Zooming-in and Zooming-out Methods for Directing Power Flows and Simulating Loop Flows

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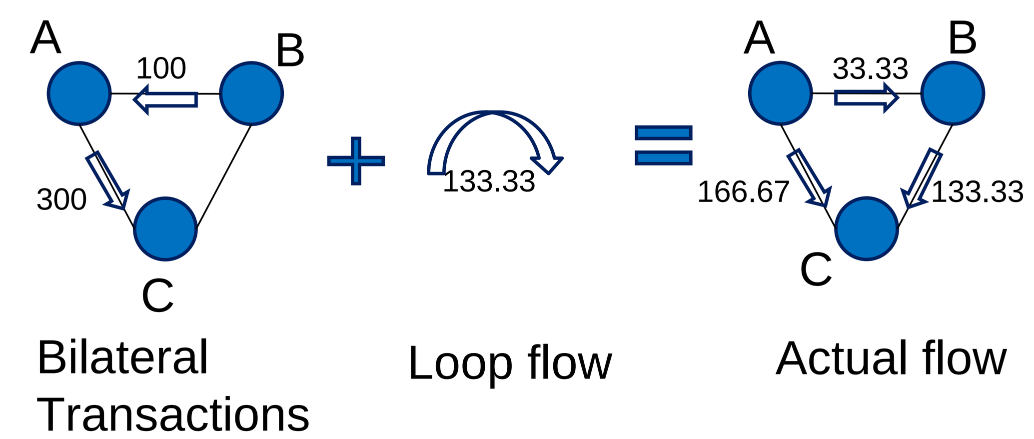
Reasons for directing power flows

- **Technical** reasons:
  - Increasing network utilization and ATC
  - Alleviating congestion through line unloading
  - Reducing losses
  - Prevention of blackouts

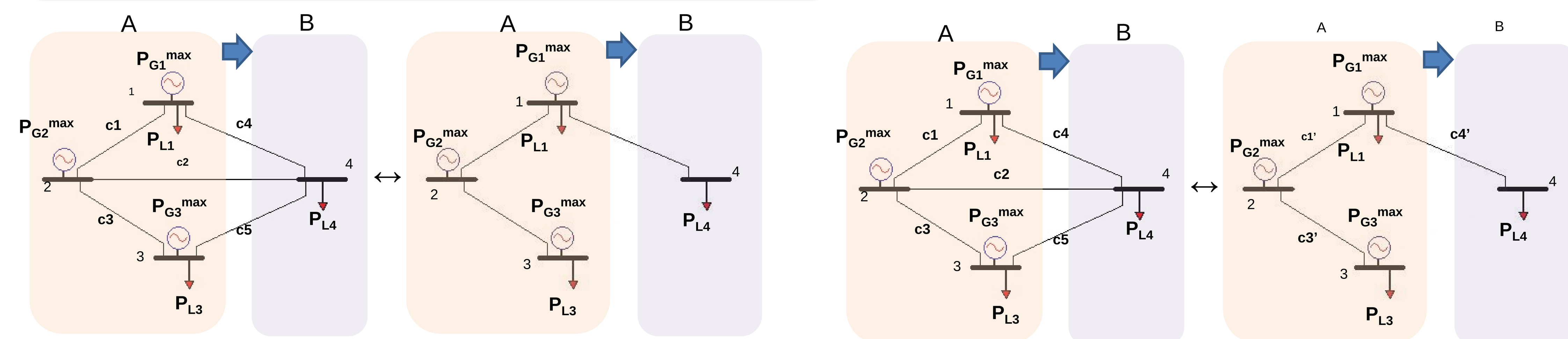
- **Economic** reasons:
  - Simple accounting
  - Enabling contract paths
  - Accurate usage-based transmission pricing for wheeling
  - Reduction of investment cost by building flow control devices instead of transmission lines
- **Environmental** reasons:
  - Increasing power transfer of clean energy to high demand regions

Loop Flow Modeling



- Main ideas:
  - Bilateral transactions as spanning tree flows and loop flows inside basic loops
  - Determine contributions of bilateral transactions to lines and loop flows
  - Design smart control that would maximize power flow through contract paths

Graph-Theoretic Algorithms



max w

$KCL:\quad {A_1}^T * J^1 = J^{nodal}$

$KVL:\quad A_1 * V_{nodal} = V_{line}$

$Ohm's\ Law:\quad Z_{11} * J^1 = V_{line}$

$|J^1| \le Cap$

max w

$KCL:\quad {A_3}^T * J^3 = J^{nodal}$

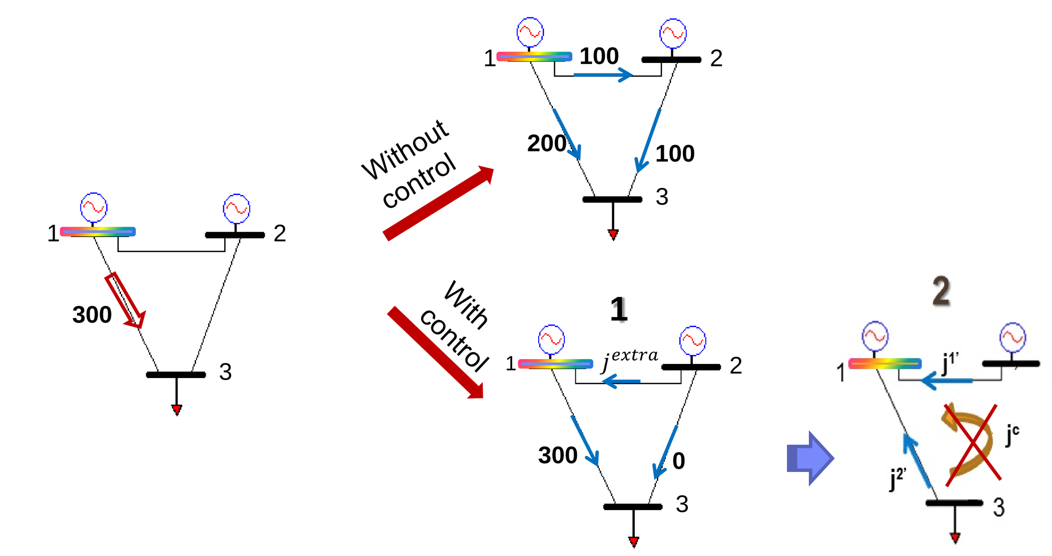
$|C_{13} * J^3| \le Cap$

$$Cap_1 = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{bmatrix} \qquad Cap_3 = \begin{bmatrix} c_1' \\ c_3' \\ c_4' \end{bmatrix}$$

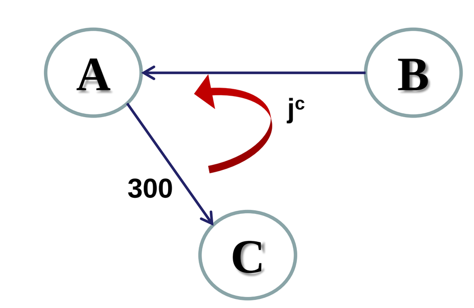
$w = c_4'$

Directing Flows

- Directing flows by canceling loop flows



- Distributed loop flow cancelation
  - Minimization of wheeling

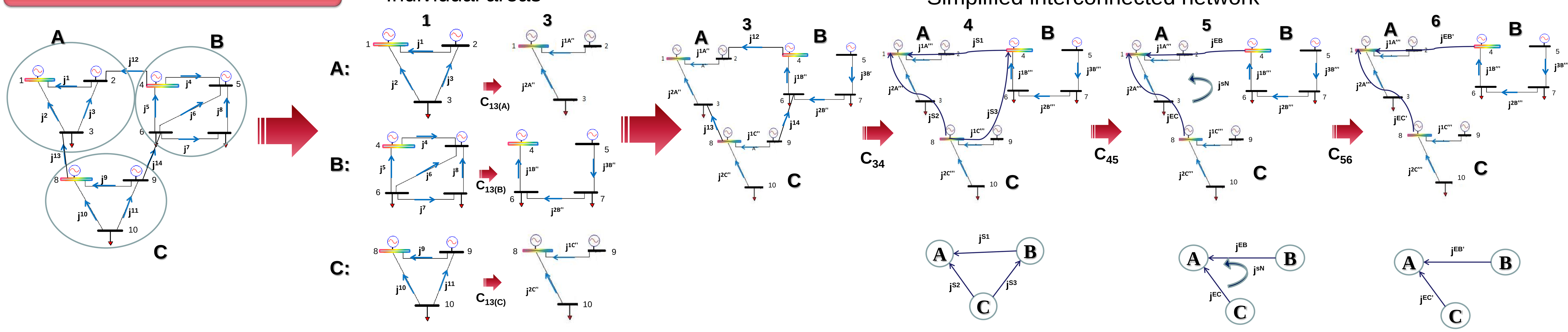


- Various mechanisms for loop flow minimization:
  - Additional generation
  - Generation displacement
  - FACTS devices: PAR, TCSC, UPFC

Tree Transformation

Individual areas

Simplified interconnected network



Bilateral Transaction Tracing

$$J^1 = C_{13} * C_{34} * C_{45} * C_{56} * J^6$$

Loop Flow Tracing

$$V_5 = Z_{55} * J^5$$

$$\begin{bmatrix} V_{bilat\_trans} \\ 0 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} * \begin{bmatrix} J^{bilat\_trans} \\ J^{loop\_flow} \end{bmatrix}$$

$$J^{loop\_flow} = -{Z_{22}}^{-1} * Z_{21} * J^{bilat\_trans}$$

Conclusions

- Efficient tracing mechanisms for the bilateral market model
- Efficient distributed algorithm for loop flow cancelation
- Tree representation allows execution of graph–theoretic algorithms

References

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[3] Sanja Cvijić, Marija Ilić, "Contingency Screening in a Multi-Control Area System Using Coordinated DC Power Flow", ISGT Europe 2011, Manchester, December 2011

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