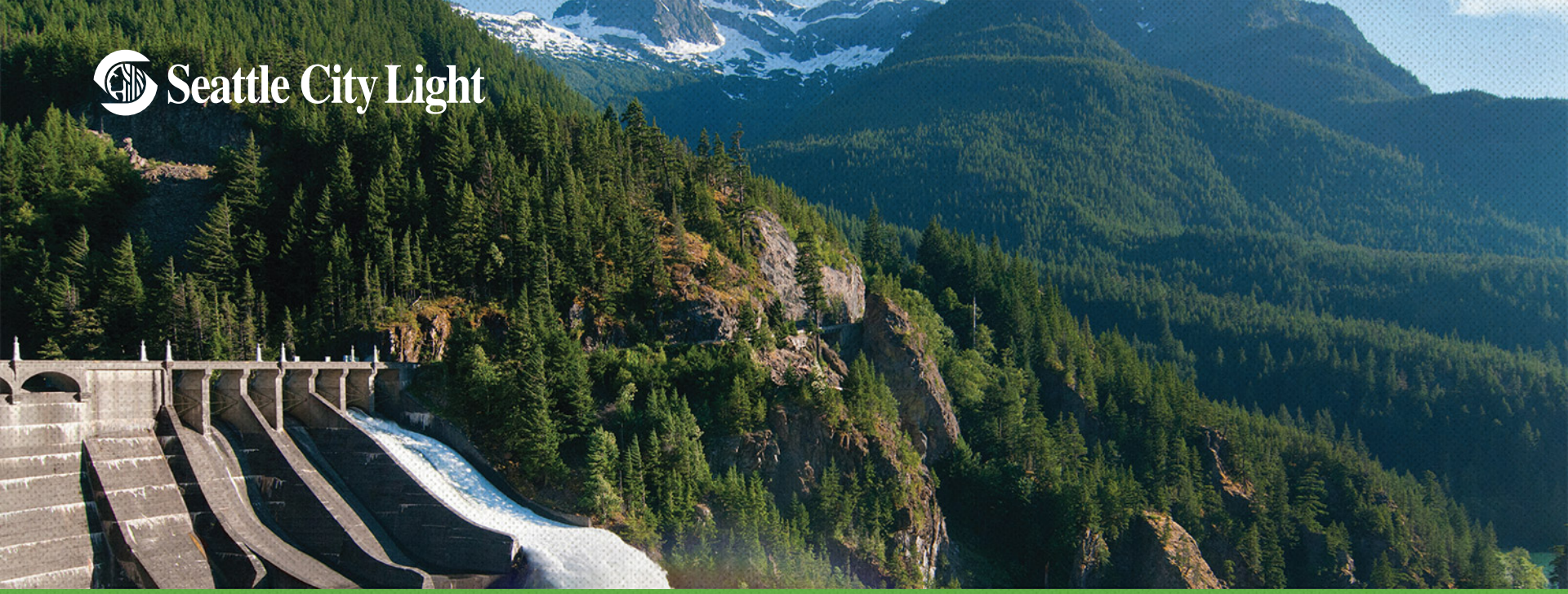


IMPLEMENTATION OF DISTRELAY

Megan Cammarano | June 7, 2017

THE NATION'S GREENEST UTILITY
SINCE 1905
SEATTLE CITY LIGHT

SEATTLE CITY LIGHT SYSTEM OVERVIEW

- Service area population: ~800,000
- ~1,900 MVA system load peak
- 15 major substations
- 50 transmission lines (656 miles)
- 93 distance relays

Seattle City Light

DISTRELAY OPERATION

TRANSFER TRIP CONFIGURATIONS

- No Transfer Trip
- Permissive Overreaching Transfer Trip (POTT)
- Direct Underreaching Transfer Trip (DUTT)
- Permissive Underreaching Transfer Trip (PUTT)
- Directional Comparison Blocking
- Differential (87L)
  - Approximated as a POTT scheme without communication delay on far end

DISTANCE RELAY OPERATION W/O TRANSFER TRIP

Under pre-fault conditions, both breakers are closed.

DISTANCE RELAY OPERATION W/O TRANSFER TRIP

A fault is applied to the system at 10% of the line.

DISTANCE RELAY OPERATION W/O TRANSFER TRIP

Zone 1 protection covers ~80% of the line and will function with no delay. The relay located at bus 1 sees the fault and triggers the breaker to operate.

DISTANCE RELAY OPERATION W/O TRANSFER TRIP

Zone 2 covers ~120% and will function with a delay of ~20 cycles. The relay located at bus 2 sees the fault and triggers the breaker to operate after a 20 cycle delay. The fault is now isolated.

EXAMPLE W/O TRANSFER TRIP

- Contingency: Three-phase fault applied at 1 second on Shoreline to Bothell Ckt 2 at 10% of the line

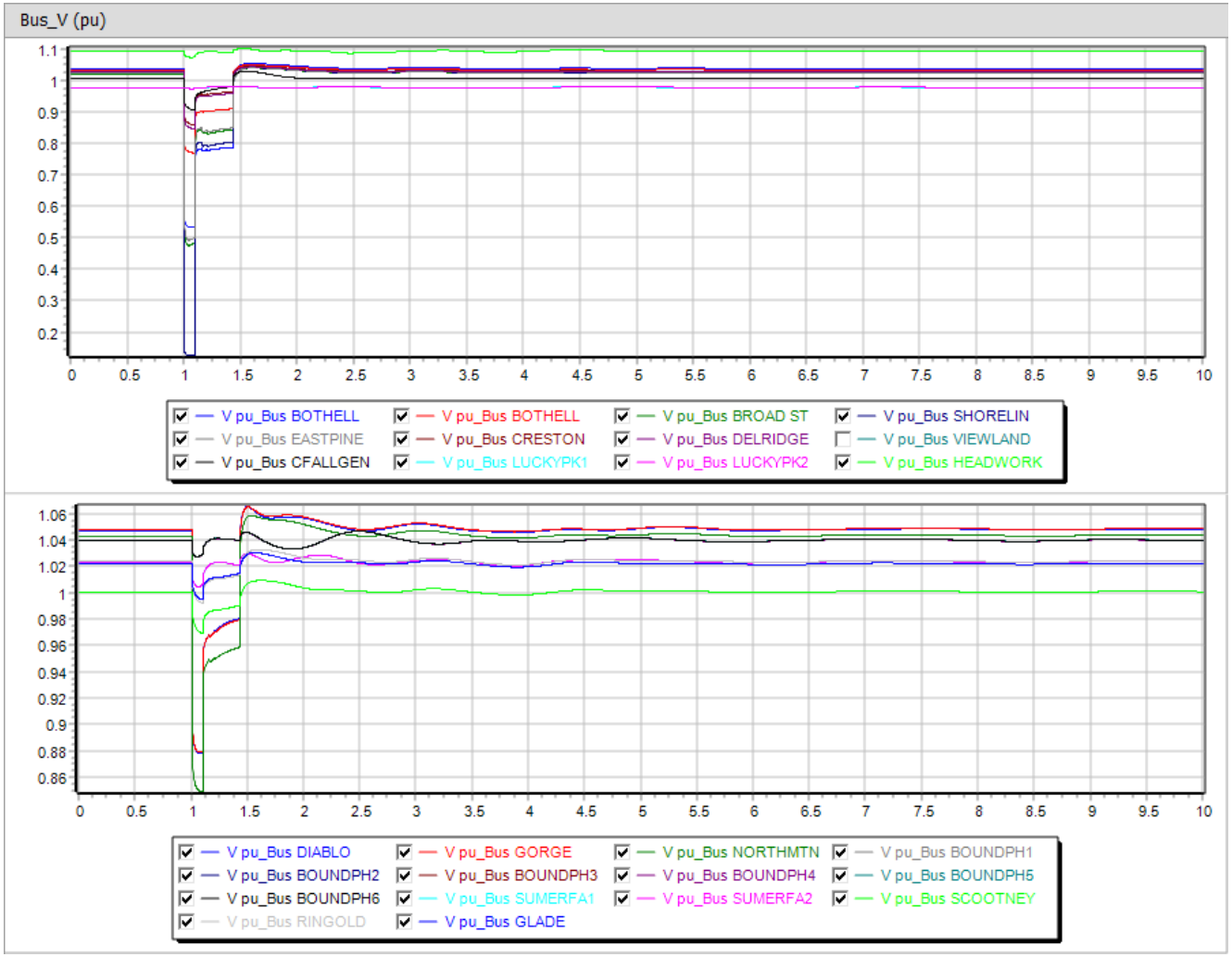
	Object Pretty	Time (Cycles)	Time (Seconds)	Object	Description
1	Line BOTHELL TO SHORELIN CKT 2	60.0	1.000000	Branch '46401' '46443' '2'	FAULT 10 3PB SOLID

SIMULATION RESULTS CORRECT!
EXAMPLE W/O TRANSFER TRIP

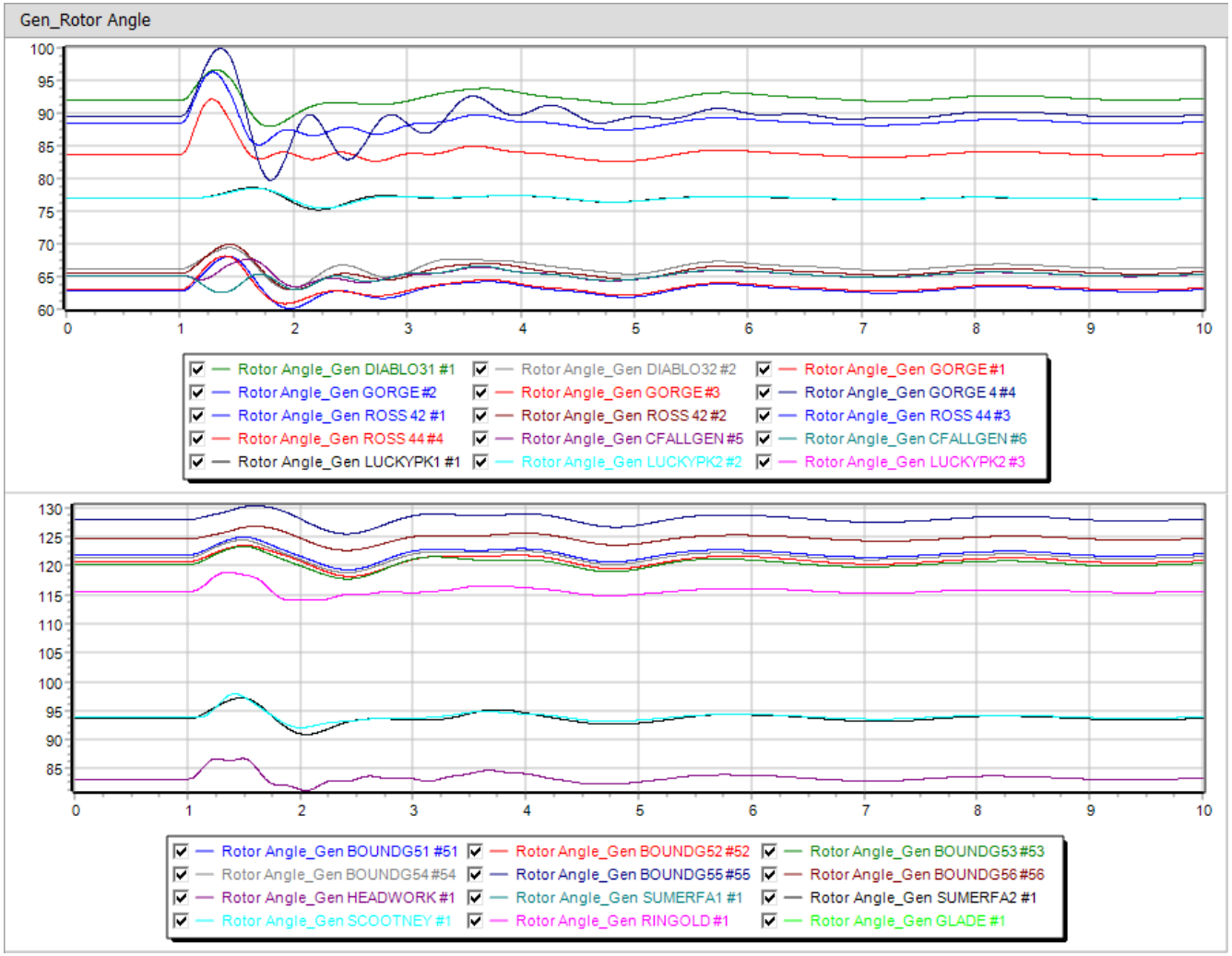
Transient Stability Started at 5/18/2017 3:06:00 PM
Time: 1.000 Event: Apply Solid Fault (3PB) Line BOTHELL TO SHORELIN CKT 2
Time: 1.000 Event: Relay A Zone 1 tripped Line BOTHELL TO SHORELIN CKT 2
Time: 1.100 Event: Line Relay DISTRELAYRF,Direct Trip action: Open From End Line BOTHELL TO SHORELIN CKT 2
Time: 1.333 Event: Relay A Zone 2 tripped Line BOTHELL TO SHORELIN CKT 2
Time: 1.433 Event: Line Relay DISTRELAYRF,Direct Trip action: Open To End (Both ends now Open) Line BOTHELL TO SHORELIN CKT 2
Transient Stability Solution Finished at 5/18/2017 3:11:01 PM

SIMULATION RESULTS CORRECT!

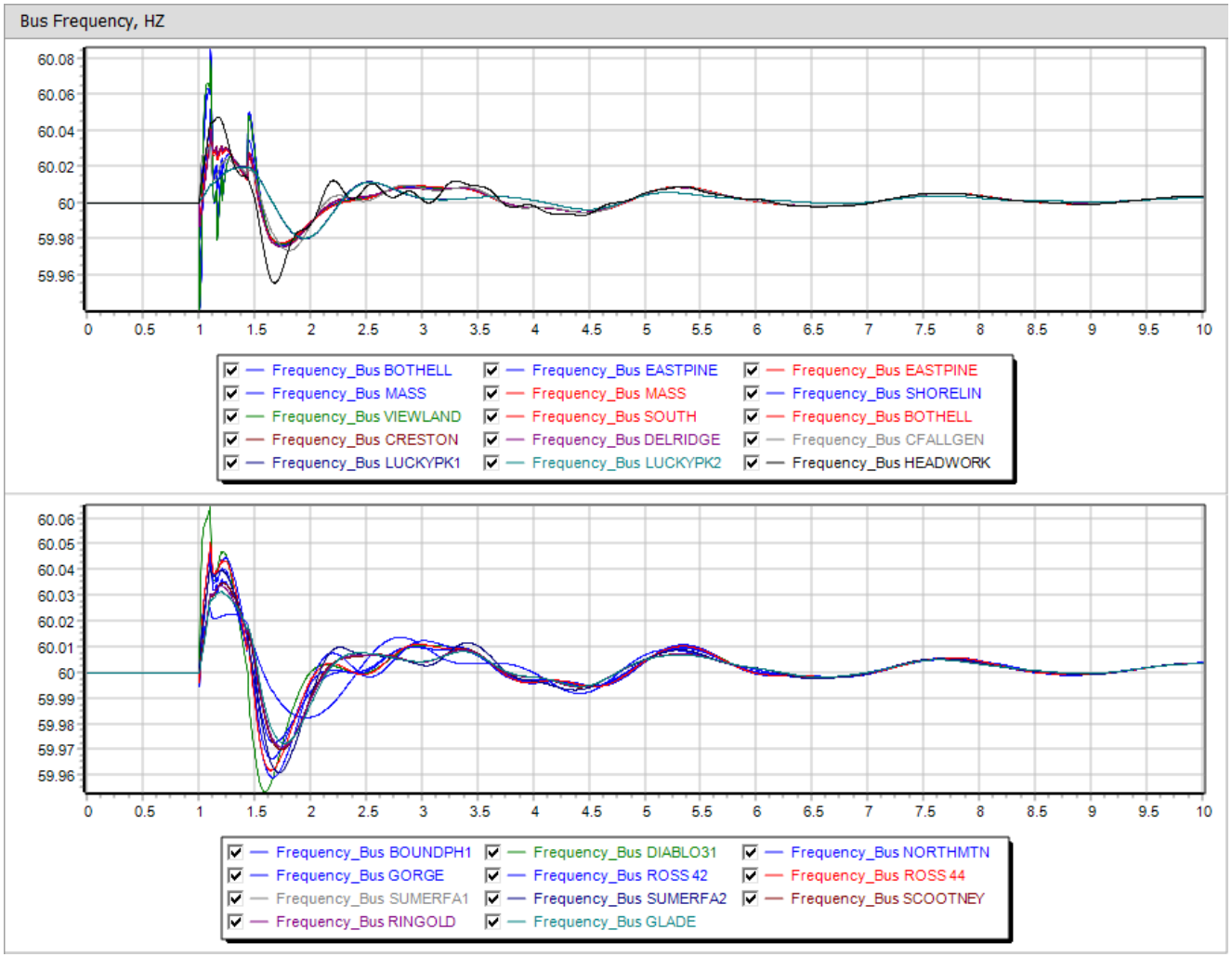
EXAMPLE W/O TRANSFER TRIP



SIMULATION RESULTS CORRECT!
EXAMPLE W/O TRANSFER TRIP



SIMULATION RESULTS CORRECT!
EXAMPLE W/O TRANSFER TRIP



DISTANCE RELAY OPERATION W/ TRANSFER TRIP

Transfer Trip allows for faster isolation of the fault.

A fault is again applied to the system at 10% of the line.

DISTANCE RELAY OPERATION W/ TRANSFER TRIP

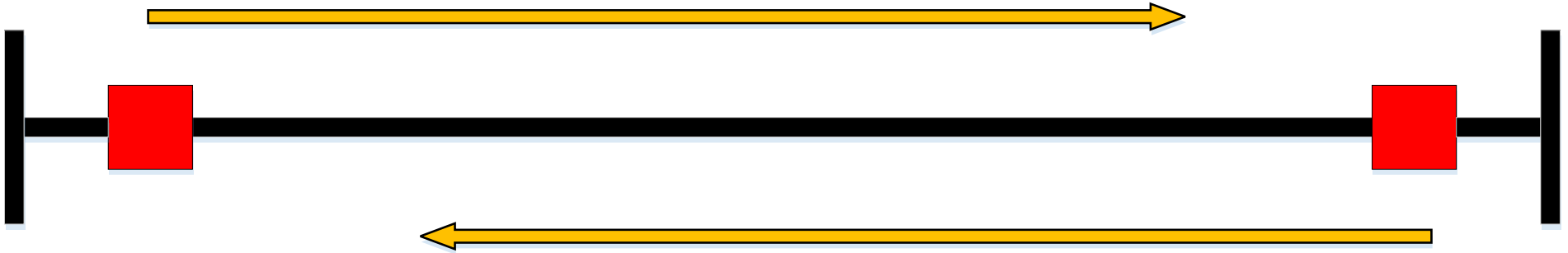
The relay at bus 1 sees the fault and triggers the breaker to operate. In this case, the relay near bus 1 is communicating with the one near bus 2.

DISTANCE RELAY OPERATION W/ TRANSFER TRIP

The relay at bus 2 receives the communication from the bus 1 relay (approximated with a 1 cycle delay). The breaker at bus 2 opens, isolating the fault.

TRANSFER TRIP: DUTT VS POTT
DIRECT UNDERREACHING TRANSFER TRIP

- Relays' protection covers less than 100% of the line
- If one end sees a fault, both ends will trip directly



EXAMPLE W/ TRANSFER TRIP (DUTT)

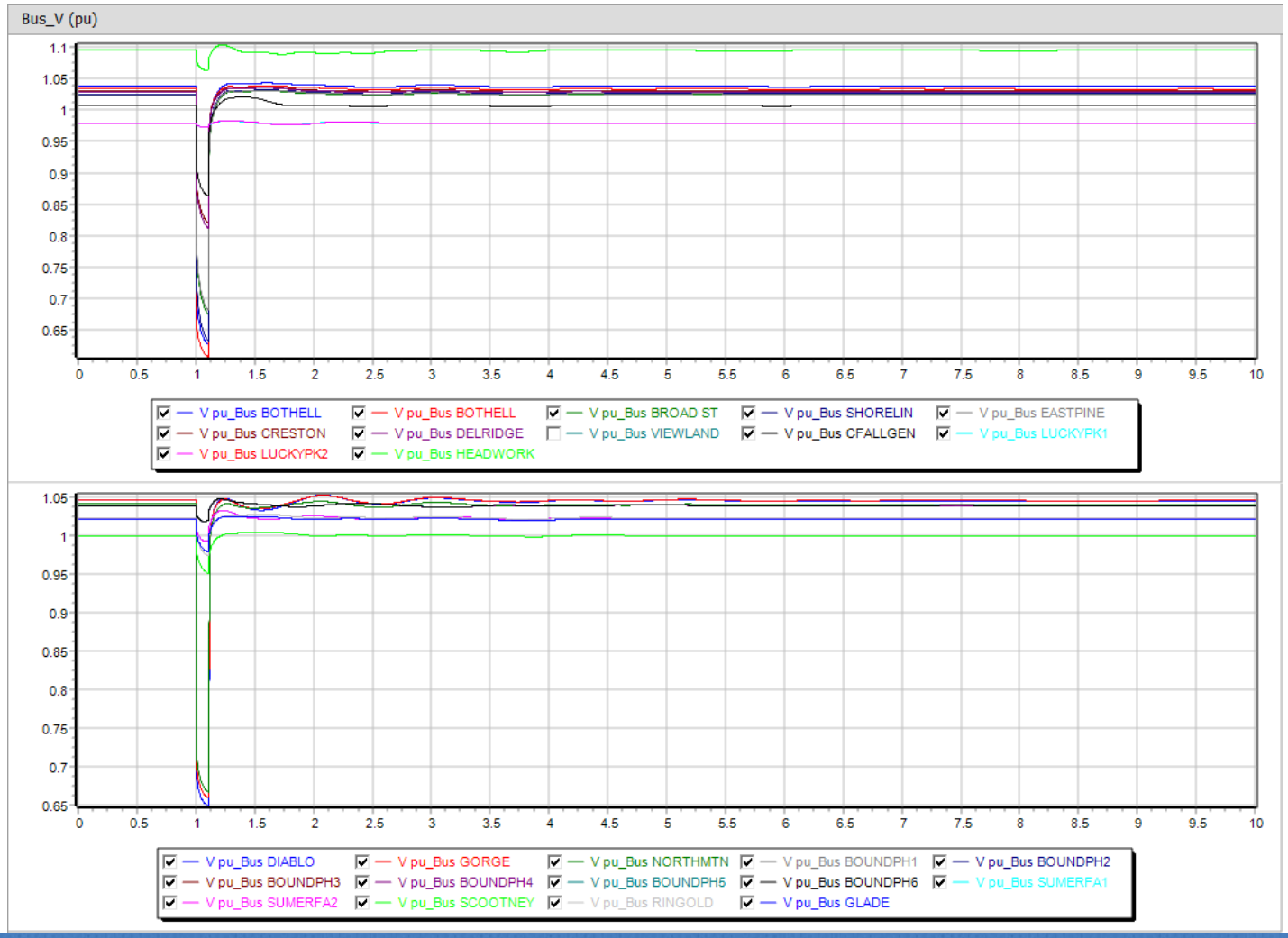
- This example is a line with a Direct Underreaching Transfer Trip (DUTT) scheme
- Contingency: Three-phase fault applied at 1 second on Bothell to Diablo Ckt 1 at 10% of the line

	Object Pretty	Time (Cycles)	Time (Seconds)	Object	Description
1	Line BOTHELL TO DIABLO CKT 1	60.0	1.000000	Branch '46403' '46421' '1'	FAULT 10 3PB SOLID

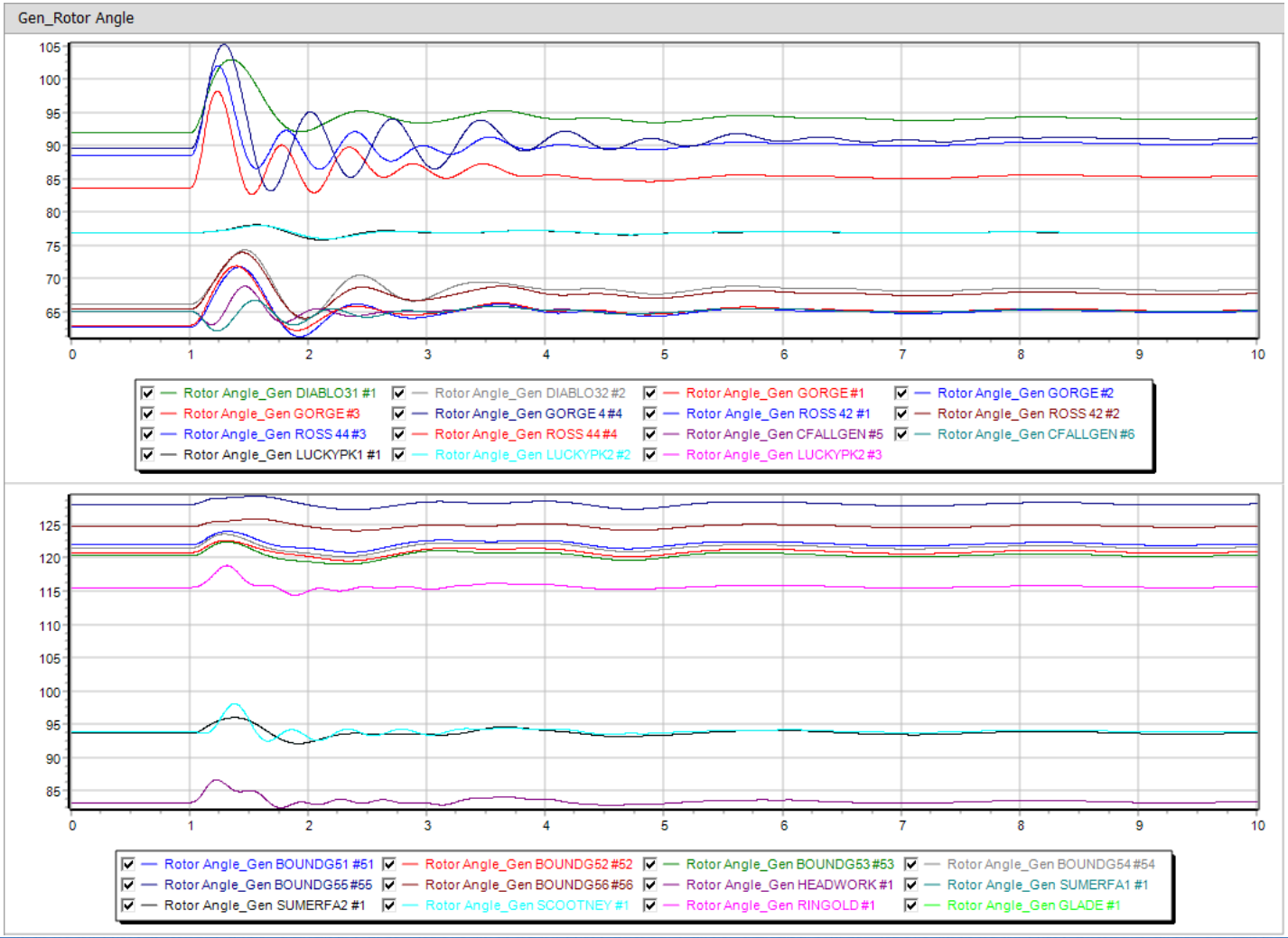
SIMULATION RESULTS CORRECT!
EXAMPLE W/ TRANSFER TRIP (DUTT)

Transient Stability Started at 5/15/2017 1:19:29 PM
Time: 1.000 Event: Apply Solid Fault (3PB) Line BOTHELL TO DIABLO CKT 1
Time: 1.000 Event: Relay A Zone 1 Entered (pickup) Line BOTHELL TO DIABLO CKT 1
Time: 1.100 Event: Line Relay DISTRELAYRF,Direct Trip action: Open From End Line BOTHELL TO DIABLO CKT 1
Time: 1.117 Event: Line Relay DISTRELAYRF,Transfer Trip action: Open To End (Both ends now Open) Line BOTHELL TO DIABLO CKT 1
Transient Stability Solution Finished at 5/15/2017 1:24:25 PM

SIMULATION RESULTS CORRECT!
EXAMPLE W/ TRANSFER TRIP (DUTT)

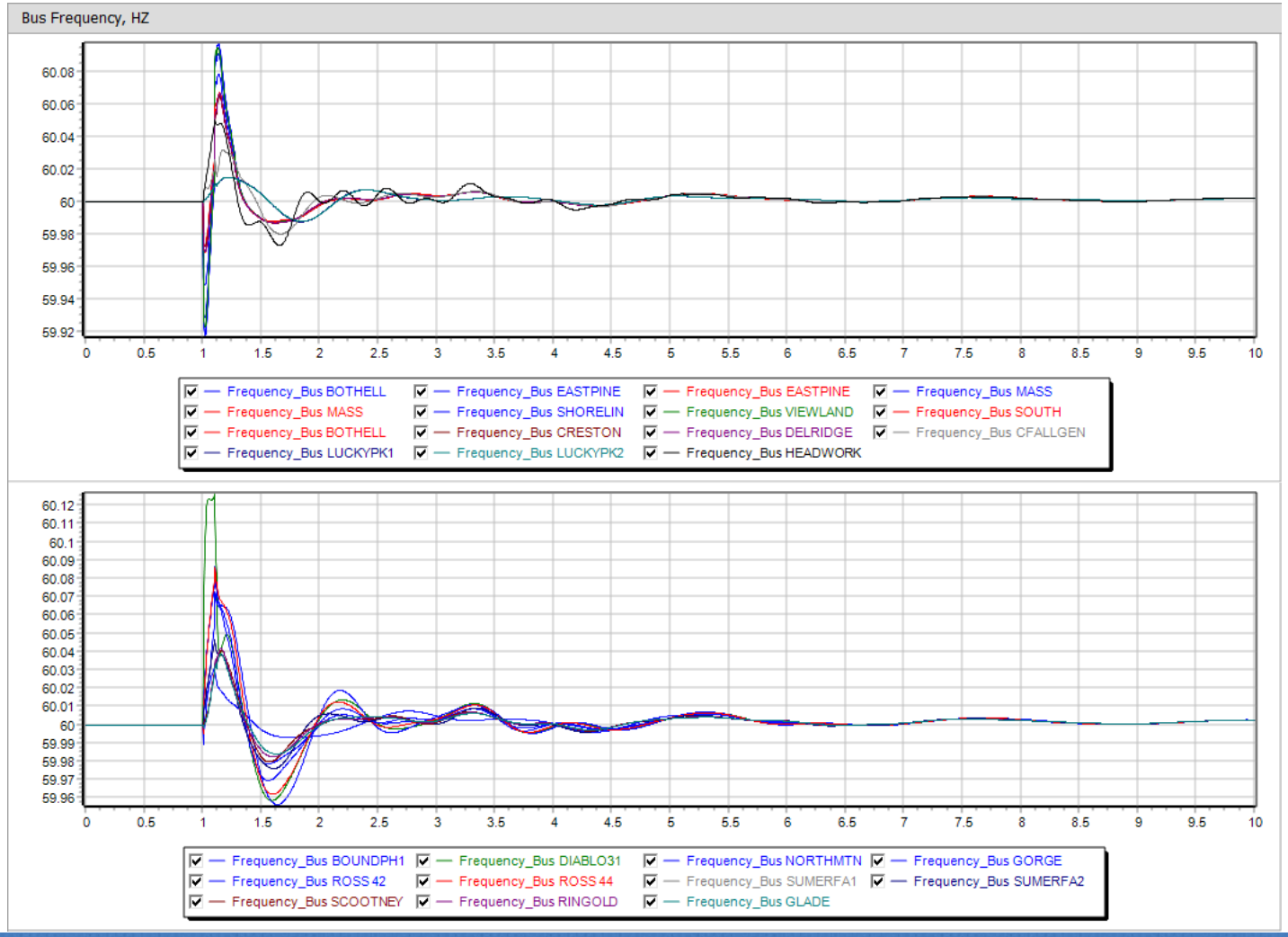


SIMULATION RESULTS CORRECT!
EXAMPLE W/ TRANSFER TRIP (DUTT)



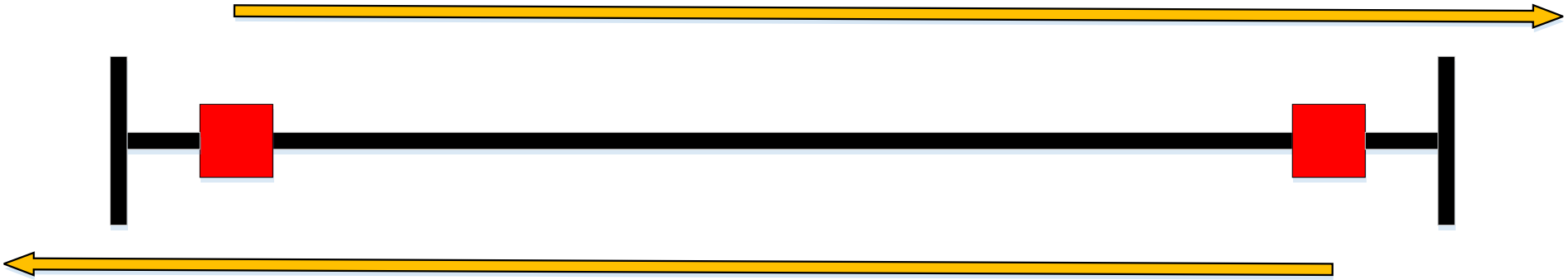
SIMULATION RESULTS CORRECT!

EXAMPLE W/ TRANSFER TRIP (DUTT)



TRANSFER TRIP: DUTT VS POTT
PERMISSIVE OVERREACHING TRANSFER TRIP

- Relays' protection covers more than 100% of the line
- Both ends must see the fault and receive permission from the other end before tripping is allowed



EXAMPLE W/ TRANSFER TRIP (POTT)

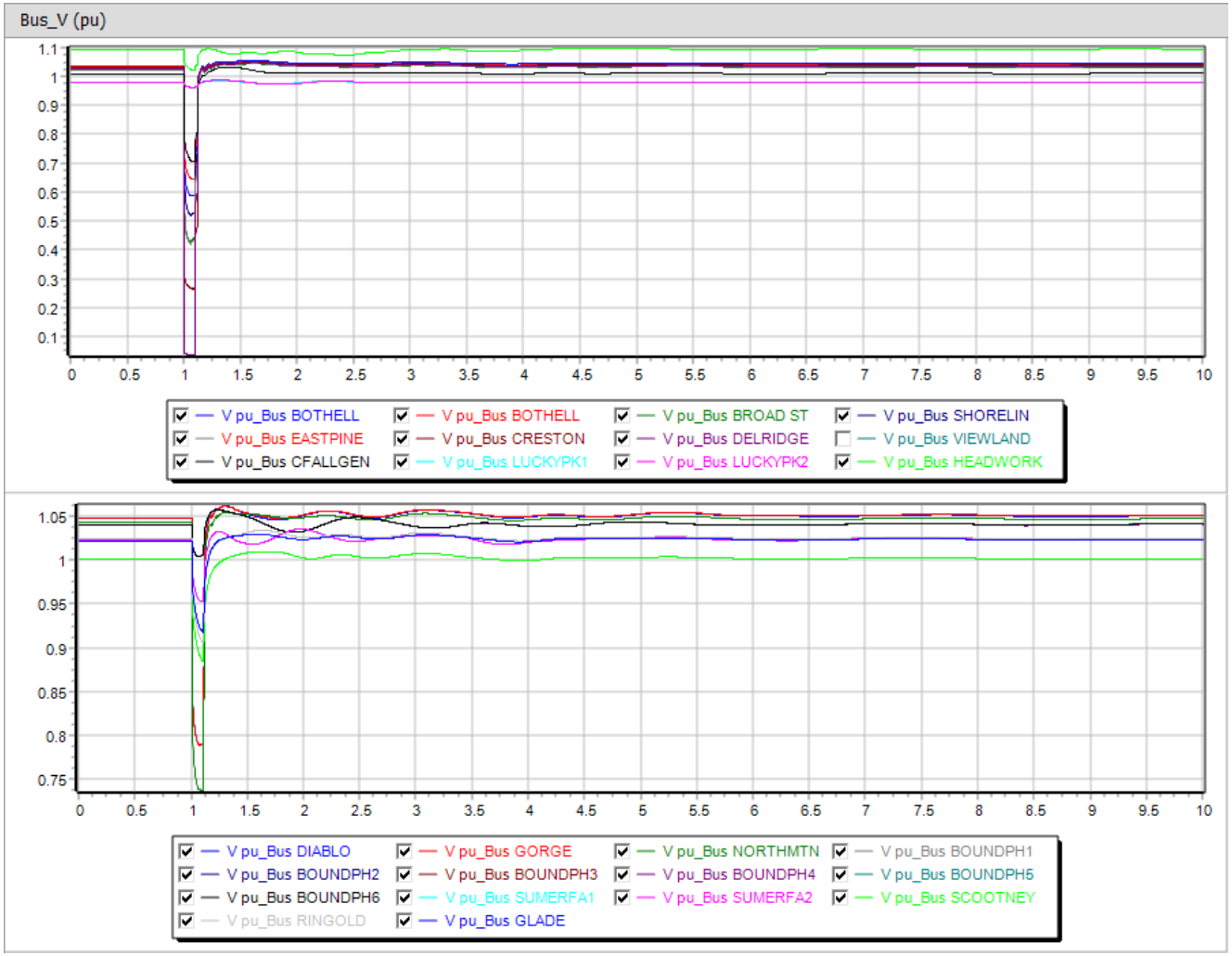
- This example is a line with a Permissive Overreaching Transfer Trip (POTT) scheme
- Contingency: Three-phase fault applied at 1 second on Delridge to Duwamish Ckt 1 at 10% of the line

	Object Pretty	Time (Cycles)	Time (Seconds)	Object	Description
1	Line DELRIDGE TO DUWAMISH CKT 1	60.0	1.000000	Branch '46417' '46423' '1'	FAULT 10 3PB SOLID

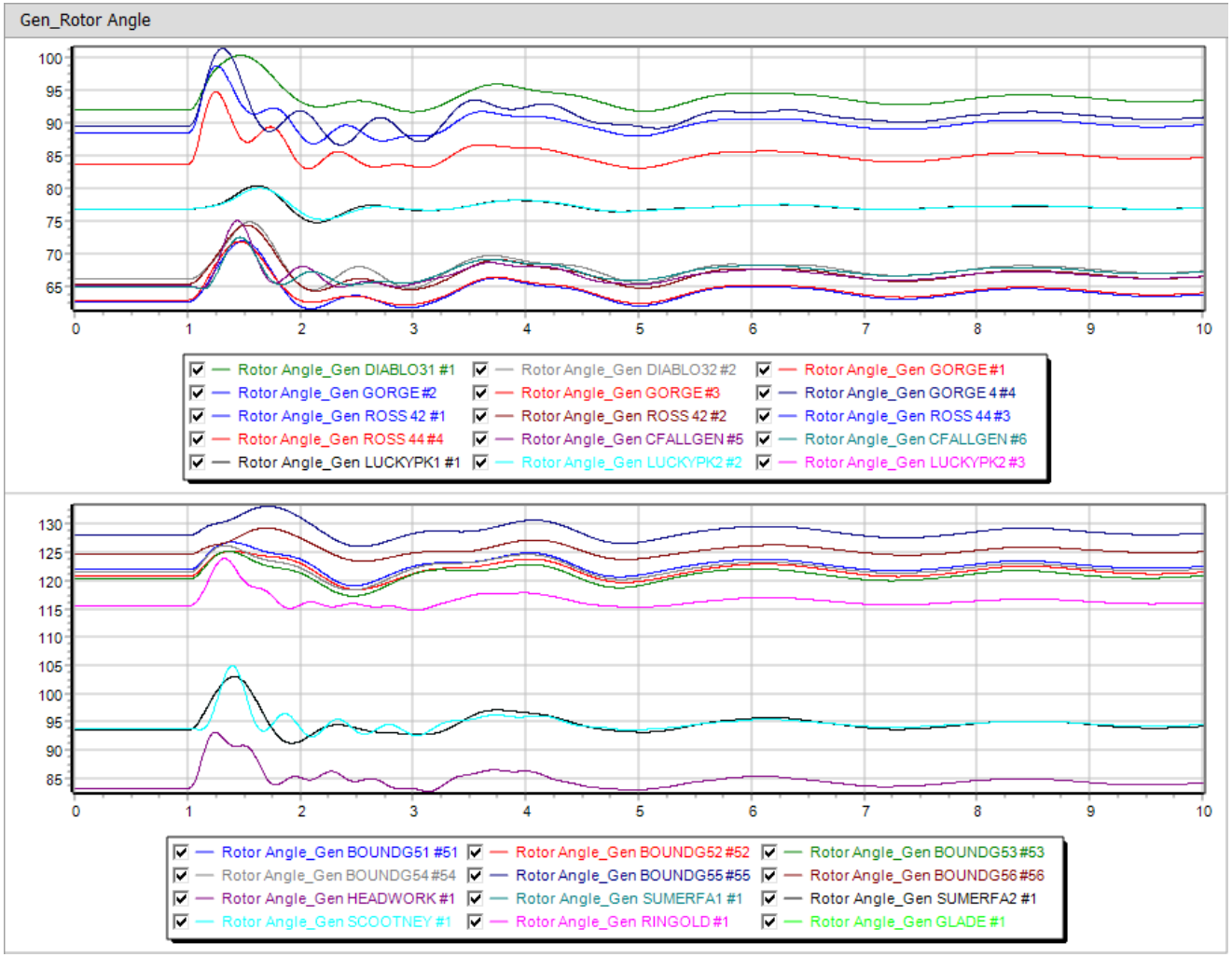
SIMULATION RESULTS CORRECT!
EXAMPLE W/ TRANSFER TRIP (POTT)

Transient Stability Started at 5/15/2017 2:06:46 PM
Time: 1.000 Event: Apply Solid Fault (3PB) Line DELRIDGE TO DUWAMISH CKT 1
Time: 1.000 Event: Relay A Zone 1 Entered (pickup) Line DELRIDGE TO DUWAMISH CKT 1
Time: 1.100 Event: Line Relay DISTRELAYRF,Direct Trip action: Open From End Line DELRIDGE TO DUWAMISH CKT 1
Time: 1.117 Event: Line Relay DISTRELAYRF,Transfer Trip action: Open To End (Both ends now Open) Line DELRIDGE TO DUWAMISH CKT 1
Transient Stability Solution Finished at 5/15/2017 2:11:56 PM

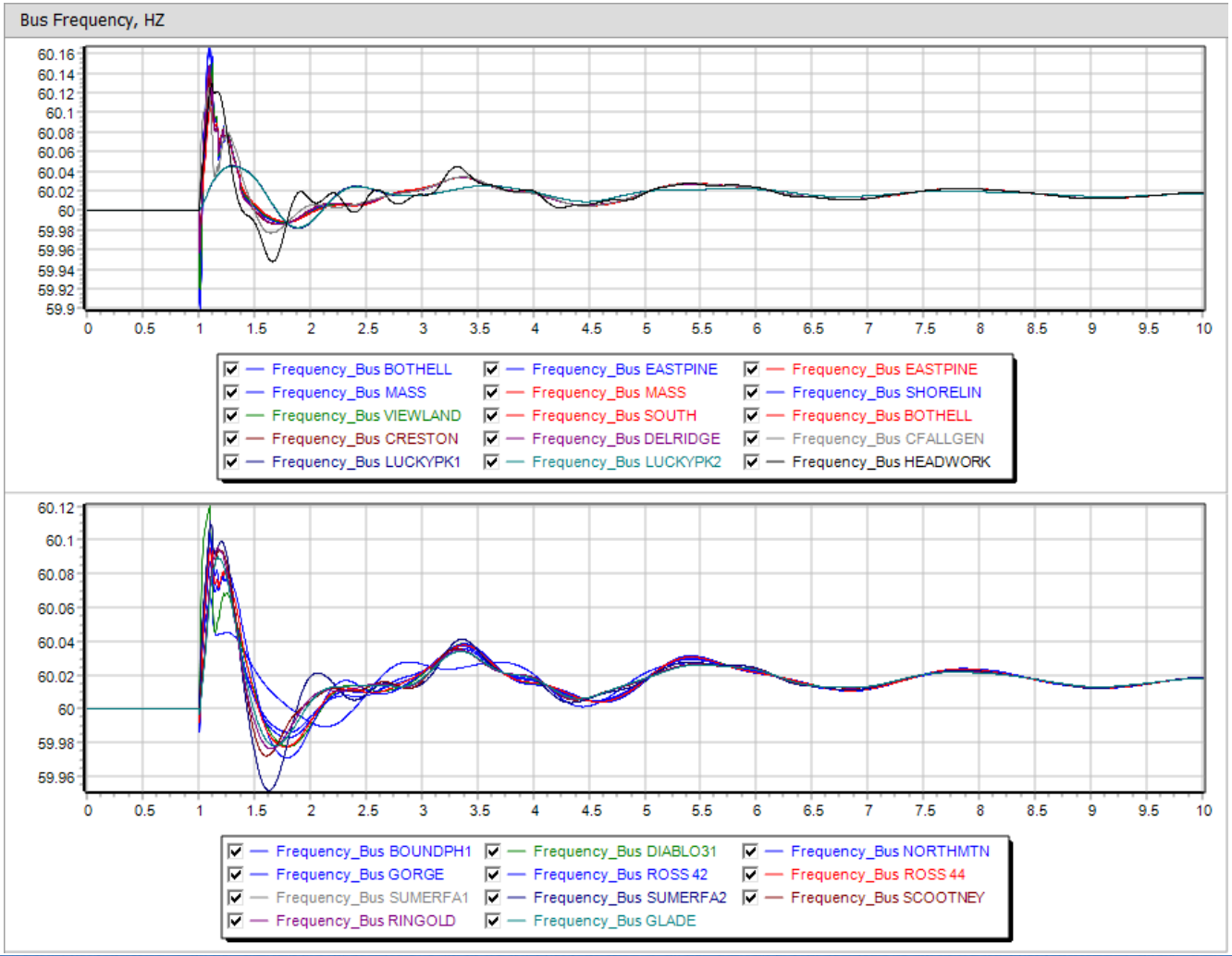
SIMULATION RESULTS CORRECT!
EXAMPLE W/ TRANSFER TRIP (POTT)



SIMULATION RESULTS CORRECT!
EXAMPLE W/ TRANSFER TRIP (POTT)



SIMULATION RESULTS CORRECT!
EXAMPLE W/ TRANSFER TRIP (POTT)



CONTINGENCY COMPARISON

- Previous contingency description:

	Object Pretty	Time (Cycles)	Time (Seconds)	Object	Description
1	Line BOTHELL TO DIABLO CKT 1	60.0	1.000000	Branch '46403' '46421' '1'	FAULT 10 3PB SOLID
2	Line BOTHELL TO DIABLO CKT 1	66.0	1.100000	Branch '46403' '46421' '1'	OPEN NEAR
3	Line BOTHELL TO DIABLO CKT 1	67.0	1.116670	Branch '46403' '46421' '1'	OPEN FAR

- New contingency description:

	Object Pretty	Time (Cycles)	Time (Seconds)	Object	Description
1	Line BOTHELL TO DIABLO CKT 1	60.0	1.000000	Branch '46403' '46421' '1'	FAULT 10 3PB SOLID

- No significant difference between runtimes!

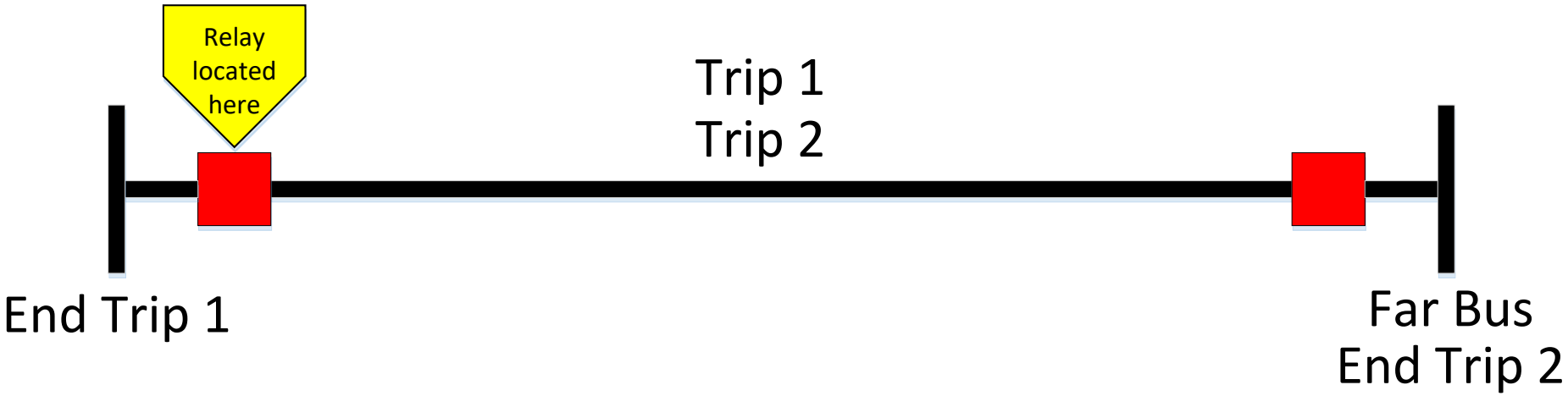
Seattle City Light

DISTRELAY PARAMETERS

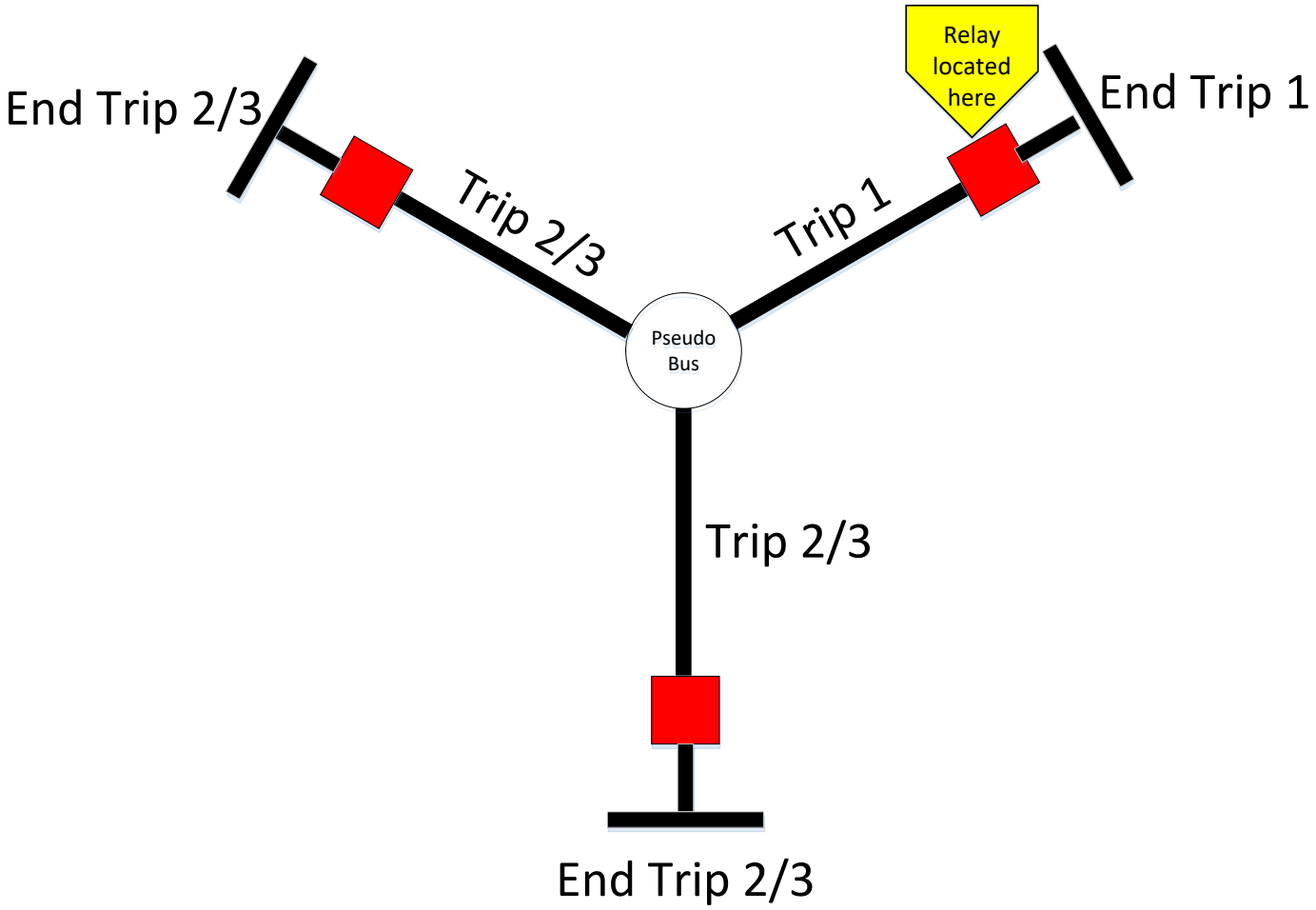
LINE/BUS SPECIFICATIONS

Parameter	Description
Far Bus	Bus that relay is looking towards
Far Line	Branch at end of series of branches
End Trip 1	Near bus
Trip 1	Line tripped by the relay
End Trip 2	Far bus
Trip 2	Line tripped by the relay
End Trip 3	Used for 3 terminal lines (explained in detail later)
Trip 3	Used for 3 terminal lines (explained in detail later)
End Trip 4-5	Used for 4-5 terminal lines
Trip 4-5	Used for 4-5 terminal lines

LINE/BUS SPECIFICATIONS

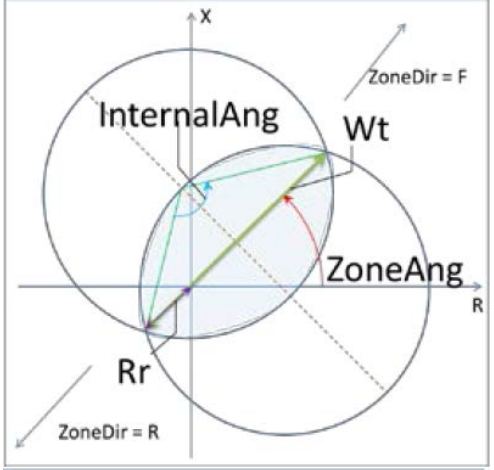


THREE TERMINAL LINES

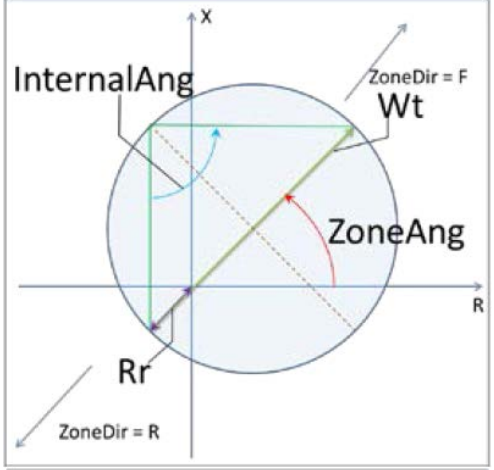


ZONE PROTECTION TYPES

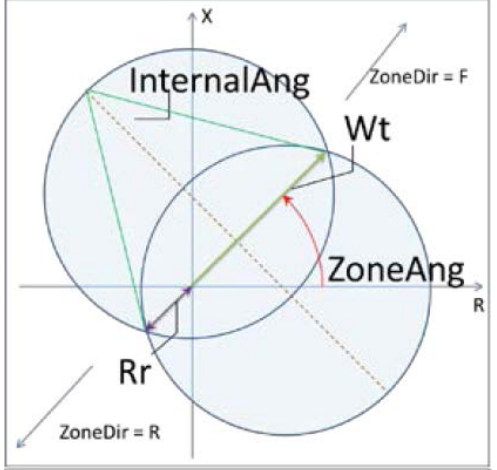
Lens Shape (InternalAng > 90°)



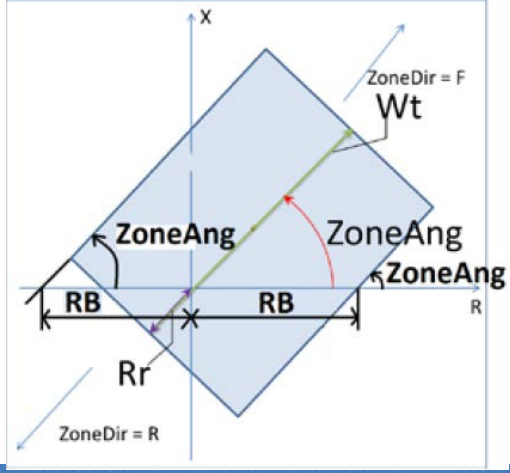
Circle Shape (InternalAng = 90°)



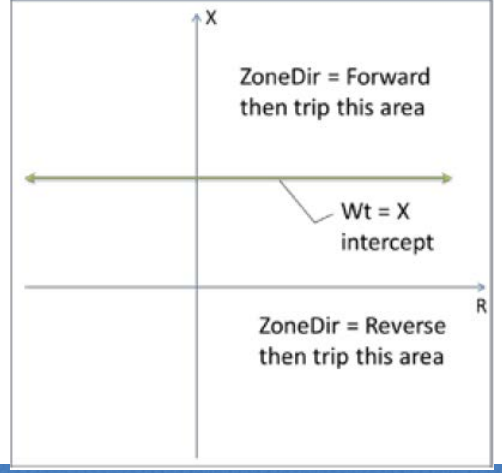
Tomato Shape (InternalAng <90°)



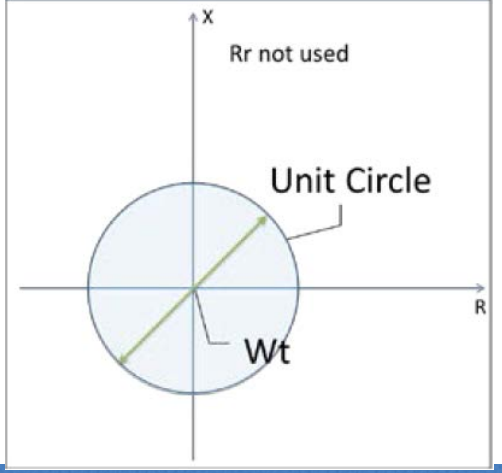
Rectangle Shape (InternalAng = none)



Reactance Distance

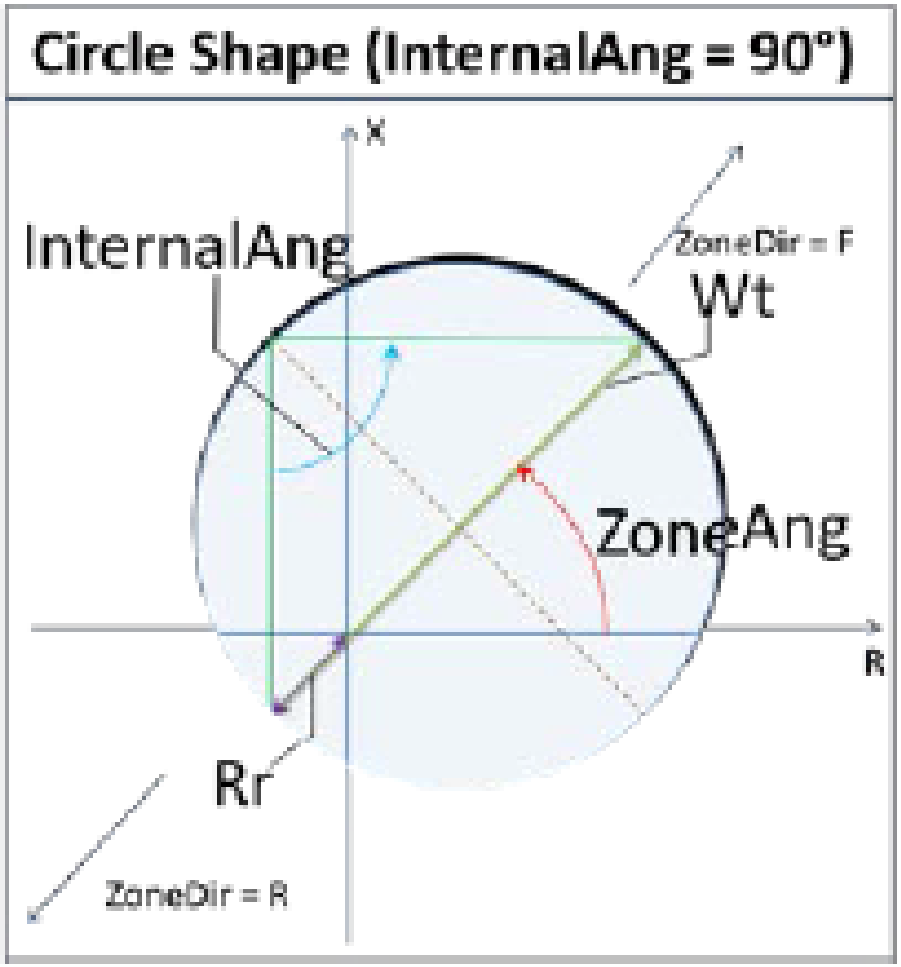


Impedance Distance



SCL ZONE PROTECTION

- Seattle City Light uses the “circle shape” for its protection schemes
  - Shape=0
  - InternalAng=90
  - Rr=0



MODEL SPECIFICATIONS

Parameter	Description
NoTrip	0 to monitor & trip; -1 to only monitor
Shape1-4	0 for circle, lens, and tomato; 1 for rectangle; 2 for reactance distance; 3 for impedance distance
TransferType	0 for none; 1 for Direct Underreaching Transfer Trip (DUTT); 2 for Permissive Overreaching Transfer Trip (POTT); 3 for Permissive Underreaching Transfer Trip (PUTT); 4 for Directional Comparison Blocking (DCB);
UseLoadEncroach	0 to disable load encroachment; 1 for load encroachment
NumDirect	Number of direct trips before transfer branches trip 1 for SCL

MODEL SPECIFICATIONS CONTINUED

Parameter	Description
DirectTrip	Self trip + communication + breaker time (in cycles) 6 cycles
DirectReclose	Self reclose time (in cycles) Varies
TransferTrip	Self trip + communications + breaker time for Transfer trip 6 cycles for 87L, 7 cycles for POTT & DUTT
TransferReclose	Transfer trip reclose time (in cycles) Varies
Angle1-4	MTA/line impedance angle, depends on relay
Wt1-4	Width total impedance aka forward reach in primary ohms
Rr1-4	Reverse reach impedance in primary ohms 0 for SCL

MODEL SPECIFICATIONS CONTINUED

Parameter	Description
InternalAng1-4	>90° for lens shape =90° for circle shape <90° for tomato shape
Rb1-4	Resistive blinder location (for quadrilateral shape only) 0 for SCL
T1-4	Delay for zones (in seconds) Usual values for SCL: 0 for Z1 0.33333 (20 cycles) for Z2 1.5 (90 cycles) for Z3
IThres1-4	Threshold Current; Not available for SCL, set to -1
Blinder params	Parameters for blinders; SCL does not use blinders, keep values at zero

Seattle City Light

RECLOSING

THREE RECLOSING SCENARIOS

- No reclosing
- Each end closes independently
- One end closes first to “test” the line
  - If the fault persists, the other end of the line will not reclose

INDEPENDENT END CLOSING

- Designated by “HB/DL” (Hot bus/dead line) values on both ends
- Means that both relays will be triggering their breakers to close onto a dead-line

INDEPENDENT END CLOSING

- Possible for relays to have different reclosing times
- Ends will reclose independent of fault clearing

LINE "TESTING"

- Designated HB/DL for Bus 1 and HB/HL (Hot bus/hot line) for Bus 2

LINE "TESTING"

- Bus 1's breaker recloses first (40 cycles after the line has been cleared) to test the line

LINE "TESTING"

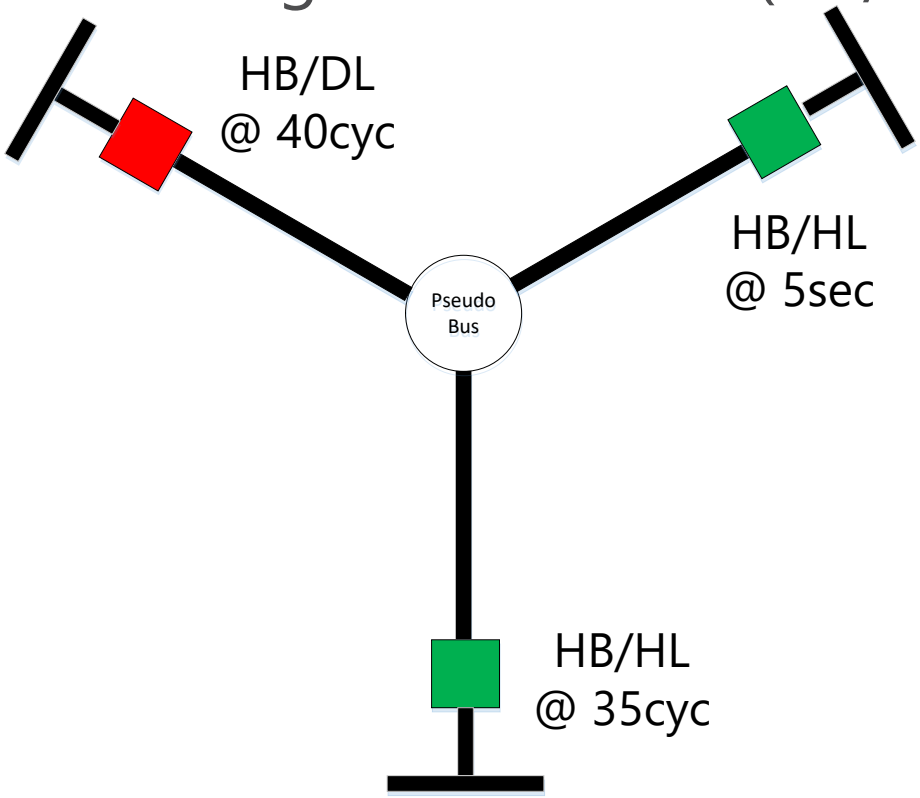
- If the fault is still present after the reclose, bus 1's breaker will open and stay open
- Bus 2's breaker will not reclose

LINE "TESTING"

- If the fault is cleared, bus 2's breaker will reclose 35 cycles after bus 1's breaker reclosed, putting the line back into service

LINE "TESTING" THREE TERMINALS

- Possible for three-terminal lines
  - One bus will be designated "tester" (HB/DL)



MODEL IMPLEMENTATION

- Can’t replicate reclosing described above
- Buses closest to fault will always reclose first
- Thoughts?

OUR VISION

To set the standard—to deliver the best customer service experience of any utility in the nation.

OUR MISSION

Seattle City Light is dedicated to exceeding our customers' expectations in producing and delivering environmentally responsible, safe, low-cost and reliable power.

OUR VALUES

Excellence, Accountability, Trust and Stewardship.

THE NATION'S GREENEST UTILITY
SINCE 1905
SEATTLE CITY LIGHT

Seattle City Light