ARPA-E is investigating the potential to fund a public Optimal Power Flow (OPF) competition. We believe we will need to partner with a third party “competition team” to help design the competition, run the competition (including hosting the computational platform for the competition), and to evaluate solutions.[[1]](#footnote-1) The competition is envisioned to involve multiple (at least two) stages corresponding to different (increasing) levels of power system model scale and/or complexity.

In our current vision, the “competition team” will need to:

* Evaluate OPF competition design options (resulting in detailed recommendations to ARPA-E).
* Execute the OPF competition (including the development of the required competition computation infrastructure and the final evaluation/ranking of solutions).

**Evaluation of OPF competition design options**

ARPA-E envisions the competition team would (in collaboration with ARPA-E staff) investigate the strengths and weaknesses of various competition structures and details. The team would then submit detailed recommendations to ARPA-E.

Competition design options to be considered include the evaluation of different competition phase structures (single phase vs. multiple phases with different objectives, different models, different levels of complexity, etc.). The team would evaluate the optimal level of power system modeling detail to be required in each phase of the competition. This would include at least an evaluation of the precise manner in which constraints should be considered/modeled, the possible inclusion of local controls (including those that have typically not been considered in conventional OPF studies), and other detailed design choices, for example, the extent to which OPF solutions should be evaluated for power system stability. The competition design team would also investigate different methods for the evaluation and validation of OPF solutions.

The design and evaluation team will also be responsible for designing a detailed competition schedule and making suggestions for when a competition victor should be declared. Is the highest scorer within a certain amount of time the winner? Does the competition terminate when a certain performance improvement relative to current state of the art is achieved? What should that performance target be?

The evaluation team would also investigate the strengths/weaknesses of different possible competition computational structures including the following potential designs:

* Participants submit solutions to the evaluation team.
* Participants run their code on evaluation team defined/hosted virtual machine.
* Participants submit executable objects to be run by the evaluation team to generate results.
* Participants are given a certain budget to build their own relevant computational infrastructures where all code is executed.
* Other/hybrid approaches.

ARPA-E is envisioning that the computational infrastructure would need to include support for the use of standard optimization solvers like GUROBI, CPLEX and/or other power system modeling and analysis tools. In order to be fully open to the full range of potential solutions, ARPA-E believes the competition format will have to be compatible with solution methods that utilize at least some degree of parallelization. The evaluation team will have to consider designing the competition infrastructure with support for a wide-range of standard and emerging software tools that support/enable parallel computation.

ARPA-E anticipates multiple competition participants with proprietary algorithms; the competition should allow the full participation of such participants without disclosure of algorithmic details to other participants, the competition team, and ARPA-E. While designing the computational infrastructure, the competition team will have to fully investigate the security of participants’ proprietary solution methods. Beyond a web-based solution submission infrastructure, the evaluation team may also need to investigate what additional verification (such as site visits and in person demonstrations) might be required to validate top scoring solutions. It has been suggested that an independent panel of industry experts/advisors could also play a role in solution validation or scoring.

Finally, the competition team will need to weigh various ways of making power system models and scenarios available to competition participants.[[2]](#footnote-2) At minimum, ARPA-E expects the following questions to be important:

* To what extent should different power system models and/or benchmarking scenarios be used for algorithm development and final scoring/evaluation?
* How many power system models and/or scenarios should be used in each individual competition?
* Should limits be imposed on the number of times each individual team can have different solutions scored during the development and final evaluation stages?

The competition team will also be responsible for the development of recommended scoring metric(s) for the competition. The scoring of AC-OPF solutions must be semi-automated, quantitative, and transparent to all competition participants. Thus far, ARPA-E has been focusing on the development of a single (aggregate) scoring metric, but is open to suggestions from the competition team regarding the use of multiple, independent metrics (i.e. multiple tracks of the competition). Though total cost is the most obvious scalar metric for the competition, there are a number of questions regarding how other dimensions of solution quality should (or should not) be scored. For example:

* In the absence of a single aggregate score, how should the weights for different solution attributes be set?
* Can/should competition scores capture solution time and convergence robustness?
* Should particularly difficult cases/scenarios be given extra weight? How should this weight be determined?
* How should constraint violations be factored into scores? In particular, how should “soft” constraints be treated (e.g. as an addition to the objective function? If so, what weights should be attached to these?)
* How should security constraints and complex contingencies be scored?

Where feasible, ARPA-E believes the competition team should answer these questions with significant input and collaboration from industry. (Though, it is important to not have the competition designed by committee.) For example, input from the broader community might suggest that solution time is not important, given that a solution can be achieved within a five minute window. This might reflect itself in a suggestion to not score solution time (but only count solutions achieved within five minutes as valid).

The team will also be responsible for designing the competition with the following questions in mind:

* How do we ensure participation that leads to maximum impact?
* How do we adequately incentivize both academic and industry participation?
* How do we make this appealing to both power systems veterans and new entrants?
* How do we lower barriers to entry (i.e. high performance computing resources, expensive software, power system technical understanding, etc.)?

Finally, the competition team would develop a comprehensive risk mitigation plan for the competition. This plan would address at least the following risks:

* The scoring targets and/or objective function construction are found to be misaligned with power system priorities.
* The scoring is constructed in such a way that competitors can “game the system” with algorithms of limited practical use.
* The rules constructed inadvertently rule out a promising solution technique (e.g. by using hardware that discourages distributed solutions or those with extensive memory requirements).

ARPA-E anticipates the initial design of the competition to be a 3-9 month effort. (Though, we are open to other suggestions.)

**Execution of the OPF Competition**

The competition team will also be responsible for developing the computational infrastructure for the competition (including a web-based solution submission interface if required).

Once the competition is launched, the competition team would, on an on-going basis, have the role of running all day-to-day aspects of the competition (with program management oversight from ARPA-E). The team would be expected to respond to inquiries from potential competitors and, as necessary, would work with ARPA-E to revise the design of the competition if problems arise. The competition team would also create and maintain a competition leader-board throughout the competition.

The duration of the final competition will depend on the detailed design. However, ARPA-E anticipates the initial phases of the competition to run for 2-3 years.

1. We are separately (concurrently) evaluating the feasibility of running a program to construct large-scale, realistic, publishable, validated power system models that can be used to evaluate new OPF algorithms (prospective performers in that program are herein referred to as the “dataset team(s)”). [↑](#footnote-ref-1)
2. Here we refer to the physical description of a power system and limits of control equipment available (including generators, loads, capacitor banks, LTC taps, etc.) as a “power system model.” Variable input data defining each snapshot in time for that model (defining instantaneous power demand, renewable generation, generator and line availability, etc.) is referred to as a “scenario.” [↑](#footnote-ref-2)