CONVERSATORIO :

Junio 10

Sistemas HVDC

SESIÓN 2 :
Operación e impacto de Sistemas HVDC en redes existentes

High-Voltage dc Conversion Boosting Transmission Capacity in the Grid

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Un evento: cigre Colombia | Universidad Pontificia Bolivariana 50 años Ingeniería Electrónica 70 años Ingeniería Eléctrica | isa CONEXIONES QUE INSPIRAN

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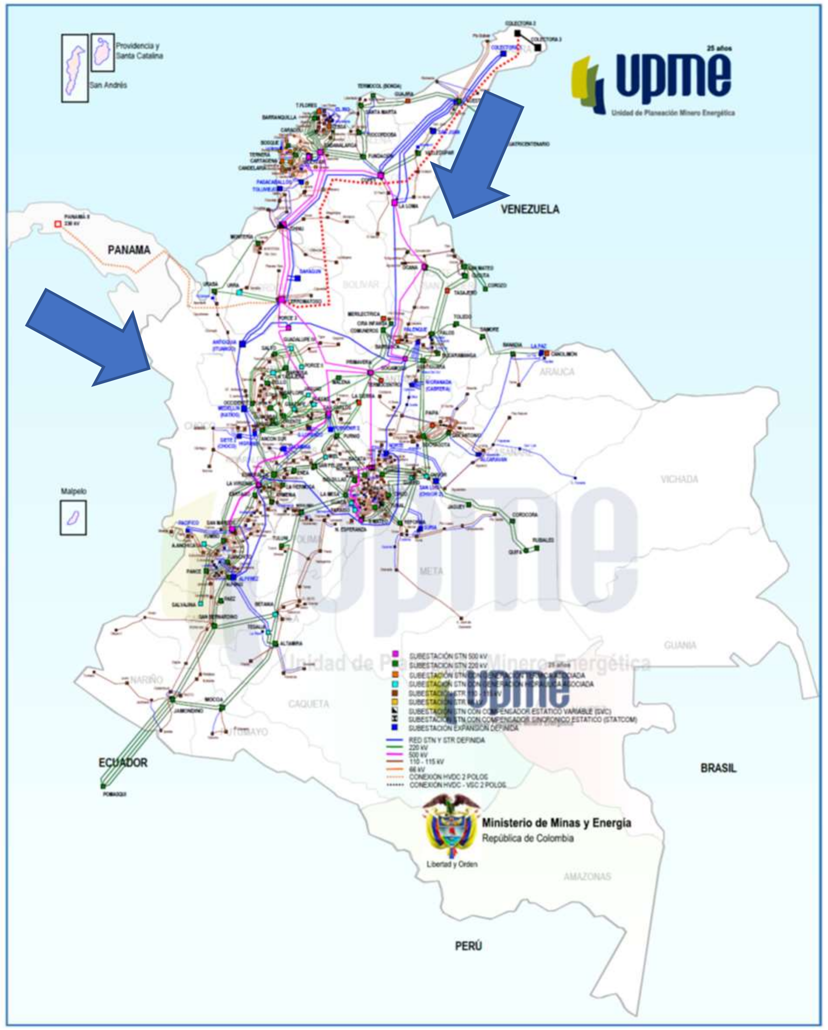
Need for Bulk Transmission Capacity

- Grid-scale solar and wind typically located far from loads
- Difficulty securing new Rights-of-Way
  - Project Identification
  - Permitting
  - Construction schedule



Advantages of AC to DC conversion

- Increase in thermal limits
- Increase in power transmission System Operating Limits (SOL)
- Power flow control and stability enhancing functions
- Relatively short outages if properly planned

Ref.: GCCIA Interconnection

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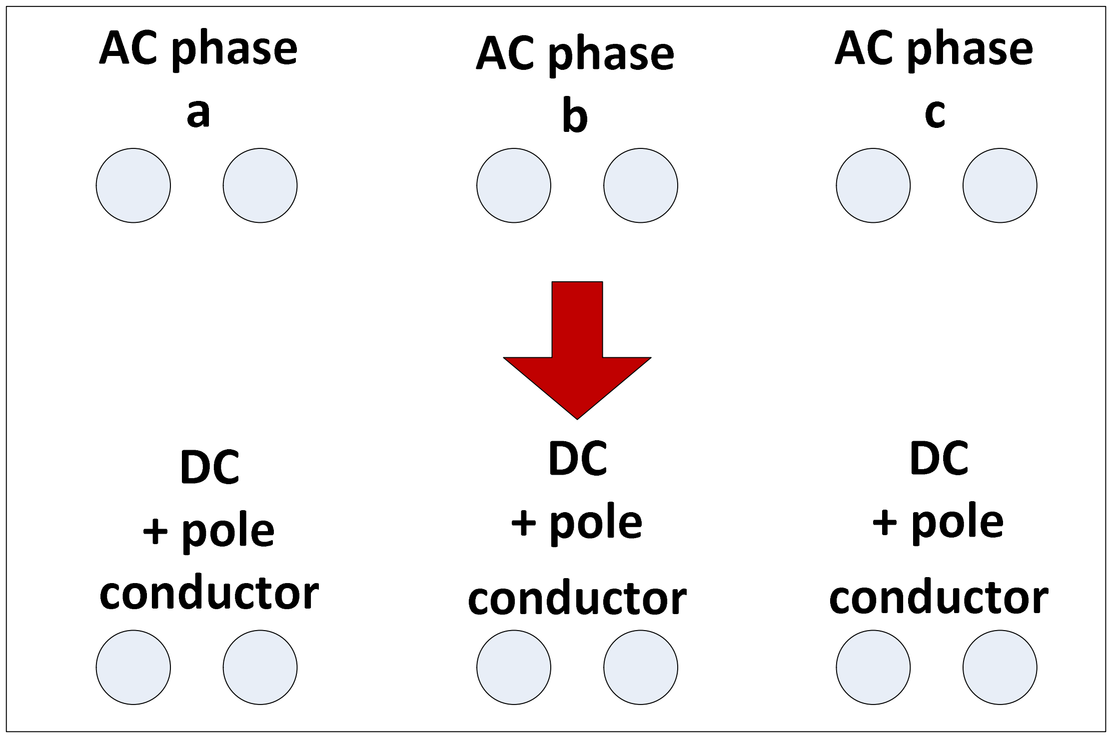
Criteria to Reduce Cost and Outage Time

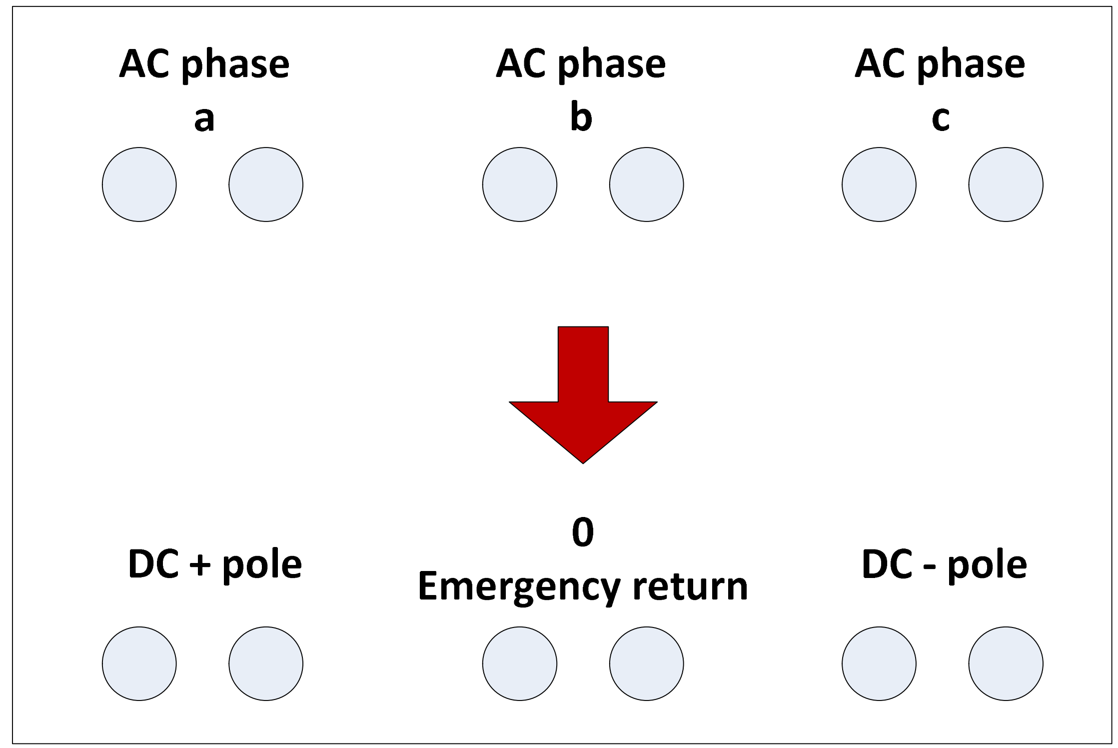
- Use of the existing conductors
- Structures and clearances unchanged
- Locate converter stations close to AC yards

Pole configurations

Single circuit AC line to HVDC monopole

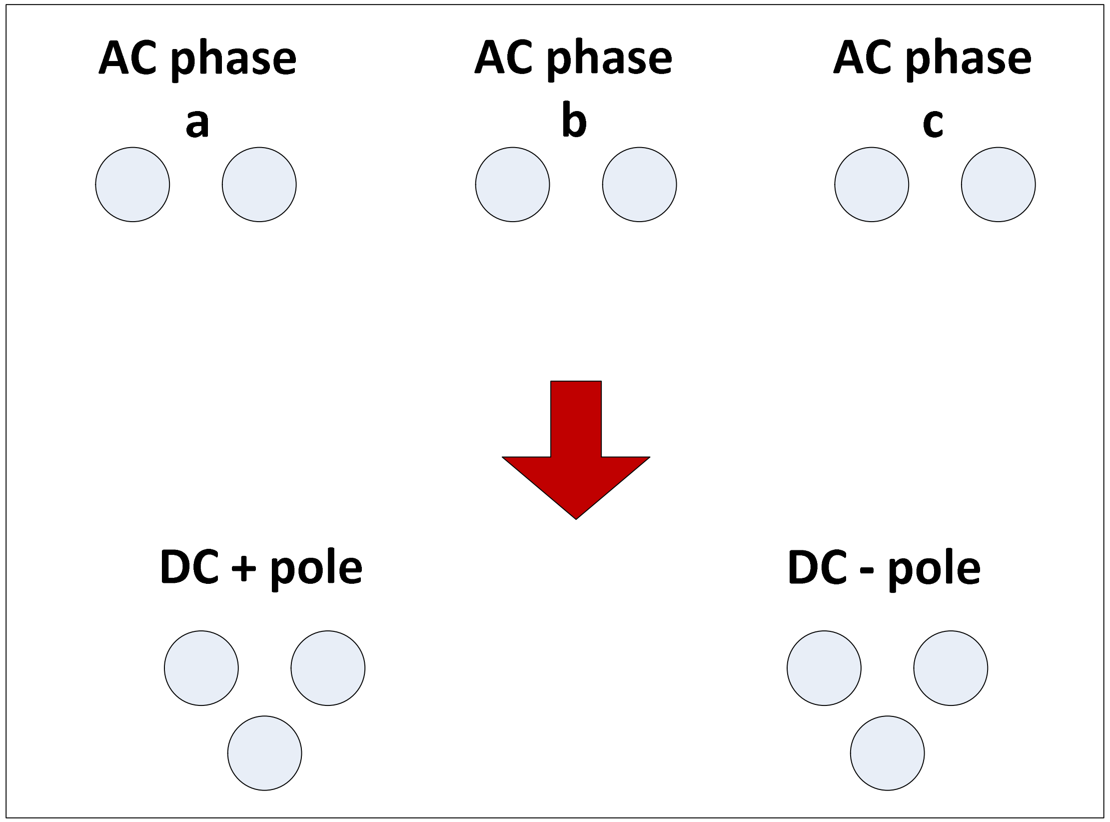


Single circuit AC line to floating HVDC monopole or bipole

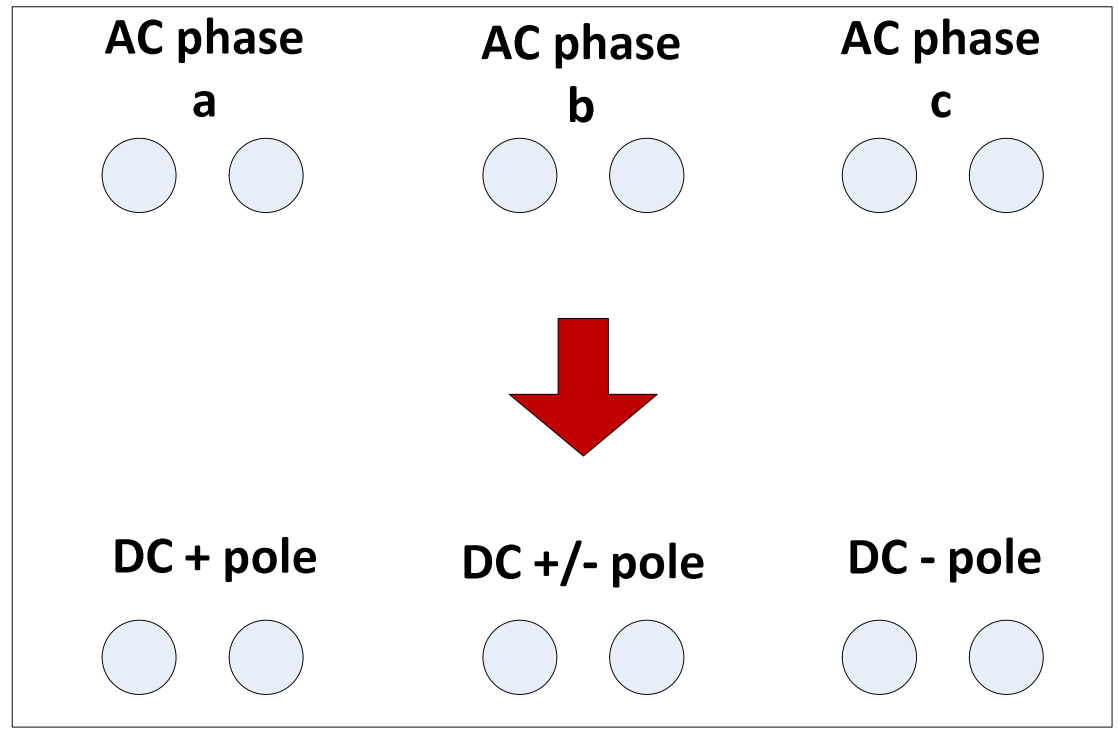


Pole configurations

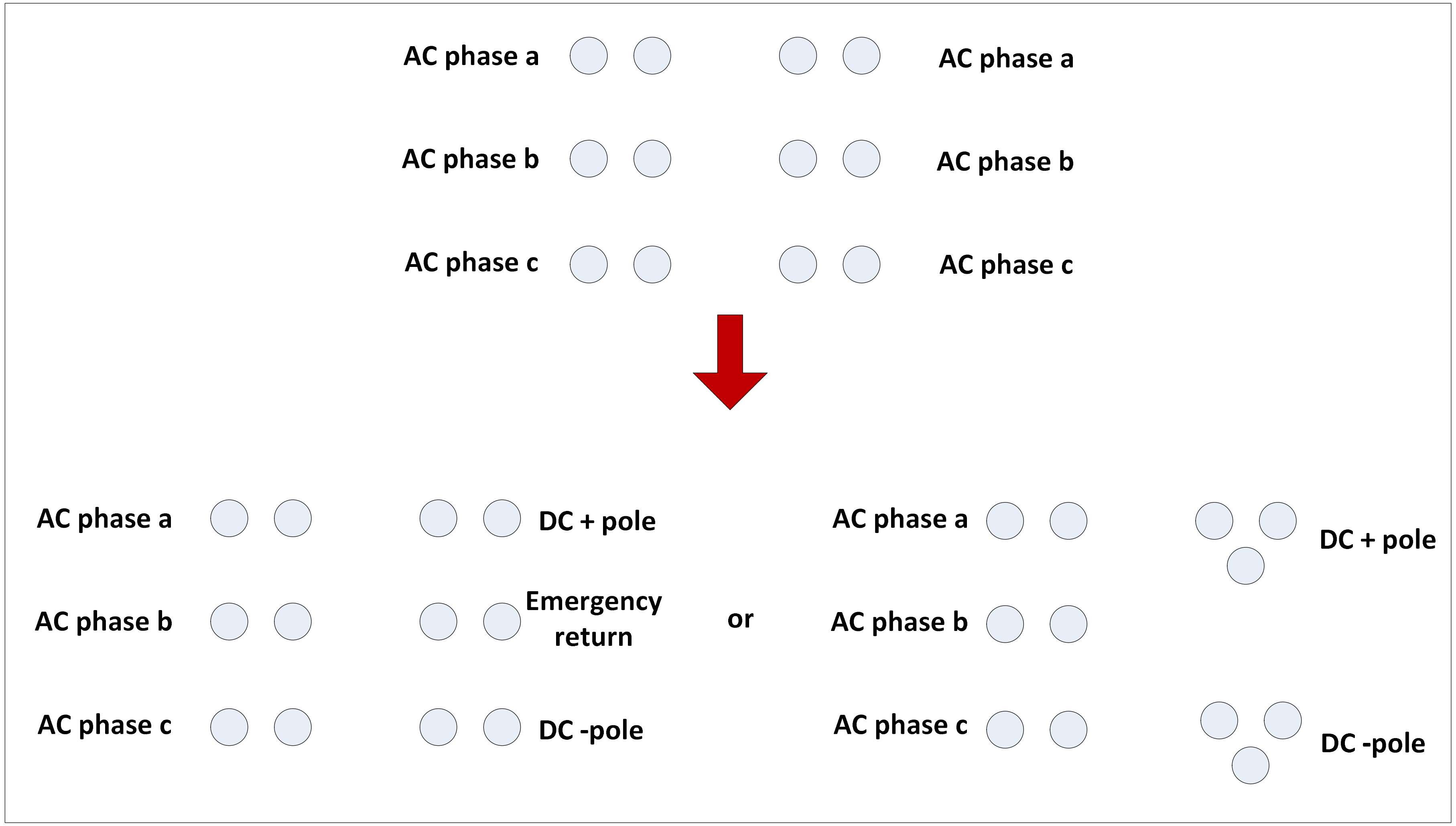
Single Circuit AC line to HVDC Bipole



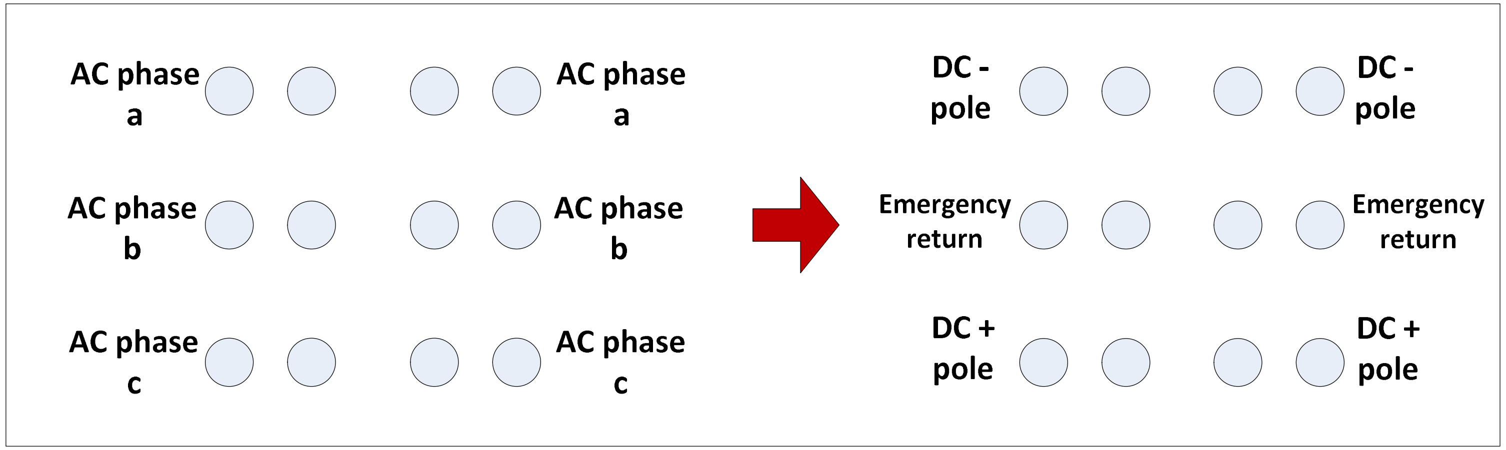
Single circuit AC line to HVDC Tripole



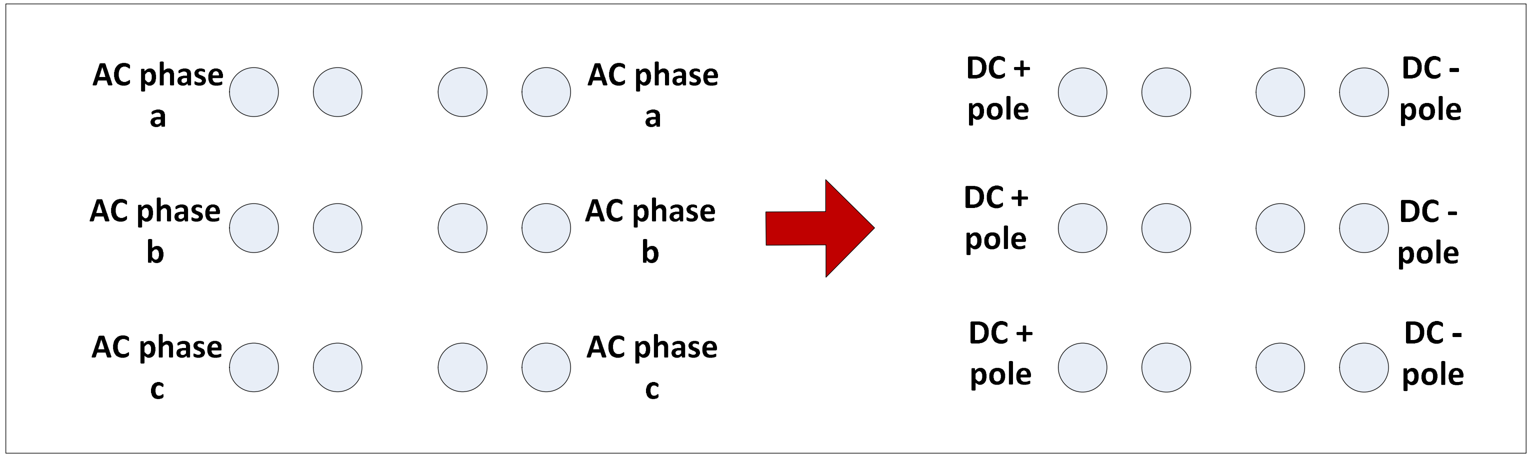
Double-circuit AC to Hybrid AC-DC



Double-circuit AC to two HVDC bipoles

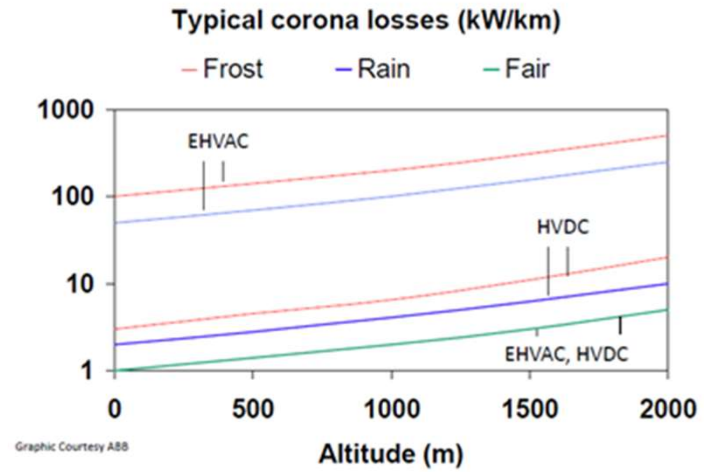


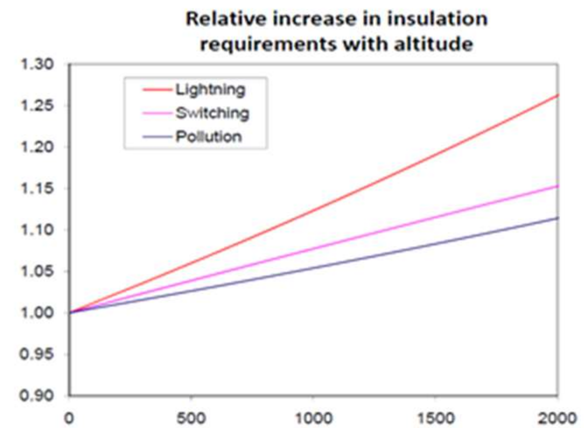
Double-circuit AC to a single HVDC bipole



Other Engineering Considerations

- Insulators (DC more sensitive to pollution)
- DC voltage selection
- Audible noise
- Corona
- Losses





Source: ABB

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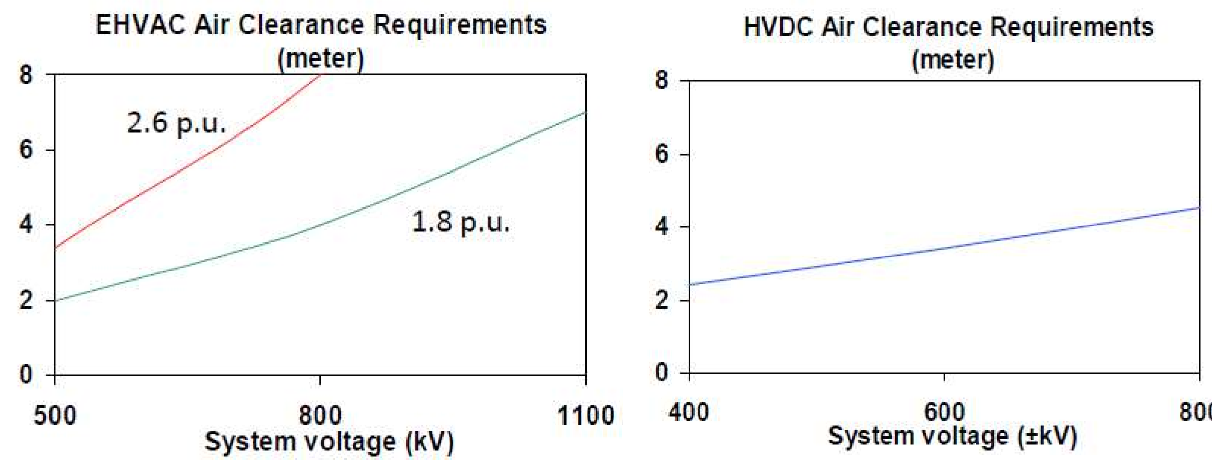
Insulation Requirements

- Air clearance: lower for HVDC

- Altitude: HVDC more sensitive



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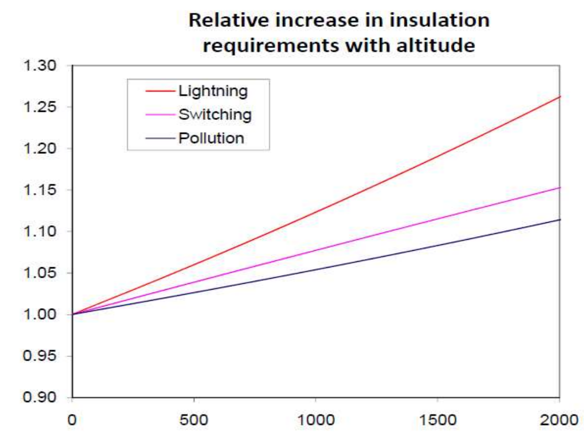

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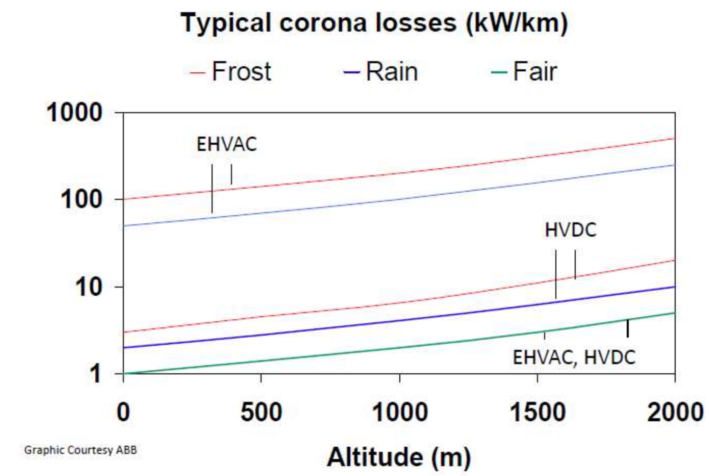
Corona and Audible Noise

- Corona losses: less sensitive for HVDC
- Audible noise: less noise for HVDC



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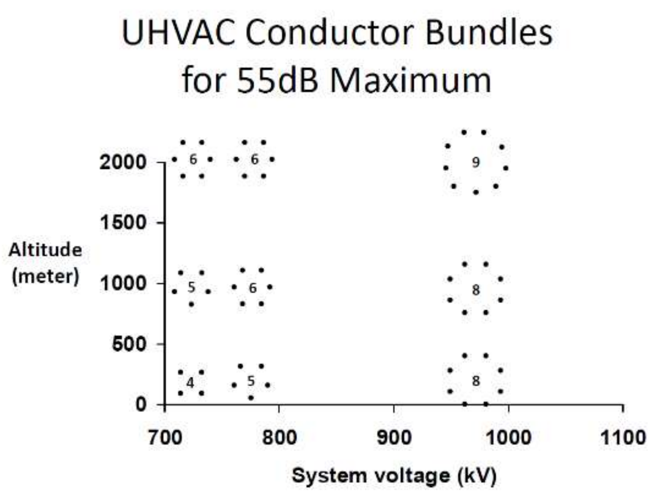

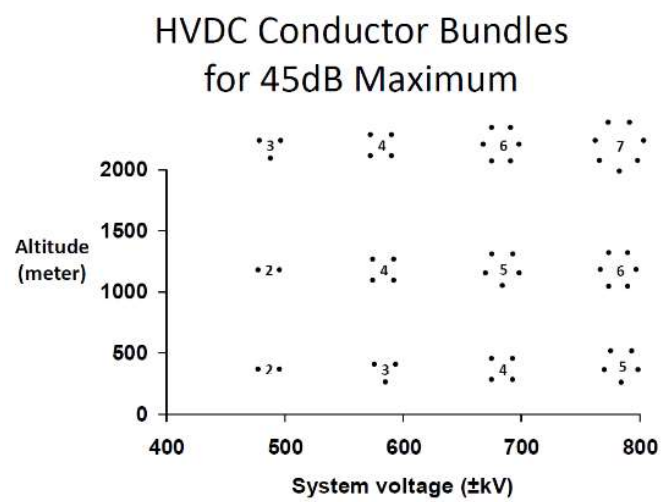

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DC Voltage Selection

- DC insulator

Zone (pollution)	IEC (mm/kV)	CIGRE B4-105 (mm/kV)	Selected (mm/kV)	Selected (in/kV)
I Light	27	26 to 34	30	1.2
II Medium	34	32 to 44	38	1.5
III Heavy	43	56	56	2.2
IV Extreme	53	70	70	2.8

- Insulator size and corresponding voltage (light pollution)

AC Voltage (kV)	Insulator length	Number of isolators	Leakage Distance	Selected DC Voltage (kV)
138	3' - 4 2/10"	7	10' - 2 6/10"	104
230	6' - 8 5/10"	14	20' - 5 3/10"	207
345	10' - 6 5/10"	22	32' - 1 4/10"	326
500	13' - 4 9/10"	28	40' - 10 5/10"	415

Sediver Insulators (DC fog type)
1. Insulator = 5 3/4"
2. Leakage per unit = 17 1/2"

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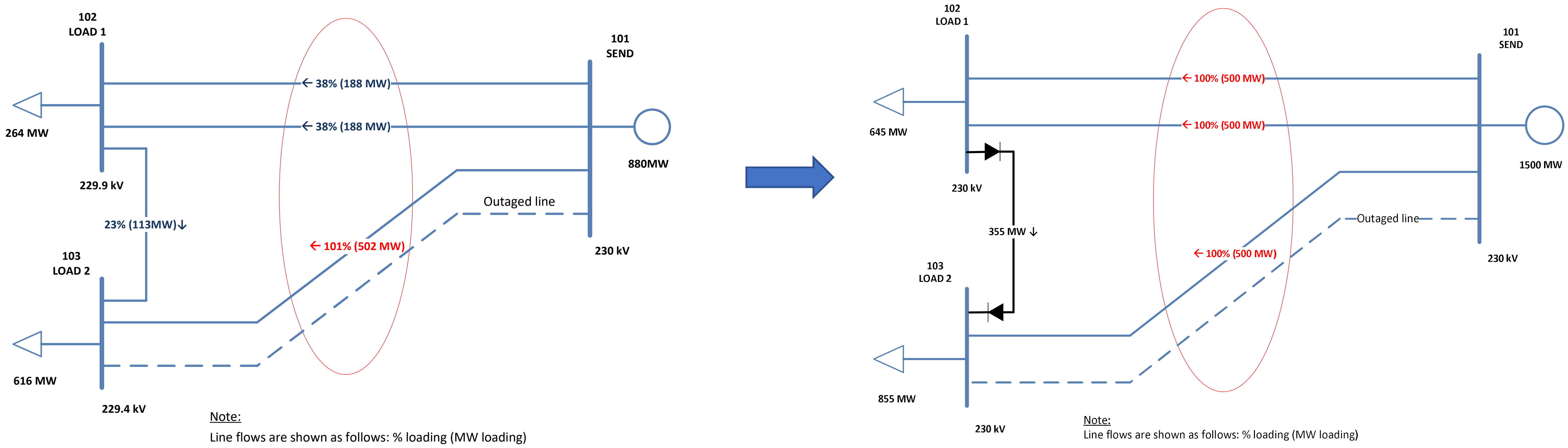
Thermal Loading limits

AC Voltage (kV)	Conductor Type	Length (miles / km)	Thermal Rating (A)	Loading Limit (MW)	DC Voltage (kV)	Loading Limit (MW)	Capacity Increase (%)
138	1192ACSR	16 / 25.8	1500	150 (3.0 x SIL)	100	300	100
230	2-1351.5 ACSR	72 / 115.9	2702	290 (2.0 x SIL)	200	1081	273
345	2-2493 ACAR	177 / 284.9	3480	560 (1.4 x SIL)	320	2227	298
500	3-1351 ACSR	250 / 402.3	4179	1200 (1.2 x SIL)	400	3343	179

Example 1: Balancing power between AC lines

No thermal increase
70% SOL increase



Example 1: Balancing power between AC lines

- The increase in SOL is not a function of increased thermal loadings obtained from the AC line
- AC to DC conversion results in a more robust solution (when compared to full AC)
- Other solutions are not as robust:
  - Back-to-back converter does not increase power transfer across the converted line
  - PST can cause stability issues

Total flow contribution (%)		Total maximum System Operation Limits (MW)		Capacity Increase (%)
Load 1	Load 2	All AC	AC to DC conversion	
30%	70%	880	1,500	70%
50%	50%	1,040	1,500	44%
70%	30%	786	1,500	91%

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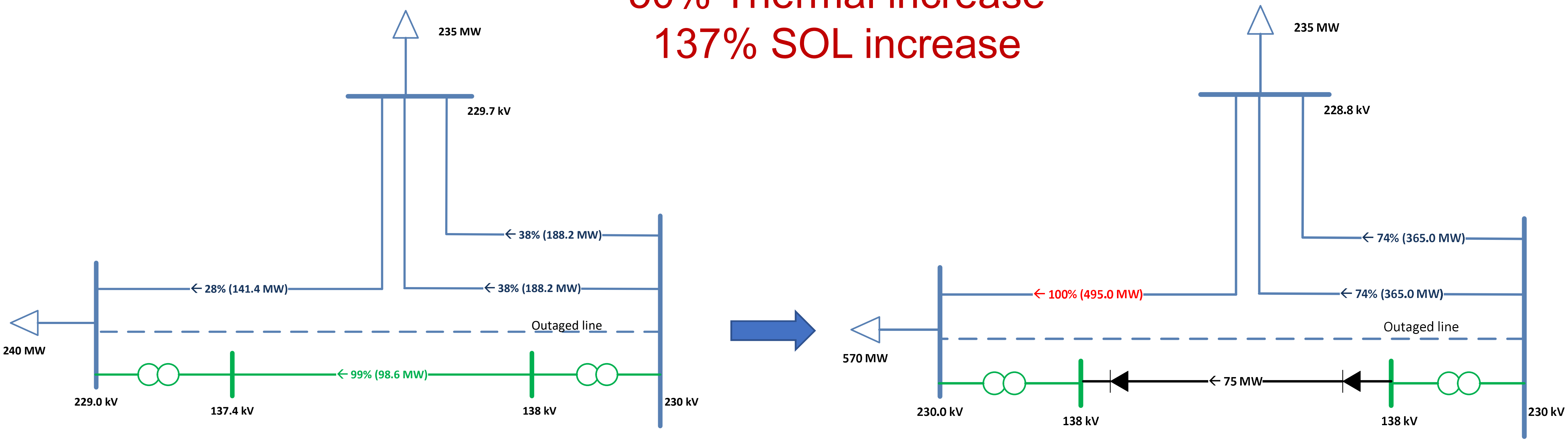
Example 2: Overload of the underlying network

50% Thermal increase
137% SOL increase



Note:
Line flows are indicated as follows: % loading (MW loading)

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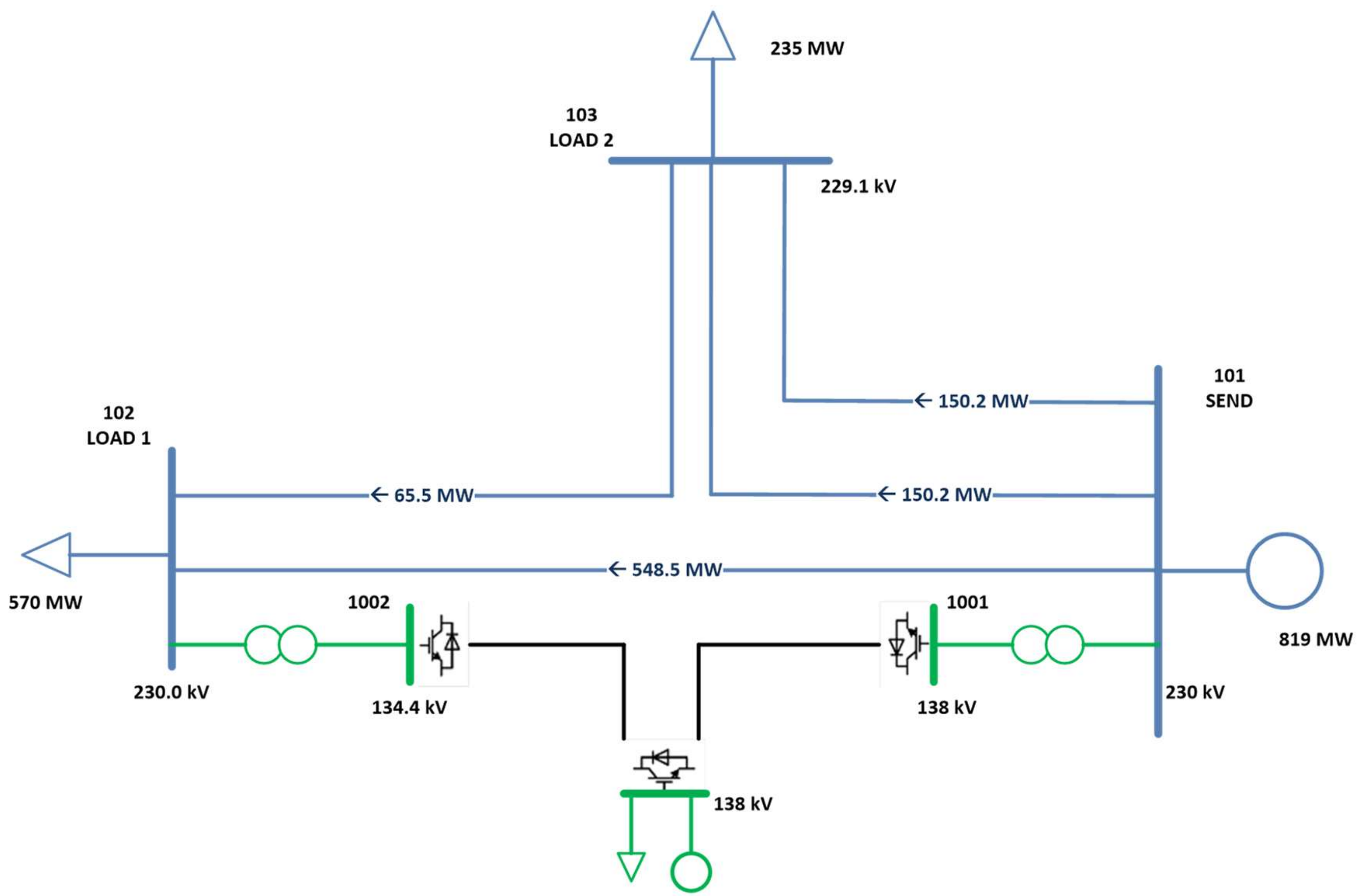
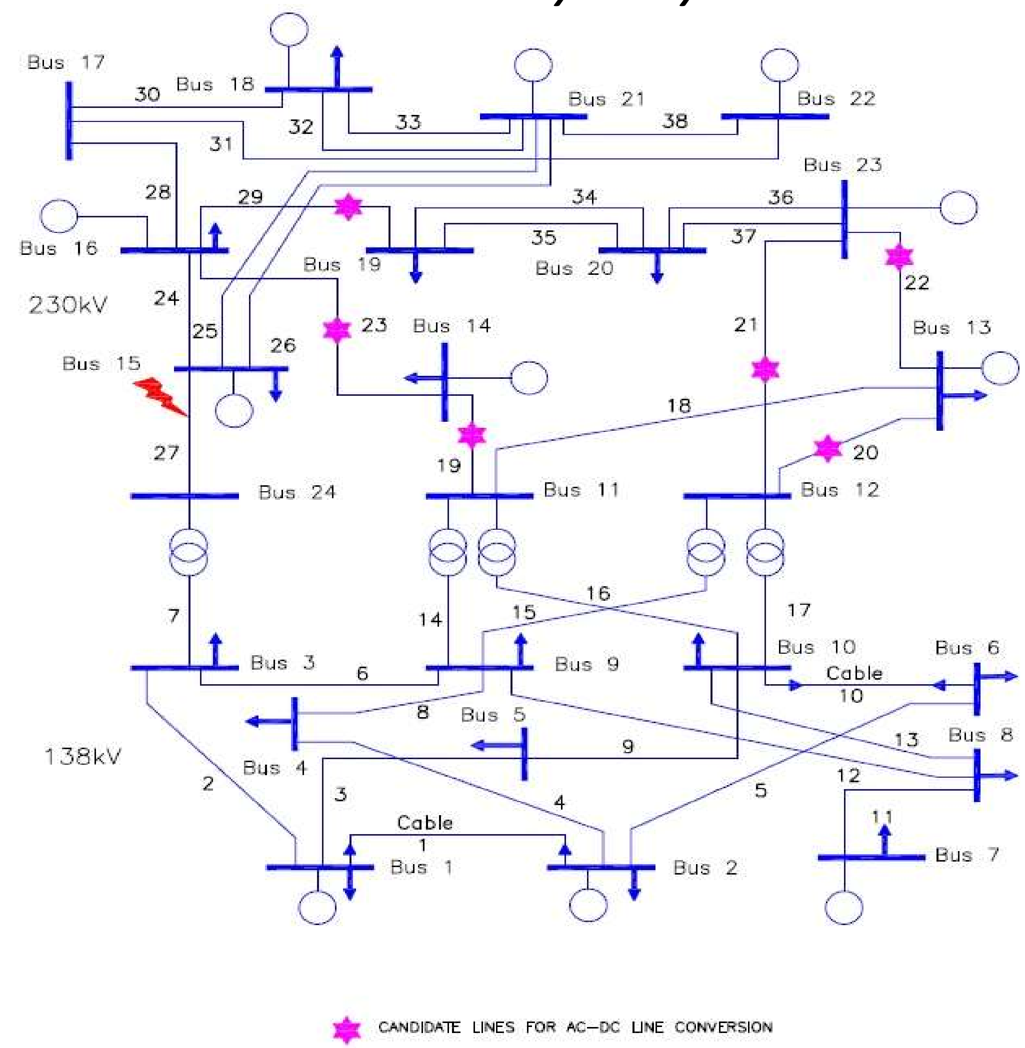
Example 3: Multi-terminal HVDC conversion



Ranking of Conversion Options

- Ranking based on sensitivity of power flow through overloaded element.
- Example (outage at line 27):
  - Limiting element is line 19;
  - power flow on line 23 is increased by 1 MW;
  - calculate power flow change on line 19; ΔPcongestion;
  - distribution factor = ΔPcongestion / 1MW;
  - best candidates for AC to DC conversion are lines 19, 23, 21, 22, 20, 29 (largest distribution factors);
  - This procedure can be repeated for any given contingency.

IEEE 24-bus Reliability Test System



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Conclusions

- AC to DC conversion can increase thermal capacity and SOL
- Proper planning is required to identify best candidates
  - System planning perspective
  - Engineering considerations for implementation

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Bibliography

[1] Cigré Joint Working Group B2.41: “Guide to the Conversion of Existing AC Lines to DC Operation,” Cigré Brochure No. 583, May 2014.

[2] P. Xu, B. Zhang, S.Chen, and K. He, “Criterion of dripping discharge of falling water droplet on a conductor-t—ground electrode with AC voltage applied”, Electrostatics Joint Conference, 2018.

[3] A. Edris, L. Barthold, D.A. Douglass, W.H. Litzenberger, D.A. Woodford, “Upgrading AC Transmission to DC for Maximum Power Transfer Capacity,” 12th International Middle-East Power System Conference, 2008.

[4] L. Barthold, R. Adapa, H. Clark, D. Woodford, “System advantages in conversion of AC transmission lines to DC”, 9th IET International Conference on AC and DC Power Transmission, 2010.

[5] X. Zhang, L. Yao, “A vision of electricity network congestion management with FACTS and HVDC”, Third International Conference on Electric Utility Deregulation and Restructuring and Power Technologies, April 2008.

[6] X. Zhang, L. Yao, B. Chong, C. Sasse, K.R. Gedfrey, “FACTS and HVDC technologies for the development of future power systems”, International Conference on Future Power Systems, November 2005.

Gracias