HVDCSTF Education Materials: Modeling HVDC Ties in ACE Equation

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PJM HVDC Ties

- PJM has two existing HVDC lines between PJM and NYISO
  - Neptune Regional Transmission System HVDC (export only PJM-NY)
  - Hudson Transmission Project HVDC (export only PJM-NY)

- PJM models these HVDC lines as Tie lines in the ACE equation as they do not directly represent generation/load transfers in/out of PJM
  - Consistent with definitions in NERC glossary of terms, and treatment in INT-009-2.1 standards
  - Actual flows on HVDC ties are included along with PJM's other AC ties in the Net Actual interchange component of the ACE equation.
  - Transfers across the HVDC ties, similar to PJM's AC ties, require interchange scheduling via submission of NERC Tags.

Relevant Definitions from NERC Glossary of Terms

Dynamic Transfer: The provision of the real-time monitoring, telemetering, computer software, hardware, communications, engineering, energy accounting (including inadvertent interchange), and administration required to electronically move all or a portion of the real energy services associated with a **generator** or **load** out of one BA Area into another.

Pseudo-tie: A time-varying energy transfer that is updated in real-time and included in the actual net interchange term (NIA) in the same manner as a tie line in the affected BA's control ACE equation (or alternate control processes).

Dynamic Schedule: A time-varying energy transfer that is updated in Real-time and included in the Scheduled Net Interchange (NIS) term in the same manner as an Interchange Schedule in the affected Balancing Authorities' control ACE equations (or alternate control processes).

Tie Line: A circuit connecting two Balancing Authority Areas.

NERC INT-009-2.1: Implementation of Interchange

R1: Each Balancing Authority shall agree with each of its Adjacent Balancing Authorities that its Composite Confirmed Interchange with that Adjacent Balancing Authority, at mutually agreed upon time intervals, excluding Dynamic Schedules and Pseudo-Ties and including any Interchange per INT-010-2 not yet captured in the Composite *Confirmed Interchange*, is:

1.1. Identical in magnitude to that of the Adjacent Balancing Authority, and

1.2. Opposite in sign or direction to that of the Adjacent Balancing Authority

R2: The Attaining Balancing Authority and the Native Balancing Authority shall use a dynamic value emanating from an agreed upon common source to account for the Pseudo-Tie in the Actual Net Interchange (NI_A) term of their respective control ACE (or alternate control process)

R3: Each Balancing Authority in whose area the high-voltage direct current tie is controlled shall coordinate the *Confirmed Interchange* prior to its implementation with the Transmission Operator of the high-voltage direct current tie.

Confirmed Interchange – NERC terminology indicating that an Interchange Schedule (in the form of a NERC Tag) has been confirmed between the Source and Sink Balancing Authorities

Area Control Error

- Area Control Error (ACE) is a measure of the imbalance between supply and demand within a Balancing Authority's Area (BAA).
- ACE is calculated as the difference between Actual and Scheduled net interchange, plus the frequency-bias contribution of the BAA.

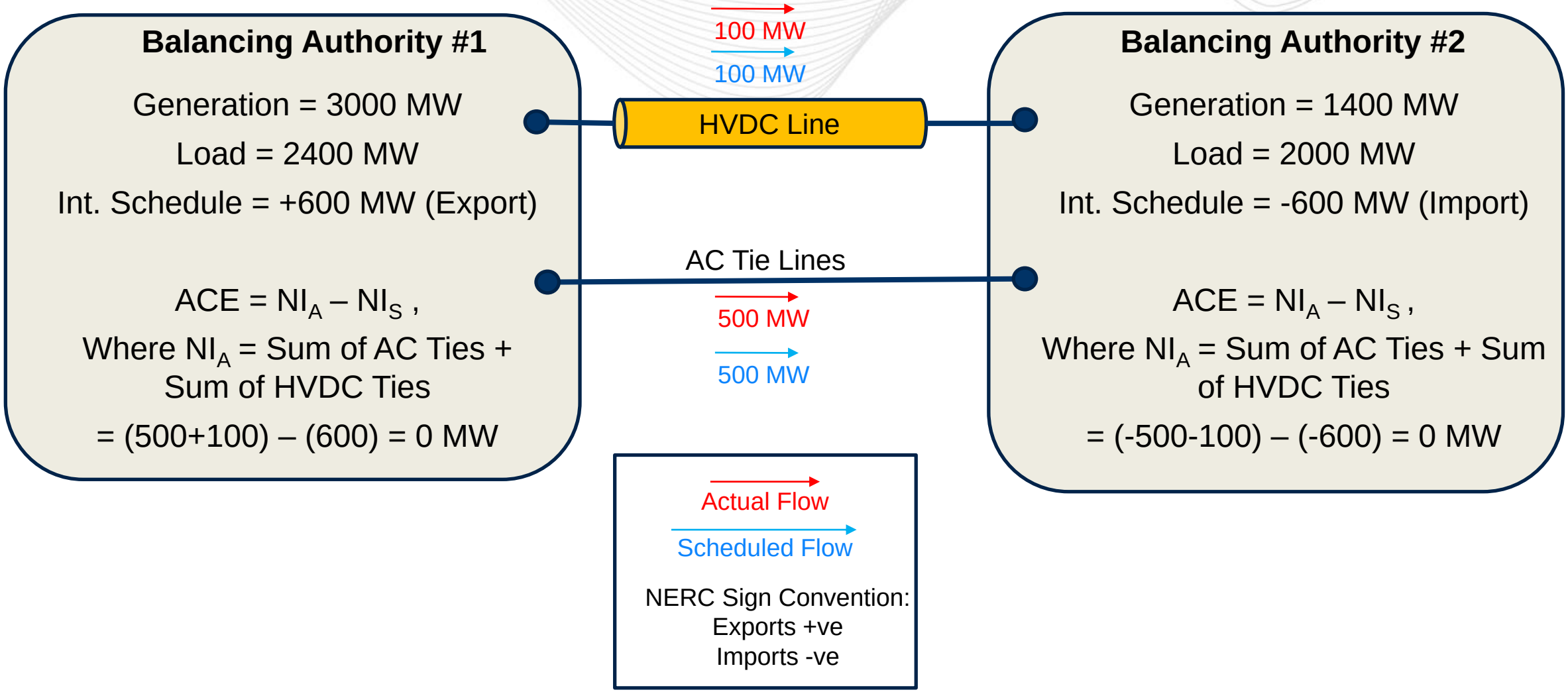
- $ACE = (NI_A - NI_S) - 10B\,(F_A - F_S) - I_{ME}$
  - NI_A = Actual Net Interchange
  - NI_S = Scheduled Net Interchange
  - B = Frequency Bias Setting
  - F_A = Actual Frequency
  - F_S = Scheduled Frequency
  - I_{ME} = Interchange Meter Error

Simplified ACE Equation

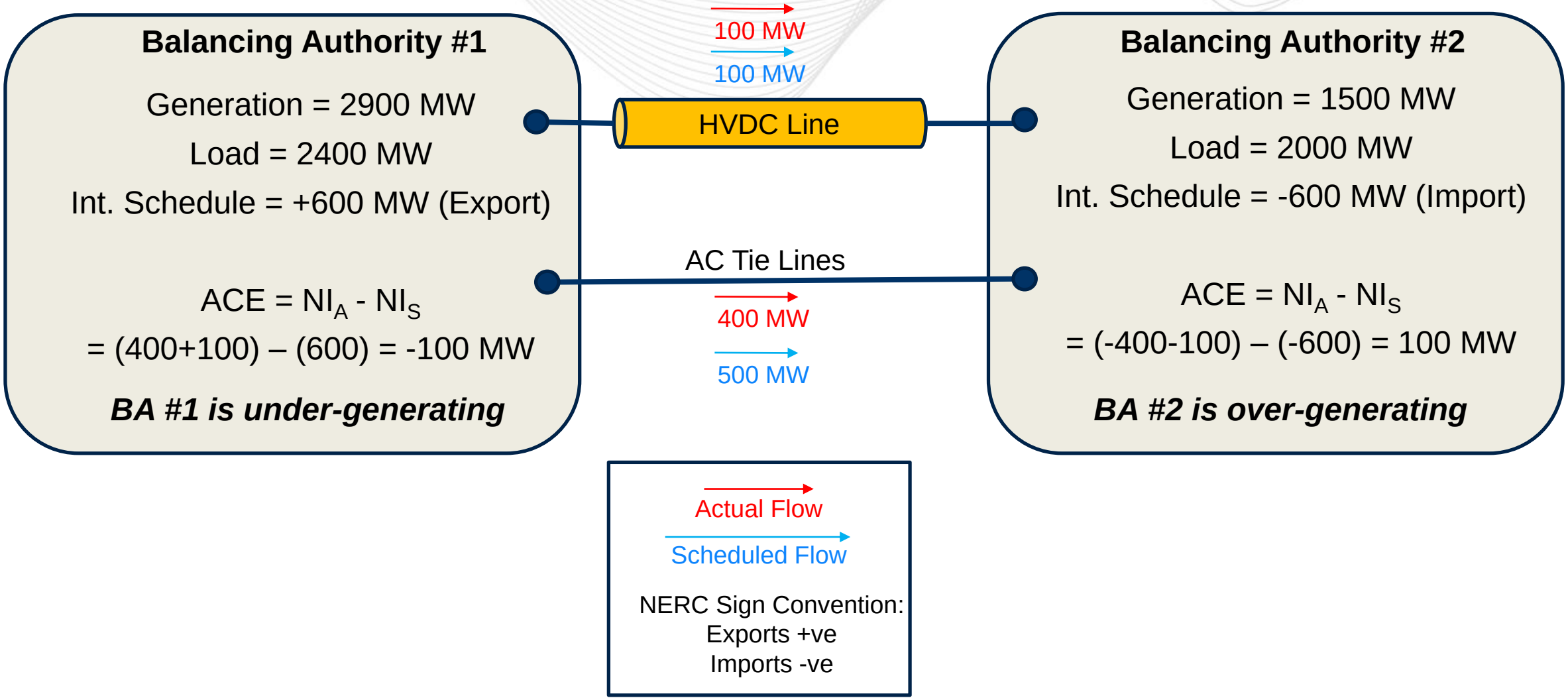
- When considering simple examples to illustrate impact of energy transfers between Balancing Authority Areas, the ACE equation can be simplified to:

Area Control Error **ACE**	=	Net Interchange Actual $\mathbf{NI_A}$	-	Net Interchange Schedule $\mathbf{NI_S}$
		Tie Line Actual Flows (AC and HVDC lines) Pseudo-ties (Gen/Load)		Dynamic Schedules (Gen/Load) Interchange Schedules

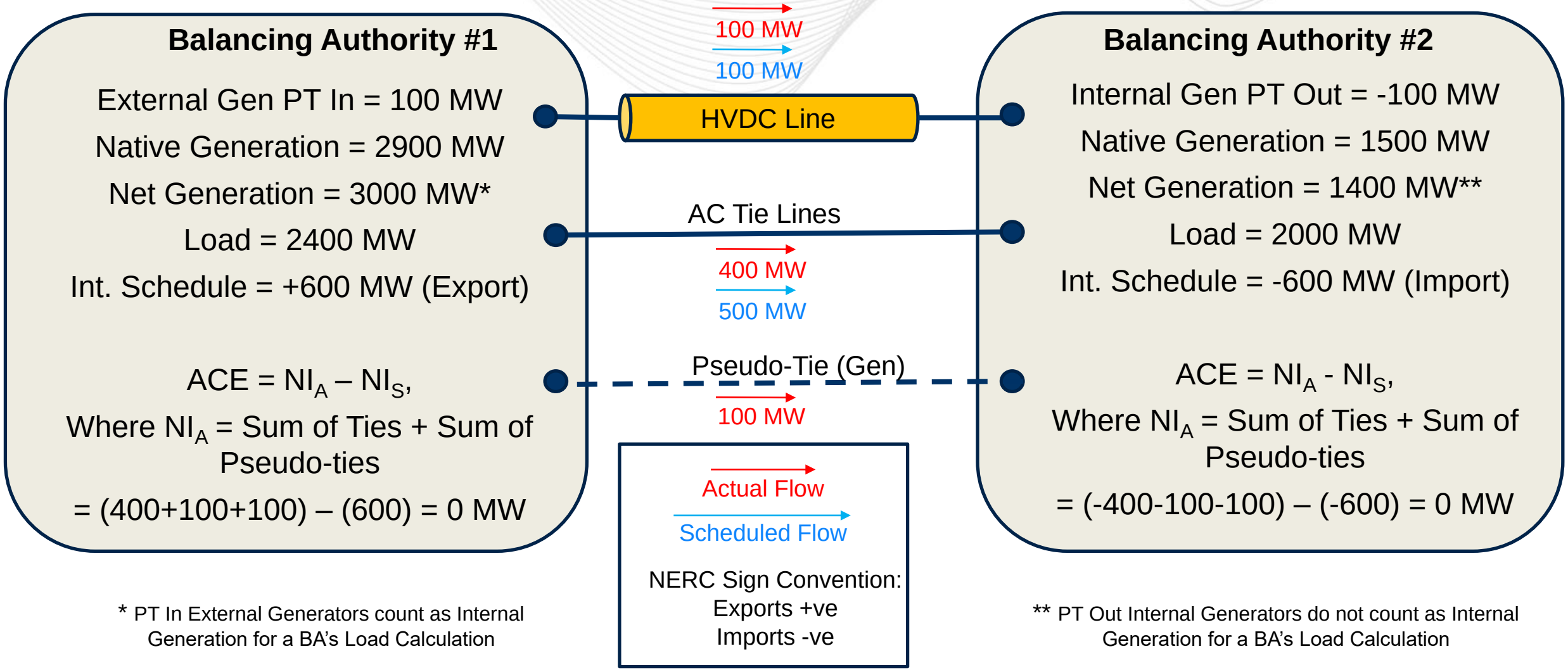
Example 1 – HVDC modeled as Tie Line



Example 2 – ACE Imbalance



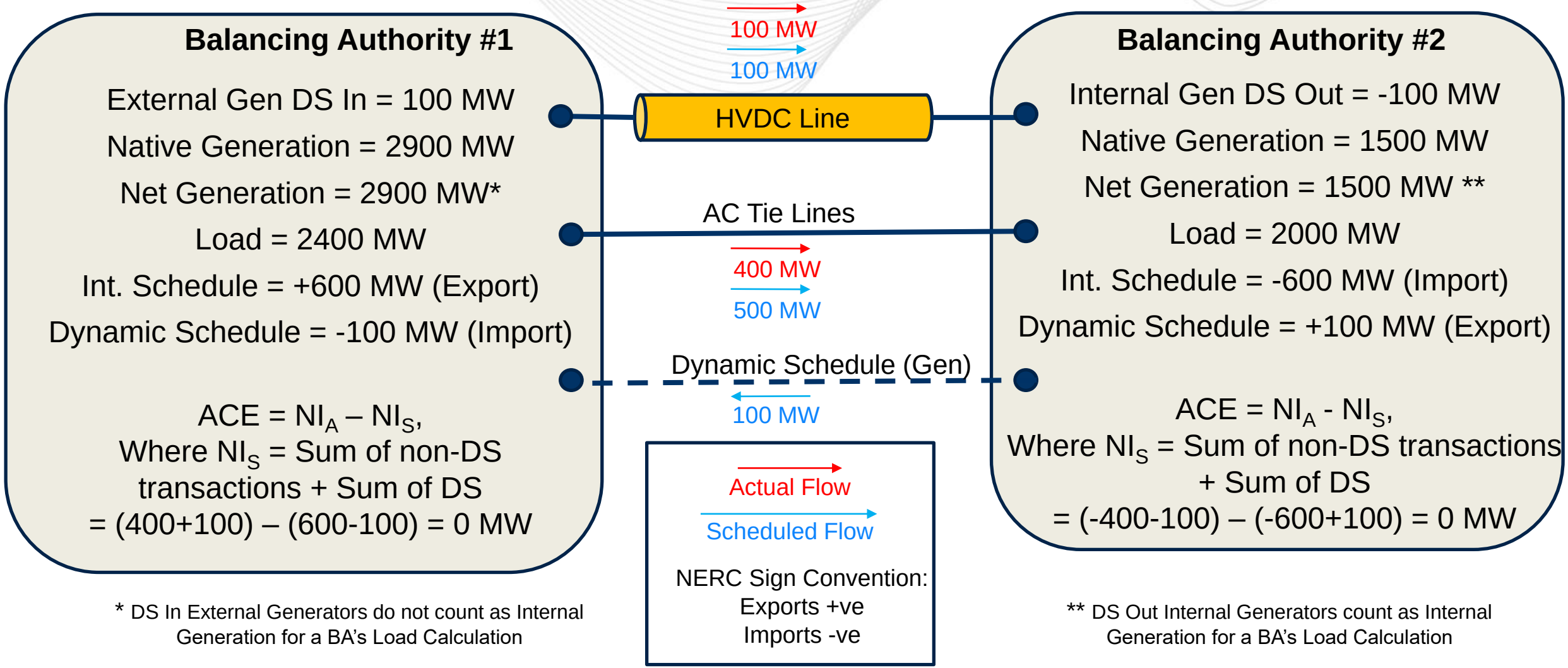
Example 3 – Pseudo-Tied Generator



* PT In External Generators count as Internal Generation for a BA's Load Calculation

** PT Out Internal Generators do not count as Internal Generation for a BA's Load Calculation

Example 4 – Dynamically Scheduled Generator



* DS In External Generators do not count as Internal Generation for a BA's Load Calculation

** DS Out Internal Generators count as Internal Generation for a BA's Load Calculation

Compliance with NERC Standards

- PJM, in its role as Balancing Authority for the entire PJM RTO footprint, is the responsible entity for compliance with the NERC Balancing (BAL) and Interchange Scheduling (INT) Standards.
- PJM must adhere to strict interpretations of the Standards as currently written to mitigate potential risk of non-compliance and impacts to its members.

References

- NERC Dynamic Transfer Reference Document, Version 4 https://www.nerc.com/comm/OC/ReferenceDocumentsDL/Dynamic_Transfer_Reference_Document_v4.pdf
- NERC Glossary of Terms: https://www.nerc.com/files/glossary_of_terms.pdf
- NERC INT-009-2.1: https://www.nerc.com/pa/Stand/Reliability%20Standards/INT-009-2.1.pdf
- NERC BAL-005-1: https://www.nerc.com/pa/Stand/Reliability%20Standards/BAL-005-1.pdf
- NAESB WEQ-004 Coordinate Interchange: https://www.naesb.org/weq/weq_standards.asp
- NAESB WEQ-005 Area Control Error (ACE) Equation Special Cases: https://www.naesb.org/weq/weq_standards.asp