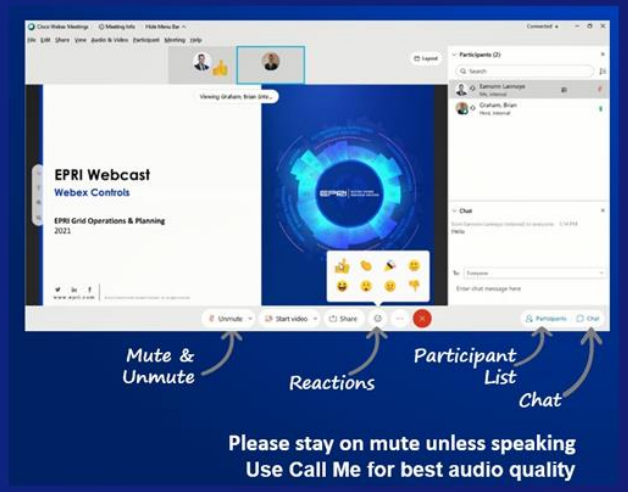
Node-Breaker Modeling in Transmission Planning

Transmission Operations and Planning
Innovating Grid Operations, Shaping Strategic Planning

View from The TOP

Transmission Operations & Planning R&D
Public Webinar Series



REC This webcast will be recorded

www.epri.com

Welcome and Agenda

Node-Breaker modeling in Commercial Software
Tamer Ibrahim - EPRI

Building and Maintaining a Planning Node-Breaker Model
Jonathan J. Perry - Dominion

Questions and Open Discussion

Transmission Operations and Planning

Innovating Grid Operations, Shaping Strategic Planning

View from The TOP

Transmission Operations & Planning R&D Public Webinar Series

New for 2026: A public webinar series

- R&D highlights from EPRI and our global collaborators
- 8-12 webinars delivered throughout 2026
- Topics spanning operations, planning and markets issues
- Coordinated with existing EPRI forums
- Open to all participants

Not a Member? Sign up Here!

Recordings & materials posted at: top.epri.com

Node-Breaker Modeling in Transmission Planning

2026 *View From The TOP* Webinar

Tamer Ibrahim
Technical Leader
Transmission Operation & Planning
EPRI

Email: tibrahim@epri.com

Disclaimer

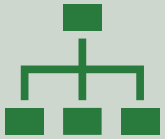
- The content of this presentation is intended solely to compare and contrast different modeling approaches for node-breaker representations in power system analysis.

- This is not an endorsement or critique of any specific commercial software product or vendor. References to particular tools or platforms are made purely for illustrative purposes and do not imply superiority or inferiority of one solution over another.

- All opinions and observations presented here reflect a technical perspective on modeling methodologies and are not representative of any organization’s official position.

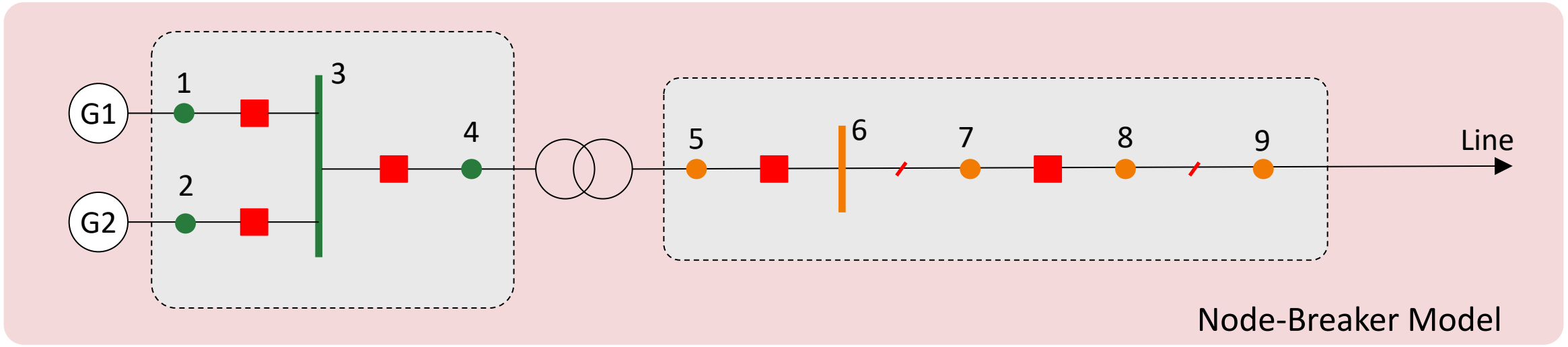
Objective

The goal of this presentation is to discuss different approaches for modeling Node-Breakers (NB) in commercial software such as PSSE, PowerWorld, PSLF, DSAtools, and TARA, with a focus on transmission planning studies for NERC compliance and interconnection studies.



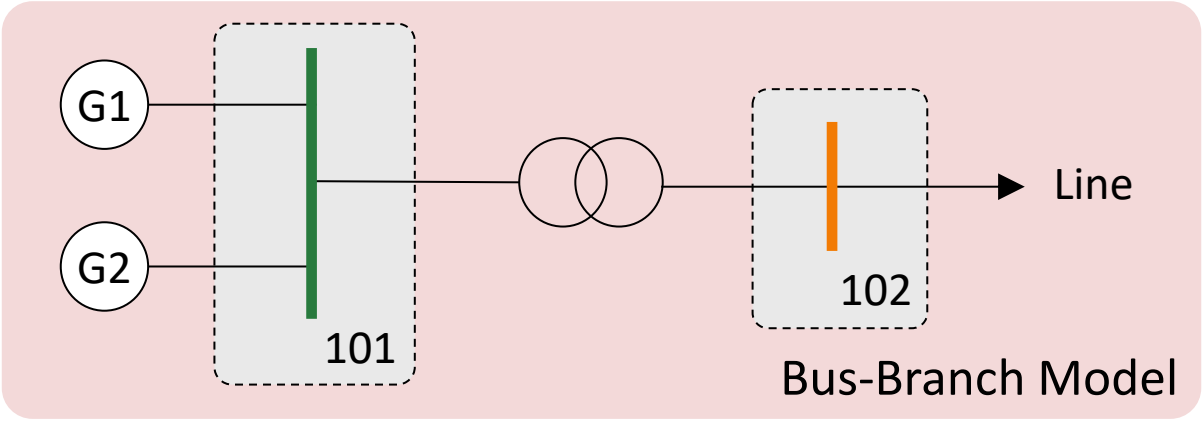
What to expect when moving to node-breaker models for planning cases.

Node-Breaker vs Bus-Branch



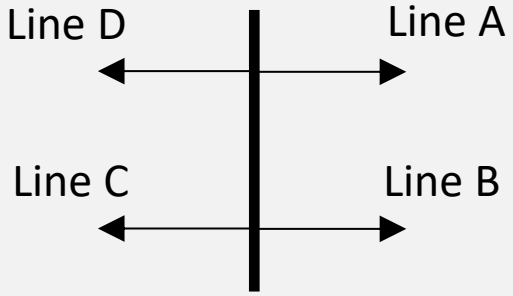
Merge nodes into buses

Planning Cases in North America (MMWG, MISO, etc.) are all in bus-branch model



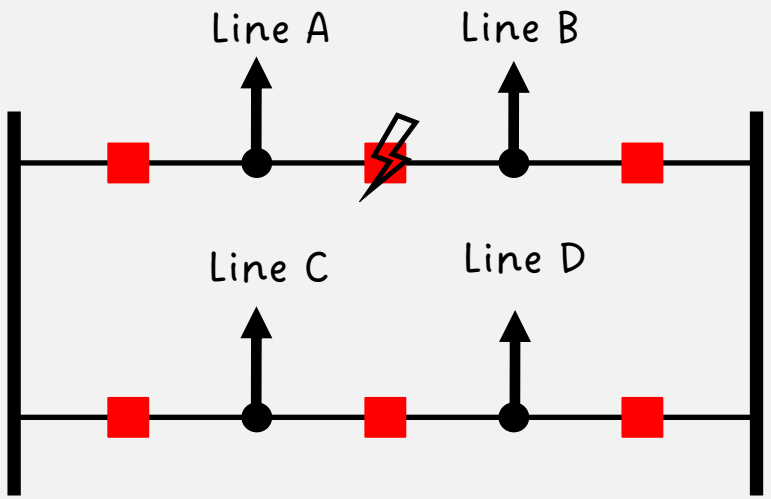
Planning Cases: A Node-Breaker Imperative

Bus-Branch model



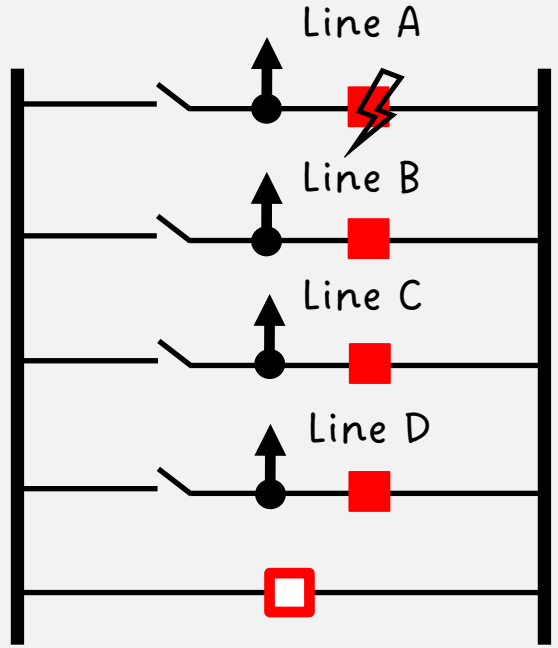
Without knowledge obtained outside the represented bus-branch model, it is not possible to determine the substation breaker configuration and how it operates during contingencies

Topology 1



Breaker Fault would result in outage of line A & B

Topology 2

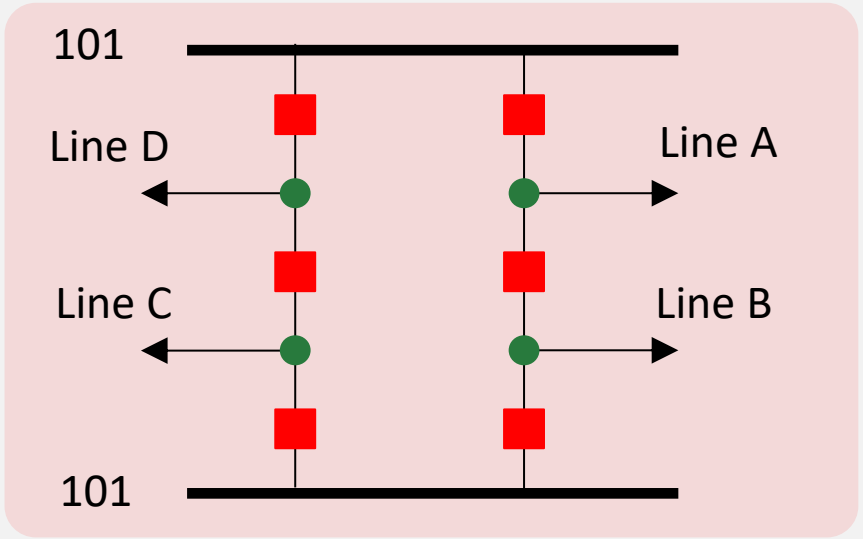


Breaker Fault would result in outage of all lines

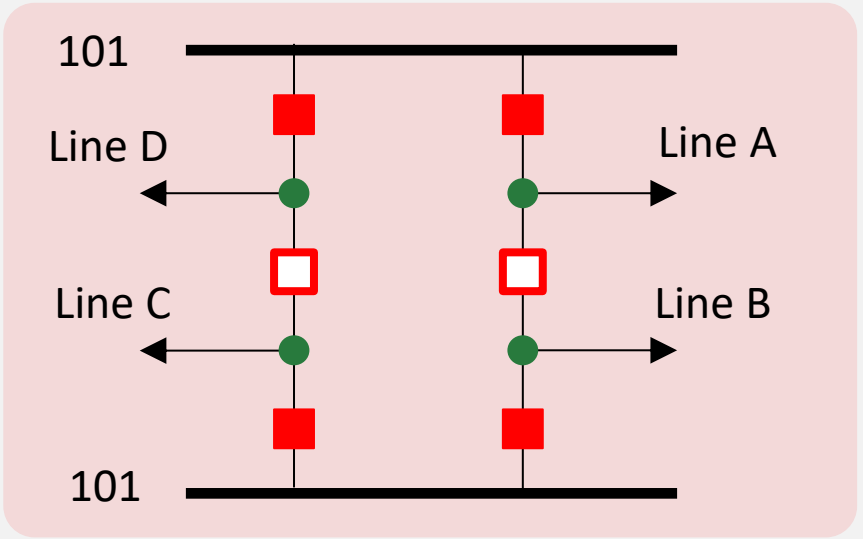
Without breaker information, NERC TPL-001 contingencies must be manually created in large numbers

Example: Bus Splitting in Node-Breaker vs Bus-Branch

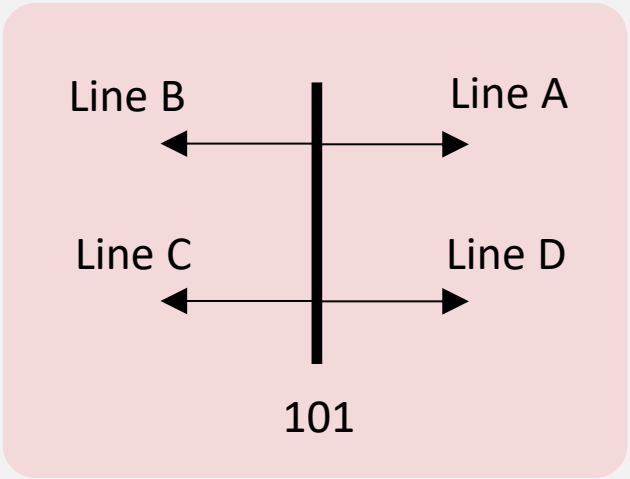
Node-Breaker representation



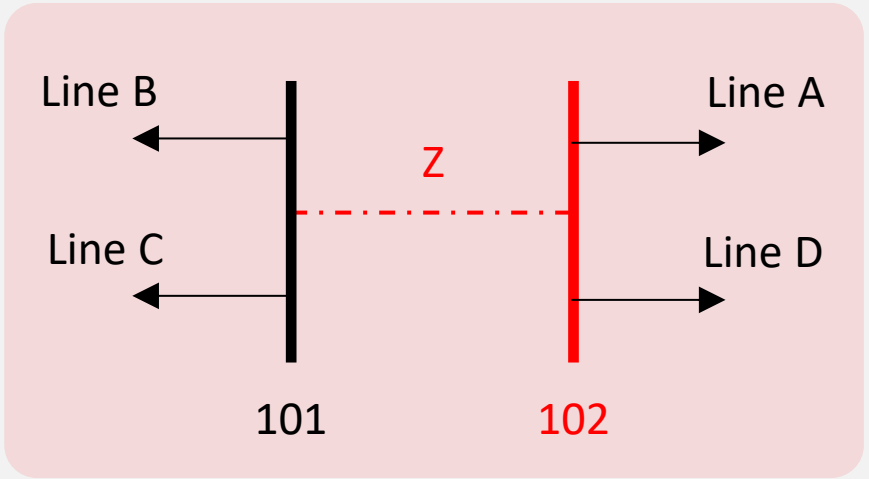
Simply Trip the breakers



Bus-Branch representation

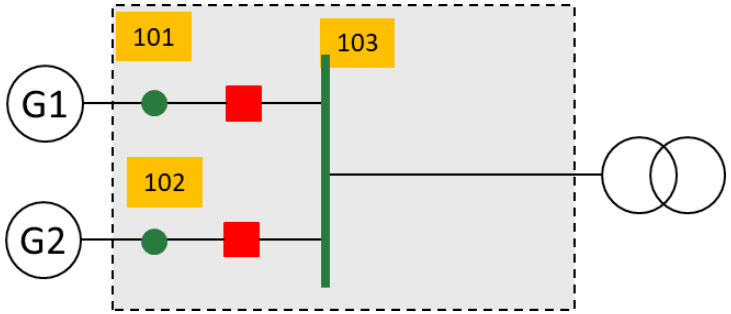


New Dummy line and bus need to be added to simulate bus split events



NB Modeling Approaches: *User Perspective*

Approach 1: Node is Bus

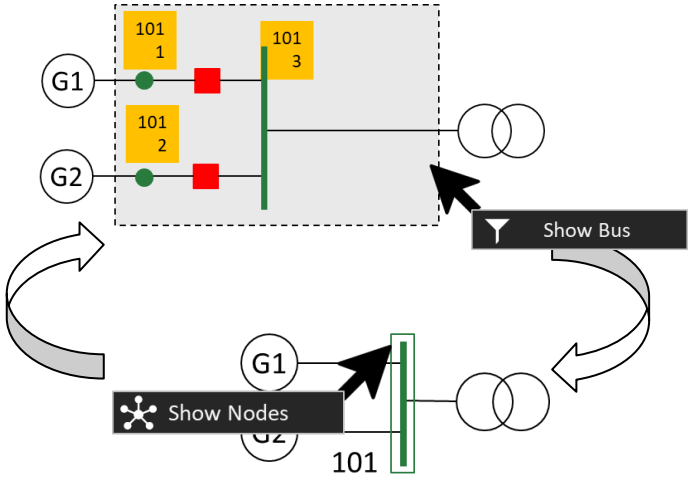


- In this approach, each node in the substation is simply modeled as a bus

- Switches like breakers, disconnectors, etc. are modeled as branches (Zero impedance lines)
  - They could be in different table other than branch table depends on the tool.
  - For ex: PSSE assign these switches to "*system switching devices*" table

Approach 2: Bus is a Family of Nodes

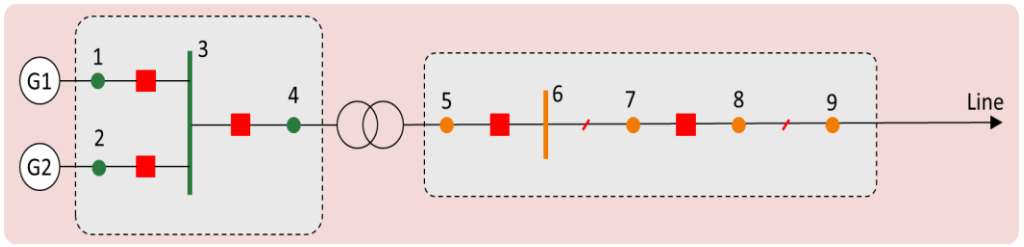
"NB: Available at a touch, invisible by design"



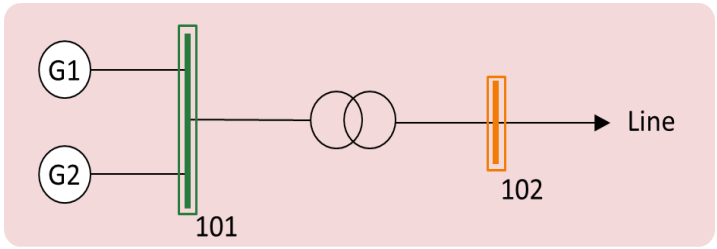
- In this approach, A bus is a group of nodes or connection points connected by switching devices (regardless of the status of the switches)
  - Family of nodes, no impedance between family members. Only switches ☺
- CIM users: Connectivity node Vs Topological node
- Introduced in PSSE 34

NB Modeling Approaches: *Software Perspective*

Approach 1



Approach 2



Topology Processor

Generate Bus-branch copy

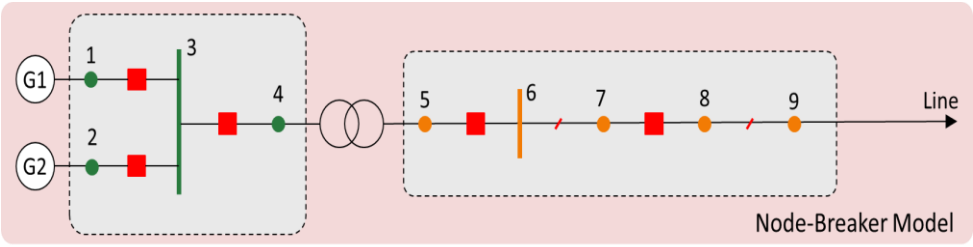
Analysis Engines

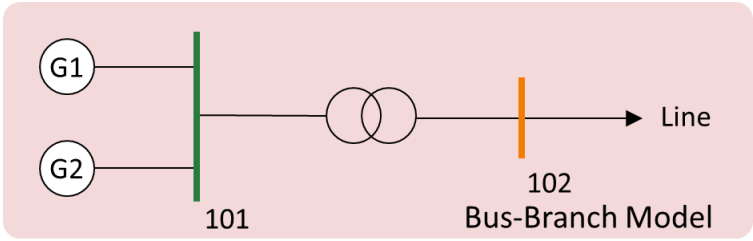
- Topology Processor merges buses/nodes that are connected through *in-service* switches or zero-impedance lines (ZILs).
- This is required to avoid numerical issues related to ZILs

From software perspective, approach 1 & 2 are just ways to present the network to the user.

Building NB models in Planning Cases: *Approach 1*

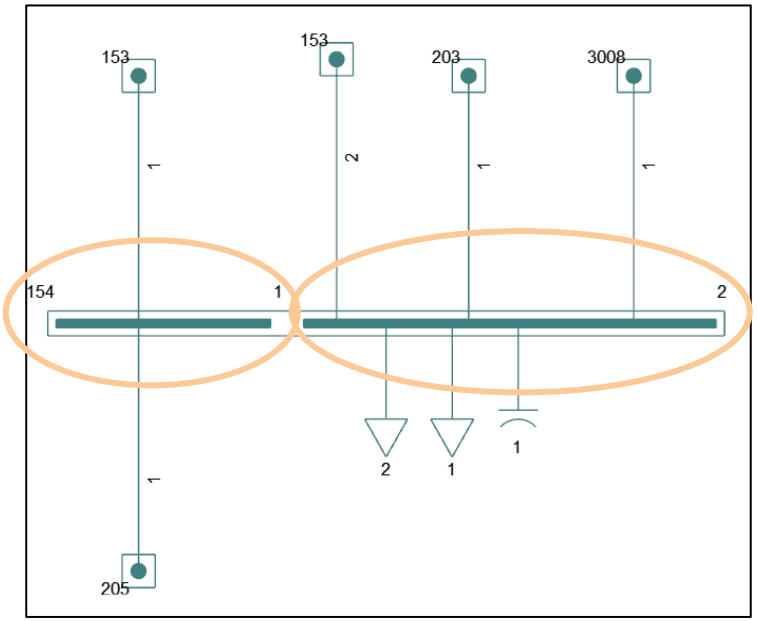
- ***With Approach 1:***
  - Pros:
    - This approach is intuitive and compatible with any software.
  - Cons:
    - 1000s of buses will be added to the network
    - Need to update all SLD, code, dynamic models (dyr/dyd), and other aux files that uses “bus number” as identifier
    - Building SLD for part of the system will be very time-consuming process.





Building NB models in Planning Cases: ***Approach 2***

- ***With Approach 2:***
  - Pros:
    - No need to add any additional buses to the system
    - All codes, SLDs, dynamic models can be used for the NB models (*no additional buses*)
    - *NB is there when you need it, but out of the way when you don't want it*
  - Cons:
    - With bus splitting, all bus sections will have the same bus number. Need to get the voltage using bus and node number. This could be confusing.



Approach 2 is designed to make it easier to move to node-breaker models as it doesn't require adding any new buses.

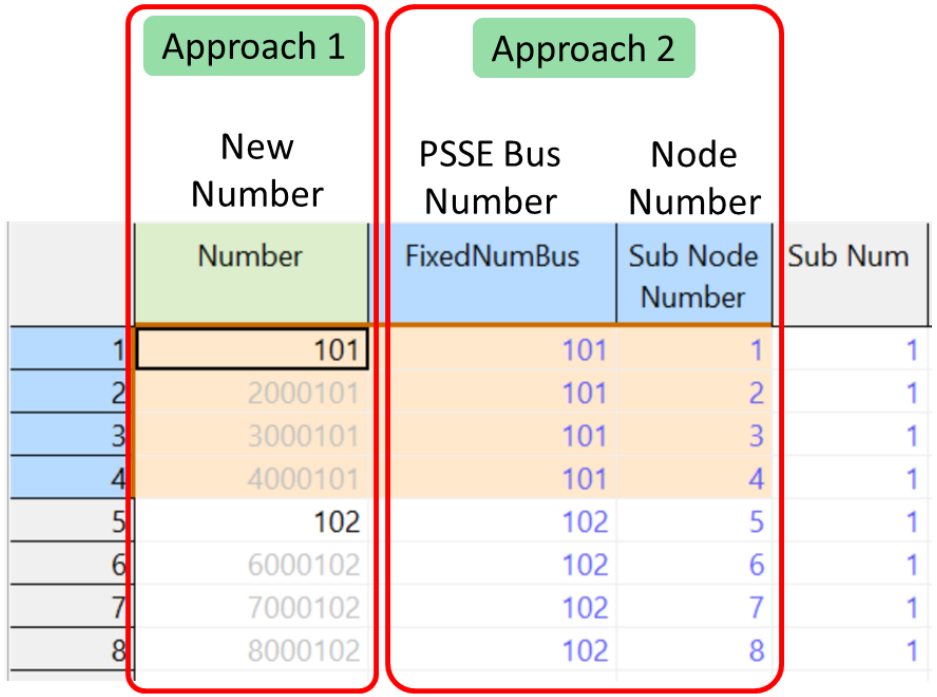
NB in Commercial Software

- As mentioned before, Approach 1 is compatible with any commercial tool
- For PSLF, as of today, reading RAW file V34 and above will ignore substation data which will ignore all node-breaker models.
- For DSATools, some caution is required if the input file has open switches (*more info in the next slides*)

Software	Approach 1	Approach 2
PSSE (≥34) and TARA	✓	✓
PowerWorld (≥V24)	✓	✓
PSLF (as of today)	✓	✗
DSATools	✓	✓*

PowerWorld (V24)

- PowerWorld V24 supports Approach 2 when reading PSSE RAW files.
- Bus number in PowerWorld will be:
  - Lowest node number will be assigned to PSSE_Bus number
  - Others numbered RAWNodeNum*1,000,000 + PSSE_Bus number
- Code, Aux files, dyr/dyd, etc. can identify components by PSSE bus number or the new bus number assigned by the software. This means files used for BB models can be used for NB models.

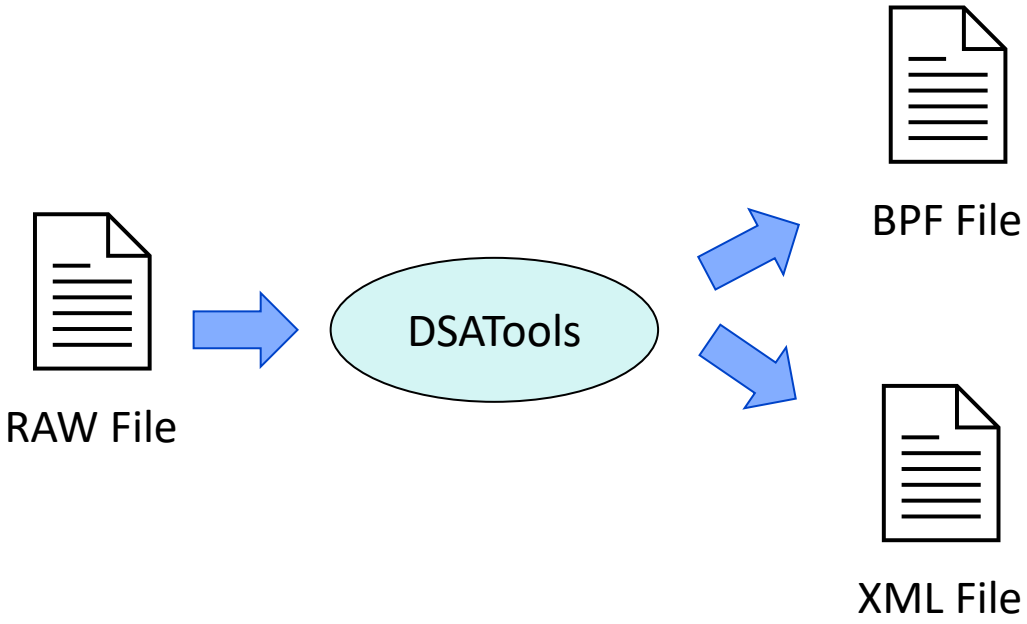


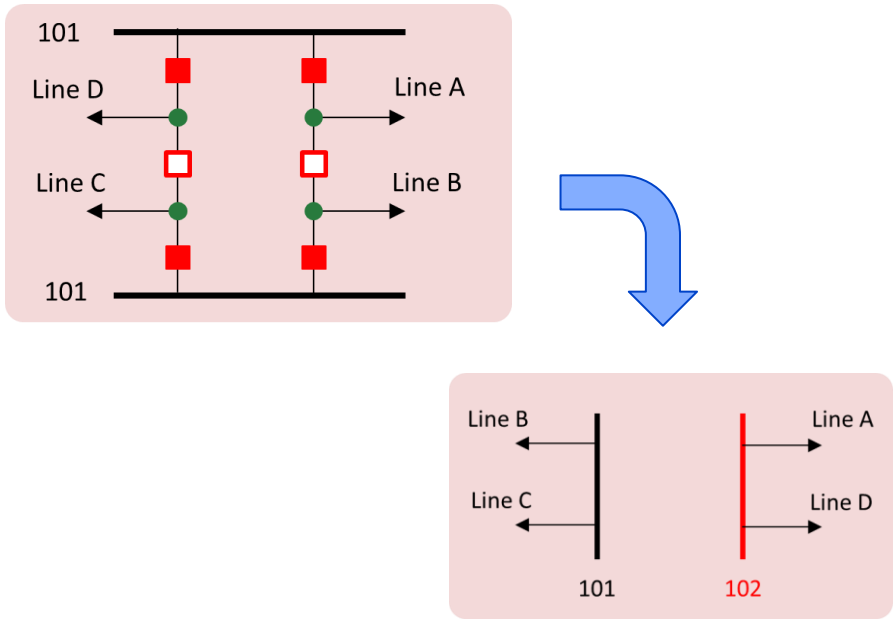
	Approach 1	Approach 2		
	New Number	PSSE Bus Number	Node Number	
	Number	FixedNumBus	Sub Node Number	Sub Num
1	101	101	1	1
2	2000101	101	2	1
3	3000101	101	3	1
4	4000101	101	4	1
5	102	102	5	1
6	6000102	102	6	1
7	7000102	102	7	1
8	8000102	102	8	1

"Load 2000101 1" is the same as "Load 101 1"

DSATools

- DSATools reads PSSE raw files and generates:
  - Binary power flow file (BFP) which contains the bus-branch model of the network
  - XML file which includes the node-breaker and substation data
- If the input file has 2 bus sections, one of the sections will take a new bus number. This could cause issues when reading dyr/switching files.
  - Use Equipment name for this scenario.





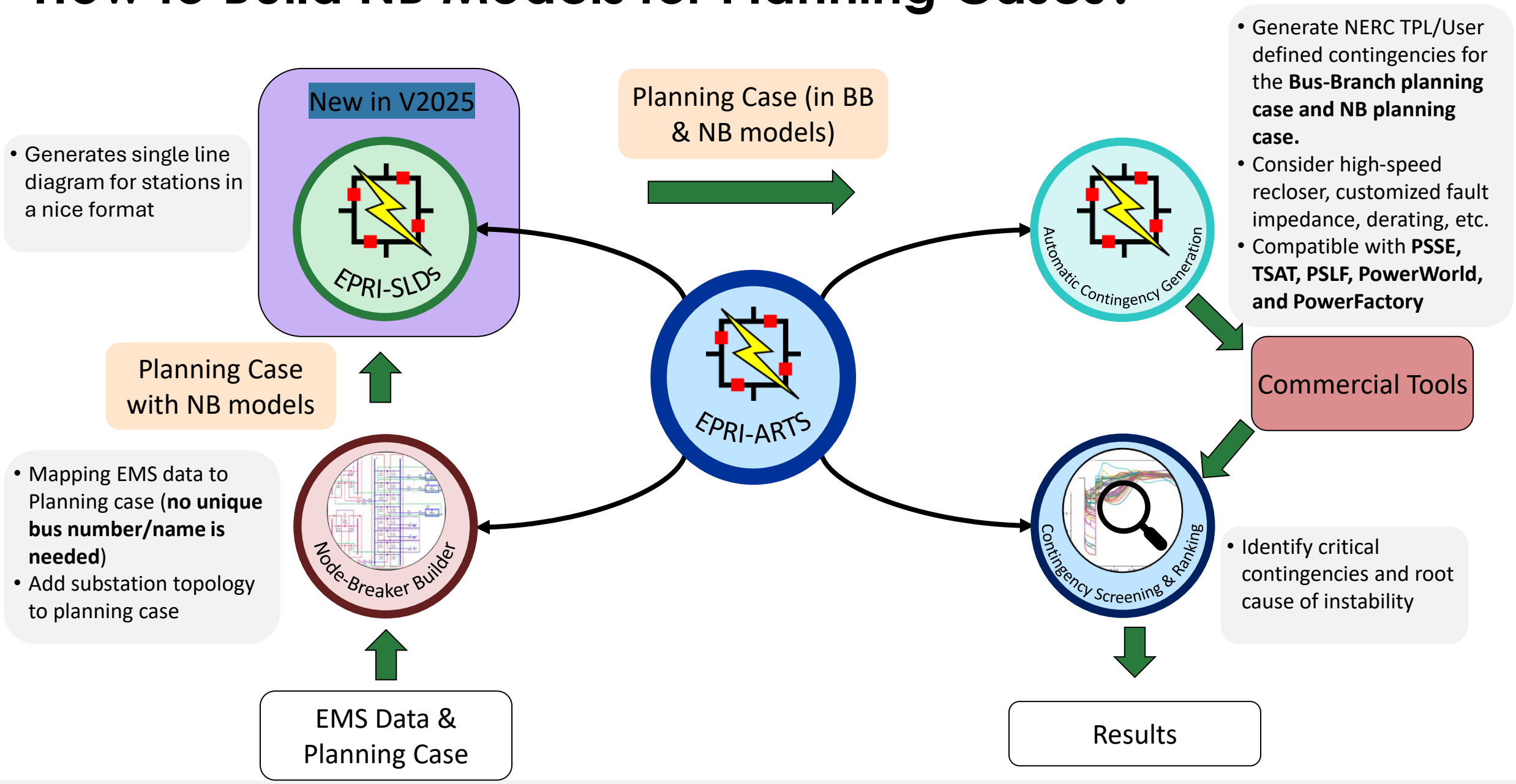
Which Approach to Build NB in Planning Cases?

- PSSE, TARA, PowerWorld, and DSATools users can use approach 2 easily with minimum friction or extra work.

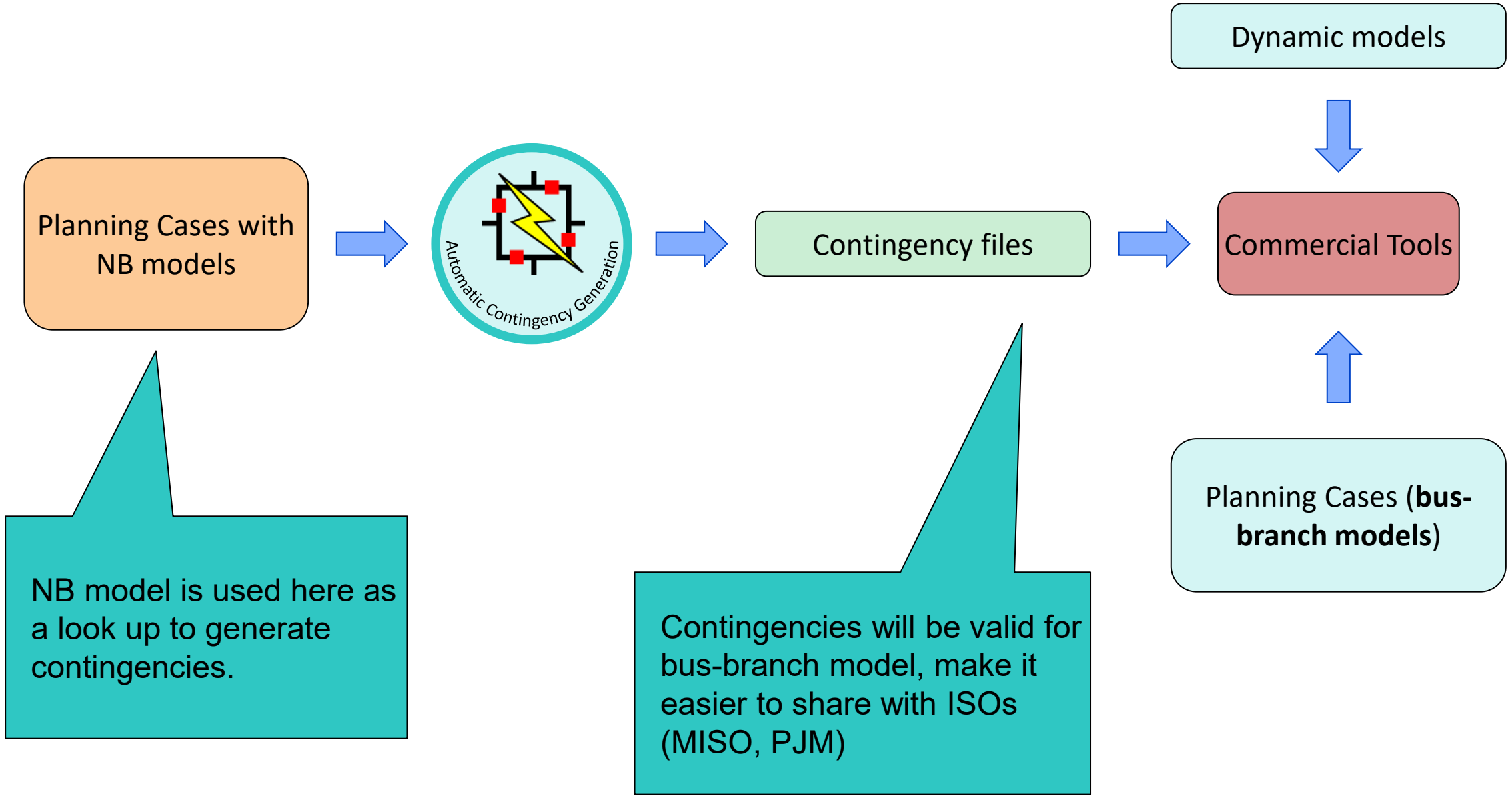
- PSLF users can only adopt approach 1 when building NB for their planning cases.

What is your objective to move to node-breaker? To generate TPL contingencies? Then use **EPRI-ARTS** tool

How to Build NB Models for Planning Cases?



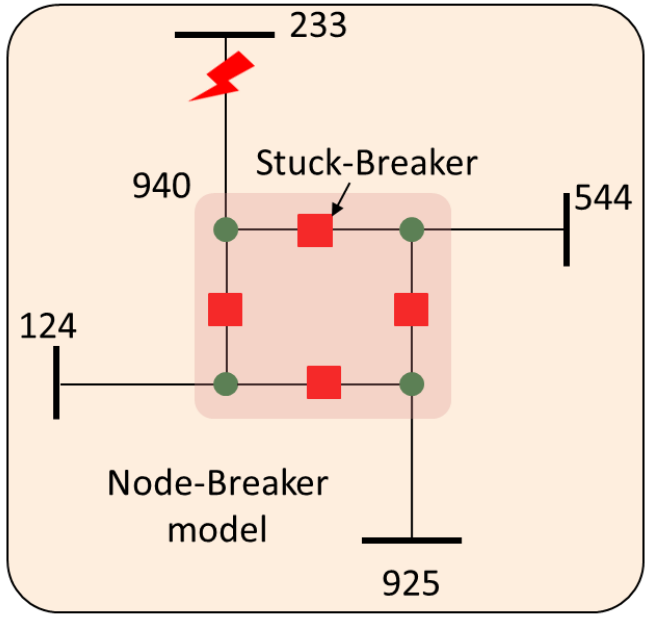
Using NB model In Contingency Generation

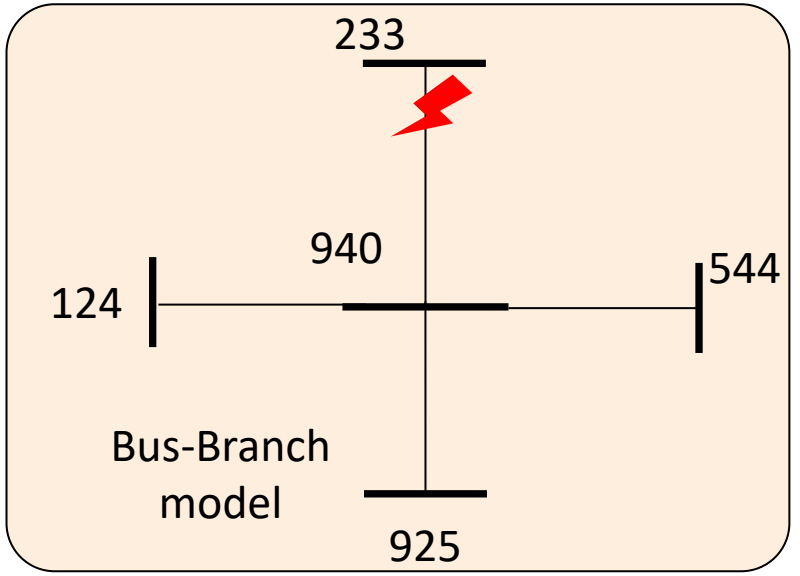


Example: TSAT Switching Files

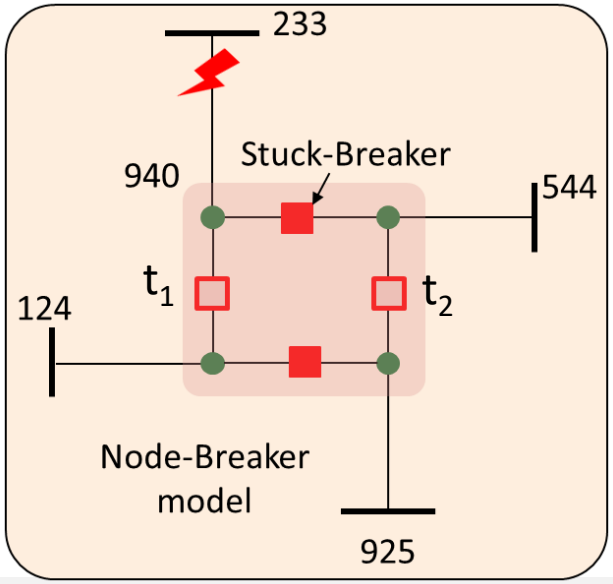
```
Description P42:138.0:XXXX:YYYYYY:ZZZZZ:1:12M9
Simulation 15.0 Seconds
Step Size 0.25 Cycles
Plot Every 5 Steps
Report Every 999 Steps
Integration RK4
/
/ 'Setup contingency event'
Tap Line ;544 ;940 ;1 ;11 100
Tap Line ;233 ;940 ;1 ;12 100
Remove Line ;12 ;940 ;1
Add Line ;12 ;11 ;1 0.0 0.0001 0.0
Tap Line ;233 ;12 ;1 ;1 10.0
/
/
At Time 1.0 Seconds
Three Phase Fault At Bus ;1
/
After 5.0 Cycles
Remove Line ;233 ;1 ;1
/
After 12.5 Cycles
Remove Line ;940 ;11 ;1
/
After 95.0 Cycles
Remove Line ;12 ;1 ;1
Clear Three Phase Fault
Remove Line ;544 ;11 ;1
/
Nomore
```

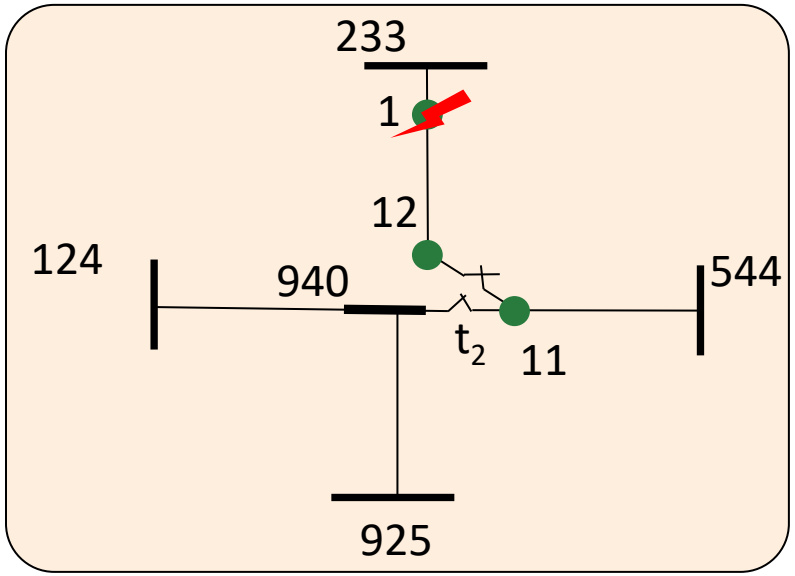
Generated by EPRI-ARTS tool





Setting up the case for this contingency





Contingency File In Other Formats

```
Script
{
   EnterMode(EDIT);
   SplitBus([BUS 940], 11, YES, NO, Line);
   Move([BRANCH 233 940 1], [233 11 1], 100);
   Move([BRANCH 544 940 1], [544 11 1], 100);
   EnterMode(RUN);
   SolvePowerFlow();
}
   TSContingencyElement (Contingency,Time,Object,Action)
{
   "P42-xxx-12M9" 1.0 "Branch '233' '11' '1'" "FAULT 10.0 3PB IMP 0.0 0.0"
   "P42-xxx-12M9" 1.083333 "Branch '233' '11' '1'" "OPEN NEAR"
   "P42-xxx-12M9" 1.291667 "Branch '940' '11' '1'" "OPEN BOTH"
   "P42-xxx-12M9" 2.875 "Branch '233' '11' '1'" "OPEN FAR"
   "P42-xxx-12M9" 2.875 "Branch '544' '11' '1'" "OPEN BOTH"
}
Script
{
   TSSolve("P42-xxx-12M9", [0, 15.0, 0.25, YES]);
}
```

Aux file for PowerWorld

```
# Setup contingency event
ierr = psspy.splt(940,11,"",138.0)
ierr = psspy.movebrn(233,940,r'1',11,r'1')
ierr = psspy.movebrn(544,940,r'1',11,r'1')
ierr = psspy.ltap(233, 11, r'1', 0.9, 1, 'Fault_Bus', _f)

# Reconciles the Z-source and X-source discrepancies
psspy.set_zsorce_reconcile_flag(1)

# Initialize simulation
psspy.strt_2([1,1], r"P42-xxx-12M9.out")

############## Run Simulation ##############

# Run to t = t0
psspy.run(_i, t0, 999, 1, 5)
ierr = psspy.dist_3phase_bus_fault(1,0,1,0.0,[0.0,-200000000000.0])

# Run to t = t0+5.0
psspy.run(_i, t0+5.0*1./frequency, 999, 1, 5)
ierr = psspy.dist_branch_trip(233,1,r'1')

# Run to t = t0+17.5
psspy.run(_i, t0+17.5*1./frequency, 999, 1, 5)
ierr = psspy.dist_branch_trip(940,11,r'1')

# Run to t = t0+45.0
psspy.run(_i, t0+45.0*1./frequency, 999, 1, 5)
ierr = psspy.dist_branch_trip(11,1,r'1')
ierr = psspy.dist_clear_fault(1)
ierr = psspy.dist_branch_trip(544,11,r'1')

# Ringdown
ierr = psspy.fact()
ierr = psspy.tysl(0)
psspy.run(1, t_ringdown, 999, 1, 5)
```

Python Code for PSSE

```
/*****************************************************************************************/
/*                                Setup the Contingency                                  */
/*****************************************************************************************/

/* Splitting bus 940 */
/* Expand bus and voltage tables */
@zz = rep("busd", casepar[0].nbus-1, 1)
@zz = rep("volt", casepar[0].nbus-1, 1)

@busidx = bix(940)
@new_idx = casepar[0].nbus-1
busd[@new_idx].extnum = 11
busd[@new_idx].busnam = "940 - 11"
busd[@new_idx].basekv = busd[@busidx].basekv
busd[@new_idx].type = 1
@ret = setbix(11, @new_idx)

volt[@new_idx].vm=volt[@busidx].vm
volt[@new_idx].va=volt[@busidx].va

/* Add zero impedance line between bus 940 and bus 11 */
@zz = rep("secdd",casepar[0].nbrsec-1,1)
@newline = casepar[0].nbrsec-1

secdd[@newline].ifrom = @busidx
secdd[@newline].ito   = @new_idx
secdd[@newline].ck    = "1"
secdd[@newline].st    = 1
secdd[@newline].nsec  = 1
secdd[@newline].type  = 0
secdd[@newline].aloss = 1
secdd[@newline].area  = busd[@busidx].area
secdd[@newline].zone  = busd[@busidx].zone
secdd[@newline].ohms  = 0
secdd[@newline].zsecr = 0.0
secdd[@newline].zsecx = 0.0001
secdd[@newline].bsec  = 0.0
secdd[@newline].ingsec = 0.0


/* Moving line 1 from 233 to 940 to be from 233 to 11
@index = rec_index(1,1,233,940,"1",1, -1,-1)
@new_idx = bix(11)
@old_idx = bix(940)
if(@index >= 0)
    if(secdd[ @ index].ifrom = @old_idx)
        secdd[ @ index].ifrom = @new_idx
    else
        secdd[ @ index].ito = @new_idx
    endif
endif


/* Moving line 1 from 544 to 940 to be from 544 to 11
@index = rec_index(1,1,544,940,"1",1, -1,-1)
@new_idx = bix(11)
@old_idx = bix(940)
if(@index >= 0)
    if(secdd[ @ index].ifrom = @old_idx)
        secdd[ @ index].ifrom = @new_idx
    else
        secdd[ @ index].ito = @new_idx
    endif
endif


@ret=soln()
/*****************************************************************************************/
/*                              Specify Fault Location                                   */
/*****************************************************************************************/


dypar[0].fault_from     = "233"                          /* 1BNBLDNGW                */
dypar[0].fault_to       = "940"                          /* 1BHRNET                  */
dypar[0].fault_ck       = "1"                         /*  Ckt Id                   */
dypar[0].fault_sec      = 1                              /* Line Sec Num              */
dypar[0].fault_position = 0.9                          /* Fault Position From bus    */
dypar[0].faultr         = 0.0                       /* 3-Phase Fault r              */
dypar[0].faultx         = 0.0                       /* 3-Phase Fault x              */
dypar[0].fault_type     = 3                          /* fault type                   */
/*****************************************************************************************/
/*                          Specify Fault On & Clearing Times                            */
/*****************************************************************************************/
dypar[0].t_fault_on   = @t0                         /* Turn On Fault After @t0 Second  */
dypar[0].t_from_clear = @t0+45.0/@frequency          /* Clear 1BNBLDNGW In @t0+45.0/@frequency  Cycles     */
dypar[0].t_to_clear   = @t0+45.0/@frequency          /* Clear 1BHRNET In @t0+45.0/@frequency  Cycles     */

/*****************************************************************************************/
/*                                  Run Simulation                                       */
/*****************************************************************************************/


 /* Run to t = t0+17.5 Cycles */

@tpause          = @t0+17.5/@frequency
dypar[0].tpause  = @tpause                                  /* Run till 1.2916666666666667 Seconds */
@ret = run()
@test = @tpause - dypar[0].delt                             /* Test That Time Is Correct     */
if((@ret < 0) or (dypar[0].time < @test))                   /* If Error Terminate EPCL       */
    logdy(" ERROR RUN TERMINATED<<<")
    logterm(" ERROR RUN TERMINATED<<<")
    mailbox[0].number[0] = -1                               /* Send Error Back To DYTOOLS    */
    end
endif

/* Trip branch 1 from bus 940 to 11 */
@ret = rec_index(1, 1, 940, 11, "1", 1, 0, -1)

 /* Run to t = t0+45.0 Cycles */

@tpause          = @t0+45.0/@frequency
dypar[0].tpause  = @tpause                                  /* Run till 1.75 Seconds */
@ret = run()
@test = @tpause - dypar[0].delt                             /* Test That Time Is Correct     */
if((@ret < 0) or (dypar[0].time < @test))                   /* If Error Terminate EPCL       */
    logdy(" ERROR RUN TERMINATED<<<")
    logterm(" ERROR RUN TERMINATED<<<")
    mailbox[0].number[0] = -1                               /* Send Error Back To DYTOOLS    */
    end
endif
dypar[0].faulton = 0          /* Turn Fault Off            */

/* Trip branch 1 from bus 544 to 11 */
@ret = rec_index(1, 1, 544, 11, "1", 1, 0, -1)


/*****************************************************************************************/
/*                                     Ringdown                                          */
/*****************************************************************************************/
```

EPC Code for PSLF

Contingency files are generated by EPRI-ARTS tool

Conclusion

- ARTS tool build NB models in transmission planning using Approach 2
- We use this NB model to generate NERC TPL contingencies for the original bus-branch format for different commercial software.
  - *For PSLF*, there is no need to build the network in PSLF/EPC. We will use only the bus-branch model in PSLF.
- With approach 2, building planning cases with NB requires no efforts to update existing code, SLD, dyr\dyd files, con files, etc.

References

- 2024 NATF-EPRI-NERC Meeting: Link
- PowerWorld Presentation: Link

TOGETHER…SHAPING THE FUTURE OF ENERGY®

www.epri.com

Building and Maintaining a Planning Node-Breaker Model

Dominion Energy®

Transmission Planning Contingency Criteria (TPL-001)

Category	Initial Condition	Event [1]	Fault Type [2]	BES Level [3]	Interruption of Firm Transmission Service Allowed [4]	Non-Consequential Load Loss Allowed
P0 No Contingency	Normal System	None	N/A	EHV, HV	No	No
P1 Single Contingency	Normal System	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer[5] 4. Shunt Device[6]	3Ø	EHV, HV	No[9]	No[12]
		5. Single Pole of a DC line	SLG			
P2 Single Contingency	Normal System	1. Opening of a line section w/o a fault [7]	N/A	EHV, HV	No[9]	No[12]
		2. Bus Section Fault	SLG	EHV	No[9]	No
				HV	Yes	Yes
		3. Internal Breaker Fault[8] (non-Bus-tie Breaker)	SLG	EHV	No[9]	No
				HV	Yes	Yes
		4. Internal Breaker Fault (Bus-tie Breaker)[8]	SLG	EHV, HV	Yes	Yes
P3 Multiple Contingency	Loss of generator unit followed by System adjustments[9]	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer[5] 4. Shunt Device[6]	3Ø	EHV, HV	No[9]	No[12]
		5. Single pole of a DC line	SLG			
P4 Multiple Contingency *(Fault plus stuck breaker[10])*	Normal System	Loss of multiple elements caused by a stuck breaker[10](non-Bus-tie Breaker) attempting to clear a Fault on one of the following: 1. Generator 2. Transmission Circuit 3. Transformer[5] 4. Shunt Device[6] 5. Bus Section	SLG	EHV	No[9]	No
				HV	Yes	Yes
		6. Loss of multiple elements caused by a stuck breaker[10] (Bus-tie Breaker) attempting to clear a Fault on the associated bus	SLG	EHV, HV	Yes	Yes

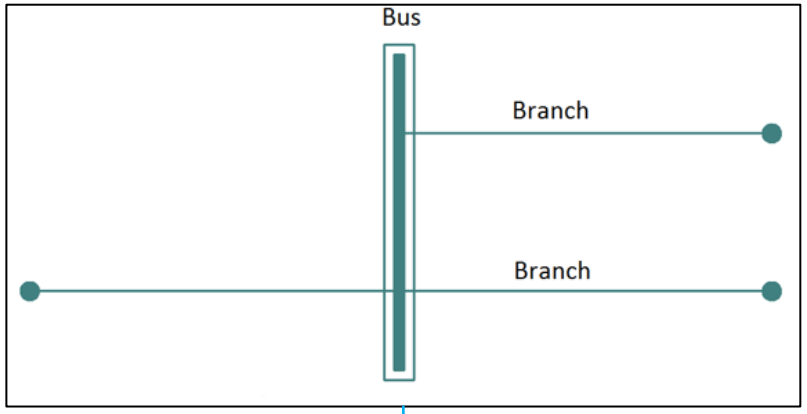
Category	Initial Condition	Event [1]	Fault Type [2]	BES Level [3]	Interruption of Firm Transmission Service Allowed [4]	Non-Consequential Load Loss Allowed
P5 Multiple Contingency *(Fault plus non-redundant component of a Protection System failure to operate)*	Normal System	Delayed Fault Clearing due to the failure of a non-redundant component of a Protection System[13] protecting the Faulted element to operate as designed, for one of the following: 1. Generator 2. Transmission Circuit 3. Transformer[5] 4. Shunt Device[6] 5. Bus Section	SLG	EHV	No[9]	No
				HV	Yes	Yes
P6 Multiple Contingency *(Two overlapping singles)*	Loss of one of the following followed by System adjustments.[9] 1. Transmission Circuit 2. Transformer [5] 3. Shunt Device[6] 4. Single pole of a DC line	Loss of one of the following: 1. Transmission Circuit 2. Transformer[5] 3. Shunt Device[6]	3Ø	EHV, HV	Yes	Yes
		4. Single pole of a DC line	SLG	EHV, HV	Yes	Yes
P7 Multiple Contingency *(Common Structure)*	Normal System	The loss of: 1. Any two adjacent (vertically or horizontally) circuits on common structure [11] 2. Loss of a bipolar DC line	SLG	EHV, HV	Yes	Yes

All but P5 & P7 are automatable through model

Dominion Energy®

EPRI

Bus-Branch Contingency Process



Station	Bus	KV	TPL Cat	Con Name	Lines	Branch of Lines	TXs	Gens	Capbanks	FACTS	Loads	Others	Valid From	Valid To
SUB 1	123123	230	P4-2	Breaker Name	13;200								7/1/2015	7/1/2059
SUB 2	123124	115	P4-6	Breaker Name	500								7/1/2015	7/1/2059
SUB 2	123124	115	P4-6	Breaker Name	613								7/1/2015	7/1/2059
SUB 3	123125	69	P4-2	Breaker Name	92								7/1/2015	7/1/2059
SUB 3	123125	69	P4-2	Breaker Name			1						7/1/2015	7/1/2059
SUB 4	123126	230	P4-5	Breaker Name	45				1				7/1/2015	7/1/2059
SUB 5	123127	230	P4-3	Breaker Name	88								7/1/2015	7/1/2059
SUB 5	123127	230	P4-3	Breaker Name	256;257								7/1/2015	7/1/2059
SUB 5	123127	230	P4-3	Breaker Name	96								7/1/2015	7/1/2059
SUB 5	123127	115	P4-2	Breaker Name	561								7/1/2015	7/1/2059
SUB 6	123128	230	P4-2	Breaker Name	333								5/20/2027	7/1/2059
SUB 6	123128	230	P4-2	Breaker Name	297								5/20/2027	7/1/2059
SUB 6	123128	230	P4-2	Breaker Name	162								5/20/2027	7/1/2059
SUB 7	123129	230	P4-2	Breaker Name	7								4/30/2022	7/1/2059
SUB 8	123130	500	P4-4	Breaker Name	624								7/1/2015	7/1/2059
SUB 8	123130	500	P4-3	Breaker Name	519								7/1/2015	7/1/2059
SUB 9	123131	69	P4-2	Breaker Name	387								7/1/2015	7/1/2059
SUB 9	123131	69	P4-2	Breaker Name	1								7/1/2015	7/1/2059
SUB 9	123131	69	P4-5	Breaker Name	356								6/1/2023	7/1/2059
SUB 9	123131	69	P4-6	Breaker Name	25								7/1/2015	7/1/2059
SUB 9	123131	69	P4-5	Breaker Name	64								7/1/2015	6/1/2023
SUB 10	123132	230	P4-5	Breaker Name	29								7/1/2015	7/1/2059
SUB 11	123133	115	P4-5	Breaker Name	56								6/15/2017	7/1/2059
SUB 11	123133	115	P4-5	Breaker Name	358								6/15/2017	7/1/2059
SUB 11	123133	115	P4-5	Breaker Name	159								6/15/2017	7/1/2059
SUB 11	123133	115	P4-5	Breaker Name	3;987								6/15/2017	7/1/2059
SUB 12	123134	230	P4-3	Breaker Name	12								7/1/2015	7/1/2059

Contingency file (.con)

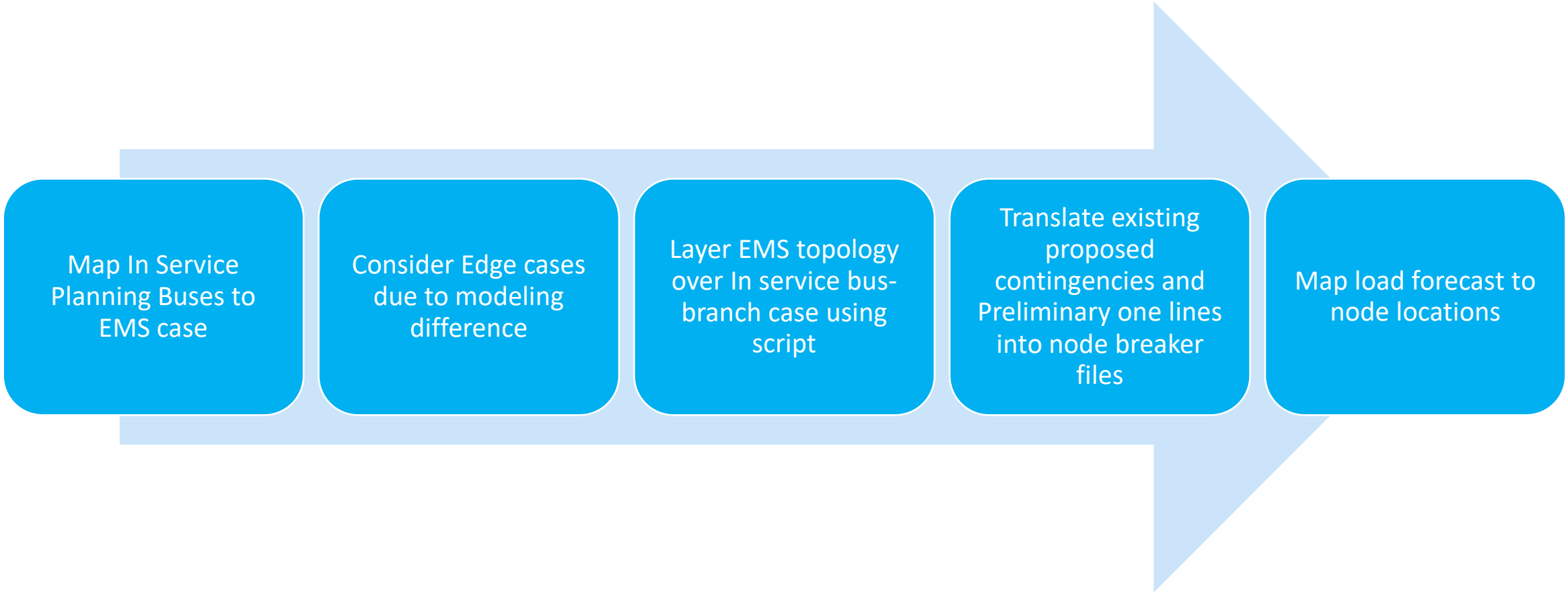
Bus-Branch Contingency Maintenance Difficulties

- Manual Process subject to large amounts of human error
- Forced assumptions
- Difficult to track change history
- Long and tedious update process
- Strict formatting for generating contingency leads to difficult error troubleshooting

Dominion Energy®

EPRI

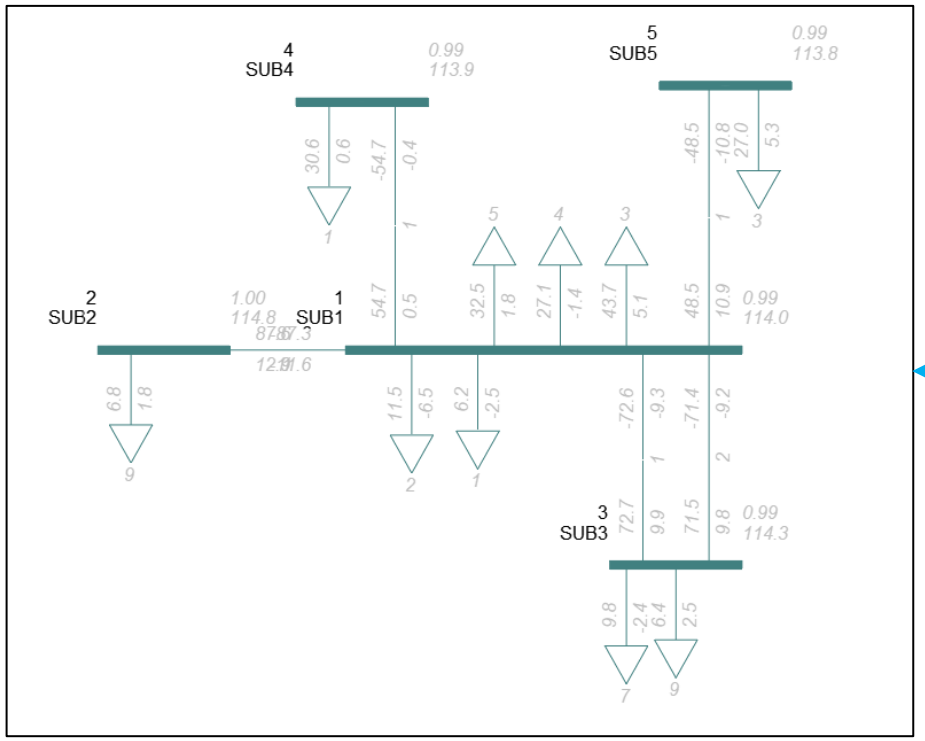
Node-Breaker Model Build Approach

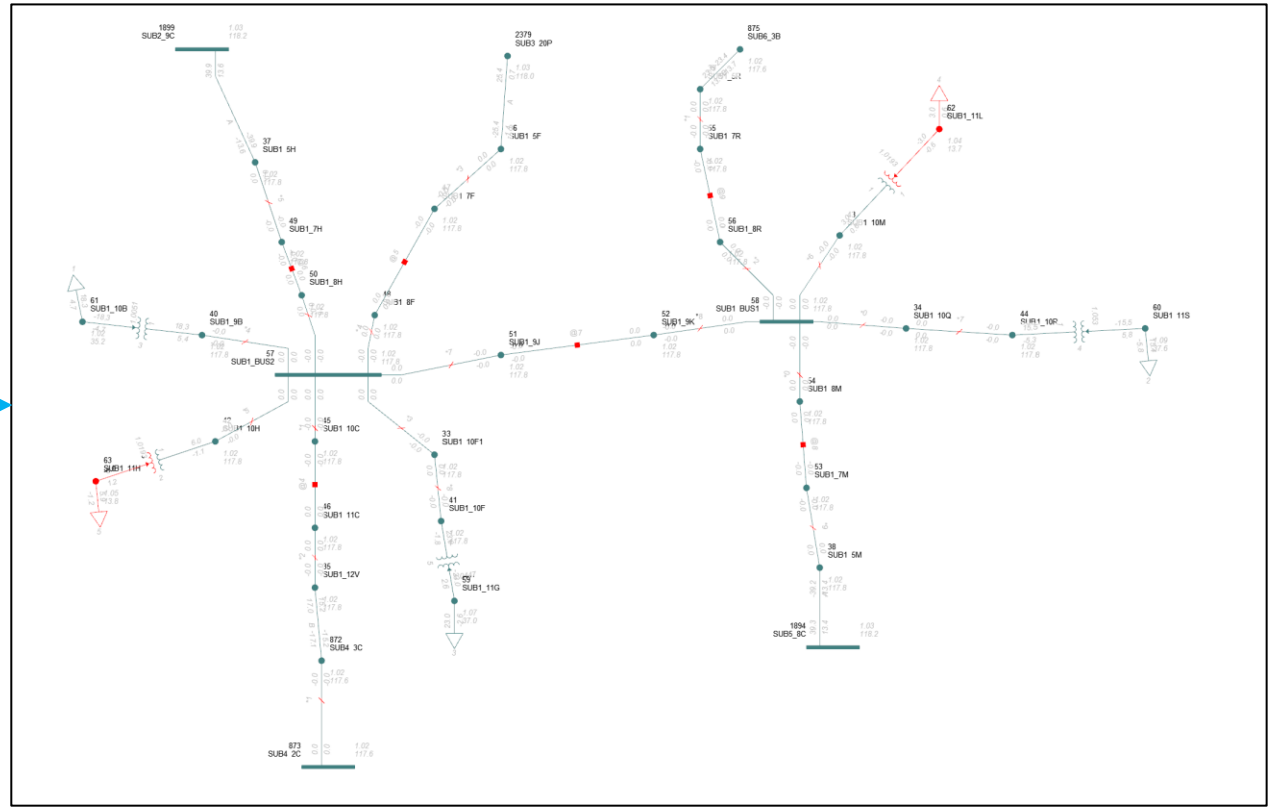


Dominion Energy®

EPRI

Mapping the EMS case To Planning Case





Dominion Energy®

EPRI

Mapping the EMS case To Planning Case

Planning PSSE model uses bus numbers as unique key while EMS uses substation names

- Determine which bus number matches to what substation/kV/node group
- Match initially using fuzzy matching
- Manually validate fuzzy matched stations and fix low confidence matches
- Explicitly define nodes for split bus scenarios

Anode Name	EMS Name	Match Heuristic	PSSE SUB	Bus Number	kV	Nodes (Split Bus)
SUB 1	SUB 1	100	3SUB1	123123	115	
SUB 1	SUB 1	100	3SUB1	123123	69	J,K,H,G,E
SUB 1	SUB 1	100	3SUB1	123123	69	N,P,L2,L
SUB 1	SUB 1	100	3SUB1	123123	69	
SUB 2	SUB 2	100	3SUB2	123124	230	
SUB 3	SUB 3	100	3SUB3	123125	115	
SUB 4	SUB 4	100	3SUB4	123126	115	B,F,A
SUB 4	SUB 4	100	3SUB4	123126	115	D,C,G,E,J,H
SUB 5	SUB 5	100	6SUB5	123127	230	
SUB 6	SUB 6	100	3SUB6	123128	115	
SUB 7	SUB 7	100	3SUB7	123129	115	F,D,1,B,C,A
SUB 7	SUB 7	100	3SUB7	123129	115	E
SUB 8	SUB 8	100	3SUB8	123130	115	
SUB 9	SUB 9	100	3SUB9	123131	115	
SUB 10	SUB 10	100	8SUB10	123132	500	
SUB 10	SUB 10	100	8SUB10	123132	115	
SUB 11	SUB 11	100	8SUB11	123133	500	
SUB 11	SUB 11	100	3SUB11	123133	115	

Dominion Energy®

EPRI

Edge Cases Mapping Considerations

Edge Case consideration when there is no “one-fits-all” assumption possible

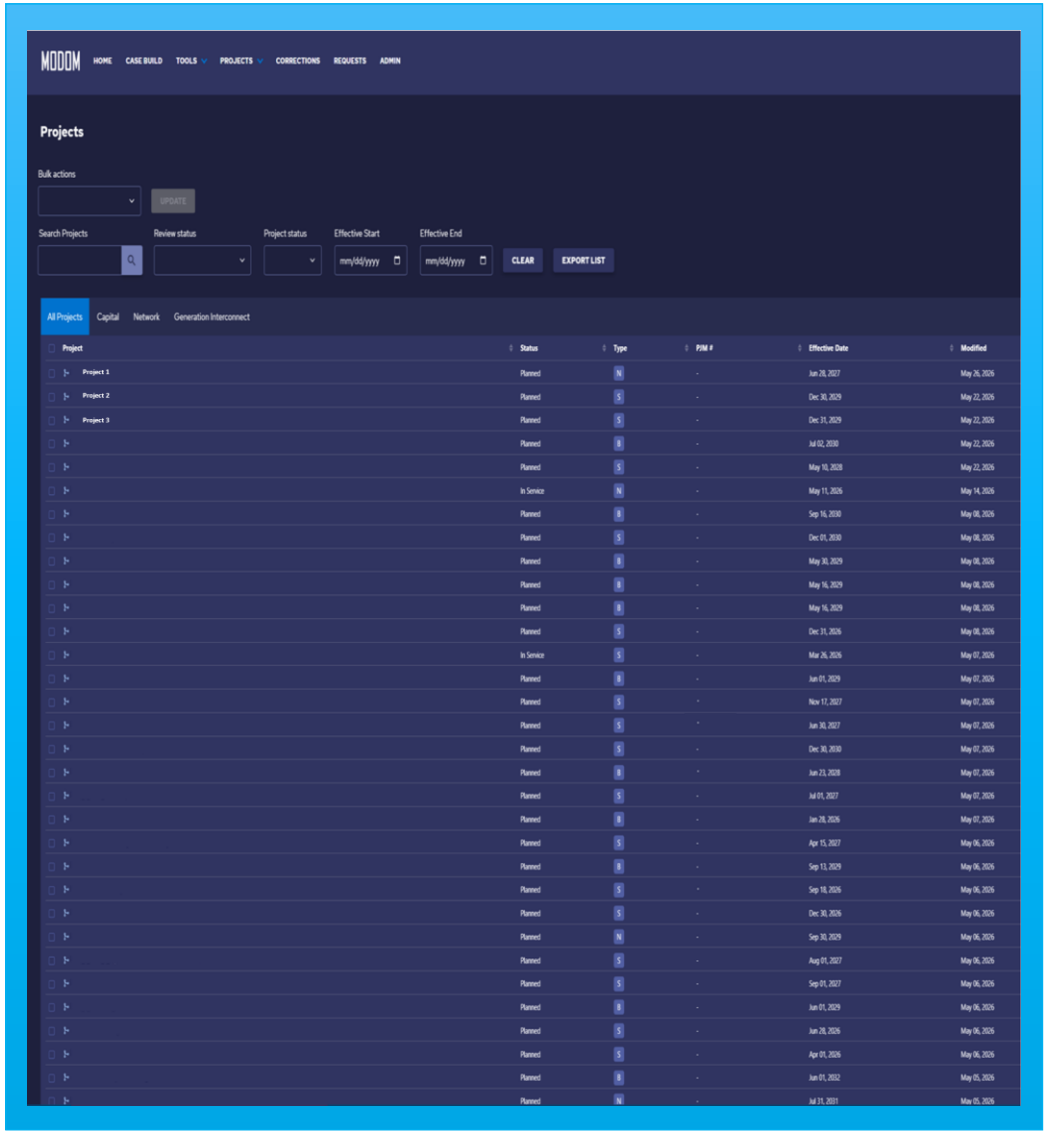
Edge Case	Reason
Double Circuits	No simple way to Identify circuit 1 vs 2 through automation
N.O. Switches/Breakers	EMS operating status likely different than the normal status
Tie Lines	No good mapping for non-DVP owned station
Zero Impedance Lines	These lines don’t exist on EMS case but do on planning case
Generators	No simple way to map which gen(s) are tied to which transmission point

These cases require explicit definition of which node the object to be placed

Dominion Energy®

EPRI

Managing Future Node breaker files



Bus Branch

```
Project Name,Baseline Upgrade,Planned,
<PHASE>,Project Name,2030-09-16,2025-06-24,
BUS,ADD,999999,'6TEST     ',230.0000,1,345,353,312,,,1.10000,0.90000,1.10000,0.90000 @!
BRANCH,DELETE,999997,999998,'1 ',2.29846E-03,1.79951E-02,0.06495,'                                                ',1572.00,1572.00,1808.00,0.00,0.00,0.00,0.00,0
BRANCH,ADD,999997,999995,'1 ',1.60900E-03,1.25970E-02,0.04546,'                                                ',1572.00,1572.00,1808.00,0.00,0.00,0.00,0.00,0.00
BRANCH,ADD,999997,999996,'1 ',6.90000E-04,5.39900E-03,0.01949,'                                                ',1572.00,1572.00,1808.00,0.00,0.00,0.00,0.00,0.00
BRANCH,MODIFY,999994,999995,'1 ',,,,'                                                ',,,,,,,,,,,,,,,,,1,2,,312,0.9608,312,0.0392,0,,0, @!
BRANCH,MODIFY,999995,999997,'1 ',,,,'                                                ',,,,,,,,,,,,,,,,,1,2,,312,0.9608,312,0.0392,0,,0, @!
TRANSFORMER,ADD,999998,999997,0,'1 ',1,1,1,0.00000E+00,0.00000E+00,2,'TX#3_271                                                ',1,312,1.0000,0,1.0000,0,1.0000,0,1.0000,'
1.00000E-04,9.30000E-03,100.00
1.00000,0.000,0.000,0.00,0.00,0.00,,,,,,,,,,0,0,0,1.10000,0.90000,1.10000,0.90000,33,0,0.00000,0.00000,0.000
1.00000,0.000
```

Node-Breaker

```
NODE,ADD,999999,201,'201',999997,1,,, @!
NODE,ADD,999999,200,'200',999997,1,,, @!
NODE,ADD,999999,43,'43',999999,1,,, @!
NODE,ADD,999999,42,'42',999999,1,,, @!
NODE,ADD,999999,41,'41',999999,1,,, @!
NODE,ADD,999999,40,'40',999999,1,,, @!
NODE,ADD,999999,202,'202',999997,1,,, @!
NODE,ADD,999999,211,'211',999997,1,,, @!
NODE,ADD,999999,207,'207',999997,1,,, @!
NODE,ADD,999999,206,'206',999997,1,,, @!
NODE,ADD,999999,205,'205',999997,1,,, @!
NODE,ADD,999999,204,'204',999997,1,,, @!
NODE,ADD,999999,210,'210',999997,1,,, @!
NODE,ADD,999999,203,'203',999997,1,,, @!
NODE,ADD,999999,39,'39',999999,1,,, @!
NODE,ADD,999999,209,'209',999997,1,,, @!
NODE,ADD,999999,208,'208',999997,1,,, @!
STATIONSWITCHINGDEVICE,ADD,999999,207,208,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,201,202,'@1','Switch Name',2,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,40,41,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,10,43,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,1,39,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,200,206,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,200,201,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,208,209,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,210,211,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,39,40,'@1','Switch Name',2,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,204,205,'@1','Switch Name',2,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,42,43,'@1','Switch Name',2,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,209,211,'@1','Switch Name',2,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,206,207,'@1','Switch Name',2,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,205,210,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,203,204,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,202,203,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,ADD,999999,41,42,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999999,201,202,'@1','Switch Name',2,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999999,202,203,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999998,40,68,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999999,205,210,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999999,203,204,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999998,33,39,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999998,39,40,'@1','Switch Name',2,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999997,3,5,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999997,4,5,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999998,33,38,'*1','Switch Name',3,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999998,36,38,'@1','Switch Name',2,1,1,0.00010,9999.00,9999.00,9999.00 @!
STATIONSWITCHINGDEVICE,MODIFY,999999,204,205,'@1','Switch Name',2,1,1,0.00010,9999.00,9999.00,9999.00 @!
TERMINAL,DELETE,999994,999993,215,'B',999995,'1' @!
TERMINAL,DELETE,999995,999995,3,'B',999993,'1' @!
TERMINAL,ADD,999999,999999,41,'2',999997,'1' @!
TERMINAL,ADD,999999,999997,203,'B',999995,'1' @!
TERMINAL,ADD,999999,999997,200,'2',999999,'1' @!
TERMINAL,ADD,999994,999993,215,'B',999997,'1' @!
TERMINAL,ADD,999995,999995,3,'B',999997,'1' @!
TERMINAL,ADD,999999,999997,208,'B',999993,'1' @!
```

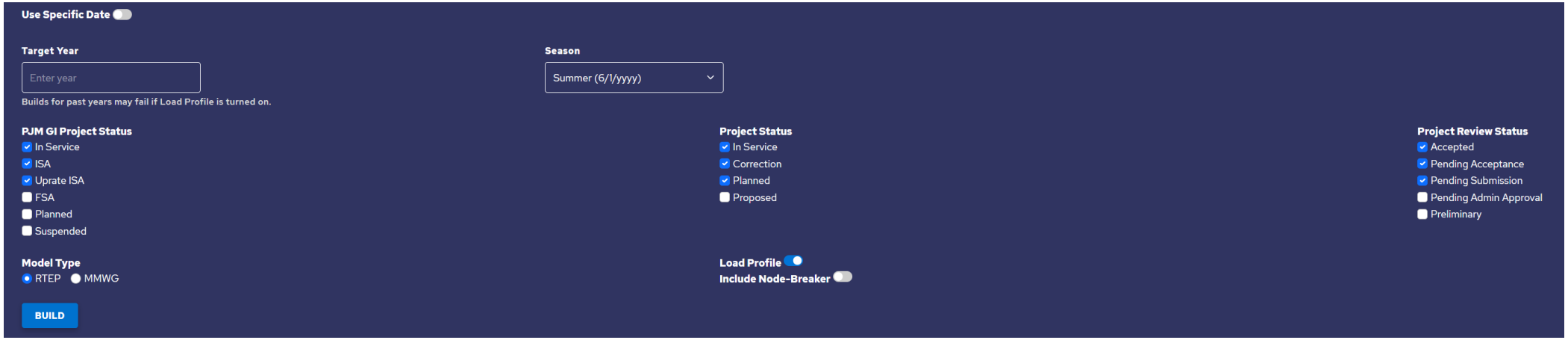

Dominion Energy®

EPRI

File Management and Case Build

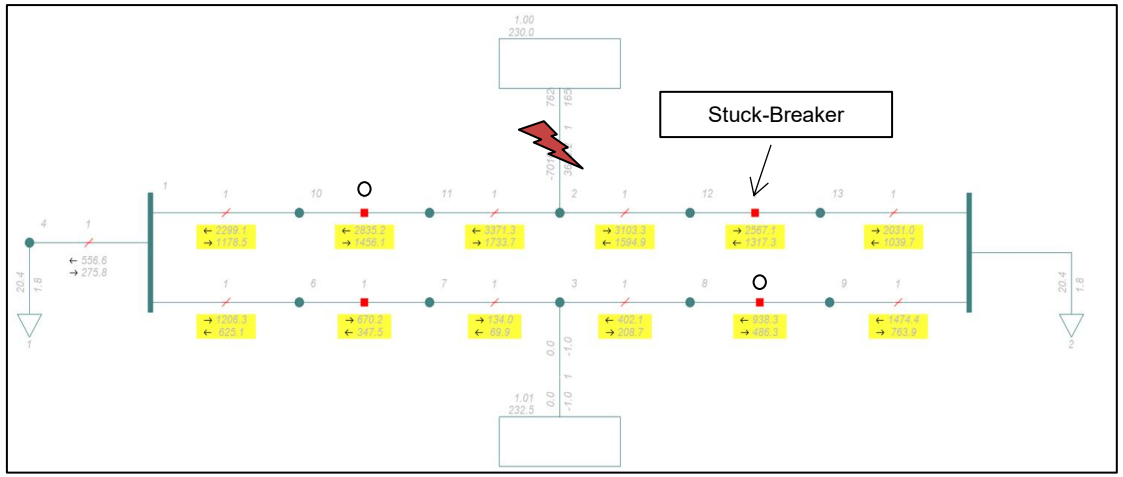
Propose new project → Make associated node breaker changes in model → Add changes to project database and check for dependencies → Update project model based on one-lines when available

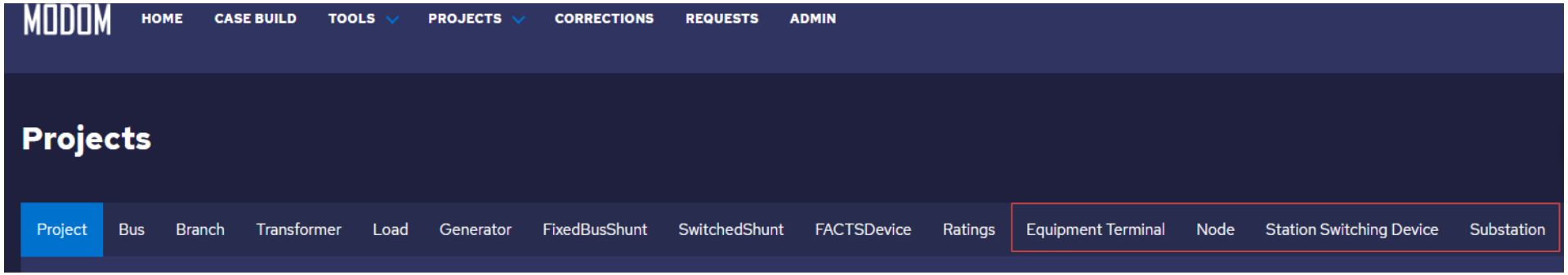
Load flow case can be built for any target date and season with node breaker topology



Unexpected Hurdles

- Difficulty in translating already proposed contingencies into a node-breaker format
- Importance of load and generation locations when determining contingency definitions
- Initial software upgrades needed to maintain the model
- Distribution side protection and transfer bus consideration





Dominion Energy®

EPRI

Overlaying Node-Breaker on Bus Branch

External bus branch case

Internal node-breaker case

→ Case compare script → Node-breaker topology change commands → Bus-branch case with overlayed node-breaker

*Node-breaker should have same bus branch topology as extern

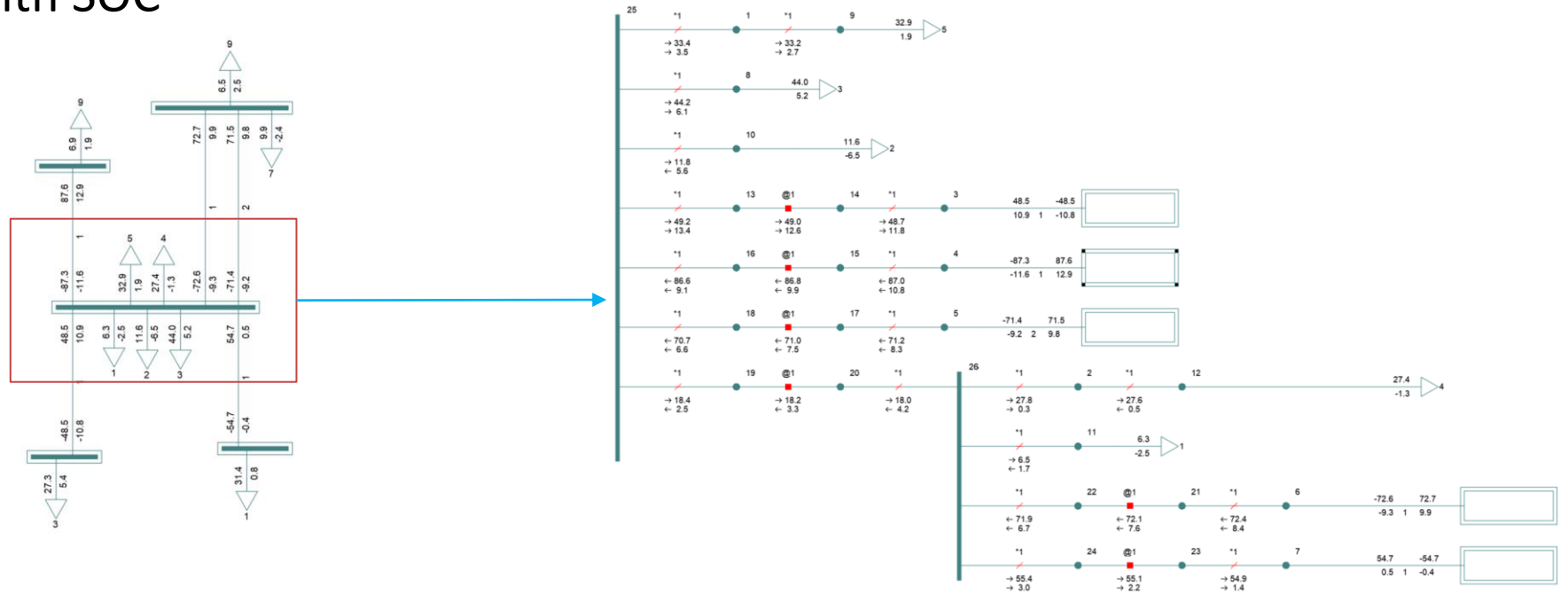
Change IDV Command
BAT_STATION_NODE_DATA,2,99,12345,1,'TEST_SUB_2_2 '
BAT_STATION_NODE_CHNG,2,1,12345,1,'NEW_NODE_NA ME ',;
BAT_STATION_NODE_PURG,2,2
BAT_STATION_SWD_DATA,2,1,99,'1 ',1,1,2, 0.00100,0.00,0.00,0.00,' ',;
BAT_STATION_SWD_PURG,2,1,2,'1 '
BAT_STATION_BRANCH_TERM_CHNG,12345,123123,'1 ',99,0

Dominion Energy®

EPRI

Transmission Planning Benefits

- Visual view of each substation in a familiar model format
- No need for manually written contingency (Excluding P7 and P5)
- Clear explanations for how each contingency gets generated
- Change history tracking through project versions
- Alignment with SOC

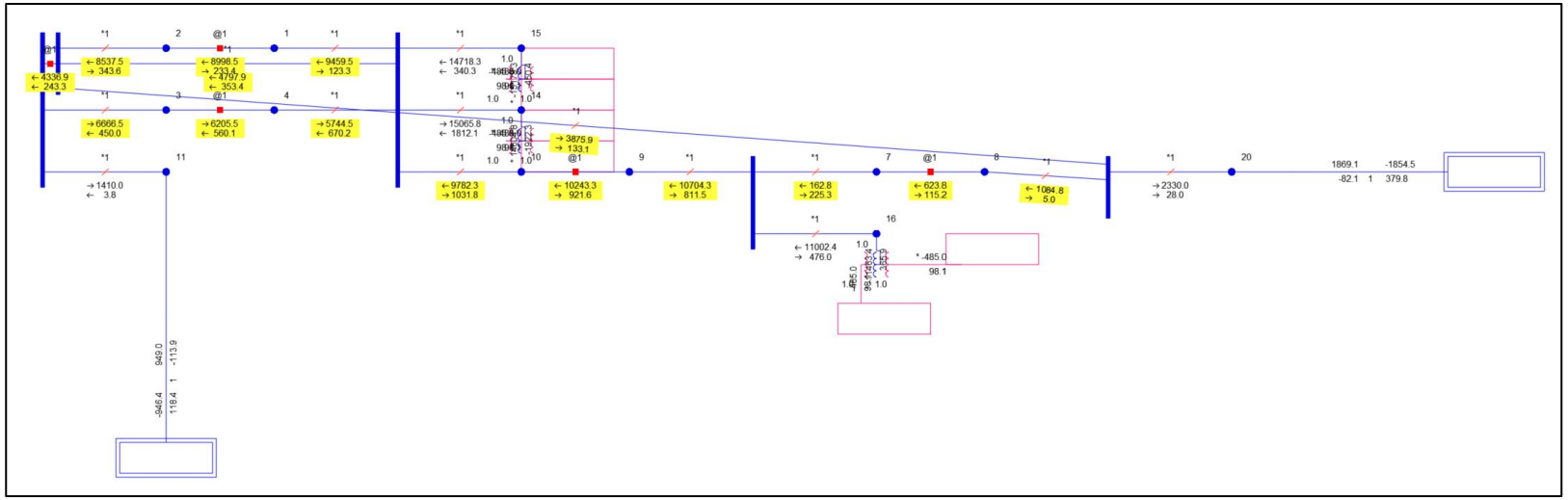


Dominion Energy®

EPRI

Future Improvements

- Breaker rating methodology to determine derates from case topology
- Regular base case updates to align with SOC
- Visual limitations of PSSE



Questions?

TOGETHER…SHAPING THE FUTURE OF ENERGY®

www.epri.com