Methods of Selecting the Desired Net Interchange (DNI) Across Multi-Control Areas:
Demonstration of Seams Solution for Large-Scale NPCC

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Key NETSS Technologies Used

• Large-scale nonlinear optimal power flow (OPF) to simulate global system optimal flow exchanges (benchmark)
• NETSS seams solution optimization for coordinated flow exchanges.
NETSS OPF

• Minimizes total real generation cost.
• Schedules real generation, voltage, transformer control settings and shunt control settings.
• Conserves real and reactive power at all buses.
• Meets all real and reactive generation, line flow and transformer flow limits.
• Implemented for large scale systems[1,2,5].
Global optimization (RTO level)

Optimization (OPF) schedules generation to minimize system cost.

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Global Optimization Challenges

• Complex large-scale optimization.
• Requires that one entity has complete knowledge of all electrical and market data, which is likely not desirable.
• May require a new oversight entity or a merger in practice.
NETSS Seams Solution (Single Tie Line)

Small-Scale Optimization

Control Area I

+ Load

Small-Scale Optimization

Control Area II

- Load

DNI*  Cost

Total  Coordinator

Load

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NETSS Seams Solution in Operation

1. Both CAs run OPFs across the permissible tie line flow range. This results in CA cost curves that are passed to the Seams Coordinator.

2. The Coordinator optimizes the system cost thereby determining the optimal tie line flow. This flow is passed back to both CAs.

3. Both CAs runs a final OPF based on the optimal tie line flow. This yields the generation to be scheduled.
Seams Solution Challenge

Multiple tie lines

→ Multi-dimensional CA OPFs

→ Multi-dimensional Coordinator optimization

→ Too complex

→ NETSS solution
NETSS Seams Solution (Multiple Tie Lines)

Small-Scale Optimization

Control Area I

+ Load₁(α)

+ Loadₙ(α)

Small-Scale Optimization

Control Area II

- Load₁(α)

- Loadₙ(α)

NETSS seams solution guarantees that the tie-line flows are electrically feasible

DNI* - Cost

Total

RITO

α

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Important Observations

• There exist two-way optimal tie line flows across the NY-NE seam.

• There exist optimal tie line flows that are counter to the economies of generation across the NY-NE seam.
NETSS Seams Solution Procedure

• Select generation bids and load profile.
• Run global OPF for comparison.
• For each CA, run several OPFs to determine generation cost as a function of net exchange. Report the cost functions to the Coordinator.
• Coordinator performs clearing to minimize total generation cost, and thereby determine the optimal net exchange.
• For each CA, run a final OPF given the optimal exchange to schedule the optimal generation in the CA.
• Run a PF to determine actual system performance.
Coordinator Clearing Example

Cost Clearing: NY Generator Costs = 1.00$/MW & NE Generator Costs = 1.10$/MW


- Total Cost
- New York Cost
- New England Cost
- Minimum Total Cost

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Cost Clearing: NY Generator Costs = 1.00$/MW & NE Generator Costs = 1.00$/MW

- Total Cost
- Minimum Total Cost
Marginal cost clearing [2]
Seams Solution Example

TieLine Flows: NY Generator Costs = 1.00 $/MW & NE Generator Costs = 1.00 $/MW

Optimal Exchange = 708.9 MW
NETSS seams exchange = 718.3 MW
Optimal Generation Cost = $376683.63
NETSS seams generation cost = $379866.84
Seams Solution Example

Tie Line Flows: NY Generator Costs = 1.00 $/M W & NE Generator Costs = 1.05 $/M W

Maximum Pattern Flow
Minimum Pattern Flow
Optimal Flow
Seams Flow
ALPS - BERKSHIRE
PLINTVLY - LONGM TN
ROTTROAM - BEARSWMP
NRTHPORT - NORWALK H
HOOS CK - BENING TN
WHITEAL - BLISVILL
PLATSBRG - SOHERO
SMITHFLD - SALISBRY

Optimal Exchange = 2136 M W
NETSS Seams Exchange = 2150 M W
Optimal Generation Cost = $379569,04
NETSS Seams Generation Cost = $379556,46

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Seams Solution Example

Tie Line Flows: NY Generator Costs = 1.00 $/MWh & NE Generator Costs = 1.10 $/MWh

Optimal Exchange = 2483 MWh
NETSS Seams Exchange = 2304 MWh
Optimal Generation Cost = $380381.2
NETSS Seams Generation Cost = $360505.43
Seams Solution Example

Tie Line Flows: NY Generator Costs = 1.00 $/M.W. & NE Generator Costs = 0.95 $/M.W.

Optimal Flow
Seams Flow
ALPS - BERKSHIRE
PLANTVLY - LONGM TN
ROTTRAM - BEARSWMP
NORTHPORT - NORWALKH
HOOGICK - BENINGTN
WHITEAL - BLISVILL
PLATSBG - SOHERO
SMITHFLD - SALISBRY

Optimal Exchange = 637.5 MW
NETSS Seams Exchange = -905.9 MW
Optimal Generation Cost = $377,987.57
NETSS Seams Generation Cost = $377,602.95

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Seams Solution Example

Tie Line Flows: NY Generator Costs = 1.00 $/M.W & NE Generator Costs = 0.90 $/M.W

- Maximum Pattern Flow
- Minimum Pattern Flow
- Optimal Flow
- Seams Flow

ALPS - BERKSHIRE
PLSNTLY - LONGMTN
ROBERTSON - BEARSWMP
NRTHPORT - NORWALKH
HOOG CK - BENIGN TN
WHITEAL - BLISVILL
PLATSBRG - SOHERO
SMITHFLD - SALISBRY

Optimal Exchange = -1705 M.W
NETSS Seams Exchange = -1894 M.W
Optimal Generation Cost = $37,6529,68
NETSS Seams Generation Cost = $37,6599,16
Seams Solution Example

Tie Line Flows: Random Generator Costs Between 0.9 $/MW & 1.1 $/MW

- Maximum Pattern Flow
- Minimum Pattern Flow
- Optimal Flow
- Seams Flow

ALPS - BERKSHIRE
PLSNTVLY - LONGM TN
RORRDM - BEARSWMP
NRTHPORT - NORWALKH
HOOSICK - BENINGTN
WHITEAL - BLISVILL
PLATSBG - SOHERO
SMITHFLD - SALISBRY

Optimal Exchange = 1195 MW
NETSS Seams Exchange = 1197 MW
Optimal Generation Cost = $379677.97
NETSS Seams Generation Cost = $379739.35
Seams Solution Example
Seams Solution Example

Tie Line Flows: Generator Costs = 1 $/M.W & 10% Load Decrease

- Maximum Pattern Flow
- Minimum Pattern Flow
- Optimal Flow
- Seams Flow
ALPS - BERKSHIRE
PLSNTVL, Y - LONGMANY
ROTTRAM - BEARSWAMP
NORTHPORT - NORWALKH
HOOSICK - BENINGTN
WHITEAL - BLISVILL
PLATSBRG - SOHERO
SMITHFLD - SALISBRY

Optimal Exchange = 643.4 M.W
NETSS Seams Exchange = 443.7 M.W
Optimal Generation Cost = $340,443.58
NETSS Seams Generation Cost = $340,470.5

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Seams Solution Example

TieLineFlows: Generator Costs = 1$/MW & 10% Load Increase

Optimal Exchange = 778.8 MW
NETSS Seams Exchange = 885.5 MW
Optimal Generation Cost = $416970.77
NETSS Seams Generation Cost = $416979.99

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Proxy bus differences vs. net tie-line flows; fixed voltages
Price difference across tie-lines vs. tie-line flows; fixed voltages
Proxy bus differences vs. net tie-line flows; optimized voltage
Comparison between the results of virtual regional dispatch (VRD) and global optimization results [2]

• All tie-lines are monotonically dependent on the price difference across the nodes connected by the tie-line.
• This means that an increase in price across the tie-line indicates a higher flow, and vice versa. This is as expected.
• No such conclusion can be drawn regarding the price difference across proxy buses in the ISO-NE and NYISO
• There exists significant range of flows between ISO-NE and NYISO for which the direction is just opposite (second quadrant)
• At the optimum trade between ISO-NE and NYISO the price differential between two control areas is not zero
• These observations hould be given a serious attention as the regions attempt to trade.

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Comments On NETSS Seams Solution

- Tie line flow patterns should contain real and reactive tie line flows for both neighbors if reactive power is to be conserved.
- The use of patterns guarantees that all tie line flows are electrically feasible.
- Individual tie line flow limits and net interchange limits are observed.
- Each seam may be optimized separately without iteration.
- Neither seam neighbor needs a model of the other.
NETSS Seams Solution-Based Operation

- New patterns are required with major electrical or economic system changes.
- Changes far from a seam appear unimportant.
- Tie line flow patterns may (likely) be developed on reduced-order system models.
- A physical Coordinator is not necessary; both neighbors can run NETSS Seams Solution software for verification.
- NETSS Seams Solution software should be robust against optimization errors.
Comments On NETSS Seams Solution Performance

• Extensive simulations show that NETSS Seams Solution always finds a near-optimum interface flows.
• The solution can find beneficial two-way flows at a seam.
• The solution can find beneficial counter flows at a seam.
• The solution can incorporate optimizations of cost, reliability and other criteria.
• Cost curve derivatives represent the marginal cost of exchange.
References


