Real-time PMU-assisted Available Transfer Capability (ATC) computation beyond on-line computation of transfer limits

Dr. Hsiao-Dong Chiang
President/CEO Bigwood Systems, Inc.
Professor of ECE at Cornell University
Chiang@bigwood-systems.com
Project Background

The following funded research project on Real-time PMU-assisted Available Transfer Capability (ATC) is conducted by Bigwood Systems, Inc. with NYISO.

The NYISO has not evaluated or endorsed the research findings in the following presentation.
Overview

- **World-Leader** in Developing Advanced Tools for **Power Grid Monitoring, Analysis, Operation, Optimization and Control**
- Broad software solution portfolio with a focus on **on-line and off-line solutions** for **EMS applications**
- Established in 1995 and 18 patents.
- **Practical software for** Energy control center operators and engineers based on **Innovative Technology with 35 major clients worldwide.**
Core Products

- System Operating Limit (SOL)
  Computation for Stability Assessment & Enhancement Control with system operating limit computation for:
  - Voltage Stability
  - Voltage Violation
  - Voltage Drops
  - Thermal Limits
  - Transient stability

- Advanced State Estimator Technology
Project Background

Currently, Available Transfer Capability (ATC) is calculated based on off-line worst-case scenarios which can be conservative.

- Transmission assets are substantially under utilized
- Variable renewable energy sources, power transactions, and storage systems can cause new power transfers that need to be seen in real-time
Project Objective

- Project team seeks to use SCADA and PMU data and BSI on-line SOL engine to develop an on-line ATC Computation system to determine real-time available transfer capability (ATC)
Monitoring & On-Line Computation
Main Window
Preventive & Enhancement Control Main Window
BSI On-Line SOL Engine

- Core technology used in the on-line ATC tool is the BSI System Operating Limit (SOL) Computation Engine which is used as an operating guideline at California ISO (running every 4 minutes).

- Solutions based on 3 U.S. Patents by BSI
The ATC System will be composed of

- ATC Determination Subsystem (based on actual system operating condition)
- ATC Monitoring Subsystem (SCADA, PMU, and State Estimator)
- Real-Time Critical Contingency Detection Subsystem.

**Testing:** System will be simulated off-line with real-time data and benchmarked against current NYISO off-line computation.
Every 5~10 minutes

BSI On-line SOL Engine

ATC arbitrary numbers used for the example

<table>
<thead>
<tr>
<th>Interface #</th>
<th>ATC</th>
<th>Binding contingency</th>
<th>Binding elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case</td>
<td>765 MW</td>
<td></td>
<td>Thermal limit</td>
</tr>
<tr>
<td>1</td>
<td>324 MW</td>
<td>#1268</td>
<td>Transient stability</td>
</tr>
<tr>
<td>2</td>
<td>345 MW</td>
<td>#596</td>
<td>Voltage stability</td>
</tr>
<tr>
<td>3</td>
<td>411 MW</td>
<td>#771</td>
<td>Thermal limit (118-09)</td>
</tr>
<tr>
<td>4</td>
<td>492 MW</td>
<td>#101</td>
<td>Voltage violation (#96)</td>
</tr>
<tr>
<td>5</td>
<td>501 MW</td>
<td>#168</td>
<td>Voltage violation (#118)</td>
</tr>
</tbody>
</table>

ATC arbitrary numbers used for the example

PMUs real-time measurement information

Monitoring of critical angle difference

Safe margin 280MW
Threshold 765MW

Monitoring of critical power transfer

Safe margin 280MW
Threshold 324MW
ATC Computation and Monitoring System

Energy Management System
- S.E.: State Estimation
- N.T.: Network Topology

SCADA (Supervising Control and Data Acquisition)
- (real-time measurements)
- (Network Topology changes)

BSI
On-line Power Transfer Capability and ATC Calculations
- Look ahead load margin estimations
- Nose-point margin estimation
- Voltage-limit load margin estimation
- Thermal-limit load margin estimation
- Calculation power flow
- Binding contingencies
- Binding constraints

PTC for each interface and connecting buses

BSI/ISO
On-line ATC Calculation and Monitoring System
- Interface #1
  - Tie-line Power flow by PMU’s
  - Static PTC (MW)
- Interface #2
  - Tie-line Power flow by PMU’s
  - Static PTC (MW)
- Interface #3
  - Tie-line Power flow by PMU’s
  - Static PTC (MW)
- ... Interface #N

Voltage Security Threat Key
- Red: Danger of Voltage Collapse
- Orange: Danger of Thermal Limit
- Yellow: Danger of Voltage Violation
- Blue: Safe

Voltage Violation Type Key
- Voltage Collapse
- Thermal Limit
- Voltage Violation
Static and Dynamic Security Assessment

- It is imperative in determining the ATC to take into account all credible contingencies.

Approaches:

(i) **Look-Ahead Contingency Screening, Ranking and Detailed Analysis,**

(ii) **Real-time detection of the occurrence of Critical Contingency (smart RTCC system)**
The objective of look-ahead contingency screening and ranking is two-fold:

1. **Screen** out (rapidly) set of **insecure and severe contingencies** from a large set of credible contingencies on a power system with committed power transactions

2. **Rank** set of **severe contingencies** according to their impacts on the power systems with committed power transactions.

The following (3) look-ahead ranking lists are thus obtained:

1. Look-ahead ranked list of contingencies for **steady-state stability limit**
2. Look-ahead ranked list of contingencies for **voltage limit**
3. Look-ahead ranked list of contingencies for **thermal limit**
Why we need Real-Time Critical Contingency (RTCC) Detection

- Current generation
  - On-line Security Assessment and Enhancement

Goal:
- Meet (N-1) criterion at all time

Assumption:
- No critical contingency occur between each security assessment

Current EMS can’t meet with this criterion!
Why we need RTCC detection

What if a fault occurs between assessments?

Problems:

- (N-1) criterion can be violated (i.e. the possibility of system instability increases)
- System security is at risk
- The intermittence of renewable energy can worsen the situation
- At present, operators cannot obtain the occurrence of critical contingencies in real time
RTCC Detection System

3% PMU installation -> Data acquisition device

Dynamic of phasors
Duration: 0.1 sec

Critical Contingency List

RTCC Control System

Data Side

System Side

No Contingency

Critical Contingency Occur

Non-Critical Contingency

Details of the critical contingency

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Data Flow

Input
• Solved Power Flow solutions
• Network Topology
• Contingency List
• Interface (Flow gate) definition
• Look-Ahead Conditions
• Actual Power Transfer of each interface (via PMUs or SE)

Output
• ATC for Entire Network
• Binding Contingencies
• Violating Elements

Violations detailed include:
• Thermal Limit
• Voltage Limit
• Voltage Stability

Data formats include PSS/e and CIM/XML

Output on ATC Display Interface
Project Benefits

Real-Time ATC will provide several benefits including:

- **Energy benefits** (on-line reliability improvement and the ability to transfer more power from renewable energy resources based on on-line calculation)
- **Environmental benefits** (support more penetration of renewable energy reducing pollutant emissions from conventional generators)
- **Economic benefits** (remove transmission congestion to allow the transfer of low-cost energy resources to load centers)
- In compliance with the recommendation from NERC regarding ATC calculations.

On-line ATC system provides a more accurate ATC calculation based on on-line data.
Data Used

BSI used the following data:

- EMS Case
- Contingency and Interface Definitions
- Substation limits
- Monitored facilities
- Generator Data
- Concept for Performing Power Transfers
ATC Evaluation

- 3 Scenarios:
  - Base Case ATC
  - Limiting Contingency ATC
  - Strategic Line Switching to improve ATC

<table>
<thead>
<tr>
<th>ATC Summary</th>
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<tbody>
<tr>
<td>Available Power Transfer Margin</td>
</tr>
<tr>
<td>Weakest Bus (Experiences most significant delay at voltage level)</td>
</tr>
<tr>
<td>Limiting Bus (Bus location with first voltage violation)</td>
</tr>
<tr>
<td>Cause of Potential Collapse (Real power transmission based or reactive power based)</td>
</tr>
</tbody>
</table>
ATC Assessment and Enhancement Results

<table>
<thead>
<tr>
<th>Base Case Power Transfer Margin</th>
<th>Limiting Contingency Power Transfer Margin</th>
<th>Line Switching Power Transfer Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW</td>
<td>Reduced MW</td>
<td>Increased MW</td>
</tr>
</tbody>
</table>

*NYISO reviewing numerical results before release to public

Optimal Line Switching Location identified
Future Research

Next Steps

- Procure PMU-data for same time window as Power Flow data
- Analyze results of computed ATC with PMU Inputs
- Incorporate the RTCC subsystem
- Develop an Enhancement subsystem for Increasing ATC.
Innovation prevails!

Questions?

Bigwood Systems Inc.

Headquarters
US Corporate Office
35 Thornwood Drive, Suite 400,
Ithaca, NY 14850, USA
http://www.bigwood-systems.com
sales@bigwood-systems.com

Taiwan Office
2F, No.58, Hsin Seng S. Rd.,
Sec.3,
Taipei, Taiwan, R.O.C.

China Office
No. 259, An Shan
West Road, Xin
Cheng Mansion 1007
Tianjin, China, P.R.C

Middle East Office
EME Energy Solutions,
LLC
Office Suite #301
Al Bateen Towers, C2 Building
Bainuna Street, Abu Dhabi, UAE