Stochastic Unit Commitment at ISO Scale: Issues and Experiences

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Paris, June 2014

Outline

The “Trailer”

- Uncertainty in increasing due to renewables
- Rather than simply increasing reserves, it may be possible to incorporate stochastics in Unit Commitment to save money
- Solution methods are needed; we have them.
- Scenarios with attached probabilities are needed; we have created them.
- We are working on full, day-ahead, ISO-scale problems, but
- we are not entering the debate on how to have a stochastic market.
- So the immediate applications would be to reliability and adequacy as well as (mult-stage) planning.

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Project Logos

Exceptional service in the national interest

Sandia National Laboratories

Iowa State University

UC Davis
University of California

arpa·e

ALSTOM

ISO new england

U.S. Department of Energy
NNSA National Nuclear Security Administration

A Teaser

- A few computational results.
- I will leave out a lot of details.
- We use Carrion and Arroyo as a staring point for the formulation
- No network constraints
- Validated against the Alstom test models

WECC-240 Family

- We use *WECC-240-r1* (85 generators) for purposes of parameter tuning and analysis.
- Then fix the PH configuration and examine performance on the out-of-sample and more realistic *WECC-240-r2* and *WECC-240-r3* cases.
- We analyze scalability to the larger *WECC-240-r2-x2* (170 generators) and *WECC-240-r2-x4* (340 generators) cases.
- Using modest scale parallelism.
- (These are harder to solve than ISO-NE instances of similar size.)

Extensive form

Solution quality statistics for the extensive form of the *WECC-240-r1* instance, given 2 hours of run time.

Scenarios	Obj Value	MIP LB	Gap %	Run Time (s)
3	64279.18	63708.67	0.89	7291
5	62857.52	62052.75	1.26	7309
10	61873.01	60769.78	1.77	7444
25	61496.24	59900.40	2.59	7739
50	61911.74	59432.08	4.01	8279
100	62388.85	3500.70	94.39	9379

Larger Instances using PH

Solve time (in seconds) and solution quality statistics for PH executing on 50-scenario instances.

Instance	Convergence	Obj. Value	PH L.B.	Time
		Red Sky Results		
WECC-240-r2-x2	0.0 (in 22 iters)	117794.429	116538.868	741
WECC-240-r2-x4	0.0 (in 19 iters)	232189.338	228992.984	1421

Project Overview

- Partners: Alstom Grid, Iowa State University, ISO-New England, Sandia National Laboratories, and the University of California Davis
- Funded by: US Dept. of Energy, ARPAe
- Goal: Develop methods and test for solving stochastic unit commitment (UC) problems at ISO scale including specification of scenarios for uncertain demand and high penetration wind power.
- We are estimating what energy savings would have occurred had ISO-NE been using stochastic UC for day-ahead commitment during the year 2011, but with high wind penetration.

Day-ahead Stochastic UC

- Unit commitments represent first stage decisions, which must be determined before values of uncertain parameters are known:
  - intermittent resources,
  - loads
  - unscheduled outages
- Economic dispatch decisions provide recourse in the second stage, following resolution of parameter uncertainty.

Scenario Trees

- Scenario trees are used to represent the possible combinations of parameter values (scenarios), in conjunction with their probabilities of realization.
- Advanced scenario creation techniques have been leveraged to compute cost confidence intervals and to minimize the number of scenarios required to achieve reliable solutions.

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Solving with PH

- Advanced decomposition strategies have been leveraged to meet run-time and memory requirements, by distributing sub-problem solutions across distinct computer nodes.
- Progressive Hedging is a decomposition scheme that works well with mixed integer variables and specific non-linear structures, and is naturally parallelizable.

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Progressive Hedging (PH)

Rockafellar and Wets (1991)

1. Decompose by scenario (a specification of the data with an attached probability)
2. Important: the expected value data can be one of the scenarios, so users of PH will be no worse off than without PH
3. The algorithm parallelizes

PH in Words

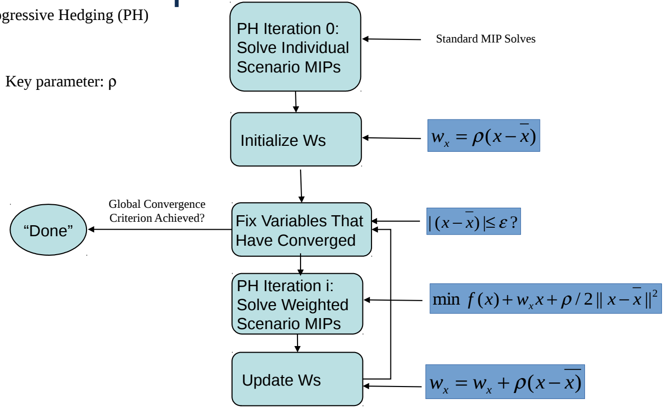
1. Solve every scenario as if it were the only problem
2. Form a non-aniticipative (but probably infeasible) solution by averaging across the scenarios at nodes of the scenario tree
3. Compute multipliers (penalties or incentives) for each variable and each scenario at non-leaf nodes
4. Solver every scenario, augmented by the penalities
5. If the scenarios solutions are similar enough, stop; otherwise goto step 2.

PH Diagram

Scenario-Based Decomposition

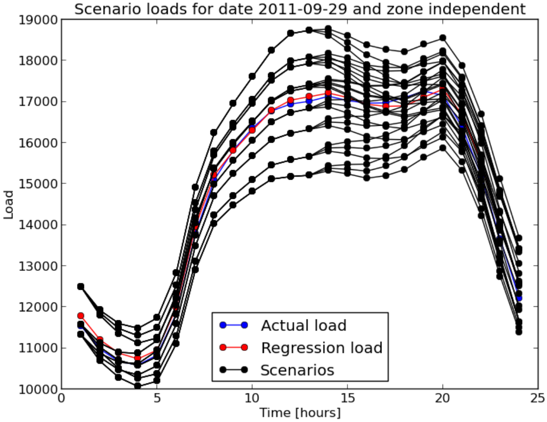
Progressive Hedging (PH)

Key parameter: ρ

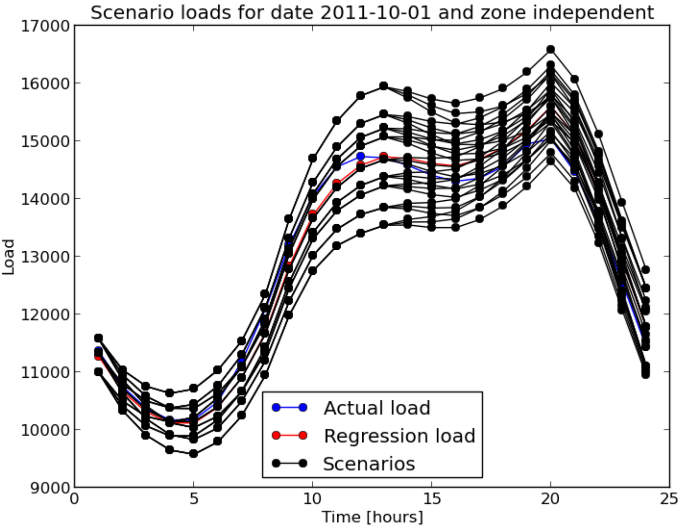


Example with 27 Scenarios

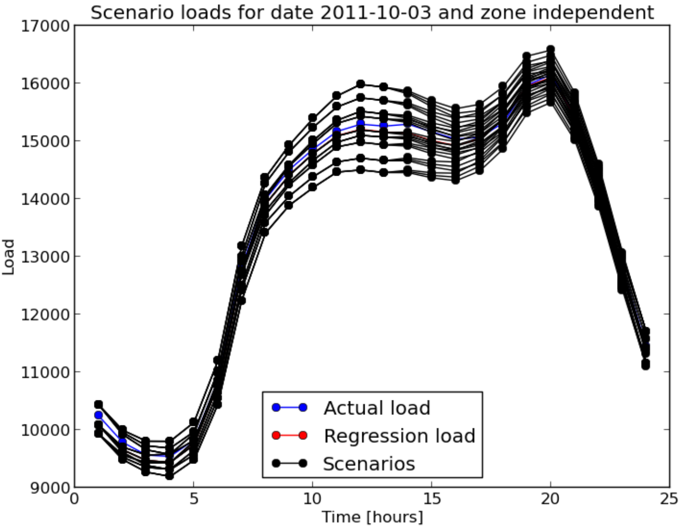
(Probabilities not shown)



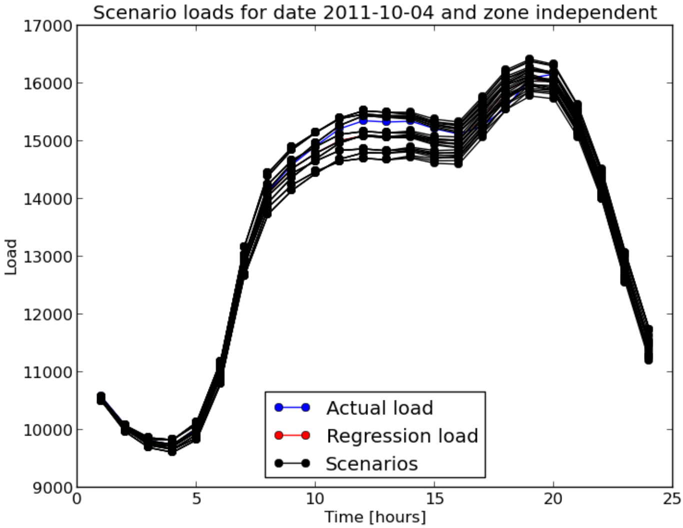
Another Example with 27 Scenarios



Yet Another Example with 27 Scenarios



Last Example with 27 Scenarios



Generating Scenarios: Overview

- Most forecasts are given as a single (vector) point
- To generate scenarios we need either:
  1. Good probabilistic forecasts, or
  2. Analysis of the error distributions of point forecasts.
- A little notation:
  - The value (perhaps vector) of interest ℓ
  - Leading indicator (if there is one) w
  - Forecast function (if there is one) $\ell(w)$

Probabilistic Forecasts

- One way: fit a function $\ell(w)$, then find a way to generate w forecasts (or values) with known probabilities
- Another way: have multiple forecast functions and assign probabilities to each.

Analysis of Error Distributions

- You need, of course, a history of forecasts (or leading indicators) and corresponding observations.
- It makes sense to group "similar conditions" thereby creating error distributions that are conditional on the grouping.
- If you are fitting your own forecast function, you can also segment the data based on forecast error characteristics and fit forecast that are conditional on the error category.

Similar Conditions

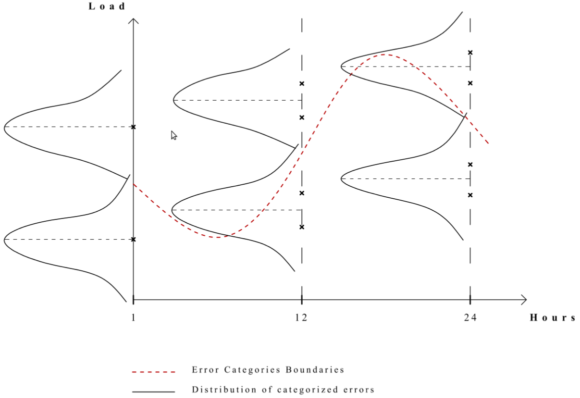
E.g.,

- Forecast level quantiles
- Derivative patterns
- Weather quantiles

Scenarios from Error Distributions

- Using cutting points of the distribution to get skeleton points for the scenarios from the center of the error distribution between the cutting points.
- The probability of the skeleton points is trivial to compute from the cutting points.
- Scenarios are formed by connecting skeleton points, if necessary.

Scenario generation
Example



Scenario generation

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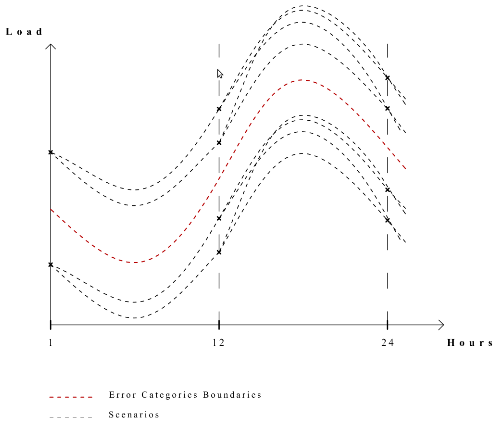

Conclusion

- Due to renewables, uncertainty may need to be handled explicity, rather than via reserves.
- To use Stochastic Programming, one needs algorithms and scenario generation methods
- We have proposed both
- Immediate application is most likely to be to intra-day reliability SCUC
- Research continues and we have some data needs/requests...

Rolling Horizon

Notre projet s'interesse a la facon dont les previsions de vent s'ameliorent au cours du temps. Nous cherchons a obtenir des donnees indiquant :

- les previsions de vent a **differentes echeances** (par exemple : prevision 2 jours avant, 1 jour avant, 6 heures avant...)
- la quantite de vent reelle pour les dates correspondant aux previsions. Elle nous permet de connaitre les erreurs de prediction.

Continued...

Nous souhaitons avoir des predictions a **differentes echeances** pour etudier la facon dont les erreurs de prediction s'ameliorent au cours du temps (plus on est proche de la date de prediction, plus l'erreur de prediction est faible). En etudiant la facon dont les predictions s'actualisent au cours du temps, nous souhaitons ainsi mettre en place une methode pour mettre a jour les nouvelles predictions de vent et avoir une erreur de prediction plus faible.

Exemple

Voici un exemple des donnees que nous souhaitons avoir :

- les donnees reelles de vent pour chaque heure de la journee J (la periode de temps peut varier : ca peut etre toutes les 5 minutes ou au contraire toutes les 2 heures)
- les previsions de vent pour chaque heure de la journee J faites au jour J-1 a l'heure h (par exemple a 11h)
- les previsions de vent pour chaque heure de la journee J faites au jour J-1 a l'heure $h' > h$ (par exemple a 23h)

Il s'agit d'un exemple. Nous sommes preneurs de tout type de donnees du moment qu'elles concernent des previsions de vent et qu'elles permettent d'etudier l'evolution des erreurs de prediction au cours du temps.