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Operations and Planning Track

Topology Processing and Real-Time Applications

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Real-Time Apps?

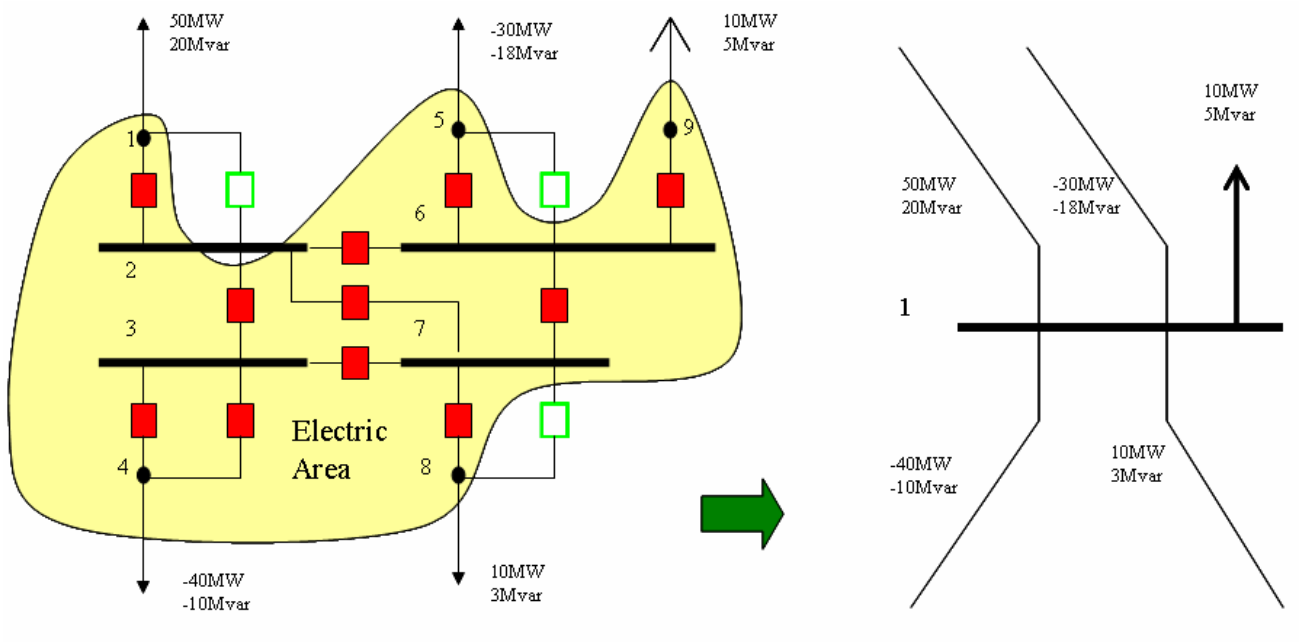
- Retriever uses a power flow case to link real-time data to power system objects and to displays those values on diagrams.
  - In some installations the **entire** state estimation data set is retrieved.
- Can we solve a power flow with the real-time data?
- Can PowerWorld make its applications available for real-time? ISONE Project.

Outline

1. Demystify the relations between power system EMS models and planning models.
2. Show how an EMS model can be represented as a planning case.
3. Introduce the ***Same-Model Topology Processing*** algorithm.
4. Present an architecture to enable using existing applications in real-time.

EMS and Planning Models

- Two different power systems models:
  - EMS systems use a ***Full-Topology Model***
  - Planners use a ***Consolidated-Topology Model***



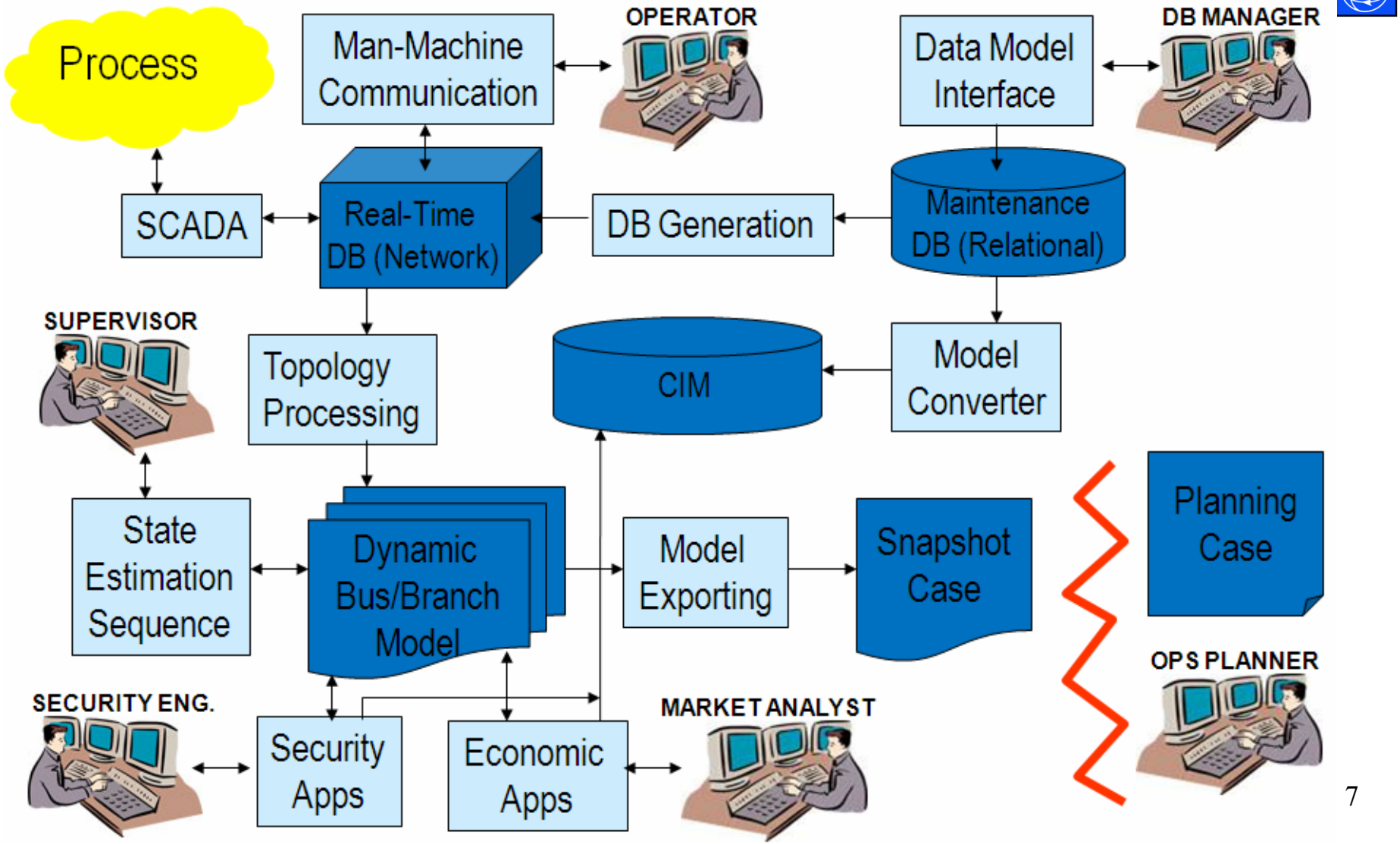
EMS and Planning Models

- Today, EMS and planning models remain largely incompatible.
- Even with great advances in computer networking, communications, databases, and software engineering, the models in one environment are essentially useless in the other.

EMS and Planning Models

- In the planning side there is a de-facto standard, PSSE.
- In the EMS industry each vendor uses internal modeling and formats.
  - During the last decade, a major effort has resulted in the Common Information Model (CIM)
  - CIM is starting to be used for data exchange, but remains to be used for the EMS core routines.

EMS and Planning Models



EMS and Planning Models

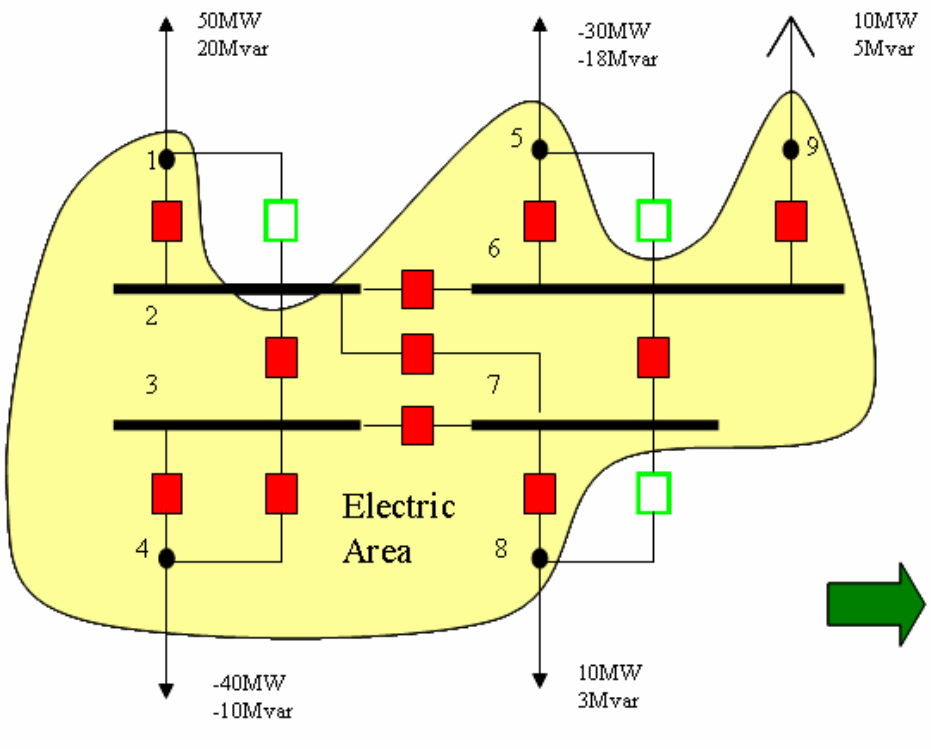
- The irony is that internally, EMS systems must use a bus-branch consolidated model to obtain the numeric solutions of state estimator and power flow.
- ***Topology Processing*** is used to obtain the internal bus-branch consolidated model.

EMS and Planning Models

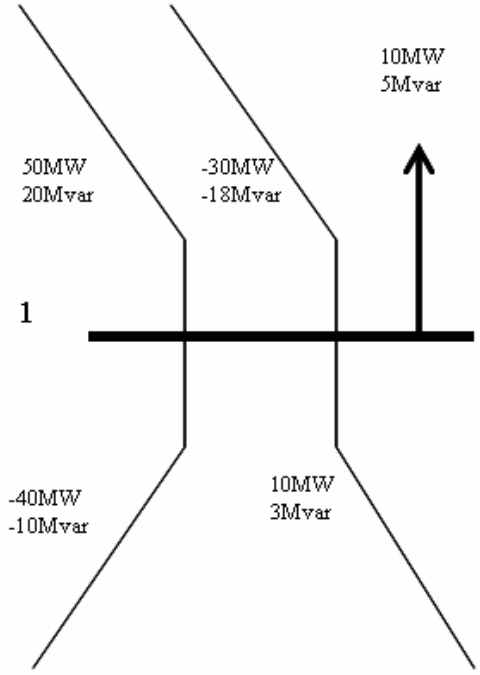
- All these different models and formats are not needed, at least not in order to study the power system in real-time.
- Why would you need so many different models to describe one real-time process anyway?

Topology Processing

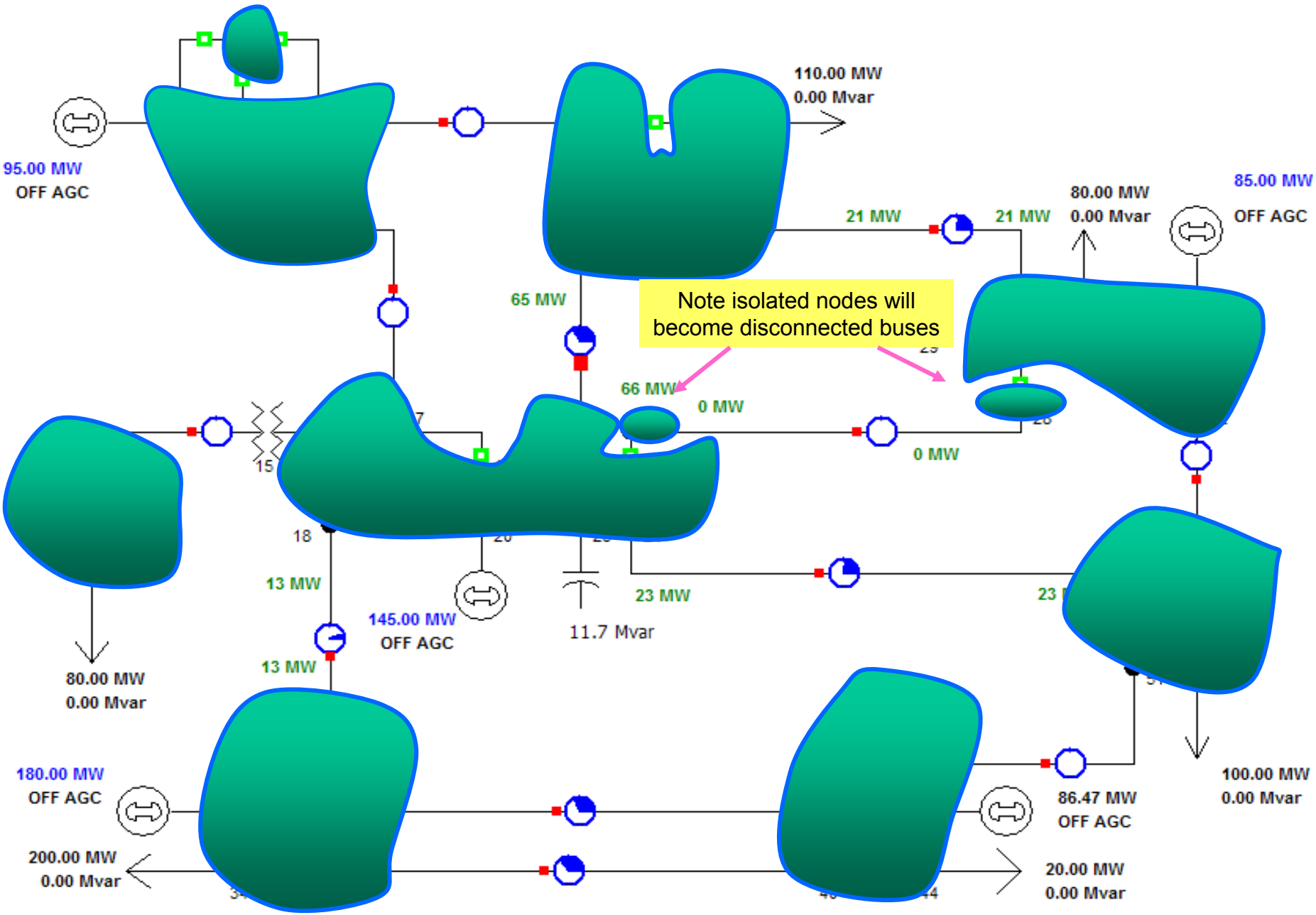
- Real-Time Model
  - Node/breaker
  - Full topology



- Planning Model
  - bus/branch
  - Consolidated



Node Groups in a 52-Node Case

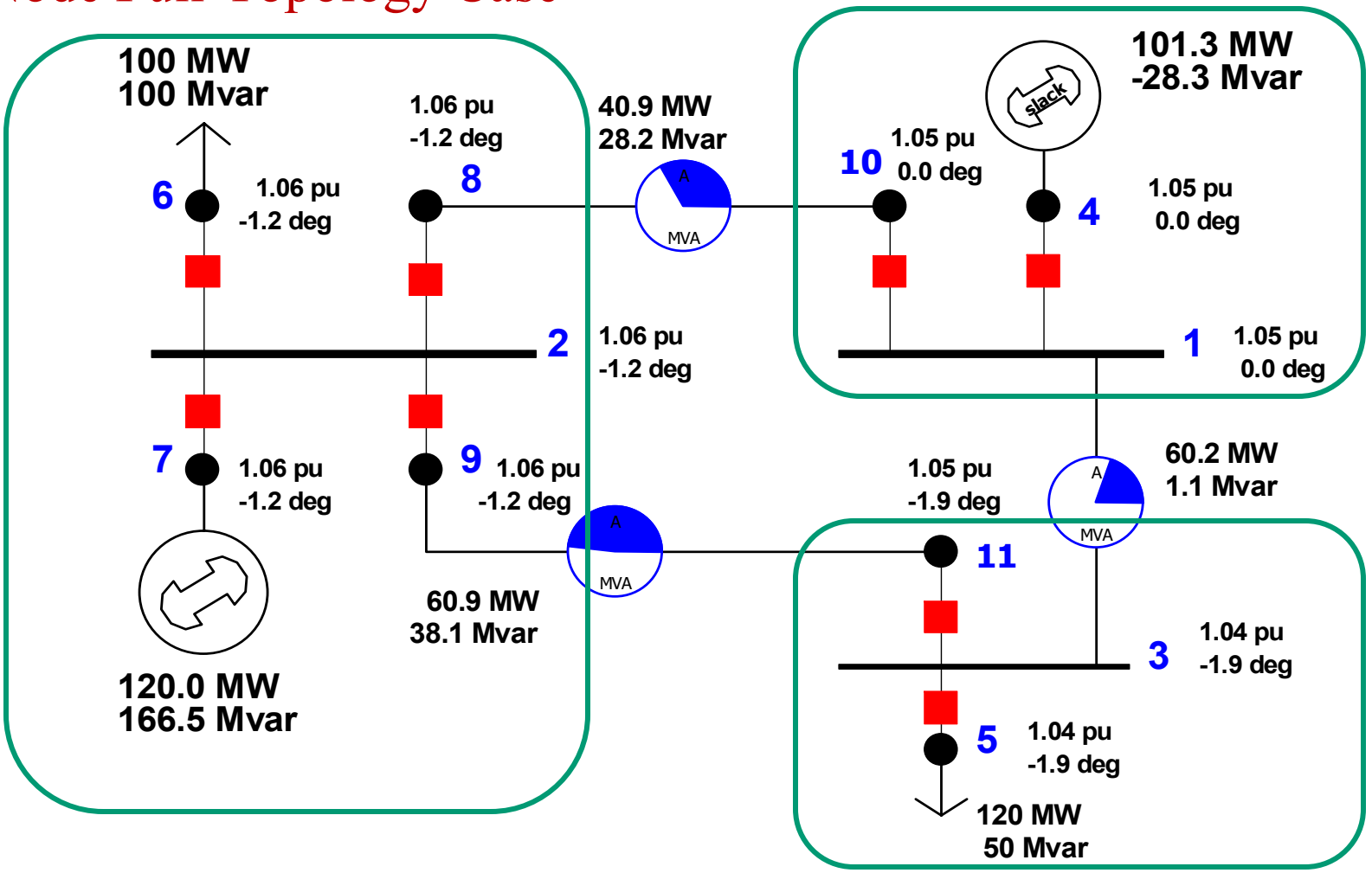


Topology Processing

- If a planning case had information about the nodes, breakers, and breaker statuses, it is perfectly possible to replicate the solution of a real-time power flow and to do so consistently over time.
- Note that resolving the topology of the EMS model is the only step needed to make EMS and planning cases compatible.

Same-Model Topology Processing

11-Node Full-Topology Case



Same-Model Topology Processing

- The real-time system can be modeled using the existing planning standard format:
  - Bus-bars, junctions, nodes can be modeled as buses
  - Circuit breakers and disconnects can be modeled as low-impedance branches.
- No changes to the format are needed.

Same-Model Topology Processing

Branch Records in Planning Format

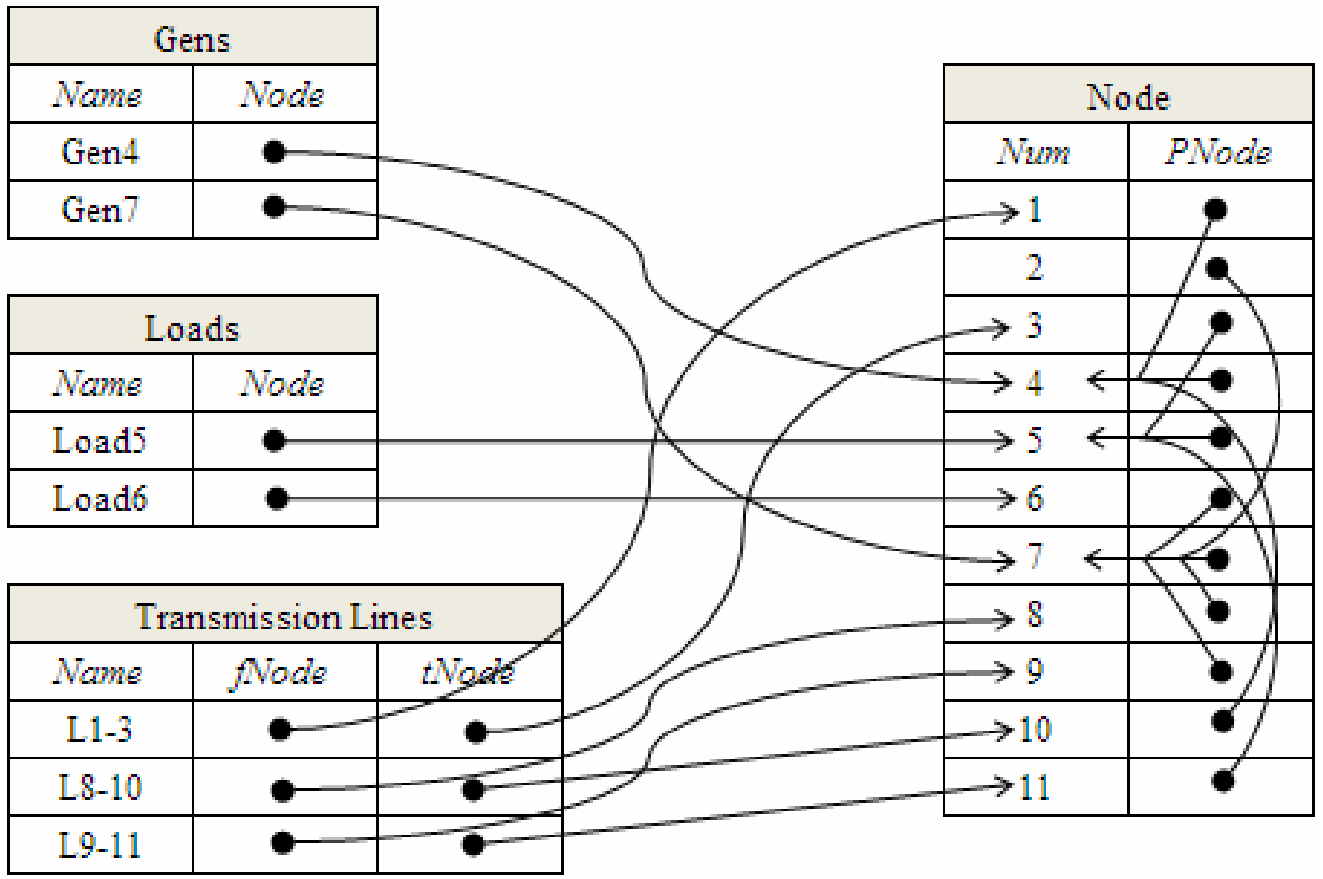
Line and Transformer Records | Branches State

Records | Geo | Set | Columns

	HDR:: From	From Number	To Number	Circuit	Status	Xfrmr	R	X	B	Lim A MVA
1	Line	10	8	1	Closed	No	0.0100	0.0500	0.020	150.0
2	Line	1	3	1	Closed	No	0.0120	0.0600	0.100	300.0
3	Line	9	11	1	Closed	No	0.0150	0.0300	0.030	150.0
4	Breaker	3	5	1	Closed	No	0.0000	0.0001	0.000	0.0
5	Breaker	11	3	1	Closed	No	0.0000	0.0001	0.000	0.0
6	Breaker	6	2	1	Closed	No	0.0000	0.0001	0.000	0.0
7	Breaker	2	8	1	Closed	No	0.0000	0.0001	0.000	0.0
8	Breaker	7	2	1	Closed	No	0.0000	0.0001	0.000	0.0
9	Breaker	2	9	1	Closed	No	0.0000	0.0001	0.000	0.0
10	Breaker	10	1	1	Closed	No	0.0000	0.0001	0.000	0.0
11	Breaker	1	4	1	Closed	No	0.0000	0.0001	0.000	0.0

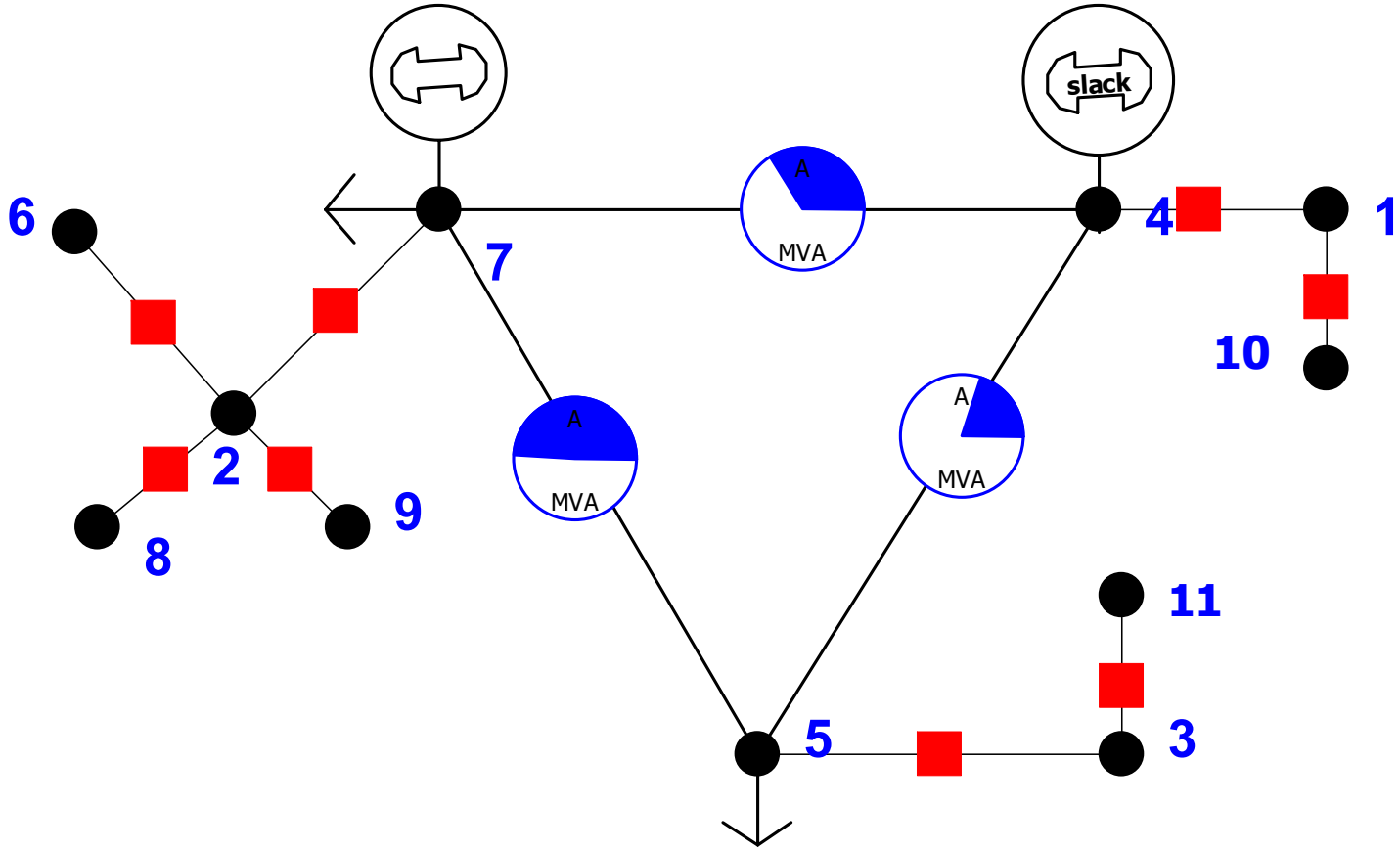
Same-Model Topology Processing

Device Node "Relocation"



Same-Model Topology Processing

System Representation after Device Relocation



Same-Model Topology Processing

Full-Topology Jacobian

	Number	Jacob Equa	Angle Bus 1	Angle Bus 2	Angle Bus 3	Angle Bus 5	Angle Bus 6	Angle Bus 7	Angle Bus 8	Angle Bus 9	Angle Bus 10	Angle Bus 11	Volt Mag Bus 1	Volt Mag Bus 2	Volt Mag Bus 3	Volt Mag Bus 5	Volt Mag Bus 6	Volt Mag Bus 7	Volt Mag Bus 8	Volt Mag Bus 9	Volt Mag Bus 10	Volt Mag Bus 11
1	1	Real	22069		-18						-11026		24		-3						-10	
2	2	Real		44931			-11232	-11234	-11232	-11232				42			-10	-12	-11	-10		
3	3	Real	-17		21647	-10814						-10815	-4		24	-9						-11
4	5	Real			-10814	10814									-12	9						
5	6	Real		-11232			11232							-12			10					
6	7	Real		-11234				11234						-9				12				
7	8	Real		-11232					11254		-21			-10					15		-5	
8	9	Real		-11232						11262		-30		-11						25		-14
9	10	Real	-11026						-21		11047		-11						-4		15	
10	11	Real			-10815					-29		10844			-10					-14		24
11	1	Reac	-26		3						11		21017		-17						-10500	
12	2	Reac		-45			10	12	12	11				42394			-10598	-10598	-10598	-10598		
13	3	Reac	4		-25	10						11	-17		20815	-10399						-10399
14	5	Reac			12	-12									-10399	10398						
15	6	Reac		12			-12							-10597			10597					
16	7	Volta																1				
17	8	Reac		11					-16		5			-10598					10619		-20	
18	9	Reac		12						-26		14		-10598						10626		-28
19	10	Reac	11						4		-15		-10501						-20		10521	
20	11	Reac			10					15		-25			-10400					-28		10427

Same-Model Topology Processing

Full Topology Jacobian after Relocation

Name		1A	2A	3A	5A	6A	7A	8A	9A	10A	11A	1V	2V	3V	5V	6V	7V	8V	9V	10V	11V
1	P	1			47		-29								16		-14				
2	P		1		-30										-14						
3	P			1			15										-28				
5	P				47		-29								16		-14				
6	P					1															
7	P				-30		51								-14		18				
8	P							1													
9	P								1												
10	P									1											
11	P										1										
1	Q											1									
2	Q												1								
3	Q													1							
5	Q				-19		15								44		-28				
6	Q															1					
7	V																1				
8	Q																	1			
9	Q																		1		
10	Q																			1	
11	Q																				1

Same-Model Topology Processing

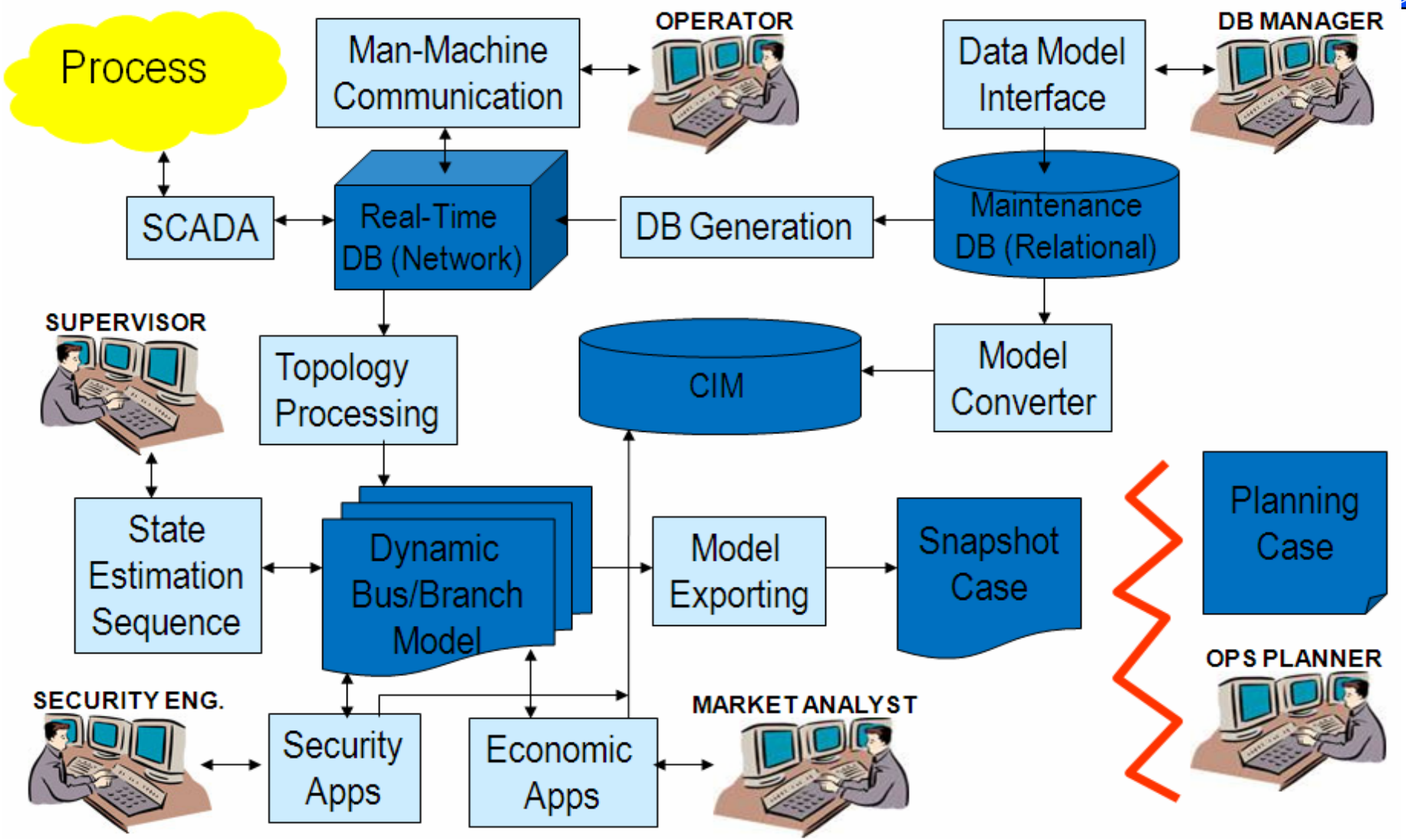
Consolidated Topology Jacobian

	Numbe	Jaco Equa	Angle Bus 5	Angle Bus 7	Volt Mag Bus 5	Volt Mag Bus 7
1	5	Real	47	-29	16	-14
2	7	Real	-30	51	-14	18
3	5	Reac	-19	15	44	-28
4	7	Volt	47	-29	16	1

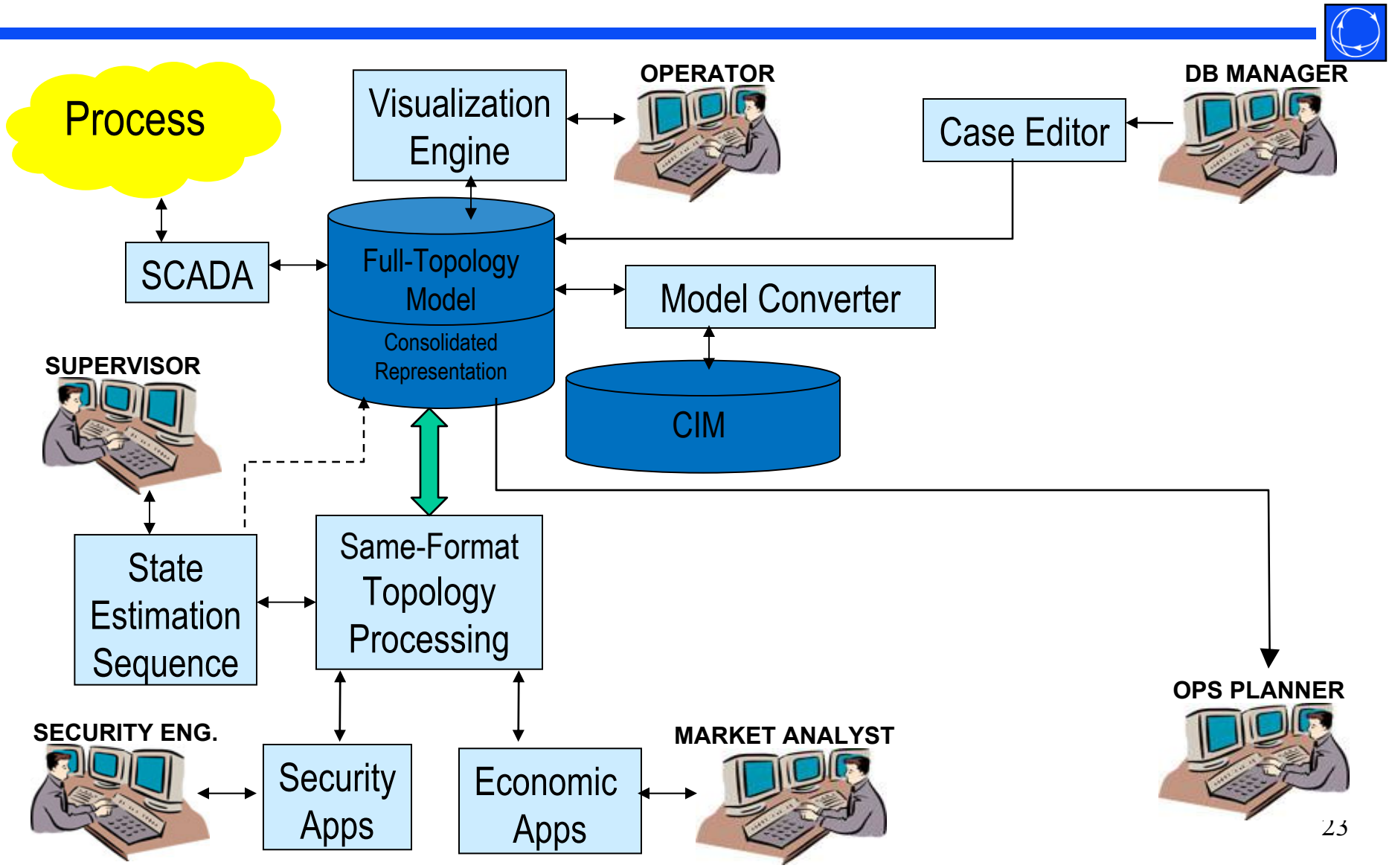
Numerical Solution

- Faster, because the consolidated representation is much smaller.
- More stable, because low-impedance branches are avoided entirely.
- Transparent to the user.
- Utilizes only one model.

Existing Architecture



Proposed Architecture



Potential Advantages

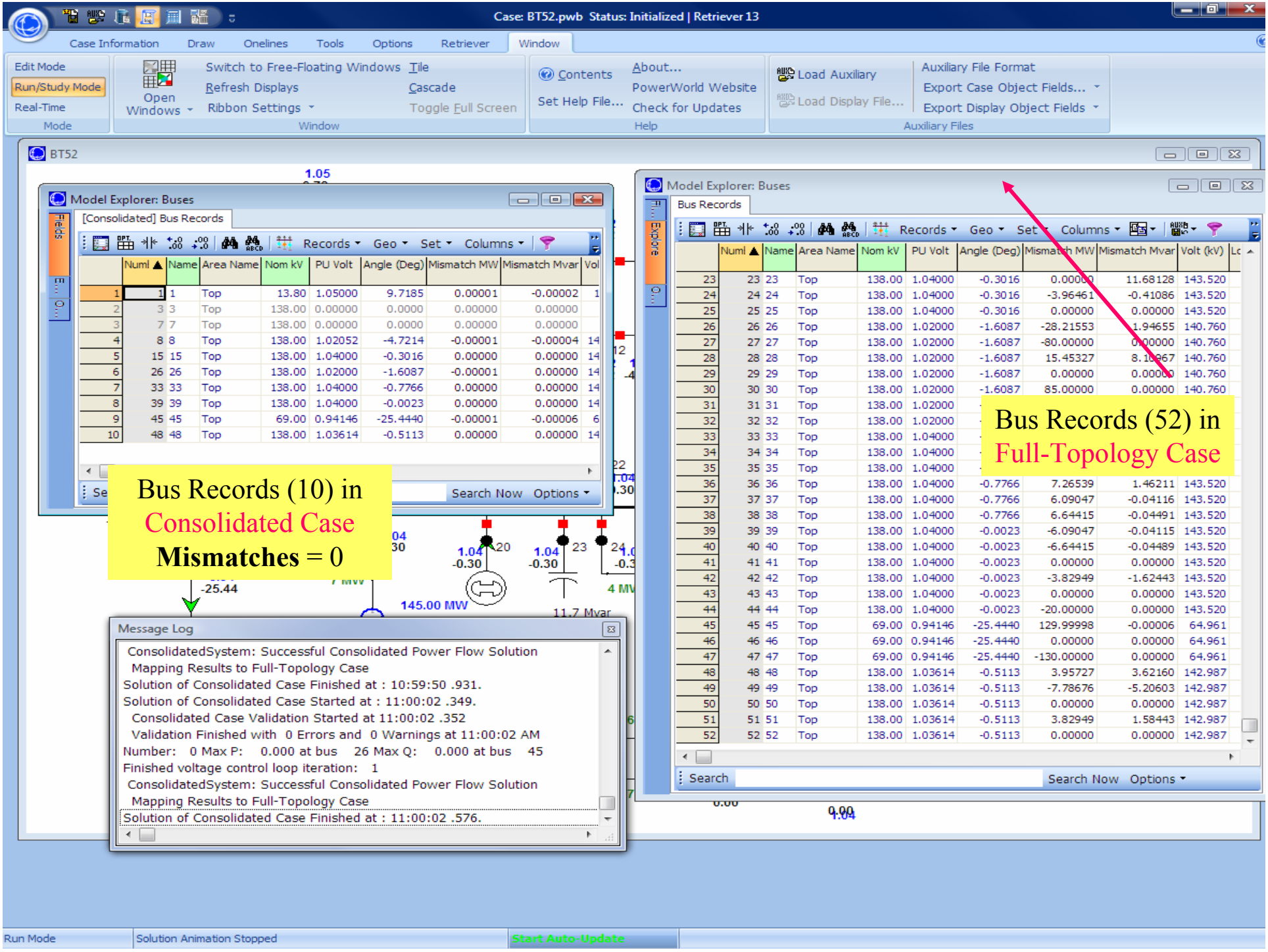
- Powerful off-line tools can be directly utilized to analyze the system in the real-time environment.
- The real-time case can be thoroughly studied in the off-line setting.
- Seamless exchange of cases between real-time and off-line environment.
- Inconsistencies between real-time and planning data can be discovered and fixed.

Potential Advantages

- Existing applications:
  - Power Flow
  - Sensitivity Analysis
  - Fault Analysis
  - Contingency Analysis
  - Optimal Power Flow
  - Security-Constrained Optimal Power Flow
  - Voltage Stability
  - Available Transfer Capability
  - Transient Stability

Potential Advantages

- Greatly simplify maintenance and operation:
  - Data managers and application engineers will deal with less formats and data models.
  - A unified set of applications and interfaces is presented to operators, operation engineers, and planners.


Case: BT52.pwb Status: Initialized | Retriever 13
Case Information
Draw
Onelines
Tools
Options
Retriever
Window
Edit Mode
Run/Study Mode
Real-Time
Mode
Open Windows
Switch to Free-Floating Windows
Refresh Displays
Ribbon Settings
Tile
Cascade
Toggle Full Screen
Window
Contents
Set Help File...
About...
PowerWorld Website
Check for Updates
Help
Load Auxiliary
Load Display File...
Auxiliary File Format
Export Case Object Fields...
Export Display Object Fields
Auxiliary Files
BT52
Model Explorer: Buses
[Consolidated] Bus Records
Records
Geo
Set
Columns
Search Now
Options
Bus Records (10) in Consolidated Case Mismatches = 0
Model Explorer: Buses
Bus Records
Search
Search Now
Options
Bus Records (52) in Full-Topology Case
Message Log
ConsolidatedSystem: Successful Consolidated Power Flow Solution
Mapping Results to Full-Topology Case
Solution of Consolidated Case Finished at : 10:59:50 .931.
Solution of Consolidated Case Started at : 11:00:02 .349.
Consolidated Case Validation Started at 11:00:02 .352
Validation Finished with 0 Errors and 0 Warnings at 11:00:02 AM
Number: 0 Max P: 0.000 at bus 26 Max Q: 0.000 at bus 45
Finished voltage control loop iteration: 1
ConsolidatedSystem: Successful Consolidated Power Flow Solution
Mapping Results to Full-Topology Case
Solution of Consolidated Case Finished at : 11:00:02 .576.
Run Mode
Solution Animation Stopped
Start Auto-Update

Conclusions

- Same-model Topology Processing allows applications to “see” the consolidated representation of a full-topology model.
- This enables Simulator applications to be used in the real-time environment.