

# Wide-Area Trans-Regional Northeast Reliability Assessment

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## Abstract

*This paper summarizes the results of a reliability assessment conducted by Northeast Power Coordinating Council's (NPCC) Regional Planning Forum (RPF). The RPF's goal is to explore innovative approaches to reliably enhancing the capabilities of the transmission grid from a Wide-Area, Trans-Regional outlook. Scenarios of Canadian to United States transfers, New England to the Mid-Atlantic Area Council (MAAC) transfers, and New England to New York transfers illustrate the constraining transmission elements in today's interconnected system, providing a starting point for additional reliability assessments. PowerWorld's linear contingency and voltage analysis programs were used to analyze the system response to the transfers resulting from the scenarios considered. An additional investigation of the factors involved in reliably increasing the size of NPCC's largest single contingency (currently approximately 1,500 MW) was also performed.*

## 1. Background

The NPCC Regional Planning Forum's (RPF) goal is to explore innovative approaches to reliably enhancing the capabilities of the transmission grid, from a Wide-Area, Trans-Regional outlook<sup>1</sup>.

This analysis reviewed recent NPCC Area reports [1], [2], [3] individual Area transmission planning efforts [4], [5], [6], Governmental initiatives [7], and previous work by the ISO-MOU Planning Working Group<sup>2</sup> to identify existing Northeast transmission

limitations, planned near-term transmission and new generation projects.

This analysis illustrated the transmission paths associated with increased transfers on today's system by using the NERC Multi-Regional Modeling Working Group's (MMWG)<sup>3</sup> Summer 2001 Peak Case with the linear contingency analysis and voltage adequacy assessment features of the PowerWorld Simulator<sup>4</sup>.

### 1.1. Linear Contingency Analysis

One of the main tools of the PowerWorld Simulator is the Available Transfer Capability (ATC) tool. The Simulator's ATC tool features the ability to generate a list of transmission system elements that may limit the incremental transfer capability of a defined transfer.

The foundation of the ATC tool is based on linear analysis techniques. These linear analysis techniques include sensitivities such as Power Transfer Distribution Factors (PTDF), Outage Transfer Distribution Factors (OTDF), etc., to approximate the possible transfer limitations of increasing transfers between a source and sink. The linear analysis is performed by calculating the linear sensitivities around the operating point of a base case, and then solving a set of linear equations to generate a list of potentially limiting elements at various transfer increases. In addition to computing the transfer capability under normal system operation, Simulator also features the

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to resolve present and future inter-regional issues (see [www.isomou.com](http://www.isomou.com)).

<sup>3</sup> The NERC Multi-Regional Modeling Working Group (MMWG) is responsible for developing a library of solved power flow models of the Eastern Interconnection for use by the Regions and their member systems in planning and evaluating future systems and current operating conditions (see [www.nerc.com](http://www.nerc.com)).

<sup>4</sup> The PowerWorld™ Simulator is an interactive power simulation package designed to simulate high voltage power system operation (see [www.powerworld.com](http://www.powerworld.com)).

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<sup>1</sup> NPCC's reliability assessment for the summer of 2002 [1] indicated that the available margin of operable capacity within the Region was reduced by approximately 5,900 MW due to transmission constraints.

<sup>2</sup> The Memorandum Of Understanding (MOU) is a formal agreement to explore ways in which the ISOs can work together cooperatively

ability to generate contingency records and perform the ATC analysis under those contingency conditions.

Assumptions:

- Branch limits were converted from MVA to equivalent Amps, where applicable;
- Radial branches were not monitored; and,
- Contingency ratings were used when computing the ATC under contingency conditions.

Results are linearized approximations:

- For more accurate results, full AC load flow ATC can be calculated; and,
- Results are additional transfer amounts above the already existing transfers.

## 1.2. Voltage Adequacy Assessment

An additional tool available for the PowerWorld Simulator is the Voltage Adequacy and Stability Tool (PVQV). The Simulator's PVQV tool features the ability to assess adequate voltage levels for a defined transfer direction. The results of the assessment provide information on the buses of the system that fall below a predetermined adequate voltage, the amount of transferred power above the base case transfer at which the first inadequate voltage is detected, the voltage collapse point during the transfer, (if one is detected) and P-V and Q-V plots of specified buses as determined during the course of the incremental transfer.

The PVQV tool is based on a Modified Newton Full AC load flow routine. The voltage assessment is performed by incrementally increasing a transfer between a specified source and sink, and solving the AC load flow for each increment. During this process Simulator monitors voltages at desired buses in the system for inadequate voltages, and generates P-V or Q-V plots for specified buses. Once the analysis is complete, a list of all monitored buses below the inadequate voltage is generated, and the P-V or Q-V curves for selected buses can be displayed. In addition to computing the voltage adequacy under normal system operation, Simulator also features the ability to generate contingency records and perform the PVQV analysis under those contingency conditions.

Monitored Elements:

- New York, New England, New Brunswick and MAAC buses at 100kV and above;
- Low voltage limit set at 0.95 per unit; and,
- Buses with base case violations are ignored.

Solution process:

- Solve base case;
- Establish list of monitored buses; and,
- Run PVQV tool for each transfer.

PVQV incrementally increases MW transfer and monitors changes in bus voltages for new low voltage violations in the monitored system.

## 2. Base Case Assumptions

This analysis identifies opportunities to reliably increase transfers based on the NERC Multiregional Modeling Working Group's (MMWG) Summer 2001 Peak Case (see Figure 1) using the linear contingency analysis and voltage adequacy assessment features of the PowerWorld Simulator.

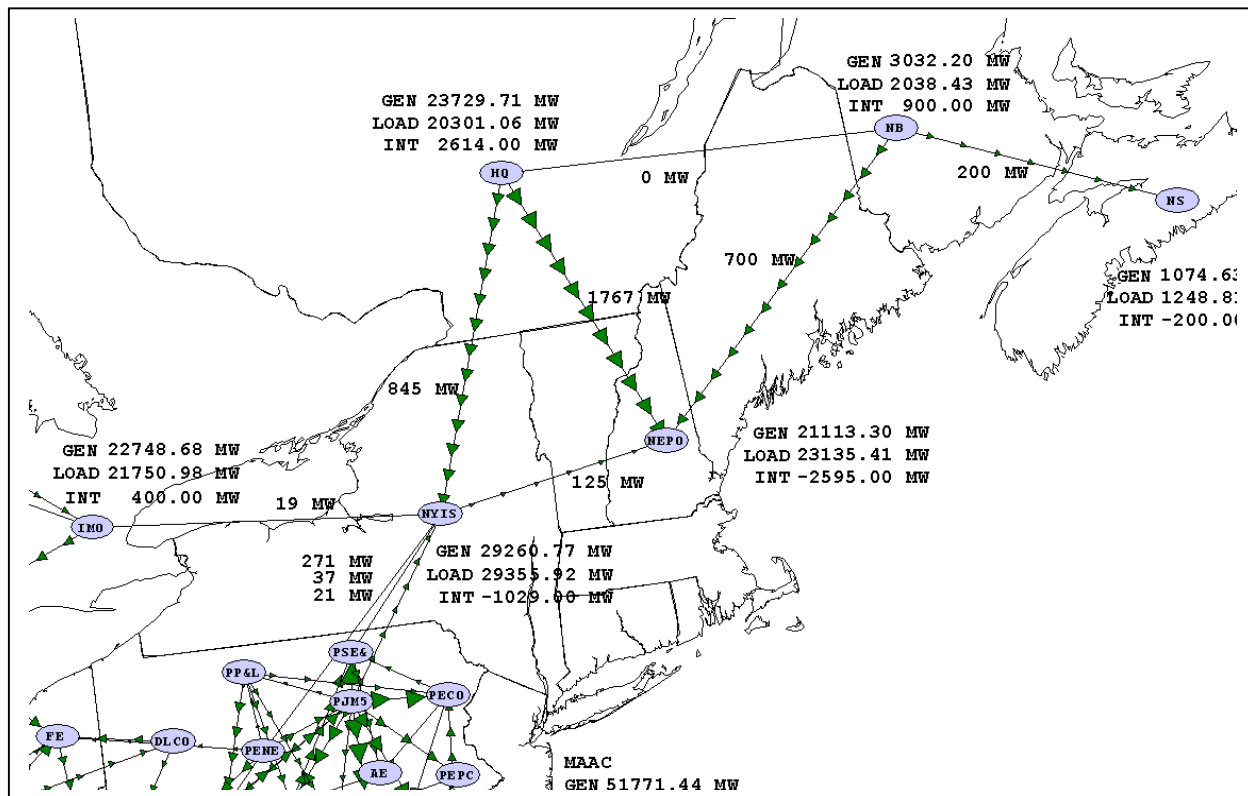
The total transfer between Hydro-Québec and New York in the Base Case was 845 MW. The Chateauguay - Massena maximum limit is 1,800 MW (1,000 MW HVDC+ 800 MW AC generators at Beauharnois)<sup>5</sup>. However, it is often restricted at the present time to 1,500 MW by the New York ISO. For the purpose of this study, the 1,800 MW limit was assumed, leaving the additional transfer on the Chateauguay-Massena line into New York to be 1,800-800 MW = 1,000 MW. Table 1 lists the assumed Base Case Interchanges.

**Table 1 - Base Case Interchanges (MW)**

PJM to New York	300
ECAR to PJM	255
Québec to New York	845
Québec to New England	1,767
Québec to New Brunswick	0
New York to New England	125
New Brunswick to New England	700
New Brunswick to Nova Scotia	200
Ontario to New York	19
Ontario to ECAR <sup>6</sup>	583

<sup>5</sup> On June 1, 2000 the New York ISO increased the scheduling limit for the Hydro-Québec to New York ISO interconnection from 1,200MW to 1,800 MW.

<sup>6</sup> East Central Area Reliability Coordination Agreement Power Systems.



**Figure 1**  
**Base Case Transfers**  
**Linear Analysis and Voltage Assessment**

### 3. Scenarios Studied

Scenarios were selected to illustrate where and how transmission limitations could restrict opportunities for increased transfers from Hydro-Québec, New England, and New Brunswick. These Areas were selected based on their expected potential for sources of available generation<sup>7</sup>.

Base Case transfers were increased for the following Hydro-Québec to United States scenarios by the following amounts:

- Hydro-Québec (Sandy Pond, NB, Chateauguy) to MAAC by 1,900 MW;
- Chateauguy to MAAC, NE, NY, & (NE+NY) by 1,000 MW, respectively;
- Chateauguy to (NE+MAAC) by 1,000 MW
- Chateauguy and Sandy Pond to MAAC by 1,500 MW; and,
- Sandy Pond to MAAC by 500 MW.

#### 3.1. Results

- All Chateauguy to United States (New York, MAAC, New England) scenarios were limited by the Central East and the Moses-South internal New York interfaces;
- Relative to transfers to New York from Hydro-Québec, transfers to New England were more sensitive to the Central East flow; transfers to

<sup>7</sup> Presentation by ISO-NE to FERC's Northeast Energy Infrastructure Conference, January 31, 2002 indicated supply additions in New England appear strong in relationship to demand growth; approximately 6,000 MW from generation projects (under construction) anticipated for the year 2002 and beyond.

MAAC were less sensitive to the Central East flow;

- The proposed operation of the Ontario phase shifters had little impact on the transfers (~ 100 MW); and,
- Combining Chateaugay and Sandy Pond for transfers to MAAC could significantly increase transfer capability (assuming that Sandy Pond is not restricted due to New York or PJM internal interface limits).

### 3.2. Increased New England to MAAC Transfers

This scenario increased the existing generation in New England and decreased generation in MAAC in order to increase New England to MAAC transfers. The Base Case assumed ~ 300 MW transfer from MAAC to New York.

**3.2.1. Observations.** The New England to MAAC transfer was limited by the New England Orrington-South interface (becomes ~100% loaded with an additional transfer of 421 MW) and the assumed New England-New York interface limit (1,000 MW).

### 3.3. Increased New England to New York Transfers

This scenario increased the existing generation in New England and decreased generation in New York (not including most 138kV generation in the Con Ed region) in order to increase transfers from New England to New York. The Base Case assumed a 125 MW transfer from New York to New England.

**3.3.1. Observations.** New England to New York transfer was limited by the New England Orrington-South interface (becomes ~100% loaded with an additional transfer of 421 MW) and the UPNY-Con Ed New York interface (becomes ~100% loaded with an additional transfer of 907 MW) before hitting the assumed New England-New York interface limit (1,000 MW).

### 3.4. Increased New Brunswick to New England Transfers

This Scenario included the proposed 345 kV branch from Pt. Lepreau to Orrington:

- Assumed a 300 MW increase in the existing New Brunswick to New England interface transfer limit (from 700 MW to ~ 1,000 MW);
- Recalculated Base Case load flow showed ~ 300 MW on the existing New Brunswick to New England tie line, and ~ 400 MW on the proposed Orrington to Pt. Lepreau 345 kV circuit.

**3.4.1. Observations.** The proposed 345 kV Pt. Lepreau to Orrington circuit provides some additional transfer capacity between New Brunswick and New England but the full benefit will require transmission upgrades of the Maine transmission corridor (Orrington-South and Surowiec- South interfaces).

## 4. Voltage Analysis

For each of the previous scenarios, the PowerWorld Voltage Adequacy and Stability Tool (PVQV) was used to evaluate incremental increases in MW transfer and monitor changes in bus voltages until a new low voltage violation occurs. The foundation of the PVQV is based on a modified Newton Full AC load flow. The voltage assessment was performed by incrementally increasing a transfer between a specified source and sink, and solving the AC load flow for each increment.

The monitored elements were:

- New York, New England, New Brunswick and MAAC buses at 100kV and above;
- Low voltage limit set at 0.95 per unit; and,
- Buses with Base Case violations were ignored.

### 4.1. Results

Overall, additional transfers of 1,000 MW (total of ~ 1,800 MW) from Chateaugay to New England, New York or MAAC resulted in pre-contingency voltage reductions on Central East (New Scotland) from 0.5 to 0.8 percent, the New England case being the most severe and the MAAC case being the less severe. This suggests that the existing Chateaugay export limit could be increased by recognizing the relative impact (voltage or thermal) of additional transfer through New York, either to MAAC or to New England.

For the New Brunswick to New England scenario (with the Pt. Lepreau to Orrington 345 kV line addition), voltage support in Maine was shown to be a problem. This confirms the linear analysis results that

without reinforcement, the existing Maine transmission system would limit transfers after the proposed line addition.

## 5. Loss of the Hydro-Québec Phase II Interconnection

Existing operating limitations of the Hydro-Québec Phase II facility below the design limit have been identified as being very costly. Analysis by ISO-NE [4] claims that moving from the current limit of 1,500 MW to the 2,000 MW design limit could reduce their total supply cost by more than \$200 M over the five-year study period.

The original reliability studies for the Hydro-Québec Phase II interconnection [8] concluded that the loss of the Hydro-Québec Phase II facility could have more severe effects on PJM and NYPP than the worst internal contingency that these systems individually protect against. Accordingly, an operating philosophy in which the Hydro-Québec HVDC exports would be limited to the extent necessary to ensure that the MAAC –ECAR-NPCC (MEN) system’s thermal, voltage and stability operating criteria are not violated was agreed upon.

The original study [9] indicated, under the conditions assumed<sup>8</sup>, that the Hydro-Québec Phase II interconnection would be restricted to approximately 1,500 MW during periods of high transmission utilization in MAAC, in order to avoid unacceptable voltages in MAAC following the loss of the Phase II interconnection.

The Joint Interregional Review Committee’s approval of this report was contingent upon the operating entities in MAAC, ECAR and NPCC establishing documented joint operating procedures to insure that deliveries to the US on the Hydro-Québec Phase II interconnection are limited to safe levels that will not jeopardize the regional reliability of the MEN systems.

The purpose of this analysis was to reexamine the Hydro-Québec Phase II interconnection restriction in light of today’s system, by analyzing differences in load flow post-contingency voltages due to a single contingency loss of up to 2,000 MW in the NPCC Area.

The previous Base Case was redispatched to increase Hydro-Québec to New England Phase II transfers from 1,500 MW to 2,000 MW. The load flow was then solved to simulate system conditions

<sup>8</sup> NY Total East Transfer Limit of 5,600 MW; ECAR to MAAC Transfer Limit of 3,950 MW.

immediately following the loss of the facility, assuming:

- Controller changes remained fixed at current settings, i.e. no LTC, Phase Shifter, Switched Capacitor, etc. changes; and,
- Generation would respond across the Eastern interconnection proportionately according to the units’ respective MVA capacity, to approximate the system’s inertial response to the contingency.

The Base Case transfer levels in MAAC, ECAR and NPCC for this analysis were set to approximate their simultaneous maximum values (shown in Figure 2):

- The Chateauguay HVDC flow was increased to 1,000 MW. The 765kV New York branch flow was increased to about 1,500 MW; and,
- The system transfer levels were considered reasonable; each Area had an acceptable response to their largest contingency.

The following interface flows and limits were modeled:

<u>Interface Name</u>	<u>Flow (MW)</u>	<u>Limit (MW)</u>	<u>%</u>
Central East	2,866	2,850	101
NY Total East	5,421	5,300	102
PJM East	5,978	6,000	99
PJM Central	2,737	4,500	61
PJM West	4,976	5,750	87
PJM – NY	1,573	2,350	67
ECAR – MAAC	3,033	4,500	67

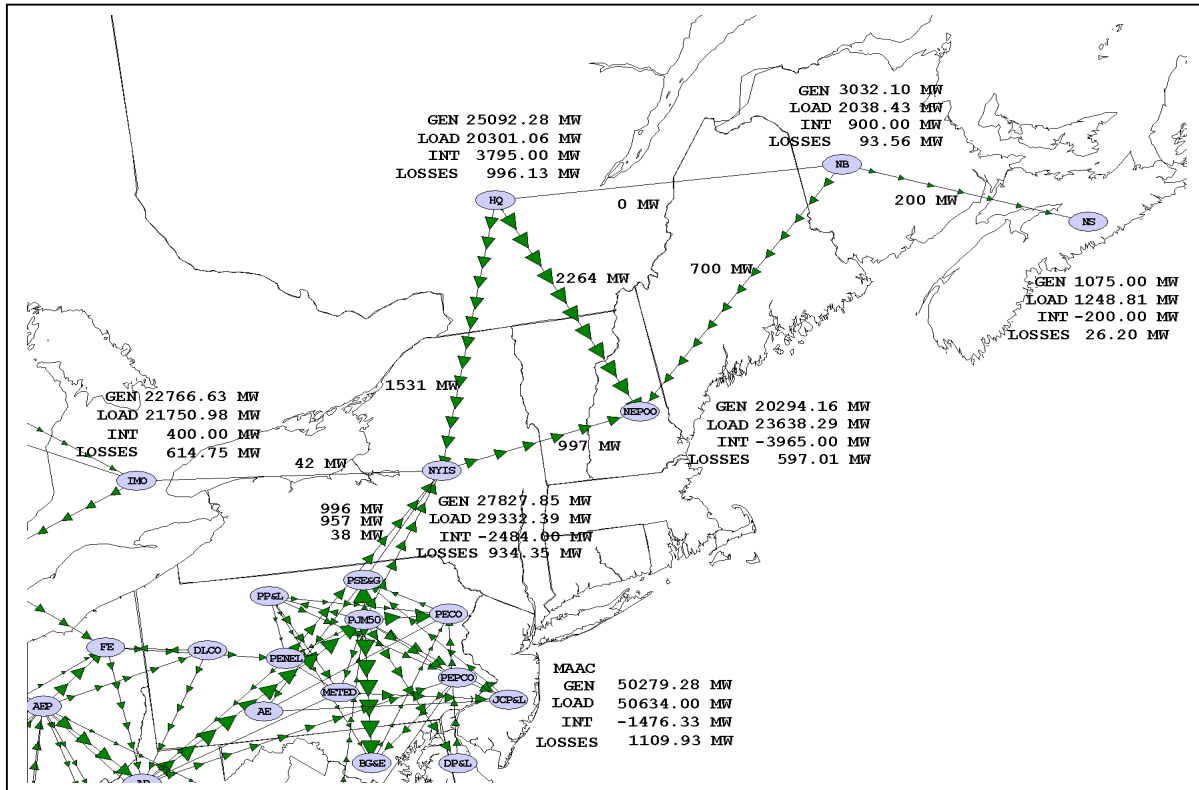
**5.1.1. Observations.** A solved load flow was reached for the contingency of 1,700 MW on the Hydro-Québec Phase II interconnection. The 1,800 MW contingency failed to solve, due to voltage collapse from lack of VAR support in New York.

The solution failure occurs on the 115 kV New York ISO system around the Oakdale substation<sup>9</sup>. A FACTS<sup>10</sup> device at the Oakdale 230kV bus was simulated by adding a generator with VAR support only (range at –200 MVAR to +200 MVAR).

A solved load flow was obtained for the contingency. The simulated Oakdale FACTS device produced approximately 166 MVAR to maintain the Oakdale 230kV bus at 1.0 per unit voltage.

<sup>9</sup> The Oakdale substation is located in the New York State Electric and Gas service territory, near Binghamton, New York.

<sup>10</sup> Flexible AC Transmission System (FACTS) devices enhance the transfer of electricity. They have been shown to increase the transfer capability in a cost-effective manner when compared with other methods (see www.epri.com).



**Figure 2**  
**Base Case Transfers for Loss of Hydro-Quebec Phase II**

- 1,800 MW Contingency – 661 MVAR
- 1,900 MW Contingency – 700 MVAR
- 2,000 MW Contingency – 758 MVAR

The 1,900 MW contingency also solved with this device in place, requiring the device to supply its maximum 200 MVAR. At the 2,000 MW contingency, the single Oakdale 200 MVAR device was not sufficient, and the load flow again failed to solve.

A second 200 MVAR device was added on the Oakdale 345kV bus, which enabled the load flow to solve for the 2,000 MW contingency. The total VAR support at the two Oakdale devices (both attempting to maintain terminal voltages of 1.0 per unit) was 200 MVAR on the 345kV bus, with roughly an additional 145 MVAR on the 230kV bus.

Similarly, a FACTS device was alternately modeled at the New Scotland<sup>11</sup> substation, with the following results:

<sup>11</sup> The New Scotland substation is located in the Niagara Mohawk service territory, near Albany, New York.

## 6. Conclusions

The NPCC Regional Planning Forum has quantified its preliminary findings for today's system, and, working with its neighboring Areas, identified how the largest NPCC single contingency could be increased by demonstrating the reliability benefits derived from the application of a strategically placed FACTS device.

The RPF analysis was not meant to be a proposal or endorsement for any particular project; a detailed cost-benefit analysis was not conducted, nor have extensive system or environmental studies been undertaken. However, the RPF results illustrate, from a Wide-Area, Trans-Regional outlook, system improvements that have the potential to increase the transfer capability of the network, thereby enhancing the reliability of the system by reducing the amount of capacity unavailable at the time of system need due to transfer limitations.

## 7. Future Work

The transfer scenarios described in this paper will be analyzed with respect to the projected changes in system facilities associated with the respective Area's transmission plans for the 2005 – 2006 time frame.

Results from NPCC's Collaborative Planning Initiative's investigation of transmission bottlenecks in the Northeast Region for this time period will be used as the starting point for this future analysis<sup>12</sup>.

Comparison of today's system response with the response of the anticipated future system for the same scenarios serves to illustrate the opportunities that exist for enhancing the transfer capability of the transmission grid.

## 8. References

- [1] NPCC Reliability Assessment for Summer 2002, NPCC, May 2002.
- [2] New York ISO Summer 2001/2002 Operating Studies, NYISO, April 2001/2002 (see [www.nyiso.com](http://www.nyiso.com)).
- [3] MAAC-ECAR-NPCC Summer 2001/2002 MEN Interregional Transmission System Reliability Assessments, May 2001/2002 (see [www.npcc.org](http://www.npcc.org)).
- [4] New England 2001 Regional Transmission Expansion Plan (RTEP01), Approved by the ISO-NE Board of Directors, October 19, 2001.
- [5] 10-Year Outlook: An Assessment of the Adequacy of Generation and Transmission Facilities to Meet Future Electricity Needs in Ontario, the Independent Electricity Market Operator (see [www.theimo.com](http://www.theimo.com)).
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- [9] 1990 Summer Interregional System Performance – Part 2 Dynamic Analysis, MAAC-ECAR-NPCC (MEN) Study Committee, April 1988.

## 9. Acknowledgements

The efforts of the NPCC Regional Planning Forum, Jean-Marie Gagnon, TransÉnergie Hydro-Québec; Robert Waldele, New York ISO; William Harm, PJM, James Helton, ISO New England Inc.; and J. D. (Dan) Rochester, the Independent Electricity Market (Ontario); is greatly appreciated and acknowledged.

## 10. Biographies

**Philip A. Fedora** obtained a M. S. in Electrical Engineering at the University of Pittsburgh. He is the Director, Market Interface at Northeast Power Coordinating Council. Previously, he has held positions at ISO-NE Inc., New England Power Planning, and the Westinghouse Electric Corporation. He is a member of CIGRE, the IEEE and is a registered professional engineer in the Commonwealth of Pennsylvania.

**Kollin J. Patten** is the Director of Engineering at PowerWorld Corporation. He received his M.S. in Electrical and Computer Engineering in 1998 at the University of Illinois. His responsibilities include software development of the PowerWorld Simulator load flow analysis program and generating power system cases in the PowerWorld Simulator environment. Full-time duties also include program training, sales and customer service, and consulting projects for both software development and power systems analysis. He has industrial experience at American Electric Power and is a member of the IEEE.

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<sup>12</sup> NPCC's Collaborative Planning Initiative – Phase I, March 2002 is currently available (see [www.npcc.org](http://www.npcc.org)).