

PowerWorld's Experience Using Real-Time Power System Models



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PowerWorld's History of Full-Topology Models



- PowerWorld Simulator – 1996
 - Planning software focused on Bus-Branch Models
- PowerWorld Retriever – 2000
 - Real-time visualization software
 - Many pilot projects with this worked by exporting a bus/branch model from the EMS (RAW file)
 - This was not a sustainable model for customers
- PowerWorld Retriever – 2006
 - ISO-New England started work on using the data already managed in their Areva EMS tool
 - Cases only initially, but progressed to reading their EMS one-lines
 - This was clearly the better approach and other real-time customers followed

PowerWorld's History of Full-Topology Models



- PowerWorld Simulator Integrated Topology Processing – 2010
 - BPA real time operations started using the direct export from their EMS
- Expanding data imports with Peak Reliability – 2016
- This is all data that was already *maintained* at Peak so we are just plugging into their existing processes
 - Direct read of the Contingency record
 - Direct read of the Remedial Action Scheme definitions
 - Direct import of 1000s of maintained substation topology oneline diagrams
 - Direct import of various overview diagrams
 - Direct import of 1000s of scheduled outages as well

Full Topology Models exist today: EMS System Models



- Industry has spent 30 years building the models
 - More importantly: maintaining these models
- Maintained by an existing large staff of engineers (dozens)
- More than just the models
 - Oneline diagrams
 - Contingency definitions
 - Remedial Action Scheme definitions
 - SCADA measurements
- Much more frequent updates than power system planners realize
 - Often done weekly
 - At most every few weeks
- Large financial commitment is already being made to keep these models up to date
 - Staff Staff Staff (\$ \$ \$)

Our Experience: Four Types of Issues



- Data Definitions
 - How are objects uniquely identified
 - How is data structured
- Tools to Manage Increased Model Size
 - Previously simple concepts getting more complicated
 - When is a line open?
 - Single Line Contingency
- Human Interaction
 - My model is huge
 - Data viewing
 - Data reporting
- Data Formats
 - Need to read information directly from the sources that manage the full topology models

Node-Breaker vs. Bus-Branch

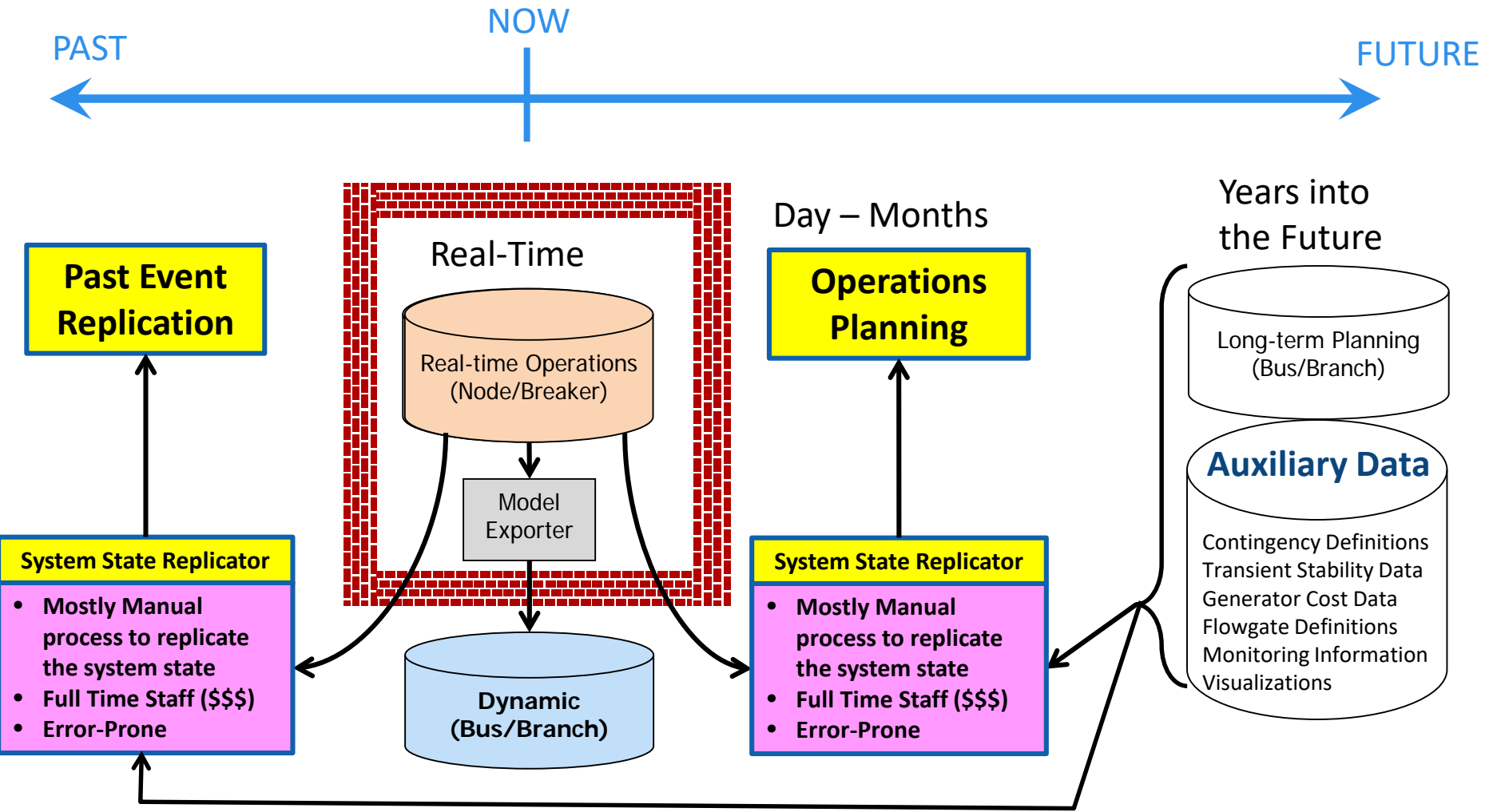
Which models are used?



- Depends on the time frame of your analysis
 - Past Event Replication Studies
 - Real-Time Studies
 - “Operations Planning”
 - Looking at the next 24 hours
 - Looking at outage schedule coordination over the next several months
 - “Long-Term Planning”
 - Looking at next several years

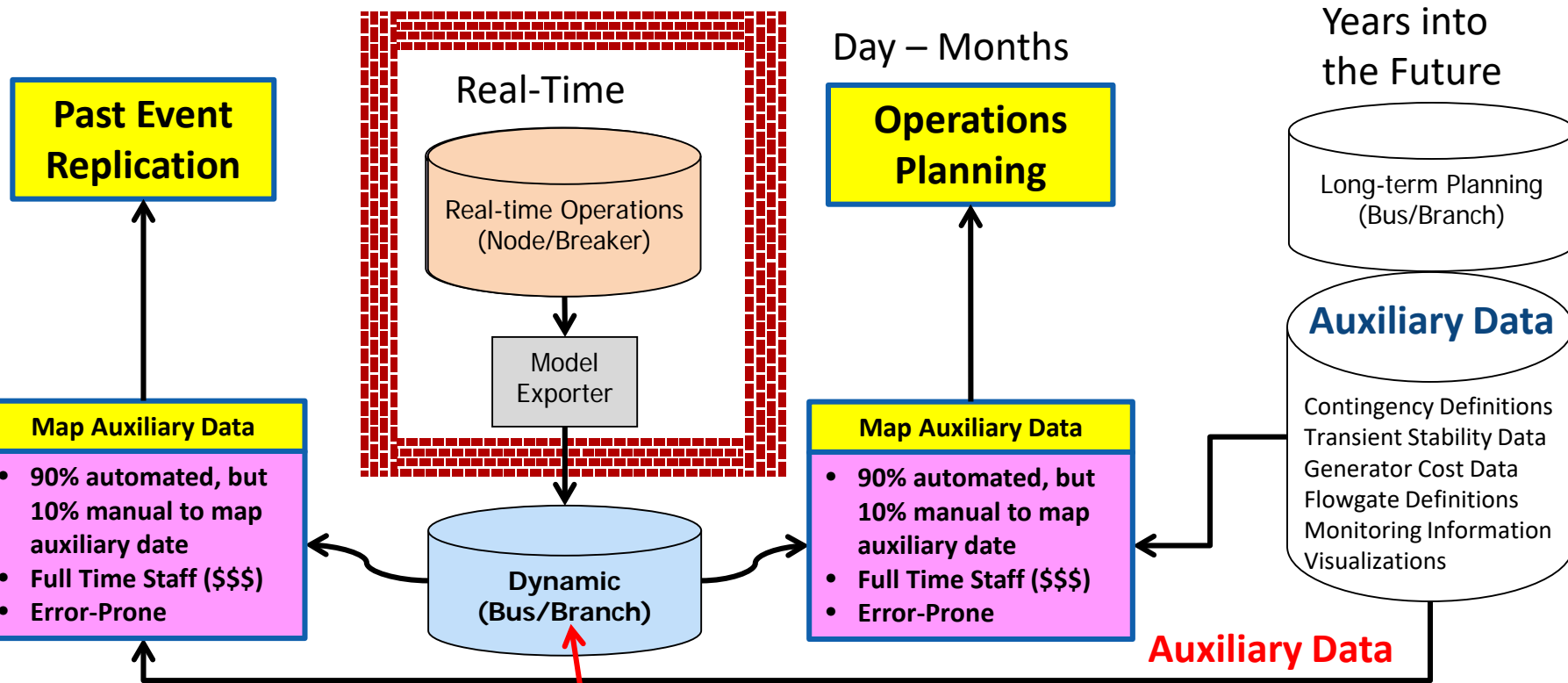
Typical Existing Power Business Stages

“State Mapping”



Typical Existing Power Business Stages

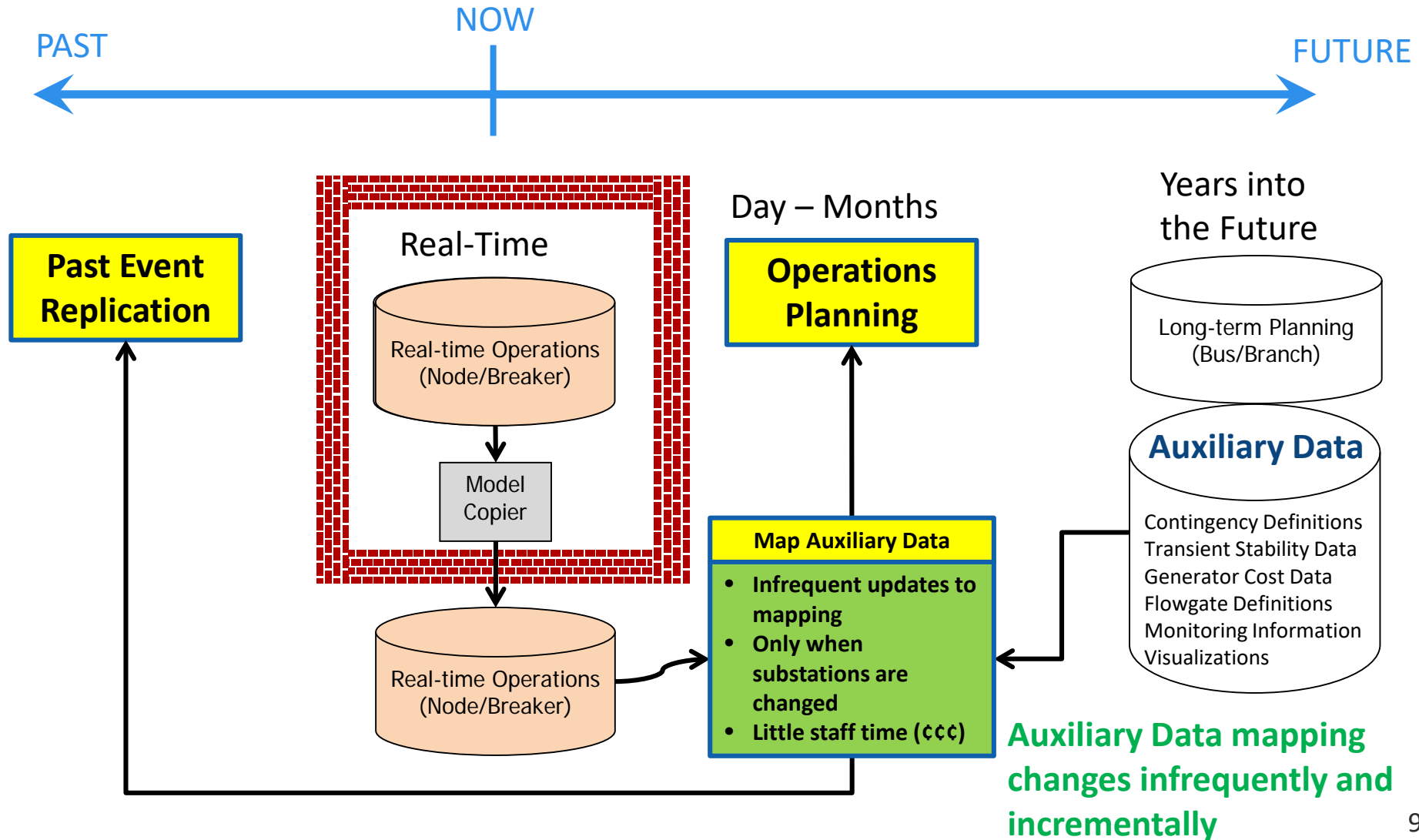
“Auxiliary Data Mapping”



This model is slightly different EVERY time it's exported

Auxiliary Data mapping is slightly different EVERY time


A Better Choice for Operations Planning




Near Real-Time Analysis of the Power System



- The starting point for this is the system state stored in an EMS system model
 - Or you must match another model to this
 - The model with the disturbance state is the full-topology real-time model
- To use this model for studies, there is a lot more than just the model to maintain



“Model” maintenance: It is more than just the model



- Large amount of Auxiliary Information to maintain
 - Contingency Definitions
 - Interface/Flowgate/Path/Cutplane definitions
 - Limit Monitoring information
 - What to monitor, dynamic limits, etc.
 - Market cost/bid information
 - Transient Stability Models
 - Various other groupings
 - Injection Groups/Subsystems
 - Substations
 - Graphical Visualization Descriptions

Use Alphanumeric Identifiers: *Labels*




- Unique identifiers for all power system objects
- Change infrequently or not at all
- Independent of topology changes
 - Bus numbers can change with each model export even if the only change is a breaker status
 - System upgrades may change where a line is connected, but its identifier should not have to change (it might, but should not be required)
- Can be used with all auxiliary data: contingency definitions, interfaces, etc.
- Created automatically from Real-Time Model object identifiers
 - Typically with a real-time system there will be some unique identifier
Substation\$RecordType\$EMS_ID
 - BrownsFerry\$UN\$Unit2 → Generator
 - Johnsville\$500\$1928 → 500 kV node



More about labels



- Even in the EMS model data space we see inconsistencies with labels
 - Labels must be unique across all devices of a type
 - But, PowerWorld Simulator allows you to have multiple labels for each device (unlimited number)
 - SCADA information referring to model information using different naming conventions sometimes
 - Different organizations using different naming (DOE-EIA cost information for example)
- There is no limit to the number of characters in a label



Are Labels enough? NO!

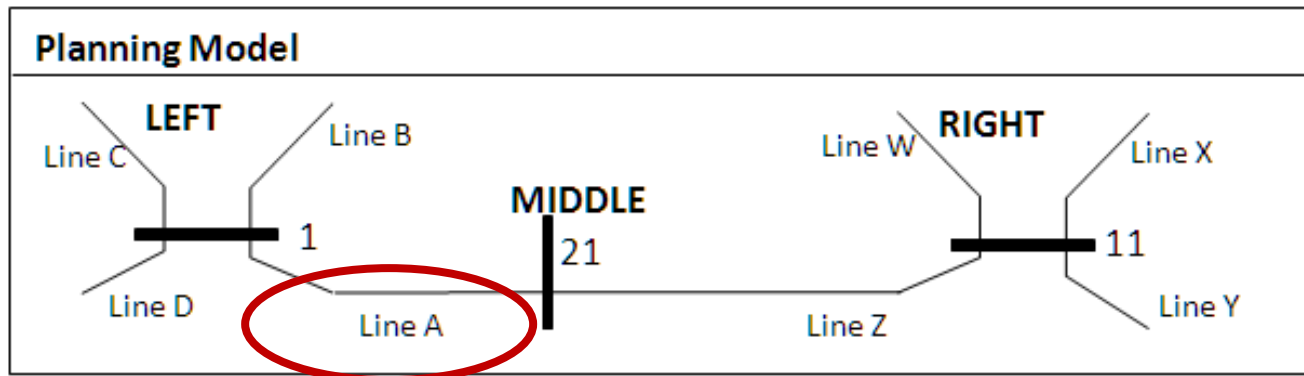
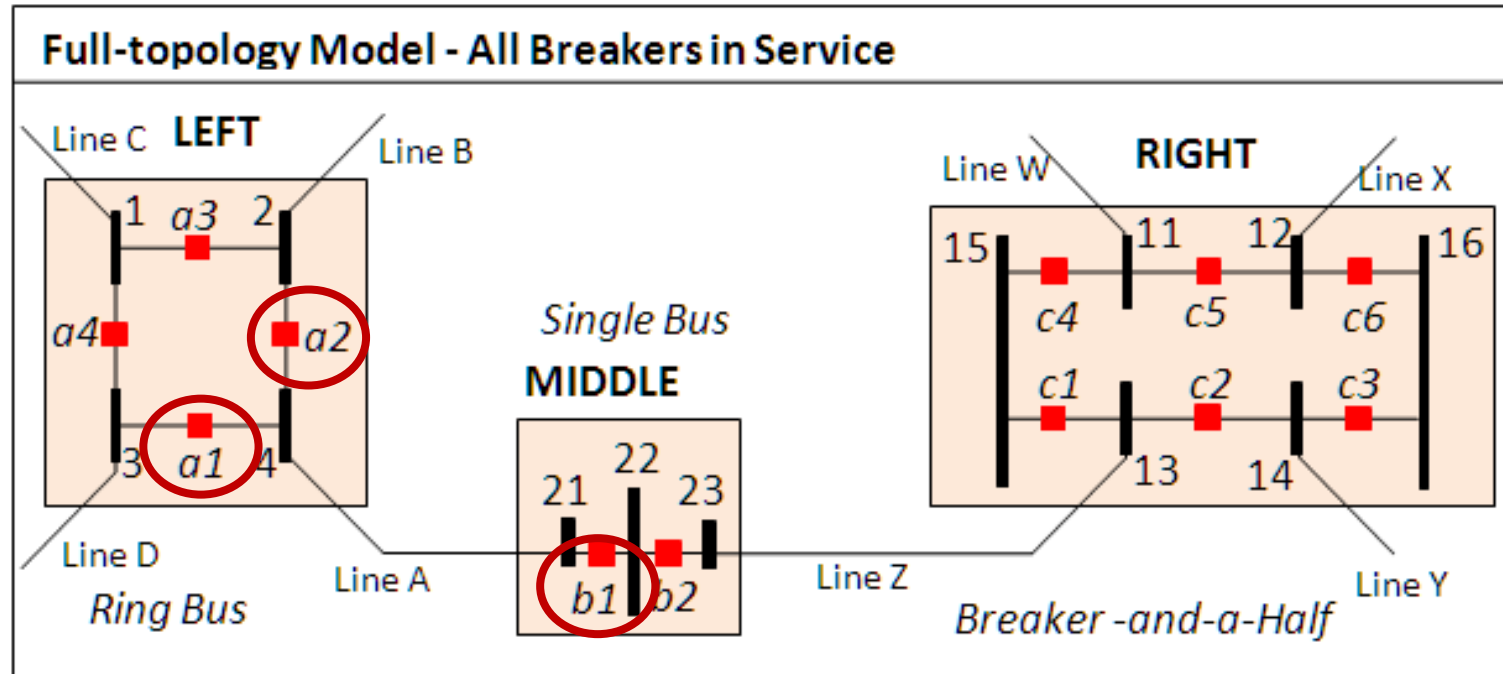
Models are Different



- First instinct → this is only a “naming” issue
 - Just build an “*Automated Conversion Tool*” that links the names from the full-topology model to the names in the planning model
 - In other words: Use Labels
- This instinct is not correct. It is more than this.
 - The models are different
 - Breaker topologies matter
 - Can not assume that all breakers are in their normal status
 - Taking a line out of service depends on the present system state

Invalid Contingency Simulations

Example 1



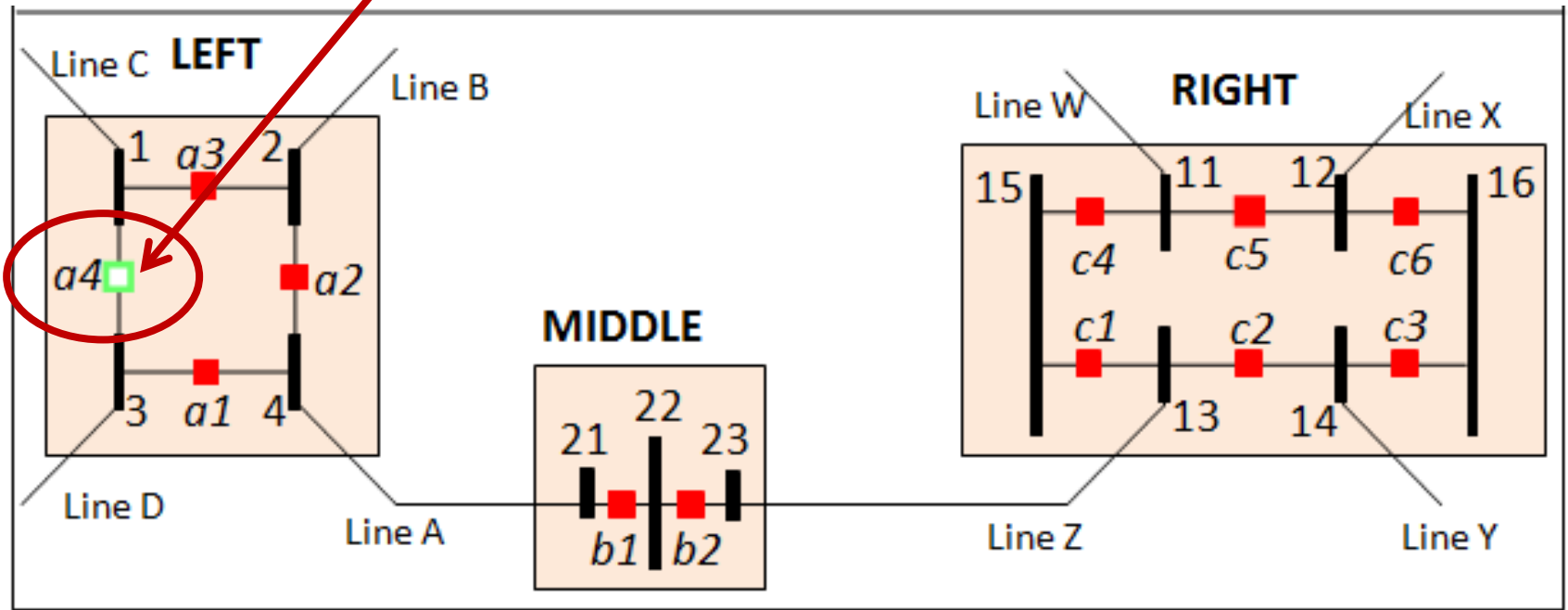
Invalid Contingency Simulations

Example 1



- How is outage of Line A modeled on following slide?
 - Planning Model
 - Open Line A
 - Actual System
 - Open breakers $a1$, $a2$, and $b1$
 - Assuming all breakers have same status as original configuration from which planning case was created, then this is a correct simulation in planning case

Breaker $a4$ Out for Maintenance



- Now what happens when Line A is taken out of service?

Invalid Contingency Simulations

Example 2



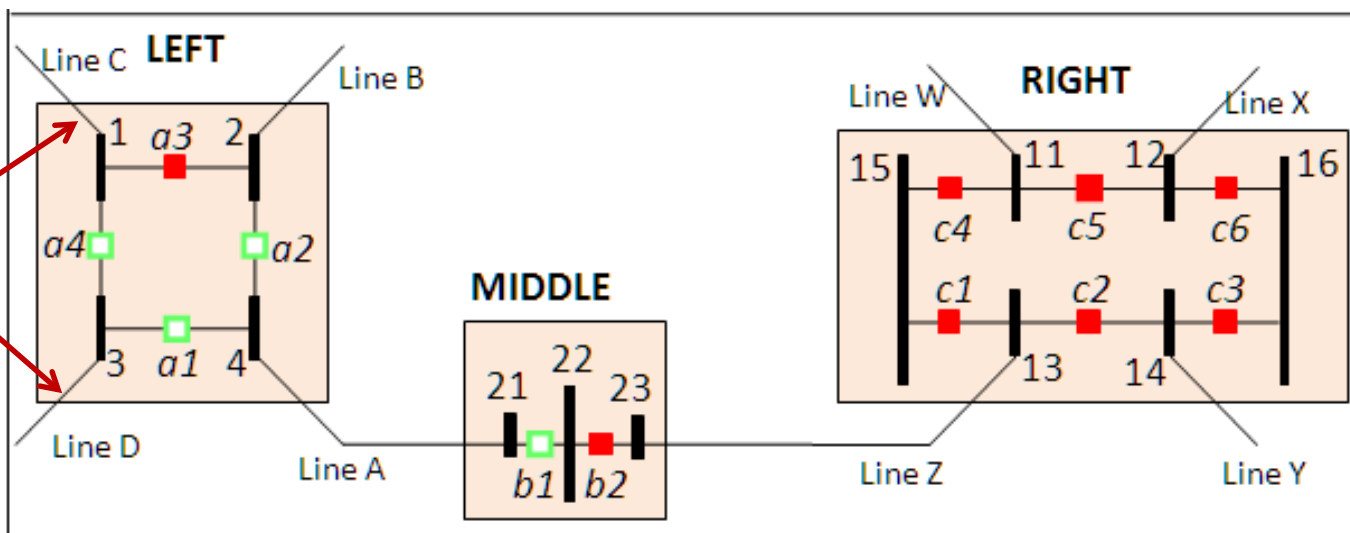
- How is outage of Line A modeled along with open breaker $a4$?
 - Planning Model
 - Open Line A
 - No other lines are isolated
 - Bus split not captured
 - Actual System
 - Open breakers $a1$, $a2$, and $b1$
 - Line D isolated from Line B and Line C
 - Modification of planning model is required to correctly model this condition

Invalid Contingency Simulations

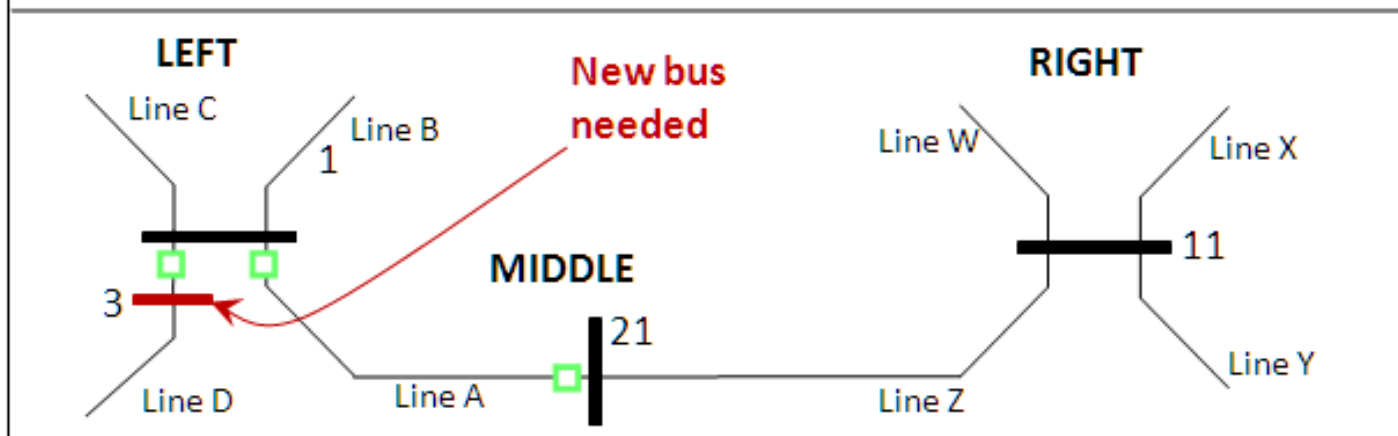
Example 2



Line D isolated from Line B and Line C



Planning Model would need to insert an additional "bus 3" to handle





Breaker Failure Outages

Example 3



- Problem
 - How to you model a breaker failure if you have consolidated the breaker in the process of creating the planning model?
- Solution
 - Do not consolidate your data, let the software do that as needed
 - To make contingency definitions more familiar, add a new action called *Open with Breakers*

Can you make an Automated Conversion Tool?



- Answer: No!
- A bus-branch model is inherently an “equivalent” representation of the breaker-node model
 - You have lost information by creating the bus-branch model
 - You can’t just convert back to something that’s not in the model now

What do you need to do?



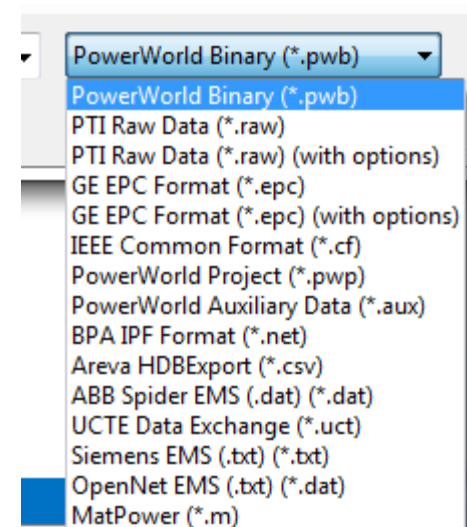
- Get the data directly from the EMS
- An enormous amount of staff time is spent building and *maintaining* the EMS models
- Read it directly

PowerWorld's

Experience with other Data Formats



- EPC and RAW files: Historically represent “bus-branch” models, though that is evolving
- HDBExport command from Areva EMS
 - A lot of experience reading from this EMS data structure for many customers for a decade
 - Data structures are very similar to those used in Bus/Branch models
 - Fundamental object is the Node (ND)
- ABB Spider EMS
 - Experience reading full cases for use in running contingency analysis, but only with 1 customer
- Siemens EMS
 - Small amount of experience loading only the topology definition so that measurements could be mapped
- OpenNet EMS
 - Very small amount of experience



Experience with Areva EMS

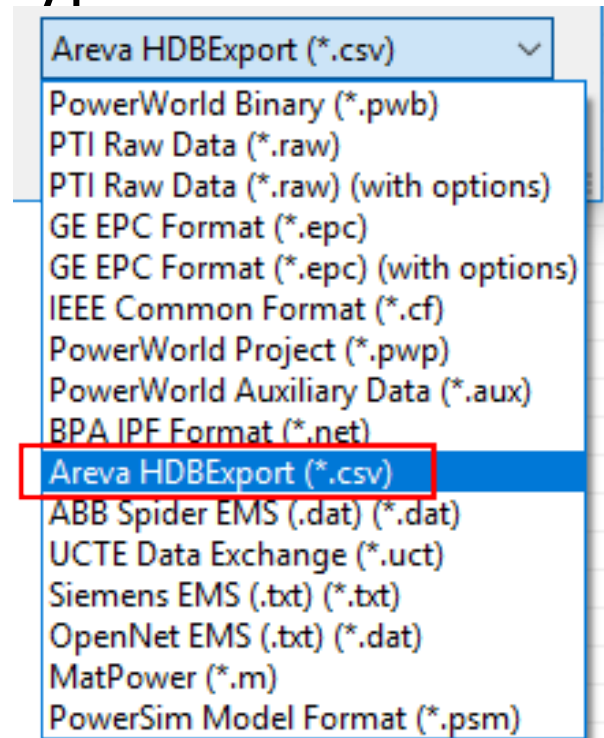
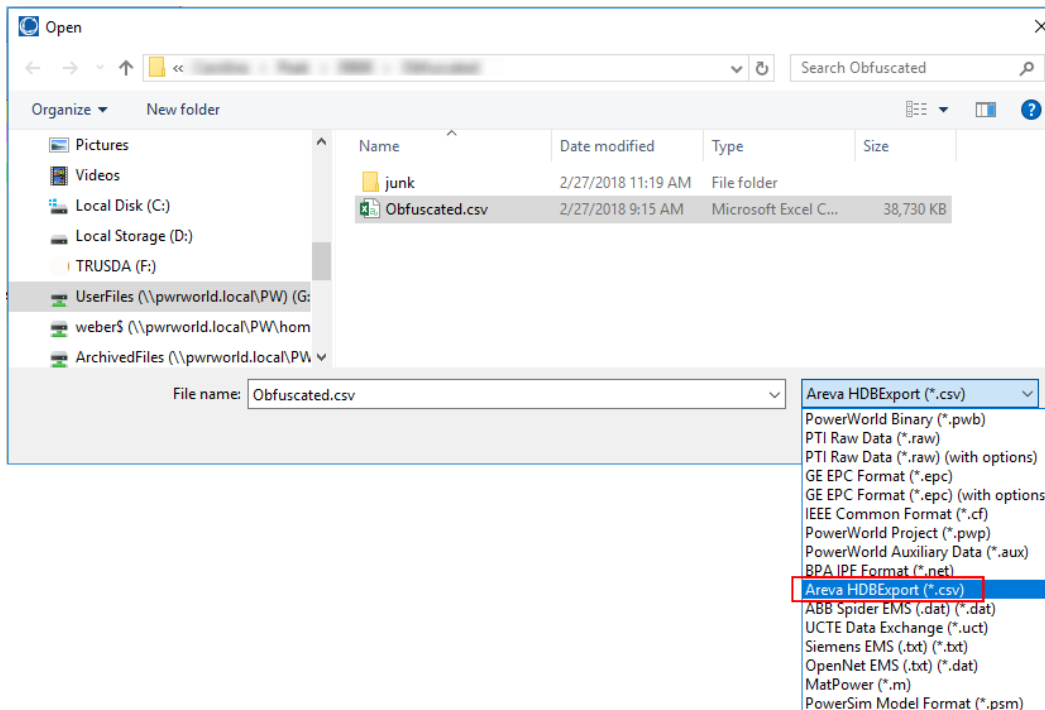


- Hdbexport command gives users of this EMS the ability to export data
 - We have 10 years of experience reading the network model
 - Also have experience exporting the Contingency and RAS definitions using similar methodology
- Oneline diagrams format is also text-based and links to these case
 - We can read these diagrams into PowerWorld as well
 - Some work up-front to translate how things are drawn as this is custom for every Areva customer

PowerWorld Demonstration



- How to open a full-topology model
 - Chose File, Open Case
 - Change to the appropriate file type



Important Data Structure Parts: Substations



- Substation Definitions
 - The fundamental data structure in a real-time model
 - Part of the unique identifier of a device
 - You must have this to make interaction with the full-topology model easier
 - Define a list of substations
 - Assign each “bus” to a substation
 - Natural place to define geography (Latitude, Longitude)

Bus Display:

each node from EMS becomes a bus



- Each bus is assigned to a Substation

Model Explorer: Buses

Explore

Recent

Network

Branches By Type

Branches Input |Branch

Branches State |Branc

Buses |Bus (104536)

DC Transmission Lines

Generators |Gen (3695

Impedance Correction

Line D-FACTS Devices |

Line Shunts |LineShur

Loads |Load (10620)

Mismatches |Bus (104!

Multi-Terminal DC |MT

Switched Shunts |Shu

Three-Winding Transf

Transformer Controls |

Voltage Control Group

VSC DC Transmission l

Aggregations

Areas |Area (42)

Balancing Authorities

Bus Pairs |BusPair (72)

Data Maintainers |Dat

Injection Groups |Inje

Open New Explorer

Buses

Switched Shunts

Breaker

Case Info Customizations

Substations

Filter Advanced

Find... Remove

Bus	Number(1*<)	Name (*<)	AllLabels (<)	SubName(<)	Latitude(<)	Longitude(<)	Ar ^
1	1	SUB0001_138_138	SUB0001\$NDS\$138	SUB0001			Af
2	2	SUB0001_138_139	SUB0001\$NDS\$139	SUB0001			Af
3	3	SUB0001_138_140	SUB0001\$NDS\$140	SUB0001			Af
4	4	SUB0001_138_141	SUB0001\$NDS\$141	SUB0001			Af
5	5	SUB0001_138_142	SUB0001\$NDS\$142	SUB0001			Af
6	6	SUB0001_138_143	SUB0001\$NDS\$143	SUB0001			Af
7	7	SUB0001_138_144	SUB0001\$NDS\$144	SUB0001			Af
8	8	SUB0001_138_145	SUB0001\$NDS\$145	SUB0001			Af
9	9	SUB0001_138_146	SUB0001\$NDS\$146	SUB0001			Af
10	10	SUB0001_138_147	SUB0001\$NDS\$147	SUB0001			Af
11	11	SUB0001_138_150	SUB0001\$NDS\$150	SUB0001			Af
12	12	SUB0001_138_152	SUB0001\$NDS\$152	SUB0001			Af
13	13	SUB0001_13.8_148	SUB0001\$NDS\$148	SUB0001			Af
14	14	SUB0001_13.8_149	SUB0001\$NDS\$149	SUB0001			Af
15	15	SUB0001_13.8_151	SUB0001\$NDS\$151	SUB0001			Af
16	16	SUB0002_69_69	SUB0002\$NDS\$69	SUB0002			Af
17	17	SUB0002_69_70	SUB0002\$NDS\$70	SUB0002			Af
18	18	SUB0002_69_71	SUB0002\$NDS\$71	SUB0002			Af
19	19	SUB0002_69_72	SUB0002\$NDS\$72	SUB0002			Af
20	20	SUB0002_69_87	SUB0002\$NDS\$87	SUB0002			Af
21	21	SUB0002_69_90	SUB0002\$NDS\$90	SUB0002			Af
22	22	SUB0002_25_78	SUB0002\$NDS\$78	SUB0002			Af
23	23	SUB0002_25_79	SUB0002\$NDS\$79	SUB0002			Af
24	24	SUB0002_25_80	SUB0002\$NDS\$80	SUB0002			Af

Search

Search Now Options

No limitation on device counts

No limitation on characters in names

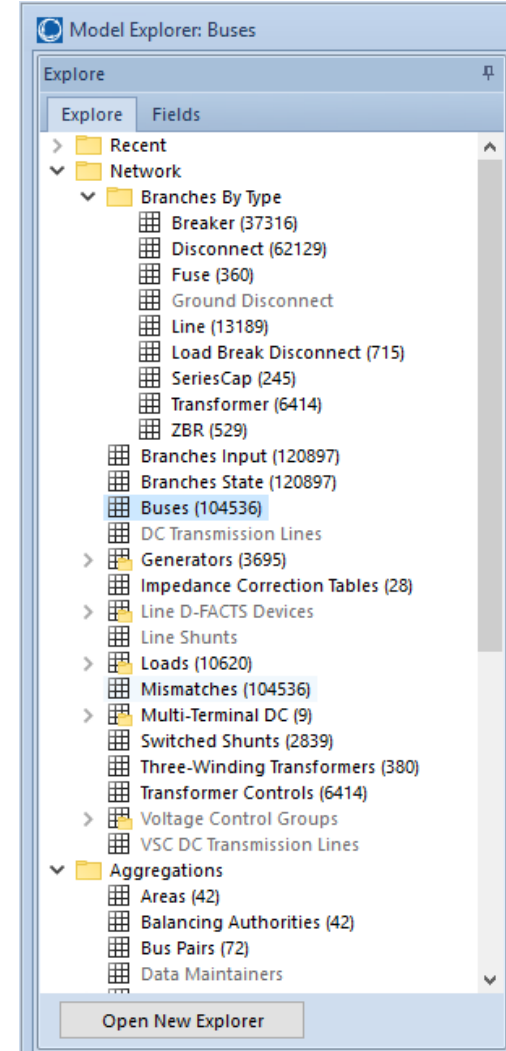


- No limit on number of substations
- No limit on the number of characters in the name of any device (nor on labels)
- No limit on the Label string length (can also have multiple labels for each device and no limit on the number of labels)
- No limit on number of nodes in a substation
- No limit on the devices in a substation

What do Full Topology Models Look Like

Like

- More nodes (about 4-6 times more)
- More branches (the switching devices)
- Similar Gens, Load, Shunts, Transmission Lines
 - 6,414 transformer
 - 13,189 lines
 - 245 series devices
 - 529 ZBRs
 - 37,316 breakers
 - 62,129 disconnects
 - 715 load-break disconnect
 - 360 fuses



Important Data Structure Parts:

More Branch Types



- Planning models already have the concept of distinct types of branches
 - *Line, Transformer, Series Cap*
- BranchDeviceTypes that represent switching devices that have very little impedance
 - At a minimum add *Breaker, Load Break Disconnect, and Disconnect*
 - Used in “Open or Close with Breakers” features discussed shortly
 - Used in “Derived Status” concepts discussed shortly
 - Also add *Fuse, Ground Disconnect* and *ZBR* for informational purposes as well

BranchDeviceType



Branches State

Options

Filter: **Advanced** | Branch | Find... Remove Quick Filter...

Branch	BusNumFrom ⁽¹⁾	BusNameFrom	BusNumTo ⁽²⁾	BusNameTo	Circuit ^(3C)	BranchDeviceType	All
1	1	Sub1\$NDS\$1	2	Sub1\$NDS\$2	1	Breaker	Sub1\$NDS\$1\$\$\$Sub1\$
2	3	Sub1\$NDS\$3	1	Sub1\$NDS\$1	1	Breaker	Sub1\$NDS\$3\$\$\$Sub1\$
3	1	Sub1\$NDS\$1	6	Sub1\$NDS\$6	1	Disconnect	Sub1\$NDS\$1\$\$\$Sub1\$
4	4	Sub1\$NDS\$4	2	Sub1\$NDS\$2	1	Breaker	Sub1\$NDS\$4\$\$\$Sub1\$
5	8	Sub1\$NDS\$8	2	Sub1\$NDS\$2	1	Disconnect	Sub1\$NDS\$8\$\$\$Sub1\$
6	5	Sub1\$NDS\$5	3	Sub1\$NDS\$3	1	Breaker	Sub1\$NDS\$5\$\$\$Sub1\$
7	3	Sub1\$NDS\$3	10	Sub1\$NDS\$10	1	Disconnect	Sub1\$NDS\$3\$\$\$Sub1\$
8	7	Sub1\$NDS\$7	4	Sub1\$NDS\$4	1		Sub1\$NDS\$7\$\$\$Sub1\$
9	11	Sub1\$NDS\$11	4	Sub1\$NDS\$4	1		Sub1\$NDS\$11\$\$\$Sub1\$
10	5	Sub1\$NDS\$5	11	Sub1\$NDS\$11	1		Sub1\$NDS\$5\$\$\$Sub1\$
11	5	Sub1\$NDS\$5	12	Sub1\$NDS\$12	1		Sub1\$NDS\$5\$\$\$Sub1\$
12	6	Sub1\$NDS\$6	122	Sub8\$NDS\$122	1		Sub1\$NDS\$6\$\$\$Sub1\$
13	7	Sub1\$NDS\$7	13	Sub1\$NDS\$13	1		Sub1\$NDS\$7\$\$\$Sub1\$
14	11	Sub1\$NDS\$11	9	Sub1\$NDS\$9	1		Sub1\$NDS\$11\$\$\$Sub1\$
15	12	Sub1\$NDS\$12	103	Sub7\$NDS\$103	1		Sub1\$NDS\$12\$\$\$Sub1\$
16	13	Sub1\$NDS\$13	14	Sub1\$NDS\$14	1		Sub1\$NDS\$13\$\$\$Sub1\$
17	13	Sub1\$NDS\$13	15	Sub1\$NDS\$15	1		Sub1\$NDS\$13\$\$\$Sub1\$
18	16	Sub2\$NDS\$16	18	Sub2\$NDS\$18	1		Sub2\$NDS\$16\$\$\$Sub2\$
19	16	Sub2\$NDS\$16	4182	Sub405\$NDS\$4182	1		Sub2\$NDS\$16\$\$\$Sub2\$
20	17	Sub2\$NDS\$17	19	Sub2\$NDS\$19	1		Sub2\$NDS\$17\$\$\$Sub2\$
21	17	Sub2\$NDS\$17	4180	Sub405\$NDS\$4180	1	Line	Sub2\$NDS\$17\$\$\$Sub4

- Line
- Breaker
- Load Break Disconnect
- Disconnect
- ZBR
- Fuse
- Ground Disconnect
- Series Cap

What do Branch Device Types Physically Represent



- Transformers, Lines, Series Devices
 - We know these
- Breakers
 - Switching device that can interrupt very high currents such as during a fault
- Load-Break Disconnect
 - Switching device that can be opened during normal loading conditions, but NOT during a fault
 - Often associated with a capacitor bank
- Disconnects
 - Switching device can not be opened when under load

Other BranchDeviceTypes

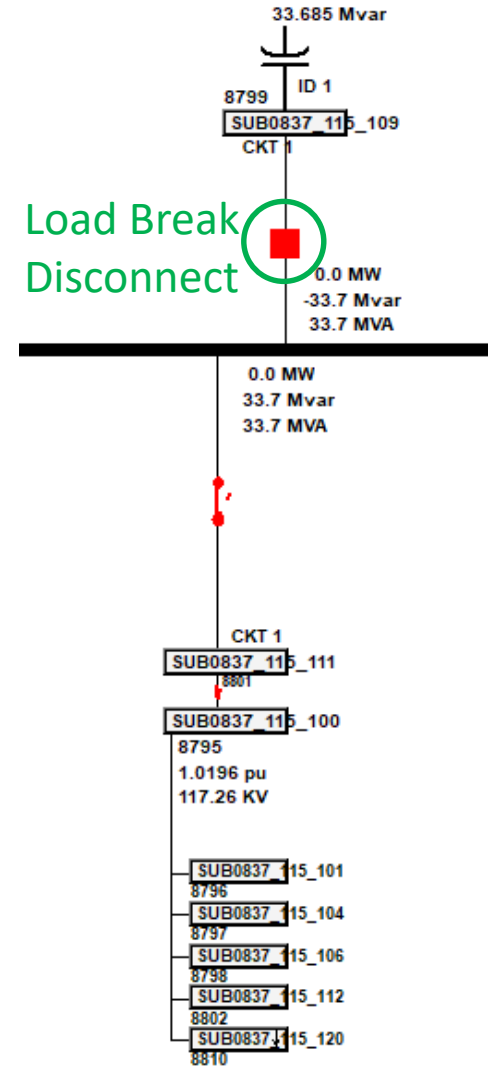
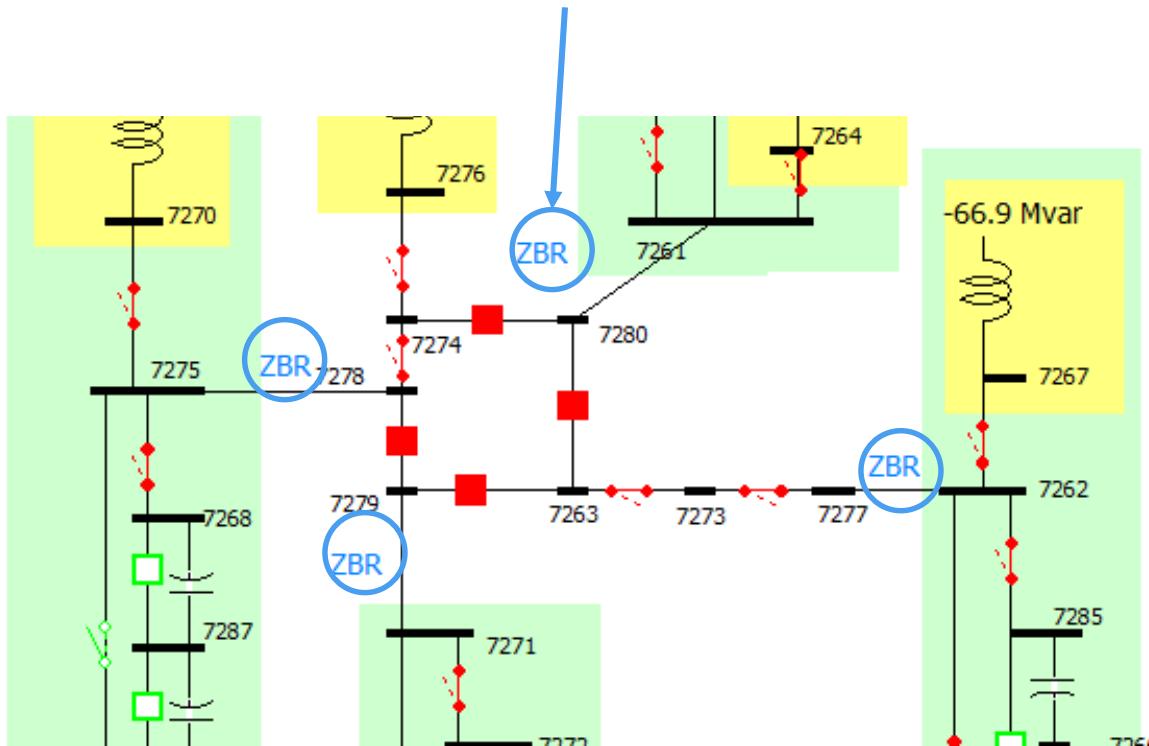


- ZBR
 - Wire that connects two points.
 - Might be there so a measurement can be taken
 - Might just be a jumper
- Ground Disconnect
 - Switching device connects to ground. Some EMS models actually include nodes that represent the ground and then an associated disconnect.
 - Obviously these should NEVER be closed in for purposes of planning activities
 - System operators however are focused on status and worker safety, so it is useful for them to know if a line is actually grounded properly
- Fuses
 - A fuse

Example ZBR and Load Break Disconnect

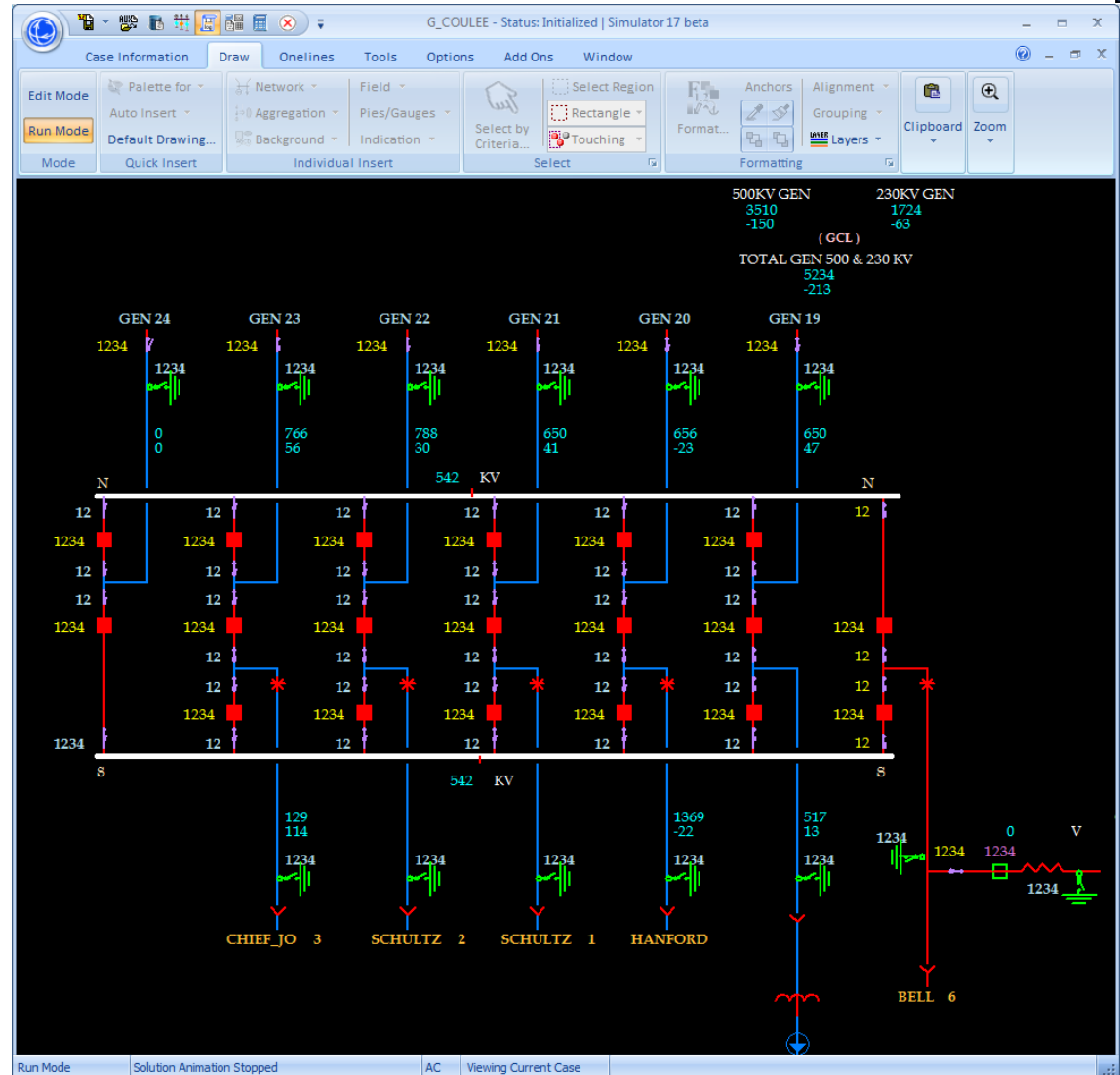


ZBR probably there so that one measurement gets flow on line



Model Detail

- To the right is a redacted detail of what the topology of a 500 kV bus
- It's a Breaker and a Half configuration
- This would be a single bus in a "planning case"



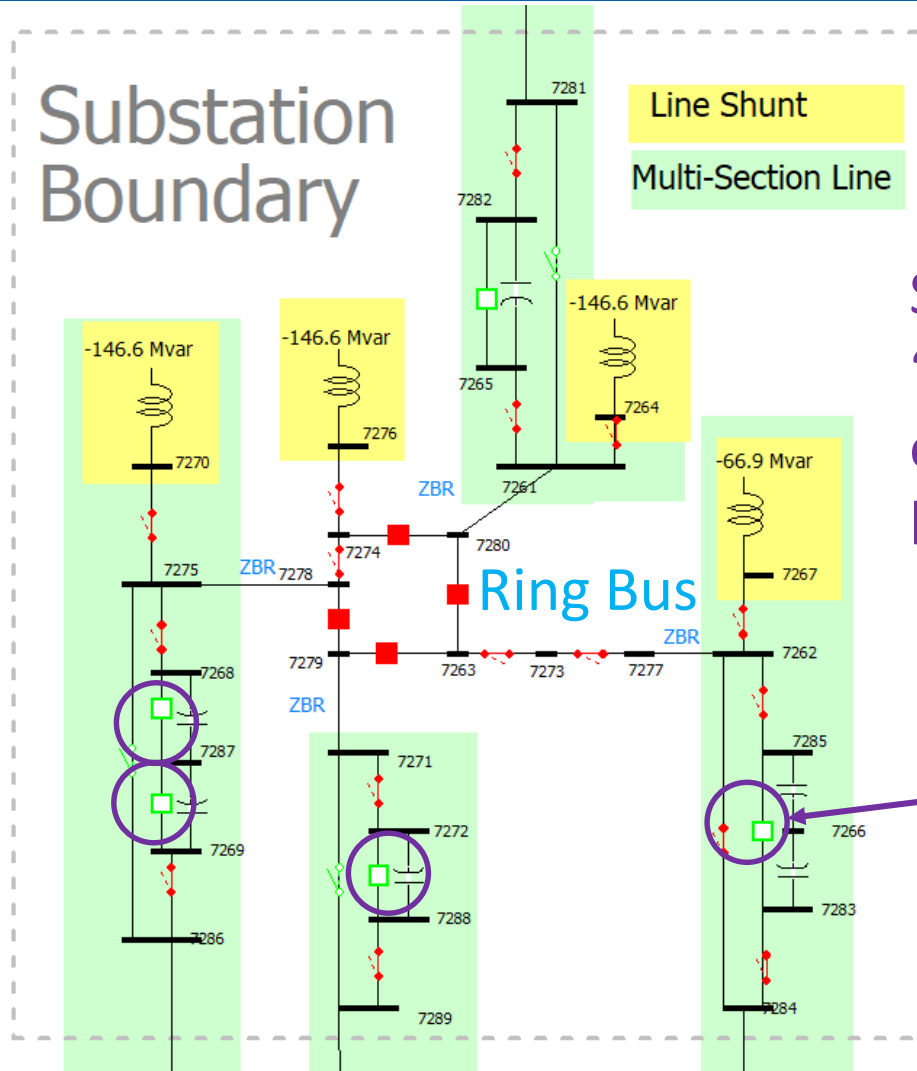
Good News:



- Some data definitions go away
 - Idea of a “Line Shunt” as compared to a “Bus Shunt” is unnecessary
 - All shunts are modeled with a connection to a bus
 - Line vs. Bus Shunt just depends on which side of the line breaker it is connected
 - Idea of a “Multi-Section Line” is unnecessary
 - Software can automatically traverse the topology to determine which branches get isolated by the same set of breakers
 - “Open with Breakers” option discussed next
 - Concept of a “Bypassed” series cap goes away
 - There will be a separate breaker to model the bypass

Capacitor/Reactors all the same

Multi-Section Line concept gone



Shunts are all the same.
“LineShunt” just means its
on the other side of the
breakers

Bypass
Breakers

Integrated Topology Processing



- Completely *integrate* the concept of topology processing inside each software algorithm
- Each algorithm consolidates in a manner appropriate to it
 - Power flow → solve directly on the full-topology model (internally consolidate the power system model as necessary)
 - Contingency analysis (only consolidate as necessary)
 - PV Curve and QV Curve behave differently
 - MW Linearized Tools (ATC, Sensitivity tools, etc.) behave differently

Full-Topology Power Flow Solution



- PowerWorld knows when it needs to make a consolidated case and takes care of that
- User only interacts with the full-topology model
 - Power Flow Solution returns flows on all devices
 - Contingency analysis limit monitoring looks at all devices including switching devices (*assuming limits are assigned!*)
 - Option to filter bus voltage reporting so only one node inside a Superbus reports as a violation

MW and Mvar flow arrows on all devices on oneline diagrams



Substation Boundary

Line Shunt
Multi-Section Line

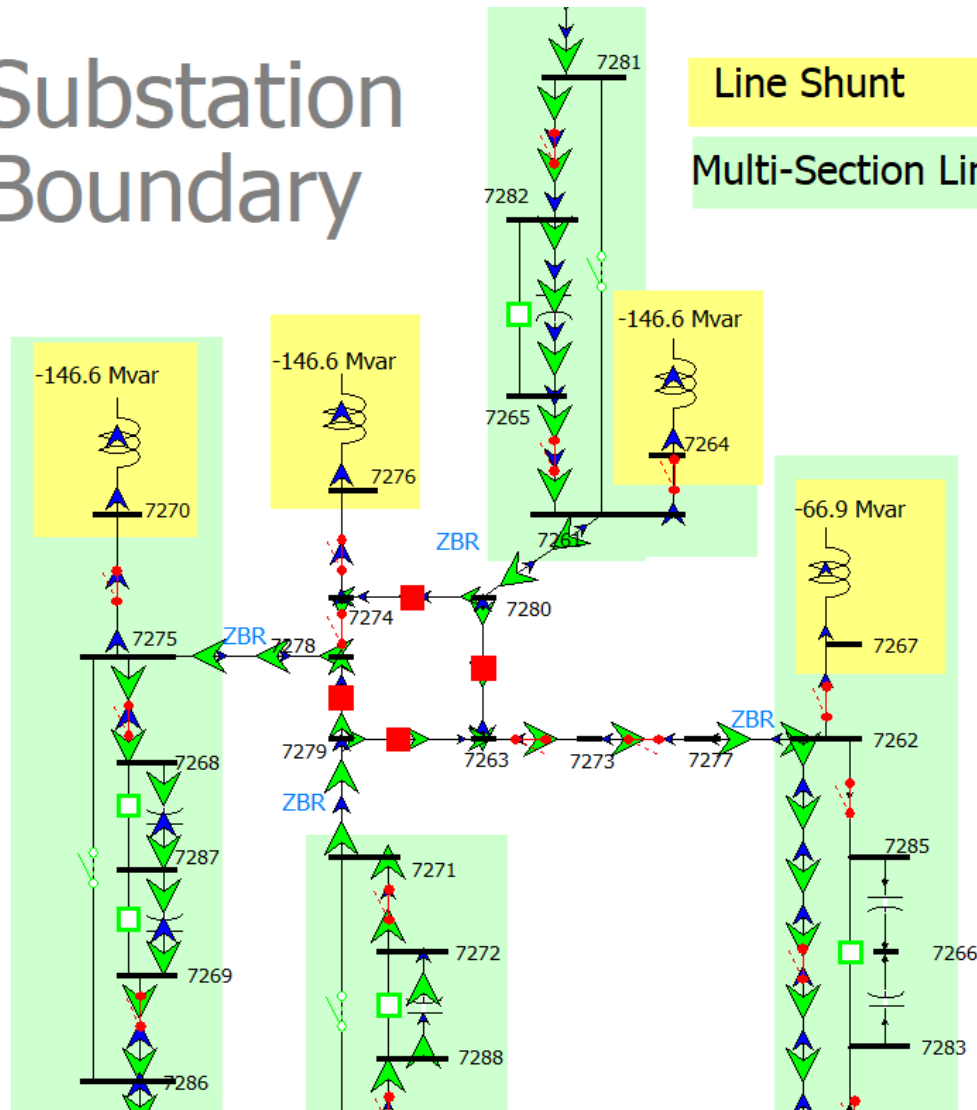


Table of Breakers showing MW and Mvar flows



Model Explorer: Breaker

Explore: Recent, Network, Branches By Type, Breaker (37316), Disconnect (62129), Fuse (360), Ground Disconnect, Line (13189), Load Break Disconnect (715), SeriesCap (245), Transformer (6414), ZBR (529), Branches Input (120897), Branches State (120897), Buses (104536), DC Transmission Lines, Generators (3695), Impedance Correction Tables (28), Line D-FACTS Devices, Line Shunts, Loads (10620), Mismatches (104536)

Breaker | Switched Shunts | Buses

Filter: Advanced | Branch

	From Number	From Name	To Number	To Name	Circuit	Branch Device Type	MW From	MW To	Mvar From	Mvar To	Allow Consolidation	Allow Oper Close Break
1	1	SUB0001_138_138	2	SUB0001_138_139	1	Breaker	-15.642	15.642	0.415	-0.415	YES	YES
2	3	SUB0001_138_140	1	SUB0001_138_138	1	Breaker	-13.467	13.467	-0.001	0.001	YES	YES
3	4	SUB0001_138_141	2	SUB0001_138_139	1	Breaker	37.771	-37.771	11.848	-11.848	YES	YES
4	5	SUB0001_138_142	3	SUB0001_138_140	1	Breaker	-0.773	0.773	4.756	-4.756	YES	YES
5	11	SUB0001_138_150	4	SUB0001_138_141	1	Breaker	-38.078	38.078	-5.463	5.463	YES	YES
6	5	SUB0001_138_142	11	SUB0001_138_150	1	Breaker	-29.576	29.576	-1.215	1.215	YES	YES
7	13	SUB0001_13.8_148	14	SUB0001_13.8_149	1	Breaker	-80.204	80.204	-26.755	26.755	YES	YES
8	13	SUB0001_13.8_148	15	SUB0001_13.8_151	1	Breaker	4.226	-4.226	2.533	-2.533	YES	YES
9	16	SUB0002_69_69	18	SUB0002_69_71	1	Breaker	29.237	-29.237	-17.143	17.143	YES	YES
10	17	SUB0002_69_70	19	SUB0002_69_72	1	Breaker	-37.777	37.777	-11.976	11.976	YES	YES
11	21	SUB0002_69_90	20	SUB0002_69_87	1	Breaker	13.303	-13.303	-12.051	12.051	YES	YES
12	22	SUB0002_25_78	23	SUB0002_25_79	1	Breaker	0.000	0.000	0.000	0.000	YES	YES
13	22	SUB0002_25_78	26	SUB0002_25_82	1	Breaker	-27.396	27.396	4.890	-4.890	YES	YES
14	23	SUB0002_25_79	24	SUB0002_25_80	1	Breaker	-14.875	14.875	1.459	-1.459	YES	YES
15	26	SUB0002_25_82	25	SUB0002_25_81	1	Breaker	-27.396	27.396	4.890	-4.890	YES	YES
16	27	SUB0002_25_83	25	SUB0002_25_81	1	Breaker	-3.325	3.325	0.733	-0.733	YES	YES
17	28	SUB0002_25_84	27	SUB0002_25_83	1	Breaker	0.000	0.000	0.000	0.000	YES	YES
18	29	SUB0002_25_85	28	SUB0002_25_84	1	Breaker	0.000	0.000	0.000	0.000	YES	YES

Search: 82125 | Search Now | Options

Limit Monitoring in the Power Flow



Only show the primary bus for each superbus

Low Voltage Buses

High Voltage Buses

Only show the primary bus for each superbus

Low Voltage Buses

High Voltage Buses

Limit Monitoring Settings and Limit Violations

Use the Modify/Create Limit Groups to tab to modify and create limit groups to which Buses, Lines and Interfaces can be assigned. Use the Buses, Lines and Interfaces tabs to assign elements to different limit groups. The Areas and Zones tabs are provided here for your convenience.

Save Monitoring Settings

Load Monitoring Settings

Elements to Show

- All Elements
- Monitored Elements
- Violating Elements

Number Of Violations

Low Voltage Buses

High Voltage Buses

Low-voltage Suspects

Lines/Transformers

Interfaces

Bus Pairs

Limit Group Values

Limit Group

Group Disabled / Do Not Monitor

Lines & Transformers | Interfaces | Buses | Bus Pairs

Percentage

Normal Rating Set

Contingency Rating Set

Treat Line Limits as Equivalent Amps

Do not monitor radial lines and buses (applied to all limit groups)
(This option is not applied if using topology processing)

Bus | Lines | Interfaces | Nomograms | Bus Pairs | Area Reporting | Zone Reporting | Modify/Create Limit Groups | Rating Set Names

Only show the primary bus for each superbus

Bus	Number(1* <)	Name (* <)	AreaName(<)	Monitor(<)	LimitSet(<)	Vpu ▲	kV (<)	LimitLowUsed	LimitHighUsed	LimitLowUsedCTG	LimitHighUsedCTG
12	41723	SUB3682_161_801	AREA23	YES	M_MON23	1.05004	169.056	0.95	1.05	0.90	1.10
13	46050	SUB4116_230_200	AREA24	YES	M_MON24	1.05044	241.601	0.95	1.05	0.90	1.10
14	43244	SUB3820_230_202	AREA23	YES	M_MON23	1.05054	241.624	0.95	1.05	0.90	1.10
15	41890	SUB3700_345_300	AREA23	YES	M_MON23	1.05067	362.481	0.95	1.05	0.90	1.10
16	67436	SUB5865_115_102	AREA27	YES	M_MON27	1.05081	120.843	0.95	1.05	0.90	1.10
17	15044	SUB1355_230_209	AREA05	YES	M_MON05	1.05096	241.720	0.95	1.05	0.95	1.06
18	12829	SUB1168_230_208	AREA05	YES	M_MON05	1.05109	241.751	0.95	1.05	0.95	1.06
19	14664	SUB1327_230_204	AREA05	YES	M_MON05	1.05116	241.766	0.95	1.05	0.95	1.06
20	16174	SUB1456_230_201	AREA05	YES	M_MON05	1.05121	241.778	0.95	1.05	0.95	1.06

PowerWorld Software Features where BranchDeviceTypes Matter



- Software has many automated features that use the BranchDeviceType Information
 - Full Topology Automatic Coordinated Switched Shunt Control
 - User Interaction features “Open Breakers to Isolate” and “Close Breakers to energize”
 - Contingency Analysis “Open with Breakers”
 - These features will only open the Breakers

Full Topology Automatic Coordinated Switched Shunt Control

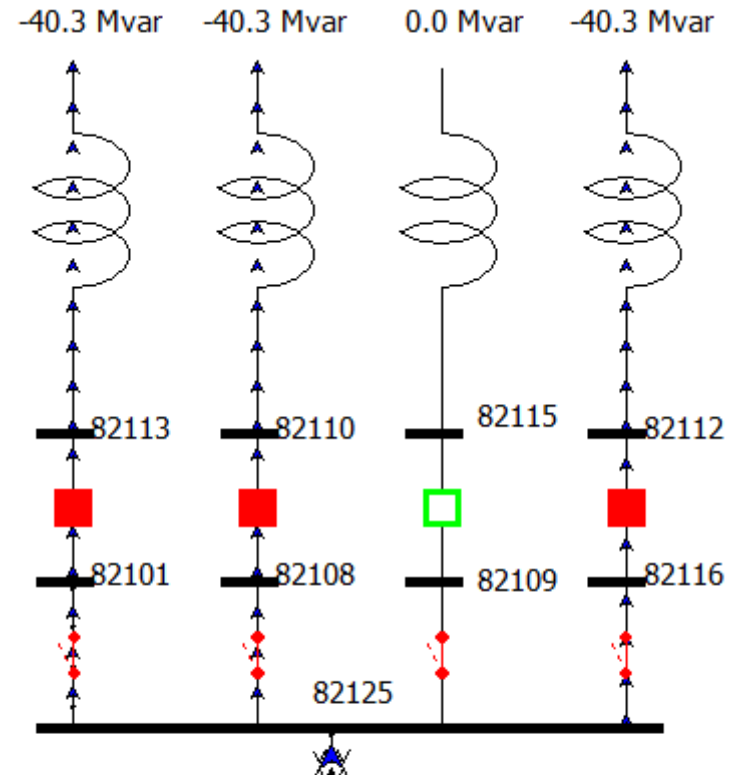


- PowerWorld automatically detects a group of Switched Shunts that regulate the voltage at the same point
 - By “point” we mean a group of buses connected by very low impedance branches
 - Don’t have to regulate the exact same node, just be connected
- Shunt will automatically close breakers and load break disconnects in series with shunt to perform shunt control
- No additional input data: PowerWorld just detects

Full Topology Automatic Coordinated Switched Shunt Control

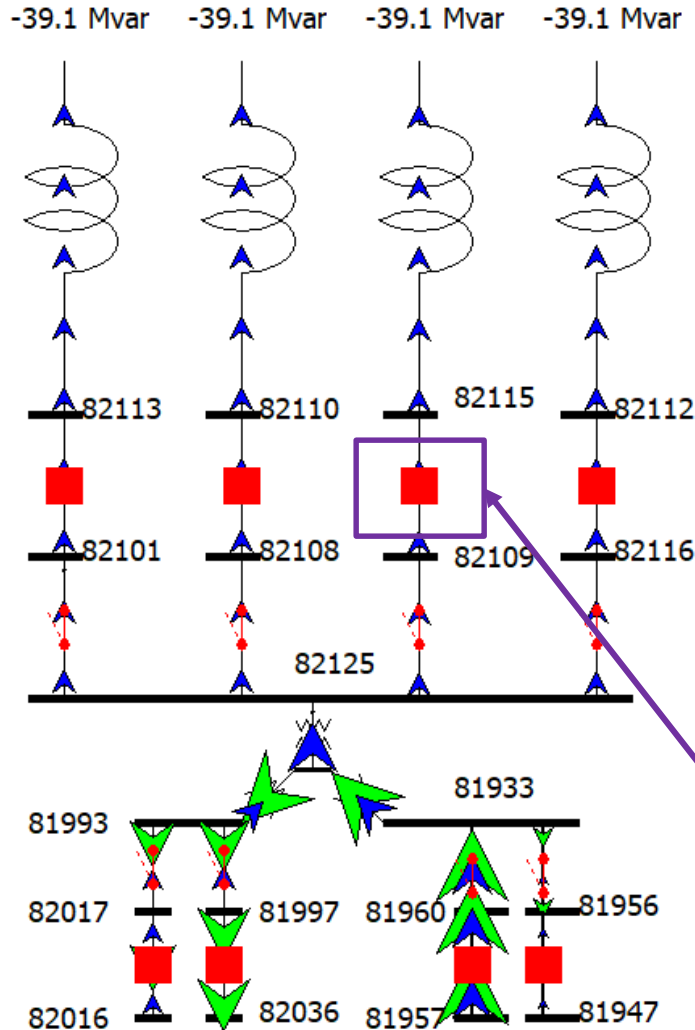


- Example: 4 shunts all regulate “82125”
- Initial solution has regulate voltage inside High/Low Range
- Change Volt High to 0.94



Number of Bus	Name of Bus	ID	Reg Bus N	Status	Status Branch	Control Mode	Regulates	Actual Mvar	Volt High	Volt Low	Reg Volt	Deviation	Nominal Mvar	Max Mvar	Min Mvar
1	82110 SUB6984_13.8_1021	1	82125	Closed		Discrete	Volt	-39.10	0.9400	0.9300	0.9321	0.0000	-45.00	0.00	-45.00
2	82112 SUB6984_13.8_1023	1	82125	Closed		Discrete	Volt	-39.10	0.9400	0.9300	0.9321	0.0000	-45.00	0.00	-45.00
3	82113 SUB6984_13.8_1024	1	82125	Closed		Discrete	Volt	-39.10	0.9400	0.9300	0.9321	0.0000	-45.00	0.00	-45.00
4	82115 SUB6984_13.8_1026	1	82125	Closed		Discrete	Volt	-39.10	0.9400	0.9300	0.9321	0.0000	-45.00	0.00	-45.00

Power Flow Solution automatically closes in the breaker



```
Message Log: Obfuscated.csv
Starting Solution using Rectangular Newton-Raphson
Consolidated 104536 Buses into 20991 SuperBuses at 2/27/2018 12:30:24 PM

Number: 0 Max P: 0.000 at bus 14290 Max Q: 0.000 at bus 37697
Switched shunt 82115 #1 moved from 0.0 to -45.0 Mvars
Finished voltage control loop iteration: 1
DC Line Flow Adjustment
Number: 0 Max P: 0.002 at bus 82125 Max Q: 39.229 at bus 82115
Number: 1 Max P: 0.000 at bus 82125 Max Q: 0.001 at bus 82125

Gen(s) at bus 81266 at max vars
Gen(s) at bus 81269 at max vars
Finished voltage control loop iteration: 2

Number: 0 Max P: 0.000 at bus 82125 Max Q: 0.501 at bus 81269
Number: 1 Max P: 0.000 at bus 14290 Max Q: 0.000 at bus 80214

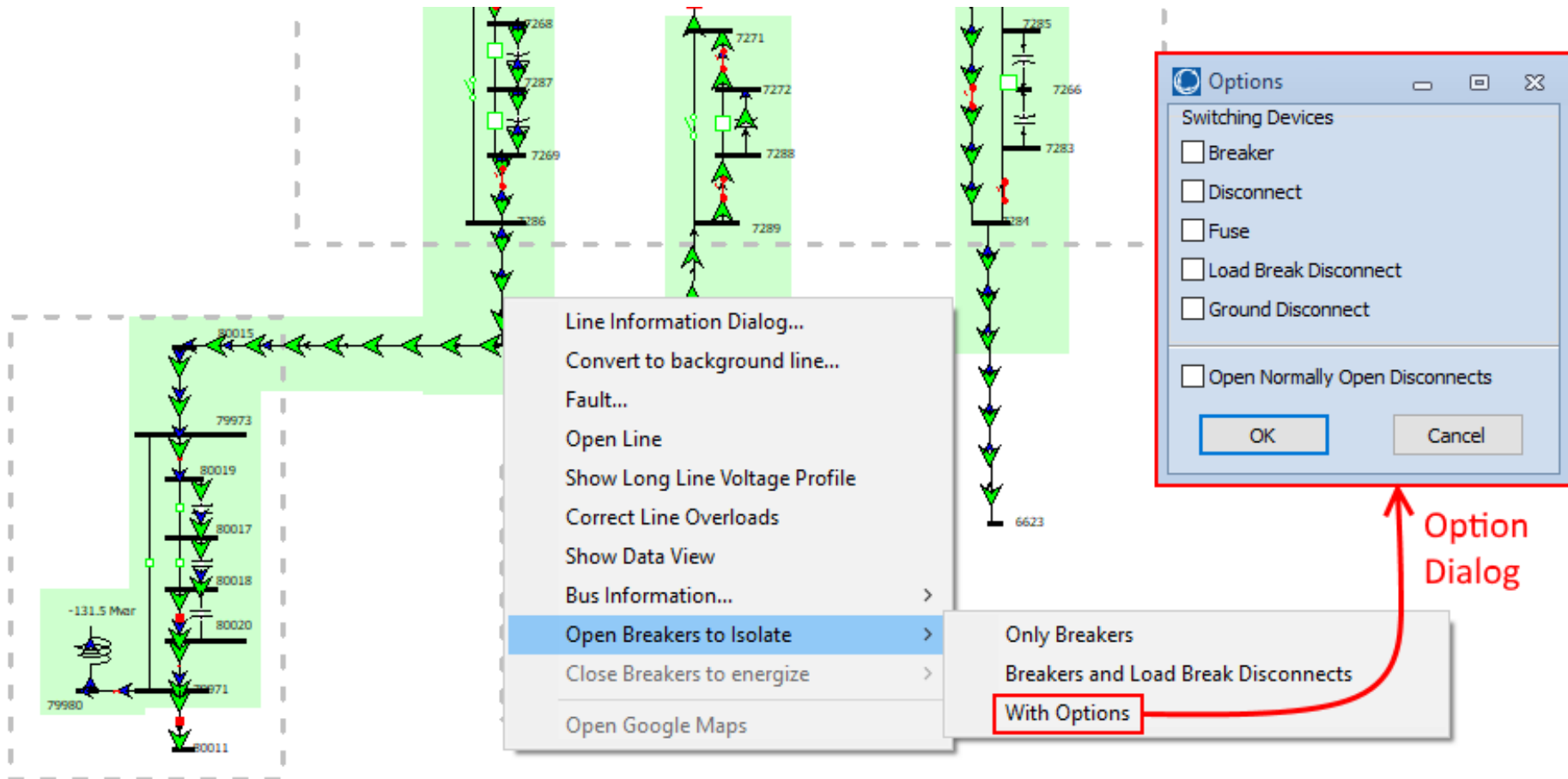
Finished voltage control loop iteration: 3

Determining the side of transformer on which regulated buses are. This is needed to write to s
Using Tap Sensitivities to determine if Reg Buses are more than 1 bus away from the From or

Deconsolidated 20991 SuperBuses into 104536 Buses at 2/27/2018 12:30:26 PM
```

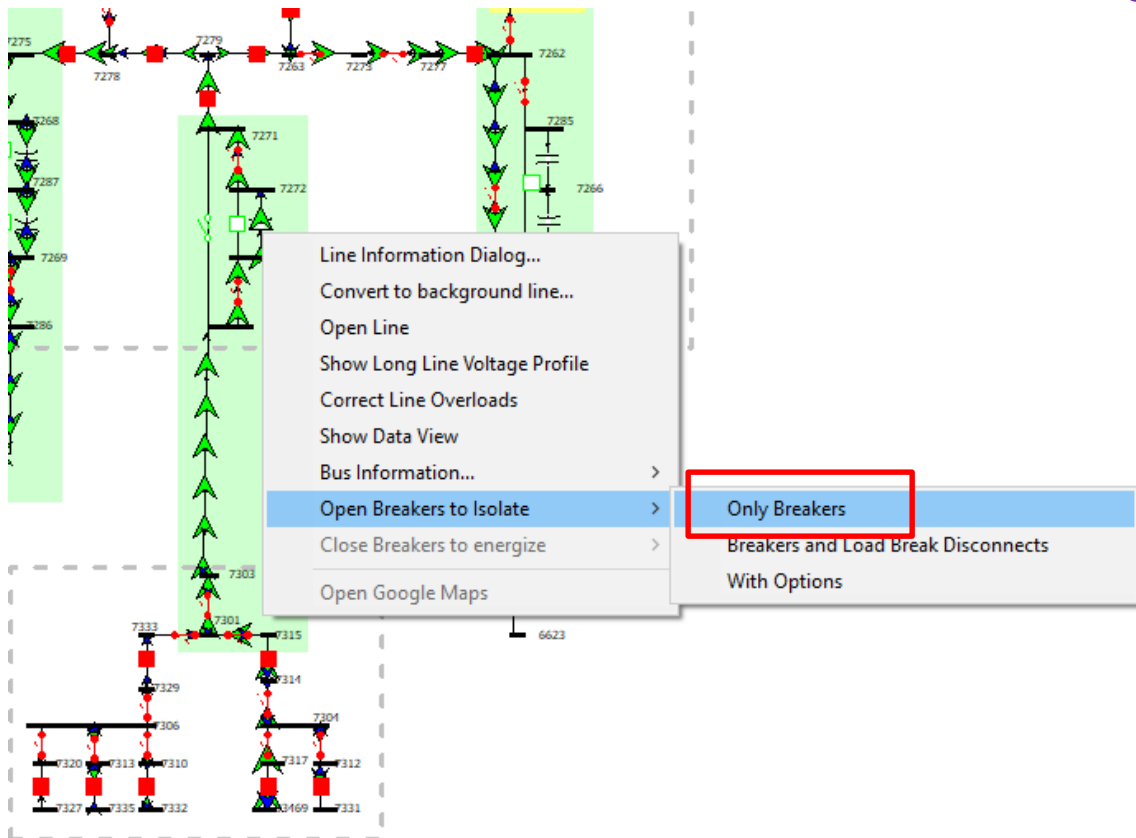
Automatically closed in Breaker
(would also close in a Load Break
Disconnect)

User Interaction features: Open Breakers to Isolate

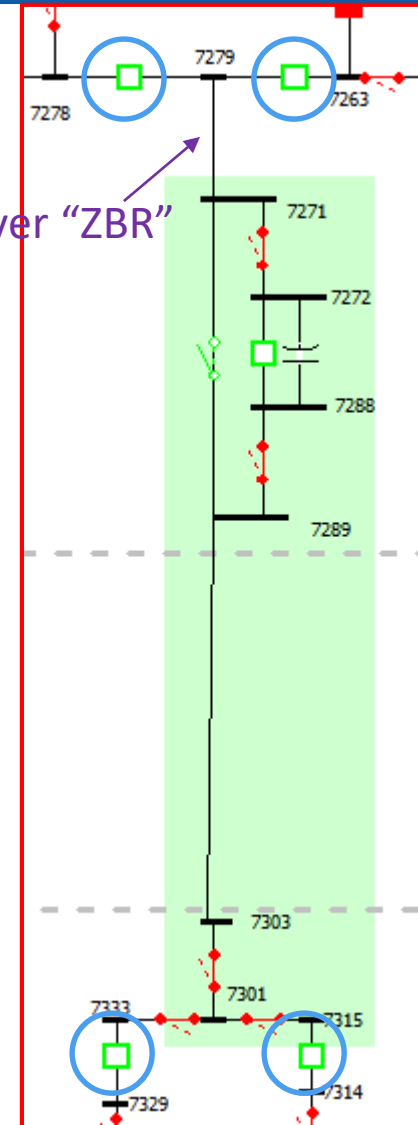


User Interaction features: Open Breakers to Isolate

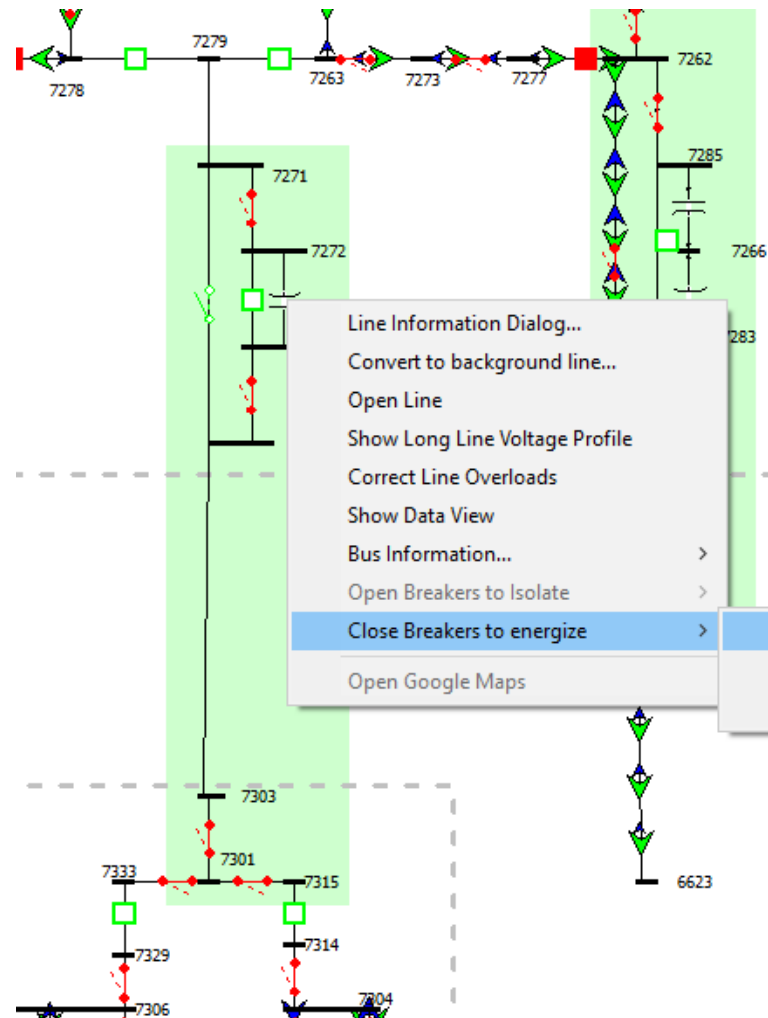
- Automatically Finds Breakers



Skip over "ZBR"



User Interaction features: Close Breakers to Energize



Select Breakers to Close

Breakers for From Terminal Bus

	From Number	From Name_Nominal kV	To Number	To Name_Nominal kV	Circuit	Labels All	Energized Bus Number	Normal Status	Branch Device Type	Close?
1	7279	SUB0716_500_5	7263	SUB0716_500_51		SUB0716\$PCBS652	7263	Closed	Breaker	YES
2	7279	SUB0716_500_5	7278	SUB0716_500_51		SUB0716\$PCBS556	7278	Closed	Breaker	YES

Breakers for To Terminal Bus

	From Number	From Name_Nominal kV	To Number	To Name_Nominal kV	Circuit	Labels All	Energized Bus Number	Normal Status	Branch Device Type	Close?
1	7315	SUB0718_500_5	7314	SUB0718_500_51		SUB0718\$PCBS145	7314	Closed	Breaker	YES
2	7333	SUB0718_500_5	7329	SUB0718_500_51		SUB0718\$PCBS135	7329	Closed	Breaker	YES

Device: Branch '7272' '7288' '1'

Device Status: Closed

Check if Can Be Energized: YES

Close Breakers Cancel

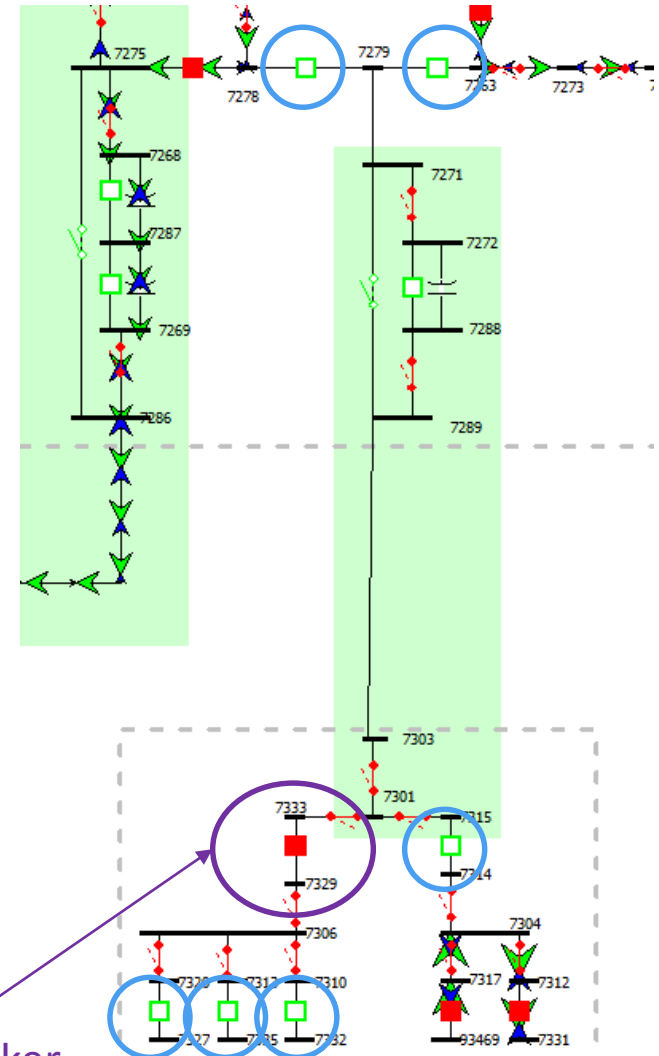
- Only Breakers
- Breakers and Load Break Disconnects
- With Options

- Dialog Appears asking you to pick which breakers to close

Model a Breaker Failure



- Perform “Open with Breakers” on a device that is a Breaker
 - PowerWorld assumes that you want to find breakers that surround the breaker
 - Assumption is that the breaker will not open (otherwise you’d just open it!)



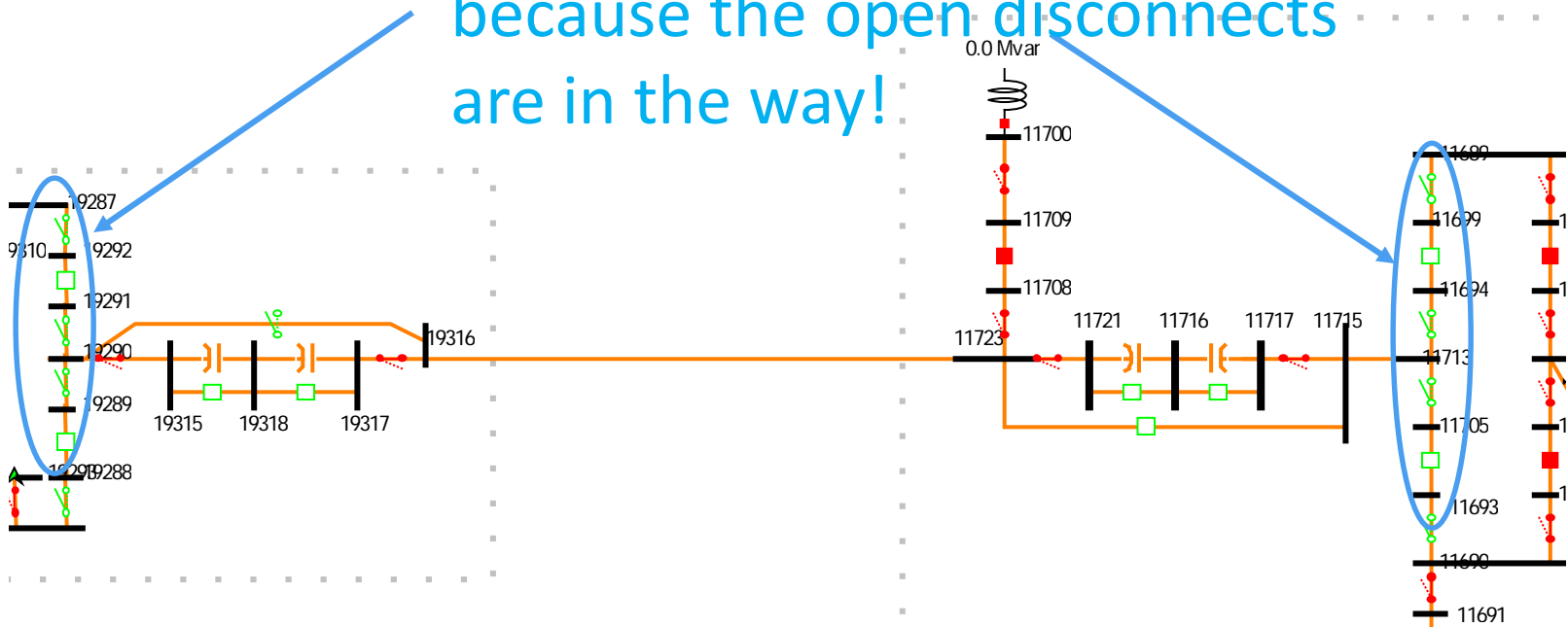
Perform Open with Breakers on this breaker

Using a Full-Topology Export that includes out-of-service lines



- Open with breakers always works fine
- Close Breakers to Energize can be troublesome
 - Out-of-service line may also have disconnects open

“Close Breakers” won’t work because the open disconnects are in the way!



Yet more options to automatically fix this trouble



- Use Close Breakers to energize “with Options”

The screenshot displays a power system diagram with a context menu open over a line segment. The menu includes options such as 'Line Information Dialog...', 'Convert to background line...', 'Fault...', 'Open Line', 'Show Long Line Voltage Profile', 'Correct Line Overloads', 'Show Data View', 'Bus Information...', 'Look for Contingency Record...', 'Open Breakers to Isolate', 'Close Breakers to energize', and 'Open Google Maps'. The 'Close Breakers to energize' option is highlighted, and its sub-menu is visible, showing 'Only Breakers', 'Breakers and Load Break Disconnects', and 'With Options'. The 'With Options' option is highlighted in blue. A red arrow points from the text 'Use With Options' at the bottom left to the 'With Options' option in the sub-menu.

Overlaid on the right is the 'Options' dialog box. It has a title bar with a globe icon and standard window controls. The 'Switching Devices' section contains the following options:

- Breaker
- Disconnect
- Fuse
- Load Break Disconnect
- Ground Disconnect

The 'Close Normally Closed Disconnects' option is checked and highlighted with a red rectangle. At the bottom of the dialog are 'OK' and 'Cancel' buttons.

Use With Options

Close Normally Closed Disconnects



- This option will look across normally closed disconnects searching for breakers
- Option will also look *in series* past breakers for disconnects
- Treats a series combination of disconnects with a single breaker as though it is “one switching decision”

Close Normally Closed Disconnects



Select Breakers to Close

Records Set Columns Options

Breakers for From Terminal Bus

	From Number	From Name_Nominal kV	To Number	To Name_Nominal kV	Circuit	Labels All	Energized Bus Number	Normal Status	Branch Device Type	Close?
1	19289	SUB1664_500_911_500.0	19290	SUB1664_500_912_500.0	1	SUB1664\$MOD\$4978		Closed	Disconnect	YES
2	19290	SUB1664_500_912_500.0	19291	SUB1664_500_913_500.0	1	SUB1664\$MOD\$4979		Closed	Disconnect	YES
3	19288	SUB1664_500_910_500.0	19289	SUB1664_500_911_500.0	1	SUB1664\$PCB\$4977		Closed	Breaker	YES
4	19286	SUB1664_500_900_500.0	19288	SUB1664_500_910_500.0	1	SUB1664\$MOD\$4976	19286	Closed	Disconnect	YES
5	19291	SUB1664_500_913_500.0	19292	SUB1664_500_914_500.0	1	SUB1664\$PCB\$4980		Closed	Breaker	YES
6	19287	SUB1664_500_901_500.0	19292	SUB1664_500_914_500.0	1	SUB1664\$MOD\$4981	19287	Closed	Disconnect	YES

Breakers for To Terminal Bus

	From Number	From Name_Nominal kV	To Number	To Name_Nominal kV	Circuit	Labels All	Energized Bus Number	Normal Status	Branch Device Type	Close?
1	11694	SUB1094_500_906_500.0	11713	SUB1094_500_930_500.0	1	SUB1094\$DSCS\$5091		Closed	Disconnect	YES
2	11705	SUB1094_500_919_500.0	11713	SUB1094_500_930_500.0	1	SUB1094\$DSCS\$5095		Closed	Disconnect	YES
3	11694	SUB1094_500_906_500.0	11699	SUB1094_500_913_500.0	1	SUB1094\$CB\$5092		Closed	Breaker	YES
4	11699	SUB1094_500_913_500.0	11689	SUB1094_500_900_500.0	1	SUB1094\$DSCS\$5093	11689	Closed	Disconnect	YES
5	11693	SUB1094_500_905_500.0	11705	SUB1094_500_919_500.0	1	SUB1094\$CB\$5096		Closed	Breaker	YES
6	11690	SUB1094_500_901_500.0	11693	SUB1094_500_905_500.0	1	SUB1094\$DSCS\$5097	11690	Closed	Disconnect	YES

Device: Branch '19316' '11723' '1'

Device Status: Closed

Check if Can Be Energized: YES

Close Breakers Cancel

Finds the Disconnects too

Bus table and Superbus



- PowerWorld treats all “nodes” as additions to the bus table
 - Represent a point where devices connect
- Superbus table (user does not create – software figures it out)
 - Superbus = group of buses connected by closed switching devices
 - It is similar in concept to an electrical island
 - Islands are added and removed in the software as branches change status
 - Island = group of buses connected by closed branches of any type
- Subnet table (user does not create – software figures out)
 - Subnet = group of buses connected by open or closed switching devices

Bus table and Superbus



- Typically as a user you will not interact with either the Superbus or the Subnet table
 - They are available to see
 - Each Superbus and Subnet also chooses “primary node”
 - This affects features that report only one bus violation inside a Superbus
 - Also possible for the user to bias the choice of the super bus by assigning a priority to the bus object

Superbus table



Model Explorer: Superbuses

Explore Fields

- VSC DC Transmission Lin
- Aggregations
 - Areas (42)
 - Balancing Authorities (4)
 - Bus Pairs (72)
 - Data Maintainers
 - Injection Groups (35)
 - Interfaces (86)
 - Islands (1022)
 - Multi-Section Lines
 - MW Transactions
 - Nomograms
 - Owners (42)
 - Substations (8540)
 - Super Areas
 - Tielines between Areas
 - Tielines between Balan
 - Tielines between Zones
 - Transfer Directions
 - Zones (65)
- Solution Details
 - Bus Zero-Impedance Br
 - Fast Decoupled BP Mat
 - Fast Decoupled BPP Ma
 - Mismatches (104536)
 - Outages
 - Post Power Flow Soluti
 - Power Flow Jacobian (1
 - Remotely Regulated Bu
 - Subnets (14901)
 - Superbuses (20990)**
 - Time Step Actions
 - YBus (104536)

Open New Explorer

Search 82125 Search Now Options

Superbuses

Subnets	Sub Name	Primary Bus	# Buses	Buses	Has Been Consolidated	PU Volt	Angle (Degrees)	Topology Status	Gen MW	Gen Mvar	Load Mvar	Load MW	Switched Shunts Mvar
1	SUB0001	8	12	1-12	NO	1.0409	-2.8698	Not Processed				21.27	43.32
2	SUB0001	14	3	13-15	NO	1.0016	1.9559	Not Processed	80.20	26.75	2.53	4.23	
3	SUB0002	18	2	16,18	NO	1.0437	-4.2068	Not Processed					
4	SUB0002	19	2	17,19	NO	1.0450	-3.3338	Not Processed					
5	SUB0002	20	2	20-21	NO	1.0432	-3.9578	Not Processed					
6	SUB0002	22	5	22,25-28	NO	1.0416	-10.1791	Not Processed			-5.62	30.72	
7	SUB0002	23	2	23-24	NO	1.0332	-0.2441	Not Processed			-1.46	14.94	
8	SUB0002	29	2	29-30	NO	1.0315	-6.7286	Not Processed			-6.27	13.73	
9	SUB0002	31	1	31	NO	1.0358	-7.6475	Not Processed					
10	SUB0002	32	2	32-33	NO	1.0273	0.3819	Not Processed	52.56	20.29			
11	SUB0002	34	1	34	NO	1.0230	-5.5619	Not Processed					
12	SUB0002	35	1	35	NO	1.0358	-7.6475	Not Processed					
13	SUB0002	36	1	36	NO	1.0320	0.9923	Not Processed					
14	SUB0002	37	1	37	NO	1.0230	-5.5619	Not Processed					

Buses

Number	Name	Labels All	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar
1	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
2	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
3	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
4	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
5	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
6	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
7	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
8	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87			22.13	12.26
9	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87			8.50	4.25
10	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87			12.69	4.76
11	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
12	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				

Subnet Table

The screenshot displays the 'Model Explorer: Superbuses' application. The left sidebar shows a tree view of the model structure, with 'Superbuses (20990)' selected. The main window is divided into two tables.

Subnets Table:

	Sub Name	Primary Bus	# Buses	# CBs	# Open CBs	Buses	Has Been Consolidated	Topology Status	Gen MW	Gen Mvar
1	SUB0001	8	12	12	0	1-12	NO	Not Processed		
2	SUB0001	14	3	2	0	13-15	NO	Not Processed	80.20	26.75
3	SUB0002	18	2	1	0	16,18	NO	Not Processed		
4	SUB0002	19	2	1	0	17,19	NO	Not Processed		
5	SUB0002	20	2	1	0	20-21	NO	Not Processed		
6	SUB0002	22	9	8	2	22-30	NO	Not Processed		
7	SUB0002	32	3	2	1	31-33	NO	Not Processed	52.56	20.29
8	SUB0002	34	1	0	0	34	NO	Not Processed		
9	SUB0002	35	1	0	0	35	NO	Not Processed		
10	SUB0002	36	1	0	0	36	NO	Not Processed		
11	SUB0002	37	1	0	0	37	NO	Not Processed		
12	SUB0003	40	2	1	0	38,40	NO	Not Processed		
13	SUB0003	41	2	1	0	39,41	NO	Not Processed		

Buses Table:

	Number	Name	Labels All	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar
1	1	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
2	2	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
3	3	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
4	4	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
5	5	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
6	6	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
7	7	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
8	8	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87	22.13		12.26	
9	9	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87	8.50		4.25	
10	10	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87	12.69		4.76	
11	11	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				
12	12	SUB0001_138_SUB0001\$ND\$ AREA01			138.00	1.04092	143.647	-2.87				



Human Interaction



- Model Navigation Obstacle
 - Can be confusing to navigate full-topology models
- Tools that graphically show bus-to-bus connections in the model can get very complicated
 - You can get stuck inside all the disconnects and breakers
 - Makes finding more important devices difficult (lines, transformers, generators, loads)
 - PowerWorld's Bus View has features to help

Planning Case Bus View

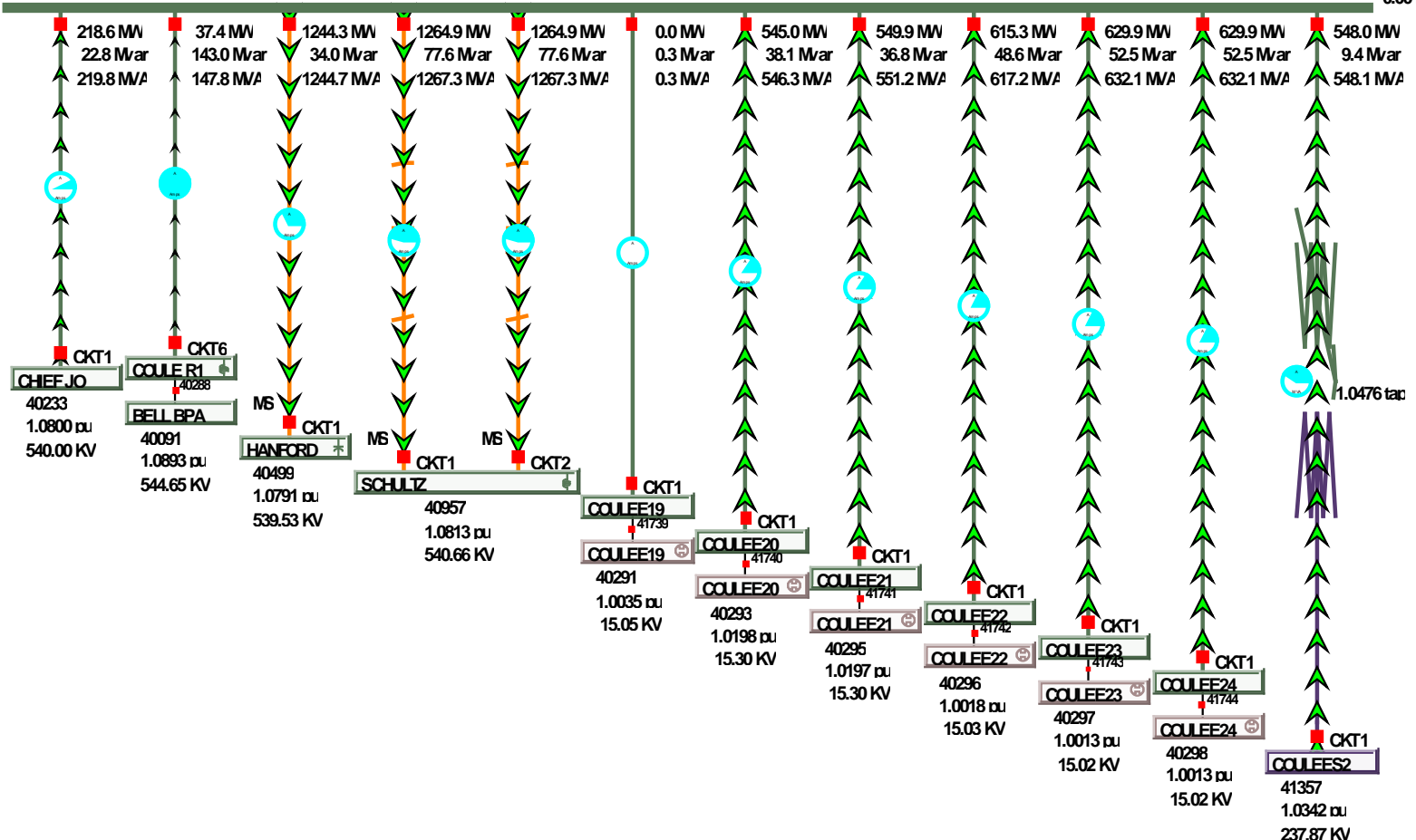


COULEE

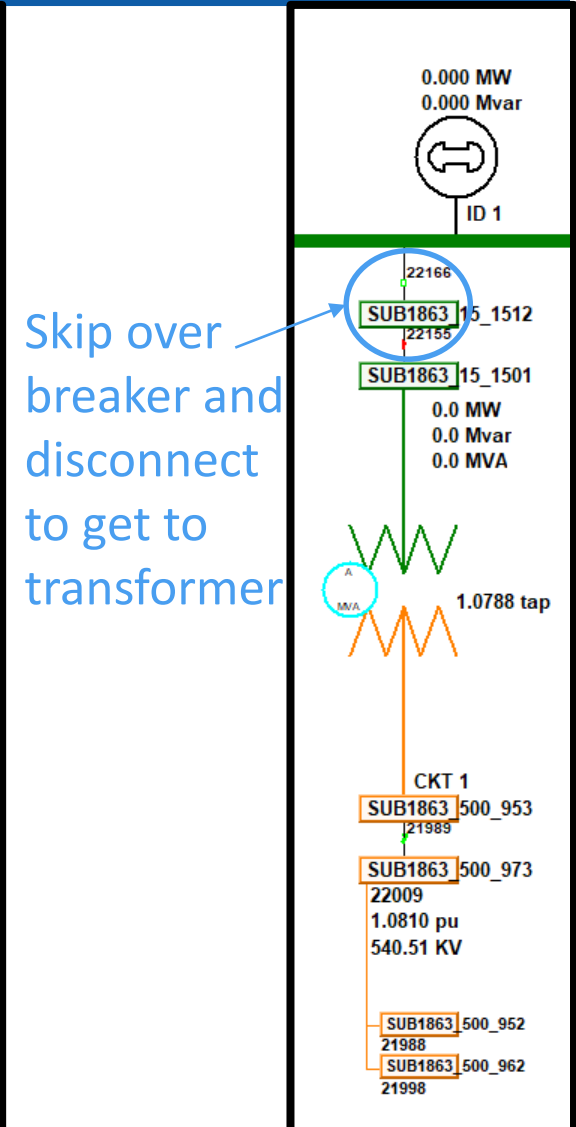
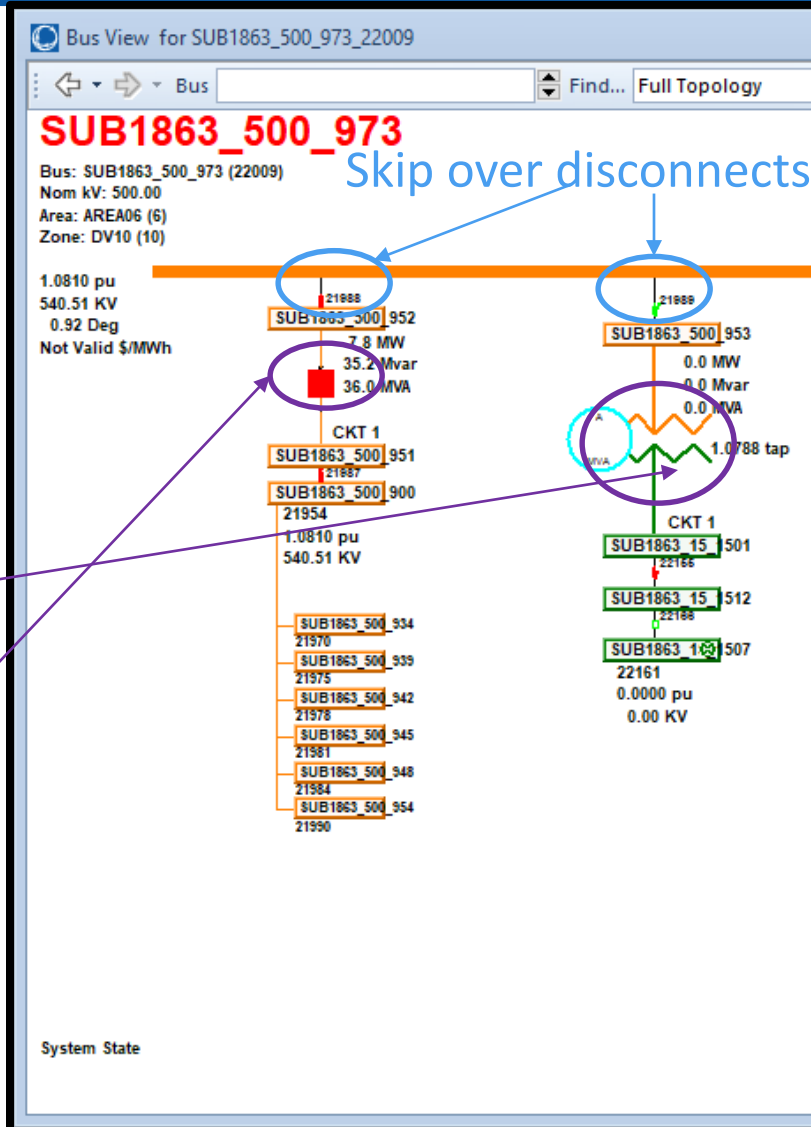
Bus: COULEE (40287)
 NomkV: 500.00
 Area: NORTHWEST(40)
 Zone: Central Washington (403)

1.0800 pu
 540.00 KV
 59.94 Dec
 0.00 \$/MWh

0.00 MW
 0.00 Mvar



Full Topology Bus View



Shows stack of serially connected nodes

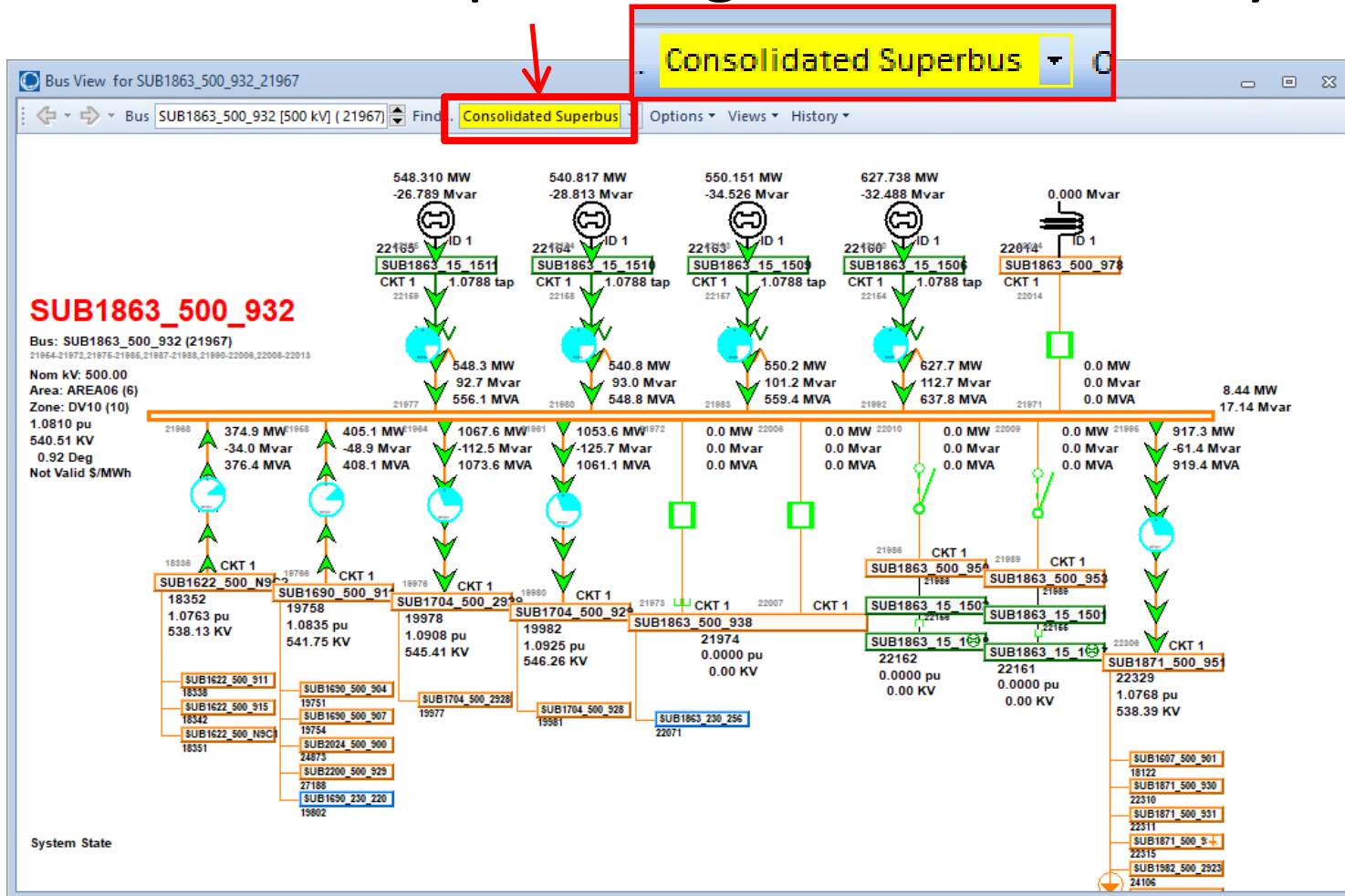
Bias to show lines, transformer, or series cap prominently

If those not available, then biases to show breaker

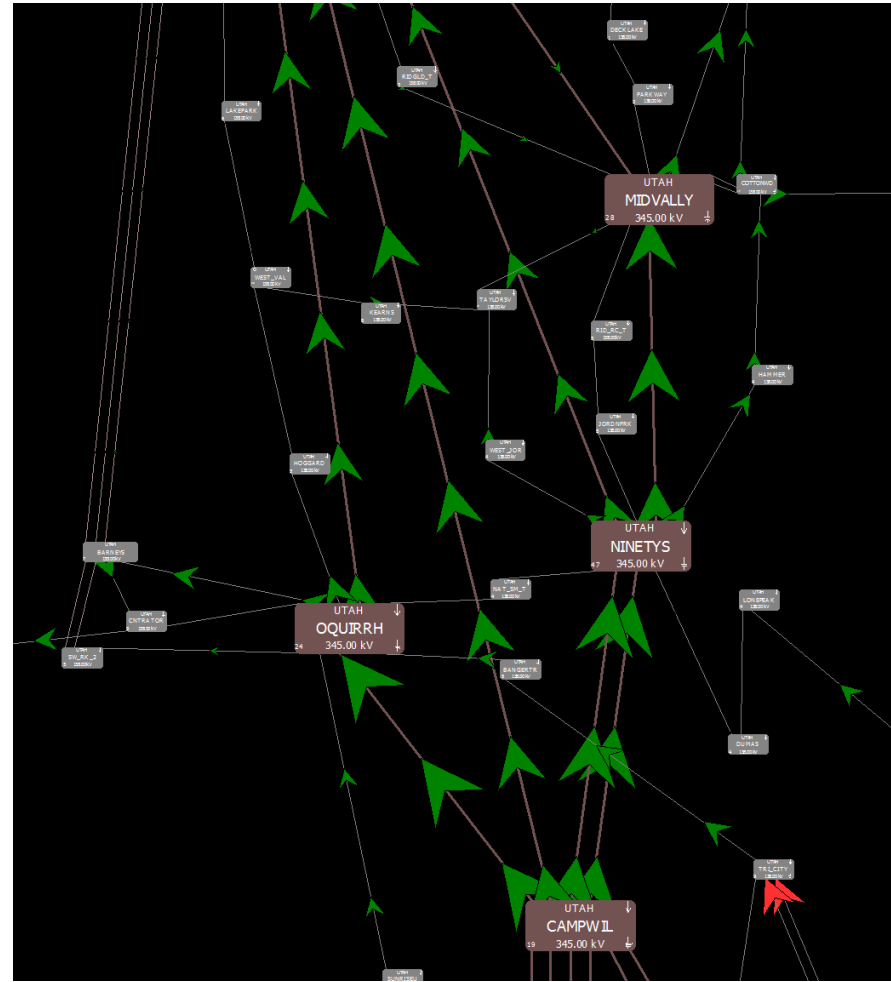
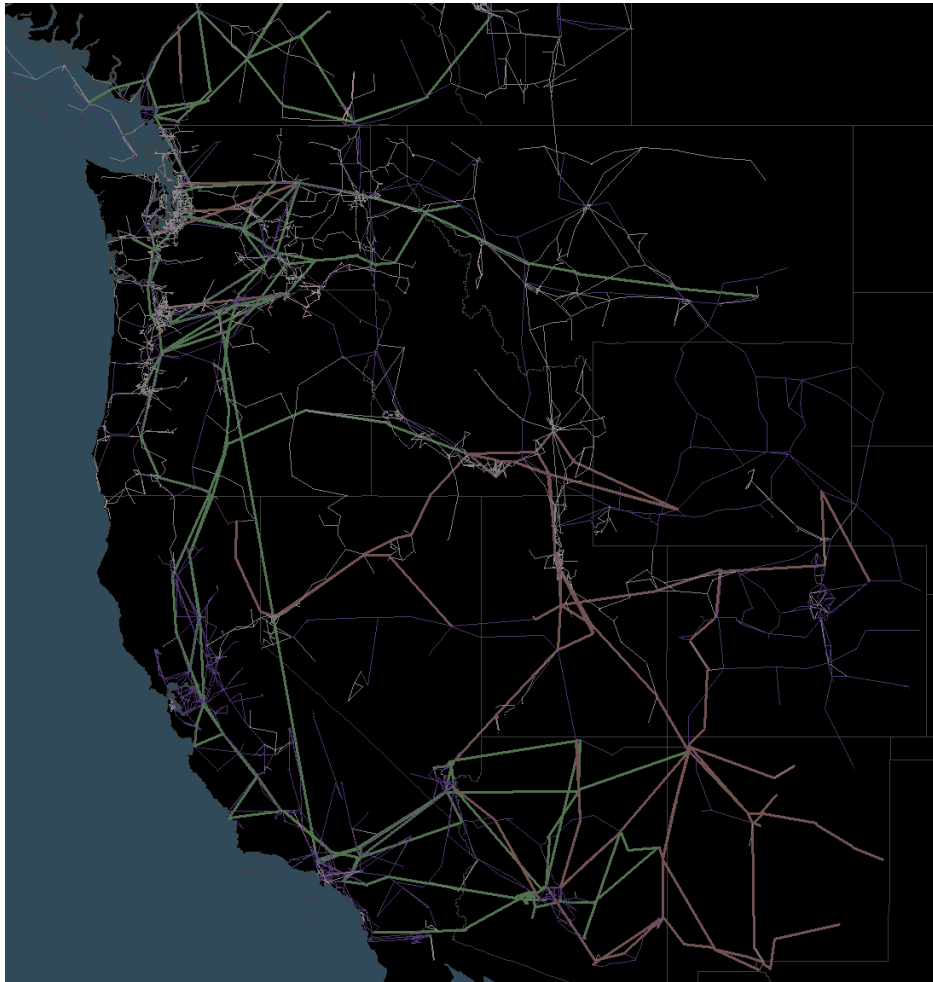
Consolidated Superbus View



- Looks like the “planning case” essentially



Overview Oneline Visualizations will likely be Substation Based

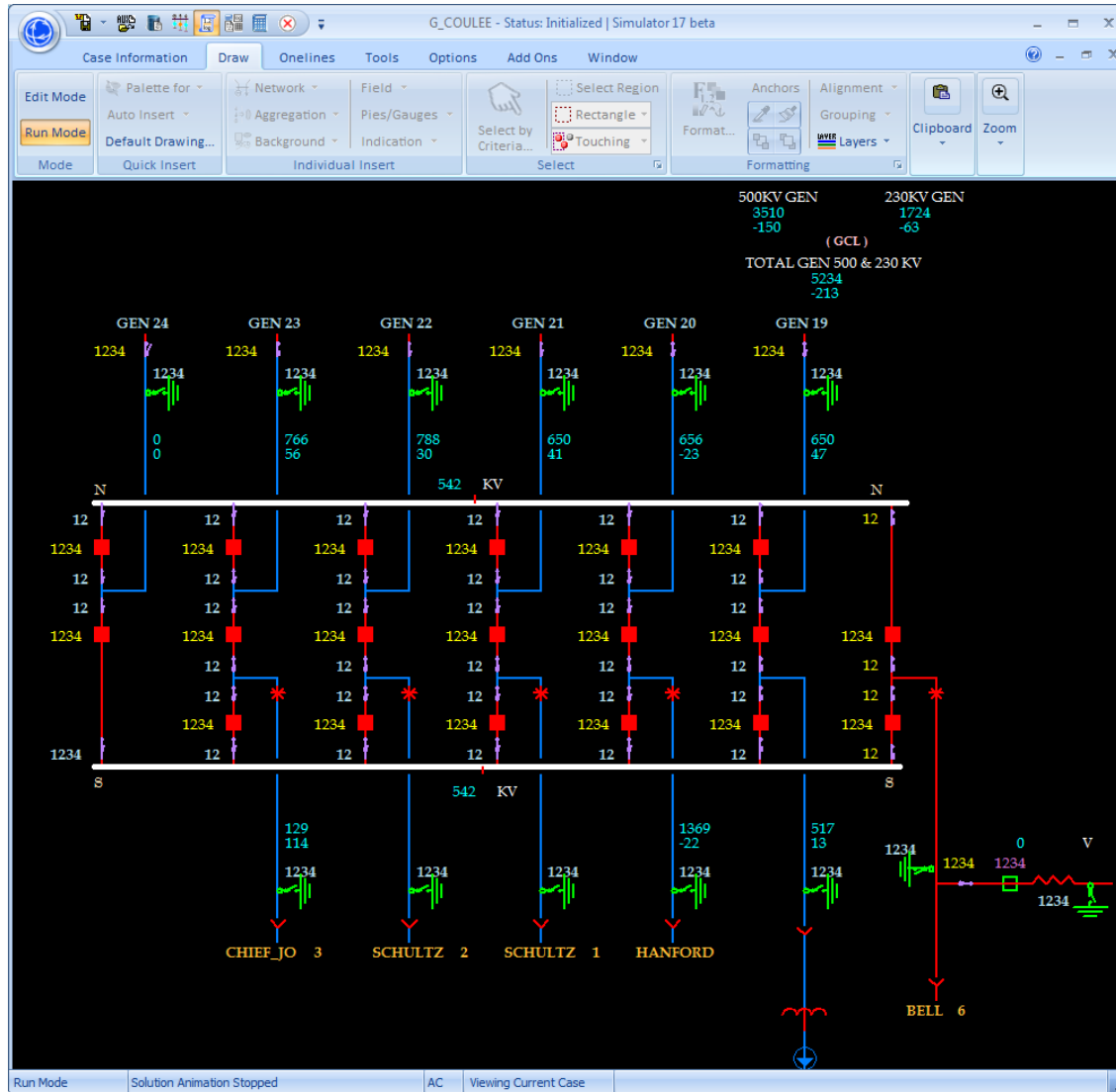


EMS Oneline Diagrams



- Peak Reliability has a lot of custom-built substation topology diagrams
 - Our most recent set from them for testing had 4,494 diagrams
 - Clearly not something that they are going to draw a second time
- After a short project (about 1 person-month of effort), we built a translation file that describes how the various symbols on their onelines are drawn
 - Areva onelines are all built around user-customized symbols, so we had to translate a few hundred symbols
 - Once Peak Reliability's symbols are translated, PowerWorld can directly read in all 4,494 of these online diagrams
 - Still working on a mechanism to keep this up-to-date
 - They add new kinds of symbols to the diagrams
 - Peak will share these with other companies
- Have done same work with ISO – New England and BPA

Build Tools to Load Substation Topology Onelines



Contingency Definitions

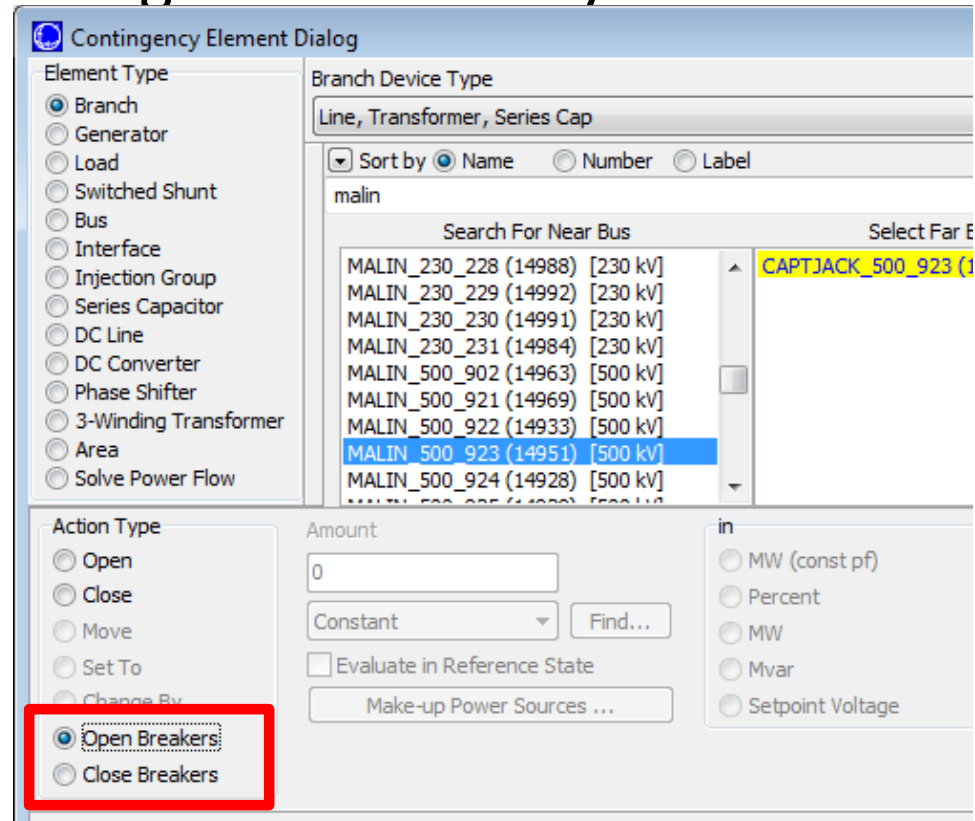


- Bad News
 - In a real-time model these can get very complicated and confusing
 - A “Single Line Outage” turns into 4 different breakers opening together
 - The breakers necessary to isolate a line change as system topology changes
 - We need a better way to define a contingency (which we have)
- Good News
 - We can model a breaker failure easily now

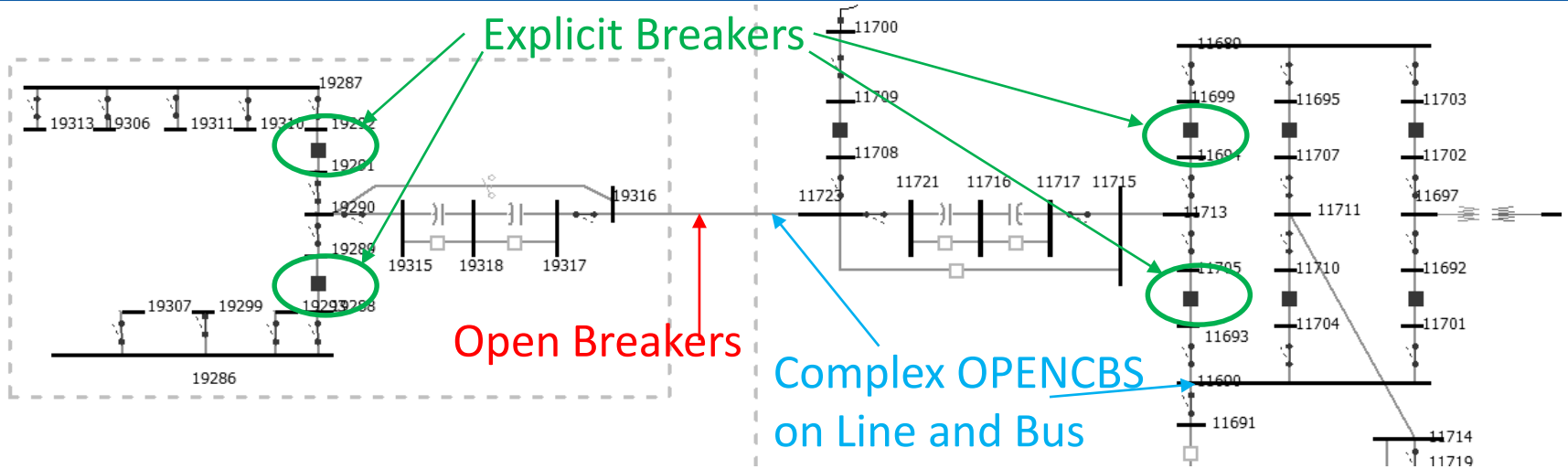
“Open with Breakers” and “Close with Breakers” Contingency Actions



- Open a device using breakers instead of changing the status of the device directly
- Ensures that accurate modeling of real-time system is achieved
- Automatically determine *Breakers* that need to open to isolate an element
- Breaker failure scenarios can be modeled by applying this action to a breaker
- Same idea for a “Close with Breakers” action



Example Contingency Analysis



Contingency Analysis

Contingencies Options Results

- Modeling
 - Basics
 - DC and Screening Options
 - Generator Post-Contingency AGC
 - Bus Load Throw Over
 - Generator Maximum MW Response
 - Generator Line Drop and RCC
 - Switched Shunt Post CTG
 - Auxiliary Files
 - Transient Models
 - Result Storage
 - Limit Monitoring
- Contingency Definitions
 - All Contingency Elements
- Remedial Action Definitions
- Legacy Definitions
- Distributed Computing

All Contingency Elements

	Contingency Label	Actions - PW File Format	Mod
1	Sample Explicit Breakers	BRANCH 'SUB1664\$PCB\$4980' OPEN	
2	Sample Explicit Breakers	BRANCH 'SUB1664\$PCB\$4977' OPEN	
3	Sample Explicit Breakers	BRANCH 'SUB1094\$CB\$5092' OPEN	
4	Sample Explicit Breakers	BRANCH 'SUB1094\$CB\$5096' OPEN	
5	Open with Breakers	BRANCH 'LN\$LINE01237\$A' OPENCBS	
6	More Complex Open with Breakers	BRANCH 'LN\$LINE01237\$A' OPENCBS	
7	More Complex Open with Breakers	BUS 'SUB1094\$ND\$901' OPENCBS	

What Actually Occurred Reporting



- OPENCBS action will report which breakers where actually open
 - “Origin of Action” = ELEMENT DYNAMIC
 - This means Simulator dynamically figured out what to open
 - What opens will not always be the same
 - If a disconnect is open that is normally closed then the contingency actions that occur are different

	Label	Skip	Category	Processed	Solved	Include Remedial Actions	Screen Allow	Post-CTG AUX	Islanded Load	Islanded Gen	Global Actions	Transient Actions	Remedial Actions	Custom Monitor Violations	Violations	Max Branch
1	Sample Explicit Breakers	NO		YES	YES	YES	NO	none			0	0	0	0	12	16
2	Open with Breakers	NO		YES	YES	YES	NO	none			0	0	0	0	12	16
3	More Complex Open with Breakers	NO		YES	YES	YES	NO	none			0	0	0	0	12	16

Violations		What Actually Occurred						
	Contingency	Applied or Skipped	Actions	Model Criteria	Status	Comment	Brief What Occurred	Origin of Action
1	Open with Breakers	Applied	OPEN BREAKERS TO ISOLATE Line 18316_500.0 TO		CHECK		#1 marked breakers isolated	ELEMENT
2	Open with Breakers	Applied	OPEN Breaker 19288_500.0 TO 19289_500.0 CKT 1		CHECK		#1 Opened flow of 993.55 MV. ELEMENT DYNAN	
3	Open with Breakers	Applied	OPEN Breaker 19291_500.0 TO 19292_500.0 CKT 2		CHECK		#1 Opened flow of 993.55 MV. ELEMENT DYNAN	
4	Open with Breakers	Applied	OPEN Breaker 11694_500.0 TO 11699_500.0 CKT 2		CHECK		#1 Opened flow of 1008.64 M' ELEMENT DYNAN	
5	Open with Breakers	Applied	OPEN Breaker 11693_500.0 TO 11705_500.0 CKT 1		CHECK		#1 Opened flow of 1008.64 M' ELEMENT DYNAN	

More Complex

What Actually Occurred Reporting



- Special #1, #2, #3 etc. marking in the “What Occurred” indicates which devices required which breakers to open

Contingency Analysis

Contingencies Options Results

	Label	Skip	Category	Processed	Solved	Include Remedial Actions	Screen Allow	Post-CTG AUX	Islanded Load	Islanded Gen	Global Actions	Transient Actions	Remedial Actions	MVA
1	Sample Explicit Breakers	NO		YES	YES	YES	NO	none			0	0	0	
2	Open with Breakers	NO		YES	YES	YES	NO	none			0	0	0	
3	More Complex Open with Breakers	NO		YES	YES	YES	NO	none			0	0	0	

Violations What Actually Occurred

	Contingency	Applied or Skipped	Actions	Model Criteria	Status	Comment
1	More Complex Open with Breakers	Applied	OPEN BREAKERS TO ISOLATE Line 19316_500.0 TO		CHECK	#1 marked breakers isolated this device
2	More Complex Open with Breakers	Applied	OPEN BREAKERS TO ISOLATE Bus 11690_500.0		CHECK	#2 marked breakers isolated this device
3	More Complex Open with Breakers	Applied	OPEN Breaker 19288_500.0 TO 19289_500.0 CKT 1		CHECK	#1 Opened flow of 993.49 MVA
4	More Complex Open with Breakers	Applied	OPEN Breaker 19291_500.0 TO 19292_500.0 CKT 2		CHECK	#1 Opened flow of 993.49 MVA
5	More Complex Open with Breakers	Applied	OPEN Breaker 11694_500.0 TO 11699_500.0 CKT 1		CHECK	#1 Opened flow of 1512.88 MVA
6	More Complex Open with Breakers	Applied	OPEN Breaker 11693_500.0 TO 11705_500.0 CKT 1		CHECK	#1,#2 Opened flow of 504.28 MVA
7	More Complex Open with Breakers	Applied	OPEN Breaker 11692_500.0 TO 11701_500.0 CKT 1		CHECK	#2 Opened flow of 252.15 MVA
8	More Complex Open with Breakers	Applied	OPEN Breaker 11704_500.0 TO 11710_500.0 CKT 1		CHECK	#2 Opened flow of 252.15 MVA

Status Finished with 15 violations, 0 custom monitor violations, 0 unsolvable, and 0 aborted contingencies. Initial state restored.

Load Auto Insert Save Other > Refresh Displays After Each Contingency Start Run Close Help

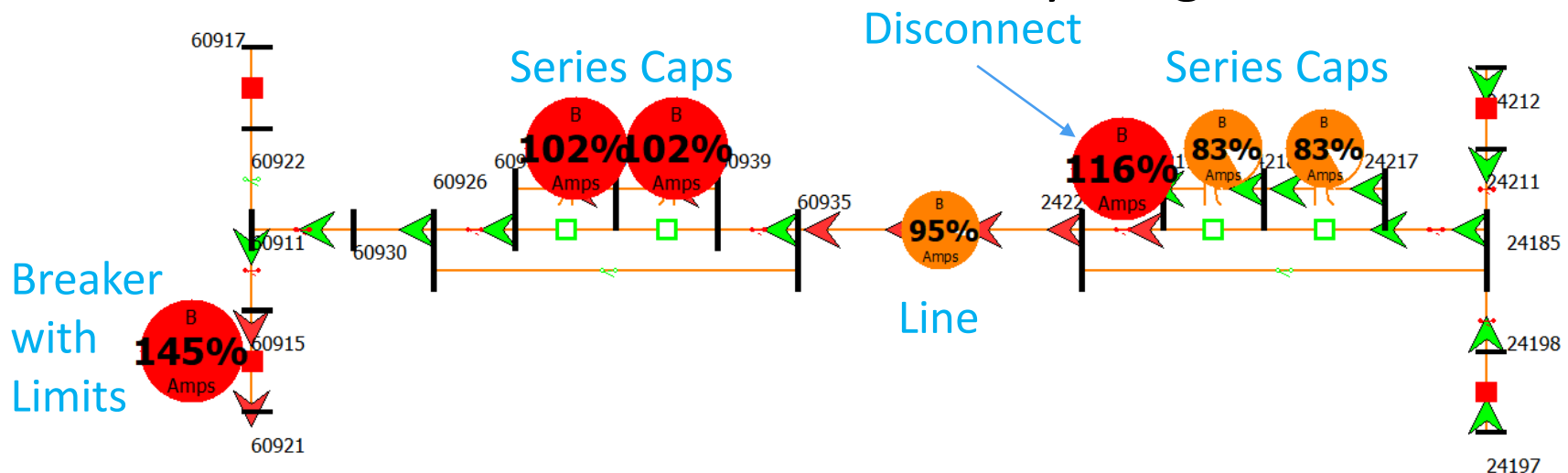
#1 marked breakers isolated this device
 #2 marked breakers isolated this device
 #1 Opened flow of 993.49 MVA
 #1 Opened flow of 993.49 MVA
 #1 Opened flow of 1512.88 MVA
 #1,#2 Opened flow of 504.28 MVA
 #2 Opened flow of 252.15 MVA
 #2 Opened flow of 252.15 MVA

#1 marked breakers isolated this device Opened flow of 2066.30 MVA
 #2 marked breakers isolated this device
 #1 Opened flow of 993.49 MVA
 #1 Opened flow of 993.49 MVA
 #1 Opened flow of 1512.88 MVA
 #1,#2 Opened flow of 504.28 MVA
 #2 Opened flow of 252.15 MVA
 #2 Opened flow of 252.15 MVA

Monitoring of Switching Devices in Contingency Analysis and Power Flow



- Nothing different than before
- A breaker, disconnect, line, transformer, and series cap are all the same
 - Any device that has a limit specified is monitored regardless of what is going on inside the solution
 - Software calculates flows on everything



Violations shown as normal



Contingency Analysis

Contingencies Options Results

Records Set Columns

Contingency	Name	Skip	Category	Processed	Solved	Remedial	ScreenAll	PostCTGA	LoadMW	GenMW	Occurred	Occurred	Occurred	ViolCustd	Viol
1	Sample Explicit Breakers	NO		YES	YES	YES	NO	none			0	0	0	0	0
2	Open with Breakers	NO		YES	YES	YES	NO	none			0	0	0	0	0
3	More Complex Open with I	NO		YES	YES	YES	NO	none			0	0	0	0	0

Violations What Actually Occurred

Show related contingencies Combined Tables >

LimitViol	Type	Element	Value	Limit	Percent	AreaNames	NomkVs
1	Branch Amp	SUB5296_500_N9C4 (60941) -> SUB5296_500_N9	3339.71	3279.35	101.84	AREA25	500.00
2	Branch Amp	SUB5296_500_N9C6 (60943) -> SUB5296_500_N9	3348.78	3279.35	102.12	AREA25	500.00
3	Branch Amp	SUB5296_500_N913 (60936) -> SUB5457_500_937	3353.73	3279.35	102.27	AREA25	500.00
4	Branch Amp	SUB5296_500_N9C2 (60939) -> SUB5296_500_N9	3350.42	3279.35	102.17	AREA25	500.00
5	Branch Amp	SUB7343_345_301 (89742) -> SUB7310_345_302 (i	482.92	473.59	101.97	AREA33	345.00
6	Branch Amp	SUB1987_500_N9C3 (24219) -> SUB1987_500_N9	3329.12	2886.75	115.32	AREA06	500.00
7	Branch Amp	SUB5296_500_912 (60915) -> SUB5296_500_923 (i	3344.87	2309.40	144.84	AREA25	500.00

Status Finished with 21 violations, 0 custom monitor violations, 0 unsolveable, and 0 aborted contingencies. Initial state rest

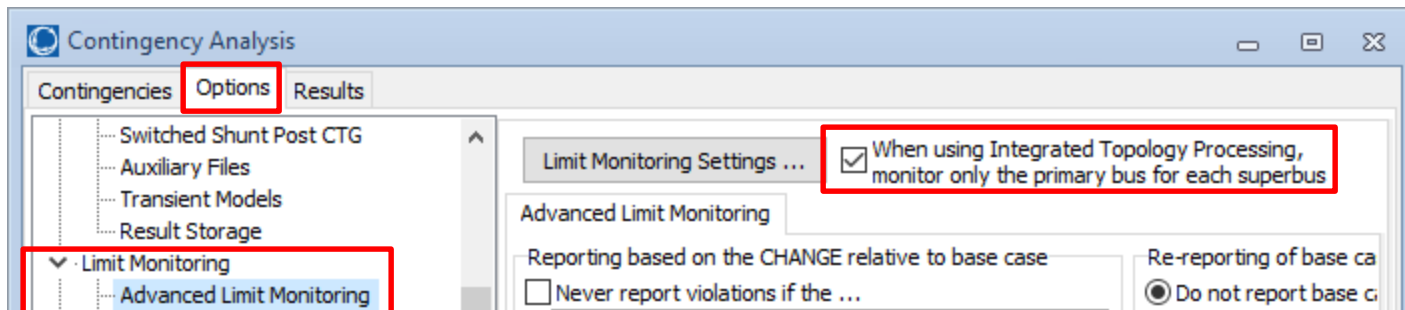
Refresh Displays After Each Contingency

Load Auto Insert Save Other > Start Run Close ? Help

Bus Voltage Limit Monitoring



- Option (checked by default) will monitor only the primary bus for each super bus
 - Caveat, buses inside a Superbus could have different limits (strange but happens)
 - Also monitors the “highest minimum” and “lowest maximum” voltage inside a Superbus



Is my Line Open?

Branch Status Confusion



- Planning software and bus-branch models
 - Two Fields: *Status* and *Online*
 - *Status*: an explicit field to determine if a device is closed/open (because breakers are not modeled)
 - *Online*: whether or not a device is energized is affected by the status of branches
- Real-time models
 - Breaker or disconnect statuses determine the status of other devices
 - No explicit status field for other devices (Generators, Loads, Lines, Transformers, etc.)



Derived Status: Device Status Confusion



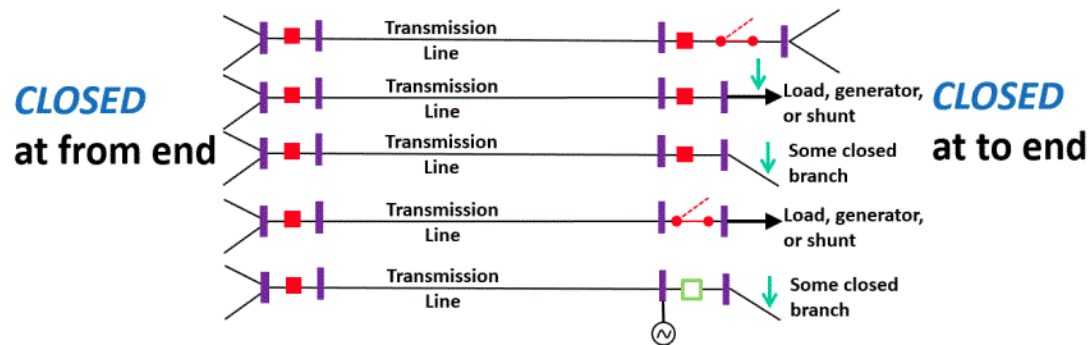
- Typically, when using a full-topology model, *Status = Closed* for all non-switching devices (Generators, Loads, Lines, etc.)
- Hybrid model with only parts of the system modeled with breaker detail can still use *Status* field of a non-switching device
- Actual status of a device is confusing
 - Status of a line is really derived from other information (breaker statuses)
 - Software automatically traverses the topology at the terminals of a device to determine its “*Derived Status*”
 - Looks at status of *Breakers* near terminals
 - Software also has a field “*Derived Online*”

For more details see Simulator Help

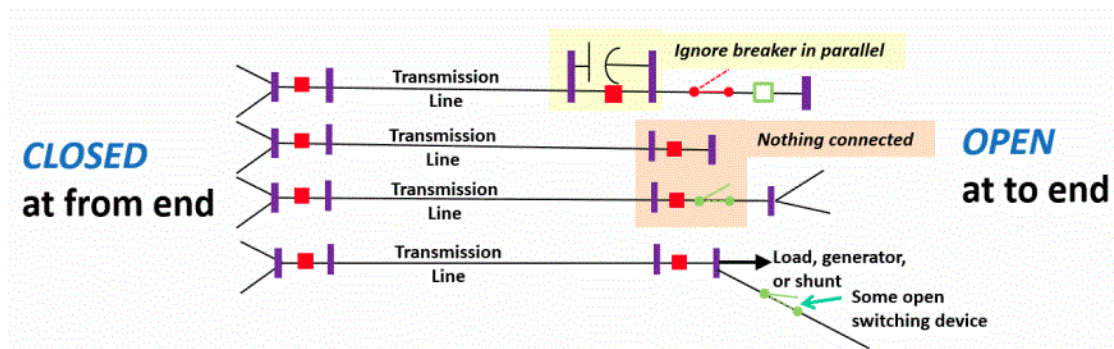


- https://www.powerworld.com/WebHelp/#MainDocumentation_HTML/Device_Derived_Status.htm

The following are examples of **Derived Status = Closed** lines:



The following are examples of **Derived Status = Open To** lines:



Script Command: ExpandBusTopology()



- This can be used to take a bus and split it up automatically
 - You then have to rearrange all the connections that come into this bus though
 - Was added for professors building fake power systems for research purposes
 - You aren't building fake stuff, so just go get your EMS data

ExpandBusTopology(BusIdentifier, TopologyType);

This action is used to expand the topology around the specified bus according to the specified topology type. New breakers and nodes (buses) will be inserted as necessary.

- | | |
|---------------|--|
| BusIdentifier | : A bus can be identified in one of these formats: BUS busnum, BUS name_nomkv, BUS label. |
| TopologyType | : These types of breaker configurations are allowed: DOUBLEBUSDOUBLEBREAKER, MAINTRANSFER, RINGBUS, BREAKERANDAHALF, SINGLEBUS, and SECTIONALIZEBUS. |

More already maintained data from the EMS system



- Over the past 2 years, PowerWorld has worked with Peak Reliability to directly import additional information
 - Contingency Definitions from Areva system
 - Remedial Action Scheme definitions from Areva system
 - Scheduled Outage information from the CROW outage schedules
- This is all possible because these systems use the same label convention as used in the EMS
- This is a presentation for another day

Summary



- PowerWorld has a lot of experience working with EMS data
- Hard-learned lessons learned
 - Investment of a huge amount of additional staff time into building parallel data sets won't work
 - It might work for a pilot project but will fail in practice
 - You need to use the already maintained data sets as much as possible
 - Industry's response to asking that additional data sets be maintained is
“Don't change my data, change your software”

What should the industry do



- Do NOT build a parallel process maintaining a second full-topology model
 - This is not sustainable
 - Would require an enormous new permanent expense of additional engineering staff
- Instead: change the starting model
 - Start with a recent EMS system model
 - Comes with already maintained: model, diagrams, contingency definitions, RAS, etc.
 - Discuss with the EMS system folks and ask them to add some more detail
 - EMS software already supports - just add more model info

Existing EMS model updates



- EMS engineers already struggle to keep models up to date communicating amongst themselves
- I can not envision a reliable process that adds to this workload by adding coordination with planning models as well

What do Planners need to ask of EMS Engineers

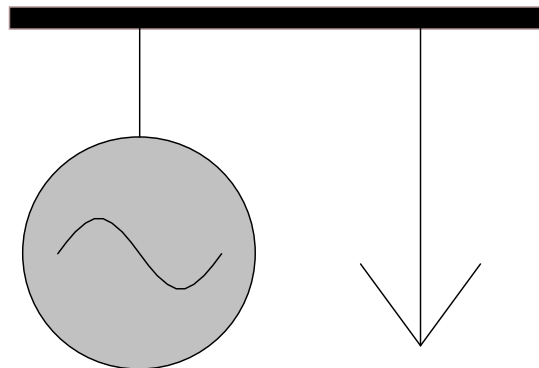


- Add more detail to EMS models.
- Existing EMS software supports: just add more model info
 - Generator station auxiliary loads
 - Generator step-up transformers
 - Keep the “normal” status of switching devices up-to-date (breakers, disconnects)
 - This are vital to putting lines, gens, etc back into service
 - Remove artificial device aggregation
 - 2 generators grouped into a single generator in the model
- Historically this detail was not vital to EMS tools such as SCADA / State Estimation / Contingency Analysis
 - This detail is important for transient stability and voltage stability analysis though

Generator Station Load



- In real-time systems, sometimes the generator station load is not modeled explicitly.
 - May not have separate measurements for generator output and station load
 - This will be a problem if trying to do some types of analysis (Transient Stability)
 - Example of where additional detail in “planning” model may need to be pushed into the real-time model



Planning Software tools need to be updated



- Must support full topology
- Remove artificial device aggregation
 - EMS models do not group together 10 capacitor banks into a single “switched shunt”
- Longer-term discussion of more complex equipment
 - DC transmission devices in particular are not consistently modeled across EMS and Planning software tools
- Use as much already-maintained data from EMS system as possible
 - Model, oneline, contingencies, RAS, etc.

Envisioned Process



- Planning engineers already have to integrate future projects into a model
 - They've done this for decades
 - They will always do this
- Just switch the starting model to be a recent EMS model export instead
 - Maybe grab this snapshot at an interval
 - The “normal” status of switching devices matter here (must put that in the EMS model)