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Simulator Tools for Building Full-Topology (Real-Time) Models

Santiago Grijalva
santiago@powerworld.com

PowerWorld Corporation

Overview

- Motivation
- Full-Topology Model
- Lessons Learned
  - General Modeling Recommendations
  - Case Debugging Tools

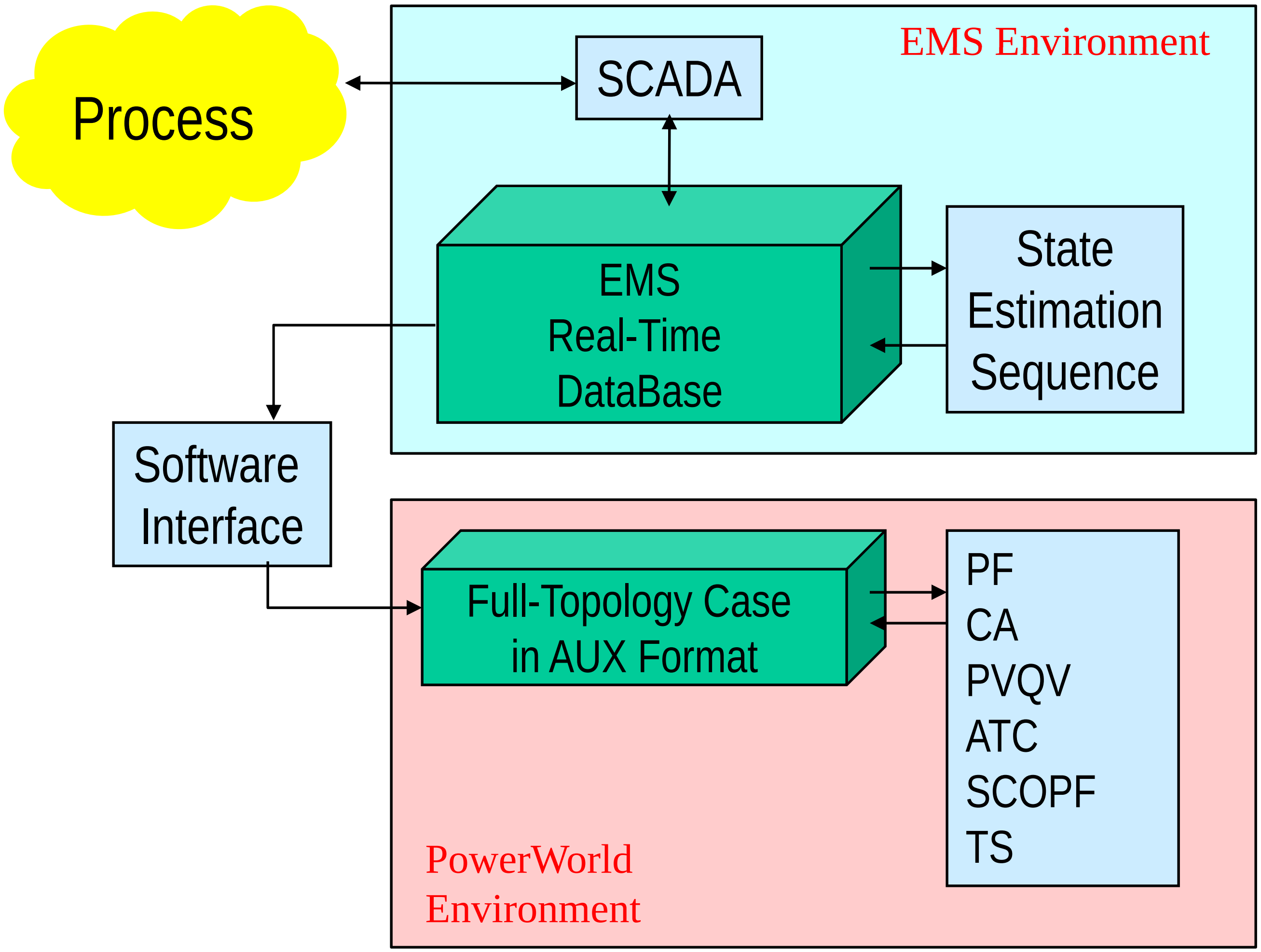
Motivation

- Integrated Topology Processing (ITP) is the Add-on that allows PowerWorld “planning” applications to be used in real-time.
  - ITP uses one model: the full-topology
- Making the full-topology model accurate is central to the overall real-time simulation process.

The Full-Topology Model

- Detailed steady-state model at the node-breaker level
- Exactly the same as the EMS model
  - Stored in EMS databases
- Queries or scripts can be written to obtain the full-topology model in aux file format.

Basic Architecture



Static Model and Real-Time Data

- A full-topology model includes *static data* and *real-time data*:
- Static Data
  – Does not change unless physical devices are added, removed or reconfigured in the actual system and modeled in the EMS
  – Ex: devices connected to a node, generator output limits, reactive capability curves, line R, X, B, etc

Static Model and Real-Time Data

- Real-Time Data
  - Provide the state of the system at a given point in time.
    - This state changes second to second or minute to minute
  - Examples: generation output, individual load MW and MVR, transmission line flows, bus voltage magnitude, breaker statuses, etc.
    - Important: Breaker Statuses!

General Modeling Recommendations

- Focus on modeling the physical system
  - Note that we use the standard planning format
    - There are no buses in the actual system
- Use PowerWorld Label field (available to every object) to store EMS device name
  - Possible if node names are static in the EMS.
  - You can index your data by device names

General Modeling Recommendations

- Terminal nodes of every device should be constant for the entire modeling process
- Note that the number of loads and generators do not change compared to a planning case
  - Sometimes switched shunts are aggregated in the planning model
- Use low impedance: $X = 0.0001$ for switching devices: breakers, disconnects, zbrs.

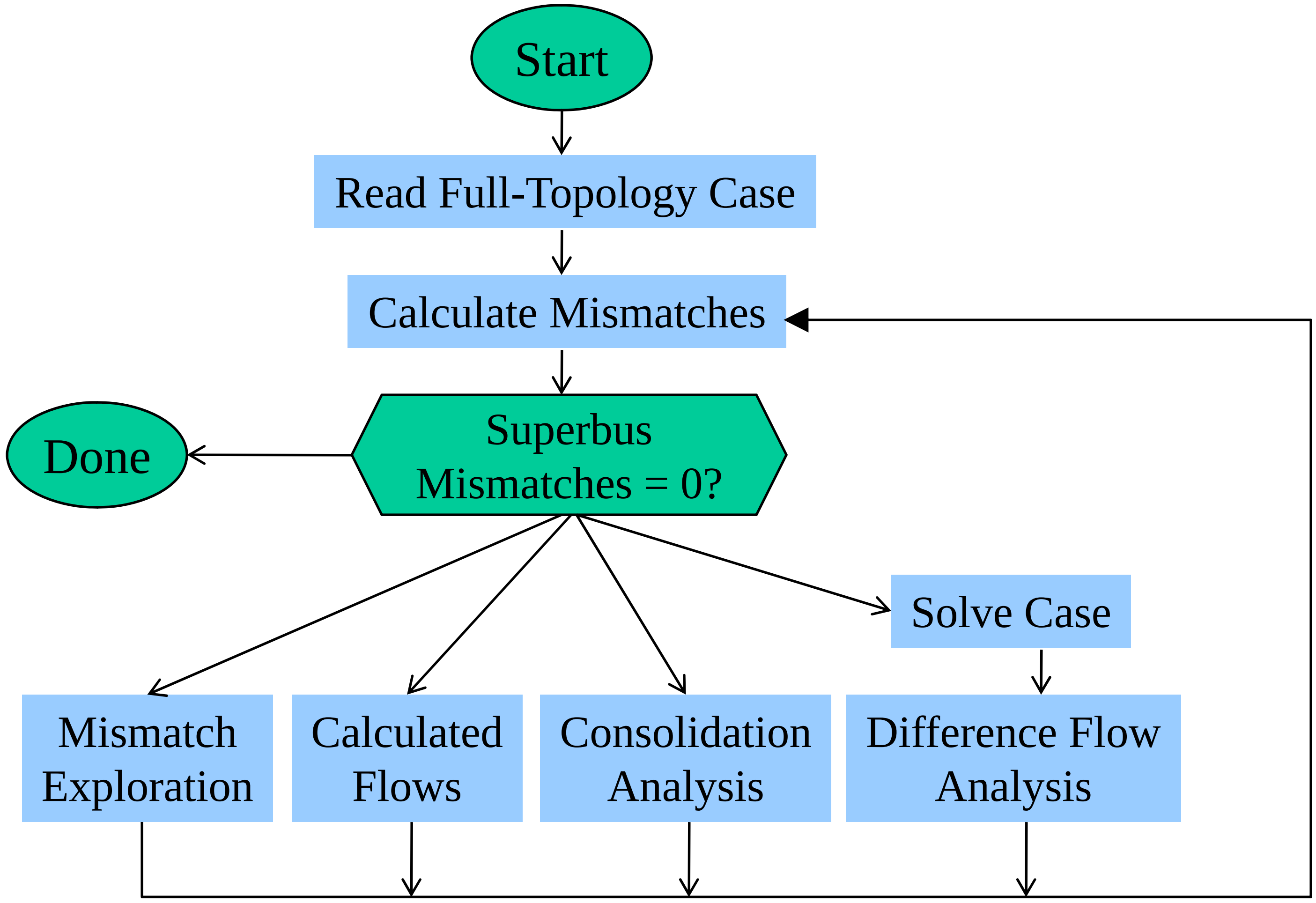
Debugging

- Goal is to create a full-topology case, for which the power flow solution will be identical to the EMS solution.
- Ideally, if everything is perfect, we would have *zero superbus mismatches* without having to solve the case.
  - The only source of error would be numerical truncation when reading stored EMS data.
    - i.e. “1.0612145” = 1.0612 in the text file.

An Imperfect World

- The State Estimator may not output a solved power flow.
  - Some SE do not enforce mismatches = 0
- Simulator’s solution options may not be the same as the EMS power flow options
  - For instance, handling remote var regulation
- User’s may not know what EMS options are being used.

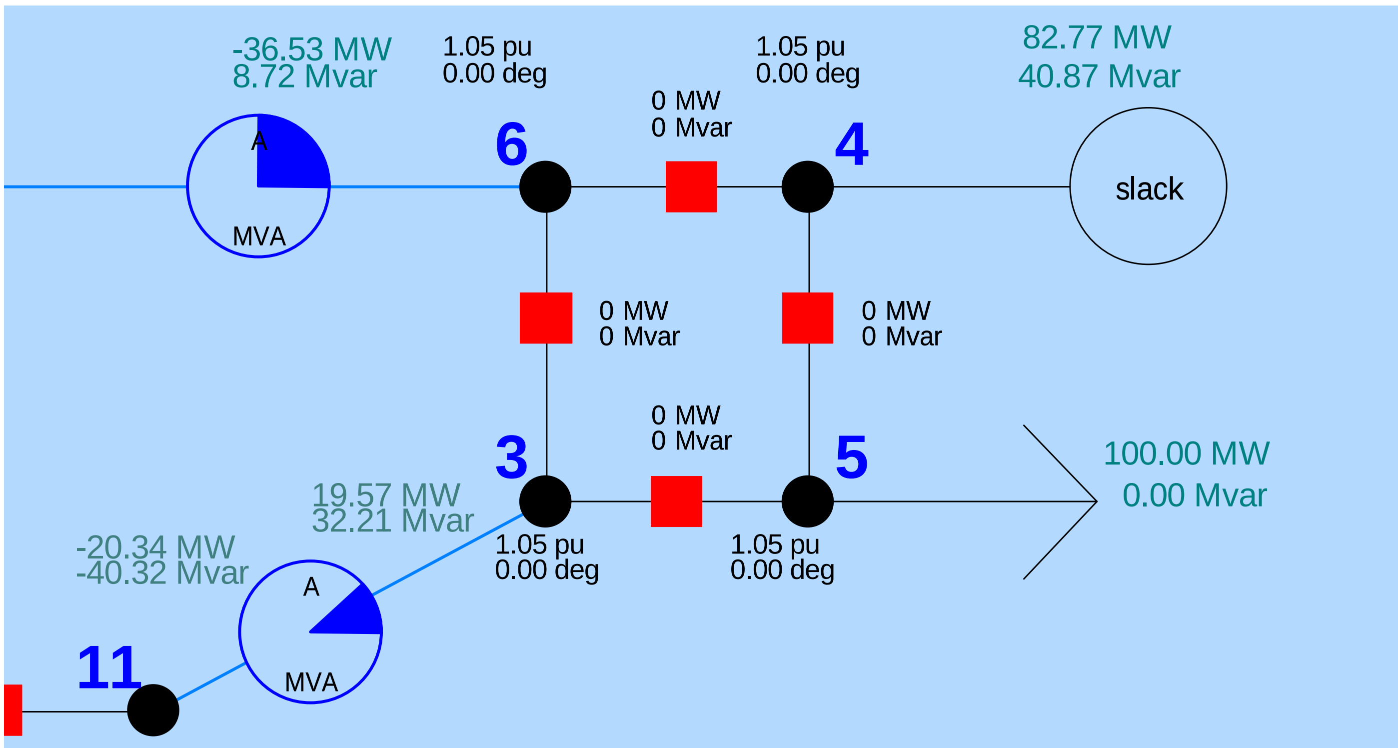
Simulator Tools for Case Debugging



1. Exploring Superbus Mismatches

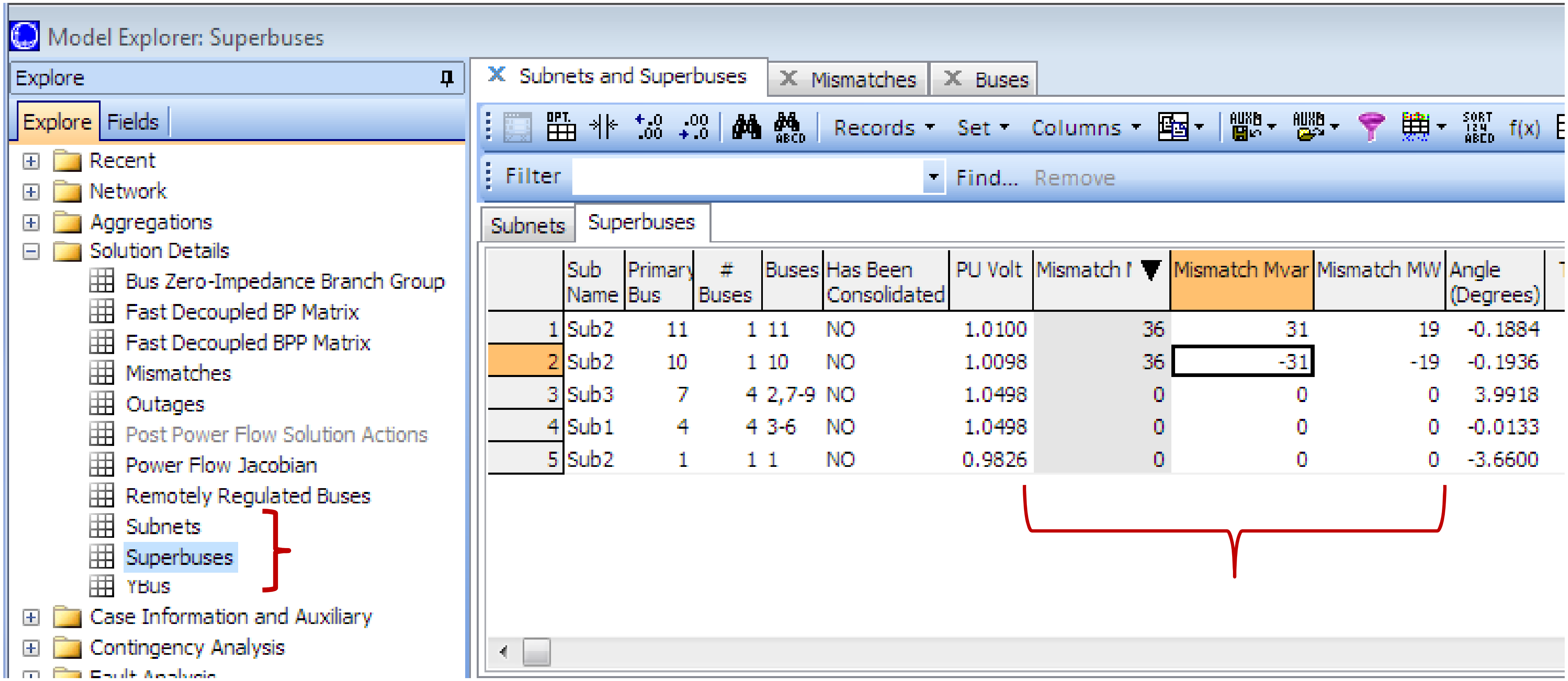
- In a perfect case, the bus mismatches are not zero, but the superbus mismatches are.
  - Breakers flows, are calculated after solving the power flow
  - Thus the largest bus mismatch after reading the case should be about the same as the largest net injection to the grid, usually the largest generator MW output.

1. Exploring Superbus Mismatches



	Num	Name	Area Name	Type	Mismatch MW	Mismatch Mvar	Mismatch MVA
1	3	3	Home	PQ	-19.57	-32.21	37.69
2	4	4	Home	Slack	0.00	0.00	0.00
3	5	5	Home	PQ	-100.00	0.00	100.00
4	6	6	Home	PQ	36.53	-8.72	37.56

1. Exploring Superbus Mismatches



Superbus and Subnet records are available in the Model Explorer

Superbus Mismatch is the net injection to the superbus

2. Calculated Branch Flows

- During the power flow, branch flows are calculated after the system state (voltage phasors) has been determined.
- For a transmission line:

$$P_{jk}, Q_{jk} = f(V_j, V_k, \theta_j, \theta_j, \mathbf{\Omega})$$

$$\mathbf{\Omega} = \text{Set of branch Parameters: } (R, X, B, t, \phi, etc)$$

  – After reading the case, Simulator will calculate the branch flows using the voltages at their terminals. These are the ***Calculated Flows***

2. Calculated Branch Flows

- Simulator can also read the branch flows determined by the EMS directly. Let us call this ***EMS Flows***

	From Number	To Number	Circuit	Status	Xfrmr	MW From	MW To	Mvar From	Mvar To	MW From (Calculated)	MW To (Calculated)	Mvar From (Calculated)	Mvar To (Calculated)
1	10	1	1	Closed	YES	120.0	-120.0	58.7	-49.9	120.0	-120.0	58.7	-49.9
2	7	2	1	Closed	NO	0.0	0.0	0.0	0.0	140.0	-140.0	30.5	-30.4
3	2	8	1	Closed	NO	0.0	0.0	0.0	0.0	37.1	-37.1	-6.1	6.1

- Usually planning applications cannot read flows directly into the branch records

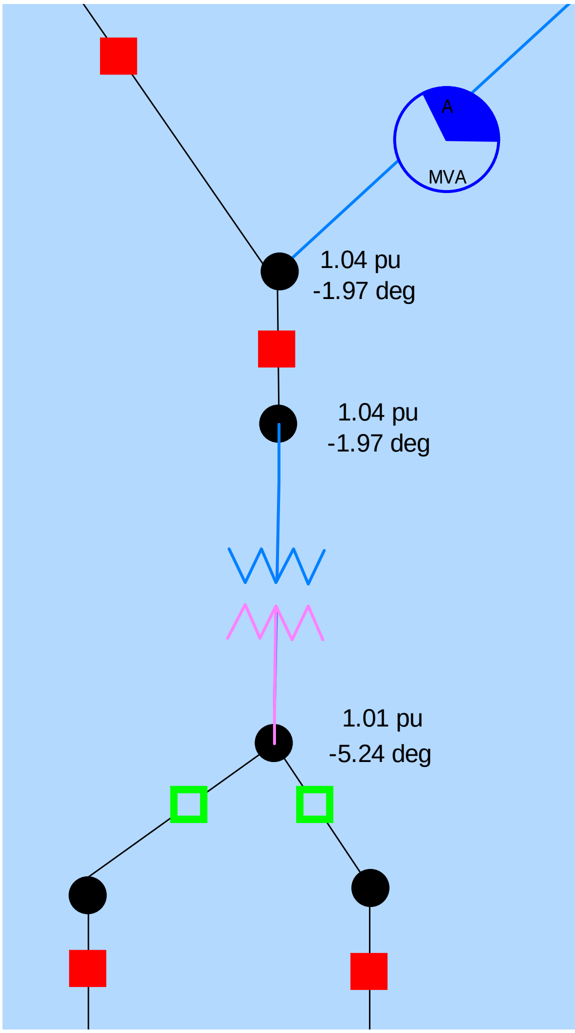
2. Calculated Branch Flows

- If the terminal voltages and the parameters of a branch are correct, then the calculated and EMS flows will be the same.
- Thus if we input the correct terminal voltages and obtain different flows, it is because of a branch parameter error.
- This allows ***decoupling*** the errors coming from branch devices and flows, which is extremely useful.

2. Calculated Branch Flows

- Usual parameter errors (transformers)
  - Direct error in values of R, X, B
  - Data is not in system base, but in device base
    - Both supported in Simulator, but need to choose the right one.
  - Tap position and tap ranges
  - Impedance correction tables
    - Errors showing up on Phase-Shifting transformer often are related to omission of impedance correction

2. Calculated Branch Flows



- Large mismatch in a "hanging" transformer
- We know that:
  - Breaker at from side breaker should be open
  - Voltage phasor at the to-terminal is incorrect
  - Tap ratio is incorrect

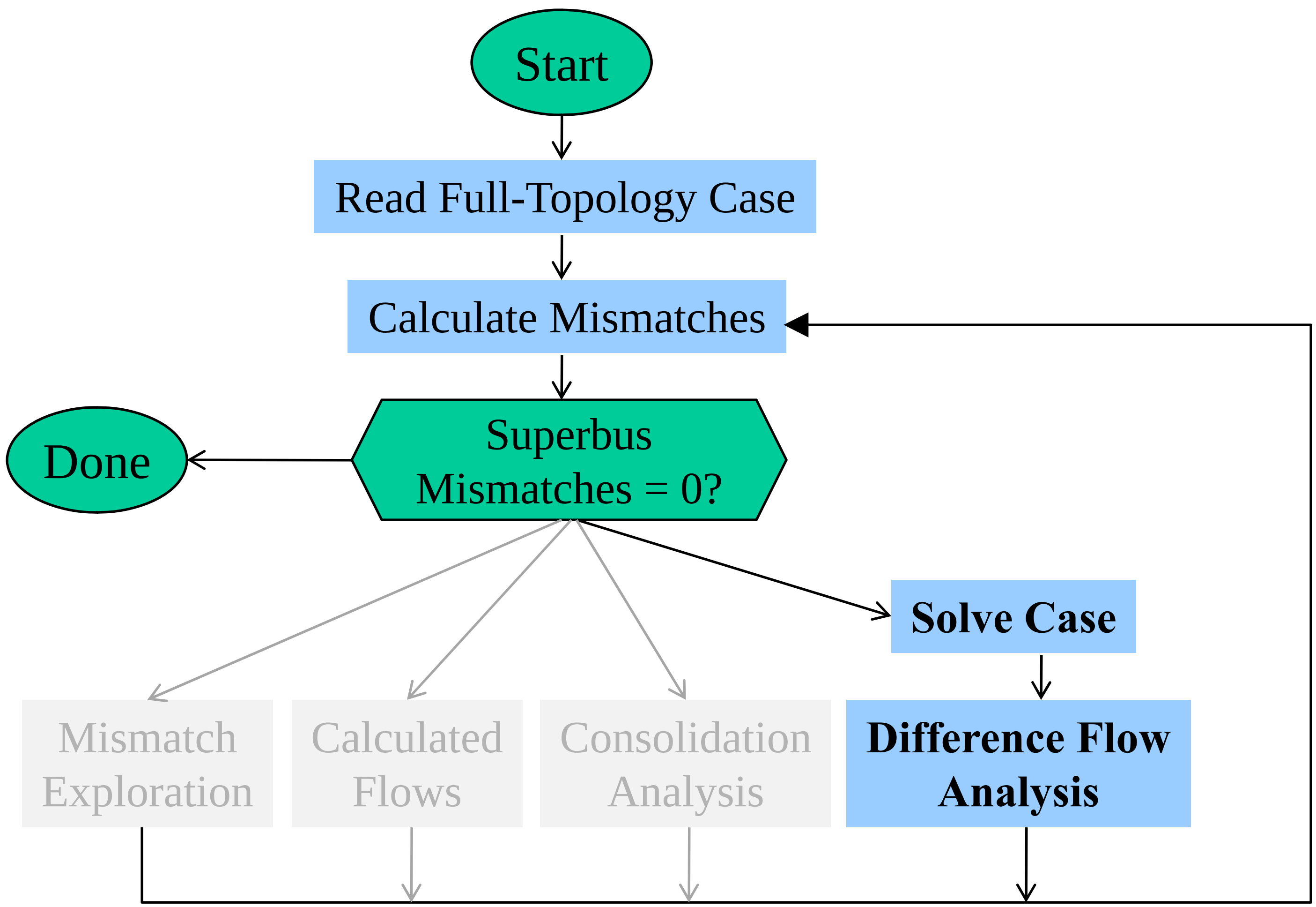
3. Consolidation Verification

- Goal is to determine that all the closed breakers that are set to consolidate are in fact, consolidated.
- Simulator may preserve some breakers
  - For contingencies
  - Model conditions and expressions
  - Interfaces
  - Tie Lines
- For debugging purposes it is convenient to consolidate ALL the closed breakers.

3. Consolidation Verification

- Some Logical Rules:
  - A closed breaker must have the same voltage phasor at its terminals. If not, it should be Open.
  - All the buses in the subnet must have the same nominal KV voltage
  - All the buses in a superbus must have the same voltage phasor.
  - Some EMS system preserve ZBRs for access to measurements:
    - If a ZBR has exactly the same voltage phasor at its terminals, then it must be consolidated.

4. Exploring the Solution



4. Exploring the Solution

- Use difference flows before and after solving the power flow
  - Solve first without device controls
- Generator active power changes
  - Incorrect MW value
  - Slack bus
  - Area interchange settings

4. Exploring the Solution

- Generator reactive power changes
  - Voltage setpoint
  - Remotely regulated buses
  - Options for var sharing, including shunts
  - Reactive Capability curves
- Using device Controls
  - For branches, apply decoupling principle. If voltages (including regulated terminals) don't move, controls should not move.
  - For shunts check control mode, actual MVR.
    - Sometimes, actual MVR is also available from EMS

Conclusions

- Even when starting from scratch, building the model is an interesting learning process.
- Besides providing ITP platform, Simulator offers several special tools to help debug errors when building full-topology models.