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Grid Optimization Competition Challenge 3 Formulation and Solution Evaluation

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Grid Optimization Competition Challenge 3 Team

Grid Optimization Competition Challenge 3 Problem Formulation

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- https://gocompetition.energy.gov/
- https://gocompetition.energy.gov/challenges/challenge-3/formulation
- https://github.com/GOCompetition/C3DataUtilities

Agenda

- GO Competition C3 model overview
- Detail on the simpler post-contingency model used by C3
- If there is time…
  - Unit commitment with AC power flow
  - Topology switching
- Other aspects of the formulation were covered in more detail in https://www.ferc.gov/media/go-competition-challenge-3-goals-and-formulation.

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Grid Optimization (GO) Competition Challenge 3 (C3) Formulation Overview

- AC unit commitment
- Applications
  - Day ahead market (DAM)
  - Real time look ahead (RTLA)
  - Week ahead advisory (WAA)
- Unit commitment
  - Discrete startup and shutdown decisions
- Multi-period
  - 5 minute to 4 hour time periods
  - 1 hour to 10 day time horizon
- AC
  - Real and reactive power balance at each bus
  - Voltage limits
  - More accurate line limits
- Security constraints
  - Branch flow limits in the base case and a set of contingencies
  - Voltage limits in the base case
- Reserve products
  - Regulation up/down
  - Synchronized (spin)
  - Non-synchronized (non-spin)
  - Ramping up/down
  - Reactive power up/down
- Bid-in demand
  - Similar modeling to generators
  - Generators and demand can have max/min constraints on energy over a sequence of time intervals
- Topology switching
  - Open/close branches in the base case
- Contingencies
  - Single branch outages
  - DC real power only

Incorporating Lessons of C1/C2 Simpler Contingency Modeling

- C1/C2 AC post-contingency model
  - Added substantial complication to the model
  - Required a separate (much looser) time limit for production of post-contingency solutions (code 2) so that solution evaluation could avoid solving an AC power flow problem to verify post-contingency constraints
- C2 contingencies did not seem to be very influential to the optimal pre-contingency solution
  - Average case contingency objective
  - High degree of load flexibility
  - A lot of complexity for a feature that did not really matter
- C3 will have
  - DC post-contingency model
  - Real power only
  - Average plus worst-case contingency objective – to make the contingencies more influential to the optimal pre-contingency solution
  - No post-contingency topology switching
  - Line limits: yes
  - Voltage limits: no
  - Reactive power reserves fill the gap left by omitting V/Q from post-contingency model
  - Post-contingency constraints can be evaluated from base case variables only, with a reliable and fast DC power flow calculation
  - No code 2 needed

$$z^{\mathrm{ms}} = \sum_{t \in T} \left(z_t^{\mathrm{ms}} + \min_{k \in K} z_{tk}^{\mathrm{ms}} + 1/|K| \sum_{k \in K} z_{tk}^{\mathrm{ms}} \right)$$

DC power flow model – in general

- Given

	M	Bus-branch incidence matrix
	B	Branch admittance (actually susceptance)
	P^{inj}	bus bus real power injection

- Find

	θ	bus angles
	p	line real power flow

- Such that

	$p = -BM^T\theta$	flow equation
	$Mp = P^{\text{inj}}$	balance equation

- i.e.

	$A\theta = P^{\text{inj}}$	
	$A = -MBM^T$	Bus admittance matrix

- Solve for θ then compute p.

Post-contingency DC power flow model

- Similar to generic version
- Real model has phase shifting transformers and DC lines

t	Time interval
k	Contingency
U_t	Branch status in interval t, 1 = on, 0 = off, from solution
U_k	Branch status in contingency k, from problem data
P_t^{inj}	Bus injections, from solution
$A_{tk} = -MU_tU_kBM^T$	Post-contingency bus admittance matrix
$A_{tk}\theta_{tk} = P_t^{\text{inj}}$	Solve for θ_{tk}
$p_{tk} = -U_tU_kBM^T\theta_{tk}$	Compute p_{tk}

Evaluating the post-contingency model

- In order to evaluate a competitor's solution, we need to solve the post-contingency DC power flow model
- Given P_t^{inj}, need to compute θ_{tk}, p_{tk}, etc.
- Commercial codes do this under the name Sequential Feasibility Test (SFT)
- Speed is important – evaluating a solution should not take as long as solving the optimization problem
- Loop(t, loop(k, form A_{tk}; solve)) – this is slow
- Some commercial SFTs use a method based on an update/downdate or partial refactorization. HIPPO concluded that this is also not very fast
- Line outage distribution factors (LODFs) can handle the single line outage contingencies, but a slow recomputation of the factors is needed for each t

Sherman-Morrison-Woodbury method

- We use methods based on the Sherman-Morrison-Woodbury (SMW) identity
  - $(A + MCM^T)^{-1} = A^{-1} - WV^{-1}W^T$
  - $W = A^{-1}M$
  - $V = C^{-1} + M^T W$
- Apply this to changes in A derived from U_t and U_k – be careful if they overlap
  - $A_t = A + M(1 - U_t)BM^T$
  - $A_{tk} = A + M(1 - U_t U_k)BM^T = A_t + MU_t(1 - U_k)BM^T$
- Following ideas from HIPPO project in
  - https://www.techrxiv.org/articles/preprint/Fast_Simultaneous_Feasibility_Test_for_Security_Constrained_Unit_Commitment/20280384
  - https://www.ferc.gov/sites/default/files/2020-09/W1-A-4-Holzer.pdf
- SMW is a generalization of LODFs to multiple lines going into or out of service

Computational savings due to SMW ideas

- Basic method
  - Loop(t, factor A_t; apply SMW to k)
  - Comparable to LODF
- So far the largest computational savings come from
  - Apply SMW to t as well as k
    - ✓ Works well when not many lines are switched from one interval to the next
  - Filter out lines where the delta term is small enough for all k that there cannot be a violation for any k, then omit further calculation on those lines
    - ✓ Works well when not many security constraints are violated

- Testing
  - Development: Modified 73 bus case has some of everything, including line switching

bus	pr	cs	sh	prz	qrz	acl	dcl	xfr	ctg	acl-ctg-out	dcl-ctg-out	xfr-ctg-out
3	2	1	2	1	1	2	0	2	2	1	0	1
14	6	11	1	2	2	17	0	3	18	15	0	3
37	8	26	8	2	2	43	0	14	57	43	0	14
73	157	51	73	1	1	105	1	15	2	2	0	0
6049	452	3368	236	6	6	4920	0	3086	3884	3884	0	0
73	157	51	73	1	1	105	4	15	139	103	4	15

  - Performance: 6000 bus case evaluation run time

Method	Time sec
Basic	178
SMW on t	113
Filter lines	96
Both	31

References

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Thank you