Reducing Transmission Investment to Meet Renewable Portfolio Standards Using Controlled Energy Flows

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Overview of Renewable Portfolio Standards

- Renewable Portfolio Standards (RPS) have been adopted in the majority of US states
  - Binding in 27 states plus DC
  - Non-binding in 5 states – but “voluntary” performance impacts rate cases to varying degrees
- Waxman-Markey requires 20% of national energy be met with combination of renewables and efficiency by 2020 (Minimum renewable content of 5%)
- RPS mandates and other pro-renewable policies (RGGI, green choice mandates) are driven by a number of factors:
  - Increasing concentration of greenhouse gases
  - Heightened demand for fossil fuels
  - National security concerns

<table>
<thead>
<tr>
<th>State</th>
<th>RPS Level (Percent State Energy Usage or Capacity)</th>
<th>By</th>
<th>Wind Capacity to Satisfy RPS (GW)</th>
<th>State</th>
<th>RPS Level (Percent State Energy Usage or Capacity)</th>
<th>By</th>
<th>Wind Capacity to Satisfy RPS (GW)</th>
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Meeting existing state RPS mandates with wind is projected to require 200 GW of wind capacity in 2030 - 25 GW installed today. Existing RPS + Waxman-Markey could require up to 360 GW of wind capacity.
Simulation Setup

- Split IEEE 39 Bus System into four, geographically distant regions (NW, NE, SW, SE)
- Each region assigned a 6-period historical average daily load profile NW (NYISO), NE (MISO-Central), SW (SERC), SE (PJM); aggregate peak of 4880 MW
- Coal-dominated generation with only 1% of annual energy initially sourced from wind
- Coal plants assigned realistic cost curves
- Wind plants assigned the 6-period stochastic wind profiles of SPP (gen 10) and MISO-WEST (Gen 8) derived from the NREL Eastern Wind Integration and Trans. Study
- Load growth of 2% applied to all load buses equally
- RPS imposed system wide: 1 percentage point increase per year
- Single OPF used to solve all four regions
- Line ratings and generation ratings set so the majority of energy is generated and used in the same region
The Challenge of Power Flow Control with OPF

- Possible to increase ATC by dispatching incremental power flows down lightly loaded paths once primary paths are constrained.
- The figure shows a desired 20 MW incremental dispatch. Only 1.5 MW reaches the target bus. Increased flows on non-path lines limit scope for an increase of ATC.
- Without power flow control, goal of increasing ATC while maintaining reliability requires new line construction – keeping overall system utilization low.
Controllable Energy Flow (CEF) Concept

Goal: Dispatch incremental power flow along a transaction path without changing existing flows on adjacent paths

- In the absence of control - each additional MW of dispatched energy changes:
  - Node voltages
  - Line flows
- To maintain pre-transaction power flows, node voltages at branch-out points must remain unaltered

Observations
- Compensation voltages are small - only compensating for the series drop along the transaction path
- Complete compensation requires a real and reactive component
- Compensation only on the line to be controlled → Investor retains benefits of investment
Realizing CEF

- 20 MW transaction requires total control effort of 3.6 MVA
- Established devices (UPFC) and new technologies (CNT) can realize the compensation necessary for CEF
- CNT augments existing LTC with fractionally-rated converter
- Installation of CNT between two control areas shows P & Q control
- CEF provides dynamic control of power flows
Transmission Investment Simulation

**GOAL:** Simulate transmission investment over the 20 year RPS phase-in window with and without the use of CEF

- Wind capacity added annually to meet annual RPS increase
- Assumed perfect demand and wind forecasts enable planning certainty
- Simulation simulates system operation and planning process - upgrades facilities until no wind output is curtailed
- Planning stage choices:
  - BAU scenario – line upgrade
  - CEF scenario – line upgrade or install CEF devices
- Operation method:
  - BAU: OPF
  - CEF: OPF of coal plants and CEF of wind plant output

Flowchart for Simulation Methodology
Comparison of Required Upgrades

- BAU case requires upgrade of 3 regional tie-lines with a total construction of 186,000 MW-miles of line (Total Cost = $186M @ $1000/MW-mile)
- CEF case requires construction of 36,000 MW-miles and installation of 708 MVA of CEF devices (Total Cost $106M = $36M + $70M @$100/kVA for CEF)
Investment Comparison and Potential Impact of CEF

Equivalent Cost to Meet RPS

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<tbody>
<tr>
<td>BAU</td>
<td>$186 Million/186,000 MW-miles</td>
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<tr>
<td>CEF</td>
<td>$107 Million/36,000 MW-miles</td>
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Assumptions

- Line cost of $1000/MW-mile
- CEF device cost of $100/kVA
- Discount rate of 0%

Current Realities

- Projected cost to meet RPS mandates are significant. US DOE estimates $3B/yr for 20 years required to supply 20% of energy with wind in 2030 (against $4.5 B/yr average annual T&D investment over the last 20 years).
- Cost, line construction delays, and opposition to new lines may curb support for higher levels of renewables
- Non-optimal incentives for merchant transmission to strengthen linkages between renewable regions and load centers

Potential CEF Impacts

- Cost-effective RPS compliance, more so if discount rates considered
- Reduced line construction
- Faster implementation
- Expanded opportunities for merchant transmission to connect renewables to load centers
Conclusions

- Existing RPS mandates require a minimum of 4x the current wind capacity if met entirely with wind. Federal mandates layered on existing RPS mandates, if met with wind, would require 14x current wind capacity - even more if met with solar.
- Simulation shows significant transmission investment required to meet RPS mandates if renewable resources are sited far from load centers and inter-area tie-lines are weak.
- Cost of RPS compliance may be reduced through Smart Grid Technologies.
- Controllable Energy Flows (CEF) can maximize utilization of existing assets and reduce RPS-compliance cost and public opposition. Requires only 20% of line build under BAU.
- Allows incremental deployment, when compared with new line buildout.
- Controllable Network Transformer (CNT) is a new technology able to realize CEF.
- CNT converts an existing dumb asset to a **smart and controllable asset** using a fractionally rated converter.
- Market benefits of CEF - especially potential for CEF to invigorate a ‘merchant transmission’ market using existing transmission lines - require further study.