	0	0.0000	5.0000	1.0199	0.0000
5	Substation '1314'	32.6430	-96.6134	Nonline	0	0.0000	5.0000	1.0153	0.0000
6	Substation '1315'	32.6615	-96.5391	Nonline	0	0.0000	5.0000	1.0201	0.0000
7	Substation '1316'	32.6891	-96.6180	Nonline	0	0.0000	5.0000	1.0228	0.0000
8	Substation '1317'	32.7837	-96.8934	Nonline	0	0.0000	5.0000	1.0070	0.0000
9	Substation '1318'	32.7030	-96.8934	Nonline	0	0.0000	5.0000	1.0033	0.0000
10	Substation '1319'	32.7588	-96.8332	Nonline	0	0.0000	5.0000	1.0157	0.0000
11	Substation '1320'	32.8081	-96.8765	Nonline	0	0.0000	5.0000	1.0402	0.0000

OK Cancel

GDV Summary Data Types



- How the object values should be summarized depends on the field type
 - E.g., sum, average, minimum, maximum
- The **Default Data Type** provides a default object

Geographic Data View Style Options

Object and Field Display Option Sets

Style Name:

Object Type:

General Display Options | Fields and Attributes | Display Attributes | Linked Objects | **Line Summary Objects** | Pseudo-Geographic Mosaic Display | Pruning |

Style

☒ Rectangle ☐ Kite
☐ Rounded Rectangle ☐ Arrows
☐ Oval ☐ Line Segment
☐ Triangle

Selection Options

☐ Can Be Selected
Line Thickness:
Line Color:

Animation Control

☐ Enable Animation
Interval (Milli-seconds):

☐ Use GDV Objects on Contours

GDV Summary Object Options

Object Type to Insert

☐ Individual Object GDVs
☒ Summary Objects by Lat/Long

Grid Count, X (Longitude):
Grid Count, Y (Latitude):

Object Center

☒ Grid Cell
☐ Object Avg.

Default Data Type

☒ Sum ☐ Avg. Abs. Values ☐ Maximum
☐ Abs. Value Sum ☐ Minimum ☐ Max Abs with Sign
☐ Average ☐ Min. Abs, No Zero ☐ Count

GDV Summary Data Types



- The Default Data Type can be overridden for individual attributes

General Display Options Fields and Attributes Display Attributes Linked Objects Line Summary Objects Pseudo-Color

Attribute	Default for Attribute	Use Field Lookup
Line Thickness	1	☐ Area Num Find...
Line Thickness Summary Object Data Type		Style Default
Line Color	Change	☐ Area Num Find...
Line Color Summary Object Data Type		Style Default
Fill Color	☒ Use Fill Change	☒ Voltage PU Volt (min Find...
Fill Color Summary Object Data Type		☐ Kite Shape Only Find...
		Minimum
Total Area	☒ Use Auto Width of Objects	☐ Scale Size, Not Total Area
Width	264.993	Generators MW Find...
Size to Width Ratio	0.500	Kite Shape Only Find...
Area Summary Object Data Type		Style Default

Field Set Metrics

Min 0.9619

Max 1.0921

Color Map

Discrete 21 Red

☒ Reverse Color

☒ Use Discrete Color Map

Darker Normal Lighter

☐ Use absolute value ☐ Ignore Zero Values

Maximum 1.06

Break High 0.00

Nominal 1.00

Break Low 0.00

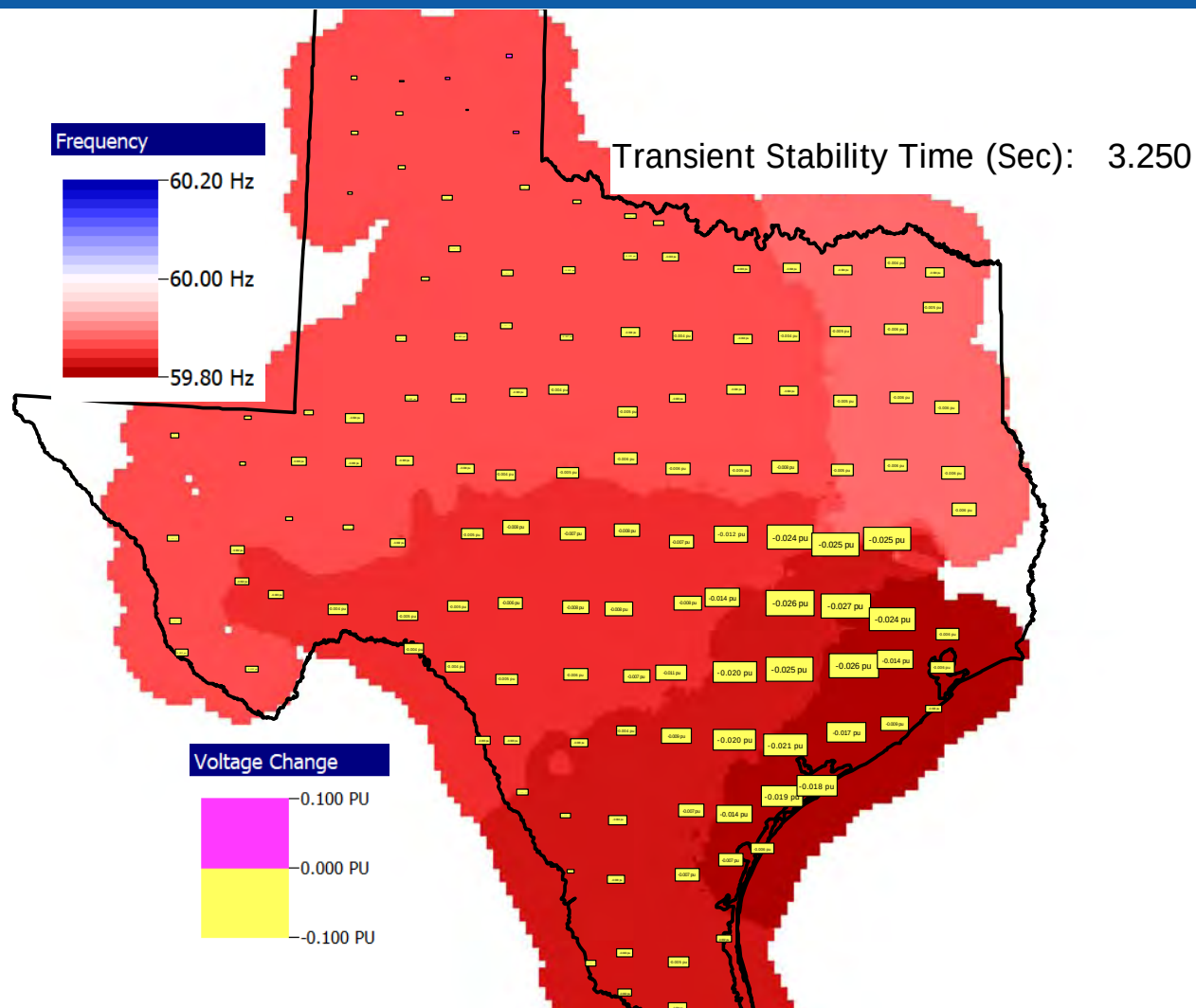
Minimum 0.94

Example Stability Application



- One useful application is to combine a GSO display with a GDV contour. This can be useful for showing two separate values, such as bus frequency and voltage magnitude
- The next slides shows an example for the Texas 7K case in which the previous 15 by 15 grid is combined with a contour is created by having small GDVs for all the grid substations
 - The example shows how it can be used with stability results, either the actual values or the deviation from initial

Example Stability Application



Result is for a time-domain stability simulation in which the goal is to show the frequency with a contour and the largest voltage deviations using GSOs (with the GSO size and color based on the voltage variation)



Aside: Storing Stability Power Flow States



- During a stability simulation (i.e., what PowerWorld has called Transient Stability), there has long been the ability to pause the simulation and transfer the results to the power flow
- Version 22 adds the ability to save and restore these time-varying power flow states. This allows the solutions to be easily examined and visualized
 - This supplements, and to some extent replaces, the **Transient Stability Contour Toolbar**

Aside: Storing Stability Power Flow States

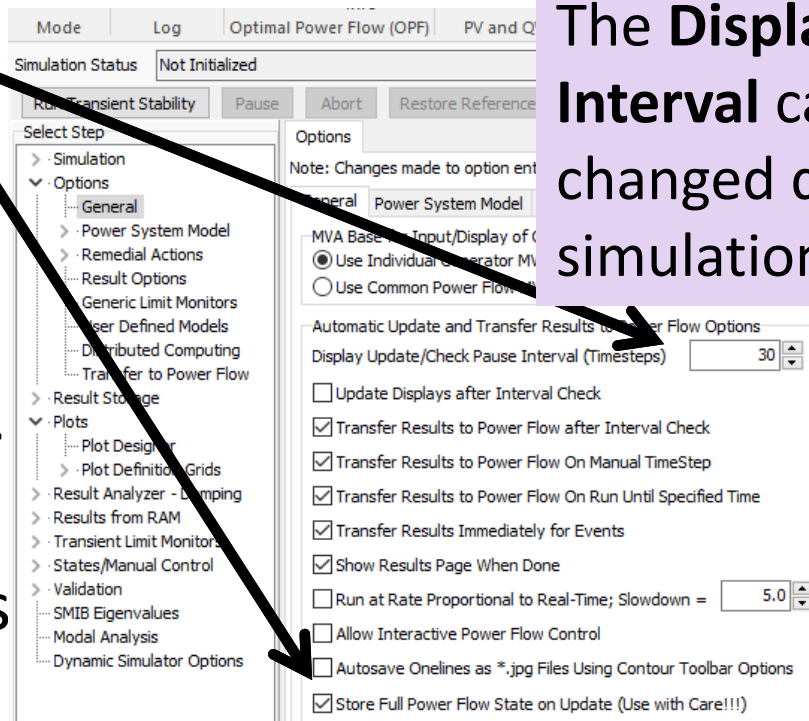


- To save the power flow states, on the **Transient Stability, Options, General** page check the **Store Full Power Flow State on Update** field

- This stores the Power Flow State at the **Display**

Update Interval
with the *.pwb

- Memory usage is about 70 bytes per bus per time (e.g. a 20K grid, for 30 seconds at 20 times per second is 840 Mb)



The **Display Update Interval** can be changed during the simulation.

Aside: Storing Stability

Power Flow States

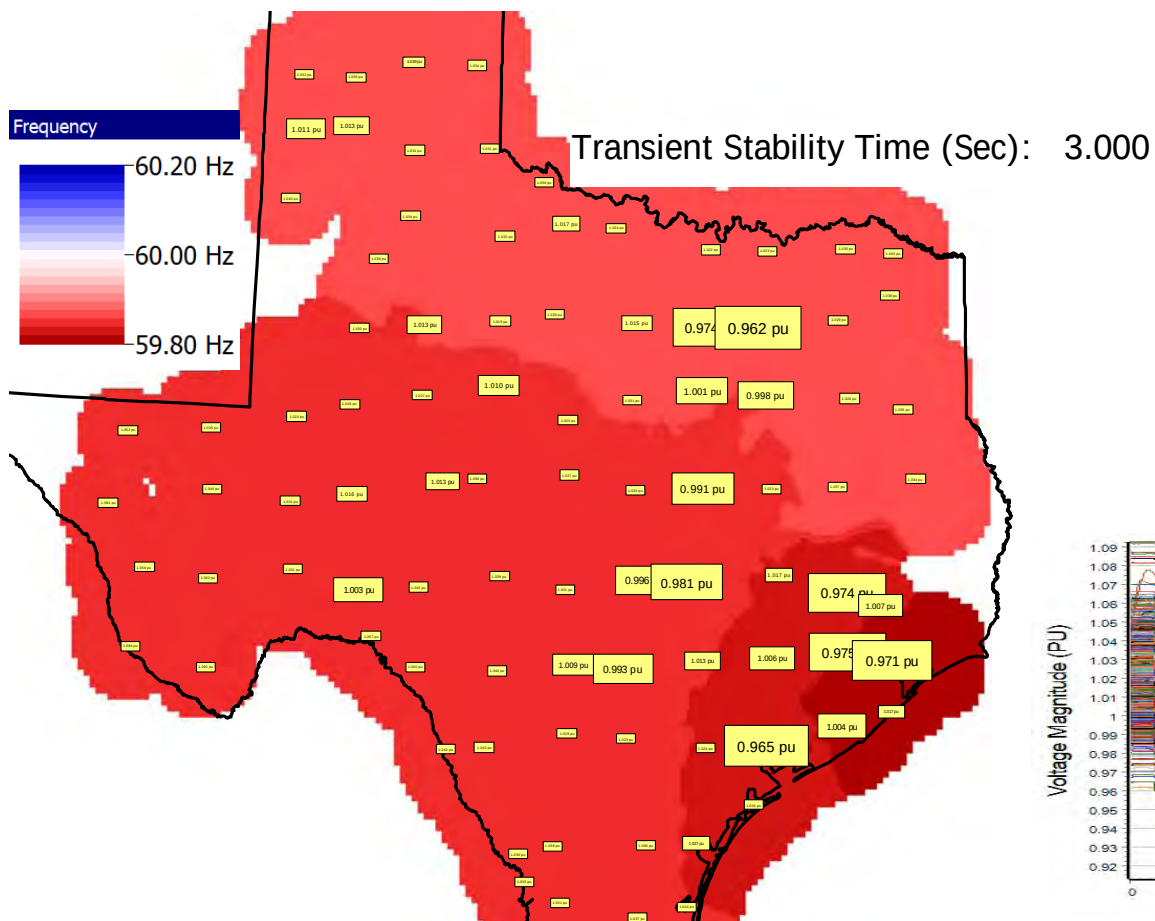


- The stored states are available at **Results From RAM, Power Flow States**
 - Right click and select **Transfer State to Power Flow** to transfer an individual time point
 - Select **Show Power Flow Transfer Control Dialog** to automatically transfer the states (useful for making movies since there is an option to store each timepoint as a jpeg).
- From a visualization perspective, the stored power flow states make it very easy to test different visualizations

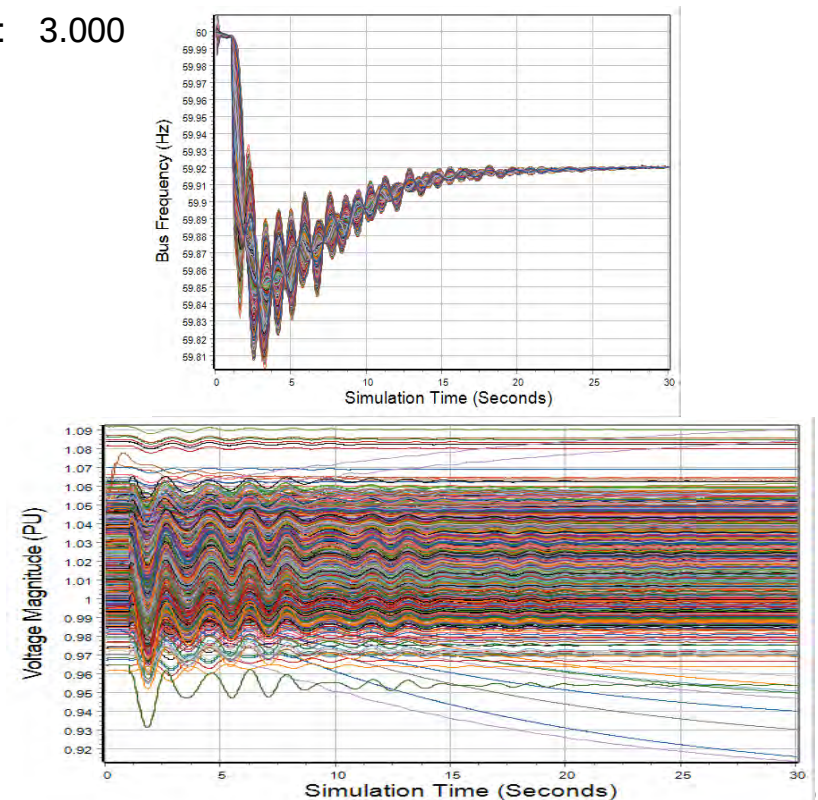
Example Stability Application



- Image combines a substation GDV frequency contour with GSOs showing the min voltage



Case is **Texas7K_Stability**

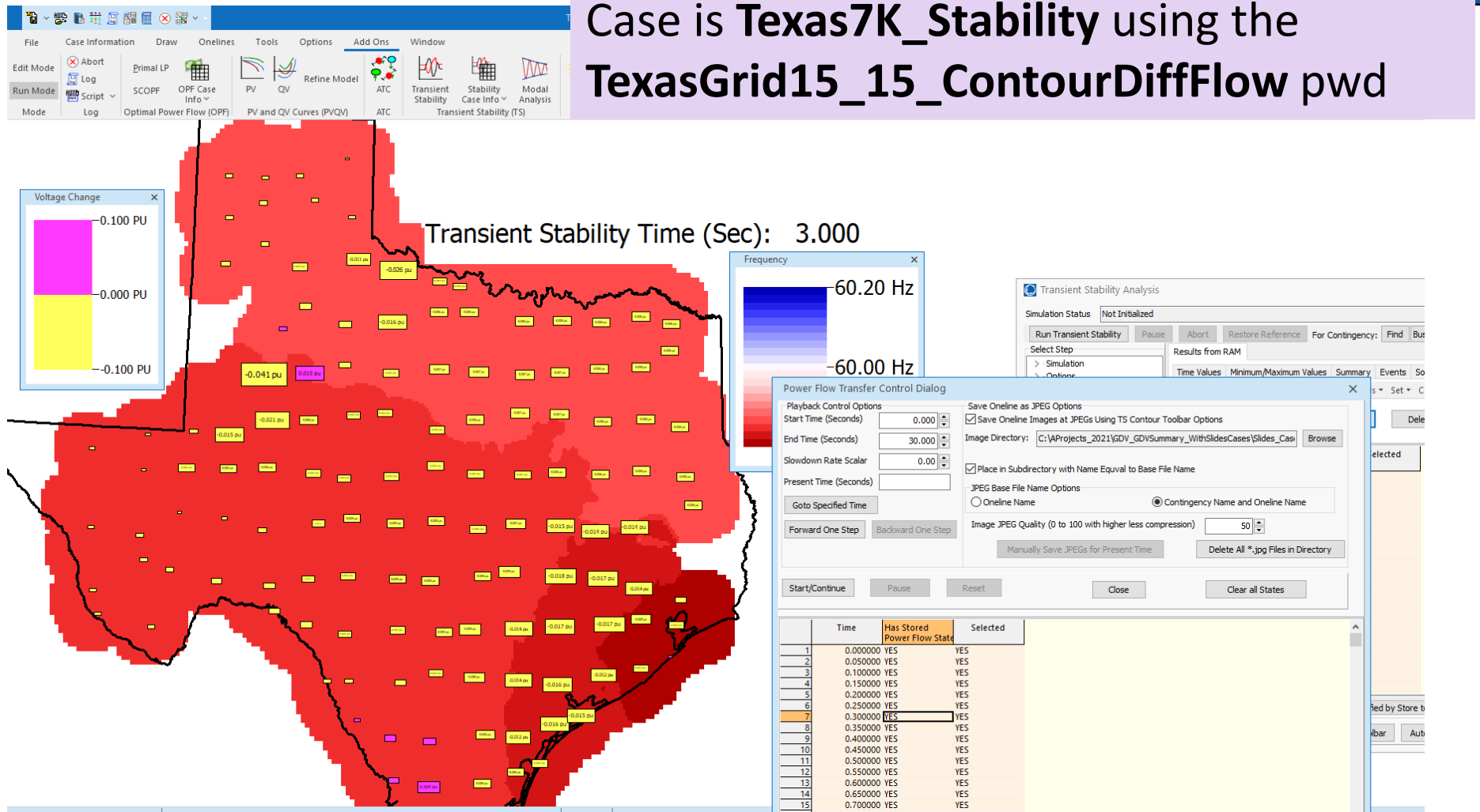


Example Stability Application



- With stability sometimes it is best to display the deviation from the initial values; this is done by using the **Tools, Difference Case**
 - Set the starting time power flow as Base, then visualize using the **Difference Mode**
 - Of course the ranges on the fields of interest need to be changed (such as showing the maximum absolute value of the voltage difference)
 - The visualizations should be made keeping the Transient Stability Form open; movies can be made using the **Power Flow Transfer Control Dialog**

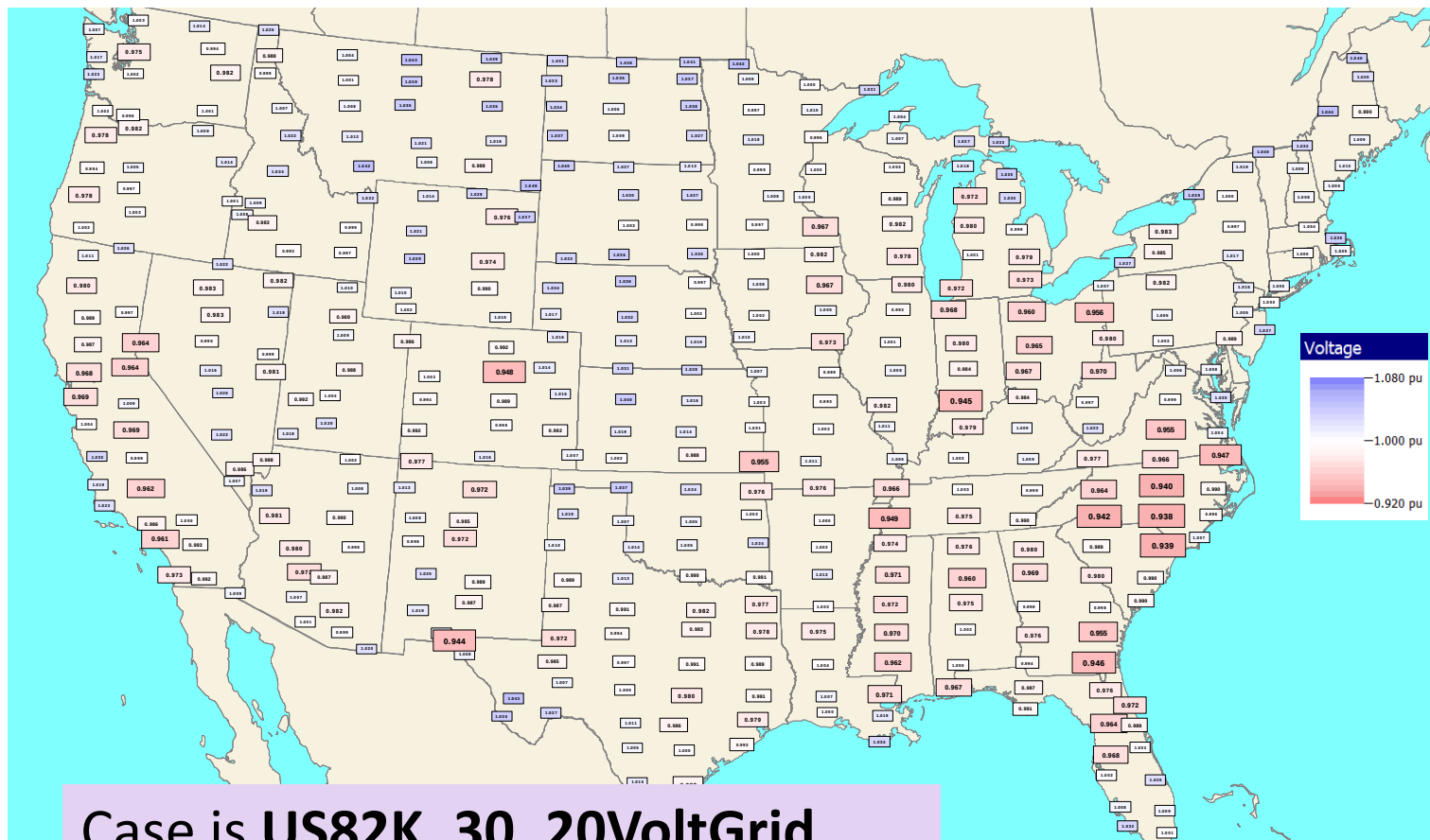
Example Stability Application



GDV Summary Display Example with a 30 by 20 Grid



- The image shows the minimum pu voltage variation across the 82K grid



The minimum voltage is shown using both color and size (larger is lower voltage)

Case is **US82K_30_20VoltGrid**

Previous Slide with Coarser Grid

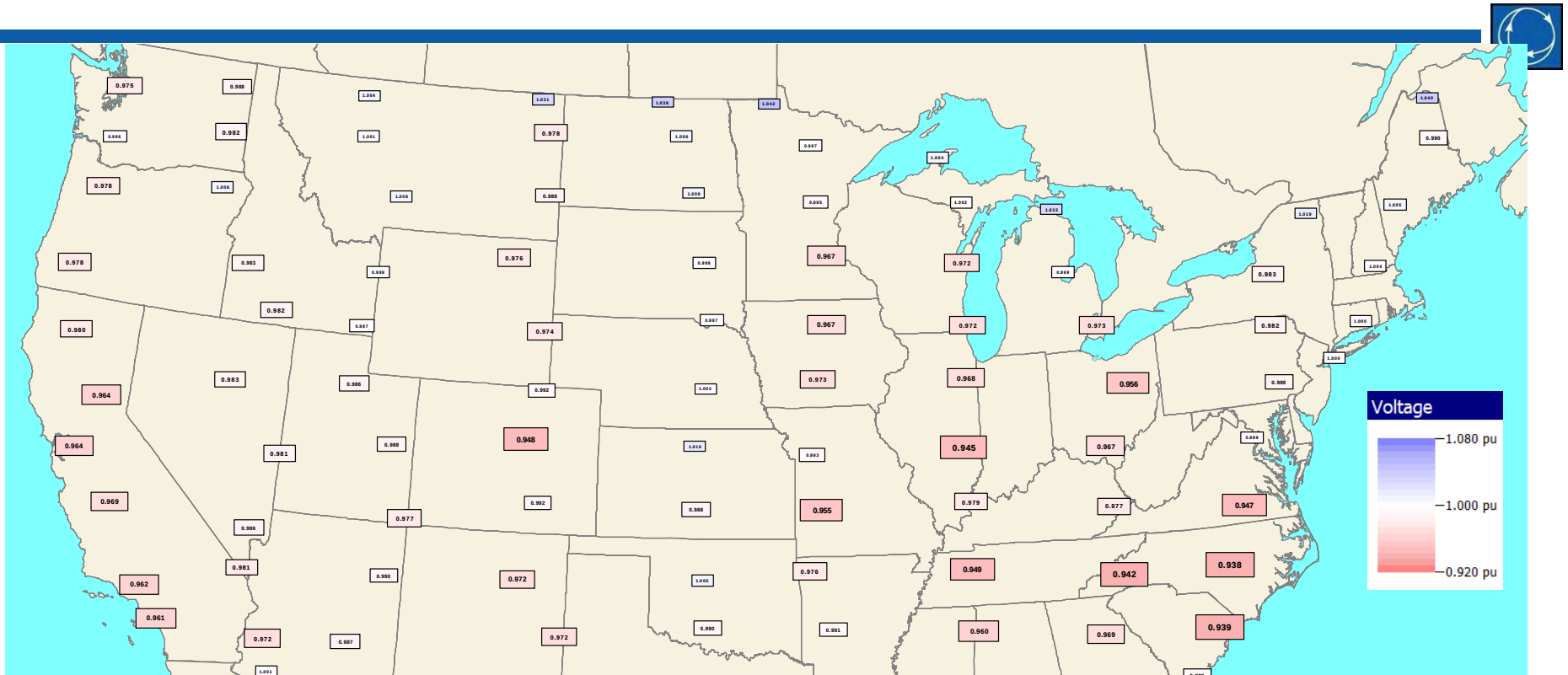


Image uses the same size scale as before, though this could be increased with the coarser grid (now 15 by 10) ; the grid can be easily using the GDV Style Options, changing the grid size and selecting **Update GDV Summary Objects**

Lines Flows and GDVs



- PowerWorld has several different ways to visualize line flows (including ac transmission lines and transformers, and dc lines)
 - These include regular online objects, case based aggregations (such as interfaces), and regular line GDVs
- To insert regular line GDVs select the line objects as normal (i.e., with the Model Explorer **Geographic Data View option**) then on the GDV form select Line Segment for the style
 - Do not show the name field

37 Bus Example of Line GDVs



Style is Line Segment

Text to Show is set to None

Geographic Data View Style Options

Object and Field Display Option Sets

Style Name:

Object Type:

General Display Options | Fields and Attributes | Display Attributes | Linked Objects | Line Summary Objects | Pseudo-Geographic Mosaic Display | Pruning | Auto |

Style:

☐ Rectangle ☐ Kite

☐ Rounded Rectangle ☐ Arrows

☐ Oval ☒ Line Segment

☐ Triangle

Selection Options

☐ Can Be Selected

Line Thickness:

Line Color:

Animation Control

☐ Enable Animation

Interval (Milli-seconds):

☒ Use GDV Objects on Contours

GDV Summary Object Options

Object Type to Insert

☒ Individual Object GDVs

☐ Summary Objects by Lat/Long

☐ Summary Objects by Custom Int 1

Grid Count, X (Longitude):

Grid Count, Y (Latitude):

Object Center

☒ Grid Cell

☐ Object Avg.

Default Data Type

☒ Sum

☐ Abs. Value Sum

☐ Average

☐ Avg. Abs. Values

☐ Minimum

☐ Min. Abs, No Zero

☐ Maximum

☐ Max Abs with Sign

☐ Count

GDV Line Flow Summary Objects (GLSOs)

☐ Automatically Include Line Flow Summary Objects

☒ Insert Planar GLSOs

GLSO Count:

First Line | Second Line | Third Line

Relative Line Size:

☐ Prefix ID with Object Type

Suffix Text: Prefix Text:

Text to Show

☐ Name

☐ Number

☐ Name (Number)

☐ Number (Name)

☒ None

☐ Field Value

☐ Sparkline

Existing Geographic Data View Objects on One-line

Count for All Styles:

Count for Selected Style:

☒ Also Delete Styles with No GDV Objects (Close Dialog if All Deleted)

37 Bus Example of Line GDVs



All the lines will be visualized using line segments with the line segment width and color parameter dependent

Geographic Data View Style Options

Object and Field Display Option Sets

Style Name:

Object Type:

General Display Options | Fields and Attributes | Display Attributes | Linked Objects | Line Summary Objects | Pseudo-Geographic Mosaic Display | Pruning | Au

Attribute	Default for Attribute	Use	Field Lookup
Line Thickness	1	☒	MW\MW (maximum) Find...
Line Thickness Summary Object Data Type		Style Default	
Line Color	<input type="color" value="black"/> Change	☒	Limit Monitoring\% c Find...
Line Color Summary Object Data Type		Style Default	
Fill Color	☒ Use Fill <input type="color" value="cyan"/> Change	☒	Amps\Amps (maximum) Find...
Fill Color Summary Object Data Type		Style Default	
Total Area	☒ Use Auto Width of Objects	☐ Scale Size, Not Total Area	Amps\Amps (maximum) Find...
Width 74.051		Amps\Amps (maximum) Find...	
Size to Width Ratio 0.500		Kite Shape Only Find...	
Area Summary Object Data Type		Style Default	
Rotation Angle	0.0 (Degrees)	☐	Amps\Amps (maximum) Find...
Rotation Angle Summary Object Data Type		Style Default	
Rotation Rate	0.0 (Hz)	☐	Amps\Amps (maximum) Find...
Rotation Rate Summary Object Data Type		Style Default	

Line Color Lookup

Field Set Metrics

Min	1.2941	Median	33.1051
Max	64.9162	Average	35.1145

Color Map

☒ Use Discrete Color Map

☐ Use absolute value ☐ Ignore Zero Values

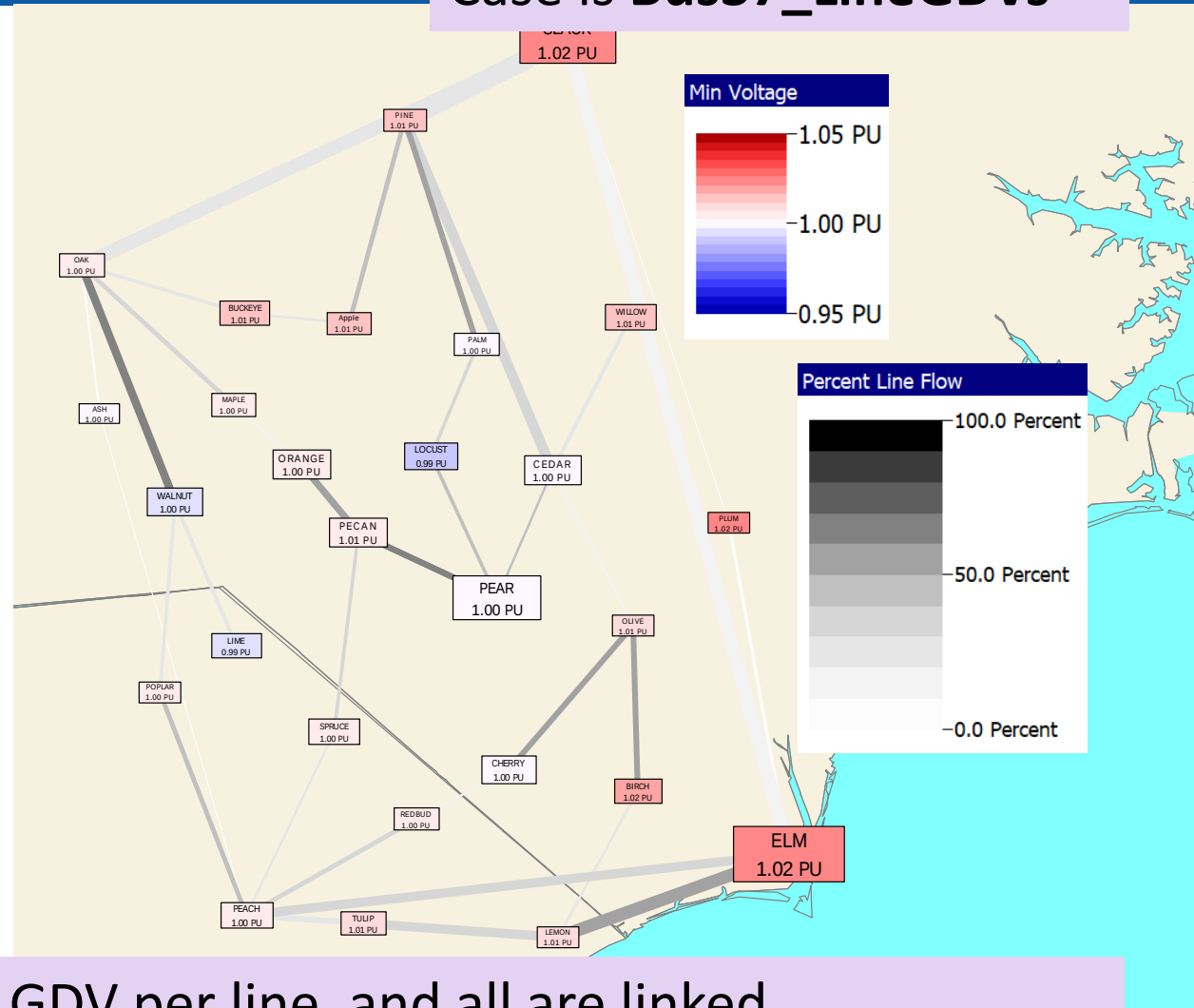
Darker Normal Lighter

Maximum Break High Nominal Break Low Minimum

☒ Draw Color Key

Color Key Title Color Key Units Decimal Points

This display shows the flow between substations GDVs; the line's color depends on its percentage loading and its width on its flow.



There is one GDV per line, and all are linked

GDV Line Summary Objects (GLSOs)



- The challenge with flow visualization is except for small cases there can be too many lines
 - Showing interface flows can help
- GLSOs can also be added to show the net flow of power between the GSOs (and actually any bus-based GDV such as substations, areas, etc.)
- The GLSOs can either be inserted automatically or by using a *.axd file
- GLSOs are always associated with a particular gdv style (and its associated objects) and can include ac and/or dc branches

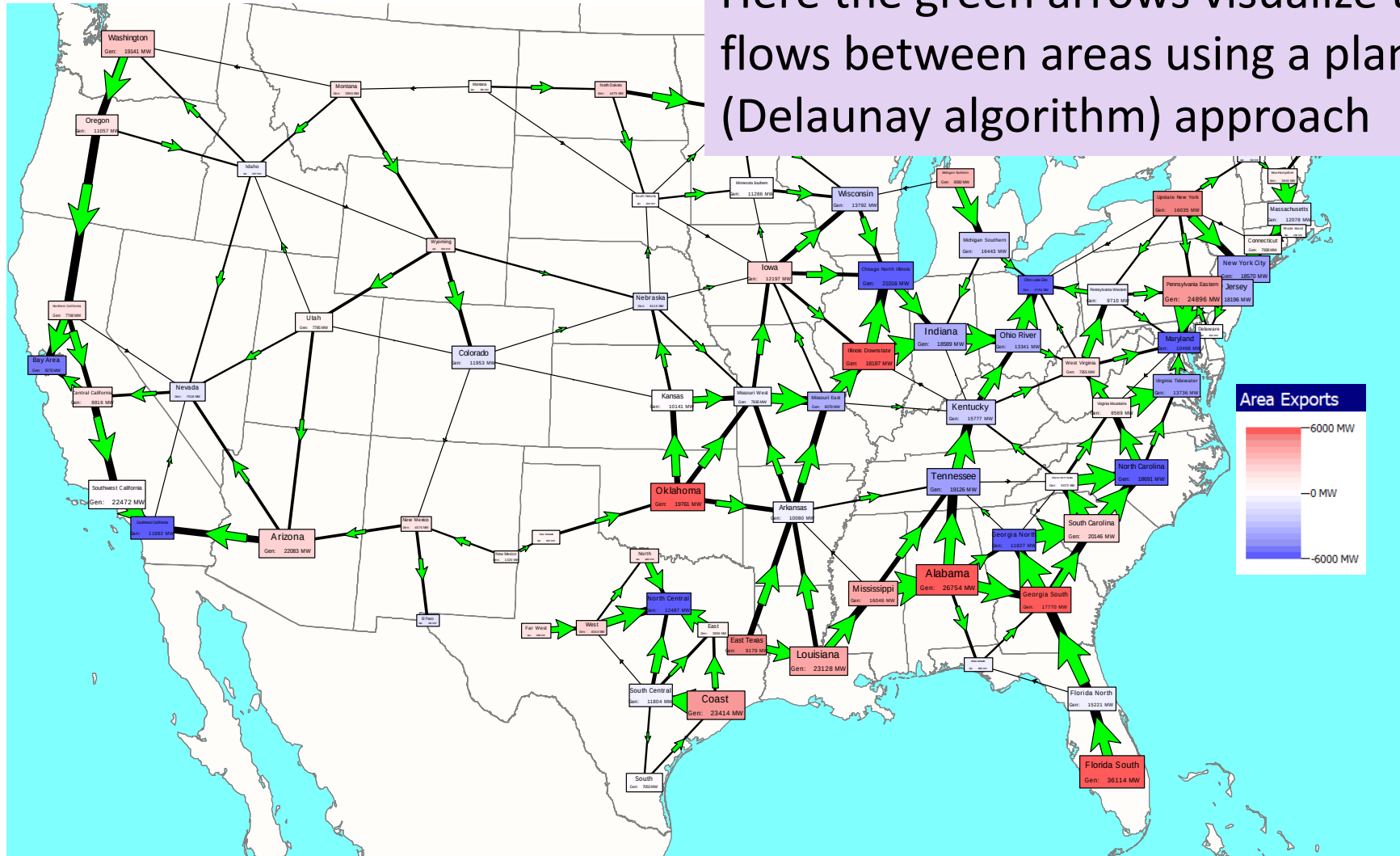
GDV Line Summary Objects (GLSOs)



- From an existing GDV display, inserting the GLSOs is simple
- As an example, open case **GDV_Example1**; view the Geographic Data View Style Options form, and select the **Update GLSOs**
 - They will be auto-inserted

A number of options are available to customize them

Here the green arrows visualize the flows between areas using a planar (Delaunay algorithm) approach



GLSO Details

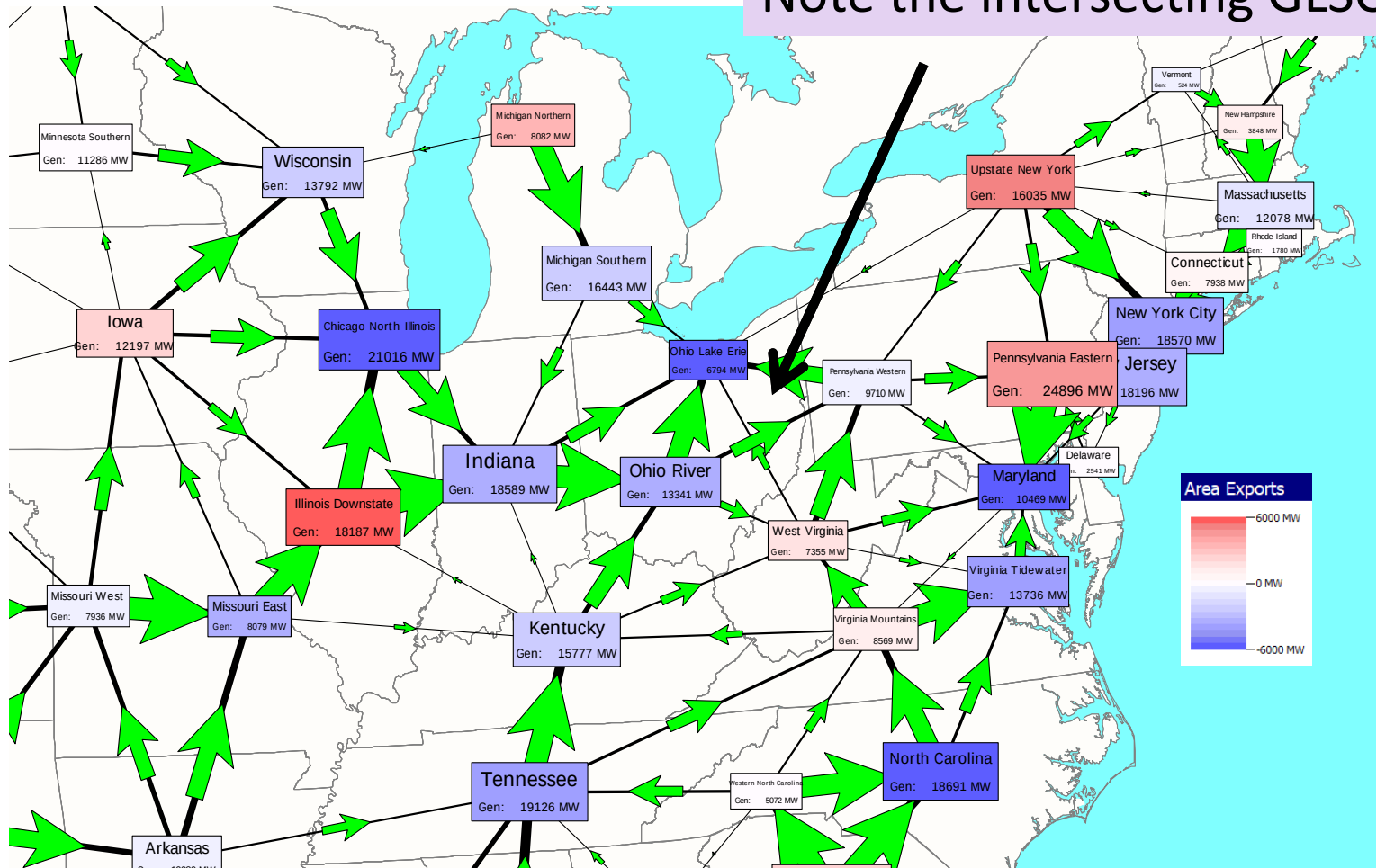


- The GLSOs are display objects just to aggregate the line flows
- There are two approaches for doing this
 - The traditional way, in which lines go directly between their end objects; this can give line overlap
 - A newer approach that utilizes a Delaunay triangulation algorithm so there is no overlap; lines can be mapped into multiple segments
 - Details on this algorithm are described in a 2021 KPEC paper, available as paper 2 in 2021 at <https://overbye.engr.tamu.edu/publications/>
- PowerWorld supports both approaches

GDV Example 1 with GLSO Insert with the Nonplanar Approach



Note the intersecting GLSOs



GLSO Dialog



- Each GLSO has an associated dialog that shows its lines

Each line is also linked, giving access to its dialog

GDV Line Summary Object Dialog

Number: 116
Name: 48_49
Number Objects: 35
Center Latitude: 38.41581
Center Longitude: -97.17021

Terminal Group Objects
First (Into) Group Object: Area Kansas (48) First (Into) Group Integer: 48
Second (Out of) Group Object: Area Nebraska (49) Second (Out of) Group Integer: 49
Positive flow is defined from the First Group Object to the Second Group Object

First Flow Value: 1101.54 First Flow Type: MW
Second Flow Value: -475.18 Second Flow Type: Mvar

Geographic Data View Style
Style Name: Area_BGAGC
Object Type: Area

	First Group Side Bus Number	First Group Side Bus Name	First Group Side Bus Nominal kV	Second Group Side Bus Number	Second Group Side Bus Name	Second Group Side Bus Nominal kV	Line Circuit	First Group Has a Terminal Bus	Second Group Has a Terminal Bus	Flow First Type (First to Second Group)	F S
1	63958	NORCATUR 1	69.00	67202	BARTLEY 1	69.00	1	YES	YES	1.25	
2	63960	OBERLIN 4 2	69.00	67203	DANBURY 13 1	69.00	1	YES	YES	0.14	
3	63961	OBERLIN 5 1	161.00	66722	MC COOK 1 1	161.00	1	YES	YES	-4.41	
4	63987	HIGHLAND 11 1	161.00	67679	FALLS CITY 4 7	161.00	1	YES	YES	19.95	
5	63988	HIGHLAND 11 2	69.00	67213	FALLS CITY 3 2	69.00	1	YES	YES	1.81	
6	64310	MANKATO 12 3	161.00	67406	RED CLOUD 2 9	161.00	1	YES	YES	-5.41	
7	64315	SUPERIOR 6 5	161.00	67406	RED CLOUD 2 9	161.00	1	YES	YES	-0.80	
8	64618	AXTELL 1 1	161.00	67176	PAWNEE CITY 1	161.00	1	YES	YES	-1.98	
9	64619	AXTELL 1 2	69.00	67177	PAWNEE CITY 2	69.00	1	YES	YES	0.70	
10	64621	BLUE RAPIDS 1	161.00	67569	TECUMSEH 9 7	161.00	1	YES	YES	-12.54	
11	64630	MARYSVILLE 10	69.00	66760	WYMORE 2 1	69.00	1	YES	YES	-0.29	
12	64631	MARYSVILLE 10	161.00	67176	PAWNEE CITY 1	161.00	1	YES	YES	-5.91	
13	64702	SENECA 12 2	69.00	67173	BURCHARD 1	69.00	1	YES	YES	-1.18	
14	64702	SENECA 12 2	69.00	67175	PAWNEE CITY 1	69.00	1	YES	YES	-1.66	

OK Cancel

GDV Line Summary Object Dialog



- The flow arrows, line thickness and line field symbols can be customized

GDV Line Summary Options Dialog

Line Flow Options | Line Field Symbol

Line Parameters

Line Color Line Max. Thickness 10.0000
Line Min. Thickness 1.0 Line Thickness Max. Flow 5000.0000
The line's thickness is dynamically scaled based on the first flow value

All Flows

Arrow Symbol Type
☐ PowerWorld Classic
☒ Bold Arrow

Arrow Density -1.0000

First Flow Visualization

First Flow Type
☐ None
☒ Actual MW Power Flow
☐ Actual Mvar Power Flow
☐ PTDF Percentage Flows
☐ GIC Amps

☒ Show Flow Arrows
Arrow Color
Arrow Size 2000.0000
Arrow Max. Flow 5000.0000

Second Flow Visualization

Second Flow Type
☐ None
☐ Actual MW Power Flow
☒ Actual Mvar Power Flow
☐ PTDF Percentage Flows
☐ GIC Amps

☐ Show Flow Arrows
Arrow Color
Arrow Size 100.0000
Arrow Max. Flow 0.0000

Animation

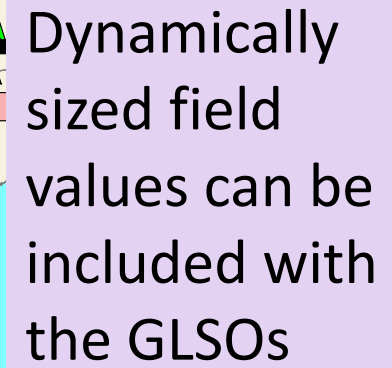
☐ Animate ☐ Scale Speed of Flow
Animation Rate
Slower Faster

Creation Options

☒ Delete Empty Line Summary Objects
☐ Store Number of Objects Per Line in Line's Custom Integer 1 Field

OK Cancel

A negative density value is used to set a specified number of arrows per segment



These fields work best with more regular layouts

GLSO Dialog, Line Field Symbols



GDV Line Summary Options Dialog

Line Flow Options | **Line Field Symbol**

☒ Show Line Field Symbols

Symbol Style
☒ Rectangle ☐ Oval
☐ Rounded Recta

Default Data Type
☒ Sum ☐ Min. Ignore Zero
☐ Abs. Value Sum ☐ Maximum
☐ Average ☐ Max Abs with Sign
☐ Avg. Abs. Value ☐ Count
☐ Minimum

Text, First Line | **Text, Second Line**

Text to Show
☐ None
☒ First Flow
☐ Second Flow
☐ Custom Field

Field Value Options
Field to Use for Custom Field:

Total Digits: Decimal Places:

Summary Object Data Type:

Font Color:

☒ Show Absolute Value

Prefix Text: Suffix Text:

Symbol Attributes

Border Thickness: Color:

Fill Color ☒ Use Fill Color: ☐ Dynamically Color with Field

Total Area Width: ☒ Dynamically Size with Field

Size to Width Ratio:

Fill Color Lookup

Field Set Metrics
Min: Median:
Max: Average:

Color Map

☒ Reverse Color Map Colors
☐ Use Discrete Color Map

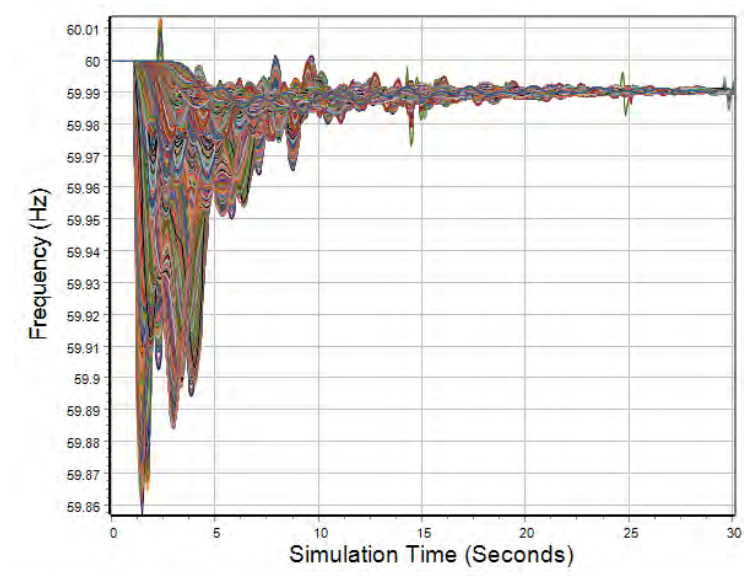
☒ Use absolute value ☐ Ignore Zero Values

Maximum: Break High: Nominal: Break Low: Minimum:

A Final Example



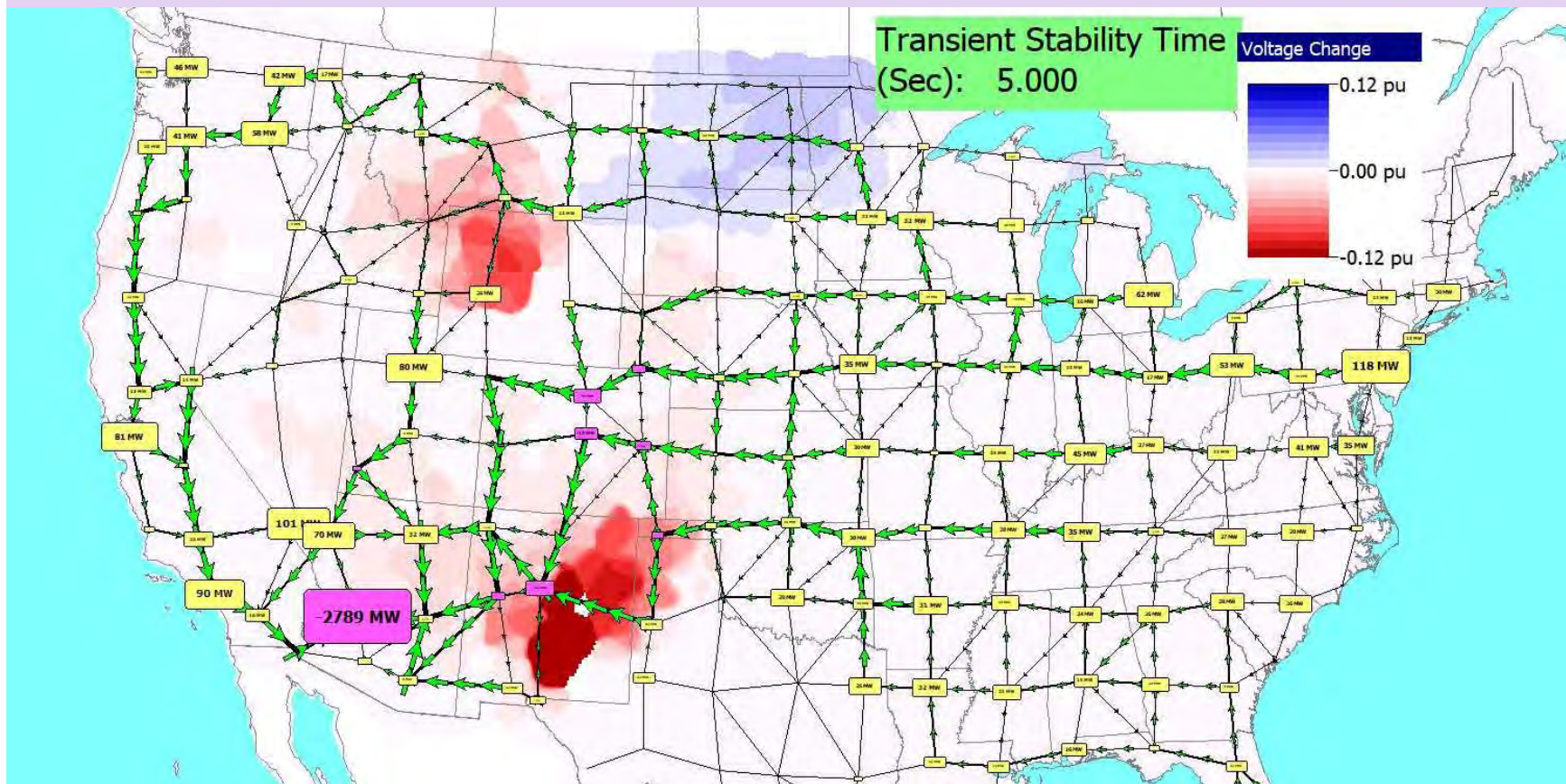
- This example uses the 82K system to visualize its dynamic response to a large generator outage
- The East and West are assumed to be interconnected
- Visualization uses substation GDVs to contour the voltage change, GSOs to show the change in generation and GLSOs to show the change in line flow



A Final Example



Here is an example image; the movie (Synthetic82K_2PV_Movie) is included with the cases



GDV Final Thoughts

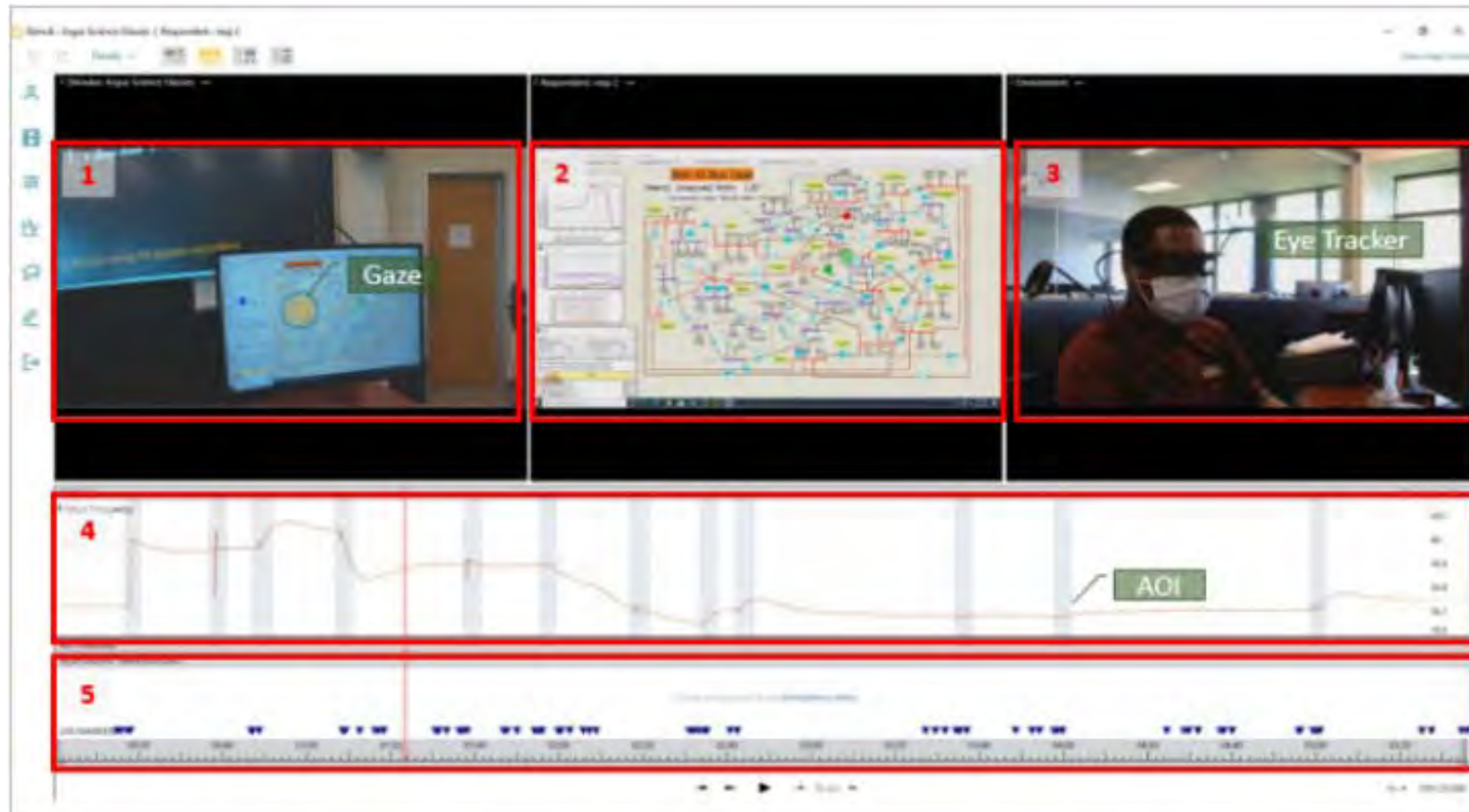


- The GDVs are meant to provide a quick and flexible way to supplement existing visualization techniques
- Many different options are available so I would encourage you to play around with them and see what works for you

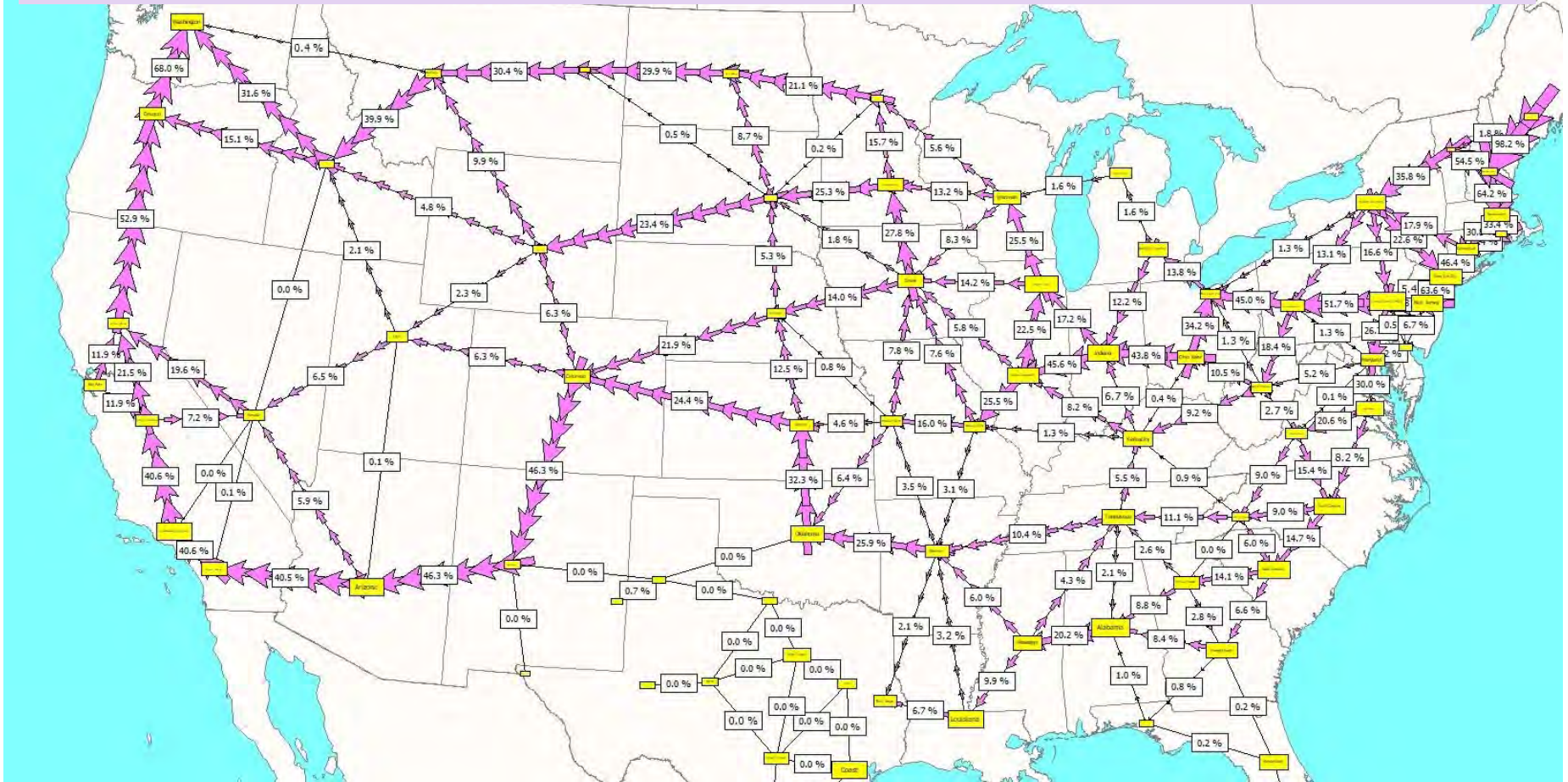
Human Factor Testing at Texas A&M



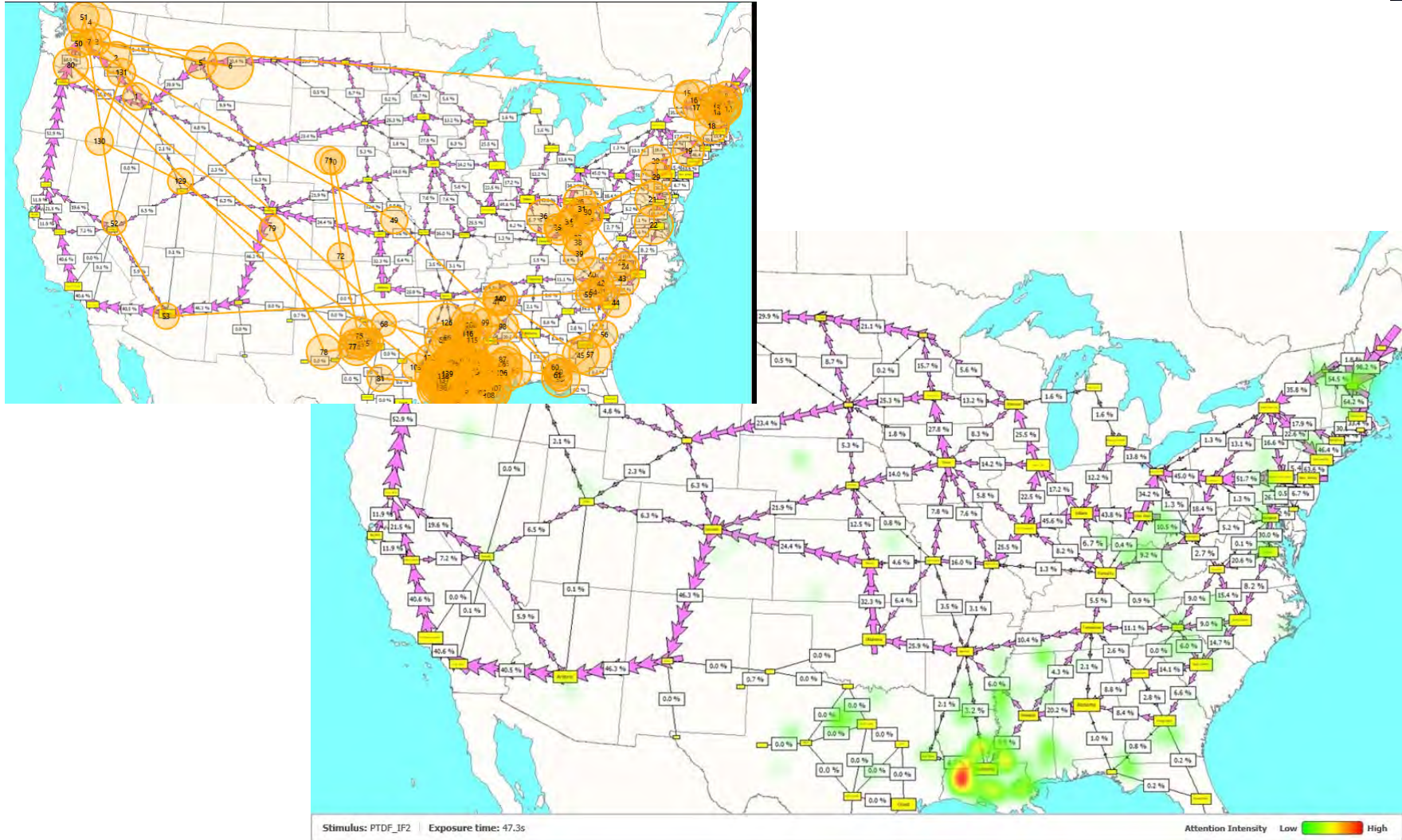
- Recently at Texas A&M we added eye tracking to allow the testing of various visualizations



software bug (that has since been corrected). Where is the error?



Eye Tracker Results

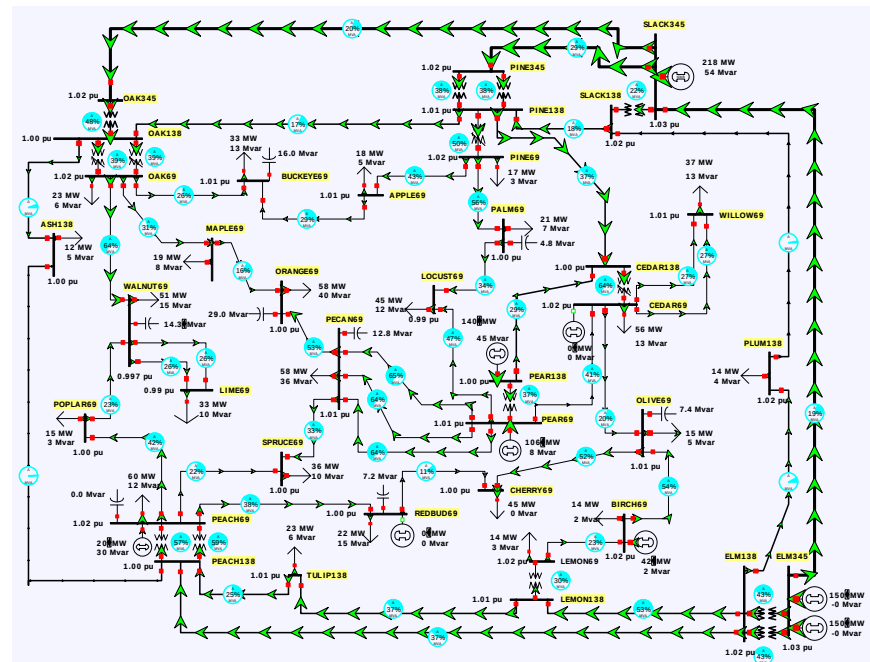
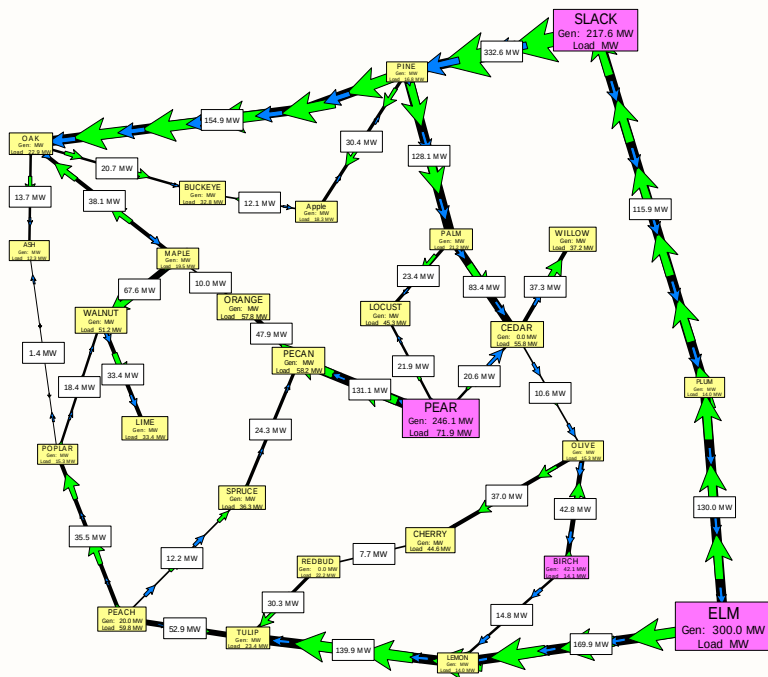


Moving Forward



- One approach might be to test visualizations using the two alternative, forced choice (2AFC) methodology

The images show the same system. What is the question?



Questions?

