CHANGING WHAT'S POSSIBLE

EPIGRIDS: Electric Power Infrastructure & Grid Representation in Interoperable Data Sets

Presenter: Chris DeMarco
University of Wisconsin-Madison

April 22, 2016

EPIGRIDS Organizations & Expertise

- Team members represent the following organizations, bringing broad capabilities:
  (i) a DOE National Laboratory with strong power grid and optimization expertise, in ***Argonne National Laboratory***;
  (ii) a major U.S. utility, in ***Commonwealth Edison/Exelon***;
  (iii) the world-leading vendor of Energy Management System software, in ***GE-Alstom Grid Solutions***;
  (iv) a innovative vendor of a general purpose optimization solver, in ***GAMS Development Corporation***;
  (v) and as lead organization, a U.S. Research I university with highly-ranked programs in electric power systems, optimization, and Geographic Information Science, in the ***University of Wisconsin-Madison***.

EPIGRIDS Team Key Personnel

- @ Wisconsin: Faculty ***DeMarco*** (power), ***Ferris*** (CS/optimization), ***Huang*** (GIS), ***Lesieutre*** (power); Post-docs ***Michini*** (graph theory),***Wangen*** (GIS/optimization);
- @ Argonne: Drs. ***Molzahn*** (Optimal Power Flow), ***Wang*** (Grid Operation & Control);
- @ GE-Alstom: Drs. ***Sun*** (OPF, contingency analysis), ***Sandala*** (EMS software);
- @ GAMS Development Corp: Drs. ***Meeraus*** (algebraic Modeling Systems) ***Dirkse*** (optimization software assurance & testing);
- @ Commonwealth Edison: Dr. ***Schooley*** (transmission planning and operations)

EPIGRIDS Synopsis

- Develop methodologies to “grow” synthetic power grid models, through algorithms that tractably represent the engineering principles underlying historic grid expansion decisions. These algorithms will represent impacts of population patterns, societal energy demand, geography, and land use on the growth of power system infrastructure.

- These engineering and geographically based models will be supplemented by analytic tools of power systems analysis, optimization, and graph theory to both aid with validation, and to ensure that the models and scenarios yield a rich range of data sets to fully exercise and challenge grid optimization algorithms.

EPIGRIDS – Four Cornerstones

- USE NONCRITICAL PUBLIC DATA AS SEEDS: start model from subset of grid component descriptions in public data (e.g., history of grid expansion 1950's-1990's; avoid CEII concerns through use of only relatively old, very public data). Develop new algorithms to **accelerate** grid expansion process from these seeds, growing systems with new load, generation, transmission, and new technologies.

- EXPLOIT FLEXIBILITY IN NEED FOR REALISM, BUT NOT REAL: To create realistic models, we need only realistically capture core features of transmission and generation expansion decisions, NOT ACTUAL PAST OUTCOMES.

EPIGRIDS – Four Cornerstones

- EXPLOIT ADVANCES IN GEOGRAPHIC INFORMATION SCIENCES: Data and algorithms to inform automated grid infrastructure expansion lean heavily on data science tools of GIS. Will include land and water features, land use descriptions, population, and inferred electric energy use density; algorithms will include path routing, low-environmental-impact site selection.

- CHARACTERIZE FEASIBLE OPERATING REGIONS: Key to expansion methodology are component additions that “capture” desired power delivery within feasible operating region. Moreover, geometry of test scenarios’ OPF feasible regions determine both realism & challenge of cases. Allows creation of a wide range of “targeted difficulty” OPF & SCOPF scenarios.

EPIGRIDS Innovation

- First novel element of approach lies in focusing on process of ***growth*** in grid models, representing social needs and land use impacts that drive/constrain this growth.
- Second innovative element in cross disciplinary coupling of Power Systems and Geographic Information Science, *informed by advances in modern Optimization.*
- As outgrowth of above, third innovation in use of feasible set characterization – key to tractable automation of grid expansion decisions. Can't afford to run huge, combinatoric numbers of production costing scenarios. Instead, take moving target of desired power injections/loads as input. Tractably describe component additions via their impact on achievable power injections in the grid.

EPIGRIDS Innovation

- Fourth innovation in metrics of model realism. In 2009, team members performed project for the Federal Energy Regulatory Commission; developed “Topological and Impedance Element Ranking (TIER).” Strong evidence that distribution of TIER values provides distinctive “signature” of a realistic grid, to be further exploited in EPIGRIDS.
- Fifth innovation in implicit multi-port network element representation, resolving dichotomy of “bus-branch” versus “node-breaker” power network data structures. We will exploit versatility of GAMS environment to allow implicit multi-ports, easing treatment of such element as ideal breakers, three-winding transformers, HVDC, and FACTS devices, while keeping backwards compatibility to power-industry-standard PSSE raw format to extent possible.

Milestones & Challenges

- Manage risks in first year by paralleling two complementary approaches: (i) modest expansions on existing test systems (New England 39 and WSCC 179), with limited GIS data needs; (ii) start development of “largely new” systems with WI footprint, for which we have rich GIS and historic grid data as inputs.
- First year deliverables will include test system and associated scenarios developed by (roughly) 50% expansion of NE-39 (by 3rd quarter); WSCC-179 follows Q1 of year 2.
- Prior work give high confidence in algorithms to add transmission links between nodes/buses. New in EPIGRIDS will be deciding substation sizes, locations, types from input data of population and energy needs – will our algorithms realistically place and size substations, with design detail to inform contingency analysis?

Milestones & Challenges

- Of particular interest will be comparisons of our TIER-based metrics with other graph theoretic characterizations of power model realism in the literature, and employed by other project teams (note: inter-team collaboration opportunity!)
- Physically based models allow other realism metrics that will be explored in year 1: consistency of line lengths with inductance/capacitance ratios, comparison of estimated capital costs of synthetic transmission expansion against historic grid expenditures.
- Delivery of WI footprint system scheduled Q1 year 2. At this meeting next year, expect to report on experience in WI test system, using GIS-based load growth and facility siting methods, feasible-region network expansion algorithms, and TIER-based realism metric.

Technology-to-Market

- EPIGRIDS goal is to make realistic power systems optimization and dynamics testbeds widely accessible, even to the non-power specialist, while ensuring the model and scenario datasets have validated realism to ensure their credibility with power specialists.
- The team membership was selected with this desired impact in mind: Commonwealth Edison brings perspective of major US utility; GE-Alstom experience of world-leadership in grid operations software development. Argonne Labs and GAMS bring exceptional optimization software and general modeling environment expertise, with experience in allowing other classes of domain specific problems to benefit from advances in optimization. Wisconsin brings advanced GS expertise, and skills and experience to bridge to both power systems and optimization.
- In addition, Wisconsin is a member of Power Systems Engineering Research Center (PSERC) consortium, which for more than 15 years has been an effective technology transfer vehicle for university/industry collaboration and technology transfer. This was the venue by which several EPIGRIDS team member discussions began, and it will serve as a dissemination vehicle as work progresses.

Opportunities for GRID DATA Collaborations

- GRID DATA has particularly ripe opportunities for constructive collaboration among the teams. As per prior slide, several other teams involve members of the PSERC consortium. GRID DATA related work has already been the topic of a March 2016 PSERC webinar by Tom Overbye. He described a number of elements in his team's approach that offer collaborative opportunities with EPIGRIDS in GIS/power grid data fusion.
- Likewise, EPIGRIDS team member Dan Molzahn spent over a year in collaboration with the University of Michigan power systems group, as a post-doctoral researcher. We envision ripe opportunities for collaboration in feasible set characterization.
- Bottom line: this is a modest size community, with many close ties, and (dare say?) a more collegial, collaborative spirit than exists in some areas of research. Constructive interaction between teams ***will*** take place – the EPIGRIDS team members look forward to it.