POWER WORLD LINEAR SENSITIVITY TOOLS

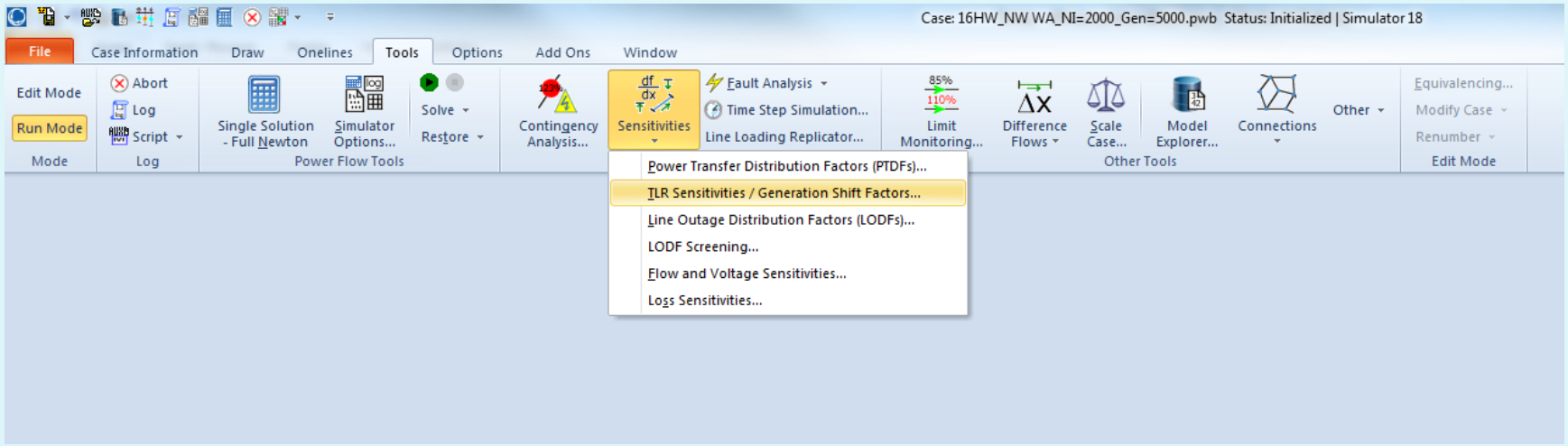
PWUWG #7

[6/30/15 – 7/1/15]

Daniel Kuraspediani,
- BPA -

WHERE IS IT LOCATED

- Run mode
- Tools/Sensitivities
  - PTDF's
  - TLR/GSF
  - LODF's & LCDF's
  - Flow and Voltage
  - Loss



PTDF's

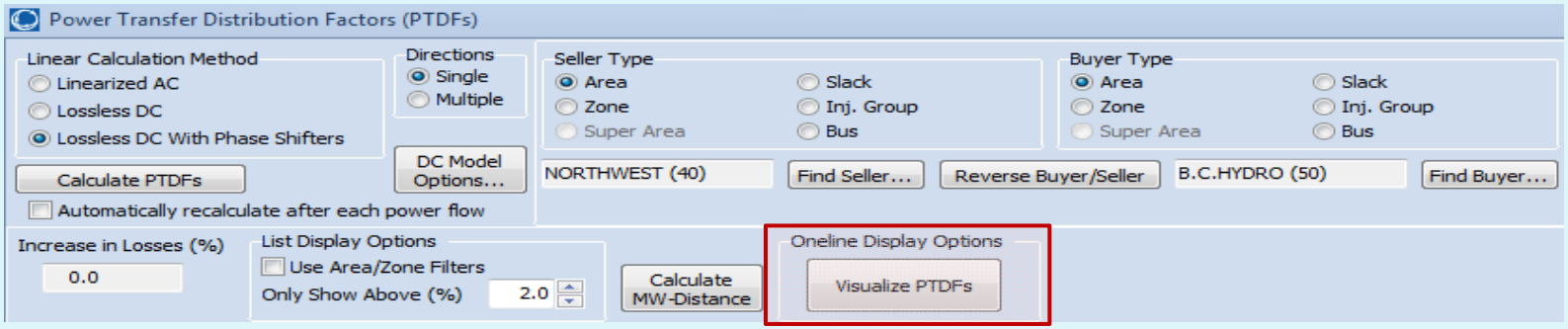
- **Power Transfer Distribution Factors**

- Indicate (%) amount of power that will distribute throughout the network given an injection at a location called the "seller" and taking the injection off of the network at a location called the "buyer"

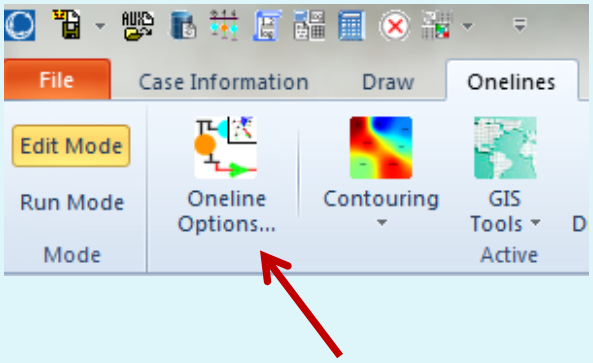
- **Purposes:**
  - How much impact a specified buyer and seller have on a path or generator etc.
  - How power distributes across the network
  - Compare multiple PTDF's to assess network impacts
  - Can visualize PTDF % on one lines

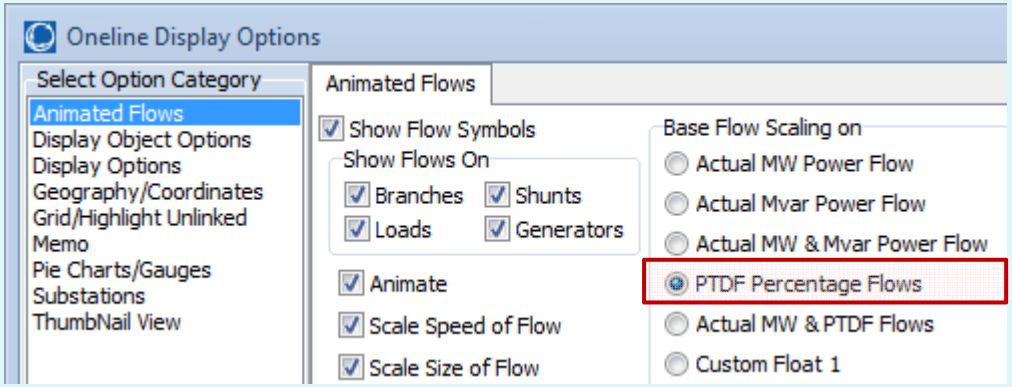
VISUALIZING *PTDF's*

- If only 1 one-line is open, **"Visualize PTDFs"** is an option in the sensitivity



- Visualizing PTDF's on a oneline is located in the ***ONELINE DISPLAY OPTIONS*** dialog under the Onelines ribbon.



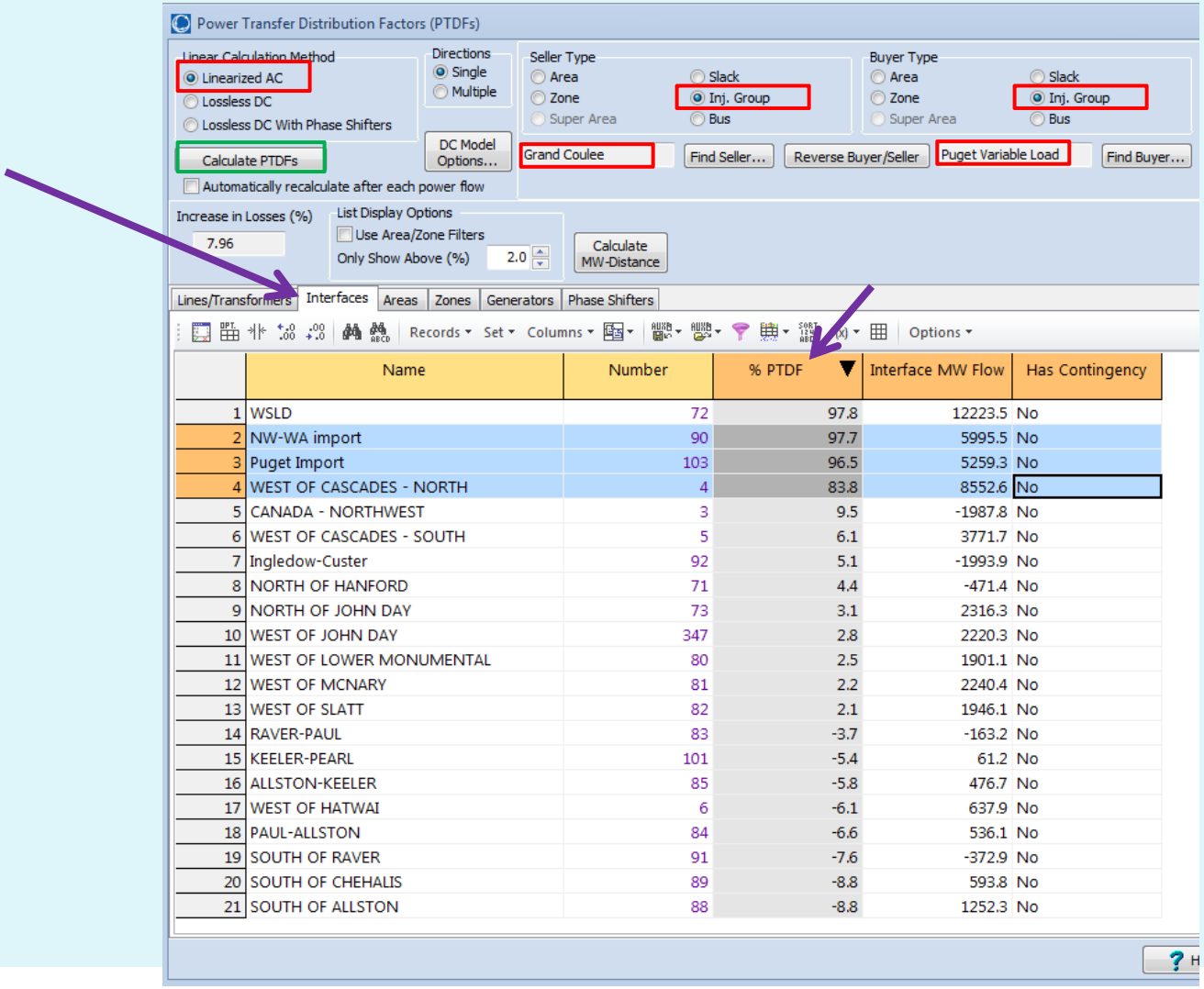


SCENARIO 1 – *PTDF's*

- **Example:**
  - Increasing transfer from Grand Coulee and sinking into the Puget Sound Area will increase flows on which flowgates and lines? Which flowgates have high sensitivities and which are offloaded?

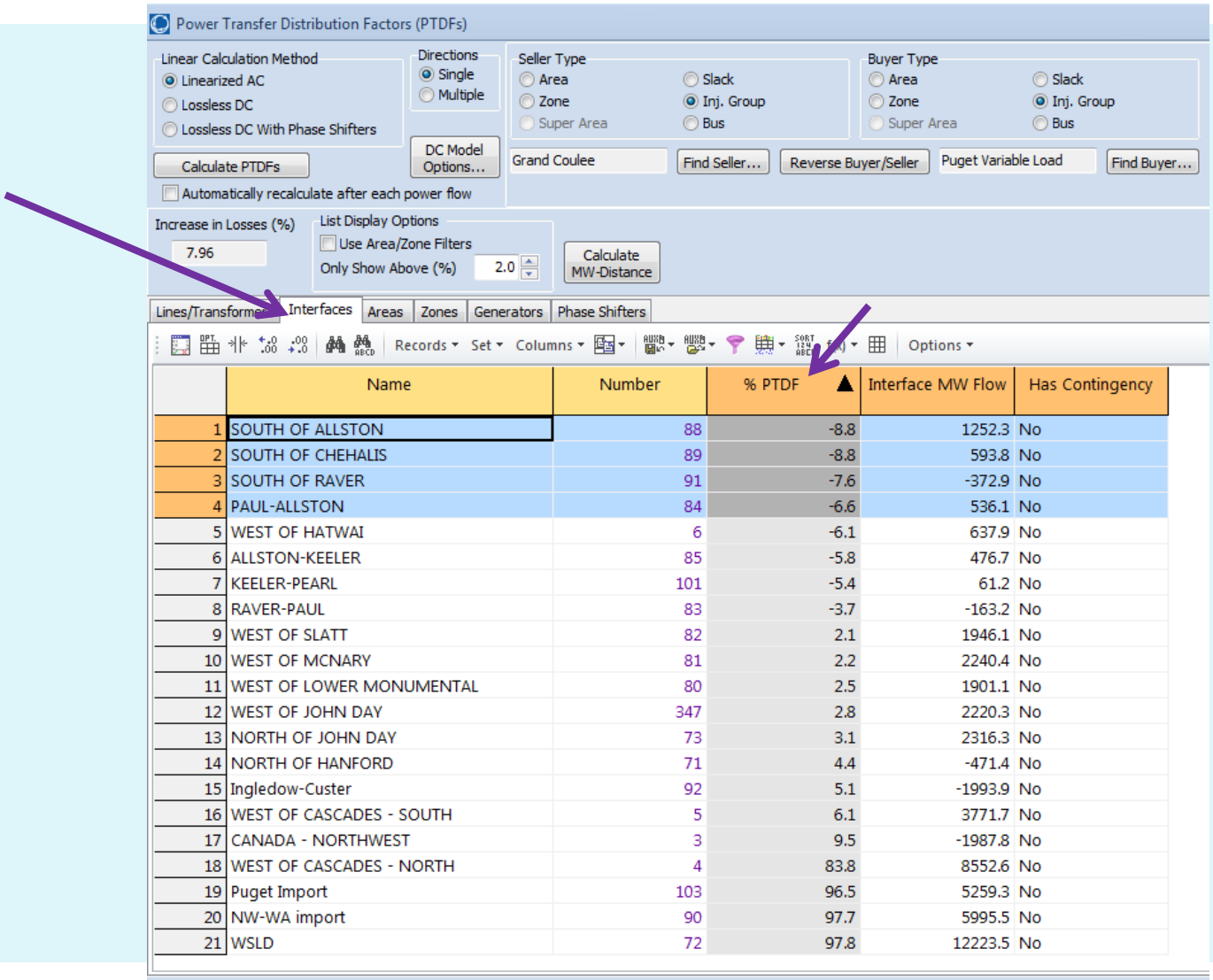
- **Setup:**
  - Buyer (sink) = Puget Sound Area Variable Load
  - Seller (source) = Grand Coulee generation
  - *Linearized AC* calculation

SCENARIO 1 – *PTDF's*



	Name	Number	% PTDF	Interface MW Flow	Has Contingency
1	WSLD	72	97.8	12223.5	No
2	NW-WA import	90	97.7	5995.5	No
3	Puget Import	103	96.5	5259.3	No
4	WEST OF CASCADES - NORTH	4	83.8	8552.6	No
5	CANADA - NORTHWEST	3	9.5	-1987.8	No
6	WEST OF CASCADES - SOUTH	5	6.1	3771.7	No
7	Ingledow-Custer	92	5.1	-1993.9	No
8	NORTH OF HANFORD	71	4.4	-471.4	No
9	NORTH OF JOHN DAY	73	3.1	2316.3	No
10	WEST OF JOHN DAY	347	2.8	2220.3	No
11	WEST OF LOWER MONUMENTAL	80	2.5	1901.1	No
12	WEST OF MCNARY	81	2.2	2240.4	No
13	WEST OF SLATT	82	2.1	1946.1	No
14	RAVER-PAUL	83	-3.7	-163.2	No
15	KEELER-PEARL	101	-5.4	61.2	No
16	ALLSTON-KEELER	85	-5.8	476.7	No
17	WEST OF HATWAI	6	-6.1	637.9	No
18	PAUL-ALLSTON	84	-6.6	536.1	No
19	SOUTH OF RAVER	91	-7.6	-372.9	No
20	SOUTH OF CHEHALIS	89	-8.8	593.8	No
21	SOUTH OF ALLSTON	88	-8.8	1252.3	No

SCENARIO 1 – *PTDF's*



	Name	Number	% PTDF	Interface MW Flow	Has Contingency
1	SOUTH OF ALLSTON	88	-8.8	1252.3	No
2	SOUTH OF CHEHALIS	89	-8.8	593.8	No
3	SOUTH OF RAVER	91	-7.6	-372.9	No
4	PAUL-ALLSTON	84	-6.6	536.1	No
5	WEST OF HATWAI	6	-6.1	637.9	No
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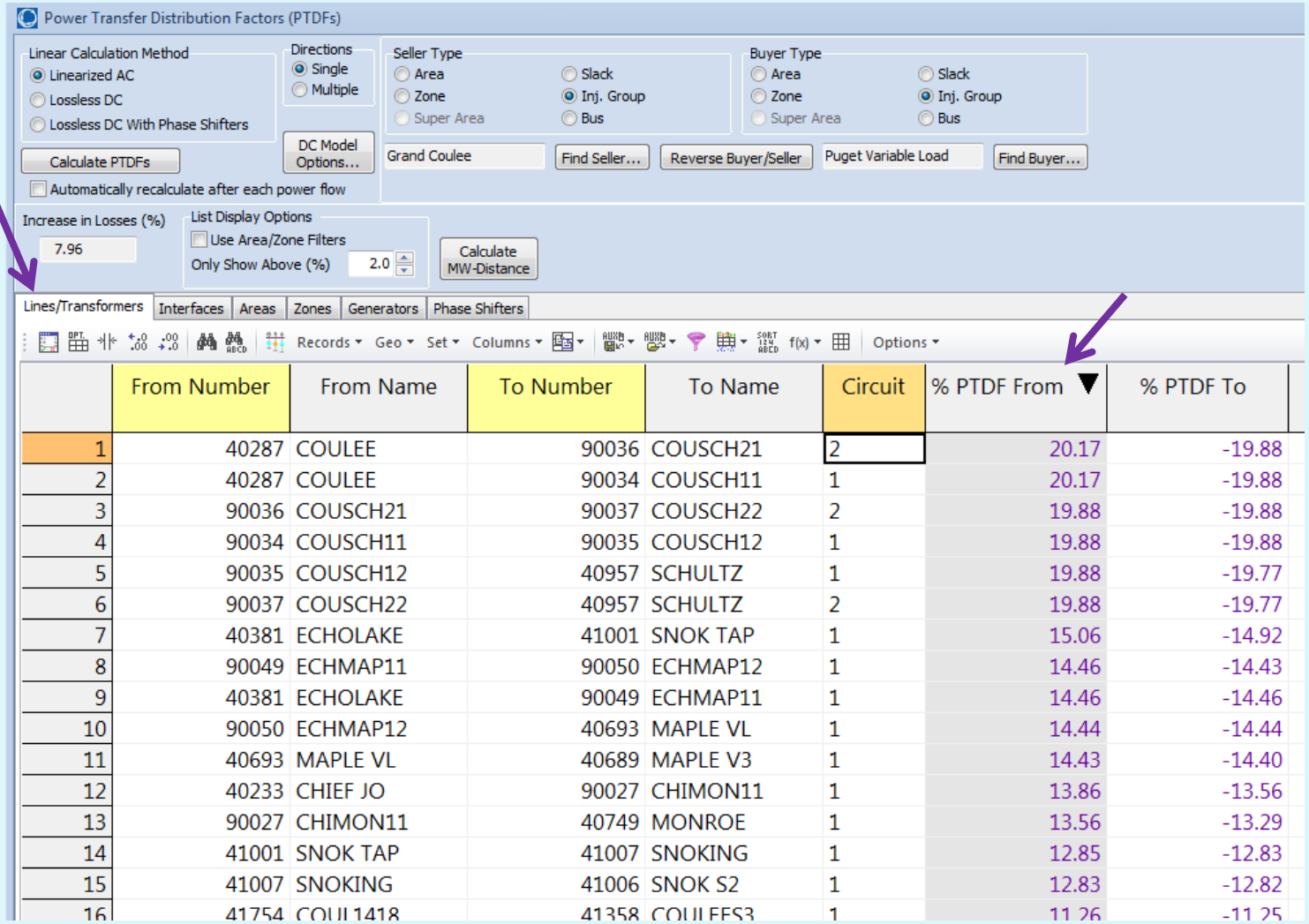
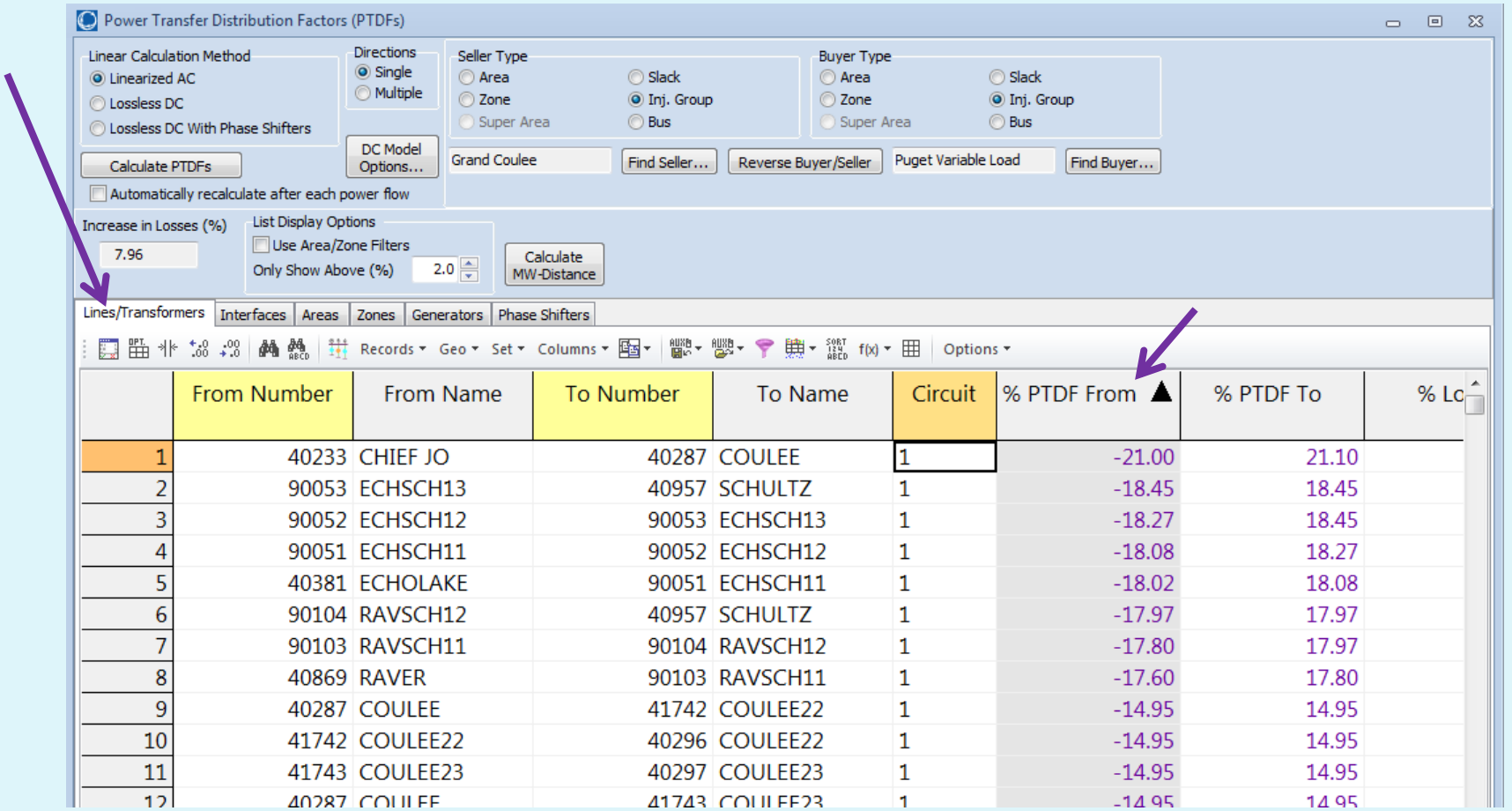
19	Puget Import	103	96.5	5259.3	No
20	NW-WA import	90	97.7	5995.5	No
21	WSLD	72	97.8	12223.5	No

SCENARIO 1 – *PTDF's*



	From Number	From Name	To Number	To Name	Circuit	% PTDF From	% PTDF To
1	40287	COULEE	90036	COUSCH21	2	20.17	-19.88
2	40287	COULEE	90034	COUSCH11	1	20.17	-19.88
3	90036	COUSCH21	90037	COUSCH22	2	19.88	-19.88
4	90034	COUSCH11	90035	COUSCH12	1	19.88	-19.88
5	90035	COUSCH12	40957	SCHULTZ	1	19.88	-19.77
6	90037	COUSCH22	40957	SCHULTZ	2	19.88	-19.77
7	40381	ECHOLAKE	41001	SNOK TAP	1	15.06	-14.92
8	90049	ECHMAP11	90050	ECHMAP12	1	14.46	-14.43
9	40381	ECHOLAKE	90049	ECHMAP11	1	14.46	-14.46
10	90050	ECHMAP12	40693	MAPLE VL	1	14.44	-14.44
11	40693	MAPLE VL	40689	MAPLE V3	1	14.43	-14.40
12	40233	CHIEF JO	90027	CHIMON11	1	13.86	-13.56
13	90027	CHIMON11	40749	MONROE	1	13.56	-13.29
14	41001	SNOK TAP	41007	SNOKING	1	12.85	-12.83
15	41007	SNOKING	41006	SNOK S2	1	12.83	-12.82
16	41754	COULI1418	41358	COULEES3	1	11.26	-11.25

SCENARIO 1 – *PTDF's*



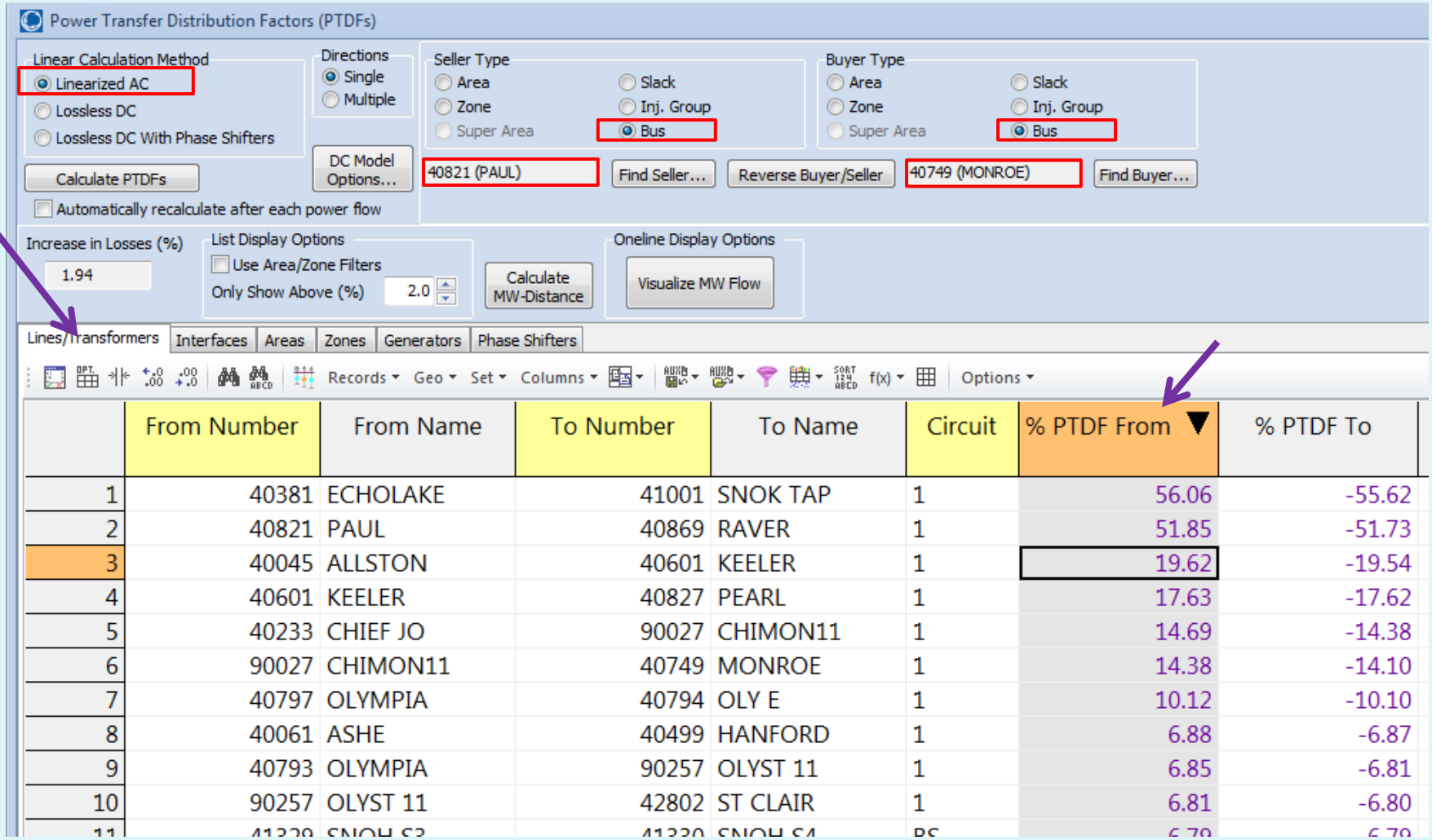
	From Number	From Name	To Number	To Name	Circuit	% PTDF From	% PTDF To	% Lc
1	40233	CHIEF JO	40287	COULEE	1	-21.00	21.10	
2	90053	ECHSCH13	40957	SCHULTZ	1	-18.45	18.45	
3	90052	ECHSCH12	90053	ECHSCH13	1	-18.27	18.45	
4	90051	ECHSCH11	90052	ECHSCH12	1	-18.08	18.27	
5	40381	ECHOLAKE	90051	ECHSCH11	1	-18.02	18.08	
6	90104	RAVSCH12	40957	SCHULTZ	1	-17.97	17.97	
7	90103	RAVSCH11	90104	RAVSCH12	1	-17.80	17.97	
8	40869	RAVER	90103	RAVSCH11	1	-17.60	17.80	
9	40287	COULEE	41742	COULEE22	1	-14.95	14.95	
10	41742	COULEE22	40296	COULEE22	1	-14.95	14.95	
11	41743	COULEE23	40297	COULEE23	1	-14.95	14.95	
12	40287	COULEE	41743	COULEE23	1	-14.95	14.95	

SCENARIO 2 – *PTDF's*

- **Example:**
  - How does power distribute across the system when injected at Paul and monitored at Monroe?

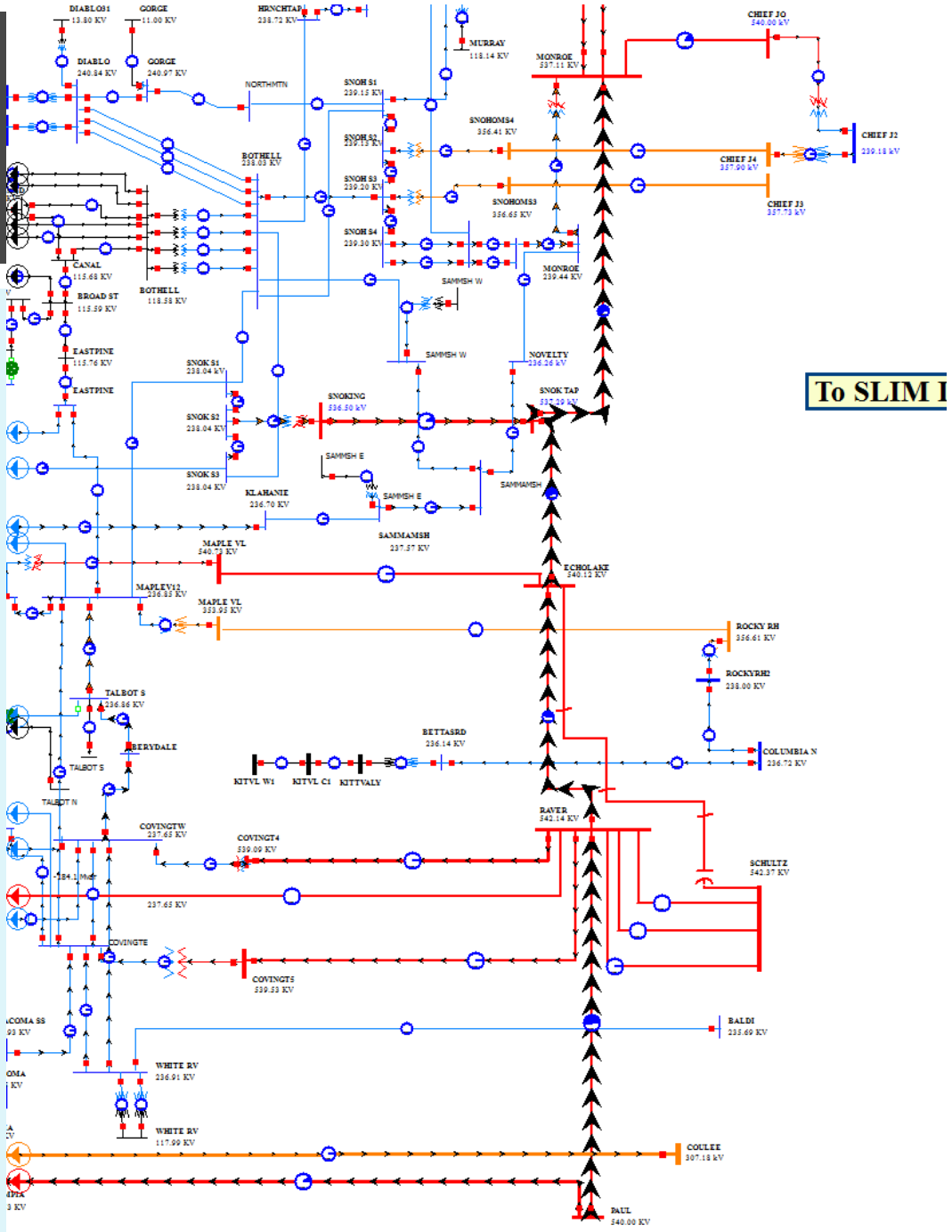
- **Setup:**
  - Buyer (sink) = Monroe 500kV BUS
  - Seller (source) = Paul 500kV BUS
  - *Linearized AC* calculation

SCENARIO 2 – *PTDF's*



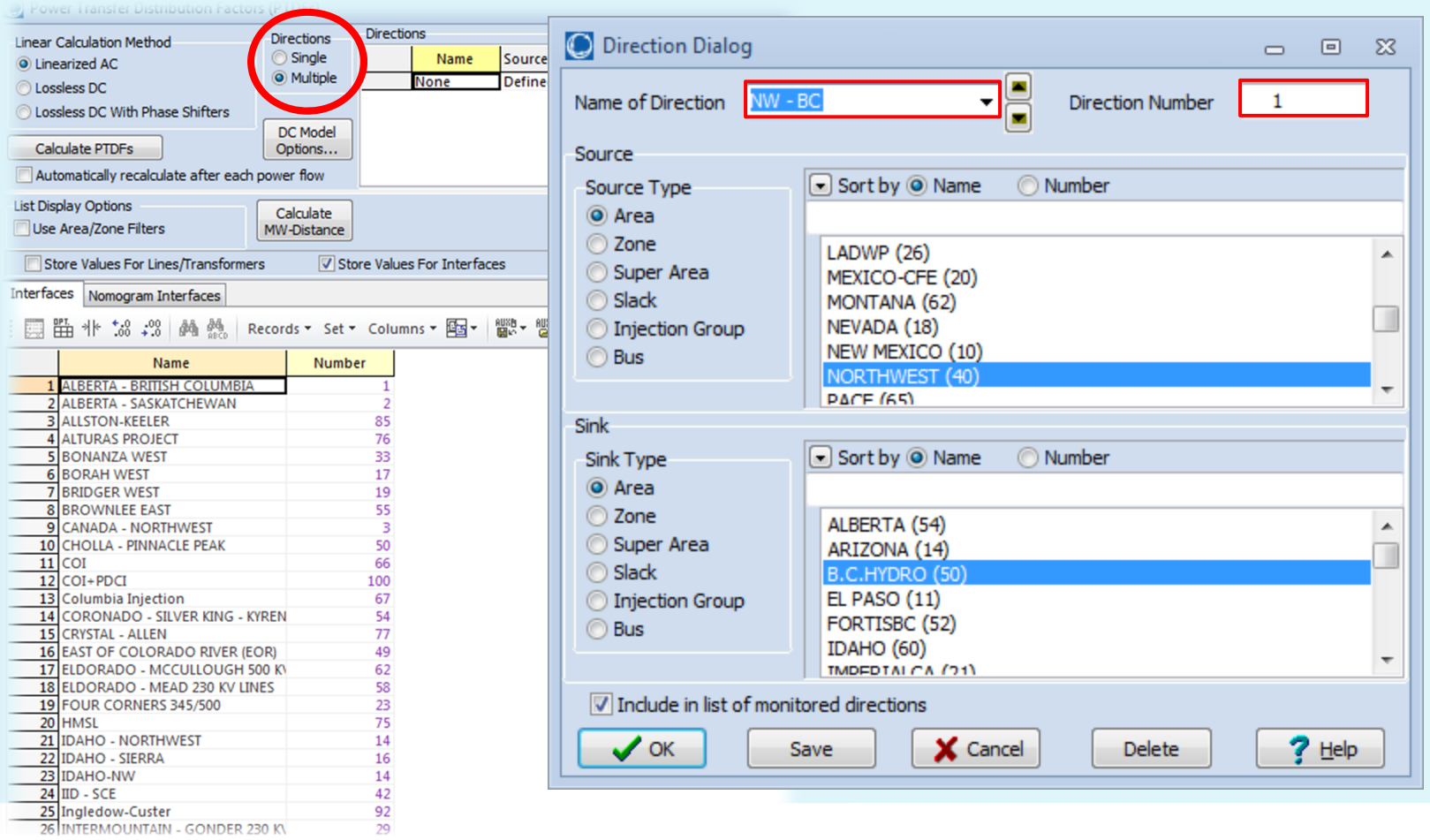
	From Number	From Name	To Number	To Name	Circuit	% PTDF From	% PTDF To
1	40381	ECHOLAKE	41001	SNOK TAP	1	56.06	-55.62
2	40821	PAUL	40869	RAVER	1	51.85	-51.73
3	40045	ALLSTON	40601	KEELER	1	19.62	-19.54
4	40601	KEELER	40827	PEARL	1	17.63	-17.62
5	40233	CHIEF JO	90027	CHIMON11	1	14.69	-14.38
6	90027	CHIMON11	40749	MONROE	1	14.38	-14.10
7	40797	OLYMPIA	40794	OLY E	1	10.12	-10.10
8	40061	ASHE	40499	HANFORD	1	6.88	-6.87
9	40793	OLYMPIA	90257	OLYST 11	1	6.85	-6.81
10	90257	OLYST 11	42802	ST CLAIR	1	6.81	-6.80

PTDF's ON ONE-LINE

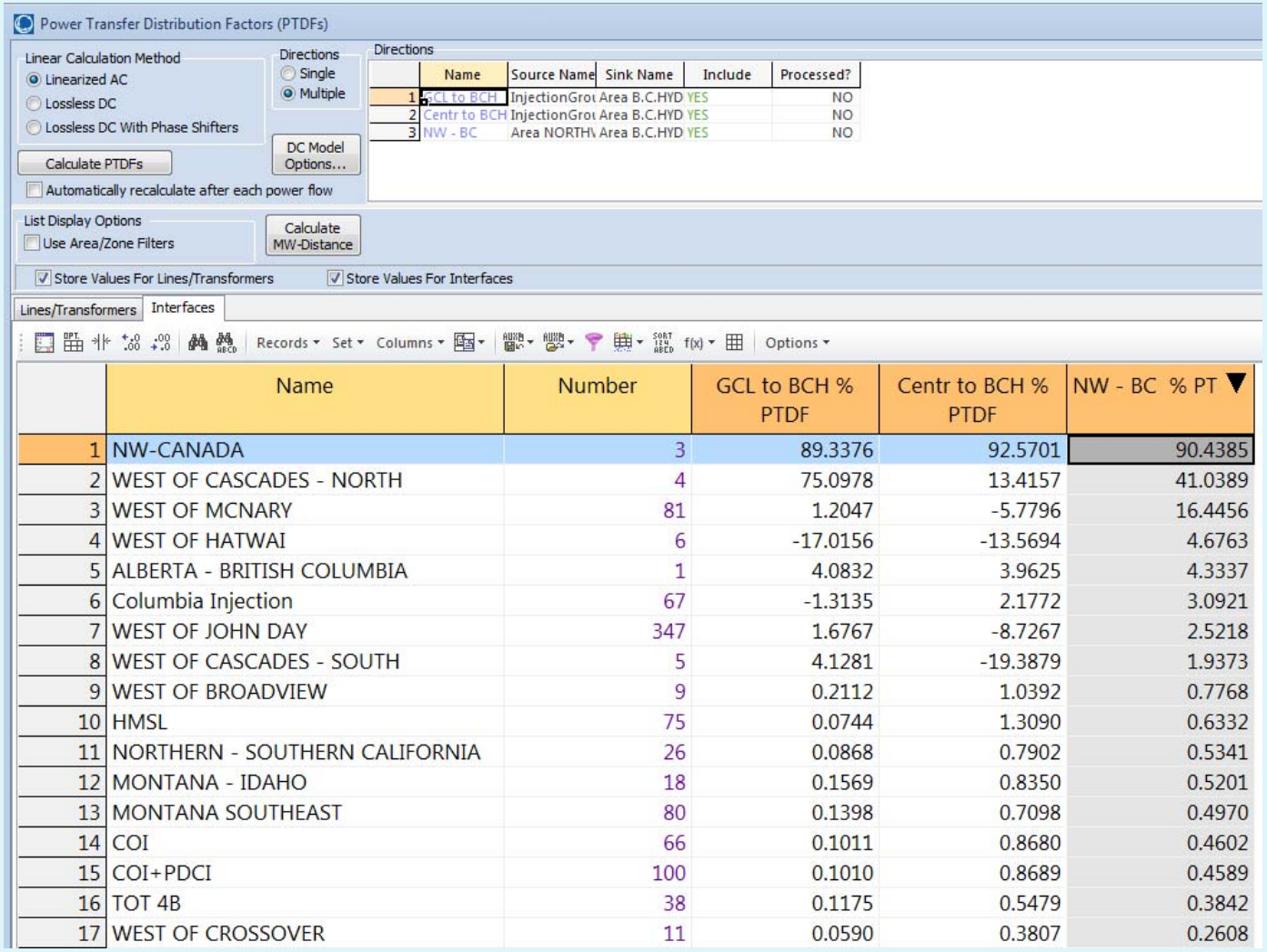


MULTIPLE PTDF's

- Which flowgates or lines are stressed when increasing flows from outside the Puget Sound Area and sinking into BC Hydro?



MULTIPLE PTDF's - EXAMPLE

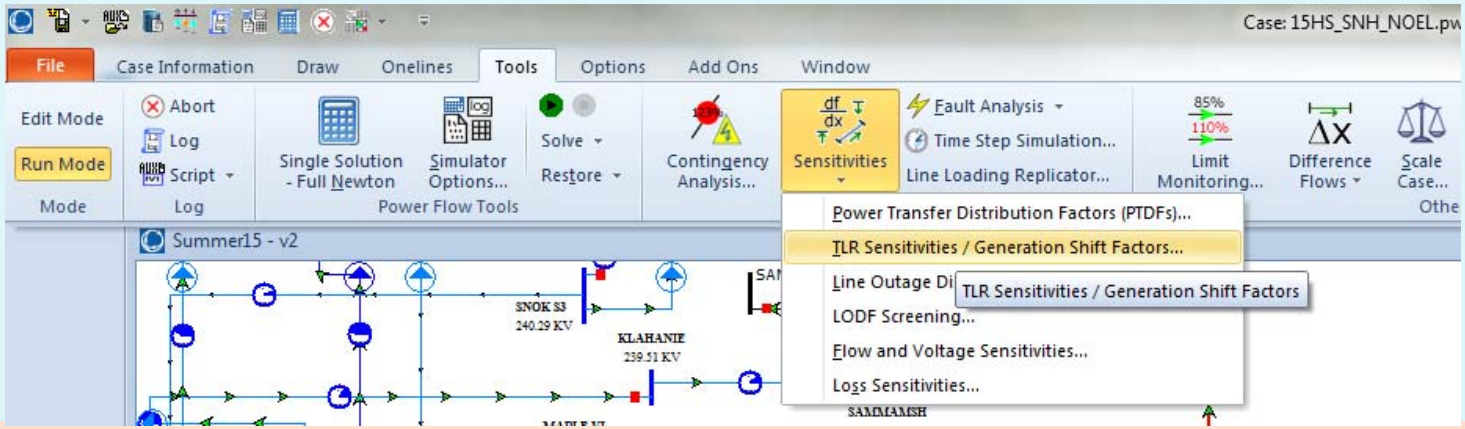


	Name	Number	GCL to BCH % PTDF	Centr to BCH % PTDF	NW - BC % PT
1	NW-CANADA	3	89.3376	92.5701	90.4385
2	WEST OF CASCADES - NORTH	4	75.0978	13.4157	41.0389
3	WEST OF MCNARY	81	1.2047	-5.7796	16.4456
4	WEST OF HATWAI	6	-17.0156	-13.5694	4.6763
5	ALBERTA - BRITISH COLUMBIA	1	4.0832	3.9625	4.3337
6	Columbia Injection	67	-1.3135	2.1772	3.0921
7	WEST OF JOHN DAY	347	1.6767	-8.7267	2.5218
8	WEST OF CASCADES - SOUTH	5	4.1281	-19.3879	1.9373
9	WEST OF BROADVIEW	9	0.2112	1.0392	0.7768
10	HMSL	75	0.0744	1.3090	0.6332
11	NORTHERN - SOUTHERN CALIFORNIA	26	0.0868	0.7902	0.5341
12	MONTANA - IDAHO	18	0.1569	0.8350	0.5201
13	MONTANA SOUTHEAST	80	0.1398	0.7098	0.4970
14	COI	66	0.1011	0.8680	0.4602
15	COI+PDCI	100	0.1010	0.8689	0.4589
16	TOT 4B	38	0.1175	0.5479	0.3842
17	WEST OF CROSSOVER	11	0.0590	0.3807	0.2608

TLR SENSITIVITIES/GEN SHIFT FACTORS

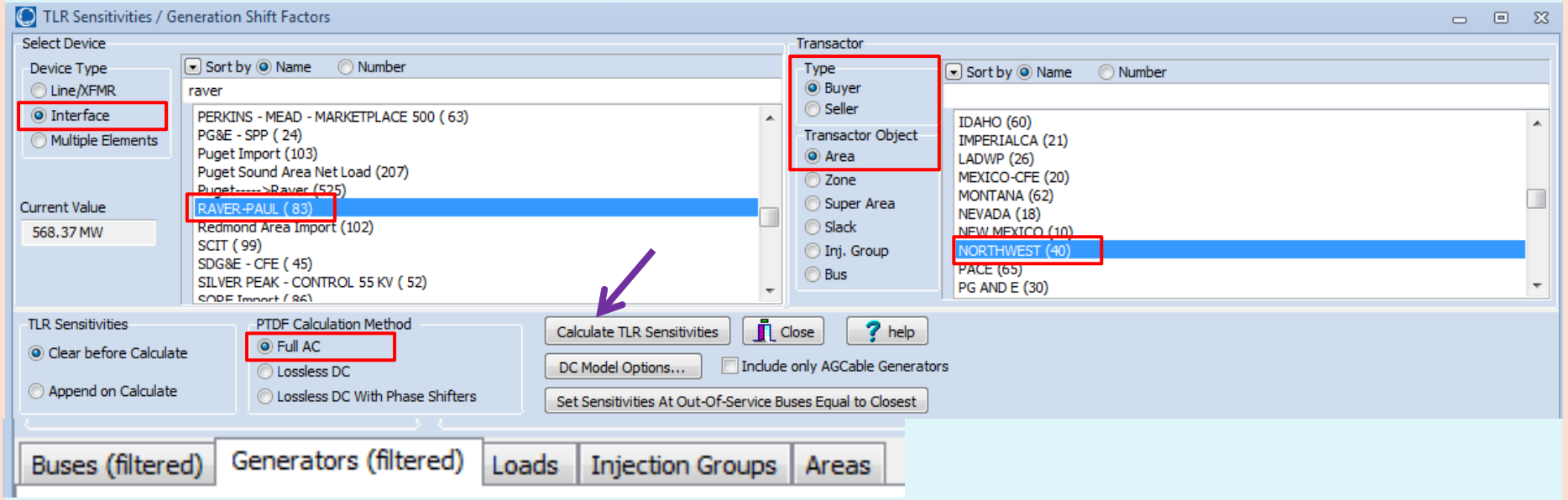
1. Useful in determining which generators have the greatest impact on a specified line or interface
2. Useful to identify which generation or load should be curtailed to mitigate an overloaded line

- **PTDF vs TLR sensitivities…**
  - PTDF's "express the sensitivity of many monitored elements to a single transaction"
  - TLR "gauge the sensititivity of a single monitored element to many different power transfers"

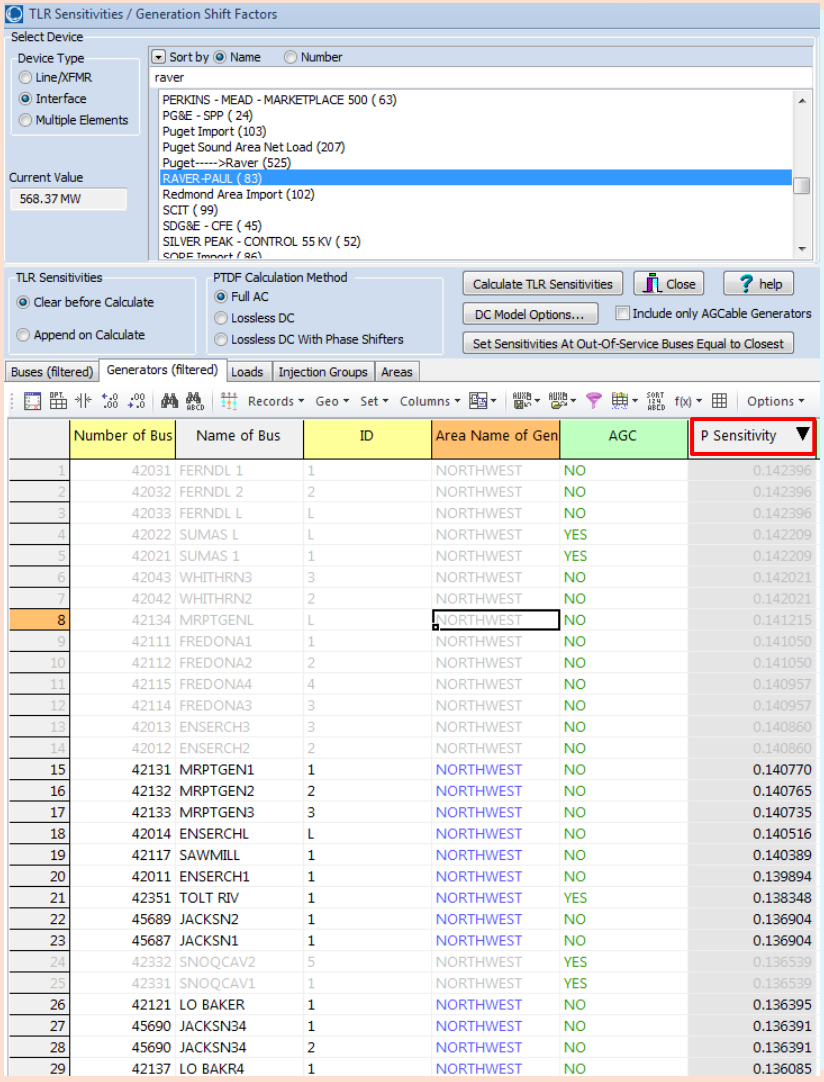


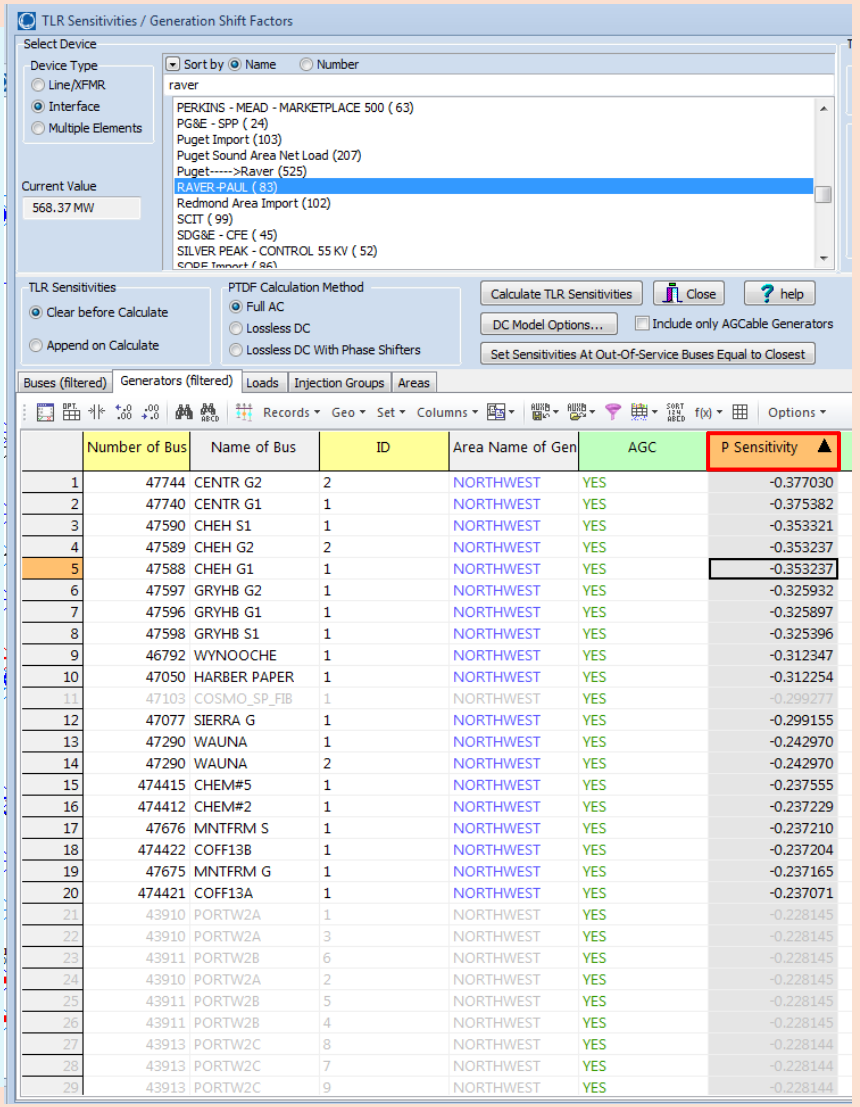
SCENARIO 1: TLR SENSITIVITIES/GEN SHIFT FACTORS

- Which generators have the highest sensitivity in the NW to the Raver-Paul flowgate?



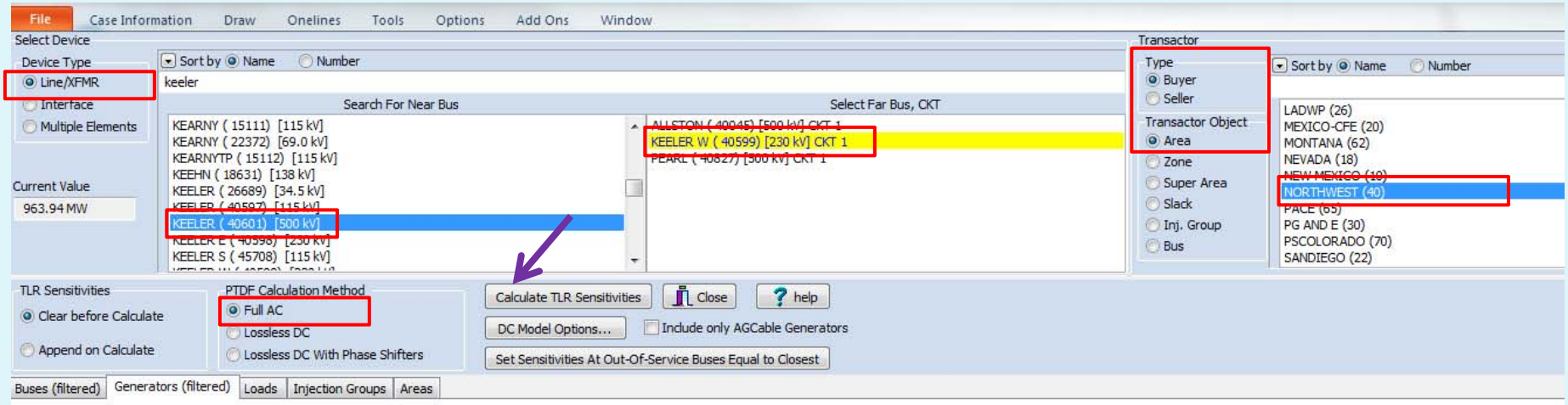
SCENARIO 1: TLR SENSITIVITIES/GEN SHIFT FACTORS

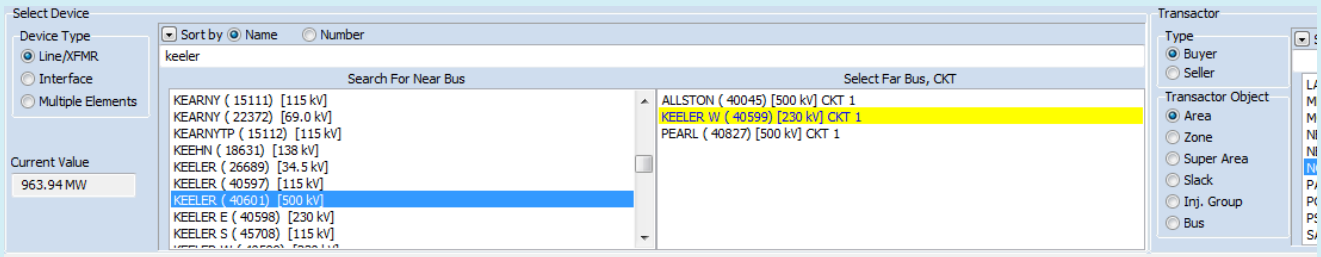




SCENARIO 2: TLR SENSITIVITIES/GEN SHIFT FACTORS

- Which generators contributing above 10% could be curtailed to mitigate an overload on the Keeler 500/230kV bk1 ?



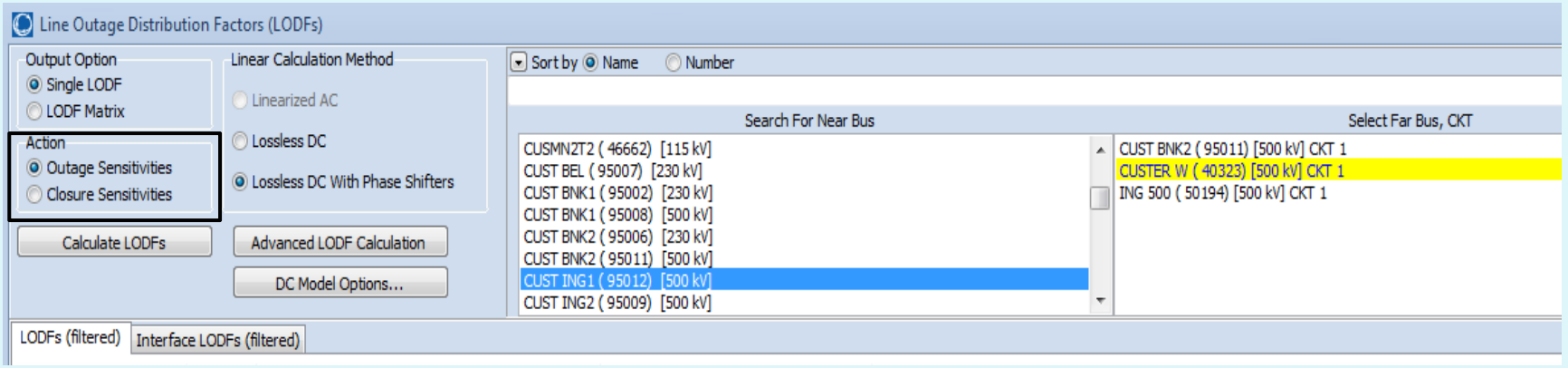


	Number of Bus	Name of Bus	ID	Area Name of Gen	AGC	P Sensitivity	Gen MW
1	47590	CHEH S1	1	NORTHWEST	YES	0.146356	224.4
2	47588	CHEH G1	1	NORTHWEST	YES	0.146318	180.4
3	47589	CHEH G2	2	NORTHWEST	YES	0.146318	180.4
4	47744	CENTR G2	2	NORTHWEST	YES	0.138717	0.0
5	47740	CENTR G1	1	NORTHWEST	YES	0.137111	736.5
6	47596	GRYHB G1	1	NORTHWEST	YES	0.126920	159.3
7	47597	GRYHB G2	1	NORTHWEST	YES	0.126914	159.3
8	47598	GRYHB S1	1	NORTHWEST	YES	0.126571	268.9
9	47050	HARBER PAPER	1	NORTHWEST	YES	0.123763	18.2
10	46792	WYNOOCHE	1	NORTHWEST	YES	0.123614	3.8
11	47290	WAUNA	1	NORTHWEST	YES	0.122417	23.1
12	47290	WAUNA	2	NORTHWEST	YES	0.122417	9.3
13	47103	COSMO_SP_FIB	1	NORTHWEST	YES	0.121013	0.0
14	47077	SIERRA G	1	NORTHWEST	YES	0.120923	9.4
15	474412	CHEM#2	1	NORTHWEST	YES	0.120619	7.8
16	474421	COFF13A	1	NORTHWEST	YES	0.120611	4.9
17	47676	MNTFRM S	1	NORTHWEST	YES	0.120252	90.2
18	474422	COFF13B	1	NORTHWEST	YES	0.120160	14.7
19	47675	MNTFRM G	1	NORTHWEST	YES	0.119766	181.1
20	474415	CHEM#5	1	NORTHWEST	YES	0.119503	37.1
21	40199	CENTRALA	1	NORTHWEST	YES	0.108677	9.8
22	46624	MAYFILD2	2	NORTHWEST	YES	0.100530	38.0
23	46624	MAYFILD2	3	NORTHWEST	YES	0.100530	38.0
24	46624	MAYFILD2	4	NORTHWEST	YES	0.100530	0.0
25	46623	MAYFILD1	1	NORTHWEST	YES	0.100396	38.4
26	46627	MOSSYRK1	1	NORTHWEST	YES	0.100297	148.2
27	46628	MOSSYRK2	2	NORTHWEST	YES	0.100165	144.8
28	40307	COWFALLS	1	NORTHWEST	YES	0.100009	23.9
29	40307	COWFALLS	2	NORTHWEST	YES	0.100009	23.9
30	47047	GLENOMA	1	NORTHWEST	YES	0.099370	29.3

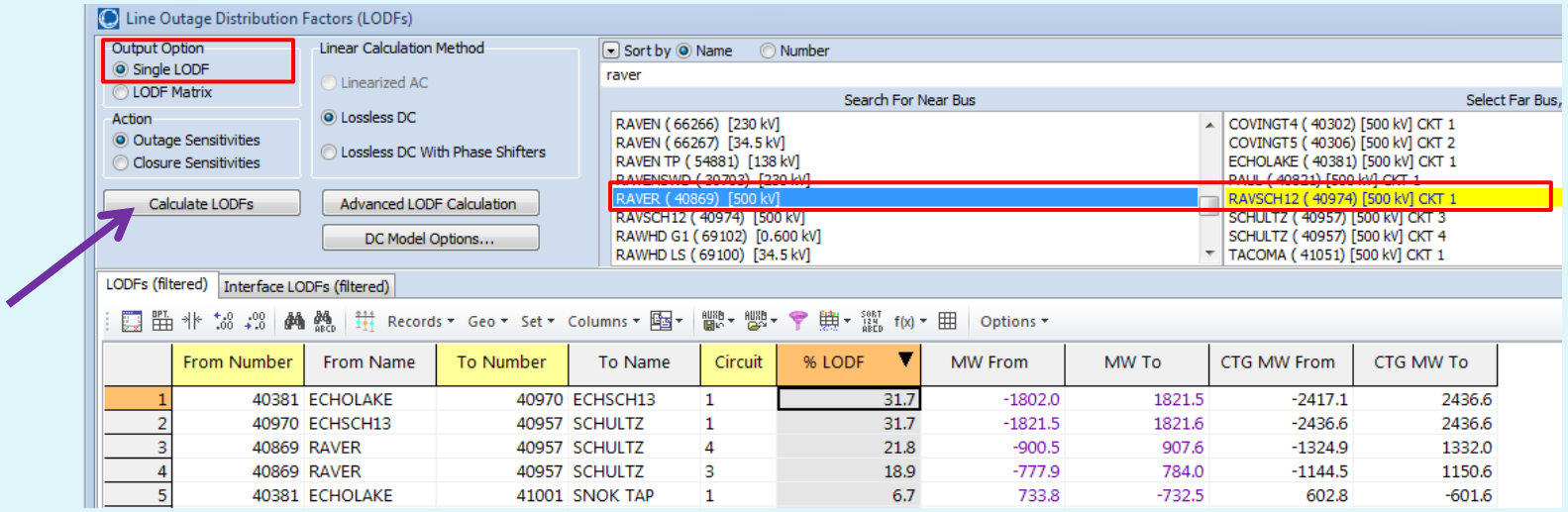
LODF's – *LINE OUTAGE DISTRIBUTION FACTOR*

1. Useful in determining the impact of a outage on other lines or interfaces etc.

2. Useful in determining the impact of energizing an outage and the impacts to the surrounding network
   - LCDF – Line Closure Distribution Factor
   - MUST HAVE THE ACTUAL LINE'S **STATUS = OPEN**



SCENARIO 1: LODF's

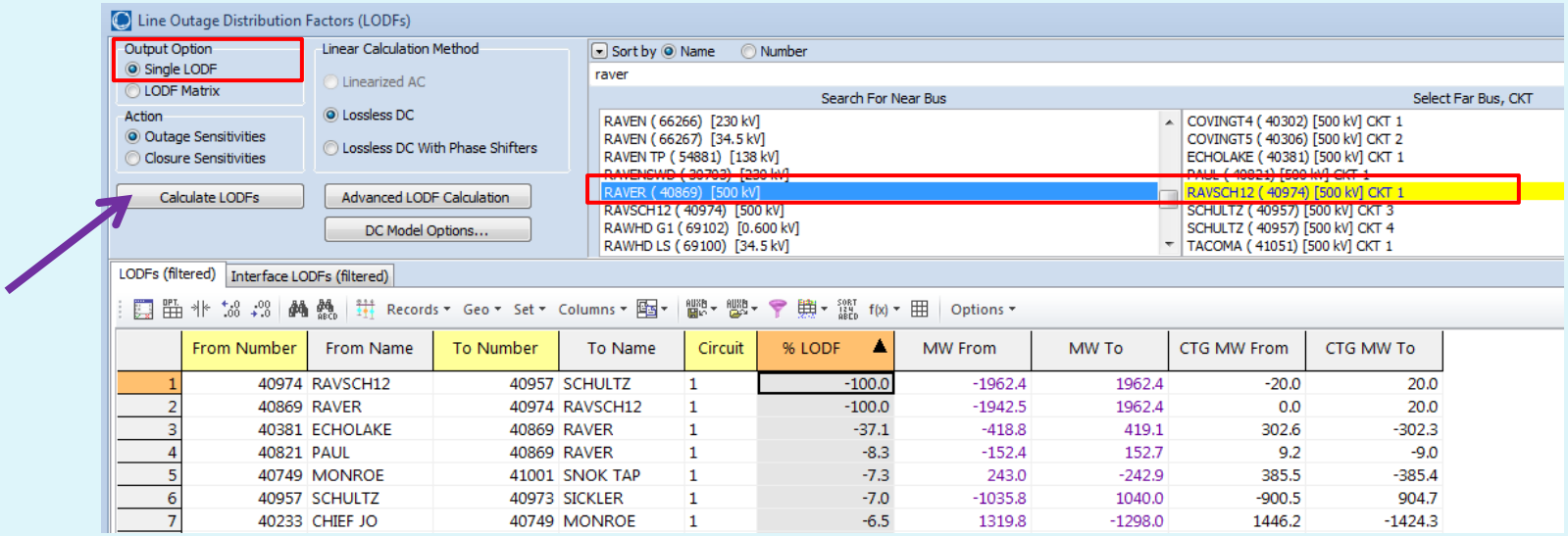


	From Number	From Name	To Number	To Name	Circuit	% LODF	MW From	MW To	CTG MW From	CTG MW To
1	40381	ECHOLAKE	40970	ECHSCH13	1	31.7	-1802.0	1821.5	-2417.1	2436.6
2	40970	ECHSCH13	40957	SCHULTZ	1	31.7	-1821.5	1821.6	-2436.6	2436.6
3	40869	RAVER	40957	SCHULTZ	4	21.8	-900.5	907.6	-1324.9	1332.0
4	40869	RAVER	40957	SCHULTZ	3	18.9	-777.9	784.0	-1144.5	1150.6
5	40381	ECHOLAKE	41001	SNOK TAP	1	6.7	733.8	-732.5	602.8	-601.6

- If there is an outage of the Raver-Schultz #1 500kV line…. The Schultz-EchoLake #1 500kV line will increase to:

1821.5 MW * 31.7% = 2398.9 MW

SCENARIO 1: LODF's



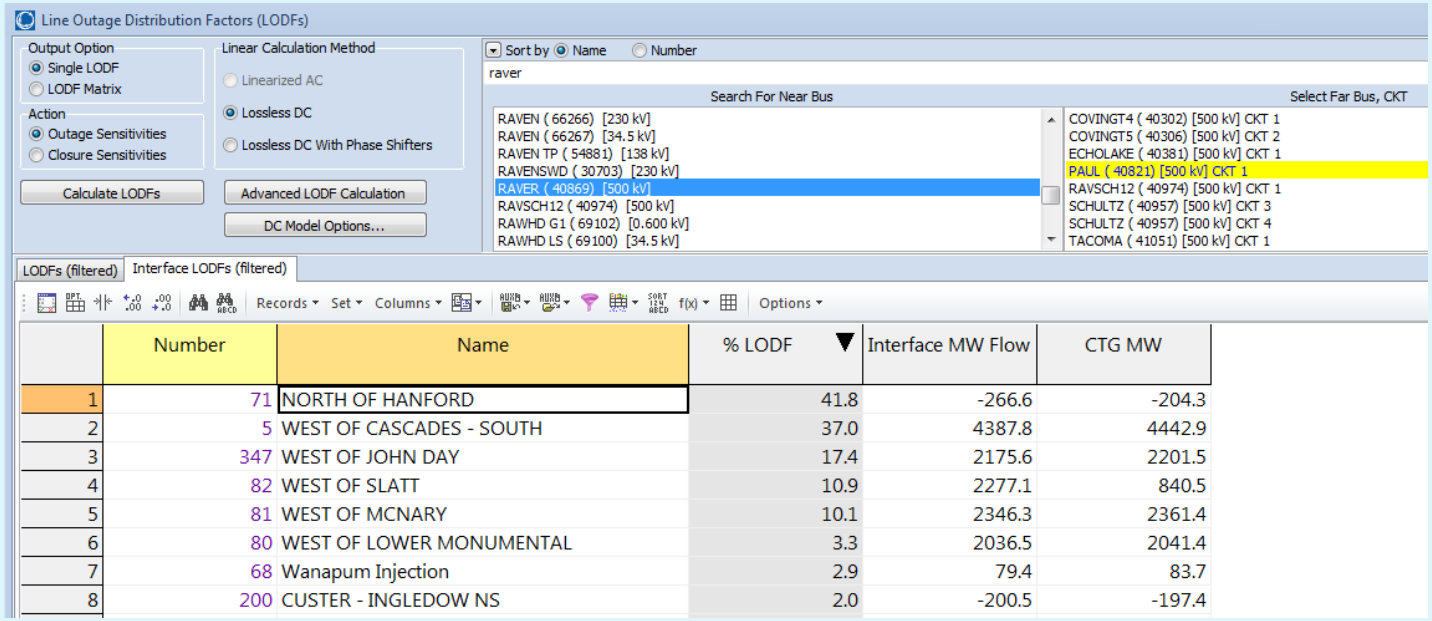
	From Number	From Name	To Number	To Name	Circuit	% LODF	MW From	MW To	CTG MW From	CTG MW To
1	40974	RAVSCH12	40957	SCHULTZ	1	-100.0	-1962.4	1962.4	-20.0	20.0
2	40869	RAVER	40974	RAVSCH12	1	-100.0	-1942.5	1962.4	0.0	20.0
3	40381	ECHOLAKE	40869	RAVER	1	-37.1	-418.8	419.1	302.6	-302.3
4	40821	PAUL	40869	RAVER	1	-8.3	-152.4	152.7	9.2	-9.0
5	40749	MONROE	41001	SNOK TAP	1	-7.3	243.0	-242.9	385.5	-385.4
6	40957	SCHULTZ	40973	SICKLER	1	-7.0	-1035.8	1040.0	-900.5	904.7
7	40233	CHIEF JO	40749	MONROE	1	-6.5	1319.8	-1298.0	1446.2	-1424.3

- If there is an outage of the Raver-Schultz #1 500kV line…. The Raver-EchoLake #1 500kV line will decrease to:

*419.1 MW * (- 37.1%) = 263.6 MW*

SCENARIO 1: LODF's

- An outage of the Raver-Paul 500kV line will increase loading on which interfaces?

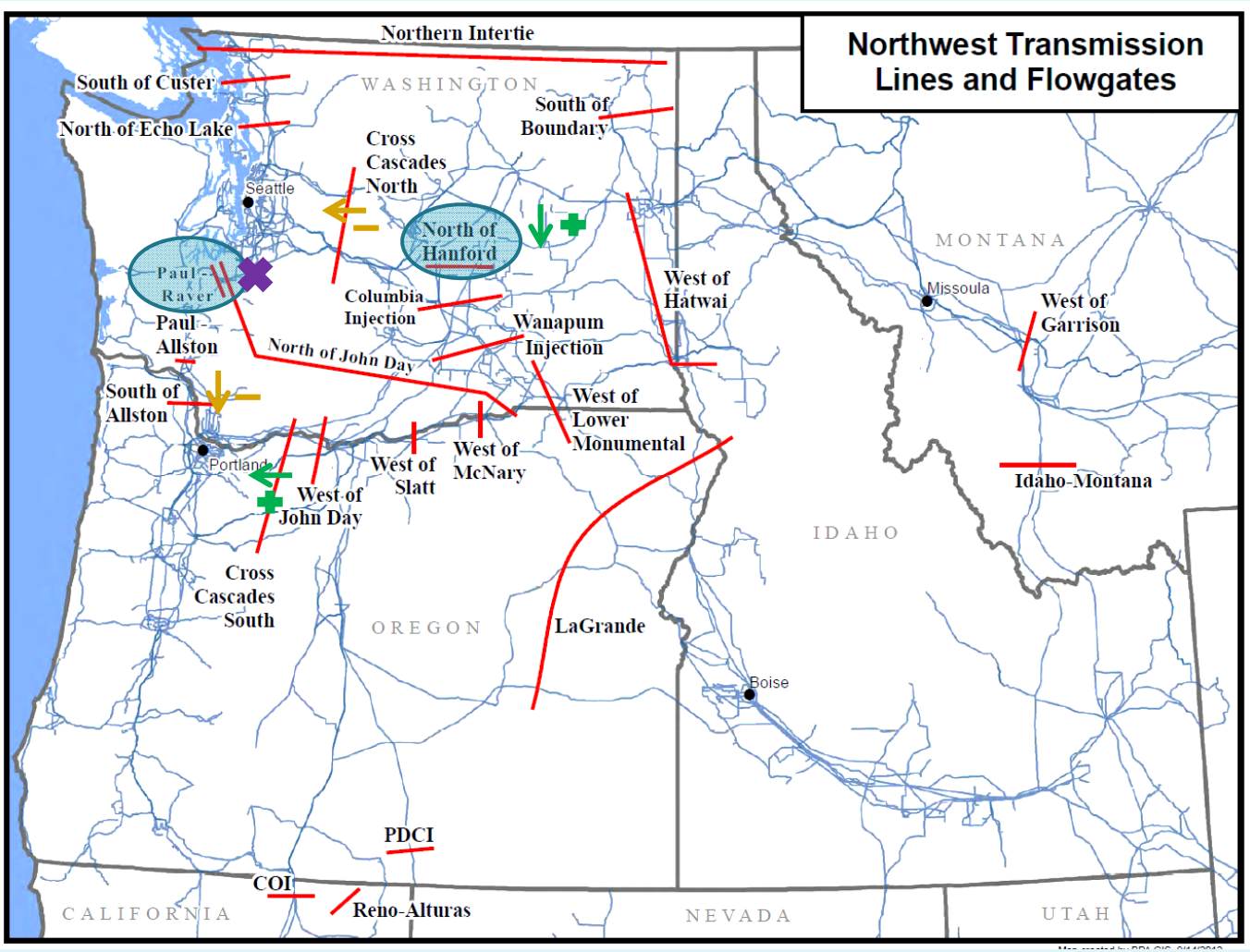


	Number	Name	% LODF	Interface MW Flow	CTG MW
1	71	NORTH OF HANFORD	41.8	-266.6	-204.3
2	5	WEST OF CASCADES - SOUTH	37.0	4387.8	4442.9
3	347	WEST OF JOHN DAY	17.4	2175.6	2201.5
4	82	WEST OF SLATT	10.9	2277.1	840.5
5	81	WEST OF MCNARY	10.1	2346.3	2361.4
6	80	WEST OF LOWER MONUMENTAL	3.3	2036.5	2041.4
7	68	Wanapum Injection	2.9	79.4	83.7
8	200	CUSTER - INGLEDOW NS	2.0	-200.5	-197.4

- Loading on the North of Hanford flowgate will increase by 41.8%

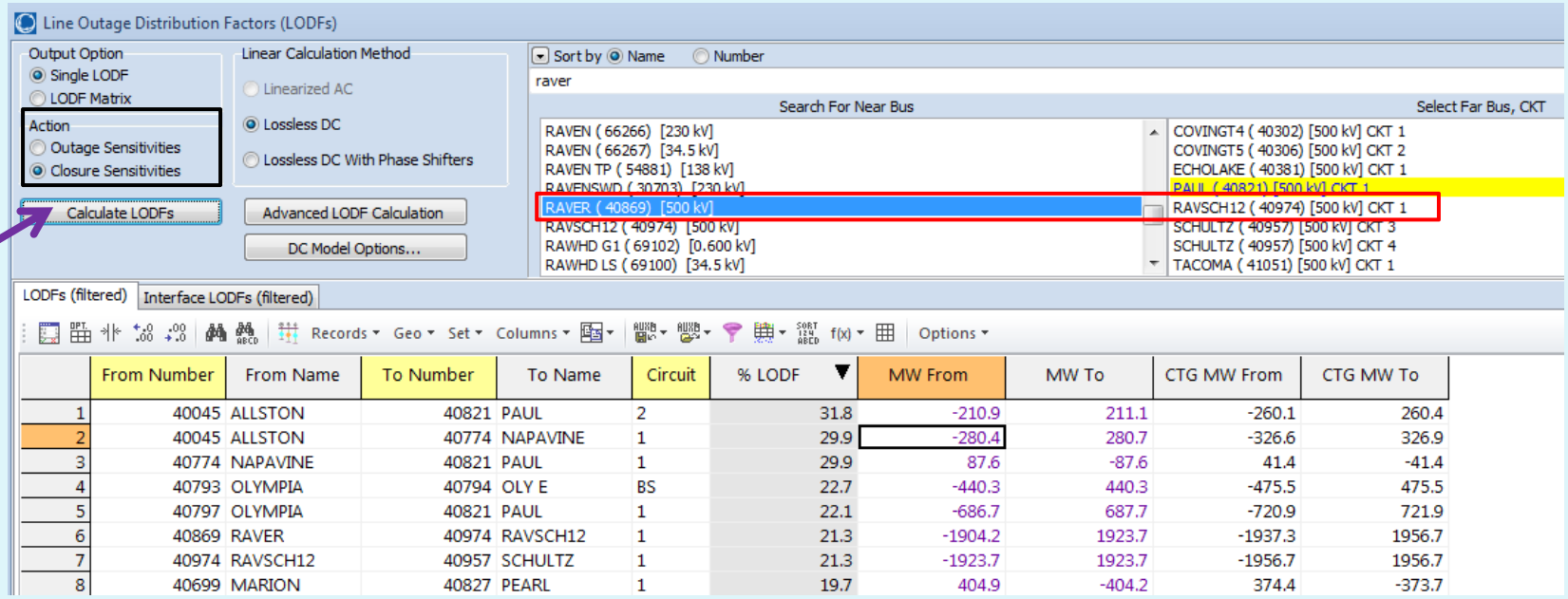
*NOH = -266.6 MW * 41.8% = 378 MW*

SCENARIO 1: LODF's



SCENARIO 2: LCDF's

- *The Raver-Paul 500kV line is out of service*. What is the impact to the surrounding network of closing the line in service?



	From Number	From Name	To Number	To Name	Circuit	% LODF	MW From	MW To	CTG MW From	CTG MW To
1	40045	ALLSTON	40821	PAUL	2	31.8	-210.9	211.1	-260.1	260.4
2	40045	ALLSTON	40774	NAPAVINE	1	29.9	-280.4	280.7	-326.6	326.9
3	40774	NAPAVINE	40821	PAUL	1	29.9	87.6	-87.6	41.4	-41.4
4	40793	OLYMPIA	40794	OLY E	BS	22.7	-440.3	440.3	-475.5	475.5
5	40797	OLYMPIA	40821	PAUL	1	22.1	-686.7	687.7	-720.9	721.9
6	40869	RAVER	40974	RAVSCH12	1	21.3	-1904.2	1923.7	-1937.3	1956.7
7	40974	RAVSCH12	40957	SCHULTZ	1	21.3	-1923.7	1923.7	-1956.7	1956.7
8	40699	MARION	40827	PEARL	1	19.7	404.9	-404.2	374.4	-373.7

FLOW AND VOLTAGE SENSITIVITIES

- *Generally, these sensitivities observe the change in voltage due to a change in P or Q from a particular device etc.*
- Single METER, multiple TRANSFERS
  - "Shows the effect of an additional injection of *real* or *reactive* power at a bus has on various parameters."

    DEVICE TYPE:
    - *Line/XFMR*
    - *Inteface*
    - *Bus*
    - *Generator*

- Single TRANSFER, multiple METERS
  - "Shows the effect of a single transfer of real or reactive power on all voltages in the system"

FLOW AND VOLTAGE SENSITIVITIES

- Self Sensitivity
  - "Shows the effect of an injection of real or reactive power at a bus on its own voltage." Each bus is process for its own self sensitivity.

- Multiple METERS, single CONTROL CHANGE
  - "Shows the impact on various quantities to a change in a control setpoint in the system"

    CONTROL TYPE:
    - *Gen Voltage setpoint*
    - *Transformer Tap Ratio*
    - *Phase Shifter phase shift*
    - *Switched Shunt nominal MVAR*
    - *Line Impedance Xinj*

FLOW AND VOLTAGE SENSITIVITIES

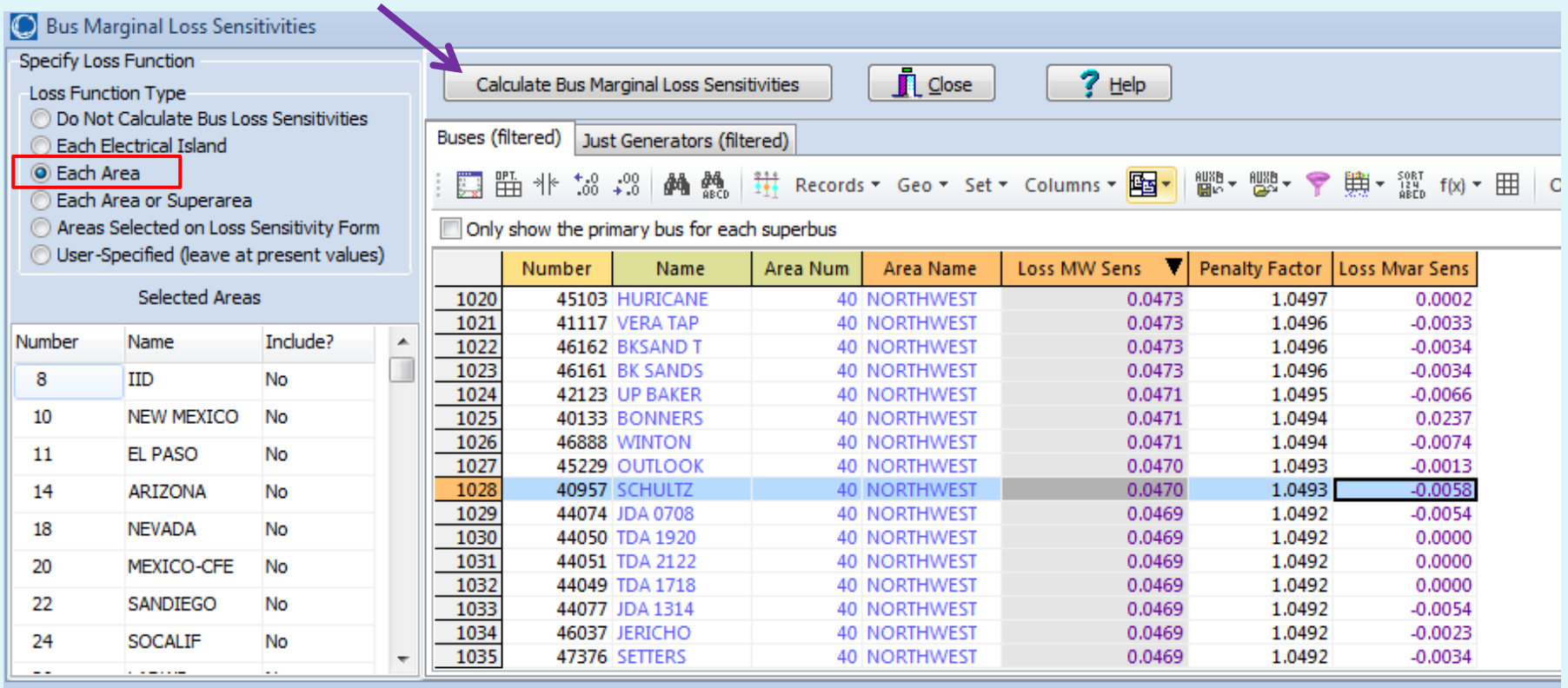
- Multiple METERS, multiple CONTROL CHANGE
  - "Shows the impact on a specific field for each device type to change in a control setpoint in the system"

    CONTROL TYPE:
    - *Gen Voltage setpoint*
    - *Transformer Tap Ratio*
    - *Phase Shifter phase shift*
    - *Switched Shunt nominal MVAR*
    - *Line Impedance Xinj*

LOSS SENSITIVITIES

- "shows how losses would change if one or more MW or MVAR of power were injected at a bus"

  Loss Function:

  - *Each Electrical Island* – Losses with respect to buses in an island
  - *Each Area* – Losses with respect to buses in an area
  - *Each Area or Super Area* – Loses with respect to the total losses for a bus in a super area
  - *Areas selected* – Loses with respect to the total losses of a bus in a group of areas.
  - *User Specified* – Saves the sensitivities of the last losses calculation to be constant when used with other PW tools.

LOSS SENSITIVITIES