Modeling the New York State Grid in EMTP

Aboutaleb Haddadi (Electric Power Research Institute)
Hossein Hooshyar (New York Power Authority)

EMTP® Summer User Conference
Denver CO
July 2022

www.epri.com

EMTP Model

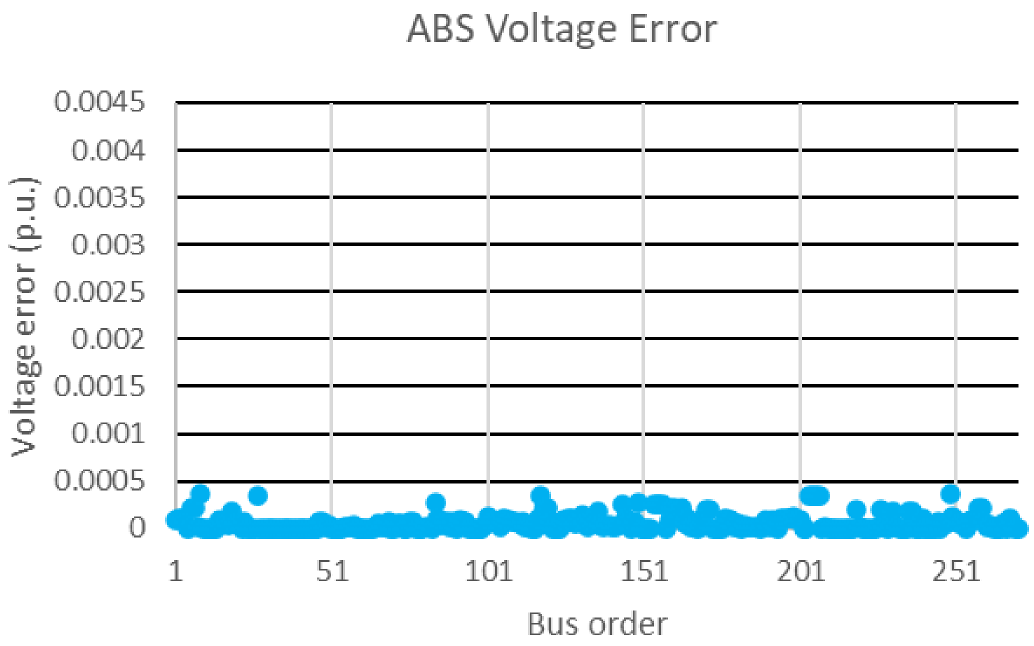
- 271 3-phase buses
- Transmission voltage levels = {765, 345, 230, 115} kVRMSLL
- Generator bus voltage = {25, 24, 22, 20, 18, 17, 16, 13.8} kVRMSLL
- 93 generators
  - Generation = 21 GW
- 139 Z-loads + 5 P-Loads
- 92 two-winding transformers
- 18 three-winding transformers
- 232 lines and cables

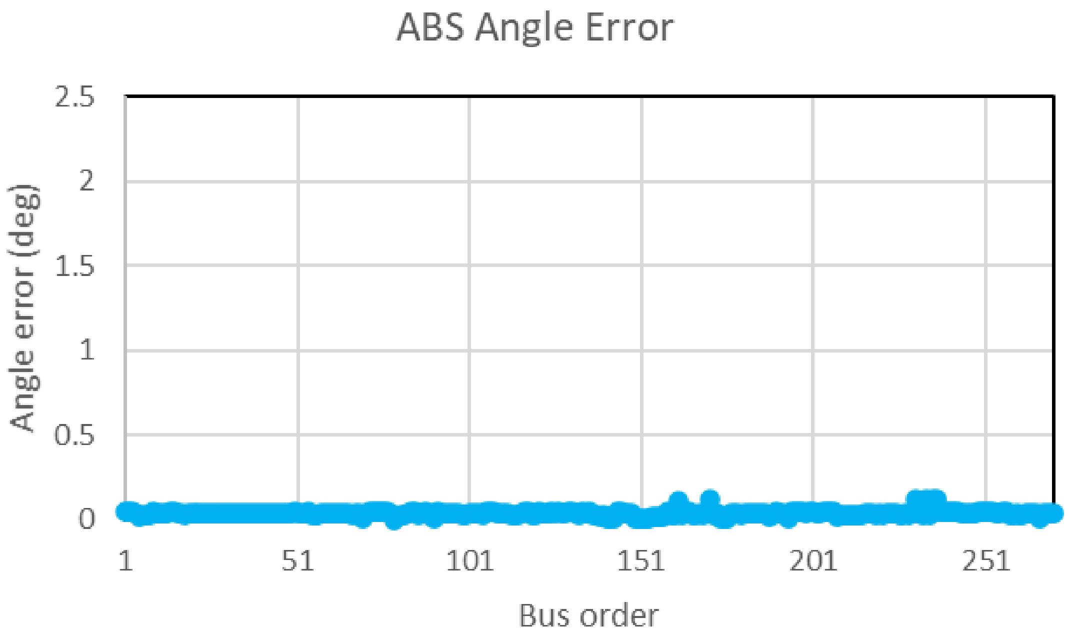
EMTP Model

Summary on network devices		
Name	Number	Number of phases
Transformer: Ideal unit	324	
RLC	1278	
CP line/cable	218	654
Ideal switch	45	
L nonlinear	12	
Synchronous machine	93	279
PQ load with load-flow (LF)	15	
PQ bus	30	
PV bus	88	
Slack bus	1	
Number of load-flow network nodes	1665	
Size of the main system of load-flow equations	5662	
Control system signals	15568	
Total number of network nodes	1845	
Size of the main system of equations	2673	

Model Verification

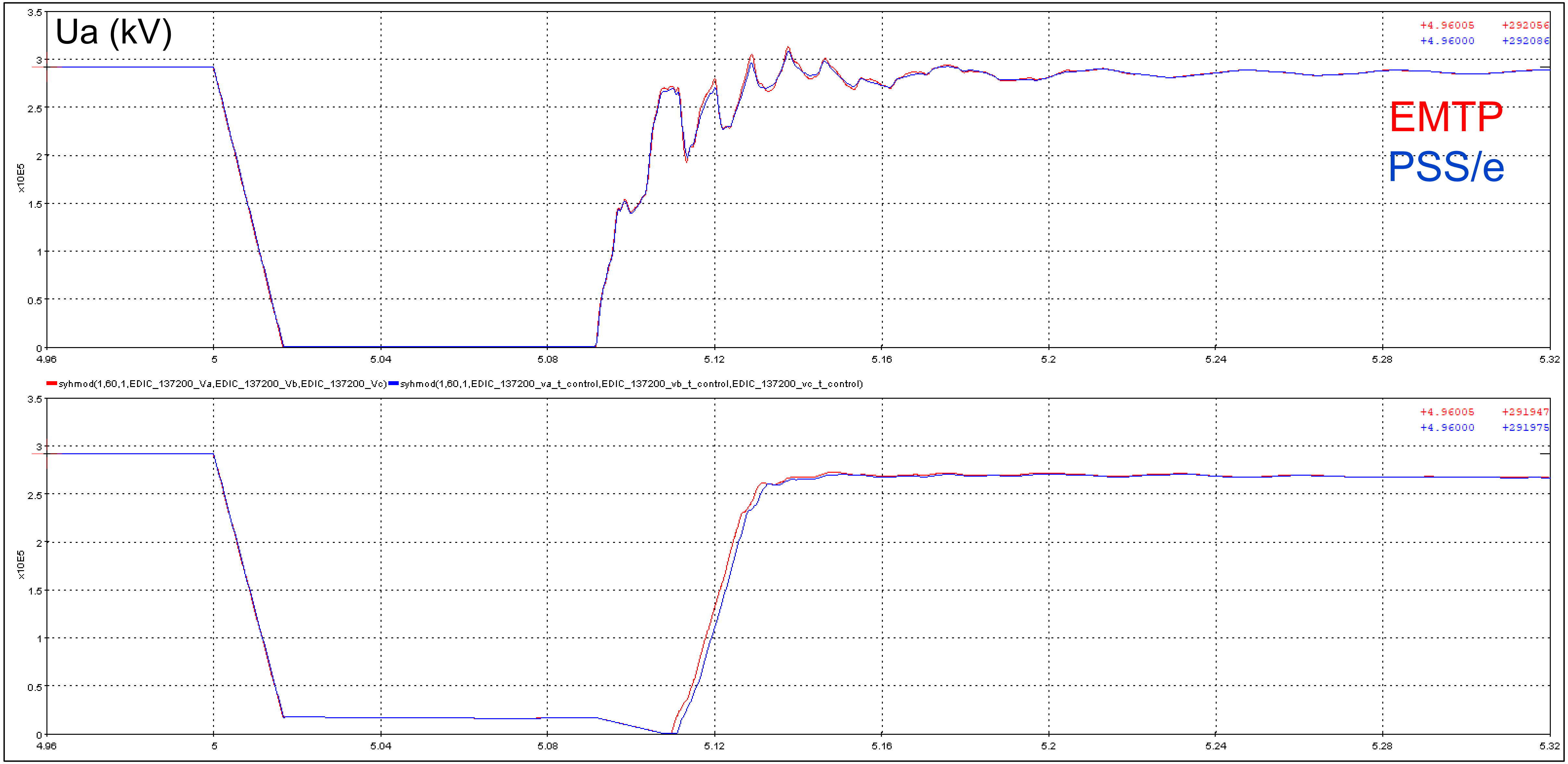
Power flow EMTP vs PSS/e





Model Verification

Dynamics EMTP vs PSS/e



Case Study: Line Modeling

Transmission Corridor

- The system has a corridor with x number of mutually coupled lines.
  - RTDS t-line tool limits the number of conductor with a maximum number 12, including the ground wires.
  - EMTP can model more than 60 conductors in parallel.
- **Objective**: Study error in calculated line parameters due to limited mutual line modeling capability in RTDS.
- **Approach**: Compare line parameters with:
  - Limited representation of mutual coupling
  - Full representation of mutual coupling (accurate)

Demonstrating Results

Positive Sequence RX Comparison (Ω/mile)		
Parameter	Limited mutual coupling model	Full mutual coupling model
R (Ω/mile)	6.6315068E-02	6.6400137E-02
XL (Ω/mile)	4.6931507E-01	4.6940315E-01
XC (Ω/mile)	1.2092219E+05	1.2089610E+05
Zero Sequence RX Comparison (Ω/mile)		
R (Ω/mile)	5.9863014E-01	4.5616438E-01
XL (Ω/mile)	2.0835616E+00	1.7260274E+00
XC (Ω/mile)	4.2416438E+06	4.2280685E+06

31% error

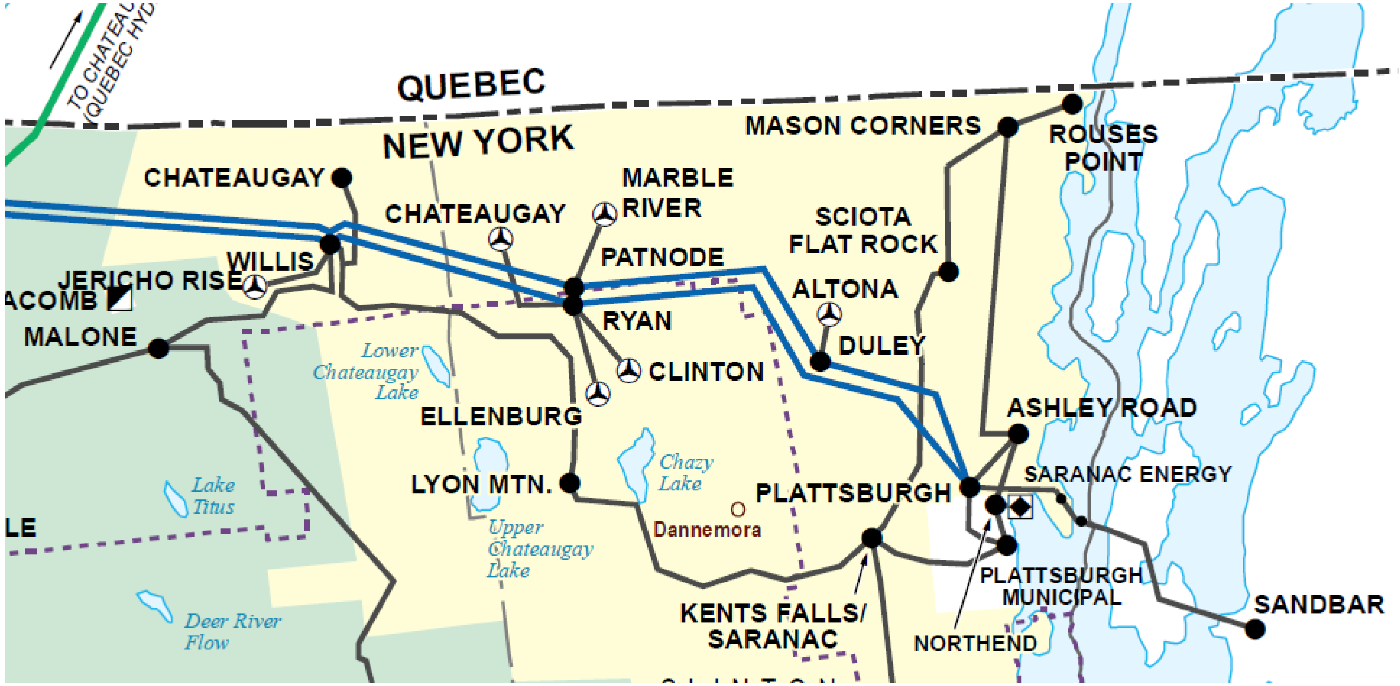
21% error

EPRI

Impact of IBRs on System Protection - NYPA Case Study

Impact of IBRs on NYPA System Protection

- **Objective**: Review protection schemes and identify potential protection misoperation cases due to wind parks of the NYS grid.
- **Approach**:
  - Verify the EMTP model against NYPA P&C model
  - Model protection schemes
  - Model wind parks
  - Perform fault analysis & protection system performance



Test system: A portion of the 230/115 kV NYS grid with high concentration of wind parks.

EMTP Model Verification

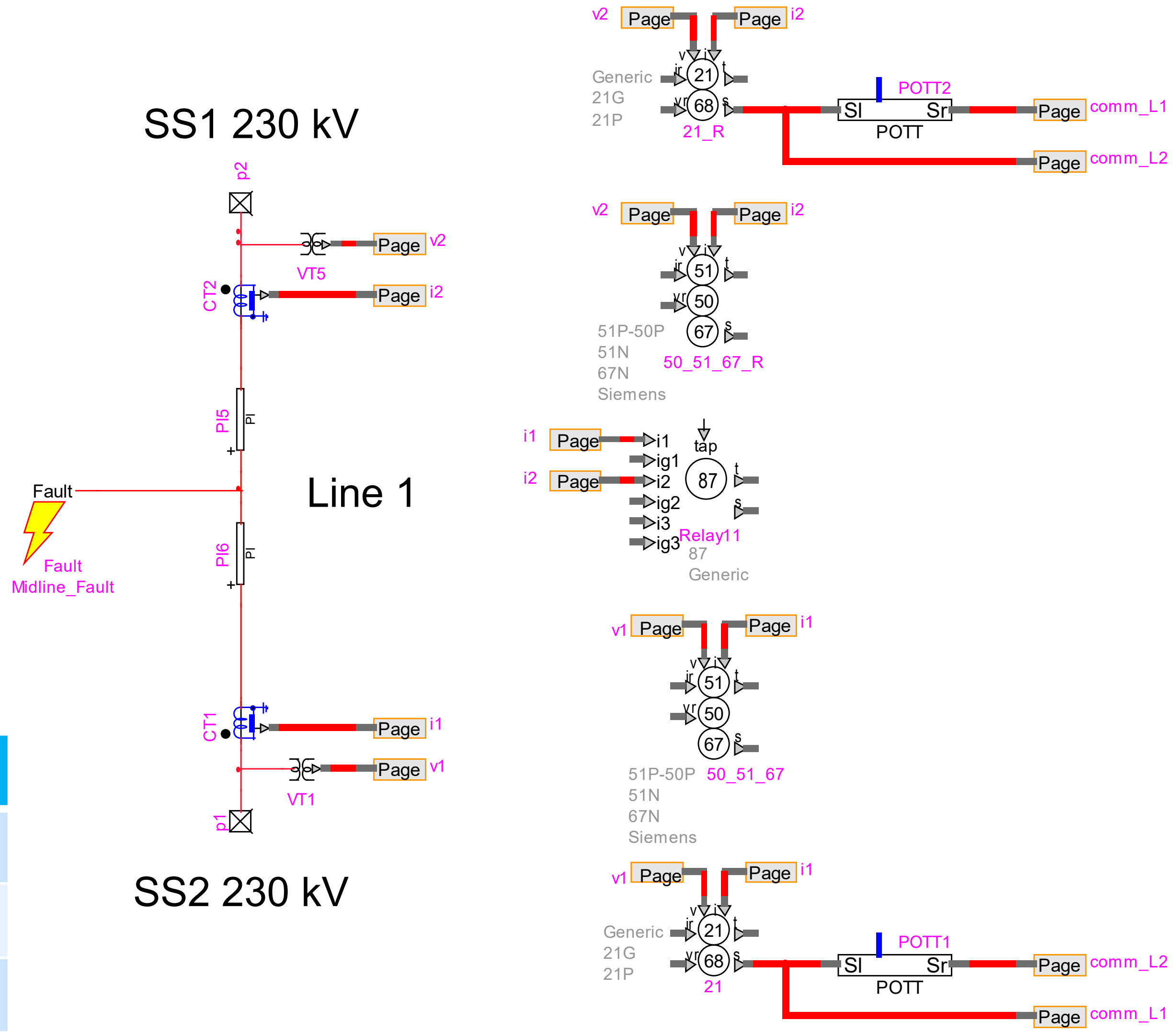
- The EMTP model was cross-examined against NYPA P&C model within ASPEN.
- The results show an acceptable match.

	Model	V1		V2		V0		I1		I2		I0	
		kV	(°)	kV	(°)	kV	(°)	A	(°)	A	(°)	A	(°)
Wind park 1	ASPEN	101.7	11.4	35.2	-163.4	47.5	-168.7	299.8	2.0	0.0	106.6	0.0	0.0
	EMTP	102.6	8.5	36.6	-167.0	47.0	-169.5	322.5	-3.1	21.6	-1.0	0.0	0.0
Wind park 2	ASPEN	114.7	11.8	22.0	-163.4	29.7	-172.6	313.1	8.9	0.0	106.6	0.0	0.0
	EMTP	113.6	12.1	22.7	-168.0	22.8	-167.5	325.5	11.5	13.0	23.6	0.0	0.0
Wind park 3	ASPEN	114.7	11.8	22.0	-163.4	29.7	-172.6	295.6	10.1	0.0	106.6	0.0	0.0
	EMTP	113.6	12.1	22.7	-168.0	22.8	-167.5	308.7	12.8	12.4	25.0	0.0	0.0

Relay Models

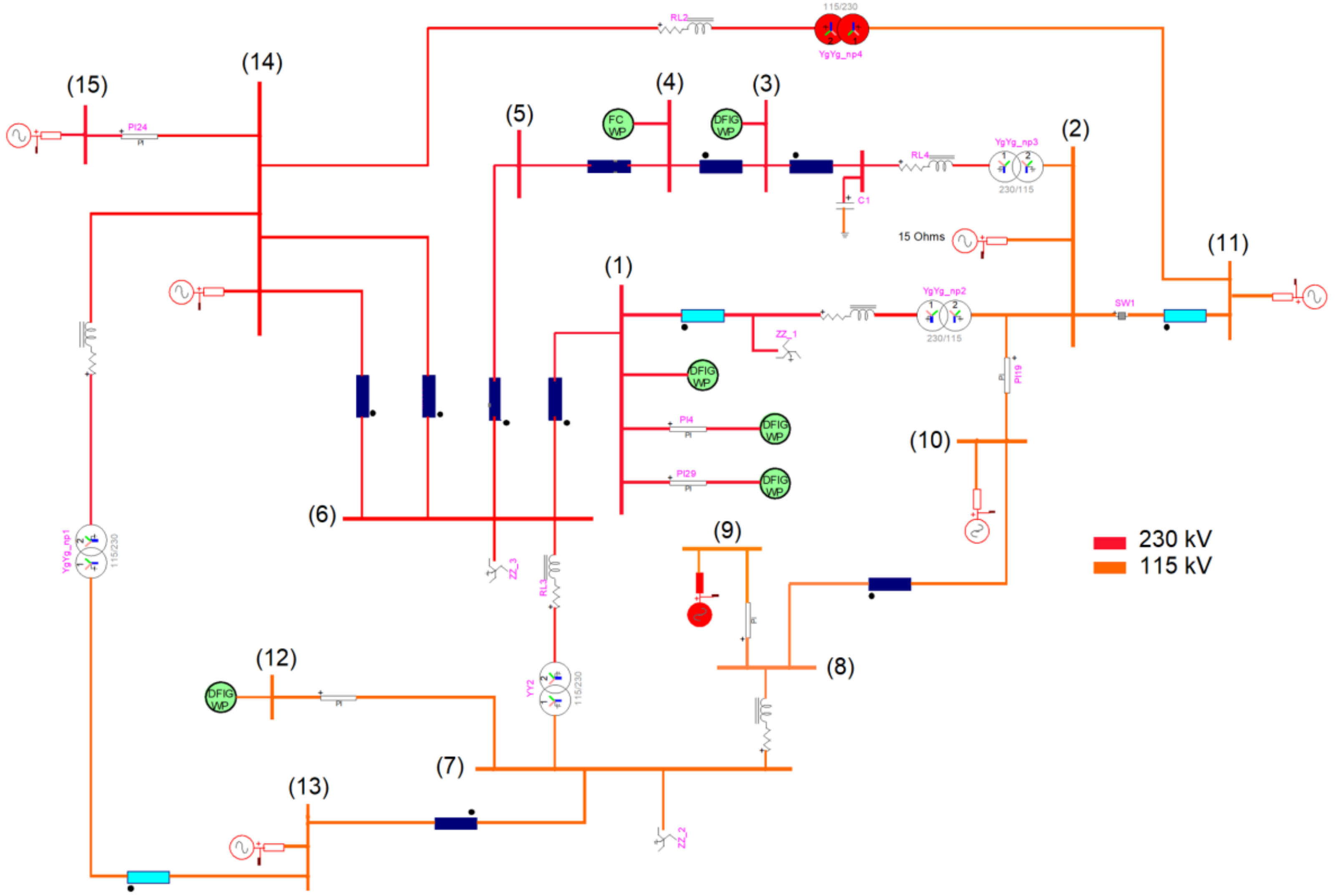
- Line protective relays close to IBRs were modeled.
- Relay makes & setting were obtained from NYPA P&C.
- EMTP Protection Library relay models were used.

Relay Identifier	Protection Functions
R1	21, 85-21 (POTT), 50P, 51P, 51N, 67N, 87L
R2	21, 85-21 (POTT), 50P, 51P, 51N, 67N, 87L
R3	21, 50G, 51G
R4	21, 50G, 51G

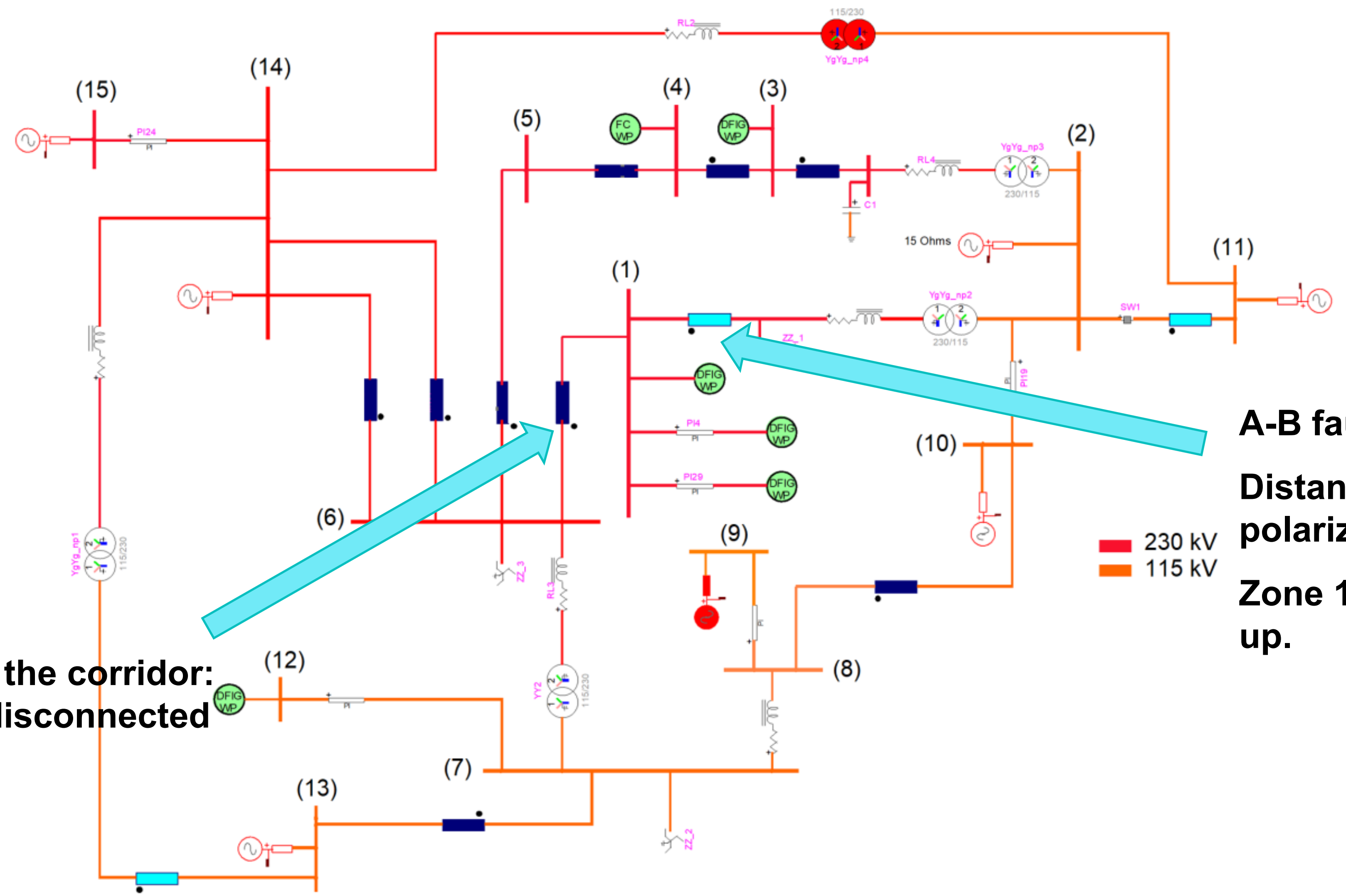


Wind Park Model

- Manufacturer models were not available.
- Generic EMTP models were used and parameterized to match available short circuit data.



Relay Performance Case Study



A-B fault on 66% of the line.

Distance relay cross-polarized mho element.

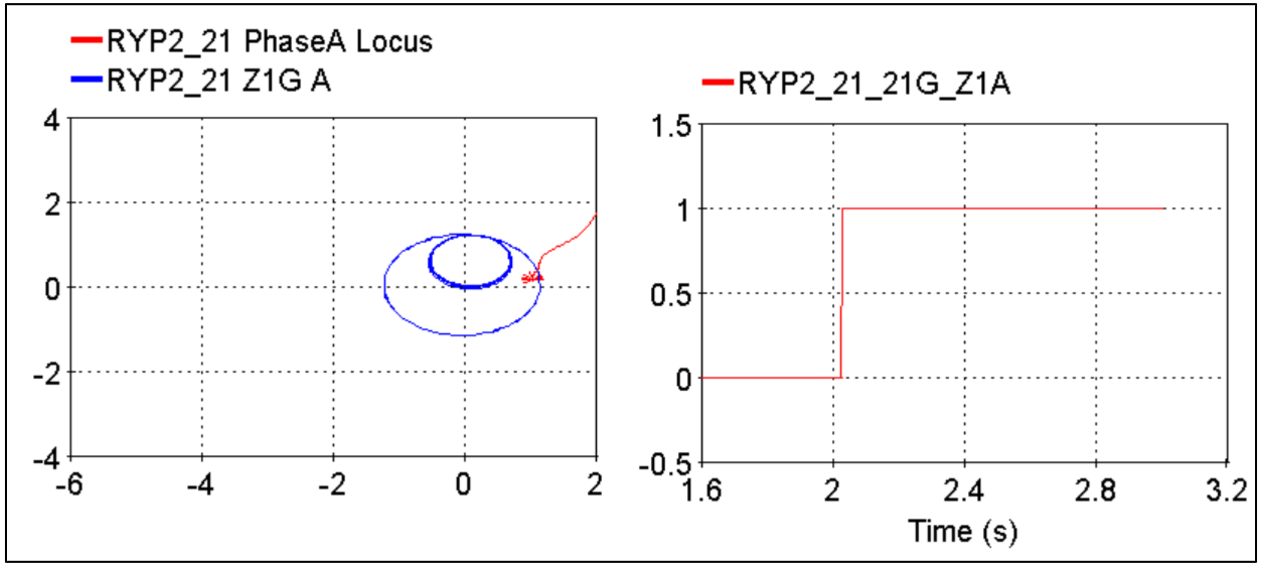
Zone 1 element should pick up.

Two scenarios for the corridor:
(i) connected (ii) disconnected

Demonstrating Results

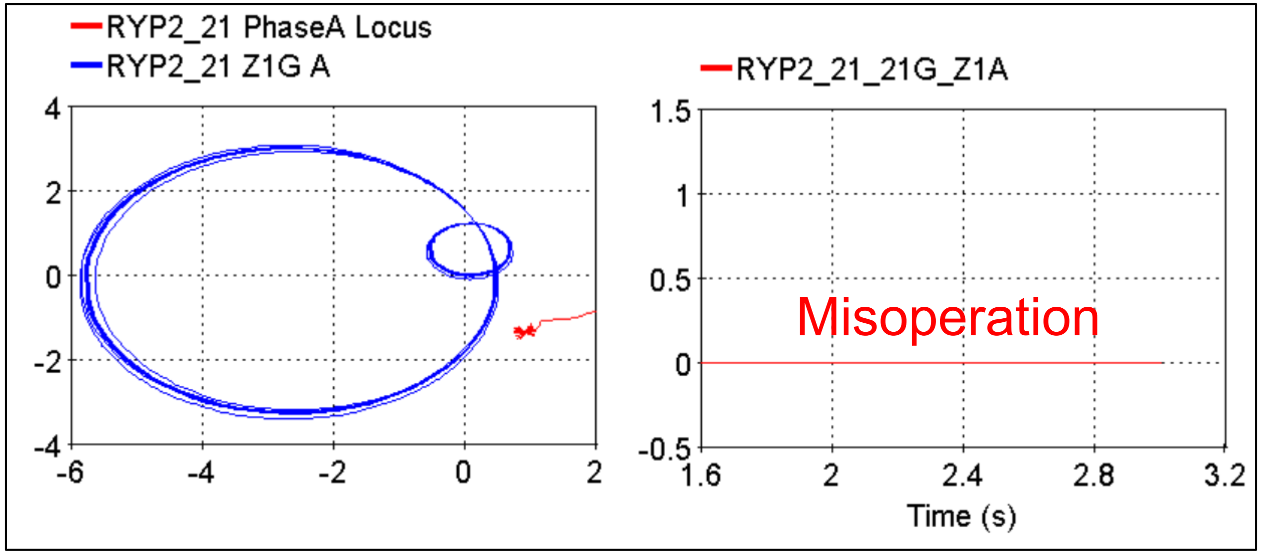
Response of distance mho zone 1 under fault AG7, scenario (i):

- Distance zone 1 successfully picks up considering the additional resistive reach due to dynamic expansion of mho zone.



Response of distance mho zone 1 under fault AG7, scenario (ii):

- Distance zone 1 fails to pick up due to changed dynamic expansion characteristics under wind parks.



Summary of Findings

Protection function	Identified Misoperation	Cause
50P	The element fails to pick up a fault within its zone of protection.	The reason is the low amplitude of fault current contribution of a nearby Type-IV WP.
51N	The element fails to pick up a ground fault within its zone of protection.	The cause is the low level of zero sequence fault current due to a nearby WP using a transformer with a high-side, Delta winding.
67N	The zero-sequence fault current is not sufficient to operate the element; the element fails to identify the direction of a forward ground fault.	The cause is the low level of zero sequence fault current due to a nearby WP using a transformer with a high-side, Delta winding.
POTT	The scheme does not pick up a fault on the protected line.	The misoperation is caused by a malfunctioning neutral polarized directional element due to which the impacted relay fails to send a permissive trip signal to the corresponding remote relay.
21	The element fails to detect a high resistance ground fault on the protected line.	The cause is the reduced resistive coverage of the mho element due to changed dynamic mho distance characteristic because of nearby Type-III WPs.