Sheffield-Highgate Export Interface

SHEI

vermont electric power company

VELCO

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VELCO Northern Vermont Export Study

- Purpose: Provide information to enable VELCO and DUs to evaluate all potential “transmission” solutions
  - Reactive support, transmission, subtransmission, and battery storage
    - Will analyze individual solutions and combinations of solutions
  - Consultant’s analysis to provide basis for costing of options
    - VELCO will estimate the cost of the transmission, synchronous condenser and battery options
    - The distribution utilities (DUs) will estimate the other options

System conditions tested

- Vermont load at 700 MW
- All-lines-in condition
- Five representative outages
  - The Essex STATCOM
  - Transmission line outside the SHEI area
  - Transmission line inside the SHEI area
  - Stowe 115/34.5 kV transformer
  - The 3317 34.5 kV line
- Trip 34.5 kV lines when they are overloaded

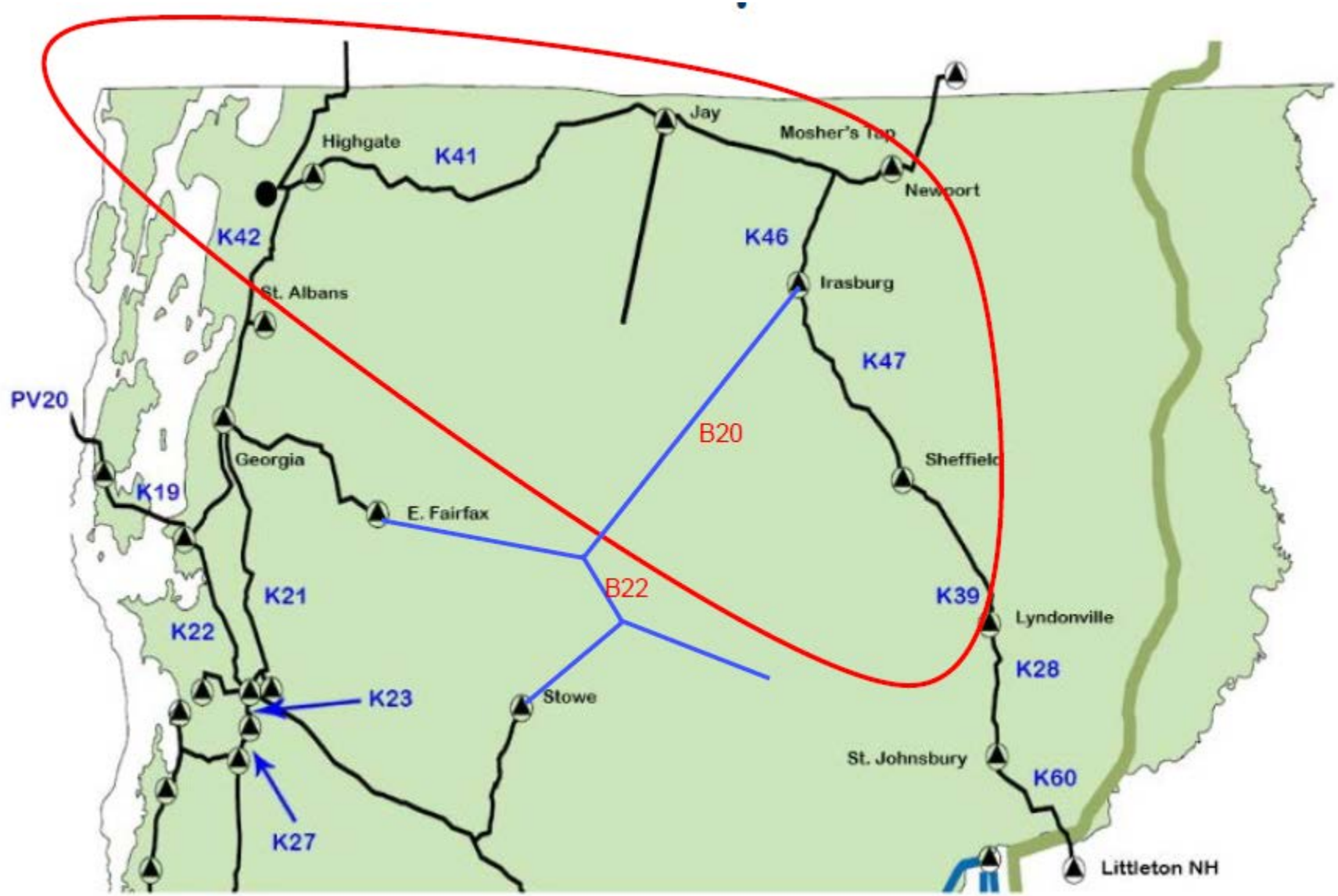
Power flow study approach

- Determine the voltage limit
  - Increase generation and Highgate imports until voltage limit is reached
    - Trip 34.5 kV lines when they are overloaded
    - Avoid tripping 34.5 kV lines when that would cause a voltage collapse
      - Voltages can be above acceptable levels in these cases
  - Reduce SHEI load if the voltage limit is not reached with max generation
    - This happens for the most robust options
    - The voltage limit is not reached in the two cases modeling new transmission lines from Irasburg
- Determine the thermal limit for the all-lines-in case and the Essex-out case
  - The K42 line does not overload in the transmission line outage cases
  - Ignore 115 kV line overloads south of Georgia and Sand Bar
    - Assuming that they can be addressed by reducing PV20 flows from NY

Notes

- MW export limit results should only be used to calculate the incremental benefit of each case/scenario
  - ISO-NE is responsible for determining system limits
  - There may be differences in assumptions from ISO-NE cases
    - Essex STATCOM, capacitor bank dispatch, load distribution, tie flows
  - Case 0 results are the benchmarks within each column of results
- Voltage limits are based on low voltage at Highgate or St Albans 115 kV
- Thermal limits are based on overloads on K42, B20 or B22
  - B20 overloads when not upgraded
  - B22 overloads when the B20 line is upgraded

The Sheffield-Highgate Export Interface (SHEI)



Initial study scope

		Cases																	
Options	Description	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Reconductor the B20 34.5 kV line and upgrade the Lowell 46/34.5 kV transformer		X	X	X	X	X	X	X	X	X	X	X	X	X					
2	Enable the Sheffield AVR			X			X	X		X	X	X	X	X	X	X	X	X	X	X
3	Recognize the Jay synchronous condenser 1.15 service factor				X		X		X	X	X	X	X	X	X	X	X	X	X	X
4	Enable the Sheldon Springs AVR					X		X	X	X	X	X	X	X	X	X	X	X	X	X
5	Install a 15MVAr synchronous condenser at Highgate 115 kV										X								X	
6	Reconductor K42 Highgate-St Albans 115 kV line											X								X
7	Install a 2nd 115 kV line alongside K39												X							
8	Install a 15 MVA battery storage at Highgate 115 kV													X						
9	Reconductor K41 Highgate-Jay 115 kV line														X					
10	Install a new Irasburg to Stowe 115 kV line															X				
11	Install a new Irasburg to East Fairfax 115 kV line																X			

MW Export limits with all lines in

Cases	Upgrades	Voltage	Thermal
0	None	400	395
1	B20	435	409
2	B20+Shef	440	409
3	B20+JaySC	435	409
4	B20+ShSprAVR	447	409
5	B20+Shef+JaySC	442	409
6	B20+Shef+ShSpr	463	409
7	B20+JaySC+ShSpr	453	409
8	B20+Shef+Jay+ShSpr	470	409
9	B20+Shef+Jay+ShSpr+HSC	481	413
10	B20+Shef+Jay+ShSpr+K42-2	476	444
11	B20+Shef+Jay+ShSpr+K39P	481	420
12	B20+Shef+Jay+ShSpr+HBESS (16MW/12 MVAR)	492	430
13	B20+Shef+Jay+ShSpr+K41	474	412
14	Shef+Jay+ShSpr+IraStowe&3312	503	468
15	Shef+Jay+ShSpr+IraEF	500	459
16	Shef+Jay+ShSpr	448	397
17	Shef+Jay+ShSpr+HSC	465	397
18	Shef+Jay+ShSpr+K42-2	455	397

The battery system consists of four 4 MW units with inverters capable of delivering a total of 3 MVAr of reactive support for each unit

MW Export limits with the Essex STATCOM out

Cases	Upgrades	Voltage	Thermal
0	None	379	379
1	B20	393	394
2	B20+Shef	411	402
3	B20+JaySC	396	396
4	B20+ShSprAVR	414	406
5	B20+Shef+JaySC	410	402
6	B20+Shef+ShSpr	418	406
7	B20+JaySC+ShSpr	415	406
8	B20+Shef+Jay+ShSpr	428	407
9	B20+Shef+Jay+ShSpr+HSC	441	411
10	B20+Shef+Jay+ShSpr+K42-2	432	430
11	B20+Shef+Jay+ShSpr+K39P	448	416
12	B20+Shef+Jay+ShSpr+HBESS (16MW/12 MVAR)	450	425
13	B20+Shef+Jay+ShSpr+K41	434	408
14	Shef+Jay+ShSpr+IraStowe&3312	464	468
15	Shef+Jay+ShSpr+IraEF	489	454
16	Shef+Jay+ShSpr	393	394
17	Shef+Jay+ShSpr+HSC	419	394
18	Shef+Jay+ShSpr+K42-2	404	394

The battery system consists of four 4 MW units with inverters capable of delivering a total of 3 MVAr of reactive support for each unit

MW Voltage export limits with other outages

Cases	Upgrades	Line inside SHEI	Line outside SHEI	Stowe 115/34.5 kV transformer	3317 (Marshfield Plainfield)
0	None	253	367	399	410
1	B20	260	371	440	450
2	B20+Shef	285	371	448	458
3	B20+JaySC	274	371	440	453
4	B20+ShSprAVR	282	371	448	456
5	B20+Shef+JaySC	285	374	448	458
6	B20+Shef+ShSpr	285	375	450	458
7	B20+JaySC+ShSpr	282	375	446	458
8	B20+Shef+Jay+ShSpr	285	387	452	460
9	B20+Shef+Jay+ShSpr+HSC	285	411	472	480
10	B20+Shef+Jay+ShSpr+K42-2	285	392	464	474
11	B20+Shef+Jay+ShSpr+K39P	285	401	467	474
12	B20+Shef+Jay+ShSpr+HBESS (16MW/12 MVAR)	315	421	476	484
13	B20+Shef+Jay+ShSpr+K41	285	398	457	472
14	Shef+Jay+ShSpr+IraStowe&3312	459	455	501	504
15	Shef+Jay+ShSpr+IraEF	458	447	500	500
16	Shef+Jay+ShSpr	275	371	439	441
17	Shef+Jay+ShSpr+HSC	275	407	456	466
18	Shef+Jay+ShSpr+K42-2	276	384	448	453

The battery system consists of four 4 MW units with inverters capable of delivering a total of 3 MVAr of reactive support for each unit

Observations

- The voltage and thermal limits are essentially equal in the existing system
  - Coincident overloads on the K42 and B20 lines as well as low voltage
- System performance affected by capacitor bank dispatch
- The B20 and battery options address both the thermal and voltage limits
- Thermal limit improved by
  - The new and reconductored transmission lines and the B20 upgrade
  - Options providing strong reactive support also increase thermal limits
- Voltage limit improved by
  - Reactive support upgrades
  - The new transmission lines and the B20 upgrade

Observations

- Cases 14 and 15 that model new transmission lines provide long term benefit
  - The actual voltage limit is higher than could be modeled
  - The thermal limit is based on a K42 line overload
- B20 thermal benefit is limited by the K42 and B22 overloads
- Case 9 that models the Highgate SC provide significant voltage support, particularly under facility-out conditions
  - Case 12 that models the Highgate battery performs better than case 9 because the battery absorbs real power while injecting reactive power
- A review of these results led us to test other options and combinations around:
  - The B20 line, the K42 line, the Highgate SC and the battery

Additional cases to be tested

		Cases																	
Options	Description	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1	Reconductor B20 34.5 kV line and upgrade Lowell 46/34.5 kV transformer				X	X	X			X	X				X				X	
2	Enable the Sheffield AVR	X		X		X	X			X		X							X	
3	Jay synch condenser 1.15 service factor									X									X	
4	Enable the Sheldon Springs AVR		X	X		X	X			X			X						X	
5	Install a 15MVAr synchronous condenser at Highgate 115 kV													X	X					X
6	Reconductor K42 Highgate-St Albans 115 kV line										X	X	X	X	X	X	X	X		
7	Install a 2nd K39 115 kV line																			
8	15 MVA battery at Highgate 115 kV							X								X				
9	Reconductor K41 Highgate-Jay 115 kV line																			
10	New Irasburg to Stowe 115 kV line																	X		
11	New Irasburg to East Fairfax 115 kV line																			
12	Close the Lowell C53 switch				X	X	X													
13	Close the Richford 14W switch and reconductor Richford-Highgate 46kV						X													
14	15 MVA battery at Sheffield 115 kV								X	X							X			
15	Install a 2nd K42 115 kV line																		X	X

Proposed next steps

- The additional scope will add about one month to the study
  - Report by end of September
  - Economic evaluation by November
- VELCO
  - Complete study including Transmission option cost estimates (lines, battery, SC)
  - Share results with stakeholders
  - Further assistance as requested by DUs
  - Evaluate T&D study cost options
- DUs “own” further analysis
  - Estimate subtransmission and the other options
  - Non-wires alternatives
  - Economic evaluation of solutions
  - Solution selection
  - Regulatory process (VELCO testimony as needed)