

Practical Experience Developing Software for Large-Scale Outage Coordination

John Condren, Boris Gisin, Jim David
PowerGEM LLC
www.power-gem.com

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Outage Coordination Topics

- Outage analysis overview and objectives
- Model building for outage analysis
- Long term future developments and needs
- PowerGEM ongoing projects



Outage Analysis Overview and Objectives



Outage Analysis Background

- Outage coordination is a critical task for effective grid operation in real time
- Large scale outage coordination brings many approaches
 - No off-the-shelf software for automated outage evaluation that includes model building and outage impact simulation/analysis
 - Both reliability and economic analysis approaches may be used
 - However, current methods are time consuming and labor intensive
- Most common solutions are based on:
 - Off-the-shelf planning software with customized automation
 - In-house EMS software and working with EMS vendor
- Presentation reflects concepts and solutions developed through several years of joint efforts with the largest US ISOs and Reliability Coordinators



Outage Analysis Background. Primary User?

- Transmission Owners
 - Develops maintenance plans
 - Determines what breakers/lines/transformers to open
- ISO, RTO, Reliability Coordinator
 - Receives requests from Transmission Owners
 - Each request consists of one or more elements to outage
 - Approve or Deny the request?
 - Number of requests can be in the hundreds for large ISO for shoulder months



How to Evaluate Outages

- Transmission Owner
 - Considers entire portfolio of outages
 - Watches out for concurrent outages
 - Watches out for outages by other TOs
 - Generator outages can have an impact

- Reliability Coordinator
 - Different time horizons
 - Near-term vs. far-term
 - For far-term, give feedback for new outage window if it does not fit original window
 - Which order to evaluate them – approaches vary



Long-term or short-term outage analysis

- The date of submission of outage request is important
- Example – ISO-NE rule
 - To be considered as part of the long-term process, an outage request should be submitted between 24 months and 21 days in advance of the requested outage start date
- A long-term process is desirable
 - More time for reliability and economic analysis
 - Better chance to re-arrange outages
 - Long-term outages are given a higher priority than short-term outages
 - Outage requests in the long-term process may also be considered in the FTR auction assumptions
- The short-term analysis focus is more on the feasibility and corrective actions available



Outage Evaluation Challenges

- Each outage/time interval should be evaluated explicitly
 - N-1 contingency analysis, SCED or SCUC
- Let's assume that
 - an outage queue contains 200 outages
 - each outage lasts an average 5 days
 - Two daily representative time intervals are evaluated (peak and off-peak)
 - Total 2,000 single period evaluations is required ($200 * 5 * 2$).
 - At least 2000 N-1 runs
 - Comparative analysis (discussed later) requires twice as many runs
- Amount of calculations can be overwhelming and require “intelligent” automation



Criteria and Evaluation Methods

Reliability Analysis

- Line/Transformer thermal overloads
- Voltage magnitude/drop issues
- Methods
 - Standard or comparative N-1, with no redispatch
 - Security Constrained ReDispatch (SCRD) – check if redispatch is available (regardless of cost, only impact)
- Can redispatch correct N-1 violations?
- TARA ORA module – Outage Reliability Analysis



Criteria and Evaluation Methods

Economic Analysis

- Economic impact of outages on day-ahead markets
- Methods
 - Determining realistic market impact requires detailed, hourly, SCUC-based market simulations that mirror DA market
 - A single time interval analysis for bid production cost impact may also be done with SCED
- Measurements: What is the cost of the outage?
 - Bid production cost change – most common solution
 - Impact on LMP, load, generation, or even FTR adequacy
 - See <http://www.pjm.com/markets-and-operations/etools/oasis/outage-accel.aspx#data2012>
- PROBE market simulation software for DA and RT markets



The Concept of Comparative Analysis

- Pre-outage model may contain N-1 violations:
 - SPS/remedial actions
 - Radial or non-fixable overload
- Objective is to find new security violations/constraints associated with the study outage
 - New problems that appear due to study outage
 - Existing overloads that may be aggravated
 - Can newly introduced problems be corrected?
 - What is the redispatch cost?
 - Without efficient implementation of comparative analysis, outage analysis automation is practically impossible
- Comparative analysis requires executing N-1 analysis twice and comparing N-1 results



Outage Evaluation Schemes

- Evaluate one day or range of days all at once
 - May involve hundreds of outages
- Evaluate outages
 - One-at-a-time individually
 - OR in sequence to find where overlapping conflicts occur
- Opportunity Window
 - When an outage overlaps and conflicts with a higher priority outage
 - Automatically search through range of days
 - Find window where “problem” outage causes no violations
- Outage return
 - Return or move approved outages in order to accommodate higher priority outage
- Automation of managing the queue of outages is the long term goal
 - Analysis of queue needs to be rerun regularly to account for ever changing system conditions, e.g. run next 35-days analysis once per day



Outage Evaluation. The Basic Scheme

- Start from the base cases with projected future conditions with all approved outages applied
- Evaluate “next” outage for all study snapshots
- If passed for each time interval, approve an outage
 - Create new set of models with just approved outages
 - Proceed to the next outage
- If failed, several options available
 - deny outage
 - try finding an opportunity time window
 - Outage return – try finding previously approved “lower priority” outage that if returned, will allow accepting study outage



Outage Evaluation. Alternative Schemes

- Evaluation order has major impact on the outcome because outages interact and studying all permutations is not feasible
- Alternative schemes
 - Test each outage one-at-a-time to see if it can be applied to “base case”, then restore it back before testing the next – find ‘incremental’ outage impact
 - Conditionally approve even “failed outages”, still build in the model before proceeding to the next outage
 - It may be possible to find a solution once we approve all outages
 - Approve all study outages, then study impact of outage return – one of the possible solution to find the “cost of outage”



Automated Modeling Building AMB



The Role of Automated Model Building

- Outage analysis requires creating numerous future load flow models
- Should account for projected future conditions including
 - Load forecast
 - Already approved outages
 - Area Interchanges and transactions
- Wide area modeling – include at least all tier 1 companies
- Centralized multi-area economic dispatch
- Concerns
 - Do we have sufficient data allowing multi-area high performance modeling?
 - Can the created model be AC solved?



Predicting the Future

- Various future time horizons to examine
 - Next 24 hours – hourly models (EMS or planning)
 - Next 30 days – hourly, daily or few daily models
 - Day 30 through 120 – typically daily peak planning modes
 - Day 180 through Day 360
- Need a model representing each of these periods
 - How to create these?
 - Can be time consuming
 - Should model not only ‘my’ control area, but also adjacent control areas.
- Can be based on EMS or planning models
 - Conceptually both approaches are similar



Models: EMS (Bus-Breaker) vs. Planning (Bus-Branch)

- Different horizons might have different model sources
- Short-term
 - EMS model based on recently observed load/gen profiles
 - EMS models are often updated on quarterly basis, limiting the use of EMS models
- Long-term
 - Planning-type models are easier to add new equipment and maintain



EMS Model

Advantages and Disadvantages vs. Planning Models

- Advantages
 - More detailed model
 - Direct use of EMS contingencies
 - Allows direct mapping and incorporation of the historical dispatch patterns
- Disadvantages
 - Potentially slower to analyze
 - More contingency events due to breaker modeling
 - Building TARA-compatible network model
 - Dumps set of network model files
 - Accessing historical state estimator information
 - Need to make available in TARA compatible format
 - EMS typically require custom development to model specifics of each control center
 - May be limited with respect to external models



MMWG-Based Models: Advantages

- Familiar to planners the US Eastern Interconnection (EI) and developed in coordination of all companies within EI
- Already have seasonal “approved” base models
 - Good starting point
- Existing AMB process
 - Many TARA users have an AMB process already in place for ATC coordination. See 2010 FERC presentation “Large-Scale Automated Model Builder” <http://www.ferc.gov/eventcalendar/Files/20100608150923-Halladay,%20Condren%20and%20Gisin,%20PowerGEM.pdf>
 - Make use of models created by this process
 - May require some “tweaks”
- Faster contingency analysis
 - Fewer events due to lack of modeling of individual breakers
- Better suited for multi-area analysis



MMWG-Based Models: Disadvantages

- Very few breakers modeled. How to model breaker outages?
- Problem: outages natively defined using EMS equipment names
 - Translation table to MMWG is required
- Defining monitored elements & voltage limits
 - Usually generic statement rather than individually defined



Market Software to Build Future Models for Outage Analysis

- The last step after all assumptions are modeled (outages, load forecast..) is to create security constrained case for follow-up study outage analysis
- Options
 - Unconstrained merit dispatch
 - Security Constrained dispatch
 - Most advanced - using market software to create future models – provides security constrained dispatch and unit commitment
 - Different approach is often used for internal areas (security constrained) vs external areas modeled via merit dispatch (or external self-scheduling process)



Long-Term Future Developments and Needs for Outage Optimization



How to Determine “Optimal” Schedule?

Current Approach for Outage Scheduling

- Follow the queue order
- Do comparative analysis for originally scheduled time window as described earlier
- If outage causes problems, consider other options
 - Move the outage to a better time as determined by TO (analysis will need to be done again)
 - Move a competing outage to a better time
 - Cancel the outage



How to Determine “Optimal” Schedule?

- Possible future application is to submit a batch of outages and determine optimal schedule
 - A possible range is provided for scheduling each outage
- Not very practical
 - Many variables involved (crews, equipment availability, union rules, etc.)
- What if all most/all outages are OK if taken together?
 - Stack all to beginning of potential time period?
- Accounting for outage priority?
 - 500 KV major outage should have a priority over conflicting 138 KV outage, but defining formal rules is not that simple



Long Term Future Work

- Corrective switching
 - Outage analysis is one of the most promising area for combination of corrective switch and redispatch
- AC OPF
 - So far we focused only on MW redispatch for thermal overload
- Uncertainties analysis
 - Today we create a single LF model for each future time horizon.
 - How to account for uncertainties in load forecast, forced outages, transactions schedules and reservations and other factors?



High Performance Computing, Multi-core or Parallel Computing

- Basic approach is to run all time periods for a given outage in parallel
- Launch multiple instances (children) of the program
 - Parent instance of the program collects results
- Multiple machine cluster computing is also possible
 - Amazon cloud
 - EnFuzion



PowerGEM Large Scale Outage Coordination Projects

- PJM and TVA in 2007-2010 co-funded major development project that resulted in the development of TARA AMB and ORA utilizing MMWG models and SDX data
- ISO-NE (2008-ongoing) economic market based analysis
 - see last year's FERC presentation, utilize PROBE market software
http://www.ferc.gov/eventcalendar/Files/20120626080541-Monday_SessionB_Blaede.pdf

PowerGEM appreciates commitment and funding of various elements of this project by PJM, TVA, ISO-NE, MISO



PowerGEM large scale outage coordination projects

- PJM

- have been using market simulation approach (PROBE) for outage acceleration (focus on congestion/FTR adequacy) since ~2006

<http://www.pjm.com/markets-and-operations/etools/oasis/outage-accel.aspx#data2012>

- The joint PJM/PowerGEM presentation also presented at today's conference provides more details on the ongoing large scale outage analysis project using EMS models for short and long term outage analysis

- MISO

- reliability long term analysis using TARA
- short term planning using combined market-based PROBE approach to build near term models with follow up reliability analysis



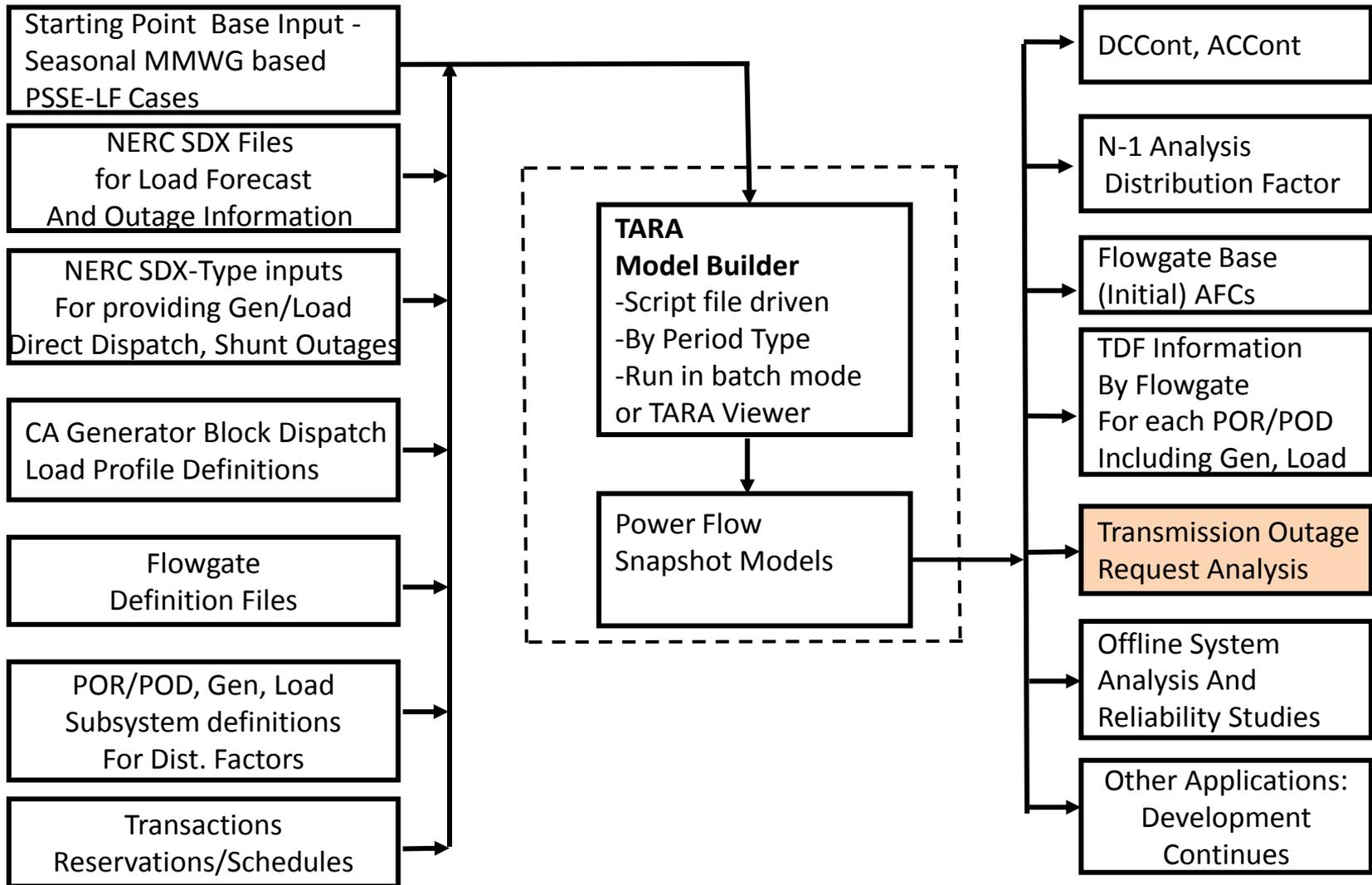
Questions & Further Discussion ?



Reference Information



TARA AMB Process using MMWG/IDC Model



TARA EMS-Based AMB Process

