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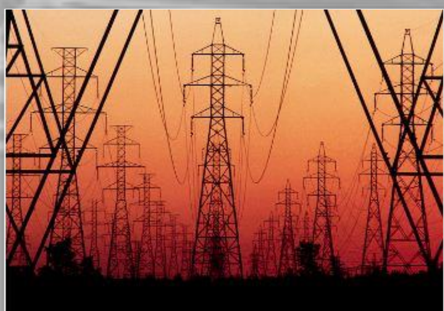
Smart Solutions, Real Results

NASPI/ International Synchrophasor Symposium



Real Time Path Transfer Limit Computation

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Contents

- BACKGROUND
- OBSERVATIONS
- METHODOLOGY
- SUMMARY

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Current TCC Approach

- Current Path Rating Process dependent on time- and labor-intensive studies -- not suited for dynamic ratings

  Dynamic ratings would:
  - Improve reliability by adapting to current grid conditions
  - Better for variable generation flow from renewables
  - Reduce costs by allowing more energy trading across paths
- In real-time a path can only be operated to *the lessor of* the long-term path rating or the seasonal path rating (SOL) regardless of real-time conditions that would allow more accurate transfer capability without threatening reliability
- This reliability-based rule was established in an age when real-time analysis of grid transfer capabilities was not feasible

Project Objectives

- Determine transfer capability based on physics of transmission system
- Maintain or enhance reliability
- Dynamically reflect transmission availability
- Anticipate new grid uses
- Responsive to available grid data and information
- Ensure consistency in line rating methodologies and practices, and can be reasonably implemented by all Transmission Operators
- Reduce costs – increase grid efficiency
- Most important, combine benefits of all existing technologies, assuming a near deployment strategy

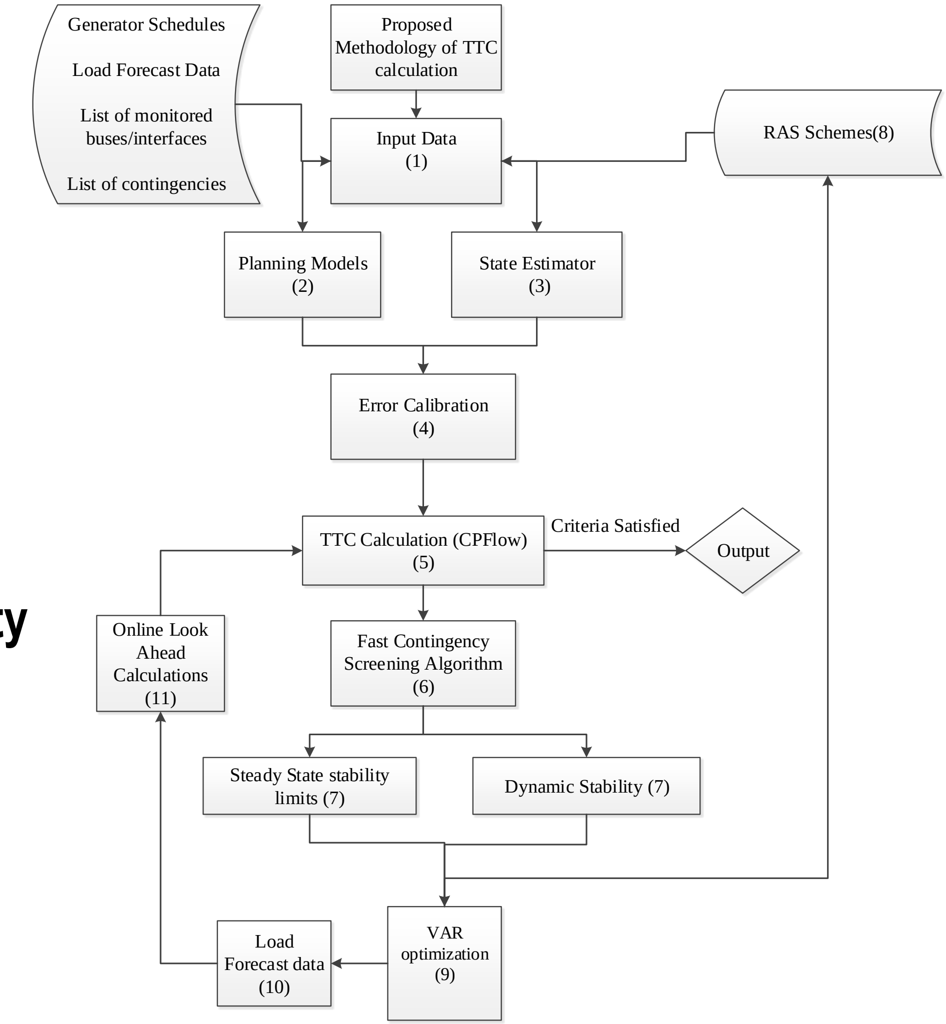
Proposed Methodology

Scalable, flexible and adaptable to multiple platforms

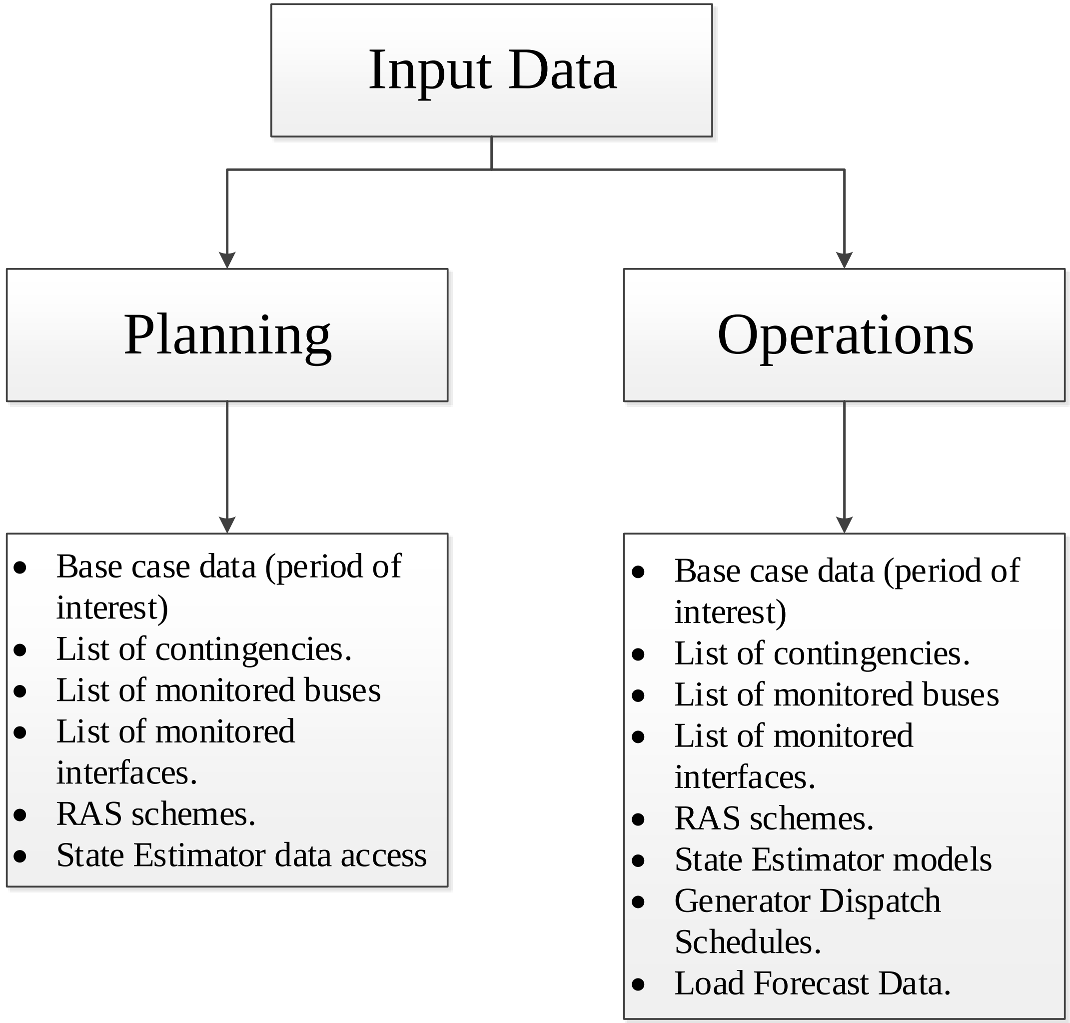
- **Flexible:**
  - Hybrid/Linear State Estimation using synchrophasor data
- **Adaptable:**
  - Additional components can be added or subtracted as needed
  - Volt/VAr control from renewable generation units can be incorporated
  - System dynamic stability can be either calculated (current method) or be replaced with predictive estimations based on historic operations and advanced algorithms
- **Scalable**
  - Load Forecast data can be replaced with aggregated AMI data at a Price node, P-node

TTC Process

1. Input data
2. Planning models
3. State Estimation
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

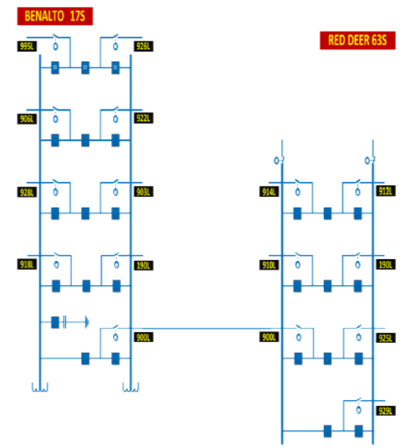


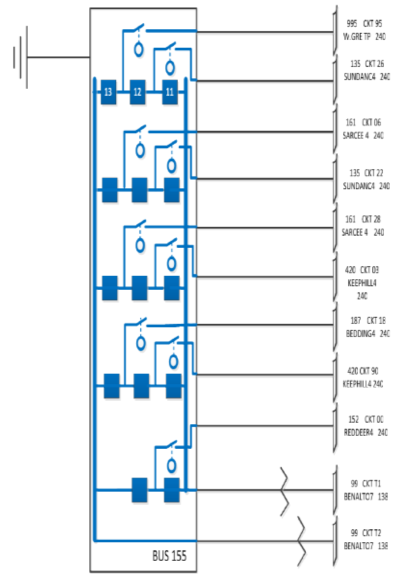
Input Data


Input Data
Planning
Operations
• Base case data (period of interest)
• List of contingencies.
• List of monitored buses
• List of monitored interfaces.
• RAS schemes.
• State Estimator data access
• Base case data (period of interest)
• List of contingencies.
• List of monitored buses
• List of monitored interfaces.
• RAS schemes.
• State Estimator models
• Generator Dispatch Schedules.
• Load Forecast Data.

Planning Models

- Planning models built representing period of study (summer, spring, winter)
- Historical Snap-shots of EMS network model available in stored repository from real time operations horizon (power flow and dynamics data file)
- Currently, wide use of bus-branch representation.
- Node Breaker representation of the traditional bus – branch configuration - Improved visibility to substation configurations and equipment
- Node breaker representation will be validated against EMS network model
  - Automated EPCL and Python scripts that verify the components at each substation
  - Most commercial tools capable of handling this kind of verification

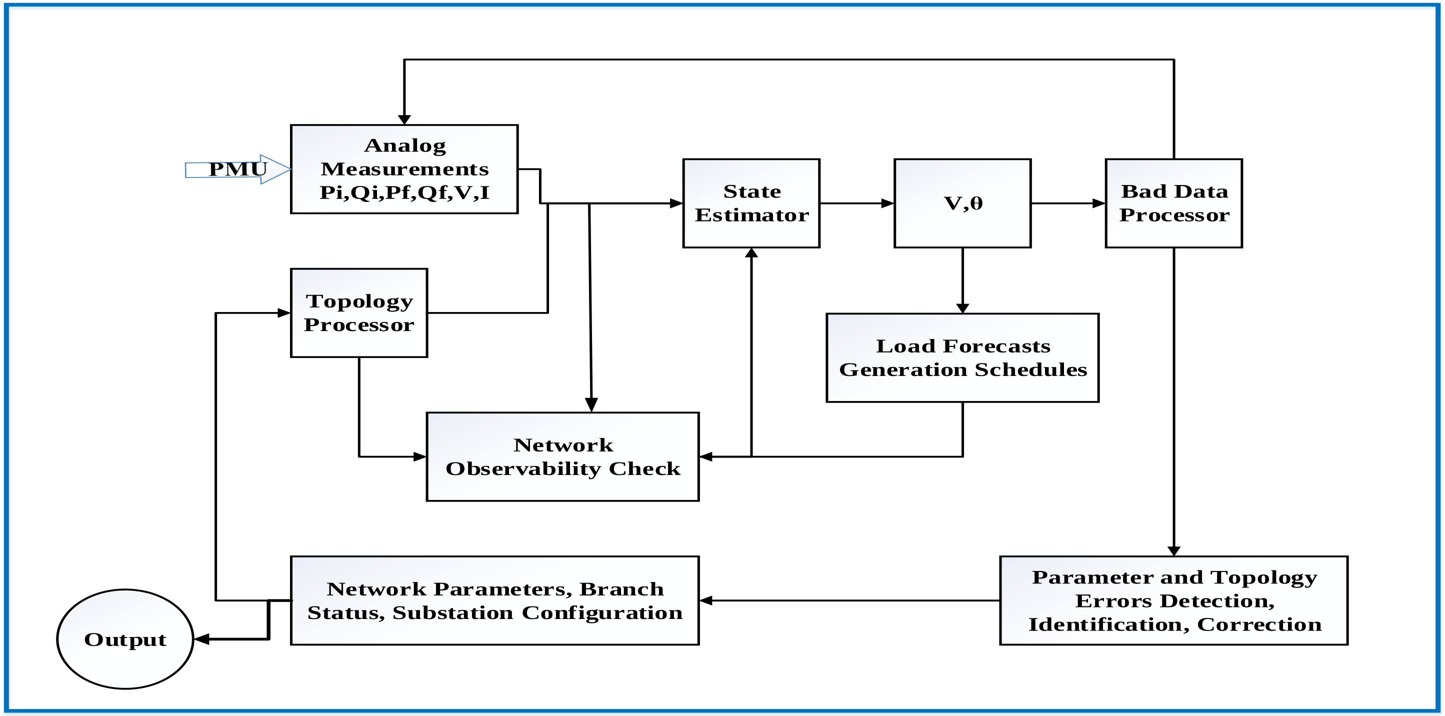




State Estimators

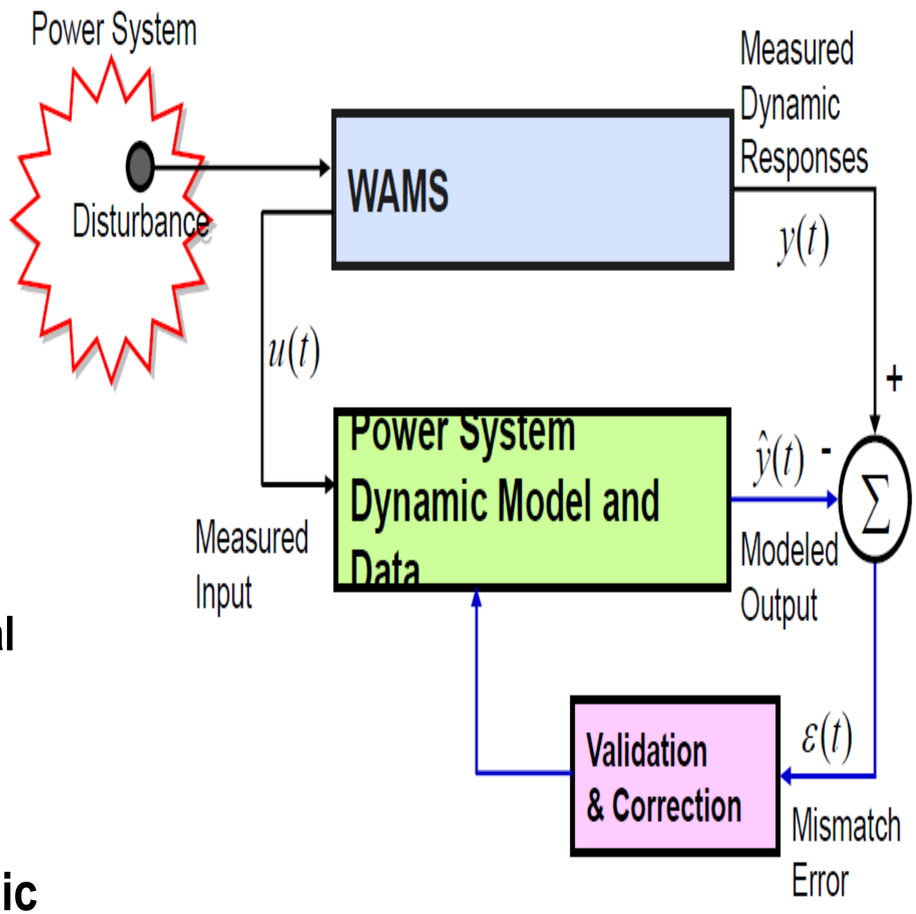
Static State Estimators or Dynamic State Estimators

- Hybrid measurements
- PMU only measurements
- 1 minute snapshot system model stored for planning activities



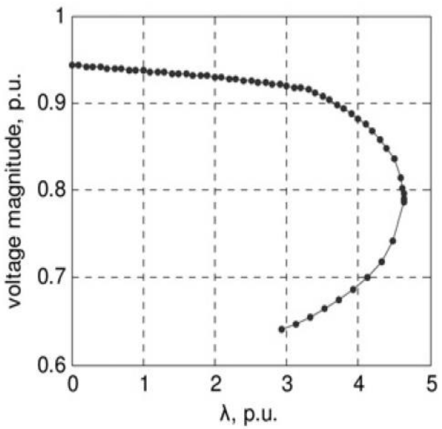
Model Calibration, Verification And Assessment

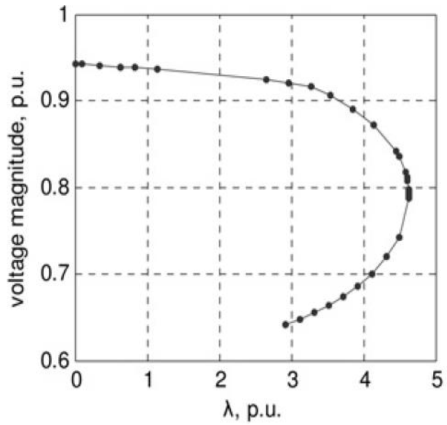
- Improve quality of dynamic models and its associated data
- Benchmarked against data collected during disturbance events from either PMUs or DFRs. The key stages are:
  - Playback of measured signals into dynamic models
  - Group the most sensitive components into batches
  - Calibration by batch tuning of individual parameters within each group
  - Comparison of simulation and measurement responses
- Tuning is common for generator dynamic models, load models and reactive compensation device models.



TTC Computation Engine

- Given a specific source and sink area, the curve can be traced till the point of maximum power transfer
- Process repeated for step size increments in the direction of load/gen. variation
- Steps involved:
  - Initialize power system data and verify pre contingency voltage and thermal overloads.
  - Choose a scalar (starting point is 1) to design prediction step size.
  - Make step size increase and predict/correct next solution.
  - If violations recorded, scale step size by 0.5, and repeat prediction/correction.
  - If no violations recorded, increase step size based on convergence monitoring as distance to divergence.





Contingency Selection and Screening

- Manual selection based on operator experience or planning recommendations.
- Automatic contingency screening algorithms - Rank contingencies based on steady state and dynamic stability
  - Post contingency voltage deviation .
  - Post contingency thermal overloads.
  - Dynamic stability contingencies based on properties of energy functions.
- Can be used in planning and operational environment.
- Contingencies identified as most critical will involve further time domain simulations.

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Steady State And Dynamic Stability Assessment

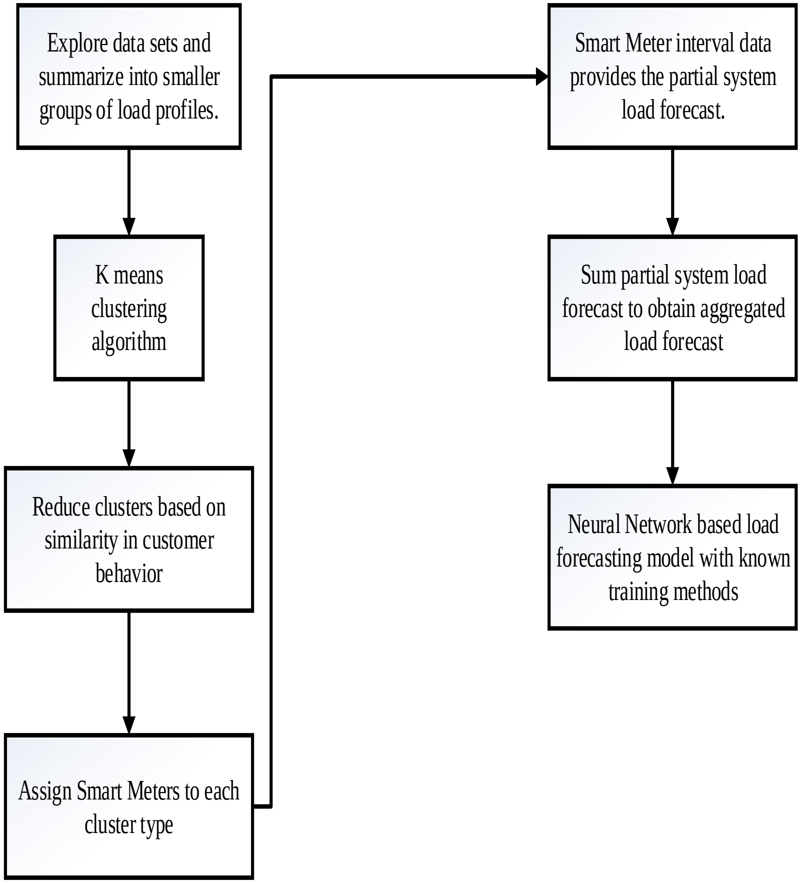
- At every step size increment of load transfer, the steady state and dynamic stability limits will be computed.
- The voltage stability criteria are monitored consistently within the process and any violations are recorded.
- Transient stability simulations in time domain are performed for critical identified locations either from past experience or through contingency screening algorithm
- The stability results are then translated to the required operating parameters.
- The total path transfer capability is identified as the minimum of voltage, thermal and dynamic stability limited path transfer along the considered interface.

RAS and VAr control

- The RAS / SPS schemes will be used as an input into the TTC calculator.
- The existing list can be added to/modified or changed a required.
- RAS Evaluation: The applicable RASs will be evaluated and their effectiveness will be determined.
  - Dynamic RAS: From a predefined list of remedial actions, RAS schemes can be dynamically updated from PMU data to improve the transfer capability along the considered path.
- At every step size increment, the different control devices in the network will be tuned to meet the objective function under consideration.
- In this work, enhancing network loadability or path transfer capability is objective - Genetic algorithm is chosen as the candidate solution.
- Few control devices considered can be:
  - Generator bus terminal voltages.
  - SVC reactive power capability.
  - Transformer tap settings.

Load Forecast Data

- **Load Forecast calculation using AMI supplied data is considered to improve the accuracy of Look Ahead TTC calculations.**
  - Availability of smart meter data provides new opportunities to generate accurate system level data.
  - Artificial Neural Networks (ANN) will continue to be used since widely accepted.
- **Data provided by load balancing authorities and reliability coordinators.**
- **Combined use of local load forecasting software tools to create a forecast model considering all system parameters such as weather , temperature and temporal conditions.**
- **Traditionally – Aggregated system level load forecasting**

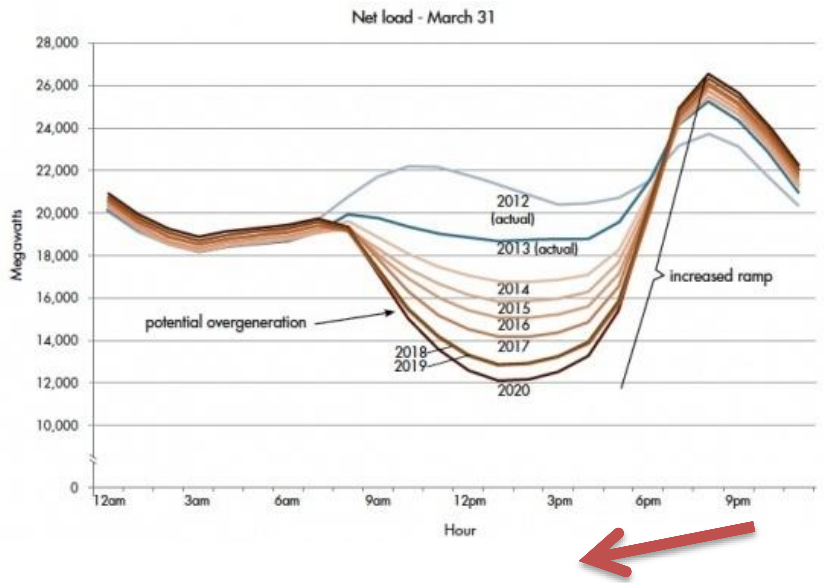


Look Ahead TTC Calculation

- Calculated using the following information
  - State of the system.
  - Proposed Power transfer agreements.
  - Load forecast
  - Generation dispatch schemes.
  - Planned Outages schedule.
- Based on the real time state estimation at hour 0, base cases for the next period under consideration are generated using the above information.

Demonstration

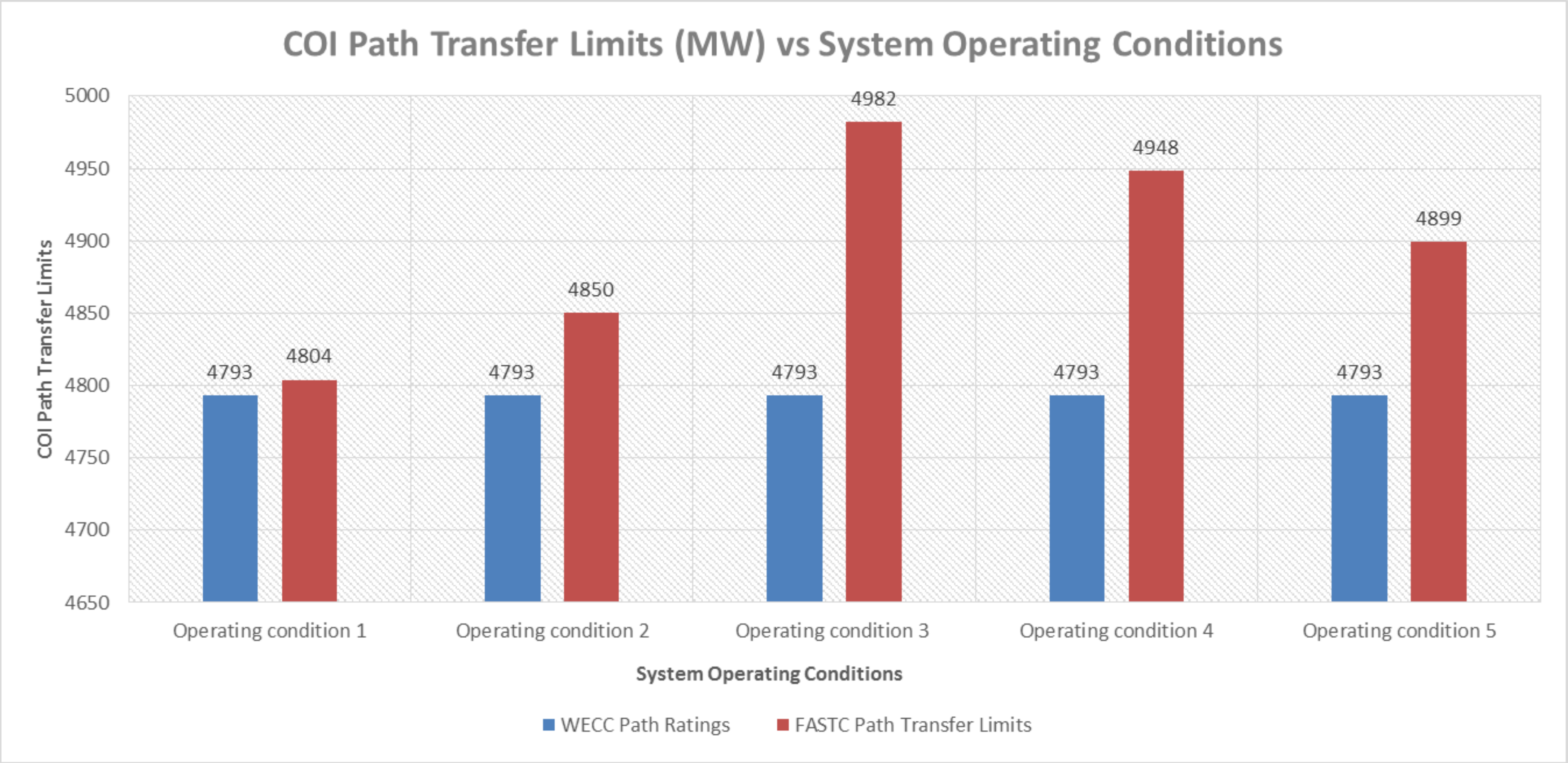
- "Base Case" Analysis
  - Generation –Load Dispatch
  - Generation – Generation Dispatch
  - All available RAS schemes modeled
  - Step size/ Transfer size increments of 100 MW



- "Duck Curve" cases
  - Simulated several hours of CAISO "duck curve" to show transfer during extreme ramp event on March 31, 2014

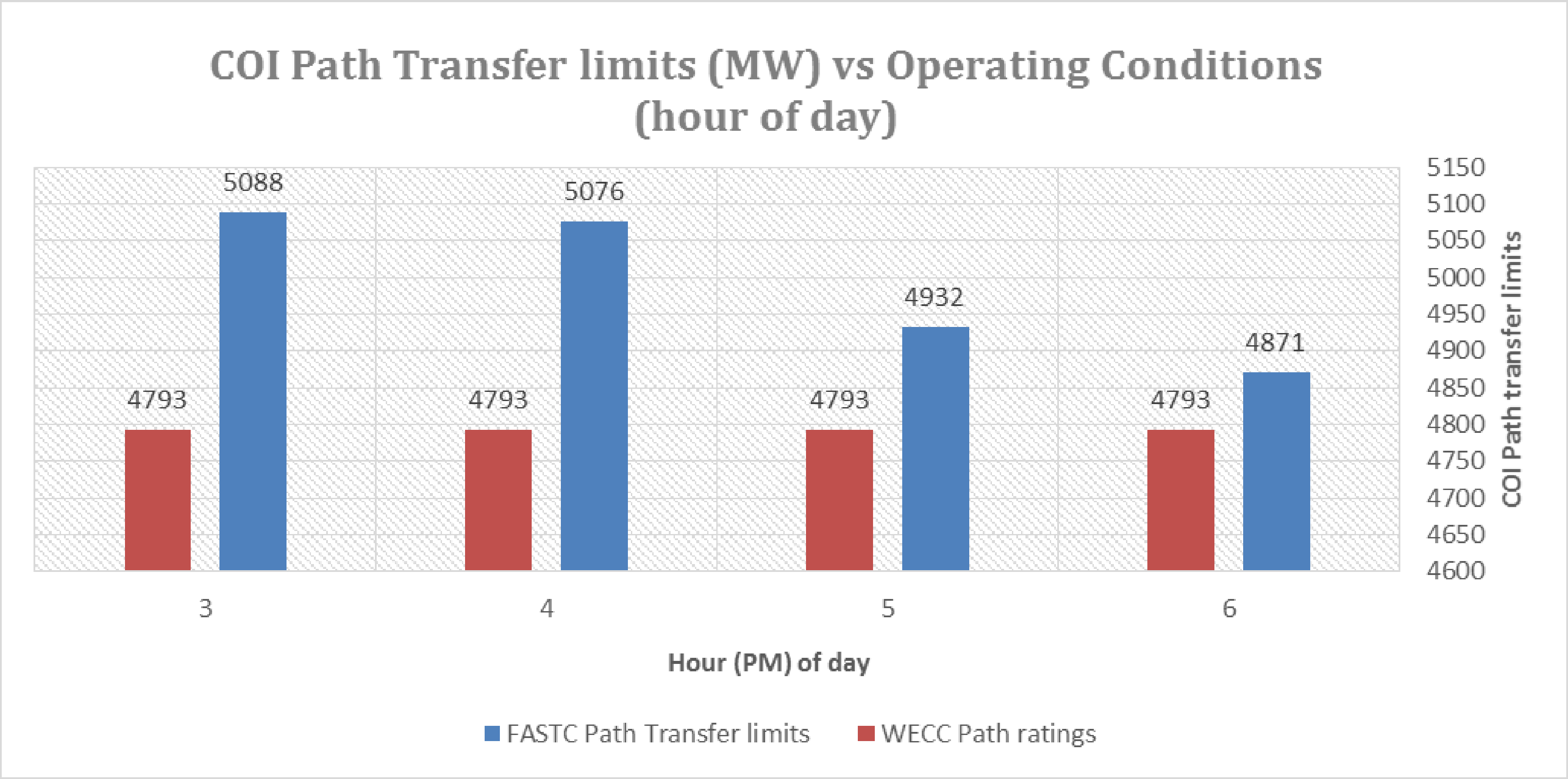
Demonstration

WECC Scenario



Demonstration

CAISO Duck Curve – March 31, 2014



Summary

- Demonstrated implementation plan under discussion with Path Operator Task Force (POTF) .
  - Component successful demonstration
  - Calculated Total Transfer Capability with increased accuracy
  - Supported by findings in other reports and literature
- TTC is not fixed - dynamically varies with system operating state
  - Examples (operating states) show variable TTC values above 4800 MW on COI
- Can be used in planning, operational and real time environments
  - Need to develop appropriate assumptions for forward planning periods

Full report of project, methodology and results available online

Thank You!

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