ERCOT's Experience in Identifying Parameter and Topology Errors using State Estimator

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ERCOT

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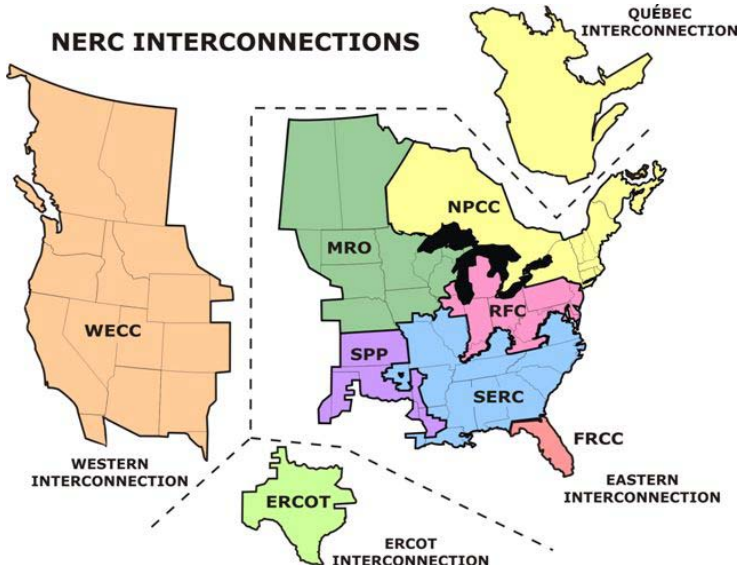
The ERCOT System

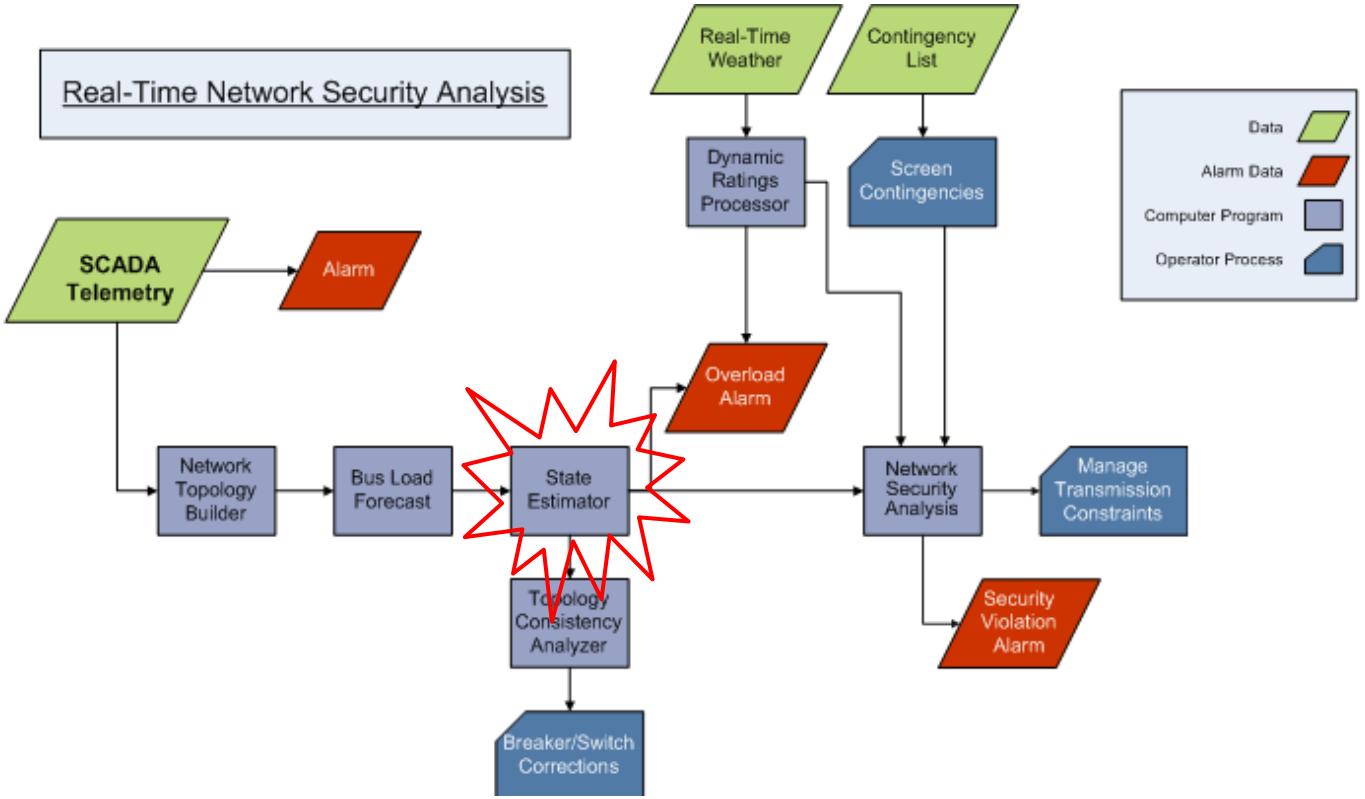
ERCOT Capacity and Demand

- **One of the largest single control areas in US**
  - 40,327 miles of transmission (345kV & 138kV)
  - 85% of Texas load
- **Capacity**
  - 75,755 MW active generation (84,237 MW installed)
  - Current reserve margin ~21.4%
  - Wind capacity: 9,117MW – most in nation
- **All-time Peak Demand**
  - 63,400 MW peak load (July, 2009)
- **Market Size**
  - 6 Million Customer with right to choose
  - $ 34 Billion Market



ERCOT EMS

- Role of the operator is to know the status of the system and make sure that it is always very secure (N-1 Secure)
- Real-Time Network Security Analysis



ERCOT EMS

- AREVA's EMS is used in ERCOT
  - Some functions were developed internally in ERCOT

- Application Functions
  - State Estimation (RTNET) –WLS Method
  - Real-time Contingency Analysis (RTCA)
  - Dynamic Ratings (developed internally)
  - Study Network Analysis (STNET)
  - Voltage Stability Analysis (VSAT)
  - Transient Stability Analysis (TSAT)

SESTATS

- SE Statistics (SESTATS)

  - SESTATS is a tool developed in-house at ERCOT.
  - It monitors SE performance and metrics, and aids in identifying possible topology errors.
  - The metrics captured by SESTATS include:
    - **Topology changes in the power system as seen by SE**

Application: **Realtime Network** Status: **Monitoring**

State Estimator Overall Monitoring

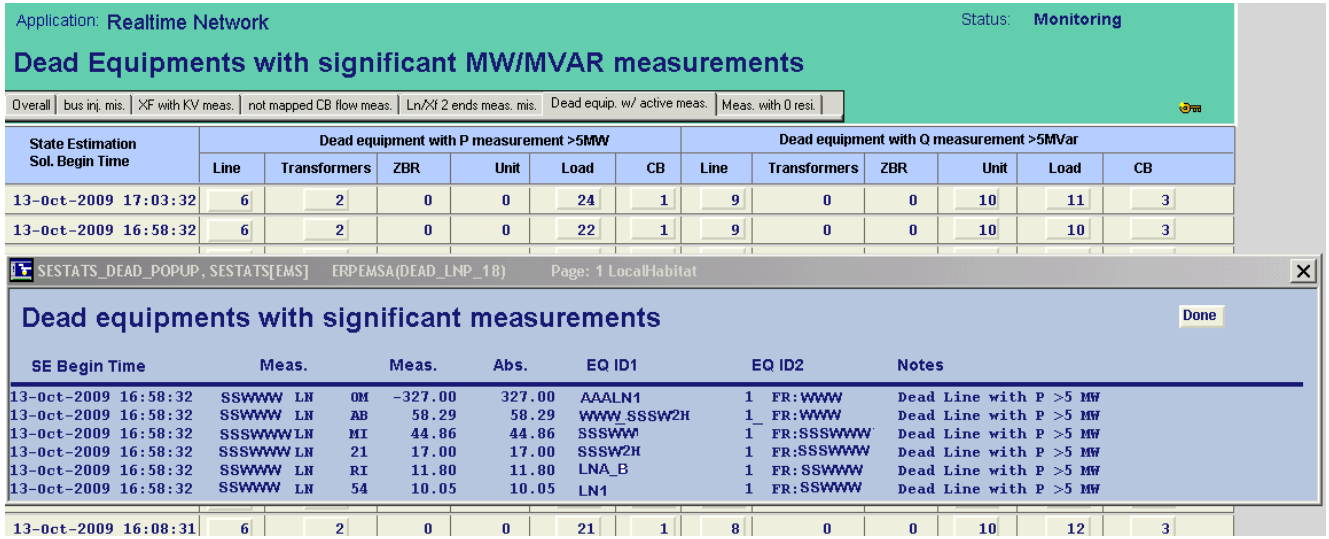
Overall Execution Summary | Detailed Execution Summary | RTNET settings | Hourly Summary | Daily Summary | Monthly Summary | Yearly Summary

SE Execution Begin Time	SE Execution End Time	Captured Time	SE Solution Status	Status Changed	Man. Req.	Gen. (MW)	Load (MW)	Loss (MW)	Loss Ratio
07-Jul-2010 10:05:06	07-Jul-2010 10:05:09	07-Jul-2010 10:05:25	VALID SOLUTION			45379	44556	854	1.92%
07-Jul-2010 10:00:06	07-Jul-2010 10:00:10	07-Jul-2010 10:00:24	VALID SOLUTION			45022	44202	849	1.92%
07-Jul-2010 09:55:06	07-Jul-2010 09:55:14	07-Jul-2010 09:55:27	VALID SOLUTION			44783	43962	856	1.95%
07-Jul-2010 09:50:12	07-Jul-2010 09:50:15	07-Jul-2010 09:50:28	VALID SOLUTION			44665	43842	858	1.96%
07-Jul-2010 09:45:07	07-Jul-2010 09:45:10	07-Jul-2010 09:45:24	VALID SOLUTION			44407	43592	850	1.95%
07-Jul-2010 09:40:06	07-Jul-2010 09:40:09	07-Jul-2010 09:40:22	VALID SOLUTION			44055	43238	851	1.97%
07-Jul-2010 09:35:06	07-Jul-2010 09:35:10	07-Jul-2010 09:35:27	VALID SOLUTION			43730	42923	843	1.96%
07-Jul-2010 09:30:06	07-Jul-2010 09:30:10	07-Jul-2010 09:30:24	VALID SOLUTION			43594	42796	837	1.96%
07-Jul-2010 09:25:06	07-Jul-2010 09:25:10	07-Jul-2010 09:25:23	VALID SOLUTION			43417	42624	829	1.95%
07-Jul-2010 09:20:10	07-Jul-2010 09:20:15	07-Jul-2010 09:20:29	VALID SOLUTION			43308	42522	825	1.94%
07-Jul-2010 09:15:07	07-Jul-2010 09:15:11	07-Jul-2010 09:15:25	VALID SOLUTION			43058	42275	822	1.95%
07-Jul-2010 09:10:05	07-Jul-2010 09:10:13	07-Jul-2010 09:10:32	VALID SOLUTION		✔	42807	42025	822	1.96%
07-Jul-2010 09:06:50	07-Jul-2010 09:06:55	07-Jul-2010 09:07:09	VALID SOLUTION			42607	41823	817	1.95%

Coherency Check Using SESTATS

- Dead Equipment with Active Measurements

SESTATS tracks discrepancies between the equipment status and the analog telemetry values



Application: Realtime Network Status: Monitoring

Dead Equipments with significant MW/MVAR measurements

Overall | bus inj. mis. | XF with KV meas. | not mapped CB flow meas. | Ln/Xf 2 ends meas. mis. | Dead equip. w/ active meas. | Meas. with 0 resi.

State Estimation Sol. Begin Time	Dead equipment with P measurement >5MW						Dead equipment with Q measurement >5MVar					
	Line	Transformers	ZBR	Unit	Load	CB	Line	Transformers	ZBR	Unit	Load	CB
13-Oct-2009 17:03:32	6	2	0	0	24	1	9	0	0	10	11	3
13-Oct-2009 16:58:32	6	2	0	0	22	1	9	0	0	10	10	3

SESTATS_DEAD_POPUP, SESTATS[EMS] ERPEMSA(DEAD_LNP_18) Page: 1 LocalHabitat

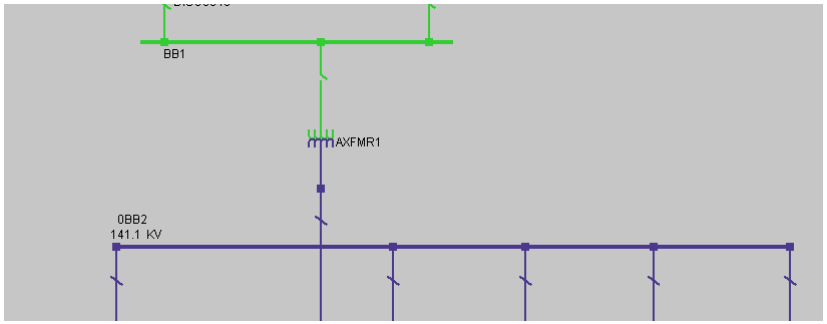
Dead equipments with significant measurements Done

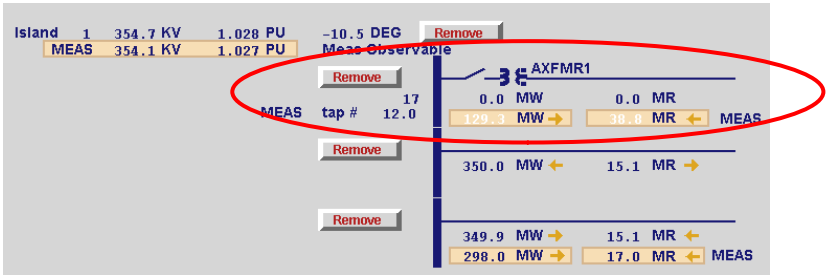
SE Begin Time	Meas.		Meas.	Abs.	EQ ID1	EQ ID2	Notes
13-Oct-2009 16:58:32	SSWWW LN	OM	-327.00	327.00	AAALN1	1 FR:WWW	Dead Line with P >5 MW
13-Oct-2009 16:58:32	SSWWW LN	AB	58.29	58.29	WWW_SSSW2H	1 FR:WWW	Dead Line with P >5 MW
13-Oct-2009 16:58:32	SSSWWW LN	MI	44.86	44.86	SSSWW	1 FR:SSSWWW	Dead Line with P >5 MW
13-Oct-2009 16:58:32	SSSWWW LN	21	17.00	17.00	SSSW2H	1 FR:SSSWWW	Dead Line with P >5 MW
13-Oct-2009 16:58:32	SSWWW LN	RI	11.80	11.80	LNA_B	1 FR:SSWWW	Dead Line with P >5 MW
13-Oct-2009 16:58:32	SSWWW LN	54	10.05	10.05	LN1	1 FR:SSWWW	Dead Line with P >5 MW

13-Oct-2009 16:08:31	6	2	0	0	21	1	8	0	0	10	12	3

Coherency Check Using SESTATS

- Branch Status Error





SESTATS_DEAD_POPUP, SESTATS[EMS] ERPEMSA(DEAD_XFP_365) Page: 1 LocalHabitat

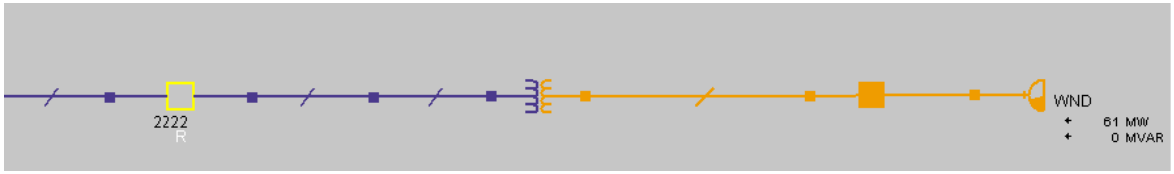
Dead equipments with significant measurements

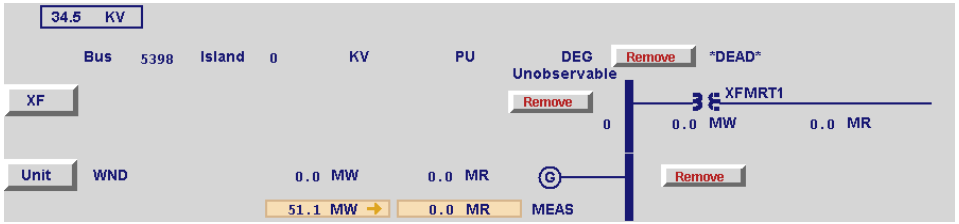
SE Begin Time	Meas.		Meas.	Abs.	EQ ID1	EQ ID2	Notes
16-Nov-2009 14:32:19	SSWWW XFH	AX	129.26	129.26	SSWWW	AXFMR1	Dead XFMR with P >5 MW
16-Nov-2009 14:32:19	SSWWW XFL	AX	-126.18	126.18	SSWWW	AXFMR1	Dead XFMR with P >5 MW

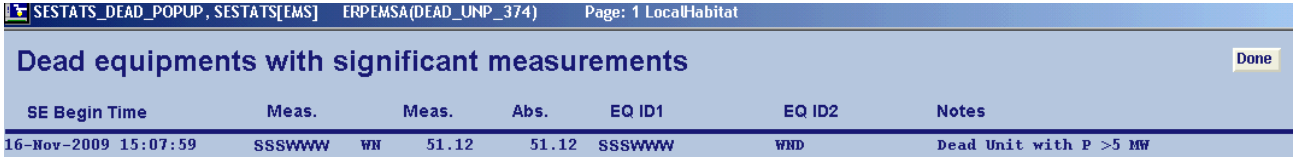
A branch in the SE model can be a transmission line, transformers or zero-impedance branch (ZBR)

Coherency Check Using SESTATS

- Injection Status Error



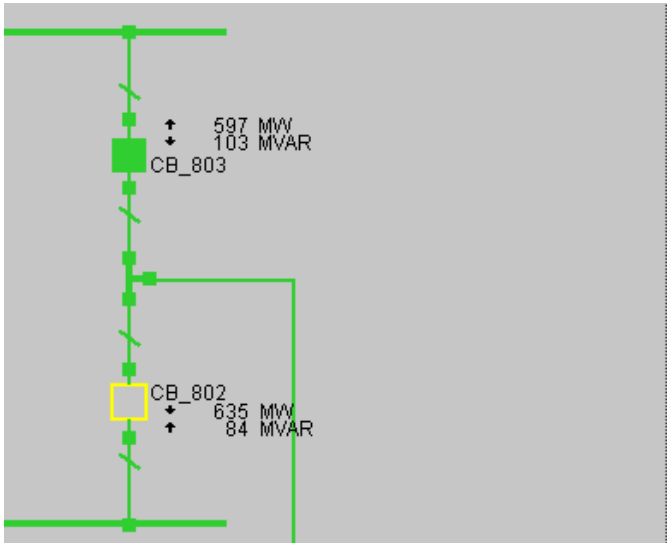




An injection could be a generator or load

Coherency Check Using SESTATS

- CB Status Error



SESTATS_DEAD_POPUP, SESTATS[EMS] ERPEMSA(DEAD_CBP_379) Page: 1 LocalHabitat

Dead equipments with significant measurements

SE Begin Time	Meas.		Meas.	Abs.	EQ ID1	EQ ID2	Notes
16-Nov-2009 15:32:59	SSSWWW	CB	-634.70	634.70	SSSWWW	CB_802	Dead breaker with P >5 MW

SESTATS also detects a discrepancy between CB status and existing analog measurements assigned to the CB

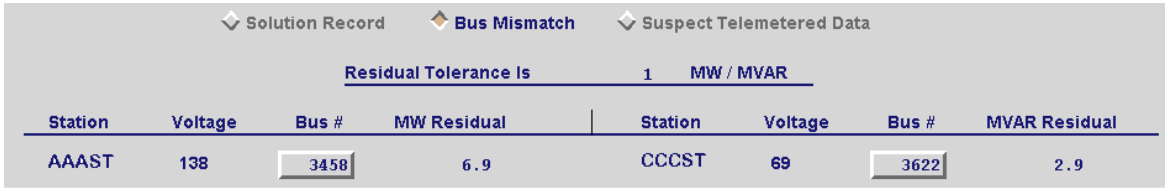
Detecting Topology Errors via SE Results

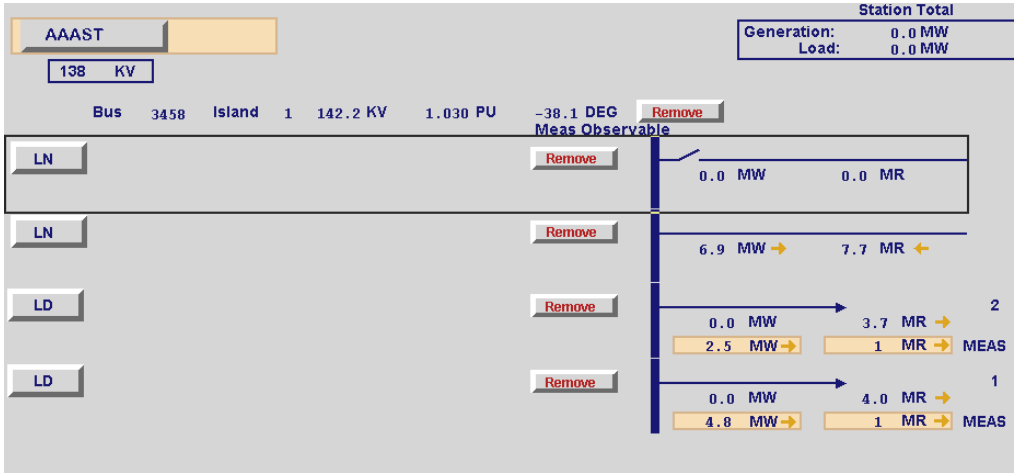
- Limitation of SESTATS
  - Requires available measurements on the elements
  - Cannot identify the complicate errors

- Topology errors lead to measurement residuals
  - Topology errors, like bad telemetry values, usually cause large measurement residuals around the locations of errors in SE results.
  - Bus mismatch is also a good indicator for the existence for topology error.

Detecting Topology Errors via SE Results

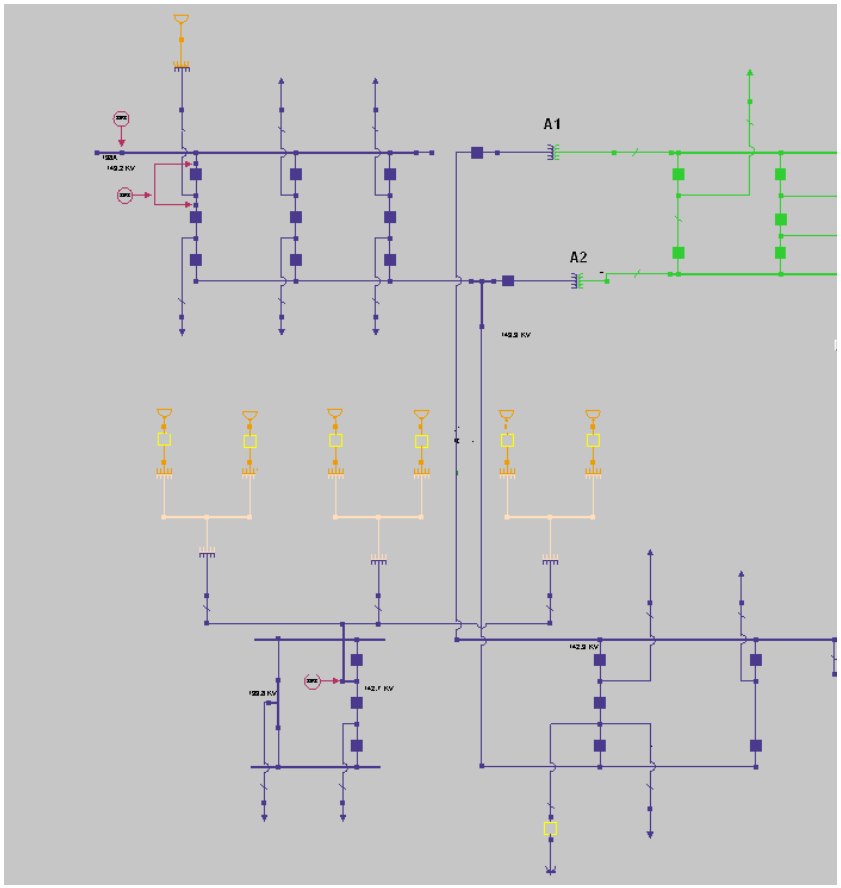
- Detecting and identifying the wrong branch status using SE results

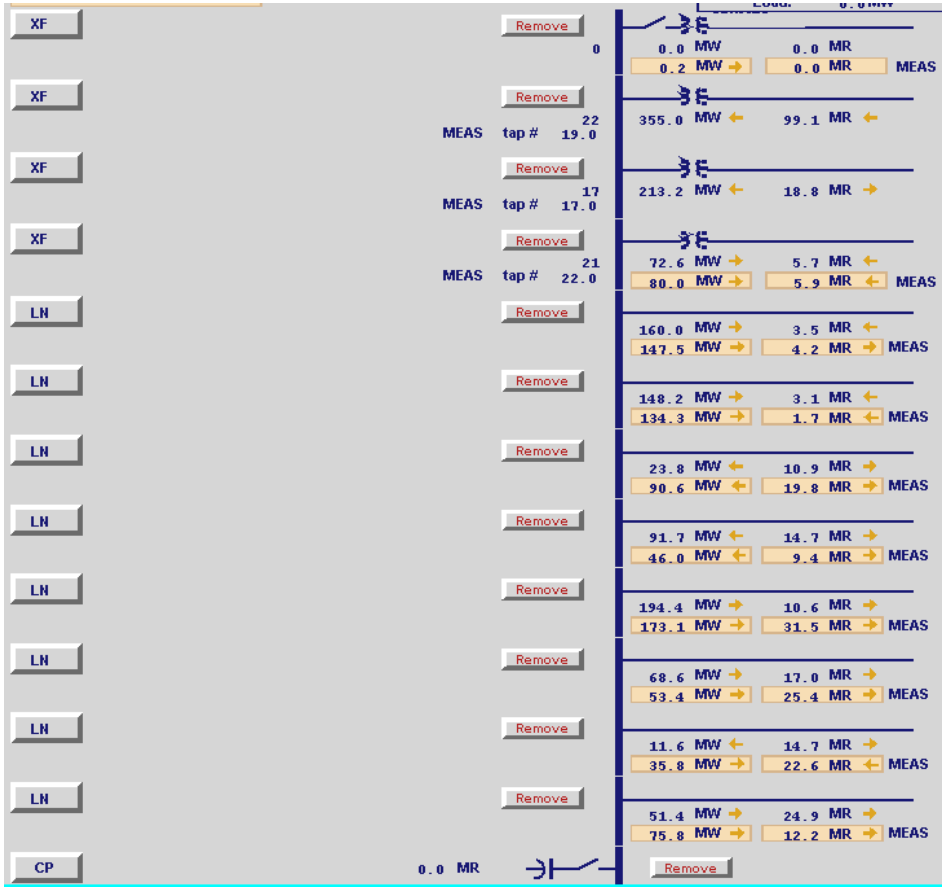




Detecting Topology Errors via SE Results

- Detecting and identifying the bus splitting/merging issue via SE result





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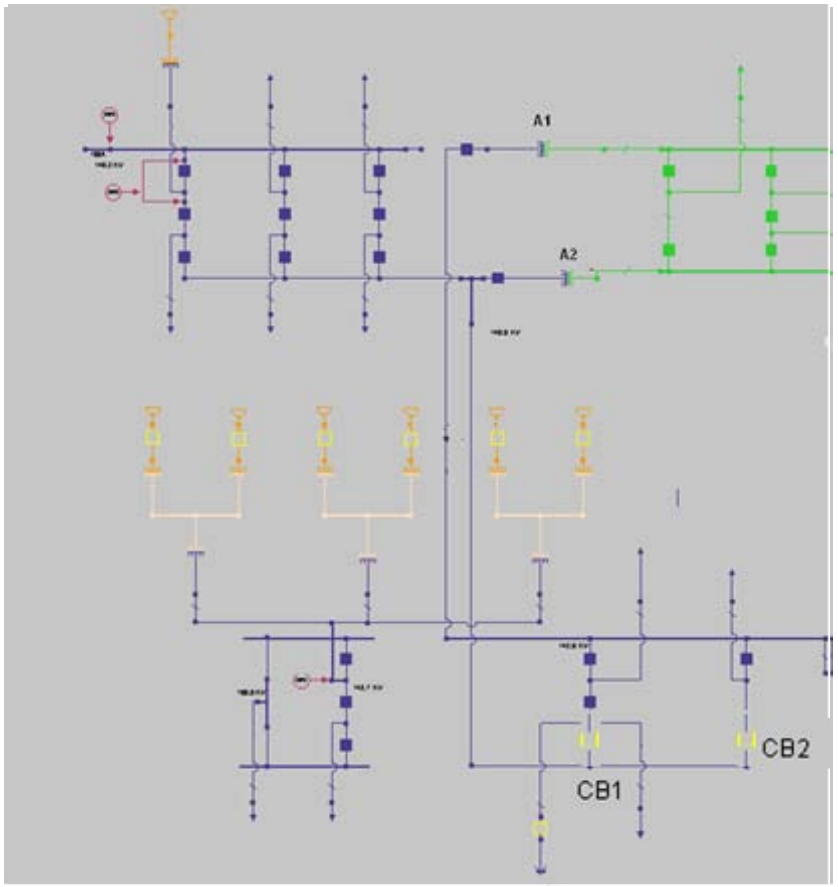

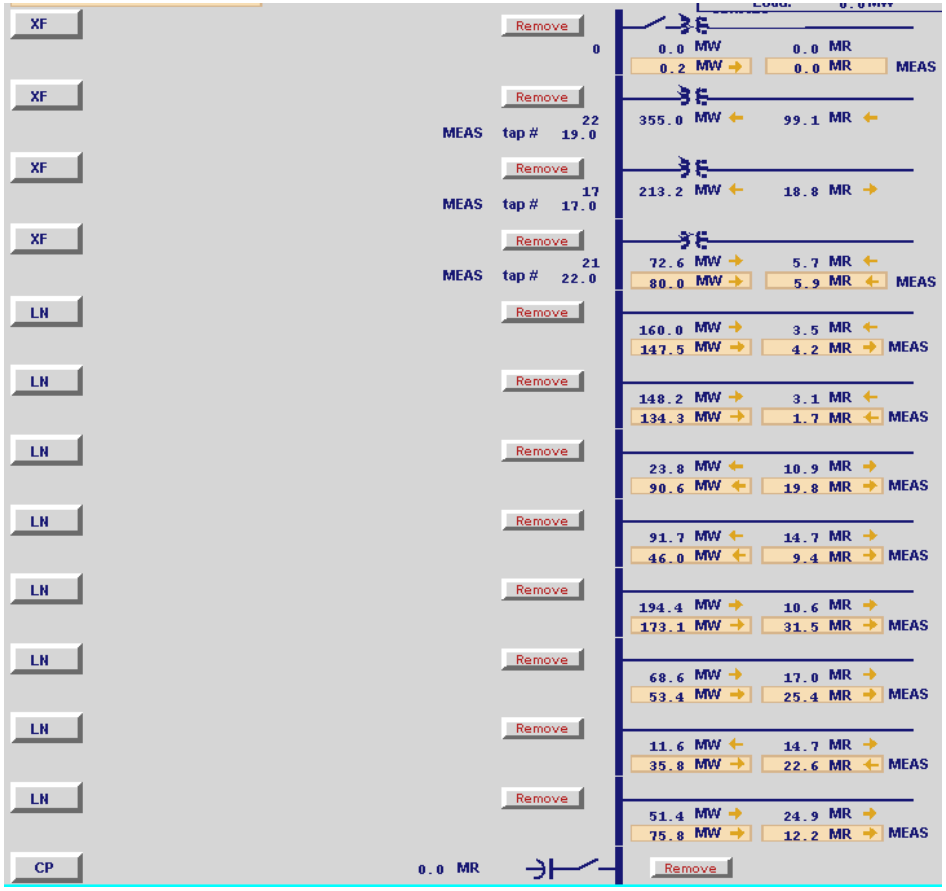

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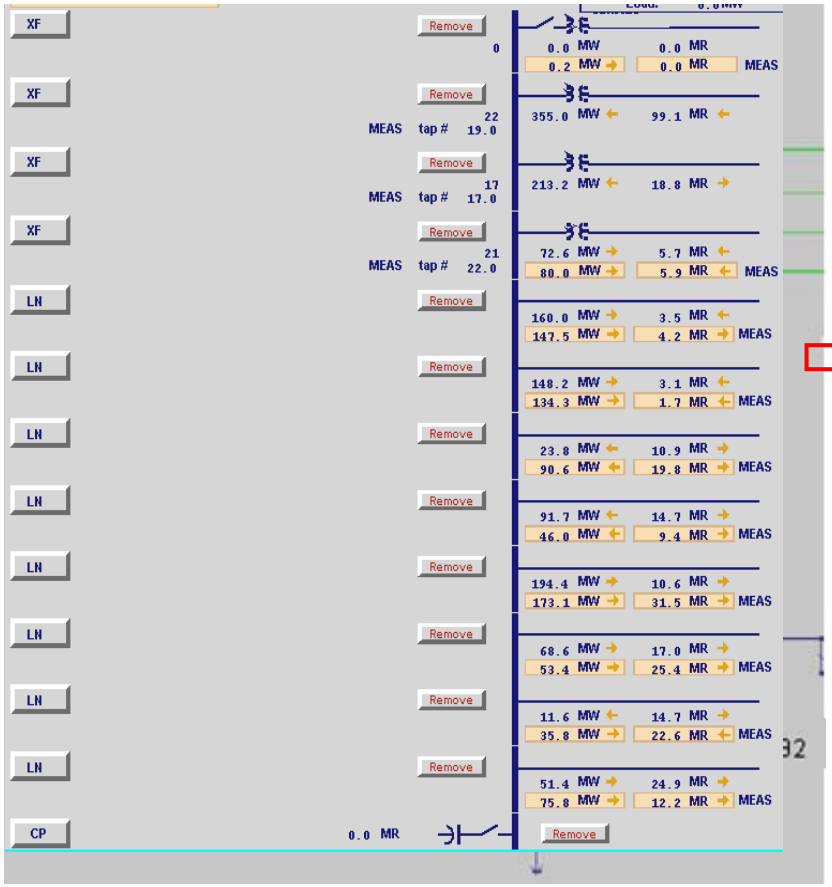

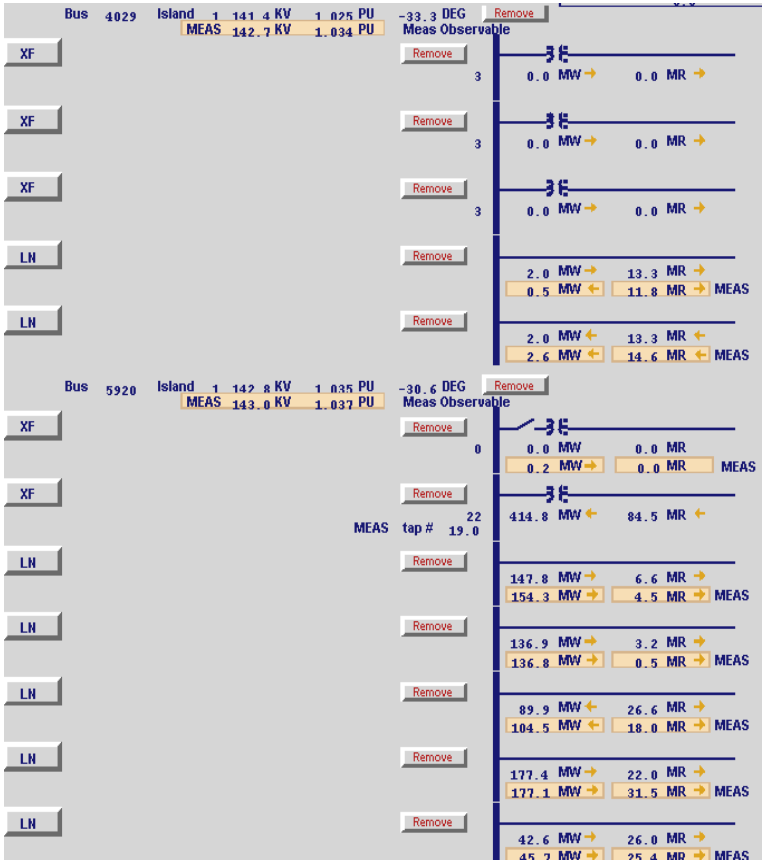

Detecting Topology Errors via SE Results

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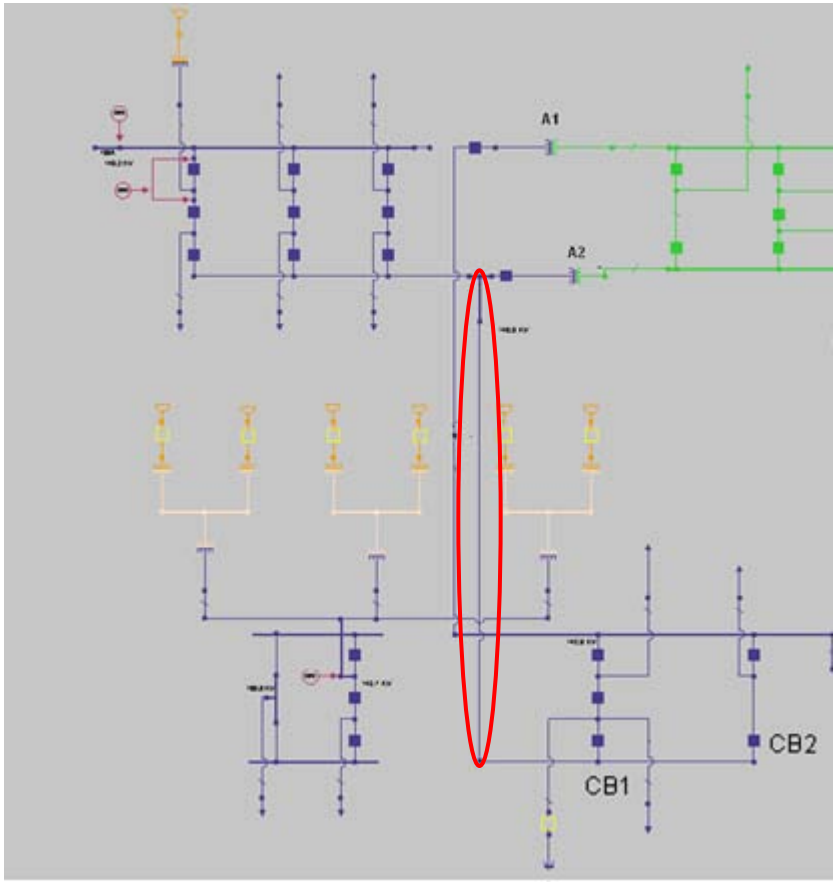
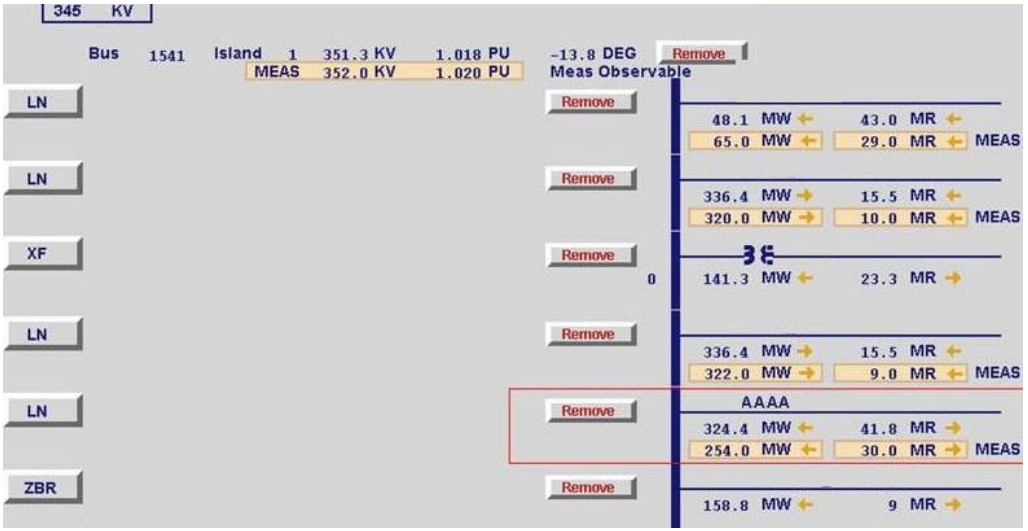
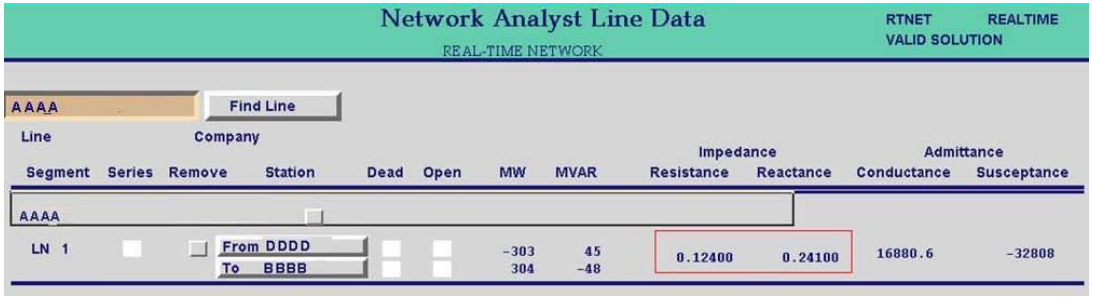


Detecting Parameter Errors via SE Results

- Detecting and identifying the bus the line/transformer impedance





- Detecting and identifying the shunt device parameter

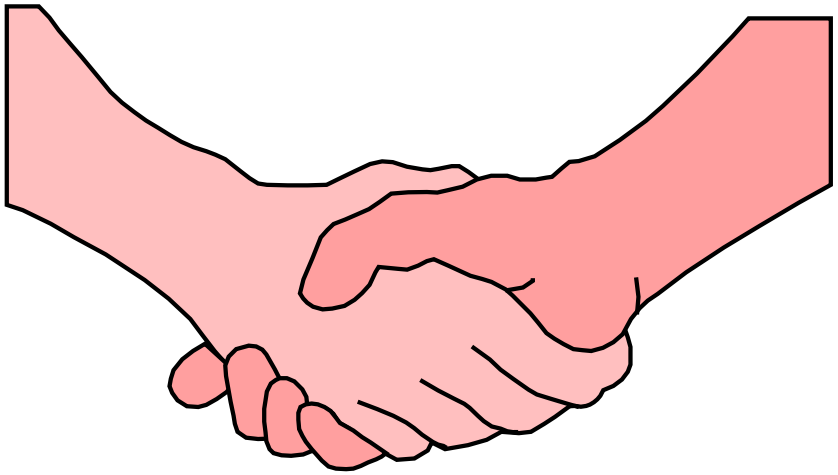
Conclusions

- Cooperation among groups inside ERCOT and between ERCOT and TDSPs is very important to identify and correct the topology and parameter errors.

- Measurement redundancy is important to detect and identify errors. Errors in areas with high measurement redundancy are much easier to detect compared to those with low measurement redundancy.

- By applying KCL rules as pseudo-measurements in SE, the bus mismatches are used as another indicator for possible errors around a specific bus.

- SE monitoring tools can greatly help operations engineers to monitor the SE performance, and check for discrepancies between analog measurements and element status to provide a simple way to detect potential topology errors.



Thank U !!

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