Grid Optimization (GO) Competition

FERC Software Conference

June 28, 2018

Outline

- Introduction
- Timeline
- Proposal Entrants and Open Entrants
- Platform and Registration
- Input / Output File Formats
- Program Submission / Using the Platform
- Scoring
- Eligibility and Rules
- Summary

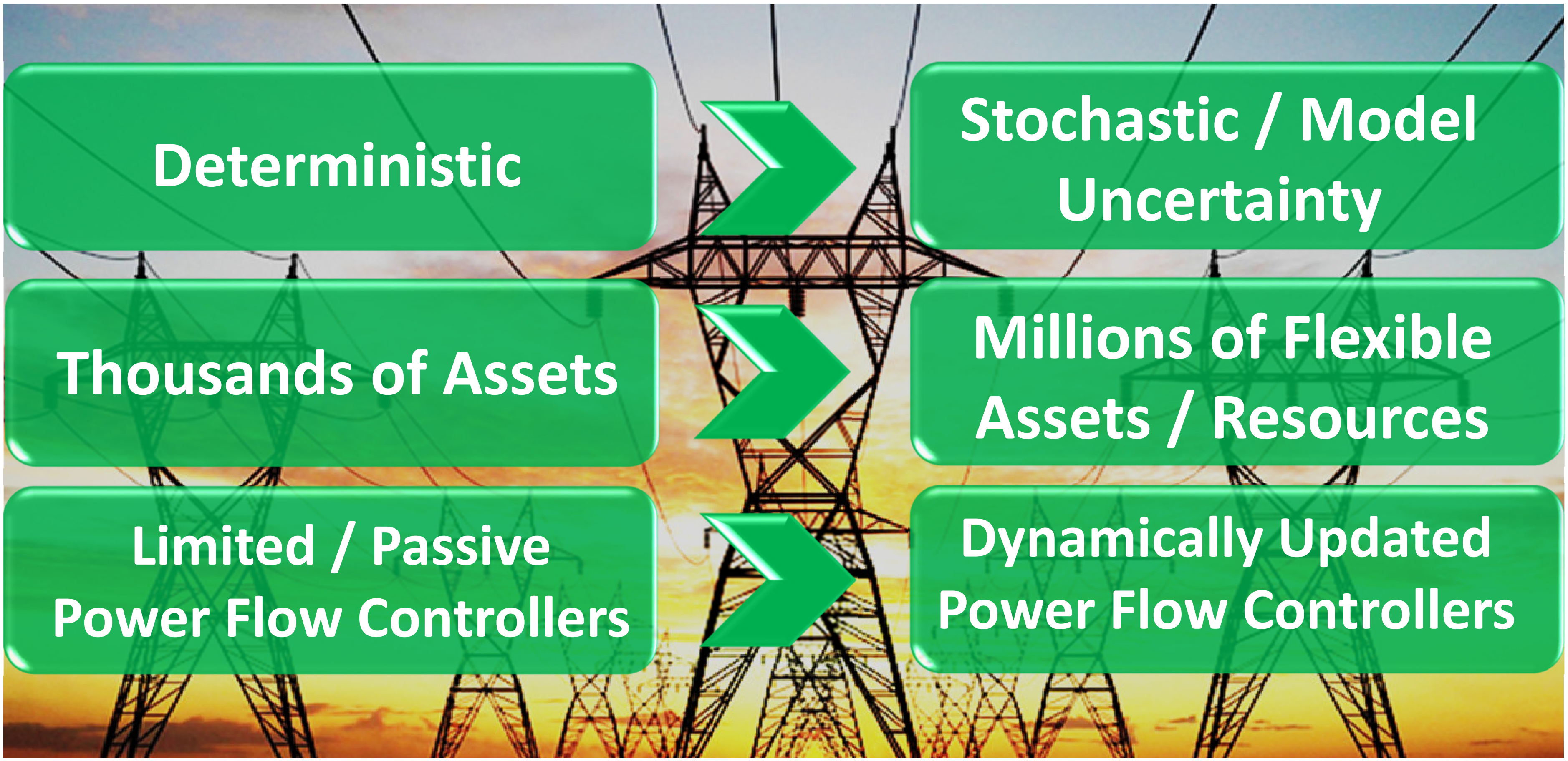
INTRODUCTION

Key Takeaway Points

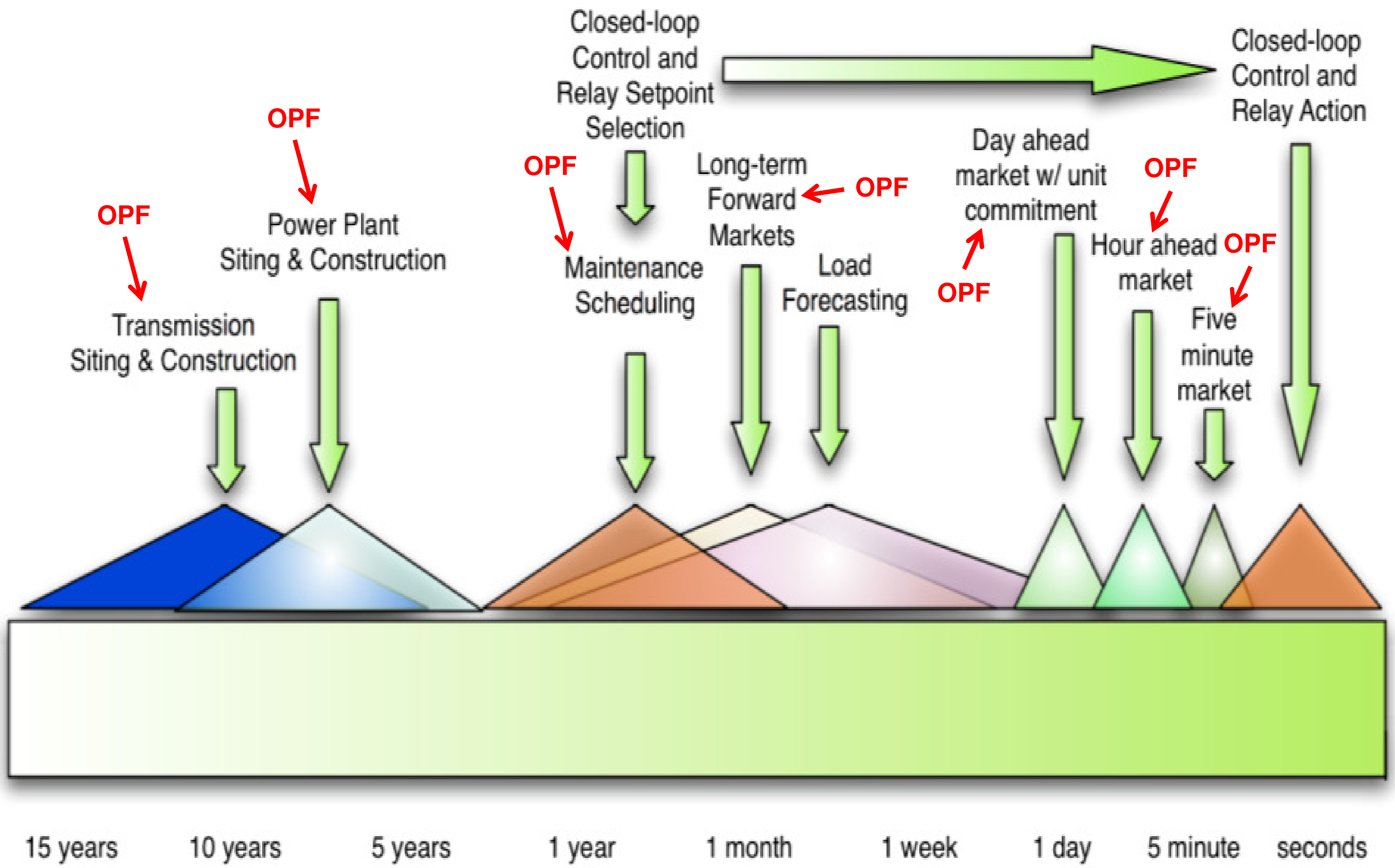
- Modern Grid: Need Modern Grid Software
  - Impacts efficiency of a $500B/year sector
  - Impacts reliability and resilience
  - Can be an inhibitor or enabler of emerging technologies

- Competition: discover breakthrough technologies & initiate overhaul of legacy management systems via a fair and transparent evaluation of innovative approaches

Fast Evolving Grid Requires Innovation in Management Systems / Decision Support Tools

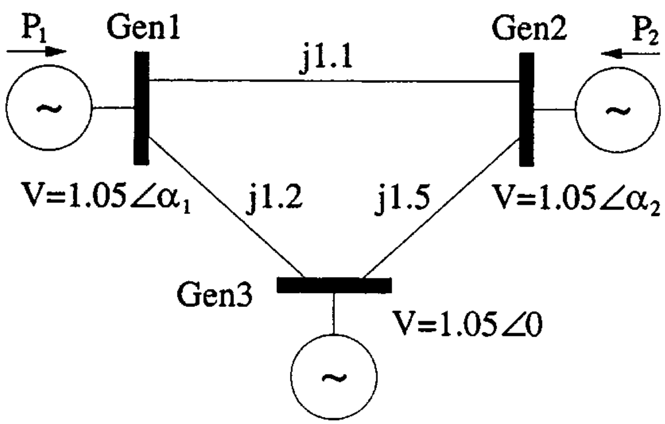


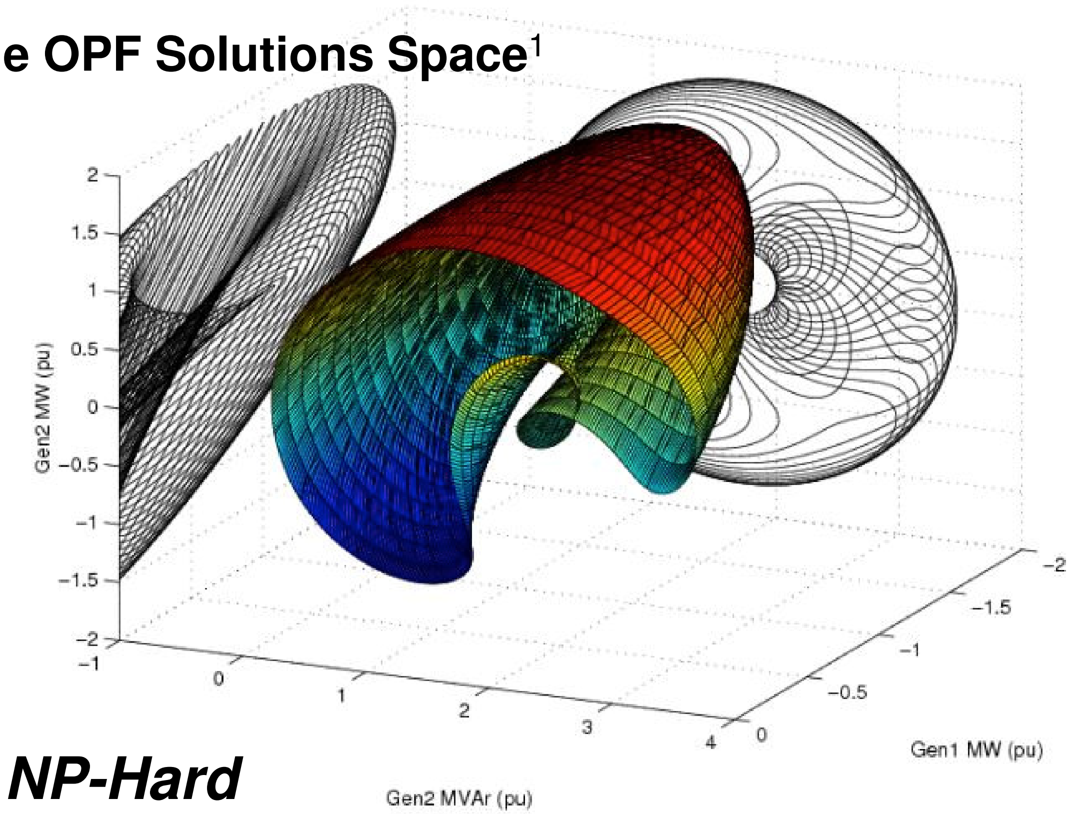
The heart of most grid software/optimization is Optimal Power Flow (OPF)



Optimizing Grid Power Flows is ARPA-E Hard

3-bus Example OPF Solutions Space[1]





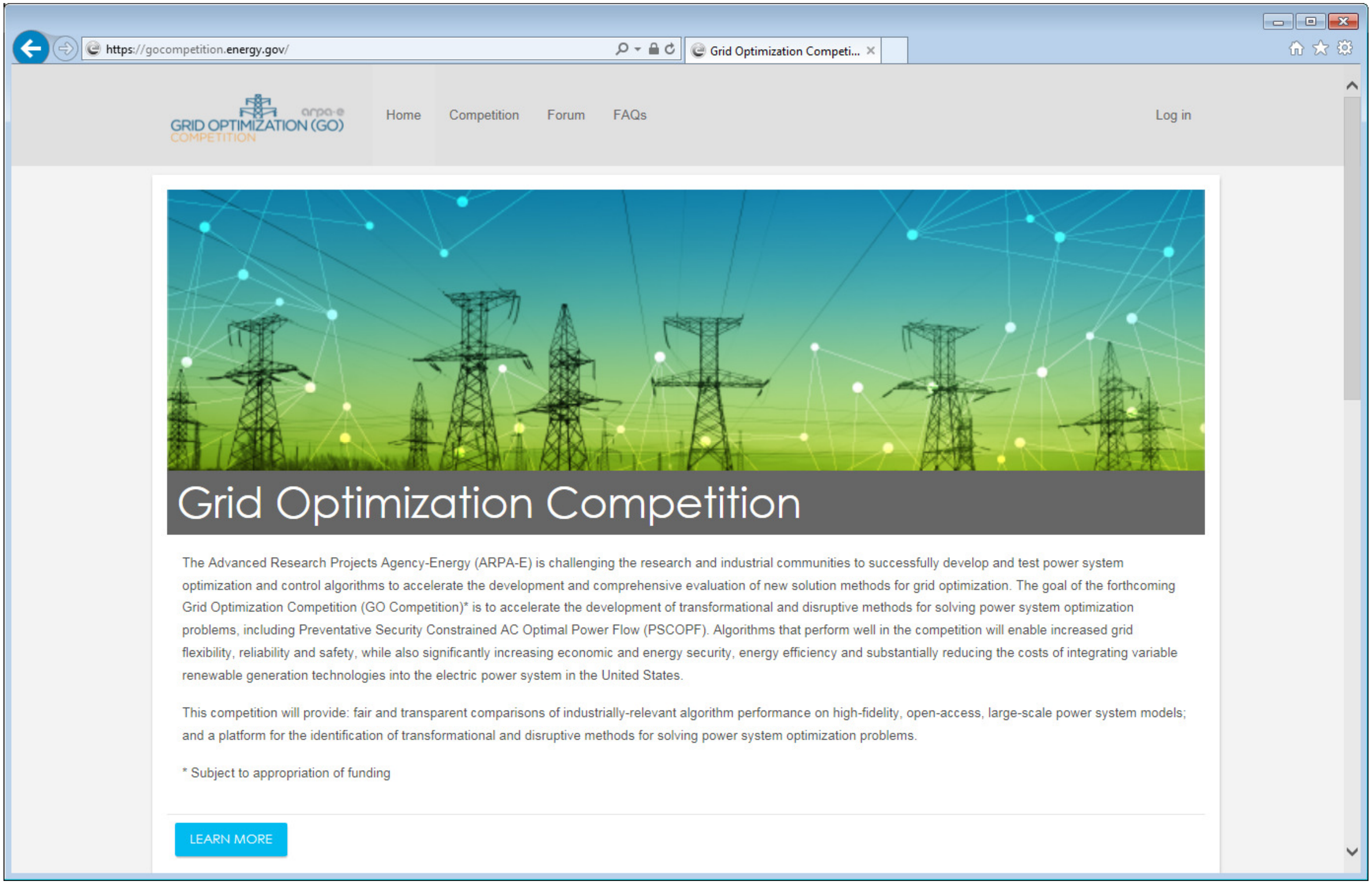
- OPF is ***non-convex*** and ***NP-Hard***
- Exact optimal solution methods are computational non-tractable
- Various approximations are widely used today (linearizations, iterative approximations)

1. I.A. Hiskens and R.J. Davy, "Exploring the power flow solution space boundary", IEEE Transactions on Power Systems, Vol. 16, No. 3, August 2001, pp. 389-395.

Website

GRID OPTIMIZATION (GO) COMPETITION

https://gocompetition.energy.gov/



PROPOSAL ENTRANTS AND OPEN ENTRANTS

CHANGING WHAT'S POSSIBLE

Proposal Entrants

- Funding Opportunity Announcement coming…
- Applicants that are selected by the FOA will receive a small grant to participate in Challenge 1
- Incentivize innovators to participate
- Encourage Entrants that may not have the resources to participate otherwise
- Encourage Entrants from all backgrounds (not just power systems engineers)

Open Entrants

- All other participants that compete (not selected by the FOA)
- Eligible Entrants: those eligible for an award (prize money) based on performance
- Non-eligible Entrants: those that can compete, will be placed on the leaderboards, but cannot receive prize money
- See the official Rules document (GO Competition website) for eligibility and/or attend the later presentation on Eligibility & Rules

Prizes

GRID OPTIMIZATION (GO) COMPETITION

$\leq \$5M$ "Challenge 1" FOA

Award-Eligible Open Entrant

Proposal Entrant
≤ 20 Team
$\leq \$250k$ Grant

Challenge 1 Final Event

$\$4M$ Total Challenge 1 Awards

Top 10 in Each Division Receive Awards

Winning, Scoring, Divisions

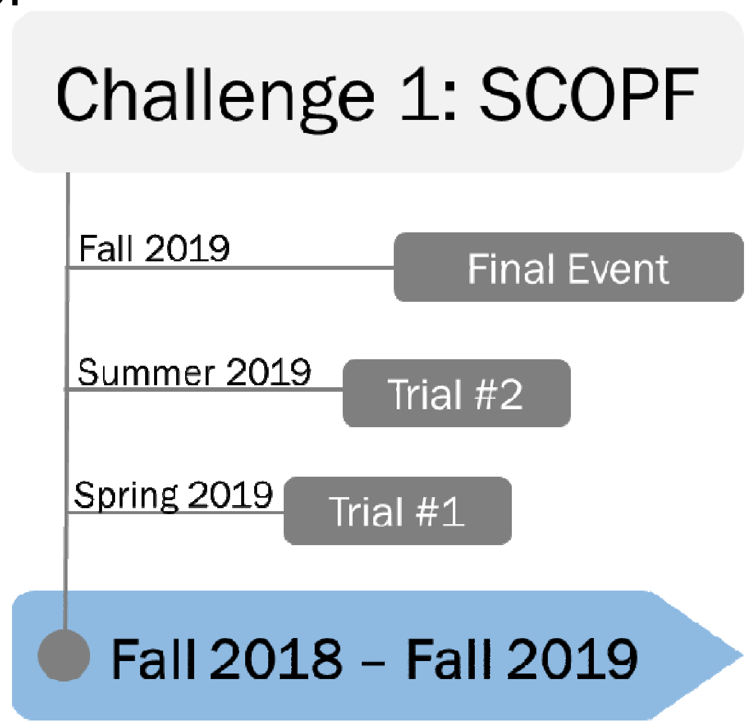
Challenge 1

	Lowest Cost	Performance Profiles
Real-Time (10 Min)	**Division 1** Top 10: $100k	**Division 3** Top 10: $100k
Offline (45 Min)	**Division 2** Top 10: $100k	**Division 4** Top 10: $100k

TIMELINE

Competition Timeline: Challenge 1

- FOA Release: Very Soon
- Full-App Deadline: ~60 Days later
- FOA Awardees Notified: Late Summer
- Competition Start Date: Early Fall
- Trial 1: Early Spring 2019
- Trial 2: Early Summer 2019
- Final Event: Early Fall 2019



Competition Timeline

	2018							2019							
	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Challenge 1 FOA															
Challenge 1															
Challenge 1 Trial 1									*						
Challenge 1 Trial 2												*			
Challenge 1 Final Event															*

	2019				2020										
	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Challenge 2 FOA															
Challenge 2															
Challenge 2 Trial 1									*						
Challenge 2 Trial 2												*			
Challenge 2 Final Event															*

* Indicates dataset release

Questions?

CHANGING WHAT'S POSSIBLE

Grid Optimization (GO) Competition Platform Overview and Registration

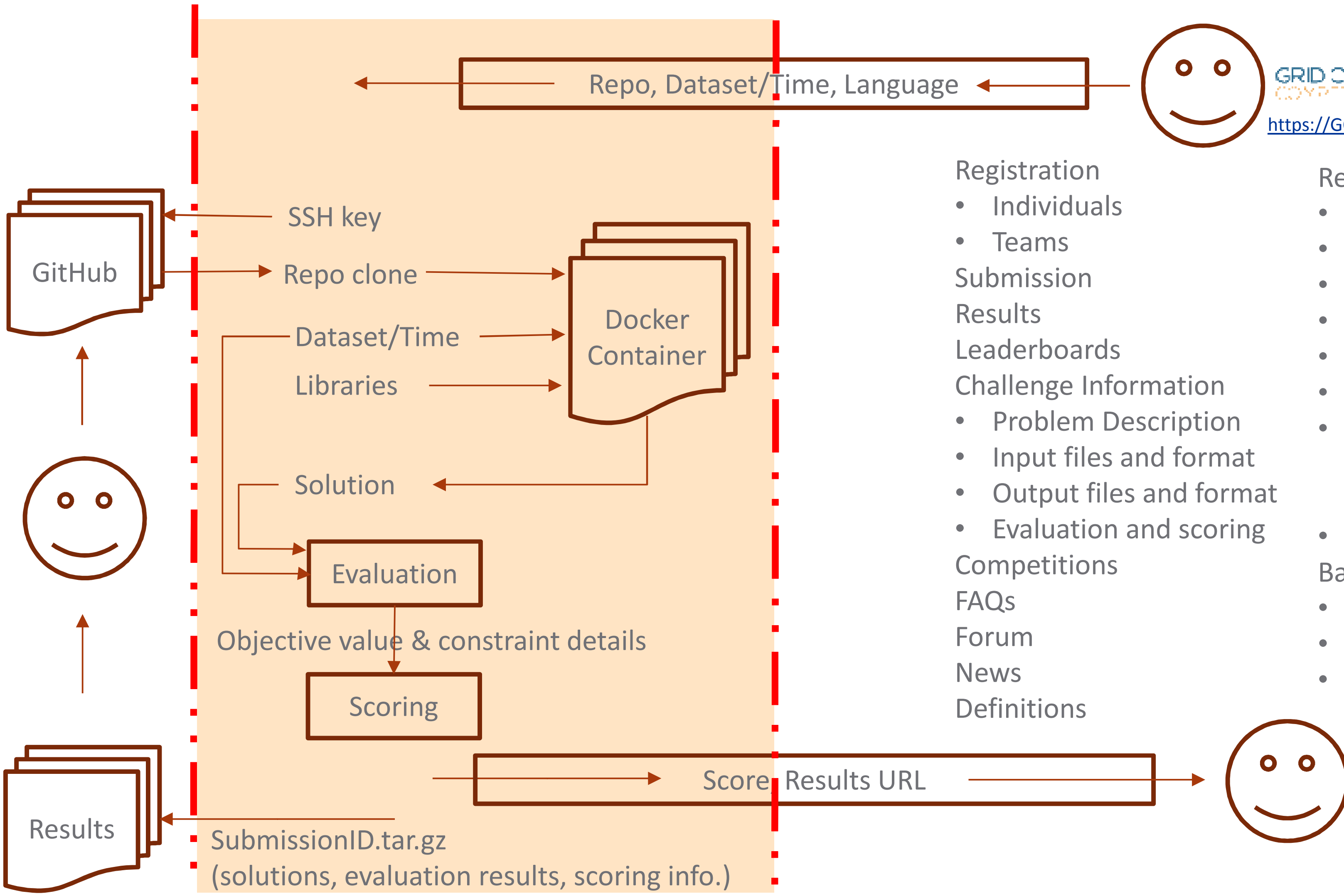
STEPHEN ELBERT

Grid Optimization Competition Workshop @ FERC Technical Conference

June 28, 2018

Competition Platform Components

Pacific Northwest NATIONAL LABORATORY



GRID OPTIMIZATION (GO)

https://GOCompetition.Energy.Gov

Registration
- Individuals
- Teams

Submission
Results
Leaderboards
Challenge Information
- Problem Description
- Input files and format
- Output files and format
- Evaluation and scoring

Competitions
FAQs
Forum
News
Definitions

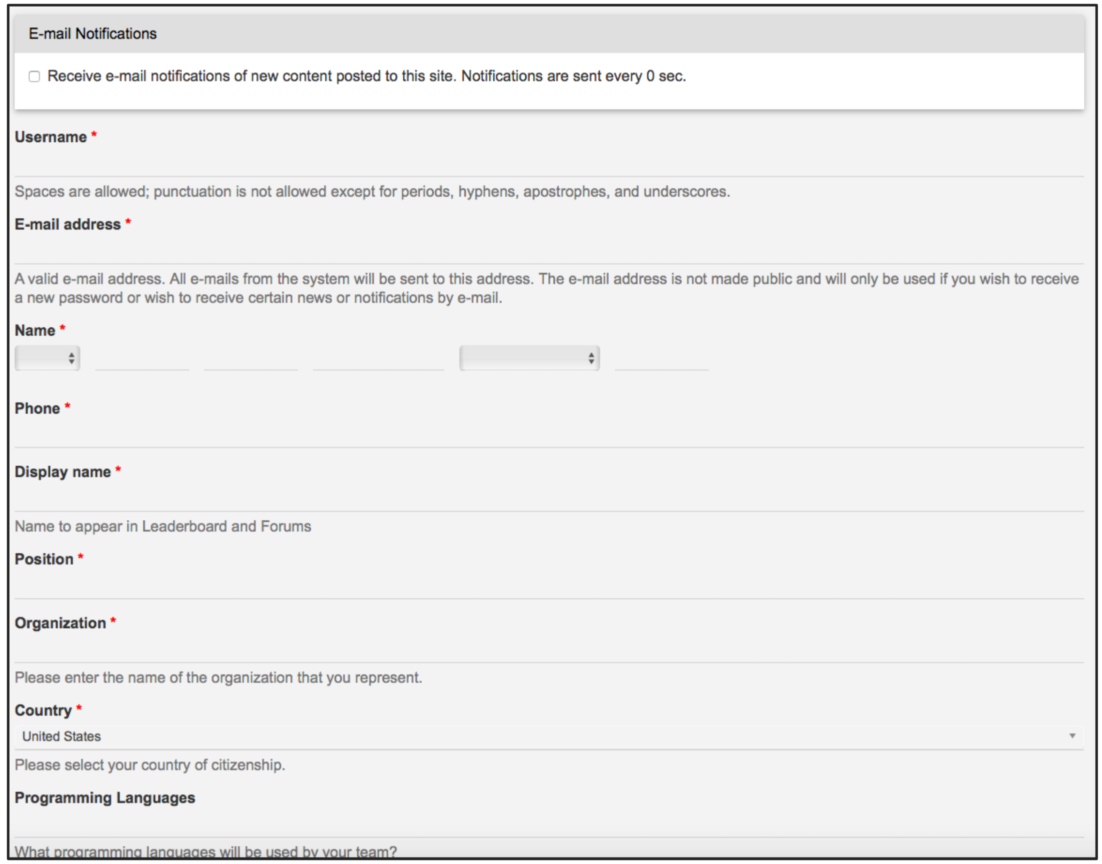
References
- Getting started
- Solvers
- Languages
- Platform
- GitHub
- Docker
- How to register; create a team; submit
- Rules

Background
- Inspiration
- Timeline
- Prizes

Web Portal Registration https://gocompetition.energy.gov/user/register

Pacific Northwest NATIONAL LABORATORY

- Provide required (*) information
  - Username
  - E-mail
  - First and Last Name
  - Phone number
  - Display name for website
  - Organization you belong to
  - Your position in the organization
  - Country of citizenship
  - Accept Terms and Conditions
- Optional: programming languages
- Respond to registration e-mail to set password


E-mail Notifications

Receive e-mail notifications of new content posted to this site. Notifications are sent every 0 sec.

Username *

Spaces are allowed; punctuation is not allowed except for periods, hyphens, apostrophes, and underscores.

E-mail address *

A valid e-mail address. All e-mails from the system will be sent to this address. The e-mail address is not made public and will only be used if you wish to receive a new password or wish to receive certain news or notifications by e-mail.

Name *

Phone *

Display name *

Name to appear in Leaderboard and Forums

Position *

Organization *

Please enter the name of the organization that you represent.

Country *

United States

Please select your country of citizenship.

Programming Languages

What programming languages will be used by your team?

Software Environment

Languages

- C/C++
- GAMS
- Julia/JuMP
- Java/Scala
- Python
- MATLAB/MATPOWER

- Linux binary executables

Solver Libraries

- CPLEX
- GAMS
- Gurobi
- Ipopt
- Knitro
- MATLAB/MATPOWER
- Xpressmp

See website for current versions and restrictions

Resources

- Challenge specific
  - Problem Definition
  - Input Files and Format
  - Output Files and Format
  - Evaluation
  - Scoring
  - Leaderboard
- Background
  - Inspiration
  - Timeline
  - Prizes
  - About
- Stay in Touch
  - FAQs
  - Forum
  - News
  - Definitions
- General References
  - Getting Started
  - Available Solvers
  - Languages
  - Evaluation Platform Information
  - GitHub
  - Docker
  - How to
    - Register
    - Create a Team
    - Make a Submission
  - Rules

Items in red: check website frequently for updates!

Questions?

Grid Optimization Competition Input and Output Data Formats

JESSE T. HOLZER (PRESENTER)

Grid Optimization Competition Workshop

FERC Technical Conference

Input Data – Instance Definition

- The data defining an instance of the GOComp SCOPF problem is contained in five text files.
  - case.raw – buses, loads, fixed shunts, generators, lines, transformers, switched shunts, areas
  - case.rop – generator cost function parameters – sample points on the cost function of each generator
  - case.inl – generator participation factors
  - case.con – contingency list, specifies for each contingency a generator, line, or transformer going out of service.
  - case.prm – a file containing miscellaneous parameters, penalty coefficients, time limits
- The data files are similar to common industry data formats.
- Complete specification of fields used and file formatting is available
- Python code for reading input files is available

Output Data – Instance Solution

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- The solution of an instance of the GOComp SCOPF problem will be read from two files that can be either text or HDF5.
  - sol1.txt or sol1.hdf5 – base case solution (operating point)
  - sol2.txt or sol2.hdf5 – solution in each contingency
- solution1.txt
  - Bus section, for each bus *i*:
    - $BusNum_i, v_i, \vartheta_i, b^{ss}_i$
  - Generator section, for each generator *g*:
    - $BusNum_g, GenID_g, p_g, q_g$
- solution2.txt – for each contingency *k*:
  - Bus section, for each bus *i*:
    - $CtgLabel_k, BusNum_i, v_{ik}, \vartheta_{ik}, b^{ss}_{ik}$
  - Generator section, for each generator *g*:
    - $CtgLabel_k, BusNum_g, GenID_{gk}, p_{gk}, q_{gk}$
  - System section:
    - $CtgLabel_k, \Delta_k$
- Complete specification of output file formatting is available
- Python code for reading output files is available

Procedure to run submitted algorithms

- E.g., Python. Competitor provides MyPython1.py and MyPython2.py.
  1. Run "python MyPython1.py" with time limit T1
  2. Read sol1.txt
  3. Execute "python MyPython2.py" with time limit T2
  4. Read sol2.txt
- No changes to sol1.txt after step (2)
- T1 is a short time limit
  - Very short for real time context
  - Longer for planning context
- T2 is long to allow full solution of each contingency, given the base case solution.
- Want to reward algorithms that get a good base case solution quickly by avoiding fully solving each contingency, but we need contingency solutions to do evaluation.

Nomenclature

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i	bus
g	generator
k	contingency
$BusNum_i$	bus number of bus i
$BusNum_g$	bus number of generator g
$GenID_g$	generator ID of generator g
$CtgLabel_k$	contingency label of contingency k
v_i	voltage magnitude of bus i
ϑ_i	voltage angle of bus i
$b^{ss}{}_i$	total susceptance of switched shunts at bus i
p_g	real power output of generator g
q_g	reactive power output of generator g
v_{ik}	voltage magnitude of bus i in contingency k
ϑ_{ik}	voltage angle of bus i in contingency k
$b^{ss}{}_{ik}$	total susceptance of switched shunts at bus i in contingency k
p_{gk}	real power output of generator g in contingency k
q_{gk}	reactive power output of generator g in contingency k
Δ_k	contingency k multiplier on participation factors of responding generators

Questions?

CHANGING WHAT'S POSSIBLE

Grid Optimization (GO) Competition: Formulation

FERC Software Conference

June 28, 2018

FORMULATION

Official Formulation and FOA Formulation

FOA Formulation is a simplified formulation for SCOPF primarily emphasizing:

- AC OPF + security constraints
- Constraint relaxations
- Real power response post-contingency
  - Complementarity constraints
- Reactive power response post-contingency
  - Complementarity constraints
  - PV/PQ switching

SEE THE WEBSITE FOR THE OFFICIAL FORMULATION!!!

Objective Function

- Piecewise linear generator cost
- δ: Probability of no contingency occurring
- $1-\delta$: Probability that there is a contingency
- Base-case violation, post-contingency penalties: nodal imbalance
- Base-case violation, post-contingency penalties: line flow violations
- All contingencies are treated equally: $\frac{1}{|\mathrm{K}|}$

$$
\begin{aligned}
\text{Min:} \ & \sum_{g\in G} C_g(p_g) \quad + \delta \sum_{i\in N} \left(\lambda^P\left(s_i^{+P}+s_i^{-P}\right)+\lambda^Q\left(s_i^{+Q}+s_i^{-Q}\right)\right) \\
& +\delta \sum_{e\in E} \lambda^S s_e \\
& +(1-\delta) \ \sum_{i\in N} \sum_{k\in K} \frac{1}{|K|}\left(\lambda^P\left(s_{i,k}^{+P}+s_{i,k}^{-P}\right)+\lambda^Q\left(s_{i,k}^{+Q}+s_{i,k}^{-Q}\right)\right) \\
& +(1-\delta) \sum_{e\in E} \sum_{k\in K} \frac{1}{|K|}\left(\lambda^S s_{e,k}\right) \qquad (1)
\end{aligned}
$$

Relaxations

- Node balance equations
- Transmission asset (lines, transformers) limits

- Penalty prices dictated by existing market rules

- Purpose: provides fair, transparent mechanism to evaluate and compare solutions that may be deemed infeasible due to precision of the solution (rounding) or truly infeasible
  - Scoring mechanism reflects this goal

Transmission Contingencies

- Single line or transformer outages
- Generators maintain their pre-contingency dispatch set-point
  - Except for adjusting injections to compensate for the change in losses
  - Adjustment due to change in losses is dictated by participation factor

Note that there are complications associated to post-contingency generator response for transmission contingencies (complementarity constraints); see the additional details in the Generator Contingency slides.

Generator Contingencies

- Single generator outages
- Participation factors dictate generator real power re-dispatch

Real Power Post-Contingency Response:

- Case 1: Generator follows assumed participation factor response
- Case 2: Generator reaches Pmax
- Case 3: Generator reaches Pmin
- ***Complementarity constraints***

CHANGING WHAT'S POSSIBLE

Generator Contingencies

- Single generator outages
- Voltage set-points dictate generator voltage control in post-contingency state

Reactive Power Post-Contingency Response:

- Case 1: Generator maintains pre-contingency voltage setpoint
- Case 2: Generator reaches Qmax
- Case 3: Generator reaches Qmin
- ***Complementarity constraints***
- *PV/PQ Switching*

Transmission Line Limits

- Current limits
  - Ampere equivalent of: thermal limit, proxy for voltage stability limit, proxy for transient stability limit
- Rate A: Base-case / pre-contingency (first stage)
- Rate C: Post-contingency (second stage)

Transformers

- 2-Winding transformer models
- No 3-Winding transformer models

- No control action available for transformer taps for pre-contingency or post-contingency state

Load Modeling

- Fixed real power and reactive power
- No Constant Current
- No Constant Impedance

Shunts: Fixed and Controllable

- Fixed Shunts (*will be identified*):
  - Given impedance
- Controllable Shunts (*will be identified*):
  - Continuous variable representing impedance within bounds
  - Not modeling discrete (switchable) shunts
  - Pre-contingency and post-contingency controllable (corrective actions)
    - First stage and second stage decision variables (recourse decision variables)

Phase Shifters, FACTS

- No modeling of FACTS
- Phase shifters are not controllable
  - Fixed, equivalent representation

Official Formulation and FOA Formulation

FOA Formulation is a simplified formulation for SCOPF primarily emphasizing:

- AC OPF + security constraints
- Constraint relaxations
- Real power response post-contingency
  - Complementarity constraints
- Reactive power response post-contingency
  - Complementarity constraints
  - PV/PQ switching

SEE THE WEBSITE FOR THE OFFICIAL FORMULATION!!!

See the Website for the Official Formulation

- Other standard SCOPF constraints exist

- Website:

https://gocompetition.energy.gov/

Questions?

Grid Optimization (GO) Competition

Submitting Algorithms for Evaluation and Scoring Using the Platform

OLGA A. KUCHAR

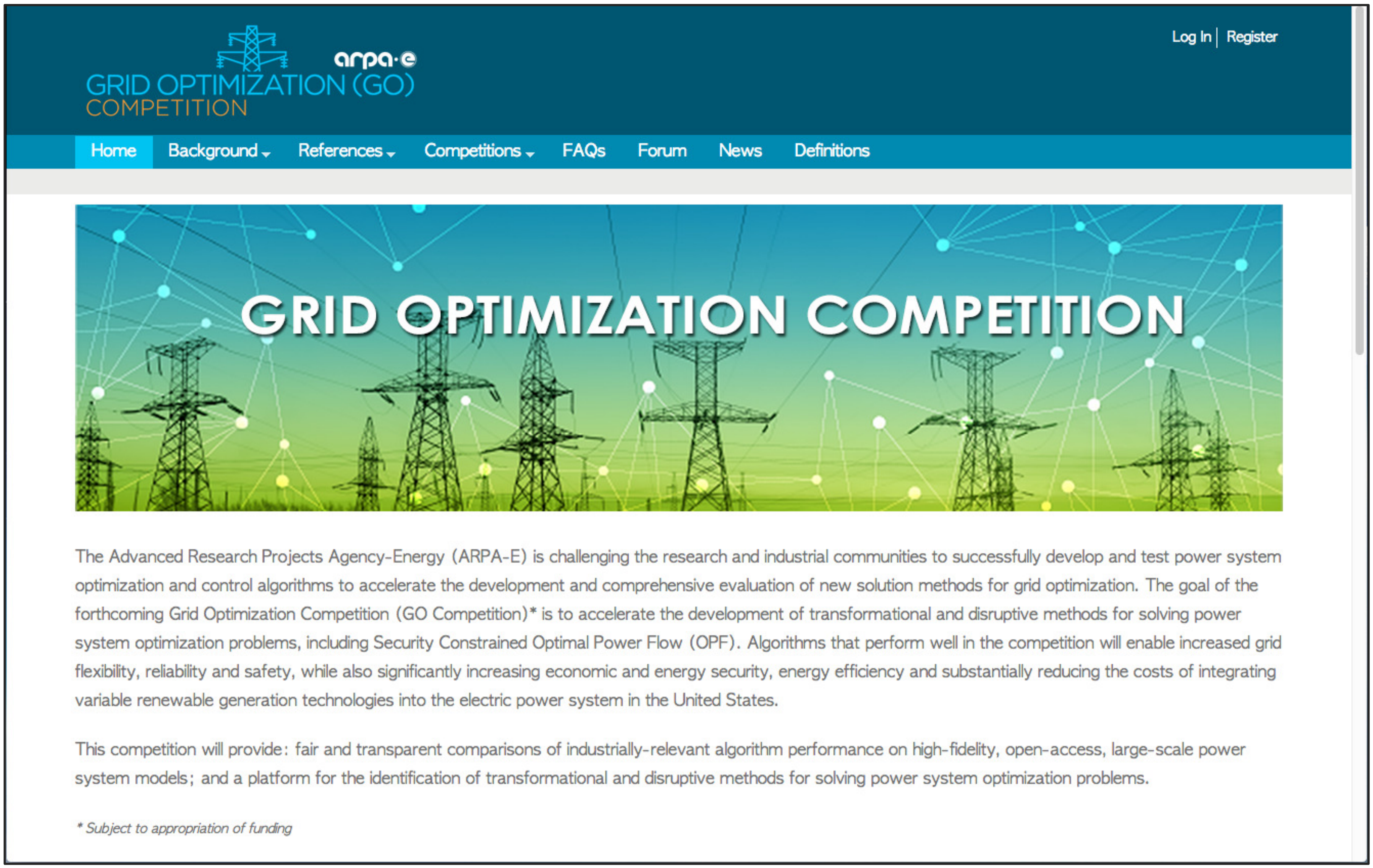
Grid Optimization Competition Workshop

FERC Technical Conference, Washington D.C.

Overview

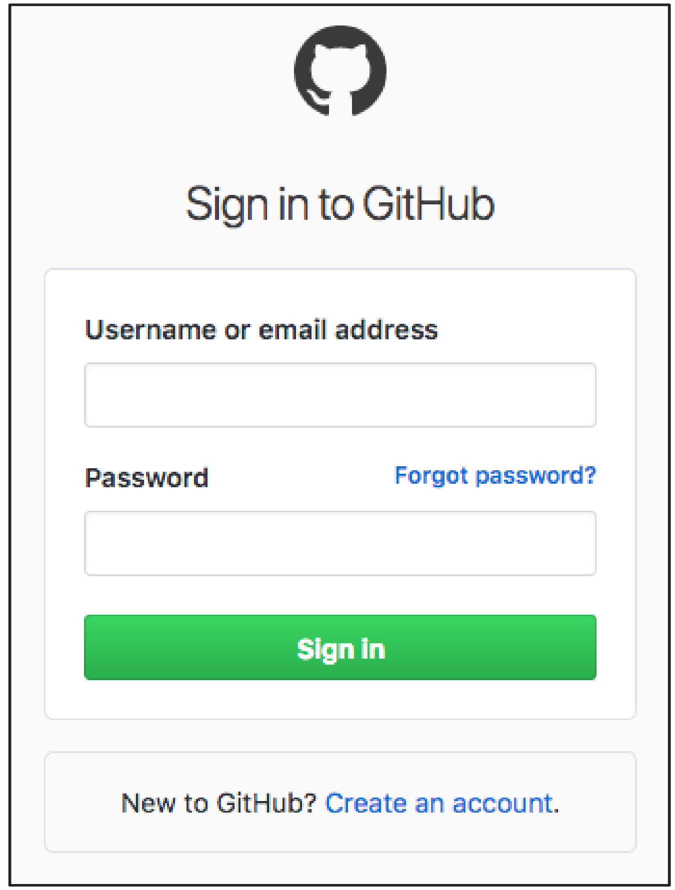
- Before making a submission
  - Create a Team GitHub Account
  - Create a GO Competition Team
  - SSH Keys and GitHub
- Submitting an Algorithm for Evaluation and Scoring
- After submitting a submission
  - Submission response
  - Download files
  - Leaderboards
- Getting Prepared and Staying Informed
  - Sandbox
  - Forum
  - Contact us

GO Competition Portal
https://gocompetition.energy.gov



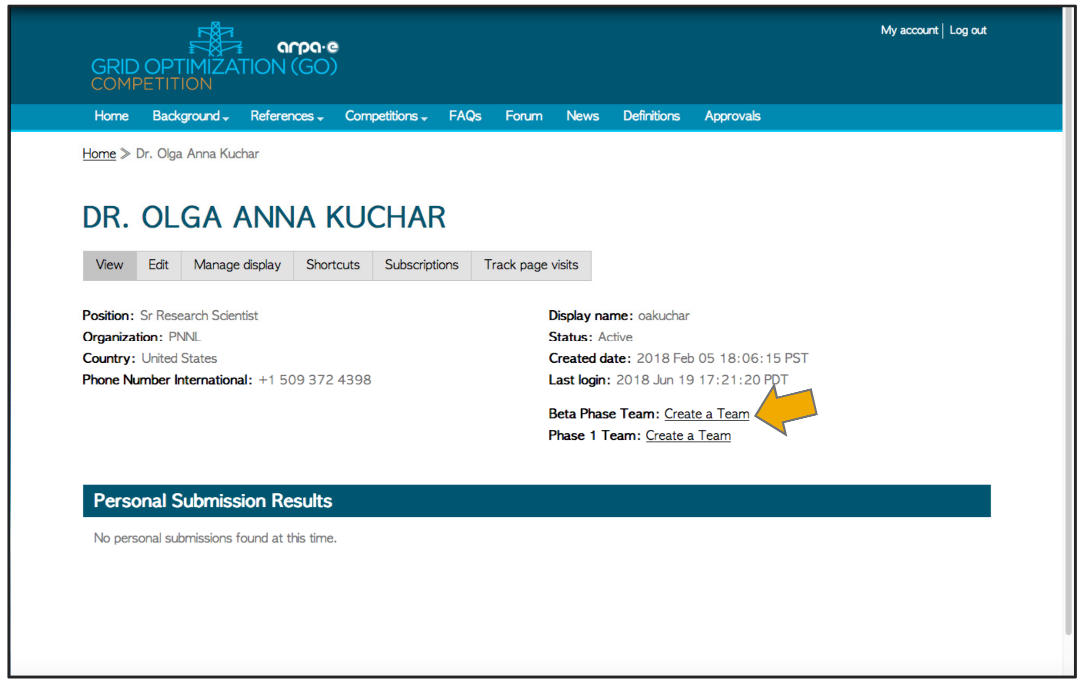
Create a Team GitHub Account https://github.com

- Each team needs a GitHub account
  - Challenge submissions require code to be placed in GitHub
- GitHub:
  - A popular code repository
  - Both public and private accounts are available (https://github.com/pricing)
    - Public accounts are free
    - Private accounts are not free
- Create an account on GitHub: https://github.com/join?source=login
- Documentation: https://help.github.com



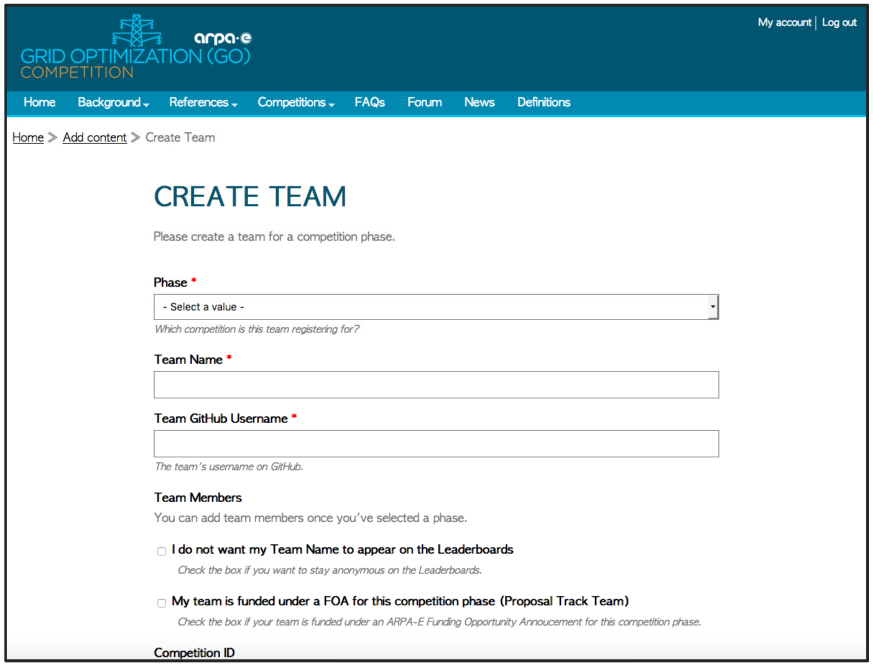
Create a GO Competition Team

- After completing account registration, access the GO Competition login page: https://gocompetition.energy.gov/user/login
- Log in using the username and password associated with your account
  - Every entrant is required to have an account
  - Accounts should not be shared
- Upon login you will land in your “My account” page
- Click on the “Create a Team” link associated with the appropriate challenge



Create a GO Competition Team Web Form and Paperwork

- Select the challenge
- Enter a team name
- Enter the team GitHub username (the username created on https://github.com)
- Select team members (or no one if you are a single-entrant team)
  - Entrant creating the team is the Team Leader
- (Optional) Check the box if you want to stay anonymous on the leaderboards
- Check the box if your team is funded under the ARPA-E FOA
- (Optional) ARPA-E Competition ID



Notice: In addition to creating a team on the GO Competition website, you need to submit ARPA-E paperwork to be eligible for prize money!

(information and paperwork requirements will be on the website, once available)

GO Competition Team Approval

- Your team information needs to be approved by the GO Competition Administrator
  - No submissions are allowed until your team information is approved
- An e-mail notification will be sent to all team entrants upon approval
  - Any entrant can make a submission for their team
- Each entrant can only belong to one team at a time
  - If you are added to the wrong team, please contact the GO Competition Administrator immediately

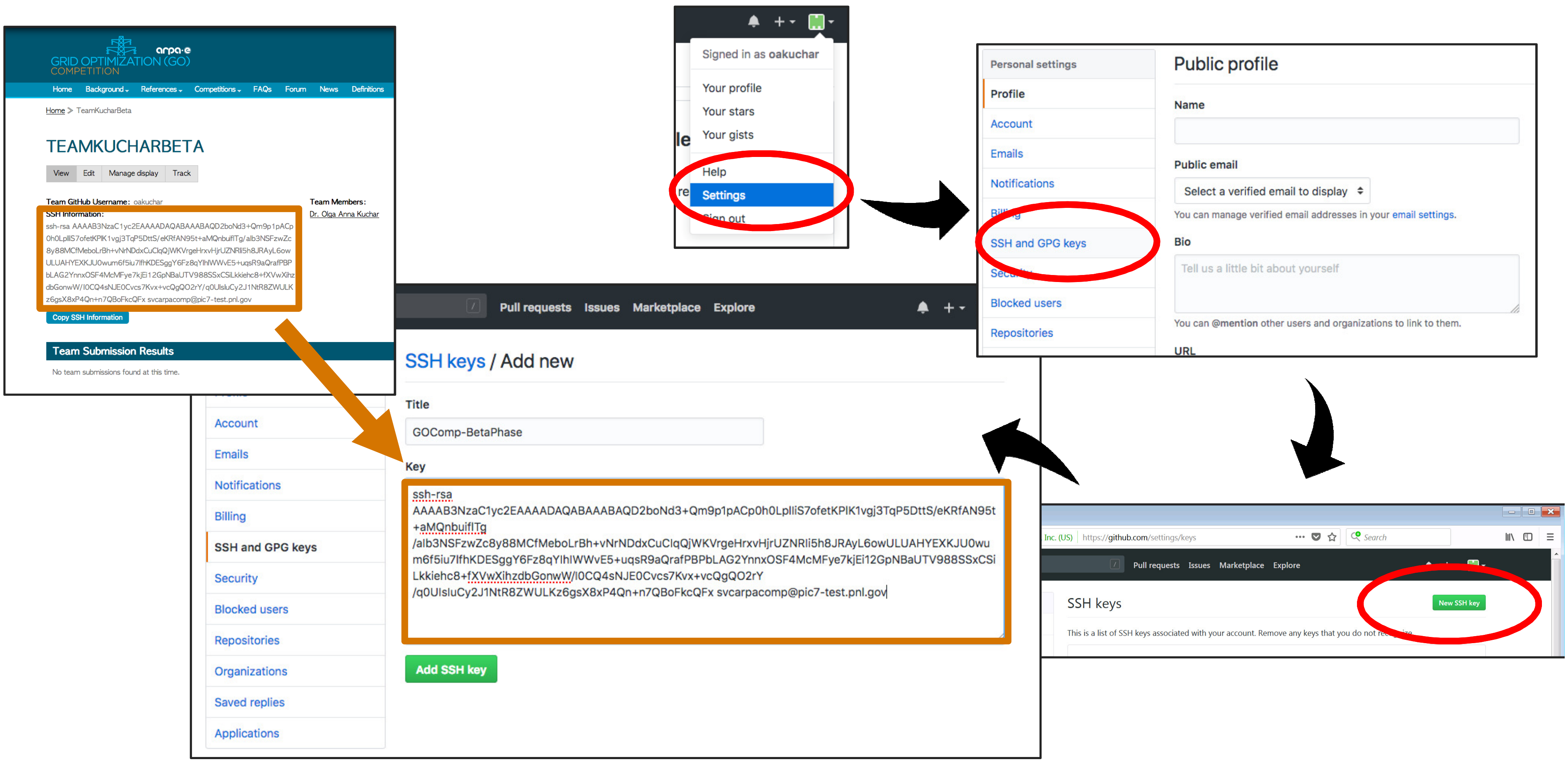
Notice: **Any changes** to a team on the GO Competition website **that do not match** your ARPA-E form **requires** new approvals AND you need to submit a **Change Request** form to ARPA-E to be eligible for prize money!

(information and paperwork requirements will be on the website, once available)

Final Step: Setting the GitHub SSH Key

- Your team will be assigned an SSH key on the Team account page
  - SSH (Secure Shell) keys are an access credential that are used in the SSH protocol
  - SSH keys are an authentication method used to gain access to an encrypted connection between systems
  - Allows the GO Competition platform to securely connect and download a team's submission code
- Copy the team's SSH key (you can use the convenient copy button)
- Log in to your team's account on GitHub
- Go to Settings under your Public Profile icon
  - Icon is in the top-right navigation menu and "Settings" is in the drop-down list
- Go to "SSH and GPG keys" in the left menu bar or https://github.com/settings/keys
- Click on the "New SSH key" green button located at the top right of the SSH keys page
  - Create a title for your key (for example, GO Competition SSH key)
  - Paste the SSH text from the GO Competition Portal Team page into the Key text box
  - Click "Add SSH key" button
- Your new key is added to your SSH Key list and you are ready to test a GO Competition submission

GitHub SSH Key Diagram



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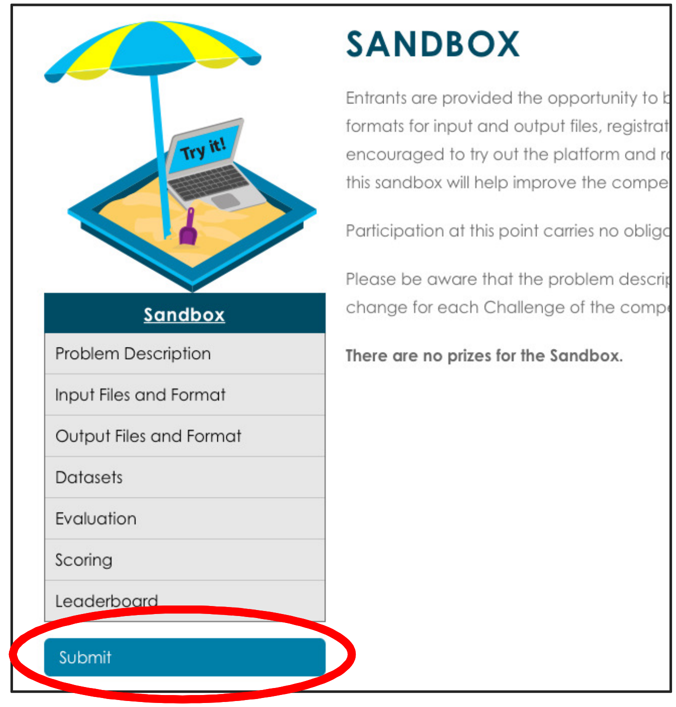
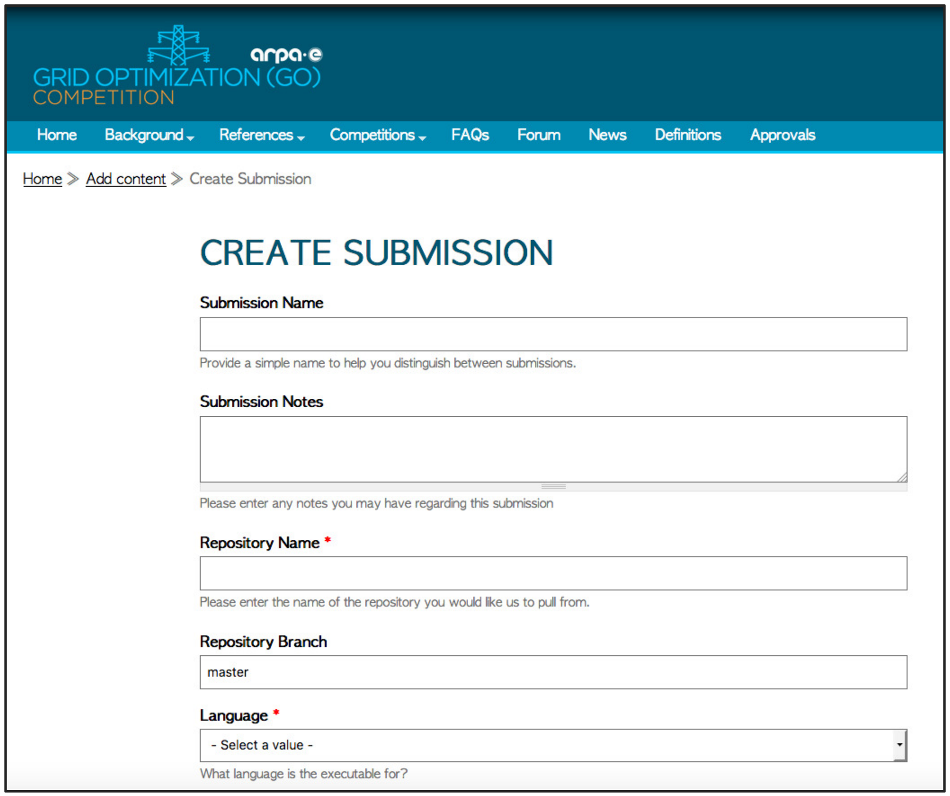
  - Contact us

Submitting an Algorithm for Evaluation and Scoring

- Go to the GO Competition login page: https://gocompetition.energy.gov/user/login
- Log in using your GO Competition username and password
- Go to the Competitions menu and choose
  - Sandbox (also known as Beta Phase)
    OR
  - Challenge
- Click the "Submit" button located under the Challenge menu located on the left side of the page



Creating an Algorithm Submission



- Enter a submission name
- Enter any notes associated with this submission
- Enter your team's GitHub Repository name
- Enter your team's GitHub Repository branch (master is default)
- Select a language environment (e.g. C/C++, GAMS, Julia/JuMP, Java/Scala, Python, MATLAB/MATPOWER, Linux binary executables)
- Select a dataset

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Submission Response

- Once a submission has been successfully submitted, a submission summary page is displayed
- Progress is reported in the Submission Results area
- You can terminate the submission using the "Terminate" button in the top-left of the Submission page
  - This terminate button disappears once the algorithm is finished
  - Only the submitter can terminate a submission
- Submissions can be viewed by any team member

Sample Submission Summary

Submission 99-123456789

Results for Download

Submission Results Filesize

Results file size: 21M

Submission Results Link

Results available here.

Submission Details

Submission Information

Submitter: Dr. Stephen Elbert
Team: Stars
Submission Name: GOComp Ref OD

Technical Details

Repository Name: gms-knitro
Repository Branch: master
Dataset: Beta Phase: Original Dataset
Language: GAMS
Competition: Beta Phase

Platform Messages

Submission Results

Date/Time	Status	Status Notes	Value
2018 Jun 12 15:35:31	Complete	Analysis complete for 23-1528842677	
2018 Jun 12 15:35:30	Complete	Evaluation complete. Archiving results.	
2018 Jun 12 15:35:25	Scoring	Final dataset score	90157.58
2018 Jun 12 15:35:24	Feasibility	Total number of constraint violations	0.00
2018 Jun 12 15:35:23	Scoring	Network model Phase_0_RTS96 score	260315.59
2018 Jun 12 15:32:18	Evaluation	Beginning evaluation for network model Phase_0_RTS96 (30 scenarios).	
2018 Jun 12 15:32:17	Scoring	Network model Phase_0_IEEE14 score	31225.13
2018 Jun 12 15:31:44	Evaluation	21% evaluation complete.	
2018 Jun 12 15:31:28	Evaluation	Beginning evaluation for network model Phase_0_IEEE14 (75 scenarios).	

Download Submission Results

- Once a submission has completed (successfully or not), a set of files with submission details can be downloaded from the submission summary page
- CSV file for Submission Summary (sample list only):
  - Submission date, dataset, and number of scenarios
  - And for each scenario in the dataset:
    - Objective value, max violation, constraint violation, time violation, run duration, and total violation (challenge specific)
- CSV file containing the scores for each scenario
- Log file for platform messages
- A list of directory folders for each scenario containing (sample list only): solution1.txt, solution2.txt, scenario submission log, a CSV file containing detailed constraint information, and an execution log

Watch the website for updates as formats are finalized!

Leaderboards

- Summary leaderboards that display the best submission result for each team for a given dataset
- Detailed leaderboards that display scenario-specific information (sample list only):
  - Objective function
  - Time
  - Maximum violation
  - Time and constraint violations
    - Challenge specific

Title

Submission Results by Scenario Number

Exposed Filters

Dataset: - Any -
Model: - Any -
Scenario: - Any -
Apply

Content

TEAM	SUBMISSION NAME	SUBMISSION DATE/TIME	SCORE	MODEL NUMBER	SCENARIO ID	OBJECTIVE FUNCTION ($)	TIME (S)	MAXIMUM VIOLATION	SCENARIO FLAG TIME VIOLATION	SCENARIO FLAG CONSTRAINT VIOLATION
go go go	python	05/31/2018 - 12:22	35987.69	1	1	35987.69	0.63	0.10	0	0
go go go	python	05/31/2018 - 11:50	35987.69	1	1	35987.69	0.35	0.10	0	0
go go go	python	05/31/2018 - 11:50	35987.69	1	1	35987.69	0.31	0.10	0	0
Stars1	GOComp Ref IEEE14	06/05/2018 - 05:29	369038.75	1	1	369038.74	0.68	0.68	0	0
Stars1	GOComp Ref IEEE14	06/05/2018 - 05:29	497363.31	1	2	497363.31	0.53	0.81	0	0

Watch the website for updates as formats are finalized!

Overview

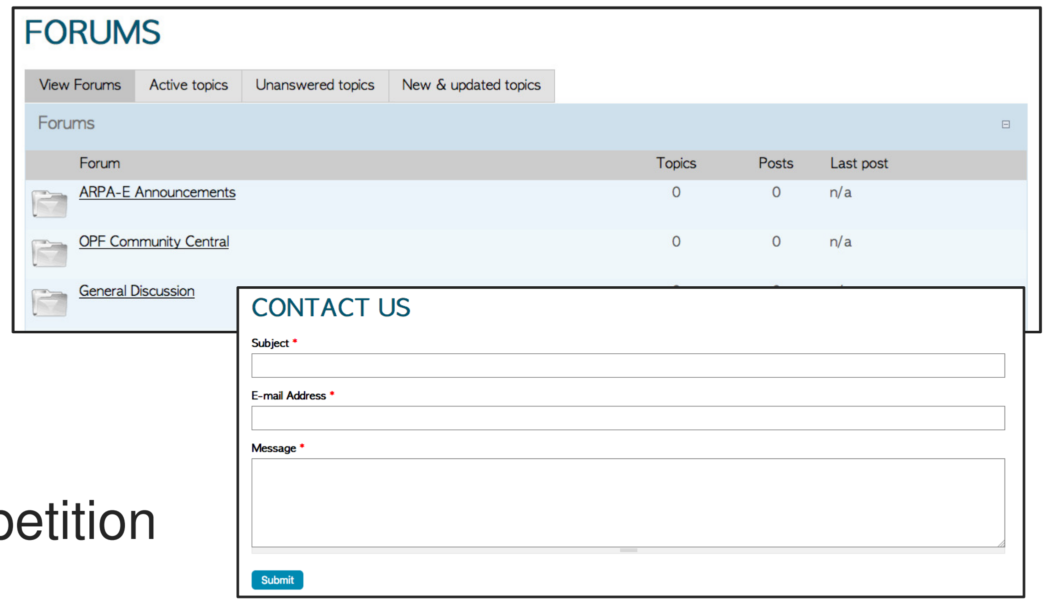
- Before submitting a submission
  - Create a Team GitHub Account
  - Create a GO Competition Team
  - SSH Keys and GitHub
- Submitting an Algorithm for Evaluation and Scoring
- After submitting a submission
  - Submission response
  - Download files
  - Leaderboards
- Getting Prepared and Staying Informed
  - Sandbox
  - Forum
  - Contact us

Get Ready for the Competition!

- Highly recommend that all entrants get acquainted with the GO Competition Web Portal
  - Create a GO Competition account
  - Create a GitHub account
- Experiment with the sandbox
  - Create a team (even if it is only a single-entrant team)
  - Make a sandbox submission
- Provide feedback

Stay Informed!

- Keep informed of the latest competition information
  - As Challenge 1 approaches, the website will be frequently updated with new information
- Forums are available on the GO Competition Web Portal
  - ARPA-E announcements
  - Community communication
  - Challenge discussions
  - Submission process
  - Performance issues
  - Scoring discussions
  - Website issues
- Contact us via the GO Competition Web Portal



Good luck to all entrants!

For any further questions or comments, please contact us:

GO Competition Administration Team
Website: https://gocompetition.energy.gov
E-mail: arpacomp@pnnl.gov

GO Competiton Development Team:

Stephen Elbert, Xiaoyuan Fan, Jesse Holzer, Xinda Ke, Olga Kuchar, James Marks, Casey Neubauer, Shannon Osborn, Feng Pan, Andrew Piatt, Arun Veeramany, Nino Zuljevic

Grid Optimization (GO) Competition Scoring Discussion

Scoring

The GO Competition needs fair, transparent, unambiguous, and quantitative method for scoring/ranking (and ranking) solutions.

Any scoring framework should consider:

- Objective function value
- Time to convergence
- Constraint violation

All three will be posted, however, we believe the most effective competition design will be one that uses a single, composite scoring procedure that reflects all of the above objectives.

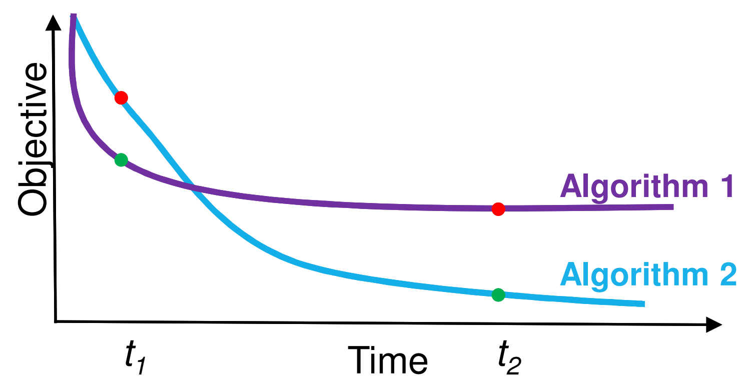
GO Competition Terminology

- ***Power system network model:*** each hypothetical grid with defined topological structure and characteristics including, locations of generators, loads, transmission lines, transformers, equipment detail, etc.
- ***Scenario:*** an operating instance in time. The scenarios define an instantaneous demand at each bus, renewable resource availability, and other temporary system conditions.
- ***Dataset:*** A collection of power system network models and scenario data. Challenge 1 will have four distinct datasets: C10D, C1TD1, C1TD2, C1FD.
- ***A scenario score (Divisions 1 and 2)*** is calculated for each scenario of a power system network model.
- ***A power system network model score (Divisions 1 and 2)*** is calculated by taking the geometric mean across all scenarios on a network model.
- ***A dataset score (relevant to Divisions 1 and 2)*** is computed by taking the geometric mean of all power system network models in a given dataset.
- The dataset score for each team on C1FD will ultimately determine winners/prizes.

DIVISIONS 1 AND 2: OBJECTIVE FUNCTION SCORING

Division 1 and 2 Scenario Scores[1]

- Each entrant algorithm submission results in an objective function for a particular scenario: $c_{m,s_m,\tau}$ Entrant Scenario Power systems model
- This objective function value includes total dispatch cost, and cost of nodal real and reactive power violations.
- Algorithms will be evaluated after t_1 =10 minutes (Real-time, Division 1) and t_2 =45 minutes (Off-line, Division 2)
- Infeasible solutions are those that violate constraints that are not relaxed in the SCOPF formulation. The score given to these solutions is the maximum of : c_{m,s_m}^{max} and c_{m,s_m}^{slack}. c_{m,s_m}^{max} is the largest cost for a feasible solution achieved by any Entrant:. c_{m,s_m}^{slack} is the cost when satisfying all load by the slack variables directly.



Two example algorithms, each winning a Division.

CHANGING WHAT'S POSSIBLE

[1] For complete information on scoring, see upcoming FOA and the scoring section of the competition website at https://gocompetition.energy.gov/

Division 1 and 2 Power System Network Model and Dataset Scores

- For a given network model, $m \in M$, for each scenario, $s_m \in S_m$, the power system network model score is computed by taking a geometric mean over the number of scenarios for that network model:

$$Score_{m,\tau} = \sqrt[|S_m|]{\prod_{s_m} c_{m,s_m,\tau}}$$

- Similarly, the total dataset score, for Entrant $\tau \in \mathrm{T}$, is a geometric mean over the power system network model scores:

$$Score_{\tau} = \sqrt[|M|]{\prod_{m} Score_{m,\tau}}$$

- Winners of Division 1 and Division 2 will be determined by their rankings on the dataset score for C1FD, evaluated during the GO Competition Final Event.

DIVISIONS 3 AND 4: PERFORMANCE PROFILE SCORING

Performance Profiles

- The creation of performance profiles is a method to compare algorithmic approaches by constructing the cumulative distribution function of a particular performance metric.
- First, define a metric for an Entrant's relative objective function on a scenario

Entrant's objective function

$$r_{m,s_m,\tau} = \frac{c_{m,s_m,\tau}}{\hat{c}_{m,s_m}}$$

Best objective function for a scenario across all entrants

- The best performing algorithm on model m for scenario s_m has $r_{m,s_m,\tau} = 1$ while all others have $r_{m,s_m,\tau} > 1$.
- Next, define $k(f, r_{m,s_m,\tau})$, a counter variable that gives 1 if $r_{m,s_m,\tau}$ is less than or equal to some f $(f \geq 1)$ and 0 otherwise.
- Finally, we can define:

Number of scenarios for which Entrant is within f-1 percent of the best Entrant

$$p_\tau(f) = \frac{\sum_{\forall m,s_m} k(f, r_{m,s_m,\tau})}{\sum_{\forall m} |S_m|}$$

Number of total scenarios

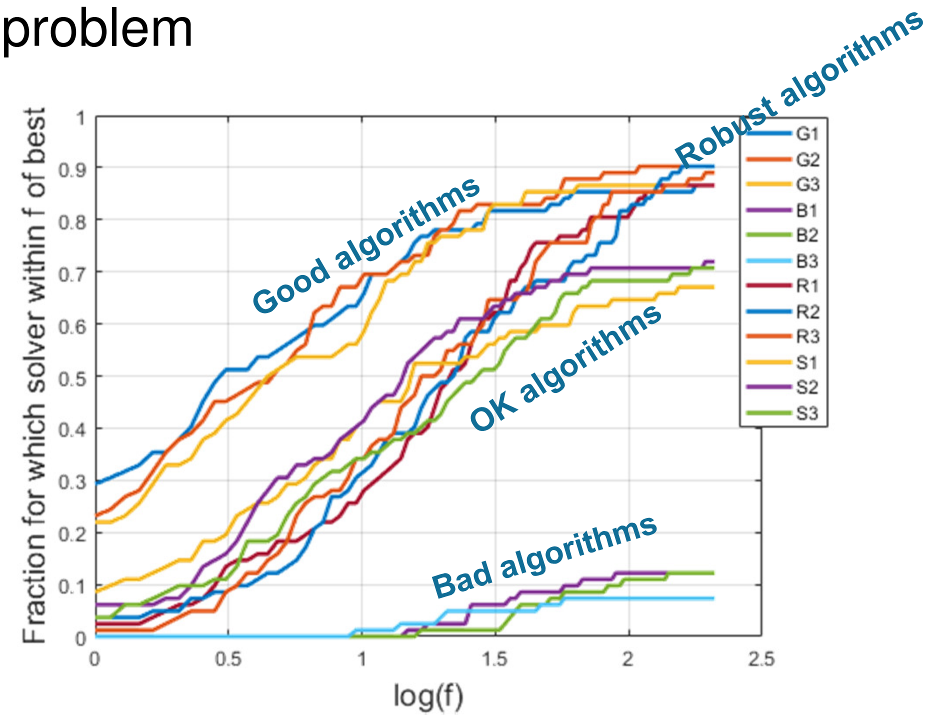
Performance Profiles

$$p_\tau(f) = \frac{\sum_{\forall m, s_m} k(f, r_{m,s_m,\tau})}{\sum_{\forall m} |S_m|}$$

Number of scenarios for which Entrant is within f-1 percent of the best Entrant

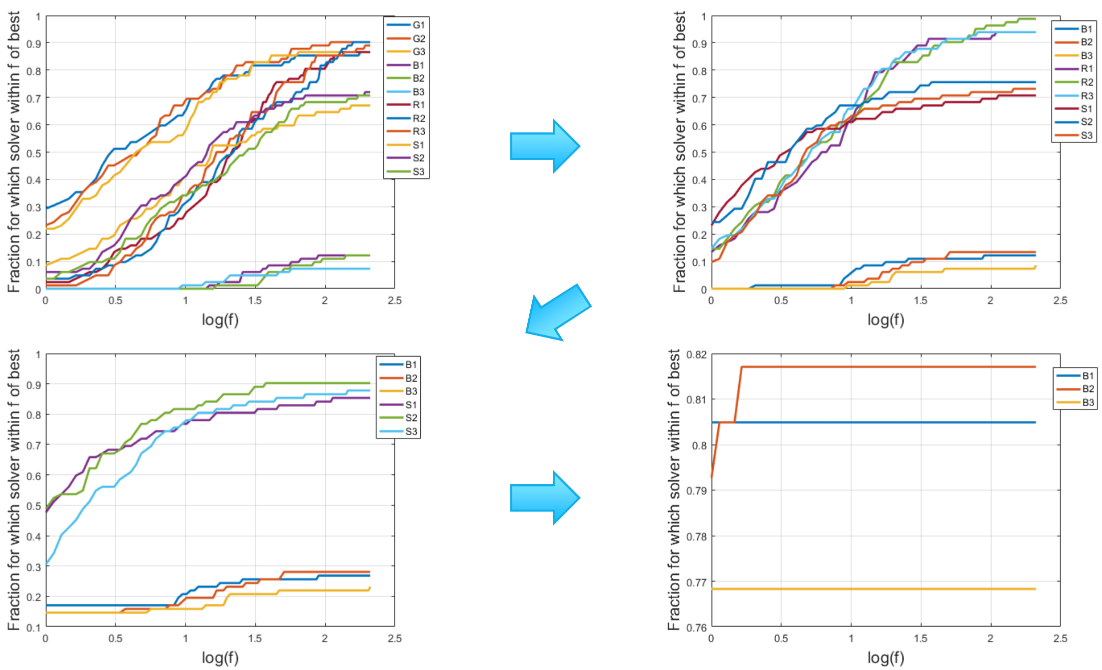
Number of total scenarios

- $p_\tau(1)$: fraction of scenarios where Entrant τ produced the lowest cost
- $p_\tau(\infty)$: fraction of scenarios where Entrant τ produced a feasible solution to the relaxed SCOPF problem



Ranking via Performance profiles

- One possible way to rank via performance profiles is to pick f, and compute integrals of curves over the range.
- Reference[1] makes the very good point that doing this can penalize algorithms which are “second place solvers” over a range of problems (see below).
- This suggests a better ranking mechanism: pick f, compute integrals over range, pick winner, remove winner, re-compute profiles, repeat.



Sequence of performance profiles successively removing top algorithms

[1]Gould, Nicholas, and Jennifer Scott. "A Note on Performance Profiles for Benchmarking Software." ACM Transactions on Mathematical Software (TOMS) 43.2 (2016): 15.

Winning, Scoring, Divisions

Challenge 1

	Lowest Cost	Performance Profiles
Real-Time (10 Min)	Division 1 Top 10: $100k	Division 3 Top 10: $100k
Offline (45 Min)	Division 2 Top 10: $100k	Division 4 Top 10: $100k

Grid Optimization (GO Competition): Eligibility and Rules

To be eligible to compete for prize money

1. Entrants must register on the competition website and send in registration forms to ARPA-E
2. Entrant teams must **include and be led be** an approved U.S. Entity
3. Entrant cannot be a Federal Entity or Federal Employee acting within the scope of his/her employment
4. Entrants cannot be funded by ARPA-E to facilitate the design and development of the GO Competition or to create or validate datasets to be used in the GO Competition
5. Entrants cannot be listed on the Specially Designated Nationals list
6. Entrants competing outside the scope of his/her employment must comply with the rules established by his/her employer

Entrants that do not meet these Eligibility requirements may still submit algorithmic approaches and be listed on the leaderboards subject to additional requirements but not eligible for prize money

Additional eligibility items

- A single organization may have multiple teams competing
- Teams must be mutually exclusive; no individual may be on multiple teams
- An organization that is funded by ARPA-E to produce or validate datasets for or to facilitate and support the GO Competition may have teams competing; however, the teams will be required to sign affidavits confirming that individuals on the competing team have not and will not receive assistance or insight from the team supporting the GO Competition

Unique technical approach

- Each Entrant must submit its own **unique technical approach** that has been developed by that Entrant team
- Minor variations in the same underlying algorithmic approach are considered to be non-unique approaches
- ARPA-E reserves the right to perform technical due diligence to verify that each Entrant's approach represents a unique algorithmic approach
- Entrants violating this policy will not be placed on the leaderboard and will not be eligible for prize money
- Approaches must be fully automated

Intellectual Property and Proprietary Software

- ARPA-E and the GO Competition Administrator will honor the proprietary nature of the software submitted by any Entrant

- Neither ARPA-E nor the GO Competition Administrator will claim rights to any follow-on use of IP submitted to the GO Competition without the written consent of the Entrant

Further Restrictions Apply

- Further rules and requirements apply
- See the official Rules Document and terms and conditions required to register for the GO Competition Challenge 1
- For full competition rules, visit the competition website:

https://gocompetition.energy.gov/

Summary

- Legacy grid software systems inhibit emerging technologies, innovative solutions
- Providing a platform for open and fair evaluation of innovative grid software
- The competition starts with an existing problem that is core to most grid software
  - ARPA-E Hard
  - Could save beyond $10B in costs per year
- Mission: start here and continue to break ground to bring innovative grid software solutions to practice
- Be an enabler for emerging grid technologies

Questions?

GRID OPTIMIZATION (GO)
COMPETITION