Development of a New Methodology for Determining the Transfer Capability of the Western Grid

Project Report

Prepared for:

State Provincial Steering Committee

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Western Interstate Energy Board

QUANTA TECHNOLOGY
Smart Solutions, Real Results

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SUBJECT MATTER EXPERTS

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1 INTRODUCTION

One of the three missions of the State-Provincial Steering Committee is to foster policies to make more efficient use of the existing grid. States and provinces have been concerned about potential underutilization of the grid for some time. In 2012, the SPSC developed an interactive Web-based tool to enable all parties to examine historical flows over transmission paths.[1] The tool compares actual flows with the Total Transfer Capability, or TTC, on individual paths.

In this project, the SPSC seeks to understand if there is a better methodology to determine TTC, specifically a methodology that might enable greater transfers on the system while improving reliability. Reliably increasing TTC can lower costs to consumers because more economic power can be transmitted to customers and reduce the cost of integrating increasing amounts of Variable Energy Resources (VER).[2]

The SPSC, with technical assistance from Grid Subject Matter Experts, LLC (GridSME), engaged Quanta Technologies to develop a new methodology for calculating path transfer capabilities to develop dynamic (as opposed to static) path transfer values to better reflect the actual transfer capability of the lines during different time periods and system conditions. The new methodology described in this report utilizes tools that will automate current labor- and time-intensive path rating methodologies, and incorporate vastly more system operations data and information than is used today. Further, the methodology can incorporate new technologies that will allow for the active management of path flows and provide far more detailed information than has been historically available to system planners and operators. The methodology can be implemented in the next five years and does not require any major technological advances. Reliably expanding transfer capacity on the existing grid is possible because of advances in computing capability, the deployment of an extensive synchrophasor network, and the deployment of new grid management and measurement technologies that are currently or will soon be implemented.

This document discusses:

- The need and goals for a new transfer path rating methodology;
- The process used to develop the new methodology;
- The new methodology;
- An example of the application of the methodology on the California-Oregon Intertie (COI), one of the largest transmission paths in the Western Interconnect; and
- Recommendations for implementing the technology in the Western Interconnect.

The appendix to the report includes a detailed description of the new methodology.

[1] Transmission paths can be single line or a group of lines between two areas.
[2] Greater transfer capabilities would enable the aggregation of variability in load and VER generation over a broader area thereby lowering overall variability and the cost of integrating VERs.

2 BACKGROUND

The goals for a new path transfer methodology are to:

- Improve reliability;
- Increase transfer capability to meet changing grid uses;
- Utilize all available grid information and emerging grid management technologies; and
- Promote consistency in path ratings from long-term planning, through operations planning and real-time operations. Below is a discussion of these goals.

The State-Provincial Steering Committee was interested in exploring what is technically possible, rather than focusing on commercial issues associated with changing the current procedures governing path transfer capacities.

Enhancing Reliability

The Western Electricity Coordinating Council's (WECC) Planning Coordination Committee (PCC) has the responsibility for oversight and review of the path rating process in the Western Interconnection, while Peak Reliability (Peak) coordinates the development of seasonal transfer capabilities for the paths. Recent failures of the bulk electric system (BES) highlight that the current processes are insufficient to meet the current and future requirements of the system. This failure was highlighted by the September 8, 2011 Southwest outage, where there was a massive cascading blackout despite the fact that all paths were operating within the prescribed limits. This concern was discussed by Gerry Cauley, CEO of the North American Electric Reliability Corporation, in a letter to WECC following the September 8, 2011 outage:

> NERC is pleased to see that WECC is holding additional discussions to clarify the role of Path Operators, including the potential to implement contractual relationships and make use of RTCA [Real Time Contingency Analysis] and other tools to improve the accuracy of system operating limits. As these discussions continue ***NERC suggests that you also review the concept of Path Ratings and whether, as the Western Interconnect has become more highly interconnected, the Path Rating and Path Operator concept, along with the use of nomograms, still has merit for real-time operations.*** Other interconnections do determine Flowgate limits for purposes of interchange scheduling, but rely more fully on RTCA for real-time operating reliability. *(emphasis added)*

In response to the September, 2011 event the WECC convened the Path Operator Task Force to identify potential issues with the current process. The Task Force identified several specific concerns with the current process to determine and manage Path System Operating Limits in the operating horizon. [3]

Finally, the current path ratings represent a mixture of technical capability and commercial interests. Long-term path ratings are proposed by transmission owners and are accepted upon completion of the WECC path rating process. with the ratings typically developed using a set of static scenarios that may not represent system conditions.

Increase Transfer Capability to Meet Changing Grid Uses

The uses of the transmission grid are changing, and with this is a need for more dynamic path transfer capability ratings. Historically, the paths were used to transmit large and generally predictable flows of energy. Increasingly there is a demand to use these paths to support variable amounts of generation, including the delivery of renewable generation and to capture the benefits from interregional intra-hour energy markets (i.e., the California Independent System Operator Energy Imbalance Market).

A more accurate and dynamic path rating would better support these grid needs, and likely result in more available transfer capacity (ATC) during certain hours of the day and times of the year.

The current path rating process is believed to systemically understate transfer capability. The process results in the development of a single value (in most cases) to reflect transfer capability on a path for all hours, so this will, by necessity, be a conservative value. In the planning horizon this value TTC rating represents the transfer capability at the time of peak path utilization during the year. Seasonally (or more frequently if system conditions warrant) the paths are re-assessed by the path Transmission Operator (TOP)

[3] WECC's Path Operator Task Force concluded that:

1. The Path SOL (System Operating Limits) concept undermines the distinction between reliability limitations and commercial limitations
2. Path SOLs often do not take into consideration real-time tools and information
3. The Path SOL paradigm potentially disguises other critical limitations
4. The Path SOL paradigm results in "chasing the SOL"
5. The Path SOL paradigm results in unnecessary TOP and RC compliance risk
6. The Path SOL paradigm pre-supposes the need for unique monitoring of all WECC paths
7. The Path SOL concept is extraneous and redundant in light of the revised SOL Methodology
8. TOP designated as the Path Operator may have limited ability to manage Path SOL exceedances
9. The Path Operations paradigm prevents full utilization of transmission and generation investments

to determine whether the transfer capability may be maintained or needs to be revised downward. These Seasonal Operating Limits (SOL) are the *lesser of* the TTC or the re-assessment analysis. These SOLs are used in real-time operation even if the real-time conditions on the grid would support greater transfers. Figure 1 summarizes the current transfer capability rating process by timeframe.

Figure 1

TIMEFRAME	**>1 Year**	**<1 year to Day-ahead**	**Current Conditions**
WHAT	Establish Path Rating	Establish Seasonal Operating Limit (SOL) and Interconnection Reliability Operating Limit (IROL)	Enforces Path Rating – monitors path flows and mitigates as needed
WHO	Transmission Facility Owners & WECC Project Review Group	Path Operator and affected systems group	Path Operators
USES	Transmission expansion planning, long term commitments	Establish Path Transfer capability to respond to near-term conditions (i.e. hydro and generation outages)	Maintains reliability
HOW	Calculated using long-term planning assumptions	Calculated using planning assumptions with known changes	Path limit - the lesser of path rating
WHEN REVISED	Not revised unless need arises or requested by Path Owner.	Seasonal; and as needed to reflect expected operating conditions	As needed to reflect current operating conditions

Utilize All Available Information and Incorporate New Technologies

Technology is enabling more precise methods to develop and maintain path ratings. New technologies, such as Phasor Measurement Units ("PMU" or "snchrophaser") and Distributed Flexible Alternating Current Transmission System (D-FACTS) devises provide substantially more granular information on path flows, and offer the ability to better manage transmission flows than was historically possible. Further, advances in computing capacity will enable grid planners, managers and operators with the tools necessary to process all of this information. To date, path ratings have been a slow and labor-intensive process due to the inability to process the large amounts of data required to develop path ratings and SOLs. Advanced algorithms will allow for the automation of many current manual processes (such as scenario-development), and distributed computing will minimize the new computing capacity that will be required to develop the path ratings.

Consistency in Rating Process

A concern with the current process is the potential lack of consistency in path rating processes among transmission owners and operators. The NERC and WECC provide criteria and guidelines for path rating, but leave the rating analysis to the individual path owners and transmission operators. Further, rating for the different paths have been developed over a long period of time using a variety of different assumptions and methodologies. Changes in these assumptions and methodologies over time may lead to inconsistencies in the rating assessments for individual paths.

Similarly, Seasonal Operating Limit assessments are conducted by a Regional Operational Study Group in coordination with Peak RC. There is currently no formal process for the reconciliation of data and assumptions between these groups, which may result in similar but different assumptions being used by the different Study Groups.

3 METHODOLOGY DEVELOPMENT PROCESS

Following approval of a project on path transfer capability by the State-Provincial Steering Committee, an Advisory Team[4] of Western transmission experts was established to assist in the vendor selection process and to review and provide comment on the vendor's methodology. GridSME was retained to help manage the vendor selection process for this highly technical project. An RFP was issued for a contractor to develop a new path transfer methodology. The RFP specified that the contractor must:

- Develop a scalable, flexible and adaptable new methodology to assess path transfer capability for the Western grid.
- Describe tools and analytical processes to develop and implement path transfer capability values.
- Specify data requirements to develop the path transfer capability.
- Conduct an example assessment of the proposed methodology on a WECC path.
- Identify technical hurdles and data access requirements.
- Develop a high level estimate of the cost to develop the tool.

Following the evaluation of bids, Quanta Technologies was selected to develop the methodology.

[4] The Advisory Team included:

- Vic Howell, Engineering Manager, Peak Reliability Council
- Philip Jones, Commissioner, Washington Utilities and Transportation Commission
- Andrew Mills, Researcher, Lawrence Berkeley Nation Laboratory
- Nathan Powell, Manager of Planning Services, WECC
- John Savage, Director, Utility Program, Oregon Public Utility Commission
- Dede Subakti, Director of Engineering, California Independent System Operator
- Chifong Thomas, Director, Transmission Planning and Strategy, Smart Wire Grid

4 PROPOSED FASTC METHODOLOGY

The proposed Flexible, Adaptable, Scalable Transmission Capability (FASTC) methodology is designed to work in all timeframes from long-term planning through the operating time horizon and real-time. It is designed to incorporate as much – or as little – information as is available regarding the path operation and control devices on the path. The methodology is designed to incorporate new information as it becomes available. The result is a physics-based line rating that meets all NERC defined reliability criteria.

The new methodology is, flexible, adaptable and scalable to multiple platforms.

- Flexible: The current process uses a State Estimator. The proposed methodology can use either the current data for computer programs that estimate the current state of the grid (State Estimator) or the new more granular phasor measurement unit (PMU) data, depending on the data available.
- Adaptable: Additional components can be added or subtracted as needed and as data allows. For example, Volt/VAr control from renewable generation units can be considered. System dynamic stability can be either calculated (current method) or be replaced with predictive estimations based on historic operations and advanced algorithms.
- Scalable: The system may be used with the level of detail available to the operator. Load Forecast data can be replaced with aggregated Advanced Metering Infrastructure (AMI) data.

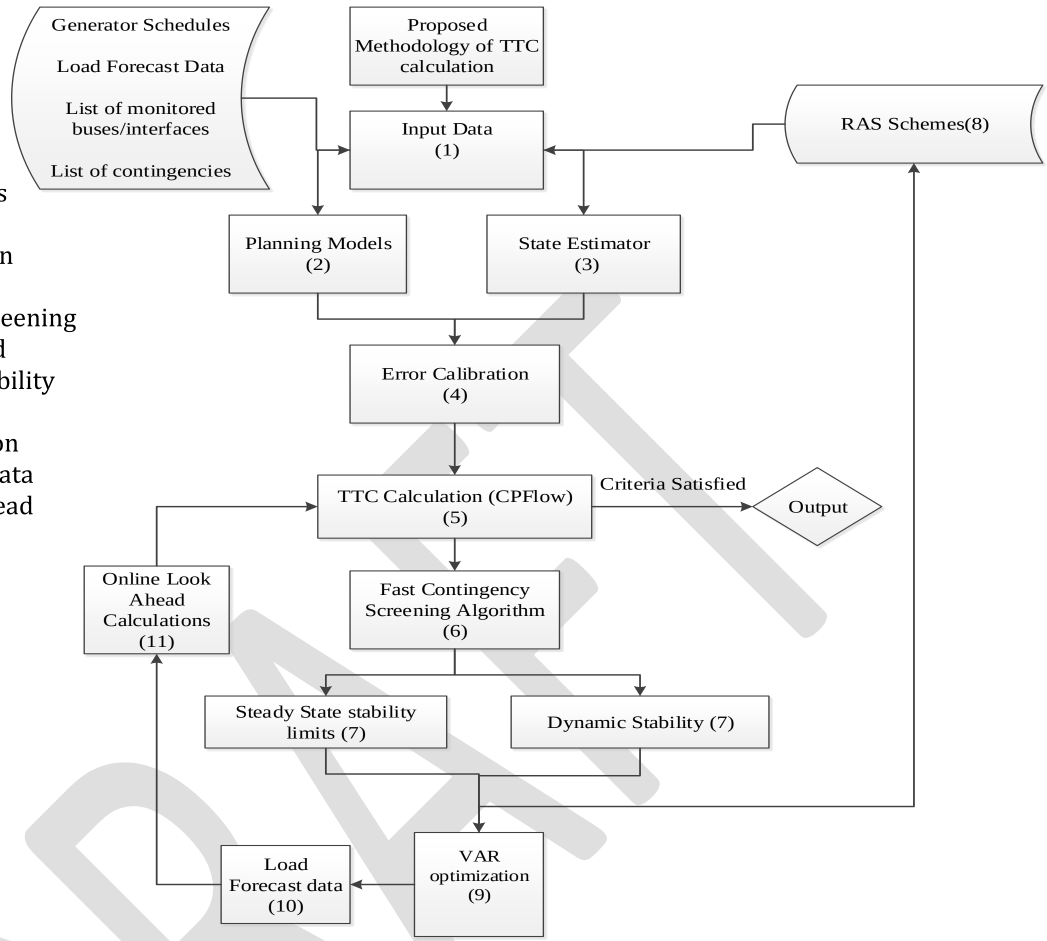
Below is an overview of the methodology, its major components, and a discussion of how the new methodology resolves concerns with the existing WECC process. The detailed methodology is included in Appendix A to this report.

4.1 Methodology

The FASTC methodology incorporates several advancements over the current process, starting with the measurement process. It includes a much more detailed representation of the transmission system (the breaker-node) than the current process (which uses a bus-level representation). In the FASTC methodology, large parts of the planning and operational path transfer calculations are automated through processes that transfer the flow of data from one stage to the other, shortening the simulation time and increasing the data-handling capabilities. Figure 2 depicts the information and process flow in the methodology.

Figure 2

1. Input data
2. Planning models
3. State Estimator
4. Error Calibration
5. TTC calculation
6. Contingency screening
7. Steady State and
   Dynamic Stability
8. RAS schemes
9. VAR optimization
10. Load Forecast data
11. Online Look Ahead
    Screening



Data Requirements

FASTC is designed to use all the transmission measurement information available in calculating the Total Transfer Capacity. The Western Interconnection now has approximately 400 synchrophasers in use that measure numerous aspect of transmission flow on a sub 1-second basis. The methodology can utilize any amount of this and additional information.

Processing Requirements

The FASTC will require substantial computing power. The methodology is designed to use distributed computing, allowing it to simulate the system across several processers simultaneously. This capability is currently in use in major university and research institutions, and is expected to become more common in industry within the next few years.

Operating Requirements

The implementation of this methodology will require a number of substantial changes to current Western Interconnection rating practices. In developing the methodology it was assumed it would be implemented within the next five years. These changes are likely to include:

- Better alignment of operating practices of transmission owners and operators throughout the system to ensure consistency in practices, tools and assumptions.
- Rules regarding the updating of planning and operating horizon ratings. This may include the formalization of when path ratings must or should be re-assessed, including allowing increases in transfer capacity beyond fixed ratings when grid conditions allow higher transfers.
- Data sharing requirements to allow access to detailed line flow data.

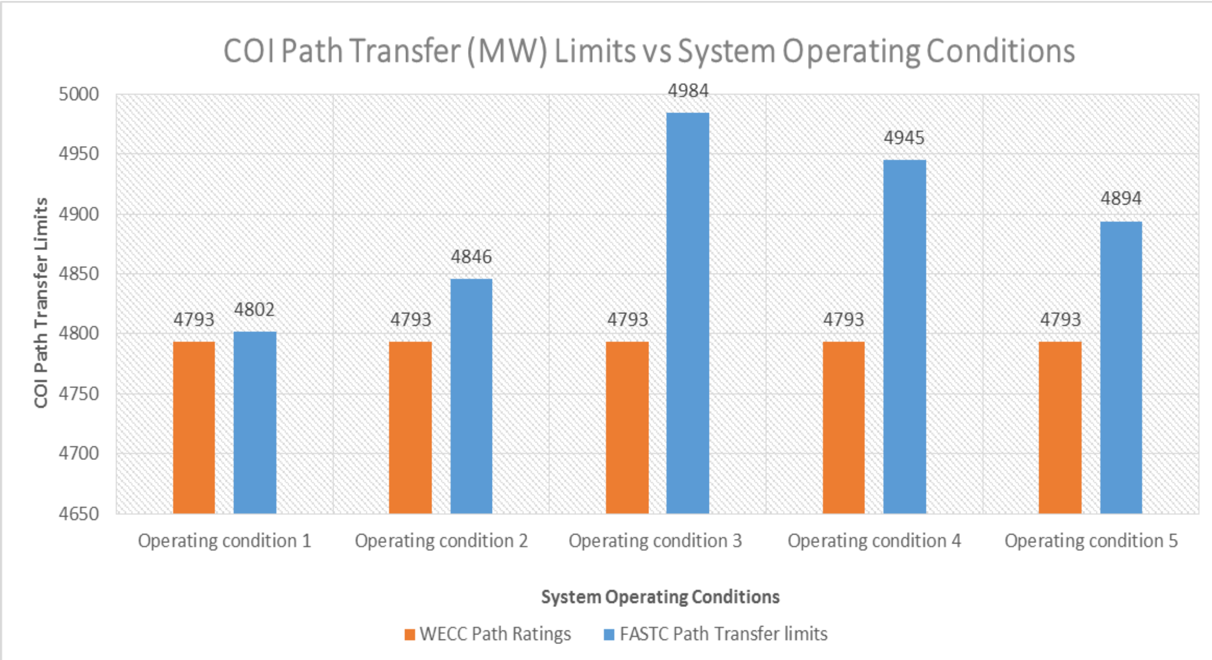
4.2 Application of the Methodology on the California-Oregon Interface

To demonstrate the FASTC methodology, Quanta simulated the development of the Total Transfer Capacity on the California-Oregon Interface (COI), an aggregation of several transmission lines that allow energy flows between the Pacific Northwest and California. Quanta assessed the "real-time" transfer capability from the Northwest to California (COI North to South) during the WECC-modeled peak flow period (defined by the WECC as the "WECC 2014 Heavy Summer 4 Base Case") as well as several hours of low flow during the spring[5]. A number of cases were created to reflect different operating conditions in the Western Interconnection. These cases were created by scaling generation and load data in different WECC planning areas, and calculating the transfer limits for each operating case. The current static methodology for path rating was also demonstrated to provide a comparison of results obtained.

Figure 3 illustrates the sample results obtained for the simulation of the WECC High Summer Loading 2014 Case. The plot compares Total COI path transfer results under four grid conditions obtained from FASTC methodology against those obtained from the current methodology. A key takeaway is that the FASTC methodology transfer limits change as system conditions change, unlike the current process that yields static transfer capacities.

[5] The low load hours represent the modeled afternoon ramp on Mach 31, 2014, the same hours modeled by CAISO in its "Duck Curve" analyses.

Figure 3



The report appendix provides a second illustration of how the FASTC methodology would address COI transfer limits during large ramping periods in the California system (the "Duck Curve" challenge). The simulated cases could be considered "real-time" simulations. The same methodology could be applied in the Operating and Planning Horizons, using a combination of historical operating data and forward planning data.

4.3 Comparison of FASTC to WECC Process

The FASTC methodology addresses many of the major concerns with the current WECC methodology. Figure 4 summarizes concerns with the current process and how the FASTC methodology addresses these.

Figure 4

Current Methodology	Main Concerns	Proposed Methodology
Total transfer capability (TTC) is computed during planning and operational (in response to system changes/outage) horizons.	The current process does not take into account most recent/up to date information of current system operating state.	Total transfer capability (TTC) is computed during planning as well as real time operations. Therefore allowing for dynamic updating of path transfer limits in 15 minute intervals.
The planning models used are bus branch representation.	Inadequate system contingency and special protection scheme response.	The planning models used are node breaker representation.
Dynamic Models are currently calibrated against historic events. However , the process Is labor intensive and typically takes a long time due to insufficient data availability and lower SCADA refresh rate; with estimations of some system data made during the process.	Dynamic models are very important to assess the transient and long term voltage dynamics of the network components. Non calibrated models can result in establishing TTC limits from models that are prone to errors.	The dynamic models are calibrated against PMU data with higher sampling times than traditional SCADA data available, and the process is automated by batch tuning of parameters of interest.
The use of SCADA measurements and static state estimators	Larger errors and slower refresh rate.	The use of Hybrid PMU and SCADA measurements with dynamic state estimators
Use of offline stability simulation tools.	Unavailability of current boundaries of safe operating region.	Use of offline and online stability simulation tools.
Typically conservative TTC limits due to planning model assumptions about future conditions.	For example- summer cases built from 1 in 10 year worst case scenario for local area studies, and 1 in 5 year for system wide studies. High hydro cases built from assumptions of future conditions.	Improved path transfer capability estimates in planning stage due to improved forecasts and real time 15 minute TTC calculation.
Repeated power flow/ Continuation power flow with load transfer increments of fixed step sizes.	Time consuming process.	Repeated power flow/ Continuation power flow with load transfer increments in adaptive step sizes.
Contingency screening and selection based on operator/ utility knowledge.	Additional renewable penetration with decreasing synchronous generation capacity can introduce new stability concerns (low spinning mass, low damped oscillations).	Dynamic contingency screening to screen out stable contingencies.
Large parts of the process are manual.	Time consuming procedure.	Automated process for planning and real time operations.
VAr control devices considered at transmission facilities in planning models, and required to operate based on assumptions of future conditions	VAr control can improve reactive power margins and increase path transfer capability.	Coordinated optimization of VAr control devices in the network to enhance path transfer capability.

5 NEXT STEPS

The FASTC methodology demonstrates that a dynamic path rating method is feasible, can maintain or improve system reliability, and will generate more accurate measurements of path transfer capabilities. However, the FASTC methodology needs to be further vetted through WECC and Peak Reliability. This vetting process should include a delineation of which existing standards, criteria and guidelines need to be changed to implement the FASTC methodology. It is recommended that the FASTC methodology be implemented in phases beginning with its real-time application. Such a phased-in approach could involve running the FASTC methodology in parallel with the existing path transfer processes to refine and test operation of the FASTC methodology. Such a test period should involve multiple transmission paths.